

Visible Structures

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by
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Abstract

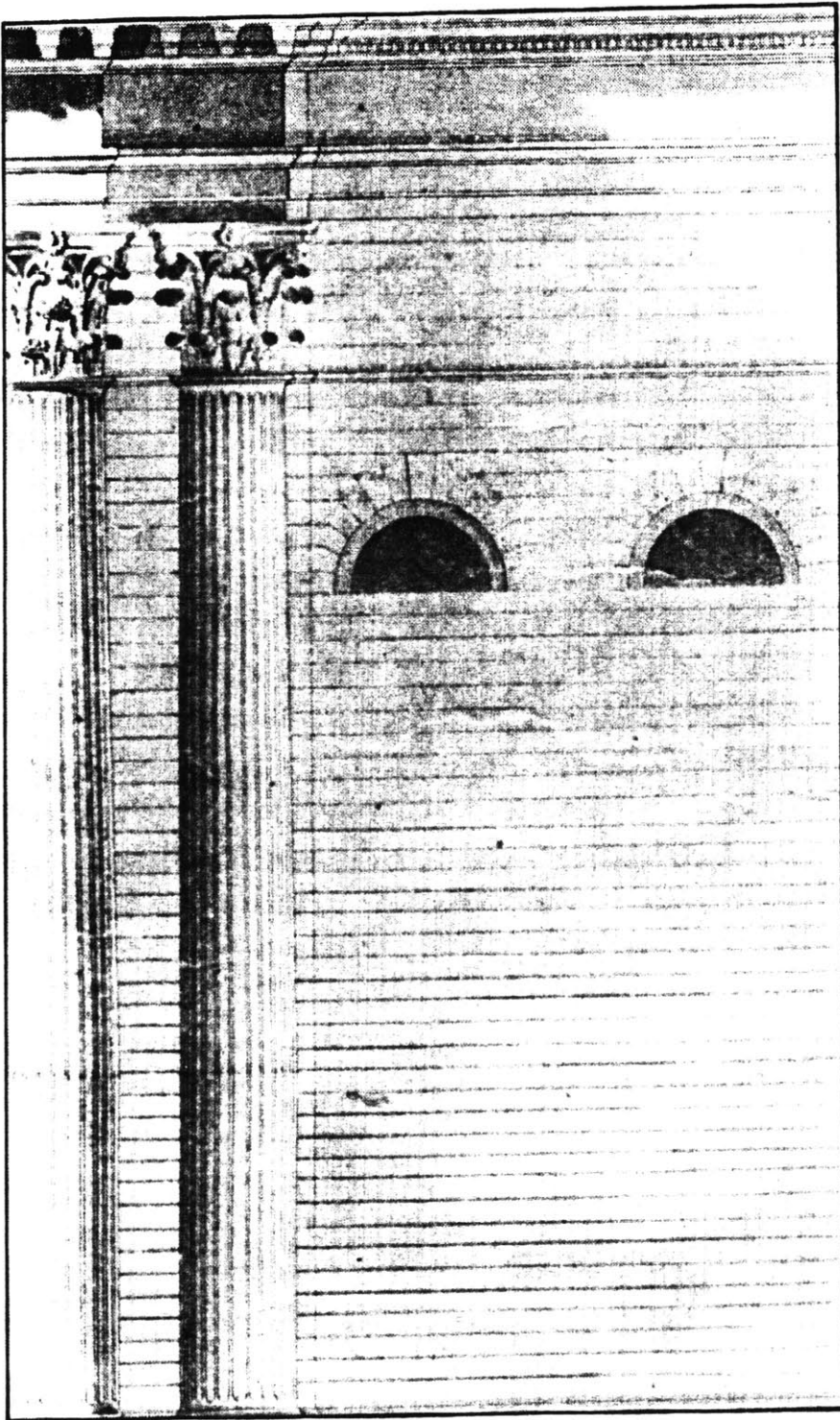
All architecture is the interplay between structure, surface and ornament. Traditionally, ornament adorned structure thereby giving it its meaning. A society with its intellectual foundations resting in faith or the abstract emphasized the ornament over the structure. The growth of Rationalism and the substitution of the empirical for the abstract necessarily caused a reordering of ornament and structure. Enabled by technology, structure subsumed ornament.

The new architecture was not designed as per canons, rather, new methods for design developed parallel to the technology which enabled its construction. The new architecture, supported by a load bearing skeletal structure represents a turning point in the history of building. The wall was dissolved and replaced by a skeletal structure. The structural members were not covered, rather, their exposure was a conscious act. They served to articulate the resulting architecture which was markedly spatial and expressive.

Architecture was no longer confined by stylistic rules. New architecture reconciling realities of how it is conceived and constructed finds meaning in and of itself. As a result, the conceiving and building of architecture factors into the architectural process. The reordering of the architectural elements of structure and ornament is indicative of the evolution of the intellectual process. Structure, made visible in architecture graphically represents the thoughts, values and intents of its builders. Architecture in which structure subsumes ornament, is more reflective of the thoughts values and intents of its builders.

Thesis Supervisor:
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Professor of Architecture



[2] drawing by Soufflot

During the course of this thesis several people have been of immense help. I would like to thank a few here: My advisor Eric Dluhosch, for his encouragement and direction. My readers David Friedman and Hashim Sarkis for their constructive criticism. And, to my family and friends whom I love very much.

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Introduction Beginning in the late 18th century, rationalized methods of thinking and advanced technologies made possible the construction of free-standing skeletal structures. Architectural production began to undergo marked changes resulting from the increased availability and acceptance of mass-produced cast iron. Formed into linear, structural elements, cast iron was used to build open structures in new shapes and in large scales. Architecture was no longer dependent on walls and mass for its structural support and delineation of form. The structural skeleton could embody the architecture. This thesis will explore visible structures presented as architecture paralleling the rise of technology.

Architecture built from a self-supporting skeletal frame and with industrially produced materials became a new type of architecture. The advent of the new architecture marks a break with history and defines the still extant period. The new materials and resulting constructional possibilities applied in ordered and rational processes, alone, were not the sole forces behind the new architecture. Questioning traditional architecture, resulted in a rethinking of architecture and the displacing of the classical orders. Increasingly, 18th century architecture became dominated by and based upon mathematics and science. Thus, acceptance of the new materials filled the vacuum created by the departure of the classical orders and traditional architecture.

This thesis proposes that in the past two hundred years, there is a persistent but not dominant relationship between structure and ornament and can be seen in a series of buildings. Examples of the new relationship between structure and ornament include the Crystal Palace and the Centre Pompidou. A common

characteristic of these buildings, is their reliance upon structure as expressive language and its presentation as such. These buildings define the *architecture of visible structures*.

The new architecture is conceived analytically in terms of discrete systems and elements. When pre-eminence is lent to the structural system, two things are achieved. First, an order is established which governs the other parts and elements of the building. Second, the reading of structure and the order created thereby is *strengthened*. By ordering our daily lives, the world is made comprehensible. Conceived rationally, the architecture is inherently ordered. This rationalism in architecture mirrors that rationalism in society. This is analogous to the practice of ordering the human world, giving it structure and thereby making it comprehensible.

There are three key differences between traditional and new architecture. First, in the new architecture, the wall is dissolved and replaced by a skeletal structure. Second, new architecture is guided by scientific method, not canons. And finally, the traditional hierarchy of structure, surface and ornament is reordered in the new architecture.

Because the wall is dissolved, the structural skeleton becomes visible, even prominent. Representing the thoughts, intentions and abilities of the age, *structure takes on meaning and value as architecture*. The new architecture, emphasizing its structure is enabled by industry and technology. Thus, scientifically based, rational processes of design and construction inform structure from utility to aesthetic. However, the pragmatic, functional realities of industry, technology

and standardized construction are not self-sufficient concepts for the design of architectural structures. Nor, do the purely tectonic and “calculated” properties imposed on the new structural “frame” become the singular forces shaping their design. The new structural possibilities are a vehicle for expression and meaning, realizing a new architecture. Technology alone is not considered as the inspiration for architectural structures. Rather, technology is incorporated into the resulting aesthetic. An aesthetic enabled by technology.

Structure, in its new role, reflects the reordering of the traditional Renaissance hierarchy of structure, surface and ornament. The new structure, displayed as architecture, subsumes the traditional roles of ornament, i.e. meaning and aesthetic. *Ornament is collapsed into structure, which, in and of itself carries meaning.* The design of the structure is guided however by aesthetics as well as function. Not only must the new structures perform their statical function, but they must impart meaning through their appearance. Each comprehensive level of the structure reflects the potential presence of ornament. These levels are defined by the joints and details, the individual structural members, the delineated geometries, the defined volumes and the structure as an object.

This thesis demonstrates that rationalized thinking and advanced building technologies reordered the hierarchical relations between structure, surface and ornament.

Prefacing the discussion of structure and ornament in the new architecture it is helpful to clarify the traditional relationship between structure and

ornament. Section 1 discusses the traditional relationship between structure and ornament inescapably tied to traditional architecture and a relationship fragmented by a new way of thinking. This is the thinking which led into the modern period. The origins of the new architecture of visible structures will be charted and analyzed in effort to better understand the present role of structure and ornament. Section 1 shall be comprised of three essays: The Intellectual Fissure, Fragmentation and Architecture Rethought.

The new structure resulting from rational rethinking of the relationship between structure and ornament shall be discussed in Section 2. Three early examples of the new structure shall be examined.

In Section 3, the work of Joseph Paxton, specifically the Crystal Palace, will be discussed in effort to explain the four main characteristics of the new architecture, the architecture of visible structures. Section 2 shall be comprised of three essays: The Skeletal Frame, Standardization *and* Prefabrication, and Spatial Qualities.

The Pompidou Centre, a contemporary example of the architecture of visible structures, will be examined in Section 3. It will be examined both as structure, produced by highly advanced industrial methods and as architecture. Section 4 shall be comprised of four essays: The Architecture of Visible Structures; The Centre Pompidou; The Structure of the Centre Pompidou; The Catalog of Parts for the Structure.

Section 1 The Intellectual Fissure

Origins and Traditions *“It should already be clear that modern architecture did not appear around 1750 and that it was not simply generated by the Industrial Revolution. The process of transformation of theory into an instrument of technological domination started with modern science itself ..” (Perez-Gomez)¹*

Towards an Architecture of Visible Structures

As a result of new constructional processes begun during the Industrial Revolution, a new architecture, an architecture of visible structures was created. Its theoretical origins lie in an intellectual fissure opened by Galileo Galilei (1564-1642), and which effected a new way of thinking, divergent from tradition. The nature of this fissure is a gradual move away from symbolic thinking based on perception, towards reductive thinking based on positivism. Effects of reductive thinking were the incorporation of non-measurable or scientifically verifiable ideas into explanations of the world (and by extension, architecture) gradually decreased.

Galileo, an Italian astronomer, conducted systematic surveys of the heavens and described his findings in mathematical language.² The heavens, which were previously understood in symbolic terms, became understood in an empirical way, in abstract terms. Galileo’s research eventually served to reorder human understanding of the world. The heavens, once mysterious, became *explainable* and ultimately, controllable through mathematics and science.

Galileo forged the beginnings of the philosophical movements of rationalism, empiricism, positivism and scientism. The source of knowledge, which previously resided in the senses and faith, relocated to the intellect. Reason, not poetics and religion, became the guiding

force of philosophy, science and by extension, architecture.

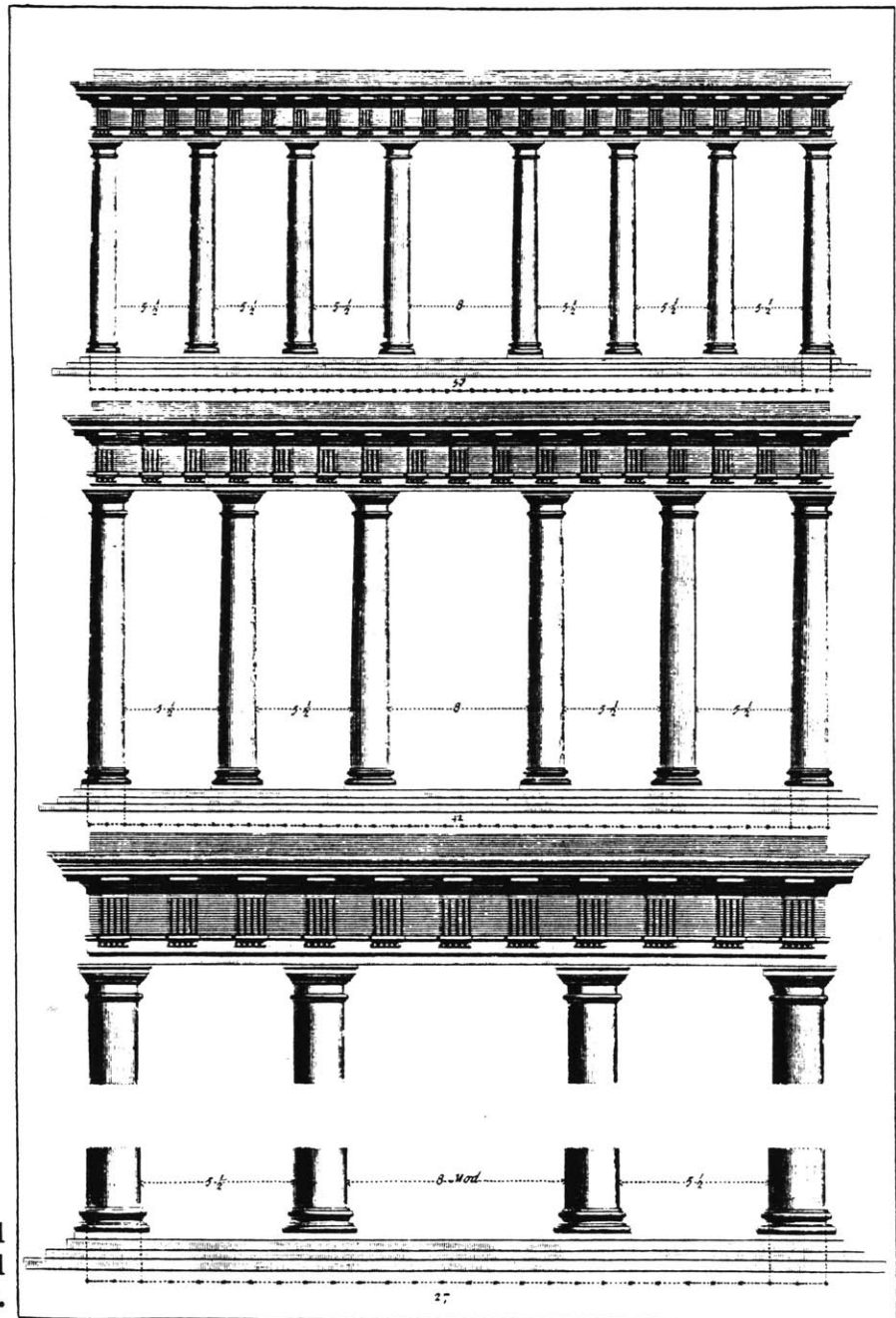
The effects of the rationalism on architecture resulted in rational, pragmatic approaches to design, based on mathematics and function. More importantly, the rethinking effected the change from designing architecture *as per canon*, to designing architecture *as per method*. Rationalism embraced the new structural and material possibilities of the Industrial Revolution. Also, as a result of the rethinking, the traditional relationship between the processes of designing and building architecture (instrumentality) and the transcendent intentions (meaning) of building changed.³

Traditionally, in architecture designed as per canon, the relationship between instrumentality and meaning has been that architectural intentions and meanings were extrinsic to the process of building and designing architecture. Meaning was transcendent to the building. Following the change to designing architecture as per method, the processes of designing and building became intrinsic to the meaning of architecture. Meaning resides within the architecture and its processes.

In the case of classical architecture, meaning resided in the ornament. However, rational thinking brought ornament into question since its value could not be quantified. Rational rethinking of classical architecture was instrumental in fragmenting the value of architecture (structure) versus beauty (ornament).

This marked a change from the classicism of Leone Batisti Alberti, the Renaissance theoretician. His belief

in the value of the classical orders was absolute. Structure and ornament were both considered necessary to architecture, ornament being perceived as integral to its meaning.⁴



[3] Proportional variations of classical columns.

J. Leoni delin.

"We have formerly observed, that the ornaments annexed to all sorts of Buildings make an essential part of Architecture, and it is manifest that every kind of Ornament is not proper for every kind of structure."
(Alberti)⁵

For Alberti, structure is the primary part of building but it must be informed by "Art" and "Proportion" to be "Beautiful." In Alberti's terms, structure without ornament is not architecture. By adorning the structure with ornament, specificity of intent comes across. Adding ornament to structure is the act of giving it meaning.

It is at this point that the dilemma associated with ornament becomes apparent. Ornament is associated with meaning and symbolism. With time, meaning is lost or obscured and ornament becomes simply 'ornament.'⁶ The fact that ornament has been an integral part of the structure, infuses structure with aesthetic and meaning even though, structure remains virtual.

Perez-Gomez has stated that the devaluation of meaning from the processes of making architecture occurred after the French Revolution, clearing the way for a technical society. This is to say, the ideas of positivism became dominant in architecture and its related disciplines. As a result of the devaluation of meaning from architecture, which at that time was classical, a tension between structure and ornament became manifest. Structure was essential and therefore not questioned. Ornament was integral to the meaning of the building. If traditional causes of meaning were no longer a part of architecture, then by reason, ornament was no longer needed.

“Ornament became a value commodity, a consumer’s product added to the work of architecture, which otherwise was essentially the result of a simple technological process.” (Perez-Gomez)⁷

The change in thinking about architecture, from the traditional to the new, happened incrementally. The instruments of science and mathematics were first used to reaffirm and strengthen the symbolic qualities of the architecture which they were used to generate. Eventually, the instruments of science, mathematics, and technology were used to reduce the scope of the content of the architecture they were used to generate. In the traditional architecture, its meanings and intents were found outside of its generative instruments. The new architecture, to a large degree, finds its meanings and intents within its generative instruments.

The meanings and intents of the new architecture changed and thus, differed from that of traditional architecture. The traditional, classical architecture referenced an antique architecture, the values of which were already fixed and understood. The traditional architecture was a ‘language’ which expressed the meaning and intent of the architecture. The value of the traditional architecture was then determined by the degree to which accepted or historically prescribed criteria (aesthetic and functional) were met. It is at this point where the effects of the fissure on architecture is best evidenced. The new architecture incorporates the *processes of its making* into its meaning and if taken further, these processes, as such, *become* the meaning. The value of the new architecture is determined by the degree to which it responds to contemporary criteria for design and construction.

The architecture of visible structures emerges during the Industrial Revolution, built primarily from metal (cast iron) and glass. These materials were not new to architecture. Previous to the Industrial Revolution, glass and iron were, in limited quantities, incorporated into architecture. However, they were not mass-produced, nor had processes for transforming them into manufactured products for construction been developed. The utilization of industrially produced metals and glass for construction was instrumental in the making of a new architecture.

The making of the new architecture relies on industry for its production. Thinking about this architecture requires acknowledgement of rationalized, industrial processes. Most of the elements of this architecture are manufactured in a factory and assembled on site. To design architecture based on the products of industry, the making of each architectural element must be understood in terms of its function within an assembly. Moreover, each element must be understood in terms of its coordination with other elements of the system of which it is a part.

The context in which the new architecture is conceived is one of science and method. This implies that the emphasis is on *rational* evaluations of design goals and *rational* processes towards their achievement. The design process is structured to quantitatively solve architectural problems, insuring expedient, economic solutions. The 'language' of the new architecture is the structure and other industrially produced elements. *Their meaning and value are implicit.* The new structures, truthfully exposed, represent the thoughts, human organization and technical rigor which has

produced them. This becomes part of their meaning and aesthetic. This is a shift from traditional, canonical thinking about architecture.

Underlying these virtual differences between traditional and new architecture are real differences in how architecture is thought about. Traditionally, western, classical architecture was thought of as a metaphysical image of the cosmic order.⁸ It served to clarify and give meaning to human perception of the world. The ordering of classical architecture was based on *perceptions* of the visible reality.

The new architecture came to be thought of in terms of mathematical and geometric solutions to technical problems. The meaning of the new architecture is to a large degree, contained in itself, in the processes of its making. The making of the new architecture is based on abstract and quantitative *descriptions* of the processes of production.



[4] Traditional ornament

Fragmentation

The two centuries which followed Galileo were defined through science and reason. They were characterized by an intellectual demand for truth, verified by mathematics and science. Truth was an understanding of the world in its material essence, clarified with mathematical certainty. This was the age of Rationalism.

The effects of Rationalism on architecture were evidenced in changes in how architecture was thought about and designed. Design processes and methods became very important, being based on empirical testing and mathematics. Architecture was analyzed and tested in terms of discrete elements and systems, such as structure, which were parts of the whole. Architects and theorists rethought architecture to align its processes with those of science.

During the 18th century, French Rationalist architects and theorists continued to challenge and revise notions about architecture which had previously been accepted as absolute. The qualities of scientific truth and validity persisted as attainable goals for architecture. The value of the classical orders was fragmented when subjected to evaluation in terms of the parts and processes of its totality. At this time, three pertinent architectural issues were examined with the purpose of establishing sound (scientific) architectural principles. They were as follows:

1. Scientific method versus canon, i.e. design as a systematic exploration of geometrical, structural and spatial possibilities towards solutions to architectural problems, versus design within the realm of an already delimited solution.

2. The role of structure in architecture, seen as necessary, was rethought in relation to the role of ornament, the necessity of which was questioned.
3. The reconciliation of technology (engineering and machines) and aesthetics was also a critical issue.

The theories postulated in the 18th century following the resolve of the above issues were very important in shaping the architecture created during and after the Industrial Revolution. Beginning with Laugier, these theories and their implications shall be examined.

Abbe Marc-Antoine Laugier was the most influential theoretician of French Neo-Classicism. His agenda was to uncover and establish principles which could work as a basis for a new conception of architecture. Specifically, the new principles would reaffirm the existence of meaning in architecture and, at the same time emphasize considerations of structure and utility. Laugier is the author of an important architectural treatise, *Essai sur l'Architecture*, published in 1753. In his search for principles, Laugier looked to nature to find the origins of architecture. It was understood that in nature, there was truth.⁹

In his treatise, Laugier presents his hypothesis on the primitive hut. He describes the primitive hut as the simplest of all structures. The column, the entablature and the pediment were essential to it, and consequently to all architectures. Laugier stated that walls and other elements contributed nothing to the essential beauty of the building.



[5] Frontspiece from
Laugier's *Essai sur
l'Architecture*

*“Laugier went further; according to him, walls and pilasters should be relieved of the task of carrying loads, which should be confined to the proper column alone: in all this, it is the primitive hut which prompts and guarantees”.*¹⁰

For Laugier, “there was to be nothing superfluous to necessity.”¹¹ Although classical forms were to be maintained, ornament and classical measures were gone. Yet, it must be noted that Laugier defines architecture in such a way that its language is structure, hierarchically placed above walls and other elements. The elements of Laugier’s primitive hut are also the fundamental elements of the classical orders which, in Renaissance theory, are ornament.¹²

The theories of Laugier were very influential throughout all of Europe, placing emphasis on two issues. First, structure was to be made very clear and very aesthetic, based on a *natural order*, and in this way find its meaning. Second, by discarding ornament and emphasizing structure, the traditional notion of ornament is questioned. Alberti defines ornament as “auxiliary Brightness and Improvement to Beauty.”¹³ Alberti states that for structure to be Beautiful, its design must be informed by “Art” and “Proportion.” In this light, structure, which is already Beautiful, does not *need* ornament. However, in traditional architecture, ornament also carries meaning. If ornament is discarded, then structure must take on its role. The understanding of “Beauty” as something which is *both* inherent and added to the form, is changed to “Beauty” as *solely* inherent in the form.

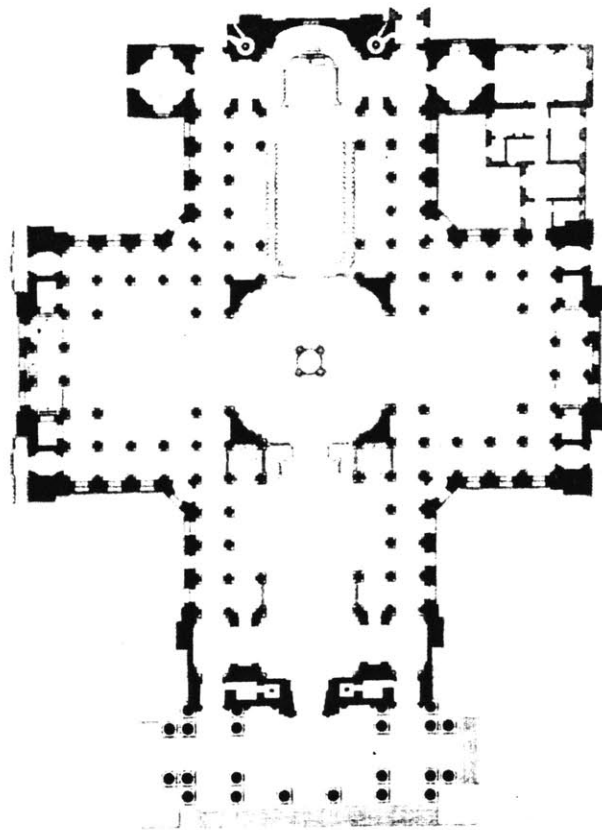
Laugier's reinterpretation of the traditional relationship between structure and ornament influenced the development French Rationalist architecture. Structure, its design informed by "Art" and "Proportion", mathematics, science and technology, was meaning. It represented human achievement.

A very important project, the church of Ste-Genevieve was built in Paris between 1756-1790 by Jacques-Germain Soufflot (1713-1780). Its structure which is clear and articulated, reflects the influence of Laugier. The church is a domed, Neo-Classical building constructed from stone. Its plan is a Greek cross. The dome over the central crossing is formed from two shells. The interior shell enclosed the crossing in a scale which is proportional to the interior space. The exterior shell rises very high, making itself prominent on the skyline. From both the interior and exterior perspectives, the form of the church is visibly legible.



[6] Church of Ste-Genevieve, section

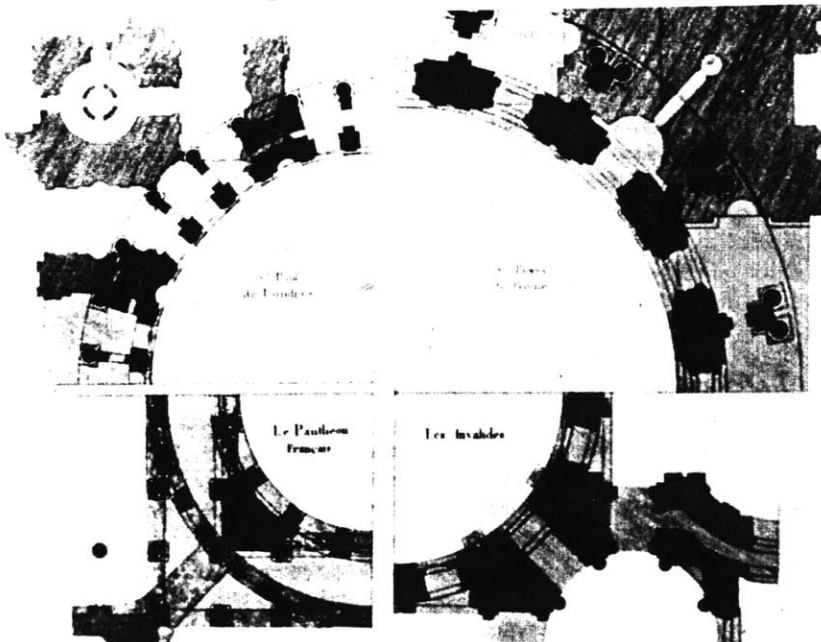
Examining the church, especially the interior, it becomes clear that Soufflot's primary concern is the structure. The interior reveals a highly articulated structural system of vaults and domes. Soufflot designed the structure for the church with the help of two engineers, Jean-Rodolphe Perront (1708-1794) and Emiliand-Marie Gauthey (1732-1808). Soufflot and the engineers "scoured France for stones, building machines to test their compressive strengths in a laboratory set up in the Louvre, coordinating and interpreting their results, and arriving at formulas and equations that they applied to the design of Ste-Genevieve."¹⁴ Soufflot and the engineers were able to achieve a structure which, in comparison to past precedents, was extremely light and of minimal mass and maximum span and openness.



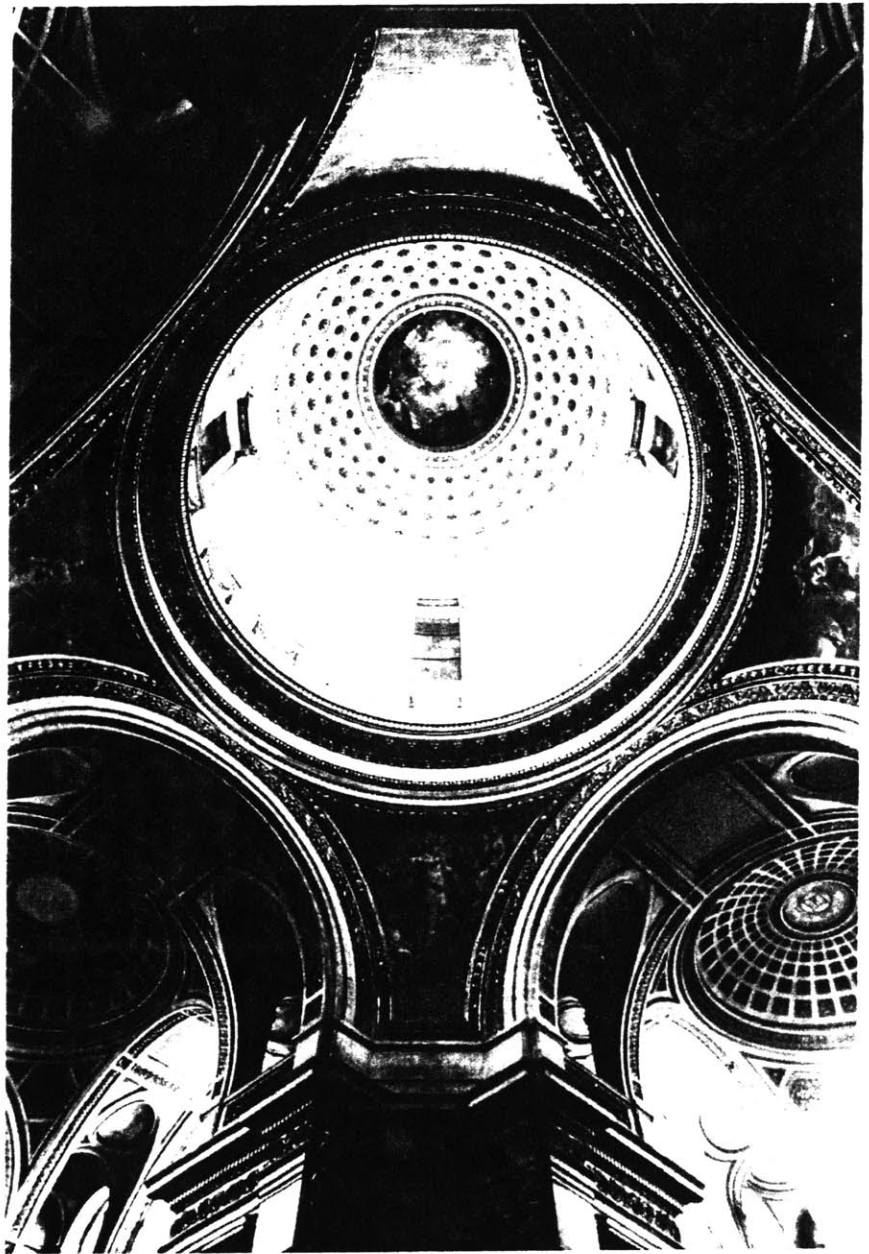
[7] Church of
Ste-Genevieve,
plan

The design and construction of this church and the discussion generated around it, greatly furthered the development of architectural and structural theory.¹⁵ Design based on the development of abstract theories, experiments and calculations gained stature. However, it must be noted that the structure failed twice, needing reinforcement and strengthening. Pierre Patte, Soufflot's contemporary and critic accused Soufflot for over reliance on abstract principles, and insufficient concern for established principles of construction as reasons for the failures.¹⁶

The structure of Ste-Genevieve is very clear and very aesthetic. It was *rationally* designed, based on empirical testing backed up by mathematical formulas. The interior is very *ornate*. The ornament is *applied* to the structure, following the lines of the vaults and dome, serving to articulate them. However, the relationship between structure and ornament has been fragmented. The structure of Ste-Genevieve is very strong and reads as such. The ornament is excessive to the degree that it reads strictly as 'ornament'. The role of ornament, as carrier of meaning has been undermined.



[8] Comparative plans between domed churches

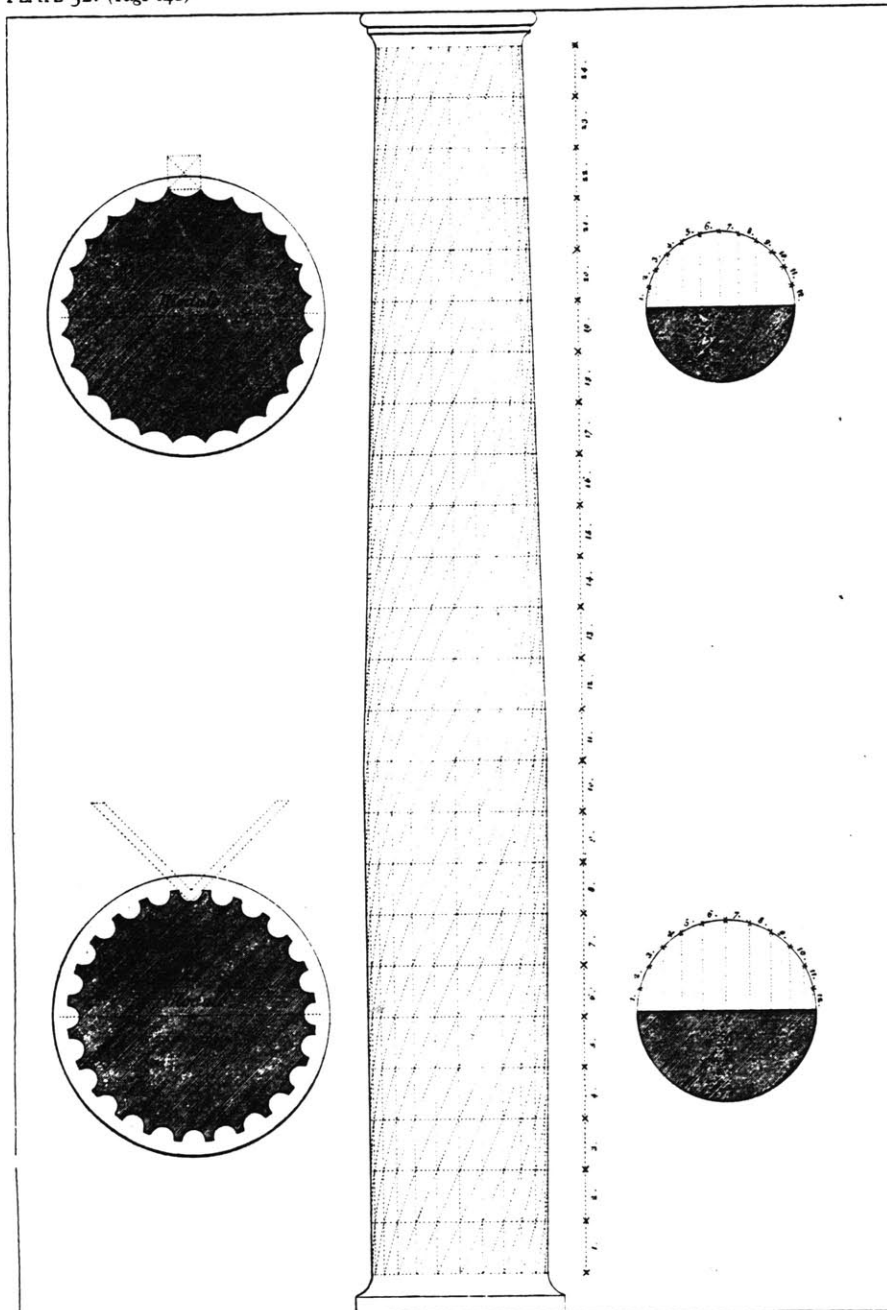


[9] Church of Ste-
Genevieve

Architecture Rethought

During the centuries following Galileo, knowledge and knowing were restructured along scientific paths. Developments in architecture reflected this *restructuring*. Structure gained pre-eminence as a rational architectural system. It could be geometrically

PLATE 32. (Page 148)

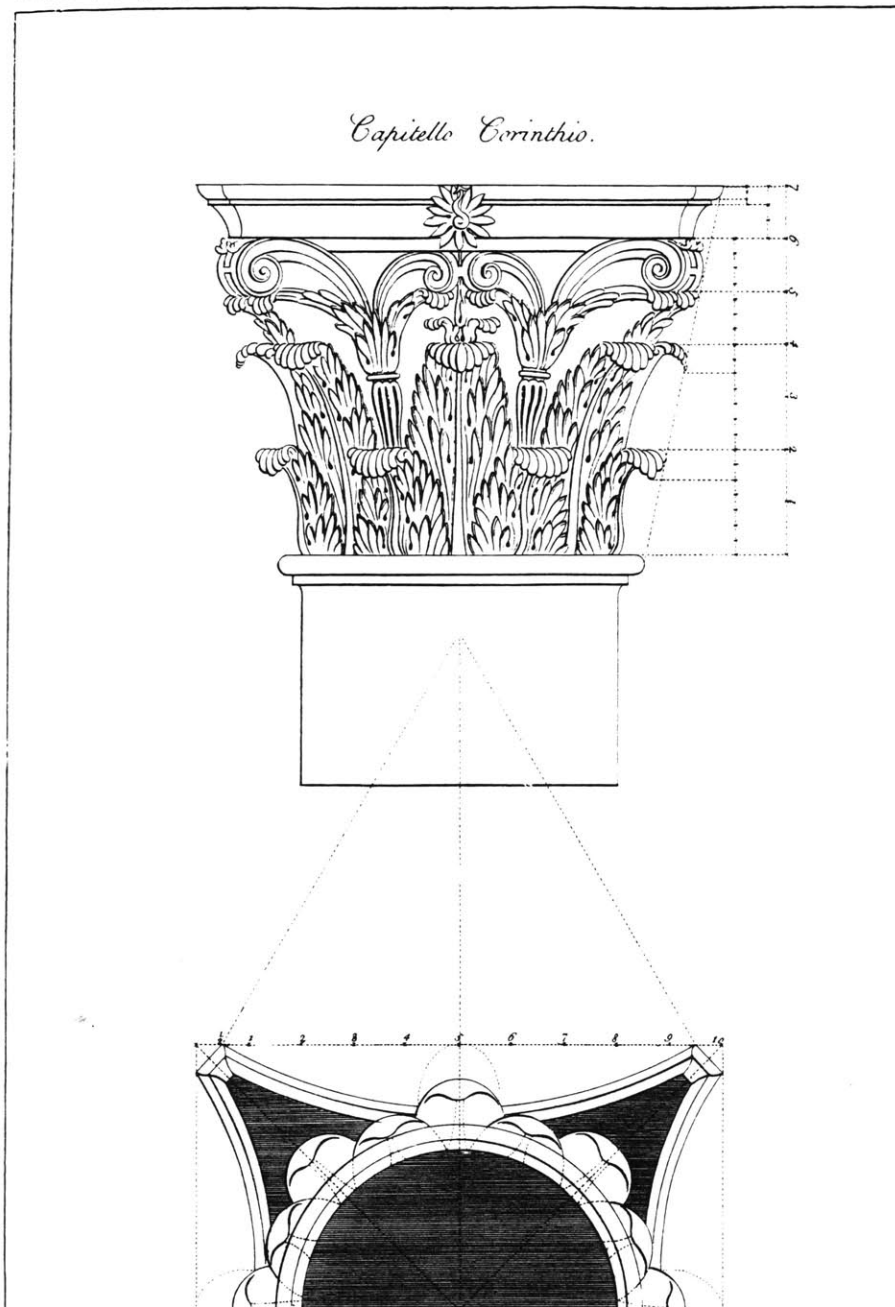


[10] Classical column

A. Leonis delin.

ordered, designed by empirical and scientific testing, mathematically verified and made to carry meaning. Following the rethinking of the traditional relationship between structure and ornament by 18th century European theorists, ornament as an architectural system was abandoned.

PLATE 27. (Page 145)



[11] Classical capitol

S. Leoni delin:

"Capitello Corinthio" = Corinthian capital.

Traditionally, structure was considered walls and piers and framing members which carried loads. The “coverings” were considered the principle ornament to structure. Columns were considered the “principle Ornament in all Architecture.”¹⁷ Ornament was applied to structure. This was the *established* traditional hierarchy.

Ornament, by definition implies adornment and decoration. Its definition can be interpreted further to mean merely an *external* display. Kept in this role, ornament is not important in and of itself, only by what it implies and articulates.¹⁸ Thus, the *established* hierarchy serves to make ornament strengthen and beautify the reading of structure. The fragmentation of this hierarchical relationship, brought on gradually by the loss of confidence in the classical system, served to break down the *established* hierarchy.

Rationalism, Romanticism and Positivism were the three dominant philosophies to influence architecture during the 18th century. Rationalism, is the philosophy based on the belief that reliance on knowledge gained by reason, the intellect, was superior to knowledge gained by the senses and perception.¹⁹ Rationalist architects instrumentalized mathematics and science to *rationalize* architecture and its processes (design and construction). This philosophy did not entail the *exclusion* of non-verifiable ideas or phenomena from architecture. Rather, mathematics, science and geometry were used to reinforce the symbolic qualities of architecture.

Romanticism, the philosophy which evolved in reaction against Neo-Classicism, which was intellectual, based on reason, emphasized imagination and emotions as

receptors and generators of knowledge.²⁰ Its effects on architecture will be discussed later in this thesis. Positivism is a philosophy which establishes natural phenomena, quantified and verified by mathematics and science, as its basis for truth.²¹ Applied to architecture, positivism led to the *exclusion* of extrinsic meaning from architecture and to the incorporation of its own generative processes into its meaning.

Jacques-Louis Durand (1760-1834), is a very important person in the shaping of architectural history. Durand was the architect of numerous important buildings and the author of two important theoretical works dated 1801 and 1802. In the later writings, *Precis*, Durand redefines architecture in contrast to all previous architectural theory, stressing the irrelevance of any transcendental justification.

“Architecture should merely be assured its usefulness in a material world ruled by pragmatic values. There was no need to look for explanations outside the field of the new theory, a theory of architecture postulated for the first time as autonomous, self-sufficient, and specialized, composed exclusively of truths evident to mathematical reason.” (Perez-Gomez)²²

Durand effectively reduced architecture to the act of building in convenient and economical terms. Positivism was the basis for Durand’s reasoning and functionalism was the result.

“This materialistic premise became the basis of the ethics and aesthetics of technology, and it still underlies the most popular historical and ideological conceptions inherited from the 19th c.” (Perez-Gomez) ²³

For Durand, architecture did not need meaning. Ornament, which was traditionally linked to meaning was reshaped for a new use. When applied to structure, it was done so to enhance the structure or make it legible.²⁴

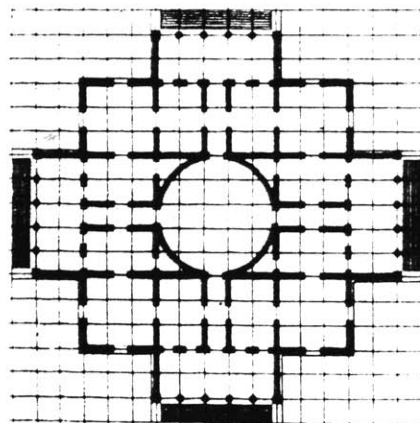
Amongst the broader implications of Durand's theory was the transformation of architecture into a self-referencing, self-generating tool for planning construction. It was to be about itself, assigned a value by the degree to which it achieved its programmatic goals. Taking this even further, the language of architecture underwent transformation into a language which is not about extrinsic meaning, rather it became a language about its task and making explained by ornamental signs. The function of architectural elements and the processes which enable the architecture, become meaningful and valuable in and of themselves.

From studying the gridded drawings of Durand, one can sense his intents. Architecture drawn over a grid is subjected to an arbitrary, controlling order. The grid as a reflection of uniformity, denies specificity and chance. An example of this are Durand's analytical drawings of Palladio's Villa Rotunda. Durand redraws the Villa with the intent of proving it rational, i.e., not generated by issues outside the realm of positivism. In order to prove that the Villa conforms to a grid, Durand must lie, he must alter the actual position of building elements so that they fall onto the grid lines. By subjecting architecture to conformity to a grid, Durand attempts to reduce architecture to positional and dimensional instrumentality.

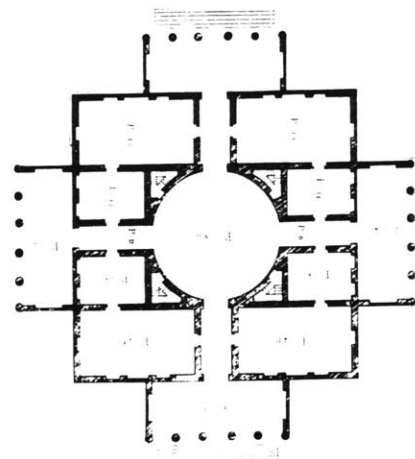
Durand's presupposition that architecture be autonomous and without extrinsic reference influenced many generations of architects that followed. The precedent for Durand's theory was set by Etienne Louis Boullée (1728-99), a French Rationalist architect and theoretician, who in his own theory divides architecture into two autonomous parts. These two parts being, "the art itself" and "the science".²⁵ Durand eliminates "the art itself" and bases the whole of architecture on "the science." The demands of positivism and the new technologies exhausted the language of classical architecture.

At the same time as Durand was promoting theories in his "science" of building, a parallel rethinking of architecture as a product of the age served to recusatate it. Using the current perceptions of the world, and desires for inspiration, the current production processes were employed to create a new architecture. It is the hypothesis of this thesis that crucial to the new architecture was the inclusion of ornament to lend meaning and "Beauty" to structure. Moreover, it is not in the traditional sense that ornament is included, rather its role was subsumed by structure and technology. The new architecture reconciled "the art itself" with the science.

[12] Drawing of
Palladio's
Villa Rotunda
by Durand



[13] Drawing of
Villa Rotunda
by Palladio



Notes:

¹Perez-Gomez, Alberto. 1983. *Architecture and the Crisis of Modern Science*. Cambridge, MA: MIT Press, p 83.

²Perez-Gomez: *Architecture*.

³Colquhoun, Alan. 1981. *Essays in Architectural Criticism: Modern Architecture and Historical Change*. Cambridge, MA: MIT Press.

⁴Perez-Gomez: *Architecture*.

⁵Alberti, Leone Batisti. 1755 Leoni Edition. *The Ten Books of Architecture*. NY: Dover Publications, Inc. p

⁶Vidler, Anthony. March, 1990. "From Tattoo to Trinket: Architecture as Adornment." Milan: *Ottogono* 94.

⁷Perez-Gomez: *Architecture*, p 279.

⁸Perez-Gomez: *Architecture*.

⁹Perez-Gomez: *Architecture*.

¹⁰Rykwert, Joseph. 1981 *On Adam's House in Paradise*. Cambridge, MA: MIT Press. p 44.

¹¹Middleton, Robin. 1977. *Neo-Classical & 19th Century Architecture* NY: Harry N. Abrams, Inc., p 21.

¹²Perez-Gomez: *Architecture*.

¹³Alberti: *The Ten Books*, p 113.

¹⁴Middleton: *Neo-Classical*, p

¹⁵Middleton: *Neo-Classical*.

¹⁶Perez-Gomez: *Architecture*

¹⁷Alberti: *The Ten Books*, p

¹⁸Vidler: "Tattoo".

¹⁹Webster's 1966. *New World Dictionary of the American Language*. Cleveland. The World Publishing Co..

²⁰Webster's: *Dictionary*

²¹Webster's: *Dictionary*

²²Perez-Gomez: *Architecture*, p 299.

²³Perez-Gomez: *Architecture*, p 299.

²⁴Perez-Gomez: *Architecture*.

²⁵ Perez-Gomez: *Architecture*

Section 2 The New Structure

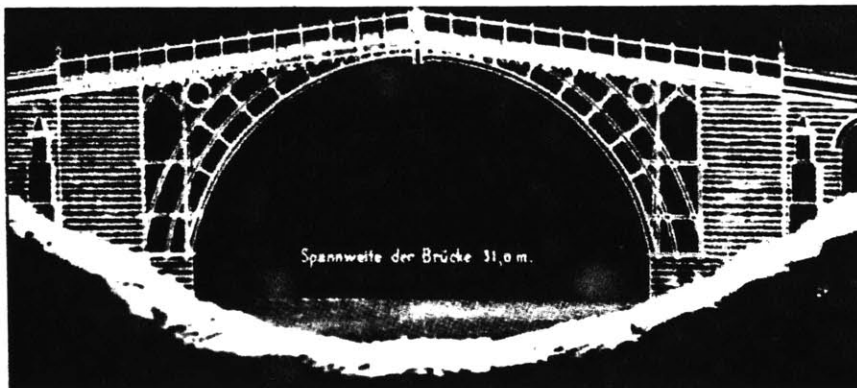
To reiterate, beginning in 18th century the impact of rational thinking on architecture resulted in the displacement of the classical orders as the pre-eminent architectural system. The *complete* classical system was composed of three elements: structure, surface and ornament which were hierarchically ordered. Rational, mathematical and scientific thinking was initially applied to architecture with the intent of strengthening the symbolic qualities of the architecture. The numeric and geometric qualities of the architecture were part of its symbolism, referencing the mathematical order of the universe.¹

The rethinking of architecture scientifically, led to an analysis of it in terms of its *separate* elements. Upon analysis and evaluation, structure was deemed essential and primary to architecture. The value of the classical orders in their *totality* was questioned and denied.

Mathematics and science themselves were meaningful and pertinent, more so than the orders, which referenced a timeless past. They served as valuable tools for extending the previous limits of structure in ways such as span, lightness, spatial openness and expressive form. Their inclusion into structure lent it meaning. *Thus, the displacement of ornament from the classical system did not mean the displacement of meaning from architecture.* Rather, structure could embody these and ornament took on a directly structural role. This point is of absolute importance to this thesis. Proceeding with this understanding, 18th century Rationalist architects redefined architecture, based on the understanding that structure was to be made explicit. ²

The new structures emerged in the late 18th century when processes for manufacturing cast iron into large scale products for construction were developing. Cast iron, a ductile material, was formed into linear members and assembled into an open structure which could be visually penetrated. It was articulated as an ordering of parts forming a regular, geometric pattern in space. The cast iron members were not covered, rather, their exposure was a conscious act. The pursuit of truth in the "Romantic" sense was one of the goals of the designers of these structures. That is, 'truth' was arrived at by stripping, laying bare and revealing the essential. By allowing the structure to be seen and seen into and thereby known, the presentation of 'truth' was achieved.

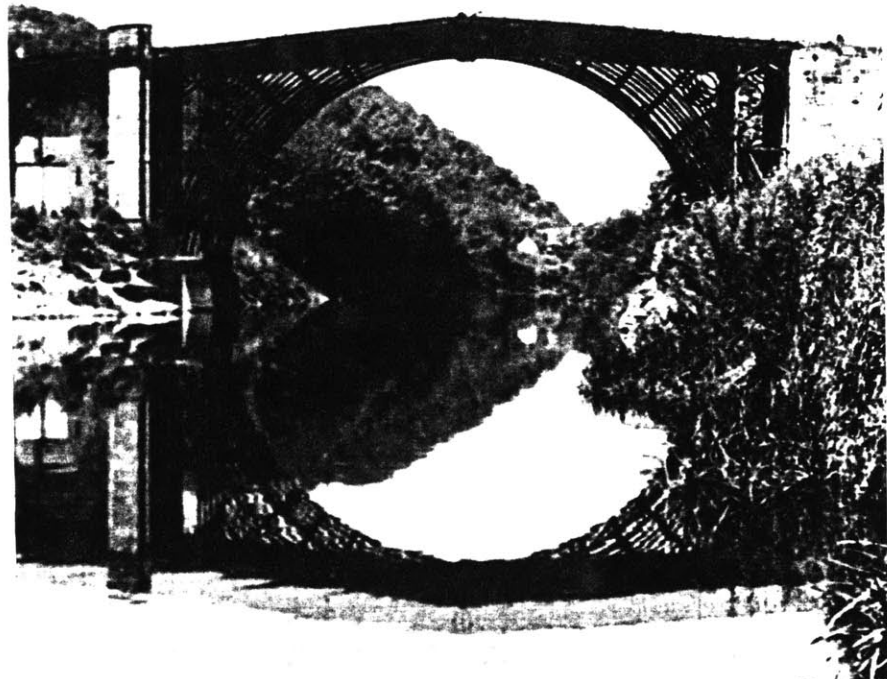
Cast iron, a new³ material for construction was very strong, capable of achieving large spans. The new structures are markedly spatial and expressive. The cast iron members could be made to span long distances and be 'infilled' with glass, thus creating a new, open type of space. Also, the cast iron could be formed to create many desired shapes which previously were not achievable. Realized through rationalized and industrialized processes, the new structures were systematized. They were calculated analytically in terms of elements to be manufactured in a factory, then assembled on site.



[14] Elevation
of
Coalbrookdale
Bridge

The new structures were not designed as per canons and, the adherence to a particular style of design was not mandated. Rather, they were designed logically and pragmatically, understanding both the processes of manufacture and the processes of assembly, towards realizing a finished product. New *methods* for design developed parallel to the technology which enabled these structures to be built.

The earliest known examples of cast iron, free-standing skeletal structures are the Coalbrookdale Bridge, built in England between 1775-9 by Abraham Darby II and John Wilkinson, and a hothouse built in Germany in 1779. They were at once dramatically different from all traditional structures and yet, in 'style', quite similar. This is to say, neither structure was dependent upon solid mass or continuous material for support and stability. They were relatively light in comparison to the traditional structures. Also, they were open structures. Never before had structures such as these been realized.



[15] Coalbrookdale
Bridge

However, the forms of each structure followed tradition. In the case of the Bridge, which spans 100 feet, its arched shape follows the lines of an already understood structural principle. The arrangement of the structural members adheres to a literal understanding of the flow of forces through an arch. Mathematical formulas for designing cast iron structures as well as general principles for design, had not yet been developed when these two structures were built. As a rule, the new structures were experimental, and formulas and principles developed parallel with them.⁴

Besides the openness of the structure, the new structures present an aesthetic quite different from traditional architecture. The Bridge has no applied ornament. Rather, it achieves its visually pleasing character and meaning through its clear forms and 'truthful' presentation of structure.

Traditional structures, from which the new structures depart, operated within a closed range of materials, specialized and craft skills and technologies, and were timeless as well as, nearly changeless. As implied by the definition of structure, they were a construction from parts, i.e. discrete, discontinuous members and elements, placed together to work in unity. Taking this definition further to explain structures of architecture, they are anti-gravity devices. Not all structures of architecture are contained in the above definition. Some are monolithic structures formed from mud or concrete. These are anti-gravity devices but not constructed from parts or discontinuous members.

Certain characteristics pertain to both the traditional and the new structures and architecture. For both, structure is an element of necessity, functioning to

transmit forces through space. In all architectures structure is an element which must be addressed. The belief that the expression of load and support is the sole and constantly recurring theme of architecture, was the basis for Schopenhauer's theory of statics.⁵ This is not to say that architecture is defined as being merely about structure. It is to say that the making of architecture lends meaning to structure.

"If architecture becomes the subject of representation, this representation necessarily includes the memory of the 'problem' of structure". (Colquhoun)⁶

The 'problem' of structure cannot be avoided in the making of architecture, It can be exaggerated, suppressed, clarified, obscured, made to be the subject or vehicle of an idea, or subordinate to an idea. The architectural interpretation of structure through history has varied from age to age. Up until the Industrial Revolution, these interpretations were limited by the range of the constructional possibilities of wood, cables (rope) and chains, and fabrics (woven materials and skins). Walls and columns, arches and beams, vaults and domes were the structural elements available, and could be implemented in a finite range of possibilities. The variations as to detail, geometry, size, and color and texture of material were infinite. Each style chose from this repertoire, thereby instituting a commentary on structural form.

From the repertoire of structural principles (trabeation, bearing wall, arch, suspension), structural systems can be realized using one or more of the structural elements. The primary delimiting factor for structure is size. Achievable spans and heights are limited only by the

strength of materials and the structural principle compatible with the materials.

The secondary delimiting factor for structure is material. No structure can be designed outside the knowledge of the properties of materials. Once the properties are understood, the geometrical configuration of the structural element can develop in accordance with a desired geometrical and spatial configuration. An example is the arch. Traditionally, arches are built in masonry, which works strictly in compression. When assembled into an arch, the individual masonry units are placed in compression, thus exploiting their material properties. However, this explanation is not sufficient to understand the development of the structural element into architecture.

The tertiary delimiting factor for structures is the joint. It functions to connect different materials and elements. In structures, the joint is crucial to the transfer of forces and stability of the structure. The amount of force which can be successfully transmitted through the joint and the degrees of flexibility and rigidity it can achieve are dependent upon the properties of the material the joint is made of, its position and its configuration.

As discussed in Section 1, the theories in architecture preceding the Industrial Revolution were moving towards an architecture of structure. Arguably, western architectures have always been architectures of structure. The classical orders are in fact, an ornamental structural language. However, the structure in classical architecture is almost always *virtual*. With the exception of the column, exposed, free-standing elements of structures were not possible. As it has already been said in this thesis, the availability of

linear, cast iron structural elements allowed the structure to be freed from the wall. The presentation of structure in architecture was now *real*.

A skeletal structure, that is, a structure in which its linear, force transmitting members are separated to varying degrees from the wall is not new. The idea of transferring structural forces through built-up and reinforced lines of an otherwise continuous structure is integral to Roman and Gothic construction. Alberti also advocates such construction for reasons of strength and economy. Timber framed construction also exploits the ideas of isolating forces into linear structural members and then enclosing the building by either 'infill' or a 'skin'. However, neither of these types of skeletal structures were free-standing due to limitation of material availability for forming strong and rigid joints.

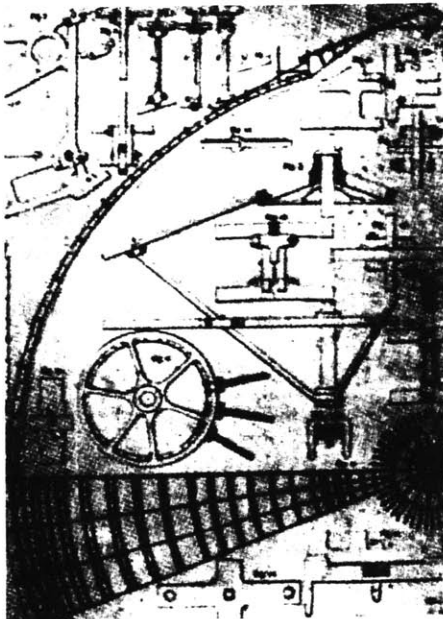
A skeletal structure which is separate from the wall, depends on the strengths of its material. A strong material such as iron can be *shaped* into strong linear elements and *framed* into a structure. Strong joints made from cast iron supply the necessary rigidity to enable the framework to be free-standing.

The new architecture is synonymous with the skeletal, structural frame. Architecture, supported by a cast iron, load-bearing skeletal structure represents a turning point in the history of building. The wall was dissolved, allowing completely new and open spatial arrangements. New forms and large spans could be achieved and the structural elements were capable of being manufactured by industrial processes. The architectures to follow could not ignore the new constructional realities.

“The frame has been the catalyst of an architecture; but one might notice that the frame has also become architecture, that contemporary architecture is almost inconceivable in its absence” (Rowe)⁷

The acceptance of the structural frame as *the* structure of architecture was at once pragmatic and inspired. Because of industrial processes, it was easy to fabricate and efficient in terms of assembly. Construction became lighter, requiring a lower weight as well as volume of materials. Because of the openness of the frame and the visibility of the actual structure, its inherent principle could be assigned “truth” value.

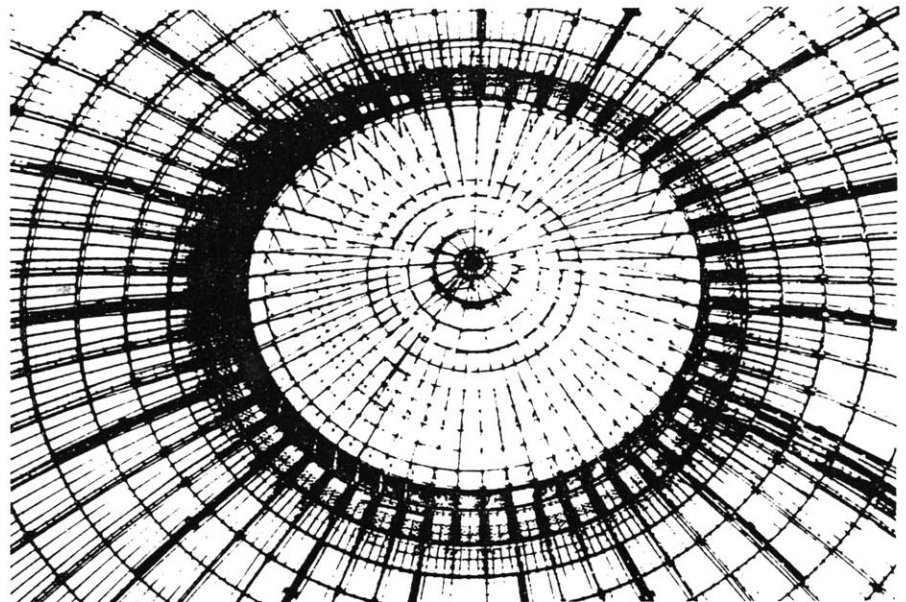
Early rationally designed cast iron skeletal structures were primarily French. The dome over the Halle aux Bles, designed by Francois-Joseph Belanger and the engineer Brunet was built in Paris in 1811. It was the first cast iron framed dome ever constructed. The open structure was ‘infilled’ with glass. The rigid connection between structural members was achieved by bolting them together.⁸



[16] Drawing of structure of the dome over Halle aux Bles

“Stiffened arches formed the space frame of the dome and took up the compressive forces along their length. Horizontal rings were incorporated to withstand the tensile forces. In cross-section the main girders, which also had to accommodate the glazing, were mostly in the characteristic form of the cast-iron rib.” (Kohlmaier)⁹

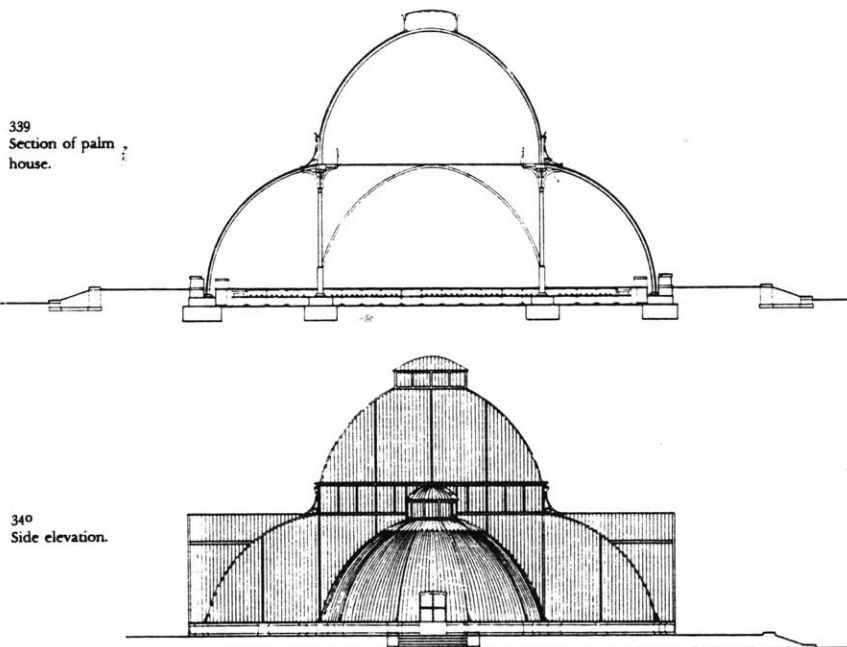
The dome over the Halle aux Bles is very important for two reasons. The first reason is that it was rationally designed in accordance with the laws of statics, i.e. “the law of the equilibrium of forces”,¹⁰ and that these forces were computed mathematically. Precedents for this project had been set by Jean-Baptiste Rondelet, a French Rationalist architect and student of Soufflot. Rondelet was an expert in building construction and rationalized structures. He was responsible for restoring structural integrity to the church of Ste-Genevieve after it failed for the second time. In his treatise, *Traite Theoretique et Praticique de l’art de Batir*, Rondelet advocated the broad use of cast iron for structure. The Halle aux Bles falls in direct line with the earlier rationalized structures by Soufflot. It represents development and advancement of the ‘new’ principles and understandings of structure.



[17] Dome over
Halle aux Bles

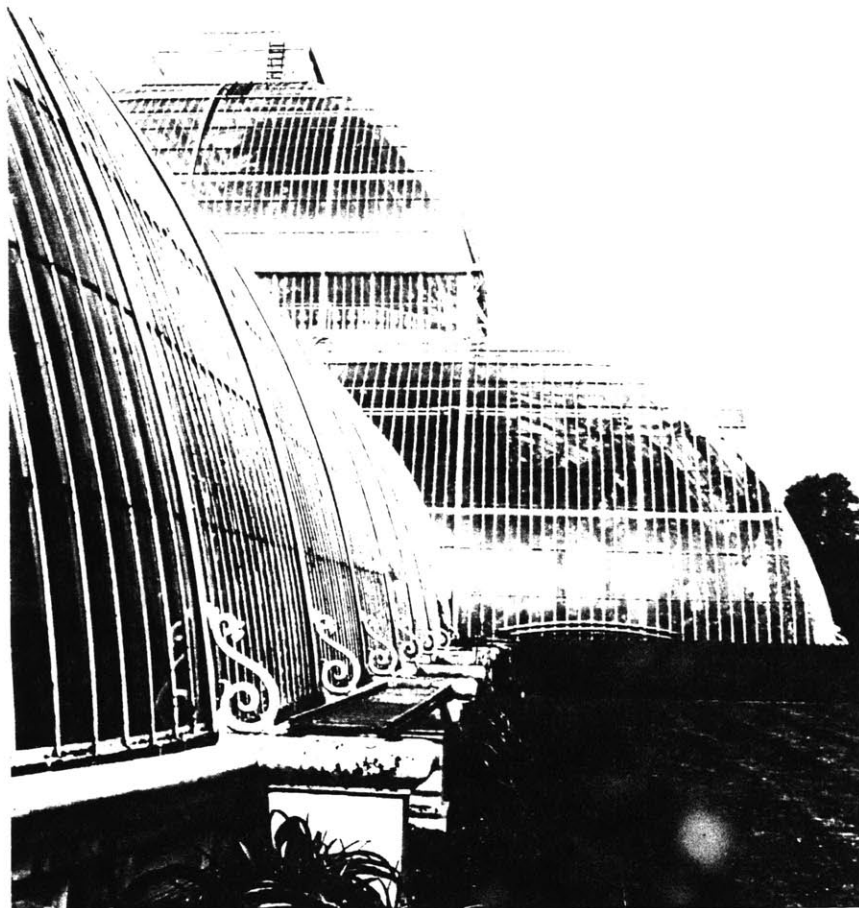
The dome is not ornamented. Its visually pleasing character strongly asserts the rational thinking behind its design, production and purpose. The second reason why this dome is very important is that it changes the traditional concept of the dome, as a celestial structure, representative of the heavens. In this new dome over the Halle aux Bles, the heavens are no longer virtual, they are real and given 'structure', seen through the framework of the dome.

The interpretation of the 'new' relationship between structure and ornament by architects in the 19th century varied by degrees and intent. A rigorous application of the understanding that ornament was collapsed into structure meant that the *entire* structure was read as ornament and be displayed as such. In such cases, the potential presence of ornament can be perceive on each comprehensive level of the structure. These levels are defined by the joints and details, the individual structural members, the geometries delineated by the structure, the volumes defined by it and the structure as an object. The entire structure and construction is made aesthetic.



[18] The Palm House
at Kew
section and
elevation

An example illustrating this point is the Palm House at Kew, England by Decimus Burton and Richard Turner. Built between 1844-48, it represents a “high point in the construction of hot houses with filigree iron rib structures”.¹¹ It is a glasshouse built from both hot rolled wrought iron and cast iron structural members. The ornamental, curvilinear form of the glasshouse structure is an ornamental object, patterned by the filigree iron members. Each rib member is a curved, very thin and light element, possessing ornamental qualities. The columns are thin, elegant members joined to the ribs with ornamental details.



[19] The Palm House
at Kew

“...Turner and Burton effected a technically elegant and aesthetically beautiful solution to the problem of the joint between columns and ribs in the large palm house at Kew...The joint to the ribs and to the transverse girders was made by stout, arched cast-iron brackets bolted by fish plates to the post. In their ascending form, with rosettes as cover plates for the bolted joints, they looked like open flowers.” (Kohlmaier)¹²



**[20] The Palm House
at Kew,
rosette Joints**

Notes:

¹Perez-Gomez: *Architecture*

²

³ Iron was a traditional material for construction and was used in small amounts as reinforcement and attachments, in the form of chains, rods, clamps, etc. However, iron was not available in great quantities for construction until the Industrial Revolution.

⁴ Kohlmaier: 1986. *Houses of Glass*. Cambridge, MA: MIT Press.

⁵ source

⁶ Colquhoun, Alan. 1981. *Essays in Architectural Criticism: Modern Architecture and Historical Change*. Cambridge, MA: MIT Press. p

⁷ Rowe, Colin: 1976. *The Mathematics of the Ideal Villa and Other Essays*. Cambridge, MA: MIT Press. p, 90.

⁸ Kohlmaier: *Houses*

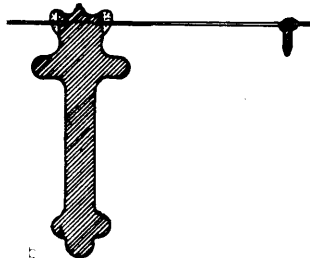
⁹ Kohlmaier: *Houses*. p96.

¹⁰ Kohlmaier: *Houses*. p72.

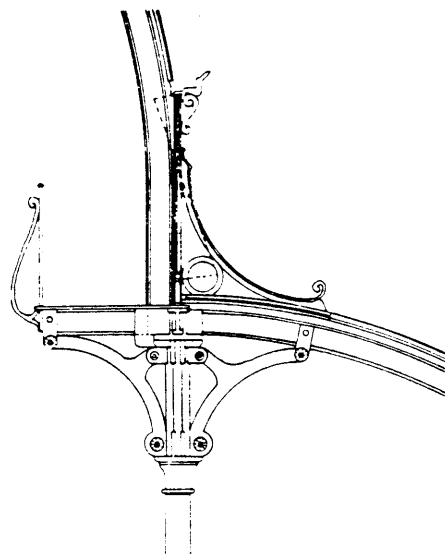
¹¹ Kohlmaier: *Houses*. p 88.

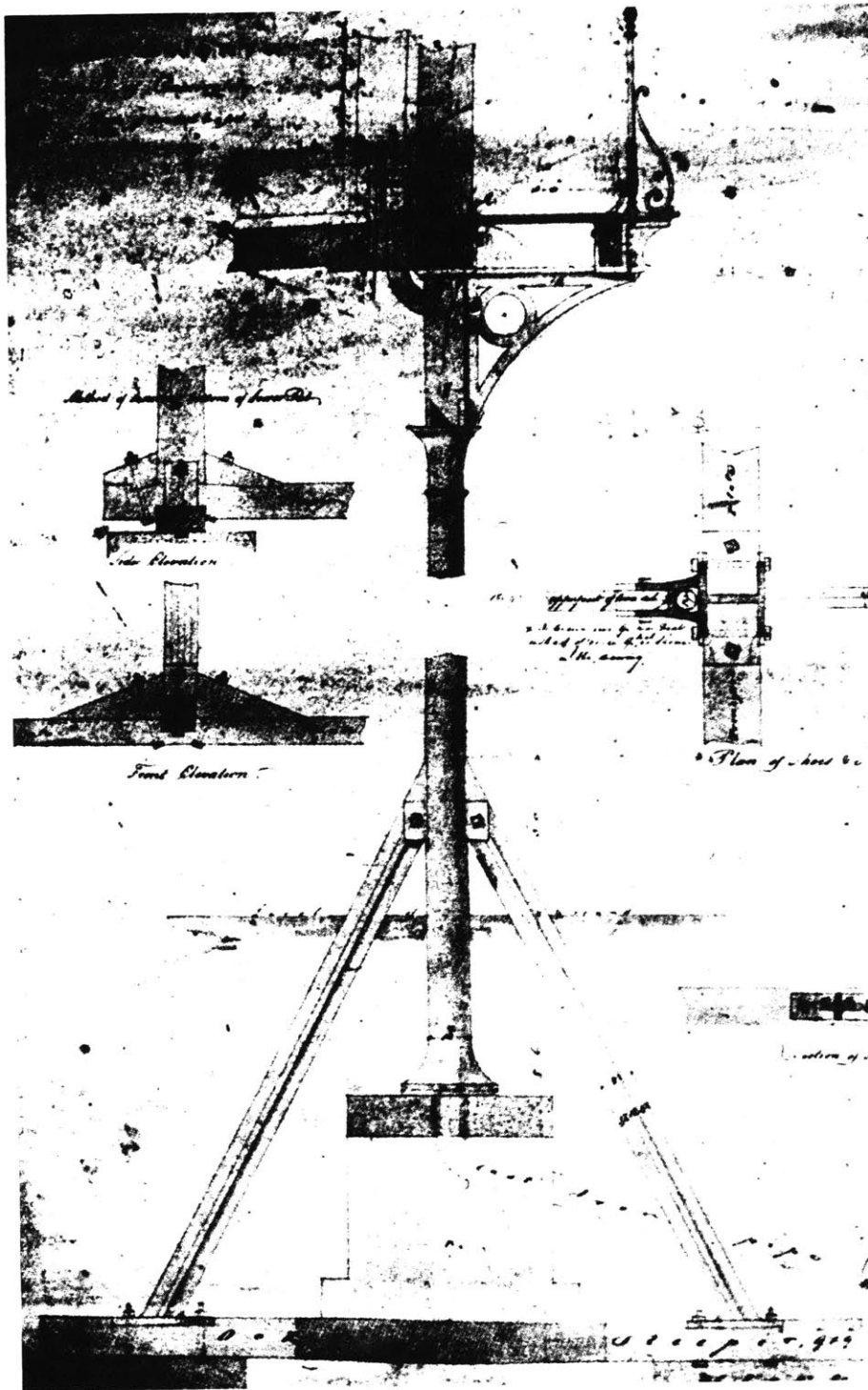
¹² Kohlmaier: *Houses*. p 102.

[21] The Palm House
at Kew
section through
beam



[22] The Palm House
at Kew,
detail of
rosette joint





• [23] Structural drawing for a glasshouse at Chatsworth by Joseph Paxton

Section 3 **Four Characteristics**
Characteristics The new structure emerged following the rethinking of
of the architecture rationally during the 18th century, and the
Architecture of increased availability of cast iron for construction into
Visible Structures open, free-standing structures. The new structure,
presented as architecture, reflected the reordering of the
traditional hierarchy of structure, surface and
ornament. In its appearance and design, the new
structure increasingly reflected the systematized
thought behind its design, fabrication and
implementation. Technology, which enables the new
structure, is celebrated through the new architecture of
visible structures.

Rigorous applications of the new architectural principles shall be studied in Section 3. It is understood that to varying degrees, these characteristics are evidenced in all modern architectures. The criteria for inclusion into this discussion are the following:

1. The skeletal frame. The entire structure is on display and thought through rationally and aesthetically.
2. Using the new constructional possibilities, the architecture is designed outside of the constraints of traditional forms and rules, achieving open, light filled spaces enclosed by a light weight structure and glass.
3. Standardization and prefabrication. Each element of the architecture is carefully designed to fulfill its purpose in coordination with the other system elements. Assembled into a building unit or space frame, these elements form the basic parts for mass-production.
4. Integration of mechanical and architectural systems with the structure.

The new architecture engages the productive forces of the age and advances them. These are incorporated into the architecture as part of the aesthetic. The resulting architecture is informed by the new processes of production.

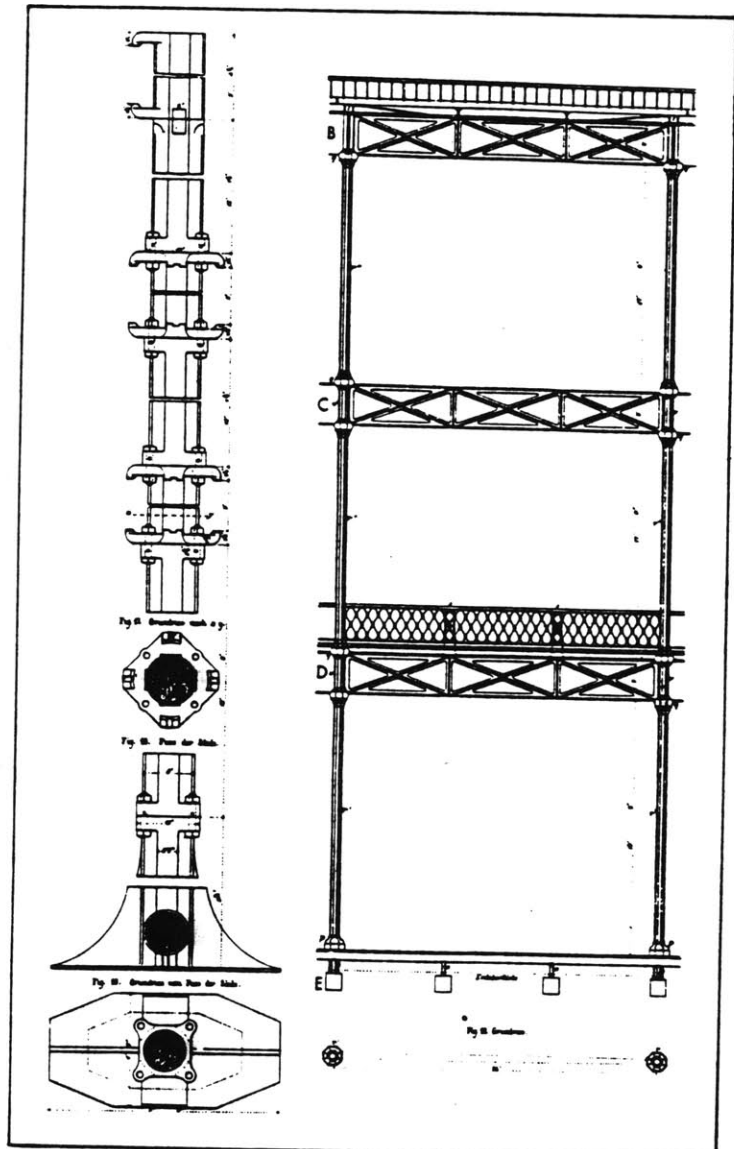
Studying the work of Joseph Paxton, a 19th century horticulturist and designer, the characteristics of the new architecture shall be examined. Because the characteristics are integrally linked, no attempt will be made to rigorously separate them in this discussion.

Mass-produced iron was a product of the Industrial Revolution and, at the same time, iron was the primary material from which its hardware and infrastructures were constructed. The major industries of the age, the railroads, steamships, etc., were built with iron. The development of the processes for producing iron were a direct result of industry's demand for it. When industrially produced iron was used as a building material, it affected a similar reciprocity with architecture. Building elements became manufactured products and their increased architectural applications furthered the development of manufacturing processes.

“The Industrial Revolution had its origins in the iron foundries and the rolling mills and expressed itself basically in the removal of the building process from the building site to the factory.” (Kohlmaier)¹

The iron skeletal frame in its most advanced state was an assembly from coordinated mass-produced building elements. By 1850, “the prefabricated cast iron skeletal building clearly represented the highest state of building technology”.² The individual cast iron members of the

frame could be shaped precisely to match the distribution of forces.³ Building elements could be designed as typical and then replicated. This led to the thinking of buildings as composite structures, i.e. assembled from specifically designed and manufactured parts. Buildings came to be designed systematically. That is, each level of the design and construction process was thought through and made to be a standardized, repeatable procedure, starting at the lowest level.



[24] The Crystal Palace
Drawing of
column and
structural bay

Typical parts are assembled into repeatable elements, for example a column. Then, those elements are repeated in regular intervals to form a building unit which can then be repeated to form a building. Specifically, a building unit is space, tectonically defined by the orthogonally standardized, three-dimensional grid of structural elements in its skeletal frame. Rational thinking guided the implementation of building units into a finished building. The architectural space was divided incrementally (gridded) in both horizontal and vertical section to establish an *invisible* mechanism for controlling the placement of the building units. Thus, method and process became a large part of architecture and were reflected in the finished 'product' in its regularity.

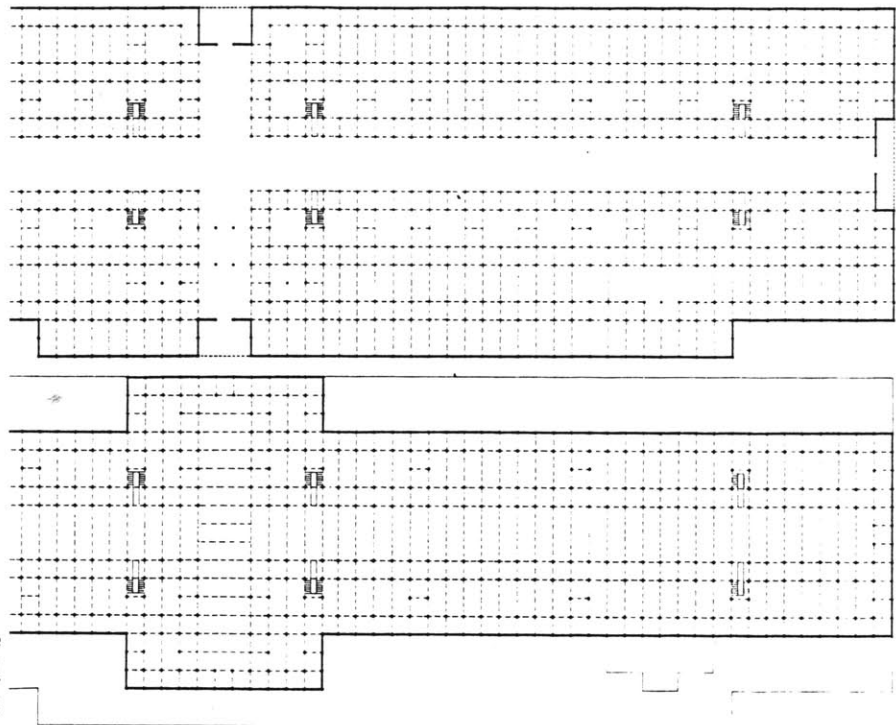
An illustration of this point is found in the drawings by Paxton for his design of a Camellia House for Wollaton Hall, dated 1834. The essential building components were drawn individually. Included were cast iron columns of the structure, frame, base plates and footings, a standard facade element and a folded roof element with gutters. Together, these elements formed a building *unit*.⁴

"This mode of presentation, adequate for the contents, was a novelty in the design of building. It declared itself no longer an objective-oriented design in which catalog listed add-on components could be assembled into various kinds of buildings". (Kohlmaier)⁵

Implied here is the creation of architecture through generation of the building unit or structural bay. The unit or bay is the result of rationally aligning architecture with current processes of industrial production. Thus, architecture generated

mathematically from these elements became the product of its own methods and processes. Ultimately, thinking about architecture in terms of standardization and prefabrication affected both the structural and architectonic orders. Their development was a direct consequence of processes of production and assembly. Architecture generated by the geometry of the standard structural bay became the norm.

To examine the development of the new architecture, as it is shaped by the productive forces of the age and by the current theories, two projects, representative of the new architecture will be examined. These are the Crystal Palace and the Centre Pompidou. Each is exemplary of the reconciliation between architecture and new technology. In this Section, the Crystal Palace will be studied to understand the characteristics of the new architecture. The continued development of these characteristics will be studied in Section 4 by examining the Centre Pompidou, a contemporary example of the architecture of visible structures.

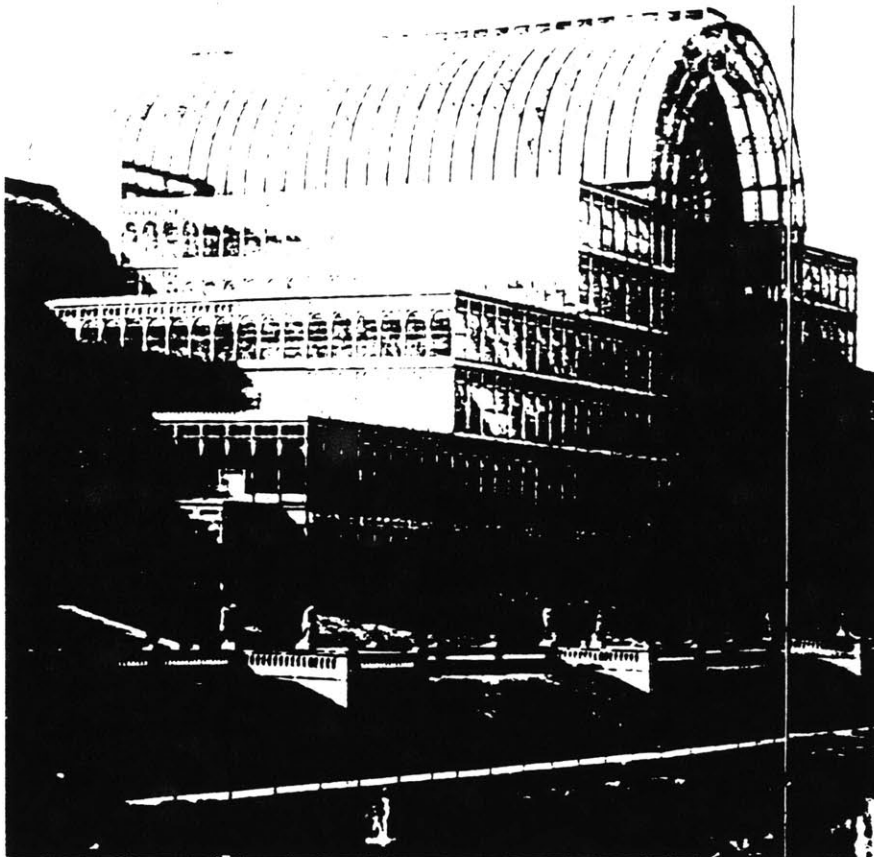


[25] The Crystal Palace
partial plan of ground
and second levels

The Crystal Palace

Between 1850-51, a very large (772,824 sq.ft.) prefabricated cast iron and glass house was built in London. The building was designed to house an international exhibition of the arts, sciences, manufacturing and technology. The site of the exhibition was Hyde Park. Following its closing, the building was to be dismantled, moved and reassembled elsewhere.

Joseph Paxton received the commission for his design of the pavilion, which came to be called the Crystal Palace. Enlisting the help of architects and fabricators, the project was designed and built in less than a year. The Crystal Palace is a very important project in the history of architecture. It is the culmination of all the original forces which were instrumental in shaping modern architecture.⁶



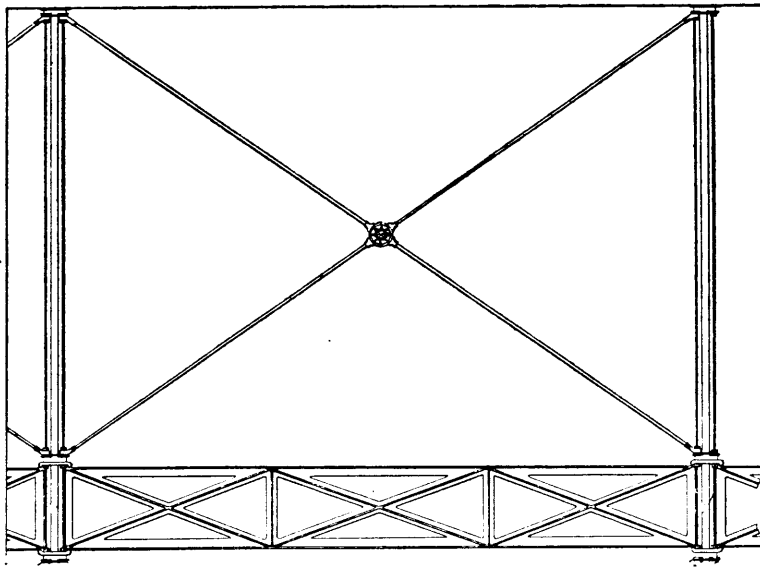
[26] The Crystal Palace

The original forces which shaped modern architecture can be grouped in categories and are as follows:

1. A rethinking of the architectural 'language' by questioning the established relationship between structure and ornament and then redefining their roles. A rethinking of design processes to align with science, mathematics and the current productive forces which enable architecture, replacing canon with method. The new architectural 'language' of real structure incorporates these influences into its appearance and aesthetic.

By 1850, at the time when Joseph Paxton was designing the Crystal Palace, exposed structure, presented as architecture was well understood and accepted by many people.⁷ The cast iron members of the structure of the Crystal Palace were at once functioning to support the building and, serving as its 'language' by carrying meaning and expressing architectural intent. The structure and its elements were designed both in terms of statical function and economy, and appearance. The elements were designed for optimal performance within the structural system. That is, they were designed to support as much load as possible with the lowest volume of material. They were also designed to be visually pleasing, in the form of light elements with clean lines. The details and articulation of the structure served to accentuate the structural elements which were on display. An example of this in the Crystal Palace is the diagonal cross-bracing which is formed from round steel sections and joined with round clamping rings.

"These clamping rings were provided with a decorative cast-iron cover plate in the form of an eight-rayed crystal." (Kohlmaier)⁸



[27] The Crystal Palace
cross-bracing

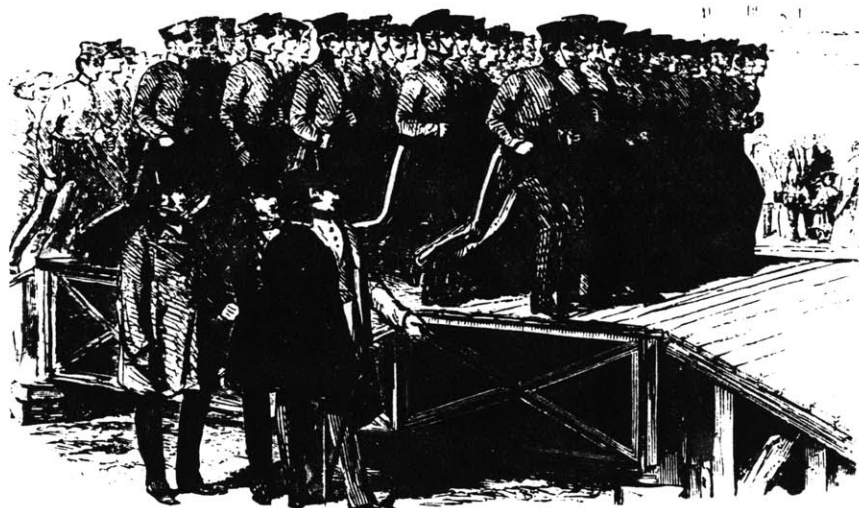
2. The implementation of new materials such as glass and iron allowed a new type of architecture to be built, characterized by light, open space.

Instrumental in achieving a clear reading of structure was the use of glass as an infill material in the facade and roof. A transparent material, glass allowed the building to be seen into and the structure to show through. It made legible the relationships between the parts of the structure and the whole.

The open, rhythmical quality of the Crystal Palace, its spaces defined and patterned by the filigree structure, was undoubtedly beautiful. Complete transparency was achieved. The structure, characterized by technical precision, invoked a new aesthetic generated by the productive forces that helped to create it. Disregarding the decorative facade, which was load bearing, it is difficult to separate the rationale behind the design of the structure from the aesthetics and expressive intents found in its elements and spaces.

3. The development of the skeletal frame into a free-standing structure built up from iron members and connectors resulted from both empirical and mathematical design. Calculations were formulated after testing the behavior of material under load and within specific assemblies.

During the 18th century the fields of architecture and engineering were officially severed and established as autonomous disciplines. The factor which led to this split was the increased ability to analyze and design structures with mathematical formulas. This led to specialization, separating aesthetic design from the rational procedures of engineering. Early in the 19th century, as cast iron structures were beginning to be built, a fissure between the theory of structures (statics and strength of materials) and traditional methods of design became evident. Inadequate understanding of material properties of cast iron prevented the development of calculations for designing cast iron structures. Hence, empirical knowledge (still considered a scientific procedure) formed the basis of design for cast iron structures up until the 1850's. This includes the Crystal Palace.



[28] The Crystal Palace
testing the girders
for strength

Testing the Galleries of the Great Exhibition Building.

“The behavior of iron under load was still not determinable in the early period of iron construction work; the improvement of the load-bearing members was based entirely on values found by experience. Paxton used marching soldiers to test the breaking strength of the cast-iron braced girders for the Crystal Palace.” (Kohlmaier)⁹

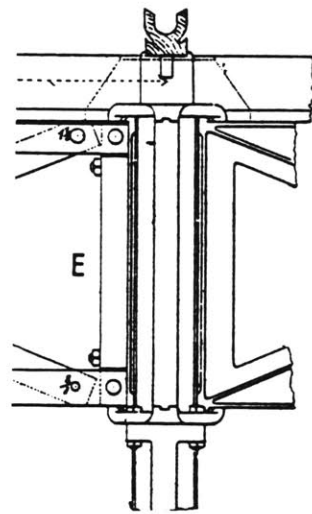
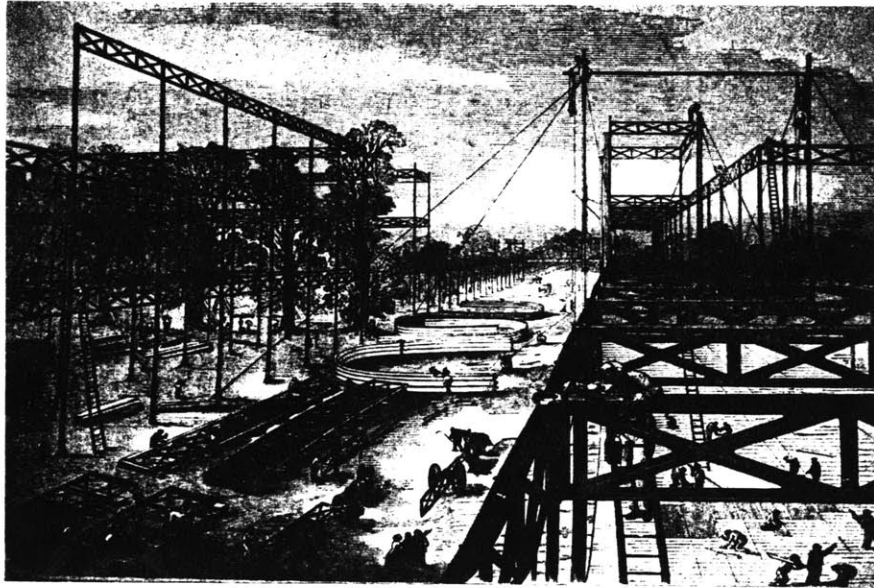
What appeared to be a phase-lag between disciplines, i.e., the inability of theory to perform in application, was overcome in practice. Paxton based his design of the girders for the Crystal Palace on empirical testing as well as existing theoretical knowledge.

As stated previously, strong materials and rigid joints are crucial to the skeletal frame. Total structures built with cast iron were only able to be constructed after the problem of connection between columns and horizontal structural members was solved. This meant, that the design of the prefabricated column had to include a means to make this connection and lend rigidity to the structure.

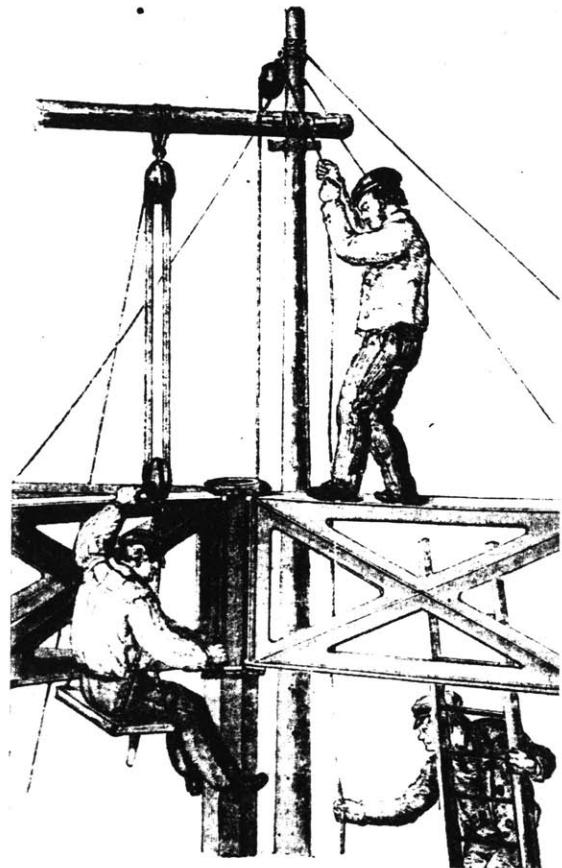
“The development of a self-supporting cast iron frame with a connecting piece for joining columns and girders in three directions was the jumping off point for solving problems of building pre-fabricated filigree structures without recourse to masonry walls and floors.” (Kohlmaier)¹⁰

Problems such as this were indicative of the new architecture. Not only was it necessary to design the connection or joint correctly, but it also had to be done in relation to the assembly of the column, the beam or girder as well as the floor and ceiling.

[29] The Crystal Palace
assembling the
structure



[30] The Crystal Palace
coupling spandrel



4. The design of architecture, aligned with science, mathematics and industry, had to incorporate all phases of the work towards a finished building. This meant thinking about architecture at its lowest level, in terms of elements to be produced in a factory all the way through to its performance as a 'product'.

As the new architecture is an assemblage from individual elements, these elements are the subject of experimentation and innovation in order to achieve architectural and structural goals. The design of these elements is informed by the notion that the entire structure and mechanical systems are part of the architecture and will be on display as such. The integration of the various systems can be achieved on five levels which are as follows:

1. *Remote*. System elements do not physically touch.
2. *Touching*. The system elements come into contact without physically touching.
3. *Connected*. System elements are permanently attached.
4. *Meshed*. Two or more systems interpenetrate and occupy the same space.
5. *Unified*. Two systems are no longer distinct. The same material is applied to more than one use.¹¹

In the Crystal Palace, many innovative solutions to spatial and technical problems are presented. Many of its solutions, i.e. systems and elements, had been realized in previous buildings, setting precedents for the design of the Crystal Palace. These precedents are characterized by a total integration of system elements to form a building unit, thereby generating architecture by

repetition and the new aesthetic presentation of these systems.

As stated previously, generation of units or structural bays to create architecture is instrumentalized by a grid. In all cases there is a horizontal grid, in some cases there is also a vertical grid. In the case of the Crystal Palace, the 24 x 24 foot grid of its plan ordered the 24 x 24 foot building unit which could be repeated in three directions.

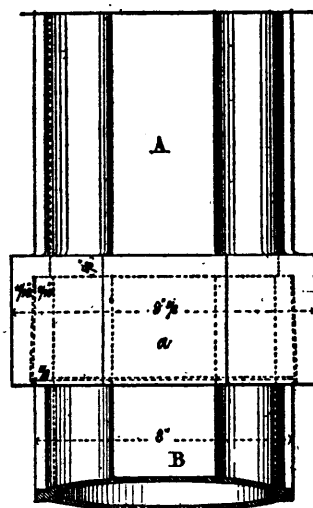
“Paxton’s Crystal Palace corresponds to the classical formulation of iron space frames, and also to that of pure prefabricated building.” (Kohlmaier)¹²

The three dimensional structural bay or space frame was the basic element for mass production. As stated in Paxton’s Brief for his design of the Crystal Palace, the building unit was comprised of the minimum number of actual parts (structural members and joints) which could be manufactured in large numbers.¹³

An examination of a structural bay of the Crystal Palace reveals a complete rethinking of architecture in terms of integration. The basis for design is the structure, from which the other systems radiate. The structure is hierarchically ordered around the column, which is the primary element of the building. Fabricated as a standardized element in lengths corresponding to floor to floor heights, the column is placed at the intersection of the grid lines, braced by cross-ribbed girders which also support the floors. The column and girder are connected by a coupling spandrel which also receives another column, continuing the generation of the building unit vertically.

The columns in the Crystal Palace are hollow, made from cast iron. They are lined with iron pipes which serve the dual purpose of fitting them together and draining water from the roof, thus, achieving integration between the structural and architectural systems. A ridge and furrow roof of special design by Paxton spilled rainwater into the pipes. The footings for the columns were specially designed to contain drains for the rainwater.

At work here is the making of architecture into a rationally thought out machine. It monitors the environment (light, air and rain), it encloses space incrementally to meet demands for it, and can be implemented to house and support many different activities. The Crystal Palace is mecano-architecture. The architecture, which is machine made, becomes a machine. It is about its mechanics and its making. However, the dominant language of the Crystal Palace remains structure. This is shown by the suppression of the reading of the mechanical aspect of the column. The flow of rainwater through the column was imperceptible to the viewer. The column reads as structure.



[31] The Crystal Palace
section through
cast iron column

Generating architecture by means of the design methods which allow expansion, interpenetration, and multiplication led to a new concept of space. Influenced by the elements which were assembled to make them, the spaces may be defined as polyvalent. Thus, a clear ordering of logical thought is evidenced at every level of the architecture.

The architecture of the Crystal Palace, again, apart from the small arches, is not easily linked to the notion of ornament. Whereas each of its elements is aesthetically pleasing, as is the structure in its totality, the structure is a presentation of the mental processes which governed its design and thus, the values from which it arose. As indicative of normative ways of design for the architecture which would follow, it is clear that the role of ornament as carrier of meaning and intent, had now taken on a directly structural role.

Real structure was the primary architectural presentation in the Crystal Palace. Ornament as a system of extrinsic representation was all but gone from its architecture. The few exceptions to this, for example the 'decorative' clamping rings, served to accentuate the structure. Ornament in the Crystal Palace could only serve to accentuate the structure and actual building since its architecture is not one of representation. Rather, its architecture was the presentation of reality; real structure, real sky through its roof, real landscape through its walls. The fact that it could present these realities was its meaning.

Ornament which traditionally carried meaning by referencing qualities extrinsic to the building now was meaningful only if it directly referenced the actual building and explained the processes of its making. In

most cases this meant the collapse of ornament into structure with the exception taken to reveal ornament if it served to heighten the reading of structure.

The architecture of the Crystal Palace is rational. It is based on mathematics and scientific principles. The presence of mathematics and science in the architecture of the Crystal Palace is seen in its regularity and use of technology. The presence of mathematics and science in this architecture is not extrinsically symbolic, rather, the fact that the architecture was generated by mathematics and science was meaning enough.

Notes:

¹ Kohlmaier. Georg. 1986. *Houses of Glass*. Cambridge, MA: MIT Press. p 68.

² Kohlmaier: *Houses*. p 90

³ Kohlmaier: *Houses*.

⁴ Kohlmaier: *Houses*.

⁵ Kohlmaier: *Houses*. p113.

⁶ Kohlmaier: *Houses*.

⁷ Here it must be noted that the acceptance of exposed cast iron architecture was not inclusive of all Victorian Society. The Crystal Palace follows many successful examples of ferro-vitreous architecture designed for the purposes of horticulture built since the early 19th century. Paxton's use of this type of construction for non-horticultural purposes is an important change. However, it was still regarded with skepticism by Gothic Revivalists like Nicholas Pugin.

⁸ Kohlmaier: *Houses*. p311.

⁹ Kohlmaier: *Houses*. p 78.

¹⁰ Kohlmaier: *Houses*. p 118.

¹¹ Rush: *Handbook*.

¹² Kohlmaier: *Houses*. p 106.

¹³ Kohlmaier: *Houses*.

Section 4 The Architecture of Visible Structures

Visible Structures The presentation of real structure as architecture carries great significance. It is a direct presentation of the thoughts and values behind the making of the architecture. The structure does not reference extrinsic architectures or values, rather, it references the abilities and aspirations of the society which builds it. The readable presence of technology which is informed by mathematics and science is meaningful since these are our tools for creating and clarifying the present reality.

As a course of action, creating and clarifying the present reality through architecture is not new and unique to the new architecture. In the traditional architecture, by building in an understood 'language' which was *symbolic* of human understanding of the world, meaning and significance was achieved. In the new architecture, by building in a 'language' which bespeaks of current human understanding of the world, meaning and significance is also achieved.

The architecture which followed the Crystal Palace could not help but be influenced by it either by assimilation or by rejection. The position taken by the Crystal Palace regarding the relationship between structure and ornament became a normative way of design for most of the architecture to follow. That is, structure in and of itself was meaningful and as such, was to be presented 'honestly'. This was incorporated into the doctrine of Modern Architecture. The idea of structure presented 'honestly' was to see many interpretations (and misinterpretations) and the meaning of structure in Modern Architecture was at times lost. This became a crisis, resulting in the loss of meaning in architecture, this also meant there was no ornament.

It is to this position that the Centre Pompidou answers. As a rigorous example of the new architecture, the Centre Pompidou clearly presents both its structure and its ornament which is 'annexed' onto the structure. These are its mechanical and circulation systems. The ornament of the Centre Pompidou is not representational. It is presenting its reality as meaningful and valuable.



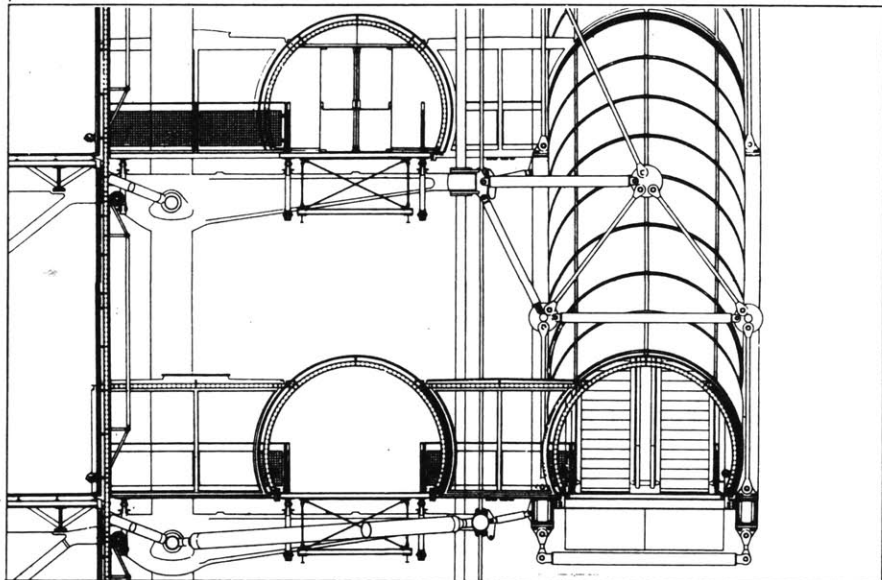
[32] The Centre Pompidou

The Centre Pompidou

In 1971, a competition for the design of a Cultural Centre for Paris was won by the architects Renzo Piano and Richard Rogers. The competition brief called for the provision of one million square feet to house a museum of modern art, a reference library, a center for industrial design and a center for music and acoustic research. It was hoped by the sponsor of the competition, this being the French Government, that by collecting these activities in one facility, exchange between these disciplines and between culture and commerce could take place.

Interpreting the program through modern sensibilities (seeking to cut across social divisions and embracing advanced technology and electro-communications), the architects sought to design a building which synthesized the four specialized activities and the city, and directly engaged the general public. The resulting design is a machine, blatantly expressed as such. Composed primarily of networks; structural, mechanical, circulation, the Centre Pompidou is a machine for synthesis and assimilation. The visitor and the art inhabit the machine.

[33] The Centre
Pompidou
section through
passerelle



The mechanical systems become the primary reading of the Pompidou Centre. Its structure, while it is highly legible, is a visual backdrop for tubes of various mechanical functions which include:

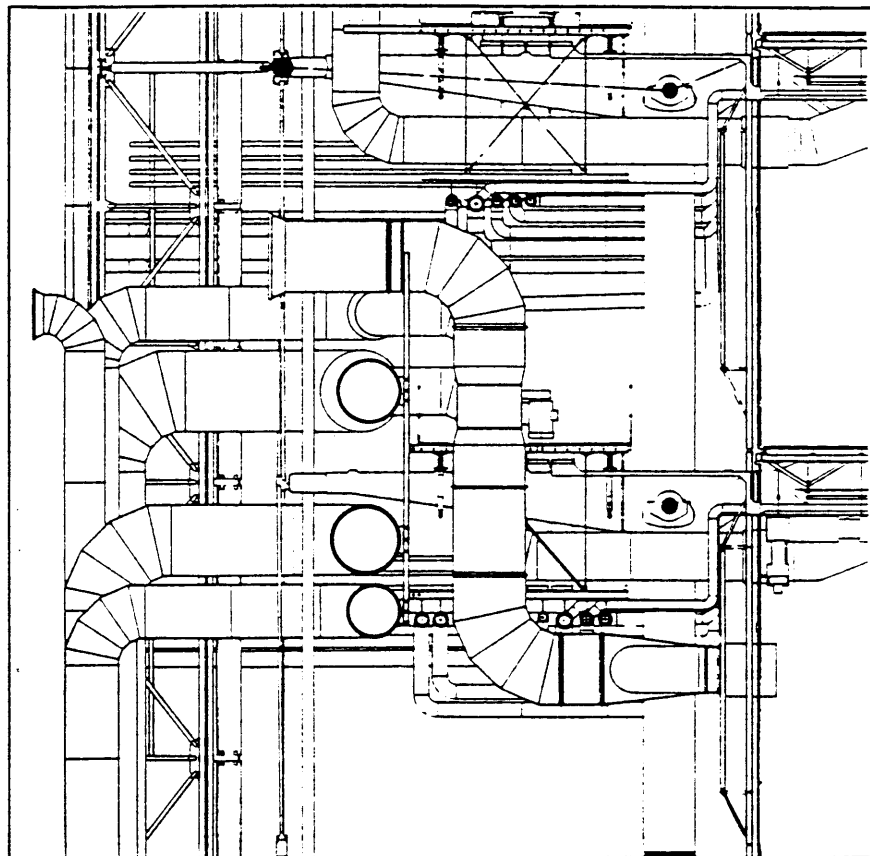
1. HVAC
2. Electrical
3. Plumbing
4. Escalators for vertical circulation

The Pompidou Centre, characteristic of non-traditional architecture, rigorously exploits all productive forces of this age, assimilating them into its architecture. This includes:

1. Implementation of a rationalized structural system which is entirely dependent upon advanced structural analysis involving computers and heavy industry. These have been instrumentalized for determining the size and shape of structural members in the design process as well as controlling the fabrication process.
2. Exploitation of specialized materials and the industrial capabilities of many nations. Examples of this are the 'toughened' glass used for the enclosure of the *passarelle*, the escalator tubes which are attached to the structure along its western face, and the fabrication of the stainless steel lattice girders in Germany.
3. Electronically monitored environmental controls including, window blinds which provide "local solar control and black-out facilities."¹

The structure, an articulated skeletal frame, is light and open and visually prominent. Yet it is no longer the primary language of this architecture. It is presented along *with* ornament, i.e., the mechanical and circulation systems.

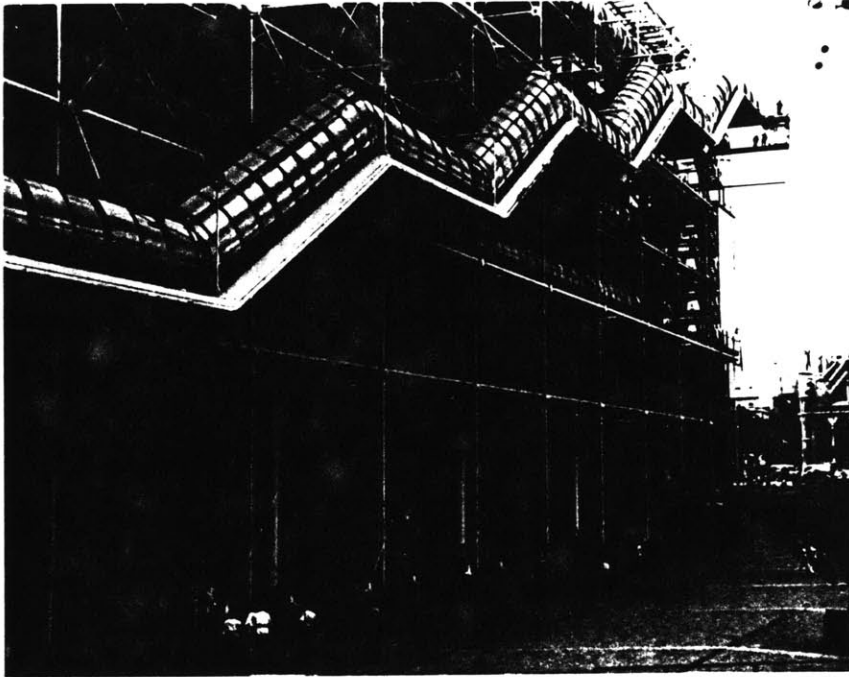
The Centre Pompidou, without de-emphasizing structure of indicates the *formal* inclusion a forth *essential* architectural element, mechanical systems. as its primary language, towards mechanics, Now structure must share the stage with mechanical systems. This is not to say that this is the first inclusion of mechanical systems into architecture. Rather, they have always been considered a secondary part of architecture. Their inclusion has typically been expressed in an ornamental language (decorative drainspouts for example) or else the systems have been hidden. In the case of Centre Pompidou, which presents real structure, it also presents real mechanical systems which are now an inextricable part of the architecture.



[34] The Centre Pompidou section through mechanicals integrated with structure

The Centre Pompidou presents both its structure and mechanical systems as its architecture, expressive of meaning and intent. In the Centre Pompidou, the interpretation of the role of structure as primary and essential has changed to make structure equal with the *also essential* mechanical systems. By infusing mechanical systems with aesthetics and meaning, they become not only significant but also part of the architectural 'language'. The formal design instruments which are used to achieve this are as follows:

1. *Color.* The ducts are painted bright colors, making them decorative.
2. *Shape.* The large round ducts are sculptural.
3. *Direction.* The vertical movement of the ducts contrasts the predominantly horizontal character of the structure.
4. *Scale.* The ducts are very large, abstracting their reading as familiar objects.
5. *Pattern.* The juxtaposition of the ducts with the structure and circulation systems creates pattern and interest along the building face.



[35] The Centre
Pompidou
the passerelle

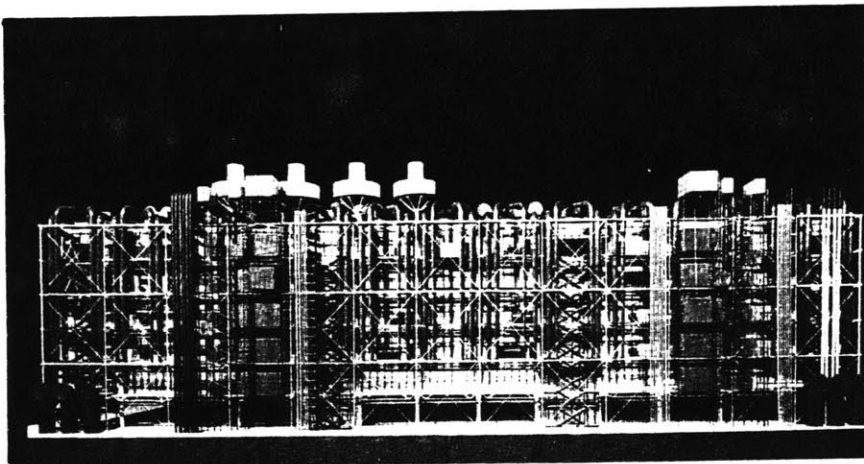
Mechanical systems, now *essential*, are integrated with the structure and other systems. As stated previously, there are five levels of physical integration. Three of the five integration possibilities expressing the integration between structure and mechanical systems, will be illustrated here. The first is to make them equal, which is the case of the Centre Pompidou. The predominant mode of physical integration of systems in Centre Pompidou is *touching*². Elements come into contact with each other without permanent connections. The second is to make structure primary and suppress the reading of the mechanical systems. An example is the column in the Crystal Palace where the role of the mechanical systems is integrated into the column in such a way that it is clearly subordinate to structure. The drain pipes, hidden in the columns are imperceptible to the viewer; the reading of the column gives no indication of its dual functions. Yet, through the integration of the drainpipe into the column, the structure is mechanized. This is an example of *unified*³ integration. The cast iron material of the column is put to two uses and the two systems are no longer distinct.

The third example is to make structure primary and *apply* the mechanical system as ornament to the structure. This is exemplified by the chains and cog-like mechanisms which operate the windows in the Crystal Palace allowing ventilation levels to be controlled. This is an example of *connected*⁴ integration.

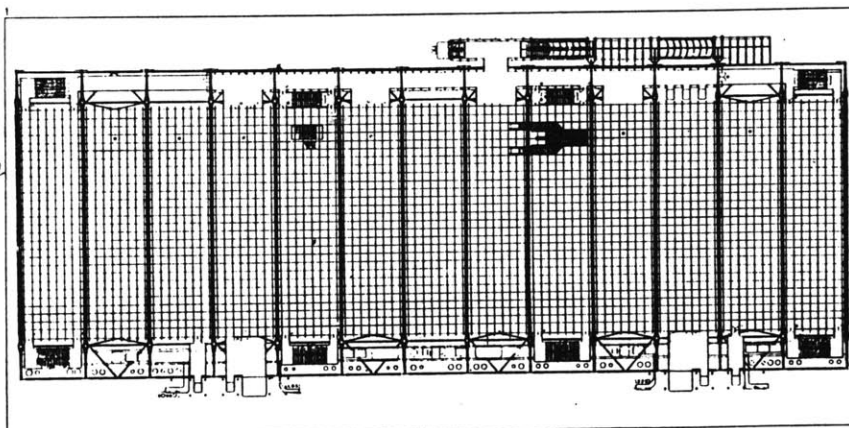
The Centre Pompidou, is realized in a 'language' of electronic and mechanical services, and in a 'language' of structure. They are each visually prominent, the mechanical systems more so than the structure. The structure is 'ornamented' by the ducts and tubes, people, and art. The meaning of the architecture is now in *both*

the structure and the mechanical systems. They are real presentations as opposed to representations.

The structure is also the building. In this way it is more important than the mechanical system which is 'annexed' onto the structure in an ornamental fashion. The structure as opposed to the mechanical systems establishes the order of the architecture.



[36] The Centre Pompidou elevation displaying mechanicals



[37] The Centre Pompidou plan

The Structure of the Centre Pompidou

An intent of the designers of the Centre Pompidou was to realize a building which could address unanticipated spatial needs or changes in the future.⁵ Expressed in the jargon of the Modern Movement, this meant designing a *flexible* building. The interpretation of this modernist notion has varied. Piano and Rogers have chosen the literal interpretation and designed a structure which can change in plan, section and elevation.⁶

“An everchanging framework, a meccano kit, a climbing frame for the old and the young, for the amateur and the specialist, so that the free and changing performance becomes as much an expression of the architecture as the building itself.”⁷(Futagawa)

Rationalized methods of design allow for a variety of solutions. Architecture which can be constantly changed is a consequence of the new rationalized thinking. To achieve closure or specificity in the resulting architecture, content or subject must be added into the work. This means, design intents or program and site constraints determine the final size and configuration of the building. This is different from canonically designed architecture where closure and specificity are achieved within set proportions, forms and typologies.

The way in which Piano and Rogers created a flexible structure was by designing a structure which is an assemblage from a kit of parts. The catalog for the kit of parts for the structure is limited, as is the basic configuration of the resulting framework. Each part, specifically designed, is assembled into an autonomous module, a structural bay of the building. When

assembled as a free standing structural frame of columns and cross members, a fixed framework is established. Change occurs by the insertion or removal of floors, thus changing the plan and section of the building.⁸ In the original design, floors could have been moved mechanically, but this was not implemented.

A kit for suspended mezzanine structures, which can be attached at any point in the building between spans, also provides the ability for change. Further change to the building can occur within the level of the envelope (the architects have said the building has no facade). Panels of metal and glass can be changed to achieve more or less transparency. Change can also occur in the partition layout since all the partitions are demountable.⁹

The structure of the Centre Pompidou is divided into two zones: the below grade substructure is formed in concrete; the above ground superstructure is assembled from prefabricated steel elements. The *complete* superstructure of the Centre Pompidou is comprised of thirteen assembled structural bays, connected together. The dimensions of the structural bays are seven meters wide by fifty two meters long. The superstructure is generated horizontally by placing the bays together at their sides and it is generated vertically by stacking the floors in pairs. In vertical section, the bay is open through its mid-center, being supported at each of its ends by pairs of columns, one in compression and one in tension. Between the two columns, which are seven meters apart, is a special 'gerberette' beam which transfers the forces between the pair of columns. The pairs of columns are forty eight meters apart, and spanned by a lattice girder, three meters deep. This assemblage of columns and beams is braced laterally by

composite reinforced concrete and fabricated steel floor plates. Cross ties stabilize the structure.¹⁰

The structure rises compactly for six stories, at which point its exteriorized support system (ducts) continue to rise to where they meet their mechanized sources at the roof. Its latticework imagery transparently delimits the building. The open space created between the paired columns is contained in this lattice. The open *zone* which is created, is filled with the mechanics and services of the building which are also ceremonial public circulation space. This is the *action* zone of the building. It replaces facade.

The transformation of this action zone into a condition which replaces facade has been effected with the formal instruments of *structure* and *color*. The uniform latticework of the structure serves as a backdrop for the 'ornaments' attached onto it. As an open and visible structure, its meaning is clearly understood. Color, which is used to articulate the various elements and indicate their functions, becomes a sign. It serves to advertise the building and engage the public. The use of color also serves to break down the large expanse of structure, the members of which are very large. Smaller elements are articulated with color to increase their visibility and larger ones are white, serving visually to reduce their size. The colorful elements serve also to relieve what would otherwise be too strenuous an expanse of structure.

The Catalog of Parts for the Structure

The structure of the Centre Pompidou is a rational, systematized assemblage from prefabricated steel elements. These elements shall be studied to understand the thinking and technical rigor which has guided the design of each element. This examination shall acknowledge the processes which have informed their design which include: "expression of the process of building, the optimization of each individual element, its system of manufacture, storage, transportation, erection and connection, all within a clearly defined and rational framework."¹¹ It is understood that these structural elements are to be displayed as architecture and are therefore made aesthetic. The thinking and efforts towards their production is contained in the elements, enhancing their meaning. Their presentation references the thoughts and values from which they arose.

The columns.

Two types of columns comprise the structural support planes of the structure. These planes function in pairs. The primary plane functions in compression, the secondary plane in tension. The compression columns are hollow, 800 mm diameter spun steel. They have been fabricated in lengths equal to two floor heights, fourteen meters. When assembled, to frame six stories, the columns are filled with treated water, pumped through to prevent corrosion and provide fire protection.¹²

Hollow, prefabricated, metal columns are a well established precedent in iron and steel skeletal structures. "Cast iron columns were in use even before 1800."¹³ The use of hollow columns continued until around 1900, and were then replaced by rolled sections. Reasons for the popularity of the hollow column were

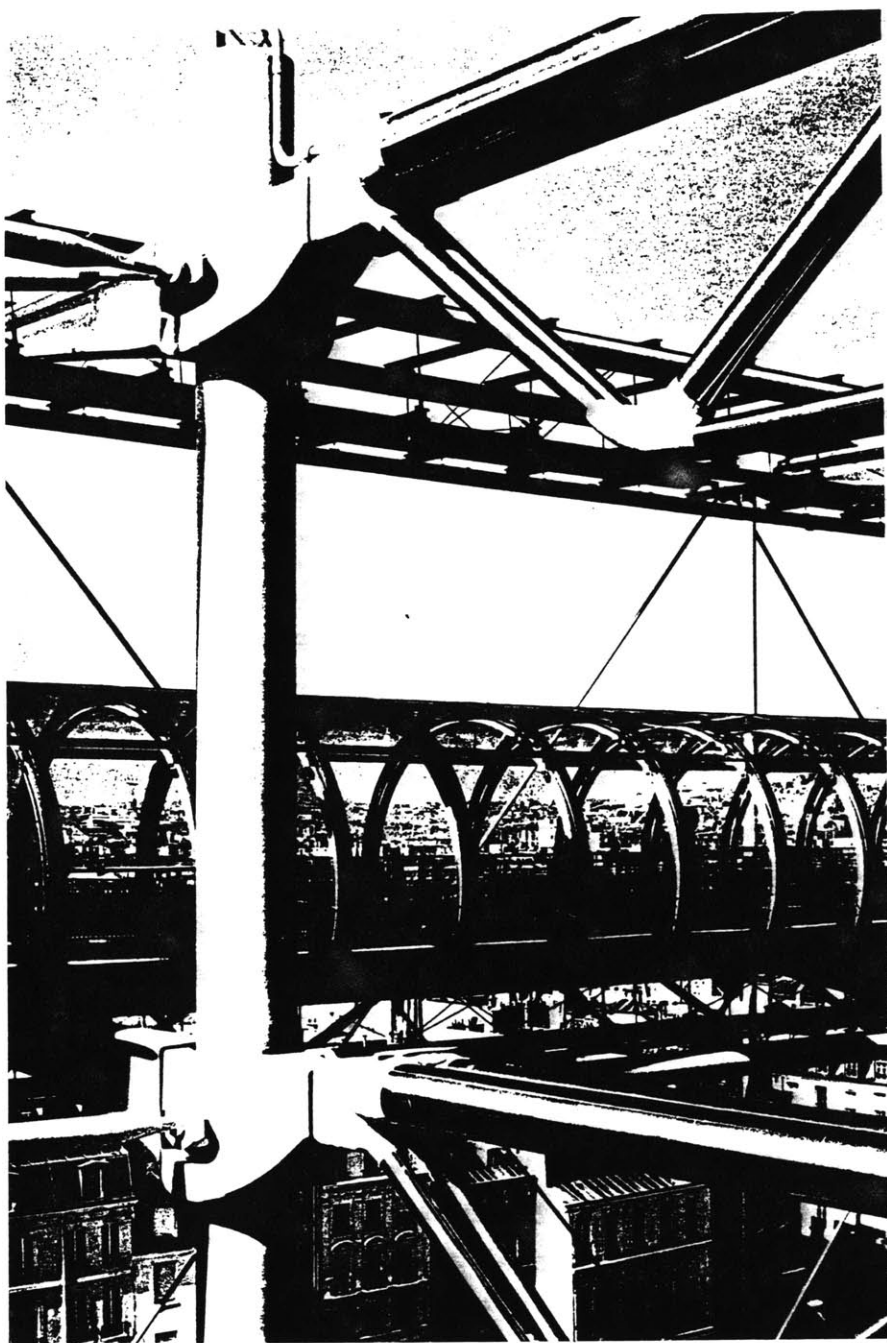
many: "favorable load-bearing behavior, their suitability for mass production, their ease of assembly, and their low manufacturing cost..."¹⁴ Also, for purposes of design, the outside dimension of the column could be standardized throughout a project, while its section could vary in accordance with the loads it would carry.

The hollow column became polyvalent when, in the glasshouse building, it was integrated with the drainage system, piping rainwater collected from the roof, through the column, into the drains in the foundations. The next step in the development of the hollow column was to connect them one on top of another with a coupling joint into an "assembled column".¹⁵

The immediate lesson here is found in the illustration of the evolution of ideas and elements. The very refined columns of the Centre Pompidou are a highpoint in the development of columns for steel skeletal construction. Yet, they are not unlike the hollow cast iron columns from the 19th century. Some of the reasons for the use of hollow steel columns in the Centre Pompidou are even the same. The load bearing properties of a hollow round column are favorable. All columns can be of the same outside dimension, yet of differing section to meet their statical function. Water can be circulated through the hollow section of the column.

The steel tension column, which comprises the secondary structural plane, is connected to the gerberette beam (see below) to carry forces transferred across it from the compression column. The tension column is approximately 200 mm in diameter and is continuous from the top gerberette down to its anchorage connection at grade. The use of the tension column reflects an analytical knowledge of statics and the elastic properties

of metals. The origins of this knowledge are traditional and empirical. In the early 19th century building statics was established as a science, as was the analysis of structures based on material properties under load: tension, compression and shear.¹⁶



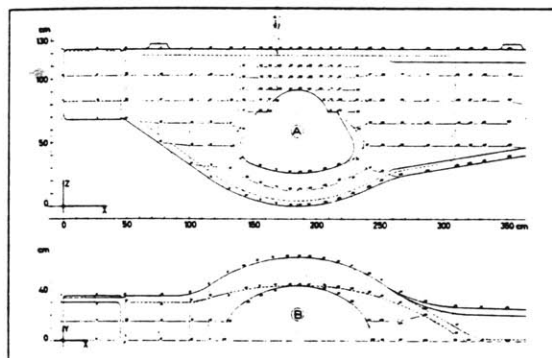
[38] The Centre
Pompidou
column

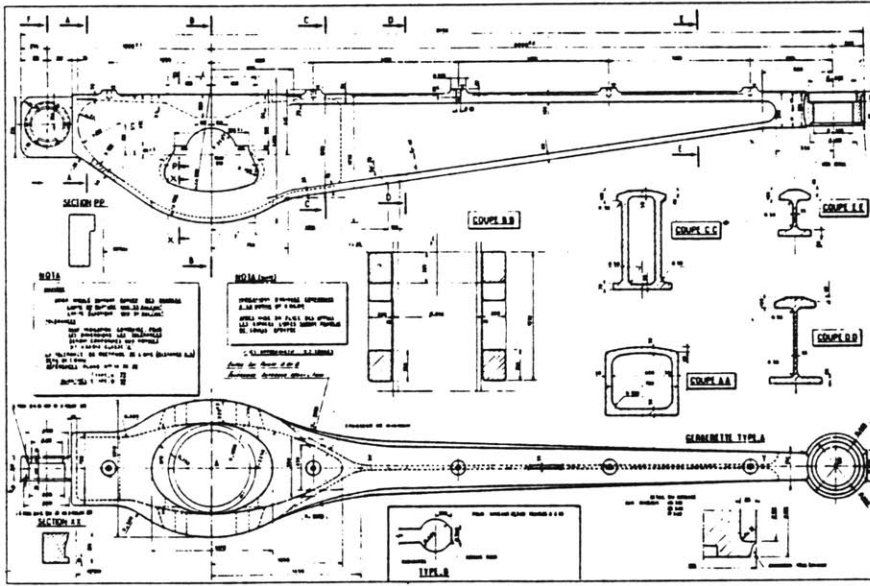
The gerberette.

Spanning between the pair of columns is a ten-ton cast steel rocker beam, called a gerberette. In principle, the beam is a lever and serves to offset the forces posed on the compression column by the lattice girders. Its shape has been determined by computerized analyses of the forces it transfers. The gerberette attaches to the compression column in the principle of a collar beam at its 'heel' end. This attachment also serves to connect columns end to end. The tension column is threaded through the gerberette at its 'toe' end. The lattice beam is attached to the gerberette at its 'heel' end, adjacent to the collar connection. This is to say, the girder is connected to a beam, the transfer of forces occurs through a pin connection, which are then passed to the columns.¹⁷

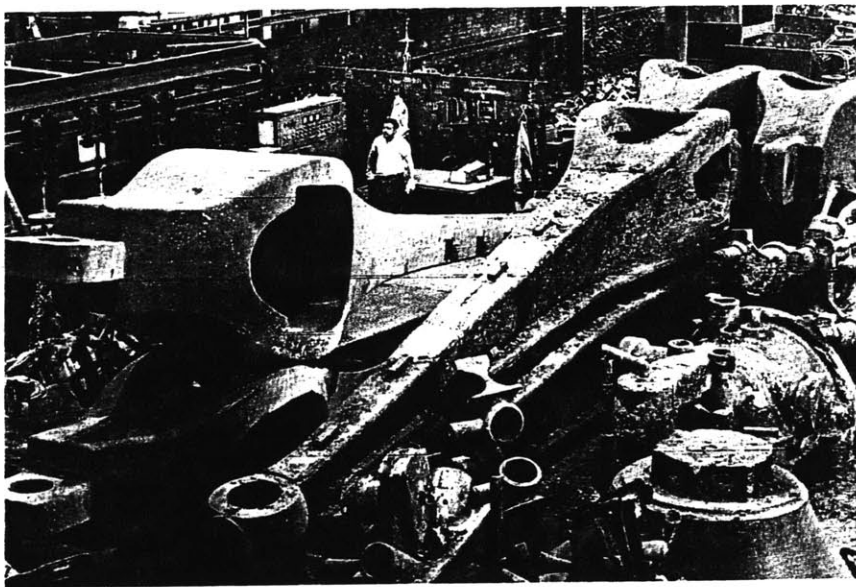
This very special beam, the gerberette, is highly polyvalent. It incorporates in its design, joints for three main connections and the possibility of supporting the *passerelle*. It functions to accept and transfer forces in a reverse hierarchical fashion. The *established* hierarchy mandates that beams can be carried by girders, however, not the reverse. The gerberette is not only a beam and connector piece to columns, but it intercepts forces which should, in principle be transferred directly to a column.

[39] The Centre
Pompidou
computer generated
drawing indicating
stresses through
gerberette





[39] The Centre Pompidou structural drawing of the geberettes



[41] The Centre Pompidou cast steel geberettes

The lattice girders.

The steel lattice girders span between the pairs of columns. Since they have no intermediary supports, they allow a large open space with no interruptions to be enclosed for accommodations of the four major specialized activities. The lattice girders are forty eight meters long and three meters deep. Each weighs one hundred and ten tons and was fabricated and shipped to the site in one piece.¹⁸ Needless to say, they are heroic in scale and were enormously expensive. The process which led to their installation was arduous. The long, continuous spaces provided within the lattice beams and floor plates have been the subject of much criticism. They are *compressed* spaces. The seven meter floor to floor height is not high enough in relation to the forty eight meters of open space.

[42] The Centre
Pompidou
steel lattice girder

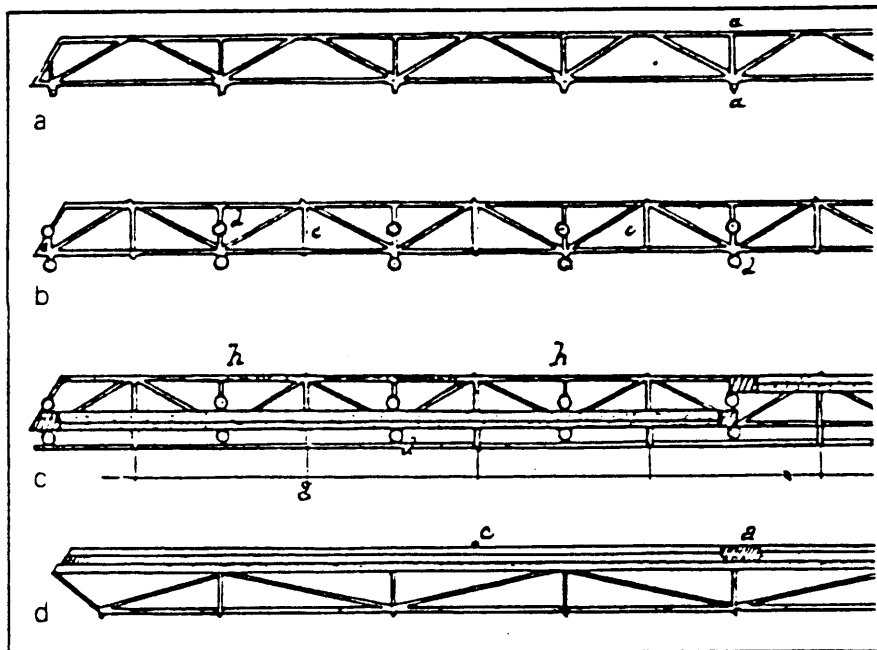


Examined in relation to historical precedents, the lattice girders are meaningful. The earliest designs for cast iron girders were by J.C.Loudon, proposed in the early 19th century. His intent was to achieve lightness and increase spans. Loudon's girders were "accurately designed base on the principles of statics. Moreover, Loudon calculated the weight of the girders and estimated the cost, including that of assembly."¹⁹ Cast iron girders developed as per the principles of statics

and in parallel with the techniques of building with iron. They represent the influence of theory on structural design and construction and are indicative of progress.²⁰

In 1851, when the Crystal Palace was built, the large spans across the seventy two foot wide nave could only be achieved by arches formed from wood. At the time that Paxton was designing the Crystal Palace, sufficient knowledge of the behavior of arched iron trusses was not available. However, in that same year, the Theory of Frameworks was formulated by Culmann. In 1854 when the Crystal Palace was rebuilt in Sydenham, Paxton was able to design iron lattice trusses to span the nave. Between this time, theory was applied to practice and the previous limits of lattice girders and trusses were reduced.²¹

In light of these developments, the lattice girders in the Centre Pompidou speak to the tradition and development of statics and structures, positioning themselves in the line of advancement.



[43] Cast Iron girders
by J.C. Loudon

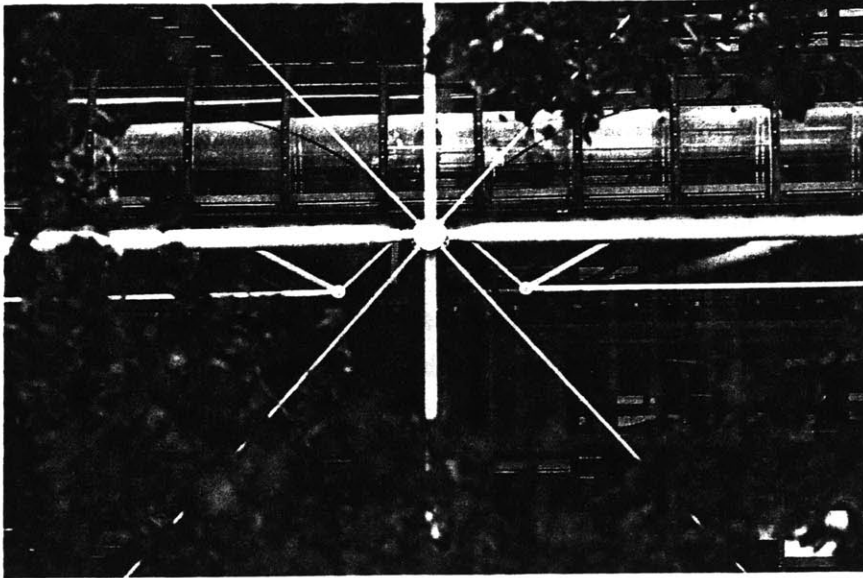
The floor plates.

The composite reinforced concrete and fabricated steel floor plates are integral to the structural system for the transfer of wind loads. Since all main structural connections in the Centre Pompidou are either pin connections or free joints, the stability of the building is achieved by cross bracing in the long facades and by stabilized end frames at the short sides of the building.

The cross bracing.

Round steel sections joined together with a clamping ring are placed diagonally between the tension columns, parallel to the face of the building. As stated, they stabilize the structure. Their implementation reflects an optimization of structural materials. Steel is stronger in tension than compression, thus, by transferring forces through tension members, less steel is used. This understanding is also evident in the design of the dual column system. An effect of all this is a light and very open structure. The lattice work image of the structure is achieved with the cross bracing. Cross bracing is not new and unique to the Centre Pompidou.

In terms of imagery, the cross bracing in the Centre Pompidou takes its precedent from both the Crystal Palace and the Menier Chocolate Factory, an iron skeletal structure with masonry infill built in France in 1852. The lesson from the Crystal Palace was that while both structurally effective and visually pleasing, the cross bracing was spatially awkward. By pulling the cross bracing out of the space of the Centre Pompidou, to the exterior face of the building, this awkwardness is minimized. At the same time, by placing the cross braces on the exterior face, as is done in the Chocolate Factory, the lattice work imagery is achieved.



[44] The Centre Pompidou cross bracing

In 1977, the Centre Pompidou was completed. Representative of state of the art construction techniques which involve advanced technology, its architecture is a product of a design process which rigorously incorporates mathematic and scientific testing, systematized requirements of industry (dimensional coordination, etc.) and craftsmanship into its making. Many of the pieces of the structure were first developed in the architects shop then fabricated in a factory by means of advanced industrial processes.

The Centre Pompidou was a very expensive building to build (approximately \$100 million). Much of the expense was taken up by the development of the unique elements of the structure. Ironically, the design methodology behind it is that which leads to generic, repeatable buildings. If the Centre Pompidou were built many times, the 'first costs' would be absorbed into the price of many buildings and thus the price of each individual building would go down. The difference here is that the Centre Pompidou is a 'generic' prototype. Whereas if many 'Centre Pompidou' were to be built, it would be a 'production' prototype. Ultimately, the thought behind

the Centre Pompidou serves as a paradigm for architecture in this modern period, which seeks to engage this society's technological potential.

“The choice of technology is implicit in the choice to build. Even the use of stone corresponds to a precise technological option. Its simply that in an advanced period like our own materials are available with high levels of cohesion and durability that are easily worked and handled. It is culturally a mistake to reject the opportunity to mould an architectural language using all this potential. It is questionable even to make an issue of it. An architect, a builder, cannot help but use technological methods when it meets the design requirements.” ²²(Piano)

¹ Rogers, Richard. p

²Rush, Richard. 1986. *The Building Systems Integration Handbook*. New York: John Wiley & Sons.

³ Rush. *Handbook*.

⁴ Rush: *Handbook*.

⁵Futagawa, Yukio. 1977. *GADocument, No. 44*. Tokyo:ADA Edita.

⁶ Rogers:

⁷ Futagawa; *GADocument. No. 44*. p

⁸ Rogers:

⁹ Futagawa, *GADocument. No. 44*.

¹⁰ Rogers:

¹¹ Futagawa: *GADocument. No.44*.

¹² Rogers:

¹³ Kohlmaier, Georg. 1986. *Houses of Glass*. Cambridge, MA: MIT Press. p

¹⁴ Kohlmaier: *Houses*. p

¹⁵ Kohlmaier: *Houses*.

¹⁶ Kohlmaier: *Houses*.

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- 17 Rogers:
18 Dini, Massimo. *Renzo Piano*
19 Kohlmaier: *Houses*. p
20 Kohlmaier: *Houses*.
21 Kohlmaier: *Houses*.
22 Dini Massimo. *Renzo Piano*. p.

Conclusion Beginning in the 18th century architectural ornament became subsumed by structure. The resulting new architecture built in the language of structure reconciles its meaning with its making. Without emphasizing the dilemma of reductivism or architecture becoming simply about its own instrumentality, this thesis focuses on architecture which takes its meaning solely from its structure and making. The structure and making of this architecture are not its only attributes. The language of structure is not an end but a vehicle.

The self-reference of the new architecture has allowed ornament to be collapsed into structure. In traditional architectures ornament carries meaning, explains the architecture and adds “Beauty” to it. In new architecture, structure is both expressive of intent and, self-evidently meaningful. Architecture created in a language of structure, grasping the current productive forces is, indicative of technology. The new architecture, incorporating rationalized methods of thinking and new technologies for fabrication and construction, uses them to clarify and redescribe our reality.

New architecture does not borrow from past architectural languages for expression. Its system of representation is not ornament in the traditional sense. Rather, its ‘ornamental system’ read in the structure, represents the making of the architecture i.e., rational thinking and advanced technologies. Its language is valid for this age since, because through technology we create our reality. Using structure as a vehicle for expressing intent, architecture is created.

The difference between the traditional architecture and the new architecture is the reordering of structure and ornament. It is my belief that the interplay of structure

and ornament are essential in the making of architecture. It is from this position that I have examined the historical and contemporary architectural examples. This thesis demonstrates that architecture made in the language of structure, is necessarily about more than the processes of its production. These additional qualities are confounded when structure is misidentified. Structure, often unornamented, is in and of itself meaningful. Structure cannot be judged within the criteria of traditional architecture. The *essential* elements of architecture must rethought and realized in a new 'language'.

The growing primacy of rational and scientific thought, beginning in the 18th century resulted in a crucial change in architectural thinking. No longer was architecture realized within a set of rules, confined within its own parameters. Architecture, guided by rational processes and incorporating advanced technologies, became open ended. The new architectural processes were clear and rigorously defined, however, the results were not predetermined. By applying the new way of thinking and the resulting new technology, the new architecture redescrbed and redefined the world.

Architecture, open and responsive to changing realities, was informed by advanced science and technology. To align itself with the scientific and industrial forces meant infusing technical precision and rigor into the design and building process.

Architecture was no longer confined by stylistic rules but rather by machines and technology. This is clearly evident in the Crystal Palace. The Crystal Palace, constructed from machine-made parts, showcased its

origins. Technology was incorporated into the aesthetic of the architecture.

New architecture functions like a machine. Its elements, structure, surface and ornament became mechanized. The result was the development of a fourth element, the incorporation of mechanical systems into the established listing of *essential* elements of architecture.

The new architecture is evolutionary. linked to the development of its prefabricated parts. these parts are linked in their development. Examples such as the development and evolution of the lattice girders were given to illustrate this. Invention and accomplishment do not occur in isolation, rather, forward progress results from borrowing from past lessons and adding to existing knowledge.

The architectural projects examined in this thesis are been examples which clearly represent the characteristics of new architecture. The projects directly present the real structure of the new architecture. It demonstrates that the architectural language of structure is a vehicle for the creation of architecture. Intents of the architecture are expressed through it and not limited to only self-reference.

All of this leads back to the original problem of reconciling meaning and instrumentality in the making of architecture in an age when architecture has no stylistic delimiting rules. Architecture must continuously engage and assimilate changing realities and thereby be meaningful in and of itself, not by reference to the past architecture or historical values. At the same time, it must reconcile the realities of how it

conceived and constructed. As a result, the present conditions of conceiving and building architecture factor in determining the outcome of the architectural processes.

In examining visible structures, my intention has been to clarify the reasons for its presentation as architecture. Structure, an *element* of architecture, represents the thoughts, values and intents of its builders. At the same time, structure is ordered by these qualities. In the process of making structure visible, these thoughts, values and intents of the builders are revealed.

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