VOLUME II / NUMBER 3 / JULY 1962

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# MODERN STEEL CONSTRUCTION

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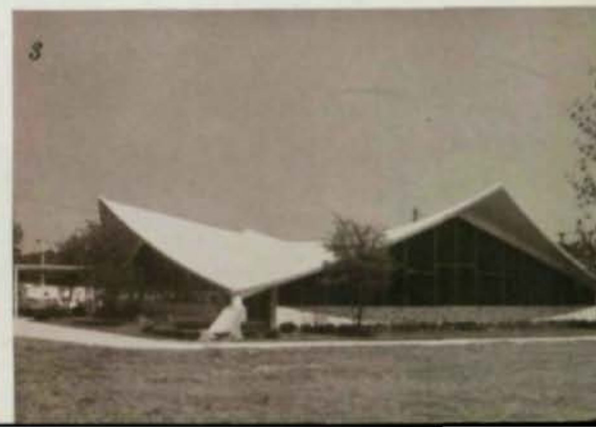


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Steel

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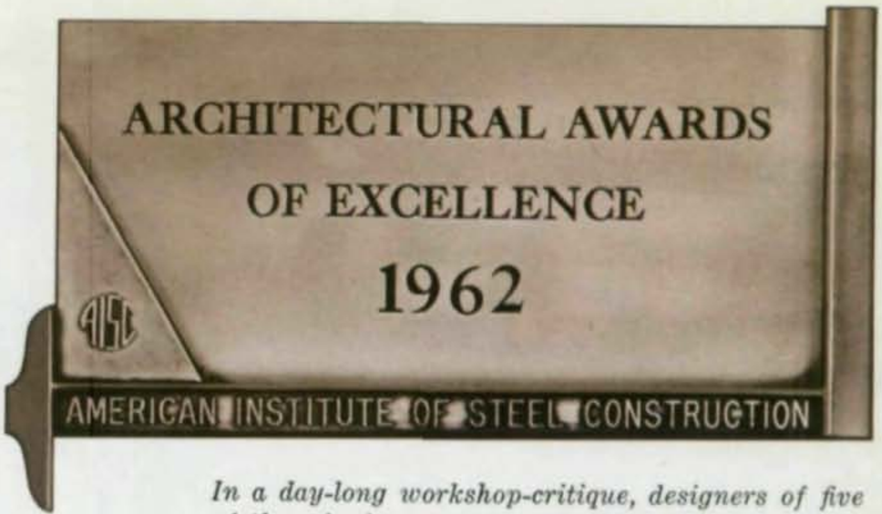
## EDITORIAL

*Starting in September, the American Institute of Steel Construction will sponsor Specification Educational Lecture Series in approximately 32 cities throughout the country. Each series will include six weekly lectures delivered by engineering professors and members of the Institute's regional engineering staff. The lectures will be a definitive indoctrination of the practical application of the 1961 Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.*

*Subjects include: Materials and Their Economy, Design of Tension Members, Beam Design, Fatigue, Fasteners, Connections, Design of Plate Girders, Composite Design, Design of Members in Compression and Bending.*

*With the new Specification already accepted in numerous states and cities, the AISC hopes that all interested will attend these lecture series. A fee of five dollars per person will be charged which includes printed solutions of specific problems.*

*Many readers of* **Modern Steel Construction** *will automatically receive program invitations as the series are scheduled. Anyone wishing more specific information may contact the nearest regional office or write directly to AISC headquarters in New York.*




*In a day-long workshop-critique, designers of five of the winning structures faced a barrage of analysis, questions, compliments and criticism from a panel of experts and a roomful of participants. Here's how they fared.*

# A CRITICAL LOOK AT FIVE WINNERS

By THOMAS H. CREIGHTON, Editor
Progressive Architecture

This year's results of the AISC Architectural Awards of Excellence Program provided the basis for a Workshop-Critique in New York. Sponsored by the United States Steel Corporation and conducted by the magazine **Progressive Architecture,** the no-holds-barred discussion session took place at the Plaza Hotel on June 14.

The Workshop Critiques were conducted in the manner that **Progressive Architecture** has for some years run its own Design Awards Seminars. One after the other, five of the AISC Award winners were presented in slides and in words by their architects and engineers, and then in each case a prepared critic briefly but pointedly discussed the results. The critics had been told that they could be as analytical, as complimentary, or as critical as they wished. After the critique, the designers of the buildings had an opportunity to respond (defend, if necessary), and then questions, comments, and discussion from the floor were invited.

Before a participating audience, largely of architects from all parts of the country, five building achievements were analyzed. The full results will be published in the November issue of **Progressive Architecture**; here, briefly, are the high lights. In most cases the critiques were favorable, and the questions asked from the floor were not overly embarrassing. This was not surprising, since a very capable jury had selected the buildings in the first place from nearly 100 submitted in the third AISC Awards program, and three of the jury members acted also as critics at the Workshop. It has often been remarked that it is the best buildings that find themselves subjected to critical analysis, while the really badly designed ones, that should be critically taken apart, are not given proper attention.

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*AISC's recent 24-page booklet,* **Architectural Awards of Excellence,** *1962 contains pictures and data on all 14 buildings and their architects. It has been sent to over 5000 architects; copies are available on request.*

**McAllen State Bank**
**Cowell and Neuhaus, Architects**

Nevertheless, the assemblage raised some important points that should cause reflection. By and large, the McAllen State Bank came off very well, with its highly disciplined, modulated, exposed steel frame. George Danforth, director, Department of Architecture and City Planning, Illinois Institute of Technology, critic for this building and a jury member, admitted that it is "the sort of architecture I like – the sort I might do myself." He raised questions of the possible glare through the glass east wall, and the architects agreed that a better shade protection by fuller tree planting outside would be desirable. From the floor, the lack of expansion joints in the steel structure, with its enframement of so much glass, was questioned. There was also some discussion of the increased insurance premium caused by the use of non-fireproofed steel. Esthetically and technically, there was no criticism; there was, rather, admiration for the high degree of craftsmanship attained.

**Philip Drill House**
**Davis, Brody and Wisniewski, Architects**

The Drill house fared equally well at the hands of its critic, John Grisdale, partner, Carroll, Grisdale & Van Alen, who had also been a jury member. Mr. Grisdale compared it to a half-timber house of exposed frame with in-fill. Floor commentary questioned the practicability of the design of some composite steel members – and cost, which the architects averred to be reasonable.

**Pittsburgh Auditorium**
**Mitchell and Ritchey, Architects**

The Pittsburgh Municipal Auditorium was reviewed by William J. LeMessurier, Boston consulting structural engineer,

*Architect: Anshen & Allen, San Francisco*
*International Building, San Francisco*

*Architect: Ballard, Todd and Snibbe, New York City*
*Tennis Pavilion, Princeton University, New Jersey*

*Architect: Harrison & Abramovitz, New York City*
*Gateway Number Four, Pittsburgh, Pa.*

*Architects: Charles Luckman Associates, Coordinating Architects, Los Angeles; Welton Becket & Associates, Los Angeles; Paul R. Williams & Associates, Los Angeles*
*Service Station for Standard Oil Company of California*
*Los Angeles International Airport*

*Architect: Murray-Jones-Murray, Tulsa, Oklahoma*
*Sts. Peter and Paul Church, Tulsa, Oklahoma*

who had also been on the AISC jury. His largely favorable commentary regretted only that the excitement of the structure had not been more fully exploited in a visual sense. Questions from the floor ranged from the basic one — "Why open the roof at all?" — to more detailed matters of assembly.

The critiques continued into the afternoon, following a luncheon at which a talk was given by Austin J. Paddock, U.S. Steel vice-president in charge of fabrication and manufacture. Perhaps because Mr. Paddock had so fully outlined the new developments in structural steels and their current architectural application, criticism and commentary in the afternoon session concentrated on planning aspects of the buildings rather than on their use of steel, which by and large was considered exemplary.

**Aragon High School**
**Reid Rockwell Banwell & Tarics, Architect-Engineer**

The Aragon High School, for which New York architect Morris Ketchum acted as critic, was discussed largely from the point of view of a flexible, large secondary-school space, within which partitions can be moved when necessary. The steel frame, intelligently used, of course, makes this possible. Some participants in the discussion felt that there was a lack of warmth in the architectural result, a condition that the designers described as intentional and desirable, since the building is a background for the color of the students themselves.

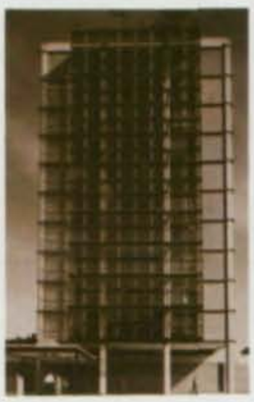
**Tulsa Terminal Building**
**Murray-Jones-Murray, Architects**

The Tulsa Air Terminal Building was analyzed by critic Emanuel N. Turano, New York architect. Conceding that the building was "good" and good-looking, Turano questioned the validity of the story-and-a-half scheme on which the plan is based, with passengers going up on entering, to go down to the apron, to climb up again into the plane. The architects explained that direct jet entrance from the fingers, though a long way off, was part of the building's design requirements. Access from the parking lot (a common difficulty) and length of walk from entrance to plane loading (equally common) were discussed, with agreement that these problems must be solved in typical airport design.

For what may become an annual affair, the Workshop-Critiques got off to a fine start. The program was well worthwhile if for no other reason than to bring the winners in AISC's important and well-conducted Awards program together — which U.S. Steel did, as host, for an organized technical bull session. Opening the meeting to other architects and engineers who wished to attend tremendously increased its usefulness and significance.

*Architect: Neuhaus and Taylor, Houston, Texas*
*Office Building for the Holland Mortgage and Investment Corporation and the Fidelity-Southern Fire Insurance Company, Houston, Texas*

*Architect: Richard J. Neutra, FAIA, and Associates, Los Angeles*
*The Garden Grove Community Drive-in-Church of the Reformed Church in America, Garden Grove, California*



*Architect: Nolen and Swinburne, Philadelphia, Pa.*
*Johnson Hall Dormitory for Men, Temple University, Philadelphia*

*Architect-Engineer: Skidmore, Owings & Merrill, Chicago, Illinois. General Office for the Upjohn Company, Kalamazoo, Michigan*

# AESTHETICS AND STEEL STRUCTURE

by H. Seymour Howard, Jr.

Structure has always been an inseparable part of architecture. In a practical sense this statement is obvious. An analysis of it from an aesthetic point of view, however, may help to find a better approach to the perpetual question of good design than the old shoulder-shrug "there's no accounting for tastes."

The essence of architecture as an art is the composition of space. People live, work, move about in various sizes and shapes of rooms, and are constantly aware of the rooms as large or small, bright or dark, cold or warm, musty or dry, orderly or chaotic, etc. Civilized man lives in architectural space as a fish lives in water. The spaces between buildings and their external forms are as important a part of this environment as the interior spaces.

Structure is essential to the space, but it is not the space itself. We must therefore place it in a secondary or tertiary role; secondary when the architect uses it as a modulator of space or a decorative element, tertiary when it is completely hidden, with little effect on what one notices when one looks at the building.

When an architect chooses to emphasize the steel framework as an essential aspect of his design, there seem to be two sincere approaches which lead to appropriate and satisfying design.

*Mr. Howard, an Associate Professor of Architecture at Pratt Institute, Brooklyn, teaches both architectural design and structural planning. Author of several articles in the architectural magazines, he has been particularly concerned with the problems of structure as related to architecture.*

In one, the disposition and the shape of the members have been derived from a careful study of forces and moments, stresses and strains. In the other, the emphasis has been on a certain aesthetic effect, with the structure used principally to enhance this. The slogan of the first would be: "forms follow forces;" that of the second: "forces follow forms." Both claim to "express the structure," but if we can clarify the differences in what they mean, we will be able to understand some of the currents in modern architecture.

Comparison of a few details will point up the difference. The "forms follow forces" school would design a column as a hollow cylinder or other closed surface because the material can be used most efficiently in this way. A perfect balance between stress and stiffness can be achieved. (See Figure 1.) Nature is full of similar forms, especially in plants and trees.

The creators of the "forces follow forms" school are more concerned with the visual effect; and, if they feel the circular shape is too bulky in appearance, they do not hesitate to use a simple prismatic member with a section in the shape of a cross, as in Mies van der Rohe's Tugendhat house. Natural analogies are difficult to find for these forms, based purely on artistic considerations.

The design of a girder would be approached in a similar way. The first group tends to favor curved, flowing lines like those found in nature; the second, a rectangular framework of prismatic elements. (See Figure 2.)

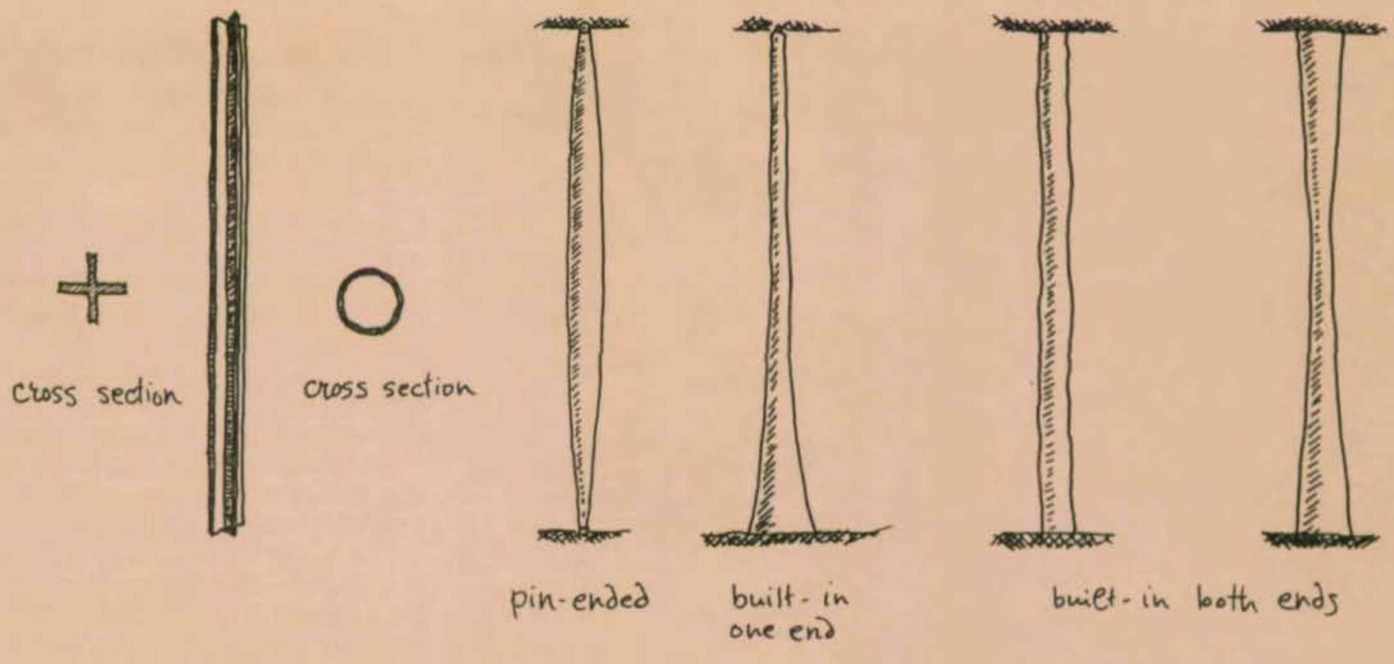


*Figure 1*

Two buildings will illustrate quite well these two approaches, one unfortunately only a project, the second now under construction.

In 1938 Paul Nelson published his three-year study of a new approach to the aesthetics of space which he called the Suspended House. A series of rooms, each designed to fit its particular function and linked by ramps, are suspended in a vast cage. The cage in turn is hung from four tree-form columns, linked by main beams and rib-like cantilevers. The photograph (Figure 3) furnished by the Museum of Modern Art, now owners of the model, shows the scheme very clearly.

The shapes of the columns and the beams they support follow very beautifully the lines of force, and the depths of the sections are everywhere proportioned to the moments. A sensitive artist has taken the structural problem and solved it very carefully at every point — with due consideration both for economy of material and for artistic effect. This is an excellent example of what can be done aesthetically by the "forms follow forces" approach.

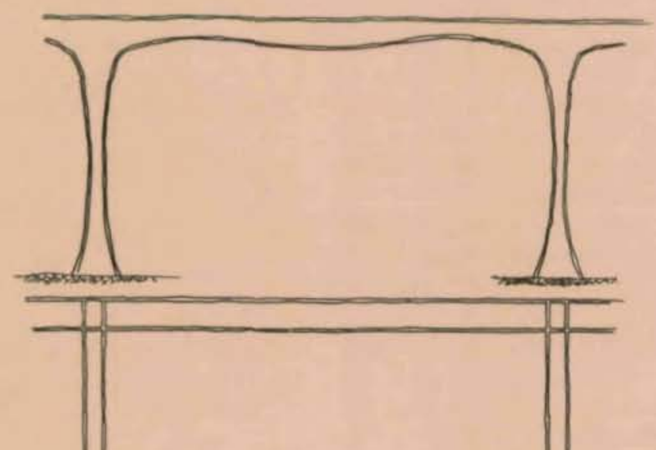


*Figure 2*

The other approach is shown by the John Deere Co., Moline, Illinois, one of the last buildings designed by Eero Saarinen.

This is an eight-story structure with *exposed steel framework. Fireproofing* was not required by codes and the architect detailed the framework as an essay in modern "post and lintel" construction. (See Figure 4.)

Photographs (Figures 5 and 6) show a full-size mock-up of the exterior portion of one bay, two stories high, which was constructed to study the detailing and the effect of the ultimate building. This was commonly done by the architect as the best way to make sure of every aspect of a new design.

A double girder, made up of two 21-in. wide-flange sections, is welded through hidden "boxes" to the sides of the columns so that they look as if they were held by magnetic force. A secondary

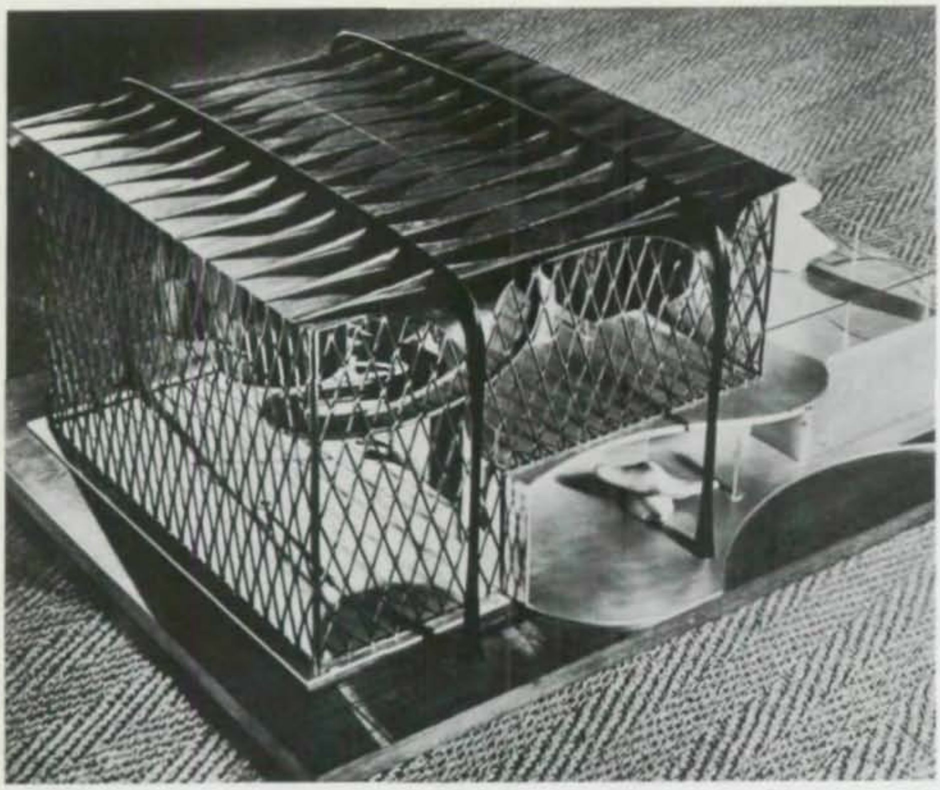


*Figure 3 Suspended House 1938 by Paul Nelson from* **Visionary Architecture** *Exhibit Collection, Museum of Modern Art, New York City*

system of ten-inch beams rests on top of the girders, and then a tertiary system of cellular decking rests on top of the beams. All of the steel is apparent. Note the short pieces of channel and wide-flange sections welded to the columns as decorative accents.

The girders, the exterior columns, the exterior beams, catwalks and sun-shading louvers are made of corrosion-resistant A242 steel which is about six times as corrosion resistant as A7 or A36. The steel will appear dressed in its natural rust-brown color.

The effect of the finished building will undoubtedly be very powerful, even brutal in its aggressive rectangularity, strong shadows and multiplicity of planes, sharp corners and overlapping sections. More than this it would not be fair to say before completion.

It is evident, in any case, that the framework follows in the "forces follow forms" tradition. The arrangement of members is based on the aesthetic effect. The loads will, of course, be carried by the members provided, but a different approach to design would have given a much more economical structure with less material. However, the appearance would not have had the particular dramatic quality which the architect sought.

What principles are common to both approaches? The age-old "principles of artistic composition" are always available: unity, through repetition of similar shapes or the dominance of one shape over others related to it (major and minor themes); contrast for interest (harmony and dissonance); economy of means; appropriateness to purpose; etc.

The teaching of these principles has gone out of fashion for several reasons. There is the danger that they can be used to foist an academic sterility on students. They can be found in many buildings which are considered dull and uninteresting as well as in those which are beautiful. There is no academic principle which cannot be broken by a skillful designer, at least from the point of view of a rigid dogmatist. Then a more sympathetic critic comes along to prove that the designer has actually observed the principle, but in a new and original manner.

While recognizing the shortcomings of such principles, we must still try to find some when we judge designs. Economy — the creation of an adequate structure with the minimum of material — is a powerful artistic quality. In its broadest sense — economy of means to achieve an end — it is found in all art: painting, poetry, drama, music. Nature follows the principle of economy in all minimal and conservation laws; e.g., of all possible configurations of a hanging chain, the curve actually assumed will be that for which the potential energy is a minimum; of all possible values for redundant reactions, the actual ones will be those for which the strain energy is a minimum. The forms of animals and plants follow this principle. It has, therefore, become part of man's subconscious, and its universal quality is probably the reason so many people find pure engineering designs beautiful.

However, natural forms, even though "economical," cannot always be qualified as beautiful. The shape of the hippopotamus probably follows this principle equally well as that of the gazelle, but the two are not equal in our aesthetic judgment.

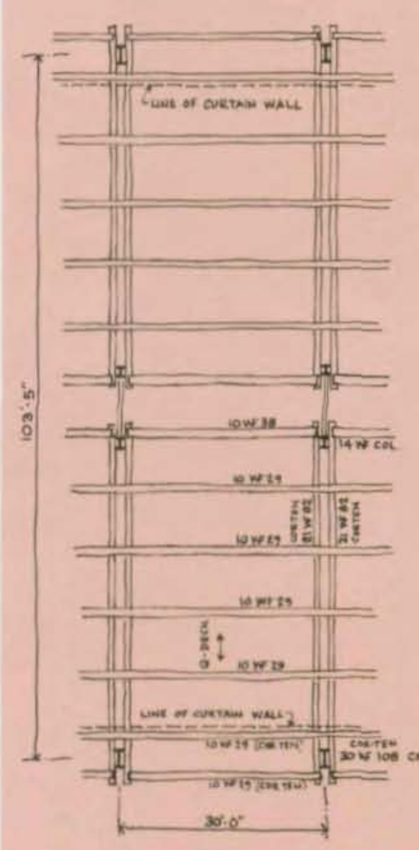



*Figure 4*

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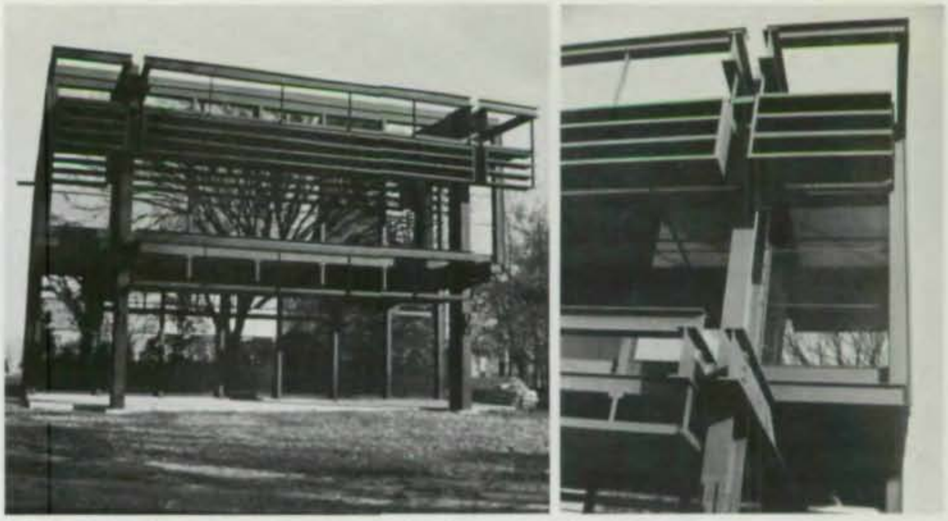

*Figures 5 and 6 Mock-up for the John Deere Building, Moline, Illinois by Eero Saarinen & Associates.*

Economy is thus a necessary but not sufficient condition for "naturalistic" beauty.

If the structure is exposed, unity of structural principle is necessary to achieve design unity. A tree, for example, consists entirely of cantilevers – the trunk is cantilevered from the ground, the limbs from the trunk, the branches from the limbs, the twigs from the branches and the leaves from the twigs – the free-body diagram of every part looks the same and every part is statically determinate.

The eye must be made aware of the nature of joints and of the behavior of the structure. If a joint is designed as a hinge, let the pin show neatly. This may cost more money, but if the true structural character is the important aesthetic message, it is worth paying for.

On the other hand, if the structure is being exposed for a certain sculptural effect – our "forces follow forms" school – unity of structural principle is still important, but the shapes of members and joints are not necessarily designed to minimize stresses. Post-and-beam designs or rectangular rigid frames are typical, with the joints used to emphasize this rectangularity, and the method of connection perhaps completely incomprehensible to the observer. Saarinen's design for the John Deere Co. building exemplifies this with rigorous logic.

A good comparison between the two approaches can be found in such a simple detail as the handling of a strip of light. In P. L. Nervi's Palazzo del Lavoro (see Figure 7), each of the tree-form elements is outlined by a strip of light between it and the adjacent element. The light serves to emphasize the clear structural separation between the elements. In the house by Eero Saarinen and Alexander Girard (see Figure 8), we find exactly the opposite. The main girders are pairs of channels, placed 2 ft-6 in. apart so that a skylight can be placed just above. The ceiling pattern of light and dark is exactly the contrary of what one would expect structurally, an intriguing visual effect. The column head is spotlighted like a jewel in a showcase.

There are many interesting structures such as bridges and roof trusses whose designs were worked out logically and economically, but which fail to achieve any quality of beauty. The reason is perhaps that their designers were not particularly concerned with how they would look. Compare, for example, the disturbing visual effect of a truss work in which the members are all at different angles and of different lengths, with the unity and rhythm established when the eye can readily perceive that all the members form parallel systems or that they are all the same length. Thus, one of the general laws of design – unity through repetition of identical or similar elements – must be satisfied.

Placing girders above the roof is a common design feature which goes under the name of "expressing the structure." From a constructive point of view, it is a poor location. The girders (unless expensively covered with insulation) are placed out in the cold, while the rest of the building is kept warm. The flashing is expensive, and the chances of leaks multiplied. Also the exposed steel requires more painting and protection than if it were inside. The only justification is a small reduction in cubage.

The real reason is aesthetic. The lines of the girders are used to subdivide an otherwise uninteresting mass. A rhythm is set up, a sense of scale established. Essentially similar is the reasoning behind Mies van der Rohe's use of exposed steel columns. The next logical step is what he devised when the need for fire protection made it impossible to expose the steel frame: place another set of steel members on the outside to be looked at.

Ultimately, then, we must recognize that aesthetics has its own laws. Designs based purely on practical considerations may or may not obey them. There is no automatic road to beauty. Life would become a mechanical nightmare if there were.

There was a time when some architects and critics raised the banner of "form follows function." They encouraged the myth that if every space were designed from the inside out, to fit its particular purpose, the result would automatically be beautiful.

And then there were the 19th century romantic ideas that if a man's heart were pure, and if he used "natural" materials in an honest way, his buildings would be beautiful as a consequence. And there was the academic Renaissance myth that the sole duty of an architect was to follow the classical orders and that his buildings would be beautiful automatically. We are forced to decide about beauty, not from principles, but from direct experience. Aesthetics depend on people; they are value judgments. We look at a building, we walk through it, we live in it. Only from continued acquaintance can we gain complete understanding, somewhat as we learn to appreciate the character of a person.

Returning to the narrower problem of the use of exposed steel structures, we can state that both the "naturalistic"

*Figure 7 International Labor Exhibition, Turin, Italy*

and the "theatrical" philosophies are valid; both can be justified. There is more than one ideal in aesthetics, just as there are many ideals of beauty in women. The important thing is to be aware of beauty and its definition in terms of an actual building. It is the building which is beautiful, not some abstract principle.

His own way of understanding and of feeling will lead an architect or engineer to choose between the "forms follow forces" approach and the "forces follow forms." The first has the advantage of being objective and measurable. It is possible to estimate and compare the quantity of material used in several designs and to say that one is the most economical (even if it costs the most!). This is a positive attribute which relates the structure to natural forms. It is beyond fashion. An aesthetic response is, however, not guaranteed. We would call an unsuccessful design straightforward, but dull; ingenious, but cold.

The second approach is subjective and may be justified by its aesthetic appeal. By following it, a skillful designer can play more directly on people's senses and perception. It is, however, the inevitable road to bizarre fashion or to academicism and sterility when followed uncritically and without sensitive evaluation.

Although an architect may prefer to design his structure for true economy (minimum material), this is unlikely to become a major trend in exposed steel. Except for very large spans, it is much costlier to use specially fabricated members of varying depth than to build with rolled sections. The need to save weight makes it possible to pay for this kind of economy in ship design, but it usually is out of the question for civil structures. This is one reason why the Suspended House was never built. We must therefore expect most of our architects and engineers to follow the "forces follow forms" tradition, though probably in a less obtrusive manner than the John Deere Building.

*Figure 8 House by Eero Saarinen and Alexander Girard, Photo by Ezra Stoller*

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# *Highlights of AISC'S*
# NATIONAL ENGINEERING CONFERENCE

The Institute's 14th National Engineering Conference opened in Columbus, Ohio on April 12 with W. F. Morris, The C. E. Morris Company, presiding. He introduced AISC President Harold G. Lewis, who welcomed 313 engineers attending and described the annual Conference as a clearinghouse for structural engineering problems and ideas.

T. R. Higgins, AISC director of engineering and research, outlined the significance of the new Specification, calling it an evolution rather than a revolution. Mr. Higgins called attention to the thorough investigation and research conducted before new provisions are incorporated in the Spec and stated that it can never be static and new provisions and revisions could be expected from time to time.

Larry Foster, Sverdrup & Parcel, Inc., described the first use of orthotropic plate design in the United States – the Poplar Street Bridge in St. Louis, Mo. Estimates were made on eight types of bridges, and the orthotropic deck plate girder design proved to be the most economical and feasible. Main river spans are 500-600-500 ft. High strength steels were used including A373 and A441.

A paper was presented by Fred Hobbs, Jr., AIA, of Tully & Hobbs, Architects, on **The Education of an Architect.** Mr. Hobbs traced the development and evolution of architecture since the 17th and 18th centuries. In 1918 the University of Virginia established the first school of architecture in the United States. He stated that the question of how much structural design an architect should know was controversial, but that the integration of architecture and structural design courses in universities and colleges was making some headway.

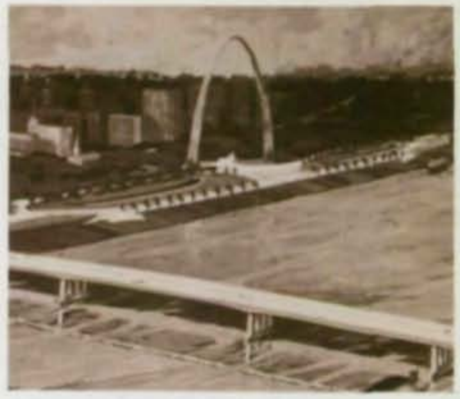
A Symposium on shop and field painting of structural steel, Robert J. Wood, vice president of Mississippi Valley Structural Steel Company as moderator, included a talk on new methods and materials in painting structural steel by John D. Keane, director of research, Steel Structures Painting Council, who discussed problems of design trends in exposed steel and the painting of welds. Eight methods of surface preparation were described. Slides of research projects under way were shown, and work on the development of a new protective coating was mentioned.

Jay P. Murphy, of Yuba Erectors, discussed his experience with airless blast cleaning equipment, called a Wheelabrator, stating that he had found this method to be economical and efficient. Gerald S. Odom, AISC regional engineer, spoke on surface preparation requirements. Maintenance painting costs were the subject of a paper by Elmer E. Gunnette, AISC regional engineer.

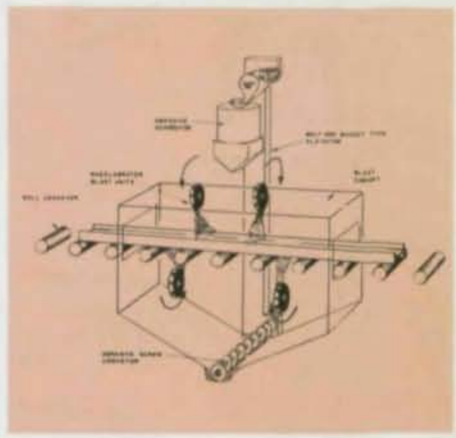
Paul Meehan, president, Meehan Steel Products Company, presided at the afternoon session. Robert O. Disque, assistant chief engineer, AISC, discussed end plate beam connections and presented figures showing savings in weight and cost compared to conventional angle connections.

Transitions in the economy and their effect on steel construction was the subject of papers by George W. James, head, Research Economics Group, and Richard T. Lasko, Batelle Memorial Institute. Mr. Lasko stressed opportunities for steel construction in residences and apartment houses.

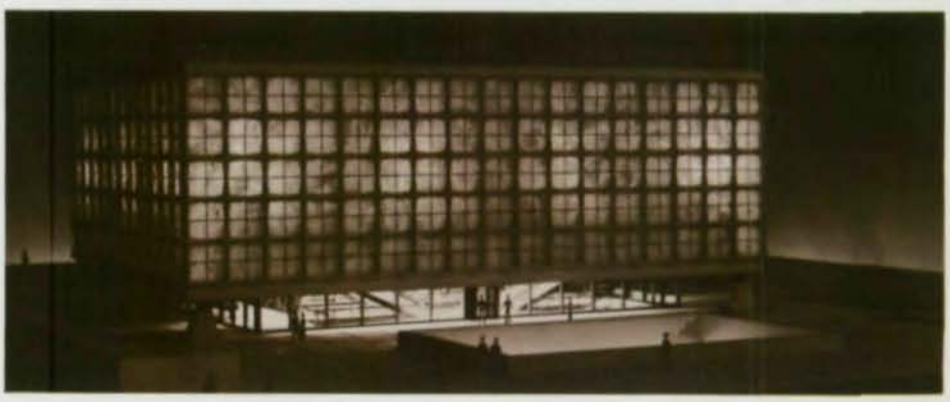
Simon A. Greenburg, industrial consultant, showed slides and discussed



*The Poplar Street Bridge, St. Louis. Jefferson Arch is in the background.*

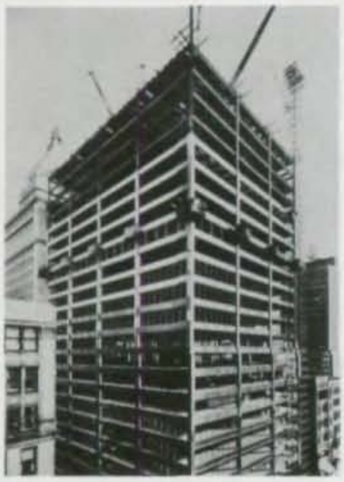


*Schematic illustration of Typical 4 wheelabrator unit structural cleaner.*



*Yale Rare Book and Manuscript Library Photo by Ezra Stoller*

*Seattle's Century 21 Space Needle*



*Continental Center Building Chicago, Ill.*

*Application of Albi-Clad spray-on coating*

*Mock-up of the John Deere Building, Moline, Ill.*

welding procedures for the five-tier Vierendeel truss which frames the Yale Rare Book and Manuscript Library in New Haven.

Samuel H. Clark, AISC chief engineer, discussed the importance of co-operation between professional engineers and architects with steel fabricators. He demonstrated how they can work together in the selection of the right steels and designs to realize the most economical and aesthetic uses of structural steel.

George S. Vincent, Division of Physical Research, Bureau of Public Roads, described research on highway bridges conducted by the Bureau.

The Friday morning session, at which Joseph Dave, Dave Steel Company, presided, opened with the showing of a motion picture, **Launching of the Space Needle,** the keynote structure of Seattle's Century 21 Exposition, shown through the courtesy of the Pacific Car and Foundry Company. The film featured the erection of 3700 tons of steel for the 600-ft Space Needle.

Consulting engineer John K. Minasian outlined the design of the Space Needle, calling it one of the most spectacular steel structures ever erected in the United States (see MSC, Vol. II, No. 1).

Jacques C. Brownson, chief designer, C. F. Murphy & Associates, Architects, described the structural steel curtain wall for the Continental Center Building, a new high rise structure in Chicago. Working stresses were keyed to the new AISC Specification – one of the first major applications since the Spec was announced in January.

Recent research in fireproofing was discussed by Dr. Howard L. Gerhart, director of research and development, Paint Division, Pittsburgh Plate Glass Company. Dr. Gerhart described research and experiments on "Porcrete," which shows possibilities as a low-cost fireproofing for structural steel.

Dr. B. B. Kaplan described "Albi-Clad," a lightweight spray-on fireproofing coating now commercially available through Albi Manufacturing Co.

Edward Cohen, Ammann & Whitney, consulting engineers, showed slides and discussed the design techniques, fabrication and erection for the movable dome of the Pittsburgh Municipal Auditorium (see also pp. 3-5).

John C. Dinkeloo, Eero Saarinen & Associates, presented a talk, illustrated with slides, on the John Deere Building, Moline, Illinois. He called the structure a new concept wherein exposed A241 steel is permitted to take on a russet patina from exposure to the air. He also described the extensive research and field tests on protective paint coatings examined for this structure.

The Friday afternoon session was called to order by Chairman Lew Cawrse, Republic Structural Iron Works Division, Consolidated Iron-Steel Manufacturing Company. Papers on quality control in structural welding were presented by Professors Robert S. Green and Roy B. McCauley of Ohio State University.

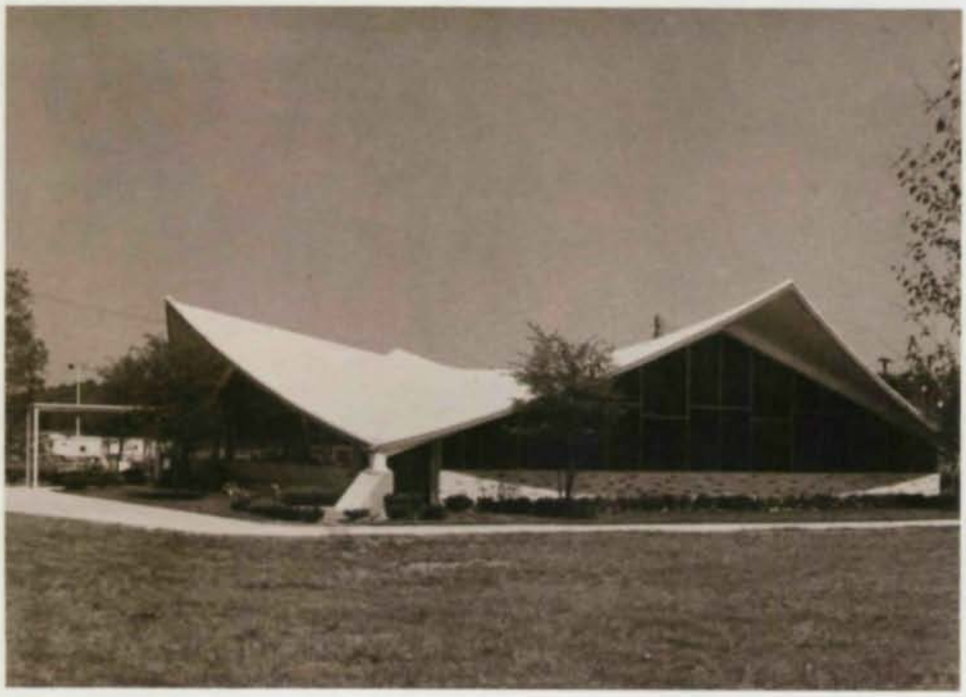
The last talk of the Conference was presented by Fred S. Adams, AISC senior regional engineer. Adams described welding shrinkage control in multi-story buildings. His talk was illustrated with slides showing methods used to control shrinkage in frames of multi-story buildings recently erected in Dallas.

A limited number of the edited Conference Proceedings are available to architects and engineers. Single copies may be obtained from AISC headquarters as long as the supply lasts.

00174

# NEW WAY TO BUILD A SHELL

*Two layers of metal decking are crisscrossed to form a four-quadrant hyperbolic paraboloid.*



*Roof for this restaurant is a hyperbolic paraboloid of welded laminated steel deck.*

by Harry T. Graham
Truman P. Young Associates

One of the top award winners in the James F. Lincoln Arc Welding Foundation competition was this structure for a Cincinnati restaurant. Program requirements called for striking appearance, square-shaped floor plan, and reasonable cost. A metal-deck hyperbolic paraboloid easily matched these requirements.

The structure consists of four paraboloids, each 33 ft-6 in. square, having a common column in the center of the structure and four exterior corner columns, giving a basic building 67 ft sq. For the sake of appearance overhangs were added on each of the four sides in the form of triangles. Since the basic paraboloid is square, this overhang complicated the design.

The analysis considered first the basic square paraboloid, and then the overhang as a simple span supported on the outside edge beam and the fascia member. The edge beam is a straight line, thus the fascia member necessarily is a curve.

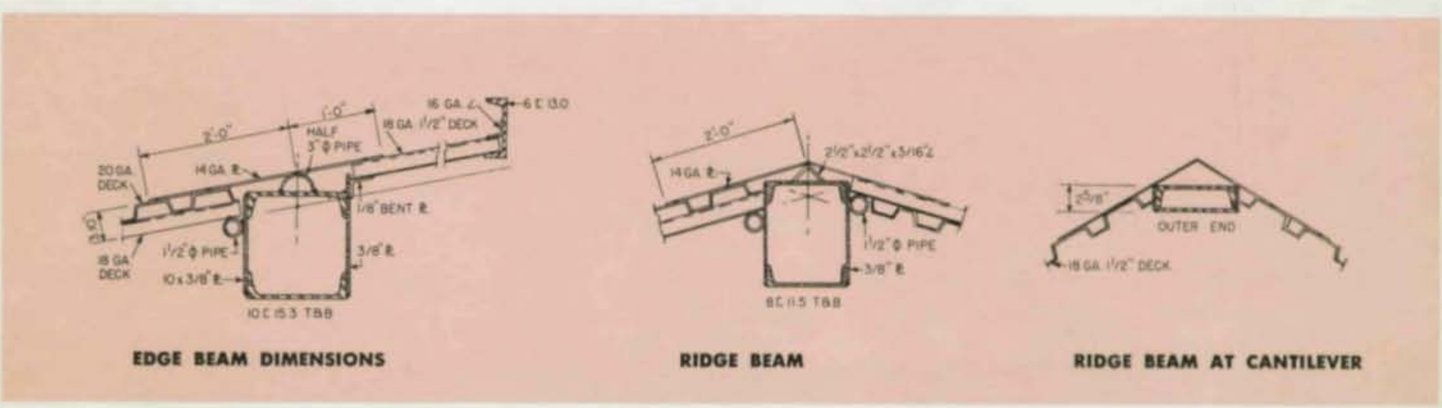
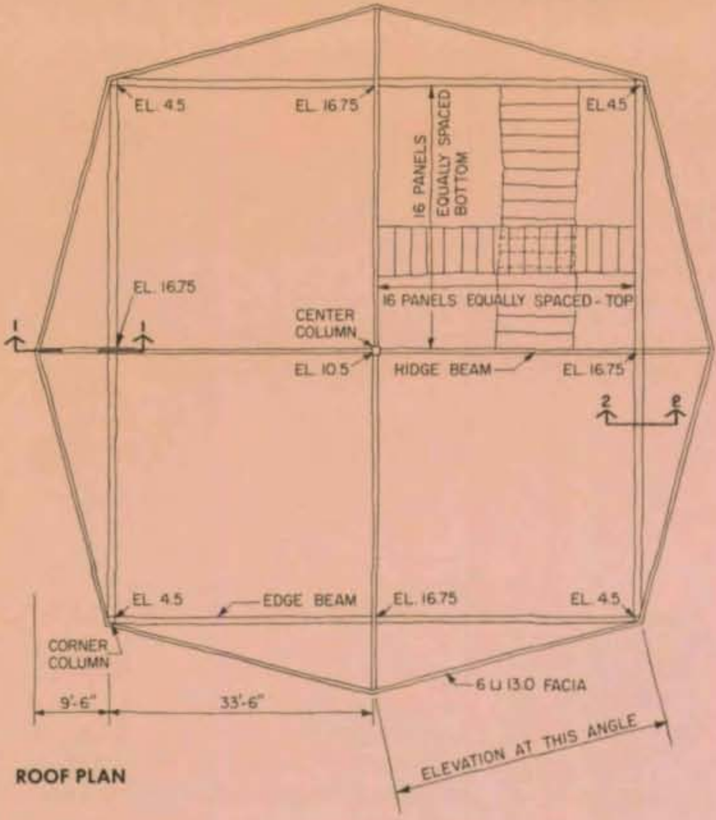
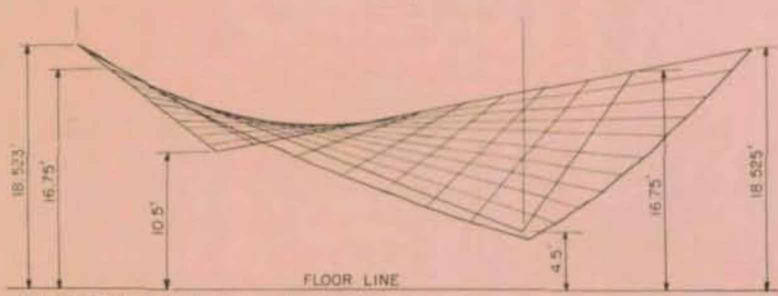


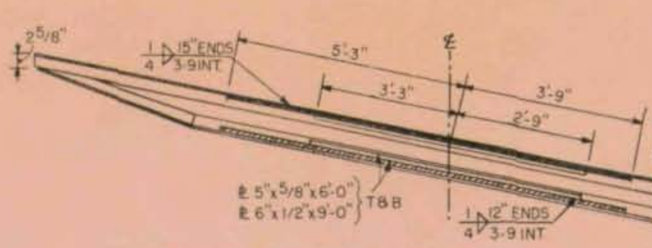

**FIGURE 1**



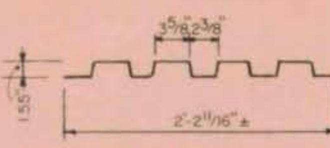

**ROOF PLAN**



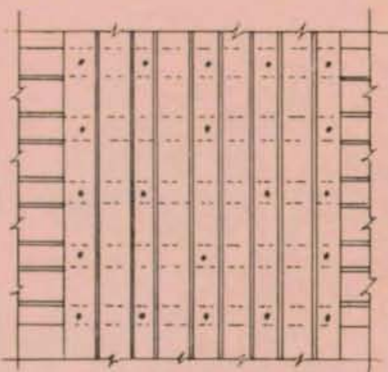

**ELEVATION at angle shown above**




**CANTILEVER SECTION OF ROOF**




**DIMENSIONS OF STEEL DECKING**



**WELD PATTERN FOR DECKING**
**18-ga. lower layer, 20-ga. upper layer**

*Figure 2 The doubly-curved hyperbolic paraboloid can be constructed geometrically by means of straight lines. Thus it was possible to build a steel-surfaced hyperbolic paraboloid using two-foot-wide sheets of fluted metal decking. There is only slight warping across each sheet. The shape of one quadrant is shown in elevation, above.*

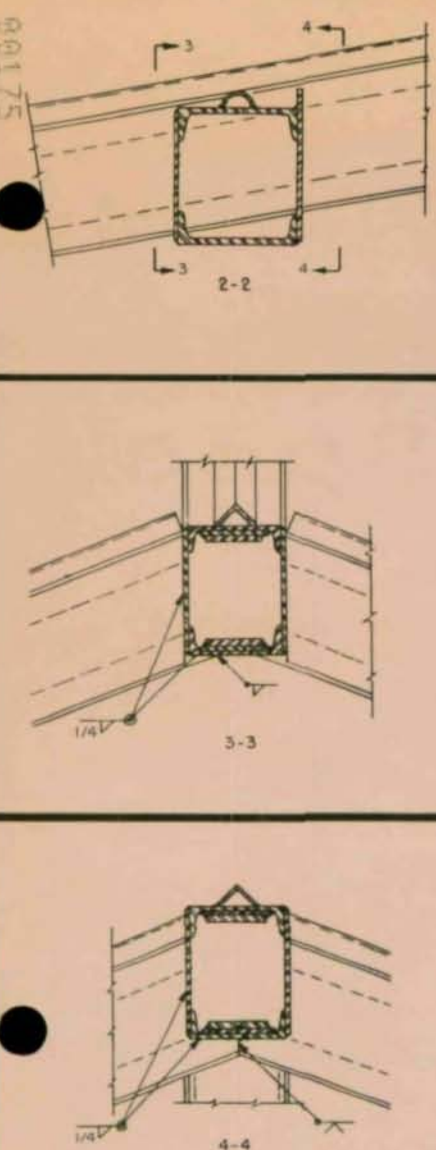
The main problem in using a membrane of laminated sheet metal was fastening the two sheets together. Riveting and bolting as well as welding were considered. Of the three methods, only welding with the semi-automatic gun gave a reliable connection that was economically feasible.

The dead load was 22 psf and the live load was assumed to be 25 psf for a total load of 47 psf. Using 20 gage deck for both top and bottom sheets, the stresses were all within the allowable range. However, for ease in welding it was decided to use an 18 gage lower layer and 20 gage upper layer with flutes at right angles to each other, and the panels of decking parallel to the edge members. This made all lines of stress at 45 degrees to the decking, but it was felt that using two layers at right angles would permit easier and faster erection, as each sheet would be essentially a straight line between members with only a slight warp in the two-foot width. The top and bottom layers were welded at each intersection by a series of plug-welds, having a maximum stress of 1190 lb per weld.

The pattern of welds is shown (Fig. 2) along with the special roof deck section used. This section is a standard shape without the edge bends, made by lifting the rolls that form the edges. The flat edges then overlapped by varying amounts and were practically unnoticeable.

The basic stress in the edge members is compression and for that reason a box section was used giving the best radius of gyration for the amount of metal used. The approximate sizes were dictated by architectural reasons, so a section composed of channels and plates was chosen. In addition to the compression and horizontal bending in the edge members, the overhang introduces vertical bending.

The most difficult problem was the method of connecting the membrane to the edge beams. After much experimentation on the drawing board, it was decided to use a small pipe for the bottom and a half pipe for the top. By using these shapes, a contact for welding was always made, regardless of the angle of the deck. The fascia member, being on a parabolic curve, became a catenary. The member could have been a bar which would have draped very readily. However, to obtain a fascia, a six-inch channel was used; and, to get enough web thickness to prevent buckling, a heavy 13-lb section was needed. The corner columns were quite short, so presented little difficulty in taking the 100,000-lb horizontal thrust. These steel columns rest on heavy concrete piers, which are tied diagonally across the




RIDGE AND EDGE BEAMS

*View from outside corner (left) with ridge and edge beams in place. The stub corner columns are cut off at an angle to receive drain scuppers. Corner view (right) without overhang showing deck welds and general arrangement. Half-round pipes on edge beams are used for welding attachment of roof.*

building just below the floor with reinforcing rods in concrete. Since the center forms a pocket, a roof drain had to be placed at this point. The drain was located directly over the column, a copper downspout was placed down through the boxed angle column and out the side of the footing. Details of the columns are shown in Fig. 3.

An unusual cut was required on the ends of the edge beams to connect them to ridge beams. This was made very well in the shop, and as a result there was perfect fit in the field. The metal deck was placed following the erection of the beams. Three lines of wooden shores were used at quarter points of the 33-ft span. The lower layer of deck was placed on the edge members and the wooden supports. The sixteen sheets were equally spaced allowing the side laps to vary across the span. The ends of the sheets were trimmed as necessary and welded to the pipe on the side of the edge members. After the entire lower layer was in place, the upper layer was laid at right angles. The ends were welded to the edge beams as each sheet was placed. After all top sheets were laid, the interior spot welds were made by one man, using a welding gun. After one quadrant was completed, the procedure was repeated on the diagonally opposite one.

Cost of completed roof structure, deck, insulation and roofing (built-up with marble chips) ran slightly over three dollars per sq ft.

Following this project, three other structures were built, similar in principle but somewhat different in shape. Cost of these has been reduced to just above two dollars per sq ft.

Woodie Garber & Associates were the architects; Hanley and Young (now Truman P. Young & Associates) were the structural engineers.

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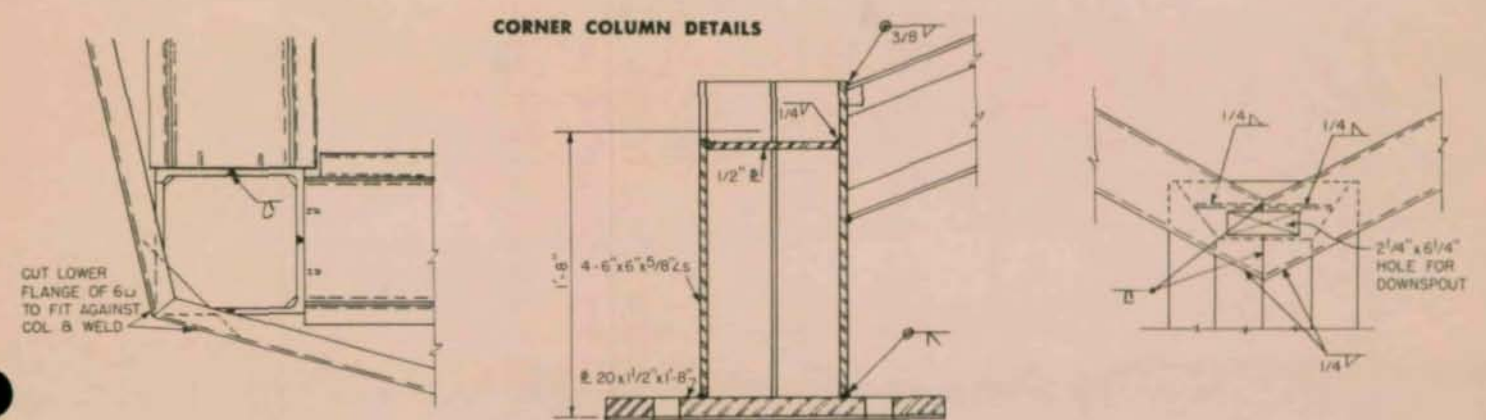
FIGURE 3



# QUESTIONS & ANSWERS on the AISC Spec

**Q. Do formulas (1) and (2) of Section 1.5.1.3 apply to tubular columns as well as wide-flange shapes?**
A. Yes, these formulas apply to any section meeting the physical requirements of Section 1.4.1.

***Q. Does the snow-load provision make* loading of alternate spans mandatory?**
A. The provision of Section 1.3.2 stating that snow load must be applied to produce the highest stresses in roof-supporting members applies primarily to large gable and arch frames. For ordinary spans of continuous design it is not the intent to use "checkerboard" loading of alternate spans.

**Q. When designing a delta girder, would the allowable stress on the flange be limited to 0.6 $F_y$ or 0.66 $F_y$?**
A. Since the objective of design of a delta girder is to provide a wide and thin compression flange braced by sloping flange plates that form the delta section, and since the web thickness would be small, it is unlikely that the proportions of the various elements of such a girder would meet the requirements of a "compact" section. Therefore, even though lateral stiffness is provided by the delta design, the allowable stress of 0.6 $F_y$ would govern.

**Q. Are built-up members having adequate w/t ratios considered to be in the "compact" category when the flange is connected to the web by rivets or intermittent welds?**
A. No.

**Q. What is meant by a "large pin"?**
A. The principle of permitting an allowable bending stress of 0.90 $F_y$ on large pins is based on the favorable "shape factor" of a round cross-section. A similar provision appeared in earlier editions of the Specification. It is intended to apply to pins used as hinges. No such provision is needed for a pin used in lieu of a rivet.

**Q. Are the 50,000 psi yield steels readily available?**
A. Yes, these high strength steels are available on a prompt delivery basis.

**Q. What are the relative cost factors for the higher strength steels with respect to A36?**
A. Information on relative cost factors is readily obtainable from steel mill representatives. In general the relative cost-to-strength factors favor high strength steels in short columns, and in tension members. The relative cost of a design in high strength steel versus a design in A36 must also take into account relative fabrication and erection costs. This information can be obtained by consultation with fabricators.

**Q. Why has the new spec discontinued the old requirement for balancing fillet welds about the neutral axis of an angle in a tension member?**
A. Tests have shown that this detailing practice is not effective in increasing ultimate strength. This is an example of "self-limiting deformation."