IIb

Light-Gage Cold-Formed Structures

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1. Introduction

An outline of theory and practice of "Light Gage Steel Structures for Buildings in the USA" was presented to the I.A.B.S.E. by George Winter, in 1952 and is recorded in the Fourth Congress. In that paper Dr. Winter summarized the research data and enumerated several applications of light gage steel in specific buildings.

The research findings since the Fourth Congress are discussed in this volume by Dr. G. Winter in his report on Theme IIa "Theoretical Solutions and Test-Results". The developments in material properties resulting from the cold-forming are discussed for strain-aging and non-aging steels. The characteristics of local stability and post-critical behavior are developed, together with the torsional-flexural buckling of cross-sections and the shear resistance of steel panel diaphragms. Future research in composite construction and connections is also pointed out. As the development of research unfolds more knowledge, the applications become more varied in number and more sophisticated in use. Old uses are expanded, and new uses are born. Improvements in cold-forming techniques and joining have assisted the rapid development of the application of light gage steel in buildings.

This paper will discuss three types of applications of light gage steel structural members and systems on the basis of (a) individual structural components, (b) complete buildings, and (c) structural systems in conjunction with other types of structural members.

2. Applications

The individual structural component may have any one of the shapes pictured in Figures 1 and 2. Figure 1 indicates those shapes which are currently produced for a specific application, and Figure 2 indicates those shapes which may be produced for structural framing applications where the sizes depend upon the loads to be carried. In general, these latter shapes range in depth from 2″ to 12″ and the material thickness ranges from 18 gage (0.048″) to ¼ inch. Such members have been used in buildings, Figure 3, up to six stories in height. In multi-story buildings greater than six stories the light gage framing members have been used as secondary members, such as joists, or floor and ceiling panels.

In the form of ribbed panels, Figure 4, many variations have been developed to serve specific purposes, as roof decks, floor decks, walls and siding. The

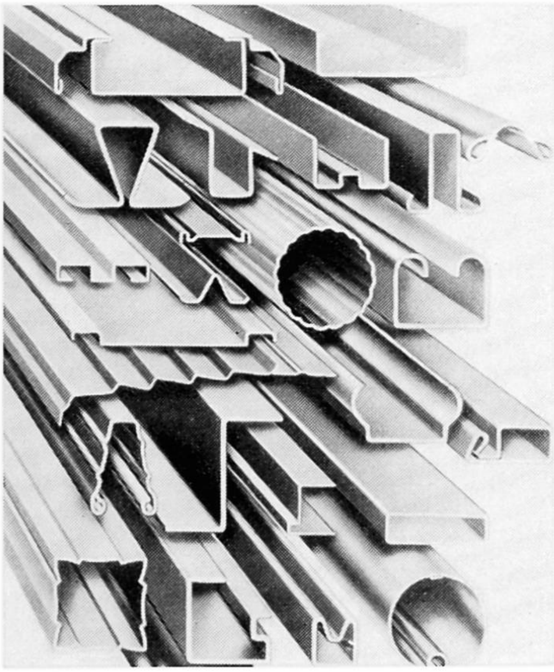

Fig. 1. Cold-Formed Shapes

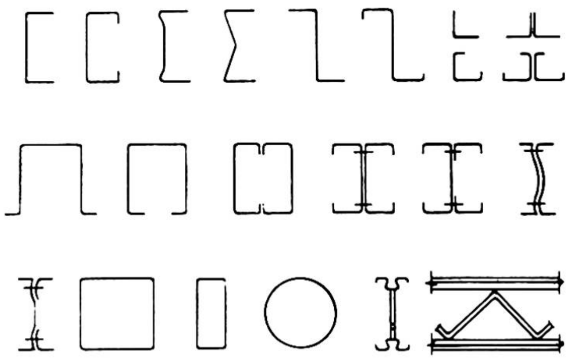

Fig. 2. Individual Cold-Formed Structural Sections

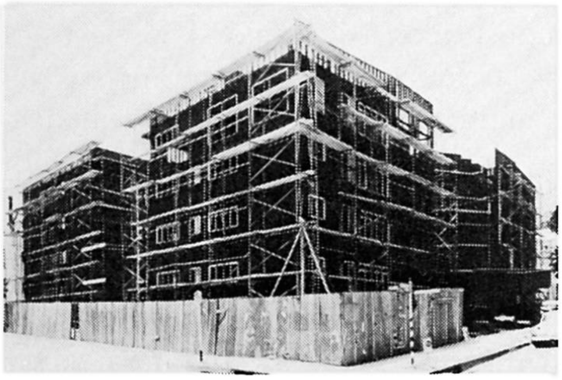

Fig. 3. Multi-Story Building Frame

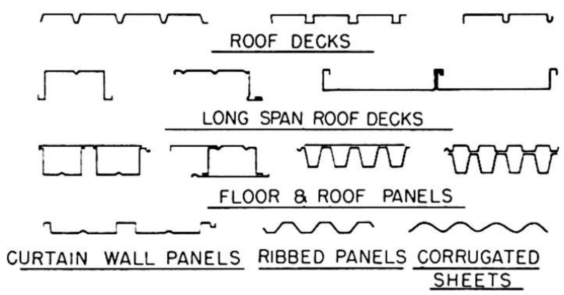

Fig. 4. Decks, Panels and Corrugated Sheets

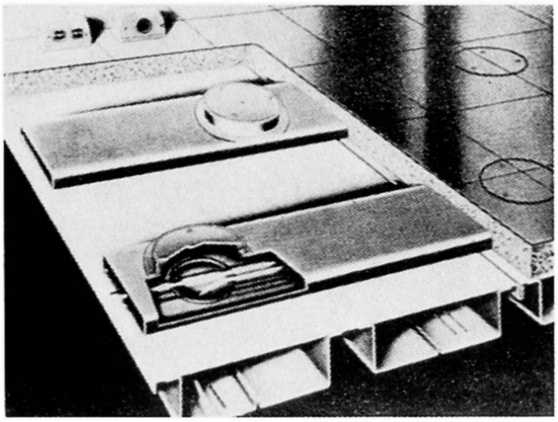

Fig. 5. Cellular Floor Panel

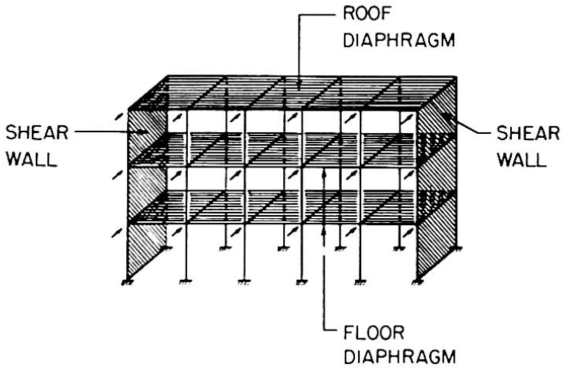

Fig. 6. Wall and Floor Diaphragms

depth of panel ranges from 1½″ to 7½″ and the thickness ranges from 26 gage (0.018″) to 14 gage (0.075″).

In some instances 30 gage steel ribbed sections have been used as load-carrying components.

As a roof deck, the steel panel provides structural strength and a surface for the placement of insulation and roofing materials. As a floor deck, Figure 5, it provides structural support for the gravity loads and serves as a conduit for electrical and mechanical utilities, combined with sound absorption material and electrical fixtures. As a diaphragm, it transfers lateral loads horizontally and vertically through floor and wall systems, Figure 6.

As a wall panel, the light gage steel serves as an exterior curtain wall, Figure 7, in multi-story structures. As an open structural member, it serves as a balcony frame, Figure 8, for an apartment house.

The use of light gage steel in partitions continues to increase as a result of the new concept of open office space adjustable to the needs of the occupant.

In regions where protection from the direct sun rays are required, adjustable louvers of steel are being used.

Continued use is also being made of light gage steel components in residen-

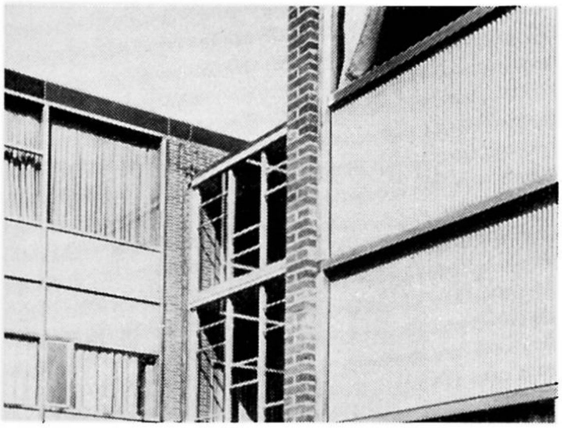

Fig. 7. Exterior Curtain Wall Panel

Fig. 8. Balcony Framing

tial construction and in some instances, the entire structural frame of the house is of steel. These steel homes consist of mass produced units of walls, roof trusses, partitions, roof covering, canopies, and entire bathroom and mechanical units.

A steel frame, Figure 9, connected to steel walls and partitions forms the skeleton of a dormitory which is sheated in stone and conventional roofing.

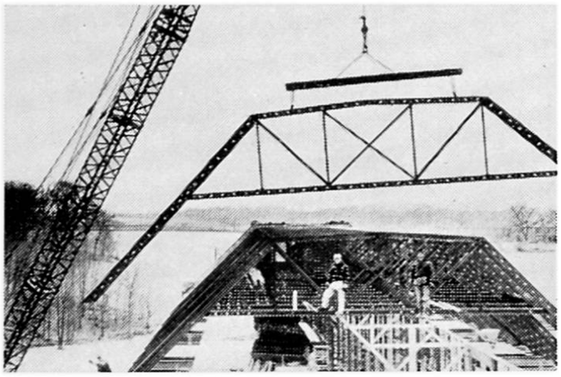

Fig. 9. Roof Truss of Cold-Formed Steel

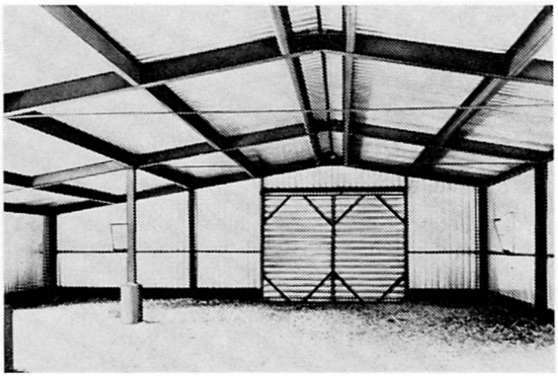

Fig. 10. Standard Building of Cold Formed Sections

Complete structural buildings of a standardized form continue to be produced as pre-engineered buildings. Many varieties are manufactured with slight modifications depending upon the final usage and manufacturer. A typical example of an all light gage building is illustrated in Figure 10. In some structures the light gage is used for girts, purlins, roofs and walls attached to a structural frame of plates and/or shapes, Figure 11.

Another unique application of a pre-engineered building consisting entirely of light gage material is the rigid frame illustrated in Figure 12 which achieves its strength by the geometrical configuration of the panels. The structure consists of four similar pre-formed units bolted together at the knee and crown to function as a rigid frame. The units are three feet wide and can be assembled into any length of building required. The gage of steel in this application is $^1/_{16}$ inch. The designer, Ernest R. Schaefer, has designs for domes referred to as Ectoforms which use pre-fabricated light gage steel panels bolted together to form a stressed-skin structure.

Some school and hospital buildings are framed in light gage steel such that the building may be considered a movable unit. The walls and roofs are of steel panels which are also removable, Figure 13.

Light gage steel gains strength by adjusting the geometrical configuration for maximum utilization of the properties of the steel. A curved shape adds strength to a flat sheet and therefore may be used as an arch with great efficiency. Some structures are built of arched trusses in which the truss members are cold-formed light-gage steel which are then covered with a steel roofing. In others, the arch itself is of light gage steel acting as a stiffened rib, Figure 14.

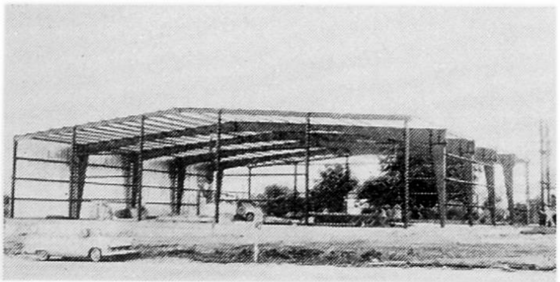

Fig. 11. Standard Building with Cold-Formed Girts, Purlins, Roof and Wall Panels

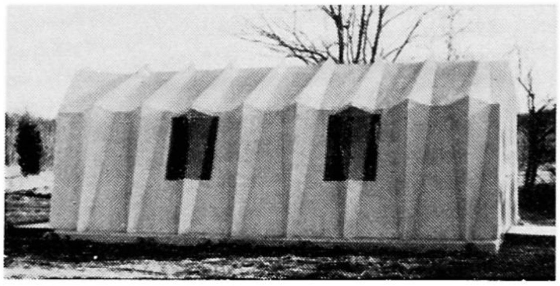

Fig. 12. Rigid Frame. Schaefer Span Structure

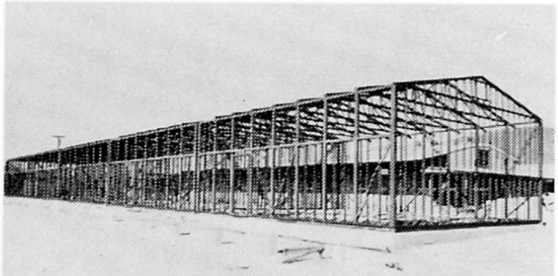

Fig. 13. Movable Classroom Units

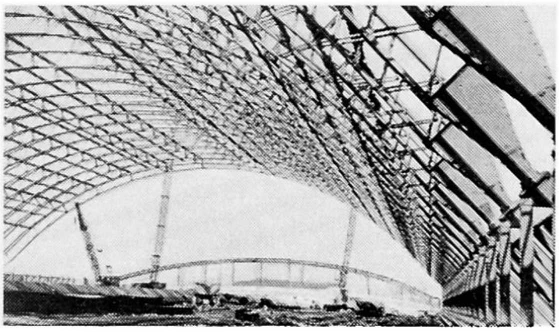

Fig. 14a. Stiff Ribbed Arch

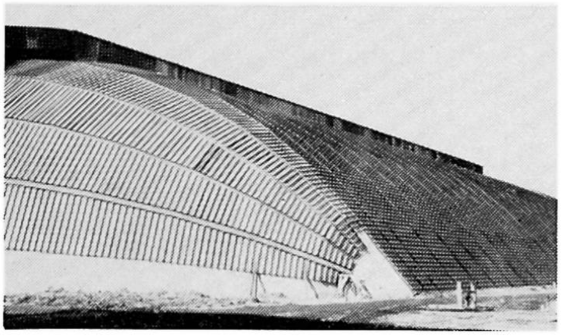

Fig. 14b. Stiff Ribbed Arch

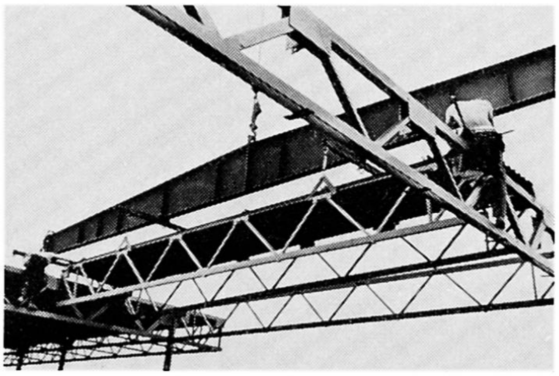

Fig. 15. Joist and Deck System

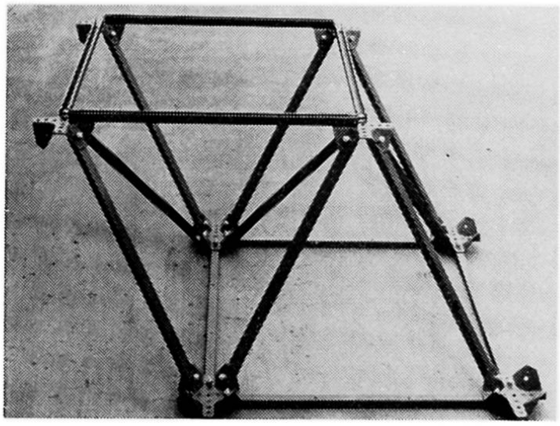

Fig. 16. Tetrahedron Unit

Fig. 17. Space Frame. Lighting Support

The concept of prefabrication of units naturally leads to the development of structural systems which may be used as entire structures or parts of larger structures. Prefabricated units result in economies of time and labor.

Figure 15 illustrates a simple system consisting of two open web joists and a steel deck being installed as a roof component.

Units such as these reduce the time of erection and have the inherent cost reduction of a mass-produced component.

The light gage steel may be cold formed into structural members which may be assembled as a single truss or a space frame made up of a series of tetrahedronal units, Figure 16. A space structure of this type may be made to serve several various functions such as a support for overhead lights for an auditorium, Figure 17, or a highway sign structure, Figure 18, or any number of roof structures, Figures 19 and 20.

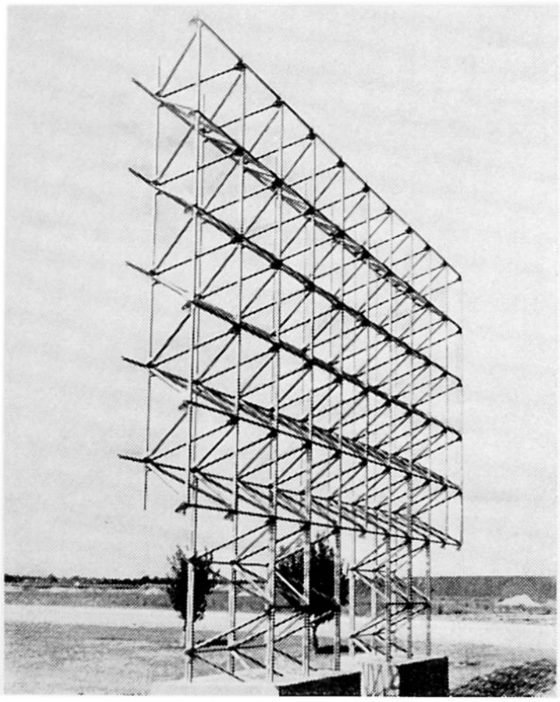

Fig. 18. Sign Support

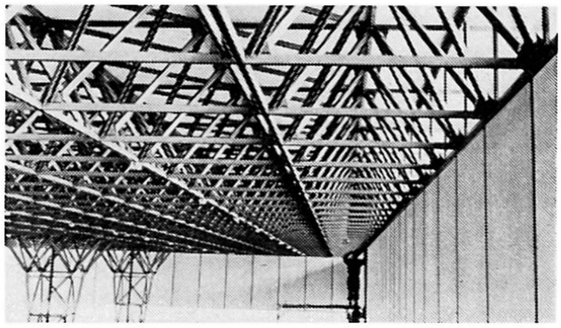

Fig. 19. Roof Space Frame

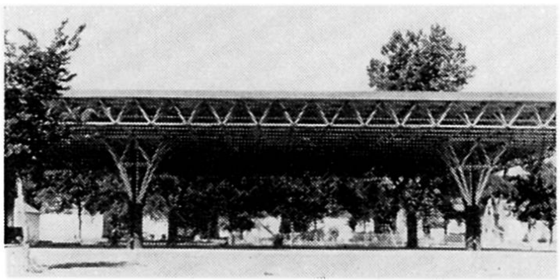

Fig. 20. Roof Space Frame

The increased interest in shell theories and membrane action has led to the development of the steel hyperbolic paraboloid, Figure 21. This paraboloid consists of two layers of steel deck, 18 and 20 gages, at right angles to each other and spot welded at a number of common intersection points. The edge shears are transferred to the ridge and edge beams which are made of hot rolled channels and plates. The warping of the deck to fit the geometry is accomplished by using pipe sections as edge supports for the deck, thus providing a positive bearing at all points. The deck panels are 1½ inch in depth and 2′ $2^{11}/_{16}$″ in width. The quadrant is 40′ × 40′, with supports at the four corners and at the center ridge point.

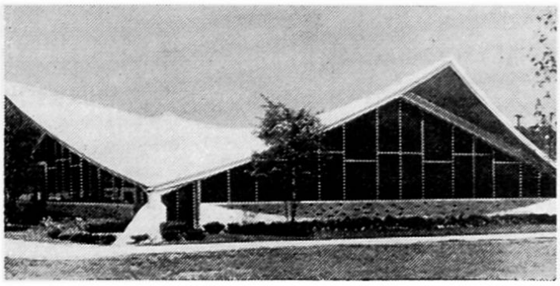

Fig. 21. Hyperbolic Paraboloid Roof Structure

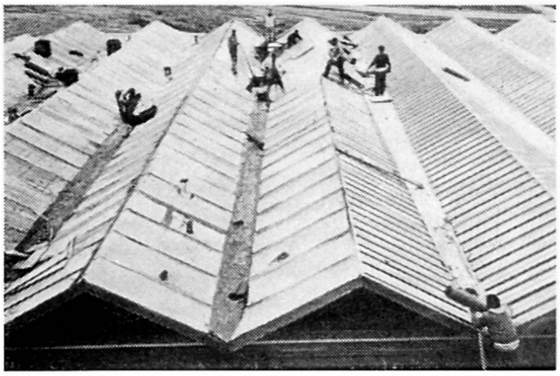

Fig. 22. Steel Folded Plate Roof

The successful use of a steel deck as a membrane was concurrent with the development of the steel folded plate. Essentially, plate girders are inclined to have a common edge at the top and bottom flanges forming ridges and valleys, Figure 23. The webs of the girders are panels formed with a flat sheet and stiffened with a ribbed sheet. Simple spans up to 100 feet are possible, as single-bay, multiple-bay, or radial folded plates.

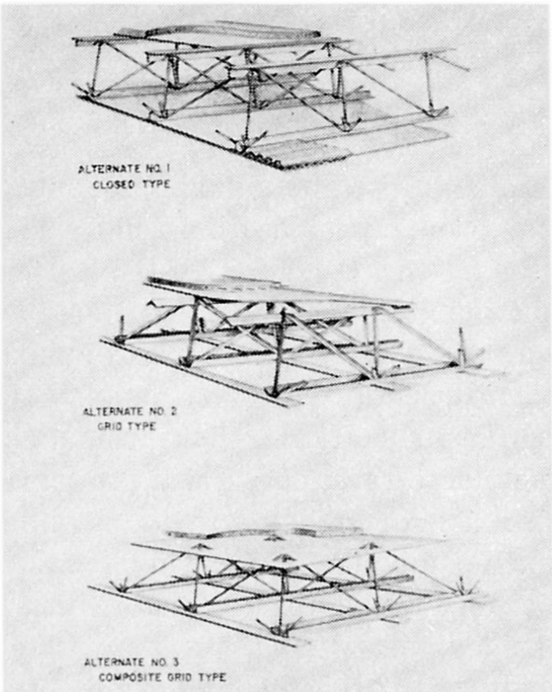

Fig. 23. Space Frame Long Span Floor Systems

3. Future Research

Although steel hyperbolic paraboloids and folded plate roofs are currently being constructed, there are many questions which are yet to be resolved for greather efficiency.

Research is now underway to develop a better understanding of the behavior of the steel hyperbolic paraboloid with respect to the relationship of beam and membrane action of the deck, the behavior of edge members as columns and tension beam components, local bending stresses, optimum slopes of radial members, and the behavior of a single layers vs. a double layer of decking for the membrane.

Folded plate structures are also being investigated for local and general buckling effects, optimum slopes, stress distribution for radial tapered plates, shear transfer at all edges, and behavior as a continuous beam.

The steel industry can look forward to greater research activity in many areas which are as yet untouched. One of the most urgent needs is the development of a floor system using light gage steel as a honeycomb or core with sheet steel as the top and bottom plate, with provisions for mechanical and electrical utilities. A pre-fabricated unit easily installed is most desirable. The problem of shear transfer at the columns and walls appears to present a challenge requiring further study. A thin uniform thickness of floor including all utilities, fireproofing and finish flooring would be the most desirable solution. Other open types of floor systems to be investigated are illustrated in Figure 23.

Because light gage steel is fabricated easily in a plant, it is desirable to develop units for shell structures such as domes, paraboloids, folded plates, etc. which may be erected easily and economically to form the desired shape, Figure 24.

Structural curtain walls with architectural appeal and versatility of construction are needed as mass produced units with utilities and wall surfacing combined into an integral component, Figure 25. Explosive techniques are being developed to shape the outer skin to the desired architectural configuration. More research is required to develop this idea to its maximum usefulness.

Although present construction techniques employ steel floor deck panels resting on a grid system of structural members, a more efficient method using pre-fabricated units may be forthcoming. These pre-fabricated floor units may embody all the components required to provide a ceiling and finished floor, with installed mechanical equipment. The desirable unit is one which provides a complete floor and ceiling system to be erected with the principal structural framing and walls.

At present galvanized steel panels are used to provide corrosion protection. In some instances painted, or vinyl-coated sheets may be found architecturally desirable, for interior or exterior panels. More research may be required to develop other textures for surfaces and corrosion protection.

At present the usual fire protection methods are employed, such as sprayed on fireproofing, suspended fire proof ceilings, and plaster in its various forms. A more desirable system constructed integrally with the panels would facilitate construction and lower costs. Fire protection incorporated with pre-fabrication could lead to many economies.

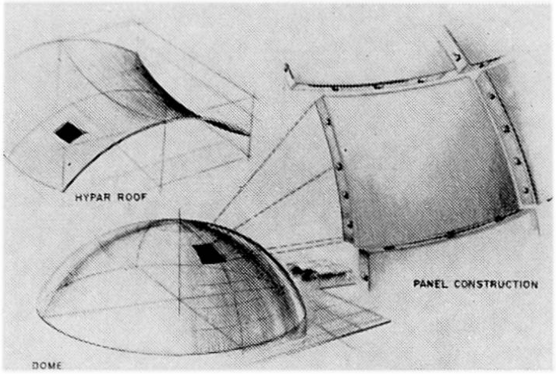

Fig. 24. Prefabricated Panels for Domes and Hypar Roofs

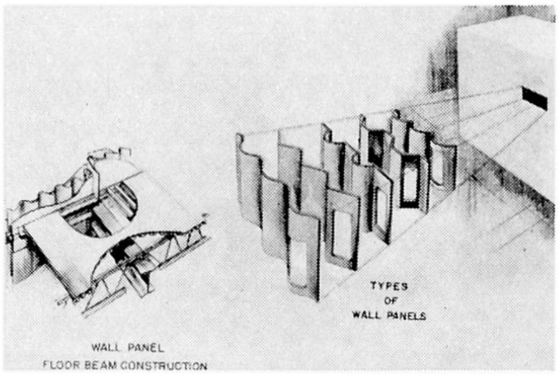

Fig. 25. Wall and Floor Panels

The developments noted above are intended to be applied to multi-story structures of all types. Some single residences and one story structures are currently on a mass produced basis and only require refinements of techniques for greather applications.

More research on all types of units and systems is needed in order to maximize the usefulness of light gage steel as a primary building component for all types of structures.