ARCHITECTURAL PRINCIPLES IN AN AGE OF FUNCTIONALISM - A STUDY OF THE ARCHITECT-ENGINEER IN BRITISH ARCHITECTURE OF THE INTER-WAR PERIOD

V O L U M E   O N E

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy by David Cottam

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C O N T E N T S - V O L U M E O N E

P A R T   T W O

THE EMERGENCE OF TWO BRITISH CONCRETE ENGINEERS - OSCAR FABER AND OWEN WILLIAMS

P A R T   T H R E E

TWO BRITISH ENGINEERS WORKING PRINCIPALLY IN REINFORCED CONCRETE WHO CONSIDERED THEMSELVES AS BELONGING TO THE MODERN MOVEMENT IN ARCHITECTURE

ABSTRACT

This study sets out to examine the relationship between structure and form in British architecture of the inter-war period, focusing principally upon the engineer's role at a time when theories of functionalism began to dominate certain architects' design methods. This seemed particularly relevant during the 1930s when the architect-engineer relationship was thrown into question as new structural techniques and the advent of functionalism suggested radical changes in future professional relationships.

To narrow the scope of this wide field of investigation, reinforced concrete was selected as the structural technology to provide a focus for research and discussion. A brief history of the development of this technology, and the institutions which pioneered its assimilation to architecture, is presented to provide the context for a more detailed discussion of the work of four individual designers. These individuals worked either as engineers for architects or as architect-engineers themselves. They are; Oscar Faber, Owen Williams, Ove Arup and Wells Coates. All used reinforced concrete as their preferred structural medium and each possessed distinct views on the relationships between structure and form in architecture, and between the architect and the engineer. Of these, only the work of Wells Coates has already been the subject of extensive research. For this reason only one aspect of his career, which has not been sufficiently well covered by others, is examined.

The study revealed, through the work of these four designers, that the structures of their buildings were insufficient on their own to be the principal determinants of building form. Structural functionalism, therefore, can be seen to have existed as an ideal but in spite of accepted evaluation it does not seem to have been of any real significance in the creation of buildings put forward as the prime examples of British functionalist architecture of the 1930s.

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NOTE ON CROSS-REFERENCING

This thesis is divided into two volumes. Volume One comprises the main body of the text and Volume Two is a series of case studies and illustrations. The latter contains information which should be consulted alongside the former and it is for this reason that they have been separated in this way.

To facilitate easy cross referencing, case study numbers and illustration numbers have been inserted into the margins of each volume. The case studies are identified by square brackets eg [10] ; the illustrations by round brackets eg (10).

I N T R O D U C T I O N

In his influential publication The Architecture of the Well-tempered Environment, Reyner Banham examined the importance of the mechanical sciences and the mechanical engineer on the development of architectural form. In his introductory chapter entitled 'Unwarranted Apology' he wrote:

'In a world more humanely disposed, and more conscious of where the prime human responsibilities of architects lie, the chapters that follow would need no apology, and probably would never need to be written. It would have been apparent long ago that the art and business of creating buildings is not divisible into two intellectually separate parts - structures, on the one hand, and on the other mechanical services. Even if industrial habit and contract law appear to impose such a division, it remains false.'[1]

It is surprising that Banham used the word 'structures' instead of 'architectural form' for this assumes that structures and architectural form are synonymous. In the period in which he analysed his subject, however, it would have been equally valid to conduct a similar exercise analysing the contribution of structures and structural engineers to architecture itself. This study, therefore, takes Banham's apology as its own starting point with the substitution of the words 'architectural form' in place of 'mechanical services'.

The separation of structure and architectural form, reinforced by the existence of two distinct professionals, 'architect' and 'engineer', has been traced to the Renaissance, when architecture became principally concerned with issues of 'taste' and 'style'. Although there are many arguments in support of this claim there is little doubt that the schism between the two became most visibly apparent during the 19th century when the roles of architects and engineers were clearly defined; the former concentrating on the stylistic issues of building design with the latter developing new structural technologies and applying them to the design of ambitious building structures. The railway stations of the period probably best demonstrate the differences between the two disciplines, the engineer producing structurally efficient enclosures of vast proportions with the architect concealing this work from the city street landscape by the design of flanking buildings decorated in either the neo-classical or neo-gothic styles.

By the turn of the century it seems clear that these polarized approaches to building design began to have their effect upon the architect's self-esteem. John Summerson, in his book Heavenly Mansions, saw such an 'identity crisis' in architecture, suggesting that it was provoked by the architect's awareness of two important issues:

'On the one hand, he (the architect) saw himself as a kind of dealer in styles with no genuine wares of his own to dispose of; on the other hand he saw the purely practical reasons for his existence being undermined by members of a new and flourishing profession.'[2]

To provide some evidence in support of Summerson's unsubstantiated observations it is useful to refer to the writings of Charles H Reilly, Professor of the Liverpool School of Architecture from 1904 to 1933. At the time of Reilly's appointment important changes were taking place in architectural education in which he was to become closely involved as a prominent member of the R I B A 's Board of Education. His early writings on this issue reveal that the proposed transformation of architectural education in Britain was motivated by the desire to change the commonly held perception of the architect's decline in status. Addressing the Senate at Liverpool University in 1905 on the 'Training of Architects' Reilly said:

'There is no doubt about the decline of the architect from the days of his greatness during the Italian Renaissance to the days of his subordination to the amateur enthusiast of the Gothic Revival, and to the business speculator of today . . . . He has consequently to suffer from inroads into his province in all directions, from the engineer in one, from the tradesman-decorator in another.'[3]

Reilly's solution, to restore the architect's status vis à vis the engineer and others, was to encourage a University education for architects with the objective of training student architects first and foremost as 'practical constructors'. In the same address he said:

'to construct with the beauty born of directness, simplicity, and suitability is the first step to fine architecture. It is the strict observance of this vital relation of construction to actual needs and conditions which can alone prevent copyism and revival of forms, which have long lost their meaning.'[4]

Only in this way, Reilly (himself a graduate in engineering) claimed, could architecture become once again a 'living art, and not a mere branch of engineering on the one hand or archaeology on the other.'[5]

The intellectual context in which Reilly initiated his changes to architectural education at Liverpool was dominated by two architectural theorists; William Richard Lethaby and Geoffrey Scott. These men had widely divergent views on the subject of architectural design, although both recognized that contemporary architecture was in a state of crisis. Lethaby was essentially of the functionalist persuasion and argued for an engineer's approach to architectural design. Scott, in contrast, believed that the aesthetic issues of 'taste' and 'style' were central to the success of architecture and argued that functionalism, in any of its various forms, was fallacious.

In an address to the R I B A in 1910, Lethaby stated his position thus:

'The method of design to a modern mind can only be understood in the scientific, or in the engineer's sense as a definite analysis of possibilities, not as a vague poetic dealing with poetic matters . . . once again I venture to suggest that the living stem of building design can only be found by following the scientific method.'[6]

Lethaby's reverence for the engineer can be noted in his best known book, Architecture, first published in 1911.[7] In his introduction he explained that conventional architectural history had encouraged a scholarly and stylistic approach to architectural design by its concentration on names and the catagorizing of 'styles'. He believed that this was a gross misinterpretation of architectural history which had been partly responsible for the architect's contemporary lack of direction. In its place he argued for a Darwinian approach to the subject, tracing the development of architectural form as an evolutionary process. His book therefore attempted to approach the subject in an evolutionary manner, explaining architectural history in structural terms and demonstrating how societies had used their most advanced techniques to solve building problems specific to their respective cultures. What was particularly relevant to Lethaby was that the best examples of past architecture had been produced by systems which recognized no separation between architect, engineer and builder or between 'architecture' and 'engineering'. It was the Renaissance, he explained, which had provoked the catastrophic division between architecture and engineering, as each developed as separate specialisms to the detriment of both. Although a very simplistic approach to architectural history, which has since received severe criticism, there is little doubt that Lethaby's approach to the subject was later to be used as the historical justification for modern architecture by modernist protagonists. This was particularly true in Britain during the 1930s when writers such as Yorke, Shand and Richards, used a similar analysis to claim that modern architecture was not a revolutionary force but part of a long evolutionary development.

Scott's approach to architectural history, and its inferred relevance to the contemporary situation, was diametrically opposed to that presented by Lethaby. In his book The Architecture of Humanism, first published in 1914, Scott took the very period which Lethaby had discarded - the Renaissance - with the intention of describing the merits of its 'aesthetic nature'.[8] To do this he believed it necessary to discard the fallacious arguments of functionalism. Unlike Lethaby who recognized no distinction between 'building' and 'architecture', Scott was quite clear that architecture was distinguished from 'mere building' by its aesthetic content. Architecture, he argued, was made up of the three categories which Wotton had used in his book The Elements of Architecture;[9] these were 'Commodity' 'Firmness' and 'Delight'. Delight in architecture was to Scott independent upon a scientific standard, 'firmness', and also of a practical standard, 'commodity'. By separating out these three elements and concentrating on a demolition of the various fallacies associated with them, Scott drew a firm dividing line between architecture and mere building. Even though his concentration on discrediting functionalism left him little scope to direct his attention to what his real objective had been - describing the aesthetic nature of the Baroque - his book proved to be highly influential. Throughout the 1920s it provided architects and educators with the philosophical justification for concentrating on issues of 'taste' rather than on new technologies and their implications for architectural form.

This was particularly true of Reilly and his school at Liverpool. Although his early principles suggested a strong connection with the views espoused by Lethaby, the practical reality of architectural education at Liverpool was more closely allied to Scott's position. Not only did he resurrect the classical tradition with a Beaux Arts approach to architectural education, but he specifically avoided training his students as practical constructors in the new structural materials of steel and reinforced concrete. This did not mean that his students were isolated from the practical issues of building, rather they were taught traditional constructive principles as they applied to what was then perceived to be the greatest style in architectural history - the early Renaissance.[10]

This approach was widely adopted in practice and was not peculiar to the Liverpool School. The introduction of the steel frame had little impact on these attitudes, indeed it could be argued that it helped to establish a demarcation between architecture and engineering. With the exception of a few isolated examples the structural steel frame was warmly welcomed by architects, not because it provided them with the opportunity to produce new forms of architecture, but because they could engage engineers to design cheap structural solutions enabling them to spend a higher proportion of their clients' money in the detailing of academically-accurate classically-styled facades. Thus many examples of architecture at this time were generally conceived by a facadist approach to design with the engineer's structural steel frame completely disguised and supporting heavy masonry facades which of themselves possessed no structural function. Reinforced concrete was used, less frequently, in the same way and was never seriously considered a viable architectural material on its own, being generally perceived as a poor quality building material only appropriate to utility structures. In this way Scott's arguments were well supported by numerous examples of architecture which unashamedly suggested a firm dividing line between the engineer's structure and the architect's facadist designs.

Towards the end of the 1920s, however, Lethaby's early writings came to be acknowledged by leading figures of the developing Modern Movement on the Continent. Le Corbusier's book, Vers une Architecture, translated into English in 1927, was the most potent of these, acclaiming the engineer's functionalist approach to design as the only sure model for architects to follow in order to create a new architecture relevant to the modern age.[11] Unlike Lethaby, however, writers such as Le Corbusier had by 1927 designed and built examples of architecture consistent with their arguments, and in this way they had a distinct advantage in generating a greater respect for their ideas. Their favoured material was reinforced concrete for they considered this to have the greatest potential to produce a synthesis between form and structure in architecture.

The significance of this assertion of functionalist theories was that it blurred the distinction between architecture and building, and by extension between the work of architects and engineers, raising utilitarian building to the level of architecture. The relationship between the two disciplines was thrown into question. Lethaby's solution had been unambiguous. His advice to architects had been to train as engineers themselves:

'If I were again learning to be a modern architect I'd eschew taste and design and all that stuff and learn engineering with plenty of mathematics and hard building experience. Hardness, facts, experiments.'[12]

As far as engineers were concerned this newly acquired status for their products presented some of them with an excuse for practising as architects themselves, permitting them to claim that their buildings were architecture. To some within the architectural profession these developments represented a threat to the status of architects and the quality of architecture. But some architects were optimistic hoping that the emergence of new structural materials in architecture would provide the catalyst that would eventually lead to a reunification of the two disciplines or at least promote a much closer relationship between them.

This study sets out to examine these issues by concentrating primarily on the engineer's viewpoint with specific reference to those engineers who made important contributions to architecture through the application of their design abilities in reinforced concrete. The principal reason why a specific technology has been chosen as the most appropriate vehicle to discuss these issues is because it isolates a line of enquiry which permits discussion, within a technological framework, of the issues under investigation. Moreover it allows the study of the work of specific individuals to be related to a wider historical context. This was considered preferable to an alternative approach - that of isolating one individual or group of similarly motivated designers, for this would have produced an unnecessarily distorted picture of developments in general.

There are three reasons why reinforced concrete has been selected as the focus for discussion. First, its development was contained within a clearly defined period dating from the mid 19th century, with its full assimilation to British building being largely confined to the early 20th century. Second, it was without question the one material which dominated the work of modernists during the inter-war period, being interpreted by them as a modern material which had the greatest potential to produce functionalist forms of architecture truly representative of the modern age. Third, unlike other building materials, reinforced concrete obliged the engineer and architect to adopt a new professional relationship. Because it was a plastic material without specific form, any designer wishing to exploit any functionalist principles it may have represented, needed a scientific understanding of its properties and possibilities. For engineers working alongside architects this gave rise to an important status as designers in their own right, elevating themselves above their traditional role as the architect's technical assistant. In this way a study of the use of the material is ideally suited to the discussion of the architect/engineer relationship, with particular reference to functionalist architecture of the inter-war period.

Four engineers have been selected for particular attention, not merely because they were leading figures at the time but because their activities and attitudes to the relationship between form and structure in architecture, and between the architect and engineer, cover a wide spectrum. They are Oscar Faber, Owen Williams, Ove Arup and Wells Coates.

Owen Williams and Wells Coates took Lethaby's views on an engineer's approach to architectural design to logical conclusion and practised as architects themselves. Oscar Faber and Ove Arup acted primarily as consulting engineers to architects believing, like Scott, that there was an artistic component in architectural design which engineers could not provide on their own. With the exception of

Faber, they believed that functionalism was a valid design objective and that to attempt to integrate structure and form in architecture was creditable.

As engineers they differed markedly from one another. At one end of the spectrum was Faber who represented the scientist-engineer basing his early practice on a reputation gained from his research activities in the field of reinforced concrete technology. His place in British architectural history is obscure primarily because most of his best work was related to conventional forms of architecture in which his contribution was subordinated to the aesthetic requirements of his architect-clients. Nevertheless he undertook many worthy projects on his own which are relatively unknown but which are important to this study. They illustrate his argument that there was an important distinction between architecture and engineering and that it was essential for engineers like himself to design projects of an 'engineering' character, provided they respected those aesthetic considerations architects considered important in designing 'architecture'.

Owen Williams did not have Faber's research background but acquired a similar reputation to Faber in the 1920s as one of Britain's leading experts in reinforced concrete design. He is important in the context of this study because he based his architectural career on the premise that only engineers were capable of producing a synthesis between structure and form in concrete architecture. Many of his buildings are regarded as having had seminal importance in the development of modern architecture in Britain during the 1930s, and their reputation remains untainted to this day.

Ove Arup, like Faber, worked primarily as a consulting engineer to architects, but unlike Faber, most of his architect-clients were modernists who wanted to produce forms of architecture in which there was a close relationship between structure and architectural form. An important feature of Arup's work, which distinguished him from the others, was the fact that he operated from a contracting background, believing that in order to produce good examples of modern architecture it was necessary to bring the constructive skills of the contractor into the design process. Unlike Williams, who never accepted the concept of collaboration in architectural design, Arup consistently argued for a teamwork approach to design in order to integrate, from the outset of a design problem, the combined disciplines of architect, engineer and builder. Through this approach to design Arup made a vital contribution to some of the finest examples of modern architecture in Britain, particularly during the 1930s. Of all the designers discussed in this study there is little doubt that Arup stands out as the most successful and internationally famous. Through his success he has done more than anyone else to raise the status of the structural engineer, by encouraging the development of an integrated approach to design. Although this reputation has been largely acquired in the years following the Second World War, any future biographer will be forced to recognize that his work during the 1920s and 1930s formed the essential basis of his success.

Wells Coates represents the most difficult subject to discuss in this company for unlike the others he was not qualified as a structural engineer and had no direct experience of work with reinforced concrete when he launched his architectural career. His background, however, was firmly rooted in the engineering sciences, albeit academically, rather than practically, and weighted towards the mechanical sciences. He has been included because of his reputation as one of Britain's leading architects in the development of the Modern Movement, and because he argued, like Williams, that his credentials as an 'engineer' made him ideally suited to the business of architectural design. Moreover the vast majority of his buildings were made of reinforced concrete.

The following chapters have grouped these subjects into two distinct sections; Faber and Williams followed by Arup and Coates. This has been done for three reasons. First was the date at which they started their careers. Although of a similar age, Williams and Faber started their involvement in building much earlier than Arup and Coates and were already well established figures of Britain's first generation of concrete engineers when Coates and Arup began their work in the 1920s. This is significant because Arup and Coates always regarded themselves as being associated with a younger generation of designers. (Arup, for example, still regards Williams and Faber as having been 'old-fashioned British engineers'.) Second was their different backgrounds. Williams and Faber were both British and had undergone similar training - both for example gaining their practical experience as reinforced concrete designers within American specialist design firms operating in Britain. Arup, although born in Britain, was schooled and brought up in Germany and Denmark and was educated in philosophy at Copenhagen University before training as an engineer. Coates, with a connection to Britain through his Canadian nationality and war service, was brought up in Japan and then received his undergraduate engineering education in Vancouver before beginning his PhD at London University in 1922. This difference in background was not of far-reaching significance, except in the sense in which a foreigner in a new country often gains a deeper insight into its institutions and is less willing to accept established conventions. Moreover, in some circles, and particularly in architectural ones at this time, to be a foreigner gave an individual added prestige. This certainly helped Arup in his relationship with British modern architects of the period, many of whom automatically regarded any foreign engineer as superior to the native produce. The third reason for associating them in this way was the milieu in which they worked. Arup and Coates both attached themselves to the British Modern Movement and it was largely in this context in which they made their contribution to architecture. Faber had no connection with this movement and although Williams's work was revered by many British modernists, he personally had no involvement with its activities.

Before discussing the work of these designers in detail, the first section of this study will attempt to place their work in its technological context by describing in broad outline the development of reinforced concrete and its early assimilation to British architecture. This section will look first at the early development of reinforced concrete technology, concentrated for the most part in the latter half of the 19th century, and second on its application to building in the early years of the 20th century. The first part is aided by a number of publications which have concentrated on the 19th century pioneers of the material, supplemented by information from British patents. The second part will look more closely at the area these publications failed to examine in any depth, that is the assimilation of the technology. The final part of this section will examine an important observation drawn from this background information; namely the importance of commercial organizations in developing distinctive forms of reinforced concrete architecture and their impact on the development of the technology itself by concentrating on one firm - the Trussed Concrete Steel Company - and the particular form of reinforced concrete technology it promoted - flat slab construction.

The remainder of the study will consist of detailed discussions of the four designers and their work, with the ultimate objective of shedding light on two important themes: first, the importance of functionalism in the design of buildings where the structure formed the essential element of the architectural expression; and second, the significance of the engineer's role in this type of work, either as architect-engineer or as a collaborator with architects.

P A R T   O N E

THE EARLY DEVELOPMENT AND ASSIMILATION OF REINFORCED CONCRETE INTO BRITISH BUILDING

CHAPTER 1

THE EMERGENCE OF REINFORCED CONCRETE TECHNOLOGY

Early Developments

The history of reinforced concrete is both long and complex. Nevertheless a brief chronology of its development in various western countries is necessary to provide the historical background to its emergence at the beginning of this century as a new and potentially revolutionary building material.

Concrete, if defined as a matrix of stone aggregate bound together by a cementing agent, has a history almost as old as civilization itself. One of the earliest examples has been discovered in Yugoslavia, dated at 5000 BC.[1] It is known that the Egyptians used the material and following them the Romans, who used it throughout their Empire for all types of structures.

Reinforced concrete on the other hand does not possess so long a history but it is well established that the concept of using metal in concrete to reinforce structures was understood and applied, albeit unsuccessfully, by the Romans in a number of their most well known buildings.[2] Following the demise of the Roman Empire, concrete and to a lesser extent reinforced concrete, appear to have only been used in isolated examples of medieval building. Collins gives two reasons for its long neglect before its re-emergence in the 19th century;[3] first, the inadequacy of ordinary lime mortar as a cementing agent and second the conviction that it was not a respectable building material as it was so aesthetically inferior to others.

It is generally agreed that the economic upheaval which followed the French revolution provided the impetus for the development of new building materials in that country. This was necessitated by the lack of a brick building tradition in France caused by relatively sparse sources of fletton-type clays. The first pioneer of concrete construction to emerge in France was an enterprising labourer, Francois Cointreraux. His interest was aroused by a newspaper advertisement which asked for someone to work on the development of simple, cheap, rural, fireproof construction. Being familiar with the pisé method of construction, (ie a traditional technique common in the south of France of casting mud between timber shuttering) he undertook to develop a construction technique for concrete. The results of his experiments were published in 1786 and for his work he was awarded a gold medal by the French government. Unfortunately the implementation of his findings to building was cut short by the advent of war.

A number of French pioneers followed Cointreraux's lead but it was the director of a chemical factory in Paris, Francois Coignet, who made the greatest impact in the field. He too was familiar with the pisé technique and built on Cointreraux's work by first directing his attention to improving the quality of concrete itself, experimenting with various aggregates and mixes. He built a number of structures using the technique and in 1855 took out two French patents. Under the second of these patents entitled 'Emploi du Béton', he claimed the sole right to build monolithic concrete structures in France for the next fifteen years. In addition to these French patents, Coignet also took out a British patent in November of the same year. In the specification he described an elementary form of reinforced concrete floor:

'This new description of floorings is established by laying on the walls to support the flooring a certain number of iron stop planks, parallel to one another and reposing on the walls by their ends, so as to be completely supported by the whole thickness of the wall . . . but instead of iron planks I can establish iron rods at convenient distances apart one from the other, and traversing through and through the four walls supporting the flooring, so that these iron rods cross symmetrically one another and look somewhat like a chess board. These rods, being in shape of a screw and having a nut at each end, will prevent the walls from losing their perpendicularity.'[4]

From the information contained in this patent, Coignet could not be credited with inventing reinforced concrete, for he perceived the iron rods as providing butresses to the walls and not as a reinforcement system within the concrete. However, whilst in structural terms he had not realized the full potential of combining iron and concrete, in a wider sphere he foresaw the architectural implications of his work: On the same date as the above patent, following an exhibition of his work at the Universalle, he wrote:

'The reign of stone in building construction seems to have come to an end. Cement, concrete and iron are destined to replace it. Stone will only be used for monuments.'[5]

This prophetic view was no doubt reinforced by the widespread acclaim which accompanied the exhibition of a concrete boat at the same exposition. The boat had been built in 1847 by J L Lambot, who applied a cement concrete mixture to a mesh of iron rods. In an intuitive way Lambot had recognized the relationship between the iron and concrete, but lacking a technical background he failed to extend the concept to a wider context. He took out

French and British patents in 1855, and his specifications support the above view for he refers to his invention as

'a damp proof substitute for wood . . . consists of a network of metallic bars, rods or wires embedded in cement to form beams and planks'[6]

Another Frenchman who failed to recognize the full potential of his own work with concrete was Joseph Monier. He was a gardener, who in 1867 perfected a technique of producing reinforced concrete flowerpots for orange trees. However his importance as a pioneer in reinforced concrete was based on the development of his ideas by G A Wayss in Germany. Wayss, a Berlin engineer, had seen Monier's work at an exhibition in Antwerp in 1885. By this time Monier had extended his range of reinforced concrete products to include pipes and tanks, but it is generally agreed that he, like Lambot, lacking technical training, did not fully appreciate the full potential of his inventions. Wayss purchased Monier's patent rights and established in Berlin the 'Corporation for Concrete and Monier Construction' which built concrete structures all over Germany during the last two decades of the 19th century.[7] He is generally credited with developing a strong theoretical understanding of the material which complemented the constructive issues which were undertaken by contemporary French engineers.

It is noteworthy that whilst the French appear to have been given credit for developing the art of reinforced concrete, the man who is accepted as the inventor of the material in its recognizable modern context (at least to the British and Americans) was British. His name was William Boutland Wilkinson (1818-1902), a plasterer from Newcastle-upon-Tyne. His early occupation is not without significance to his later work in reinforced concrete, for plasterers had always used animal fibres or meshes of various materials to prevent cracking in their work. Clearly this principle is not so far removed from that of reinforced concrete, and therefore it is not surprising that someone of Wilkinson's background could build upon this concept and relate it to more fundamental structural issues. (This concept of preventing cracking is undoubtedly one which lay behind the work of Monier and Lambot.) His work on concrete was based on the development of portland cement by Smeaton and Aspdin.[8] After spending some time perfecting concrete paving slabs using granite chippings and portland cement he turned his attention to concrete building. On October 27, 1854, he left at the Patent Office his specifications for what was entitled "Improvements in one construction of fire-proof dwellings, warehouses, other buildings and parts of the same". In the specification he referred to a number of strips of hoop iron laid on edge and embedded in mass concrete at distances about two feet apart. He wrote:

'The distance may vary depending on the desired strength of floor; if set in a low position, the strips will act with more power as tension rods'[9]

In this quotation he was referring to curved ceilings, but in his section on flat ceilings he was more explicit about the tension function of reinforcement. In this he suggested using old colliery ropes embedded in fresh concrete with the ends formed into loops or splayed to prevent the rope moving in the concrete under load. The drawings in the patent specification show the ropes following the line of tension - (ie in the upper part of the concrete over the supports and lower in the beam at midspan.) Clearly he understood how to combine the different structural properties of concrete and iron. There are a number of examples of buildings erected using these principles, the most notable being a concrete house in Newcastle (1860) which was demolished in 1954.

1855 was therefore an important year in the development of reinforced concrete in Britain as it saw the publication of the three British patents described (Coignet, Lambot and Wilkinson). Each showed different methods of combining concrete and iron to produce homogeneous structures. It is surprising, considering the inventive nature of these patents, that the British patents which followed did not build upon the principles which they contained. Instead the patents relating to concrete in the following three decades concentrated on specialized interests, and in a sense this was a rediscovery of the basic concepts of reinforced concrete by working from first principles. These specialisms fell into three categories; shuttering systems for concrete walls, reinforcement for plasterwork and fireproof floors.

By far the most numerous, in terms of patents granted, were the specifications relating to shuttering systems. From 1860 to 1890 the Patent Office granted over twenty patents for such systems. However whilst these were important, particularly those for sliding shuttering and permanent shuttering using precast blocks or tiles, all were concerned with the construction of concrete walls, not frames, and none gave information on reinforcement or even about the need for it. Consequently as they were largely concerned with improvements in the mode of production of simple mass concrete walled structures, they contributed little to the science of reinforced concrete, as such, at this point in time.

The group of inventors working on the reinforcement systems for plasterwork, however, did contribute significantly to the technology by extending their work to include reinforcement of concrete structures. A good example of this 'follow through' can be seen in a series of patents by P Brannon between 1870 and 1874.[10] His first patent in 1870 (No 3398) was entirely concerned with a reinforcing mesh to plasterwork. However in his second patent in 1871 (No 2765) he extended the concept to building structures. It was entitled Fireproof Structures and in it he specified the application of a netting to a metal framework and a covering of concrete, containing within it a fibrous material to take the tensile stresses.[11] He intended using concrete with netting as a membrane to cover iron frame buildings. In 1874 he moved one step further, suggesting that for heavy bridge work the webbing should consist of wire rope or cable (No 2128). While this work could not be seen as an advance of Wilkinson's previous work it is noteworthy that by 1874 concepts of reinforced concrete were still emerging in Britain from individuals whose prime concern was improving techniques of plasterwork.

The third 'specialism' which received particular attention in Britain was that relating to fireproof floors. The problem of fire in buildings, particularly in industrial structures, provided the most important impetus to the development of concrete in Britain and abroad. Iron frame buildings with timber floors had proved a disastrous combination when subjected to fire; and an alternative to these materials had been sought. But inventors had not generally concentrated on entirely new structural systems. Instead they had directed their attention to the floors, for it was recognized that iron columns could be protected from fire by encasing them in masonry, terracotta or concrete. In the 1880s and

1890s large numbers of British patents, some from American sources, addressed themselves to this problem. The vast majority of them followed the lead established by James Frost in 1822, who used an arched form of concrete cast between iron 'I' beams.[12] In the last two decades of the century well over thirty patents were granted which specified variations on this basic theme. It is difficult to understand how so many similar patents could claim any originality whatsoever, but it has been suggested that the technique became so common that many were taken out, with minor adjustments to preceding ones to lessen the likelihood of legal suits by other patentees.[13]

However what is interesting about this latter group of patents is that a number of their authors, possibly aware of related developments, began to consider different and more efficient ways of combining iron beams and concrete. One of the most interesting was a system devised by Lee & Hodgson in 1885. Their patent specified a diagonal grid of overlapping, small section 'I' beams covered with concrete.[14] Although extravagant in its use of iron, it suggests a direct link between the 'I' beam and the concrete arch form of construction and the later development of reinforced concrete slabs. Another series of patents which could be classed as 'intermediate' were those that used wire, cable or chains between the 'I' beams, as reinforcement to the concrete. Patents using this technique were granted in Britain between 1894 and 1900. Two of the most interesting were of foreign origin. The first was by A L Johnson in 1895.[15] He was an engineer, later associated with the '<u>Patent Indented Steel Bar Company</u>' both in America and Britain. His patent specified wires slung between adjacent 'I' beams to follow the line of tension, and the whole encased in concrete. The second was by a Frenchman, A de Man, whose British patent was granted in 1898. The illustrations which accompany his specification show twisted wires attached to both top and bottom flanges of an iron girder. The concrete is shown cast around these wires in two horizontal sections, leaving a cavity in the middle of the floor. What is most interesting about this patent is his tentative suggestion for prestressing the wires or rods:

'For wider floor spans, the metal bars are put under tension by a lever which engages with the flange of the girder'[16]

The engineer who is credited with replacing the iron girders in this form of construction with rods of reinforcement in the lower portion of the ribs to take the tensile forces was E L Ransome (1844-1917). He was the son of Fredrick Ransome, the superintendent of Ransome and Sons Ironworks in Ipswich. Fredrick Ransome had himself been involved in the development of concrete, patenting a system for the production of hollow concrete blocks in 1866 (British Patent 1866 No 458). In 1870 his son emigrated to San Fransisco USA to manage the Patent Concrete Stone Company which was producing reconstituted stone. It was in the 1880s that he developed the floor in question, and in 1884 he took out a US Patent (No 305 226) for twisted square rods which he found to be stronger than plain rods.[17] By 1889 he had removed the arch form from his floor system producing the 'Tee' beam. Following this logical progression Ransome went on to develop a precast system of construction - known as the 'Ransome Unit System' patented in 1902.

It is uncertain what effect Ransome's US patents had in Britain for he did not take out any equivalent British patents before the turn of the century (with the exception of the British Patent, 1885 No 3965, relating to a shuttering system for walls). The only British patent which resembled Ransome's 'arch and ribbed' concrete floor was one taken out by W Orr in 1894.[18] Orr, like Ransome, retained the arch form but replaced the tension and compression flange of the discarded girder with hollow metal tubes. It must be concluded from the evidence available in the patent records up to 1900 that British designers, whilst working successfully on specific issues relating to concrete construction, contributed very little to the development of reinforced concrete technology as a structural entity in itself. This was in part due to the concentration on immediate requirements, (eg fireproof floors) and also due to restrictive legislation which discouraged the implementation of experimental techniques. A review of developments on the continent and in America reveals that the technology in Britain was at least ten years behind, permitting foreign competition to make inroads into practice here. For example Thaddeus Hyatt (1816-1901), a New Jersey lawyer set out to investigate, in a series of systematic tests, the best means of combining iron and concrete.[19] He built many beams containing varying quantities and distributions of bent bar reinforcement and tested them to find the best positions for resisting tensile stresses. Although an American, most of his work was conducted at Kirkaldy's laboratories in London. The results and conclusions of some of these tests are described in a book published privately in 1877 entitled '<u>An Account of some experiments with Portland Cement concrete combined with iron as a building material with reference to economy in construction and for security against fire in the making of roofs</u>.'

In the same year he took out his second British Patent (1877 No 2968)[20] which specified combining concrete with metal skeletons, using the metal to take the tensile forces, and the concrete to resist the compression force. Through these two publications it appears as though Hyatt began to regard the reinforcement as the tension members of a trussed system, thus anticipating modern practice. His British patent was far more advanced than any other emerging in the latter half of the century. Unfortunately he did not develop his patents commercially, a failing which was certainly not emulated by that other great developer of concrete technology, who also patented extensively in Britain, Francois Hennebique.

Hennebique (1842-1921) was primarily a building contractor operating in France. He was born in Neuville, Belgium and started his contracting business in 1867. He first used concrete in 1879 in the construction of a villa for a friend at Lomborzeide, where he decided to substitute concrete for the timber joists for fire resistance reasons. Recognizing the potential in concrete as a fireproof substitute for timber floors he began a twelve year period of secret research. His first French patent, in which he specified the use of round reinforcing bars with 'fish-tail' ends, was granted in 1892. This was followed by his invention of the cranked bar in 1897, the 'v' stirrup and 'Tee' beam in 1898.[21] He apparently claimed that he was unaware of research being carried out by his contemporaries in France and elsewhere until he read an American journal in 1892.[22] There is no evidence to support this claim and even if it were true, many of the ideas behind his patents had been conceived by others well before 1890. For example the 'Tee' beam had been developed by Ransome in America in

1889, and also in Amsterdam twelve years before Hennebique's patent of 1898. Nevertheless, it is generally agreed that whilst Hennebique may not have possessed the technical competence to develop the technology of reinforced concrete single-handedly, it was he who first brought together the fragments of concrete technology into one system of construction. But more important it was his great aptitude for business organization that enabled him to expand his enterprise and consequently his system of reinforced concrete throughout the western world. His importance to the development of reinforced concrete in Britain will be assessed in the following section.

It would be reasonable to assert that whilst British pioneers were working on various aspects of concrete technology in the latter half of the 19th century, they had not developed so systematic an approach to the subject as their contemporaries abroad. There are many reasons given for this failure, amongst them restrictive legislation, the vested interests of the British steel industry, and the general attitude common amongst the professions and builders that concrete was a poor, unreliable building material. However the fact that foreign entrepreneurs were successful here in the early years of the 20th century suggests that resistance from legislation and the steel industry was not as important as one is often led to suspect. The most probable reason is that expounded by Marion Bowley[23] who suggested that it was the conservatism of both architecture and engineering professions which prevented reinforced concrete developing as speedily here as it had in France. In the engineering profession it is argued that this conservative attitude stemmed from the great iron building tradition which had been established by

British engineers early in the 19th century. By the late 19th century this attitude had hardened, creating a suspicion of new materials and methods. It is indeed a fact thatBritish engineers resisted the introduction of steel as a replacement for iron well into the 1890s. It is not surprising therefore that engineers would be highly suspicious of reinforced concrete and this would almost certainly have had a consequent effect on the architectural profession, which was, generally speaking, less technically competent than its engineering counterpart.

The Application of Reinforced Concrete to British Building

The turn of the century marked an important watershed in the development of reinforced concrete in Britain. As has already been stated, one of the factors behind its slow acceptance in Britain was the generally held view that it was a poor material both aesthetically and structurally. In structural terms the fears of many designers and builders were well founded, as the quality of cement was so variable that the performance of the material was very much in question. Although Britain had led the world in developing Portland cement, up to 1900 there was no rotary kiln in the country which could produce a consistently good cement in large quantities. (The Rotary Kiln itself had been developed here by Ransome but was never adopted commercially on a large scale - the system being taken up by the Americans).[24]

In 1900 the recently-formed 'Associated Portland Cement Manufacturers' purchased the right to install rotary kilns in a number of Thames-side works. As a result of building these kilns the manufacturers were able to produce cement of a consistent high quality in large enough quantities to bring its price down to a level competitive with other building materials.

However whilst this development provided an important stimulus to the British building industry it was of greater assistance to a number of foreign firms who established themselves as concrete specialists in Britain about the same time. Their arrival here from 1897 onwards was the most important factor in the development and acceptance of reinforced concrete technology in Britain. Their motives were generally to protect their patent rights to various systems of construction and to achieve commercial success. Their influence on the development of reinforced concrete in Britain was substantial.

The first of these concerns was established by Hennebique in 1897 under the agency of Louis Gustave Mouchel. His 1892 French patents, which have already been mentioned, secured him a monopoly in Belgium and France. In the same year he discarded his contracting business and established himself as a consulting engineer. He believed this was a necessary step if he was to apply his patents more widely, for as a consultant he would be free from the profit-making suspicion directed at building contractors. Nevertheless in an effort to keep control over the contracting side of his commissions he affiliated a number of building contractors to his new enterprise, granting them concessions to operate his patents, whilst expecting them to observe his meticulous standards in return.

He recognized the need for publicity if his operation was to be successful, and to achieve this he adopted the tactics of new artistic or political movements by convening an annual congress (the first of which took place in Paris in 1897). He published a monthly magazine entitled '*Le Béton Armé*'; and adopted the slogan 'Puis a Incendies Desastraeux' - a phrase which was stamped on all the drawings leaving his office to highlight the fireproofing potential of the material. His ability in commercial organization proved immensely successful. In the first six years of his enterprise his contracts had doubled annually, and by 1898 his Paris office was working on 827 projects.[25]

The Hennebique system of reinforced concrete was first introduced into Britain in 1892 with a patent taken out by his British agent W P Thompson. The specification of the British patent referred to the:

'carefully determined combination of the characteristic properties of two substances of entirely different natures, which, while being suitably united, give, from certain points of view, results impossible to be obtained by means of any one of these substances of equal weight and of any form.'[26]

The drawing which accompanied the patent showed a 'Tee' beam floor, the beam having splayed sides and containing stirrups of hooped iron to diminish what Thompson referred to as:

'the tearing action which is exerted when the joists bend . . . placed at intervals according to the calculations.'[27]

This specification was later extended by Hennebique in 1897.[28]

In that year, Mouchel (1852-1908) established an office in Britain to operate the Hennebique system of construction. After resigning his position on the staff of the *Ponts et Chaussées*, under which he had been engaged on marine and harbour

works, Mouchel moved to Briton Ferry, South Wales, where he settled in 1875.[29] In 1885 he used the Hennebique system in the erection of a number of houses and industrial buildings in South Wales. The success he had with these commissions encouraged him to undertake introducing Hennebique's system of reinforced concrete to Britain. In 1897 he established an office in Westminster from where he directed a nationwide enterprise. His first principal works as Hennebiques's British agent were at Southampton where he built a river wall founded on Hennebique patented piles, and at Swansea where he applied Hennebique's main British patent of 1897 to the design and
(8) construction of the Flour Mill for Weaver and Company.[30] For the next seven years the development of reinforced concrete in Britain was dominated by the Hennebique construction method carried out under the direction of Mouchel. Indeed the term 'Ferro-concrete', used by Mouchel became the one of the most popular terms to describe the new form of construction. It was frequently used in the British press well into the 1930s, many years after it had been agreed to use the term 'reinforced concrete' to prevent unfair association with a particular firm of specialists.

This French invasion into the British building industry was soon followed by others, notably by Edmond Coignet and Armand Considere.

Coignet arrived in 1904 with a patent to protect his system of reinforcement. In his specification (British patent No 24371) he described how the main bar members and stirrups were to be wired together before being lifted as a single unit into the shuttering. For the beams he suggested that the stirrups could be oblique, an idea which he extended in his later 1906 British patent No 14693.[31] The 1904 patent coincided with the establishment of Coignet's London office by W G Workman, his British agent, and the building of their first structures in Britain, multi-storey tobacco warehouses beside the Avon near Bristol. This was followed in 1905 by some warehouses at Rainham, Essex, for Messrs Fields.[32]

Messrs Considère Constructions Ltd was established in Britain in 1908. This was six years after Considère's first British patent (1902 No 14871) which specified the use of spiral reinforcement for reinforced concrete in compression - a system which became universally popular. The company's first British structure was a 750 ft long multi-span bridge in North London, with seventeen spans of 42 ft 9 in each. Their first important building was a Furniture Depository for the Pall Mall Deposit Company in 1910.[33]

The French were by no means the only pioneers of reinforced concrete to make inroads into the British building industry in the first decade of the 20th century, although most publications tend to suggest otherwise (possibly in an effort to uphold the common view that modern architecture - both its technology and style - came to England from the continent). The Americans also provided an enormous input through a number of subsiduary firms, patenting various types of bar reinforcement, at about the same time. One of the most successful, and one which had a strong architectural interest was the Trussed Concrete Steel Company of America. The company was formed in the United States by

Julius Kahn in 1891.[34] Kahn was the third of eight children who had emigrated with their German parents from Luxembourg to Detroit in 1880.[35] He had studied engineering at the University of Michigan in the 1880s, and in the course of his studies had invented what became known as the "Kahn Trussed Bar". The bar was designed to integrate the functions of tensile and shear reinforcement and improve the adhesive bond between concrete and steel. It could be of several alternative shapes, but that which came into common usage was a square bar, with the diagonals of the square placed horizontally and vertically. Along the horizontal diagonal were fins which could be cut, slit and bent up at 45° to provide stirrups connected to
(3) the main body of the bar.[36] An American company was formed to extend the use of patents of the bar throughout the country and ultimately throughout Europe. Many other patents were lodged, most of them concerned with other types of bar and reinforcing mesh.[37]

The eldest of the Kahn family was the architect Albert Kahn (born 1869) who had started his architectural career at the office of Mason and Rice in 1884.[38] At the time of the formation of his brother's company he was touring Europe on a $500 travelling scholarship he had been awarded by the American Architect and Building News. He started his own practice in 1896 in partnership with Nettleton and Trowbridge. It was not until 1902 that his new firm 'Albert Kahn Architect, Ernest Wilby Associate' began effective collaboration with his brother's firm the Trussed Concrete Steel Company, a collaboration which resulted in the most advanced examples of industrial architecture in America. In 1906 Moritz Kahn, sixth child of the Kahn family, came to England to negotiate the sale of the Trussed Concrete Steel Company's patents. In that year he took out a number of British patents in the name of his brother, Julius, and began to build up a subsiduary organization here. In 1907 the Trussed Concrete Steel Company of England was registered as a British company and Moritz was retained as its managing director until 1923 when he returned to the United States to become an associate of Albert Kahn's architectural firm.[39] The English company was very successful, particularly in promoting reinforced concrete for industrial building in association with a number of British architects. (Some of these will be examined later.) By 1926 the company had completed 4,000 structures in Britain and had assisted reinforced concrete work in a further 30,000.[40]

Another American company was established in Britain in 1906 on similar lines to the Trussed Concrete Steel Company. This was the Patent Indented Steel Bar Company formed to exploit a patent by A L Johnson, a civil engineer from Missouri.[41] His 1904 patent, like the Kahn patent of 1906, used the design of the bar as the basis of the invention. The bar in question was designed to provide a secure fixing to the concrete by indenting the bar along its length. It was square in section and was indented so as to give the appearance of a series of staggered cubes welded together.[42]

There was a distinct difference between the organization of the American and French firms established in Britain. The American firms were primarily interested in selling a patented form of reinforcing material. They produced the bars, mesh etc. and provided an extensive design service to their customers, if required. They did not insist upon their own engineers' involvement in the design and supervision of structures, although in the first three decades of the century they were, in fact, extensively used. French firms, on the other hand, followed general continental practice in endeavouring to retain all rights to design and supervise the structures which used their patents.[43] As patents generally became less enforceable, particularly when regulations laid down specific guidelines for engineers using reinforced concrete, these organizations slowly changed their functions. The Americans continued to act as suppliers while reducing their design rôle to that of an advisory function, whilst the French firms became conventional consultant engineering practices. However it was many years before British engineers became entirely competent in using the material without the assistance of such specialists. In 1910, the Institution of Civil Engineers set up a Committee on reinforced concrete to prepare a report. The committee's interim report in the same year revealed that out of six engineers questioned, three always employed specialists to do the reinforced concrete work, three sometimes did so. As the engineers questioned were called to give evidence to the committee because of their known interest in reinforced concrete, they must have been representative of the state of the art. It may be inferred, then, that in 1910 the civil engineering profession in Britain was generally incapable of using the material with any pronounced degree of proficiency.[44]

Professional Institutions and the Reinforced Concrete Specialist

The development of reinforced concrete in the early years of the 20th century in the hands of foreign specialists presented both the established architectural and engineering professions with two important questions - one, how to regulate the use of a material which neither profession understood sufficiently well, and two, what form of relationship should they encourage between commercial ventures and their own members?

The Royal Institute of British Architects (R.I.B.A.) was the first institutional body to enquire into conditions for the use of reinforced concrete in building structures, by its formation of a Reinforced Concrete Committee in 1906. The reasons behind the initiation of this enquiry were undoubtedly the recent arrival of new foreign specialist firms, combined with the lack of government willingness to produce effective legislation to control their products. This was directly contrary to the situation in France where a government commission had been established in 1900, under the chairmanship of Armand Considère, to produce legislation containing rules for the design of reinforced concrete, which was published and made legally binding in 1906. Having failed to persuade the British Government to adopt a similar position the First Commissioner of Works, Sir Henry Tanner, asked the opinion of the R.I.B.A. As a result the Reinforced Concrete Committee was formed comprising representatives of the War Office, the Incorporated Association of Municipal and County Engineers, the District Surveyors Association and the Institute of Builders. It was chaired by Sir Henry Tanner himself and its vice-chairman was Professor W G Unwin, a civil engineer who in 1911 became president of the Institution of Civil Engineers.[45] It is notable that this Institution did not cooperate with this committee formally, establishing its own enquiry in 1910.

The Committee's First Report was published in 1907, recommending a number of rules applicable to the design of reinforced concrete. Although is had no legal standing at this stage, most of the specialist firms naturally feared that its publication heralded some form of legislation. They were for the most part hostile to this possibility, fearing that it would reduce the strength of their patents and open up reinforced concrete design to more generally qualified engineers who could ultimately supplant their role. Moreover they argued that legislation would greatly retard the development of the technology for at that time they were prepared to take financial responsibility for the implementation of new techniques, and legislation would prevent them from continuing this practice. (Hennebique used this argument in 1900 in his opposition to pending French legislation.)[46]

It was probably in an effort to resist this possibility that a circular was issued in 1907 inviting the specialist firms to join together to protect their interests. However professional architects and engineers, recognizing the potential threat of an exclusive trade society perpetuating and extending various patented systems, requested Edwin O Sachs (Chairman of the British Fire Prevention Committee on Concrete 1906) to convene the nucleus of a more widely based professional society.[47] The result of this was the formation of the Concrete Institute in 1908, the forerunner of the Institution of Structural Engineers. Its initial membership was 200, and included engineers, architects, public officials, manufacturers, specialist designers and contractors, all of whom had interests in the material. Sir Henry Tanner took the key position of Vice-President of the Institute, in addition to his leadership of the R.I.B.A.'s committee.

In 1911 the R.I.B.A. asked this new institute to nominate two representatives to its own committee. In addition the L.C.C., which under the 1909 General Powers Bill was proposing to make regulations dealing with reinforced concrete construction, was also asked to send representatives. The Committee then changed its name to the "Joint Committee in Reinforced Concrete" and proceeded to revise its First Report which it reissued in 1911. It was an extensive report dealing with materials, permissible stresses, loadings, bending moments, reinforcement details and methods of calculation. It attracted widespread attention, due mainly to the collaboration of the L.C.C. and the prospect of the findings being implemented by the council. The report was comprehensive and recommended a method of calculation that had been established by the theoretical work of Tedesco and Chistophe in France at the Ponts de Chaussé. Both Coignet and Considère had assisted in this work and the latter's findings on helical reinforcement for concrete columns were also included.

In November 1911 the Building Acts Committee presented draft regulations, largely based on this Second Report, to the L.C.C. for approval.[48] Disquiet amongst some sections of the concrete industry was voiced by Hennebique's firm through the pages of its trade journal Ferro-concrete.[49]

Its main objection was the method of calculation, for each specialist firm had developed distinctive methods of its own and objected to having an alien method thrust upon it. (no doubt the Considère Construction Company and Edmond Coignet's firm had few objections as most of the regulations proposed were based on work they had developed in France.) Ferro-Concrete argued that concrete had developed along empirical lines and needed not to be based on the post-rationalized theoretical approach that was being proposed. Arguments continued for some time with the promoters of the proposed legislation claiming that Ferro-Concrete's objections were due to the fact that its engineers, working under Mouchel, were designing structures with lower permissible stresses than those included in the draft regulations.

However such objections had little effect. The Concrete Institute itself was generally enthusiastic about the prospect of regulations, believing they would encourage the wider acceptance of reinforced concrete by engineers outside the ranks of specialist firms. And because the regulations were not directly included in an Act of Parliament, but were made independently by the Superintending Architect under the provisions of an Act, it was felt that they could be easily changed to respond to developments in technology. The draft regulations were sent to the Surveyors Institute, the Institution of Civil Engineers, the R.I.B.A. and the Concrete Institute for additional suggestions. They were finally brought into effect in 1915, but had little impact until after the war when reinforced concrete became widely accepted as a viable building material. Crown buildings, gas companies, dock companies etc were exempt. Moreover they applied only to frame buildings and not to monolithic structures.

Quite apart from the issue of regulations, the reinforced concrete specialist engineering firms were at this time voicing concern about the relationship between themselves and the professional designer - usually the architect. Unlike the professional relationship which had developed between architect and consulting engineer, architects and engineers themselves generally treated the specialist firm as subcontractors - often inviting each firm to tender for the structural elements of their designs, requiring from each a price and detailed drawings. This was convenient to the architect for it frequently meant that he could dispense with the services of a consulting engineer, even for supervision during the construction process, and also payment to the specialist in this arrangement was made not from the client but through the contractor.

The specialists found this most unattractive for three reasons. First it involved each firm in a large amount of work for a contract, or even a tentative contract, which would frequently not reach fruition. Consequently their costs had to be added to the contracts in which they were successful - thus increasing the price of reinforced concrete structures unnecessarily. Second the practice of treating the specialist as a nominated subcontractor, with payment made through the general contractor, bound him financially to the contractor whose work he was commissioned to supervise - an illogical situation. And third, the fact that they were brought into the design process when the design of the building had been finalized by the architect, prevented them from advancing their own views on the design which invariably meant that the architecture was conceived as a separate entity from the structure.

In an article to the journal Concrete and Constructional Engineering, the representative of a French firm operating here, Lucier Serraillier, raised these three issues. He requested that architects select only one firm at the outset and treat its representatives as colleagues and not as nominated sub-contractors. As to how the specialist, in proper circumstances, could aid the production of good concrete architecture he wrote:

'We are but on the threshold of what may be accomplished in the outward expression by form and colour of the new material. Here is the architect's opportunity, and far from a conflict of interests between him and the specialist, we discover rather a community of interests in the design and execution of structures which combine beauty with utility and practicability.'[50]

It was not until 1915 that the council of the Concrete Institute appointed a committee to report on the relationship between architects and the specialist engineers. Sir Henry Tanner was again elected chairman. It did not report until after the war.

In the report much emphasis was placed on the historical development of the building industry, and continual specialization brought about by scientific development. The first stage of this specialization had been the emergence of an engineering profession in the 18th century, followed by the profession of quantity surveying. Both developments were presented as inevitable, as too was the further specialization of the engineering profession into iron and steel, reinforced concrete, and mechanical services. The question the report addressed was how the architect could co-operate with these specialist functions, particularly those relating to reinforced concrete. The report identified two groups -

first the specialists whose work formed an integral and essential part of the structure "such as steel framework, or, in a stronger degree, reinforced concrete construction",[51] and second, those concerned with additions to the finished structure - essentially services. The committee was of the opinion that the work of the first group should not be subject to competitive tender. In addition it was argued that if the architect was to properly integrate this work then:

'his knowledge should be much more than superficial . . . . The architect in these days must be a capable organizer, but there must be no danger of his degenerating into an organizer solely.'[52]

It was recommended that the architectural profession, as a first step, should follow the example of the American Institute of Architects (A.I.A.) by insisting that the client pay an additional percentage on the design and supervision of work undertaken by these specialists in the first group. This would allow more collaboration between architect and specialist engineer. In addition,the committee recommended eight general points covering the tasks the specialist should adhere to in the design and supervision of his work particularly in relation to the architect's duties and responsibilities. Unfortunately the R.I.B.A. decided not to consider the report. Thus while the institute was keen to produce rules governing the design of reinforced concrete structures it was not willing to allow its members to collaborate effectively with the engineers of specialist firms.

This contractual separation between the professional designer and reinforced concrete specialist inevitably hindered the development of reinforced concrete as a material for architectural use in Britain and even further retarded the emergence of forms of architecture which were responsive to its peculiar characteristics, a situation that was exacerbated by the generally poor image that architects had of the material.

Nevertheless the specialist firms did make significant inroads into the field of British architectural design, either working on their own or in collaboration with a small number of interested architects before the end of the First World War. For the most part their contribution was a sporadic one and it can only be properly assessed by studying a selection of isolated examples. Such examples tend to fall into one of two groups. First, those which were technically advanced yet provided little influence on the architectural expression because their structures were concealed behind traditionally detailed architectural veneers; or second, those buildings whose appearance, either consciously or by chance, responded to the unique qualities of the material. In general, the latter are to be found amongst industrial structures whose clients regarded aesthetic issues to be of little importance thus allowing designers to be innovative in their use of the material. In such situations architects could allow their specialists a degree of freedom in the design, in the safe knowledge that the resultant buildings would not be considered as "architecture" by contemporary architectural critics. It is for this reason that most of these buildings were only reported in the engineering press despite their architectural significance. The former on the other hand tend to be concentrated in non-industrial, civic buildings whose architects were enthusiastic to use reinforced concrete for reasons of expediency but were unprepared to allow the resulting structures to have any pronounced influence on the architectural expression. Unlike industrial buildings, they tend to have been reported in contemporary architectural journals but with minimal discussion on the technical issues.

In the midst of this haphazard development there was one particular specialist firm,which in addition to working on a wide range of projects falling into both of the above categories, pursued its own "house-type" of concrete architecture in association with a small number of British architects which it engaged as design consultants. The firm was the Trussed Concrete Steel Company whose parent body was the American firm of the same name. Its objective was to promote its patented reinforcement systems and structural design services in Britain by introducing into this country specific types of concrete buildings and patterns of working that had proved to be successful in America. Both in that country and in Britain the company's simple objective was commercial success. An important part of the company's strategy for achieving this success was to produce distinctive, well designed concrete buildings which would themselves advertise the virtues of reinforced concrete, and specifically its own particular structural systems, from both a functional and visual point of view. It was primarily directed towards industrial buildings because it was in this area that the company recognized its most important market. There were three reasons for this. Firstly, for sound practical reasons the reinforced concrete frame could be shown to be ideal for multistorey factory buildings. Not only was it a cheap and fireproof form of construction but by using frames instead of loadbearing external walls, factory owners would be able to provide a maximum admission of daylight into their buildings. Secondly, unlike non-industrial building, the structural problems of large factory units tended to be very similar, despite their differing functions, thus lending themselves to the production of a distinctive "house-type" which could readily be associated with the Trussed Concrete Steel name. And thirdly, because factory buildings had rarely been considered to be worthy of aesthetic consideration, particularly in Britain, it was evident that a company producing a visually pleasing and distinctive range of factory buildings would be certain to attract a large amount of publicity.

There is little doubt that the company was immensely successful in introducing these American concepts and built forms into Britain. It is hardly surprising, however, that its contribution to the development of British architecture, and specifically concrete architecture, received very little attention in contemporary architectural criticism and in later historical accounts. For even though the company's products form an important part of 20th century British architecture, architectural criticism has always contained a snobbish aversion to such blatant commercialism and particularly if its origins were American. This can also be noted in the history of the technology itself, where one often finds a concentration on the success of individual pioneers in preference to that of anonymous commercial organizations whose important developments in various techniques are generally overlooked or undervalued because of their commercial objectives.

In an attempt to redress this balance the following chapters will concentrate on two specific areas in which commercialism, particularly in its American forms, can be shown to have made important contributions to the development of reinforced concrete technology and its application to British architecture. The first will look at one specific company - the Trussed Concrete Steel Company; the second on the emergence of one specific branch of reinforced concrete technology - flat slab construction.

Inevitably, such a concentration will inhibit any broad survey of more general developments in Britain up to 1919. In terms of the technology, for example, important pioneering activities in pre-cast concrete construction and more advanced reinforcement systems will be omitted.[53] Moreover, a concentration on the work of one American company will preclude detailed analysis of other important contributions made by many more firms of both continental and American origin. Nevertheless it is hoped that by relating some examples of the Trussed Concrete Steel Company's work to comparative buildings by other specialists it will at least be possible to indicate the much wider field of activity.

CHAPTER 2

THE TRUSSED CONCRETE STEEL COMPANY

Origins and Early Work in the United States of America

The Trussed Concrete Steel Company was formed by Julius Kahn of Detroit in 1891 primarily to exploit his patented reinforcing bar - "The Kahn Trussed Bar". Three years later his firm was aligned with his brother's architectural practice - Albert Kahn Architect, Ernest Wilby Associate.[54] This association was to prove immensely successful, particularly in the field of industrial architecture. Both brothers recognized a great potential market for reinforced concrete in industrial building and it was in an effort to capture as much of this as possible that they initiated their collaboration. Their intention was to provide clients with a well integrated architectural and engineering design service and produce high quality products that would provide both their firms with good advertisement and further commissions.

The client who provided them with their first important industrial scheme was the car manufacturer Henry Joy in 1905.[55] In 1902 Joy had been influential in helping the Kahn brothers acquire their first joint project - the 'Engineering Building' at the University of Michigan, a traditional classical building with an 'L' shaped plan form.[56] It was shortly after the completion of this building that Joy became the manager of the Packard Motor Company and engaged the Kahn brothers to undertake the design of a new factory complex comprising ten separate buildings.

Study of the first nine of these buildings reveals how in the early stages of their collaboration, Albert Kahn found it difficult to depart from the classicism of his architectural education. These buildings, although using reinforced concrete frame techniques for their structures, were each encumbered with classically detailed facades and in their massing they were reminiscent of the Yorkshire mill buildings with which Kahn's English partner, Ernest Wilby, was well acquainted. In addition, instead of being planned around the functional priorities of the manufacturing process, the whole site was laid out around the axial precepts of classical planning.

[1] However, a noticeable difference emerged in their tenth building on the same site. Whilst it conformed with the classically orientated site layout, its reinforced concrete frame was simply expressed on the facades with each bay infilled with sill-height panels of brickwork and glazing above. This represented a departure from the design approach adopted for its predecessors, for it conveyed none of their architectural pretentions. Indeed so sharp was the contrast between this and other buildings on the same site that one is persuaded that its stark utilitarian quality was to a large extent the responsibility of Julius Kahn, with Albert providing little input into the design. Whatever role Albert Kahn played, however, it is reasonable to conclude from this polarized approach to architectural design at Packard's that at this time the Kahns were not particularly successful in integrating their technical and aesthetic expertise in built form.

Despite such problems the successful completion of one of America's

first purpose built car manufacturing complexes earned Albert Kahn a reputation which led to many other commissions of a similar nature. The next arrived in 1906 when his firm and the Trussed Concrete Steel Company were asked to undertake the design of another car manufacturing plant for the Geo N Pierce Company, Buffalo, which was to house the production of the Great Arrow Car.
[2] Study of the buildings the Kahns erected there reveals three important advances on their earlier work at Packards.

First was the decision to site and plan the main buildings around the organizational requirements of efficient production techniques, rather than on purely visual lines. Second was Julius' improvement of the structural frame system to allow much greater areas of glazing. And third, and most important, was their combined attempt to produce visually pleasing architectural forms which did not attempt to disguise the structure, and did not permit the basic economics of the structural frame to dominate the elevational treatment. Instead the design approach appears to have been to articulate the main structural components to produce well-proportioned facades, and to restrict architectural decoration to positions which would highlight certain key elements of the structure. In this way the completed buildings were able to combine a modernist use of concrete frame and glass with traditional classical proportions. To achieve this it was considered perfectly reasonable to increase the size of some of the external columns for "architectural effect".[57]

Thus at the Geo N Pierce plant the Kahns began to produce buildings which, whether they were aware of it or not, respected the tenets of early modernism by their acknowledgement of the reinforced concrete frame as the most important ingredient of the architectural expression.

The individual who stimulated the further development of this modernist tendency in the Kahns' work was Henry Ford. Impressed withtheir work at Packards and Pierce, Ford commissioned them in 1908 to undertake the design of his new car plant at Highland Park,Detroit, to house the production of his latest - and what was to become one of his most successful products - the Model 'T' Ford Car. Ford was one of the most innovative of car manufacturers and pioneered many revolutionary production processes. He wanted his new buildings not only to be 'tailor made' to suit these processes but to possess an architectural quality that would reflect the dynamism of his firm and its products. He saw reinforced concrete as not just an ideal building material for structural use in industrial building, but as a material which, if used with skill and imagination, would provide him with the image he desired. In functional terms there were three other important criteria that formed part of Ford's brief to Albert Kahn. The development should as far as possible consolidate all the major operations within one built enclosure. It should accommodate the gravity-chute method of production, which meant that the main assembly process took place at ground floor level with parts and sub-assemblies fed down chutes from upper floors onto the production line. And, the building should provide high levels of illumination by natural means. Ford was obsessed with this latter requirement, commenting at one point: 'You know when you have lots of light you can put machines closer together.'[58]

In the first completed building at Highland Park (1909) the Kahns accommodated all these requirements within a remarkable concrete

[3] framed structure in which classical trimmings were reduced to an absolute minimum. Whereas at Pierce the arrangement and size of the exposed concrete frame was articulated to produce classically well-proportioned facades, at Highland Park architectural interest in the extensive elevations was created by the frank expression of the concrete frame (the two principal elevations were 860 ft long and four storeys high). Also omitted was the sill height brickwork panels within the structural bays. Instead large steel sash windows, imported from England, completely infilled each bay from floor to ceiling thus externally highlighting the framed structure and internally producing well lit spaces which led its inhabitants to name their new building 'Crystal Palace'.[59]

There were still, however, traces of Albert Kahn's classicism successfully incorporated into the modernist facades. These were, for the most part, restricted to the ground floor, cornice,
(7) staircase blocks and corners to the building. Their integration with the frame and glazing can be shown to have been of some significance, for their inclusion formed part of the Kahn 'house-type', which was reproduced on numerous occasions, particularly in Britain where it became known as the 'Kahn Daylight Factory'.

At ground floor level the size of the columns was increased by their encasure in brickwork, a device adapted from Renaissance architecture to give the base of the building a more substantial appearance. The cornice was decorated with a series of simple dentils to provide a visual termination to the concrete frame at the top of the building. More important however was Kahn's decision to break up the repetitive rhythm of the frame with occasional service and staircase blocks, faced in brickwork with smaller window openings.

At the corners, these blocks of brickwork were given added emphasis by their slight projection beyond the building line and their vertical extension above roof level. These were used, even if they contained no subsidiary elements such as staircases, to prevent the visually disturbing illusion of weakness which would have resulted had the concrete frame been simply returned around each corner. These 'corner blocks' were one of the most characteristic features of British industrial building which the Trussed Concrete Steel Company produced in the early 1920s, particularly those designed in collaboration with Thomas Wallis.

To the casual observer these classical features at Highland Park may appear to spoil the overwhelming impression of modernity that its elevations exhibited. However it can be argued that they were not as heavily influenced by classicism as those contemporary German structures which have generally been regarded as the most significant examples of early modernism in architecture. (For example Behrens' Turbine Factory, Berlin 1909; and the Gropius and Meyer factory for the Werkbund Exhibition of 1914.) Indeed in many respects, expansive areas of concrete frame and sheets of glazing at Highland Park provide much better illustrations of the embryonic beginnings of modern architecture than these German examples.[60] The Kahn brothers' American work was without doubt of much greater significance, in respect of British developments, for it was this particular approach to industrial architecture that they introduced into Britain at the time of the First World War.

The Trussed Concrete Steel Company of England

Two years before Albert Kahn began work on the Highland Park complex a younger member of the Kahn family, Moritz Kahn, was dispatched to London to take out a number of British patents in the name of his brother Julius Kahn. These included, among others; the 'Kahn Trussed Bar' and the 'Hy-Rib' metal lathing reinforcement.[61] In 1907 the Trussed Concrete Steel Company of England was formed with Moritz Kahn as its managing director.[62]

The date roughly coincided with the arrival of many other foreign specialist firms in Britain.[63] One notable exception was the French, Hennebique firm of L G Mouchel and Partners Ltd. It had already become a British company in 1895 and had by 1908 established itself as Britain's leading specialist in the design of reinforced concrete structures, operating a system of licensing contractors to carry out 'ferro-concrete' construction to its specifications.[64] One of this firm's earliest structures is generally regarded as Britain's first reinforced concrete framed building. This was the flour mill
(8) for Messrs Weaver & Co at Swansea, (1897), a remarkable structure for its early date, one of its most striking features being a series of heavily loaded cantilevers along one of its elevations.

By the time Kahn's new firm was established Mouchel had already been involved in thousands of reinforced concrete contracts in Britain.[65] Possibly the best illustration of Mouchel's important reputation in Britain at this time was his firm's involvement in the structural design of what was referred to in contemporary journals as Britain's
[4] first skyscraper - the 'Royal Liver Building' in Liverpool. The significance of this building was that it was the first important British example of reinforced concrete used in a purely architectural, as opposed to engineering, context. It was designed in collaboration with the architect Aubrey Thomas who designed a

(10) simply detailed masonry veneer to enclose the eleven storey concrete framed structure. At the time of its design and construction other examples of prestigious civic architecture were only just being accommodated to structural steel framework techniques.[66] For Mouchel, therefore, to undertake the structural design of this building in reinforced concrete bears testament to the reputation of his firm at this time. Such was the competition, therefore, that Kahn faced when he launched the <u>Trussed Concrete Steel Company of England</u> in 1907.

It did not take long, however, before his new company was competing on terms with the Mouchel practice. Between 1911 and 1913 it
[5] acquired numerous commissions. Of these the 'YMCA Building' in Manchester stands out as its most accomplished. Built on a restricted city centre site, the complex plan form required a highly intricate structural solution. Study of the building clearly demonstrates the advanced state of the company's technical competence at this early date, the completed building containing many outstanding structural features including reinforced concrete
(15) walls designed to act as 'I' beams, and the feat of supporting a swimming pool on the top floor of the six storey structure. On purely technical grounds the structure of this building was far more impressive than the highly publicized work of the Mouchel firm at the Liver building. Moreover, unlike the framed structure of the Liver Building, which was concealed behind a simply detailed granite veneer, the external walls of the YMCA building were built of insitu concrete cast behind a permanent external shuttering of terracotta slabs.

Unfortunately, however, the Edwardian styled elevations completely disguised the important structural features of the building even though it represented one of the earliest examples of British architecture using reinforced concrete for external walls. In stylistic terms it could therefore be argued that the Liver Building was more advanced in as much as its masonry veneer and fenestration were sympathetic to the structural framework it enclosed.

Although the traditional architectural expression of the YMCA building was undoubtedly the responsibility of the architects; Woodhouse Corbett and Dean, there is evidence to suggest that the Trussed Concrete Steel Company agreed with this approach to design for non-industrial building at this time. Not only did the company have American precedents for disguising the concrete surfaces of civic buildings, in the non-industrial work of Albert Kahn, but in a lecture Moritz Kahn delivered to the University of Sheffield in 1908 he expressed his own view that for many buildings exposed concrete surfaces were visually unsatisfactory. A contemporary journalist, reporting on Kahn's lecture, agreed, writing:

> 'We do not think that the higher possible forms of architectural expression can ever be evolved from so artistically uncompromising a material."[67]

Even in the company's industrial work before 1914 a similar approach was usually adopted. In these schemes, as in the YMCA building, the company was employed as a nominated subcontractor, and in such situations it was inevitable that the architectural preferences of its architect-employers would prevail. Two examples which illustrate the different types of architecture resulting from the architects who employed the firm on industrial schemes before 1914 are the 'Harrod's Depository' (1912) and the 'Factory for the Gramophone Company' at Hayes, Middlesex (1912).

[6] In the former, the architect, W G Hunt, enclosed a reinforced concrete frame behind brickwork detailed facades decorated with alternating bands of different coloured bricks, and including conventionally sized windows in each of the structural bays. The only exposed elements of concrete were a series of cantilevers
(18) over the loading bay, very similar to those used by Mouchel at Swansea, but notably hidden at the rear of the building. (It is perhaps noteworthy that contemporary photographs of this building concentrate on this rear elevation.)

In the latter example, the architect was the 'Arts and Crafts' designer Arthur Blomfield who had earlier expressed his own view that concrete should not be disguised in any way.[68] Architectur-
(21) ally, however, the building he produced with Kahn's engineers at Hayes was disappointing. As in the American company's tenth building for Packard, there appears to have been no attempt on the part of Blomfield to exercise any architectural control over the elevational design. The rather crude exposure of the concrete frame in combination with panels of brickwork and glass reinforced the commonly held view in architectural circles that concrete was only appropriate for utilitarian engineering projects.[69]

In these and many other buildings, for which the company designed structures, its engineers were unable to have any pronounced influence on the resulting architecture by virtue of the fact that they were employed as subcontractors to architects who had their own architectural preferences. Moritz Kahn realized that if his company were to produce its own distinctive 'house-type' of

concrete industrial architecture it would be necessary to forge an alliance with one particular architectural practice, thus recreating in Britain the successful collaboration of its American parent company with Albert Kahn. Consequently in 1914 he approached the English architect Thomas Wallis with an offer of formal collaboration. He had worked with Wallis previously in 1909 on the building of an extension to the Town Hall at Stoke-on-Trent, a commission that Wallis and his then partner, Bowden, had gained as the result of a competition. Apart from the success of their early collaboration at Stoke, it was undoubtedly Wallis's ability as a classical designer which attracted the attention of Moritz Kahn for it was an attribute which his brother, Albert, had successfully assimilated to industrial building in America.[70]
Wallis, born in 1873, had trained in a number of architectural practices, including that of Sydney R J Smith - the architect of the Tate Gallery. Although he had not undertaken any formal architectural education, he developed a strong preference for classical architecture and the competition drawings he and Bowden entered between 1908 and 1914 reveal how successfully he could design large public buildings using the classical style.[71]

However, he had no previous experience in industrial architecture and it was for this reason that Kahn arranged for Gilbert, an American industrial architect, to join Wallis in partnership in Britain. For some reason, Gilbert never arrived and so Wallis began his collaboration with the company alone although the name Wallis, Gilbert and Partners was retained (and is still used today).

It was unfortunate that the initiation of this alliance coincided with the outbreak of war. Throughout its four year duration building work was severely restricted and most concrete specialists began to concentrate on the development of concrete ships for the war effort, the Trussed Concrete Steel Company undertaking research and development work in Liverpool. Nevertheless, between 1914 and 1918 Kahn and Wallis began work on the design of a number of factory units to be built after the war, and compiled a book, under Kahn's authorship which was to provide publicity for his company and the type of industrial architecture that he and Wallis were hoping to promote when the war ended.[72]

This book provides invaluable information on the motives of Kahn's firm and clearly illustrates the important influence of existing American work by Albert Kahn on the proposed British work by Wallis. Published in 1917, and entitled The Design and Construction of Industrial Buildings, the book contained many illustrations of American and British building executed or proposed by the Trussed Concrete Steel Company in both countries. With the exception of
(21) the Gramophone Company building by Blomfield and two similar structures erected in Glasgow, all the remaining British examples
(30) to (35) were sketch designs by Wallis, illustrated with plans and perspectives. Most of the American examples, which were by far the most numerous, were photographs of car factories designed by Albert Kahn. The similarity between these American examples and Wallis's proposals is unmistakable, each using the reinforced concrete frame with extensive areas of glazing in combination with classically detailed robust corner blocks and traces of classical decoration to highlight certain structural features.

Although no specific references were made in this book to the Trussed Concrete Steel Company nor to its British alliance with the Wallis practice, reference to Kahn's preface clearly demonstrates the importance of the company's American work and Wallis's role in recreating American successes in Britain:

'My experience in the construction of such buildings (factories) having been largely obtained in America, I have naturally found it convenient to my purpose to give a preponderance of illustrations of typical American factories; at the same time, some noteworthy English examples are included and with respect to several of these I wish to express my indebtedness to Mr Thomas Wallis MSA if the firm Wallis, Gilbert and Partners. To him also my thanks are due for the assistance he has given me in compiling this book.'[73]

The book itself appears to have had two major objectives; first, to encourage industrialists to treat their potential factory buildings as works of architecture, worthy of detailed design consideration both functionally and aesthetically; and second, to promote reinforced concrete as the only viable material for their construction. In an effort to promote this Kahn, in his chapter on various methods of construction, presented statistics of relative costs which left his readers in no doubt that, quite apart from the improvement it gave in fireproofing, reinforced concrete was in the vast majority of situations cheaper than conventional systems of construction.

He supplemented this cost advantage by describing, in a chapter devoted solely to the subject, the improved lighting conditions that could be achieved by using the concrete frame with large areas of glazing. Referring to American practice, he described how it was becoming common there to build multi-storey factories with little or no wall surface. Good daylighting was an essential part of Henry Ford's brief to his designers for it was shown that good daylighting improved productivity and reduced accidents. Kahn included a graph which supported this point; and to show how it was to be achieved he described the thumb rule measurement which his firm was applying to the dimensioning of industrial building to achieve satisfactory light conditions,(namely 14 ft 6 in window height on both sides of a building 60 ft wide; 17 ft 0 in for buildings 80 ft in width).

His chapter on the architectural treatment of factory building was his most interesting. He began by attempting to correct the English view that 'factory building' and 'ugliness' were almost synomynous. He explained that, treated with architectural skill, most industrial buildings could be acceptable or even imposing additions to the environment. However he was eager to stress that factories should be designed to appear as industrial structures, and not decorated to disguise this fact. To achieve this aim without recourse to decoration he advised the adoption of the modernist theme of structural expression:

'For effect they (factories) should rely on the straightforward expression of their structures, on mass, and on the skilful disposition of their parts, the whole being co-ordinated into a well-designed architectural scheme. To attempt to make an indifferent building look presentable by applying ornament to it with a lavish hand is bound to prove a failure. The right method is suitably to arrange the main parts, to study the proportions of solids and voids, to emphasise structural lines by relief or colour - in a word - to articulate the structure. And this method can be followed inside the building as well as outside, for it involves an expenditure that is only a fraction of the total cost of the building.'[74]

To justify this minimal expenditure, Kahn explained to his readers that, externally, a well designed building could provide valuable advertisement for the factory owner, whilst internally it would improve the morale and therefore the productivity of the workforce. This, he insisted, was the experience of industrialists in America.

It is interesting that this theme of 'expression of structure', although by no means new, should be aired in Britain at this time by an American whose objectives were primarily commercial. The commercial advantages of adopting this strategy were two-fold. First for the industrial client, the concept of articulating the structure to produce visually pleasing facades was attractive essentially because of its cheapness. The structure was an essential part of any building, and if it could be designed to look attractive it would avoid the unnecessary expense of adding functionally redundant and costly masonry veneers. Second, from the Trussed Concrete Steel Company's point of view, the expression of structure provided the simplest means it had at its disposal to advertise its design services and reinforcement products.

A review of some of the buildings Wallis designed to accommodate these criteria, reveal a similar development to the work of Albert Kahn. Like Kahn, in his earliest examples Wallis found it difficult to depart from traditional classicism, adding structurally redundant columns and sometimes imitating stonework in concrete to produce satisfactory facades. This is probably best illustrated in his GEC
[7] workshop at Witton, Birmingham. In other larger multi-storey
(30) to (35) buildings he borrowed extensively from Albert Kahn's work at Highland Park combining the simply exposed concrete frame with large areas of glazing and introducing robust corner blocks, usually executed in concrete, to terminate the repetitive grid pattern of frame and glass along each of the facades. The 'Tilling Stevens
[8] Engineering Works building' was one of his first completed projects which demonstrates the importation of these American factory build-
(26) to (29) ing types into Britain. One problem with this building was that it was to be built in two phases. Consequently, on the principal elevation the completed building was to contain four 'corner blocks' in order that the first phase of the development would appear as a

completed building in its own right.

In the early 1920s, Wallis and Kahn completed many buildings of this type each following the same basic architectural format as
(6) first established by Albert Kahn for Henry Ford. Illustrations of them were extensively used by the Trussed Concrete Steel Company for its advertisements, and for this purpose they were collectively known as the 'Model Kahn Daylight Factories'[75]

In all these buildings the use of the reinforced concrete frame formed the essential part of the architectural expression providing Britain with its first significant series of buildings which demonstrated both the value of architect/engineer collaboration, and the visual and cost benefits of adopting a functionalist approach to architectural design in reinforced concrete.[76] However as all were restricted to factory buildings they stimulated very little interest in architectural circles because the architectural establishment still regarded industrial work as 'engineering' and thus falling outside the mainstream of an architect's work.

Nevertheless it is surprising that little historical interest has been shown in these buildings, illustrating as they do important developments in modern British architecture. Perhaps one reason for this is the derision Wallis received at the hands of British modernists in the 1930s for his extravagant facadist designs in a number of factories he designed in the late 1920s and 1930s. Certainly these later buildings represented a reversion to stylistic design on Wallis's part, a role he willingly accepted from American clients who began to build British factories from 1926 onwards. Unlike British companies who were generally prepared to accept standardized architectural solutions to their factory buildings, these new American clients began to demand that their architects produce buildings that would themselves advertise in a distinctive way their company's image. To accommodate such wishes Wallis abandoned the use of 'structural expression' in his design approach and began to face his utilitarian factory buildings with lavishly decorated administrative blocks using his own distinctive Art Deco style.[77] Thus the commercial advantages for the Trussed Concrete Steel Company in expressing the structures of their building in the early 1920s were within a few years replaced by a facadist approach to design initiated by the commercial interests of industrial clients themselves.

CHAPTER 3

FLAT SLAB CONSTRUCTION

One of the first buildings that the Trussed Concrete Steel Company, with Wallis as its architect, designed for an American
(49) client in Britain was the factory for Wrigley's at Wembley in 1926. This building in its overall layout and architectural composition was similar to earlier structures, (unlike later American buildings) but with one important difference. Whereas all previous buildings erected by Wallis and the Trussed Concrete Steel Company had used conventional reinforced concrete frames, this latest building provided the occasion on which the company introduced the American technique of flat slab construction into Britain.[78]

This form of construction, which removed the need for downstand beams by treating the floor slab as a structural entity in itself supported on a regular spacing of 'flared-head' or mushroom columns, had many technical and constructional advantages over conventional frame techniques. However for clients its principal attraction was that it allowed uninterrupted areas of glazing along the facades of their buildings, thus improving the daylight conditions within, and a speed of construction far more efficient than conventional frame techniques.

The Early Development of Flat Slab Construction in America

The two individuals who are normally credited with the invention
of the flat slab system of construction are the Swiss engineer
Robert Maillart and the American Claude A P Turner. Their two
systems are thought to have been developed independently and
although both produced the same visual and functional effect they
were based on entirely different notions as to the structural
function of the slab. Briefly described, Maillart's system was
(42) based on the assumption that the concrete slab was a structural
(43) unit in itself capable of transferring loads directly to the
columns without the need of beams. Thus the layout of the
reinforcement in his slab consisted primarily of a mesh which
became more concentrated over the supports to resist 'punching
shear'. Turner's system, although appearing 'girderless', in
(44) reality used a four way system of reinforcement over the supports.
(45) Thus he conceived of the slab as a series of continuous shallow
beams within the depth of the floor spanning over the supports.

Most publications suggest that these two systems were developed at the same time. This does not appear to be the case, however, for not only did Maillart's first Swiss Patent of 1909[79] postdate Turner's U S Patent application by five years, but Turner's own work was based on previous American patents which appeared as early as 1902.[80] (Indeed, it will later be shown that Turner's reputation is undoubtedly based as much on his commercial drive as on his innovations in structural technique.) One could therefore speculate that when Maillart began his work on flat slab floors in 1905, he was already aware of American developments and attempted to improve their structural efficiency. In addition many authors, writing of the development of modern architecture specifically in Britain, suggest that Maillart had the greater influence on European architecture. This appears to have been proposed, firstly because his system was more advanced than that developed by the Americans and secondly, because protagonists of the Modern Movement were eager to reinforce the link between British modernism and continental work.

In fact Maillart's work does not appear to have been well known by British engineers and architects until well into the 1930s when architectural publications began promoting his work. Ove Arup for example, highly respected in Britain for his work on reinforced concrete slab systems during the 1930s, maintains that he knew nothing of Maillart until 1938 when 'architects began to make him famous'.[81] Indeed there is little doubt that American work was far more influential in Britain in the earlier years. For example the first British patent for flat slab construction was taken out by Turner in 1906, and the British technical press reported extensively on American flat slab buildings from 1910 onwards, describing in detail the calculation methods for each system and the performance of various buildings applying them. Clearly the American reinforced concrete specialist firms who were operating in Britain in the years immediately following the First World War, possessed the technology to produce similar buildings in Britain but were prevented from doing so by the conservatism of most local authorities, a conservatism that was to be enshrined in legislation that came into effect in 1915. (The earliest British examples began to appear from 1925 onwards, built mainly outside London.)

Because of the importance of American techniques of flat slab construction on British work, it would be prudent here to outline briefly its development in that country:

The first American to address the problem of the 'girderless floor' was Orlando W Norcross. In 1902 he took out an American patent in which he described his construction as consisting:

'essentially, of a panel of concrete having metallic network encased therein, so as to radiate from the posts on which the floor rests . . . . The posts are first erected and a temporary staging built up level with the tops of posts (sic). Strips of wire netting are then laid loosely in place on top of the staging . . . . The concrete is then spread upon or moulded in place on the staging to inclose the metallic network . . . . If the forces acting upon a section of flooring supported between two posts be analysed it will be found that the tendency of the floor section to sag between its supports will cause the lower layers of the flooring to be under tension while the upper layers of the flooring will be under compression, these stresses being, of course, the greatest at the top and bottom layers respectively."[82]

However Norcross's design, which included flared column heads, did not take account of the tension which occurred in the upper part of the slab above the supports, caused by 'hogging'. This is evidenced by the fact that his slab reinforcement was placed in the lower portion of the slab above his column heads where the stress pattern is reversed. In an attempt to rectify this error Freeman C Coffin of Boston amended Norcross' specification later the same year by bending the reinforcing rods to the upper surface of the slab over the supports. Shortly afterwards he built an enclosed reservoir at the Bridgewater works, using this amended specification.[83]

It was in 1904 that C A P Turner of Minneapolis applied for a U S patent for his own system of flat slab construction, which he called the 'mushroom system'. Whereas Norcross and Coffin had simply placed rods of reinforcing material running parallel and diagonally to the structural grid over the column supports, Turner realized that the efficiency of the system would be greatly improved if the column heads were to form part of the slab by connecting 90° projections of the column reinforcement to the slab rods via rings of radial reinforcement. The patent however was not granted until 1911, seven years after the initial application.[84] The delay was caused by 'interference proceedings' and although the objectors to Turner's patent are not recorded in the press, it seems fair to assume that Norcross initiated them. Possibly due to the slow progress in America with his patent, Turner deposited his specification at the British Patent Office in 1906. A British patent was granted in that year and in its specification it is clear how Turner intended to improve the Norcross system. In it he states:

'The vertical bars reinforcing the floor columns are bent horizontally at the top so as to form radial arms which carry (circular) bars forming a table for traverse, longitudinal and diagonal bars in the concrete floor.'[85]

The patent does not appear to have had any immediate impact in Britain, although it does establish for the historian an early American source of this technique in Britain.

The delay of his patent in America did not impede the application of his system to early American structures, and in 1905 he built his first structure using the technique. This was the'C A Bovey Building' in Minneapolis, a five-storey warehouse building.[86] The city's Building Department refused to grant Turner a normal permit for the 'mushroom construction' he had requested permission to use. Instead they agreed to allow its construction if it was considered an experimental building and was designed to carry a load of 700 lbs per square foot with a maximum deflection $\frac{5}{8}$ inch in the centre of each slab. When built with a slab span of 16 ft in each direction, it was tested to a load of 750 lbs per sq ft. The deflection in the slab was recorded as $\frac{1}{4}$ in only ten weeks after striking the shuttering. Following the successful completion of this building further examples began to appear either from Turner as a consulting engineer or from engineers who used Turner's system under licence.

Although Turner was the first to apply the 'mushroom' system widely, he was soon to face competition from many other individuals and companies.

In 1907 Theodore L Condron, a civil engineer from Chicago, developed a similar system in collaboration with his partner F F Sinks.[87] No doubt aware of the Norcross patent and Turner's early buildings, they devised a system which used the flared head capitals, common to both Norcross and Turner, but instead of the four-way reinforcement used by both these men they retained the two-way spanning technique.

The system they devised appears at first sight to be less advanced than that of either Turner or Norcross, due mainly to the shallow downstand beams which occurred above the columns, which meant that it could not be correctly termed 'Flat Slab'. However in terms of structural efficiency it was far superior and was undoubtedly cheaper to construct. It was called the 'Panelled Slab Floor System' and consisted essentially of flared head columns (Normally octagonal in form) supporting large panelled floor slabs. These panels, up to 25 ft square, were made up of shallow but wide 'beams' spanning across the supports at right angles, cast integrally with the slab. By introducing these 'downstands', Condron and Sinks were able to achieve spans of 25 ft compared with Turner's recommended span of 16 ft, and a slab depth of only 6 in, with downslab projections of 11 in, as against Turner's flat slab of 11 in - a depth he required to cover his complex pattern of reinforcement.

One of the most probable reasons behind Condron and Sink's improvements over previous systems was the fact that they had based their design upon extensive tests carried out on a series of $\frac{1}{8}$th scale models.[88] By measuring the performance of these models they were able to predict more accurately than their contemporaries the stresses in various portions of the slab. (It appears as though Turner's work was undertaken only on full scale examples which of necessity had to be designed with a large factor of safety.)

Later developments in this system culminated in a flat slab floor with the downstand beams replaced by simple rectangular drop-panels over the column heads. This became known as the
(47) 'Akme System' and one of the first buildings to use it was an
(48) 'Assembly Plant' for Henry Ford in Chicago built in 1914.[89]

Another American engineer who contributed to the development of flat slab construction was W S Thomson, chief engineer of the Corrugated Bar Company of Buffalo (New York). His work was based on a series of deformation tests he undertook on rubber panels, in an effort to determine the stress patterns in flat slab floors.[90] He conducted these tests between 1911 and 1912 and produced a large number of contour diagrams which illustrated the deformation recorded with differing loads. One of his most fundamental findings was that, contrary to current notions as to the performance of the slab, tension occurred in the upper part of the slab along the centre line between the columns. Thomson pointed out that the four-way system of reinforcement, as devised by Norcross and applied by Turner, took no account of these forces and it was this neglect which accounted for the surface cracking that had occurred in these positions in some of Turner's buildings.

In addition he argued that the four way system did not provide sufficient reinforcement in the centre of the floor slabs where tensile stresses were higher than had been anticipated by Turner. (It was no doubt this finding which encouraged Turner to amend his earlier specification, to include radial reinforcement in the centre of his slab, in addition to that over his column heads - thus complicating his pattern of reinforcement even more.)

Thomson's Company used this work to introduce its own two-way system of flat slab construction similar to Maillart's, which became known as the 'Corr Bar System'.

Other systems which were developed at the same time were the 'Cantilever Slab System' from the Concrete Steel Products Company of Chicago (1910), the 'Unit System', a modification of Norcross' system, by Barton, and the 'Umbrella System' by Pierce Cowles of Minneapolis.

The rapid expansion of various flat slab techniques at this time produced many legal arguments as to which system infringed others' patents. Turner, clearly regarding himself as the pioneer of the technology despite Norcross's earlier work, was by far the most prominent figure in the many legal suits which were filed in the years immediately preceding the First World War. For example, in 1911, as soon as his own U S Patent was granted,[91] he brought an action against Moore and Scriver, the owners of a building in Minneapolis which had been constructed using Pierce Cowles's 'Umbrella System'.

The court's decision was announced in April 1912 against Turner, the judge ruling that the construction did not infringe the Turner patent No 985 119.[92] Turner appealed, but in 1914 the District Appeal Court upheld the original decision and went even further than the lower court by stating that:

'the plaintiff merely selected and assembled old things in aggregation and pushed them with enterprise and publicity . . . . The constituent elements of the patent suit were well known and performed the same functions in the same art, though not all disclosed in a single prior patent, publication or structure.'[93]

The court's decision appears to have provoked the holder of the Norcross patent to file a suit against Turner for his infringement of that early 1902 patent. The action was brought in 1913. In an effort to gain some support for his case, Turner commissioned Professor Eddy of the University of Minnesota to undertake a comparative test between his own system and that of Norcross.[94] Each patent specification was adhered to in the construction of the test slabs, regardless of the fact that Turner's system included much more reinforcement and had columns several inches larger than those specified by Norcross. The inevitable results showed conclusively that Turner's slab would take several times more load than Norcross's and also yielded slowly whereas the Norcross slab collapsed suddenly.

As Professor Eddy's findings were presented as a scientific experiment with no mention of Turner's involvement, the response of various readers was inevitable. All claimed that there was no possible parity between the two specifications and no need for an unfair test to be conducted to prove what was generally understood. Replying to one such letter Turner wrote:

'The writer finds himself in complete agreement with Mr Godfrey's impatient characterization of the Norcross test slab as an 'unheard of construction' and a 'man of straw'. Such it is and nothing else and the present writer would have assumed that everyone was of the same opinion also had not this Norcross patent been made the basis of a suit in equity in which the claim is made in pretended good faith that the Norcross construction with strips of hog wire netting in the bottom of the slab for reinforcement is identical with and has the same merit as the Turner 'mushroom' construction.'[95]

Regardless of this attempt and after a number of court hearings, the Norcross patent was upheld and Turner was fined 200 dollars.[96] Although Turner continued legal proceedings it became clear that the courts considered Norcross the inventor of the technique, even though his specification was structurally inefficient and commercially unfeasible. Consequently pioneers such as Turner, Condron and Thomson were forced to obtain licences for their patents from the then owners of the Norcross patent - the Flat Slab Products Company.[97] This meant that for any scheme which they built using their own systems they had to pay royalties of one cent per square foot to that company.

Although discussion of these legal proceedings is discursive, it is necessary to include references to them in order to place Turner's reputation in context. Clearly he was only one of many who sought to make the Norcross invention a commercially viable proposition.

It must be emphasized that the individuals who developed these various systems of flat slab construction promoted them through the commercial enterprises they had established and not generally through professional practices. Between 1914 and 1916 these organizations experienced a large increase in business when various city authorities began producing legislation which authorized the application of the technique to buildings in their respective areas. The city which was undoubtedly the leader in producting such legislation was Chicago.

In 1911 the Commissioner of Buildings in that city, on receiving an application from the Concrete Steel Products Company for authorization to construct a building using its patented 'Cantilever Flat Slab System', realized that there was insufficient knowledge within his department to judge it fairly. He immediately established a commission of enquiry to examine the whole range of flat slab techniques. This commission, consisting of three eminent engineers, carried out numerous tests on existing structures at the Engineering Experimentation Station of the University of Illinois. Its findings were made the basis of the Chicago Building Ordinance of 1914, which laid down conservative rules governing the design and construction of flat slab structures in the Chicago area.[98] This ordinance was quickly adopted by other American city authorities as the model for their own legislation. Thus this legislation, supported by the American Society of Civil Engineer's own report of 1916,[99] gave flat slab building a seal of official approval, effectively removing it from its stage of experimentation.

However this legislation did not immediately open up the field of flat slab design to professional engineers, for its application remained largely in the hands of the specialist firms. This monopoly was caused by the strength of the Norcross patent, which forced all those designing flat slab systems to pay royalties to its owner - the Flat Slab Products Company. Professional engineers were forced to add these charges to their fees and consequently building owners often selected specialist firms in preference, for such organizations would not pass on these charges directly to their customers.[100] This situation did not change until 1920 when the major patents lapsed, thus opening up flat slab design to a wider cross section of the engineering fraternity.[101]

Introduction of Flat Slab Construction into Britain

It is often assumed that flat slab construction was almost unheard
[29] of in Britain until the beginning of the 1930s when Owen Williams produced his architectural masterpiece, 'The Boots Factory' (1931-32). This assumption is probably partly based on the fact that British legislation did not provide for this form of construction until 1933, almost 20 years after the Chicago Building Ordinance, when the Institution of Structural Engineers[102] produced provisional rules to be included in the new Code of Practice. However, although the assumption may generally be correct with regard to the architectural profession, in relation to the engineering profession it is grossly incorrect in three important respects:

First, by reference to British patents it can be shown that a number of flat slab systems were patented in Britain from 1906 onwards. Whilst a large proportion of these were from American sources, a number were of British origin. Second, a review of the technical press in Britain reveals that a number of leading journals reported on American developments in the technique from 1910 onwards. From this it must be assumed that their readership would have become familiar with the technique, both in its structural design and architectural application, many years before the 1930s. And third, a small but significant number of flat slab structures were erected in Britain during the 1920s. These were designed by both American specialist firms operating here and by native engineers, despite restrictive legislation.

The combined strength of this evidence, to be described in more detail below, will be used to show that a significant proportion of the British engineering profession was familiar with flat slab construction well before the First World War, and in some small way contributed towards the development of the technology. Nevertheless it is true that the widespread application of the technique in Britain was delayed until the 1930s, twenty years after its general acceptance in America. Although legislation played a part in this delay, the appearance of British flat slab structures in the 1920s suggests that it was only one of a number of contributory factors. These will be discussed later.

Turner's British patent of 1906[103] has already been referred to as the first recorded written evidence of flat slab construction in Britain. One would suspect that such an innovation would not go unnoticed in Britain. This was in fact the case, for a review of contemporary patents reveals that at least two British pioneers used this patent as the basis of their own distinctive approach to flat slab building. The first of these appeared in 1909 with a patent specification by H K Dyson, civil engineer and architect in collaboration with the contractor Leslie and Co Ltd.

Their patent was entitled '<u>An improved system of Reinforced Concrete Floor Construction</u>'.[104] In it they referred to earlier patents which used top reinforcement to accommodate the reverse bending which occurred above the supports. This they noted, suggested a 'cantilever action'. This recognition of the cantilever as an important element of Turner's patent, although not fully exploited by Turner himself, formed the basis of their own invention. They conceived of the floor slab as consisting of cantilevered portions over the columns, supporting plate slabs in between. They arranged their floor slab on a diagonal grid with the columns positioned as diamond shaped in section underneath the cantilevered sections. They wrote:

'the portions of the floor belonging to the first series being reinforced to act as cantilevers and the parallelepipeds of the second series being reinforced to act as floor plates. By treating the floor area in this way a considerable saving of reinforcing material is obtained and the reinforcements are arranged to resist the various stresses to which the structure is subjected in a more efficient manner that has been heretofore been practicable.'[105]

In effect their system extended the Turner mushroom columns heads to provide 50% of the floor surface, maximizing the cantilever potential of his system. In this way their system can be seen to be a logical progression from Turner's improvement to the Norcross slab.

Unfortunately there appears to be no published evidence to show that the '<u>Leslie and Dyson system</u>' was ever applied to a British structure at this early date. However it must be noted that American pioneers soon began to treat the flat slab as a series of cantilevered slabs supporting intermediate plate slabs, at least in their calculation methods. (eg <u>The Concrete Steel Products Company</u> with its cantilever system). As these American developments occurred at the same time as this British work one could speculate that some collaboration my have taken place.

A second British patent based on Turner's work appeared in 1910 from two Scottish pioneers Thomson and Thomson.[106] Their system was a simplified version of Turner's four-way reinforcement and could not be considered to represent an advance on either the Turner or Dyson patents. However it is worth recording for it supports the view that British pioneers were interested in developing the technique. What they attempted to do in their specification was to simplify Turner's system by removing his complex web of reinforcement over the column heads. Instead of using flared head capitals they provided a metallic collar to the head of each column, to which the four-way reinforcement was anchored. Thus they conceived of the slab as a series of simply supported beams cast within the depth of the slab - but like Norcross they discounted the cantilever effect. Evidence has yet to appear to suggest that this patent was ever successfully applied to any built structure.

In addition to these native inventions, a number of further British patents were granted to American patentees in the years leading up to the First World War. One of the most important was a patent from Alfred E Lindau of Minneapolis in 1912.[107] The date coincides with W S Thomson's work in America on rubber panels which showed the inadequacy of Turner's four-way system of reinforcement in not providing sufficient tensile reinforcement in the upper surfaces of the slab between the supports. Lindau's British patent addressed this criticism with a two-way system of reinforcement which became more concentrated in the upper part of the slab above his flared head capitals. He claimed that his specification was more economical than previous systems as it dispensed with the complex pattern of reinforcement necessitated by Turner's widely applied four-way system.

Other British patents granted to American pioneers at the time included a further Turner patent of 1911, John Wunder 1912 and Francis Barton in 1916.[108]

A British patent of American origin which ought to be described here, although it does not properly constitute flat slab construction, is a type of floor system which is commonplace at the present time - the 'waffle system'. It was devised by Julius Kahn in 1912, of the Trussed Concrete Steel Company. Kahn's system, which he called the 'Egg Crate' technique, treated the floor slab as a series of intersecting 'T' beams. Its merit over other floor systems was its reduced dead weight and its simplified construction. In his British patent specification, Kahn described that it was to be built by placing corrugated metal moulds on a permanent shuttering of corrugated metal. The moulds were placed side by side with approximately 6 inch space between them on each edge and 'trussed bar' reinforcement was then placed in the bottom of the troughs thus formed. Concrete was then poured in between and over the moulds thus creating two-way spanning 'T' beams with the floor slab providing resistance to the compressive stresses.[109] Although the floor could not be described as a flat slab system, the fact that the closely spaced beams were recognized as an integral part of the slab, without the need for primary and secondary beams, suggests that the floor could be compared favourably in terms of structural efficiency to the systems by

Turner and others. From the specification it is clear that Kahn was attempting to marry the advantages of the hollow pot floor to those of the flat slab.[110] He claimed that it was cheaper than the flat slab system to construct and was more efficient than the 'hollow pot' in that it provided a reduced dead load (ie the terracotta tiles increased the load without contributing to the strength). It must also be noted that the egg crate system
(3) permitted the use of his firm's 'Kahn Trussed Bar', a type of reinforcement which was ill-suited to ordinary flat slab floor construction. Nevertheless Kahn's company was one of the first specialist firms to introduce flat slab construction to Britain although there appears to have been no British flat slab patent granted to the company.

From these British patents, it is clear that between 1906 and 1912 the leaders of concrete technology in Britain were becoming well acquainted with American techniques of flat slab construction, and as has been shown, in two instances attempted to produce their own variations. From 1910 onwards the information on various techniques was disseminated to a wider section of the British engineering profession through a series of articles published in the British technical press. It is surprising that none of the published information referred to the work of British pioneers, particularly the patent by Leslie and Dyson. Instead the journals concentrated entirely on American work, no doubt because developments in that country could be directly related to completed structures. <u>The Builder</u> was one of the first journals to present examples of Turner's work in a brief description included in its 1911, April and June editions.[111] However the first detailed assessment of the system appeared in <u>Concrete and Constructional Engineering</u> in

1911.[112] It was a direct reprint from the American journal Engineering News, written by Arthur R Lord of the University of Illinois. It concentrated on the results of tests he had undertaken on the 'Deers & Webber Co Building', an eleven storey warehouse in Minneapolis, designed as a four-way flat slab system by the Concrete Steel Products Company of Chicago. Measurements on an eight slab portion of the structure had concentrated on deflections of the slab, deformation of the steel both in the centre of the slab and over the supports, the deformation of the concrete at the edge of the capital and on the curvature of the 'elastic surface' in two directions. The results in the deformation of the steel were the most interesting, revealing that the stresses at the centre of the slab were much lower than expected, suggesting that the reinforcement in this area was overdesigned, whilst over the supports the tests showed that it was here that the greatest stresses were located, quite contrary to contemporary notions. The tests also revealed, by the location of minute cracks, the positions at which moments should be calculated. It was this type of information which formed the empirical basis upon which future formulae were determined. This can be clearly shown in a later article published in the same journal in 1913. It was a paper which Stanford E Thompson had delivered to the National Association of Cement Users, U S A in March 1912.[113] Basing much of his work on Lord's findings, Thompson presented to his British readership simple formulae and tables which could be used to determine the slab size, column heads and quantities and details of reinforcement for particular loads and spans. (Much of this information supplemented general design criteria which Thompson had published in an American text book on the design of reinforced concrete structures.)[114]

The first American flat slab building to receive detailed coverage in the pages of the Concrete and Constructional Engineering was the Ford Assembly plant at Chicago.[115] It was one of Ford's first
(47) flat slab structures built at the same time as a similar structure
(48) in Detroit. However whereas his previous schemes had been designed by the Kahn brothers, this building used the Akme system of construction as developed by Condron and Sinks whose company, Condron Co designed the structure in collaboration with the Detroit architect John Graham. This was a six storey structure built around a central atrium. The columns, octagonal in form, varied in size from 2 ft to 3 ft 4 in diameter, with flared heads and drop panels 7 ft square supporting a flat slab, 11 in thick with spans of between 25 ft and 28 ft. The British article on this building was again reprinted from the pages of the Engineering News.[116]

The American origin of the above articles clearly supports the evidence extracted from British patents, which suggested that British developments in flat slab construction were directly influenced by American techniques.

After the war, American authors continued to supply articles on this form of construction to the British engineering press. However, whereas before they had simply described various system and calculation methods, from 1918 onwards they directed their writings towards encouraging the British to adopt the technique whilst expressing some bemusement that such a well established form of construction in America had not been accepted as suitable in Britain.[117] The main objective of their articles was undoubtedly to provoke the L C C into allowing for flat slab construction in its legislation, for its restrictive regulations were widely considered to be the main stumbling block to the effective development of the technique in Britain. It must be pointed out that the L C C regulations of 1915 did not directly prohibit the construction of flat slab building but rather precluded its implementation, as the system could only be designed on the basis of empirical data. This was incompatible with the regulations, as they required engineers to use rationalized calculation methods for their designs, methods which assumed ordinary primary and secondary beam type systems of concrete frame construction.

Regardless of this legislation and no doubt influenced by the above American articles a number of British engineers began to produce flat slab structures. Owen Williams, whose Boots factory of 1931
(102) has already been mentioned, included a flat slab floor in his design for the Wembley Stadium of 1923.[118] He was undoubtedly well acquainted with the technique through his early employment with two American firms in Britain, The Trussed Concrete Steel Company and the Indented Bar Engineering Company. Although this fact was never published in reviews of the Wembley Exhibition, in the following year (1925) the journal Concrete and Constructional Engineering included an article on what it presented as the first flat slab building in Britain.[119] The building in question was a factory in Norwich for Messrs Fred Sexton Ltd. It was designed by E W B Scott, an architect who the journal credited with introducing 'these latest American methods' to Britain. He had apparently visited America in 1923 to study factory buildings and was so impressed with the advantages of flat slab construction he had

witnessed there that he decided to use the system on a British building. It was the above contract which provided him with his first opportunity. He selected Lewis Rugg & Co of London as his engineers and together they were able to persuade the then City Engineer of Norwich, A E Collins, to interpret the by-laws in a generous manner to allow the construction of a flat slab structure.

The building, although one unified unit, was separated both structurally and architecturally into two distinct sections; the administrative block which was constructed with a beam and slab floor supported on concrete walls which used permanent shuttering walls of Neo-Georgian brickwork, and the manufacturing area which used the flat slab technique with the frame and brick infill panels frankly expressed on the exterior.[120]

This architectural treatment contrasted strongly with the Neo-Georgian detailing of the office accommodation which provided a visual flank to the factory. Nevertheless the functionalist elevations led the writer of the journal's article to comment:

'By careful use of these simple means a quiet and dignified appearance with an American flavour has been achieved which is certainly pleasing, and should help to break down the old idea that industrial buildings are necessarily ugly.'[121]

Following on from this structure a large number of more impressive factory schemes were built in Britain using the American technique. One of the most important firms in its introduction was the Trussed Concrete Steel Company of England which produced a whole series of flat slab structures from 1925 onwards. Two of its
(49) earliest appeared in 1926 - the 'Wrigley Factory' at Wembley and
(50) the 'E M I Building' at Hayes, Middlesex, the executive architect

of both being T Wallis of Wallis, Gilbert and Partners.[122] At the same time the company was also involved in the reinforced concrete design of flat slab factory units at Welwyn Garden City in collaboration with the architects of that scheme, Louis de Soissons and Kenyon.[123] All these schemes, based on American models, differed from the Norwich scheme in one important respect - they removed the external columns from the elevations allowing the floor to cantilever out and provide long alternating horizontal bands of glazing and concrete upstand beams. The appearance of these elevations created some amount of confusion in architectural circles as they appeared to defy gravity. For example in one architectural journal it was suggested that such elevations could not constitute architectural design as plainly the buildings appeared to lack one of the central criteria of architecture - firmness.[124]

Alongside these successful factory buildings further applications of the technique became more widespread. In 1926 for example Oscar Faber used mushroom columns to provide partial support for his
[11] stands at Lords Cricket Ground.[125] Williams continued his own experiments with the technique in one or two of his Scottish Bridge Schemes, and in 1929 the Trussed Concrete Steel Company produced
[23] two bridges using the four-way spanning technique on the Larne Railway line using as a design guide the code of the American Concrete Institute.[126]

As all these structures were reported in the engineering press and a small number in the architectural press, it must be assumed that by 1930 both professions were becoming familiar with the technique and particularly its architectural implications as first demonstrated in America.

The fact that these British buildings appeared at least twenty years after their American equivalents raises an important question - what caused the delay? As has been noted from American correspondents in British journals, the L C C regulations undoubtedly contributed towards its slow acceptance in Britain. However, these regulations do not appear to have prevented British flat slab structures built in the 1920s, for they were not revised until 1933. Indeed it is clear that legislation, with regard to building structures, usually postdates the general acceptance of a particular technology, it rarely anticipates developments even when such developments are well accepted by similar legislative authorities abroad. Recognizing, therefore, that it is the infringement of regulations which provokes authorities to update their legislation, one must look to other contributory factors which retarded the application of this technique.

One obvious factor was the slow development of reinforced concrete generally in Britain, for in the preceding pages it has been shown that from the mid 19th century onwards Britain was at least ten years behind the Europeans and Americans. This 'catching-up' effect undoubtedly continued up to the 1930s and was partially responsible for the delay in the arrival of British flat slab structures.

However apart from this general issue, a review of the technical press reveals that the First World War had an enormous impact on the development of reinforced concrete in Britain. In the war years, the steady flow of articles on American flat slab buildings appears to have stopped. Instead concrete engineers were pre-occupied with the war effort and this diverted them from working on developments which were inappropriate to immediate needs. It becomes clear from evidence available in journals between 1915 and 1920 that shortages of steel and timber forced engineers to use concrete in ways, and for projects, that would never have been considered under normal circumstances. For example the shortage of steel, which was caused by the need to restrict its use for the production of armaments, led to the numerous projects throughout Britain for the development of concrete ships.[127] A large proportion of reinforced concrete engineers contributed towards this work and the journals reported extensively on what was considered to be a rather intriguing use of reinforced concrete. A more important factor was the chronic shortage of timber which continued well after the war. This shortage prevented engineers from continuing to design insitu concrete structures, for such projects required large amounts of timber shuttering. Consequently precast concrete became a feasible proposition and it was during the war that a number of precast systems were devised, patented and applied with varying degrees of success.[128]

Therefore the war, although useful in encouraging engineers to extend the application of reinforced concrete, effectively put a halt to insitu concrete buildings. This must have cut short the attempts of American engineers to introduce flat slab construction into Britain and therefore it was not until timber became more readily available in the mid 1920s that the natural development of insitu systems could recommence.

PART TWO

THE EMERGENCE OF TWO BRITISH CONCRETE ENGINEERS

OSCAR FABER AND OWEN WILLIAMS

CHAPTER 4

THE BACKGROUND TO TWO OF BRITAIN'S FIRST GENERATION OF CONCRETE ENGINEERS

Although there were a number of British engineers who contributed to the development of reinforced concrete technology from the mid 19th century onwards, their influence on its application to British structures (as has been suggested in the preceding chapters) was minimal compared with that of foreign specialist firms operating here from 1890 onwards. Reference to the Interim Report of the Institution of Civil Engineers' Committee on Reinforced Concrete (1910) clearly supports this observation. Its survey of specialist firms revealed the extent of its own members' reliance upon the services of these firms when engaged in the design of reinforced concrete structures.[1] This situation prevailed at least until the end of the First World War when a number of British engineers began to emerge as specialists themselves, basing their new found practices on work they had done as part of the war effort. Even so, the predominance of foreign firms continued well into the 1930s when British professional engineers eventually began to supplant them.

In the field of architectural design it seems clear that the continued dominance of the concrete specialist companies was nurtured by members of the architectural profession, who used them throughout the inter-war period as a preferred alternative to collaboration with professional consulting engineers. So long as the structure of an individual building was conceived as a separate entity from its architectural form the employment of specialists as subcontractors not only relieved clients of professional engineers' design fees, but it also meant that the architect could retain his professional status vis à vis the engineer and contractor. Thomas Wallis, whose work with the Trussed Concrete Steel Company has already been examined, illustrated this in unpublished notes he prepared for his lecture to the R.I.B.A. on Industrial Building (1933) in which he presented the deceptive impression that his firm was able to work without engineering assistance.

"The Architect should always remember that the client is not employing him as a luxury man, on the contrary as a necessity man. We have to correct the aspersion that Architects are a luxury. When we make it clear to the public that we are necessity men out to protect their interest financially and that our designs are prepared showing our thorough knowledge of layout, construction and of pleasing elevation, then indeed will the Architect hold a position of necessary importance. We Architects must hold our own against the Engineer who attempts architectural design, and the Contractor who poses as the man who charges nothing for designing."[2]

Without any reference to the engineering input of the Trussed Concrete Steel Company or of the firms which designed some of his later steel framed factories he observed in his written answers to questions:

"The Factories that were shown on the screen were dealt with entirely by our firm, no Consulting Engineer was employed, although we do occasionally work in conjunction with a Consulting Engineer."[3]

Nevertheless, the R.I.B.A.'s own enquiry into reinforced concrete design of 1906, by paving the way for legislation, ultimately opened up the field of reinforced concrete design to more generally qualified engineers. Between the first draft issue of regulations in 1911, and their enforcement in the L C C

General Powers Act of 1915, educational bodies began to introduce comprehensive courses on reinforced concrete design into their engineering curriculae, Kempton Dyson initiating the first at the Brixton School of Building in 1913. Prior to this the City and Guilds Institute, which co-ordinated engineering education throughout Britain, had included only elementary courses on the basic principles of reinforced concrete design in its civil engineering syllabus.

It is perhaps surprising that Oscar Faber and Owen Williams, the two engineers who came to be regarded as Britain's first leading specialists in reinforced concrete design, taking advantage of the gradual erosion of the specialist firms' monopoly, did not benefit from such early educational courses. Faber had undertaken post-graduate research in reinforced concrete after completing an education in electrical engineering. Owen Williams had only received the early City and Guilds elementary course in reinforced concrete. They received most of their design training in the material through practical experience as engineers employed by two American specialist firms - the Trussed Concrete Steel Company and the Patented Indented Bar Engineering Company.

The following chapters will concentrate on the careers of these men for two principal reasons. First; they both acquired important reputations during the 1920s as Britain's leading experts in the field of reinforced concrete design - Faber primarily through his research work and text books which disseminated information on the subject to a wide cross section of the engineering fraternity; Williams through his work as a practitioner. Second; because they both undertook to design 'architectural' projects as principal designers (ie working without the assistance of architects) their work and writings in this particular field of activity provide valuable insights into the contemporary relationship of engineering and architecture. In this respect Faber and Williams provide ideal subjects for discussion, for although they both challenged the conventional view to which Thomas Wallis gave expression - that is, of architects being "necessity men" in the modern building industry - their own attitudes to the role of the engineer in architectural design contrasted sharply. Faber occupied a traditional standpoint. Not only did he work as a consulting engineer producing structures for some of the most traditionally-minded architects of the 1920s and 1930s, but he constantly maintained that there was an important distinction between engineering and architecture. In his role as principal designer of anything not strictly belonging to engineering, he only addressed industrial structures whose identity in terms of 'architecture' or 'engineering' was ambiguous. One of his objectives in the design of these buildings was to prevent the encroachment of architects into types of projects which, he argued, were legitimately within the engineer's sphere of influence. Architects, he said, did not or should not possess a monopoly of the aesthetic aspects of building design. In view of his engineering background it is perhaps surprising that the design philosophy he applied to these buildings was based more upon the traditional values of classical architecture, than on the functionalist dogma of the Modern Movement.

Williams, in contrast, took on the role of architect for all types of building projects during the 1930s, severing his connections with the consulting work through which he had established an early reputation in the 1920s. By this stance he challenged the professional demarcations of his day, believing that the development of all forms of concrete architecture required a scientific approach to design which traditionally-trained architects were unable to produce. Unlike Faber's built work, which never having received extensive publicity has remained relatively obscure, many of Williams's buildings of the 1930s attracted considerable acclaim, making him something of a hero in the eyes of other British modernists.

Both men started their own practices shortly after the end of the First World War. Prior to that, their respective careers had been dissimilar, the only common denominator having been their employment as assistant engineers at the Patent Indented Bar Company.

Oscar Faber was four years older than Williams. He was born in London in 1886 of Danish parents.[4] On completing his secondary education at St Dunstan's College, Catford, in 1903, he was awarded a Clothworkers' Scholarship to study engineering at the Central Technical College London (later it became the City and Guilds College). He chose to read electrical engineering believing it to provide the best prospects for his future, and he completed his studies in this subject in 1905. By the time of his graduation, however, he had become familiar with reinforced concrete through the influence of the Dean of the College, Professor W C Unwin.[5] He decided to spend one year as a student researching the properties of this material. Thus without any formal education in reinforced concrete he began the research work that was to continue throughout his working life.

On the completion of his post graduate year and qualification as a civil engineer he took employment with the Associated Portland Cement Manufacturers, working as an assistant under the direction of P C Taylor. At that time this organization was involved in the design and construction of wharfs, jetties and minor industrial buildings. Projects to which Faber was attached at this time included a precast concrete jetty for the Swanscombe Works on the Thames, for which he helped in the design and supervised the construction as site engineer, and the development of a reinforced concrete industrial chimney.[6]

In 1909, having developed some competence as an engineer in reinforced concrete and having published two articles on the subject,[7] Faber moved to the newly established American concrete specialist firm in Britain, the Patent Indented Bar Company.[8] He remained with this firm, working as an assistant under the chief engineer R W Vawdrey, for three years, acquainting himself with the latest available techniques.[9] His two most important achievements here were his research work on shear forces in reinforced concrete and the writing of his first textbook with his colleague P G Bowie.

The work on shear was begun in 1910 at the City and Guilds College and the Northern Polytechnic Institute. On its completion it was acclaimed as the most significant British research undertaken on reinforced concrete.[10] Its specific objective had been to improve the efficiency of shear reinforcement design, and through his findings Faber was to demonstrate amongst other things, that contemporary conceptions of shear stresses were too simplistic.[11] The work was undoubtedly related to the current needs of his employer, for unlike its chief competitor - the Trussed Concrete Steel Company, it did not have a patented form of shear reinforcement. Perhaps unfortunately for his employer though, the results were not to be kept secret. Two years after he left the company, Faber compiled his results in a thesis entitled 'Researches on Reinforced Concrete Beams with New Formulae for Resistance to Shear'. For this he was awarded the degree of Doctor of Science by London University in 1915. Over the following two years the thesis was serialized in the journal Concrete and Constructional Engineering, thus disseminating what was widely considered a very original piece of work by those involved in similar scientific fields.[12]

His text book Reinforced Concrete Design was published in 1912.[13] Its immediate success was no doubt partly due to the fact that the City and Guilds was beginning to treat reinforced concrete seriously in its syllabus.[14] What was particularly interesting about this book, quite apart from the detailed design information it contained, was Faber's assertion that while textbooks and regulations were opening up the field of concrete design to a wider section of the engineering fraternity, specialist firms like his employer still had a great advantage over the "general practitioner". This comment was retained even in the second edition of the book in 1924. Referring to the secrecy that surrounded the specialist firms operating in Britain, particularly the French ones, and the regulations which had helped to break their monopoly he wrote:

"they (the regulations) have done much to lead engineers along the right lines. But it is a long step from that to the idea that every man should now design his own concrete work. It is not denied that he can, and if he makes his factor of safety sufficiently large to cover 'factor of ignorance' his work will stand . . . . But even so, this work will be more expensive than that of the specialist, since on the one hand he has to find by laborious methods what a specialist has trained himself to see almost instinctively, and, secondly, because his 'factor of ignorance' must be greater it will therefore entail the use of more material to secure an equally safe structure."[15]

The publication of this book coincided with Faber's move to the London contractors George Trollope & Sons and Colls & Sons Ltd[16] and the reorientation of his career towards practical building work.[17] This firm was one of the largest and most highly respected contractors in the London area, responsible for a large proportion of the high quality buildings erected within the metropolis throughout the 19th century. Faber was appointed as chief engineer and was given the task of establishing a design department with the aim of using his expertise on reinforced concrete to enable the firm to compete with the growing number of specialist firms. The imminent publication of Faber's book must have given him a great advantage in arranging his terms of employment. These allowed him to develop his own practice simultaneously; and it was agreed that if he should decide to work entirely on his own, the firm would allow him to take any of the staff he had employed within his department and any of the clients he had attracted. In addition he would be retained by the firm as its consultant.[18]

While this provided Faber with an ideal basis on which to establish his own firm, it did have the long term effect of directing his work from civil into structural engineering and the widening of his engineering abilities into structural steelwork. This was because the majority of contracts undertaken by Faber while with Trollope & Colls were in respect of architect-designed buildings. Many of these schemes were designed by architects of traditional persuasion who conceived of their buildings as masonry facades supported on steel frameworks. His contributions were therefore relegated to substructure concrete work and steel frames.[19]

The only significant break in this architecturally related work, allowing Faber an opportunity to undertake more research, came during the First World War when Trollope & Colls received government commissions related to the war effort. He was assigned to two projects in this period; the development of non-magnetic mines and the design and construction of concrete barges. There appears to have been no published information on Faber's involvement in the latter project, the various contemporary journals preferring to describe systems designed by others.[20] His work may simply have been overlooked: more probably, though, he was not sufficiently motivated to make it a success, for in an article he published much later he made it clear that he regarded the concept of concrete ships as rather misguided.[21] His work on the development of non-magnetic mines was by contrast highly successful, and for his achievements in this project he was awarded the OBE.[22]

Three years after the war, Faber established his own professional consulting engineering practice, taking with him two members of his staff from Trollope & Colls[23] and many architect-clients who had used his services before. It was these clients who were ultimately responsible for Faber's break with civil engineering and the direction of his career into architecture and structural engineering.[24] One of these clients, and possibly the most important, was Herbert Baker who provided him with a large number of contracts including the Bank of England. This project was an enormous engineering undertaking, providing his practice with a constant work-load from 1924 to 1942.

Nevertheless his reputation as a theoritician was not overshadowed by his success as a practitioner. On the contrary he still found time to further his interest in research and in this field his reputation was enhanced by his technical paper of 1927 on the 'plastic yield' of reinforced concrete beams (later to be known as "creep").[25] His discovery, which was the result of tests he had carried out over a period of five years, overturned contemporary assumptions on the nature of deflection in concrete beams over long periods of time. While it was to have particular consequences for the design of reinforced concrete structures, perhaps its most significant by-product was the theoretical information it provided for the full development of pre-stressed concrete by others.[26]

. . . .

Owen Williams's early career[27] was not as impressive as Faber's. Whereas Faber's reputation was firmly established through publications and research by the time he launched his own practice in 1921; Williams, who established his firm of professional consulting engineers in the same year, was a relatively unknown figure. Factors contributing to this were their age difference, and Williams's lack of a background in research. Nevertheless within three years he more than made up for this imbalance through the extensive publicity he received for his work at the Wembley Exhibition of 1924.

Williams's career began in 1906, following his secondary school education at Tottenham Grammar School, when he became an articled pupil to the Metropolitan Tramway Company, the engineering department of which was involved in the design of electric tramway and power stations. Throughout his apprenticeship he undertook part-time study in civil engineering through the City and Guilds provision, obtaining a first class honours degree in 1911 (London University external). In the year of his graduation he took employment as an assistant engineer in the firm in which Oscar Faber was working at the time - the Indented Bar and Concrete Engineering Company.[28] There is little doubt that Williams's experience within this firm would have been his introduction to the complexities of reinforced concrete design, for as has been said, engineering education in pre-First World War Britain provided only superficial coverage of the principles of this medium. No records exist of which projects he was associated with during his twelve months' employment within the company. Contemporary journal evidence, however, suggests that one of the firm's first major projects, which would have been passing through the design office at the time of Williams's employment, was a factory for Sainsbury's in Blackfriars, London.[29] This was a six storey concrete post and beam framed structure, faced with conventionally designed brickwork facades, supplied by the architect, A Sykes. It is probable that Williams was involved in this project, but since he would have been operating in a junior capacity, it would be wrong to suggest that he contributed significantly to its design.

Of far greater importance to Williams's future career was the four years between 1912 and 1916, when he joined one of the Indented Bar Company's major rivals - the Trussed Concrete Steel Company of England. Work undertaken by this firm has already been discussed, particular attention having been paid to the fact that it was influential in introducing American techniques of reinforced concrete and industrial architecture into Britain. Williams, who two years after his start became one of the company's chief designers, clearly played an important part in this process. It will be argued that many of his 1930s' buildings have close affinity to schemes produced by the company at the time of his employment.

Due to the anonymity of large commercial organizations, it is impossible to say precisely which structures Williams designed at this time. His papers indicate that he was primarily involved in factory schemes and not large public buildings, general reference being made in his autobigraphical notes to "many" such projects particularly those erected for "war purposes".[30] Unfortunately there is sufficient evidence, in the form of his own calculations and photographs, only positively to affirm his involvement in one such project - the 'Gramophone Company Building' at Hayes,
(21) Middlesex (1913).[31] The completed building, representing the firm's first British industrial project, was a six storey post and beam reinforced concrete framed structure, surmounted at one end by a water tower which projected approximately twenty feet above roof level.[32] The frame was exposed externally and each of the bays along the long facades was infilled with brickwork up to sill height with steel framed glazing above. On the shorter end walls the bays were infilled with monolithic concrete walls, inset approximately six inches to maintain the expression of the frame.

The influence of this and other Trussed Concrete buildings on Williams's career cannot be overestimated, for prior to 1912 he had had only one year's experience with a similar American based organization, and possessed minimal theoretical knowledge. Consequently his experience within the Trussed Concrete Steel

Company would have formed the basis of his understanding of reinforced concrete technology, and a knowledge specifically related to efficiently designed American factory buildings. As a commercial organization supplying buildings to industrial clients who themselves had pressing economic motives, it was natural that efficiency in building design should be the hallmark of Trussed Concrete Steel Company's image. This commercial necessity for efficiency was a feature of which Williams attempted to make a virtue in the later projects he undertook on his own account in the 1930s. When with the firm he must have become well-acquainted with American developments, particularly through the agency of the Company's quarterly journal Kahncrete Engineering (published from 1913) which reported exclusively on the Company's work in Britain and America. Although Williams's papers contain no references to this journal it is safe to assume that he was familiar with its contents. A respect for American practices is also suggested by the fact that after the First World War he was a subscriber to the American journal, Engineering News, which regularly published articles on the development of concrete technology as applied to factory buildings in America.[33]

Of more speculative interest in relation to the 'Gramophone Company Building' is the role of Arthur Blomfield. In 1871 he had published views on reinforced concrete as a material for architectural design in the R.I.B.A. sessional papers.[34] Many of the ideas expounded here - for example, the use of shutter markings as part of aesthetic treatment, maximizing the visual impact of daywork joints and expansion joints - were later used by Williams in his own writings and work. It is possible that

Blomfield may have passed on some of these ideas to Williams in their early collaboration. This may represent then an interesting combination, in Williams's later work, of American commercialism and Arts and Crafts notions about using the properties of a material to determine architectural form.

In 1917 Williams left the Trussed Concrete Steel Company, after supervising the design and construction of a number of war factories, to take employment as an aircraft designer with the Wells Aviation Company. After a little over twelve months here he became involved in government-initiated research into the development of concrete ships. He led a syndicate in Poole, Dorset, which operated under the name General and Marine Concrete Construction (Williams System).[35]

Evidence suggests that Williams, unlike Faber, endeavoured to make concrete ship design a success.[36] Although this success was
(51) limited the experience he gained through the project allowed him
(52)
(53) to develop abilities in two areas which were to prove invaluable.
First, the severe design constraints presented him with an opportunity to develop skills as a reinforced concrete designer. Prior to this his experience had been largely confined to reproducing standard American reinforced concrete frame solutions for industrial building in Britain. While this furnished him with necessary basic skills, it did not encourage him to be innovative. Although he came to the conclusion that concrete ships were inferior to steel ones, due mainly to their poor resistance to impact and abrasion, his work here effectively filled a gap in his experience.[37] The stringent requirements for efficiency, in both the use of materials and in economy, sharpened

his design abilities, forcing him to devise unique structural forms which opened his mind to the vast potential of reinforced concrete as a building material. And, as leader of the project he developed organizational abilities which gave him confidence to launch his own firm once the war had ended.

The firm Williams established in 1919, Williams Concrete Structures Limited, promoted a system of pre-cast concrete construction known as "Fabricrete", the details of which Williams protected through a series of British patents granted in the same year.[38] Precedent would have suggested that the most successful concrete specialists operating in Britain were organized as limited commercial companies, as opposed to professional practices, promoting particular systems of concrete construction or reinforcement design. Thus by forming a company, Williams was following the traditional pattern that had developed in Britain since the commercial introduction of concrete technology in the late years of the 19th century. Like these companies, Williams's own firm was based upon a patented system of construction - in his case a pre-cast system specifically related to industrial building. In this enterprise Williams was attempting to meet the demands of post-war reconstruction. During the war precast concrete had been developed by a number of companies (amongst them the Trussed Concrete Steel Company), as the technique became commercially preferable to insitu work due to acute shortages of timber and labour.[39] Although after the war many of these shortages were eased, precast systems still provided a favourable solution to factory building, both in terms of cost and time, for the industrialist who required new premises quickly.

The precast system Williams patented was not dissimilar to the successful system he had helped the Trussed Concrete Steel Company to produce during the early part of the war.[40] Both were based on standardized precast concrete flared column heads and beams jointed together with insitu concrete filling. It was only in the details of the jointing technique that Williams's system differed from that of his former employer. Williams's company appears to have lasted for approximately two years during which time he erected a large number of factory buildings using his 'Fabricrete' system (Tanneries, Glassworks and Patent Fuel Works). One of these buildings was a tannery at Runcorn, the photographic records of which show a crude utilitarian structure devoid of any
(54) "architectural" pretentions.[41] As illustrations of this building were included in many of the company's advertisements, it must be assumed that it was representative of other buildings erected during this period using the same techniques, suggesting that Williams had no architectural ambitions at this time.

Williams began to turn his attention to the architectural potential of reinforced concrete in 1921 when he accepted a commission for the structural design of buildings to form part of
[18] the 'British Empire Exhibition' at Wembley (1924). This project was one of the first large scale architectural schemes to be built of reinforced concrete in Britain and in its design Williams collaborated with the architects Sir John Simpson & Partners.

The date of his involvement, in what was to be an enormous engineering undertaking, coincided with the change in status of his firm from that of a commercial specialist company to a professional consulting engineering practice. Thus in 1921 both

Williams and Faber began their involvements in architecture as consulting engineers. Their transition to consulting engineers was important. In their new roles, with specialist interests in reinforced concrete design, they could offer British architects effective collaboration.

CHAPTER 5

OSCAR FABER

Faber - The Consulting Engineer

Work undertaken by Faber from 1921 to 1939 falls into two separate categories; projects which he accepted in the capacity of consulting engineer to various architects, and those in which he provided a complete design package to clients working without architectural assistance. Whilst it was his work in the latter category which is of most relevance to the present study, it is important to recognize that the mainstay of his practice throughout the period was the former. In a large proportion of this work, Faber was prepared to play a supportive role to architects who requested his services, allowing his engineering contribution to be subservient to architectural form. Occasionally, however, his design brilliance did surface in architect-designed projects making a significant impact on the resulting architecture. These buildings will be discussed at more length after a brief survey of the typical work he undertook in his capacity as consulting engineer.

Faber's reputation attracted commissions by leaders of the British architectural profession, seeking the best technical assistance the engineering profession could provide. Architects who used Faber's practice in this way included Herbert Baker, Reginald Blomfield, Cowles Voysey, John Burnet, Curtis Green and many others. The most important of these from Faber's point of view was Herbert Baker.[42] Their working relationship was highly successful and they collaborated on a large number of projects.[43] This may seem a little surprising in light of the highly traditional architecture with which Baker's name is associated, based as it was on a clear distinction between the artistic and scientific aspects of building. However this distinction of Baker's paradoxically aided their collaboration as the roles of both architect and engineer were precisely defined. Baker always insisted that it was impossible for one individual to have a full grasp of the necessary artistic and scientific knowledge required and so maintained that collaboration between architect and engineer was essential. To make this collaboration effective, however, it was clear that mutual respect was of vital importance, a condition that could only be achieved if each partner enjoyed equal status. Thus while for him engineering was always subordinate to architectural requirements, he ensured that Faber's contribution to its success was given full publicity. He said:-

'It is most important for the engineer to see things from the architectural point of view, and for the architect to understand the engineer's point of view and adapt his design to it. Dr Faber is pre-eminently able and sympathetic to understand what the architect is driving at.

This conflict between the artistic and scientific side must always be a very real one amongst architects. The older one gets, the longer art seems and if one does one's purely artistic work, . . . , it would be almost superhuman to have enough energy left for the scientific side; and so collaboration with an engineer becomes really essential. This ought I think to be recognized in public.'[44]

One of the most important projects undertaken by the two men was the rebuilding of Soane's Bank of England.[45] The scheme was an enormous design and construction project covering a site area of over four acres with a larger cubic volume of work below ground level than above. Design work began in 1924 and while it provided Faber's firm with employment which lasted for over fifteen years, possibly its chief significance to his practice was the entension of his range of services to include heating and electrical engineering. This arose following Baker's failure to extract early service engineering information from the firm he had initially commissioned. He approached Faber to see if he could take on the work. The subsequent servicing design undertaken by Faber's enlarged practice was undoubtedly one of the most interesting aspects of the entire scheme, based as it was on Faber's suggestion to develop an "integrated-energy system" for the power and heating requirements of the building.[46]

Other Baker-designed buildings for which Faber provided services, usually designing steel frame structures to support traditional masonry facades as at the 'Bank of England', included a building for 'Martin's Bank', Lombard Street, London;[47] 'Rhodes House', Oxford, (1928);[48] 'India House', Aldwych, (1928);[49] the 'Ninth Church of Christ the Scientist', Marsham Street, London, (1930);[50] 'South Africa House', Trafalgar Square, (1932);[51] the 'Royal Empire Building', Northumberland Avenue, (1936);[52] and 'Church House', Westminster, (1939).[53] Their only collaborative scheme in which reinforced concrete was used for the main super structure was the [11] 'Grandstand at Lord's Cricket Ground'.[54]

Cowles Voysey was another architect who frequently employed Faber as his consulting engineer. He was the son of C F A Voysey and gained his own reputation in the 1930s for a number of Town Hall and associated municipal buildings which he designed for local authorities in the south of England.[55] Faber was involved in most of these projects, usually providing steel frame structures which were enclosed by Voysey's carefully detailed neo-Georgian brick facades. Only in one of these projects, at Watford in 1936, does a reinforced concrete frame appear to have been used instead of steel.[56] In each of these projects Faber's contribution did not substantially affect the architectural form, not even at Watford where his brick clad reinforced concrete frame was surmounted with a traditional pitched timber roof .

A scheme which was stylistically similar to Voysey's buildings was 'Apsley House', a seven storey block of flats in Finchley Road, London, designed jointly by Sir Aston Webb and Son and Messrs C E Blackburn and Partners in collaboration with Faber.[57] In this project Faber's contribution, while not affecting the building's form or elevations, was important for the constructional technique employed. Instead of enclosing a concrete or steel frame structure in cavity brickwork it was decided to design an entire concrete structure using pre-fabricated brickwork panels as permanent shuttering to the 5 in thick concrete walls behind.

Other important building designs for which Faber collaborated with various architects include the 'Queen's Hotel', Leeds, by Curtis Green (1936);[58] the 'Menin Gate' by Reginald Blomfield (1924);[59] and a large residential flats complex at Dolphin Square, London by Gordon Jeeves (1936).[60]

The conventional nature of these buildings offer few hints of Faber's contributions. This was particularly true of their sub-structure work in reinforced concrete where his outstanding design abilities in the material were, of necessity, completely hidden from view. However in a small number of architect-designed projects for which Faber provided structural engineering services, the architecture was so heavily dependent upon the success of their reinforced concrete structures that his contribution to the visual aspects of the architecture must be regarded of paramount importance.

In each of these schemes Faber's influence on the architectural form varied dramatically, depending on the degree of architectural control imposed on his work by the architects who employed him.

At one end of the spectrum was his design for a 'Grandstand at
[11] Lord's Cricket Ground' (1924-1925) which he undertook for Herbert Baker. Although Baker, as the MCC's architect, was responsible for the design of many other buildings around the ground, he considered the designing of the grandstand to be "engineering" and therefore gave Faber a free hand in its design. Faber's solution was a remarkable piece of concrete engineering for its day, consisting of large concrete cantilevers from which a semi-circular stepped terrace of reinforced concrete was suspended. Visually it was very impressive, for by designing the structure with a minimum
(56) of well-concealed column supports, Faber was able to produce the deceptive appearance of a heavy structure freely supported above the ground. There is little doubt that Faber was able to produce such an effective piece of design work through Baker's decision to exert no architectural control over the design process.

A later scheme which illustrates the converse situation was the
[12] 'Royal Horticultural Hall', Westminster, (1925-1928). In this project the architects Easton and Robertson appear to have imposed a strict architectural control on Faber's contribution, much to the detriment of the completed building. Faber's role was to design the reinforced concrete, parabolic arch structure to the main body of the hall. Although his work was very successful and attracted widespread acclaim (even though this was credited to the architects), its relationship to the overall architecture had two important shortcomings which were directly attributable to the architects

unwillingness to allow effective collaboration between the architectural and engineering contributions to the design. The most conspicuous result of this lack of collaboration was the architects failure to allow the potentially simple, impressive structure to have any pronounced influence on the architectural form. Instead of using the structure to create or contribute to visual interest in the elevations, they enclosed the entire struc-
(59) ture with neo-Georgian styled brickwork elevations which were in direct contrast to the modernist imigery of Faber's structure. The most serious criticism however was less apparent. In exerting architectural control over Faber's work in the hall's structure itself the architects obliged him to produce an unnecessarily
(61) complex and contrived structure which made a mockery of the simple structural concept they had requested Faber to use.

Neither of these aspects was recognized in the contemporary architectural press. On the contrary most commentators unreservedly acclaimed the building and used illustrations of Faber's structure to pronounce that the 'clean functional structural solution' demonstrated that continental modernist influences were beginning to infiltrate British architecture.[61] Faber's contribution to this was not acknowledged. Indeed one noted architectural critic, Charles Reilly, made a virtue of the architects' predominant influence in the design by writing:-

'Everyone of any school of thought will be glad that it is designed by architects. For once we have stolen a march on the engineers; and, as abstract design is certainly more our province than theirs, if we follow Messrs Easton and Robertson's lead we ought to steal many more.'[62]

Another scheme will serve to illustrate what might have resulted here had there been a more effective architect/engincer

[13] collaboration - the 'Nairobi Market Hall' which Faber designed with the architects Rand Overy and Blackburn between 1929 and 1930. The structural concept of this building was identical to that used in the Easton and Robertson scheme. However at Nairobi a much closer collaboration resulted in a building which exhibited an harmonious relationship between the overall architectural form and its parabolic, reinforced concrete, structure. Not only was Faber
(68) able to design his structure correctly from an engineering point of
(69) view but in the elevational treatment the architects took full advantage of the structural concept, allowing it to have an important influence on the massing of the building's envelope and in its elevational treatment. It is unfortunate that the building did not receive as much publicity as its predecessor.[63] If it had it would have helped to demonstrate the shortcomings of Easton and Robertson's work.

There is little doubt that Faber's contribution to these two projects was of vital importance to their success, even though in each case he did not receive the recognition he deserved. Unfortunately little evidence is available, in the form of correspondence between Faber and his architects, to gauge how Faber reacted to the different roles he was expected to play and to the influence these differences had on the types of buildings produced. However his son has been able to outline the general background to his father's personality which helps towards an understanding of his attitudes. He describes his father's character as rather argumentative with a complete disregard to social graces. Of the effect this had on his relationship with the architects who worked with him John Faber has written:-

'Some architects whilst wanting his technical competence did not want to be coerced as to their architectural proposals; indeed they wanted an engineer who would help them realize their aspirations, not one who would argue against them.'[64]

Bearing this in mind it would be reasonable to assume that whilst Faber would have enjoyed his work at Nairobi, he would have been frustrated by the attitudes adopted by Easton and Robertson in the design of the 'Royal Horticultural Hall'. It seems clear that in this scheme the architects merely used Faber as their technical assistant, disregarding any comments he may have made concerning their structural ignorance and concealment of his work behind traditionally detailed facades. To an engineer of Faber's abilities such attitudes, reinforced by an ill-informed and prejudiced architectural press, must have led to a great deal of frustration.

However while this frustration was in part responsible for Faber's decision to undertake the design of a number of structures without architectural assistance, it did not prevent him from continuing his collaborative work with architects (unlike the position taken by his contemporary Owen Williams, which is discussed below). There appear to have been two reasons for this. First, by 1930 his practice was well-established, with a large work-load based essentially on commissions awarded by architects. Consequently it would have been rather foolhardy of him financially to terminate this work. Second, unlike Williams who saw architects as a hindrance to his mission to develop unique forms of concrete architecture, Faber neither possessed such an objective nor developed such an exclusively engineering view of architectural design. Like Baker, whom he greatly admired, Faber developed traditional attitudes which recognized essential differences between architecture and engineering believing that engineers should be responsible for designs with an overiding engineering content, while architects should restrict themselves to work of an essentially architectural nature. (This was the policy that Baker and Faber applied to their work at 'Lord's Cricket Ground'). In this way conflicts between the two disciplines would have been avoided and both architect and engineer would have been able to reach their full potential. Where architects required technical assistance in designing traditional forms of architecture Faber was always prepared to collaborate because in such schemes the design skills required by the architect were in complete contrast to those of the engineer and thus little conflict arose. However it is notable that throughout the 1930s he avoided architectural commissions of a modernist character, where architects attempted to use the structural engineering as the basic concept of their design approach. As was demonstrated at the 'Royal Horticultural Hall', projects of this nature paradoxically exacerbated the conflicts between the two disciplines and if the architects were unwilling to promote effective collaboration with their engineers it would be impossible to reconcile differences in the architectural solution. It appears, therefore, that Faber preferred to develop his engineering abilities (particularly those in reinforced concrete) in schemes where these conflicts did not arise - that is in 'traditional' architectural projects where the engineering was of necessity always subordinate to the aesthetic requirements or in 'engineering' projects where he could work legitimately without architectural assistance.

Faber's Work as Principal Designer

From 1927 to 1939 Faber undertook the design of six major projects working as principal designer without architectural assistance. These included four industrial buildings (1931-1937), a further grandstand scheme (1927) and a public arena (1936).

There are two important themes which run through Faber's involvement in this type of work. First was his view that he was an engineer producing high-quality engineering work and not a 'psuedo-architect'. It might be argued that this stance was adopted to prevent him prejudicing his relationship with members of the architectural profession who continued to provide him with a large proportion of his work throughout the 1930s. However on the basis of his writings it will be argued this was not the case, for if there were any underlying motive to his work at this time it was to demonstrate that aesthetic considerations ought to be as valid a part of the engineer's education and design procedure as they were of the architect's. Second, the aesthetic theory he himself applied was based on traditional architectural values emanating from that well established Vitruvian phrase - "Commodity, Firmness and Delight" popularized during the 1920s and 1930s by such writers as Geoffrey Scott, Trystan Edwards and Howard Robertson.[65] This is particularly interesting in view of the fact that Faber's buildings appeared strikingly functional and were often received as such in the architectural press. However he himself, while appreciating that structural function could determine architectural form, maintained that unadulterated functionalism was a dangerous fallacy, particularly in engineering.

So whereas projects designed by Faber during the 1930s were regarded as works of architecture by many commentators, he himself never accepted that he was producing architecture. On the contrary he constantly maintained that he was an engineer producing engineering structures, applying to their design the same regard for aesthetic considerations as an architect would. In this way, Faber was attempting to challenge the conventional view that the artistic content of building design was exclusively the preserve of the architect whilst scientific matters were exclusively those of the engineer. To Faber, building projects could be considered as falling into three groups; those pre-eminently within the engineer's sphere (eg bridge schemes); those pre-eminently within the architect's sphere (eg the domestic dwelling); and a large intermediate group lying legitmately within the scope of both professions.[66]

His views on this subject first became apparent in 1932 in his reply to a lecture the architect Goodhart-Rendel had delivered in Manchester entitled "Art and the People".[67] In this lecture Rendel had attempted to diminish the work of modernists by claiming that "functionalistic architecture" was essentially another term for "civil engineering" as both were based upon utilitarianism. He had said:

'Civil engineering is in my interpretation, building that has nowhere been shaped by aesthetic choice. Directly a designer chooses on aesthetic grounds between equally practical possibilities his production ranks as architecture; it remains engineering only so long as no such occasion has arisen . . . .

. . . civil engineering is the work of man the animal, and it can be wonderful as a honeycomb or a beaver's dam is wonderful; architecture is the work of the human spirit.'[68]

Faber responded to Rendel's definitions in a letter to the editor of the <u>Journal of the R.I.B.A.</u>, in which he charged Rendel with conferring on the engineering profession a second-class status, and drew his attention to the many engineer-designed structures which had been shaped by aesthetic considerations but which could not be described as architecture:

'I know of no obligation on civil engineers to renounce aesthetic considerations where they arise, nor does a work of engineering become less good engineering if it is aesthetically satisfactory.'[69]

In turn Rendel tried to reassure Faber by insisting that he had misunderstood his lecture. He claimed he had been attempting to define the content of architecture and engineering and not the roles of individuals associated with each:

'When a civil engineer excercises aesthetic choice he is attempting architecture, when an architect calculates stress and strains he is attempting civil engineering. There is nothing to prevent either from making such attempts . . . .'[70]

Such reassurance from a well established member of the architectural profession might have been ultimately acceptable to Faber, even though he disagreed with Rendel's definition, had it not been for a later dispute between the two men in which Rendel revealed the true character of his prejudices. The dispute arose in 1935 after The Builder had published illustrations of one of Faber's recently completed buildings, with an accompanying caption referring to Faber as its "Architect" and including his honorary title Hon ARIBA. Rendel spearheaded an R.I.B.A. assault upon Faber in a series of private letters which passed between them during 1935 and 1936. Even though Faber assured Rendel that The Builder's use of the honorary title was completely unauthorized he was asked to prove that his firm were not practising as architects in the design of such buildings.

One concession Faber managed to extract from the R.I.B.A., with the aid of the Institutions of Civil and Structural Engineers, was an agreement that warehouse buildings were legitimate building types for engineers to design without architectural assistance. Nevertheless he was still asked if he felt that it was consistent of him to undertake the design of such buildings while holding the honorary qualification. In a summary letter to Rendel he outlined his predicament:

'. . . there was a discussion as to whether engineers or architects are both entitled to design buildings of an industrial type without encroaching on the preserves of the other's profession, and the R.I.B.A. agreed with the civils and structurals that this was entirely in order. After this it is absurd to suggest that we have infringed the term of Honorary Associateship, which stipulates that we should not act as architects, and we have only practised as engineers.

. . . I cannot now resign without appearing to admit that we have been practising as architects, and this I can never admit. At the same time I do not wish to continue as an Honorary Associate to an Institution which does not desire that one should continue.'[71]

From this dispute it can be concluded that Rendel, when forced into a decision, projected the conventional view of the architectural profession that aesthetics in building was the substantial concern of the architect and not the engineer. However by agreeing that industrial buildings could be designed by engineers, he was obliged to accept crude engineer-designed structures which could be defined as 'engineering' (ie untouched by aesthetic considerations), but not good engineer's designs which he would be forced to define as 'architecture'.

To Faber, this fundamental contradiction in Rendel's argument entirely vindicated his own position; namely that as engineers were frequently employed as principal designers in the design of visually important structures it was their public duty to accept aesthetic responsibility for their creations, regardless as to whether clients made it a condition of their contracts:

'The idea that some structures deserve aesthetic considerations and others do not has nothing to justify it and everything to condemn it.'[72]

Nevertheless, he recognized that engineers generally failed to accept this responsibility and it was his fear that if the profession as a whole continued to ignore this important element of engineering design then they would force important client bodies to employ architects in the design of large scale structures which were fundamentally of an engineering type. He made his views on this subject explicit in an article entitled 'The Engineer as Designer' which he wrote for the Structural Engineer in 1934. In this he explained that the ascendancy of the architectural profession in many areas of work was becoming a well established principle and with it a second-class status was being imposed on the structural engineering profession. Citing the example of four recently completed Thames bridges he wrote:

'. . . these are associated in the public thought with the names of four architects. Who knows who their engineers were?'[73]

Such a situation was quite unacceptable to Faber, particularly as most of these bridges concealed their engineer-designed structural components behind traditionally designed arched-stone veneers. However he was forced to accept that with very few exceptions, engineers would have been incapable of producing more visually pleasing solutions had architects not been involved. Addressing the question as to who was at fault he placed the blame squarely with the engineering profession itself:

'It must regretfully be admitted, I think, that many engineers consider the problems of appearance and aesthetic consideration as outside their function, and in some way of limited importance, and as long as this is so, it is clear that the public authorities cannot do otherwise than put the architects in supreme command.'[74]

Faber recognized that the only effective way this situation could be reversed was for educational provision for British engineers to treat aesthetics as a serious part of its curriculae. However, whilst his reputation did give him a certain amount of authority within the profession generally, his direct influence in the field of education specifically was limited.[75] Consequently it was through his own work as an "engineer" designing "engineering structures" in combination with lectures and articles on the relationship between aesthetics and engineering design that he tried to demonstrate the importance of his message, hoping that by such means sufficient interest would be generated to lead educational bodies to treat the subject seriously. It is in this context that Faber's work as a principal designer should be appreciated, for while his buildings received only modest publicity in the architectural and engineering press, they proved to be particularly successful as illustrations of good engineering design in his award-winning lecture 'The Aesthetics of Engineering Structures'.[76] For this lecture he was awarded the 'Baker Gold Medal' from the Institution of Civil Engineers and it led that body to initiate a series of lectures and the publication of a book on the subject, thus provoking the profession to attach to the issue of aesthetics in engineering the importance Faber had always argued that it should.[77]

As this lecture, later summarized more effectively in book-form, describes the design theory he applied to his own work, it would be prudent to examine its principal themes before assessing how he applied them to built examples.[78] In general terms his approach to design theory was very similar to that promulgated by such writers as Howard Robertson and Trystan Edwards.[79] These writers had throughout the 1920s and 1930s published several articles and books on the subject of architectural style and composition with the aim of providing British architects, and in Edwards's case engineers as well, with "aesthetic ground rules" which would help them to produce modern buildings without recourse to the doctrines of functionalism.[80]

Like these authors Faber saw a main target in functionalism. He recognized this to be particularly important in the field of engineering as he witnessed many engineers using arguments of functionalism to avoid any consideration of aesthetics in their design procedure. Consequently one of his first objectives was to demonstrate that functionalism, when used in isolation, provided no means to achieving beauty in engineering structures. He isolated two types of functionalism - "Honesty of Structure" whose adherents argued that if a structure were designed honestly to meet all its scientific requirements, in an efficient way, the result would of necessity be beautiful; and "Honesty of Construction" or the frank expression of the constructional techniques used. On the former Faber was unequivocal, stating that this approach to design was "perhaps a perfect example of wishful thinking".[81] Although in his book he later conceded that on some occasions, usually when an engineer was designing at scientific limits of a particular technology (eg in the design of a very large span bridge), it was possible that the scientific requirements produced beautiful results, for the most part this rarely happened. He wrote:

'From a very long experience, however, I warn you that this is the exception, and that in most structures you will not achieve a thing of beauty without a definite aesthetic choice between varying designs and a deliberate attempt to produce certain effects.'[82]

On the question of honesty in the expression of construction, Faber was more ambiguous. In certain circumstances he could agree that the expression of construction could add a certain amount of interest to a structure, but generally he argued there was no reason why designers should not entirely conceal the constructional techniques they had used. Taking the dome at St Paul's Cathedral as an example of a structure which concealed its construction, he argued:

'The author sees no reason whatever why modern builders and designers should be under any obligation to confine the domical form to domes of stone construction just because their ancestors had the misfortune to be unable to construct them in any other way, since they had at their disposal only small blocks of material which could only be jointed in such a manner as to give tensile strength, and had to limit the form to such constructions as could be made stable by compression across the joints alone.

If present day builders, having the advantages of other forms of construction, such as reinforced concrete, can produce these desirable aesthetic shapes more cheaply and with greater lightness in other ways, they would appear to the Author to be absolutely entitled to do so.'[83]

Perhaps the best example in Faber's own work where he disguised the
[14] construction was at'Northolt Park'(1927). It was here that Faber
erected two grandstands, each with impressive parabolic cantilevers
(75) executed in structural steelwork, but with their principal members
encased in concrete to produce the deceptive appearance of elegant reinforced concrete forms. Indeed most architectural reviews of the grandstands acclaimed them as highly successful illustrations of reinforced concrete structures whose forms had been solely determined by scientific criteria and the frank expression of the construction
(74) used. The Architect and Building News, for example, concluded of
Faber's work at Northolt:

'(This stand) reveals the well known fact that pure engineering often produces interesting and even delightful forms . . . . This is exactly contrary to the methods of the older school, who design their structures on paper to please the eye and leave it to the engineer to build as best he can. Both have precedents, but it must be surely obvious which is the right one for the twentieth century and which we must adopt if the art of architecture is to survive.'[84]

Clearly, Faber's deception in this project was entirely successful, demonstrating that he always placed most emphasis on achieving the right visual solution and using the cheapest constructional techniques at his disposal to create it. In one of his lectures he referred to this scheme to demonstrate this important point:

'The production of a parabolic curve in this way may be thought to give a line of some beauty, which has nothing to do with the stresses, but is deliberately sought in the interests of aesthetic treatment.'[85]

However, although Faber endorsed the subordination of engineering and constructional issues to the aesthetics of a design problem he made an important distinction between this approach and the use of decoration to improve the visual appearance of a structure. This distinction was particularly important, for he believed that many engineers avoided addressing the aesthetic issues in their design procedure through their mistaken belief that the appearance of a structure could be improved by delegating the application of decoration to others. Faber was vehemently opposed to this method of designing:

'A beautiful structure does not mean an ordinary structure with applied ornament added to it. It is no use saying that you will design your structure and hand it over to somebody else to add the architectural features or to apply suitable ornament which will convert it from a plain into a beautiful structure. Beauty arises from the essential lines, the fitness, the harmony and so on of a structure, which cannot be superimposed but which either are or are not in the original conception. Either the original conception is a thing of beauty . . . or else it is not . . . .

. . . the treatment from the aesthetic aspect cannot be delegated without also delegating the whole basic design.'[86]

It was from this premise that Faber argued the necessity for engineers to treat the aesthetic aspect of structural design as just an important function of their design procedure as the other three functions they usually fulfilled: (These were, - the fulfillment of the 'primary functions' for which any structure was designed; 'permanence' and 'reasonable economy'). To integrate this 'aesthetic function' with the others, the designer had to satisfy four of its most important components: - 'Harmony', 'Composition', 'Character' and 'Interest'.

'Harmony', he argued, itself had two components - external and internal. The former was essentially concerned with the harmonizing of the structure to its surroundings. Internal harmony could only be produced by designing the component parts of any structure with a consistency in their proportion and detail so as 'to produce the effect that they are part of a unified whole and have a family relationship'.[87]

For 'Composition' he advised his audiences and readers to refer to Howard Robertson's book Principles of Architectural Composition.[88] Summarizing Robertson's work, Faber explained that for satisfactory composition in design a balance should be achieved by ensuring that the 'centre of gravity of the masses' should usually lie near the centre. Although symmetrical compositions created this balance naturally, he argued that asymmetrical compositions should achieve the same degree of visual balance by careful arrangement of the masses. With respect to symmetrical solutions, however, he recommended the avoidance of the well known aesthetic effect of "unresolved duality" whereby a restlessness would be created by the placement of two symmetrical units in themselves side by side.

'Character', he maintained, formed an important part of the aesthetic impact of structures though it was difficult to define. Usually it could be created by the natural expression of the function the structure fulfilled and through the influence of factors relating to its 'composition'. Decoration also played a part - the lack of it could produce characteristics of 'simplicity' and 'directness', though if carried to excess on large structures it could create the undesirable quality of 'austerity'. The feeling of strength and stability was another positive characteristic that buildings could exhibit, a feature that could readily be achieved by simple visual means - for example by the introduction of 'set-backs' in the upper portion of a structure. As far as Faber was concerned the most effective way of testing whether a structure had 'character' was to assess if a 'thumb-nail' sketch enabled easy recognition. It was partly for this reason that he encouraged engineers to start their design work at the small scale before working up the detail. Only in this way he maintained, could 'character' be attained.

The fourth quality that Faber argued a structure should possess to be visually pleasing was 'Interest', usually created by the expression of something. In this respect he argued that the 'expression of function' and the 'expression of construction' could be used to produce interest or a secondary intellectual satisfaction. Both these devices were in his view legitimate means of exciting interest in structures so long as they did not over-ride the more important qualities of 'composition' and 'harmony'. 'Rhythm' in structures, produced by the fenestration and structural arrangement, in combination with variations of colour and texture, was another means of producing the quality of 'interest'. In addition to these devices, Faber also argued that by attempting to produce effective silhouettes, through the careful arrangement of all the components of a structural design, the quality of 'interest' in a structure would be enhanced.

Possibly the best examples of Faber's effectiveness in applying these rather traditional concepts to reinforced concrete structures, were the three buildings he designed for the flour millers
[15] Spillers Ltd at Avonmouth, Cardiff and Newcastle between 1931 and 1937. Each of these buildings consisted of three separate parts - silos, mill-house and warehouse, each being very large in scale and all executed in reinforced concrete. (The mill-house at Avonmouth was the exception having a structural steel framework.)

The essential design problem was to combine these three large units in an harmonious and interesting relationship, a task made particularly difficult by the visual dominance of the unfenestrated 150 ft high walls of the silo blocks, and the different scales of the mill-house and warehouse units created by the need for different floor to ceiling heights. One of his first design objectives, therefore, was to vary the proportion and arrangement of the units to achieve the most visually satisfactory solution in terms of massing and interesting silhouette, concentrating principally on the river frontage aspect to each. In this respect it is interesting to note that the most visually appealling of the three schemes was at Newcastle where the site was most restricted. Whereas at Cardiff and Avonmouth the three units were arranged in a linear relationship, at Newcastle
(78) Faber combined the mill-house and warehouse vertically, thus overcoming the visual clash in scales which was readily apparent in the earlier schemes.

Faber's success at Newcastle reveals one of his most notable abilities, in being able to turn severe design constraints to aesthetic advantage. This is particularly apparent in his design of the silo-blocks to each scheme. These presented him with overwhelmingly difficult visual problems for their function suggested large cubic forms built with unrelieved, sheer walls of reinforced concrete which if untreated would be visually offensive in every possible respect:

'Aesthetically, however, it (the silo block) is entirely unsatisfactory in every conceivable respect. It fails to express its function or its construction, or indeed anything whatever, and therefore fails to excite interest. It is lacking in rhythm, and its silhouette is very unsatisfactory. It cannot be said to have any character unless it be the character of a small sugar box sitting on a large one. In composition it offends in every way, being bad in proportion and balance; and as far as harmony is concerned, it obviously has neither self contained harmony, nor harmony with its surroundings, unless the latter are extremely unfortunate.'[89]

To Faber this type of engineering structure provided design opportunities on which he thrived. Moreover by addressing the visual problems of these structures he was able to illustrate his point that engineers did have a public duty to accommodate aesthetic considerations in their design procedure. In the many lectures he delivered to engineers and students on the problem of aesthetics he always used the silo buildings at Spillers as examples of what could be achieved by the careful consideration of his four ingredients for beauty in building.

He admitted that it was very difficult to achieve 'harmony' between a large silo building and its surroundings. However it was perfectly possible to produce a structure which of itself possessed this desirable quality. The first issue that could be examined to achieve this quality was in the overall proportions of the structure. Functionally it was necessary to provide 96 to 100 bins, each 13 ft 6 in square. The most economical arrangement was a square plan form (10 x 10 bins) to reduce external walling costs. However Faber insisted that as the height would then be approximately equal to the length and width this would produce a visually clumsy cubic form:

'. . . there is something akin to an unresolved duality in the square. The eye seems to require to be told whether the treatment in a particular case is vertical or horizontal.

In the case of a rectangle this problem is settled immediately, whereas in the case of the square, the eye is left wandering in indecision.'[90]

Simply by reorganizing the overall proportions into a rectangular

(79) plan form of 16 x 6 bins, he was able to produce a much improved

building in which the length and height of each elevation was determined by the proportional ratio 1:2 for little extra cost.

To achieve a satisfactory 'composition' Faber had visually to accommodate the receiving house on the top of the silos with its small lift motor room which projected above the main roof line. Ideally Faber would have preferred the lift motor room to form a central position in the structure but for unavoidable functional reasons it had to be located at one end of the block. This created an imbalance in the composition giving a lop-sided appearance. To compensate for this incorrect position of the "visual centre of gravity" he intro-
(82) duced a high level connecting bridge just below the lift motor room, functionally linking the silo block to the mill-house, but visually correcting the necessarily imposed imbalance. To reinforce the appearance of stability he introduced a set back in the relationship between the receiving house and the silo structure below.

To provide 'interest' in these structures, Faber used two separate devices - 'the expression of construction' and the legitimate
(83) introduction of fenestration to express the function of the building. For the former he decided to modulate the walls by expressing on their surfaces the position of the internal cross walls of the bins at 13 ft centres. Structurally this was unnecessary but he claimed that by simply acknowledging the internal construction externally, by including a series of 6 in deep piers on the external walls, he was able to produce an effective rhythm which added to the structures'visual interest.

Clearly fenestration could only be included in parts of the building in which people worked - that is, the receiving house at roof level and the conveyor floor at ground level. At ground level he introduced window openings with the same proportions that he had used in each of the elevations - that is the double square, to accentuate what he termed the 'internal harmony'. At roof level he used circular windows located in the set-back wall surfaces of the receiving house, which had the effect of producing a visual termination to the sequence of expressed bin-walls below - the equivalent of the cornice in earlier forms of architecture.

By introducing these well considered features into the design of the silo buildings, Faber was able to give this enormous mass some visual appeal without resorting to crude decoration or deceit. Nevertheless it is noteworthy that in his own descriptions of these structures, at least in his lectures on "aesthetics", he made little reference to the structural and constructional techniques he had used. This observation is particularly relevant in view of the fact that they were erected using the relatively new technique of "slip-
(83) form" construction, whereby the four foot high shuttering was raised by screw jacks at the rate of six inches per hour to allow the fixing of reinforcement and the placing of concrete to form part of a continuous process.[91] Even though his use of this technique was one of the earliest, large scale examples of its application to British structures, pre-dating Arup's use of the technique at Highpoint I by at least twelve months, his failure to make reference to it in his lectures on aesthetics clearly demonstrates that he regarded it merely as an expedient way of solving the constructional problems. Moreover, despite the fact that the technique had important and inevitable implications on the design and the resulting built form, Faber's decision to concentrate most of his design effort in relieving the visual monotony it created by adding superfluous structural features, indicates that as far as aesthetics were concerned he regarded the constructional issues to be of secondary importance

to the visual aspects of the design problem.

By contrast, the mill-house and warehouse structures for Spillers used more conventional systems of post and beam reinforced concrete structures. Nevertheless the same conclusions can be drawn, for while it was the articulation of the structural arrangement that produced the essential features of the architectural composition, in his lectures he never referred to the structural arrangement itself, preferring to describe how it was his concern for producing 'harmony', 'composition', 'interest' etc, that determined the resulting built forms. In this respect it is notable that at the
(77) Avonmouth mill-house he produced an identical external appearance to the other buildings by using structural steelwork instead of concrete. Clearly he saw no reason why differences in structural technique should have any significant difference on the resulting architecture.

The same observation can be made of one of his most successful
[16] warehouse schemes on the Thames, London - 'The Nine Elms Warehouse' (1935). Here a similar post and beam concrete framed solution was used creating a repetitive gridwork pattern of frame with brick and glass infill panels on the elevations. While this provided him with the basic ingredient of his design, in his descriptions of the building from an aesthetic point of view he argued that the most important aspect of the design was to achieve an effective 'composition' and 'silhouette' by creating a strong visual relationship between three electric cranes on the wharf and the three lift
(89) motor rooms positioned on the roof of the building.

Although Faber may have overemphasized the "aesthetic" aspects of his design approach in order to demonstrate to engineers that

functionalism provided no means to achieve beauty in buildings, it is clear that in each of his schemes, expression of the structure formed an important part of their success. When one studies his
[17] work at 'Harringay Arena' (1936) this observation becomes readily apparent. Unlike the silo and warehouse buildings which possessed an internal arrangement and logical structural solution that could be articulated in the design of the elevations, the arena consisted essentially of a large internal volume with lightweight steel roof which presented few clues as to what could be achieved on the facades. To resolve this enclosure problem Faber was forced to adopt the conventional architectural solution of adding a stylistic veneer to conceal his own engineering work. This was not a problem with which he was familiar and consequently he looked to architect-
(93) ural precedents in his detailing of unconvincing brickwork facades. Visually the result was a failure and it appears as though he recognized this himself for in all his lectures and articles on aesthetics he never referred to it. This clearly demonstrates that Faber needed projects with an important structural content if he was to achieve success and in many ways it represents a vindication of his own argument that there was an important distinction between engineering and architectural projects. Whereas his other buildings could legitimately be defined as 'engineering' because of their overriding structural content, schemes like the 'Harringay Arena' possessed architectural problems largely unconnected to their structures which would probably have best been resolved by effective collaboration with an architect.

Faber's work at Harringay was his last major project as principal designer, with the exception of the Newcastle Spillers' project which although designed in 1935 was not completed until 1937.

Within their own terms of reference all his other projects undertaken in the capacity of principal designer were undoubtedly successful. In each one, Faber was able to take on projects which had little potential to be attractive additions to their environments and produce visually satisfactory results. In a wider context, however, it must be admitted that they could not be regarded as outstanding examples of reinforced concrete architecture. Although in terms of their scale and massing they had a powerful visual effect, they each possessed a type of indeterminate, styleless quality which was undoubtedly one of the major reasons why they failed to excite especial interest in the contemporary architectural press. (This is excepting, of course, the Northolt stands which were mistakenly reviewed as examples of functional reinforced concrete design.) Perhaps the most surprising observation to be drawn from his work is that unlike other notable engineers who undertook design work as principal designers, Faber appears to have been reluctant to produce exciting structural forms in reinforced concrete. Despite his unequalled reputation in Britain as a leading theoretician in the material, he appears to have been inhibited or unwilling to maximize the visual potential of the technology he was using.

On the one hand this failure may simply represent a weakness in his design abilities. On the other it may be seen as an understandable reluctance in as much as he was never prepared to adopt novel systems of construction that would be at the expense of, what he considered to be, more important functional and human requirements. The balance seems to be in favour of the latter, for there is little doubt that his own approach to design was modelled on that established by the many traditional architects with whom he worked and admired which seems to have ensured that even in his own work he saw the engineering to be subordinate to the broader "aesthetic issues". In this sense he may be regarded as a traditional engineer, always prepared to see the engineering as an expedient means of solving a particular problem. The issue which set him apart from most others, however, was his dedication to making aesthetic issues an important function of the engineer's design procedure.

CHAPTER 6

OWEN WILLIAMS

Williams - The Consulting Engineer 1921-1929

Williams's career as a consulting engineer in the first eight years of his practice was substantially different from Faber's. During the same period Faber had worked for a large number of traditionally minded architects and improved his abilities in structural steelwork to provide them with the support structures they required for their facadist designs. Williams in contrast worked primarily with one architect - Maxwell Ayrton of Sir John Simpson and Partners - and together they collaborated on a large number of contracts with one specific objective in mind; namely to develop reinforced concrete as a visually attractive material and to combine its engineering and aesthetic qualities to elevate it above its contemporary association in many people's minds with cheap, utility engineering and industrial structures.

At the outset, both men believed that this could only be achieved through the effective collaboration of architect and engineer and it was on this basis that they established their association. As one would have expected, each brought to their joint work distinctive approaches to design; Williams, as an engineer trained within the commercial pressures of concrete specialist firms, placed his highest priority on achieving an 'economy of means' in their work, whilst Ayrton, a traditionally trained architect, directed most of his attention to the 'architectural treatment' of concrete - a term frequently used at the time but from Ayrton's point of view was primarily related to creating acceptable surface finishes. It is the interaction of these distinctive approaches to design as is manifested in their built work rather than in their personal relationship, that will be discussed below.

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The initiation of Williams and Ayrton's collaboration came in 1921. In that year both men were brought together to design the principal buildings and the overall site layout of the British
[18] Empire Exhibition at Wembley. It was a vast design undertaking and as it was the first major British architectural project to use reinforced concrete as the principal building material, outside the field of industrial building, it provided Williams with a spectacular launch to his new career as a consulting engineer. Not only did his engineering contribution earn him a knighthood at the early age of 34 years, but through the extensive publicity he received, both in the technical and national press, he acquired an unequalled and broadly based reputation as Britain's leading authority in reinforced concrete design. (The popular press for example often referred to him throughout the 1920s as 'Concrete Williams'.) Apart from the publicity value, the exhibition was useful to Williams for two additional reasons in that it initiated his interest in architectural design and enabled him to form a close working relationship with Ayrton which both men continued throughout the 1920s.

The exhibition was first suggested by Lord Strathcona in 1913,[92] but it was not until after the war that a firm decision was taken to stage the event. The aftermath of the war undoubtedly gave a great impetus to the idea of organizing such an important event in as much as it was politically conceived as something of a jingoistic display to reassure British subjects of the strength of the British Empire. It was intended that each of the British colonies would be represented at the exhibition by separate buildings ranked in order of size according to the relative importance of each. (Thus Australia and Canada were assigned the largest pavilions whereas colonies such as Bermuda were given the smallest.) Great Britain was to be represented by three major buildings - the Palaces of Industry, Engineering and Arts. All these buildings were intended to be temporary, although two remain today.[93] The only permanent structure was to be a new national sports stadium - the Wembley Stadium - which was to be designed to accommodate 125,000 people. Concrete appears to have been chosen as the principal building material for four reasons: first on grounds of cost; second to ensure a short construction period of approximately twelve months; third because concrete was considered, quite wrongly, to be an appropriate material for temporary buildings; and fourth to display the advanced state of British involvement in reinforced concrete technology.[94]

The location chosen was a triangular, tree covered, 225 acre site at Wembley, north-west London, and design work began in
(94) 1921. Looking at the site layout it is clear that Beaux Arts principles of symmetrical planning with a strong central axis were the controlling features of the design. The main north-

south axis - 'Wembley Way' - was positioned centrally on the site, with a view from the main north entrance up the slope to the Stadium at the southerly end. On each side were placed the most important of the exhibition buildings - to the north, the Palaces of Engineering and Industry and in front of the Stadium the Pavilions of Australia and Canada. Between these an artificial lake was created, bridged by a simple three arched concrete structure which formed part of 'Wembley Way'.

It is interesting that in the many lectures Williams gave after the opening of the exhibition, he ignored the aesthetic principles which had governed the site planning, emphasizing engineering considerations. For example he claimed that the position of the stadium had been decided because its elevated position on the site provided the best location with regard to drainage. He also maintained that the artificial lake had been created at the foot of the hill below the Stadium, primarily as a balancing pool for surface water run-off.[95] Whilst these factors were clearly important aspects of the site planning and undoubtedly formed part of Williams's contribution to his collaboration with Ayrton, it is noteworthy that at this early date Williams should consider these functional issues as the major parameters of the design problem.

The Beaux Arts strategy Ayrton applied to the overall layout of the exhibition was reflected in the elevations to the individual buildings. Each of these, with the exception of the smallest colonial pavilions in which neither he nor Williams had any involvement, adopted a classical style even though their facades were erected in concrete. As Ayrton had never used concrete before, at least not on this scale, he was forced to collaborate with Williams and the contractor McAlpine in design process. This enforced collaboration of these disciplines received as much favourable comment in the contemporary press as the buildings themselves, suggesting that at this point in time the integration of Williams and Ayrton's skills was something quite new in the building industry. For example the editor of the Architectural Review wrote:

'Theirs was the marriage of true minds to which there has been no impediment . . . . They have affected something more lasting at Wembley - they have shown the possibility of collaboration and co-operation between architect and engineer, each enhancing the work of the other.'[96]

Although this type of observation was common to many contemporary reviews, the most cursory assessment of the buildings they produced reveals that their collaboration was dominated by Ayrton's architectural pretentions with Williams's primary role being to translate what were essential classically detailed masonry build-
(95) ings into economical concrete forms. Indeed from the overall
(103) layout of the exhibition to the smallest details of the buildings' facades, Ayrton imposed a highly traditional classical approach to the design and his only real contribution to the collaboration was to devise with Williams and McAlpine a range of shuttering systems that would recreate the rustication, jointing and tooling
(96) effects of traditional stone craftsmanship in insitu concrete. Moreover, in most of their buildings a clear distinction was made between the engineering and architectural content with Ayrton concentrating his attention on the most visually important facades leaving Williams to devise the remainder.

Whilst these criticisms are relevant to all of their buildings

it is perhaps the Stadium which exposes them most fully. From a purely visual point of view the most important element of this structure was the south facade which formed the termination point of 'Wembley Way'. Ayrton's first perspective drawings of this facade confirms his architectural decision to make it appear as a classical masonry structure with a wilful disregard for allowing the peculiarities of reinforced concrete construction to have any influence on the design.[97] Williams's role was to design the working details in concrete to produce this masonry effect. Thus whilst he collaborated with Ayrton, their work was directed to producing nothing less than a 'sham'. This is not only apparent in the surface treatment which carefully imitated the horizontal and vertical joints of masonry construction but in the overall proportions. Examination of Williams's working drawings clearly reveals the structural deceit he was forced to employ in producing this architectural effect. Ayrton's drawings of the wall panel between the two twin towers shows excessively large concrete columns, 6 ft x 2 ft and 4 ft x 2 ft in section at very close centres of 13 ft and 17 ft. However from Williams's
(99) working details it can be seen that most of these columns provide little structural function. Indeed each was made hollow with an outside thickness of only 3 in to 4 in.[98] The main column supports were only 16 in x 3 ft in section and located in the centre of every third hollow column at more appropriate centres of approximately 40 ft.

The twin towers surmounting this facade were a more complex
(100) example of reinforced concrete design and construction. Reference to the drawings produced by Williams shows how he was able to use his skill in reinforced concrete design, borrowing from his

experience in concrete ship design, to produce a structural solution which accommodated all the architectural idiosyncracies
(98) of Ayrton's simply drawn outline.[99] The domes themselves were designed on similar lines to Williams's concrete ship projects with a 3 in thick concrete shell reinforced by shallow curved ribs and tied by concrete cross members at their bases. They were supported on 4 in concrete walls, stiffened by piers and buttressed by four concrete turrets.

This example of the principal facade of the Stadium typifies the approach to design that was used for the principal facades of all their other buildings at Wembley. Nevertheless in other parts of the buildings Williams appears to have been given a free rein in adopting whichever form of structural means was most suitable to the functional requirements. This is most readily apparent in the remainder of the Stadium. (As most of the drawings for this are to be found in Williams's collection it is reasonable to assume that he was largely responsible for the design decisions in areas of the building which were not as visually important as the main facade.)[100] The elevations were
(101) constructed with solid concrete columns, 9 in x 18 in in plan section, at 24 ft centres supporting parabolic arches which were simply repeated around the external envelope. These were occasionally interrupted by monolithic concrete stair towers
(97) providing access to the upper part of the open terrace.[101] The very poor quality of the concrete surfaces of these towers lends support to the assertion that Ayrton had little involvement in either their design or construction. Unlike the principal facades these wall surfaces received little consideration being left untreated from the roughly erected shuttering.[102] Internally,

Williams departed from insitu concrete construction using a lattice steel framework to support the upper terraces, while the lower terraces were supported on earth excavated from the bowl. The composite nature of the stadium's structure supports Williams's insistence that as engineer he felt it necessary to use whichever structural materials and solutions were best fitted to the particular problem both on economic and structural grounds. In one of the lectures he gave on the design of the exhibition he explained this point.

'It has been my guiding principle to use no material where another material would better serve. To have used concrete where concrete should not be used would, apart from bad engineering, be of no service to the material itself.'[103]

An interesting observation of the principal features of Williams's design for the Wembley Stadium is their similarity to features of contemporary American stadia, described in the New York journal Engineering News - Record, which Williams was receiving at that time. (Indeed, in Williams's own 1921 and 1922 copies of this journal all the articles on stadium design have been marked by him.)[104] Take for example his decision to support the lower half of the sloped terraces on earth excavated from the bowl. This engineering device received much favourable comment at the time, and although it was undoubtedly a solution that Williams could have arrived at on his own account, it seems more than coincidental that two contemporary articles from this American journal describe the same technique used in the building of the Stamford Stadium at Washington University.[105]

Furthermore the combination of lattice steel stanchions supporting the upper concrete terraces at Wembley was a type of composite construction which had been given full publicity in the same journal's October 1922 issue in which the attributes of an identical structural arrangement, used at the Ohio Stadium, were fully described.[106]

It is clear therefore that in parts of the exhibition buildings where Ayrton had little involvement, Williams was given the opportunity to experiment with many different structural techniques, a significant number of which can be traced to important American sources. Not only did he develop his abilities in insitu concrete, experimenting with flat slab construction in a
(102) small area of the Stadium's design,[107] but he also ventured into structural steelwork[108] and developed pre-cast concrete techniques - particularly noteworthy in the roof construction
(104) of the Palace of Industry.[109]

Despite Ayrton's strict architectural control in the design of the principal facades, Williams constantly referred in his lectures during 1924 and 1925 to the design principle he had observed throughout - 'the economy of means'.[110] This, he claimed, was the basic tenet of all engineering design and any structure which failed in respect of this principle was in his view bad engineering. It is therefore necessary to question how he reacted to the 'economy of means' he was forced to apply in producing the extravagant structural solution of Ayrton's classical facades. Although he never directly criticized the 'misuse' of concrete in these parts of the exhibition buildings, many of the articles he published between 1924 and 1925 contain veiled references to his disapproval. For example in a lecture he delivered to the Institution of Municipal and County Engineers in 1924 he appears to have justified the use of concrete in this way by claiming that architecture was some years behind engineering in its assimilation of new structural techniques. He was hopeful, however, that through an evolutionary process architects and engineers, working in close collaboration, would be able to produce new forms of architecture which were more responsive to the unique qualities of the material:

' . . . . Architecturally it (concrete) has largely been regarded as a somewhat mysterious alternative, only to be adopted for economy, or put in to support a facade of other materials in which it is hastily clothed to hide its nakedness. The buildings of the Exhibition witness a new architectural stage in the history of reinforced concrete. It is entering upon an era possibly of slow acceptance to architects, but ultimately must develop an architecture of its own, in the same way as it has developed a branch of engineering.'[111]

This view may be compared with Ayrton's. Like Williams he regarded the Exhibition buildings as a landmark in the development of reinforced concrete, not through the creation of new architectural forms (although he admitted that it had the potential to achieve this), but in its proof that concrete could be used to produce visually acceptable buildings. This he claimed was its greatest significance for previously concrete had always been regarded as a cheap material associated with the utilitarian designs of the engineering profession. Justifying his own 'classical' designs, he maintained that architects were under an obligation not to produce 'revolutionary' architectural forms that would be prejudicial to the material by alienating conservative public opinion.[112] An evolutionary development was Ayrton's preferred approach to developing concrete as an architectural material and in this he was convinced that engineers and architects would have to collaborate - engineers providing the essential technological skills with architects producing acceptable surface finishes. Only in this way, he maintained, would concrete develop a distinctive 'style' of its own.

This then formed the basis of Williams and Ayrton's subsequent work together, both men sharing the same commitment to collaboration and a similar objective. (The word 'similar' is important in as much as Williams referred to his objective as being 'Concrete Architecture' while Ayrton referred to a 'Concrete Style of Architecture'.) As most of their later work was directed towards bridge designs, their working relationship was something of a reversal of that which had pertained at Wembley. In these schemes Williams took the responsibility for the major structural decisions with Ayrton, acting officially in the capacity of 'consulting architect', contributing to the visual aspects of the designs by concentrating on the details of the surface finishes. Nevertheless while the predominant structural issues of bridge design gave Williams a strong position in his collaboration with Ayrton, it appears to have taken some time before his confidence developed sufficiently for his own engineering instincts began to express themselves in built form. It is the continued dominance of Ayrton's visual requirements therefore which characterizes their work up to 1926.

Their first bridge project was the 'Lea Valley Viaduct and Bridge' (1924) which formed part of the new North Circular Road, London. Like the exhibition buildings this project was unsuccessful in integrating the engineering and architectural contributions of the design. Indeed the demarcation between Williams's and Ayrton's work was so distinctive that it could readily have been undertaken as two separate contracts.

The essential engineering problem was to continue the road over a large expanse of low lying ground, for the most part a shallow depression of only 16 ft. Williams's structure was simply designed as a flat concrete road deck supported on a series of reinforced concrete frames, each made up of four large tapered columns with downstand beam. (His first drawings indicate a flat slab structure which was later superseded with the frame solution.)[113] Although Ayrton advised that the concrete surfaces receive a bush-hammered finish and he undoubtedly contributed to the decision to use brick parapet walls, Williams's structural solution was devoid of any decorative treatment or stylistic modifications.

The principal visual problem that Ayrton addressed was the unobtrusiveness of Williams's structure. The fact that the viaduct was barely noticeable in its surroundings and was completely hidden, from the road-users point of view, clearly offended his architectural instincts. To resolve this self-imposed problem he added four large monumental entrance features, termed 'pylons',
(106) one to each side of both entrances. These wholly redundant, independant structures consisted of high, curved concrete walls reminiscent in their detailing of the heavy classical styling applied to the concrete buildings at Wembley. It is clear that Williams contributed nothing to their design.[114] Justifying these structurally redundant additions in a paper he delivered to the R I B A in 1931, Ayrton said:

'In many instances there is nothing to call ones attention to the fact that one is approaching or even crossing a bridge. I feel that this definitely justifies, in certain cases, some form of superstructure, as in the case of the Lea Valley Viaduct and Bridge over the Lea Navigation River . . . . I am well aware that this can be defended solely on aesthetic grounds . . . .

There is no doubt that the future of concrete as a monumental material is full of possibilities, but these can only be discovered by the frank acceptance of the material with all its difficulties and disappointments, using it as engineers would have us use it, but adding that spirit which is lacking from any design produced solely upon scientific principles.'[115]

Williams's attitudes to these 'architectural' additions is not recorded. However, it can be assumed from his later more general pronouncements that had he not agreed to their inclusion, he might have used them to illustrate his argument that the objectives of engineer and architect were in direct conflict - the one committed to 'efficiency' the other 'effectiveness'.[116]

Ayrton's compulsion to make an architectural statement of bridge design was to some extent repeated in their next important com-
[19] mission at Tomatin, Scotland. However in this scheme the effect was more convincingly produced by devising an engineering solution that would cater for both the visual and structural requirements. Built over the Findhorn valley, the Findhorn bridge (1925) was one of the first of forty bridges to form part of the A9 road reconstruction between Perth and Inverness, the most important of which were assigned to Williams and Ayrton by the Ministry of Transport.[117]

Instead of allowing Ayrton to devise some unnecessary monumental additions to draw attention to the existence of this bridge, it was decided to suspend the road deck from deep concrete trusses,
(108) thus providing an impressive arcade for the road user. As well as satisfying Ayrton's visual criteria there were sound engineering reasons for adopting this form of construction in as much as it produced much smaller loadings than a comparable arched form of construction (the ground conditions were particularly poor).[118]

It was the arrangement of reinforcement within these trusses that

(112) suggested the size and shape of the roughly triangular openings
included within them. Ayrton used the shape of these openings to
great advantage in the modelling of the concrete surfaces in using
(110) them as the basis for producing visually effective faceted
surfaces along the external faces of the trusses.[119]

While the integration of Williams and Ayrton's skills in the design of this structure produced their first convincing project, it must be noted, however, that this was achieved at considerable cost. The contract price was £33,146, by far the most expensive of the bridges to be erected along the A9 road, even though in terms of span and site conditions it was comparable with many equally successful structures though much less expensive. Thus while Ayrton and Williams were beginning to integrate their design skills, the effectiveness of their collaboration was still unrelated to the economics of efficient engineering design.

This tendency to produce over-structured solutions in order to
create interesting visual forms was repeated in three other
bridge designs along the A9 road before 1926. The smallest of
[20] these, at 'Crubenmore and Loch Alvie', were effectively designed
to appear as rock-like protrusions in their surroundings with the
surfaces of their concrete spandrels carefully faceted with the
use of angled triangular shuttering.[120] The basic structure of
each, however, consisted of two slender reinforced concrete
arches concealed behind the angular spandrels whose prime function
was to contain the hardcore filling supporting the road deck.
This structural solution was repeated in the design of the 'Spey
[21] Bridge', the largest of the A9 bridges. The spandrel walls in
this scheme, however, were curved throughout their height producing

something of the appearance of a dam-structure.[121]

In all these schemes, therefore, it is clear that while the visual effect was good, the engineering considerations were still subservient to Ayrton's stylistic preferences.

. . . .

A significant departure from this approach to bridge design appears to date from 1926 when Williams began to impose on his collaboration with Ayrton a greater respect for the structural integrity of their designs. The first series of bridges which indicate this development were open spandrel structures, followed by a number of simple flat-deck beam solutions which Williams argued were the most appropriate forms for bridges constructed of reinforced concrete.

The turning point seems to have been their design for the 'Wansford
[22] Bridge' on the Great North Road (A1) in Huntingdonshire.[122] An important design requirement, imposed by the Ministry of Transport, was that the completed structure should harmonize with the vernacular tradition of adjacent buildings. For this reason a traditional three arched structure was proposed, very similar in
(121) scale to the Spey bridge. However whereas at Spey Williams was prepared to conceal his slender reinforced concrete arches behind monolithic concrete spandrel walls, at Wansford he decided that if he were to reproduce a traditional form of masonry-type structure he would design it along traditional lines by eliminating tensile stresses and thus the need for reinforcement. Consequently he designed the Wansford bridge as a mass concrete structure, using

as one of his precedents a similar contemporary American example at Sidney, Ohio.[123]

Williams was a keen advocate of mass concrete when he could demonstrate that in specific circumstances it would be cheaper than using reinforced concrete.[124] In this respect the use of the technique at Wansford was entirely justifiable in as much as there was a ready supply of aggregate in adjacent land and because the isolated location would have increased the price of reinforcement through excessive transportation costs. It is surprising, however, that the completed structure should appear more efficient than their earlier concrete bridges in both the size and disposition of its structural members, despite the omission of reinforcement. Whereas many of the earlier reinforced concrete structures appeared to have been built from mass concrete because of their heavy visual appearance created by the use of solid spandrel panels, at Wansford Williams pierced the spandrels with a series of secondary, semicircular arches supported on the main
(122) mass concrete arches below and carrying the road deck on top.

In subsequent reinforced concrete schemes, largely in Scotland, this development was advanced one stage further by the full adoption of open spandrel solutions. In these, principally at
[23] 'Duntocher, Dalnamein and Carrbridge', the concrete frame structure was simply exposed with slender reinforced concrete columns supporting downstand beams or cruciform capitals, transmitting the loads from the road decks onto slender reinforced concrete arches below.[125] All these examples were built between 1926 and 1927, and in none of them does Ayrton appear to have made any attempt to adjust the structural solution or impose decoration to

create added visual interest. Indeed it seems highly probable that Ayrton had little involvement in their design.

The most significant change in the development of their bridge work, however, appears to date from late 1927 when Williams further simplified his approach to reinforced concrete design by disregarding the arch-form, replacing it with flat-deck beam and column solutions. What is particularly interesting is that as Williams's increasing concern for economy began to create simpler structural forms, Ayrton began to reapply inappropriate decorative motifs to their surfaces in order to create visual interest.

This is most readily apparent in their design for the 'Lochy
[24] Bridge' (1927), near Fort William. From a structural point of
view this bridge represented an important technical advance on
Williams's earlier work.[126] The parapet walls were designed to
act as beams and cantilevers in conjunction with the concrete
(136) road deck itself. Each unit along the length of the bridge was
supported on two pairs of columns with their ends cantilevered
out 19 ft to meet a duplicate arrangement. Ayrton was clearly
unwilling to allow this structural arrangement to be the dominant
visual characteristic of the structure. Not only did he apply an
inappropriate decorative treatment to the parapet walls, created
by the casting of radiating flutes into the concrete, but he also
(134) reintroduced the monumental 'pylon' structures, used earlier at
the Lea Valley Viaduct, to mark the entrances to the bridge. It
[25] is fortunate that in subsequent bridges of this type Ayrton's
decorative excesses appear to have been restrained largely because
of his limited involvement.

However when Williams and Ayrton were commissioned to undertake the design of their largest and most prestigious of bridges - at
[26] Montrose, Scotland, - Ayrton appears to have been instrumental in rejecting Williams's argument for simplicity.[127] His wish to make an architectural statement in this scheme led to a decision to
(141) build what was essentially a suspension bridge in reinforced concrete, primarily to give the road user the arcade effect that they had successfully used at Findhorn. This peculiar decision attracted severe technical criticism, particularly from the American engineering press.[128] Although Williams defended the scheme on economic and structural grounds, his arguments appear unconvincing, and one is led to speculate that, whilst never admitting it, he basically agreed with the criticism.

This is borne out in his design proposal for the Waterloo bridge
(143) which he produced in March 1932. Although post dating his collaborative period with Ayrton in its bold, self-asserting simplicity, devoid of any decorative treatment, the Waterloo Bridge design represents the goal that Williams seems to have been striving for in his earlier partnership with Ayrton. Indeed it could be legitmately argued that had Ayrton not been involved in their later 1920s bridge schemes, then the functional simplicity of the Waterloo design could have attained physical form much earlier.

In essence the structural concept of the Waterloo bridge design was very similar to that used for the Lochy bridge, but on a much larger scale with the solution adopted there extended to its structural limits and with the complete removal of decorative effects he had used at Lochy.[129] Instead of the two rows of columns to each side of the road he substituted just one row positioned centrally under

the deck. Each column, 20 ft in diameter and located at 150 ft centres, was to support cantilevered slabs which projected out
(142) 40 ft in all four directions from the centre of each support. Between these slabs were to be cast suspended reinforced concrete 'boxed-decks', 10 ft deep, jointed by open lapped joints to allow expansion.

Williams presented his uninvited proposal to London County Council together with a firm commitment to undertake the entire project, including demolition of the old bridge, for a price of £693,000 in 3½ years. (This was apparently the first time on record that an engineer made such an offer for a structure of this magnitude.)[130]

Although his proposal received extensive publicity in the press, it appears to have been too far ahead of its time in terms of its simple visual appearance at such an important location to attract admiration from the influential institutions who might have made it a reality. One of the most frequently quoted criticisms was that emanating from Herbert Morrison who is reported to have said of Williams's proposal:

'A mere roadway on upturned drain pipes utterly unworthy of the site.'[131]

The general consensus was that for an important Thames bridge a traditional arch structure was the only visually appropriate solution. The director of British Steelwork Association, C J Kavanagh, seized upon this general aesthetic criticism of the proposal to promote his own natural preference for a steel structure. In a letter to The Times he wrote:

'. . . . There would not be the slightest difficulty in constructing more economically a steel bridge of attractive appearance of the arch type similar to other bridges over the Thames. As an illustration, a bridge recently built in Cologne is considered by many to be the most beautiful in Europe. It is built entirely of steel, it is nearly one and a half times as long as Waterloo Bridge, carries six lines of traffic, provides an uninterrupted waterway for river traffic, and cost less than £600,000.[132]

Williams replied to this letter in a subsequent contribution to The Times exposing Kavanagh's fallacious comparisons and noting his failure to include the cost of demolition work in his quotation. Referring to the issue of concrete versus steel he wrote:

'Not being interested in propoganda of any particular material, I naturally investigated stone and steel as well as reinforced concrete before making my offer, and can speak with confidence on the relative economies.'[133]

Reference to Williams's drawings show that he did produce a steel
(144) proposal, although it adopted the same simple form as the concrete scheme with the main support structure in concrete and the intermediate decks constructed from structural steelwork.[134] Despite this attempt to address the vested interests of the steel industry, neither proposal was adopted. Instead Sir Giles Gilbert Scott was appointed to produce a traditional scheme which was designed as a masonry arched veneer to clad his engineer's steel and reinforced concrete structure behind.[135]

While Williams was disappointed that his scheme was not accepted, the publicity it provoked was helpful both to Williams in exposing his views and to the small group of modernists in architecture who used the controversy to illustrate their own problems in producing forms of architecture which truthfully responded to the properties of modern materials and modern conditions. P Morton Shand, for example, was so impressed with Williams's scheme that he sent the drawings to Maillart for his informed comment. Maillart replied that he liked its 'elegance' but questioned some of the engineering details. 'How interesting', Shand claimed, that misinformed British architects and public opinion should criticize Williams aesthetics whilst applauding its engineering. Explaining this he wrote:

'. . . our eyes have grown accustomed to arched spans because brick and stone can only be built in that manner. When, therefore, we are brought face to face with another material that is able to ignore the arch convention we upbraid the author's choice of material, his lack of 'taste', or his inexcusable disregard for the aesthetic sensibilities of others. This, if we only knew it, is equivalent to reminiscence over resource, approximate over precise, amateur capacity over technical proficiency and waste of space and material over exact calculation of how much of each is required.'[136]

. . . .

Confirmation that it was Williams's influence in his collaboration with Ayrton that led to the development of simple structural forms in their bridge work and that it was Ayrton who continued to impose unnecessary decorative additions when the engineering solutions became too austere, is to some extent amplified in the complete subjugation of Williams's structural forms in a small number of building projects they designed towards the end of the 1920s. In these projects, designed and built between 1928 and 1930, the Wembley professional relationship was reintroduced and reinforced by Williams's reversion to Ayrton's technical assistant in producing buildings whose architectural features bore little relation to their structural solutions.

Two schemes which are typical of this collaborative phase are the
(145) 'National Institute for Medical Research, at Frognal, Hampstead'
(1929-1930)[137] and a warehouse and factory building for the
(146) 'Pilkington Glass Company, Hoxton, North London' (1928-1930)[138]
A common feature of these was the enclosure of Williams's reinforced concrete frames behind traditionally detailed brickwork facades. Even though the buildings had entirely different

functions, certain features of their architect-designed facades were identical - for example the use of semi-circular window heads where windows extended two to three floors above ground floor level, and the vertical emphasis of the brickwork staircase blocks, projecting beyond both building line and roof level and surmounted by pyramidal roofs. The Pilkington's Warehouse was the more successful of the two schemes, though Williams's traditional post and beam frame concrete structure was only notionally respected by Ayrton in his elevations, with his brickwork piers arranged to coincide with the concrete columns behind.[139]

In the context of Williams and Ayrton's earlier commitment to enhancing reinforced concrete as a visually appropriate material for architectural purposes, this and their other later buildings were complete failures. Indeed, they could reasonably be described as being even more reactionary than their work at Wembley in as much as Williams's concrete frames were completely concealed behind traditionally detailed facades built in other materials. Although this regression is a little surprising it provides an explanation for Williams's decision, some time in 1929, to operate as an architect in his own right abandoning collaboration as an effective means of achieving forms of architecture responsive to the properties of reinforced concrete.[140]

. . . .

Descriptions of Williams and Ayrton's work between 1921 and 1929 confirm their joint commitment to developing concrete as a building material of quality, and reveal a number of changes in the form of the structures they produced as their work progressed. Although from the built evidence it is reasonable to assume that the development of simpler structural forms was attributable to Williams's engineering instincts while it was Ayrton who was largely responsible for the decorative additions, it is generally difficult to be precise about the different roles they played in the decision making process of each project. It is unfortunate that no correspondence seems to remain between the two men, which might have helped illuminate these issues. In the absence of this, it is necessary to rely on their published articles to explain the basis of their collaboration and the reasons for various changes in their design approach. Their first articles to appear in the wake of the Wembley Exhibition provide a clear indication of both Williams's and Ayrton's views regarding their future in developing concrete, and of the need for close collaboration between architect and engineer if concrete was to produce its own forms of architectural expression.

Williams's most notable pronouncement appeared in a London evening newspaper. Under the heading - 'Concrete as a Partnership of Engineering and Architecture' [141] he put forward the view that if the possibilities of concrete construction were to be fully realized it was essential that architect and engineer collaborate. To him there was little differentiation between the disciplines of architecture and engineering, and he maintained that it was necessary for architects and engineers to recognize this fact and ultimately unite in a single profession if concrete was to achieve the high qualities associated with more traditional materials. He wrote:

'A considerable amount of time must elapse before the 'concrete sense' can be acquired; that is to say, before any individual can achieve singly a complete and easy mastery of both the engineering and architectural technique. The engineer and architect have a long road to travel before their separate roles can be played by one man. Till that end is achieved the fullest expression of concrete can not be attained. But the goal may be reached more quickly by sympathetic collaboration on both sides. The engineer must realize that sound architecture is only sound engineering and the architect must believe that sound engineering is the only sound architecture. Beauty of design must not be considered the sole property of the architect, nor must the engineer assume exclusive possession of the theories of stability. The eye of the architect may often be a more truthful guide than the slide rule of the engineer. On the other hand, the theories of the latter may achieve something more perfect than the architect can, because the engineer is in closer touch with the demands of the material.'[142]

It is clear from this quotation that Williams regarded the unification of architectural and engineering abilities in one individual as the ideal solution to developing a form of architecture which truthfully responded to the qualities of reinforced concrete.[143]

Ayrton was less enthusiastic about the eventual unification of the two disciplines, believing architects to be generalists who could never be expected to take on the scientific exactness required of the engineer in designing reinforced concrete structures. He was therefore more defensive than Williams, and in one discussion at the R I B A he warned his professional colleagues that if they did not begin to work more closely with engineers in developing architectural forms responsive to the needs of new materials, they would be in danger of losing a large amount of their workload to the engineering profession.[144] He clearly felt that this threat would be effective in bringing about a closer working relationship between the two disciplines, but in other lectures he was less direct in his approach:

'The close union between these two great professions is one of the benefits which should transpire from the coming general use of reinforced concrete. The practice of working separately has unfortunately been too general.'[145]

As for the architect's precise role in this union, he believed that he could contribute most by concentrating on the aesthetic appeal of concrete, particularly in relation to its surface finishes:

'As a material used by engineers, the surface treatment is not one which they have had to consider very seriously . . . it is largely in the surface treatment of reinforced concrete that the architect will find his opportunity.'[146]

Williams appeared to agree with Ayrton about the architects role in developing the aesthetic qualities of concrete. In an unpublished, unfortunately undated, manuscript in his private papers there is this passage:

' . . . . For this material architects are under an obligation to engineers and they must pay their debt by the study of its aesthetic qualities and do for it what their predecessors did in the past for the ancient materials of construction.'[147]

The above quotations, therefore, dating from 1924 and early 1925, help to explain the basis upon which Williams and Ayrton effected their collaboration. Both were committed to developing concrete as a building material of quality and both were convinced of the need for collaboration to effect this objective. Furthermore the above evidence seems to support the hypothesis that Ayrton's primary concern in the partnership was to develop acceptable surface finishes with Williams concentrating on the major structural decisions. The question which must now be addressed is what written evidence exists to explain the apparent over-structuring of the first group of bridges they produced between 1925 and 1926. Explanations appear in replies both men made to a lecture Professor Beresford Pite delivered in March 1925 entitled 'The Architecture of Concrete'.[148] While there were many other interesting issues arising from this lecture, it was Pite's suggestion that reinforced concrete by its very strength produced proportions which would revolutionize architectural design, which provoked the responses pertinent to this discussion.

Williams used this as a cue to explain the main reason for the prevailing attitude, both within and without the architectural profession, that concrete was a cheap material whose structural forms unfortunately defied 'all the canons of architecture'. He claimed that the main reason for this attitude was that architects largely regarded the structure of their designs as an element independent of the facades. Frequently they passed out of their offices the structural design to a variety of specialist firms for competitive tender on the sole basis of cost. It was no surprise therefore, he maintained, that the solutions they received from their respective engineers appeared so 'spindly' in their overall layout and proportions:

'I maintain that if you put out to tender on the basis of design coupled with cost, you would be staggered at the dimensions to which engineers would reduce brick columns. Then, I suppose, architects would say 'this looks very skinny, I shall have to put more brickwork round these columns', and they would put it without a bond, and the result would be a sham.'[149]

Unlike masonry, reinforced concrete had developed scientifically and this was a major reason for its appearance of structural efficiency. While this had disadvantages in producing attitudes described above, its major advantage was that designers could design freely with it knowing what its minimum dimensions were:

'The early history of reinforced concrete has the advantage, however, that we had to start from zero; we know what is the minimum amount of material which can be put to do the job from the point of view of cost first. After that, other considerations will come in such as the matter of permanence, the matter of beauty. From the zero start can be built up a structure which is not a building of affectation but one which has grown into a robust state of health by a process of evolution from zero.'[150]

It is therefore clear that at this point Williams did not equate structural efficiency with beauty. This view was reinforced by

Ayrton who in his reply to the same lecture repeated Williams's main points:

'. . . why should we sit down and imagine that in future we have to design spiders' webs? It is not fair to the material . . . . It is only engineers who have had the courage to use the material as architecturally as they can; and it is for us now (ie architects) to get down to it and see what we can do, treat it seriously and generously, or we shall lose all the work which is going in that direction.'[151]

These quotations go some way to explaining the over-structured and heavily modelled qualities of the early bridges designed by Williams and Ayrton (Case Studies 19, 20 and 21). Clearly they were consciously designed with a certain disregard for structural efficiency in an attempt to produce visually appealing structures. The assumption of both men was undoubtedly that, just as good traditional architecture was over-structured at extra cost to produce impressive effects, so should concrete architecture be. At this early date, it could further be argued that this approach, while supported by Williams was largely initiated by Ayrton, for shortly after 1926 Williams began to produce his own technical and general design articles which suggest a return in his attitudes to his engineering instincts of structural efficiency based on the cost implications of design. This development is reflected in their later structures.

The first structure that was indicative of this change was the mass concrete bridge at Wansford.[152] In deciding to use plain as opposed to reinforced concrete in this scheme Williams was attempting to produce a structure which was more closely related to its heavy traditional appearance, in contrast to his earlier projects. In his reply to Pite's lecture (op cit) he provided a further argument for the use of mass concrete in arched-form structures:

> 'Throughout Professor Pite's paper, I find that he has discarded arches; he feels that arches are no more. I have a very definite opinion that the only permanent structural element is the arch. It is the only member in which tension can be eliminated, leaving only compression; that is to say, that the structure then depends entirely on the force of gravity . . . . The introduction of steel into concrete pre-supposes tensile stresses, the introduction of steel also means corrosion. Professor Pite imagines the ancients using reinforced concrete for monumental buildings; I feel they would never have used reinforced concrete for monumental buildings. The function of reinforced concrete is as a commercial expedient for the production of cheap buildings, to last a period not exceeding 100 years . . . . Had the ancients known the secrets of concrete as we know them, they would have built in concrete without reinforcement, and that they would still have built in arches . . . .'[153]

While this argument does offer important insights into Williams's attitudes to temporary versus permanent structures, (for example he always maintained that the distinguishing characteristic of modern architecture was its short projected life-span), it also lends support to the argument that in the design of the Wansford bridge Williams revealed a conscious attempt to make the structural form relate more closely to its engineering properties.[154]

A later paper compiled by Williams for the Institution of Civil Engineers is of considerable relevance here, even though it was published twelve months into the construction period. It was entitled 'The Philosophy of Masonry Arches' and was one of two technical papers for which he was awarded the Telford Gold Medal.[155] His objective in this paper was to apply modern structural analysis to the ancient arch form of construction, the development of which had been along empirical as opposed to scientific lines, and to assess how relevant these forms were to modern conditions. These conditions, he maintained, had radically changed the design of bridges. Not only was the modern bridge sited to suit the convenience of existing populations, whereas previously populations had grown up around bridges, but modern traffic demanded a flattening of the bridge's structure with its ever increasing spans, necessary reductions in height and its need to accommodate heavier loads. By analysing 200 structures with spans of up to 300 ft Williams was able to present criteria that would enable designers to assess the structural limits of tension free structures, and when reinforcement would be required for arch bridges subjected to modern conditions.[156]

Complementary to this paper was an address which Williams delivered to the Institution of Municipal and County Engineers in March 1926.[157] Whereas the Masonry Arch paper concentrated on the arch form of construction, this earlier address was concerned with the 'Design of Beam and Slab Concrete Highway Bridges'. Its objective was to present rough guidelines to engineers, enabling them to select the right relationship between beams and slab for a variety of span conditions. What is particularly significant about this paper was Williams's concentration on the issue of cost as the basic design parameter in deciding the structural form of any bridge structure. In his introduction he suggested that as reinforced concrete was such a flexible material, the designer was forced to use the cost factor as the only valid starting point of his design process.

'the very flexibility of reinforced concrete as a designing medium makes it difficult to settle such questions (re. structural form to be adopted) <u>without a general investigation into cost</u>. There are no standard sections of beams or troughing to guide the designer; he is free to make sections as he pleases and at any spacing. Indeed, it is at once the delight and difficulty of the material that it is so untrammelled with conventional dimensions.'[158]

He then examined the cost implications of various combinations of slabs, with or without beams at a variety of centres, concluding with a summary table which broadly outlined the economic flexibility of the various permutations. His insistence that beams were an unnecessary extravagance until a span of at least 20 ft was reached is interesting, for it was 'the slab' that was to dominate many of his building designs of the 1930s with a large number of flat-slab structures. His main argument for the beamless slab, first presented here, was that the increased simplicity of the shuttering greatly reduced the cost.

His recommendation for simplicity in concrete design, however, was not solely based on its economic merits. In another article, published at the same time though directed at a wider readership, he made a similar call for simplicity as a means to achieving concrete forms of architecture more closely related to the material's properties:

'A simple, direct, even unmathematical outlook on concrete and reinforced concrete will alone shape the material into its own peculiar forms, instead of imitating the forms which other materials have developed for themselves . . . .

The growth of concrete and reinforced concrete in the next 21 years would be phenominal if all engaged in the industry took as their guiding principle - Simplicity.'[159]

It is perhaps significant that at this point Williams was becoming acquainted with the work of the German architect - Erich Mendlesohn, and was developing his wider interest in architectural design through his membership of the 'Architecture Club'. His knowledge of Mendlesohn is confirmed by the inclusion in his archive of a book on Mendlesohn's work, given to him as a present in 1926.[160] Two central themes permeate this publication - Mendlesohn's attacks on 'facadism' in current architectural design and his argument for honesty of structural expression in concrete design. While there is little in common between the romantic expressionism of Mendlesohn's work and Williams's 1930s projects, it could be argued that Mendlesohn's plea for honesty in design helped Williams to confirm his own thoughts on the engineering basis of modern architectural design.

It seems clear then that during 1926 Williams became more closely committed to the cause of simplicity in the design of concrete structures. This helps to explain the change which occurred at this time in his work with Ayrton when their bridges began to rely on a greater degree of structural efficiency and simplicity for aesthetic appeal. As no similar published evidence can be attributed to Ayrton, and as the change coincided with two struc-
[25] tures Williams completed on his own account, it seems reasonable to assume that Williams was largely responsible for the move away from the over-structured nature of the bridge schemes he designed with Ayrton prior to 1926.

However it is interesting to note that when the move towards simpler structural forms in their joint work resulted in a series of flat-decked bridge schemes, these were accompanied by an increase in applied decoration. This is particularly noticeable
[24] in the Lochy bridge scheme[161] in which Ayrton applied to their first design drawings a totally inappropriate decorative treatment of the elevations. This exposes a dichotomy in their respective approaches to design, for in those flat bridges which Williams designed alone, decorative effects were completely absent. This is best illustrated in the pure engineering form he used in his design proposal for Waterloo bridge. As applied decoration was not a prominent feature in any of their post-1926 arched structures, one must assume that in these instances Ayrton considered engineering forms to be sufficiently satisfactory in visual terms and not to require additional decoration. It must

therefore be concluded that their collaborative work in bridge design was only effective when the structural forms conformed to Ayrton's aesthetic preferences. Although this did produce a series of successful bridges, many of them well fitted to the structural requirements of reinforced concrete construction, Ayrton's involvement does appear to have restricted Williams's own creativity.

The 'acid test' of the effectiveness of their collaboration however was when they returned to building design. As their earlier pronouncements make clear, their ultimate objective after Wembley was to work towards the production of concrete buildings whose forms were directly related to the properties and techniques of reinforced concrete construction. If their collaborative work in concrete bridge design was to have any significance to the wider architectural problem, one would have expected their successes in producing simple structural forms to have been reflected in the building projects they designed together between 1928 and 1929. Surprisingly these buildings were even more reactionary as examples of concrete architecture than their early work at Wembley, with a clear distinction made between the traditionally detailed brickwork facades and the concrete framework they concealed. These projects clearly indicate Ayrton's unwillingness to face the architectural consequences of using the structural characteristics of reinforced concrete as determinants of architectural form. They also suggest that with his inability to escape the architect's traditional stylistic role he effectively denied Williams the opportunity of exercising his own creative skills.

There is little doubt that the complete failure of these buildings to approach Williams's objective of a modern form of concrete architecture, (as well as the fact that he had, in effect, reverted to the position of technical assistant) provoked him to abandon collaboration with architects. Instead he decided to practise on his own account, and by the end of 1929 he had already acquired two important commissions - the Dorchester Hotel and the Daily Express buildings. These were accompanied by a series of articles in which he outlined the design philosophy he intended to apply to these and subsequent designs. The only published evidence which confirms that it was the ultimate failure of his collaboration with Ayrton which encouraged him to opt for his own architectural career appeared in 1931. It was in a recorded reply he made to a lecture on 'Modern Bridges' that Ayrton had delivered to the R I B A in April that year. He asserted that after eight years of collaboration with Ayrton, and despite 'many difficulties', they were still friends. After enlarging upon various trivial points in Ayrton's lecture, he offered his opinion that the philosophical standpoints of the architectural and engineering professions were irreconciable. Although this was presented in general terms, it seems reasonable to assume that he was basing much of his information on his experiences in working with Ayrton:

'. . . I do not believe an architect, as an architect, can collaborate with an engineer as engineer. Two men collaborate and do something, that is a matter for their own mutual arrangement. . . . You have the opposition of two philosophic ideas. If you talk in terms of architecture, which I think many architects do, with some detriment to their profession, in which they claim they are more or less decorative merchants. ('No'), - I don't know what you will call it but their objective appears to be ornament. ('No') . . . . We are all after the same thing, attempts are made by two paths, and the question is, which path best achieves it? You can either maintain practicality, carry it to the extremist point. With a philosiphical basis, you will in this way produce the finest form of art, that is to say, art is the capacity to do a job, having regard to every condition. Practicality is a method of achieving the effect without making the effect a method of achieving itself. On the other hand, you have a doctrine that by effect, conscious effect, you can deliberately achieve beauty. To my mind this is similar to a man who sets up in life and says "I shall be a very beautiful character" and you say to him "Be honest first and if you are honest you will be beautiful, but do not attempt to be beautiful and dishonest". And if you think of architecture and engineering, one trying to be practical and the other one trying to say "We have a God-given mission to be effective" these two things together are actually opposing doctrines which cannot collaborate.'

He then continued using the analogy of two gentlemen, walking on the same side of a young girl:

'I think that those two competitors for beauty represent very much the position of effect and practicality. I do not know which should retire, but I do think one of the two gentlemen ought to retire in favour of his opponent.'[162]

This quotation clearly exposes a complete reversion from Williams's earlier pronouncements in 'Concrete as a Partnership of Engineering and Architecture' (1924). Although he maintained his view that architecture and engineering of themselves were essentially identical,[163] experience with Ayrton and other architects confirmed for him that the diversion of the two professions over a long period of time had resulted in two groups with polarized views on the nature of design. Partnership between them, in the forms they had assumed by the 1930s, he concluded, was therefore impossible.

<u>Williams - The Architect:Engineer</u> 1929-1939

Williams's speech at the R I B A, while useful in illuminating the outcome of his collaboration with Ayrton, must be considered as having been a highly mischevious contribution. This is because then, in 1931, there could have been no-one at the R I B A unaware of Williams's self appointment to the profession of architecture, his outright rejection of conventional architectural approaches to design, and the adoption of a functionalist creed which he had already put to practical effect in the design of three important buildings. Not only were his views and buildings known to the profession itself, but they had also become public knowledge through their having been featured in the British press from 1929 onwards.

The essence of Williams's design philosophy was that only through an engineering approach to design could true 'effectiveness' (ie beauty) in modern architecture be achieved. This approach, he claimed, largely excluded members of the architectural profession because of their inability to undertake the design problem from the engineer's standpoint. The theoretical basis of this view had two important components: first his adoption of the 'Law of Least Action as a basis for Engineering and Architecture'; and second its application, limited almost exclusively to the modern material of reinforced concrete. (Williams would have disputed the latter, but examination of his writings and buildings is conclusive.) His writings on both these issues are concentrated in the years 1929-1932, that is, prior to the vast majority of his built designs. For this reason it seems sensible to discuss them first so as to inform later discussions of his projects.

The 'Law of Least Action' was a phrase Williams frequently used from 1929 onwards to describe the principal means whereby beauty could be achieved in modern building and engineering design. Although closely aligned with functionalist traditions of the time, Williams never attributed his own views to any conventional source - for example the pronouncements of continental modernists such as Adolf Loos; or the British tradition as expressed by

Lethaby and the Design and Industries Association (D I A); or even the 'streamliners' in America who used a similar phrase, 'The Law of Least Resistance', to justify their philosophy of 'dynamic functionalism'. It is likely that he was aware of and influenced by such sources, but since he never made any reference to them, claiming instead that the conclusions he had reached were based exclusively on his own experiences, it is only right to examine his theory independently first and to speculate later about theoretical associations.

The basis of his functionalist doctrine was essentially founded on an antagonism to the architectural forms that surrounded him in the 1920s and early 1930s, including those which he himself had helped to produce when working in collaboration with Ayrton and other architects. This is clearly evident in an article he published in August 1929, just at the time he was completing the last of his collaborative ventures with Ayrton. As usual, he used an analogy to present his argument, in this case the example of a tank designed in the style of a medieval castle at a recent Royal Tournament. Why, he asked, did people find a piece of modern armour clothed in medieval dress amusing, but contemporary buildings whose modern framed structures were similarly clothed in archaic architectural facades unamusing?

'The designer who has fewer necessities of his material to observe has only the greater opportunities for displaying his folly. When stone no longer carries weight, the size of pier and the abutment of arch no longer have meaning or need for observance. The pier proportionate to its load is always right, but what is the sure, if any, guide when the stone no longer has load to carry, has no foundations and stands on the glass of a shop window? Is that a picture differing in one iota from the castellated tank with wheels peeping out from the slot between its stone appearance walls and earth? Only that people pay to laugh at the funny tank.'[164]

This anti-facadist theme which occurs in all his writings at this time was not merely restricted to traditionally-styled buildings. He was equally critical of modernist architecture which he claimed was just as objectionable because its protagonists, like their traditionalist adversaries, were attempting effectiveness at the expense of efficiency and practicalities, while purporting to be 'functional'.

'Modernism when it said express the structure was again trying a method of effectiveness, and was then even more objectionable than the whole-hearted adoption of archaic forms. Why should the structure be expressed any more than any other part of the building, the drains for example? Why not leave it to express itself?'[165]

Williams must be credited with a degree of foresightedness in reaching this conclusion before the vast majority of modernist buildings had been erected in Britain. He was clearly basing his judgements on illustrations of continental buildings in the architectural press and perhaps also a small number of British modernist structures erected or proposed at this date (for example Tait's white-washed brick flat roofed homes at Silver End, Emberton's steel framed Yacht Club building at Burnham, and Connell Ward and Lucas's High and Over).

It is unfortunate that Williams never indulged in criticism of individual architects or buildings, preferring instead to generalize in his publications, for primary or secondary source material on these matters would have provided a clearer impression of his views. There is, however, some anecdotal evidence which can be cited to illustrate his distaste for both extremes in British architecture in the 1930s.[166] Lutyens, for example, he is said to have described as 'An architect very good at spending his client's money'; whilst Lubetkin's views and their relationship to his buildings were anathema to him. There is more substantive evidence of his attitudes to Mendlesohn's work. His acquaintance with the work of this designer was recorded above; and in 1930 both men were to be found addressing the annual dinner of the Architecture Club at the Savoy Hotel.[167] While only records of Mendlesohn's speech exist, there is little doubt that Williams had Mendlesohn's sweeping monolithic concrete structures in mind when he said:

'The engineer when he introduced the material (ie concrete) found himself in a new world, a monolithic. First of all he thought how wonderful to have a monolithic structure which was without a joint. But he soon discovered that it had peculiarities with which he had to deal; and those peculiarities were, that it is very difficult to build anything more than about 40 ft square of a monolithic nature which does not crack . . . . If a man tries to be effective before he has dealt with cracks, he is laying himself open to criticism.'[168]

His central point, therefore, was that the designer had to have a full command of the techniques he intended using before he could remotely consider the effect he wished to achieve. He also extended to the realm of modern painting this lack of willingness on the part of contemporary designers to acquire necessary technique. Ultra modern painters he claimed, were similarly limiting their imagination by their insufficient application to acquire the techniques of their craft.[169]

Williams's criticisms of modernist architecture and painting clearly established him and his own perception of his work as quite independent of the 'Modern Movement' as such. This is reinforced by the fact that he refused to join the MARS group when invited to do so by Wells Coates and Morton Shand in 1935.[170] Although his work was greatly admired by Coates and his small band of followers in the early 1930s, Williams must have presented them with something of a problem for his views could be interpreted as highly conservative, yet the buildings he produced were far more radical than any which members of this group were able to design before 1939.

It was therefore the 'conscious aesthetic', the striving for effectiveness, in the realms of traditional architecture, modern architecture and modern painting to which Williams adversely reacted. In its place he made a plea for the 'Beauty of Utility' based upon 'the Law of Least Action'.[171] He claimed that this law could be seen to be effective in modern industrial design (particularly in modern forms of transport), in the best historical examples of architecture, and more importantly in Nature herself. His reference to modern modes of transport is noteworthy for a number of architectural theorists and stylists were using the same analogy at roughly the same time. The most prominent among them was Le Corbusier, who included illustrations of liners and aeroplanes in his book - <u>Vers une Architecture</u> (published in English in 1927).[172] Possibly of more significance however were the American streamliners - the most notable amongst them being Raymond Loewy - who had enshrined the naturalistic analogy in their design philosophy and were applying it to the very same industrial artefacts at precisely this time. Their own use of the phrase 'The Law of Least Resistance' suggests that there could be a tenuous link between their own ideas and those expounded by Williams, even though paradoxically they were essentially 'stylists' applying 'streamlined' enclosures to artefacts engineered by others.[173]

The naturalistic analogy was central to Williams's theory. He consistently argued that the law of least action was the only principle that determined beauty in natural forms. Surely if living organisms achieved beauty through the pursuit of efficiency, then designers could best achieve beauty in artificial forms if they followed Nature's lead.

An early indication and possible source of Williams's appreciation of this relationship, is to be found in one of his marked articles in the June 1927 issue of the journal Engineering News Record.[174] The article, entitled 'Nature as a Column Builder', included a scaled drawing of a palm tree annotated with arithmetic details to show the perfect efficiency by which the trunk of the tree catered for its loading requirements. Williams was obviously very impressed with this illustration for he marked the drawing with his own rough calculations in which he examined the relationship between the variations in the trunk's diameter and height from the ground. This evidence clearly reveals that as early as 1927 Williams was developing his interest in the relationship between natural and artificial forms, later presenting it as a central part of his design philosophy in 1929.

The application of his Law of Least Action' he argued, based upon this premise, did not ease the difficulties of the designer. On the contrary it made a substantial demand on him to ensure the least demand on others. A conscious striving for effectiveness, on the other hand, consumed unnecessary materials and exerted cost liabilities, either because of the designer's laziness or his irresponsibility.[175] It was for this reason that architects were largely incapable of applying functionalist theory for they were, with only few exceptions, inhibited by the desire to produce particular effects at the outset of designing. Furthermore they lacked, at this point, a grounding in the use of revolutionary techniques.

This did not mean however that the designer had to proceed solely from a mathematical basis. Indeed, in a number of Williams's articles he expresses the clear view that intuition was a vital element in the design process. His first references to this appeared in his paper on masonry arches in 1927. Although referring to the design of arched structures in relation to the scientific elements of elastic theory, the specific comments he made can be interpreted generally as a recognition that scientific design methods were not sufficient on their own:

'The elastic theory is generally accepted as the only solution that comprehends all the complex variables of the arch, but a study of the treatises on the theory hardly encourages the instinct of proportion without which there is no real first stage in design. A theory which is not capable of visual conception unhampered by mathematical intricacies is a poor instrument for everyday use. The specific application of the theory depends on a tentative selection of arch dimensions and form, yet of all engineering theories it has been rendered the least useful in assisting preliminary judgement. Its value applied specifically is comparable with consulting the map of a locality after the journey.'[176]

This quotation is very revealing, and raises an important question as to how intuition related to his 'law of least action'. Williams obviously did not believe that intuition was incompatable with his 'law' for in a later article in the Architectural Review he presented a general philosophical argument in which he related intuition to creation in nature, and thus by extension to his own design theory:

'If we must think of time other than the present, is today the effect of yesterday or the cause of tomorrow?

It would seem that effect has the power of influencing its cause - that seeing many moves ahead, Nature arranges its causes accordingly, being not the slave to cause and effect, but commanding the law. It follows that there is not always a reason for the existence of anything on the basis of a prior cause, it may be introduced from the blue to anticipate effect - a twist in the steering to avoid the corner ahead. Skill in play is ability to see by intuition many strokes ahead and to play to them. Nature is at least as good a player as the best of us. The periodic interposing of new causes to anticipate effect is the continuance of creation.'[177].

Two important observations ought to be made about Williams's design priorities before proceeding to a discussion of his building projects. The first relates to his lack of regard for the environmental performance of his buildings thus revealing that his 'law of least action' was substantially limited to the structural aspects of the design problem. The second was his restriction of this law to the realm of reinforced concrete, to the exclusion of other viable building materials. (eg structural steelwork or loadbearing brickwork)

Although many 'modern' buildings of the 1930s and later can be criticized for the high levels of energy input required to maintain acceptable living environments, the criticism is particularly relevant to Williams's schemes because of his claim to efficiency. When one examines Williams's writings it becomes clear that his references to efficiency were intentionally restricted to structural arrangements and not to environmental performance. This is best illustrated in an article he contributed to <u>The Studio</u> in 1931 when he wrote:

'If I could I would work, eat and sleep in the open air. But the elements drive us to shelter. In times gone by the shelter was within walls. Walls because support was needed, and artificial heat was difficult to come by, and windows were a luxury. Man suffered from want of light. Times change. Supporting walls are no longer needed, coal has been discovered, glass is cheap. But still from habit man persists in lack of light. And there is unemployment in the mines. We keep out the light and neither do we save the expense of artificial heat. We put it on the dole!'[178]

Williams therefore attached much greater importance to the daylight levels and structural efficiency of his buildings than he did to energy, treating it at a time of cheap energy with a degree of indifference.

It is little wonder therefore that many of his buildings should be criticized for their inefficiency in terms of their thermal performance. Although analogies often breakdown at a certain point, it could be argued that the naturalistic analogy which Williams enshrined in his functionalist design theory was not fully observed by him. This is because in living organisms the efficiency of the control of energy consumption contributes to structurally efficient forms. Clearly as buildings do not grow but are designed there appears to be a basic flaw in Williams naturalist analogy which he either consciously or unconsciously ignored.

His preoccupation with structure in the building design problem can be seen to be even more pronounced when one considers that the vast majority of his contracts, throughout the inter-war period, were constructed in reinforced concrete. Although he maintained that he always considered all structural materials in terms of economic feasibility before deciding which to use for a particular project, the predominance of reinforced concrete solutions in his designs places an important question mark over his proclaimed open-mindedness. This point is partly clarified in two articles Williams published between 1931 and 1932, in which he provided emotional and economic reasons why, in his opinion, reinforced concrete was a superior building material for universal application.

The least convincing of these arguments was the emotional one presented in a contribution to the Architectural Review in 1932.[179] Under the heading 'A Concrete Thought' Williams described 'the joy of contact with a universal material', explaining how in a world reducing in size the universal use of a material common to all nations would encourage people to think internationally rather than nationally. A more plausible argument, however, had appeared nearly 12 months earlier in a paper he had delivered to the London Society entitled 'The Portent of Concrete'.[180] In this paper he made generalized cost comparisons to support his hypothesis that as reinforced concrete was cheaper than its chief competitors, structural steelwork and loadbearing brickwork, it would eventually supersede them both for most structural purposes.

Comparing reinforced concrete with structural steelwork, he claimed that the bone of contention as to economic superiority depended on whether plain concrete was cheaper than steel when both were subjected to the same compressive forces. This was because plain concrete was a compressive material while steel was largely a tensile one. As reinforced concrete combined the properties of the two, the only true basis for comparison was their separate costs in compression. He claimed, that the cost of carrying compressive loads on steel was three times as great as on reinforced concrete, without allowing for the fact that the cost of structural steel columns would be increased even more by fireproofing. Even for structural members in tension, he continued, the cost of fabricating a steel member was by virtue of the labour required much more expensive than the same area of steel bars in a reinforced concrete member. He concluded by dismissing steel as a lasting competitor of reinforced concrete asserting that as steel was properly a tensile material and as concrete was properly a compressive one, the combination of both in reinforced concrete would in the end wear down all competition.

He then examined reinforced concrete versus brickwork. First he showed that the cost of a brickwork pier was almost ten times the cost of a reinforced concrete pier taking the same load. He then proceeded to compare their relative economies in two buildings subjected to the same ground conditions. He showed that a reinforced concrete frame building in London could reach a height of 500 ft before the ground was fully loaded, whereas a load-bearing brick structure would be restricted to 100 ft, and would be further disadvantaged by one quarter of its total plan area being devoted to structure. Furthermore the amount of structure required in the latter condition would seriously restrict the amount of daylight penetration. He concluded by inferring that the height limits imposed by the L C C were now made structurally obsolete by the emergence of reinforced concrete and that if a realistic figure of 500 ft were introduced, substantial economies would ensue.

It could be argued that Williams was remiss in not comparing the height limitations of steel and reinforced concrete, for this would inevitably have shown steel as the superior material due to its lighter weight. In fact Oscar Faber responded to Williams's paper in a well argued article in which he defended structural steelwork by exposing serious weakness in Williams's calculations.[181] Using the L C C regulations (although admitting that they were hopelessly out of date for both steel and concrete) Faber provided detailed costings which proved that for column design (ie structural members subjected to compression) an encased steelwork stanchion worked out at 1.71 times the cost of a comparable concrete column, and an unencased one at 1.50 times. These figures were roughly half those presented by Williams. Of more significance, however, was the percentage cost of any structure in the overall contract figure for a typical building. Faber had had wide experience in designing all types of buildings and argued with some authority that for even a minimal factory building the framework only represented about 10% of the overall cost, while for a more 'pretentious bank building' for example, the figure was 6.6%. Taking these important figures into consideration the overall cost saving for an architect using a concrete frame as opposed to a steel one was in the region of 3½%. Furthermore, he argued that even this figure was too high as it was based purely on a comparison of compressive loadings; if tension conditions were compared the figure would more realistically be around 1.6%. Set against this minimal cost advantage to reinforced concrete, Faber claimed that in many situations steelwork had distinct advantages, mainly in reduced size of structural members, thus improving floor to structure ratios and, of far more importance, speedy construction. He argued therefore that by taking these factors into consideration there would be many instances in which steel was economically preferable to reinforced concrete. Concluding his article Faber wrote:

'I should not have dealt with the matter so extensively if Sir Owen had not stated that the onus of proof lies on the structural steel advocate. May I hasten to add that while Sir Owen appears to be an advocate of reinforced concrete under all circumstances, I have a strictly open mind on the question and consider that there are cases when either is the better material to adopt for a given work, and act accordingly in my practice; and I should not like to be considered as an advocate of either material for all purposes.'[182]

This controversy clearly brought to light Faber's superior judgement in the matter of relative costs based, as he correctly pointed out, on his broad experience in both modes of design. Williams on the other hand did not possess the same breadth of experience, and one must conclude that his arguments for the universal application of reinforced concrete were largely justifications for the degree of his own specialism.[183]

. . . .

Williams's decision to operate as an architect and his pronouncement on his 'law of least action' coincided with his remarkable appointment

as architect to the proposed Dorchester Hotel, Park Lane, London
[27] in November 1929. The person who helped gain this commission for Williams was his friend Sir Malcolm McAlpine, of the building contractors Sir Robert McAlpine & Sons and the largest shareholder of the Dorchester House Syndicate Limited (the corporate client for the proposed hotel).[184] Williams's architectural ambitions were well known to McAlpine and they had become close friends through their joint work on many building and bridge contracts over the preceding decade, the most significant of which had been the Empire Exhibition Buildings.[185] Following the failure of the original architects, Wallis Gilbert and Partners, to produce a viable scheme within the client's time limits, McAlpine approached Williams to take over the project.[186]

Thus Williams was presented with an outstanding opportunity in his first architectural project to extend his expertise to architecture and to prove that his functionalist design theory was the most relevant basis for modern building design. His appointment aroused great interest and speculation in the press with surprisingly little comment in architectural publications. Headlines such as 'ENGINEER INSTEAD OF ARCHITECT'[187] and 'UTILITY IN NEW BUILDINGS - THE ENGINEER AND ARCHITECT - WHO WILL BE MASTER?'[188] abounded, with correspondents claiming that the appointment of Williams for the design of a prestigious hotel building represented a direct challenge to the architectural profession and to traditional building forms:

'There is much curiosity to see how the innovation will be received by the R I B A and among the profession generally. The appointment even of so eminent an engineer as Sir Owen Williams will almost certainly be regarded as a challenge to the traditional status of the architect.'[189]

The most detailed and reassuring commentaries on the significance of Williams's appointment to the future of architecture came from the architect Fredric Towndrow, at that time architectural correspondent to The Observer.[190] Williams's adoption, he claimed, did not represent a challenge to the architectural profession but was merely indicative of the serious changes that architecture was undergoing at that time. There was nothing historically innovative in engineers doing architectural work, but recently, he argued, the unfortunate division of the two disciplines had resulted in two distinctive professions. For the most part it would be a 'dangerous precedent' if engineers were to take over completely the architect's role, however in the case of Owen Williams there was, he maintained, nothing for architects nor the public to fear. Here was a man who was not just an engineer but an artist as well, who with his functionalist approach would produce buildings to which architects had paid lip-service for far too long. His role, therefore, would be to point architecture in the right direction and suggest changes in architectural education that would allow architects to follow his lead.[191]

Williams by this time had already begun the project, recruiting a young architectural assistant, J M Richards from Oliver Bernard's office, to joint his all-engineer staff to help with the production drawings.[192] Work proceeded rapidly and early in 1930 started on site. Morely Horder (consulting architect to Gordon's Hotels Ltd), however, had not been approached during the design process and when presented with Williams's reinforced concrete proposal he decided that it was totally unsuited to the site. As he had been presented with a fait accompli he resigned in protest. In a statement to The Observer he made his reasons clear:

'From the day of the appointment of Sir Owen Williams I was not consulted in any way as to the design, and when the final plans were put before me there seemed no alternative but to resign, as they were so complete in their manner and expression of the material that there was no hope of changing the character of the design.

I should like to make it clear that the plans and elevations put before me by Sir Owen Williams are an extremely able expression of concrete forms, and my only objection is to the introduction of this manner of building into the neighbourhood of buildings distinctly foreign in character . . . .

The proposed building will, no doubt, have a certain freshness and gaiety when first erected, but the London atmosphere will soon make the surface very dismal and depressing. I cannot suppose that it is the intention to paint the surface every 3 years, which would be the only way to keep it at all cheerful in appearance. I question if any gain in the apparent rapidity of erection will compensate for all the difficulties in making so thin a structure architecturally satisfying from within, or comfortable to live in so variable a climate.

. . . The violence of the reaction of the engineering mind, however interesting cannot be permanently satisfying if architecture, as an Art, has any meaning as Alfred Stevens understood this.'[193]

Horder's departure seemed to leave Williams unencumbered, and to the press his resignation suggested that concrete had scored an important victory over stone and the engineer over the architect. However some weeks later, as Williams's true intentions to avoid any kind of decoration to the facades or internal spaces became clear, the client became hesitant, particularly at the prospect of the ballroom being conceived as a 'great whitewashed barn'.[194] Williams was asked if he would agree to work alongside Curtis Green, a well respected architect, who would add the necessary embellishments to the elevations and the interiors. Not surprisingly, Williams refused and was obliged to resign.[195] The contract then passed over to Curtis Green.

The problem that Green and his consulting engineers from Considère and Partners faced, was that Williams's concrete frame structure had already reached ground floor level on site and now there were very pressing time limits. Consequently he was forced to accept Williams's design and merely modify the offending elevations rather than redesign them completely as he would have liked. There has been some degree of speculation as to what extent Green modified Williams's design because ever since Williams's resignation, the Dorchester Hotel has always been officially accredited to Green. Although Williams himself tried to correct this accreditation in a letter to The Times of 1956,[196] attempts at conclusively establishing Williams's authorship have been frustrated by two factors. First, none of Williams's drawings remain as most of them were sent to Green when he acquired the contract, and those which Williams retained were destroyed by fire during the war.[197] Second, in more recent publications J M Richards has suggested, by his reference to 'flying buttresses' over the main entrance, that Williams intended the concrete frame to be continued up through the height of the building.[198] This misleading information has lent some support to the view that Green terminated Williams's concrete frame at first floor level with a three feet thick concrete slab in order to provide himself with a new structural base that would have allowed him to affect a radical redesign of the eight storey bedroom accommodation.

(149) Recently, however, photographs of the model that Williams prepared
(148) for the Dorchester, together with a perspective drawing by Keith Murray (1930) have been discovered.[199] These demonstrate conclusively that the hotel was built substantially in accordance with Williams's design, and that Green's only role was to restyle the elevations and to conceal Williams's structure in the interiors of the ground floor public rooms behind a pastiche of colonial-classical styled stage sets. Neither the structure, planning arrangement nor the materials used on the external walls were altered by Green.

Considering that this building was Williams's first attempt at
architectural design it is remarkably authoritative. The structure
was made up of two separate systems.[200] For the large spans of the
(152) basement, ground and mezzanine floors he devised a concrete frame
system consisting of large columns, each 6 ft square and each
comprising four separate legs supporting twin beams spanning
distances of up to 56 ft, cast integrally with 'Tee' beam floor slabs.
The first floor immediately below the bedroom blocks was designed
as a flat slab which was in places 3 ft thick and supported on
flared head capitals to the columns. Above first floor level he
designed the external and corridor walls of the bedroom floors as
the main structural support for the floors and roof slab. For the
most part therefore the external walls were of monolithic concrete
construction, although in places, particularly over the main
entrance, the fenestration reduced these walls to a slender frame
(148) arrangement. Reference to the perspective drawing reveals that it
was Williams's intention, rather than Green's adaptation, for these
walls to be cast behind a permanent shuttering of reconstituted
(153) stone blocks.[201] This is also supported by Towndrow's article to
The Observer of 1929 which was published when Williams's design was
just emerging from the ground and well before Green's adoption. In
it he wrote:

> ' . . . we need not be concerned that the building is to be of reinforced concrete, for I have seen the material to be used and it compares with a polished stone of great beauty.'[202]

(155) It was the planning solution to the bedroom floors that had the
greatest effect upon the overall form of the building. Although
none of Williams's plans remain, the similarity between the form of
the built scheme and that of Williams's solution leaves little
doubt that Green merely repeated Williams's plan. The bedrooms were

arranged on either side of a central corridor in four wing blocks. These blocks were planned in the form of an 'E' shape with the longest element facing Hyde Park made slightly concave along its length and terminated at its extremities with the extension of the wings at top and base of the 'E'.

(157) The principal difference between the two schemes was in the
(148) fenestration. In Williams's design the window openings within the monolithic concrete walls of the bedroom floors adopted a horizontal form with the floor slabs projecting beyond the facades. (The model shows these floor slabs continuing around the entire perimeter of the building producing a strong horizontal emphasis. In the perspective, however, these projections were limited to the length of each window opening.) Each corner of the building was made curved with curved glazed inserts at each level. At ground floor level Williams used large amounts of glazing, with the elevation facing Park Lane being particularly impressive with its glazed facades curved over onto the roof. The fire escapes on the rear elevation were similarly impressive being designed as glazed tubes
(151) interrupted along their height with the projection of concrete landings. In Green's adaptation, the modernist imagery of Williams's design was replaced with a restrained classical approach to design. The glazed walls at ground floor level were completely removed and constructed instead with monolithic concrete walls pierced with traditionally proportioned window openings. For the eight storey bedroom block, Williams's expression of the floor slabs was discarded and Green reduced the amount of glazed area by detailing the window openings along classical lines. Green's only substantial alteration to the elevations was to the corners of the building. In order to give the building a much lighter appearance he terminated the

concrete structure at each corner, concealing the gap with full
(158) height oriel windows fabricated with bronze and glass.

Despite the fact that the completed building was a stylistic compromise enforced on Green, it was generally well received by the architectural and engineering press. To the moderates, the building represented the true modern spirit in architectural design while still retaining links with the past and displaying a national identity.[203] Modernists in Britain, however, were disappointed. For them it was a wasted opportunity for Britain to proclaim its acceptance of the Modern Movement in the building of a large prestigious example of functionalist architecture. Richards, for example, described Green's adaptation as 'a genteel period piece which looks the compromise it is'.[204] What is particularly surprising is that no credit was given to Williams for its design, not even from the engineering press which regarded Considère and Partners to be responsible for what was proclaimed to be Britain's most advanced example of reinforced concrete design.[205] The fact that Green himself never credited Williams with the design of the building is even more alarming when his only rôle was to restyle Williams's elevations. As Green has never been noted for plagiarism, and had in 1930 a well established reputation which would not have been discredited had he admitted his minor involvement in the project, one can only conclude that he genuinely believed that he had been greatly responsible for the design. This does not appear to be a far-fetched conclusion, for it lends powerful support to the argument that many British architects at this time believed their prime function to be that of stylists. In this sense the history of the Dorchester Hotel provides the perfect illustration in support of Williams's objectives, in its demonstration that engineering principles were the determining criteria of architectural form and that architecture had degenerated to a general concern for stylistic effect.

This early phase of Williams's architectural career, in which he was consciously usurping architects, was naturally dogged by controversy. While he was working on the Dorchester scheme he was also acquiring for himself the design contract for the 'Daily Express Building' in
[28] Fleet Street, London (1929-1931). His dominant role in this scheme did not provoke as much publicity, however, largely because the architects were retained by the client, even though they, like Curtis Green, were working on a building conceived by Williams. Furthermore, a newspaper warehouse and office block may not be as sensitive an issue as that posed by a first class hotel on Park Lane.

The architects originally commissioned were H O Ellis & Clarke, a firm who were currently designing many newspaper buildings for a variety of clients.[206] Their initial scheme for the Daily Express building was very similar to their other buildings, comprising a structural steel framework, clothed in Portland stone facades and styled in the
(159) stripped classical idiom.[207] The site on Fleet Street, however, was very restricted having a frontage of only 80 ft and a depth of 115 ft where it adjoined a small existing steel framed extension. The steel framework they intended using in the new building was based on a 25 ft by 30 ft grid. This short spanning structural system on this tight site severely restricted the usable floor space and made efficient planning of the printing presses at basement level particularly difficult.

Either by chance or arrangement one of Beaverbrook's associates discussed this problem with Owen Williams, sometime between October and November 1929. Williams immediately suggested replacing the steel frame with a long spanning reinforced concrete structure, claiming that this would solve many of the planning problems. Seizing his opportunity he produced an outline solution which he presented to the Daily Express Building Company the following day. They were very impressed with the superiority of his structural solution with its attendant saving in floor space which appeared greatly to improve the planning of the press-machine runs. Consequently they immediately commissioned him to redesign the entire structure, while retaining the services of Ellis & Clarke.[208]

There is no doubt that the basic conception of the new design was originated by Williams and not Ellis & Clarke, even though the latter were officially credited with its design. This is apparent from four pieces of evidence which support the anecdotal evidence cited above. First with the initial drawings that Williams produced (between November 1929 and February 1930) he included sketched
(161) elevations which approximate very closely to those as built. From
(162) illustrations of these it is clear that they are design drawings completed in his office and not copies of the architects' suggested elevational treatment of his frame.[209] Second, the expression of the structure on the elevations in these drawings represent a 'modernist' approach to design which was completely alien to Ellis & Clarke's work both before and afterwards.[210] Third, Williams's account correspondence reveals that his fees were paid directly by the client-The Daily Express Building Company - and not by the architect, as would have been normal practice if he had been working as the architect's consulting engineer. Furthermore, contained in this correspondence is a letter from Williams to the client (dated 27 April 1934) requesting out of pocket expenses, which included the item -

'Perspective'. Clearly if the elevational interpretation of the frame had been conceived by Ellis & Clarke, it would have been they who would have commissioned an artist's perspective and not Williams.[211] Fourth, in two later Daily Express buildings, at Manchester and Glasgow, the client commissioned Williams as both architect and engineer. Although these buildings were structurally different, in other terms they were identical to the London scheme. If Ellis & Clarke had been primarily responsible for the London building surely the client would have appointed them again. (With regard to the planning of the London Daily Express, however, it is highly probable that the decisions taken by Ellis & Clarke in their original proposal were not radically altered by Williams in his redesign. This is confirmed by Williams's drawings, which include little indication as to space use.)

The structural system that Williams devised for the building comprised a series of primary reinforced concrete cross frames, each
(166) consisting of two tapered columns, 56 ft - 58 ft apart, supporting a deep concrete beam which cantilevered out 13 ft and 18 ft to either side. These frames supported a Tee-beam floor made up of closely spaced secondary beams cast integrally with the 3 in
(167) concrete floor slab.[212] (To reduce the effective span of these secondary beams Williams introduced a single transverse beam at their mid spans - a technique borrowed from the strutting in timber floor construction.)

(168) Even without reference to Williams's calculations it is reasonable to infer from the drawings themselves that the design of these frames was remarkably efficient with the differences in stress distribution used to create visually stimulating structural forms.

However if Williams's law of least action can be seen to have been effective in the design of these internal frames it does not appear to provide an adequate explanation for the different frame solution he used on the elevations. This is most apparent on the Fleet
(165) Street elevation where instead of reusing the internal frame arrangement he produced a very shallow rectilinear frame consisting of two wide columns with deep spandrel beams. What is even more surprising, in the light of Williams's functionalist position, is that the spandrel beams on this elevation were returned along the Shoe Lane facade where they possess no structural function. Indeed from a structural point of view they are seriously disadvantageous at this position in their applying excessive loads at the critical end portions of the cantilevered frames. Clearly the only possible justification for their inclusion is architectural, either in producing acceptable elevations or by providing the occupants of the building with a sense of security which would have been difficult to achieve with floor to ceiling glazing. Since these apparent inconsistencies were illustrated in Williams's first sketches it seems reasonable to assert that it was not the architects who had insisted on their inclusion. Consequently it is possible to illustrate from his work at the Daily Express a basic contradiction between Williams's theoretical position and his work in practice.

Despite these contradictions and inconsistencies, the design of the elevations themselves was entirely unencumbered with the architectural trimmings normally associated with city street architecture at
(161) this time. In Williams's first elevational drawings the concrete frame of the Fleet Street elevation and the spandrel walls of the Shoe Lane facade were frankly expressed with infill glazing between. The corner of the two facades was made curved, allowing the

horizontal bands of concrete to run continuously around the elevations without interruption. To add to the visual interest of the building the upper floors were stepped back in accordance with the L C C 's height regulations. Although the overall form and structural arrangement of the building was retained in the design as built, the glazing was brought out in front of the frame with the concrete surfaces clad in black 'vita' glass thus produc-
(160) ing a completely glazed structure. It is unclear as to who was responsible for this decision to produce what amounted to Britain's first example of 'black box' architecture. It is possible that it was suggested by the architects in an attempt to prevent insitu concrete surfaces forming part of London's street architecture. On the other hand it may have been a device Williams introduced himself to conceal the inconsistencies between his internal structural arrangement and its distorted expression on the facades. Whatever the reason, there is little doubt that the completed building (1932) was acclaimed as a revolutionary piece of British architecture. Surprisingly this acclamation came from most quarters of the architectural profession, save the die-hard traditionalists. Even by moderates, such as Howard Robertson and Goodhart Rendel, it was received as a well-considered piece of architecture, although it was thought too individualistic to form a precedent for the street architecture of the future.[213] (Their response may have been different had its design been accredited to Owen Williams instead of Ellis & Clarke.) The modernists could find no praise high enough, proclaiming it to be Britain's first large scale example of modern architecture. Perhaps the most influential commentary was that written by Serge Chermayeff for the Architectural Review's July edition, 1932. He was greatly aided in the propogandist content of his article by the juxtaposition of the new Daily Telegraph

building in Fleet Street. Comparing the two buildings, Chemayeff wrote (first of the Telegraph):

'Nothing in the stone-faced elevation gives one a clue as to the function of this structure except the letter of the name . . . . The Express is quietly elegant in tight fitting dress of good cut which tells with frankness and without prudery of the well made figure wearing it. It commands admiration and respect from the onlooker, who must needs remain ignorant and indifferent to whatever charms and horrors are hid behind the upholstery of the Telegraph.'[214]

If Williams's role in the Dorchester and Daily Express schemes was disguised, other projects of his were conducted entirely in the
[29] public gaze. The 'New Packed Goods Wet Building' for the Boots Company at Beeston, Nottingham ('The Boots Wets Building') was the first of such projects and his first building design in which he worked without the assistance of an architect.[215] Even though it was followed by a number of other successful industrial buildings that Williams erected during the 1930s, it is the one project that is most commonly associated with his name and his functionalist design approach. It was in 1927 that Williams had first spoken of his revolutionary visions for the modern factory. In a lecture to the Art Workers Guild, replying to his rhetorical question 'What is a factory?', he said:

'I would define it as a place protected from wind and weather where, things, mostly unnecessary, are made most efficiently. It is always dangerous to be curious as the 'why' and 'wherefore' of the article to be manufactured. The result of any such investigation may be somewhat depressing to enthusiasm. It is enough that the manufacture must be efficient.

The object of the factory builder should therefore be fitness for purpose at minimum cost in a combination with complete flexibility for replanning and alteration:

'Fitness for Purpose' I would like to regard very radically. For example, I would challenge the necessity for floors in the vast majority of factory buildings . . . . Actually the factory building is the shell surrounding a process, and I venture to say that many processes are hampered by the imposition of floors. Once eliminate that conception of a factory and the process would take on a new efficiency. The factory can be likened to, for example, a colossal typewriter, but weatherproof and containing stages for its workers. The worker should control volume and not floor area, and requires a niche and not a surface . . . .

I can picture the factory of the future as a great single span shell housing a vast machine with its workers dotted about in no way that can be related to definite horizontal planes or floors.'[216]

There is little doubt that Williams came nearest to achieving this vision at Boots. This building was one of his finest achievements having a conviction in its overall concept and engineering details which seemed to prove his 'law of least action'. At the time of its completion in 1932 it was highly acclaimed in the architectural press, being represented as a prophecy of the type of architecture that would become universally dominant as designers returned to the sanity of 'science, reason and order'.[217] Its reputation from the day of its completion has remained untarnished and it is now regarded as a building of seminal importance in the history of modern architecture in Britain.[218]

However neither journal articles devoted to this building nor histories of the period attempt to place the factory in its true context, as a structure whose planning conception and technique of construction had precedents reaching back to pre-First World War factory design in America, and one which was closely related to many British structures already in existence. The preference of many writers has been to overlook this ancestry, and to present Boots as an unprecedented flat slab building structure created by an exceptionally skilled engineer or else as a building whose functionalist imagery first illustrated that the continental Modern Movement was beginning to infiltrate architectural design in Britain. In fact, it was neither of these.

The argument presented for the building's American ancestry is made

plausible by the fact that when Williams was designing the factory in 1930, Boots was under the ownership of the American firm - The United Drugs Company of America.[219] Clearly, as owners, this company would have had an important contribution to make to the basic design brief and undoubtedly based much of its contents on American practice. This manifested itself in the decision to erect a complete factory complex in one building that would ultimately accommodate the production and packaging processes of all Boots's pharmaceutical products - both 'wets' and 'drys'. The building process however was to be phased, with the first phase devoted to 'wets' production. Williams's design therefore had to be conceived as a total unit with a 'wets' portion that would operate independently until the 'drys' extension could be completed. In the event however only the 'wets' portion was built, for when Williams was recommissioned to design the 'drys' section, a separate and
[36] distinctive building was erected. The precise reasons for this change are unclear but it is highly probable that the company's reversion to British ownership in 1933 resulted in a different type of brief. (It will later be argued that in addition to this change in ownership, Williams's approach to design had undergone a significant change. It was probably a combination of these facts which resulted in a distinctive 'Drys' building.)[220]

The site upon which the Boots complex was to be erected was a 300 acre piece of virgin land purchased by the United Drugs Company in 1926 outside Nottingham, at Beeston.[221] The details of the brief were determined by Williams working in consultation with Boots's chief engineer and the Works Planning Committee, established especially for this purpose. Through this consultation procedure Williams was able to gather essential data on the production processes, machinery and workers' requirements, eventually conceiving the building as one with two halves linked by a 'shipping dock' which ran through the centre of the building itself. Thus the production processes for the 'wets' and 'drys' sections were intended to work inwards from the south and north elevations respectively, towards the centre. This allowed him to design the 'wets' unit as an independent element with the proposed 'drys' extension being merely a mirror image to be completed at a later date.[222] (As only the 'wets' section was ever built this study will confine itself to this as a building in its own right, although it must be recognized that its north elevation was initially intended to be the centre-line of the fully completed scheme. Provision was also made for extension to the rear east elevation, again never built.)[223]

The most important aspect of this building was the complete subservience of almost every feature of its design to the efficiency of the structural layout and the dominance of an uncompromising functionalist approach to the smallest detail of Williams's design decisions. If at the Daily Express Williams was forced to amend his structural frame on the principal elevation to produce an architecturally acceptable facade, at Boots there exists no hint at compromise.

(175) The entire building was conceived as a simple four storey reinforced concrete flat slab structure arranged on a rigid grid layout, with vast light wells carved out of it at appropriate positions for the
(174) ground floor production process. (The upper floors were used essentially for the storage of raw materials and finished goods.) Around these atrium spaces and the external walls, the floors were cantilevered out beyond the extremities of the flared head capitals

supporting them. No attempt whatever was made to give different areas of the building a distinctive architectural expression on the facades. This is most noticeable on the elevations to the administrative block which flanked the production areas on the western side
(184) of the building. Most architects designing industrial buildings at this time treated the administrative block as a distinctive architectural unit complete with conventional stylistic trimmings, its main function being to conceal the factory areas behind. At Boots however the administrative block formed an integral part of the simple rectangular plan form of the building with the facades themselves treated in an identical way to every other elevation - that is with uninterrupted lengths of patent glazing fixed between the narrow strips of the projecting cantilevered floors. Not even for the main entrance did Williams provide any distinctive features, the entrance doors themselves being recessed only 3 ft from the building line at ground floor level. A similar observation can be
(172) made of the staircases, lift shafts and toilet accommodation. Whereas many architects grouped these functions in tightly planned blocks along the elevations of their factory buildings, largely to create visual interest, Williams positioned them in strategic positions in the centre of his building and treated them as structurally independent from the main flat slab structure. Thus the facade design and the ancillary accommodation were all made subservient to the simplest possible arrangement of the flat slab structure. The only substantial part of the building where Williams departed from flat slab construction, excepting the steel trusses over the atria, was for the unloading docks on the long south elevation. Here his mastery of reinforced concrete design was seen at its best with large double cantilevered beams supporting

(174) both a heavy roof construction and travelling crane, itself
(183) supported from concrete hangers suspended from the ends of the 40 ft cantilevers. (In common with the rest of the building the spaces between these hangers were infilled with bands of patent glazing.)

If the basic concept of the main bulk of the building's structure was simple and direct the organizational system for which it was created was emensely complex. Williams, with advice from the Works Planning Committee, produced something of a masterpiece by organizing the entire production process to operate within a highly intricate three dimensional planning arrangement. The manufacturing process took place at the ground floor level on a series of production lines running across the width of the building with the upper floors used largely for storage purposes. Raw materials arrived at the unloading dock to the south and were transported to the upper storage floors by the travelling cranes. From here the materials were fed down onto the production lines with the finished 'wets' goods emerging to the southern side of the main packing hall. From the upper storage floors packaging materials were fed onto the packing lines by long gravity chutes. Along the northern edge of the hall twenty eight elevators lifted the packaged goods to appropriate positions on the four storey finished goods stores. Here they were sorted prior to their dispatch by train and lorry on the northern side of the building. The railway line itself was cut through the centre of this northern portion of the building, ventilated by vast holes carved out of the flat slab structure.

(186) The confluence of this three dimensional planning system was the main packing hall. Williams appears to have borrowed from Ford's

pre-war buildings in making this centre-piece of production process a vast atrium space, cathedral-like in its proportions and separated into four sub-units by three narrow connecting bridges at each floor level joining the storage floors to each side. No-one can fail to be impressed by the visual dynamism of this space with its vast steel truss roof structure supporting a glass disc and concrete deck which provided effective diffused light at ground floor level.

It is difficult to be precise about Williams's sources for his design work in this and other buildings, for he always maintained that he would only consult precedents after he had completed his design work and not before.[224] Nevertheless, no designer can be uninfluenced by his past appreciation of others work, and the evidence suggests that Williams was no exception. This is clearly illustrated by examining the two most important features of the Boots building; first, the extensive use of flat slab construction in combination with glazed facades which immediately express the nature of the construction; and second, the central importance of the main packing hall, designed as an aweinspiring atrium. Both these features (the former on its own and in combination with the latter) had American precedents of which Williams must have been aware.

The development of flat slab construction from 1902 onwards has already been discussed in some detail.[225] Its introduction into Britain during the 1920s was shown to have been based largely on American, as opposed to continental, origins. The most important agent in its transfer across the Atlantic was the Trussed Concrete Steel Company, which employed Williams as chief designer between

1912 and 1916. In 1925 this firm designed two flat slab factories; the first, in collaboration with Kenyon and Louis de Soissons, was the Shredded Wheat Factory at Welwyn Garden City; followed by the Wrigleys factory designed in association with Wallis Gilbert and
(49) Partners (1926).[226] While neither of these buildings received extensive coverage in the architectural press they were reviewed in the engineering journals and Williams would undoubtedly have been aware of them. Both structures were very similar to the structural arrangement at Boots except that they included 3 ft deep spandrel walls at each floor level. (The Wrigleys factory also possessed heavy corner staircase towers - a hallmark of Thomas Wallis's work.) In addition to these, another American firm operating in Britain at that time, the Indented Bar Engineering Company (which had also employed Williams as a junior engineer in 1911) was designing a flat slab structure - Viyella House - which had elevations comparable to the Boots scheme at precisely the same time, in the same city of Nottingham.[227] Like the Boots factory this building used extensive glazing between narrow strips of cantilevered floors. Its elevations however were less convincing than Williams's owing to the architects addition of rather incongruous classical details to the main entrance and narrow horizontal floor strips. If the engineer's framework had been left undecorated it would have more closely resembled the Boots factory.

Each of these three British buildings had their origins in America, designed by specialist firms originating there both of which had employed Williams in his early career. They therefore help to set the technology of the Boots building in its context. The American origins of its structural system are also suggested by the fact that the combination of large atrium spaces and flat slab construction,

(47) as used at Boots, was originally used by Henry Ford in Detroit
(48) around 1910.[228] It was Ford who had introduced the atrium and gravity feed method of car production before the First World War, immediately prior to the development of his 'assembly line' concept, and one of the engineers he employed to design these buildings was the Trussed Concrete Steel Company. These earlier American atrium schemes contained long tall spaces, very similar to that at Boots, through which the cars passed longitudinally. Components were fed onto the assembly floor either by gravity chutes or travelling cranes. (Flat slab construction was used in these buildings for a variety of reasons - including Ford's obsession with high daylight levels. It was not a system peculiar to this type of three dimensional planning, although the lack of columns immediately around the galleries did aid movement and flexibility in the positioning of the chutes.) Photographs of the interiors of these buildings with their atria surrounded by cantilevered balconies at 4-5 floor levels have a close affinity with
(48) Williams's packing hall at Boots.[229] The primary difference between them is that Williams arranged his lines of production transversely and not longitudinally in these spaces. As these pre-war Ford buildings were being designed by, amongst others, the Trussed Concrete Steel Company, at the time that Williams was employed by their English subsidiary it is inconceivable that he would have remained unaware of them.

It is noteworthy, however, that he never repeated this atrium arrangement in any of his later industrial projects, although he did continue to develop the flat slab technique at every opportunity. This could have been due to the American brief he was given for this building or it could be that he recognized many of the problems such atria produced and was eager not to repeat them. Certainly on a purely functional level it is difficult to justify such an enormous cubic volume merely to provide roof lighting, impressive though the space is, for the heating costs are phenomenal.[230] Neither are the gravity chutes a valid justification, for these could have been located as vertical spirals through a series of floor slabs. (This was the system Faber used at Spillers for example). On a human level also, there is little doubt that while the packing hall is very aweinspiring, it is also dehumanizing, for it is a dominant piece of building design whose scale and efficiency seemed to reduce the individual worker to virtual insignificance.

Despite these criticisms however, the Boots factory was almost certainly the most impressive example of British industrial architecture in existence at that time.[231] Its American and British precedents, while clearly forming the basis of Williams's own design, were improved upon by him, for these had been designed with the involvement of architects whose training appears to have obliged them to add decoration to their engineers' structures. In this way the Boots building could be interpreted as representing an important stage in the architectural assimilation of flat slab construction, for here the building's success relies entirely on the rejection of architectural styling and its displacement by a ruthless functionalist approach to the design problem. In its design Williams was entirely free to apply his 'law of least action' to all his design decisions, unencumbered by the involvement of an architect for the first time in his career. The result was an impressive structure whose forms and details could clearly be seen to have been determined solely by the function of the building and the most efficient use of the structural materials employed. The architectural press received it as an unprecedented example of functionalist architecture in Britain, which proved that scientifically conceived structures could achieve great beauty. The editors of the journal Building noted that it would have been impossible for an architect to produce a structure of this type.

'it is difficult for a trained architect to be of the true functionalist faith - his aesthetic training and temperament make it almost impossible. And thus it is hardly surprising that Britain's most outstanding functionalist building has not been designed by an architect at all, but by an engineer.'[232]

To Williams himself the building proved that his 'law of least action' was effective and it provided him with the confidence to proceed with the same philosophy in the design of other projects. To those committed to the modernist cause, the building represented the first large scale example of modern architecture in Britain, providing the evidence that only through a rejection of stylism and the adoption of functionalism could appropriate 20th century architectural forms be created in Britain. The moderates and traditionalists within the profession were less enthusiastic, considering the building to fall into the category of engineering and not architecture.[233] In this way they could applaud it as a well considered piece of engineering work, designed by an exceptionally gifted engineer, which unlike the Dorchester represented no particular threat to the traditional status of the architect.

There is little doubt that these attitudes to the relationship between architecture and engineering made it difficult for Williams to acquire the type of work normally within the exclusive preserve of the architectural profession. This does not mean that individuals within the profession directly prevented him from acquiring such work, rather that the institutional conventions were prejudiced against him. However, to overcome these prejudices it was essential that he gain such projects in order to prove that his design abilities, wedded as they were to his functionalist standpoint, were equally effective when applied to all types of buildings. Had the Dorchester project succeeded this barrier might have been substantially removed at the outset. In the event it was not until 1933 that he gained an opportunity to prove his point.

In that year he acquired two such commissions - the 'Empire Pool at Wembley (1933-1934)' and the 'Pioneer Health Centre, Peckham (1933-1935)'. Both of these buildings had a recreational content and both received extensive publicity; the former through its importance as an international sports arena, the latter because of the unique, pioneering social and medical activities it contained. In assessing them as buildings it is necessary to question Williams's effectiveness when designing structures with a non-industrial function.

No firm evidence is available to suggest why Williams was adopted
[34] as designer for the Empire Pool at Wembley. However he had already undertaken work for the client, Wembley Stadium Limited at the 1924 Exhibition, and the fact that he himself was a shareholder may have had some bearing on the client's choice.[234] Furthermore his recently acquired reputation from his work at Boots undoubtedly provided reassurance to the client that he would be able to produce the type of structure envisaged - 'a building unique in the world as regards design and general utility'.[235]

The building was to house one of the largest swimming pools in the world (200 ft x 60 ft), which was to be convertible into an ice rink and tournament arena, with sufficient raked seating to accommodate approximately 4,000 spectators. It was therefore apparent from the outset what general form the building would assume, namely a large, clear span, rectangular structure providing a complete enclosure for the above activities, without visual obstruction for spectators.

The chosen location was within the original site of the Empire Exhibition, permitting a direct comparison to be made between two types of concrete buildings which responded to polarized approaches to the design problem. Whereas the surrounding 1924 buildings had been designed in concrete to express a traditional architectural style, in his latest Wembley structure Williams was able to reveal the different type of concrete architecture that would be created when he applied his 'law of least action', whereby the function of the building and the efficiency of its structure were the sole determinants of the elevational effect. He made this point amply clear in a lecture he presented to the Architectural Association shortly after the building's completion.[236] There were two types of racketeers he claimed - 'those who get out their guns and those who get out their elevations'. He was not interested in elevations but in the methods of achieving 'a complete agreement or harmony between all the conditions of the building problem'.[237] In the same lecture he noted that the most difficult part of the design process was in establishing the starting point. This was where he differed from the vast majority of architects. Whereas they would start by considering the elevational effect they wished to achieve, often seeking inspiration in precedents, his own inspiration came from a more mundane source - the Middlesex County Council's Building Regulations. These asserted that for a building of this type the steps to the terracing were to have a going of 11 in and a rise of

6 in. This established not only the raking of the terraces and consequently the overall size of the building (the pool was a fixed size of 200 ft x 60 ft), but the horizontal and vertical grids for the entire structure. (Williams adhered rigidly to this grid in the planning and structural arrangement of the building using a three unit module for the horizontal grid (2 ft 9 in) and a six unit module for the vertical (3 ft).)

The planning of the building was in essence very simple comprising
(216) three principal elements. The largest was the pool area itself
with raked seating to either side and changing facilities and plant
located in the basement. It was divided, at regular intervals of
(221) 44 ft with staircases providing access to the terraces, and between
them each space was designed identically with toilets, buffets and
fire exits.[238] To the western side of the pool Williams designed a
two storey structure which accommodated the main entrance area at
ground floor level with office accommodation above. The annex-type
structure was repeated at the eastern end of the building with, the
ground floor used for kitchens and additional floor space to the
pool area, and offices above.

In terms of its massing this plan form did not produce an entirely
successful result, for the subsidiary structures to either side of
the pool, being of a much smaller scale to the remainder of the
building, tended to appear as extensions to the pool area completed
(224) at a later date. In many respects the structural arrangement
exacerbated this conflict of scale for by working in accordance with
his functionalist principles Williams applied to these annexes a
different structural arrangement from that used over the pool area.
Thus instead of continuing the main structural form over the entire
plan area and planning his subsidiary spaces within it, Williams

designed both additions to east and west as simple reinforced concrete frame structures with their primary frames positioned at right angles to the main frames over the pool.

This criticism however cannot detract from his impressive structural
design for the roof and terracing over the pool. This structure
comprised a series of insitu concrete three pinned frames each with
(217) an unprecedented span of 236 ft. Each frame consisted of two halves
(218) made up of a long tapered cantilevered arm, from which the roof was
suspended, with a lower triangular form of concrete used as the main
terrace support structure.

From an architectural point of view the most important feature of
these frames was their large concrete fins, cast at the junction
point of the cantilevers and the terrace supports, which projected
on the external elevations of the building. Their structural
function was to act as counterbalances, reducing the horizontal
reaction at the apex to a minimum where the two cantilevers met.
In his first design drawings these counterbalances were shown as
(226) semicircular in form producing a spectacular elevational effect.[239]
However in the design as built Williams changed them to a simple
rectangular form in an attempt to simplify the construction process
and save money.[240] Visually this decision was not as impressive as
his first idea. Nevertheless as these rectangular fins still had a
dramatic effect upon Williams's elevations it is necessary to
question their structural usefulness in order to ensure that he was
attempting visual effectiveness by including them.

Recently, calculations have been undertaken to determine the effectiveness of these fins.[241] The conclusion was that the 'counterbalance' effect is minimal, reducing the horizontal reaction of 70 tons at the apex by only 10%. Moreover it has been noted that had they been entirely successful in reducing these reactions to zero, then the increase in the bending moments of the cantilevered arms would have required the arms to be much larger in section. This clearly places an important question mark against Williams's integrity in applying his 'law of least action'. If he was aware of their minimal structural effect then one must conclude that he included them on his elevations to aid visual interest - the complete antithesis of his stated objectives.

There is no evidence, however, to suggest that he was aware of this fact and one is forced to speculate that he designed them intuitively without fully analysing their structural function. This is supported
(225) by the results of photoelastic tests which have been conducted on a scaled model of the frame.[242] These clearly reveal that the fins do take a considerable portion of the load, yet the stress distribution adopts a semicircular form with the upper and lower parts of the rectangular fins unstressed. Thus the stress pattern is more closely related to the circular forms which Williams had adopted in his earlier design. If they had been built in this way then their significance might have been more clearly understood.

It seems apparent, therefore, that by failing to fully apply his 'law of least action' in order to save construction costs (replacing structural efficiency with cost efficiency) Williams appears to have left this important element of his work at the Empire Pool open to criticism. Although there exists no conclusive evidence, his elevational design for this building does therefore suggest that he consciously attempted to produce an interesting external form by overemphasizing some of the structural features.

Similar observations may be made about certain features of his work [35] on the 'Pioneer Health Centre at Peckham', a smaller building that Williams was designing at the same time. Unlike the Empire Pool, however, at Peckham Williams did not introduce questionable structural features to add interest to his building. Where he does appear to have been inconsistent to his principles was on the main elevation where he modelled the wall surface to produce a particularly stylistic effect, and in his overprovision in the planning to maintain the simplicity of his symmetrical structural arrangement.

From a structural point of view the building was improtant in that it was one of Britains first non-industrial buildings to use flat slab construction. Although reference was made of this fact in some architectural journals, the building received particular attention because Williams's radical functionalist design principles seemed to respond,and indeed enhance,his client's radical social and medical brief. To many modernists of the time this combination of radical concepts made the Peckham Health Centre something of a cause célèbre for the British Modern Movement, as it was regarded as a scientifically conceived structure with a socially progressive function - two essential requirements for truly modern architecture. The Architectural Review was particularly influential in projecting the building in this way,[243] although the writer of this journal's article - J M Richards - was not wholly impartial in as much as he had helped the client to formulate the brief and was predisposed to admire Williams's work because of their earlier contact. Although it is understandable that the building was used by modernists to support their claim that the true function of the modern architect was to be the instigator of social reform, the evidence suggests that it was entirely fortuitous that Williams was appointed as architect to implement this client's progressive ideas. Indeed, it appears as though the prime reason for his appointment was that he offerred to design and construct the building at a much lower cost than a number of other architects who were invited to tender in what the R I B A regarded to be a wholly unprofessional 'design and build' competition.

The official name of the client was the Pioneer Health Centre Limited,[244] comprising three directors: two doctors, Innes H Pease and G Scott Williamson, and the sociologist J G S Donaldson. They had two interrelated objectives: first, to make a biological and sociological study of the working-class family unit; and second to provide leisure and health-care facilities for a specific working-class community, in the belief that the true function of medicine was to preserve health.[245] Their intention was to combine these in a recreational and health-care setting to which families would subscribe (at one shilling per family per week) and where they would join in sport activities and receive regular medical checks and health education. For their part, the researchers intended to operate the centre like a laboratory in which they could undertake research, collecting essential sociological and medical data on the health and social development of working-class family units.

In order to assess its feasibility they had established a pilot project in 1926, using a private house in Peckham for a period of about two years. The results of this project were sufficiently encouraging for them to proceed, and consequently in 1930 they decided to publish their initial findings in book form to attract patrons for a purpose-built scheme.[246] In this book they included initial design proposals for the centre, elaborated for them by

E B Musman.[247] In 1933 however, when their financial position was sufficiently strong to seriously contemplate the design of a new building, they abandoned Musman's scheme recruiting instead J M Richards not to design the building but to formulate a more comprehensive brief by sketching out space allocations and organizational relationships. Richards, who had recently returned from Ireland and was contemplating entering journalism, recalls in his autobiography Williams's surprise when he visited the doctors' house at Peckham and recognized his once junior assistant already at work on the drawing board.[248] However Richards seems to have been unaware that his preliminary sketches were initially circulated by the doctors to a number of architects, in order to obtain from them sketch designs and a series of cost quotations.[249]

One architect who received these sketches was Goodhart-Rendel. With them was a covering letter in which Innes Pearse requested confirmation that the proposed building could be erected for less than £25,000, and for each architect to supply a tender figure for its design and construction.[250] Rendel immediately wrote to McAlistar (Secretary of the R I B A) to fulfil his 'professional duty' in exposing the possibility of unprofessional conduct. Enclosing a copy of Pearse's letter and referring to the promoters of the enterprise as 'cranks' he wrote:

'I need hardly say that I do not send this correspondence to you with the least intention or even desire of preserving the job for myself, but because I do feel that anybody who sent a reply, in a different sense to mine, ought to have his knuckles rapped.'[251]

The R I B A 's competition committee was informed when it became clear to Rendel, via a letter from Pearse, that other architects had contravened the Institute's code of conduct by submitting prices.[252] However, neither Rendel nor McAlistar were able to discipline the successful tenderer when they realized that Owen Williams had been awarded the contract. Rendel noted:

'I have heard unofficially that it is extremely probable that Owen Williams has undermined all opposition to him and landed the job. Over him we have no control.'[253]

This correspondence confirms that the client's main concern in commissioning an architect was the factor of cost, with the type of structure being of secondary importance. Its clear implication is that had Goodhart-Rendel submitted a lower priced proposal he would have been appointed, even though his approach to architectural design was substantially different from that of Williams. It seems conclusive, therefore, that Williams cannot be credited with initiating any radical socio-medical ideas himself. His contribution was to provide a built enclosure which responded as efficiently as possible to a predetermined brief.

Williams located his three storey building at the north-eastern edge of a two acre site in Peckham off St Mary's Road. This was done in order to preserve as much as possible of the site's south-westerly aspect, fronting the road, for open air leisure facilities which included running track, tennis courts and a children's play area. (The play area was continued under part of the first floor, providing an open-covered play space, which adjoined a nursery in the buildings south-eastern wing.) To maximize the visual and physical contact between the internal and external spaces on this south-westerly interface, he positioned his main entrance in the centre of the rear elevation. Although the rationale for this decision can be clearly understood, it did result in an unimpressive entrance to the building, approached down a dark, narrow alley,[254] feeding a long rectangular foyer which directed visitors to the two staircases and corridor doors, placed at its extremities.

In planning and structural terms, the building was organized as a symmetrical composition with four distinctive rectangular blocks
(230) grouped around a centrally positioned internal swimming pool.[255]
(232) The enclosure to the pool occupied the entire height of the structure providing a focal point for the recreational spaces at first floor level (the surface of the pool was at this level). The blocks around the pool occupied three storeys in height comprising two wing blocks to the south-east and north-west, with insert blocks to the north-east and south-west. At ground floor level the two wing blocks contained a gymnasium, nursery and lecture room with the insert blocks reserved for machinery, changing spaces, and covered playground. First floor level was intended to be the part of the building where most of the occupants would socialize in a lounge area, which occupied most of the south-west frontage, overlooking both the pool and the outdoor sports facilities, and with a cafeteria to the north-east (significant portions of the wing blocks on this floor contained the upper parts of the gymnasium
(231) and lecture room). The second floor was the only part of the building where a distinction was made between the staff's private research rooms and the public spaces. The former were positioned above the cafeteria to the north-east with the remaining 'U' shaped floor area, around the glazed roof of the pool, being occupied by library and study and recreation spaces.

Movable glazed partitions were used extensively for the subdivision of spaces, allowing visual contact between activities and a means for the researchers to observe the activities of the families. Even the vertical separation of spaces, imposed by the necessity of floors, was partially overcome by the use of glazed walls around the pool, allowing views across and upwards. This extensive use of glazing, which was repeated on the external walls, produced high daylight levels within the internal spaces and a quality of openness which was one of the buildings most notable attributes. The clients were particularly pleased with this latter quality. In their book they wrote:

'The general visibility and continuity of flow throughout the building is a necessity of the scientist. In the biological laboratories of biology and zoology the microscope has been the main and requisite equipment. The human biologist also requires special sight for his field of observation - the family. His new 'lens' is the transparency of all boundaries within his field of experiment. Sixteen steps down from the consulting room and he is engulfed in action which is going forward, and which, by the very design of the building, is visible and tangible to his observational faculties of all times.[256]

This quality of openness was a direct result of Williams's concrete frame structural solution. (A traditional masonry structure would have required extensive loadbearing walls which would have created a more cellular and closed plan form.)

Although Williams used a traditional post and beam framed solution for a sizeable portion of the structure it was his use of a modified form of flat slab construction for the insert blocks to either side of the pool which contributed most to the openness of the planning and the overall visual quality of the building. Normally flat slab construction was used for heavily loaded industrial structures but at Peckham no such loading requirement could justify its use. Williams however was convinced of its appropriateness for the Health Centre for two important reasons. First was his wish to provide uninterrupted glazed facades both to the principal elevation and to the walls to either side of the pool in order to maximize visual contact between the internal and external activities and within the envelope of the building itself. Second, the system would provide the client with flat soffits free from downstand beams that would enable relatively simple future rearrangements of the glazed partitions. Because the loading

requirement on the structure was minimal in comparison to that of
industrial buildings, Williams devised a structurally efficient flat
slab system by designing slender, cruciform columns with their
capitals consisting of four tapered arms merging elegantly into the
(235) concrete soffit.[257] In visual terms this modification of the flat
slab technique was well in keeping with the small scale building
problem and internally the relationship he created between the
proportions of the spaces and the structural supports appears
entirely harmonious. Externally the technique allowed him to achieve
his objective of a fully glazed facade by the cantilevering of the
floor slab eight feet beyond the column positions. The glazed walls
themselves were made up of folding glass screens, arranged on a
zig-zag plan form, which could be opened up in good weather conditions
converting the lounge areas into open blaconies overlooking the
external sports area. The angular plan form of these screens did not
contribute significantly to the elevational design for Williams
designed the edges of the protruding floor slabs as curved in plan,
producing the misleading impression of a series of domestic curved
(229) bay windows joined together. (In Williams's first design drawings
this does not occur, the floor slabs possessing a zig-zag plan form
(227) related directly to the folding glazed screens.)[258] One can only
assume that he designed this facade in this way to give his building
something of a domestic quality in keeping with its function. Although
he can be legitimately criticised for attempting visual effectiveness
on this elevation one can understand his decision, for if the elevation
had been designed with straight lines of glazing between the floor
slabs then the building would immediately have possessed the quality
of a scaled down industrial structure, very similar to his work at
Boots. Indeed if it is compared with the Boots factory many

similarities can be noticed. Not only were both flat slab structures grouped around a central light well (atrium at Boots, pool at Peckham) but in both schemes Williams can be seen to be attempting to produce transparant internal environments by reducing to a minimum the vertical division of space. Furthermore in the detailing of the finishes Williams applied the same rationale to each structure - namely exposed concrete surfaces except where specific conditions dictated otherwise (eg in the tiling around the pool). It must be noted however that many of these finishes appear rather crude and in complete contrast to the refined detailing associated with most public buildings at that time.

In the design of the health centre, therefore, it seems clear that Williams used many of the same features that he had used at Boots and in other industrial buildings. While the transfer of these ideas from the industrial reinforced concrete building to the recreational building had distinct advantages in providing high daylight levels, flexibility and the aiding of interaction between various activities within the centre, it did create two important disadvantages: first, in using extensive areas of glazing around the perimeter of this relatively small building, Williams produced a thermal control problem which appears to have been more acute than that encountered at Boots; and second, in parts of the building the planning of the spaces appears to have been subordinated to the symmetry of Williams's efficient structural framework. This is most readily apparent at
(231) second floor level where Williams included two identical spaces in the wing blocks, each complete with two open fireplaces, and both being labelled 'Study and Recreation Rooms'. Although there may have been a valid justification for this duplication, one suspects that he felt compelled to provide what is in effect superfluous space

in order to maintain the simplicity of his symmetrical arrangement. (In the large factory this problem seldom arises because the structural grid is generally of the same order - 20 ft - 30 ft - whilst the overall space requirement is much larger.)

This observation of the similarity between the Health Centre and industrial buildings could be interpreted in two ways. On the one hand it could be argued that Williams was far-sighted in introducing these techniques to the more domestic scale building, marred only by conscious attempt to humanize this structure by introducing incompatable domestic features, such as the curved bays and the open fireplaces. (Its advantages in this case would have been overlooked as inevitable problems that would result when any designer attempted an unprecendented problem.) On the other hand, the more cynical observer could argue that as an engineer committed to a functionalist approach, Williams failed when he tried to resolve the less tangible, humanistic elements of architectural design.

Fortunately for Williams, contemporary critics either ignored the building or adhered to the former view. Richards for example, recognizing its faults, though surprisingly claiming that the structure was a deceptive asymmetrical composition wrote in his conclusion to his article in the Architectural Review:

'This building bears out the universal principle that, so long as the designing of a building is approached in the right spirit, so long as it is designed on strictly realistic architectural (as opposed to antiquarian) basis, standards of detail design are only important as detail. This building is architecturally alive, and no crudity of execution can destroy that vitality - any more than elaborate consideration of detail can bring a dead building to life.'[259]

Although Richards could not be considered an impartial observer in view of his early involvement in the project, the conclusion he reached in the above quotation appears to be a fair assessment of the building and of Williams's role as its designer. The clients were similarly impressed with their new building as references to their later book testifies. Indeed, despite the criticisms referred to above there seems little doubt that it was Williams's functionalist design approach that enabled him to produce a building that was sympathetic to his clients objectives. While there is no evidence to suggest that Williams necessarily sympathized with these objectives, in contrast to the assumptions made by many observers at that time, it could be argued that this detached position was an important ingredient in the success of the project. This approach undoubtedly had its source in his earlier engineering type contracts where he judged his prime role to be that of providing as cheap a structure as possible to meet predetermined requirements. This would have been in marked contrast to the approach of many contemporary architects, whether traditional or modern, who frequently interpreted their client's brief in ways that would allow them to introduce their own architectural preferences.

. . . .

Three important questions emerge from the above descriptions of Williams's most influential projects: first, for what reasons were they widely regarded as important pioneering examples of British modern architecture; second, to what extent were they successful within their own terms of reference; and third, why were many of his other 1930s' buildings less influential?

There is little doubt that the five buildings described above were vitally important to Williams in establishing a reputation, not just as an architect who had successfully transferred from engineering, but as one of Britain's first building designers to produce structures that conformed to newly emerging canons of architecture. The principal reason why they should receive such widespread acclaim was that they were built at a time when there was an increased interest in Modern Movement architecture, the functionalist theories of which were being propogated in various British architectural journals. It was this coincidence that provided Williams with an ideal milieu.

It is important to realise that when he was designing the Dorchester, Daily Express and Boots buildings around 1930 he was working to a large extent in isolation. In general terms British architecture at that time was still characterized by various conventions, with barely a handful of architect-designed buildings that could be referred to as 'modern architecture'.[260] Nevertheless a small group of designers and journalists were already attempting to introduce the continental modernist architecture of Le Corbusier and others into this country and were actively promoting functionalist theories through the architectural press in an attempt to supplant normal approaches to design with a popular acceptance of modern architecture. Two of their most powerful arguments were that new structural materials demanded new forms of architecture and that only through a functionalist approach to design could appropriate new forms be achieved. Their favoured material, and one that was being widely used by their mentors on the continent, was reinforced concrete. Maxwell Fry who was one such committed modernist at that time has more recently provided an explanation why this material in particular should have been considered so important.

'I know that when I came into the picture at the turn of the 1930s, it (reinforced concrete) was unquestionably the material by means of which we could best express the form of ideas which the movement had already made current in Europe. I had very little real knowledge of reinforced concrete when I came to my first building, enough only to realize that it was the way to release and that it contained the dynamism of the new world.'[261]

It is hardly surprising therefore that when Williams, who was regarded as Britain's leading expert in reinforced concrete design, established himself as an architect committed to an uncompromising functionalist position, he should immediately be welcomed as an authoritive convert. Moreover, while modernists were having difficulty in acquiring the smallest of building contracts, either through inexperience or because of obstructions from various public bodies,[262] Williams had been given opportunities of designing some prestigious, large scale buildings. The Dorchester Hotel for example, successfully completed to Williams's design (but without Green's elevational styling) would undoubtedly have been the first large scale example of modern architecture in Britain. The Boots building, however, was entirely untainted by involvement from architects and once completed it became a rallying point for most British modernists. A further argument the modernists advanced in the cause of modern architecture was that it would essentially be directed towards creating new socially progressive patterns of living. In this sense Williams's work at the Peckham Health Centre supported their admiration of his work, for here this British engineer, by engaging himself on a project with radical socio-medical purposes, was perceived as a modernist designer with the necessary social commitment.

It was perhaps surprising that the admiration Williams received from committed modernists was not reciprocated. Not only did he criticize their work as stylistically conceived, but when invited to join their Modern Architectural Research Group (MARS) in 1933 and 1935 he declined.[263] Thus while Williams's work was received as Britain's best and earliest illustrations of this country's acceptance of the Modern Movement, Williams appears to have been unconvinced of any connection.

A further important reason why Williams's work was regarded as significant in the early 1930s was because it was perceived by some influential individuals as forming an important part of a much wider historical perspective. One such individual was P Morton Shand, a well respected architectural journalist who was instrumental in establishing the MARS group in 1933.[264] There appear to be two reasons why he found Williams's early work so appealing. First he recognized in the monumental simplicity of these structures - particularly the Boots Factory and to a lesser extent the Waterloo Bridge proposal - features that he had admired in the early work of German architects such as Behrens.[265] Shand had regarded these early German structures as some of the most important sources of modern architectural design. However he had argued that economic upheavals in Germany and France during the 1920s had prevented any capitalization, for example in the design of large commercial and industrial buildings.[266] The arrival of Williams's work suggested to Shand that, after years of architectural stagnation, Britain was at last beginning to see the emergence of forms of architecture that might have been possible ten years earlier on the continent had economic conditions allowed. Shand also valued Williams's status as an engineer, his non-architectural background and his abilities in reinforced concrete design. He had frequently argued that the essence of modern architecture was in the direct functionalistic application of new structural technologies to modern building problems, but felt that its achievement was frustrated by the fact that conventionally-trained architects lacked necessary skills and were also handicapped by their Beaux-Arts training which had conditioned them to design their buildings stylistically. This indicated to Shand, as it had to others (most notably Lethaby), that the new architecture was most likely to emerge in the work of individuals who did not suffer from this dual handicap, and it was from engineers in particular that he had expected the lead to come. It is perhaps not too discursive to refer briefly to the evidence for Shand's bias towards engineers. Take for example his 1932 article in the Architectural Review in which he first cited the work of Williams.[267] In this he included 19th century French quotations from the French architect Baudot which illustrated his view that engineers would become the true inheritors of the architect's role in the modern world:

'For long the influence of the architect has been waning and the engineer, l'homme moderne par excellence, is beginning to take his place. Were the latter in the position to replace the architect altogether, the former could doubtless disappear without art being extinguished as a result. Form will no longer be the basis of the new architecture. It will find its expression in the laying out of the plan and in the structural system which it necessitates.'[268]

At about the same time as he wrote this article Shand suggested to Sigfried Giedion that the chairman of the British MARS Group should be Wells Coates, an engineer who at that time had completed no architectural work.[269] This also indicates that Shand was naturally drawn to engineers for he was clearly convinced that Coates's technical abilities and his commitment to the cause of modern architecture were ideal qualifications for leadership of the British Modern Movement.[270]

It seems clear therefore that on a number of counts Shand would have been predisposed to admire Williams's work. The Boots Factory in particular would have appeared to him not only as the first positive indication of Britain's acceptance of the Modern Movement but also an affirmation that engineering concepts were at last beginning to reveal themselves as the rightful determinants of modern architectural forms. Despite this, later writers such as Nikolaus Pevsner had difficulty in providing an adequate interpretation of Williams's work and its precursors.

Nikolaus Pevsner seems to have known Shand's views when he published his thesis in 1936 which became the accepted historical account on the sources and development of the Modern Movement.[271] In this publication, Pioneers of the Modern Movement, Pevsner advanced the (by now familiar) argument that the Modern Movement had two of its most important sources in 19th century Britain - the Arts and Crafts Movement with its concern for 'simplicity of form' and 'truth of materials', and Britain's great engineering tradition. It was suggested that during the first years of the 20th century British advances were passed to the continent where they were developed principally in Germany while Britain lapsed into thirty years of reaction. Although Pevsner's account terminated with the early work of Walter Gropius the popular extension grafted onto his model, and tacitly endorsed by him, was that as the Modern Movement declined on the continent, and as a number of German emigrés from Nazism began to arrive in Britain, the movement which had started in this country was re-imported.[272] For many British modernists in the late 1930s this was a very attractive model giving their own work a respectable ancestry.

The essential problem in providing an explanation for Williams's work was that it did not support this model. There is no evidence to suggest that Pevsner was aware of the American concrete sources of Williams's work. However, in an article published in 1942 he attempted to justify his exclusion of early British work in his 'Pioneer' thesis.[273] In this he described fourteen pre First World War British buildings which compared favourably to advanced continental examples, but he concluded that they were insignificant as they did not form part of a coherent aesthetic attempt to establish a new form of architecture. Three of his examples were reinforced concrete factories designed by the Trussed Concrete Steel Company, buildings which were undoubtedly the closest ancestors of Williams's early 1930s' buildings, especially the Boots Factory. In the light of Williams's important reputation in the 1930s it seems difficult to understand how Pevsner remained unaware of this important connection. Could it be that Pevsner was unwilling to suggest that another source of modern architecture had its roots in the mundane, commercially expedient American concrete factory buildings because it would have radically upset his theory? Or did he simply fail to establish the connection? Whichever answer is closest to the truth there is little doubt that Pevsner never attempted to place Williams's work in a wider historical context. Although he admired his work, his preferred interpretation has been that it was essential in providing support to the young British architects of the 1930s whose sources for their own work came more properly from the continent.

A more important criticism of most references to Williams's best known buildings in contemporary and more recent publications has been the failure of writers to judge his buildings against his design intentions. For the most part critics have assessed his work subjectively, accepting without question that the forms he created were a bona fide product of his professed scientific design philosophy. This is surely a crucial error, based as it was on the contention that the engineer's functionalist approach to design was the only legitimate means to achieve new forms of architecture.

Analysis of his buildings described above shows that in a number of respects their assumptions were illfounded. If one examines the relationship between structure and form in each of these projects a number of detailed anomalies occur. Take for example the relationship between Williams's structural solutions and his elevational effects. In each of his buildings he can be seen to have adjusted the structure to achieve a particular elevational effect. This is readily apparent on the principal elevations of both the Daily Express building and the Peckham Health Centre. Inconsistences in his work at the Empire Pool are less readily apparent, for it is only with the benefit of recent calculations that it has been possible to suggest that he may have been attempting visual effectiveness in overemphasizing certain structural features on his elevations. (The Boots Wets factory however stands out as the exception in that Williams made no attempt here to amend the planning or structural arrangement to produce a more interesting visual effect.) A further inconsistency that can be noted in two of his buildings is his overprovision in the planning in order to maintain the efficiency of his structures and the forms they produced. His atrium arrangement at Boots, impressive as it is, and his second floor planning at Peckham are perhaps most indicative of this.

A more general criticism that can legitimately be levelled at Williams is that by placing his highest priority on structural efficiency he failed to address other aspects of the building problem. One of these was his failure to appreciate the thermal problems associated with large areas of glazing. At both the Boots Factory and the Peckham Health Centre the spaces behind their south-facing elevations are subject to extreme variations in temperature. At Boots this problem manifested itself shortly after the building's completion and the company was forced to install canvas screens in an attempt to reduce heat gain. (Fortunately, Williams's decision to extend the floor slabs outside the line of glazing provided ideal fixing positions for these screens so enabling them to appear as if they had been included as part of the design.)

A further anomoly caused by Williams's adherence to his 'law of least action' relates to the surface treatment of his structures. Despite his earlier work with Ayrton, who had concentrated on producing acceptable surface finishes in concrete, in the buildings he produced on his own account Williams was not greatly influenced by such matters. Except where specific conditions dictated otherwise, he believed it to be consistent to his principles to leave the concrete surfaces of his buildings just as they emerged from the shuttering. In both the Peckham Health Centre and at the Empire Pool, where large areas of external concrete surfaces were exposed to the weather, the surfaces became badly discoloured shortly after their construction producing a false impression of poor execution. Both these buildings, and others described later, have since been regularly repainted in order to maintain an acceptable appearance. Williams's insistence on untreated concrete surfaces, therefore, has perhaps produced one of the most significant contradictions to his principles in that he presented his clients with large maintenance costs for repainting work. Had he anticipated how his clients would have reacted to the dull, grey and badly discoloured surfaces of these buildings he may well have revised his principles and concluded that some surface treatment of concrete during the construction process was functionally expedient.

It therefore seems conclusive that in certain features of Williams's best known works he departed from his 'law of least action' either to produce particular visual effects on his elevations or by making overprovision in the planning to maintain the simplicity of his structural arrangement. In other respects, by applying his principles to the exclusion of other important building problems he produced some inconsistences which he did not perceive at the time.

The final question to be addressed is why many of his other buildings of the 1930s were less well known and less influential. There appear to be three reasons why this should have been so. First; a significant proportion of these buildings were visually ineffective and in some cases blatantly 'clumsy' in their architectural expression. This was largely restricted to buildings of a small scale or those which used materials other than concrete for their facades. Second; the Boots Drys factory, which was designed in 1935 and was completed in 1938, suggested a radical departure from the design approach used in the earlier Boots building of 1931, the relationship between its structure and architectural form being a complete reversal of the earlier practice. This, coupled with the introduction of various stylistic devices, may have been perceived as a betrayal of his principles by those enthusiastic about his earlier work. And third; as the decade proceeded a variety of factors created less favourable opinions towards Williams's work and his principles, and as a consequence less interest was shown in many of his later projects.

Williams's projects of the 1930s which possessed little architectural merit were those in which he was unable to use his abilities as a reinforced concrete designer to any great effect. They fall into two main groups; those which possessed no overriding structural problems because of their small size and those for which he was forced to use brickwork on the facades, concealing his reinforced concrete structure.

His first attempt at addressing the small scale building problem came
[31] in 1932 when he was approached by the Tunnel Cement Company to design a small single storey laboratory building for its works at East Thurrock. Reference to Williams's design drawings indicates his difficulty in applying his principles to the small scale problem, his first sketches, for example, showing an inept attempt to use a form of flat slab construction. In the built solution he produced a monotonous external appearance to the building by using the glazing mullions as slender reinforced concrete columns at centres of only three feet.
(202) After patenting the system he used it once more in the design and
[32] construction of three, four storey blocks of flats at Stanmore, infilling between the mullion supports with rendered brickwork where glazing was not required.[274] Like in the earlier Tunnel building the elevations of these buildings were unconvincing.

In two of his later small scale buildings Williams appears to have recognized the visual clumsiness of his earlier attempts and seems to have consciously created interest on his elevations by using stylistic devices. This is most readily apparent in another building for the
[41] Tunnel Cement Company at Pitstone, this time two storey, where he introduced cantilevered concrete canopies over the window heads. An
(273) early design sketch indicates that their function was to protect against direct sunlight and reduce overheating but they were continued round the building onto the north facades where they could only be justified in visual terms.[275] A similar stylistic approach
[36] can be noted in his Fire Station for Boots (1938). Not only was the framed structure to this building proportionately too large, appearing

as a scaled-down model of the adjacent factory building, but he included a hose tower decorated with a triangular and diamond shaped groupings of glass bricks.

The most striking difference between these small concrete framed structures and similar sized buildings designed by modernist architects of the period is the latter's predominant use of monolithic wall construction. In the early years of the 1930s Williams was unconvinced of the economic validity of this form of construction for low rise buildings, believing brickwork or concrete frame construction to be more suitable. However in 1938 he too produced two small scale schemes using concrete wall techniques - the Newspaper Offices for the
[37] Provincial News in Salisbury Square (1936) and the Dollis Hill
[42] Synagogue (1938) - suggesting recognition on his part of the visual incompatability of concrete frame construction with domestic sized buildings. Both schemes were without doubt more visually appealing than his other small buildings, but examination reveals that this was not the direct product of his functionalism but rather a self-conscious effort to add visual interest to their elevations. This was best revealed at Dollis Hill where he produced an interesting,
(283) though contrived, structural form at the outset and invented technical justifications later. This was not missed by some architectural reporters at the time. In a contribution to the <u>Architects Journal</u> one wrote:

'. . . Sir Owen in his new design for synagogue has let me down. Architects are bad at engineering but engineers are very good at architecture - provided always that they are not aware that it <u>is</u> architecture. Sir Owen has been consciously putting art on his Synagogue and he seems to be aware that it is art.'[276]

In situations where Williams was forced to use materials other than concrete - principally brickwork facades - similar conclusions may be

[33] drawn. For the 'Cumberland Garage Car Park' for example, the local authority's insistence on brickwork facades forced Williams to conceal an ingenious concrete frame solution and adopt a stylistic approach to design which produced a visually sterile result. Precisely the
[40] same problem recurred at Odhams, Watford although a substantial proportion of this building was of structural steelwork. Like the development observed in his small scale buildings, in his later brick-
[43] faced garage building for the Daily News Williams self-consciously attempted to create interest in the elevations of this building, on this occasion producing structural forms in brickwork as if they had been built in concrete. Once again the effect was unconvincing and one is forced to conclude that in any project where Williams was unable to let his abilities as a concrete engineer significantly affect the external appearance of buildings his 'law of least action' failed him and he was forced to adopt more of an architect's stylistic approach, which he was unable to execute successfully. It is hardly surprising, therefore, that these buildings were not perceived in the same light as the Boots Factory.

A further reason why Williams's later buildings may have been regarded as of less importance is that the dramatic change perceivable in his
[36] Boots Drys Factory may have suggested to some that he had departed from his earlier principles, thus betraying the modernist cause. The differences between these two buildings are particularly relevant because the Drys building was originally intended to be a mirror image of the Wets building, expensive provision having already been made in the design of the latter to accommodate the new extension. However the new building was different in many respects. Not only was it constructed as an independent structure but in its massing and details it bears no resemblance to its neighbour. Although the change

may have been partly due to the reversion of the company into British ownership in 1932, there is so little in common between the two buildings that one must assume that Williams's approach to building design had undergone a dramatic change between 1930 and 1935.

The essential elements of the production process were the same as in the Wets building but were arranged in a vertical rather than horizon-
(240) tal relationship. As Williams had initially supposed the production process to be identical to that of the Wets, one must assume that the changes were related to a reappraisal of his earlier solution in both organizational and architectural terms. The manufacturing process was accommodated in a multi-storey spinal structure with single storey structures to either side (to the west containing unloading dock and sorting; to the east packing and dispatch). This produced an architectural form comprising a tall rectangular spinal unit flanked by low lying blocks of different sizes to each side. Thus, whereas the earlier building appeared as an homogenious multi-storey block with differences in the production process only perceivable in the internal disposition of large atrium spaces, in the Drys building Williams dispensed with atria and used the different parts of the production process as the determinants of an external form. Furthermore he made a
(236) distinctive feature of the main entrance to the new building in marked contrast to that at the Wets, by extending the multi-storey block beyond the building line and with the main staircase and lift shaft protruding even further with splayed corners and 'wrapped-round windows' at each landing level. Although these changes may have suggested to some that Williams had betrayed his earlier position, examination of the structural arrangement reveals important factors which tend to temper this conclusion for in some respects it is more impressive as an example of his structural abilities than his

earlier work.

The multi-storey structure was constructed with flat slab construc-
(247) tion using similar cruciform capitals and columns as in the Peckham
(234) Health Centre. It was his structural design for the single storey elements where his abilities in reinforced concrete design are seen at their best. Here he designed an impressive roof structure con-
(241) sisting of 9 ft deep 'Z' beams cantilevering distances of 30 ft and 48 ft to each side. At the position where these beams met the multi-storey flat slab structure it was important that no columns
(243) be included. To overcome this problem Williams supported the end of his beams on large concrete hangers exposed on the elevations of the building and supported from large roof beams projecting above
(242) the roof line of the multi-storey portion. (The hangers were therefore effectively supported on the two rows of mushroom columns in the centre of the building.) Not only did these hangers have an important structural function but they were also made hollow to be used as the main extract ducts for the entire building.

In many respects Williams's remarkable structural design for this project was more closely suited to the function of the building than was the case at the Wets factory. The difficulty however is that no-one would have been especially aware of Williams's ingeneous structure without reference to his drawings, for although the elevations do not conceal the structure neither is it used to produce sensational architectural effects.

Thus whereas in the earlier building the principal generator of the architectural form had been the efficiency of the structural solution, often at the expense of other functional considerations such as excessive areas of glazing and the inclusion of large atrium spaces

where only single storey units were required, in the later building the architectural form was generated by a more rational approach to the planning with efficient structural design employed at the service of this form. This difference clearly reveals a shift in the relationship between structure and form in Williams's design philosophy. Moreover, along with this change he appears to have accepted
(246) what would have been anathma in the early stages of his architectural career - namely that stylistic devices were valid as a means of expressing the function of a building where the structure itself failed to convey the necessary information. To many this radical shift in emphasis would have suggested that Williams was beginning to operate in a similar way to many of the architects he had once criticized, a conclusion that would have been supported by his later small scale buildings. This seems a perfectly legitimate argument, for undoubtedly if Williams's career was supposed to prove anything it was that a purely engineering approach to design was the only valid way to achieve modern forms of concrete architecture. It is possible therefore that as Williams's experience as an architect increased he began to appreciate that his early assumptions, if not irrelevant, were perhaps somewhat naive.

While this dramatic change may have contributed towards less interest being shown in Williams's later work there were a number of other more general factors that combined to create a climate of opinion less sympathetic to his ideas.

The most important of these was that from the mid 1930s onwards examples of British modern architecture became more numerous with the vast majority of architectural journals reviewing a higher proportion of modern buildings than traditional ones. Thus Williams's buildings became less significant because they became increasingly less unique. Concurrent with this development was the gradual displacement of 'functionalism' as the Movement's principal driving force. As examples of modern architecture multiplied, architects became increasingly conscious of a preoccupation with style, a self awareness brought sharply into focus with Hitchcock and Johnson's 1932 publication, The International Style .[277] As a consequence Williams's engineer status and his functionalist principles became gradually less relevant. A further factor may have been his unwillingness to align himself with the British Modern Movement and particularly the MARS group. It is perhaps significant that a large proportion of the MARS membership consisted of influential journalists who actively promoted the work of their colleagues in the group, sometimes to the exclusion of others.[278] Furthermore one of the principal reasons why Williams had been invited to join MARS in 1933 and 1935 was that as an engineer he would be able to provide the technical input that was embarrassingly absent from the group's early membership. By 1935, however, this deficiency in MARS was filled by Ove Arup and Felix Samuely, two engineers who readily aligned themselves with the Modern Movement. Not only were these engineers of continental origins, thus reinforcing the European connection that was greatly encouraged, but, unlike Williams, they were prepared to help architects as consulting engineers in producing the buildings they wanted. Thus not only was Williams's role supplanted in this influential group but the significance of his position as an architect/engineer became less important when other engineers like Arup proved the effectiveness of architect and engineer collaboration.

P A R T   T H R E E

TWO BRITISH ENGINEERS WORKING PRINCIPALLY IN REINFORCED CONCRETE WHO CONSIDERED THEMSELVES AS BELONGING TO THE MODERN MOVEMENT IN ARCHITECTURE

CHAPTER 7

OVE ARUP

Arup's Pre 1930 Career

Arup's post Second World War international reputation and his firm's recent involvement in some of the world's best known buildings have led to a common perception of him as the archetypal engineer. It is perhaps surprising therefore that his early background did not follow the established pattern of many of his contemporaries. His early University education in philosophy was one such difference, providing him with a broadly based background in the humanities which was quite unique for an engineer of his generation. The other was that for twenty years he developed his abilities as a designer within the field of contracting, in contrast to many other engineers of his standing who worked principally in a professional capacity. Both these features of Arup's early career had an important affect upon his approach to design and the structures he produced.

In 1913, at the age of eighteen, Arup entered the University of Copenhagen to read philosophy.[1] His naive hope was that through such a course of study he would be able to reconcile the conflict between the spiritualism of his Christian upbringing and the rationalism of science that his early interest in natural history had provoked. Inevitably, perhaps, it did not provide him with the metaphysical answers he sought. It was partly due to his disillusionment with academic study in philosophy, brought sharply into focus with the catastrophic impact of the First World War, together with a pragmatic recognition that he needed employment of some sort, that provoked him to decide on a career as an engineer. It is perhaps with a certain amount of romantic hindsight that he has recently recalled his thoughts at this watershed in his life which gives a deeper significance to his transfer from philosophy to engineering:

'I can remember at that time (1918) thinking about a joiner making tables. A table can be good or bad. It can be strong, durable, practical, well proportioned, beautiful etc . . . , or it can lack some of these desirable qualities. A good table gives pride and satisfaction to the maker, his customers are delighted, he has friends. It is not the ultimate good, it doesn't solve anything, but if you can't solve the metaphysical problems it may help to solve one's private problems, to get involved. I was not sure that I would make a good joiner, I was not sure either that I had it in me to become a great architect - which I would have liked to be - but I knew I could become an engineer and I also knew that this knowledge could come in very useful should I ever be inclined to study architecture as well.'[2]

This quotation should not be dismissed as a piece of idealized post-rationalization on Arup's part, for within it is contained certain themes which are fundamental to an understanding of his life and work. He has never regarded engineering as an applied science, although he readily admits that it relies heavily upon an understanding of certain scientific principles. On the contrary he has always maintained that the work of an engineer is, or should be, more closely allied to that of the artist than to the scientist because in any particular engineering project, or detail of it, there are always an infinite number of solutions which can never be directly compared by quantitative methods. Producing the right solution depends as much upon the imagination, intuition and deliberate choice as it does upon scientific enquiry.[3]

Thus in 1918 at the age of 23, Arup entered Copenhagen's Royal Technical College to study civil engineering. The course was apparently wide ranging in its content, but Arup notes that it was the study of reinforced concrete which stimulated greatest interest amongst his fellow students. Not only was it seen as a modern material which on a purely theoretical level was the subject of extensive research both inside the college and outside, but for many students and particularly Arup, the material's plastic nature appeared to offer the engineer a degree of freedom in design which was largely absent from other structural materials. He referred to this special status of reinforced concrete in a lecture he gave to the Architectural Association in 1935.

'. . . reinforced concrete offers a much wider scope for ingenuity or originality in design, it is therefore an attractive material for the engineer to work in; he feels himself more in the position of an architect, not as a mere technical assistant doing some routine work.'[4]

Throughout his working career Arup has had a close affection for reinforced concrete and it is not without significance that many of the schemes on which his reputation is based have been built primarily in this material.

On graduating in 1921 Arup found employment with the Danish civil engineering design and construction firm Christiani & Nielsen. This company had already established a highly regarded international reputation in the field of reinforced concrete structures and it was for this reason that Arup joined them in an attempt to further his interest in the material. Like many concrete specialist firms, Christiani & Nielsen was established at the turn of the century (1904) and quickly expanded beyond its country of origin. By 1926 the firm was involved in hundreds of contracts throughout the world, operating from ten centres.[5] The Hamburg office was Arup's first posting, but although he had made many personal contacts there in the city of his youth, he was keen to widen his experience and so he applied to join the firm's Paris office. His application was not granted. Instead he was asked to go to London. Thus quite unintentionally he arrived in his country of birth in 1923 to begin what was to be a lifetime's career here.

It is important to recognize two important features about Christiani & Nielsen because of their relevance to Arup's career. First, it was essentially a contracting organization specializing in the building of concrete structures to designs produced by both external engineers and its own engineers from within the firm's design department. Second, it was primarily concerned with large civil engineering contracts, its main specialism in Britain during the 1920s being marine works (sea walls and jetties).[6] Only on rare occasions did it become involved in the construction of small buildings designed by architects. This meant that for the first ten years of Arup's work as an engineer he developed his expertise as a designer in reinforced concrete through the 'contractors office' gaining a thorough understanding of the building process itself and its implications for design. Furthermore as he was largely involved in the design and construction of civil engineering type contracts he had little experience of architecture, or even of working with architects, when he began to redirect his career towards architectural work in the early 1930s. (In this way his early career was very different from that of either Williams or Faber, the bulk of whose work during the 1920s was confined to working alongside architects.)

Arup found two important advantages in working for a contractor in preference to a consultancy practice. First was the fact that an engineer in a contracting firm was in direct contact with the materials and the construction process itself and was able to allow experiences from such contact to influence his own designs. This was particularly important in reinforced concrete structures, for as Arup soon discovered, the realities of site work were very different from the theoretical assumptions he had made about the material previously. His early work as an estimator within the company's design department, costing the designs of external consultants and in-house engineers, brought these realities sharply into focus. Through this he came to understand the vital importance of cost implications to design best summed up in his catch phrase 'engineering design is creative accountancy'.[7] The pursuit of simplicity and balancing the costs of labour and materials became Arup's objectives very early in his career and alongside it he also began to appreciate that any designer 'must know what he wants to achieve and know the means of execution available to him and how to evaluate their effectiveness both theoretically and practically'.[8] What surprised him most was that consulting engineers, who submitted schemes to Christiani & Nielsen for pricing, frequently revealed their failure to appreciate these important facts, a failure which Arup regarded as detrimental to both the advancement of reinforced concrete as a building material and to the clients' interests.

The second advantage was that the working environment within such an internationally famous contracting firm suited innovative minds. The pursuit of new and cheaper ways to design and build in reinforced concrete was encouraged within the firm primarily for commercial reasons (either to beat competition from other firms or simply to maximize profit). This provided a young engineer who believed in his own ability with an ideal opportunity to enhance his reputation. Arup usedthis opportunity to the full, developing new techniques for the building of jetties, producing patents for cooling towers and in addition publishing many articles on technical subjects throughout the 1920s.[9] Through this work he quickly rose to the position of chief designer within the company's London office.[10]

Nevertheless the resistance he encountered from numerous bodies and individuals caused many frustrations which tempered this opportunity to be innovative.[11] One of the most annoying was the resistance he experienced from external engineers who sent their designs to Christiani & Nielsen for competitive tender. Arup notes that in many instances there were opportunities for improving the design with significant cost savings, but he soon discovered that consulting engineers were loathe to accept advice on their designs from contractors and if such advice were forwarded the contractor risked removal from the tender list. This proved to Arup the absurdity of the British building industry's imposition of a complete separation of design from construction. He did have some successes on a few occasions in changing the designs submitted by external engineers, but these had to be achieved by delicate negotiation.

However even designs produced by Christiani & Nilesen's own engineers were not entirely free from resistance to new ideas. There were three reasons for this. First, as contractors, the firm was almost always working in competition with other firms. If it produced an innovative idea which it presented to its client, the design might be circulated to other contractors for pricing. Thus the firm's desire to produce innovative ideas was always tempered by the fear that competitors might ultimately benefit. In addition to this was the resistance all designers faced from legislation and from manufacturers who were unwilling to experiment with new machinery to improve the construction process.

The most telling frustration from Arup's point of view was not exclusively related to the field of contracting; it was the growing importance of the quantity surveying profession. In the early days of reinforced concrete the quantity surveyor was rarely used, his main activity being in traditional building work. However by the late 1920s the practice of quantity surveying was becoming very popular within reinforced concrete engineering. One significant consequence for a designer using a quantity surveyor was, and still is, to allow the project to be comprehensively specified and measured in contract documents before a designer finishes his drawings. Arup regarded this to be - 'a thoroughly bad excuse for a bad practice'.[12] For the contractor the job of pricing an unpriced bill was always laborious and an abstraction from the realities. A serious indictment of the system was that the involvement of a quantity surveyor always imposed on the designer accepted methods of building. When faced with an original idea using new methods of construction, the system was unable to respond. Thus the system itself was always an impediment to innovation.[13]

Despite these frustrations Arup remained in contracting until 1944 believing that the advantages outweighed the disadvantages and recognizing that the most serious impediments to innovation, namely the organization of the British building industry itself, applied equally to engineers working within professional consultancies.[14]

He did however arrange a strategy for his working life in the 1930s to relieve these frustrations, providing himself with more opportunities to be innovative. The essence of this strategy was to provide modern architect-clients, who were enthusiastic about new structural technologies, with an integrated structural design and construction package. By combining these two components of the building problem Arup believed he could greatly improve the quality of building with cost benefits, and remove many of the frustrations he encountered as a contractor often prevented from making an invaluable input into the design process. Its implementation, it will later be argued, made a vital contribution to some of the best examples of British modern architecture in the 1930s.

There is little point in examining Arup's work during the 1920s in any depth. Such a study would involve the analysis of many jetty designs and piling systems which have little direct relevance to his work with architects during the 1930s.[15] His experiences during this early stage in his career have a more general significance to his work in the 1930s; namely the importance he attached to integration of design and construction, the development of his abilities as a designer in reinforced concrete and his belief in the pursuit of simplicity in any design problem.

. . . .

Arup explains that his interest in architectural design, and his decision to become involved in it, was stimulated by a chance meeting with Lubetkin in 1931.[16] This does not appear to be entirely accurate for an article he wrote for the journal, Concrete and Constructional Engineering, shows that he was applying his mind to architectural issues as early as 1926.[17] The fact that Arup cannot now remember writing this article indicates that his memory of his thoughts during the 1920s has become increasingly vague with the passage of sixty years. It is therefore necessary to examine his writings of this period in order to piece together some picture of his ideas prior to his decision to become involved in architecture in the early 1930s.

There is little doubt that Arup would have been familiar with the discussion of how architecture should respond to the development of reinforced concrete through his reading of contemporary engineering journals during the 1920s. One of the most important of such publications was the monthly journal Concrete and Constructional Engineering in which Arup published at least three articles before 1930.[18] After the British and French exhibitions of 1924 and 1925 most issues of this journal contained some discussion on the relationship of reinforced concrete to architectural design, and its 21st anniversary issue of January 1926 included articles by leading architects and engineers on this specific subject, (included amongst them Oscar Faber, Maxwell Ayrton and Owen Williams). It was an article in this issue by A E Richardson entitled 'The Relation of Reinforced Concrete to Present Day Design'[19] which appears to have awakened Arup's interest in the subject.

The main objective of Richardson's article appears to have been to convince the journal's engineering readership that whilst the engineer understood the technical complexities of reinforced concrete, its development as an architectural material lay exclusively within the architects sphere of influence. To do this he had to explain the important differences between the functions of the architect and engineer and to dispel the notion that a functionalist approach to architectural design necessarily produced beautiful buildings. Addressing the question as to why concrete was widely regarded as a cheap utility material Richardson explained that this view had developed because the material had been used almost exclusively by engineers for cheap utility structures which could never have been considered of architectural interest, while architects had generally been too timid to use the material for architectural purposes. This, he explained, would change through a slow evolutionary process which would allow the development of concrete as an architectural material without 'loss of qualities which are the very fibres of architecture'.[20]

In essence Richardson's article was a defence of Beaux-Arts principles and the retention of the architect's status as the 'devisor of structure'. In conclusion he wrote:

'The architect is more than a decorator, he is a devisor of structure . . . . An engineer on the other hand confronted with a complex planning problem generally follows the line of least resistance and plans directly without observance of the laws of architectural planning . . . .

There are many who appreciate the value of ferro-concrete as a material for modern building. It is a pity that so far its use has been limited to utility buildings. The issue of fine planning remains constant, the theory of dimensioned structure will remain in the hands of the architect, but it is not to be expected that architects as a body will do ought else but rely on expert advice where questions of integral calculus are concerned.'[21]

Arup responded to Richardson in an article published under the same title in the Journal's March edition. His argument was centred around his own view that architecture could not simply be defined as buildings designed by architects. Unlike Richardson, he regarded any built form to come under the heading of 'architecture' and in this respect he wrote in his introduction:

'. . . I venture to suggest that the best architecture in reinforced concrete is generally to be found among these big engineering structures of today rather than in ordinary buildings planned by architects'.[22]

To give credance to this view, Arup referred to unspecified 'current architectural theories' which suggested that an essential feature of good architecture was 'truth' -

'whereby it is implied that the purpose of the building or structure is met in a simple, logical, and economical way, and that this purpose is openly and frankly expressed in the building, without disguise of any kind, but with respect for, and knowledge of, the material employed.'

In this respect he argued that:

'. . . if an engineer with a thorough knowledge of the material succeeds in creating a structure which combines a high degree of efficiency with economy in design, this structure automatically satisfies one of the first claims of architecture.'[23]

While he admitted that the types of contracts undertaken by 'architects' and 'engineers' were different, he maintained that this difference was essentially one of scale and complexity. In both instances, however, the design problem could be considered to be one of an 'architectural nature. Generally speaking in engineering structures the scale was relatively large and the functions small in number whereas:

'In ordinary building, the architectural problem is much more complicated. There are a hundred different considerations to conciliate. The possible solutions are much more numerous even if truth and simplicity are aimed at, because even small alterations in the proportion and number of windows, in the sloping of the roof . . . etc, may be of great consequence and may completely alter the style of the building. A thorough knowledge of the material is therefore not sufficient in this instance.

Faced with these problems, the architect is naturally inclined to apply traditional forms and proportions which were natural for brick and stone, but which do not fully utilize the extended possibilities of the new material. It must be the aim of architects to develop a new form of architectural beauty which does justice to the material without taking refuge in disguise.'[24]

To achieve this, however, Arup claimed that there was only one possible source which the architect could consult, namely in the domain of concrete engineering structures, where knowledge of reinforced concrete was most advanced, where the properties of the material were of most value, and where the architectural proposition was as simple as possible. However unlike Williams, who came to the opinion that only engineers were capable of producing concrete architecture, Arup believed, like Richardson, that architects themselves would have to address these problems if they wished to produce a form of concrete architecture which would be able to compete in harmony and expression with stone and brick buildings:

'but perhaps at this stage they might learn something of the treatment of the material by studying the simplicity and efficiency of some modern utility structures.'[25]

This article provides very useful information on Arup's views at this early point in his career. What is particularly surprising is that his views have changed very little with the passage of sixty years or more from those expressed here.[26] In summary they are: First, his unwillingness to regard architecture and engineering as fundamentally different, preferring instead to regard both as elements of environmental design. Second, his recognition that simplicity and efficiency were important objectives in any design problem. And third, his pragmatic recognition of the necessary existence of two distinct professions - architect and engineer - not because of differences in the essential nature of their work, but because of the detailed differences in their content.

In terms of the development of his interest in architecture, this article clearly reveals that Arup was beginning to take a keen interest in architecture well before his meeting with Lubetkin in 1931. Further evidence which supports this view is that in 1930 Arup was attending meetings of the Architecture Club and the Architectural Association, presumably to widen his knowledge of architectural design.

In May 1930 for example, his papers reveal that he attended the annual dinner of the Architecture Club at the Savoy Hotel.[27] The topic to which the speakers addressed themselves was 'The Architecture of Concrete'. Mendlesohn was the principal guest speaker with Owen Williams and Banister Fletcher delivering in-house speeches. Although no records of the dinner speeches exist, similar lectures delivered by Mendlesohn in Britain at the same time provide an idea of the basic issues that would have been raised. For example, at a lecture to the

Architectural Association (A A) the following month, Mendlesohn said:

'To build in concrete involves a revolution in building technique. We build frames, that is we concentrate the load on single points, instead of distributing it over the wall as a whole. We pour concrete instead of, as formerly setting the single parts, bricks or stones on top of each other. We assemble a building like a machine; mechanical accuracy replaces the skill of the craftsman. For our buildings we calculate exactly beforehand every detail of construction, we organize on a large scale instead of being contented with empirical attempts and occasional lucky results. This fundamental attention in the methods of building is one of the causes of the change in ideas on architectural form.'[28]

It is reasonable to assume that the issues raised by Mendlesohn, together with Owen Williams's contribution, must have aroused Arup's interest. Here was a situation in which a German architect and a British engineer were laying the foundations for a new approach to architectural design in Britain. Concrete, and to a lesser extent steel, were to be the materials that would create the new architecture, and functionalism was to be the guiding theory. If this was to be the future of architectural design in Britain then Arup must have recognized that with his experience he would be able to make valuable contribution.

In the following year, during one of his visits to the AA, Godfrey Samuel - a recent graduate of the school - introduced Arup to Lubetkin.[29] This was to be a meeting of great significance. Samuel had met Lubetkin the previous year in Paris and on his arrival in Britain in 1931, Lubetkin had contacted Samuel and had begun to establish contacts at the AA. It was here in 1932 that the Tecton group was formed, comprising six recent AA graduates with Lubetkin as its unofficial leader. From its inception it formed a close liaison with Arup, Lubetkin and Arup forming a particularly close friendship.

Arup provides a number of reasons why he and Lubetkin should have developed a close friendship shortly after their first meeting. First was the fact that both were foreigners in Britain. Lubetkin's command of English on his arrival was poor and he and Arup spoke mainly in German. Second was their mutual interest in philosophy, and although their positions were very different it provided a common subject of conversation.[30] Third, from a purely practical point of view, Lubetkin saw in Arup skills that he needed to produce the architecture he wanted. What particularly attracted him was Arup's background in contracting, for Lubetkin had learnt from his experience at Perret's atelier in Paris that an important ingredient in the success of Perret's concrete architecture was the fact that he operated from a contracting enterprise. Lubetkin was eager to follow in Perret's footsteps in this respect, but lacking the essential background in reinforced concrete or contracting himself, needed a contact such as Arup to provide the necessary integration of design and construction skills that he regarded to be essential to the success of modern architecture.

From Arup's point of view Lubetkin's wish to produce concrete architecture based on the integration of design and construction skills presented him with the ideal opportunity to initiate innovations in structural design. Furthermore, he realized that through collaboration with Lubetkin he would be able to learn more about architecture and increase the scope of his work.

It would be wrong to assume that Arup's interest in architecture at this time was exclusively related to his contact with Lubetkin. Through the AA and later the MARS group, which he joined in 1934 as a member of its Central Executive Committee, he came into contact with all the leading figures of British modernism. In all these individuals he found a stimulating enthusiasm for new ideas. In a recent lecture he made reference to this enthusiasm, contrasting it with the frustrations he was experiencing in civil engineering at that time. Referring to himself in the third person he said:

'Here he met a number of young people who really were interested in new ideas, who in fact had plenty themselves, and were very fond of discussing them. It was stimulating, amusing and also puzzling.'[31]

The puzzling part of this enthusiasm was the interest these architects professed to have in engineering in general and reinforced concrete engineering in particular. While this enthusiasm was welcome to Arup he soon discovered that it was very superficial. Not only did architects know next to nothing about the technologies they wished to use, particularly reinforced concrete, but their general interest in engineering was in the main a romantic one. Nevertheless it provided the context for him to make a valuable contribution both in education and practice.

. . . .

Although Arup worked for many British architects during the 1930s, the majority of his built work was undertaken in collaboration with Lubetkin and Tecton. Moreover, of all the architects with whom he was associated, it was Lubetkin's work which he claims to have had the largest influence on his own design approach. Because of this close connection between these two men it is necessary to compare the differences between them in terms of their background and views on architecture.

The most fundamental difference is to be found in their conflicting views on the relationship between philosophy and architecture.

Lubetkin has always maintained that a philosophical standpoint is essential if the designer is to produce good architecture, while Arup never recognized such a connection. Lubetkin's standpoint was based on rationalism and his Marxist position. Arup recalls that he and Lubetkin had endless discussions on the subject, even though Lubetkin's philosophical approach remained incomprehensible to him. Arup came to the opinion very early that architectural theories did not produce good architecture - 'only good architects can do that'.[32] Lubetkin, on the other hand, maintains that Arup's incomprehension was due to his western background which blinkered his insight within the tradition of pragmatic empiricism.[33] He claims to have recognized this problem in all British architects who produced modern buildings during the 1930s and he believes that it was their failure to appreciate the essential philosophical basis of architecture which was responsible for their work being inferior to his own.

There is little doubt that Lubetkin's background was substantially different to both Arup's and all other British modernists of the 1930s.[34] Unlike them, Lubetkin was a Russian who had had direct experience of the 1917 revolution, and as a consequence had learnt to appreciate, very early in his career, the close relationship between revolutionary art and social change. Although six years younger than Arup their involvement in building and design had been concurrent. However, whereas Arup had abandoned philosophy in 1919 and had throughout the 1920s gained practical experience as an engineer in the design and construction of many reinforced concrete structures, Lubetkin had devoted the whole of this period to developing a theoretical basis for his design approach from leading European designers and theorists. (These included, the Russian constructovists, Tatlin and Rodchenko; Warringer in Berlin, and the Atelier Perret in Paris.) These influences provided Lubetkin with a theoretical approach to design which had two important themes; first that architecture should be considered to be a key instrument in affecting social change along Marxist lines; and second, that rationalism was the only valid architectural design theory for achieving this objective. When he arrived in Britain in 1931 he had completed only one building which could be credited to him in association with Jean Ginsberg - a block of flats in the Rue de Versailles, Paris.[35]

In comparison to Arup therefore, Lubetkin's record as a practical designer by the early 1930s was severely limited. With regard to his experiences in reinforced concrete, this contrast was even more marked, for although he attended classes on the subject when a student at Berlin, his understanding of the material was elementary.

Related to their differences in background was an important difference in the personalities of both men.

Lubetkin's experiences in Russia and with the avant-garde in various European centres prior to 1931 had convinced him of the Marxist's viewpoint. This led him to distrust authority of all kinds, particularly in a capitalist society such as Britain. Furthermore, events in the Soviet Union under Stalin had fueled his hatredof authority for he felt that the government there had opted for the simplest solution by retreating into opportunism, betraying all the Marxist ideals he regarded so highly. This led him to an anarchist position in his contempt for groups and institutions who used the argument of pragmatism to maintain a state of minimum disruption. He openly admits that his bitterness towards society led him to 'rebel' against, and 'jeer at', institutions of all kinds, including groups of admirers whom he felt had a very superficial understanding of his aims and objectives. For these reasons he refused to take an active part in the MARS group and stood firm against the approaches of individuals like Charles Reilly who tried all manner of means to persuade him to join the RIBA.[36] Lubetkin considered both these groups to exist as a means of protecting mediocrity, an objective abhorent to him.

His stand against authorities and institutions of all kinds ultimately forced him into an isolationist position. Shortly after the abandonment of his architectural career he wrote down his fundamental reason:

'I agree with Picabia that the only way to preserve one's self-respect is to sacrifice one's reputation, keeping one's independence of mind by living as a dissident, since "individual resistance remains the only key of the prison" (A Breton).'[37]

Arup was very different. In political terms he could be described as a progressive in the 1930s, but his experiences did not lead him to Lubetkin's Marxist position. He was and still is a pragmatist, a characteristic noted in his early decision to abandon philosophy and train as an engineer. He, unlike Lubetkin and other modern designers, could not regard architects and engineers as prime movers in the reconstruction of society, but merely as servants. His experience of authority, particularly with regard to his involvement in the Air Raid Precautions (ARP) episode in 1938,[38] convinced him that as an individual one was forced to work within the accepted political framework. His self respect had to be earned by working hard on the schemes in hand, attempting to bring his influence to bare within the parameter's set. Unlike Lubetkin, he was prepared to accept the embrace of various institutions and attempt to reform them from within, a standpoint that was anathema to Lubetkin. He has accepted the honours and prestige bestowed upon him by society in return, whilst Lubetkin insists that status acquired in this way is ultimately self-destructive.

This divergence in the personalities of Lubetkin and Arup does not appear to have been a barrier to their collaboration and friendship during the 1930s. However as their position became more entrenched later, and as Arup began his rise to fame, their relationship became more strained, and after the Second World War they ceased to collaborate. In the early 1930s it was very different. At that time Arup was inexperienced in architectural design and was prepared to accept Lubetkin's rebel-like instincts in return for valuable experience. Lubetkin was his tutor in architecture and although Arup could not accept the link that Lubetkin claimed to exist between his design skills and his philosophical standpoint, he freely admits that his influence in design matters was overwhelming. Lubetkin on the other hand is less generous about Arup's influence and his contribution to their joint work, a fact no doubt linked to his resentment at Arup's present-day reputation. He accepts that Arup played an important part in the structural aspects of their designs, but he remains bitter that Arup's pragmatism forced him to conform to the institutional trappings of capitalist society.[39]

Arup's Contribution to British Building in the 1930s

Arup's entry into architectural design took place between 1932 and 1933 when he was involved in the design of two relatively small buildings - a Gorilla House at London Zoo and a Café at Canvey Island. The former was undertaken in collaboration with Lubetkin and Tecton, while he alone was responsible for the design of the latter.

[44] The Gorilla House was the debut for Lubetkin and Tecton, as well as for Arup, as it was the first of their design projects to be built in

Britain. The opportunity to design the Gorilla House, which ultimately led to a series of Zoo buildings throughout Britain, is attributed to Godfrey Samuel's friendship with Solly Zuckerman (Research Anatomist at the Zoo). It was through this contact that Lubetkin was introduced to Dr Vevers (Superintendent of the Zoo) to discuss the arrangements for the housing of two gorillas which the Zoo had purchased in August 1932.[40] Design work began in September of that year and by mid November building work had begun, Christiani & Nielsen being the contractors.[41]

It seems clear from the design development drawings that the overall form of the building was not determined to any great extent by the use of reinforced concrete, although all the drawings assume its use as the principal building material. The essence of the design problem was to provide appropriate environmental standards, protection for the gorillas against human infection, and good viewing conditions for the visitors. Climatic considerations suggested a building with two parts, an internal area for shelter surrounded by windows for viewing, with a second, outdoor, caged area which could be converted into an indoor space and an extension to the permanent shelter in inclement weather conditions. The final solution consisted of a simple concrete drum split in half with the outer, caged area adopting a similar semi-circular plan form and surrounded internally by sliding walls which allowed conversion into an extended indoor area when required. On
(293) either side of the main concrete structure was a large entrance porch and a smaller exit porch, their flowing shapes created to assist the movement of visitors. The decision to build the porches in this way had been preceeded by intense debate within Tecton. Samuel, insisting on a purely functionalist approach to the design, suggested simple holes in the 'drum', while Lubetkin wanted the porches to entice the

visitor to enter and create a more stimulating piece of architectural sculpture. (Lubetkin's views in this respect indicate that at this early date he did not equate his rationalist design theories with the functionalist ones propounded by many British modernists). In structural terms the building presented Arup with little difficulty. His role in this particular instance was to design a simple semicircular wall in reinforced concrete (4 in thick) with flat roof, very similar to his previous work in the design of concrete silos. Although this structurally simple building could have easily been built in rendered brickwork, a solution which Arup claims would have been much cheaper,[42] Tecton's desire to produce a reinforced concrete building meant that Arup's engineering assistance was indispensable. (Evidence of Tecton's inexperience in reinforced concrete design is constantly referred to by Arup - he even invited each member of the group to visit the site to mix some of the concrete himself to enable him to 'get a feel for the material'.)[43] There is no evidence to suggest that Arup's previous experience in the design of circular concrete structures encouraged Tecton to adopt this form for their building. Rather Arup provided a reinforced concrete structure most appropriate to the predetermined form.

Concurrent with this scheme was Arup's own design for a café building
[45] on the promenade at Canvey Island. He acquired this commission from a design competition in 1932, a competition from which members of the RIBA were excluded by their Institute because the rules contravened its code.[44] Arup's built design has many features in common with the Gorilla House and displays his own sensitive approach to architectural design. Arup planned the café accommodation as a circular space at
(297) first floor level (40 ft 6 in diameter) surrounded by continuous glazing to allow visitors all round views of the estuary to the south

and parkland to the north. To provide uninterrupted glazing, Arup cantilevered the flat concrete roof 6 ft 6 in from a circular concrete beam supported on six reinforced concrete columns. An illustration of Arup's sensitive approach to the design is the way in which he designed this circular beam. Instead of using the
(295) cheapest rectangular section he produced an inverted 'T' section beam to provide an ideal position for concealed light fittings. At roof level the slab over the beam was formed as a gutter, transmitting rain-water to pipes cast within the concrete columns. Because the site fell sharply from south to north and was made up of poor ground, these columns penetrated ground floor level at the rear of the building emerging as free standing columns supported on precast concrete piles. At ground floor level he located the kitchen and toilet facilities within the boundary of the concrete columns, separated by a staircase which was positioned centrally on the north-south axis leading visitors up to the café directly from the promenade.

The most striking resemblence between the café and the Gorilla House is the geometry and disposition of the architectural forms. The dominant feature of each scheme was the circular form of the main
(296) accommodation. Moreover, at Canvey Island, Arup provided two long open-sided shelters to each side of the café directly off the promenade. While providing an important function, it seems clear that their primary purpose was visual, in that they counteracted the dominance of the strong circular feature in a similar manner to the porches at the Gorilla House. At roof level these porches provided open terraces as extensions to the café space.

A noteworthy feature is the use of cast iron columns as supports to the shelter roof and part of the café floor on the south elevation.

Economically it would have been more appropriate to use reinforced concrete, but Arup recognized that such columns would give this relatively small building a rather clumsy appearance. By substituting cast iron poles he gave this elevation a much lighter appearance. It is interesting that this use of cast iron columns reappears in Tecton's later work for small buildings or where it was thought desirable to conceal structural support altogether. (Might this feature have been originated by Arup?)[45]

Whilst Arup was generally pleased with the building, there were four particular points that displeased him.[46] First were the reinforced concrete columns to the rear of the building which emerged from the circular soffit as crude rectangular units. Bearing in mind their obscure position, it was for cost reasons that they were built in this way. Second was the glazing which again for economy had to be fabricated from standard window units. Third was the client's later decision to add two kiosks in the shelters thus disrupting his planning solution. And fourth, he had a rather paradoxical problem, namely control over the contractor for this scheme was not built by Christiani & Nielsen - but by D G Somerville. Arup was critical of the standard of the reinforced concrete work and was displeased when the contractor decided, against his wishes, to conceal their inaccuracies under a cement render.

Apart from these understandable disappointments there is little doubt that in the design of his first building, Arup revealed a well developed design ability and a sensitivity to the aesthetic problems of even the smallest details, not found, for instance, in the work of Owen Williams. As an example of early British modern architecture in reinforced concrete it ranks equally with the Gorilla House and other contemporary structures. However, unlike them, this building received only a minimal amount of publicity at the time and it is still virtually unknown.

In the light of its obscure position in the history of modern British architecture it is all the more surprising that the building should be
(298) illustrated in the contemporary Italian publication Gli Elementi Dell
(299) Architettura Funzionale by Alberto Sartoris.[47] Shand on reviewing this book for the Architectural Review made particular reference to the building's inclusion. In his commentary on Sartoris' chapter on Inghilterra he wrote:

'With two exceptions every British example is the work of a man of MARS . . . . These two show what Owen Williams put into the Daily Express and a decidedly interesting restaurant at Canvey Island which I for one had never seen before.'[48]

One possible reason for its lack of publicity in Britain was that the censorship imposed by the RIBA on the original competition may have had some influence within the editorial boards of the various journals. Another contributory reason, perhaps, was that the design was officially credited to Christiani and Nielsen and not Arup. Although the British architectural establishment was prepared to embrace the work of individual engineers such as Owen Williams, in many cases reluctantly, it would never accept that a contracting organization could produce buildings which came under the heading of 'architecture'. It is ironic therefore, that whilst many modernists regarded an important feature of modernism to be its anonymity the vast majority of modernist journalism was directed towards the promotion of buildings produced by individual designers to the exclusion of buildings produced by anonymous individuals within contracting organizations.[49]

Nevertheless his work at Canvey Island and London Zoo did mark the beginning of an important change in Arup's career. Through his involvement in them he decided to broaden the scope of his own engineering work to include more projects of an architectural nature, recognizing that modern architects were receptive to new structural ideas even though many did not understand them. His first step was to ask the directors of Christiani & Nielsen to develop a stronger interest in architectural work in general and form a close link with Lubetkin and Tecton in particular, arguing that developments in modern architecture would provide the firm with a potentially important and expanding market. The request was turned down because the directors believed that the profit margin in such work was too small for their organization.[50]

It is a tribute to Arup's commitment to a future in architecture that he should at this point seek out an alternative. His problem was to retain the integration of design and construction within contracting, for he believed that to move into a consultancy role would be a retrograde step.

An old Danish colleague, whom he had worked with at Christiani & Nielsen's in 1924, provided him with the ideal opportunity.[51] He was called Olaf Kier (in 1924 - Kjaer) and headed a relatively young contracting enterprise, similar but much smaller than Christiani & Nielsen, specializing in reinforced concrete. In return for the introduction Arup could provide to Lubetkin and Tecton, Kier offered him a directorship and a percentage of the gross profits obtained from each Tecton contract.[52] He would work on these projects in addition to design work on more conventional civil engineering contracts - silos, seawalls etc. Arup accepted the proposal and forwarded his resignation to Christiani & Nielsen on 30th December 1933, formally terminating his contract with them in April the following year.[53]

It is important to understand that the scope of Arup's work at Kier's during the 1930s was not exclusively related to his collaboration with Lubetkin and Tecton. During his four-year period as a director there he worked as an engineer and contractor to a number of architects, both 'traditional' and 'modern', and continued his work in civil engineering. Nevertheless there is little doubt that it was in his work with Lubetkin and Tecton that Arup was able to make the most significant contribution to modern architecture. For this reason the following discussion will concentrate principally on his work with this architectural practice and more specifically with those projects over which he had the most important influence.

. . . .

As an engineer interested in developing new techniques of reinforced concrete construction, Arup's most important contribution to modern architecture in Britain was made through encouraging his architects to make the forms of their buildings responsive to these techniques, and in providing the technical and contractural means to realize them.

One of the most important techniques of construction which Arup promoted during the 1930s and beyond, and the one which made the biggest impact on British modern architecture, was what he referred to as 'the slab technique'. In essence Arup's commitment to 'the slab', most simply described as a method of constructing buildings with slabs for walls and floors, was a reaction against the predominance of the 'frame' as the natural form of construction for reinforced concrete buildings. It would be reasonable to assert that, for the most part, the development of reinforced concrete in most countries since 1900 had been characterized by its use as a material for building frames. Most concrete specialist firms had developed the material in this way in order to provide customers with cheap and fireproof alternatives to steel frameworks, particularly for large industrial and commercial projects. Engineers like Owen Williams, who had been trained in these organizations, continued to use and develop the material in much the same way, interpreting the emergence of flat slab construction as the ultimate in its development - a framed system unique to concrete which clearly distinguished it from steelwork. Architects too had used concrete in the same way. Perret, for example established his reputation by exploiting the architectural possibilities of the concrete frame. Le Corbusier as well, although his domestic buildings appeared as concrete walled cubes, had argued that it was 'the frame' which liberated the plan, thus presenting the architect with the opportunity to revolutionize architectural form. Arup, however, maintained that the development of reinforced concrete as a mimicry of the steel framework did not do justice to the potential of the material. He argued that to regard reinforced concrete or steelwork as alternative solutions to the same structural framework problems was to misunderstand the essential economic and physical differences between the two materials. Weight for weight, he asserted, concrete was much cheaper than steel, and consequently its quality of mass should be used as a determinant of architectural form.[54]

It would be wrong to assume that Arup was developing a revolutionary approach to architectural design in reinforced concrete. On the contrary, it could be argued that his approach was reactionary, in as much as the development of the 'concrete wall' as a structural member was a technique the earliest pioneers had tried to perfect in the mid 19th century, with scores of patented shuttering systems granted long before the material was considered appropriate for frame construction.[55] Neither was the use of the 'slab' unique in its built form. Many British buildings had already been built with reinforced concrete walls and floors without frames (eg Dorchester Hotel 1931)[56], and Maillart on the continent had already conducted extensive research into the concrete slab as a structural entity in itself and had built many impressive bridges using the technique well before the 1930s. Arup is not dismayed by these well established precedents. He claims that he was simply unaware of them. All he was trying to do, he maintains, was to answer the simple question - 'What is the most sensible way of building structures in this material?'

There is little doubt that he found the answer to this question from his experience as a civil engineer with Christiani & Nielsen. The vast majority of his work there, in the design and construction of sea walls; concrete silos, etc, relied upon the use of the monolithic properties of the material, in situations where concrete frames would have been inappropriate. It is not surprising, therefore, that upon his introduction to the world of architecture, Arup should regard the extensive use of the concrete frame as rather peculiar. In this sense his experience was very different to structural engineers such as Williams and Faber who, in working as consultants to architects during the 1920s, had become conditioned to regard the frame as the natural technique of construction for architectural purposes.

What is particularly interesting about Arup's interpretation of the material is that it coincided with the stylistic effects that architects were trying to achieve at the same time. Generally speaking, however, architects were unable to detail their buildings in the way they conceived them - as flat concrete walled structures. On other than small domestic scale buildings, they were forced to resort to visual deception to achieve the imagery they required - either by using rendered brickwork or, more frequently, concrete framed structures clothed with 'structurally redundant' concrete walls.[57]

By developing and promoting the slab technique of wall and floor construction, Arup was able to provide his architects with structural solutions to their buildings with a degree of integrity which was in harmony with their 'rationalist' theories and the imagery of the 'white-box style'.

Arup's opportunity to bring his ideas on 'slab construction' to the forefront of architectural debate come in 1934, just at the time of his transfer to J L Kier's, when he worked alongside Lubetkin and Tecton on the design of two important buildings - the Penguin Pool at London Zoo and Highpoint I, a block of flats in Highgate, London. Both these buildings received extensive publicity in the architectural and national press, and both are now regarded as two of Britain's most outstanding contributions to the international Modern Movement.

[46] Although designed at the same time (1934) the Penguin Pool was the first to reach the attention of the architectural world.[58] Much has been written about this small structure, but from Arup's point of view it provided a physical statement on the enormous architectural potential of the 'concrete slab' as an entity in itself. The centrepiece of this elliptical shaped pool, itself built from insitu concrete walls with its upper canopy and ring beam supported on cast iron poles (as at Canvey Island), was the sculptural form of two

(307) interlocking concrete spiral ramps. These curved ramps were cast integrally with the upper terraces and the pool's base, without any form of intermediate support. (46 ft in length and designed to carry an evenly distributed load of 20 lbs per sq ft, their section was tapered from 6 in inside to 3 in outside to even out the stress distribution.) It is difficult to confirm which member of Tecton was responsible for the idea. Samuel asserts that Drake was probably the one who produced the first sketch, whilst Lubetkin insists that it was his own idea and claims that it was he who suggested tapering the section through the ramps to even out the stress distribution. Arup's role, so Lubetkin maintains, was to do the necessary calculations and decide upon the dispositions of the reinforcing bars.[59] Arup is not too concerned by these wild claims, asserting that he quickly learnt 'to expect this kind of thing from architects'.[60] His own version is that the idea emerged from discussions he had had with members of Tecton on the potential of the concrete slab. As to the engineering details he is uncompromising in his belief that Lubetkin was inexperienced in reinforced concrete design[61] and there was no question of any member of the group advising him on a suitable section. What is incontrovertible is that the highly complexed calculations
(301) required were undertaken by Arup's employee - Felix Samuely - a structural engineer who had recently emigrated from Germany and found a position within Arup's department at Kier's.[62]

The publicity given to the project allowed some commentators the opportunity of asserting that the continental brand of modernism had been imported into Britain. Here was a structure designed by individuals of continental origins with curved elegant concrete slabs which bore a close resemblance to the work of Maillart in Switzerland and France. This connection is understandable, but Arup himself maintains that to relate his work to that of Maillart cannot be substantiated. As an engineer who worked in British engineering for ten years, he had no knowledge of Maillart or his work, and it was not until much later in the 1930s that he became aware of this Swiss engineer when architects 'began to make him famous'.[63]

From Arup's point of view the most important feature of the Penguin Pool was its revelation to architects in Britain of the great potential of the concrete slab as an important structural element in modern architectural design. However he still needed an opportunity to prove how this type of concrete construction could be applied to more conventional building types.

[47] An opportunity was presented to him in the design of Highpoint I.[64] Like the Penguin Pool this project was one of the most successful to emerge from the Tecton group and it formed an important element of
(317) Kier's advertisements for the remainder of the 1930s. There is little doubt that much of its success was attributable to the integration of Arup's and Lubetkin's engineering and architectural design skills in producing a building which has often been referred to as the most perfect example of what early British modern architects were aiming at in their own work - ie an architecture whose form and structure were indivisible. As Furneaux Jordon noted succinctly in his article on Lubetkin (1955):

'This building mattered because it proclaimed that their (ie young modernists) modernism really was a structural revolution, not just a style.'[65]

Whilst a cursory assessment of the building supports this claim, a more detailed analysis of the structure reveals that its presentation of a perfect harmony between the aesthetic and technical considera-tion was deceptive.

The building was commissioned by Gestetner to provide apartment accommodation for middle-class tenants on the brow of Highgate Hill, London. In planning terms, it was separated into two distinct vertical zones - a public zone with servant accommodation at ground floor level, with the flats themselves occupying seven upper stories. There were two types of flats - one two-bedroomed with combined living and dining rooms, the other three-bedroomed with separate living and dining rooms. Each upper floor contained four of each type, arranged in the shape of a cross of Lorraine, a plan-form necessary to achieve the agreed density of occupation with maximum privacy, and a minimum of party wall separation (there was only one party wall on each floor of the building). At the intersection of the crosses were located the services, lifts and staircases. An ingenious device used by Lubetkin to ensure a maximum amount of privacy to the entrance areas of each flat was his adoption of a split-level planning
(308) solution, using the half landings of the staircase as the levels of different floors to each side.

Possibly the best example of Lubetkin's refined planning abilities is to be found at ground floor level. Here the main axis of the building, determined by the most sensible disposition of the upper storey flats, was at right angles to the road approach. To bring people into the building on this axis would have given undue significance to the staircase and lift shaft nearest the road. To overcome this, Lubetkin provided a separate entrance foyer, positioned centrally on the front elevation, which was extended to one side into a widening corridor
(308) terminated at the centre of the building in a circular seating area. This had the effect of directing users of the building along its main axis, with a blank wall towards the building, then turning them through 90°, up three long steps to a central position equidistant

from each lift shaft.

This superb planning solution was necessary to accommodate the different planning priorities of the public areas at ground floor level and the private apartments above. Although successful in reconciling these planning differences, Lubetkin was not able to cater for the differences they created structurally. As with any building of this type - hotel buildings are the most representative - the overriding structural problem is to be found in supporting a large amount of small-span cellular structures on top of larger-spanning public spaces.

Arup recalls that Lubetkin's first tentative sketch proposal for the structure was disastrous.[66] Instead of regarding the two elements of the structure as essentially different, Lubetkin imposed on his upper storeys a reinforced concrete frame layout appropriate to the ground
(309) floor accommodation. Not only did this impair the quality of the living spaces, but externally it required the use of 'structurally redundant' concrete walling between the columns to achieve the visual effect he required. Furthermore, had it been built in this way, cracking of the concrete would have been inevitable.

This presented Arup with his opportunity to bring his ideas on slab construction to the fore. He suggested the removal of Lubetkin's frame arrangement above ground floor level and in its place recommended that the floors and roof be supported on the internal and external walls, all cast integrally so that the structure would be completely monolithic. Lubetkin and other members of Tecton are reported to have been delighted with this suggestion, and they replanned the living accommodation accordingly.

To ensure that this form of construction would not add extra expense,
Arup began work on devising an efficient constructional system. He
first thought of a form of sliding shuttering that would remove the
need for scaffolding, an expensive and time consuming part of any
building contract. He had already had direct experience of using
this form of construction in the building of concrete silos and his
(83) firm was at that time building some similar structures for Oscar
[15] Faber at the Spillers Flour Mill building, Avonmouth.[67]

However whilst the principle of sliding shuttering was well estab-
lished, Arup broke new ground in adapting the system for architectural
purposes - that is in making provision for the similutaneous casting
of floor slabs and openings for windows and doors within the walls.
(312) He achieved this by stepping the internal and external shutters of the
external walls. For the inner shuttering of the external walls he
used 1 in thick cork slabs, to be left in place as the shutters rose
to provide thermal insulation. The shutters were jacked up on
columns positioned at the corners of the building.[68]

The constructional system was very effective and excited as much interest in the press as the completed building itself. It must be noted however that had Arup not been contractor, the building in all probability would not have been built in this way. As a contractor he had the confidence of knowing what could be achieved. Had the shuttering technique been the subject of a more traditional designer-contractor relationship, it is certain that its novelty would have forced contractors to return high tenders as a cautionary measure. By controlling the pricing of the contract, Arup was able to confirm at the outset a realistic price based upon his own assessment of the technique. Lubetkin, incidentally, was not prepared to see the client make an enormous saving on the initial cost plan. In return for extracting a keen price from Kier's, so he has argued,[69] he persuaded Gestetner to provide some flats at subsidized rents for working class tenants - a token gesture towards his social commitment. Furthermore he used some of the savings to include non-standard architectural fittings which would be more in keeping with the character of the building. This allowed Lubetkin to argue later that the impact of modern technology should not be seen as the prime cause of the new architecture. Its value was that it allowed the architect to provide better amenities at lower cost.

The deceptiveness of the integration of form and structure, referred
(314) to earlier, can be seen from a study of the engineering drawings.[70]
Arup's aim in advising Lubetkin to adopt a 'slab' solution in preference to a frame, at the outset, was to simplify the construction process, reduce costs and produce a more satisfactory structural solution. If one examines his drawings, however, it becomes clear that Arup's concept of a simple concrete wall and floor slab structure was complicated by the fenestration and planning arrangement imposed on him by Lubetkin.

Arup's structural plans show an absolute minimum of supporting
(310) internal walls - the structure being reduced to a number of wide and
(314) narrow columns. Externally the length of loadbearing walls was
severely restricted by Lubetkin's desire to include long horizontal window openings. These openings also included doors which fed rather meaningless balconies. These door openings meant that the only structural connection between the two narrow strips of wall to each side was the floor itself which consequently had to be heavily reinforced. As a result of the stylistic effect Lubetkin wished to

achieve, Arup's concrete provided a visual veneer to a highly complex arrangement of reinforcement.

While Arup agrees that the visual effect is good, the contorted structure he was forced to produce, at extra cost, offended his purist engineering instincts. Recently he has written:

'I didn't like this kind of contorted structure. The architects didn't mind. They got what they wanted, it couldn't be seen, it wasn't their money.'

'Simplicity is what I have always strived for. A tortuous structure is not an architectural asset - it is a flaw in the total architecture.'[71]

It is clear, therefore, that whilst Highpoint I was proclaimed as a symbol of unity between the aesthetic and technical aspects of architectural design and of an harmonious architect/engineer relationship the reality was very different. Not only was the simplicity of its overall form deceptive, but in achieving Lubetkin's stylistic requirements Arup was forced to renage on his commitment to simplicity. However from Arup's recent disclosures it is evident that apart from the conflict between himself and Lubetkin in their collaboration at Highpoint, there was also a degree of conflict in Arup's own mind. For whilst he was critical of the building's 'tortuous structure' he admitted that Lubetkin's 'architectural gimmicks' were important to the visual success of the scheme.[72] (Although visually less impressive, on economic grounds Arup argued that the best solution would have been to start the sliding shuttering at ground floor level, reduce the size of window openings and remove architectural gimmicks, such as the curved concrete balconies, which at Highpoint were justified as fire escapes but added extra stresses at critical points on the structure.)

His own work at Canvey Island must have presented him with similar conflicts, for many features of this small scheme reveal that in a number of instances Arup disregarded his engineering instincts in order to produce visually acceptable solutions. These experiences made Arup sympathetic to the 'aesthetic' aspects of architectural design, and highly critical of the functionalist theories propounded by his colleagues in the MARS group. Nevertheless this did not mean that he considered the objectives of the Modern Movement to be futile. On the contrary he fully supported, and still does, what he regarded as the central theme of the movement; namely that architects needed to face the facts of modern industrial society and produce architecture based on a sound understanding of the technologies they wished to use. He believed that in his own sphere of structural engineering, through hard work, education and closer collaboration with architects the buildings they produced would eventually reach this ideal. Needless to say, he did not regard Highpoint I as coming close to this objective.

One can see Arup's attempts to achieve this aim in subsequent work by improving his reinforced concrete 'slab' system of building and in persuading his architects to make their buildings visually more responsive to its requirements. Many projects in which these efforts were apparent were never built. The two which followed hard on the heels of Highpoint were schemes he submitted to the Working Mens Flats competition of 1935 promoted by the Cement Marketing Company;
[48] one in collaboration with Tecton (awarded First Prize), and the other
[49] with Eugin Kaufman (commended). Whilst in both schemes one can recognize important changes in Arup's structural design and its relationship to the architecture, there were two features of the competition which forced the architects to consider more closely the technical issues of their designs. First was the cost constraints

imposed upon the entries.[73] The prime objective of the competition was to prove that reinforced concrete flat dwellings could be built to costs appropriate for working class tenancy. (In this respect the competition was well timed to coincide with the Government Committee set up to investigate Working Class housing with specific reference to new building materials.)[74] By imposing severe cost restraints it was perhaps inevitable that the resulting architecture would approximate more closely to the simplest engineering solution. Second was the fact that the competition was to be assessed from a technical, as well as visual, aspect, and for this reason it was open to entries from architects and engineers with joint entries recommended to encourage 'closer collaboration between the two professions'.[75] It was therefore clear from the outset that the assessors would be looking specifically for a close correlation between the aesthetic and technical aspects of the entries, a feature which helped Arup persuade Tecton and Kaufman to achieve integration between the form and structure of their architectural solutions.

[48] The scheme which best illustrates these changes was the Tecton-Arup scheme. As it was designed so soon after Highpoint I, it is not surprising that many of its features reappeared in their entry. Principally these were; the raising of the four separate five storey blocks on piloti, (this was not as important as at Highpoint because here there was no requirement for large public spaces, but it was justified by the provision of smaller two bedroomed flat units for older inhabitants at ground level) and the use of structural concrete walls for the external envelope to be built using Arup's slip form construction technique.[76]

However there were many important differences. Externally the most

noticeable were in the simplicity of the form and in the fenestration. Whereas Highpoint adopted a complex plan form to provide maximum privacy, the competition entry consisted of four simple rectangular blocks which could be built at much lower costs. Furthermore in the fenestration Arup persuaded Tecton to limit the size of window openings in order to maximize the area of wall surface for structural purposes. This is most evident on the east elevations where the bedroom windows consisted of simple square openings in the facades.
(318) On the west elevations, as at Highpoint, balconies were provided but the doors onto them were located at right angles to the elevation thus allowing a greater continuity of structure.

However the most important difference was in Arup's rationalization of the structural arrangement. Whereas at Highpoint I he was forced to compromise on his concept of a concrete walled structure internally, for the competition entry he dispenses with internal walls for structural purposes, using instead a row of columns with shallow downstand beams running down the length of each block. His experience at Highpoint had proved that to use concrete walls internally imposed too many constraints on the plan arrangement, which had only been resolved by incurring excessive costs and conflicts within the building design team. To avoid repeating these problems,he designed the
(319) structure to each block with 3 parallel lines of support - the two outer walls with the inner line of support positioned in accordance with the architects' plan - generally just off-centre dividing the living accommodation from the bedroom areas. In this way the shallow downstand beam between the columns would not interrupt the soffit of the rooms to each side. The floor slabs were to span in only one direction - across the width of each block which meant that columns could be positioned almost anywhere along each longitudinal line of

support and could therefore be located so as to be concealed either in built-in cupboards or as part of the division walls. In articles Arup published later, he referred to this system of 'parallel support' claiming that it provided the ideal structural solution to flat dwellings. Comparing it with conventional framed two-way spanning solutions he outlined its principal advantage to be the greater freedom it provided architects in the internal planning. Moreover by using the external walls for structural purposes it had cost advantages in removing the need for structural frames. Nevertheless he emphasized that in adopting this structural system, close collaboration between the architect and engineer was essential to achieve 'a natural unity between the structure and the plan'.[77]
(318) Reference to the plan indicates how effectively this unity was achieved.

[49] The scheme Arup prepared with Kaufman for the same competition was similar to Tecton's entry in as much as it used Arup's external walls, cast in sliding shuttering, with a one way spanning slab for the structural arrangement. However Kaufman planned his block without internal structural support, relying entirely on the external walls.[78] This meant that the width of each block was restricted to an economic floor span of approximately 15 ft which led him to adopt a maisonette form for each unit. The main disadvantage of this entry over Tecton's was the cost, created by the disproportionate ratio of external wall area to volume.

Shortly after this competition Arup was able to apply his 'parallel support system' to two further schemes. One in collaboration with a colleague from the MARS group - Pilichowski, the other with the traditionalist architect Griffiths.

[50] The Pilichowski building was built at Golders Green, London, providing
15 flats for middle class occupancy.[79] It was arranged as an 'L'
shaped block, three storeys in height with an overall width of 30 ft,
(322) split into 2 spans of 15 ft by a centrally located beam. The
external envelope was different from Arup's earlier work with Tecton
in that Pilichowski emphasized the framework of wide columns and deep
spandrel beams by giving each member a different surface treatment.
Even though in essence the structure was similar to Highpoint I this
elevational treatment made the building appear more like a conventional framed structure. When one examines the interior of the building it becomes clear that Pilichowski had assumed from the outset a normal concrete framed structure with two way spanning slabs, because the planning was organized around a regular grid of column positions. Whilst this neither impairs the quality of the building nor the relevance of Arup's 'parallel support' structure it does suggest that the integration of architectural and engineering design skills was not as effective as in Arup's earlier work with Tecton.

It is ironic that the architect who appears to have made the most of
the flexibility that Arup's 'parallel support' structure provided was
the traditionalist architect E D Griffiths in his unbuilt design for
[51] a block of flats at Brixton.[80] This building was six storeys in
height and like the previous scheme adopted an 'L' shaped plan-form.
The structural problem was to accommodate the different floor plans
that Griffiths had created at alternate levels through his use of
maisonette units with living accommodation at one level and bedroom
(325) areas above. Access to the living areas was via long corridors which
ran down the back of the flats within the external envelope. The
bedroom floors were divided down the length of the building with a
division wall providing rooms which looked out in both directions. A

cross section through the building clearly illustrates the structural problem. The bedroom floors were well arranged for Arup's parallel support system, whereas the lounge floors required either single span floors or a series of frames/walls running at right angles to the external walls. Arup's solution was to adopt a row of centrally placed columns and downstand beam along the main division wall of the bedroom floors, locating the columns at positions appropriate for
(326) cross frames on the lounge floors below. Unlike his schemes with consciously-modern architects, the external load-bearing walls were to be faced with a veneer of brickwork.

. . . .

The common characteristic of the above schemes, with the exception of the Griffiths building, is that the structure of each building formed the basis of the elevational treatment, usually using Arup's concrete walls without any attempt to conceal them. In producing buildings in this way the designers were attempting to implement what they perceived as an important objective of modern architecture - that is, to design buildings whose structure and architectural form were combined in a natural unity. Arup, for his part, had accepted this objective and had devised and improved his reinforced concrete slab system to accommodate it. However from 1936 onwards, none of the schemes which Arup designed with Tecton used the structure as the principal feature of the architectural expression. On the contrary, in each successive scheme one can detect an increasing distancing from this earlier feature, until ultimately in 1939, it is possible to analyse the buildings they produced in two separate parts - the structure and the elevations.

There are many articles and lectures by Arup which show that he regarded this move away from 'functionalism' or 'structural honesty'[81] as an important step forward. Unfortunately many of them post-date the buildings whose elevations reveal this change. It is therefore difficult to determine if Arup was instrumental in persuading his architects to change course, or if it was the architects who changed their own views, obliging Arup to be responsive. Arup himself cannot remember events in sufficient detail to shed more light on this important question. However he does recall that his reading of Geoffery Scott's book The Architecture of Humanism at about this time, made a deep impression on him, confirming what experience of working with architects had already taught him - that is the fallacy of the functionalism.[82]

The two earliest buildings which are indicative of this change were
[52] the 'Finsbury Health Centre' and 'Highpoint II'. It is the wing blocks to the Health Centre where the move towards the separation of structure from elevational effect can be seen at its best.[83] To allow flexibility for the arrangement of internal partitions in these wings, Arup produced a concrete frame structure consisting of closely
(333) spaced columns and deep spandrel beams for each external wall. The floors and roof spanned across the width of the building onto these external walls without any intermediate support. (The external wall structure was similar to that used for the Golders Green Flats with Polichowski.) However instead of exposing this concrete frame arrangement directly on the elevations, Lubetkin designed screens of teak framing, glazing and infill panels which were positioned on top
(334) of the concrete structure. Although the arrangement of the teak framework was related to the structural grid, the use of a separate form of construction for the elevations did mark an important change

in the design direction of the firm.

This was repeated and extended in the more controversial scheme of
[53] Highpoint II - a block of flats positioned only 6 ft away from Highpoint I.[84] To many observers who regarded the functionalism of Highpoint I to have been a triumph for British modernism, Highpoint II was seen as a betrayal. At the heart of their criticisms was the formalist approach to the design which its elevations exhibited. Whereas the elevations of Highpoint I appeared to have emerged naturally from a functionalist approach to the design of plan and structure, no such messages could be read into the facades of Highpoint II. Not only were its concrete surfaces clothed in ceramic tiling, but the central portion of the building displayed a wilful
(338) pattern of brickwork, glazing and concrete columns arranged without any specific reference to the structure or the plan form. Perhaps the most telling feature of the scheme which emphasized that these changes were not simple inconsistencies in Tecton's work were the two
(341) caryatids used to support the concrete canopy on the main facade. Many of Tecton's supporters suggested reasons for this change, amongst them being Tecton's supposed need to appease the local authority which had not wanted to see a repeat of Highpoint I. Lubetkin, however, was not defensive about the scheme even though the local authority did prove difficult. He argued that the formality of the design was a common feature of all his schemes - it was simply more developed in this latest building. He did not, however, agree that formality and formalism were the same. In his respective definitions he wrote:

'<u>Formality</u> is the concern that what has to be stated is conveyed in a clear, orderly, organized way leaving no room for ambiguity or misrepresentation.

<u>Formalism</u> is the reduction of the meaning of art to the sum of directly perceived visual qualities without any mental reference and without reference to systematic thought. Yes I believe in <u>Formality</u>

in the discipline of self imposed restraints, in wilful limitations expressed in orderly geometrical ratios.'[85]

However for all Lubetkin's theorizing and the critical comments of contemporary critics there exists a very important difference between the two buildings in the relationship between their elevations and their respective structures, a difference which although readily apparent has never been examined in close detail.

The overall plan form of Highpoint II was of a simple rectangular block. To avoid overlooking there was no possibility that the build-
(337) ing could be a repeat of Highpoint I, which meant that only the top portion of the site be used.[86] Consequently the area of building space was much smaller than at Highpoint I and so only luxurious apartments at high rentals would make the scheme fincancially feasible. Lubetkin decided on a maisonette system with each unit comprising two levels with its own staircase. He provided two types
(340) of units, the more luxurious occupying the central part of the building (each with double height living rooms), with cheaper units to each side. (Horizontally each double floor contained 4 units - the two luxurious ones in the centre with cheaper ones to either side with 12 units in total and 6 storeys in height.) A staircase and lift shaft were provided to either side of the two central units each
(339) serving two maisonettes at three levels. Ground floor level consisted of a ramped entrance foyer, servants' accommodation and garaging.

Arup produced very different structural arrangements for the two types of dwellings, which in turn produced equally different forms of architecture. The elevations of the flanking blocks, containing the cheaper units, used the external walls of the building as the main structural elements supporting the floors and roof - as at Highpoint I. This produced a close relationship between the structure

and the architecture even though its surfaces were covered in ceramic tiling - a device though necessary to prevent the high maintenance costs of repainting, already apparent at Highpoint I. It was the central portion of the building where the most important changes took place. Here Arup dispensed with the longitudinal lines
(344) of support, using instead a series of concrete cross frames with the floors spanning across the frames parallel to the external walls. Although this was in part necessitated by Lubetkin's wish to include double height living rooms, it initiated an important change in Arup's approach to structural design. By relieving the walls of structural function he discovered that he could give the architect a maximum amount of freedom in designing the elevations and avoid many of the conflicts that had been created between architect and engineer in their attempts to reconcile the technical and aesthetic aspects of elevational design, (as at Highpoint I for example).

Shortly after the completion of this building and during the course of the controversy it provoked in the architectural press, an interview with Arup was published in Building.[87] This interview, while containing no specific references to the building, provides useful quotations from Arup which indicate that he regarded the relationship between the structure and architecture of Highpoint II to be closer to 'modernism' than his earlier buildings with Tecton. The interviewer was Myerscough-Walker, who undoubtedly had Highpoint II in mind when he repeated the functionalist rhetoric of the modernists in claiming that modern architecture should be based on the functional qualities of the new structural materials of steel and reinforced concrete. Why, he asked, did modern buildings use these materials but not take advantage of the possibilities they presented for revolutionising architectural form? In older forms of architecture, he maintained, there was always a natural harmonious relationship between the appearance of a building and its structure. He cited the Penguin Pool as a modern example which came closest to his ideal of 'pure design' but expressed surprise that this was not emulated by designers in more conventional building types:

'There must be some way of expressing clearly the form of the structure . . . . Expression of purpose both in function and structure is supposed to be an ideal in Architecture, and we seem, somewhere, to have lost this ideal.'[88]

Arup's reply was unambiguous:

'Why should the form of the structure be clearly expressed - is that not an artificial demand?'[89]

To illustrate his point Arup isolated 'the external wall' as one of the most important components of building and listed five functions it had to fulfil - (1) it should be strong enough to support things resting on it; (2) it should be weatherproof; (3) it should provide thermal insulation; (4) it should provide sound insulation; (5) it should possess a satisfactory appearance. He explained that before the advent of new structural materials (steel and reinforced concrete) one material such as masonry catered for all these requirements. However it was never very efficient. Often the need for weather-proofing meant that a wall was much stronger than what was needed; or to build higher it had to be much thicker than was absolutely necessary for weatherproofing purposes. Arup's very simple point was that in modern construction there was a trend towards specialization, using separate materials for each function of the wall, the principle being to make the wall only as strong as was needed to be safe and then add other materials for the other functions. In this way buildings could be produced at lower costs. Steel construction provided the best example. It was a very expensive material without 'body', only economically feasible for providing the structural framework of a building. It could therefore only satisfy that one function. Reinforced concrete was different in that it was cheaper and did possess body and could therefore be used 'to enclose space'. However, Arup maintained that it did not fulfil the other functions of a wall without the addition of other materials. In a later article he was more direct:

'Unless the use of concrete is justified for structural reasons it is not the best material for external walls.'[90]

He therefore concluded that it was not surprising that modern architecture did not rely exclusively on the structure for its formal expression - the structure was only one function of the building.

In this interview, therefore, Arup provides information which makes sense of his work with Lubetkin on Highpoint II. The flanking blocks of the building clearly reveal that they had decided that concrete was not suitable as a facing material for buildings, whilst the central part of the elevation clearly expresses the move towards specialization which Arup had come to regard as the most important feature of modern architectural construction. Their early experiences in building in reinforced concrete had proved that their attempts to integrate the conflicting functions in building design in one material was in direct conflict with this modern characteristic of 'specialization'. Apart from producing buildings with unsatisfactory wall surfaces, these attempts at integration created unnecessary complex constructional problems which, in addition to being uneconomic, produced unhelpful conflicts in the building design team. In effect, in their earlier work Arup and Lubetkin had failed to distinguish their commitment to the integration of engineering and architectural design skills, from the integration of conflicting functional requirements of the constructional problem.

This realization had only been acquired through direct experience in designing and building structures of similar types. To those who had not gone through this learning process this realization was not apparent and it was for this reason that Highpoint II provoked the controversy it did. By its authors' acknowledgement that the most rational approach to design was in separating the structure from the elevational effect, it suggested that stylism in architecture was just as important in modern buildings as in more traditional ones. To many British modernists this was unacceptable. However in their failure to appreciate that the structures of many of the buildings they admired had been contorted to produce particular stylistic effects, they exposed the subjectivity of their preconceptions.

Arup believed that it was necessary for architects to face up to this reality. In his later work he enlarged upon his experiences at Highpoint II developing new forms of reinforced concrete slab structures which provided architects with a maximum amount of freedom to design their elevations in any way they chose.

The system he began to use and promote was called 'Box-Frame Construction' (other names include - 'Cross-Wall' or 'Egg Crate' Construction). This was a method of forming the structure to a cellular-type building as a simple framework of horizontal and vertical cross slabs - the horizontal members being the floors; the vertical ones being the cross walls. In essence the technique was very similar to Arup's earlier work in slab construction. The principal difference was in the walls. Previously he had used the external walls as the main vertical supports, arguing that cross-walls would impose too great a restriction on the architectural planning. However, experience had taught him that for most buildings of this type, (ie cellular structures), a regular pattern of cross-walls developed naturally out of the planning. In architectural terms therefore, he began to argue, it was preferable to give the architect greater freedom in designing the elevations whilst sacrificing some planning flexibility. Furthermore conflicts between the aesthetic and technical aspects of the building design problem could be minimized. There were two other advantages which the system had over his earlier structures which had used concrete external walls and longitudinal beams. From a technical point of view, he argued, the system only used reinforced concrete where its properties were of most value and avoided using the material where it had disadvantages. In very simple terms, he claimed that by restricting the use of reinforced concrete to internal walls and floors he could fully utilize the three positive attributes of reinforced concrete, namely its strength; its quality of 'body' for enclosing space (not used in the central part of Highpoint II); and its weight for sound insulation. Its negative qualities of unsatisfactory appearance, poor weathering performance in British climate and bad thermal insulation, were completely avoided. It was also very simple and economical to build. Complexities such as downstand beams and 'architectural gimmicks' normally associated with the elevations were completely avoided. As a contractor, Arup found this simplicity particularly appealing.

It would be wrong to claim that Arup pioneered the development of this system of building in Britain. The natural association of his name with the technique is based more upon the extensive publicity he gave to it in numerous articles published throughout the Second World War and afterwards. Like Turner's promotion of flat slab construction during the first decade of the century, Arup did not develop or invent the technique himself, but took an existing system and then

modified and promoted its use. Indeed, when Arup first used the technique for two housing schemes he designed with Tecton during 1938 (completed after the war) it had already been successfully used and publicized in at least three earlier British buildings. Two of these schemes had been built in 1935 to designs by Burnet, Tait and Lorne in collaboration with the structural engineer Bethune-Williams, while Owen Williams had used an adaptation of the technique in his design of
[37] an office block at Salisbury Square.

What was different about Arup and Lubetkin's use of the system was the successful elevational treatment that Lubetkin applied to the simple box framework. In Burnet, Tait and Lorne's buildings the entire structure was simply covered on each elevation in a 9 in skin of brickwork, pierced at regular intervals with simple square openings. Thus whilst the engineering fraternity was fully informed about the structural attributes of the design through the technical press,[91] its rather dull appearance failed to attract any informed comment in architectural publications.

The two schemes that Tecton and Arup designed before the war using this technique were high rise housing developments for Finsbury Borough Council located at Roseberry Avenue and Busaco Street. (Sometimes referred to as the Spa Green and Priory Green Estates). The design of both schemes began shortly after construction work on the Finsbury Health Centre had started. Unfortunately because of the war the buildings were not completed until 1946 and 1951 respectively to amended designs.[92] Nevertheless for both the pre-war and post-war designs of both schemes one can detect a marked difference in the elevational treatment with Tecton and Arup's earlier work, a difference directly related to the box frame technique of construction used.

[54] The Roseberry Avenue scheme in its completed form consisted of three separate blocks of flats - two identical to each other being rectangular in form and eight storeys high, the third curved in outline and five storeys in height (known as the serpentine block).[93] The rectangular blocks best illustrates the important stylistic changes
(347) that had taken place, particularly as the planning of the two blocks
(318) was a replica of Tecton's entry to the Working Mens Flat competition of 1935. As with this earlier scheme, each block was raised on piloti at ground floor level with the reduced area used for smaller flat units, reception areas and pram stores. Above ground floor level the similarities are marked with the flat units occupying the entire width of the block and each served by a staircase and lift shaft providing access to two units at each floor level (the lift shafts seem to be the only important addition). Even the room layout of the flats themselves was a direct copy of the Competition entry with the bedrooms located along one elevation, living areas, bathrooms and kitchen on the other and recessed balconies positioned in front of two adjacent groups of bathrooms and kitchens. The structure, however, was radically different using Arup's box frame technique of construc-
(351) tion. The blocks were each divided into four vertical zones of structure separated by three vertical shafts containing the staircases and lift shafts. These shafts were structurally isolated from the flats to either side providing expansion joints and a reduction in sound transmission between the public areas and private quarters. It was the cross walls between the separate rooms in each flat unit that provided the main vertical supports for the floors and roof instead of the external walls and longitudinal beam with columns for the earlier scheme. It is interesting that Arup was able to apply the box frame system of construction to a plan form that had

apparently been developed in connection with an entirely different structural concept. Clearly the new system was not as inflexible as Arup had previously assumed. However as far as the elevations were concerned it provided distinct advantages. Whereas the elevations to the Competition entry were forced to respond to the structural requirements of the reinforced concrete external walls, at Roseberry Avenue Lubetkin was free to add almost any type of elevational treatment he chose. He exercized this stylistic freedom to the full. For the bedroom facades to the two blocks, for some reason both facing
(348) into the centre of the site, he applied a simple veneer of cavity brickwork pierced with a regular series of square openings and surrounded by a band of concrete to provide a visual frame to his composition. On the other principal facades Lubetkin used an entirely different treatment splitting his composition into seven alternating vertical strips relating to the living room walls and balconies. The four strips of living room walls were faced with brickwork in a similar manner to the bedroom facade. It was in the three intermediate strips, containing the double recessed balconies, where the main visual interest in the elevations was created. For these, Lubetkin designed each balustrade with two different materials - concrete walls and metal railings. For each alternate balcony he reversed the positions of concrete wall and railings thus creating a chequerboard effect.

In the serpentine five storey block, Lubetkin repeated the chequerboard theme but with an important difference. Instead of merely staggering the arrangement of solid to void in the balustrading to the balconies, which could only be construed as simple and rather crude
(349) pattern making, he staggered the arrangement of alternate floor plans positioning bedroom areas with balconies over living rooms on each

level. He achieved this whilst retaining the vertical lines of the cross walls producing larger living room areas by increasing their depth rather than width. Unlike the eight storey rectangular blocks, the Serpentine block contained only one staircase feeding access balconies provided along the east elevation.

The use of long balconies for access purposes and the staggering of
[55] floor plans was reused in the six blocks of flats at Busaco Street, completed in 1952, where financial constraints forced Lubetkin to depart from his earlier concept of individual access to flat units from a number of staircases or lifts.[94] It would be wrong to suggest that the completed post-war scheme was similar to the design produced
(355) before the war. However the later scheme is noteworthy for it confirms that the development in Lubetkin's and Arup's work follows a consistent pattern. The scheme consisted of six blocks of flats - two very large ones each eight storeys high and made up of three separate units stepped in plan, and four smaller four storey rectangular blocks. As with the Roseberry Avenue scheme, the site planning does not seem to respond in any rational way to the orientation. For example each of the three units in the large storey blocks faced in different directions - east or west - with the smaller blocks facing south. Thus the site arrangement seems to have been dictated by Lubetkin considering visual effect to be more important than environmental factors. This is particularly interesting because in the Working Mens Flats Competition of 1935 Lubetkin had argued that in flat buildings of this type it was preferable, wherever possible, to keep the bedrooms facing east with the living areas and balconies occupying the west facade. Thus at Busaco Street one notices an important departure from Lubetkin's previous concerns, suggesting that he was becoming more and more preoccupied with the external appearance

of his building at the expense of other important functions. This feature can also be noted in the elevations themselves which like the Roseberry Avenue schemes adopted the chequerboard theme, achieved by staggering the arrangement of alternate floor plans. The four storey block displays this effect at its most brutal, with the pattern rigidly defined by the exposure of Arup's box frame construction, and
(360) given added significance by the use of different building materials. (The concrete surfaces were covered with cream ceramic tiling; living room walls - brick panels built up with straight vertical joints to
(358) emphasize their non-loadbearing function; and the balconies a lattice work of cast iron.)

Arup, personally, was very pleased with these projects, primarily because they responded to what he then regarded to be a vital ingredient of modern architectural construction, that is the specialization of functions which necessitated a degree of separation between the engineering and the stylistic effect. He was surprised, however, that Lubetkin still maintained that he was producing rationalist architecture. Arup recalls visiting Lubetkin's studio on a number of occasions during the course of their design work on these projects and notes the numerous alternative elevational solutions Lubetkin had produced for application to the same structural framework.[95] While Arup regarded this exercise in pattern-making to be perfectly valid, he found it difficult to believe that Lubetkin could still argue that he was producing rational architectural solutions.[96]

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The key to an understanding of Arup's work in the 1930s is a recognition that he operated first and foremost as a contractor. (This fact is often forgotten in the light of his post 1945 consultancy work). His engineering abilities within contracting, particularly in the field of reinforced concrete, were of course of great importance, but it is evident that his primary concern was always to improve the mode of production of reinforced concrete structures. In this way his role was different from that of other famous engineers of the period such as Maillart, Freyssinet or Nervi who either pioneered a particular branch of reinforced concrete technology (eg prestressed concrete) or produced outstanding structural feats in the material. Arup adopted neither of these approaches. His position as an engineer within a pragmatic contracting organization always led him to determine and execute the most sensible means of erecting reinforced concrete structures for architectural purposes.

What was unique about Arup's work in Britain at this time was his commitment to integrating this concern for the 'building process' into the design programme itself, by uniting the disciplines of contractor and designer. This was very different to the established tradition within the British building industry which generally imposed a rigid contractual separation between the professional designer and builder. Arup's achievement was to overturn this tradition in a large proportion of his own work at Kier's by developing a working strategy with a small number of architects, which allowed him both as engineer and contractor an important input into the design process of many buildings almost from the day of inception.

At the outset of his involvement with architecture in the early 1930s Arup, somewhat naively, thought that this objective was in harmony with the architectural theories propounded by modernist architects in Britain. They too had argued for a radical change in the design process and had claimed that modern buildings should be determined by the rational application of modern structural technologies and their modes of production. While many such architects agreed with Arup, for the most part they only paid lip service to his ideas preferring to conduct their own professional affairs along traditional lines, which usually amounted to producing stylistically modern designs and then passing them over to their engineers and contractors for execution. This was a disappointment to Arup for he still argues that in operating in this way modernist architects failed to grasp what the central theme of the Modern Movement should have been. Recently he has written:

'they did not think it necessary to learn how to build differently, for them designing and building were two different domains. They are not. A design should show how to build so as to fulfil the purpose of the building in the best way, or to the greatest extent, and this cannot be done without knowing how to build. It is as if there is a streak of dishonesty running through the architectural profession. They do not face facts, they fake facts.'[97]

It is not surprising therefore that Arup's best work during the 1930s was with those architects who were willing and able to enter into an unconventional working arrangement which allowed the integration of design and constructive skills. This narrows down principally to his work with Lubetkin and Tecton.

For the type of building contracts Tecton acquired during the 1930s, Arup developed his 'slab system' of building, a system to which he was naturally drawn as a contractor because of its constructional simplicity. What it required however, if the architectural results were to achieve a high standard of excellence, was effective collaboration between all members of the design and building team. It has already been suggested how this collaboration worked and how the changes in architectural expression were closely related to the development of Arup's structural slab system. The most interesting observation is the radically different relationship that existed between the structure and form in their early as against their later buildings. In their early work their objective appears to have been to produce buildings which exhibited a fusion of structure and form, whereas in their later buildings Arup created structures which encouraged architects to indulge in pattern making to create architectural interest.

The evidence suggests that it was their work at Highpoint I that was primarily responsible for their rejection of the integrated structure and form logic. To Arup this building demonstrated the irrationality of attempting to combine the constructional simplicity of his system with the visual simplicity of the architectural form. For projects of this complexity, the two aims were proved to be entirely incompatible; for in attempting to produce a visual expression of simplicity the construction was forced to become anything but simple. From Arup's point of view this completely negated his objectives as a contractor, even though ironically it produced a visually deceptive impression which seemed to support them. In later projects therefore, he consistently tried to improve the constructional simplicity of his system whilst reconciling it to the architectural needs of planning and the architect's natural desire to produce stylistically acceptable results. This reached its most advanced stage of development in his 'box frame' schemes. the structures of which, whilst having an enormous influence on the overall massing of the architectural form, allowed the architect complete freedom in the design of appropriate elevational treatments.

Even though many contemporary observers regarded Lubetkin's work after Highpoint I as a betrayal of modernist principles, his own position like that of Arup's, can be seen to have been entirely consistent. He had never accepted the functionalist propoganda of the British modernists, and although he agreed with Arup as to the necessity of integrating constructional issues into the design process, he had never accepted that architecture should respond exclusively to the pragmatic constructional solutions of the building problem. Analysis of Highpoint I provides ample demonstration of this in the way that he forced Arup to distort his simple structural and constructional concept to accommodate his stylistic requirements.[98]

The effect of Highpoint I however, together with some smaller structures that Arup designed during the early 1930s (most notably the Penguin Pool), was to create a climate of architectural opinion in Britain which recognized Arup as a skilful engineer who, like Owen Williams, was capable of producing outstanding examples of functionalist architecture by approaching design from a purely scientific point of view. What is surprising is that this view has remained largely intact, despite the overwhelming amount of physical and written evidence which clearly demonstrates its improbability. There is little doubt that this misunderstanding is based on the assumption that any engineer involved in early British Modern Movement architecture must have been closest to its underlying 'engineering' principles, best summed up in those well known catch phrases - 'form follows function', 'the law of least action', and 'structural honesty'.

What emerges from a study of Arup's work, is that he for one did not only disregard these principles in his post Highpoint I buildings, as indeed did Owen Williams, but consciously rebelled against them as his role as contractor and engineer forced him, for largely pragmatic reasons, to enforce a degree of separation between the structural shell of buildings and their architectural treatment. What is perhaps significant is that his written justifications for this line of approach appeared in the 1940s and 1950s when he published numerous retrospective articles on his attitudes towards architectural design with specific reference to its relationship with structures.

It would be too discursive to examine these later writings extensively. However a short summary of the main themes they contained (looking principally at two of these articles) does provide information which helps towards a deeper understanding of his work. The difficulty is determining to what extent these writings represent conscious post-rationalization on Arup's part of the reasons for the changes that had occurred in his 1930s work.

In most of these articles he reaffirmed his commitment to the engineering principle of 'the economy of means', and explained that this principle was equally relevant to the field of architectural design. His argument was essentially that architects ought to appreciate that their main function, like that of any engineer, was to maximize the cost effectiveness of the buildings they produced. Indeed in a number of articles that Arup published, he devoted a great deal of effort to propounding an equation he had formulated which combined all the features of architecture in a mathematical relationship. This was as follows: 'efficiency or architectural quality' equalled the sum of 'basic commodities','excess commodities' (eg extra insulation), and 'delight or aesthetic quality' divided by the 'total cost'; ie: $E = \frac{BC + EC + D}{COST}$ [99]

This equation was his personal attempt at improving Wotton's three principles of 'Well Building', namely 'Commodity, Firmness and Delight'. Whereas Wotton had given equal weight to these components.

Arup had significantly removed 'firmness' believing it to be a constant factor in the equation (discussed below), and forwarded his view that the essence of architecture was:

'a struggle to get as much as possible of commodity and delight out of a given expenditure of effort and money.'[100]

He recognized, however, that although a useful explanatory model the equation was inapplicable because of the impossibility of assigning any quantitative value to 'delight' or 'aesthetic quality'. Nevertheless the facts of life for those involved in architectural design, he argued, meant that although it was impossible even to obtain agreement on what constituted 'delight' in architecture, it was:

'Generally agreed that delight has a value, and that it is the business of the architect to fight for it.'[101]

Arup maintained that the greatest danger to architecture in the 20th century was the architects' general inability to evaluate the cost implications of design:

'If the architect cannot himself use a slide rule and if he cannot make a quantitative cost analysis of alternative planning solutions, he is in danger of losing touch with the foundations of practical facts on which alone his Art can flourish.'[102]

The most conspicuous omission from Arup's equation was 'Firmness' or 'Structure'. The reason for its omission was well argued and provides enlightenment on Arup's own retrospective views on the relationship between structure and architecture. 'Firmness' he argued was a condition that had to be fulfilled in order to obtain commodity and delight. Generally speaking, therefore, it was a constant factor. From the engineer's point of view the function of structure, he maintained, was to:

'ensure stability at as low a cost as possible, consistent with the preservation or creation of Commodity or Delight'[103]

The engineer's problem was in accommodating the architect's wishes as to what extent the structure should be used to create 'Commodity' and 'Delight'. He was absolutely clear that it was the architect's responsibility, as leader of the design team, to determine to what extent the structure should be used to create these qualities. As an engineer, he argued, he was perfectly willing and saw no contradiction in either producing structures which were clearly expressed in the architecture or were completely concealed behind an architect-designed veneer. Indeed on a purely practical level he saw distinct advantages in the latter approach, an approach which was the dominant theme of his later work with Tecton. With specific reference to these schemes he wrote:

'Take the case of a block of flats in 'box-frame construction'. Should this frame be expressed on the outside? Some architects think that it is the structurally honest thing to do, and it may or may not add to delight - according to how it is done - but surely the practical thing to do is to let the weatherproofing and heat-insulating skin cover the whole of the building, including the structure. The other may lead to complications or bad practice. It may even lead to the use of external additions to indicate the structure within - express it, as the saying goes - but what happens to honesty then.'[104]

This quotation provides definitive evidence of Arup's views on the relationship between architecture and structure, views that had emerged from his involvement with modern architects, particularly with Lubetkin and Tecton in the 1930s.

How then did he specifically respond to the modernist demands for 'functionalism' or 'structural honesty' as the controlling theories in architectural design? He could appreciate the demand for functionalism in the 1930s as a necessary reaction to the view commonly held in traditionalist circles that delight in architecture was essentially concerned with ornament added at extra cost:

'Functionalism recognizes that there is 'delight' in fitness for purpose, and in the forthright expression of that purpose. But functionalism degenerates into 'funkiness' on the part of the architect if it leads to the attitude "Leave it to the engineer" - whatever he proposes must be functionalism and es ipso beautiful.

That is too easy and wrong. 'Delight' must be fought for, and it must be based on knowledge of facts, physical and economic - hence the engineer - but also on a subordination of these facts to a higher unity.'[105]

In examining the phenomenon of 'structural honesty' in closer detail he came to the conclusion that it was an architectural fetish that its proponents completely misunderstood. To Arup there could only be one of two types of 'honest structure' - either 'organic structure' or 'economic structure'. Many architects, he claimed, failed to distinguish between the two:

'The organic structure is economical in the use of materials, the economic structure is economic in the means of production. The two may coincide, but mostly they don't.'[106]

The only instances where the two did coincide were in large engineering works, particularly those built in insitu reinforced concrete when it became economically necessary to save material and reduce the dead weight of structures. But in ordinary building, simplicity of formwork tended to predominate over saving in concrete from an economic point of view. Thus, he argued, for most buildings 'structural honesty' could only ever refer to 'economic structure'. But if the goal were economic structural solutions then architects would usually decide to conceal the structure altogether:

'If structural honesty means practical and economic building then it does not necessarily imply the display or expression of the structure, or the use of 'organic' forms so much in favour with the advocates of 'structuralesque architecture'.'[107]

In this criticism Arup was careful not to denounce the legitimate means of producing delight in buildings by emphasizing the structure. His principal objection was directed towards the dishonesty or ignorance of architects who used arguments of economics to justify their creations.

'For it is of course true that honesty cannot be found in structures, but in architects and engineers. And honesty to my mind, consists in knowing yourself what you are doing and being open about it. It is perfectly honest to use structure to create architectural unity, strength, interest or to use interesting structural shapes to achieve poise, crispness or economy of means in the aesthetic sense; and it is equally honest to try to keep the structure out of the way and out of mind altogether - provided you make no bones about it.'[108]

There is little doubt that the views Arup expressed in the above quotations, ones which he repeated in many other articles in the post-war years, both clarify and justify the changes that can be observed in his later work in the 1930s, despite the fact that they were retrospective. What clearly emerges from them is a support for the view that it was his pragmatism as an engineer within a contracting organization which forced him to depart from the naive modernist theories to which his early work at Highpoint I gave sustenance.

The paradox, however, is that of all his 1930s buildings, Highpoint I stands out as one of the most impressive from a visual point of view. Could it be therefore that Arup's search for practical solutions to the problem of both construction and architect/engineer collaboration was ultimately at the expense of architectural quality? Or was it simply that as Arup produced constructional solutions which gave Lubetkin a greater freedom in elevational design, it was Lubetkin who was unable to respond effectively. The latter argument seems the most convincing, for designers in general tend to work best when faced with severe constraints. In this sense it would be legitimate to argue that at Highpoint I Lubetkin produced a visually effective architectural solution by stretching Arup's constructional system to its structural limits.

Arup would not accept this argument believing that his endeavours to find the most sensible approach to constructional issues was highly beneficial to the quality of architecture. This pragmatic characteristic of Arup's is a constantly recurring theme in his career. As early as 1919, for example, it had been largely for practical reasons that he had abandonned philosophy to train as an engineer. During the 1930s, it was for similar reasons that he had directed his work with architects away from the largely visionary integration of structure and form towards solutions which gave his architects greater stylistic freedom and a collaborative framework that allowed the integration of architect, engineer and builder to operate as efficiently and effectively as possible. Although his motivation for these changes is understandable what is harder to appreciate is Arup's later decision in 1944 to abandon contracting. As has been noted, his commitment to the integration of design and constructive skills was one of the most important features of his work in the 1930s. The slow departure from this commitment began in 1938 when he resigned from Kier's and established two separate firms in partnership with his cousin A S Arup - Arup & Arup Limited and Arup Designs Limited.[109] His hope was to continue his involvement in both contracting and design work, believing that this could be achieved by having two organizations. However by 1945 his contracting firm was not proving as successful as he had hoped and he realized that if he wanted to become more involved in design then it was essential that he should conform to the established conventions and operate solely in a consultancy capacity. Once again he sacrificed his ideals for purely practical reasons. His decision ultimately proved to be sound, but as regards the integration of designer and builder he was only able to unite these disciplines in his own work (as a consultant engineer who possessed valuable experience in the world of contracting) rather than in the building industry at large.

CHAPTER 8

WELLS COATES

Unlike the other engineers in this study, Wells Coates has already been the subject of a number of academic dissertations and publications by authors who have successfully established his reputation as one of the leading figures in the development of modern architecture in Britain. The first important assessment of his career was undertaken in 1965 by Farouk Hafiz Elgohary in a doctoral thesis devoted entirely to Coates's life and work.[110] This was followed by a monograph, published in 1974, by Sherban Cantacuzino[111] and an exhibition in 1979 by Oxford Polytechnic.[112] It would therefore be inappropriate for this chapter to attempt a detailed consideration of all aspects of Coates's work as a large proportion of its content would inevitably draw upon secondary sources of the above works. Moreover a complete reappraisal of their work is made difficult by the inaccessibility of an important section of Coates's papers, held by his daughter Laura Cohn.[113]

What this chapter will attempt to do is to examine the engineering basis of Coates's career, and its implications for his design work, comparing it with the work of the other engineers discussed in preceeding chapters. This aspect of Coates's career has not been sufficiently well covered by the above-mentioned works despite the fact that Coates himself used his credentials as an engineer as the basis of his architectural practice in the early 1930s. Although many authors have made reference to his background in the engineering sciences most have tacitly assumed that it formed an important ingredient of his success as a modern architect. In the context of this study it is essential that Coates's work be examined from this angle for there is little doubt that his reputation stands out as one of the most successful of British architects whose basic education was in engineering. It will be suggested, however, that while Coates used his engineering credentials to establish his architectural practice in 1928, the buildings he produced and the process by which they were designed had little bearing on his engineering background. The somewhat surprising conclusion is that Coates was very similar to many of the more traditionally-trained contemporary architects in Britain during the 1930s, in as much as his primary concern appears to have been the pursuit of an 'engineering aesthetic'. Like them, Coates relied upon the services of concrete specialist firms or consulting engineers to design the reinforced concrete structures of his buildings and the evidence suggests that he was unwilling or technically incapable of allowing the structural design to have an important influence on his own design approach.

The Background to Coates's 1930s work as an Architect:Engineer

'I am a trained engineer; and I believe that house building is today the business of the engineer plus painter. Architects are mostly finished - at least in England.'[114]

In this extract from a letter he wrote to his wife, Coates states his belief that as a trained engineer he was ideally suited to the business of modern architectural design. Shortly afterwards, in early 1928, he established his architectural firm which traded under the name 'Wells Coates BA BSc PhD' with the important subtitle 'Architect/ Engineer'.[115] In expressing this view and establishing his design firm on this basis Coates was adopting the same position as Owen Williams at approximately the same time. Indeed Williams represented for Coates one of Britain's greatest hopes for modern architecture during the early 1930s, as many extracts from his papers illustrate.[116] He even agreed with Williams in his rejection of the notion that collaboration between architect and engineer was a legitimate means of producing modern buildings. In his diary he wrote:

'We don't want engineer and architect combining in plans . . . but the architect/engineer, or rather the engineer/architect; and I pin my faith on Owen Williams'.[117]

Although the similarity between the positions established by Coates and Williams suggests that a detailed comparison between their modes of operation and the buildings they produced would be useful, there are two important points that should be made at the outset. First, Williams does not appear to have been Coates's inspiration for establishing a career as an architect, for when Coates wrote 'Architects are mostly finished' [118] Williams was still operating as a consulting engineer and it was at least two years before he started his own architectural work on the ill-fated Dorchester Hotel project. Second, while Coates's papers suggest that he had a high regard for Williams and his work, and on two occasions tried to persuade him to join the MARS group, there is no evidence to suggest that this admiration was reciprocated.[119] Indeed Williams's refusal to join Coates's group of modernists indicates at the very least a lack of interest for Coates's work or ideas. This is hardly surprising in the light of Coates's limited record as a practical designer in the early 1930s. It was not until 1934 that he completed his
[57] first building - 'The Lawn Road Flats', by which time Williams's architectural reputation was firmly established. Moreover, unlike Williams who throughout the 1920s built up a successful engineering

practice, Coates's involvement in engineering had been entirely academic and weighted to the mechanical sciences rather than to structural engineering. In this and other important respects Coates's career prior to 1930 had been wholly dissimilar to that of Williams and the other engineers discussed in this study.

Coates's career began in 1914[120] when he entered the University of McGill to study mechanical, structural and electrical engineering completing his course in 1922 with BA and BSc.degrees. (His course was interrupted during the War, in which he fought with the Canadian Gunners and the Royal Naval Air Service.) In that year he came to London to pursue his interest in mechanical science by enrolling for doctoral research at London University. The subject of his thesis - 'The Gases of the Diesel Engine' - provides little indication that he would ultimately turn to architecture as a career. Indeed when he completed his PhD in 1924 it appears as though he had little idea of what course his career should take, for he abandoned his involvement in both engineering and scientific research by taking employment as a part-time journalist and translator with the Daily Express.

It was while working as a journalist that he began to take an interest in architecture. To supplement his income he obtained a part-time secretarial position in the architectural offices of Adams and Thompson. Here he met, and formed a close friendship with, Maxwell Fry - a newly qualified architect from the Liverpool School of Architecture. It was through Fry's influence that Coates gained an introduction to the world of modern architecture.[121] In 1925 he went to Paris in an official capacity with the Daily Express and on Fry's advice sought out the work of Le Corbusier and Mallet Stevens at the Exposition de l'Art Decoratif. Although no evidence of his visit exists in the pages of the Daily Express, it is clear from comments he made in contemporary records that he was attracted by the bold simplicity of the work of certain exhibitors there, incorrectly interpreting their creations as the work of engineers rather than architects.

Although Fry was responsible for stimulating Coates's interest in architecture, undoubtedly the greatest indirect influence on his decision to become an architect himself were the writings of Wyndham Lewis. It is well established that Coates greatly admired Lewis's work and he was particularly fond of two of his books - The Caliph's Design[122] and The Art of Being Ruled.[123] It was in the former publication that Coates appears to have discovered all the justifications he needed for pursuing an architectural career. In this publication Lewis, himself referring to Lethaby, concentrated on denigrating the work of architects whilst applauding that of engineers, concluding that the new architecture would or should be created by the latter. In a section of his first chapter, which is very reminiscent of Coates's 1927 letter to his wife, Lewis wrote:

'I have thought of a way out for the Architect. It has often been suggested of late that the Architect might become a branch of the Engineering Industry. But why sould he take all his bric a brac shop over to that clean, fresh, erect institution across the road? Rather let the Engineer and Painter fix up a meeting and take over the sadly-involved affairs of this decayed concern, which is of all the scandals of the Art World, the most scandalous and discreditable. The Painter and the Engineer could buy him out, going into partnership, and produce what would neither be a world of boxes on the one hand, as it would be if the Engineer controlled house construction (Vide Skyscraper), nor of silly antique fakes on the other, as happens when the Architect has his sweet and horrible way.'[124]

The greatest problem Coates would have faced once he had decided to launch his career as an Engineer/Architect would have been to gain commissions, a task made particularly difficult by his lack of a design-education either in architecture or structural engineering. It was undoubtedly this handicap which delayed his full development as a building designer and most of his early schemes were largely restricted to the area of interior design where a knowledge of building was not of critical importance.

The person who provided him with his first opportunity in this type of work was Alec Walker. They are reported to have met by chance during the summer of 1928.[125] (They had previously made an acquaintance in Paris in 1925.) Walker who had established the Crysede silk business in 1924 with Tom Heron, invited Coates to visit their factory at St Ives, Cornwall and there offered him his first commission - the fitting-out and shop front design of the Crysede shop in Cambridge.

Coates produced a convincingly modern scheme. His admiration for Mallet Stevens is immediately apparent in the shop front itself where he produced a simple composition using plate glass and simple, direct lettering for advertising purposes. Most of his design effort, however, was concentrated in the interior where he designed a series of standardized shop fittings using mainly plywood and glass, arranging them to create a well organized and simply presented internal space. Shortly after its completion, disagreements between Heron and Walker led to Heron's break with the company and the establishment of his own firm - Cresta Silk Ltd, at Welwyn Garden City. Coates followed him and was commissioned by Heron to undertake the interior design of his new factory workshop and the fitting out of a number of new Cresta shops in the south of England.[126] In all these schemes Coates built upon his success at Cambridge, adopting the cubic forms reminiscent of Mallet Steven's work for the external arrangement of display cabinets and reusing his standardized plywood fittings internally.

It was his logical use of plywood, first demonstrated at Cambridge, that attracted the attention of Jack Craven Pritchard, a director of the plywood manufacturing firm Venesta Limited. In March 1929 he wrote to Coates asking for photographs of his fittings for his company's use in its advertisements.[127] Their subsequent contact was to prove invaluable to Coates as it was Pritchard who was to provide him with his first opportunity to design a building - a house in Lawn Road. London; ultimately developed as the 'Lawn Road Flats' (1934).

The two men discovered that they had many interests in common. Like Coates, Pritchard had undergone an academic education in engineering and was also enthusiastic about the modern architecture of France and Germany.[128] Coincidentally, Pritchard had recently commissioned the architect St John Harrison to design a house for his family in Lawn Road, Hampstead, London. Coates asked if he could examine the early plans and eventually persuaded Pritchard to allow him to produce an alternative scheme in unofficial competition with Harrison. In February 1930 Coates wrote to Pritchard asking him for the authority to proceed. Denigrating Harrison's rather 'traditional' proposals as a 'proper botch' - he wrote:

'I can plan you a house - a machine to live in - that will give you better accommodation than that provided by the present plan . . . at a price strictly within the limits you set, provided you are willing to accept radical alterations in principle, construction, design and finish . . . . I should like your authority to proceed on these lines.'[129]

Pritchard was impressed by Coates's idea to produce a radical house in Lawn Road, similar to those erected by Le Corbusier, and he was clearly convinced that Coates's engineering background made him ideally suited to the task of designing 'a machine to live in'. Referring to Coates's status as an 'Architect/Engineer' he wrote:

'You have put Architect/Engineer. I rather you had put Engineer/ Architect or better still 'plumber' or possibly 'plumber - engineer'.'[130]

Apart from these important qualities which impressed Pritchard, he was also attracted to Coates's proposal because of his commitment to charge no professional fee. Instead of charging a percentage fee, Coates claimed that apart from 'out-of-pocket' expenses he would prefer to regard the project as a joint venture:

'a form of mutually helpful scheme in view of making fullest use of the publicity value - ie my remuneration would largely take the form of credit accruing from that publicity value'[131]

The condition that Coates attached to this was that he should be given the final say on the selection from a range of possible alternative schemes in view of maximizing the publicity. Furthermore, he undertook to take no remuneration whatsoever should:

'I fail to give you the house you want at the price you can pay.'[132]

To this Pritchard replied:

'that is generous I am very glad to accept'[133]

Perhaps with the benefit of hindsight, it would be reasonable to describe the faith that Pritchard placed in Coates as naive. He was certainly unaware that the commission was for Coates's first building-design project, believing, quite mistakenly, that Coates had a wealth of previous experience as an 'architect'.[134] Moreover, he placed quite a different interpretation on what Coates meant by a 'mutually helpful scheme'. Coates had much grander ambitions than Pritchard was led to believe at the outset. His real objective was to persuade Pritchard to join him in a business relationship for the purpose of producing low-cost, standard, modern house units, complete with furniture, with Pritchard's scheme forming the prototype model.

As the design for the scheme proceeded Coates gradually introduced

Pritchard to these ideas. His main argument was that for the type of radical house he envisaged it was necessary for them both to have complete control over its construction, primarily to avoid the extravagant tenders that normal builders would submit because of its innovative construction techniques. In addition to this, he successfully persuaded Pritchard to extend the brief to include a house with office accommodation for his own use. In April 1930 he outlined his initial proposals on the 'business deal', referring to the two houses as 'models' - as a basis for 'exhibition and operation'.

'It might even be advisable to commence operations with a small staff of our own . . . and to let work directly to subcontractors, or by direct labour, the main object being to train the nucleus of a staff for further operations when the model houses had been established as a basis of exhibition and operation . . . I am convinced that it will save a lot of money on the houses, as well as form the best possible basis for the sort of concern we have in mind.

I am not strong on the technique of financial operations, but it may be that the formation of a small holding company, with a purely nominal capital, may in the end be the best method of raising the money through the building society.'[135]

Pritchard's response was cautious. He apparently agreed with Coates's objectives but thought it preferable if their first project be organized along roughly conventional lines - 'as if we were two strangers carrying out a business deal'.[136] Coates took some exception to this but convinced himself that his client might be persuaded once he had produced the first set of drawings. These were presented in July with a request that they be kept secret so as to maximize future publicity.

Pritchard's reaction was generally enthusiastic but on the question of Coates's unconventional business proposal he was still unconvinced:

'Future procedure - I have ideas of what might be done in the future but it depends entirely on what your attitude to various problems is. As I see it we have got to decide between two methods of development and which of these we adopt will depend on the relative importance to you of (a) propagating the general idea of modern living (b) becoming famous (c) making money. Not until you have decided which of these points are the most important can we decide what our course of action is going to be in the future.'[137]

This provoked an eleven page response by Coates in a highly philosophical letter which criticized Pritchard for his short-sightedness and his intolerable suggestion that money was an important issue.[138]

The outcome was Pritchard's agreement to form a limited company, a course of action that he was ultimately willing to undertake for what appears to have been three important reasons. First, Coates had convinced him that truly modern house construction had to be organized on industrial lines, in a similar way to car production - and that by forming a 'design and build' company they would be leading the field in Britain with an impressive future ahead. Second, he felt that Coates had as much to lose in the venture as himself, in that he would be sacrificing his professional status by forming a limited company. (He was clearly unaware that in 1930 Coates had no professional status to sacrifice.) And third, he was persuaded by Coates's argument that the houses could be built more cheaply by forming a company. Thus he reassured himself that if the company's wider objectives were not realized he would at least have derived some cost benefit from the venture.

Consequently, in September of that year the company - Wells Coates and Partners Limited was formed. Pritchard's shareholding was the largest but was held by a nominee to prevent prejudicing his position at Venesta. Coates's father-in-law, the civil engineer Frank Grove, made up for Coates's rather small contribution taking the position of chairman. Two other directors were Pritchard's solicitor, Graham Haw, and the electrical engineer Lord Pentland, who joined the board in November.[139] Coates was to be the only full time director. concerning himself principally with design matters and was to be paid a salary in addition to remuneration from future profits. For publicity purposes and financial advice, Pritchard engaged his brother's advertising firm, F C Pritchard, Wood and Partners Ltd, a director of which was the architectural critic and writer John Gloag.

To furnish this firm with the necessary information for its publicity campaign, Coates drew up a memorandum listing the company's principal objectives:

'The company is to act as architects, engineers, designers, entrepreneurs and constructors for dwellings for modern people.

The watchwords to be 'standardization of parts', 'rationalization of processes and methods', 'modern industrial design, based on the principle of conspicuous economy' (as opposed to 'conspicuous waste') 'decoration is desecration' . . . . 'Form is organic only when it is natural to materials and natural to function', an organic form grows its structure out of conditions as a plant grows out of the soil . . . both unfold similarly within etc etc

The first aim of the company to be to erect (out of ground into the light) two modern houses in one composite block at Lawn Road, Hampstead, to be used primarily for demonstration and publicity purposes . . .'[140]

Coates's catchphrases, while useful in clearly establishing his strong connection with the Modern Movement, tend to detract from the essential features of his new company. Pritchard, probably better encapsulated its aims when he wrote to Lord Pentland in October 1930 attempting to persuade him to join the board:

'We [Coates and Pritchard] have both felt that there was something radically wrong with the organization of building, the main cause being that the architect has been working at petty exteriors instead of designing according to function on the one hand and according to the material available on the other; while the builder has been so frightened at anything new (owing to architects' fundamental incompetence and lack of the new machine - craft knowledge) that whenever anything new comes he multiplies the estimate by five and kills the project.

Wells Coates and I feel that the time has come to build an organization that will at once perform the function of architect and agent to the client and also that of entrepeneur in the pure sense - ie a bringer together of various functions.

The first job of the company is the construction of two experimental houses in Hampstead . . . our plan is to make them as cheap as possible and we believe that sooner or later (probably sooner) our method of construction and organization will enable us to make modern houses cheaper than the ordinary house and at the same time give greater space and convenience. If we cannot do this, modern methods mean nothing.'[141]

Thus by September 1930, Coates had successfully persuaded Pritchard and others to form a company which had the potential to revolutionize modern architectural design. He had a different objective to that of Owen Williams who had merely substituted the professional architect with the professional engineer. Moreover the integration of architect, engineer and builder in the company even surpassed the successful association of these disciplines by Lubetkin, Arup and Kier's. Whereas Arup and Lubetkin continued to operate within the broad framework of professional conventions, Wells Coates and Partners Ltd had been created to avoid the conflicts these conventions produced. By abandoning 'professionalism' and integrating the functions of designer, technologist and constructor in one commercial unit it was intended that the company would be ideally suited to making Corbusier's '*machine d'habiter*' a reality in Britain.

However, in the event,no buildings were produced by this company. Just three months after its formation Coates destroyed its, and his own,credibility by requesting his removal as a director. The reason given was that he considered his association with a Limited Company would prejudice his professional status. From a memorandum Pritchard produced in January 1931 it seems certain that it was Coates's recent acquisition of the BBC studio contract that provoked this rapid *volte-face*.[142] This prestigious commission, which Coates undertook with McGrath and Chermayeff, clearly convinced him that even without professional qualifications he could work as a conventional architect.

and if he continued to head a Limited Company he would deny himself the opportunity of acquiring such future work from other important client bodies. Pritchard was devastated and was forced to agree with his brother that Coates's request-'knocks the bottom out of the whole thing'.[143]

Over the ensuing twelve months extensive negotiations between all parties finally resulted in Coates's removal as a director of the company and a change of name to Isokon Ltd.[144] It was agreed that Coates could retain a relationship with the new company as its 'consulting architect' with payment made according to the RIBA's standard fee scale. However, the company would be free to engage other designers and it was intended that, at the outset at least, it would appoint builders in the traditional way.

Thus within a little over twelve months, Coates's ambitious proposals for effecting a radical transformation in the way buildings were to be produced had evaporated. Instead, he was proposing to produce modern buildings along traditional professional lines. Surprisingly, Pritchard still had sufficient confidence in Coates's design abilities to allow him to proceed with the design of his house.

[56] When one examines Coates's early 1930 proposals for Lawn Road one is forced to conclude that Pritchard's confidence was completely unfounded. The most superficial assessment reveals that Coates was wholly inexperienced, suggesting that Pritchard had not only been unduly influenced by Coates's self-confidence in business matters, but with regard to his design abilities as well.[145] Perhaps the most obvious feature of his inexperience was his inability to appreciate the cost implications of his proposals. One of the most basic economic considerations in the design of any building is the

relationship between the area of external walling to the cubic volume enclosed. Coates's first proposal consisted of an elongated 'L' shaped, two storey plan form in which Pritchard's house and his own occupied each of the two legs with integral garages separating
(364) them at ground floor level.[146] In each of these the main living areas faced in one direction only, with circulation spaces on the reverse side. Not only was the proportion of circulation space excessive but the high proportion of external walling to cubic volume should have immediately indicated to Coates that the costs would be excessive. Even on Coates's own very optimistic cost estimate the scheme priced out at approximately 10% above Pritchard's maximum outlay of £4,000.[147] Despite this, in a later letter to Pritchard, Coates indicated that he intended to elongate the plan even more to obtain a maximum of window area.[148]

The most severe criticism however, and one which had direct cost implications, was his failure to relate the structure to the plan. Taking Le Corbusier's concept of the 'frame liberating the plan', it is clear that one of Coates's first design decisions was to use a reinforced concrete frame. He therefore produced a regular grid of concrete columns at approximately 18 ft centres, superimposing on this grid his plan arrangement. The relationship between the two was inept with at least four rooms rendered useless by the wilful intrustion of columns in their centres. In this early proposal there appears to have been no attempt made to adjust either the plan or the structure to produce a more satisfactory solution. This criticism cannot be countered by an assertion that the intention was to produce a flexible internal arrangement. for had this been the case it would clearly have been more appropriate to position the columns of the concrete frame along the external walls.

(365) The elevations reveal yet more features of Coates's inexperience. Considering that it was intended that these facades should be flexible, allowing future changes in the internal arrangement, it is alarming to discover that Coates's intention was to erect them in precast concrete. This might have been acceptable had Coates directed some of his attention to designing a series of standardized precast concrete panels that could be easily moved but on examining the fenestration he wished to use, it becomes immediately apparent that each panel would have had to have been uniquely designed and manufactured. Not only would the costs have been extortionate but they would have made future rearrangements of the facades impossible. It is therefore clear that Coates's technical abilities were not as useful as his engineering credentials suggested. From his correspondence with Pritchard it also emerges that his engineering abilities did not extend into the field of reinforced concrete design. For this he approached two firms - the Trussed Concrete Steel Company and the British Reinforced Concrete Engineering Company.[149] It is hardly surprising that neither of these firms agreed to take on the structural design,or even supply a budget cost,for it would have been immediately apparent to both that the proposal was unfeasible.

Pritchard appears to have been oblivious to these many problems. He was clearly so confident of Coates's engineering abilities that he saw no reason to question the technical issues raised by the proposal. On aesthetic grounds also,his fundamental assumption was that as the building was to be 'modern' the elevational treatment was a direct consequence of the 'logical' planning solution and the constructional techniques used and, therefore, satisfactory. In his written response to Coates's first set of drawings he wrote:

' 1) Design - by this we understand that you refer to the idea of mushroom construction and the general methods you have suggested. If so the design is OK with the obvious provision that the method works and that costs are comparable with its advantages.

2) Plan qua - Plan, it is OK and here are a few minor queries: . . . .

3) Elevation As I see it these follow on from 1 and 2 and are therefore OK.'[150]

Coates's reply to Pritchard's comments provides a useful indication of the priority he attached to the technical issues of his design:

'By design I do not mean mushroom construction or any other construction. I mean, of course, the appearance of a thing, what it looks like, the shape of the feeling, or the feeling of the shape . . . .

Elevation of course 'follows on 1 and 2' but doesn't it give any feeling of anything at all? No descriptive words?'[151]

It is therefore clear from this quotation, and from the drawings he produced, that Coates had little or no conception of the constructional complexities he had created. Moreover they serve to illustrate, quite apart from his basic inexperience, the low priority he placed on using the structure and constructional techniques as determinants of architectural form.

During 1931, when negotiations were taking place for the reorganization of Wells Coates and Partners Ltd, Coates abandoned his early 'L' shaped scheme and started work on an alternative proposal. The change appears to have been stimulated by Owen Williams's suggestion to Coates that it was usually possible to persuade the authorities to allow building over underground tunnels - Coates's early proposal had been carefully positioned on the site to avoid two LMS tunnels which had produced a large amount of wasted space. Referring to his chance meeting with Williams, Coates wrote to Pritchard to outline his new proposal:

' . . . Williams has recently got some amazing things past the LCC and he cheered me up a lot. I think that if we ask him officially to pronounce on the question of building over or near the tunnels at Lawn Road, we might easily be able to put across an entirely new type of plan for the site, in spite of the LMS and LCC put together. The advantage of this will be immediately apparent to you, and might mean the possibility of definitely three houses on the existing land plus the extra strip, thus splitting land-costs all round. By getting him to pronounce on this and getting it past these people (he is bound to have connections with the LMS as well), we might be able to put something really startling across. What say you?'[152]

There is no evidence to suggest that Williams had any further involvement in the scheme. However his very limited involvement appears to have provoked Coates radically to rethink his proposal. Instead of building what was to all intents and purposes a 'one-off' scheme, he decided it would be more appropriate to design five minimum house-types which the Company could use as standard house units, and to build three of them on the Lawn Road site as models for future development. In October 1931 he wrote to his co-directors:

'I propose that as soon as the Company is reorganized (or before, if you so desire) you ask me to prepare plans and specifications for five types of minimum houses as follows: Type A costing £750; Type B costing £1,000; Type C costing £1,250; Type D costing £1,500; Type E costing £2,000.'[153]

The proposal was accepted and it was agreed that Pritchard's house would be a Type 'B'.

Much to Pritchard's regret the first Type plan proposals did not
(378) appear until February 1932, Coates's involvement in the BBC and Kensington Palace Gardens interior design contracts being the prime reason for the delay as these commissions were taking up too great a proportion of his time. There is little doubt, however, that when the first of the Isotype plans were eventually produced, with the name 'Isotype Dwelling', they represented a remarkable improvement on his earlier proposal.[154] Even though the drawings reveal little of the construction to be used they appear to be far more convincing. Not only does their tight planning suggest that Coates was beginning to appreciate basic cost issues of building design but they appear at least to approach Coates's concept of the standard house unit with

standardized unit pieces of Isokon equipment which would allow the Company to sell not just houses but associated equipment as well. It is possible that this improvement in Coates's design abilities was partly due to the influence of Maxwell Fry who helped Coates in the early stages of the design process.[155] Unfortunately, however, the preliminary cost estimate for Pritchard's prototype 'Isotype dwelling' for Lawn Road was significantly higher than the budget figure of £1,000. This late setback appears to have provoked Pritchard and his codirectors (Coates by this time had been removed as a director) to reconsider the fundamental basis of the entire scheme. In an undated, handwritten memorandum to Coates, Pritchard's wife, Molly, wrote:

'Wells, please let me say what I have to say before you chip in with your personality and muddle me up; a) Type plans good, but can't be built on account of expense. Therefore we think what about flats - will they also work out 50% too much and therefore dish (sic) the scheme.'[156]

There has been much debate as to who was primarily responsible for the decision to change the scheme at Lawn Road from houses to flats. The above quotation undoubtedly lends support to Molly Pritchard's claim that it was her idea, although as her memorandum was undated it would be unfair to place too much emphasis on it.[157] Although the contemporary correspondence provides no definite answer, there are two incontrovertable facts contained in it which suggests that Coates's contribution was much smaller than recent histories of his career have indicated. First, although it is plausible that Coates might have been considering an ultimate 'minimum dwelling' alongside his other Isotype proposals, in none of his correspondence with Pritchard, before the decision to build flats was taken, was any reference made to a 'minimum' flat proposal. Second, the correspondence between the directors of Isokon reveal that the primary motive for switching to a flat proposal was economic - to maximize the financial returns on the land.[158] Coates, by severing his connection with the company was not a party to this decision; indeed, he was still writing to directors of Isokon on the houses proposal at least four weeks after the company had made a positive decision to build a block of flats.[159]

The basic idea for the flat proposal, whether it originated with Molly Pritchard or Coates, was that it should provide minimum living accommodation for young professional people at competitive rents. It would perhaps be too cynical to suggest that the idealistic motive - to create modern forms of living space for the modern man - was a justification for maximizing economic returns by reducing the square footage per flat to an absolute minimum. If this had been the case then the scheme was to prove unsuccessful for the building cost was almost three times more than Isokon's initial budget figure of £5,000. However as it was intended that the flat scheme would form part of the wider Isokon programme, being a prototype building for duplication on other sites, it appears as though Pritchard was willing to spend more money on this first venture believing that substantial economies would be made on future blocks. In addition to this, Coates was to continue his work on the Isotype dwelling units, for which alternative sites would be found in other locations, and was to design more Isokon furniture units for inclusion in each proposed building.

The brief that the Pritchards prepared for Coates, with advice on its economic viability from F C Pritchard, Wood and Partners Ltd, provided Coates, at last, with the ideal opportunity to translate his 'machine to live in' concept into built form.[160] He was to provide approximately twenty flat units on the Lawn Road site, a large proportion of which were to be of the 'minimum' type, each comprising bed-sitting room, small kitchenette, bathroom with associated dressing space and provision for a spare sleeping facility and dining space. A smaller number of larger flat units were to be included, with the suggestion that these could be made up of two 'minimum' units combined. They were all to be centrally serviced to reduce 'labour-making' to a minimum through the provision of constant hot water. partial central heating, telephone on each floor, cleaning provision, laundry and meal facilities, with ancillary accommodation for caretaker and cleaning staff and garaging for approximately eight cars. (The closest comparison for such a brief was hall of residence accommodation for students.) Pritchard asked Coates if he would be able to provide this amount of accommodation and facilities for a maximum outlay of £5,000.[161]

Coates was confident this could be accomplished and proceeded enthusiastically, taking on the architect David Pleydell Bouverie to help with the preparation of drawings. The first set of completed drawings was ready by September 1932 and they were presented to Isokon, however, with a budget price of £10,500, a figure estimated by the Quantity Surveyor, Cyril Sweet.[162] Although the price was significantly higher than Pritchard's budget figure, Isokon were persuaded that for the type of development it had proposed and bearing in mind the anticipated returns, this was a realistic contract sum.[163]

This proposal underwent a significant number of changes before the final design drawings were produced almost nine months later. but the essential elements of the proposal remained the same. These were the

overall massing of the building within an 'L' shaped form, containing
minimum dwellings on four floors served by external access galleries;
and the angled orientation of the block to make maximum use of the
site between the underground tunnels and to provide a south-westerly
aspect to each of the flats on the rear elevation of the block.[164]
The most obvious changes were in the room layouts themselves - much
simplified in the built scheme - and the replacement of a centrally
(367) placed, circular staircase enclosure feeding the external galleries
(370) with a simple cantilevered concrete stairway to one end of the block.

Between September 1932 and the following Spring the relationship between Isokon and Coates came under considerable strain. The prime reason was Coates's failure to produce a final set of Isotype house plans and his slow progress on refining the flat scheme. The correspondence between them became acrimonious, and following Isokon's decision to withhold Coates's fees until the necessary drawings were produced, Coates felt the need to defend his reputation:

'You may feel a lack of confidence in me. I ask you to explain why it is that I have been able to carry through a large number of intricate and difficult jobs, such as Broadcasting House - with all its 'personalities' and personal situations - , or indeed any other work actually done, if I am the sort of person sometimes Jack assumes I am. And recently, I have been made vice chairman of the architects committee for the Dorland House Exhibition, chairman of the architects lighting committee of the International Illumination Congress, and chairman of the proposed British delegation to the International Congress of Modern Architects. (This last information is strictly confidential and for you alone.)[165]

It was undoubtedly the Dorland House Exhibition of British Industrial
Art that restored Isokon's confidence in Coates. For this exhibition
Coates arranged for a full scale model of the minimum flat for Lawn
(369) Road to be one of the most important exhibits. It attracted a con-
siderable amount of attention and a significant number of potential
tenants, providing Isokon with the reassurance it needed. In July 1933

therefore, Coates's drawings and Bill of Quantities went out to tender to eight builders. George Barker submitted the lowest tender of £13,587 and was awarded the contract. The design of the reinforced concrete was given to the specialist firm The Helical Bar and Engineering Company, who apparently won the contract in competition with the Trussed Concrete Steel Company, and its construction formed part of a substantial sub-contract by Billings Ltd.[166]

[57] The building was completed by July 1934 and through the extensive publicity it received it quickly came to be regarded as one of the most important modern buildings erected in Britain. There is little doubt that it became something of a rallying point for the British Modern Movement and was primarily responsible for Coates's reputation as one of the movement's most important leaders. There appear to have been two principal reasons why this small, austere building received such acclaim. First was the machine concept it appeared to enshrine both in the internal planning of the minimum flats and in the wilfully brutal monolithic concrete facades, particularly on the principal elevation where the horizontal bands of the access galleries produced something of the appearance of a battleship. To many British modernists this mechanistic architecture created to accommodate modern patterns of living,and which appeared to have been produced by a functionalistic approach to design, epitomized their objectives for future modern architectural design in Britain. James Richards, for example, later wrote of this building: 'it is nearer to the machine à habiter than anything Le Corbusier designed'.[167] No one was surprised that it had been designed by a man who had trained as an engineer. The second reason was undoubtedly helped by Coates's own reputation at the time of its building and his own flare for publicity. Even before it had been completed,and despite the fact

that this was his first building, he had already created for himself (with the aid of P Morton Shand who was enthusiastic about engineers taking over architectural design) a position of leadership within the British Modern Movement through his creation of the MARS group.[168] As chairman of this group it was natural that his membership would be looking up to him to provide some sort of lead.

When one examines the building in more detail, particularly the structural solution, it becomes readily apparent that the success of the building depended far more upon its imagery than on its technical merits.[169] Certainly the relationship between the structure and the plan form was more successful than Coates's earlier disastorous attempt for Lawn Road House of 1932. However one would have expected this for whereas in the earlier scheme he had tried to design a complex plan form around a rigid structural framework and failed, the repeti-
(370) tive linear arrangement of identical flat units in the flat scheme was ideally suited to a rigid structural grid, providing Coates with little opportunity to create conflict. Where legitimate criticism can be levelled at Coates's structural solution is in its excessiveness, which apart from being bad engineering had direct cost implications for his client.

From its appearance one would immediately assume that the monolithic concrete wall surfaces expressed the essential structure of the building, similar to the concrete slab structures that Arup was developing for Lubetkin at about the same time at Highpoint.[170] However, the floors, roof and cantilevered galleries at Lawn Road were not supported on the walls but on a conventional reinforced concrete cross frame, with the columns to the primary frames located at 10 ft
(374) 8 in centres and carrying hollow pot and beam floors. The walls

themselves, although cast integrally with the frame (4 in thick with a cork lining for insulation), were merely providing rigidity to the structure which could have been catered for much more cheaply. Moreover, not only could the building have been designed without the frame but the frame that Coates had proposed was itself overstructured by his decision to locate the columns on a narrow grid dimension established by the width of the living area to each flat (10 ft 8 in) instead of using the width of the flat unit itself which would have been structurally more efficient. There is little doubt that Coates was playing for safety in devising this excessively over-structured building, and one must assume that he was unwilling to engage a consulting engineer to prevent damaging his credibility as one of Britain's new breed of architect/engineers. It is seldom appreciated that while Coates decided the arrangement of the structural frame, the calculations and detailed design of the reinforced concrete were undertaken by the Helical Bar and Engineering Company whom Coates had appointed. There is little need to question why this firm should not have advised Coates on his excessive structural provision, for the Company's remuneration was directly related to the amount of reinforcement they could supply.

Pritchard must have become aware of these problems towards the end of the construction period, for in April 1934 he wrote to Coates asking for his co-operation in allowing two consulting engineers to visit the site to assist them in reporting on the economics of the structural shell to the building:

'We are anxious to learn as much as possible from the experience we are having at Lawn Road especially in the construction of the shell of the building.

We believe that, as a result of this experience, we will be able to make economies in future construction. We have therefore asked Alan Moncrieff MA AMInstCE MIStructE and R A Buchanan BEng to advise as to how economies could be effected in the future, and would be glad if you would give them any assistance you can.'[171]

Coates's response was wholly obstructive,recommending to Pritchard that as the structure was just within the LCC's permitted stress limits there would be little point in Isokon wasting time and money on such discussions.[172] Indeed,for merely entering into preliminary discussions with Moncrieff and Buchanan,he would be charging a fee of 10 guineas.[173] Pritchard clearly sensed that he had touched a raw nerve in questioning Coates's technical competence. In his letter agreeing to Coates's fee he wrote:

'I wonder why you seem to be putting so many difficulties in the way of this investigation? Perhaps I am misreading your letter - anyway please write to Moncrieff and fix as early a date as possible.'[174]

Despite this,Coates appears to have been successful in obstructing a full investigation into his structural design for Lawn Road and was therefore able to retain something of his credibility. However it is notable that for all his subsequent schemes he employed a consulting engineer for the structural design thus indirectly admitting that he was unable to produce economic solutions on his own.

It seems clear therefore, that while the Lawn Road Flats provided Coates with an important reputation as one of Britain's leading modern architects, from his own point of view it fell far short of the radical objectives he had hoped to achieve when he had first launched his scheme with Pritchard. Not only had the integration of designer and constructor been abandoned as the only effective way to produce modern buildings but by his failure to produce an effective. efficient structural solution he was forced, in future projects, to operate as a conventional architect, thus undermining the entire basis upon which he had founded his architectural practice as an engineer-architect in 1928.

Coates's work in collaboration with Felix Samuely

There is little doubt that Coates's decision to begin collaboration with members of the engineering profession had a beneficial effect upon his later projects. The engineer he used more than any other was Felix Samuely, the designer who, whilst working under Ove Arup, was responsible for the structural design of the Penguin Pool at
[58] London Zoo.[175] Their first joint project was the 'Sunspan House of 1934', a scheme which had its origins in the Isotype plan that Coates had designed for Isokon. The change to 'Sunspan' appears to date from February 1934. In a letter of this date to Graham Maw, Coates admitted that the reinforced concrete 'unit construction' Isotype dwellings he had produced were economically unfeasible from Isokon's point of view:

'There is little doubt that a solution is possible - . . . . - but the first house on this basis would probably cost £100,000 and the thousands which would follow would probably be sold profitably at figures which bear the same relation as do the 'first cost' (including machinery and equipment) of a Ford car to the actual cost of one Ford, to-day . . . . Already, in America the newly formed General Housing Corporation have set down a programme of immense construction on these lines, backed by such organisations as General Motors and General Electric.'[176]

Only with such backing, Coates claimed, could the authorities be persuaded to relax their regulations to enable such houses to be erected economically. He therefore outlined his latest proposal -

'a new set of plans, in which a construction which combines brick with concrete slabs is employed . . . - a solution which is more directly related to English customs and climate than of any other plans'[177]

To finance this proposal and his own work, he requested reinstatement as director of Isokon Ltd. Although the directors of Isokon were willing to go along with his new system of construction, they understandably refused Coates's directorship request.

Shortly after this Samuely was brought in to help Coates with the

structural design. Although he was fully conversant with the intricasies of reinforced concrete design, as his work on the Penguin Pool testified, Samuely's greatest design abilities were in the field of structural steelwork. With his assistance, therefore, Coates was persuaded to use a steel framework for the house proposal, clad in corrugated steel sheets (Lewis Dovetail Steel Sheeting) and
(380) rendered externally to give the appearance of a concrete building.[178] Much to Pritchard's annoyance Coates betrayed Isokon by selling the design to the builder E & L Berg Ltd, which effectively terminated his relationship with the company.[179] The Sunspan House was exhibited at the Daily Mail Ideal Home Exhibition of 1934 and following its successful reviews there, Berg proceeded to erect an estimated number of fifteen houses at various locations around Britain, most of which were built without Coates's knowledge or consent. The limited commercial success of 'Sunspan', although benefitting Berg rather than Coates, seems to have convinced Coates of the necessity for him to collaborate with structural engineers in the design of his buildings. In most of his subsequent schemes therefore, he re-engaged Samuely as his consulting engineer.[180]

The largest and most reputable of Coates later 1930s' buildings, to which Samuely made a vital contribution with his reinforced concrete structural designs, were two flat schemes at Brighton and London -
[59] the 'Embassy Court Flats' (1935) and the 'Palace Gate Flats,
[60] Kensington' (1938). The most interesting aspect of these structures, and particularly in the relationship to the planning, is the close affinity with Arup's work on reinforced concrete structures for flat design at about the same time. Moreover, the development in the structural arrangement in the four years that separated the two schemes bears a close resemblance to the improvements that Arup

made between his two structures for the Highpoint buildings at Highgate, suggesting that Samuely derived his structural ideas for these Coates buildings from Arup's work. Although no direct evidence exists to confirm this important connection, it is nevertheless a valid assumption for Arup and Samuely shared high mutual respect and collaborated throughout the 1930s in many areas of work, indicating that interaction between them on specific designs was highly probable.[181]

[59] Coates acquired the Embassy Court Flats project shortly before the completion of the Lawn Road Flats. Unlike the latter however, the Embassy Court Building was to provide luxurious accommodation, at high rentals, on the sea front, each flat (approximately 65 in total) comprising large living room, bathroom, kitchen and three bedrooms with all units having separate lift access.[182] The plan-
(384) ning of the 'L' shaped block on a corner site on the Brighton promenade, bears a close resemblance to the Lubetkin/Arup competition
[48] entry to the Working Mens Flat Competition of 1934.[183] Every pair of flats was served by a common lobby space containing two lifts with the rooms to each flat planned on either side of an off-centre
(386) corridor. Like the Working Mens flat building by Lubetkin and Arup, balcony provision was made on the principal elevation by reducing the depth of one room, with access from doors placed in the side walls of adjacent rooms. Along the rear elevation Coates provided for servicing and fire escapes with a series of galleries and external staircases, very similar to those used for main access at Lawn Road.

It is clear from the planning that the simple cross frame reinforced concrete structure Coates had used at LawnRoad would have been wholly

unsuitable for the Embassy Court Flats as the main lines of such a structure could not be made to align with the rooms to either side of the corridor. Had it been used in this later project many down-stand beams would have appeared across the ceilings of rooms, being not only visually unsatisfactory but creating severe obstructions to service runs. There were only two structural solutions that could have been employed to avoid these problems - either a type of flat slab structure that would have provided a continuous floor thickness without downstand beams or Arup's concept of longitudinal lines of support. The latter would have restricted downstand beams to the external walls and one corridor wall providing the designer with the flexibility to locate columns or wall supports at positions convenient to the plan and allowing for relatively simple service runs along the length of the building. The former option was apparently considered but did not meet with the local authority's approval.[184] (Had it been seriously considered, however, it would have required a very different plan form to accommodate a more regular spacing of column supports.) Thus it was a longitudinal structural concept that was used, a solution that was receiving extensive publicity in the press at the time, following the success of Arup's entry to the Working Mens Flat Competition. However Arup himself had not yet used the idea in a completed building and consequently Samuely was the first to apply its principles to a built example. Thus at Embassy
(385) Court, Samuely provided Coates with three longitudinal lines of
(387) support that allowed him a certain amount of freedom in the placement of columns and the opportunity to use structural walls where columns would have been too obtrusive. It may be argued too that Samuely also enabled Coates to claim priority in the use of a concept initiated by Arup.

Although the integration of the plan and structure in the completed building was less refined than that created by Arup and Lubetkin in their proposed and built schemes, the essence of the concept in Coates's Embassy Court was the same, even down to the space between the central line of columns which, like the Arup/Lubetkin scheme, was used for built-in cupboards with the area above used for the principal service runs. One vitally important difference, however, was Coates's decision to bring the outer lines of support within the envelope of the building, cantilevering the floors beyond these
(386) lines to both front and rear. This decision completely negated one of the advantages of Arup's system in as much as it prevented Coates from using the external walls themselves as the two principal lines of support. Arup had, in his own work, argued for this arrangement for two reasons - first it had significant cost advantages in integrating the structure with the enclosure properties of the wall; and second, it allowed the modern architect to produce monolithic buildings with a degree of structural integrity. The important effect of Coates's decision, therefore, was to relieve the facades of Embassy Court of any significant structural function, providing him with the opportunity to apply any stylistic veneer he wished. In the light of Coates's 'engineer' status and his commitment to forging an integration between the architectural and engineering aspects of building design this decision appears highly contradictory. The only controlling feature of the design of the facades was the plan arrangement
(388) behind. Coates used this freedom to the full, producing very different elevational treatments to the front and rear elevations. At the rear of the building he re-used the Lawn Road elevations with cantilevered galleries and external concrete stairways, while for the
(389) principal elevation he appears to have borrowed from William's Daily

(161) Express building (Fleet Street), by curving the corner of his building, running along the facades horizontal bands of concrete walling and introducing set-backs on the uppermost three storeys.[185]

It is interesting that in his first major project, and with the undoubted engineering abilities of Samuely at his service, Coates should have decided that the structure should have little, if any, influence over the design of the elevations. Admittedly, there were sound pragmatic reasons for adopting this approach in as much as it allowed him to produce an expediently random structural arrangement that could be completely hidden from view. What this clearly indicates, however, is that despite his 'engineer' status and his Modern Movement rhetoric, Coates was principally concerned with the external appearance of this building and so long as it gave the appearance of a type of architecture created by its structural form, such deception was to him perfectly legitimate.

It was probably this Beaux Arts approach to modern architectural design which attracted the praise of the renowned architectural commentator Charles Reilly. In January 1936 he unreservedly acclaimed the building to be the best British building of 1935. Paying tribute to Coates's engineering and architectural abilities, though recognising the essential differences between them, he wrote:

'If this is the result of a mathematical training and a doctoral degree for research into the gases of combustion inside the cylinders of a diesel engine, the architectural curriculae of our schools must be altered at once. Of course it is not. Engineering knowledge and clear thinking have kept Wells Coates away from fripperies, but this great building was not composed without an appreciation of solids and planes, of lines and colours and all things which combine to make architecture.'[186]

Clearly Reilly was either unaware of Samuely's involvement or preferred to consider his structure as a purely utilitarian aspect

of the design. In this way, however, he ultimately did Coates a disservice for shortly after the completion of the building, serious technical problems began to emerge in Coates's facades which otherwise might have been attributed to Samuely. As at Lawn Road, these walls were simply constructed with 4 in thick insitu concrete walls cast behind a permanent cork insulation lining, but within a little over twelve months they began to weather very badly and produce dampness problems internally. (It is difficult to determine just what influence Samuely had over the design of these facade walls.) To be fair this was not a problem unique to Coates's early work as it was a common failing of many modernists' concrete buildings of the early 1930s, including Highpoint I. At Brighton however, it was exacerbated by the building's exposed position on the sea-front. Like many of his contemporaries though, Coates learned from these
[60] mistakes and in his next major project with Samuely, at Palace Gate, a decision was made to cast the concrete walls behind artificial stone slabs.

Like the Embassy Court Building this later project by Coates and Samuely bears a close relationship to the work undertaken by Arup and Lubetkin.[187] This is most noticeable in the planning of the flats where Coates developed Lubetkin's duplex plan form which had
[53] been used at the Highpoint II building, Highgate. However the structure was essentially different from that used at Highpoint II, with the exception of the external walls which in both schemes consisted of concrete walls cast behind a permanent, durable panel system (ceramic at Highpoint, reconstituted stone at Palace Gate). Whereas at Highpoint Arup had introduced a cross frame system for the central portion of the building, at Palace Gate Samuely refined Arup's earlier longitudinal frame system producing a remarkable

solution which integrated perfectly with Coates's planning, suggesting that Coates was beginning to learn the true benefit of effective collaboration with his structural engineer.

A comparison between the plans of Highpoint II and the Palace Gate
(390) Flats immediately reveals that this earlier Lubetkin building provided
(340) Coates with the inspiration for his last major scheme of the 1930s. Both buildings were simple rectangular blocks providing four flat units, at each floor level, symmetrically arranged around a central entry point. The entrance area to both buildings was given visual prominence by a centrally located concave form - at Highpoint this took the form of a curved entrance porch supported on caryatids, whilst at Palace Gate Coates extended this feature vertically to provide the main vertical access and an additional flat unit at each level. The most notable similarity, however, was in the design of the flat units themselves for both were based on the American 'Duplex' system and both were regarded as two of Britain's foremost examples of what became known as 'Planning in Section'. At Highpoint II, Lubetkin had introduced what he termed the 2/1 section, providing each flat unit with a double height living room with ancillary accommodation located on two levels served by a staircase individual to each unit. The problem with Lubetkin's system, and its American precedents, was that the 17 ft height of the living room was excessive and could only be used in the most luxurious of situations where the overall proportions of the room could be large enough to make the high ceilings appear visually satisfactory. At Palace Gate therefore, Coates produced an ingenious development on Lubetkin's system by creating what became known as the 3/2 Section. In this solution the height of two living rooms was made equivalent to three ancillary rooms thus producing a more reasonable ceiling height of 13 ft. This, however, created enormous planning problems which required the elaborate

(391) interlocking of flat units both horizontally and vertically. There
(392) is little doubt that Coates's planning solution was something of a masterpiece and when considered alongside its relationship to Samuely's structural solution it stands out as the most accomplished of all his 1930s' work.

To allow the constant changes in floor levels across the depth of the
(393) building, Samuely reused the longitudinal support system in reinforced concrete that Arup had first developed for the Working Mens Flat Competition and which he had used to some effect himself with Coates at Brighton. However whereas at Brighton, Coates had concealed the structural arrangement, at Palace Gate Arup's intention to use the outer walls as two principal lines of support was used, together with another centrally positioned line of support separating the living rooms from the ancillary accommodation. This was ideally suited to the requirements of the complex plan and section, eliminating the potential conflict that would have occurred had a cross frame solution been adopted. By arranging the essential lines of the structure longitudinally, differences in the floor levels along the length of the building could be accommodated with relative ease. Although most of the external walls were constructed with concrete columns Arup's slab concept was used in many other parts of the building, particularly on the end walls which were designed as monolithic slabs with no window openings to provide end restraints and wind bracing for the reinforced concrete frame. Internally a number of walls along the central line of support were designed as deep concrete beams providing partial support for the floors which were themselves designed, in part, as shallow horizontal beams in accordance with Arup's ideas.

There is little doubt however that whilst the essential elements of the structure can be traced back to Arup's work, the Palace Gate Flats exploited the technique more effectively than any of Arup's work with Lubetkin. What is particularly interesting is that at the time of its construction Arup was beginning to argue for cross wall slab construction, one benefit of which was that it allowed the architect a degree of freedom in the design of the elevations. At Palace Gate the structural arrangement had an overwhelming influence on the elevational design by virtue of the fact that the two principal lines of structure were located along the most important
(395) elevations. Thus whilst Arup's work with architects at this time was tending towards a more facadist approach to architectural design, at this late stage in the 1930s Coates's work was beginning to demonstrate what none of his previous schemes had successfully achieved - an harmonious relationship between the structure and the architectural form. Unfortunately, however, this building was the last substantial project that Coates undertook as an architect and it is therefore difficult to determine whether this concern for integrating the structure and the architectural form was an aberration caused by the peculiarities of this specific project or whether Coates was at last beginning to translate his early ideas on the integration of engineering and architectural requirements into built form. In the light of his incompetence in the early years of the 1930s it is plausible that the latter interpretation is closest to the truth. In many ways it would be legitimate to argue that his early work with Pritchard and Isokon provided him with an opportunity to learn the basic essentials of architectural design through immersion, and that it took him approximately five years to acquire the necessary skills to put his ideas into practice.

CONCLUSIONS

Throughout the entire period of British industrialism commentators have expressed regret at the separation of the disciplines of architecture and engineering and have looked forward either to a reunification or to a general adoption of the architect's role by engineers. Speculation as to which of these two options was the more likely appears to have been most acute during periods when new technological developments were assumed to have far-reaching implications for architectural form.

Such speculation was initiated by the introduction of reinforced concrete into building in the early years of the 20th century. While it is difficult to appreciate this now, when the material is as commonplace as bricks and mortar, in the early years it was regarded as a revolutionary building material. Unlike other materials that were assembled in units, in its insitu form of construction, concrete was a plastic material which appeared to require a peculiar scientific understanding on the part of the designer. Thus, while it was generally appreciated that it possessed the potential to revolutionize architectural form, it prompted an important question - who would be responsible for determining this form? Was the engineer to take over the architect's role in the design of reinforced concrete buildings because of his supposed superior judgement in technical matters? Or was this new material to become a catalyst of the reunification of the two disciplines?

An historical survey of reinforced concrete led to two important observations. First, the assimilation of the appropriate technology to architecture was effected, not by architects or engineers but by concrete specialist firms motivated by commercial considerations. Second, long before the advent of the Modern Movement in British architecture a successful attempt had been made by one specialist firm - the Trussed Concrete Steel Company - to integrate the abilities of the engineer and architect in the production of forms of architecture truly responsive to the particular structural properties of reinforced concrete. Its intention was not to pioneer a new architectural movement but rather to produce distinctive forms of architecture which would serve as useful advertisements for its products. Whether or not it was consciously realized, an architectural philosophy of 'truth to materials' was ideally suited to this commercial objective. Moreover, in the field of industrial building it was an attractive design approach for many clients who wanted cheap, yet attractive functional buildings. Consequently, these two commercial considerations coincided to provide the ideal conditions for the production of modern concrete buildings.

The remarkable feature of such early examples of architect/engineer collaboration within this specialist firm, was that the resulting buildings, whose form and structure were closely related, went largely unnoticed at the time of their erection. There were two reasons for this. Architects who aligned themselves with what were essentially commercial trading organizations were generally regarded as unprofessional and for this reason the architectural establishment wished to discourage such practice. And, the buildings so produced were of course industrial, and during the years immediately following the First World War such structures were generally considered to be 'engineering' and consequently as having little architectural significance.

Such attitudes underwent significant change towards the end of the 1920s, producing a different context for the development of reinforced concrete as an architectural material and at the same time generally favourable conditions for the initial careers of the four designers discussed in this study. These changes were significant both with regard to architecture and to engineering.

In engineering the greatest change was the gradual erosion of the specialist firms' monopoly over reinforced concrete design. The architectural establishment had encouraged this outcome from the early years of the 20th century by initiating changes in regulations which would open up the field of concrete design to other qualified designers. Allied to this was the creation of a new professional body - the Institution of Structural Engineers, formerly the Concrete Institute, whose main raison d'être was to disseminate design information relating to reinforced concrete beyond the narrow scope of the specialist firms. The significance of the creation of a new professional body was that it provided architects with an opportunity to collaborate on a professional level with engineers in the design of reinforced concrete structures, removing the need for unprofessional relationships with trading organizations.

Concurrent with these important developments in engineering were equally important changes in architecture. These were stimulated principally by a growing appreciation of modern European architectural theories which emphasized functionalistic approaches to architectural design, encouraging architects to consider the work of engineers as models for modern forms of architecture. This development influenced a reassessment of the similarities between the two disciplines, provoking a belief in some architectural circles that a widespread acceptance of essentially engineering approaches to design - the functionalism of modernism - would open up the field of architectural design to many designers without an architectural training. This is evident in the vote of thanks presented by the Earl of Crawford and Balcarres on the occasion of the inauguration of Sir Giles Gilbert Scott as President of the R I B A in 1933 :

'But what interests me much more than the contest between schools (re. the traditionalist-versus-modernist approaches to design) is the contest between professions. I am anxious to know if the architect of the future is going to be able to carry on the profession of architecture or if there is going to be an increasing proportion and percentage of his art carried out by those without artistic education. That I am afraid, is the real issue, and now more crucial than ever it has been before; and I for one, say frankly that it fills me with apprehension.'[1]

This was the context in which Faber, Williams, Arup and Coates, the four engineer-architects who have been the principal subjects of this study, made their contributions to architecture in the inter-war years; a context in which reinforced concrete was moving away from the control of specialist firms to more generally qualified engineers nurtured by the new profession of structural engineering. In architecture there was turmoil and flux, uncertainty as to the future, imprecise ideas about architectural responsibilities in respect of engineering, and growing demands for protective legislation in the form of the much heralded Registration Bill (enacted at the very end of the period under review).

If one compares the careers of Williams and Faber the issue which tends to predominate is the question of the engineer's role in architectural enterprise. Williams's activities in the early 1930s were perceived as clearly posing a distinct threat to the traditional status of the architect. His appointment as designer of the Dorchester Hotel, in particular, was widely interpreted as an indication of the architect's limited role in future architectural design. There seems little doubt that Williams believed this to be true, making no attempt to suggest that his decision to become an architect was peculiar to his own situation. Faber, on the other hand, perceived the architect-versus-engineer controversy from a completely different point of view. As one of the leading members of the new Institution of Structural Engineers, he was anxious to ensure that the primary function of his colleagues should not simply be to provide technical assistance to architects. He thought that there was a class of work - primarily industrial building and bridge schemes - which engineers were eminently qualified to undertake without architectural assistance. His fear was that if architects became increasingly involved in this type of work, perhaps because clients wanted their artistic abilities, or more likely because of professional expansionism, structural engineers might find themselves labelled second class designers. Williams's objective in establishing himself as an architect was motivated by a similar perception of the engineer as a designer in his own right whose activities should not be confined to playing a supportive role in the creation of buildings devised by others. The reasons why Williams adopted an aggressive strategy, whereas Faber fought what amounted to a rearguard action, are to be found in their contrasting views on the relationship between architecture and engineering, the place of reinforced concrete in architectural design, and, in particular, the validity of functionalism as a useful design theory.

The differing backgrounds of Faber and Williams help to explain their contrasting views on such issues. Through the reputation Faber had acquired from his pioneering research work in the science of reinforced concrete his practice became a magnet for many eminent, though perhaps conventional, architects requiring his engineering services. Like these architect-clients Faber came to regard architecture as an 'art' essentially concerned with prestigious civic buildings or small scale domestic work. For such work Faber expected structural engineering - whether reinforced concrete or structural steelwork - to be subservient to the artistic ideas of the architect. Just as the overall design concepts of these buildings were determined by the architect, he argued, so it was necessary for the overall design concept of an engineering structure to be determined by the engineer.

The distinction Faber recognized between architecture and engineering had little effect upon his attitudes towards functionalism as a design theory. He consistently argued that even in engineering projects functionalism was fallacious. Although he recognized that 'expression of the structure' could help to create visual interest in buildings he argued that if applied in isolation it could never achieve beauty. In this sense he regarded reinforced concrete merely as an expedient medium for projects in hand, not as a material whose characteristics should be used as the principal determining features of the design. Moreover, he believed that if Williams's structural functionalism became widely accepted by engineers it would exacerbate the architect's encroachment upon engineering. In a world of little difference between the two disciplines, clients would avail themselves of the status of employing architects. In his own work and writings Faber attempted to prevent this encroachment by encouraging engineers to develop aesthetic sensibility, as an aspect of a more fully developed discipline, in their training and practice.

Williams's experience of work with architects - principally Maxwell Ayrton - led him to a completely different perception of the nature of building design. He came to regard architecture, as practised by contemporary architects, as an essentially decorative discipline. Unlike Faber, Williams had developed almost exclusively as a practical designer of reinforced concrete structures, and his objectives from the mid-1920s onwards (following the success of Wembley) had been to originate new forms of concrete architecture. At the outset he believed that this could be achieved through architect/engineer collaboration, hoping, like many others, that a developing relationship might ultimately lead to a reunification of the two disciplines. However, as he became increasingly convinced of the architect's obsession with decoration he came to regard the architectural profession as one which had lost touch with basic structural issues, and therefore as totally unsuited to producing modern concrete architecture. The demarcation between architecture and engineering as disciplines had less relevance for him than his distinction between the two types of work he believed they would come to be preoccupied with. Temporary structures he maintained - those with designed lives not exceeding one hundred years - would become the largest proportion of buildings required in the modern world. The principal requirement of these structures would be to cater for their functions as cheaply as possible, and so modern structural materials, particularly reinforced concrete, would be ideally suitable. Permanent structures on the other hand - monumental buildings - would not use modern structural materials because of the need to avoid tensile stresses. Williams anticipated that architects with their knowledge of traditional building materials would continue to work on an ever decreasing number of 'permanent' structures, whereas engineers, or perhaps a new breed of technically competent architects, would become the designers of an increasing proportion of 'temporary' ones. Functionalism was central to Williams's design approach. He believed that only through the forthright expression of the function of a building and its efficient structural arrangement could an effective, modern, reinforced concrete architecture be achieved, completely untainted by stylistic or decorative additions.

The paradox of Williams's work, however, was that it appeared to demonstrate the validity of Faber's argument. This happened in three respects. First, Williams's work indicated an important distinction between 'engineering' and 'architectural' projects. There is little doubt that Williams's successes were largely confined to bigger industrial projects which Faber had claimed were the legitimate concern of the engineer. (There were notable exceptions such as the Dorchester Hotel.) In such projects Williams was able to give his abilities as a reinforced concrete designer full rein, producing superb buildings which an influential few were keen to recognize as 'architecture'. In smaller building projects (which, confusingly, were conventially defined as 'architecture') he usually failed to achieve similar success principally because they did not provide him with opportunities to display his strength as a designer of the large scale.

The second feature of Williams's work which lent support to Faber's argument was his failure to fully apply his functionalist theory. This is most readily apparent in his small scale schemes for which he can be seen to have adopted a self-consciously stylistic approach to design because of the lack of any predominant structural problems. Although not so apparent, some of his later large scale schemes indicate a similar tendency. This is most marked in his Boots Drys factory where the structure can clearly be seen to be playing a supportive, rather than a dominant role. Here Williams's work indicates that a functionalist approach to structural design was not the sole reason for the success of his buildings. This had a wider significance in that by separating the structural and formal issues in some of his buildings,Williams seemed to respect the conventional relationship between architecture and engineering. Thus while his early career in architecture had as one of its objectives the synthesis of the disciplines, his later work accepted a convenient separation. The third observation drawn from Williams's work which supports Faber's arguments was his failure to demonstrate the validity of a universal application of reinforced concrete. Once again his failures in this respect tend to be obvious in small scale schemes where bricks and mortar would probably have been more appropriate both financially and structurally. This showed what Faber had consistently argued, namely that the characteristics of building materials should not be the sole determinants of building form, particularly in the sphere of 'architecture'. In spite of these criticisms, however, there is little doubt that Williams's most accomplished works stand out as some of the most impressive buildings created in Britain during the 1930s, and although both his successes and failures tend to bear out Faber's arguments, the quality of Williams's better work far surpassed anything that Faber achieved.

It is similarly possible to compare the work of Arup and Coates in as much as one practised as a consultant to architects while the other attempted to work as an architect-engineer, but there are important differences which inevitably shift the basis of discussion. The most important difference was that the vast majority of their work was concerned with the kind of projects which could conventially be described as 'architecture' rather than 'engineering'. Consequently, whereas a comparison of Williams's and Faber's work hinges on the demarcation between architecture and engineering projects, and on the engineer's role as designer, such a discussion is not especially pertinent in respect of Arup and Coates. A further important difference was that unlike Williams and Faber, Arup and Coates were firmly aligned with the Modern Movement in British architecture, both being members of the Central Executive Committee of the MARS group. A survey of their contribution to architecture in the 1930s is therefore directly related to developments in British modernism.

Le Corbusier and Walter Gropius argued that a fundamental element of all great architecture was its utilization of the scientific and technological achievements of the age in which it was produced. This was the vision that had motivated Coates, and just as Le Corbusier admired the work of engineers such as Freysinnet because of their abilities to produce remarkable forms by utilizing current technological developments in reinforced concrete, so Coates and other British modernists found similar qualities in Owen Williams's work.

To achieve a comparable degree of success himself Coates believed it necessary to go one step further than Williams by reintegrating all the disciplines of the building industry - the artistic abilities of the architect, the structural and mechanical abilities of the engineer and the constructive skills of the building contractor. He was convinced, however, that collaboration between these parties was undesirable, believing that modern technological architecture could only be fully achieved by one individual, ideally an engineer like himself, embodying all these skills. Through his writings on this issue, and his early claims to be achieving such an integration in his own commercial enterprise, Coates propelled himself to the forefront of the Modern Movement in Britain. Unfortunately he failed in every conceivable respect to achieve what he proposed, both in the organizational structure he established and in the buildings he produced. Not only did his integrated approach collapse before he had the opportunity to produce any buildings, but in the buildings he did then produce he relied upon the engineering services of others. Moreover, it is possible to argue that Coates's real objective was the appearance of an engineering approach to design and not the reality.

What is particularly significant about Coates is that he acquired a reputation as a modernist second to none. There seems little doubt that this was in part attributable to successful self-publicity and a persuasive personality. Also contributing was his largely uncritical group of admirers who were impressed by the 'engineering aesthetic' of his buildings and either failed to recognize, or were not unduly concerned by, the fact that his buildings did not match the claims he made for them. In a sense, therefore, Coates's status as an engineer, although increasingly played down by him as his architectural career progressed, helped to perpetuate the myth of the technological basis of modern architectural design.

Comparable observations can be made of Arup's contribution to modern British architecture of the 1930s. These, however, have a deeper significance because where Coates failed to achieve a synthesis of architect, engineer and builder, Arup succeeded. By operating as both engineer and contractor and by working in close collaboration with architects who were enthusiastic about integrating structural and constructional issues - thus creating an effective teamwork approach to architectural design - Arup was better placed than most to assist in achieving the modern architect's vision of a new architecture based on the rational application of modern structural technologies. His first building which appeared to demonstrate this was Highpoint I, a building which when completed became a cause célèbre of the British Modern Movement because its elevations suggested that a perfect synthesis had been achieved between the simplicity of the structural concept and the architectural form. The building was regarded as being equivalent to Williams's Boots Wets building in that both demonstrated that the best examples of modern architecture were not concerned with stylistic issues but with the functionalist application of pure technology - in both cases reinforced concrete technology. In terms of the 'architect-versus-engineer' controversy, however, each supported different conclusions. The Boots building seemed to suggest that architects were unnecessary, while Highpoint I proclaimed that a synthesis of structure and form could be achieved by effective collaboration between architect and engineer.

Unfortunately, Highpoint I exemplified no such synthesis. The building's appearance of a perfect harmony between the structure and form is deceptive. In reality, Arup's simple structural slab concept was made highly complex to produce a visually simple architectural form. This was something of a revelation to Arup providing him with his first step in a long process of self-education which resulted in two principal objectives; first, to help architect-clients by devising reinforced concrete structures that would enable them to achieve the effects they required without, if possible, resorting to unnecessarily complex and costly engineering structures; and second, to work with his architects in producing architecture which made collaboration between the three disciplines as effective as possible.

The eventual product of this, towards the end of the 1930s, was Arup's promotion of the box frame system of construction, the chief merit of which was that it allowed a clear distinction to be made between the structure and the architect's elevational treatment. This was undoubtedly an unexpected result, indicating that Arup, and presumably his architects, came to accept what would have been anathma to modernists a year or two earlier - that the contemporary architect was still principally concerned with stylistic issues.

From this it would be tempting to conclude that Arup's work with architects was essentially similar to Faber's, both men allowing their contributions to be subservient to the architect's elevational treatment and both recognizing that functionalism alone did not produce acceptable architecture. The clear implication of both their arguments was that what was known as 'modern architecture' was only special in respect of its outward appearance, or its 'style'. If it was a 'style', it was one which Arup found particularly congenial, for he distinguished between 'service to architecture' and 'servitude to architects'[2] and there is little doubt that Arup perceived his role as the former, while it would be reasonable to argue that Faber's work more closely ressemble the latter. In modern architecture Arup found a sympathetic and responsive medium and his contribution to it provides a valuable insight into the two principal themes to which this study has addressed itself - the relationship between structure and architectural form and between the architect and engineer.

Arup's conclusions on the integration of form and structure in architecture, drawn from direct experience of work with architects, were unambiguous. His principal point was that it was perfectly legitimate for architects to create architectural delight by using the structural concept as the determing feature of the architectural form. (Indeed Arup's own reputation as an engineer is centred on buildings of this type, from Highpoint I to his more recent work on the Sydney Opera House.) Arup's main assertion, however, was that this type of architecture owed nothing to functionalism, for in order to produce buildings of this type there was usually a heavy cost penalty created by the unnecessary degree of structural complexity required to produce architectural effect in the structure itself. For the vast majority of architectural projects, where strict cost limitations applied, he argued that it was frequently the cheapest and best solution to separate the structural arrangement from the elevational treatment. Coates's work demonstrates the same principle, best illustrated in his Embassy Court Flats where the structural frame had no influence on the elevational design.

The principle of separating structure and elevational effect is of course conventional, and quite unremarkable, except in the sense that modern architects tried to make a virtue of defying it. They referred to the work of Arup, Coates and Williams (and some architects whom Faber served) as evidence of such defiance; and the question that must now be addressed is why none of these three admitted to conventional practice at the time this would have been most relevant - that is during the 1930s. In the case of Coates and Williams this inadmission is understandable as such honesty would have undermined the basis upon which they had established their careers as architect-engineers. This was not true of Arup and one is led to speculate, in the absence of any substantive writing, that he was either unaware of the contradictions or was unwilling to admit to something which at the time would have deprived his work of notoriety and mystique. The former seems the more likely as the conclusions which he later presented were those which could not have been determined by theoretical analysis but through a long process of direct experience. In this sense it seems reasonable to argue that Arup would only have become aware of the contradictions through later reflection. Could it be, therefore, that those who misinterpreted Arup's work did so, not through wilful intent, but by virtue of the fact that they had not undergone the same learning experience?

Similar conclusions can be drawn from Arup's views on the integration of the disciplines of the architect, the engineer and the builder. Once again his writings on this question only emerged after the 1930s. Nevertheless, his work during this decade implied quite different conclusions from those inferred at the time. What it demonstrated was that the aspirations of Williams, Coates and other British modernists to produce modern architecture by reuniting these functions in their own practices - emulating almost the medieval master builder - were impracticable and unnecessary. Like them Arup recognized that specialization in the building industry was a barrier to the production of good modern architecture. Through his work, however, he came to realize that'specialization' was an inevitable characteristic of modern architecture and that only through a teamwork approach to design could the conflicting requirements of specialists be reconciled. Therefore, not only did he later argue that the prospect of reunification between the disciplines was unrealistic but that it was in conflict with one of the main features of modern architecture itself. Certainly by the end of the 1930s there was hardly an architectural theory that was not based on the basic premise that collaboration between specialists was essential.[3] While this was generally accepted during the years following the Second World War it is not the conventional view of what happened in the 1930s , which has been seen as a decade of (above all) individualism. If one accepts that Arup's collaboration with Lubetkin produced some of the best examples of modern architecture in Britain during the 1930s, then one is forced to conclude that a perceived 'individualism' was never really effective because, at least in these examples, their success relied principally upon a teamwork approach to design. This is clearly one of the many misinterpretations applied by historians to the development of British modernism in architecture during the 1930s. Another common misinterpretation, particularly of the work of Williams, Arup and Coates, was that their functionalist architecture was 'modern' by virtue of the fact that it embraced the latest technological developments in reinforced concrete. This was patently not the case.

A general conclusion drawn from a history of reinforced concrete was that developments in its technology were well in advance of their assimilation to architecture. Furthermore, it was the concrete specialist firms who pioneered this assimilation, rather than architects or professional engineers. Many of the structural techniques used by Williams, Arup and Coates during the 1930s, had already been tried and tested by these firms in many noteworthy buildings at least twenty years earlier. Williams's extensive use of flat slab construction, for example, cannot be considered to have represented an advanced technological application in the 1930s for it had been widely used in American industrial architecture before the First World War and had been introduced into Britain by concrete specialist firms from the mid-1920s onwards. Williams simply took a well established form of construction and maximized its architectural potential at a time particularly susceptible to an enthusiastic response. Arup's promotion of the 'concrete slab' during the 1930s can be seen in a similar light. Indeed, the concept of designing reinforced concrete walls as deep beams had been used as early as 1911 by the Trussed Concrete Steel Company at the Y M C A building in Manchester. Moreover, the use of slip-form construction as a method of assembling buildings designed on these lines had precedents as early as 1919, largely in America. In Coates's Lawn Road Flats (the only work he undertook as an 'architect-engineer') this gap was even more pronounced, its inefficient structural frame being similar to many very early, clumsy, experimental structures. Its most notable structural feature, given extensive publicity at the time of its erection, was its cantilevered concrete galleries. These were interpreted by contemporaries as a highly advanced use of reinforced concrete construction despite the fact that both the Trussed Concrete Steel Company and Mouchel and Partners had used almost identical structural arrangements at the Harrod's Depository and St Thomas's School in 1912 and 1916 respectively. Moreover, the use of the cantilever in concrete architecture was evident in what is commonly regarded as Britain's first example of reinforced concrete architecture - Mouchel's Flour Mill at Swansea (1895).

As the work of these designers cannot be considered as having particular advanced technological relevance, then, it should be asked why their precursors, which were clearly advanced at the time of their erection, have never been given a place in the history of modern architecture. For buildings in which the structure was disguised this exclusion is understandable because like many architects, commentators and historians have often paid lip-service to the importance of technology in creating new architectural forms, being generally more concerned with appearances. In this way they have unconsciously excluded from their surveys important technical developments which could readily be interpreted as the embryonic beginnings of modern structural form. However, this does not provide an explanation for those early buildings which did base their architectural expression on the structural characteristic of reinforced concrete. This is particularly relevant to the early industrial work emanating from the Trussed Concrete Steel Company for many of this firm's buildings were for all intents and purposes excellent examples of early modernism. The most probable reason for their exclusion from histories of modernism is that they did not have the ancestory which was thought appropriate as a possible source of modern architecture. Most histories of modern architecture have concentrated on European developments and particularly on the influence of specific, individual designers. It is highly probable that the work of specialist firms such as the Trussed Concrete Steel Company was consciously overlooked because its origins were American and because its products were designed by corporate bodies, not individuals, and with commercial rather than aesthetic objectives.

The architectural historian of the Modern Movement, whose work has been used as a model for many others, was Nikolaus Pevsner. His work has recently been criticised as a misrepresentation of the period because of his failure to recognize the design genius of certain individuals who practised outside modernism.[4] The accusation has been that Pevsner was too selective in his research in order to maintain his own biased interpretation. The evidence from this study supports this view but with one important difference. Whereas recent criticisms have looked at work specifically outside modernism, the evidence presented in this study suggests that there exists important, early examples of modern architecture itself which have been censured for very different reasons. One of these reasons is that their functionalist architecture was motivated by issues of cost rather than by a conscious attempt to create visual effectiveness. As Pevsner and others have relied primarily upon purely visual judgements, it seems reasonable to argue that they would naturally respond more enthusiastically to designers who presented evidence of a strong visual functionalistic aesthetic. This type of work was more likely to originate from those whose principal concern was structural effectiveness rather than commercial expediency, for of course, cost effectiveness possesses no readily apparent visual merits. The facts demonstrate, however, that it is not possible to separate issues of cost from considerations of functionalist architecture.

When one examines the theoretical basis of functionalism in relation to the cost implications of design then a fundamental contradiction emerges which demonstrates that received wisdom concerning functionalism was redundant. Functionalism can be interpreted in many different ways - the forthright expression of the planning of a building; the expression of the efficiency in the structural design; expression of the constructional system used or the expression of the mechanical services. This study has concentrated principally upon functionalism as it relates to structural design in architecture - structural functionalism. Within structural functionalism, however, there exists two possible modes of design which frequently conflict with each other. Either the structure can be designed with the utmost regard for efficiency in the use of materials, or with a prime concern for efficiency in the mode of its production. The former is principally concerned with the idealistic notion of 'organic structure', analogous to the growth of natural forms; the latter is more pragmatically related to the issue of cost. It is possible that in large engineering structures the two can coincide. In most 'architectural' type projects, however, the two are found in direct conflict. It could be argued that many commentators failed to draw this important distinction. Indeed, they may well have been misled by many of the designers whose work they admired in that they failed to perceive this distinction themselves. This seems particularly true of Owen Williams. In his writings he frequently justified his functionalist approach to design, at least in the early years of his architectural career, by using the naturalist analogy, arguing that just as efficiency in the growth of natural forms produced beautiful results so could similar results be achieved in artificial forms by the designer pursing efficiency in the use of materials. In his work however, Williams can be seen to have confused this ideal with his desire to save his clients unnecessary expense, with the result that his structural forms often responded directly to the cost implications of design. An isolated example of Williams's work, which exposes this difference most clearly, is his design for protruding fins at the Empire Pool, Wembley. In his early design drawings these fins adopted a semi-circular form - clearly determined by a concern for efficiency in the use of materials. Later in the design process they were changed to a simple rectangular form which respected economy in the means of their production. This understandable preference for cost efficiency over structural efficiency is vitally important, for as Arup correctly observed - if in architectural design, economy in the means of production is of paramount importance, then it usually precludes any attempt to use structural efficiency as the principal characteristic of architectural expression. Indeed, it may frequently be preferable to conceal the structure altogether. On a theoretical level, therefore, the concept of 'structural functionalism' possesses an inherent contradiction which completely undermines its credibility as a working design theory.

When one examines the practical effects of structural functionalism in British architecture of the 1930s this theoretical contradiction can be seen to have had direct implication on the buildings themselves. This is best illustrated by isolating the three principal buildings of the decade generally regarded as having been significant because they were seen to emphasize the virtues of a functionalistic approach to design - Arup's work at Highpoint I, Coates's Lawn Road Flats, and Williams's Boots Wets Factory.

Highpoint I demonstrates this most effectively. Its <u>appearance</u> suggested a complete agreement between the efficiency of the structural form and efficiency in its means of production. In fact it conformed to neither, both being sacrificed in order to produce the architectural effect which <u>suggested</u> a rigid adherence to both. In many respects the Lawn Road flats scheme was very similar in that it conformed to neither approach of structural functionalism, being both a heavily over-structured building and having been erected without due regard to economy in the building process itself. Unlike Highpoint I, it did not attempt to conceal these contradictions. Nevertheless, it was still regarded by commentators as an exemplary illustration of structural functionalism in British architecture. The Boots factory by Williams was very different. Unlike most other buildings discussed in this study this building came close to the purist concept of an 'organic structure'. As has been demonstrated, however, this approach to design produced a number of penalties which were in direct conflict with other important functional considerations - excessive planning provision and poor environmental performance.

The significant fact which emerges is that these designers never repeated these approaches to design in their subsequent buildings. This demonstrates that through direct experience they came to regard structural functionalism as a fallacious design theory, although they did not admit it at the time. This is important because their buildings have always been regarded as among the best British examples of functionalist architecture of the 1930s. It seems clear, therefore, that as the designers who produced, or helped to produce, these buildings never repeated their efforts in later buildings, then structural functionalism as a design ethic was one in which only critics believed.

Contrary to conventional wisdom therefore it seems apparent that there was never a time in British architecture when functionalism was of paramount importance in the creation of modern built forms. If it never did exist, at least in its pure form, then the question as to responsibility - architect or engineer - becomes largely irrelevant. What then can one conclude about the engineer's role in the architectural enterprise? If one takes the example of Williams and Coates - the two engineers who based their careers as architect-engineers on the premise that only engineers were capable of designing modern architectural forms - then a conclusion at once profound and obvious must be drawn, namely that when engineers practise architecture they become architects. The distinction is not between individuals but between the two disciplines. Coates accepted this distinction very early in his architectural career, progressively distancing himself from his engineering background as the decade advanced. The same observation is relevant to Williams, for in his later schemes there exists a convenient separation between the structure and architectural form which indicates that while he was prepared to undertake both roles himself, unlike Coates, he came to recognize the good sense of separating them. Faber's work bears out similar conclusions although,to be fair,Faber had always accepted the truth of this in any event.

What seems clear is that when engineers engage themselves with work of an architectural nature they are forced to perform differently than they would in engineering projects. The principal difference between the two disciplines appears to be confined to two specific areas; one, the degree of complexity in the functions to be reconciled, in that most engineering structures have a clearly and simply defined function to perform whereas most architectural projects possess a multitude of conflicting functional requirements; and the other, that visual quality is in architecture a function in itself, equal in importance to other functional considerations. Although, as Faber rightly argued, visual performance should be an important function in engineering projects,the predominance of important structural functions inevitably dominates in engineering.

This evidence clearly demonstrates that the fears and expectations of many within the architectural establishment, during the early

1930s, of an engineers take-over of the architect's role or the subsuming of architecture within engineering, were entirely groundless. Neither the engineer nor functionalism posed any threat to the architect or architecture for two simple reasons. First, functionalism, if interpreted in its purist form as pure engineering was ineffective in producing satisfactory architecture. And second, when engineers practised architecture they ceased to perform as engineers and became architects. On a more general level three principal conclusions should be drawn. Structural functionalism as a design theory was inapplicable to architectural design, and was never of particular significance in the production of functionalist forms of architecture in Britain during the 1930s. There existed a fundamental difference between characteristically-architectural and characteristically-engineering projects. And, only through a team-work approach to design could good modern architecture be achieved in the period in question.

These conclusions entirely vindicate Arup's position. What is surprising, however, is that Arup's reputation, based on his work both before and after the Second World War, is centred on a superficial perception of him as the 'purist' engineer who has produced, or helped to produce, excellent examples of architecture in which the form and structure are combined in a perfect synthesis. This is directly at variance with the evidence presented in this study and one is therefore persuaded that, despite Arup's own attempts to correct this misinterpretation, architects and commentators are still seduced by the idealistic notion of pure structural form in architecture.

ENDNOTES - INTRODUCTION

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8 Scott, G : The Architecture of Humanism (Constable, London, 1914). Reprint edition : Architectural Press, London, 1980.

9 Wotton, H : Elements of Architecture (Gregg, Farnborough, 1969). Fascimile reprint of 1st edition ; J Bill, London, 1624).

10 It is interesting that Reilly maintained that this approach to architectural education was still valid during the 1930s, despite the fact that he approved and encouraged modernist work. He argued that modern architects still needed to learn how to design as classicists with a thorough grounding in traditional constructive principles. In a published debate with Harold Falkner (who accused Reilly of contradicting himself by becoming an enthusiast for modern architecture when he had encouraged the copyist tradition through his Beaux Arts system of education at Liverpool), Reilly wrote:

'The best modern men of today, like Erich Mendelsohn, and Maxwell Fry . . . are men who have passed through the gymnasium of a complete past style whether they had practised in it or not. Far from a sound knowledge of classical architecture, or any other style equally refined, being useless to the modern designer I would say it is essential. I cannot see how otherwise his taste can be trained or how he can have surety in what he is doing. The clumsy modern stuff one sees about, especially in cinema buildings, is no doubt due to the fact that a great many of the younger architects today have not had this training. I fear some of the schools of architecture are thoughtlessly giving it up.'

Reilly, C H : 'Professor Reilly Speaking' ; The Architects Journal, 26 May, 1938 ; pp 893-894 (Reilly Papers Liverpool, reference D207/3/8/17). For full debate see ; The Architects Journal, 28 April, 1938 ; pxxxi ; The Architects Journal, 26 May, 1938 ; The Architects Journal, 23 June, 1938 ; p1055. (Reilly Papers Liverpool, reference D207/3/8).

11 Le Corbusier : Towards a New Architecture (John Rodker, London, 1927 ; translated from the 13th French edition with an introduction by F Etchells) Corbusier's original title was Vers Une Architecture.

12 Meynell, V (ed) : Friends of a Lifetime Letters to Sydney Carlyle Cockerell (Jonathon Cape, London, 1940) Quotation from letter ; Lethaby to Sydney Carlyle Cockerell.

ENDNOTES - PART ONE

CHAPTER 1

1 Stanley, C C : Highlights in the History of Concrete (Cement and Concrete Association Publication, Slough, 1979) p3.

2 The Colosseum (80AD) - some of the arches were reinforced with bronze rods. However, the different rates of thermal expansion between bronze and concrete led to failures. It is probably for this reason that the technique was not applied more widely.

3 Collins, P : Concrete - A Vision of the New Architecture - A Study of Auguste Perret and his Precursors (Faber and Faber, London, 1959) p19.

4 UK Patent 1855 No 2659 (Coignet).

5 ibid n3 p29 (Coignet, F : L'Ingénieur 1 November 1855).

6 UK Patent 1855 No 330 - French Patent 1855 No 22120 (Taken from Lambot's abstract in UK Abridgements 1855 No 330 Class 20).

7 ibid n3 pp 60-61.

8 Baker, A L L : 'The Growth of the Concrete Industry' ; The Engineer, Centenary Number 1956 ; pp 179-180.

9 UK Patent 1854 No 2293 (Wilkinson).

10 UK Patents : 1870 No 3398 ; 1871 No 2703 ; 1874 No 1246 and No 2128 (Brannon).

11 ibid n3 p38.

12 For example, Potter, T : Concrete, its uses in Building (1877). Potter himself took out a number of patents in the late 19th century - two relating to shutter systems, one to fireproof floors and one to hollow pot floors forming 'T' beams. UK Patents 1874 No 3945 ; 1892 No 2899 ; 1898 No 23568 ; 1901 No 16400.

13 ibid n3 p38.

14 UK Patents : 1885 No 14726 (Lee and Hodgson) ; 1887 No 14554 (Lee).

15 UK Patent 1895 No 22518 (Johnson).

16 UK Patent 1898 No 4632 (de Man).

17 Hamilton, S B : 'A Note on the History of Reinforced Concrete Building' ; National Building Studies Special Report (No 24, 1951) pp 8-9.

18 UK Patent 1894 No 22793 (Orr).

19 ibid n8 p180.

20 Other UK Patents by T Hyatt : 1873 No 3381 (Honeycombed Walling) ; 1877 No 2968 (Combining Cement and Metal Skeletons) ; 1880 No 3186 (Corrugated Metal Structures) ; 1881 No 934 (Metal Lathing for Centering) ; 1882 No 2549 (Concrete Infill to Steel Skeletons).

21 ibid n3 pp 65-68.

22 Simultaneously in Germany, Monier's patents were being developed, both practically and theoretically by a number of German and American engineers. (ibid n3 p61.) Wayss was the first to purchase the German rights and he was followed by R Schuster who obtained similar rights in Austria in 1880. Schuster and Wayss later formed an alliance which in 1893 was absorbed into Wayss's own firm of Wayss and Company. Wayss also absorbed the rights which had been obtained from Monier by the two German firms, Martenstein and Josseaux, and Freitag and Heidschurch. In 1886 K Koenen (1849-1924), who had published formulae for the design of reinforced concrete structures, was commissioned by Wayss to develop from the tests Wayss himself had conducted, a system of computation. The results were published in a work entitled 'The Monier System (Iron Skeleton with Concrete Filling) in its application to building'.

The Wayss-Koenen collaboration had by 1890 produced the most advanced theoretical understanding of reinforced concrete. Their theory was based on four principles. First that the steel alone took the tensile stress (many engineers at this time believed that the concrete did provide some tensile resistance - Koenen and Wayss discarded this). Second, that the transfer of forces to the steel took place through the adhesion between the two materials. Third that the coefficient of thermal expansion of the two materials were virtually equal and fourth, that the neutral axis of the beam was at its mid depth. (ibid n17 p4.) Although not entirely accurate, Wayss and Koenen's theories set a precedent in Germany for the scientific calculation of concrete structures.

In France, at this time, the principal developments in the theoretical understanding of reinforced concrete was being undertaken by Edmond Coignet (1853-1915). He was the son of Francois Coignet, originator of 'Beton Agglomières' but unlike his father he had trained as an engineer at the Ecole Centrale des Arts et Manufactures. In 1888 he made his first important contribution to the science by presenting a theoretical paper on reinforcement to the 'Societé des Ingénieurs Civils de France'. In 1890 he took out a patent for the use of reinforced concrete in the construction of pipes, aqueducts and tunnels and in 1892 his proposal to use reinforced concrete for the main sewer system in Paris was accepted by the Parisian authorities. He, like Wayss, conducted numerous tests in collaboration with N de Tedesco from which a working theory was evolved. This formed the prototype for the Modular Ratio Method. (ibid n3 p76.)

Another Frenchman who advanced and applied the theory of reinforced concrete was Armand Gabriele Considère (1841-1916), chief engineer of the Ponts et Chaussées. In 1895 he began an extensive series of tests to determine the resistance of beams and columns. The most significant outcome of these was his suggested replacement of the simple rodded column with a system of helical hooping for which he took out a French patent in 1900 and a British patent in 1902. UK Patent 1902 No 14871 (Considère). By the late 1890s his work on the theory of concrete was sufficiently advanced for Charles Rabut to start a course of instruction on the design of reinforced concrete for students at the Ecole des Ponts et Chaussée. (ibid n17 p6.)

23 Bowley, M : The British Building Industry. Four Studies in Response and Resistance to Change (University Press, Cambridge, 1966) pp 28-29.

24 ibid n17 p9.

25 ibid n3 pp 65-67.

26 UK Patent 1892 No 14530.

27 ibid.

28 UK Patent 1897 No 31043.

29 Concrete and Constructional Engineering, Vol 21, January 1926 ; p89.

30 Ferro-Concrete, Vol 2, 1911 ; p16 and ibid n1 p28.

31 Coignet's early UK Patents : 1904 No 24371 ; 1906 No 14693 ; 1913 No 22812 ; 1914 No 7120.

32 ibid n29 pp 99-103.

33 ibid n29 pp 93-98.

34 Kahncrete Engineering (Trade Journal); Vol XI, No 59, Sept-Oct, 1924.

35 Hildebrand, G : Designing for Industry - The Architecture of Albert Kahn (M I T Press, Cambridge, Massachussetts & London, 1974) p5.

Hildebrand suggests that the Trussed Concrete Steel Co was formed between 1902 and 1903, at the time of Albert Kahn's first major project. This does not correspond to the date given by the Trussed Concrete Steel Co itself.

36 Kahn Trussed Bar ; UK Patent 1903 No 17556 (Kahn, J).

37 Further Kahn UK Patents : 1906 No 5322 (Kahn, J) ; 1916-1919 No 131619 (Kahn, M and Ritchie) ; 1916-1929 No 157140 (Trussed Concrete Steel Co).

38 He had previously worked for the architectural firm John Scott & Co, but only in a junior capacity.

39 ibid n35 p100.

40 ibid n34.

41 ibid n29 p128.

42 Indented Bar : UK Patents 1904 No 21297 ; 1905 No 27026 (Johnson) ; 1907 No 15808 (Johnson).

43 ibid n17 p14.

44 ibid n17 p18 and Concrete and Constructional Engineering, Vol V, 1910 ; pp 707f and 799f.

The only two native British organizations to be established as specialist firms before 1910 were the British Reinforced Concrete Engineering Company and Johnson's Reinforced Concrete Company of Manchester. Both followed the American model in that their prime function was to manufacture and sell patented systems of reinforcement whilst in addition providing a consultancy service to their clients.

The British Reinforced Concrete Engineering Company was formed in 1908 to produce the reinforcement systems patented by R Surtees between 1905-1907. Two of his patents, (1905 No 19403 and 1907 No 19060) referred to stirrup designs formed out of twisted metal. His 1905 patent (No 4540) covered the use of spiral reinforcement for concrete columns, a system which was a slight adjustment to Considère's earlier patent of 1902. This company continued in a small way until 1911 when it was reorganized on broader lines in order to deal with the manufacture of reinforcements as well as the preparations of designs. Most of the company's early work was concentrated in grain elevators, coal bunkers, other industrial structures and, later, bridges. (ibid n29 pp 114-115.) Johnson's Reinforced Concrete Company of Manchester was initially a subdivision of Messrs Johnson, Clapham and Morris Ltd, a firm producing steel wire lattice, which was first used for reinforcing the floors at the Savoy Hotel, London in 1903. (ibid n29 pp 129-130.) Johnson's became an independent company based in Manchester in 1919, producing reinforcements known as the Lattice and Keedon system. They produced a number of important warehouse designs in the north of England during the 1920s. Many of these are worthy of serious attention in the development of industrial architecture. However neither this firm nor the British Reinforced Concrete Engineering Company was as influential as their foreign counterparts until many years after the First World War.

Where native expertise was beginning to develop in the first two decades of the century was in contracting. A review of the important contracting firms specializing in reinforced concrete in Britain up to 1925 reveals that out of a total of thirty firms only two were of foreign origin - both Danish - and nine were sufficiently proficient by 1920 to provide a design service to their clients (Concrete Year Book, 5th edition, 1929 ed. Faber & Childe). It is noteworthy that two eminent reinforced concrete engineers received their practical training in two of the design offices of these latter contractors - Ove Arup at Christiani and Neilsen and Oscar Faber at Trollope and Colls. (The Danish design and contracting firms appear to be the only organizations operating in Britain who were originally established on German developments in reinforced concrete.) A number of the larger contractors were initially allied to the foreign specialist firms either as licensees or recommended contractors. For example, the firm Holland, Hannen and Cubbits, formed from two companies in 1909, though operating at different sections, undertook a large proportion of the work handled by Hennebique and Trussed Concrete (Holland and Hannen are credited with taking up to 50% of the Trussed Concrete Steel Company's capital. - Truscon Review 'The First Fifty Years 1907-1957' p7.) It was not until the 1920s that British engineers could be said to be competent enough to handle reinforced concrete design, without the assistance of the specialist firms.

45 ibid n17 p15.

46 ibid n3 p74.

47 ibid n17 p16.

48 Concrete and Constructional Engineering, Vol VI, 1911 ; p895f ; 'LCC Regulations for Reinforced Concrete'.

49 Vawdrey, R W : 'The Revised Report of the Royal Institute of British Architects' ; Concrete and Constructional Engineering, Vol VII, 1912 ; pp 190-192.

50 Serraillier, L : 'The Reinforced Concrete Specialist' ; Concrete and Constructional Engineering, Vol VII, 1912 ; p93.

51 Concrete and Constructional Engineering, Vol XIV, 1919 ; pp 17-20 'Report of the Special Committee of the Concrete Institute on Relations between Architects and Specialist Engineers'.

52 ibid.

53 A useful survey of early developments in pre-cast concrete construction can be found in : Moore, R P ; 'Innovations and Developments in Heavy Prefabrication. The Liverpool System, its Inspirations and Influence'. Unpublished PhD thesis, University of Liverpool, 1969.

CHAPTER 2

54 Albert Kahn's early life and that of his brother Julius Kahn have been briefly described in the preceeding pages. As regards the early development of Albert Kahn's firm - it was in 1897 that Trowbridge left the partnership Netherton, Kahn and Trowbridge, accepting an academic position at Cornell. Three years later Netherton died leaving Kahn the sole partner of a firm which had not been particularly successful. In 1901 he advertised for an assistant. Ernest Wilby, an Englishman from Harrogate, applied and was appointed to Kahn's staff as chief designer and associate. At the same time Julius Kahn was brought into alliance with the firm to provide the engineering input it required. (It is not exactly clear what precise form this alliance took. Certainly Julius was not employed by Albert, even though they shared the same premises. Therefore, one must assume that he was brought in as a consulting engineer for each individual project.) For information on the Kahn family's early life see ibid n35 pp 5-23. Other publications which describe Albert Kahn's work include: Munce, J F ; Industrial Architecture. An Analysis of Industrial Building Practice (Iliffe Books, London, 1961). Winter, J ; Industrial Architecture a survey of factory architecture (Vista, London, 1970).

Whilst the Trussed Concrete Steel Company worked in collaboration with a number of American architects during this period it is only its work with Albert Kahn which will receive detailed consideration in the accompanying case studies. This is because of the special relationship between both firms and the outstanding success of their resulting buildings. It will be shown that their early American work was of seminal importance to later developments in Britain.

55 Albert Kahn had been introduced to Joy by Joseph Boyer, one of his earliest clients. It would be wrong to suggest that these early Kahn factories were the first to be built of reinforced concrete in America. Ernest Ransome had in 1898 designed and built a four-storey industrial structure for the Pacific Coast Borax Company at Bayonne, New Jersey. It compares favourably with Kahn's early industrial work.

56 This led to other important commissions for the University of Michigan most notably the Arthur Hill Memorial Auditorium (1911). This too, like most of Kahn's non-industrial buildings, was a heavy classically detailed building. Throughout the period under examination, Albert Kahn undertook both industrial and non-industrial projects, although the industrial schemes were his most numerous. A common denominator of his work was its monumentality, for in stylistic terms his non-industrial buildings were almost entirely traditional in their classical expression whilst his industrial schemes proclaimed, in a pragmatic manner, the virtues of modern construction and modern machine production with the forthright expression of concrete and steel frames contrasted with large areas of glazing. (Classical trimmings were frequently used in his early factory buildings but they did not detract from the overall impression of 'modernity'.)

57 'The Typical Factory' (Trussed Concrete Steel Company, 1907) p16. Hildebrand refers to this booklet. The only known existing copy is held by Ms Malbin.

58 Nevins, A and Hill, F E ; Ford The Times, the Man, the Company (Charles Scribner's Sons, New York, 1954) p454.

59 ibid.

60 These German structures owe much of their reputation to the German born architectural historian Nicholas Pevsner in his book: Pioneers of Modern Design (Penguin, London, 1974) pp 204-217. In this re-written edition of 1974, Pevsner casually and incorrectly refers to Albert Kahn's work as 'ordinary steel frame factory buildings' (p204), claiming that in aesthetic terms they were not as advanced as similar German work. It is perhaps significant that in the first edition of this publication - Pevsner, N ; Pioneers of the Modern Movement from William Morris to Walter Gropius (Faber and Faber, London, 1936) - Pevsner includes no reference to Kahn. One is entitled to speculate, therefore, that at the time of the first publication Pevsner was unaware of Kahn's work and in later editions was compelled to include dismissive references to it so as to preserve his argument of the central importance of early German work.

61 Early standard advertisements for these reinforcing materials are available in the firm's trade literature at the Chancery Lane Patent Office (ref OJ 50 - X - Y).

62 As previously stated Moritz Kahn remained the manager of the British company until 1923 when he returned to Detroit to become an associate of Albert Kahn's architects firm. See :- ibid n34.

63 For example : Edmond Coignet Ltd (France) 1904 ; Considère Constructions Ltd (France) 1908 ; The Patent Indented Steel Bar Company (USA) 1906.

64 The system of licensing British contractors was terminated in 1926. In an advertisement in Concrete and Constructional Engineering, Vol XXI, 1926 ; p602 the firm announced: 'As ferro-concrete construction is now so widely employed, Messrs L G Mouchel and Partners Ltd are of the opinion that the original object of licensing contractors no longer exists.'

65 By 1910 Mouchel's firm is reported to have been involved in approximately 40,000 contracts, many of them concerned with piling - see Collins, A R (ed) ; Structural Engineering - Two Centuries of British Achievement (Tarrot, London, 1983) p83.

66 Two of the best well known of Britain's earliest steel framed structures were The Ritz Hotel (London) 1904 and The R A C Building (London) 1909. Both of these structures were clad in masonry adopting the architectural expression of French classicism.

67 Kahn, M : 'The Adaptability of Reinforced Concrete', reported in The Builder, 22 Feb 1908 ; p202.

68 Blomfield, A : 'The Use of Portland Cement Concrete as a Building Material' ; R I B A Sessional Papers, 1871 ; pp 181-183.

69 A young engineer working for the Trussed Concrete Steel Company on this project was Evan Owen Williams. See Chapter 6.

70 Their alliance did not mean that the Trussed Concrete Steel Company reduced its workload with other architects. On the contrary this work still provided a majority of its workload. Wallis's role was to spearhead the development of a particular approach to industrial building design that would be repeated by other architects at the request of their clients.

71 Most of Wallis's early drawings are held in the archives of his grandson's firm, Wallis, Gilbert and Partners, Cardiff. For a history of the firm see :- Architectural Review, Vol CLVI, No 929, July 1974 ; pp 21-27 and Skinner, J : 'Not Just a Pretty Face'. Unpublished BA dissertation, Leicester Polytechnic, 1980.

72 Kahn, M : The Design and Construction of Industrial Buildings (Technical Journals, London, 1917)

73 ibid pv.

74 ibid pp 47 and 48.

75 Some other examples of Wallis's early work with the Trussed Concrete Steel Company include :-

(i) Offices for Caribonum Company, 1918. Illustrated in Architectural Review, Vol CLVI, No 929, 1974 ; p22 ; Wallis, D T ; 'Modern Factory Planning' ; Architecture, May-June, 1929 ; p65.

(ii) Transformer Tank Erection, Manchester for Metropolitan-Vickers Electrical Company Ltd. Kahncrete Engineering, Vol 7, July-Aug, 1920 ; p81.

(iii) Shannon Factory. Wallis, D T ; 'Modern Factory Planning'; Architecture, May-June, 1929 ; p66.

(iv) Optical Instruments Factory, Lewisham. Kahncrete Engineering, Vol 7, Jan-Feb, 1920 ; pp 10-12.

(v) Napier Car Factory, Acton. Kahncrete Engineering, Vol 11, Jan-Feb, 1924 ; p10 Architects Journal 24 March, 1920 ; pp 377-380; ibid n72. Plates XVIII, XIX, XX Architect and Builder's Journal 16 Jan, 1918 ; pp 30-32.

(vi) Albion Works, Glasgow ibid n72. Plates XXXIX, XXX, XXXI, XXXII.

(vii) New Factory at Hayes, Middlesex. (Extension to earlier building by Blomfield. Later extended in the 1920s using flat slab construction.) Kahncrete Engineering, Vol 11, Nov-Dec, 1924 ; pp 104-108.

(viii) Offices for East Surrey Water Company, Redhill, Purley. Architect and Building News, 15 March, 1929 ; p371 Kahncrete Engineering, Vol 8, March-April, 1921 ; pp 27-33.

(ix) Stannards Factory, Leek. Architect and Building News, Vol 119 18 May, 1928 ; pxxxv.

76 There were other examples of non-industrial building in which the designers used the structure of the reinforced concrete frame for the essential elements of the architectural expression. For the most part, however, they were only isolated examples. Studies of two such buildings are included in Vol 2 - Case Studies 9 and 10. These are: St Thomas' School, Birmingham 1916 (Architect - Harrison and Cox ; Engineer - Mouchel & Partners Ltd) and Extension to Children's Hospital, Leicester Royal Infirmary (Architect and Engineer - Everard Son and Pick). The designers of the latter building were also involved in industrial work. This has been noted in a recent history of British industrial architecture: Brockman, H A N ; The British Architect in Industry, 1841-1940 (Allen and Unwin, London, 1974) pp 131-132.

77 Wallis's most well known examples of such buildings for American clients were his Firestone Building and the Hoover Factory on the Great West Road, London.

CHAPTER 3

78 According to the trade journal Kahncrete Engineering the American client for the Wrigley's factory insisted on flat slab construction because of its speed of construction. See - Kahncrete Engineering, Vol 14, Jan-Feb, 1927 ; pp 2-5. Wallis also referred to this speedy construction in his draft notes of a lecture to the R I B A (Wallis archive Cardiff - lecture notes - 'I have great pleasure in coming here to give you a few notes on my experience on industrial buildings' pp 2-3.)

Although the Trussed Concrete Steel Company was instrumental in introducing this technique into Britain, it appears to have had no involvement in its early American development during the first two decades of the 20th century. Its failure to become involved in these early developments was undoubtedly one of the reasons why Henry Ford turned to other concrete specialists to design a number of flat slab buildings after Highland Park.

79 Swiss Patent 1909 No 46928 (System Maillart and Cie). Source : Billington, D P : Robert Maillart's Bridges The Art of Engineering (Princeton University Press, New Jersey, 1979) p55. Billington explains that Maillart began his flat slab work in 1905 and was probably prevented from obtaining an earlier Swiss patent due to the slow development of patent law in that country (The Swiss had no patent law until 1888 and then only an ambiguous one until 1907.)

80 This refers to Norcross patent of 1902 which will be discussed later.

81 Cottam - Arup interview September 1982.

82 US Patent 1902 No 698542 (Norcross).

83 Described by Barton in Engineering News, (New York) 11 April, 1912 ; p694.

84 Final granting of Turner's patent, reported by Engineering News, (New York) 21 September, 1911 ; p354.

85 UK Patent 1906 No 21631 (Turner).

86 Engineering News (New York) 12 October, 1905 and 4 October, 1906 ; pp 361-362.

87 Condron, T L ; 'A Unique Type of Reinforced Concrete Construction' ; Engineering News (New York) 27 January, 1910 ; pp 108-111. Sinks applied for a US patent for this system in 1910.

88 ibid. The $\frac{1}{8}$th scale models (actual size 20 ft square) were tested with loads up to 970 lb per sq ft. Assuming a dead load of 85 lb per sq ft and live loads of 150 lb per sq ft they were able to achieve a factor of safety of 3 - theoretical ultimate strength being 705 lb per sq ft. They also assumed that the models would take the same load as full size examples - not $\frac{1}{8}$th of the load.

89 Concrete and Constructional Engineering, Vol 10, Jan 1915 ; pp 77-84.

90 Engineering News, 29 February, 1912 ; p403. Engineering News, 20 November, 1913 ; p587.

91 US Patent 1911 No 985119 (Turner). Amended specification US Patent 1911 No 1003384.

92 Reported in Engineering News, 18 April, 1912 ; p750.

93 Reported in Engineering News, 5 February, 1914 ; p329.

94 Eddy, H T ; 'A Comparative Test of Two Full Size Reinforced Concrete Flat Slab Panels' ; Engineering News, 27 March, 1913 ; pp 624-628.

95 Letter by C A P Turner to Engineering News, 29 May 1913 ; p1140.

96 Engineering News, 24 June, 1915 ; p1245 'Another 'Final' Decision - Flat Slab Patent'.

97 ibid.

98 Engineering News, 24 September, 1914 ; pp 632-635.

99 ibid n23 p53.

100 One of the letters to the Engineering News reveals this dilemma which faced the engineering profession in America - see Engineering News, 21 October, 1915 ; p803.

101 Wynn, A E ; 'The American Flat Slab Type of Building : Its Advantages and Design' Concrete and Constructional Engineering, Vol XVI, 1921 ; p98.

102 Formerly the Concrete Institute - name changed in 1922.

103 ibid n85. Turner had been granted a UK patent in 1905 No 5202. This was for a floor system which combined precast beams with an insitu concrete floor slab. It was devised by Turner in collaboration with John Wunder, a building contractor from Minneapolis.

104 UK Patent 1909 No 4807 (Leslie & Co and Dyson).

105 ibid.

106 UK Patent 1910 No 27082 (Thomson and Thomson).

107 UK Patent 1912 No 13696 (Lindau).

108 Further British flat slab patents :
(i) UK Patent 1911 No 13946 (Turner) - three variations on the mushroom technique, one flat slab and two with girders included.
(ii) UK Patent 1912 No 19575 (Wunder) - a variation on Turner's system.
(iii) UK Patent 1916 No 100457 (Barton) - simplified unit of prefabricated reinforcement for slab over column heads.

109 UK Patent 1912 No 6201 (Kahn, J - communicated from Detroit).

110 Hollow Pot System UK Patents : 1909 No 20596 (Eichberg) and 1912 No 11507 (Schmeling).

111 The Builder, 28 April, 1911 ; p517. The Builder, 9 June, 1911 ; pp 720-721. Two buildings by Turner : Snead Building and Louisville Toledo Lamp Factory, G E C.

112 Concrete and Constructional Engineering, Vol VI, 1911 ; pp 920-929 (reprinted from Engineering News (New York), 22 December, 1910 ; p697f).

113 Thompson, S E : 'The Practical Design of Reinforced Concrete Flat Slabs' ; Concrete and Constructional Engineering, Vol VIII, 1913 ; pp 27-35.

114 Taylor & Thompson : Concrete Plain and Reinforced (1911 2nd edition) as cited in ibid.

115 Concrete and Constructional Engineering, Vol X, 1915 ; pp 77-84.

116 Engineering News (New York), 19 March, 1914 ; pp 600-603 : 'Special Features of a Concrete Building'.

117 For example : Thomson, W M S : 'Flat Slab or Girderless Floor' ; Concrete and Constructional Engineering, Vol XIII, 1918 ; pp 760-762.

118 Owen Williams's Wembley Stadium Drawing (Birmingham Office) No 154 - E55 ; MF 1932.

119 Flat Slab System at Norwich. Concrete and Constructional Engineering, Vol XX, 1925 ; pp 600-607 'New Reinforced Concrete Building Embodies Latest American Methods'.

120 The flat slab portion of the factory was a three-storey structure occupying a site area of only 144 ft x 35 ft. Each floor was divided longitudinally into two bays by a row of centrally placed hexagonal columns, 17 in in diameter with mushroom heads, at 18 ft centres. The external columns were 15 in square with cantilever brackets projecting out 20 in under the floor. These columns supported a $6\frac{1}{2}$ in deep floor slab reinforced on the four-way system. Above each column head a drop panel was included in the floor slab to improve its shear resistance. The windows in the manufacturing area extended to the underside of the ceiling at each floor level thus providing maximum daylight provision and below cill level each bay was infilled with brickwork. The remainder of the concrete frame was left exposed.

121 ibid n119.

122 Wrigley Factory, see - Kahncrete Engineering, Jan-Feb, 1927 ; pp 2-5. EMI Building, Hayes, see - Architect and Building News, 22 August, 1930 ; pp 232-237.

123 Shredded Wheat Factory, see - Kahncrete Engineering, Sept-Oct, 1926 ; pp 83-87.

124 Architect and Building News, 22 August, 1930 ; p233.

125 Lords Cricket Ground - see Case Study No 11.

126 McIlmoyle, R L : 'Reinforced Concrete Railway Bridges ; Concrete and Constructional Engineering, Vol 25, 1930 ; pp 37-45.

127 Twenty shipyards in Britain were developing concrete ships between 1917 and 1919. Similar developments were taking place in America and Norway. 1917-1920 Concrete and Constructional Engineering reported extensively on different systems. For detailed material of developments at one of these yards see Owen Williams's Papers at Birmingham (Concrete Ship Files).

128 One of the most successful patented systems was the Manchester System by Heathcote and Osborne. (UK Patents : 1916 No 115457 and 1918 No 119987.) Applied at Ford Motor Works, London - see Concrete and Constructional Engineering, Vol XIII, 1918 ; p70f.

ENDNOTES - PART TWO

CHAPTER 4

1 The Preliminary and Interim Report of the Committee on Reinforced Concrete, appointed by the Council of the Institution of Civil Engineers, on 15 December 1908 was published in Concrete and Constructional Engineering, 1910 ; pp 707-719 and p798f. It consisted of 7 memoranda:

Memorandum A - analysed various systems of reinforced concrete available in Britain. Of the thirteen organizations listed only four were indubitably British. Of these four only two provided a design service to their clients, being primarily concerned with the distribution of reinforcing material.

Memorandum F - six engineers with a particular interest in reinforced concrete were asked to explain the circumstances in which they used the material. Five admitted using reinforced concrete specialist firms to undertake the entire structural design, their own role being restricted to checking calculations. A Mr Webster was the only respondent who claimed to design in reinforced concrete himself, but added that often his clients insisted on the employment of a specialist.

2 Wallis lecture notes to R I B A (Wallis's Papers, Wallis Gilbert and Partners, Cardiff - Item marked 'INCEPTION - I have great pleasure in coming here to give you a few notes on my experiences of industrial buildings') p5.

3 ibid. (Item marked - 'I am sorry that time did not permit of my answering the questions raised on February 20th') pp 3 and 4. The only building he admitted designing with a consulting engineer was the Victoria Coach Station (engineer - Oscar Faber).

4 Biographical details have been taken from an unpublished history of the firm: Faber, J ; Oscar Faber and Partners - The First Fifty Years ; unpublished manuscript, 1981 ; pp 4-6. Harald Faber (1856-1944), Oscar Faber's father, had studied natural sciences at Copenhagen University, graduating in 1881. Employment ; first in Denmark, then the USA and finally Britain in 1884. In 1888 he was appointed Agricultural Commissioner for Denmark, centred in London. On their retirement in 1929 Oscar Faber's parents returned to Denmark.

Oscar, the first of six children, was brought up entirely within the British culture and always regarded himself as British. This is an important fact, for it is necessary to make clear that he had no connection with the Danish concrete industry of the 20th century which produced many important engineers of Faber's generation, some of whom worked in Britain during the inter-war period and beyond (eg Christiani and Nielsen, Holst, Kier, Lind and Arup). Erik Faber, Oscar's younger brother also became a civil engineer establishing his own practice in Hong Kong. (p7).

5 Unwin was one of the leading figures in the Institution of Civil Engineers at that time and was taking an interest, though not of a pioneering kind, in reinforced concrete. In 1906 he was elected vice-chairman of the R I B A 's Committee

on Reinforced Concrete. In 1911-1912 he was president of the Institution of Civil Engineers.

6 Taylor and Faber's work was published in 1908: Taylor, P C, Glenday, C, and Faber O ; 'The Design of Ferro-Concrete Chimneys', Engineering Vol 85, 13 March, 1908 ; pp 325-326. The following year Faber took out a patent in his own name ; UK Patent 1910 No 19760 (Chimneys and C).

7 Faber, O ; 'Economy in Ferro-Concrete Design' Engineering Vol 86, 7 Aug, 1908 ; pp 163-164. 14 Aug, 1908 ; pp 197-198

8 For the origins of the Patent Indented Bar Company see Chapter 1 p33.

9 Owen Williams worked for this firm as a junior engineer while Faber was still there - in 1911. There is no evidence to suggest that they established any relationship at this date.

10 Baker, A L L : 'The Growth of the Concrete Industry' The Engineer, Centenary Number, 1956 ; p182.

11 Faber introduced the concept of 'secondary stresses due to shear'.

12 Serialization in Concrete and Constructional Engineering, Vol XI; 1916 and Vol XII; 1917. The thesis was later published as a textbook : Faber, O : Reinforced Concrete Beams in Bending and Shear (Concrete Publications, London, 1925). In this Faber challenged contemporary design methods based on elastic theory suggesting an alternative based on ultimate loads and safety factors very similar to the limit state theory as used in CP 114 of 1948. In his preface he wrote:

'Apart from the fact that formulae becomes less rational when the elastic limit is passed, it is really the factor of safety on ultimate loads which is of most immediate practical value. An engineer is more concerned with what load his beam will carry than at what load the proportionality of load and deflection ceases'.

13 Faber, O and Bowie, P G : Reinforced Concrete Design (Edward Arnold, London, 1912).

14 It was not the first British textbook on reinforced concrete design. The first was published in 1904. Marsh, C F and Dunn, W : Reinforced Concrete (A Constable and Co., London, 1904).

15 ibid n13 pp 256 and 257.

16 The firm was later renamed Trollope and Colls Ltd. It was formed in 1903 with the amalgamation of two well established London contractors : George Trollope and Sons, Westminster (1778) and Colls and Sons, City of London (1840).

17 In addition to his research work on structural analysis of reinforced concrete structures Faber did take out a number of patents: UK Patent 1908 No 12443 (Concrete Railway Sleepers); UK Patent 1919 No 127482 (Concrete Railway Sleepers); UK Patent 1912 No 7586 (Hollow Pot Floors - a variation on the system developed by Mouchel); UK Patent 1922 No 185327 (Improvements in Rotary Kiln - Faber and Brisio); UK Patent 1930 No 338118 (Floor Boxes for Electric Wiring Conduit).

These patents tend to confirm that Faber was not involved in pioneering new forms and techniques of reinforced concrete structures.

18 ibid n4 p24.

19 Consequently he was obliged to apply his knowledge of the material to improving the efficiency of foundation design and piling systems whilst beginning to learn more about structural steelwork. Paper presented to R I B A on substructure work - see, Faber, O : 'Modern Methods of Construction' ; Concrete and Constructional Engineering, Vol XX, 1925 ; pp 443-447.

20 For example, Owen Williams at Poole ; Christiani and Nielsen at Tilbury ; and Ritchie and the Trussed Concrete Steel Company at Liverpool.

21 Concrete and Constructional Engineering, Vol XXI, 1926 ; p48.

22 ibid n4 pp 18 and 19. On this project he collaborated with Professor Lamb who worked on the inner mechanism. Faber's role was to devise a non-magnetic casting. Naturally, he used concrete with a non-ferrous alloy for reinforcement.

23 J S Vaughan, born 1895, was employed by Faber after his graduation in civil engineering from the City and Guilds in 1920. He remained with Faber throughout his career, becoming a partner of Oscar Faber and Partners in 1945.

24 Although Faber enjoyed his work as a structural engineer he was frustrated by the specialization in the building industry which removed him from playing an important role in civil engineering. (J Faber - Cottam interview 1st March, 1983).

25 Faber, O : 'Plastic Yield, Shrinkage and other Problems of Concrete and their Effect upon Design' ; Proceedings of the Institution of Civil Engineers, November, 1927. The tests themselves were undertaken by Harry Stanger working under Faber's direction. Faber's findings were confirmed by Granville at the B R S in 1928-1929. Hamilton in his report on the history of reinforced concrete referred to Faber's paper as a 'bombshell' : Hamilton, S B : 'A Note on the History of Reinforced Concrete in Buildings' ; National Building Studies Special Report, No 24, 1956 ; p21.

26 Freyssinet led the field in prestressed concrete. Faber's work on 'plastic yield' confirmed scientifically Freyssinet's assumptions, enabling him to establish his theory of prestressing in the early 1930s. - see, Stanley, C C : Highlights in the History of Concrete (Cement and Concrete Association, publication, Slough, 1979) p36.

27 Evan Owen Williams was born in 1890, the son of a Tottenham grocer who had moved to London from the Lleyn peninsula some years before Owen's birth.

28 ibid n9. It was earlier known as the Patent Indented Bar Company. In 1911 it was enlarged to undertake reinforced concrete design on a larger scale while continuing to supply its reinforcement - hence the change in name.

29 Architect and Building News, 11 Sept, 1912 ; p285.

30 Williams's curriculum vitae (2 pages only). Williams's private

papers (Sir Owen Williams and Partners, Birmingham Office - referred to later as the Williams's Papers Birmingham).

31 Williams's Papers Birmingham : Photograph File ; Author's reference A/2/1 - Includes a number of photographs of this structure. Calculations File ; Author's reference A/4.

32 See Chapter 2 p54.

33 The Williams's Papers Birmingham contained Williams's own marked copies of Engineering News (New York) from 1921-1934.

34 Blomfield, A : 'The Use of Portland Cement Concrete as a Building Material' ; R I B A Sessional Papers, 1871 ; pp 181-183.

35 The name General and Marine Concrete Construction (Williams System), Poole appears on all the title blocks of his drawings and in letter headings to Kirkaldy's Laboratories, London. (Williams's Papers Birmingham). The evidence available of his work in this capacity is a little fragmented. His papers include extensive laboratory test reports from Kirkaldy's Laboratories in London; a series of his own sketches and calculations; and a number of photographs of ships under construction and completed. Published evidence is to be found in the Patents he was granted during 1918 and an article he wrote for the journal Engineering entitled 'The Economic Size of Concrete Ships'. (See Endnote 36 for details).

36 Patents taken out by Williams for concrete ships and associated works at this time include : UK Patent 1918 Nos 117702 ; 118142 ; 118264. (Reinforced Concrete Ships and C); UK Patent 1917 No 104017 (Construction, reconstruction and strengthening of timber vessels, tanks and C); UK Patent 1918 No 120306 (Slipway for concrete ships, barges). See also : Williams, E O :'Economic Size of Concrete Ships' ; Engineering, Vol CVII, 14 February, 1919 ; pp 195-197 and - Photographs of two completed vessels ; Chetacre (No PD 25) and Chetwell (No PD 29) (Williams's Papers Birmingham).

37 His own criticisms are to be found in an unpublished report he wrote about another system - 'S T Créteropé' (Williams's Papers Birmingham - Author's reference A/5/3/18).

38 The existence of this company and its product 'Fabricrete' does not appear in Williams's own records. These indicate that after the termination of his employment with the Admiralty he established a professional consulting engineers practice in 1919. Whether this information was censored from his records is unclear. However, the existence of the company is confirmed by advertisements in contemporary engineering journals and patent records. Advertisements appeared monthly in Concrete and Constructional Engineering during 1919 and 1920. Patents awarded to the company and Williams include: UK Patent 1919 No 123657 (Stirrups and C for reinforced concrete beams and C) ; UK Patent 1919 No 125241 (Reinforced concrete post piers) ; UK Patent 1919 No 136619 (Reinforced concrete floors and C) ; UK Patent 1920 No 173862 (centring for floors).

39 The development of precast concrete during this period is well documented in : Bowley, M : The British Building Industry. Four Studies in Response and Resistance to Change (University Press, Cambridge, 1966) pp 61-64.

40 One of this company's most important British contracts using precast concrete was the Small Arms Factory, Birmingham. See - Concrete and Constructional Engineering, Vol XIII, October. 1918 ; pp 503-512.

41 See Plate No 54 (Williams's Papers Birmingham 'Concrete Ship File').

CHAPTER 5

42 Baker was a traditional architect of the interwar period and very much a part of the architectural 'establishment'. Although his work was highly regarded as examples of the style - 'free classicism' - many of his buildings were derided for their academic inaccuracies. Charles Reilly, one of the most diplomatic of architectural commentators at that time, wrote of him :
'Sir Herbert Baker always seems to me rather like Wren in being the amateur inspired by fine ideas but sometimes making howlers.'

Architects Journal, 14 January, 1931 ; p61.

43 This was confirmed by Faber's son, John Faber in an interview with the author - 1st March 1983 - Baker and Faber shared office accommodation in the same building during the 1930s.

44 Journal of R I B A, Vol 36, 26 January, 1929 ; p232.

45 The Builder, Vol 128, 8 May, 1925 ; pp 700-701, pp 708-709. The Architects Journal, Vol 61, 6 May, 1925 ; pp 706-715. The three storey basement was constructed from reinforced concrete. Faber devised a special keyed rubber lining to face his shutters so as to provide a good surface on which plaster could be placed. The superstructure was of a steel framework.

46 The environmental engineering of this complex building requires detailed investigation. Faber used the waste products - both the gas and steam - from the diesel generators to supply hot water radiant heating throughout the building. By this means he was able to raise the efficiency of the generators from 30% to 75%.

The highly traditional architectural facades of this building are undoubtedly responsible for the fact that this highly advanced system of environmental engineering has been overlooked by historians such as R Banham in his book The Architecture of the Well-Tempered Environment (Architectural Press, London, 1969).

47 Martin's Bank, Lombard Street, London (Architects - Baker and Scott ; Engineer - Faber) see - Architect and Building News, Vol 124, 28 Nov, 1930 ; pp 715-721. Architects Journal, Vol 73, 11 March, 1931 ; pp 373-377. Also, Lloyds Bank - a neighbouring property in Lombard Street designed by Burnet, Tait and Lorne (Architect and Building News, Vol 124, 28 Nov, 1930 ; pp 715-721). Both buildings were steel framed with classically detailed brick and stone dressed facades.

48 Architect and Building News, Vol 121, 10 May, 1929 ; pp 605-611. Rhodes House was one of Baker's most derided buildings.

49 Concrete and Constructional Engineering, Vol XXV, 1930 ; pp 430-439 - an article by Faber on the reinforced concrete foundations and basement work with brief reference to the steel

framework. The curved facade was faced with Portland stone. See also – Architect and Building News, Vol 119, 16 March, 1928 ; pp 380-385, p718. Architects Journal, Vol 71, 7 May, 1930 ; p727. Architectural Review, Vol 68, Sept 1930, pp 127-129. The Builder, Vol 139, 31 Oct, 1930 ; p728, pp 737-742.

50 Ninth Church of Christ the Scientist (1930). The Builder, Vol 138, 14 March, 1930 ; p512, pp 522-528. The Builder, Vol 138, 9 May, 1930 ; p899. Architects Journal, Vol 73, 14 Jan, 1931 ; p61. Architect and Building News, Vol 123, 21 March, 1930 ; pp 377-381.

51 South Africa House (1932). Concrete and Constructional Engineering, Vol XXVIII, 1933 ; pp 83-84. 'Retaining Wall at South Africa House'. Architects Journal, Vol 77, 29 June, 1933 ; pp 861-863.

52 Royal Empire Society Building (1936). The Builder, Vol 151, 23 October, 1936 ; pp 786-790.

53 Church House Westminster (1939). The Builder, Vol 158, 14 June, 1940 ; p690, pp 696-702. Architects Journal, Vol 92, 4 July, 1940 ; pp 7-13.

54 See Case Study No 11.

55 Projects in which Faber collaborated with Cowles Voysey include the Town Halls at Hastings, Bognor, Worthing, Bromley, Watford, Winchester, Cambridge, Wembley and High Wycombe. ibid n4 p81.

56 The Builder, 1 December, 1939 ; pp 758-761. The building was designed in 1936 – see, The Builder, 14 August, 1936 ; p295.

57 Concrete and Constructional Engineering, Vol XXXI, 1936 ; pp 141-144.

58 Architects Journal, 13 January, 1938 ; p97.

59 Concrete and Constructional Engineering, Vol XIX, 1924 ; pp 151-153. See also – Blomfield, R T : Memoirs of an Architect (MacMillan & Co, London, 1932) p188. Blomfield wrote of this scheme :
'I have a profound admiration for engineers when they are dealing with steel and reinforced concrete construction, but very little when they are dealing with bricks and mortar.'

60 Concrete and Constructional Engineering, Vol XXXII, 1937 ; p212. ibid n57 pp 265-273.

61 For example – Building, July 1928 ; pp 316-321.

62 Reilly, C H : 'Landmarks of the Year' ; Architects Journal, 19 January, 1929 ; p47.

63 The only journal reference to this building appears to be – Faber, O : 'Recent Developments in Building' ; Journal of R I B A, Vol 40, 1932-1933 ; pp 398 and 399. A paper read at the R I B A 20 March, 1933.

64 ibid n4 p105. Restated in Faber – Cottam interview, 1 March, 1983.

65 Faber encouraged engineering students to read books by the following authors; Trystan Edwards, Howard Robertson, Geoffrey Scott and Lewis Mumford, and more particularly:

Edwards, A T : The Things Which are Seen. A Reevaluation of the Visual Arts (P Allan & Co, London, 1921). Robertson, H M : The Principles of Architectural Composition (Architectural Press, London, 1924) -cited in his lecture 'Aesthetics of Engineering Structures' at the Institution of Civil Engineers, April 1941.

66 Faber, O : 'Aesthetics of Engineering Structures' ; Journal of the Institution of Civil Engineers, Paper No 5264, April, 1941 ; p164.

67 Goodhart-Rendel, H S : 'Art and the People' ; Journal of R I B A, Vol 39, 1931-1932 ; pp 685-687.

68 ibid.

69 Journal of R I B A, Vol 39, 1931-1932 ; p764. Letter from Faber to Editor dated 19 July, 1932.

70 Journal of R I B A, Vol 39, 1931-1932 ; p815. Letter from Rendel to Editor dated 26 August, 1932.

71 Correspondence Faber to Goodhart-Rendel, 1 April, 1936. Goodhart-Rendel Papers (R I B A Library - GReH/3/2/1 - 122).

72 ibid n66 p159.

73 Faber, O : 'The Engineer as Designer' ; The Structural Engineer, Vol 12, May 1934 ; p267.

74 ibid.

75 Unfortunately Faber had little direct influence over the educational provision for British engineers at that time, and so he had to use indirect means, such as, published articles and lectures, to keep the issue at the forefront of debate. During the years 1935 to 1936 his attitudes to the problem were given a certain amount of authority due to his elevation to the Presidency of the Institution of Structural Engineers. However, whilst this seniority helped him to forward his ideas, he was acutely aware that the very existence of this Institution reinforced the division between the disciplines of engineering and architecture. He had always opposed the change which had occurred when this institution changed its name and function in 1923 from the previously loose association of all individuals and firms interested in reinforced concrete (then known as the Concrete Institute) to the professionally exclusive body it became. It was partly in an attempt to make up for the losses that such a change created that he, in collaboration with H L Childe, established and published the annual publication The Concrete Year Book from 1924 onwards.

In addition to this he used his influence to try and prevent the further specialization within the engineering profession itself which he thought would exacerbate the divisions (eg throughout his presidency he vehemently opposed the proposed establishment of an Institute of Welding - ultimately unsuccessful). Ideally he would have preferred the professional unification of architecture and engineering under one body with specializations forming part of the whole. However he recognized that such hopes were illusory particularly since his own association with the Structural Engineers prevented him from acquiring any significant position in its parent body - the

Institution of Civil Engineers. If these two bodies had difficulty in integrating there was little hope of unity between the architects and engineers.

76 ibid n66.

77 In a notice published in the Journal of the Institution of Civil Engineers, Vol 17, Nov 1941 ; p4, the profession pronounced its opinion that aesthetics were an important element of the engineers work:
'In response for a request for a pronouncement to be made, the council wish to remind members that the aesthetic treatment of engineering structures falls within the scope of the engineers function.'

Lectures on aesthetics and engineering at the Institution of Civil Engineers following Faber's lecture included: Hindley, C : 'Engineering, Economics, Organization and Aesthetics' ; Journal of Institution of Civil Engineers, Vol 17, 1941-1942 ; pp 49-61. Myers, C S : 'Psychology as Applied to Engineering' ; Journal of the Institution of Civil Engineers, Vol 17, 1941-1942 ; pp 296-315. Goodhart-Rendel, H S : 'Engineering and Architecture' ; Journal of the Institution of Civil Engineers, Vol 17, 1941-1942 ; pp 334-348. Rowse, H : 'Engineer and Architect - Possibilities of Collaboration' ; Journal of the Institution of Civil Engineers, Vol 22, 1943-1944; pp 53-67.

78 Faber, O et al : The Aesthetic Aspect of Civil Engineering Design (Institution of Civil Engineers, London, 1945). In addition to a chapter by Faber the book included other chapters by architects and engineers - Charles Holden, Charles E Inglis, P Abercrombie, G A Jellicoe and E Wadsworth.

79 ibid n65.

80 Edwards, A T : 'The Structural Engineer as Artist' ; The Structural Engineer, Vol 4, 1926 ; pp 25-29, pp 60-64, pp 84-88, pp 126-130, pp 155-158, pp 191-195, pp 221-223 - pp 281-285, pp 310-313, pp 376-379.

81 ibid n66 p160.

82 ibid n78 p9.

83 ibid n66 p161.

84 Architect and Building News, 19 July, 1929 ; p65. Another writer who used Faber's Northolt structure to demonstrate the visual effectiveness of engineering forms was P Morton Shand - Morton Shand, P : 'Biotechnics - Functional Design and the Vegetable World' ; The Architectural Review, Vol 81, 1938 ; pp 21 and 22. (An essay adapted by the author from an article originally composed by the Czech architect Karel Honzik.) Also illustrated in Martin, J L (ed) et al: Circle - International Survey of Constructive Art (Faber and Faber, London, 1937) pp 256-262.

85 ibid n78 p20.

86 ibid p3.

87 ibid n66 p145.

88 ibid p147

89 *ibid* p157.

90 *ibid* p148.

91 It was not known as 'slip form' construction at that time but as 'climbing or sliding shuttering'. There are many late 19th century and early 20th century patents for this technique - most originating in America. For example, UK Patent 1904 No 23720 (Boult - Patent agent for Metcalf Company USA). The first publicized use of the system by MacDonald Engineering Company of Chigago appeared in *Engineering News (New York), Vol 62, No 25, 2 December, 1909* ; p624. In Britain the technique was advertised in the early 1920s by the specialist firm, the Climbing Steel Shuttering Company (see *Concrete and Constructional Engineering, Vol XVI, 1921*). Faber's use of the technique was one of its first largest applications in Britain. It is perhaps significant that Ove Arup's firm, Kier, built Faber's structure at Avonmouth prior to the Highpoint I flats in 1933.

CHAPTER 6

92 Luckhurst, K W : *The Story of Exhibitions* (Studio Publications, London, 1951).

93 The Palace of Industry and the Palace of Arts remain today, used primarily for warehouse purposes. The Palace of Engineering was demolished in the late 1970s.

94 It was undoubtedly for the fourth reason that a young British engineer was chosen in preference to a specialist firm of foreign engineers, such as Mouchel and Partners or the Trussed Concrete Steel Company.

95 *The Builder, 13 February, 1925* (Williams's Papers London). Report on the address by Owen Williams to the Architectural Association on his work at Wembley.

96 *Architectural Review, 24 June, 1924* ; p221.

97 Illustrated in *Concrete and Constructional Engineering, Vol XVII, November, 1922* ; p695.

98 Owen Williams's Drawing No 154 - E - 68 (Williams's Papers Birmingham, Microfilm No 1906, 16 Dec, 1922).

99 Owen Williams's Drawing No 154 - E - 95 (Williams's Papers Birmingham, Microfilm No 1977, 16 Dec, 1922). Maxwell Ayrton's Drawing No 5 (Williams's Papers Birmingham, Microfilm No 1930).

100 Williams's drawings of the stadium, all referenced as No 154 - E - 1f. (Williams's Papers Birmingham, Microfilm Nos 1906-1988 and Nos 1752-1797).

101 Owen Williams's Drawing No 154 - E - 39 (Williams's Papers Birmingham, Microfilm No 1757, undated).

102 Oscar Faber was highly critical of these surfaces. In his article to the *Architectural Review*, he wrote:
'the inside was the roughest looking concrete job I had seen for some time.'

Faber, O : 'The Concrete Buildings' ; *Architectural Review, June, 1924* ; pp 222-229.

103 Concrete and Constructional Engineering, Vol XVIII, 1924 ; p421. Abstract of Williams's paper at the Annual Meeting of the Institution of Municipal and County Engineers.

104 Williams was a subscriber to the American journal The Engineering News Record from 1921 to 1934, bound copies of which he kept throughout his lifetime.

105 Engineering News Record (New York), Vol 86, 24 February, 1921 ; pp 326-329. 'Large Earth Fill Stadium by Sheerbound Method'. Engineering News Record (New York), Vol 89, 4 May, 1922 ; pp 724-726. 'Stamford Stadium Built of Timber on Earth Fill'. Both of Williams's copies of these articles have been marked by him with incidental observations.

106 Engineering News Record (New York), Vol 89, 19 October, 1922 ; pp 640-644. 'Ohio Stadium, a Double-Deck Steel and Concrete Horseshoe'. (Williams's copy is marked). For Williams's lattice steel stanchion details see, Williams's Drawing No 154 - E - 104. (Williams's Papers Birmingham, Microfilm No 1970, undated).

107 Flat slab construction appears to have been used for a small portion of the flooring in the buildings forming the main facade to the Stadium. It seems reasonable to assume, bearing in mind his work with the Trussed Concrete Steel Company, that his precedents for this construction were American. It represents one of the earliest British applications of the technique. Williams's Drawing No 154 - E - 55 and 99. (Williams's Papers Birmingham, Microfilm No 1932 and 1974).

108 Used for the roof construction of the Palace of Engineering and the support structure to the Stadium's terrace. In both he used the lattice girder technique similar to that described for the Ohio Stadium (ibid n106).

109 See Williams's Drawings Nos 154 - E - 265 to 283. (Williams's Papers Birmingham, Microfilm Nos 1861-1879).

110 ibid n95.

111 ibid n103 p423.

112 Ayrton, M : 'A Note on Concrete Buildings' Journal of R I B A, Vol 31, 1924 ; pp 298-302.

113 Williams's Drawings, Microfilm No 25001 and No 25016 (Williams's Papers Birmingham).

114 From Williams's drawings it is clear that he had no involvement in the design of the pylons. On one drawing it is noted - 'For pylon details see architects drawing'. (Williams's Papers Birmingham, Microfilm No 25040).

115 Ayrton, M : 'Modern Bridges' ; Journal of R I B A, Vol 38, 16 May, 1931 ; p487.

116 For example - Williams, E O : 'The Effective and the Efficient' The Studio, Vol 101, February, 1931 ; pp 79-83.

117 Brief details of the A9 road and bridge construction were outlined in a paper delivered to the Institution of Civil Engineers by Robert Bruce (Chief Engineer). Minutes of Proceedings Institution of Civil Engineers, Vol 232, Paper 4812, 1930-1931 ; pp 113-130. 'The Great North Road over the Grampians'.

118 Evidence of these conditions can be noted from the extensive piling required. See Williams's Drawing No 247 / 2 (Williams's Papers Birmingham, Microfilm No 25085).

119 Williams's Drawings Nos 247 / 1, 2, 7, 14-16. (Williams's Papers Birmingham, Microfilm Nos 25084, 28085, 25095, 25097-25099).

120 No drawings remain of these schemes in Williams's collection. However the bridges are still in existence although the Crubenmore bridge is no longer in use.

121 Williams's Drawings Nos 246/1-12 (Williams's Papers Birmingham, Microfilm Nos 25073-25083).

122 Williams's Drawings Nos 248/4-18 (Williams's Papers Birmingham, Microfilm Nos 25103-25117. Dated April 1926 to January 1927). Also described in: Concrete and Constructional Engineering, Vol XXIV, May, 1929 ; pp 281-285.

123 The mass concrete bridge at Sidney, Ohio was described in - Engineering News Record (New York), Vol 91, 11 October, 1923 ; pp 586-590. Williams's personal copy of this article is marked. Although much larger than the Wansford bridge the structural arrangement and overall concept are very similar. It seems reasonable to assume that Williams used this as his precedent, in a similar way that he borrowed from American practice in the design of the Wembley Stadium.

124 In lectures on his work at Wembley, for example, Williams frequently referred to his economic use of mass concrete for the foundations. ibid n95 and ibid n103.

125 See Case Study No 23.
Duntocher Bridge (1927) Williams's Drawings Nos 261/1-261/12 (Williams's Papers Birmingham, Microfilm Nos 25118-25130).
Dalnamein Bridge (1927) Williams's Drawings Nos 328/1-328/4 (Williams's Papers Birmingham, Microfilm Nos 25184-25187). First outline drawing January 1926, bulk of drawings April 1927.
Carr Bridge - no drawings remain and the bridge has been demolished. Photographic sources only - Concrete and Constructional Engineering, Vol XIV, May 1929 ; pp 285-287.

126 Lochy Bridge (1927) Williams's Drawings Nos 336/1-336/12 (Williams's Papers Birmingham, Microfilm Nos 25188-25199). The scheme as built was very similar to a smaller bridge erected in Ohio, America - overall span 116 ft. It is illustrated in the Engineering News Record (New York), Vol 91, 2 August, 1923 ; p191. This issue is not available in Williams's own bound copies suggesting that he kept it back for his own use and misplaced it.

127 Montrose Bridge (October 1927-1928) Williams's Drawings Nos 323/1-323/45. (Williams's Papers Birmingham, Microfilm Nos 25141-25155 and 25168-25181). also - Architect and Building News, 27 Feb, 1931 ; p305.

128 See Engineering News Record (New York), Vol 107, 20 August, 1931 ; p300 ; Vol 107, 1 October, 1931 ; p540 ; Vol 107, 12 November, 1931 ; p784 ; Vol 108, 28 January, 1932 ; p145 ; Vol 108, 10 March, 1932 ; p375.

129 Waterloo Bridge (1932) Williams's Drawings Nos 394/3-394/8 (Williams's Papers Birmingham, Microfilm Nos 25260-25263).

130 Daily Express, 12 September 1932.

131 Evening Standard, 12 October, 1932.

132 Letter to The Times, quoted in full in Concrete and Constructional Engineering, Vol XXVII, October, 1932 ; p281f.

133 ibid.

134 Photograph of his alternative proposal (perspective) in drawing collection at Williams's Birmingham Office. (Author's reference A/2/2).

135 For Scott's scheme see - Architects Journal, 13 June, 1935. Engineering details in - Journal of Institution of Civil Engineers, Vol 20, Papers 53 and 59, 1942-1943. Engineers - Rendel, Palmer and Tritton.

136 Morton-Shand, P : 'Concrete and Steel' Architectural Review, Vol 72, November, 1932 ; p176.

137 Architect and Building News, 20 Sept, 1929 ; pp 346-347.

138 Architects Journal, 22 July, 1931 ; pp 105-107. Concrete and Constructional Engineering, Vol XXIV, 1929 ; pp 459-466.

139 Brockman, H A N : The British Architect in Industry 1841-1940 (Allen and Unwin, London, 1974) pp 150-151.

140 Other important buildings for which Williams designed the reinforced concrete structure between 1928 and 1929 include:

(i) Salford Trades Exhibition Building (never built) Architect: Robert Atkinson. See - Williams's Account correspondence re - fees 1928 (Author's reference A/5/2). Architect and Building News, Vol 119, 27 April, 1928 ; pp 603 and 608. Architect and Building News, Vol 119, 11 May, 1928 ; p685.

(ii) Daily Telegraph, Fleet Street Architects: Elcock and Sutcliffe with Sir John Burnet. See - Williams's Account correspondence re - fees April 1929 - June 1930 (Author's reference A/5/2). Architects Journal, Vol 126, 6 February, 1929 ; pp 239-245. Architect and Building News, Vol 124, 19 December, 1930 ; pp 813-819.

(iii) Farm Buildings, Wappingtham, Steyning, Sussex Architect: Maxwell Ayrton. See - Architects Journal, 14 Jan, 1931 ; p95f.

141 British Engineers Export Journal, July, 1924. Quotation from unnamed London newspaper (Williams's scrapbook, Sir Owen Williams and Partners, London Office).

142 ibid.

143 In the light of his decision in 1929 to unite these roles himself by practising as an architect/engineer, it might be suggested that he intended his collaboration with Ayrton to be a time in which he could develop his own architectural skills before uniting the two roles himself in a subsequently successful architectural practice. This however, seems highly unlikely.

144 *Journal of the R I B A, Vol 32, 4 April, 1925* ; p338.

145 *ibid* n112 p298.

146 *ibid* n112 p299.

147 Williams, E O : 'The Economic Proportioning of Reinforced Concrete Construction', unpublished MS (Williams's Papers Birmingham. Author's reference A/4/2/8. 'The increasing recognition of reinforced concrete as an economic and adaptable material of construction has been reflected in the number of publications devoted to this study.') p4. Whilst this manuscript is undated one can assume that it originated from the period in question. This is supported by the fact that Williams rejected collaboration with architects after 1929, and in his own 1930s' projects largely ignored the special concrete finishes which Ayrton had developed for their joint work.

148 *Journal of the R I B A, Vol 32, No 11, 4 April, 1925* ; pp 329-340.

149 *ibid* p336.

150 *ibid*.

151 *ibid* p338 (present author's emphasis).

152 See Case Study No 22.

153 *ibid* n151.

154 It is uncertain as to whether the Wansford bridge was intended to be any more permanent than other bridges designed by Williams. It is far more probable that the style adopted was primarily responsible to Ayrton who was attempting to meet the Ministry's requirement for a sensitively designed scheme in this particular locality.

155 Williams, E O : 'The Philosophy of Masonry Arches' ; *Selected Papers of the Institution of Civil Engineers, No 56, November, 1927*. Originally in *Proceedings of the Institution of Civil Engineers, No 4618, 1927*. (The other paper for which he was awarded the Telford Gold Medal was 'The London to Birmingham Motorway, Luton - Dunchurch, Design and Execution' ; *Proceedings of the Institution of Civil Engineers, No 353, April, 1960*).

156 It is noteworthy that many of his sources for this paper were American (both in bridge structures he analysed, from the pages of the E N R, and in his literature references). This fact adds weight to the argument that the precedent for the Wansford Scheme was the Ohio structure. Indeed it seems highly probable that the paper was based on information that Williams had initially collected as the research data he needed for the design of the Wansford structure.

157 Williams, E O : 'Beam and Slab Concrete Highway Bridges to Carry Ministry of Transport Loadings' ; *Journal of the Institute of Municipal and County Engineers, Vol LII, No 19, 16 March, 1926* ; pp 985-991.

158 *ibid* pp 985 and 986 (present author's emphasis).

159 Williams, E O : 'Towards Simplicity' ; *Concrete and*

Constructional Engineering, Vol XXI, January 1926 ; p19 (present author's emphasis).

160 Scheffauer, H G : Erich Mendlesohn, Structures and Sketches (Ernest Benn, London, 1923). This is the only architectural book in what remains of Williams's Papers Birmingham.

161 See Case Study No 24.

162 ibid n115 p492.

163 Best illustrated in Williams's proposition for debate at the Architecture Club, February 1931 - 'that there is no fundamental difference between Architecture and Engineering'. Opposed by Goodhart-Rendel and Howard Robertson. See - The Architect, 6 February, 1931.

164 Williams, E O : 'Building of Tomorrow III' ; Building, August 1929 ; p344.

165 Aberdeen Press 12 February, 1930. Report on Williams's paper to the Aberdeen Association of Civil Engineers, 'How to Achieve Beauty - Defects of Modernist Designs'.

166 O T Williams - Cottam interview February 1982.

167 Invitation card to the Architecture Club's 1930 Annual Dinner at the Savoy Hotel. (Ove Arup Papers, Sir Ove Arup and Partners, London Office).

168 ibid n115 p491 (present author's emphasis).

169 ibid n165.

170 MARS Papers, ArO/1/5/7 (i), 21 January, 1935 (R I B A Library). Proposed by Morton Shand, seconded by Coates in Minutes of Central Executive Committee.

171 ibid n165.

172 Le Corbusier : Vers Une Architecture (Paris, 1923). Translated by F Etchells and published in English by Rodker, London, 1927.

173 Bush, D J : The Streamlined Decade (New York, 1975).

174 Engineering News Record, Vol 99, No 25, 23 June, 1927 ; p1034. (Williams's copy marked by him).

175 ibid n165.

176 ibid n155 p4 (present author's emphasis).

177 Williams, E O : 'A Concrete Thought' Architectural Review, November, 1932 ; p162. (present author's emphasis).

178 ibid n116 pp 82 and 83.

179 ibid n177.

180 Williams, E O : 'The Portent of Concrete' Concrete and Constructional Engineering, Vol XXVII, January, 1932 ; pp 42-43, also, The Architects Journal, 23 December, 1931.

181 Faber, O : 'The Portent of Concrete - An Answer to Sir Owen Williams' ; The Architects Journal, 20 June, 1932 ; pp 121 and 122.

182 ibid.

183 To provide some evidence of the limitations of Williams's engineering abilities it would be useful to use the unfortunate consequences that resulted from a steelwork structure Williams designed in 1940. The building was a 1 million sq ft war 'shadow factory', commissioned by the Air Ministry for Vickers-Armstrong on a site in Blackpool. Although a highly secretive venture, a few letters and photographic records remain to enable a general history to be compiled.

It was envisaged as a temporary, single-storey structure, and for these reasons plus the speed of construction required, a structure of steelwork seemed the most sensible proposition. This seems to be why a Mr Cunningham of the steel fabricators Sir William Arnold & Company questioned the client at the outset of the design project about the suitability of Williams's appointment, recognizing his specialism in concrete:
'Today they tell me you have chosen Sir Own Williams and conclude that the work will be mainly reinforced concrete. There may be reasons for this . . . but I cannot think if these buildings are not going to be required after the war that it is a cheap form of construction. The Wembley Exhibition indicated the futility of reinforced concrete in temporary buildings, and I do not think the first cost is cheaper or that the rate of construction can be quicker than steel.'
(Correspondence Cunningham to Dumbar, 17 November 1939. Williams's Papers Birmingham. Author's Reference A/5/3).

The return letter clarified both the decision to use steel and not concrete and Williams's appointment.

There is a dearth of information on the type of structure designed and an absence of drawings and any further correspondence. However from extensive photographic records in Williams's papers, his built solution appears to have collapsed half way through the construction period. It would be wrong to place too much significance on this failure and to conclude that Williams's abilities as a steelwork designer were severely limited. However it does indicate that by 1940 his name had become inextricably linked with reinforced concrete and it does suggest that his specialism did exclude other building materials. The final irony of this particular incident however, was that Oscar Faber was brought in by the client to complete the project. (Faber - Cottam interview, 1 March, 1983. Oscar Faber's son was not prepared to discuss detail - merely to confirm that his father took over Williams's role in the contract).

184 The client's name was the Dorchester House Syndicate Ltd which formed part of the larger hotel group Gordon Hotels Ltd. Directors : Sir Francis Towle (Managing Director) ; Sir Malcolm McAlpine ; Major General Guy Dawnay ; John Rothwell Milne. (Letter heading of correspondence received by Williams, see - Williams's Papers Birmingham. Author's reference A/5/1).

185 Other Williams's projects which McAlpine's built included ; the Duntocher, Findhorn, Spey and Montrose Bridges.

186 McAlpine was one of a few directors comprising the Dorchester House Syndicate Ltd, the client for the proposed new building which formed part of the larger hotel group Gordon Hotels Ltd. The project was clearly intended to be a 'modern' building from the outset for in 1928 the first architects commissioned

were Wallis Gilbert and Partners (see The Observer, 23 February, 1930), the firm which was just completing work on the Firestone factory on the Great West Road. However, little progress was made on their design due to protracted debate with the consulting architect to Gordon Hotels Ltd, P Morely Horder, whose main brief was to ensure that the completed building harmonized with the surroundings, as envisaged by the Duke of Westminster's consultant Sir Edwin Lutyens. To make up for lost time McAlpine and his directors decided on an entire change and approached Williams to take over the scheme. (Lutyens had been used as consultant architect to an adjoining building on Park Lane - Grosvenor House. He was largely responsible for the facades with the planning undertaken by Wimperis,Simpson and Grutherie. See - Architectural and Building News, Vol 119, 22 June, 1928 ; pp 887-889.)

187 The Yorkshire Post, 28 November, 1929.

188 The Daily Telegraph, 20 December, 1929.

189 The Daily Telegraph, 27 November, 1929.

190 Towndrow, F : 'The Engineer in Park Lane' 'Beauty and Efficiency'. The Observer, 1 December, 1929.

191 In the light of Towndrow's favourable comments, with regard to Williams's appointment, it is surprising that he made no mention to him or his work in his book Architecture in the Balance (Chatto and Windus, London, 1933).

192 Oliver Bernard had been connected with Williams at Wembley - his role in that project being in overall charge of the displays. The story of J M Richards's transfer to Williams's practice is told by him in : The Listener, 11 September, 1969 ; p34, 'A Brace of Original Hotels', and Richards, J M : Memoirs of an Unjust Fella (Weidenfeld and Nicolson, London, 1980) p49f.

193 The Observer, 23 February, 1930 'Concrete in Park Lane'.

194 Anecdotal evidence ; O T Williams - Cottam interview, February, 1982.

195 Daily Chronicle, 8 March, 1930 'New Sensation over Giant Concrete Hotel - Sir Owen Williams Resigns'.

196 In his letter to The Times, 27 March, 1956, Williams replied to a statement made in the papers issue 21 March, 1956, which had referred to Curtis Green and Partners as the architects of the Dorchester Hotel.
'In your issue of March 21, under the heading 'Extension to three London Hotels', with particular reference to the Dorchester Hotel, your report finishes with the sentence " . . . W Curtis Green, Son & Lloyd, who designed the original hotel." I was appointed and did in fact plan and design the original hotel and it was built substantially in accordance with my designs, although during construction, owing to an insoluble disagreement on decoration with the clients, I resigned and thereafter the firm mentioned by you became the architects for the completion.' (Present author's emphasis).

197 On Williams's resignation the drawings were apparently sent to Green's office in a taxi - almost immediately. (Anecdotal

evidence, O T Williams - Cottam interview, February, 1982).

198 The Listener, 11 September, 1969 ; p34.

199 Dorchester file photographs - (Williams's Papers Birmingham).

200 Information on structure from : Concrete and Constructional Engineering, Vol XXVI, April, 1931 ; pp289-303. Architect and Building News, 24 April, 1931 ; pp 105-124. Architects Journal, 22 April, 1931 ; pp 577-582, also - Curtis Green's drawings (Green, Lloyd and Adams, Office, London).

201 To emphasize that these terrazzo panels were not load bearing Williams aligned the vertical joints. This was followed by Curtis Green.

202 ibid n190.

203 Architect and Building News, 24 April, 1931 ; pp 105-124, also, Robertson, H : Modern Architectural Design (Architectural Press, London, 1932) pp 14 and 15. He uses the Dorchester to illustrate how framed structures were liberating the plan and wrongly credited it to Curtis Green.

204 ibid n198.

205 Concrete and Constructional Engineering, April, 1931 ; pp 289-303. Williams was less concerned about the wider architectural significance of his enforced resignation than about the treatment he received at the hands of his client. He is purported to have been very annoyed and although he received fees from them totalling £13,250 (approximately 1% of the contract figure), in retribution he refused to allow McAlpine's to tender for any of his subsequent designs until many years after the Second World War. (Figures taken from Williams's Account Correspondence (A-D) with the Dorchester House Syndicate Ltd January - June 1930. Williams's Papers Birmingham. Author's reference A/5/1).

206 They were, for example, responsible for the design of a series of buildings for Associated Newspapers Ltd - all with the name 'Northcliffe House' - which appeared in different parts of the country from 1927 to 1933. For illustrations of Ellis and Clarke's typical newspaper buildings see : The Builder, Vol 135, Jan-June, 1929 ; p309 'Northcliffe House, London'. The Builder, Vol 36, October, 1929 ; p687 and Architect and Building News, 11 October, 1929 ; plate xxxv 'Northcliffe House, Bristol'. The Builder, Vol 137, 16 May, 1930 ; p944 Architect and Building News, Vol 149, 16 October, 1936 ; pp 71-74. Associated Newspapers Ltd, Victoria Embankment, London.

207 Architectural Review, Vol 69, 1931 ; p211. Illustration of Ellis and Clarke's original scheme. (It is strange that this should be published at this time when work on Williams's scheme was already in progress on site!).

208 This anecdotal evidence was supplied by R E Foot (partner of Sir Owen Williams and Partners) ; Foot - Cottam interview, June 1979. Also O T Williams (Owen Williams's son and managing partner of Sir Owen Williams and Partners) ; O T Williams - Cottam interview, February 1982.

209 See Daily Express Drawings, Nos 390 - 15 and 390 - 16. (Williams's Papers Birmingham, Microfilm 0016 and 0017 dated 19 February, 1930).

210 ibid n206.

211 Williams's Accounts Correspondence File A-D (Williams's Papers Birmingham. Author's reference A/5/1). Seven letters re - fees to Daily Express Building Company, 15 May, 1930 to 27 April, 1934.

212 Details of structure from Williams's drawings Nos 390 - 1 to 390 - 244. (Williams's Papers Birmingham, Microfilm Nos LDE 0001-0228). Also The Builder, 15 July, 1932 ; pp 37-97. Concrete and Constructional Engineering, Vol XXVI, 1931 ; pp 631-636.

213 Goodhart-Rendel, H S : English Architecture Since the Regency (Constable, London, 1953) pp 258-259. Originally a lecture given in 1935 'The Preferment of Engineering'.

214 Chermayeff, S : 'Daily Express' Architectural Review, Vol 72, July, 1932 ; pp 3-12. Although Chermayeff credited the engineering content to Williams, he officially referred to Ellis & Clarke as the architects. Clearly he was unaware of the building's history, particularly of Ellis & Clarke's original scheme, and Williams effective usurption of their role in the design process. Furthermore he was also unaware that Williams had been the consulting engineer to Elcock & Sutcliffe in the design of the Telegraph building, just 3 years previously. (Williams's involvement in Daily Telegraph building 1929 noted from his Accounts Correspondence A-D (Williams's Papers Birmingham. Author's reference A/5/1. Correspondence dates from 15 April 1929 - 27 June 1930).

215 The job number of the Boots building (No 378) predates the Daily Express and the Dorchester - suggesting that Williams started design work early in 1929. Most of the drawings, however, retained by the Boots Company are dated 1930-1931. (There are no drawings existing in Williams's own collection. The Boots Company at Beeston holds all the copy negatives.)

216 Williams, E O : 'Factories - A Few Observations Thereon Made by Sir Owen Williams at a Discussion of the Art Workers Guild, 21 October, 1927' ; Journal of R I B A, Vol 35, 26 November, 1927 ; pp 54 and 55. (The lecture was originally intended to have been given by Thomas Wallis - Williams replaced him due to illness.)

217 Architect and Building News, 8 January, 1932 ; p56.

218 For example : Richards, J M : An Introduction to Modern Architecture (Penguin books, Harmondsworth, 1962, 2nd edition) p85. 1st edition 1940. Banham, R : Guide to Modern Architecture (Architectural Press, London, 1962) p62. ibid n139 pp 169 and 170.

219 This American company purchased Boots from its founder Jesse Boots in 1920. Jesse Boots died in 1931, and at that time the American company was undergoing some financial difficulties. In 1933 Jesse's son - John Boots led a British consortium to bring back the firm into British ownership. (Details from Boot's Information Officer. Also chronicled in ; Walker, E : 100 Years Shopping at Boots (High Wycombe 1977).

220 See later study on the Boots Drys Building, 1937 (Case Study No 36).

221 The first building constructed there was a relatively small soap factory designed by Boot's former architects Bromley Watkins, Crawley and Brothers in 1927. For some reason this firm of architects were not interested in designing the enormous Wets and Drys complex that the company had in mind, and it was for this reason that Williams was approached.

222 Recorded in Williams's own article on the building which appeared in the American journal - Engineering News Record, 25 May, 1933 ; pp 675-676. This was missing from Williams's own bound copies. The Wets portion covered a site area of 6 acres - 700 ft long x 300 ft wide ; only $\frac{1}{3}$rd of the size of the final scheme.

223 Details of the construction have been extracted from Williams's contract drawings, site visit notes and the following journal articles : Concrete and Constructional Engineering, Vol XXVIII, January, 1933 ; pp 12-26 , Building, September, 1932 ; pp 392-401, Architect and Building News, 8 January, 1932 ; pp 50-53 and p93 ; 25 November, 1932 ; p102, The Architects Journal, 3 August, 1932 ; pp 125-139 ; 13 July, 1933 ; pp 53-54, Architectural Review, Vol 72, 1932 ; pp 86-88, pp 169-235.

224 He is reported to have said this to Stephen Rosenberg, an architect employed in his office during the 1960s. Rosenberg - Cottam interview, April 1982.

225 See pages 63-86.

226 See pages 83 and 84.

227 Architect ; F A Broadhead. See - Architectural Review, September, 1933 ; pp 91-93.

228 See pages 69 and 81.

229 See - Engineering News (New York), Vol 71, 19 March, 1919 ; p602.

230 Information supplied by one of Boots's own engineers. Apparently the company have produced many proposals to floor over these areas to provide extra storage space but have been prevented from doing so by the building's listed status.

231 In his book, H A N Brockman describes the Boots factory as being Britain's 'Crystal Palace' of the 20th century, unreservedly acclaiming it to be the most advance piece of industrial architecture created in Britain before the Second World War. See ibid n139.

232 Building, September, 1932 ; p392.

233 For example Reilly said of this building ; 'The factory for Messrs Boots in glass and concrete is of course not so thrilling as the Van Nelle tobacco factory at Rotterdam by Brinkman and Van der Vulzt in the same materials, but one can hardly expect an English engineer in his first experiment to equal two of Holland's best architects. Still it is a great step forward in this land of muddled, illogical factories.' Manuscript for 'The Years Work' The Architects Journal, 1932 (Reilly Papers, Liverpool University, D207/3/5/26).

234 The fact that Williams was a shareholder of Wembley Stadium Limited emerged from a study of his Accounts Correspondence. (Williams's Papers Birmingham, Author's reference A/5/3).

235 Prospectus Wembley Stadium Limited 1933 (Williams's Papers London Office).

236 The Builder, 31 May, 1935 ; p1026.

237 ibid.

238 Details of the planning and structure have been taken from Williams's own drawings Nos 411/1-203 (Williams's Papers Birmingham, Microfilm Nos 1981-2143). Also journal articles : Architectural Review, Vol 76, 1934 ; pp 92-96. Concrete and Constructional Engineering, Vol XXIX, 1934 ; pp 575-579. Engineering, 3 August, 1934 ; p117f. The Architects Journal, November, 1933 ; p555. Architect and Building News, November, 1933 ; p125.

239 See Williams's drawings Nos 411/6, 7, 9 (Williams's Papers Birmingham, Microfilm Nos 2033, 2034, 2036).

240 The building was completed within 8 months of site work. Work commenced on site only weeks after the design had begun. The change to the rectangular fins occurred in March 1934 - see drawing No 411/95 (Williams's Papers Birmingham, Microfilm No 2062).

241 Perlmutter, R and Mark, R : 'Engineer's Aesthetic v Architecture : The Design and Performance of the Empire Pool at Wembley' ; Journal of the Society of Architectural Historians, Vol 31, 1972 ; pp 56-60.

242 ibid.

243 Richards, J M : 'The Pioneer Health Centre' and 'The Idea Behind the Idea' ; Architectural Review, Vol 77, 1935 ; pp 203-216.

244 See Williams's Account Correspondence to the Pioneer Health Centre Limited, February 1934 to August 1935 (Williams's Papers Birmingham. Author's reference A/5/2/P).

245 Information relating to the background to the project and its socio-medical concepts are best dealt with in the book : Pearse, I H and Crocker, L H : The Peckham Experiment - A Study in the Living Structure of Society (Allen and Unwin, London, 1943).

246 Patrons to the Pioneer Health Centre included the names: Earl of Sandavia, Countess Chichester, Earl of Dysart, Lady Henry Bentinok, Viscount Hambleden, Viscountess Wimborne, Viscount Borodale, Bishop of Salisbury, W Trobler, Lord de Ramsey, Lady Redesdalee, Dawayer, Lady Swaythling, Sir Geoffrey Collins MP, Sir Adrian Palook, Lady Jowitt, C J Bond, Walter de la Mare, E J Fox.
The book : Pearse, I H and Williamson, The Case for Action (London, 1930).

247 Musman's perspective for this building was exhibited at the Royal Academy in 1931. Although his building appears to use concrete frame construction in combination with brick and horizontal strips of glazing, in planning terms it was a

rigid classical concept bearing a close resemblance in its general layout to the 'public baths' architecture appearing in many partsof the country at this time. Its rejection suggests that the client had always intended Musman's scheme to act as an additional advertisement for attracting funds.

248 Richards, J M : Memoirs of an Unjust Fella (Weidenfeld and Nicolson, London, 1980) pp 88-90.

249 Richards was not aware of this. Richards - Cottam interview, April, 1982.

250 Correspondence Pearse to Goodhart-Rendel, 23 October, 1933 (R I B A Library; reference GReH/3/1/1-53).

251 Correspondence Goodhart-Rendel to McAlister (R I B A Library; reference GReH 3/1/1-53).

252 It became clear to Rendel that a number of architects had submitted prices, for on 30th October 1933 he wrote again to McAlister enclosing an extract from a letter he had received from Pearse in which she had written:
'I fear that practice has made it clear that even the rough notion of costs shows a wide margin which we presume can only be due to the capability of one designer doing it more cheaply than another.'
He concluded from this ;
'that other architects have not shared my scruples, and if this is so I must say that I think it is a pretty bad example of the kind of thing we are out to stop'
McAlister agreed, informing Rendel that he had asked for the advice of the competition's committee.
(R I B A Library; reference GReH 3/1/1-53).

253 Correspondence Goodhart-Rendel to McAlister, 2 November, 1933. (R I B A Library; reference GReH 3/1/1-53).

254 The present owners have relocated the main entrance in a new staircase block to the south east elevation, thus providing a more congenial entry requirement.

255 It is interesting that Richards in the Architectural Review (ibid n243) went to some lengths to show that the building whilst appearing symmetrical was in fact assymetrical. The reasons for this are unclear for there is little doubt that the building is based on a symmetrical axial arrangement. For example, at 2nd floor level Williams included two identical spaces on the south-east and north-west facades labelled 'study and recreation'. This appears to have been done to preserve symmetry for it is unlikely that two identical spaces of this size were needed. Other journal sources for information on the building include : The Architects Journal, April, 1935 ; p515 and 28 May, 1936 ; p857. Architectural Record, June, 1935 ; pp 437-444.

256 ibid n245 p68.

257 Williams first used this type of column and capital on the Dalnamein Bridge (see Case Study No 23) and later at the Boots Drys Factory and the Daily Express Building, Manchester. (Case Studies Nos 36 and 39).

258 Perspective from Williams's Papers Birmingham.

259 ibid n243 p216.

260 Reference to any architectural journal of this period supports this observation. As also does the publication : Reilly, C H : Representative British Architects of the Present Day (B T Batsford, London, 1931) - a book compiled from earlier contributions to the journal Building. In it Reilly examines the work of a number of traditional architects, excluding such architects as Emberton whom he had included in one of his journal articles.

261 Fry, E M : Art in a Machine Age. A Critique of Contemporary Life Through the Medium of Architecture (Methuan, London, 1969) p105.

262 Resistance to modern architecture in the early 1930s was widespread. The R I B A 's advisory panels to local authorities were particularly influential in preventing modernist designs, as were important client bodies, particularly in commercial work. One of the MARS group's key objectives was to weaken this opposition - one of its most important subsections was entitled 'Obstructions Committee'.

263 MARS Papers 'Enlistment' (R I B A Library ArO/1/2/1 and ArO/1/5/7).

264 It was Shand who had earlier recommended to the Congrès Internationaux d'Architecture Moderne (CIAM), his cousin H Robertson, for leadership of the British group. It was Robertson's failure to form a coherent committed British group which led Giedion (Secretary of CIAM) to ask Shand's advice in forwarding an alternative British name for leadership. Shand suggested Wells Coates, an engineer who had recently decided on a career in architecture, and had already established his theoretical interest in architecture through his earlier formation of the British 20th Century Group in 1930. See - Elgohary, E H : Wells Coates and his Position in the Beginning of the Modern Movement in England . Unpublished PhD thesis, University of London, 1966 ; p71. Architectural Review, Vol LXXX, 1930 ; p425. Shand and Coates prepared the first draft constitution of MARS, 28 April, 1933 (MARS papers, R I B A Library ArO/1/1/23).

265 ibid n136.

266 With, perhaps, the notable exception of Gropius's Banhans building at Dessau, 1925.

267 ibid n136.

268 ibid n136.

269 ibid n264.

270 He also appears to have been the only writer who attempted to raise Faber's engineering work to the category of architecture.

271 Pevsner, N : Pioneers of the Modern Movement (Faber and Faber, London, 1936).

272 This popular view remained folklore for many years. It has since been published. Most notable : Fry, M : How Modern Architecture Came to England (Pidgeon, London, 1980 - Cassette and Slides). Richards, J M : An Introduction to Modern Architecture (Penguin, Harmondsworth, 1962, First ed 1940).

273 Pevsner, N : 'Nine Swallows - No Summer' ; Architectural Review, May, 1942 ; pp 109-112.

274 UK Patent No 408955. Application 13 October, 1932 ; complete 9 October, 1933 ; accepted 13 October, 1934.

275 Design sketches and calculations for Pitstone Laboratories (Williams's Papers Birmingham. Author's reference A/4/6).

276 The Architects Journal, 11 March, 1937 ; p414.

277 Hitchcock, H and Johnson, P : The International Style ; Architecture Since 1922 (New York, 1932)

278 Members of MARS in journalism included :
John Betjeman (Evening Standard) ;
H de Conin Hastings (Editor : The Architects Journal) ;
J M Richards (Ass Editor : Architectural Review) ;
J Summerson (Architect and Building News) ;
V Goldsmith (A director of the BBC) ;
R L Lambert (Editor of The Listener) ;
J Gloag (The Architects Journal) ;
P Morton Shand (Architectural Review)
(Source : List of Membership, MARS papers, R I B A Library ArO/1/2).

ENDNOTES - PART THREE

CHAPTER 7

1 Ove Nyguist Arup was born in Newcastle-upon-Tyne on 16 April, 1895. Both his parents were Scandinavian; his father Danish and his mother Norwegian. The family were in England at that time on account of his father's occupation as a cattle and meat inspector for the Danish government. However, their stay here was short and soon after Ove's birth his father was posted to Hamburg, Germany where the family resided for most of his childhood. At the age of twelve, Arup was sent to boarding school in Sφro, Denmark. While this schooling reinforced his Danish identity, which had to some extent been threatened by his early childhood in Germany, the school itself was modelled on the British public school tradition, thus providing Arup with a background, he has argued, which helped him assimilate to life in Britain when he returned here in 1923. He recalls that his interests during his adolescence were directed towards science and natural history.

Biographical sources : Arup - Cottam interviews and conversations, September - December 1981. 'People Today', 1964. Interview with Ove Arup (Arup Papers, Ove Arup and Partners, Fitzroy Street, London - hereafter referred to as the Arup Papers London).

2 Arup, O N : 'What I Believe' ; unpublished MS, March 1979. (Arup Papers, black file XII, No 53 p3).

3 This is intentionally expressed in Arup's own terms because of the difficulty in interpreting his view of philosophy at this time. All that can be summized is that a broad education in the humanities was beneficial to his engineering career.

4 Arup, O N ; Lecture Notes to AA Students, 1935 (Arup Papers London. Lecture Notes, File No 9).

5 Centres from which Christiani and Nielsen operated in the 1920s were ; Copenhagen, London, Stockholm, Oslo, Paris, The Hague, Hamburg, Rio de Janero, Buenos Aires and Melbourne. See - Concrete and Constructional Engineering, Vol XXI, 1926 ; pp 115-116.

6 The firm's concentration on marine works was largely because reinforced concrete was proving to be the most natural material for this type of work and could beat competition with steel, masonry and timber on economic and structural grounds.

7 Arup, O N ; The World of the Structural Engineer - notes for the Maitland lecture ; unpublished MS, 1968 ; p17 (Arup Papers London).

8 ibid pp 4 and 5.

9 Arup Papers London contain numerous drawings of pier and jetty designs of the 1920s. Cooling Tower Patent - UK Patent 1931 No 363016. Arup, O N ; 'Strengthening Existing Bridges' Concrete and Constructional Engineering, Vol XXI, 1926 ; pp 545-549. Arup, O N ; 'Dolphins with Loose Fillings' Concrete and Constructional Engineering, Vol XXII, 1927.

10 Arup's correspondence with the directors of Christiani & Nielsen

between 1926 and 1933 shows how successful he had been within the company. (Arup Papers London - Correspondence File, Christiani & Nielsen, 21 August, 1926, 16 December, 1927). In January 1928 he was awarded 2% of the London's office profits.

11 Most of this information has been taken from the author's discussions with Arup. (Arup - Cottam interviews and discussions, September - December 1981). See also, ibid n7.

12 ibid n7 p9.

13 Arup has always been antaganistic towards the existence of the quantity surveying profession. Recently he has written: 'I have nothing against quantity surveyors personally and in many cases they are the most useful members of the design team in the present circumstances. But as I have preached in lectures and articles for forty years - I am convinced that the whole system as used in only the British Commonwealth is wrong. Costing should be an integral part of designing . . . costing must act as a check on designing. If something is wrong it is not cured by costing but by better design. What we need is quality purveyors.' (Present author's emphasis). Arup, O N : 'The Engineer Looks Back' ; Architectural Review, November, 1979 ; p320.

14 When Arup decided to become a consulting engineer in 1944, abandoning contracting, his papers indicate that he did so with great reluctance. He prepared handwritten sheets listing the advantages and disadvantages. The principal reason for the change was his desire to spend more of his working life actively designing. (Arup Papers London, Arup & Arup File).

15 Some examples of his work at Christiani & Nielsen include :
(i) Jetty at Hamble (1924) for Messrs Shell Mex Ltd (Ref ON 2817)
(ii) Reconstruction of Stow Bridge (1924) (Ref 7649)
(iii) Open Air Swimming Baths, Bideford, 1928 (Ref 11567/1)
(iv) Jetty at Deptford, 1932, (Ref ON 11749 DN 43)
(v) Jetty at Shad, Thames, 1933 (Ref 1641/3)
(vi) Water Tower at Lowestoft for the Alliance Artificial Silk Ltd, 1929 (Designer : Harold J Turner)
(vii) Cooling Tower Patent (ibid n9)
Drawings of these projects are available in Arup Papers London, file marked 'Christiani & Nielsen'.

16 Arup - Cottam interview, September 1981. Also, many recent articles, some citing Godfrey Samuel as first contact eg Journal of R I B A, April, 1965 ; p176.

17 Arup, O N ; 'The Relation of Reinforced Concrete to Present Day Design' ; Concrete and Constructional Engineering, Vol XXI, March, 1926 ; p234-238.

18 ibid and ibid n9.

19 Richardson, A E ; 'The Relation of Reinforced Concrete to Present Day Design' ; Concrete and Constructional Engineering, Vol XXI, January, 1926 ; pp 37-41.

20 ibid p41.

21 ibid p40.

22 ibid n17 p234.

23 *ibid*.

24 *ibid* p234 and 235.

25 *ibid* p235.

26 Ove Arup was quite surprised himself when shown the article by the author in December 1981. On reading it he was surprised that he had been interested in the subject at this early date. He said - 'It's quite good, isn't it?'

27 The Architecture Club was established in 1921 by Sir John Squire. Its objective - to stimulate architectural debate and public appreciation of architecture. A souvenir of Arup's presence at its annual dinner 1930 exists in his personal papers.

28 Mendelsohn, E : 'Architecture in Concrete' ; *Concrete and Constructional Engineering, Vol XXV, 1930* ; pp 393 and 394 (a transcript of his lecture to the AA).

29 Personal correspondence G Samuel - Cottam, 13 December, 1981.

30 Arup - Cottam interviews and discussions, September, 1981 - January, 1982. Lubetkin - Cottam interview, 7 January, 1982.

31 *ibid* n7 pp 9 and 10.

32 *ibid*.

33 Lubetkin - Cottam interview, 7 January, 1982.

34 Berthold Lubetkin was born in 1901 in Tiflis, Georgia, at that time a state within the Russian Empire. His family were middle class with apparently liberal-progressive politics. The revolution of 1917 had had an important impact on him and it was shortly after the Bolsheviks' success that he became interested in architecture, apparently stimulated by its political significance. It is central to Lubetkin's marxist position that his background should be seen to be based on the premise that art and architecture were instruments for affecting social change. It is suggested that this conviction was the motivation for him to undertake the study of architecture at the age of 19. It is certain that his architectural education in Russia during these post-revolutionary years - 1920-1922, at the Vkhutemus in Moscow and the Svomas in Petrograd - involved intense discussion on the relationship between revolutionary art and revolutionary social change. At that time two schools of thought had emerged. The first was propounded by Bogdanov through the organization 'Proletcult' which insisted on the design and production of utilitarian objects for the needs of proletarian culture. The second was more intellectually based containing people who believed that if art was to fulfil its proper role in society then it was necessary to reassess the whole range of objectives and the means of achieving them in a more abstract way.

Lubetkin found himself attracted to the ideology of the latter camp - that of the Russian Constructivists - and he received part of his early training from two leaders of this movement - Tatlin and Rodchenko. However, the architectural solutions proposed by this group of progressive Russian architects in the early 1920s were visionary and way beyond the technological capacity of a country that was essentially based upon an agricultural and not an industrial economy. We are told that it was this gap between vision and reality which drove Lubetkin to leave Russia in 1922. (There may have also been political reasons for his departure, the date corresponds with the beginning of Stalin's rise to power). From Moscow he moved to Berlin, ostensibly to improve his knowledge of building technology and to learn more of the European art tradition in general. For technical information he attended classes at the Bauschule, which concentrated on the study of reinforced concrete, whilst to learn more about aesthetic theory he went to the Textile Academy. It was in the latter institution that he came into contact with Worringer, a philosopher who he claims to have had an enormous influence on his career.

In 1923 he travelled to Warsaw where he began a formal architectural training at the City's Polytechnic, in an attempt to compensate for the piecemeal manner in which he had acquired his education up to that point. He stayed there until 1925 when he moved to Paris continuing his studies at four separate institutions - the Ecole Speciale à Architecture, L'Ecole Superior de Bèton Armé, L'Ecole des Beaux Arts (Perret Atélier) and L'Institut d'Urbunisme (Sorbonne). Perret was to have a lasting significance in three important respects. First was Perret's concentration on the development of reinforced concrete buildings, the success of which hinged on the contracting firm from which he operated. It is reasonable to assume that in his partnership with Arup, Lubetkin was attempting to recreate the essential ingredients of Perret's success in the design and construction of his own reinforced concrete buildings. Second; Lubetkin learnt from Perret the importance of being meticulous in the smallest details of the design problem. A hallmark of Lubetkin's own work was his meticulous attention to detail, with every detail of his design work being based on sound reasoning. He himself readily admits that the source of this quality of his work was his experience with Perret. Third was Perret's classicism. Lubetkin recalls that the sense of order in Perret's work had an important impact upon his own design education. In an attempt to reconcile this apparently reactionary affection for classicism with his revolutionary politics he has written:
'Looking back, it becomes clear to me that our early inspiration to revolt against the old order was certainly justified and inevitable; but it did not imply or justify a revolt against order as such. The old order had to be replaced by a new order, not disorder.'

Before moving to Britain in 1931 Lubetkin had completed only one building which could be credited to him, in association with Jean Ginsberg - a block of flats in the Rue de Versailles, Paris.
Biographical details from : Coe, P and Reading, M : <u>Lubetkin and Tecton - Architecture and Social Commitment</u> (The Arts Council, London and Bristol, 1981). Allan, J : Modern Architecture of Classicism ; unpublished MS, 1982.

35 Coe, P and Reading, M : <u>Lubetkin and Tecton - Architecture and Social Commitment</u> (The Arts Council, London, 1981) pp 105-107.

36 Lubetkin - Cottam interview, 7 January, 1982.

37 <u>ibid</u> n35 p196. Lubetkin, B ; 'The Credo'

38 The history of Arup and Tecton's involvement in the building of air raid shelters from 1938 onwards is long and complex. Politically Lubetkin's approach was unfeasible and it caused great arguments between him and Arup. Arup's own work was more closely tailored to the economic realities of the situation but he soon discovered that his objective advice to the government was discarded. (Arup - Cottam interviews, September, 1981 - January, 1982).

39 Lubetkin - Cottam interview, 7 January, 1982.

40 ibid n35 p111.

41 Details of the building: ibid and also Architect and Building News, Vol LXXXIV, 2 June, 1933 ; pp 257-259. The Architects Journal, 28 September, 1933. Architectural Design and Construction, June, 1933 ; p316f. Architectural Review, July, 1933 ; pp 241-245.

42 Arup - Cottam interview, September, 1981.

43 ibid and ibid n13 p316.

44 Arup does not seem to remember this aspect of the project. The information transpired from a notice in the Architect and Building News, Vol 132, 25 November, 1932 ; p224 ; which read : 'Competition for Cafe and Shelter, Canvey Island
Members of the Royal Institute of British Architects and of its allied societies must not take part in the above competition because the conditions are not in accordance with the published Regulations of the Royal Institute for Competitions.'

Arup was either unaware of the R I B A 's decision or has consciously overlooked it, for he maintains there was no question of an architect being employed because the client was not prepared to pay the fee. (Arup - Cottam interview, September, 1981). Lubetkin can only vaguely remember Arup's design for this project. (Lubetkin - Cottam interview, 7 January, 1982). The only journal to review this building was Architect and Building News, 19 February, 1934 ; pp 227 and 228.

45 Arup provides no answer to this question - he can't remember (Arup - Cottam interview, January 1982).

46 These were outlined to the author in conversation in September, 1982. He was anxious to explain that it was designed to a very tight budget.

47 Sartoris, A : Gli Elementi Dell Architettura Funzionale (2nd edition, Ulrico Hoepli, Milan, 1934) pp 308 and 309. Two illustrations of this building were included along with :
Gorilla House - Tecton
Daily Express Building - Ellis and Clarke
House at Grayswood - Connel, Ward and Lucas
Royal Corinthian Yacht Club - Emberton
Universal House - Emberton
Hop Field House - Lucas
House at Rugby - Chermayeff
Lawn Road Flats - Coates

This publication provides a useful photographic record of a number of Modern Movement buildings from twenty-nine countries.

48 Morton Shand, P : 'Avanti Savoia' Architectural Review, Vol 78, July, 1935 ; p29.

49 Martin, J L et al : Circle - International Survey of Constructive Art (Faber and Faber, London, 1937), chapter by J M Richards ; 'The Condition of Architecture and the Principle of Anonymity' ; pp 184-189.

50 Arup - Cottam interview, November, 1981.

51 Arup, O N : 'Jubilee Forward' The Arup Journal, (25th Anniversary Issue) April, 1971 ; p3.

52 Correspondence, O Kier to Arup, 27 December, 1933 (Arup Papers London, file marked - 'Arup & Arup, Arup Designs, J L Kier and Co').

53 Details of salary and % of company profits : Arup in his contract with J L Kier was to receive 20% of the gross profits from Tecton Contracts - Correspondence, Arup to Christiani and Nielsen, 30 December, 1933 (Arup Papers London).

54 In many articles and lectures of the 1930s Arup refers to this important difference. See - Arup, O N : 'Planning in Reinforced Concrete' Architectural Design and Construction, Vol 5, July and August, 1935 ; pp 297-313, pp 340-343.

55 See pages 20-21.

56 See Case Study 27 and also the YMCA Building Manchester [5].

57 'Structurally redundant' only in as much as they did not contribute to the support of floors and roof slabs. They generally did provide a rigidity to the structure. (For example, Lawn Road Flats, pages 319-320 and Case Study No 57).

58 Architect and Building News, 1 June, 1934. The Architects Journal, 14 June, 1934. Architectural Review, July, 1934. R I B A Drawings Collection, references RAN 19/D/R and RAN 30/L/21.

59 Lubetkin - Cottam interview, 7 January, 1982.

60 Arup - Cottam interview, September, 1981.

61 ibid. His actual words to me were 'Lubetkin was a charlatan as far as reinforced concrete was concerned'.

62 The calculations and engineering drawings exist in the Samuely Papers housed at F J Samuely and Partners, Consulting Engineers, London. File marked, 'Penguin Pool'. Samuely was another very important engineer in British Modern Movement architecture - his own specialism being welded steelwork. Unlike Arup he set up a consulting engineer's practice in 1936 and collaborated with many architectural figures. He, like Arup, was a member of the MARS group. Some of his most famous buildings were: Bexhill Pavillion - with Mendlesohn and Chermayeff; Simpson's Store - with Emberton; Palace Gate Flats - with Coates.

63 Arup - Cottam interview, October, 1981.

64 Architect and Building News, 10 January, 1936 ; and 15 January, 1937. The Architects Journal, 17 January, 1935 ; pp 113-119 ; 2 May, 1935 ; pp 660-664, p685 ; 14 November, 1935 ; pp 739-740. Architectural Review, Vol 79, January, 1936 ;

pp 3-16. The Builder, Vol 150, 14 February, 1936. R I B A Drawing Collection, reference RAN 19/E/1,1-3.

65 Furneaux Jordan, R : 'Berthold Lubetkin' Architectural Review, July, 1955. Reprinted in Sharp, D : The Rationalists - Theory and Design in the Modern Movement (Architectural Press, London, 1978) p104.

66 Arup - Cottam interview, September 1981. To provide some idea of Lubetkin's original structural solution see - The Architects Journal, 17 January, 1935 ; p114. In the information sheets Tecton compiled, originally for AA students, this frame solution was entitled, 'Solution of project based on old regulations', alongside final scheme marked 'Final Project According to New Reinforced Concrete Regulations'. In fact the new regulations did not permit this type of construction. It was possible to build the structure in this way because the site was just outside the LCC's area. The change was entirely due to Arup's input not because of changes in regulations which did not come into operation in any event until after the building had been completed.

67 This project for Oscar Faber, officially under the construction direction of Arup's co-director, O Kier, appears to have been the largest of Kier's projects in the 1930s with a contract value in excess of £100,000 (Highpoint was £50,000). Arup must have been familiar with its details as it was built at the same time as Highpoint. (See Kier's list of contracts with steel tonnages - Arup Papers London, 'Kier File'). See also, Case Study No 15.

68 For history of sliding shuttering and early patents see Vol 1 Part II Endnote 91.

69 ibid n35 pp 121 and 122.

70 Kier drawing No 1088/010 (typical floor arrangement), Arup Papers London.

71 ibid n13 pp 316 and 317.

72 ibid.

73 These were laid down in the rules to the competition. Copy in Arup Papers London. The competition was promoted by the Cement Marketing Company Ltd.

74 Working Class Housing - Government Committee under Minister of Health Secretary - A Zaiman. Amongst its members were: Oscar Faber and W L Scott (engineers), L Keay and F Lorne (architects).

75 ibid n73.

76 The best description of the Arup - Tecton scheme was published in Concrete and Constructional Engineering, Vol XXX, 1935 ; pp 218-231. Handwritten manuscript of this article in Arup Papers London.

77 ibid and ibid n54.

78 The Architects Journal, 28 March, 1935 ; pp 482 and 483.

79 The Builder, Vol 151, 11 December, 1936 ; pp 1149 and 1150.

<u>Building, July, 1935</u> ; pp 260-265 (Review by Myerscough - Walker).

80 <u>ibid</u> n54 p307 - another design by Griffiths is illustrated on p304.

81 'Structural expression' was another phrase frequently used. Whereas 'structural honesty' referred to the direct expression of the structure in architecture, 'structural expression' generally referred to the use of the structure as the controlling feature of the architectural treatment. Arup used both phrases without distinguishing between them.

82 Arup - Cottam interview, September, 1981.

83 Best described by : Arup, O N ; 'Reinforced Concrete' <u>The Architects Year Book, 1945</u> ; pp 210-211. See also, <u>Architect and Building News, Vol 157, 13 January, 1939</u> ; pp 65-74 ; <u>19 January 1940</u>. <u>The Architects Journal, 12 January, 1939</u> ; pp 48-53 ; <u>20th October, 1938</u> ; p632. <u>The Builder, 13 January, 1939</u>.

84 See - <u>Architect and Building News, 14 October, 1938</u> ; pp 30-31, pp 35-42. <u>The Architects Journal, 13 October, 1938</u> ; pp 601-607; <u>1 December, 1938</u> ; pp 907 and 908. <u>Architectural Review, October, 1938</u> ; pp 161-164.

85 Letter, B Lubetkin to E J Carter, November 1976. Published in <u>ibid</u> n35 pp 33-35.

86 Charles Reilly observed this problem that had been created at Highpoint I in his review of this building in, 'The Years Work' ; <u>The Architects Journal, 16 January, 1936</u> ; p110. (Reilly Papers, Liverpool University, reference D 207/3/5).

87 <u>Building, June, 1938</u> ; pp 255 and 256. 'Conversation between R Myerscough-Walker and O N Arup on <u>Structure</u>'.

88 <u>ibid</u>.

89 <u>ibid</u>.

90 Arup, O N : 'Reinforced Concrete' <u>The Architects Year Book, 1945</u> ; p206.

91 Snow, F P : 'Modern Methods of Flat Construction' <u>The Structural Engineer, May, 1935</u> ; pp 230-245.

92 It is outside the scope of this study to examine the social and political background to these schemes. For information see - <u>Architect and Building News, 21 October, 1938</u> ; 'Finsbury Acts - A Note on Policy, Including Housing Programme'. Also <u>ibid</u> n35 pp 169-176.

93 <u>The Builder, 2 August, 1946</u> ; pp 112-115. <u>Architectural Review, Vol 109, March 1951</u> pp 138-149.

94 <u>The Architects Journal, 9 October, 1952</u> ; pp 433-442. Earlier pre-war design illustrated in <u>The Builder, 21 October, 1938</u>.

95 Arup - Cottam interview, November, 1982.

96 Lubetkin's own view was that he was simply introducing human scale and variety into his facades. The elevations were still a product of a rational approach to the planning but Arup's

structure provided him the opportunity to adjust the proportions and relationship of the different parts of the elevations to produce well balanced architectural compositions. Comparing his work in both these schemes with similar building types he had produced earlier he wrote by way of justification:
'Too often in buildings of this kind the elevational proportions with their repetitive rhythm of openings, seem to form part of a continuous band of indeterminate limits, which could be snipped off by the yard at any point. It was our endeavour to devise a design which, instead of relying solely on the interplay of main volumes, irrespective of their treatment, would take the basic rhythm proceeding from the plan and further develop this rhythm in an overall pattern of light and shade bringing human scale to the main abstract forms.'
(Lubetkin, B ; 'Flats in Roseberry Avenue' Architectural Review, Vol 109, 1951 ; p140.)

Whilst his objectives were laudible the result seems to emphasize rather than detract from fundamentally inhuman character of the buildings. Even though many commentators used the above quotation to support their view that Lubetkin was not indulging in architectural pattern making, it seems reasonable to assert that in producing elevations in this way Lubetkin was admitting that the only way to produce any visual interest to such monolithic pieces of structural engineering design was to indulge in the stylistic mode of design he professed to abhor.

97 ibid n13 p320.

98 As J S Allan has demonstrated, in this and later buildings Lubetkin always worked within the classical tradition that he had learned from Perret in France. Allan, J S : 'The Modern Architecture of Classicism' ; unpublished MS, 1981.

99 ibid n90 p195.

100 Arup, O N : 'Structural Honesty' Architect and Building News, 8 April, 1954 ; p410f (Extracts from a paper read at the AA, 25 March, 1954).

101 ibid.

102 ibid p411.

103 ibid p412.

104 ibid.

105 ibid n90 p195.

106 ibid n100 p412

107 ibid.

108 ibid.

109 ibid n14. Information on the turbulent history of these firms is available in Arup Papers London, file Arup and Arup.

CHAPTER 8

110 Elgohary, F H : Wells Coates and his Position in the Beginning of the Modern Movement in England, unpublished PhD thesis, University of London, 1966.

111 Cantacuzino, S : Wells Coates, A Monograph (Gordon Fraser, London, 1978).

112 Exhibition Catalogue - Wells Coates, Architect and Designer 1895-1958 (Oxford Polytechnic, 1979).

113 Coates Papers held by Laura Cohn, (Oxford) - closed access. It would appear that the only individual who has had full access to these papers was Elgohary. Possibly other works have used Elgohary's thesis for most of the information relating to these papers.

114 Letter - Wells Coates to Marion Grove, November, 1927 (Coates Papers Oxford). Referenced in ibid n110 p20 and ibid n111 p16.

115 See letter headings in his correspondence to J C Pritchard, 1929 to 1930 (Pritchard Papers Newcastle University, School of Architecture Library. Referred to hereafter as Pritchard Papers Newcastle).

116 For example: letter - Wells Coates to J Pritchard, 17 June, 1931 Pritchard Papers Newcastle - reference NU/PP/15/5.

117 Wells Coates - His Book (Coates Papers Oxford) Referenced in ibid n111 p13.

118 ibid n114.

119 MARS Papers (R I B A Library - Ar/0/1/5/7(i) and Ar 0/1/2/1).

120 He was born in Japan in 1895, the eldest of six children. His parents, both Canadian, had gone to the East as missionaries. His father, the Rev. Harper Havelock Coates, was a theologian and Professor of Philosophy. His mother, Sarah Agnes Wintemute, was the co-founder of the first missionary Girls Schools in Japan, and had prior to her emigration worked in an architectural capacity with Frank Lloyd Wright in Sullivan's office. (Coates later tried to use this fact to his advantage when he decided to undertake an architectural career for he claimed that she had told him before his departure to Canada - 'if you still think you want to be an architect, I give this advice - don't stay at architectural school longer than you can bear it; study engineering' (ibid n110 p11).

Coates regarded the most important influence in his formative years in Japan to be his private tutor, G E L Gauntlet, an Englishman with a Japanese wife. It was he who provided Coates with an informal education within the Eastern culture in which he was brought up. Although it is difficult to assess his precise influence on Coates it is clear that the early education he received would have been in sharp contrast to the more conventional formal education of his western colleagues.

He left Japan in 1913 at the age of seventeen on a 4½ month cruise which terminated in Vancouver, Canada, where he began his engineering career. (Biographical details from ibid n110 and ibid n111).

121 This was confirmed by Maxwell Fry in a letter to the author, 4 December, 1982.

122 Lewis, W P : The Caliphs Design. Architects! Where is your Vortex? (The Egoist, London, 1919).

123 Lewis, W P : The Art of Being Ruled (Chatto and Windus, London, 1926).

124 ibid n122 pp 6-7.

125 ibid n111 p40.

126 Coates's drawings for the interior design of the workshop and some of his shops are in the R I B A Library, reference COW/1/1/1-39. Shops were completed at: Brompton Road, London; Bournmouth; Bath; Bristol; Brighton; Bromley; Baker Street, London: and Bond Street, London. See - Building, December, 1932 ; pp 564-565. ibid n111 pp 40-45.

127 Letter - J C Pritchard to Wells Coates, 14 March, 1929, (Pritchard Papers Newcastle, NU/PP/15/6).

128 Jack Craven Pritchard, born in 1899, had studied engineering and economics at Cambridge. He was brought up in a wealthy Edwardian family but later became dissatisfied with the rigid class structure in Britain. In 1925 he took employment with Venesta, a company manufacturing amongst other things plywood. It was through his friendship with Mansfield Forbes that he was introduced to modern architecture, attracted by its social commitment and engineering basis. (Forbes house - 'Finella' designed by Raymond McGrath, was one of Britain's first publicized examples of continental modernism).

129 Letter - Wells Coates to J C Pritchard, 14 February, 1930. (Pritchard Papers Newcastle, NU/PP/15/5 - 'Dear Jack . . . I have visited Lawn Road'.).

130 Memorandum - J C Pritchard to Wells Coates, undated. (Pritchard Papers Newcastle, NU/PP/15/5 - 'It is regrettable . . . .').

131 Memorandum - Wells Coates to J C Pritchard, 14 February, 1930 - item 3 (Pritchard Papers Newcastle, NU/PP/15/5 - 'This memorandum is an attempt to arrive at a datum level').

132 ibid item 17.

133 ibid.

134 This fact emerged from Pritchard's discussion with the author, 10 June, 1982. He clearly stated that he had been misled by Coates into believing that he was a well-established building designer. This is also supported in some correspondence from Pritchard to Coates. For example, on 27 April 1933 he wrote to Coates asking for technical information on skyscraper design, clearly expecting Coates to possess the necessary knowledge. Although Coates supplied some information he humbly admitted - 'I have been at the top of a skyscraper but never designed one . . . ask Owen Williams' (Pritchard Papers Newcastle, NU/PP/23 - 'Dear Wells, . . . I had an argument the other day with Huxley').

135 Letter - Wells Coates to J C Pritchard, 29 April, 1930. (Pritchard Papers Newcastle, NU/PP/15/5 - 'Dear Jack . . . I am writing this memo to confirm in part the discussions.').

136 Letter - J C Pritchard to Wells Coates, 2 May, 1930. (Quoted by Coates in his letter to Pritchard, 13 July 1930. Pritchard Papers Newcastle, NU/PP/23/1 - 'Dear Jack . . . On the 2nd May last, in reply to my memo dated 29 April, you wrote . . . .').

137 Letter - J C Pritchard to Wells Coates, 11 July, 1930. (Pritchard Papers Newcastle, NU/PP/16 - 'Dear Wells . . . Re your letter 2.7.30 enclosing plans'.).

138 Letter - Wells Coates to J C Pritchard, 13 July, 1930. (Pritchard Papers Newcastle, NU/PP/23 - 'Dear Jack . . . On 2 May in reply to my last letter you wrote . . . .').

139 The Articles of Agreement of Wells Coates and Partners Ltd, 30 September, 1930 (Pritchard Papers Newcastle, NU/PP/15/2/9). The directors were:
Graham Maw (Pritchard's solicitor) - 100 shares
Wells Coates - 500 shares
Frank Grove - 300 shares
J C Pritchard's nominee - 800 shares
Lord Pentland - 200 shares
(Lord Pentland joined the board of directors in November - see NU/PP/15/2/12).

140 Memorandum Re Proposed Company. Wells Coates, 8 August, 1930 (Pritchard Papers Newcastle, NU/PP/15/2/2).

141 Letter - J C Pritchard to Lord Pentland, 18 October, 1930 (Pritchard Papers Newcastle, NU/PP/15/2/10).

142 Memorandum Re Change of Constitution, 13 January, 1931, p4 (Pritchard Papers Newcastle, NU/PP/15/2/40).

143 Letter - Fleetwood Pritchard to J C Pritchard, 23 December, 1930 (Pritchard Papers Newcastle, NU/PP/15/2/29).

144 It was not merely a change of name as Cantacuzino has suggested (ibid n111 p55). Negotiations were protracted and the new company's objectives were much debated. The name Isokon came from Coates - a derivative of Isometric Unit Construction. New company registered 21 December, 1931 (Pritchard Papers Newcastle, NU/PP/15/2/54 - Articles of Agreement).

145 In a letter to the author (8 April, 1982) Pritchard admitted that by December 1931 he was 'much relieved' that Coates was severing his business connection with the company.

146 Plans available in Coates Papers Oxford and the R I B A Library. Also ibid n111 pp 54-55.

147 The uppermost figure of £4,000 was agreed in Coates's memorandum to Pritchard, 14 February, 1930 (ibid n129). Coates's amended estimate of £4,500 was prepared on 9 September, 1930. (Pritchard Papers Newcastle, NU/PP/15/5).

148 Memorandum - Wells Coates to J C Pritchard, 11 September, 1930 (Pritchard Papers Newcastle, NU/PP/15/5).

149 Letter - Wells Coates to J C Pritchard, 23 July, 1930: 'Dear Jack, I am enclosing herewith the reply I have received from the Trussed Concrete Steel Company in answer to my request for details of the cost of erecting the type of unit-construction I have shown for the Lawn Road Houses . . . . The British Reinforced Concrete Engineering people have a full set of plans and are still working on them.' (Pritchard Papers Newcastle, NU/PP/15/5).

150 ibid n137.

151 ibid n138.

152 Letter - Wells Coates to J C Pritchard, 17 June, 1931. (Pritchard Papers Newcastle, NU/PP/15/5 - 'Dear Jack - I was sorry . . .').

153 Wells Coates to J C Pritchard and Graham Maw, 26 October, 1931 (Pritchard Papers Newcastle, NU/PP/15/5 - 'My dear Jack and Graham - I am very glad that you propose to change the name of the company . . .').

154 ibid n111 p56.

155 In a letter to the author (23 April, 1985) Maxwell Fry admitted that he had helped Coates in producing the plans to these dwelling units. In it he wrote:
'I certainly stimulated Wells' interest in architecture and discussed with him a minimum house which he wanted me to work up for him on his return from Paris. It was so influenced as nearly to be Corbusier's model.'

The author was interested to know if Fry had any involvement in the Lawn Road Flats scheme as built. The evidence suggested that there may have been some collaboration between them as Fry's Sasoon House was very similar and used the same firm of subcontractors for the reinforced concrete work. There was no involvement however. In his letter Fry continued:
'Before anything happened Wells disappeared from my life as he was apt to do when pursuing his own interests and I had nothing to do with his Lawn Road Flats either in the large or detail. That is not a line to pursue.'

156 Memorandum - Rosemary Pritchard (Molly) to Wells Coates (Pritchard Papers Newcastle, NU/PP/15/3/267 - undated).

157 There exists another piece of evidence, again unfortunately undated, which adds further weight to Rosemary Pritchard's claim. It is to be found in a letter to Coates in which she wrote:
'There is another point in your letter that I would like to take up - you accuse me of putting over the flat idea as mine - well so it was. I have also felt you to be unkind when I have heard you put it out as yours - therefore, presumably the truth must be that as a result of a germ dropped from you and another from me the idea came to both our minds independently.'
(Pritchard Papers Newcastle, NU/PP/15/6 - undated - 'Dear Wells, I have taken the liberty of not showing your letter to Jack.' reply to a letter from Coates to Molly Pritchard, 20 March, 1933 (NU/PP/16/1/100).

158 For example in his early draft proposals (21 April 1932) Pritchard wrote:
'Would it be advisable to try and raise more money and increase the number of flats by building more floors? This would spread the price of the land and so increase the return.'
(Pritchard Papers Newcastle, NU/PP/16/1/26 p3).

159 Pritchard wrote to his brother, Fleetwood (24 March, 1932), informing him of Isokon's decision to build flats instead of houses (reference NU/PP/16/1/21). On 30 April, 1932 Coates wrote to J C Pritchard asking him if he would allow him to build a small studio on the Lawn Road Site before building 'Pritchard's house' (Pritchard Papers Newcastle, NU/PP/15/5 - 'Dear Jack - I have been frantically busy and have not had time to write to you on a host of things . . .)
He was clearly unaware that a decision to build flats had been taken.

160 A handwritten draft memorandum to Coates from Pritchard contained the essential features of the brief (reference NU/PP/16/1/24). The typed amended copy dated 21 April, 1932 (NU/PP/16/1/25 and 26).

161 ibid.

162 Sweet was later to become the only member of Coates's MARS group who was a quantity surveyor.

163 Coates's arguments for the higher price were presented by Molly Pritchard in a letter to Graham Maw, 27 September, 1932 (Pritchard Papers Newcastle, NU/PP/15/3/255).

164 For details of Coates's early flat proposal - see - ibid n111 p58.

165 Letter - Wells Coates to Molly Pritchard, 20 March, 1933 (Pritchard Papers Newcastle, NU/PP/16/1/100).

166 For details of tenders see letters; Wells Coates to J C Pritchard, 3 July, 1933 to 15 July, 1933. (Pritchard Papers Newcastle, NU/PP/16/1/125 and 126). The subcontract to Billings Ltd was not referred to in the above. See - Concrete and Constructional Engineering, Vol XXIX, 1934; p506.

167 Richards, J M : 'Wells Coates 1895-1958'; Architectural Review, December, 1958 ; pp 357-360.

168 For Coates's work with MARS and CIAM see - ibid n111 pp 47-50, ibid n110 pp 66-103. MARS papers (R I B A Library - Ref ArO).

169 See - Concrete and Constructional Engineering, Vol XXIX, 1934 ; pp 504-506. It is noteworthy that simultaneously Maxwell Fry was using a similar structural arrangement at Sasoon House. He, however, had employed the engineers Mouchel and Partners although the Helical Bar and Concrete Engineering Company supplied the reinforcement. See - Concrete and Constructional Engineering, Vol XXIX, 1934 ; p 638f and ibid n155.

170 For details of Arup's concrete slab structures see Chapter 7 pp 257-286.

171 Letter - J C Pritchard to Wells Coates, 11 April, 1934. (Pritchard Papers Newcastle, NU/PP/16/1/362).

172 For correspondence between all parties see Pritchard Papers Newcastle, NU/PP/16/1/362-366, 377, 378, 423 and 436. Coates's main reasons for preventing Moncrieff and Buchanan from advising on the structure were that his design was as efficient as possible because: 1) LCC code still prohibited truly efficient reinforced concrete construction; 2) reinforced concrete work had been let to the lowest tenderer; and 3) the difficult ground conditions. In one letter he wrote: 'The whole position with regard to reinforced concrete construction in this country is very unsatisfactory, and until a great many more firms of specialists are able to carry out works, the economics to be achieved are not those which professional men can provide.' (Letter Coates to Pritchard, 17 April, 1934 - Pritchard Papers Newcastle, NU/PP/16/1/377).

173 Letter - Wells Coates to J C Pritchard, 7 May, 1934 (Pritchard Papers Newcastle, NU/PP/16/1/436).

174 Letter - J C Pritchard to Wells Coates, 8 May, 1934 (Pritchard Papers Newcastle, NU/PP/16/1 - 'Dear Wells, Thank you for your letter of May 7th').

175 Felix Samuely (1902-1959), born in Vienna, had worked in Austria, Germany and Russia before settling in Britain in November, 1933. Ove Arup employed him at Kier's, for approximately eight months, until he left to form a partnership with Helsby and Hamaan. His first large job was the Bexhill Pavillion with Mendlesohn and Chermayeff (he had previously worked with Mendlesohn in Germany). He joined the MARS group and undertook many structural designs for modern buildings in Britain.

See - Architectural Association Journal, June, 1960 ; pp 1-31. 'Felix James Samuely (1902-1959)'.

176 Letter - Wells Coates to Graham Maw, 7 February, 1933 ; p1. (Pritchard Papers Newcastle, NU/PP/15/5 - 'Dear Graham Maw, You will forgive me for having delayed my reply to your letter of February 1st . . .').

177 ibid p4.

178 Photographs of the unrendered building are to be found in the Samuely Papers (F J Samuely and Partners, Consulting Engineers, 231 Gower Street, London). See Vol II Illustration No 380.

179 In an acrimonious letter to Coates (10 April, 1934), Pritchard wrote:
'one day you may learn to be as great as your sincerity in design deserves. You will of course have success, but what a poor success for you . . . . Unless Berg concentrates on Sunspan homes only and all that they stand for his organization cannot be more than a stopgap, which will assist in the creation of only a few buildings. Berg will build anything and everything that pays him.'
(Pritchard Papers Newcastle, NU/PP/16/1/353).

180 Samuely's papers indicate his involvement in the following Coates buildings:
(i) Flats at Hove - 1934 (not built)
(ii) Sunspan Houses in Wales and Surrey - 1934
(iii) Embassy Court, Brighton - 1935
(iv) Ekco Laboratory, Southend - 1935
(v) 'Experimental job' - 'Wells Coates floors' (unspecified) - 1936
(vi) House at Leigh-on-Sea - 1936
(vii) J E N (unspecified)
(viii) News Chronicle Schools Competition - 1937 (Coates and Lasdun)
(ix) No 1 Palace Gardens - 1937
(x) Home at Esher - 1937 (Coates and P Gwynne)
(xi) 32 Newton Road - 1937 (Coates and Lasdun)

181 Samuely and Arup had first worked together at Kiers and were both members of the MARS group, being the only two bona fide engineers on its Central Executive Committee. Moreover, they both lectured on the same structures course at the Architectural Association.

182 For details of the Embassy Court building see - ibid n111 pp 80-84. Architectural Review, November, 1935 ; pp 1[illegible]-173.

<u>Architect and Building News, 8 November, 1935</u> : pp 165-170.
<u>Architects Journal, 14 November, 1935</u> ; pp 741-746.

183 See Chapter 7 pp 268-271.

184 <u>ibid</u> n111 p82.

185 See Chapter 6 pp 188-190.

186 Reilly, C H : 'The Years Work at Home' ; <u>Architects Journal, 16 January, 1936</u> ; pp 109-110. (Reilly Papers Liverpool, D207/3/5/54 and 55).

187 For details of No 10 Palace Gate Flats, Kensington see: <u>ibid</u> n111 pp 64-71. <u>Architectural Review, Vol 85, March 1939</u> ; pp 174-184. <u>Architectural Record (New York), November, 1939</u> ; pp 34-39.

ENDNOTES - CONCLUSIONS

1 Journal of R I B A, 1933-1934, 11 November, 1933 ; p11.

2 Arup, O N : 'Art and Architecture; the architect : engineer relationship' Journal of R I B A, August, 1966 ; p350.

3 Summerson, J : 'The Case for Theory of Modern Architecture' Journal of R I B A, June, 1957 ; p307.

4 Watkin, D : Morality and Architecture (Oxford University Press, Oxford, 1977).