Nov 16th, 12:00 AM

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COLD FORMED STEEL APPLICATIONS ABROAD

by

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The authors are given in alphabetical order. This paper was edited by Teoman Pekoz[5] based on contributions by all the authors.

INTRODUCTION

Cold formed steel structural members have been used for many years on a steadily increasing scale. Such members offer great advantages due to the possibility of optimization in size and configuration. Connected with this broad versatility are several challenging theoretical and practical design problems and the possibility of ingenious solutions to practical problems in application.

The practice of cold forming structural steel goes back more than a century, but the wider use in the last two or three decades has been the result of various factors. The increased knowledge of the behavior and design of cold formed steel, the availability of design specifications and of appropriate sheet material, and the needs of the construction industry have led to the wide and still growing use of this type of structural elements.

Early developments in terms of intensive research, theory and design methods have taken place almost exclusively in the U.S. in the 1940's and early 1950's. Since then significant amounts of research and development of design specification also have taken place in Canada, Europe, Asia, and elsewhere. A large scale international research effort has been sponsored by C.E.C.A. (European Community for Coal and Steel) in West Germany, Belgium, France, Holland, and Italy in recent years.

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General specification activity is taking place in several countries such as Canada, the United Kingdom, Sweden, the Netherlands, France, West Germany, Poland, Japan, People's Republic of China, to name a few. Making the national specifications compatible or in agreement as much as possible has been one of the objectives of an ECCS-CIB (European Convention for Construction Steel Work and International Council for Building Research) joint committee.

In several countries, the cold formed steel construction is the fastest growing branch of steel structural applications. Sound design specifications are essential for competent applications and product development. In recent years along with the basic research leading up to design specification, there have been many exciting, imaginative and innovative product development activities abroad. These new developments have been taking place, perhaps at a faster pace abroad than in the U.S. The success and the development of cold formed steel application abroad can be attributed to several causes.

Companies in Europe and Japan have been willing to invest increasing amounts of money in research and product development. Often the product development efforts take place at the universities where basic research has been conducted and where specialized expertise essential in cold formed steel design exists. This is the situation for example in Sweden, Germany, Great Britain, Japan. Rather aggressive exporting activities in these countries have been helped by the ease the university involvement offers in obtaining approvals in the importing countries.

A technical factor that has been significant in the success and competitiveness of cold-formed steel products is the fact that in most countries margins of safety can be reduced significantly if sound analytical and experimental data exist.

Another factor in competitiveness of cold formed steel is not only the economy but also the emphasis in certain applications on the functional, aesthetic and architectural requirements. Among these one can mention a few examples of wide scope such as architectural use of long-span exposed roof panels, wall cladding material of extremely pleasant appearance and cold formed steel roof tiles that are very durable, water-tight, easy to apply and of good appearance. These examples will be further discussed below.

The objective of this paper is to review some of the developments in Europe and Asia. Since the field is quite wide the paper is not claimed to be a full survey.

APPLICATIONS IN EUROPE

Since the 1950's the major use of cold formed sections in building in Europe has been as purlins or girts. However, recently there have been moves to use sections in other structural applications, e.g. as columns and beams in raised storage platforms, as wall studs, as main frame members, as roof trusses. These developments are now quickening in pace as cold formed steel becomes increasingly more competitive in price with timber and hot rolled steel.

In the field of sheeting and cladding, steel has progressed enormously in recent years. In Sweden, profiled metal sheeting accounts for 90% of the roofs and 70% of the walls in industrial buildings, and the annual consumption of profiled steel and aluminum sheeting is approximately 3 square meters per head of the population. The profiles have become more sophisticated and can span up to 40 feet or 12 meters.

In the rest of Europe, the use of sheet steel in construction is important, although it does not approach the Swedish figures. For instance, in Britain, a breakdown in cost of an actual 100 foot span x 300 foot long x 20 foot high to eaves (30 m x 90 m x 6 m) pitched roof building with steel sheeting is as follows:

Hot Rolled Steel	%	
Main frames	27	
Gable framing	3	
Tubular bracing	1	
Subtotal		31%
Cold Formed Steel		
Purlins and girts	6	
Roof sheeting	23	
Side sheeting	13	
Subtotal		42%
Other		
Gutters and downpipes	3	
Insulation to roof and walls	24	
Subtotal		27%
TOTAL		100%

It is seen that the cost of the cold formed steel exceeded that of the hot rolled steel, although the latter accounted for almost all of the design effort.

Further evidence of the importance of cold formed steel in industrial buildings is given by the figures in the following table which relate to three pitched roof portal frame buildings which were fabricated by one of the largest construction firms in Britain.

It can be seen from the following table that the cost of cold formed sections and sheeting was of the same order as the cost of the hot rolled steelwork, yet again, the design effort involved in specifying the cold formed sections and sheeting was minimal. In most cases, the safe load tables given in a manufacturers catalogue are regarded as adequate.

In Europe the mass production of sheeting on a large scale started in the 1960's. In the 1970's the functional requirements for the building performance along with increased load-carrying capacity became the basis of developments. The optimization for the load-carrying capacity has led to the use of higher strength steels with yield stresses of about

	Building 1		Building 2		Building 3	
Floor area	22,000 sq.ft. ($2040m^2$)		17,000 sq.ft. ($1580m^2$)		10,600 sq.ft ($988m^2$)	
Spacing of frames	20 ft. (6 m)		20 ft. (6 m)		20 & 26.7 ft. (6 & 8 m)	
	Weight Tons*	Cost £**	Weight Tons	Cost £	Weight Tons	Cost £
Hot rolled steel	61	19,570	26	10,471	19.7	6,871
Cold formed steel	7	2,360	7	2,540	6	2,305
Steel sheeting	15.3	8,289	12.6	7,207	8.7	4,891

*1 ton = 2205 lb. **£1 = $2 approximately

Cost of hot rolled and cold formed steel in three buildings.

350 N/mm^2 and properly designed deeper sections. Cold forming techniques were improved to enable profiling in longitudinal and transverse directions. Also in the 1970's, the acceptance and use of stressed skin (diaphragm action) design demonstrated its economic benefits.

These developments will probably continue in the present decade. Special emphasis will be on considering the entire structure with all its functional requirements. This will lead to the development of composites of cold formed steel with wood and other sheeting material and to the development of ways of maintaining energy efficiency.

It may be of interest to follow the logical development of panel geometries in more detail as shown in Fig. 1. In this figure the ratio of the weight of the sheeting to the appropriate span is plotted against the allowable span. Three different generations of spans are shown. The first one (I) has plane flanges and webs. In the second (II) intermediate longitudinal stiffeners have been used. The third generation panel (III) has both longitudinal and transverse stiffeners. The transverse stiffeners provide stiffness needed due to the rather large spacing of the webs. As seen in the figure, each generation of panels covers a span range with a minimum weight located close to the center of this range. As the dead weight of the panels has a significant influence on the economy of roofing, the producers have sought to minimize weight and at the same time increase the optimum spans. The panels are designated by their approximate depth and thickness in mm. The reduction of the ratio of the weight to span throughout the three generations is remarkable. The third generation covering a span range of 6 to 12 meters seems to reach maximum preferable span lengths from the point of view of transportation and ease of erection. This type of panel will be further discussed below.

Some of the well established applications in Europe such as purlins, girts, and panels are common in the U.S. also. In the following summary only some of the recent developments in Europe will be presented.

Long Span Panels. — The third generation panel mentioned above designated TRP 200 is manufactured by Plannja AB of Lulea, Sweden. TRP 200 is successfully marketed in several countries including Great Britain and Germany.

In erection, support cleats are first fixed to the main steel frames or beams (Fig. 2) by cartridge fired pins, using spacing jigs. The panels are then put into position. The cleats also reinforce the web at the concentrated reactions from the supporting beams. The troughs of adjacent units are fastened by self-drilling, self-tapping screws (Fig. 3), and the longitudinal joints between the units are made, not over the supports, but near the inflection points as shown in Fig. 3. In this manner the panels are virtually continuous.

The range of panel thicknesses is 0.9 to 1.5 mm, and for uniform frame spacing the end bay panels are of heavier gauge than in interior bays where the bending moments are smaller.

The transverse corrugations in the top flange serve to distribute the load to the stiffened corners; in fact the transversally corrugated portion of the panel may be perforated for acoustic reasons. A scheme of applying the insulation is illustrated in Fig. 4.

For roofs having TRP 200 panels, the stress skin (diaphragm action) can be used to transmit the horizontal forces in the interior of the building to the end walls. The possibility of using TRP 200 in concrete composite construction is also being investigated at the present time.

Truncated Pyramid Dome (Pyradome). — The design of steel roof structures in which the surface participates actively in resisting in plane load and also increases the overall stiffness, has been an area of interest in recent years. Different forms of "surface active structures" were developed in the U.S. during the 1960's. These included steel folded plate roofs, hyperbolic paraboloid and cylindrical shell shapes. One of the most impressive examples was that of a 70 m hypar cantilever for an aircraft hangar. A number of folded plate roofs for halls and gymnasiums up to 30 m span were constructed using a welded double skin deck. In the U.K., the philosophy was recently strengthened by using standard mechanical fasteners and single skin sheeting in the load test at Salford University to failure of a 21.6 m roof span in 1976. The basic structural principles inherent in the above structures are also present in pyradomes.

Pyradome is a truncated pyramid of 15° side slope, supported at its four corners as shown in Fig. 5. Its members comprise an upper compression ring which supports the roof light and lower tension ring (eaves member). The rings are separated by sloping hip members. Sheeting spanning from eaves to ridge not only serves to transfer wind loading across the roof by stressed-skin (diaphragm) action but also contributes to the folded plate behavior when adjacent modules are compositely permitting a clear span between corner columns as can be seen in a recent application in Fig. 6. If clear edge span is required, then a compound Z-section may be used. Otherwise, a mid-span support is necessary for the perimeter eaves. Horizontal load resistance is provided by a bracing member or a knee joint.

The economy of structural action, for single and multi-module action is matched by the ability for quick erection of the roof panels and easy transportation to site.

Recently some tests were conducted on pyradomes at the University of Salford. In these tests the minimum yield strength of all the members considered was 258/N/mm^2. The fasteners for sheet edges and seams were 6 mm self-tapping screws.

V-Shaped Beams. — Recently at the University of Karlsruhe in West Germany, a research project on a beam system using trapezoidal panels provided with cold-formed steel edge members has been started. As illustrated in Figs. 7 and 8, mass produced V-shaped beams will be used to span 15 to 30 m by varying the distance between the beams. This range of spans is typical for light industrial buildings. For the maximum span where the top flanges of the V-shaped beams are close together, an orthotropic structural system of beams in one direction and trusses in the other is obtained by providing the lower flange of the beams with another plane of trapezoidal sheeting. This two-way load bearing system makes increased spans possible. The purpose of this project is on one hand to study special design problems with respect to stability, connection and structural performance and on the other hand to demonstrate new possibilities of using thin-walled cold formed steel structural elements.

Zeta Purlin Section. — A new purlin section was developed entirely at the University of Salford for Ayrshire Metal Trim Limited. One of the reasons for considering a new section was to allow an increased flange width which would be adequate for any type of roofing material and insulation. It would not have been adequate to increase merely the flange width of existing Z-purlins, since this would have had the effect of increasing the inclination of the principal axis, which was already about 15°. At the time the traditional Z-purlins were developed most roof slopes were also about 12°-15°, so the section had little tendency to deflect laterally.

During the past 10 years there has been a tendency for roof slopes to reduce, so that a common slope today is about 8°. It was therefore decided to develop a section with a principal axis at about this inclination. Another requirement was that the sections should nest so that sleeved systems or overlapped systems could be used.

Several sections fulfilling the above requirements were press-braked and tested at the University of Salford. On the basis of these preliminary tests the choice was narrowed down to the cross-sectional configurations shown in Fig. 9. Continuous purlin tests were conducted on the shapes shown in the figure. The Zeta purlin showed less tendency to twist than the Z-purlin. Therefore more intensive tests were conducted on the Zeta purlin. Continuous purlin tests as well as studies on the different sleeve types were carried out.

In summary, the mode of development of this section was by an ideal colloboration between a university and the industry. A significant amount of interest has been shown by the industry in this new section compared with the conventional Z-purlins.

Thermal Girt. — A new thermal girt developed and marketed by Plannja AB of Luleå, Sweden is illustrated in Fig. 10. Due to the fact that the cutouts are reinforced by folding the cut edges, these sections have obtained high load-carrying capacity while possessing excellent thermal properties.

Storage Platforms. — Storage platforms, sometimes known as mezzanine floors, are a most efficient way of providing additional floor area in buildings where there is sufficient headroom. Usually the columns consist of rectangular hollow sections on a 3 to 4 meter grid, the main beams are of hot rolled beams, the secondary members are hot rolled or cold rolled sections and the flooring is often of chipboard or plywood. A typical imposed loading is 5 kN/m^2.

A new design using entirely cold formed steel sections was developed as a result of colloboration between the University of Salford and Ayrshire Metal Products Ltd. The evolved structure consists of rectangular section columns composed of two 170 mm x 85 mm x 1.8 mm thick channels welded toe to toe or 100 mm x 100 mm hollow sections.

The beams are channel sections shown in Fig. 11. Primary beams span between the columns and the secondary beams span between the primary beams. Both the primary and the secondary beams have the same basic shape except for the thickness. The primary beams are two channels bolted back to back whereas secondary beams are single channels.

The corrugations in the beam webs increase connection stiffness and strength significantly. The beams are bolted to the column tops through a gusset with corrugations as shown in Fig. 12. The connection between a primary and two secondary beams is shown in Fig. 13. A view of the full scale test setup is shown in Fig. 14.

Lattice Portal Frames. — In the early 1950's the 21 m span cold rolled lattice frame shown in Fig. 16 was studied. At that time the cost of fabricating the frame was found to be too high. However, at the present time there is a renewed interest in such frames because of the new possibilities of automatic cutting to length and punching.

A new portal frame under study at the University of Salford for Ayrshire Metal Products Ltd. is shown in Fig. 16. This portal frame is fabricated from 220 mm x 6.5 mm x 1.5 mm cold rolled channels and has a 21.6 m span.

Systeme M.100. — This system is one of the most interesting applications in France where a significant amount of cold formed steel products are used not only for their practical advantage but also for aesthetic reasons.

Systeme M.100 was developed by Mr. Pierre Oudot and Mr. Léon Pétroff and marketed by Profilés et tubes de l'Est. The development was directed and financed by "Centre de Recherche et d'Architecture, d'Urbanisme et de Construction." The basic component of the system is shown in Fig. 17a. The basic component can be used to make up columns and beams as shown in Figs. 17b and c, respectively. The connections between components and between beams and columns make use of clamps shown in Fig. 18a and b. Upon tightening, these clamps cause indentations which assure a simple but rigid and strong connection. The connection between primary beams is as shown in Fig. 18c. Examples of finished structures are illustrated in Fig. 18d.

Great architectural versatility in creating spaces, ease with which the spaces can be changed, high degree of dimensional accuracy as well as the extremely simple manner in which the structure can be constructed are among the advantages of Systeme M.100.

Galvapoutre GG. — Another interesting cold formed steel application in France is the Galvapoutre GG (Fig. 19). This section marketed by Societe des forges of Haironville. The Galvapoutre GG can be used as a non-composite (Fig. 20) or composite (Fig. 21) member.

Scantile. — This roof tile modelled after the glazed Dutch roof tile has been developed and marketed by Plannja AB of Lulêa, Sweden. It is cold formed from hot dipped galvanized color coated steel. The tiles and an application are illustrated in Fig. 22. Glazed clay tiles are fragile, heavy, and expensive. The Scantile overcomes these disadvantages and provides a roof that is virtually the same in appearance as the glazed tiles.

APPLICATIONS IN JAPAN

Cold formed steel products were first produced in Japan in the mid-1950's. The first "Design Standard for Light Gage Steel Structures" was published in 1957 by the Architectural Institute of Japan. This document was based upon Japanese research and the AISI Manual for Light Gage Steel Members. As a result of this publication and the development efforts a rapid growth in light gage steel products followed. The production was 10,000 tons in 1955, 40,000 tons in 1958, 100,000 tons in 1959, 200,000 tons in 1960, and 700,000 tons in 1965. In 1970 the production was approximately one million tons and has remained steady at that yearly amount since then. The latest edition of specifications concerning cold formed steel sections was published in 1974.

In Japan, cold formed steel sections are now considered as one of the important construction materials, and are consumed in various sectors of the construction industry, such as building, civil engineering, shipbuilding, and vehicle. In 1980, more than 70% of the total production of cold formed steel sections is estimated to be for construction usage; consumption in the machinery, vehicle and shipbuilding industries is not a major part since those areas are far below 10% of the total each. Among the various types of cold formed steel sections, the channel section is the most popular where applications vary from members like, purlins, girts and studs for steel buildings such as factories and warehouses, to framing members for single houses and small buildings. Several tens of thousands of pre-engineered single houses are built each year using channel sections and other cold formed steel sections (Fig. 23). At first, cold formed steel sections were widely used even for large scale steel buildings as columns and girders, by assembling them into truss or lattice configurations shown in Fig. 24, but recently these sorts of applications have almost disappeared because of their high fabrication cost. As a special application in Japan, the deep channel sections for beams in wooden houses is seen in Fig. 25. These are adopted economically for rather long spans in the heavier snow-load zones of the islands. A small amount of hat-type cold formed steel section is being steadily consumed by the shipbuilding industry.

Similar to the other cold formed steel sections, Cold-formed Structural Tubing produced by the electric resistance welding process is used in a variety of markets. More than 50% of the total domestic consumption is for building usage and the rest is for machinery, vehicle, furniture, road facilities, civil engineering. The production of large size structural square tubing was initiated only about five years ago. However such members successfully penetrated into the steel building market as column members (Fig. 26) and are expanding as roof truss members (Fig. 27). The production nearly tripled from 1978 to 1980. Currently, there is a considerable research effort on the behavior of connections for larger tubular sections.

Steel Floor Decking is the most typical member of cold formed steel panel which is widely used in the building market. There are various types of section configurations and depths presently available, and almost all types are used as temporary formwork for concrete or permanent structural members of the floor of steel buildings. Very recently a new type of Steel Floor Decking for composite slab, shown in Fig. 28, has been brought out and it is expected to play an important role in building construction in the future.

Wall (siding) and roof panels cold rolled from precoated or vinyl film laminated sheet steel are also indispensable materials for building construction in Japan (Fig. 29).

Cold formed steel products play significantly active roles in various other areas of civil engineering construction as well. The importance of guard rails is increasing more and more. Light gage sheet piles such as the one shown in Fig. 30 are widely used for excavation construction. The use of corrugated steel pipes is expanding from conventional pipelines to breakwater piers shown in Fig. 31.

APPLICATIONS IN THE PEOPLE'S REPUBLIC OF CHINA

In the People's Republic of China cold formed steel construction was first initiated in the mid 1960's. The first edition of the specification for the design of cold formed steel structures was published in 1969. Since then the use of cold formed steel structural members have been increasing gradually in building construction and other areas. Based on the findings of the research conducted and the accumulated practical experience, the specification was revised and issued in a new edition in 1975. This specification is quite detailed and includes recommendations for various construction details.

At present, the cold formed steel members are mainly used as purlins, frames, as well as roof trusses. Square or rectangular tubes are mostly used in trusses. At the present time there is considerable interest in developing the cold formed steel industry. However in general, compared with the other structural materials, cold formed steel is still not widely used.

A typical roof panel application is shown in Fig. 32a. This panel is used for spans between 4.5 to 6 meters. The wall panel illustrated in Fig. 32b is used for spans of 1.2 to 1.8 meters.

FUTURE TRENDS

Cold formed steel members and structural systems are well established and form an important part of structural steel applications. In the years ahead developing nations will produce more and more cold formed structural elements. This is not only due to the economical way the material is used but also due to the fact that the production of a line of cold formed members requires a smaller capital investment than that required for hot rolled members.

As was the case in some of the recent developments discussed above, more and more whole structural systems will be studied and developed. This is a point of departure from the development of individual members that has dominated the activities in the cold formed steel applications. In such developments the strength and rigidity requirements become a part of the total functional demand for the end product--that is the creation of the space which needs to be evaluated in terms of verified qualities such as durability, climate, sound, and fire protection.

Consideration of the total system may lead to composite structures with material layers depending on functional requirements. In such a system panels alone or combined with suitable materials have load-carrying and stabilizing functions. These materials such as plaster, plywood, fiber, or mineral wool have been found to have considerable influence on the behavior of thin-walled steel panels as long as adequate connection and bonding between the materials are provided. At first glance, the relatively low modulus of elasticity of such materials seems to indicate that the effect of composite action is negligible. However, Fig. 33 illustrates that the equivalent thickness is of the same order as the steel thickness. Apparently the main effect of the composite action is to prevent local buckling of the slender parts of the section.

Results of tests with composite structures, built up by C-shaped sheet steel panels and composite materials such as gypsum board, plywood, fiberboard, etc. have shown that the stiffness and load-carrying capacity can be increased substantially and that the effects of local buckling can be reduced or eliminated. Appropriate load deformation curves are illustrated in Fig. 34 for beams and Fig. 35 for diaphragms in shear.

The above concepts will probably serve as the basis for further structural system developments.

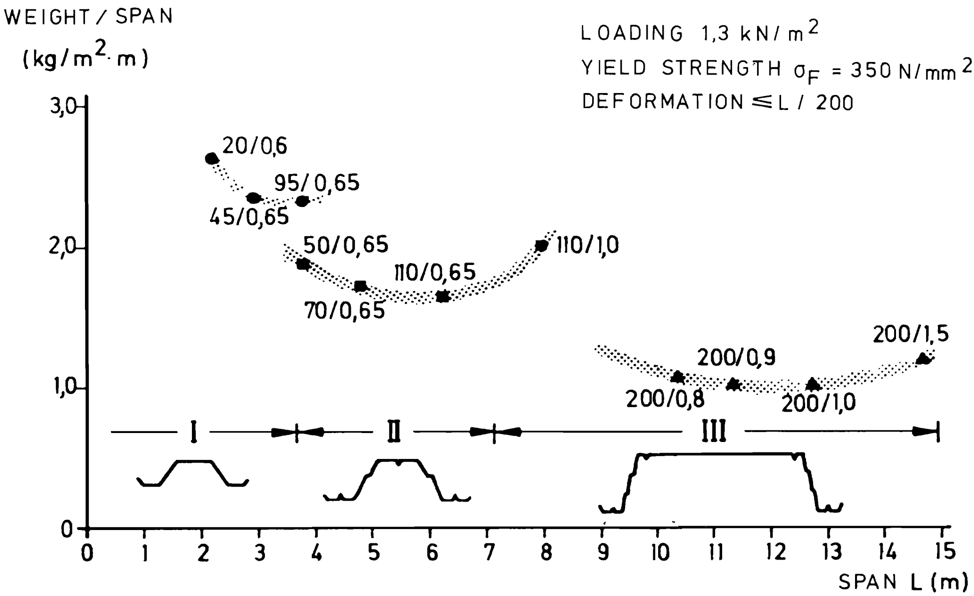


Fig. 1. Efficiency of Trapezoidal Panels, Generations I-III.
(Profiles are designated by depth/thickness.)

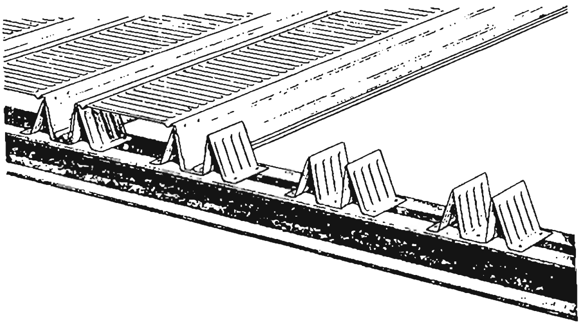


Fig. 2. TRP 200 Support Cleats

Fig. 3. TRP 200 Erection

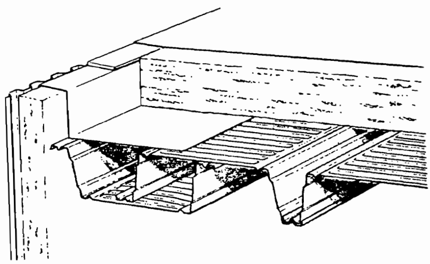


Fig. 4. TRP 200 An Insulation Scheme

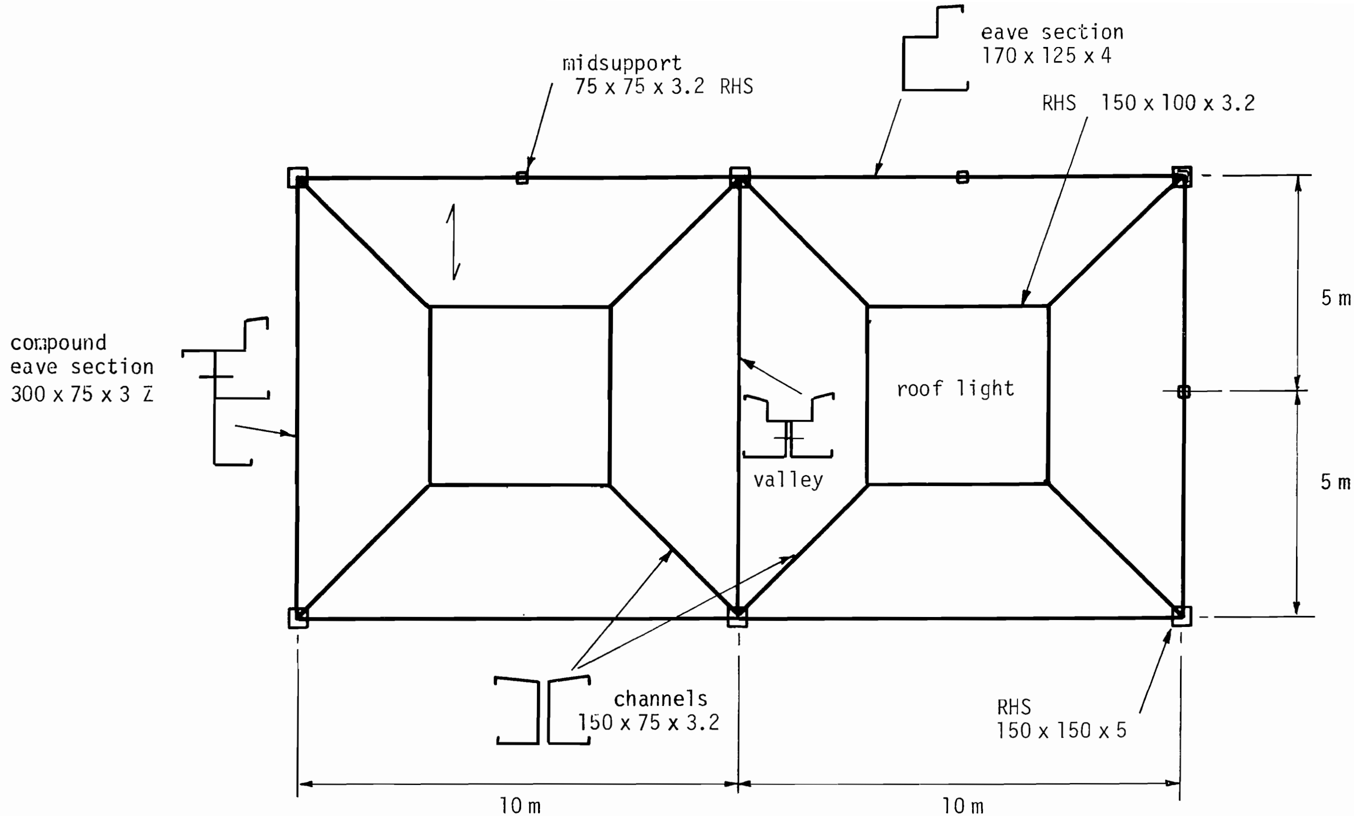


Fig. 5. Pyradome Plan View (dimensions in mm except as noted)

Fig. 6. A Market Using Pyradome

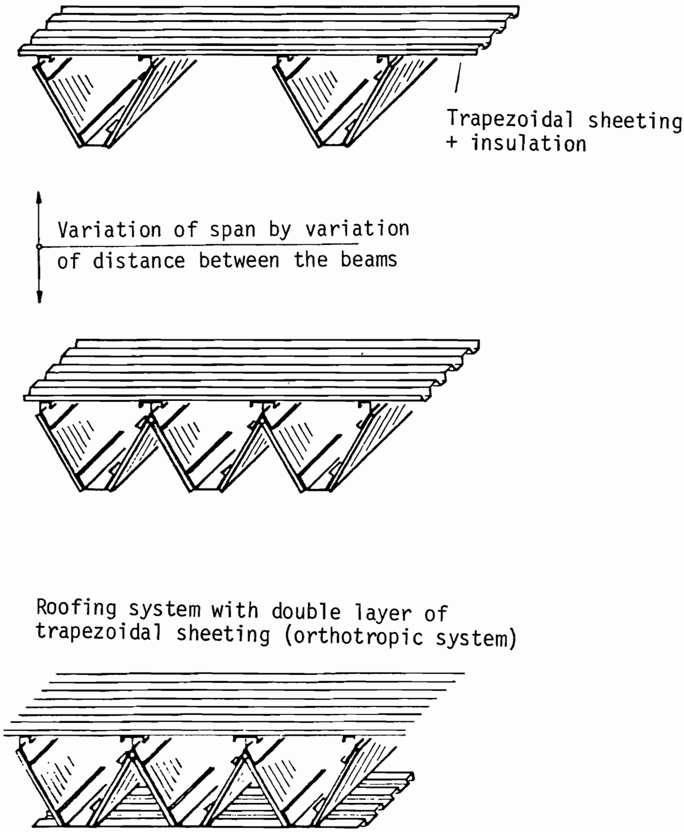


Fig. 7. Research Project: V-shaped Beams of Trapezoidal Sheeting and Cold Formed Sections

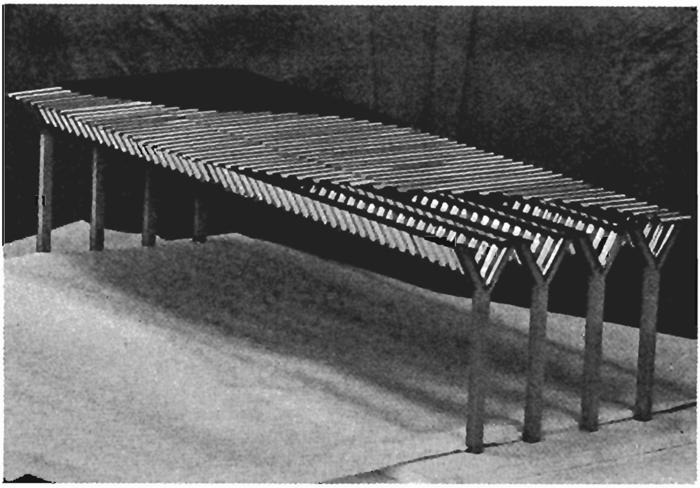
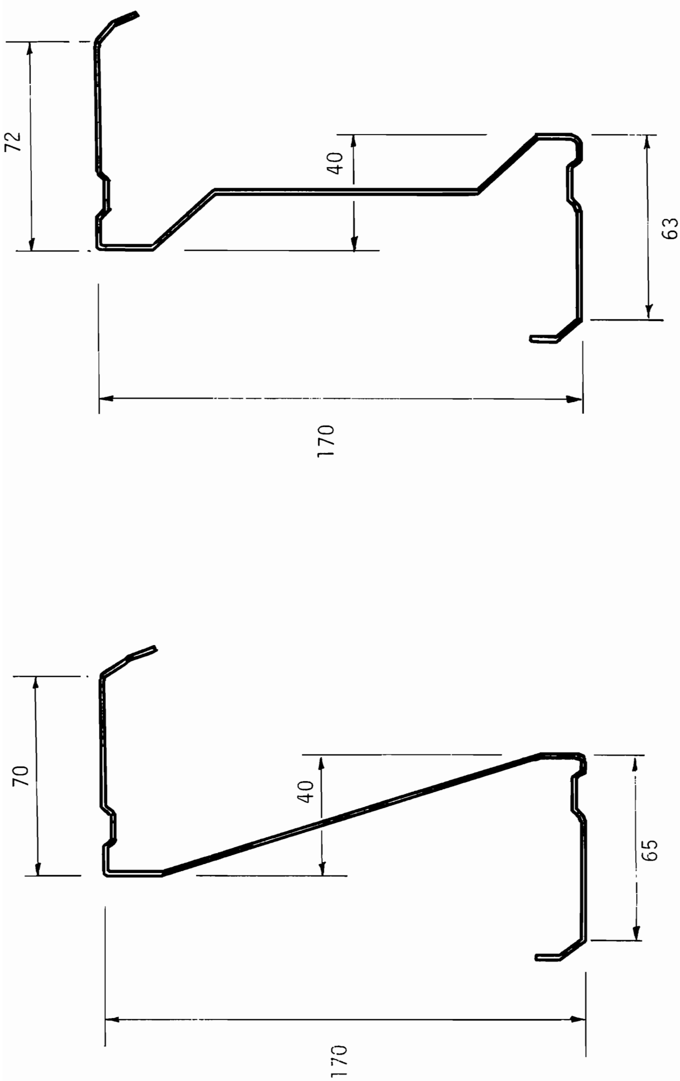


Fig. 8. Model of the V-Shaped Beams



b) Zeta Purlin

a) True Z-purlin

Fig. 9. Purlins (dimensions in mm)

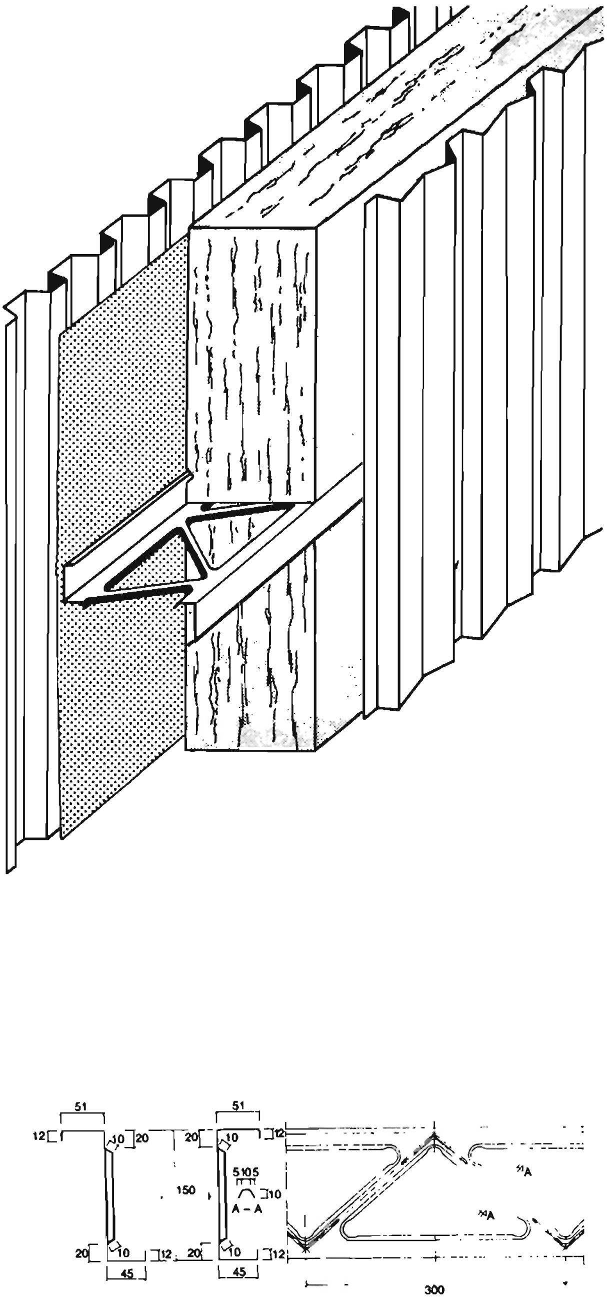


Fig. 10. Thermal Girt

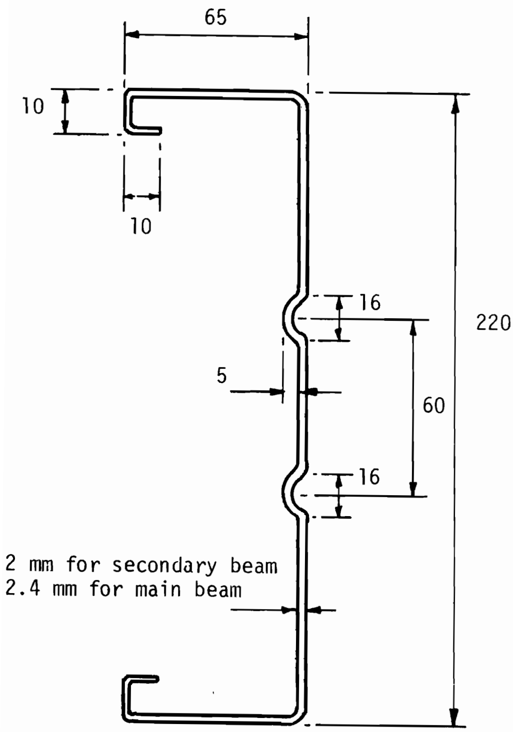


Fig. 11. Storage Platform Channel
(dimensions in mm)

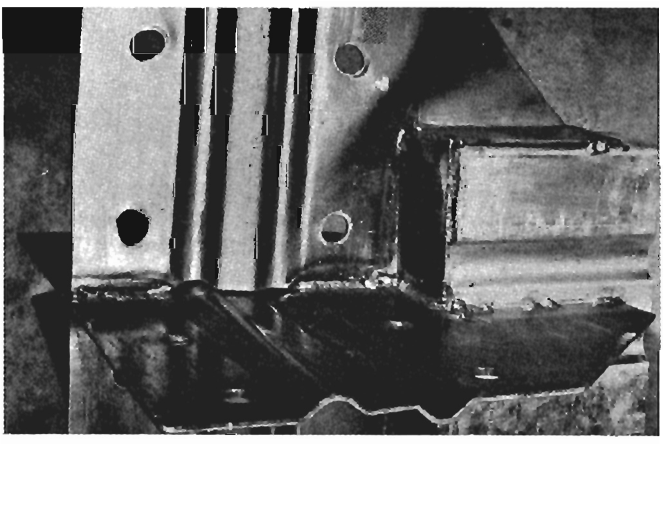


Fig. 12. Beam-to-Column Connection

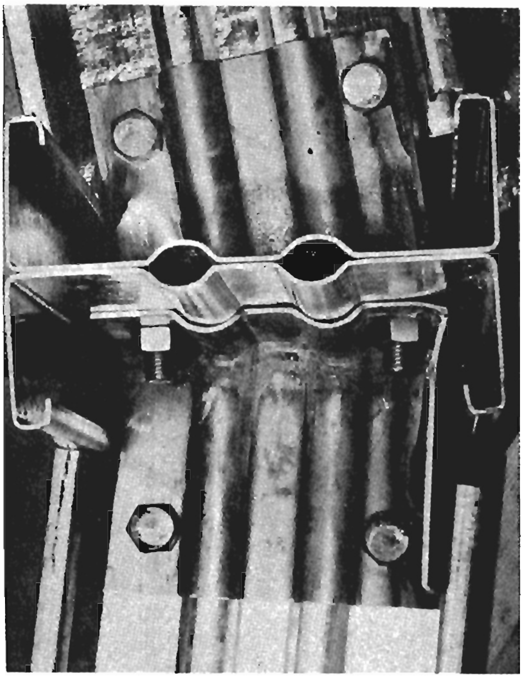


Fig. 13. Beam-to-Beam Connection

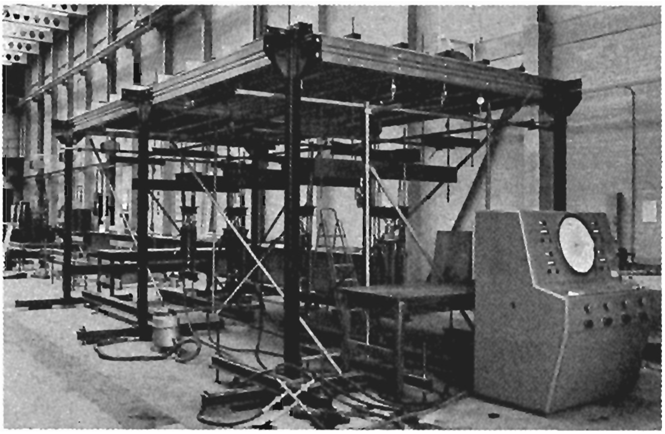


Fig. 14. Storage Platform Test Setup

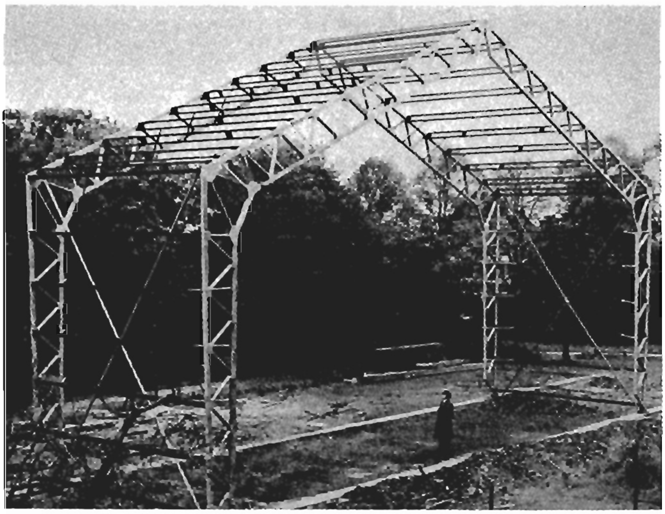


Fig. 15. Early Lattice Portal Frame

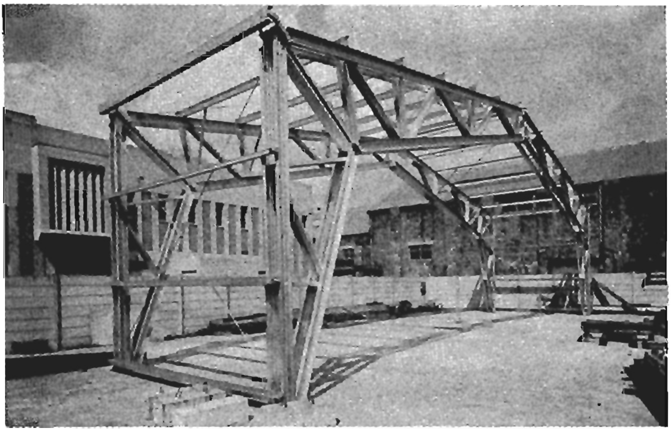
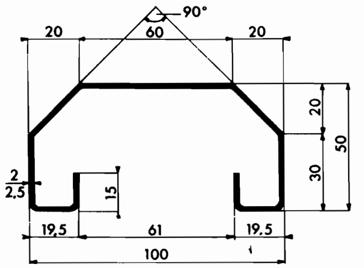
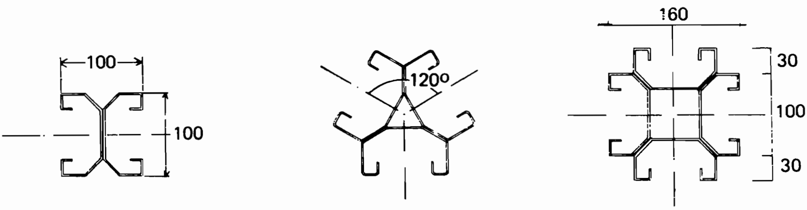


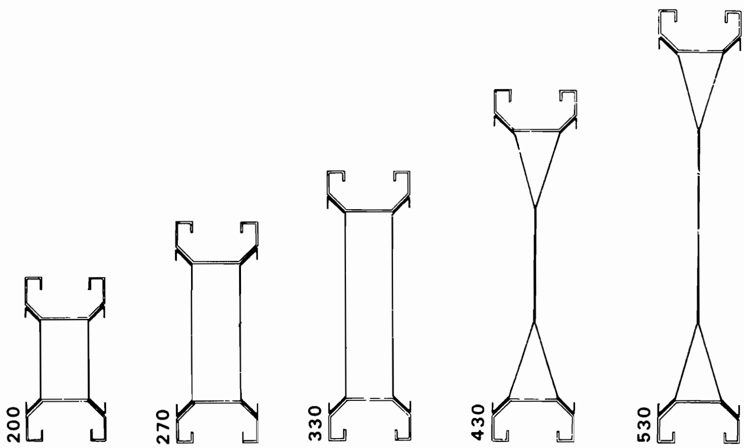
Fig. 16. New Lattice Portal Frame



a) Basic section

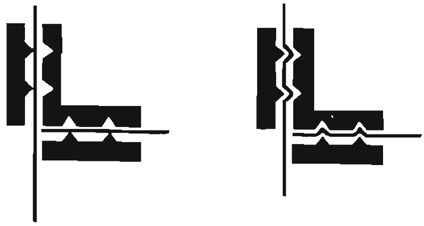


b) Columns

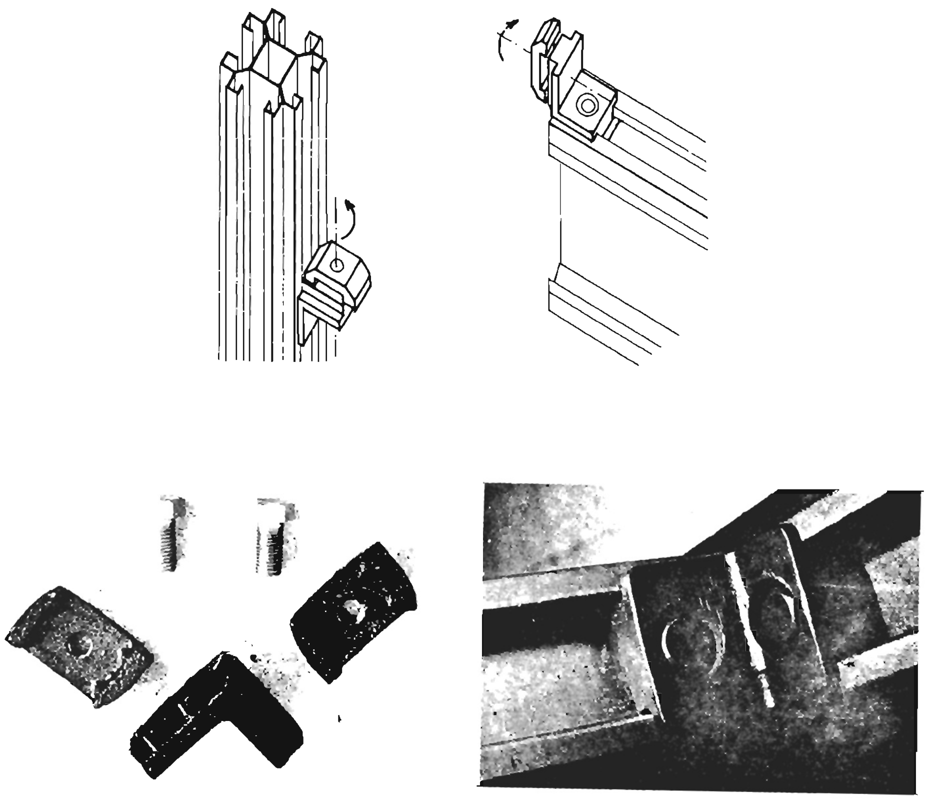


c) Beams

Fig. 17. Systeme M.100

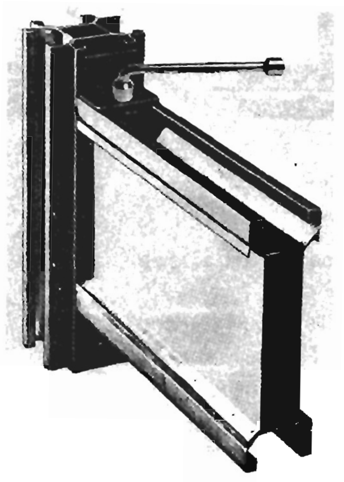


a) Connection clamps

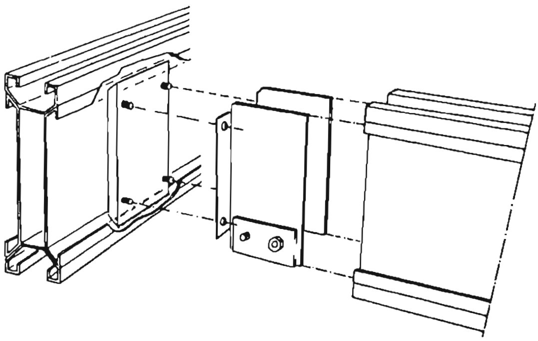


b) Connection details

Fig. 18. Systeme M.100

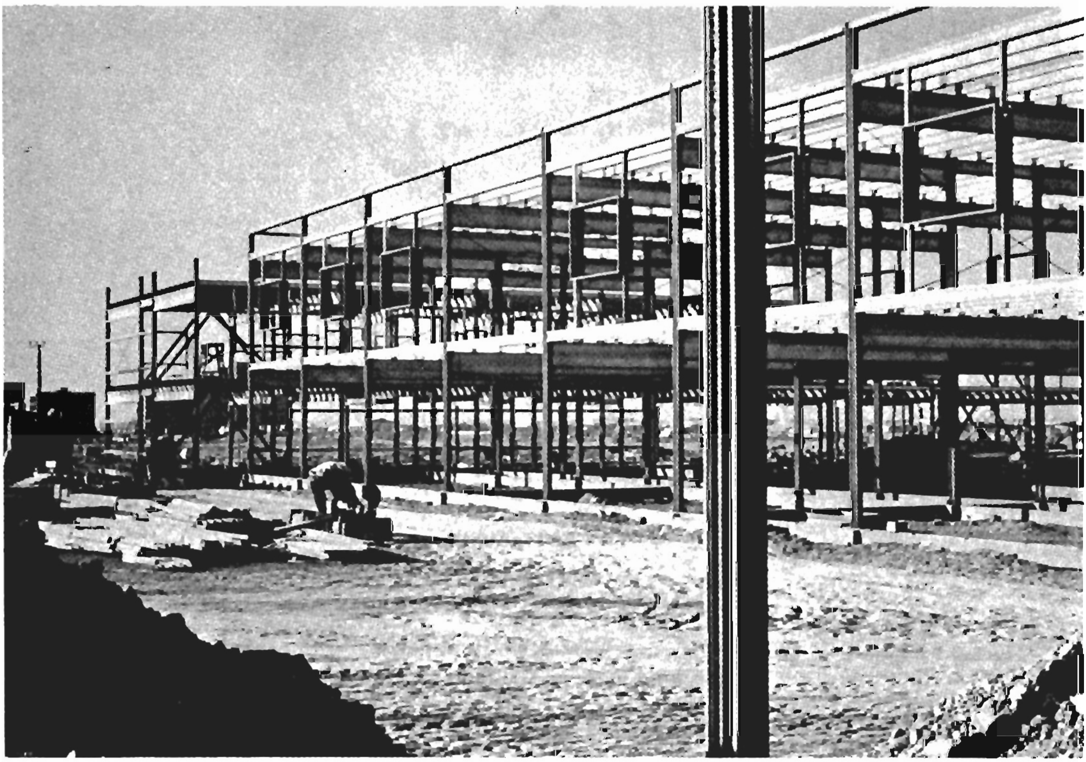


b) Connection details (cont.)



c) Beam-to-beam connection

Fig. 18. Systeme M.100 (continued)



d) Erected frame

Fig. 18. Systeme M.100 (continued)

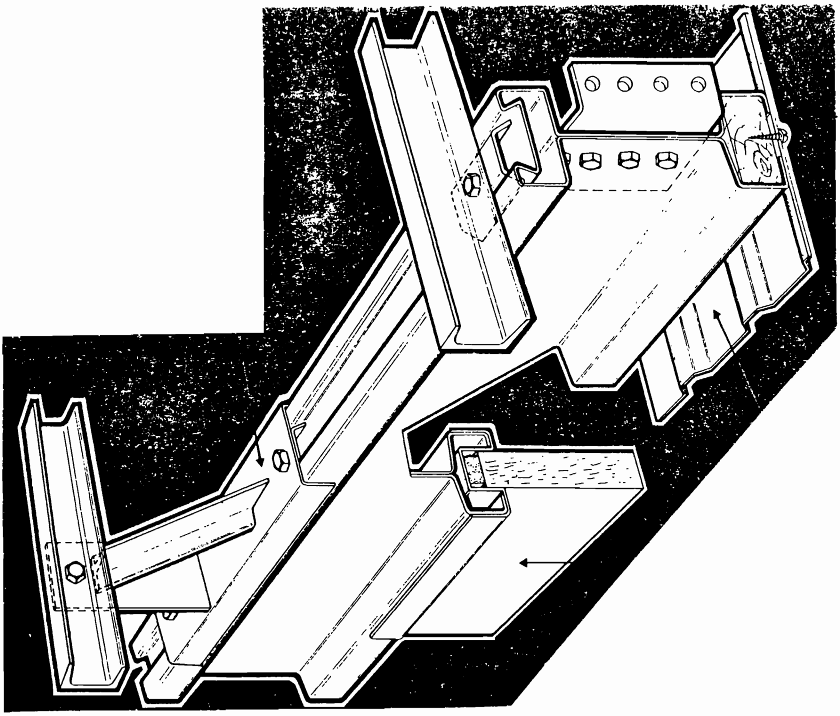


Fig. 20. Non-composite Galvapoutre

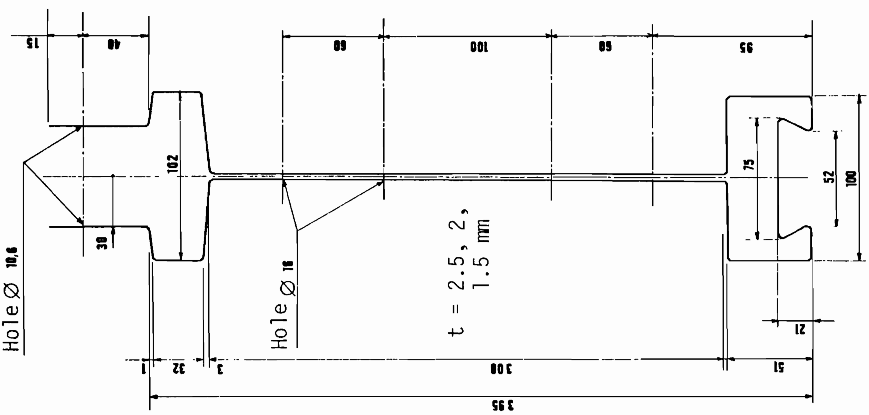


Fig. 19. Galvapoutre

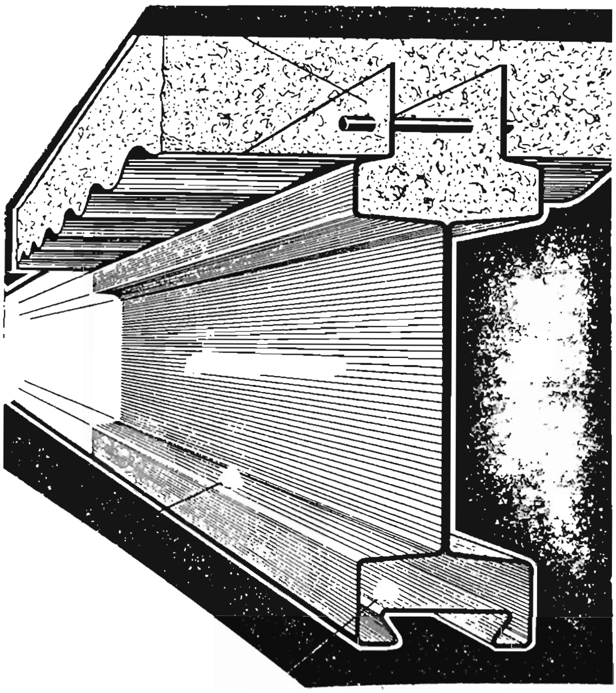


Fig. 21. Composite Galvapoutre

Fig. 22. Scantile

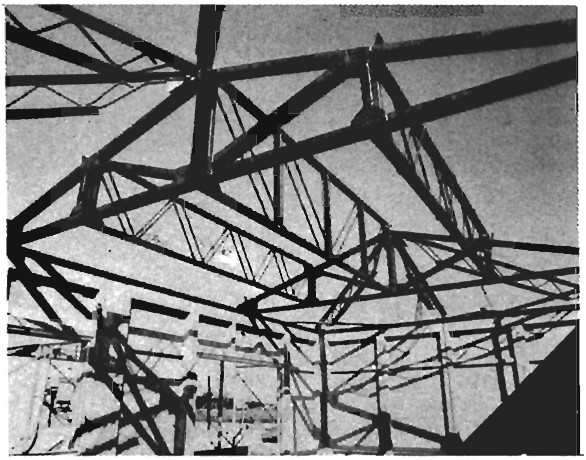


Fig. 23. Truss Made up of Channel Sections

Fig. 24. Trusses

Fig. 25. Channel used in Wooden Houses

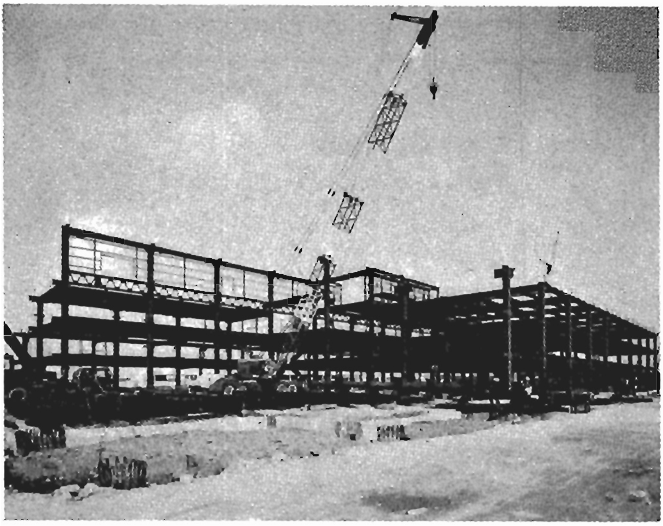


Fig. 26. Construction with Tubular Columns

Fig. 27. Roof Trusses with Tubular Members

Fig. 28. Composite Floor Deck

Fig. 29. Wall and Roof Panels

Fig. 30. Sheet Piles

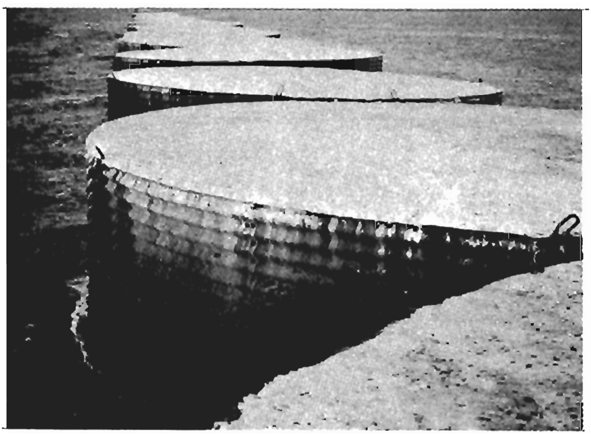
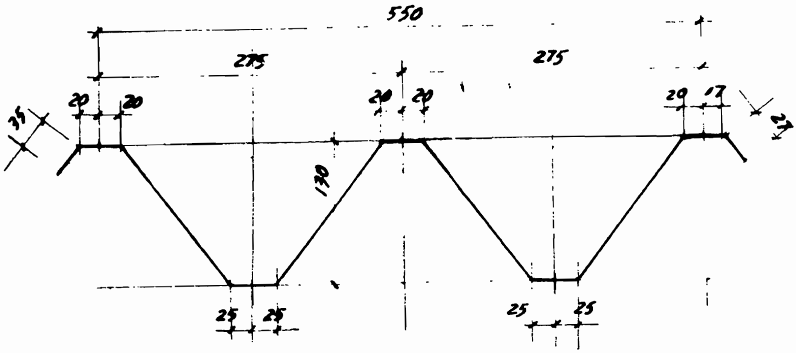
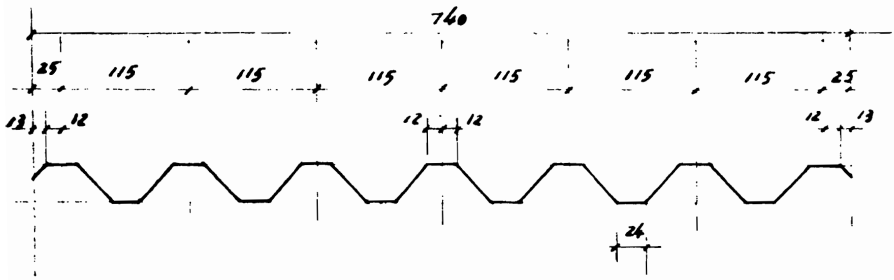


Fig. 31. Breakwater Piers



a) Roof panel W-550



b) Wall panel V-115

Fig. 32. Some Profiles Used in the People's Republic of China

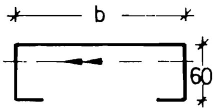
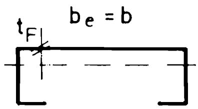
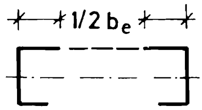
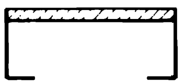
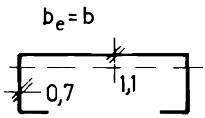
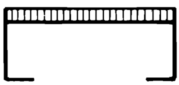
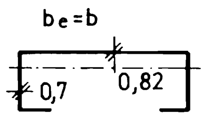
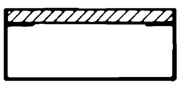
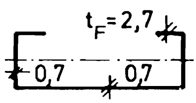
	SECTION	EFFECTIVE SECTION	EQUIVALENT THICKNESS t_F (mm)	RELATIVE MOMENT OF INERTIA I / I^{*}_{St}
1			0,7	2,3
2			0,7	1,0
3	12 mm PLYWOOD 		0,7 + 0,4 = 1,1	2,6
4	13 mm GYPSUM BOARD 		0,7 + 0,12 = 0,82	2,4
5	12 mm PLYWOOD 		0,7 + 2,0 = 2,7	4,7

Fig. 33. The Effect of Composite Action Between Thin-Walled Sections in Compression and Different Composite Materials

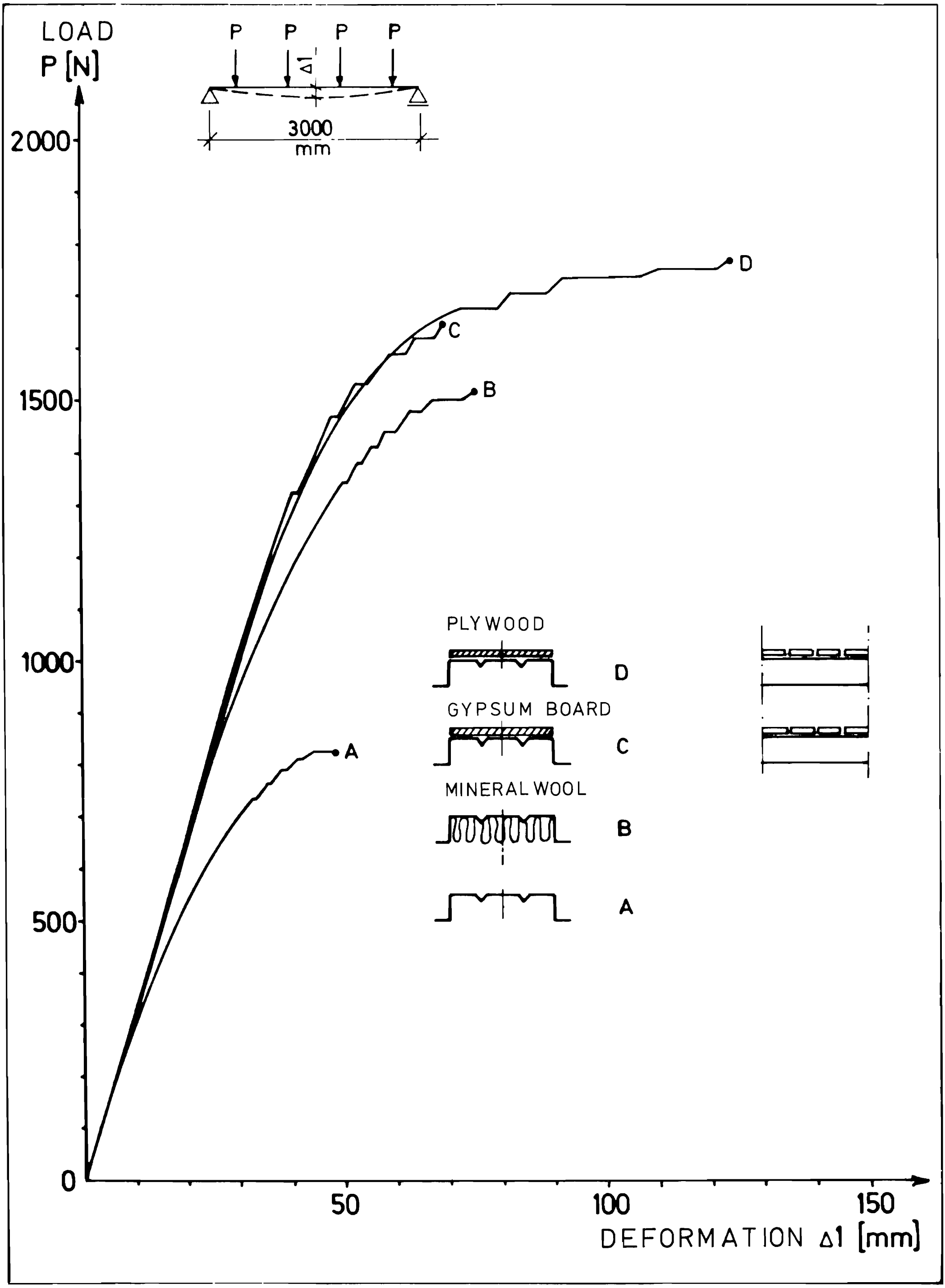


Fig. 34. Load Deformation Curves for Composite Beams in Bending

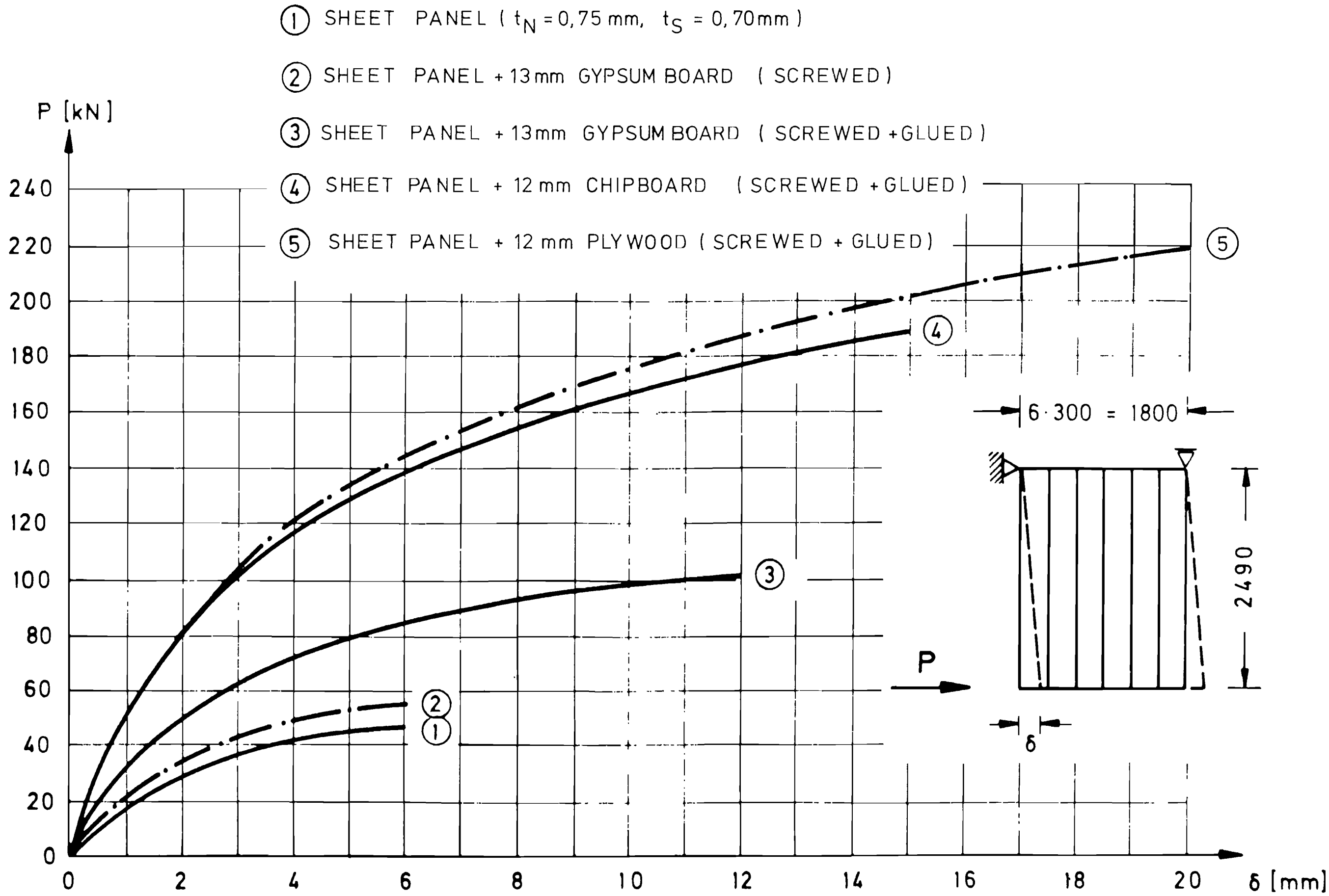


Fig. 35. Load-Deformation Curves for Composite Action of Diaphragms, Built up by C-Sections (100/300 - 0.75)