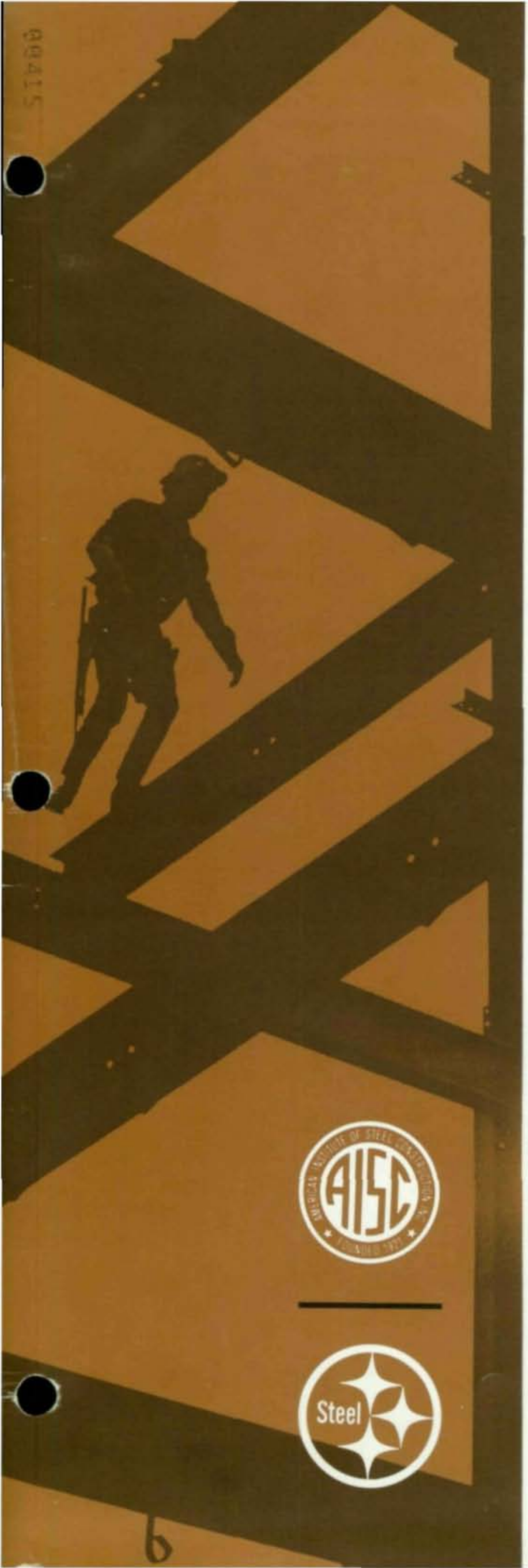
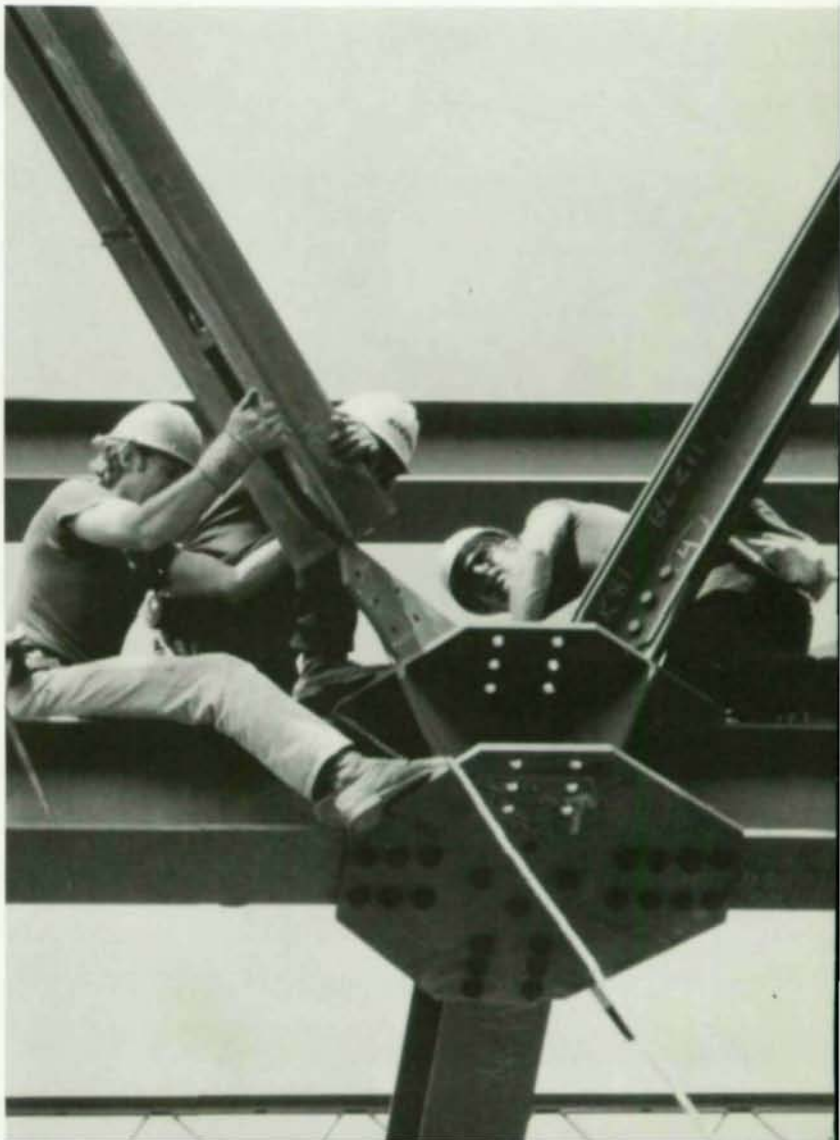
VOLUME XXII NUMBER 4/FOURTH QUARTER 1982

MODERN STEEL CONSTRUCTION



Spaceship Earth: Gateway to Tomorrow
Steel—Healthy Approach to a New Market
For World-famous Hospital, Diagnosis was Steel
Pyramidal Truss Key to Clear-span System
Steel "Reflects" an Architect's Choice
Rehabbing Steel Bridges in Maine

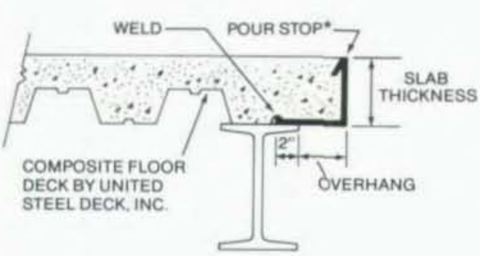


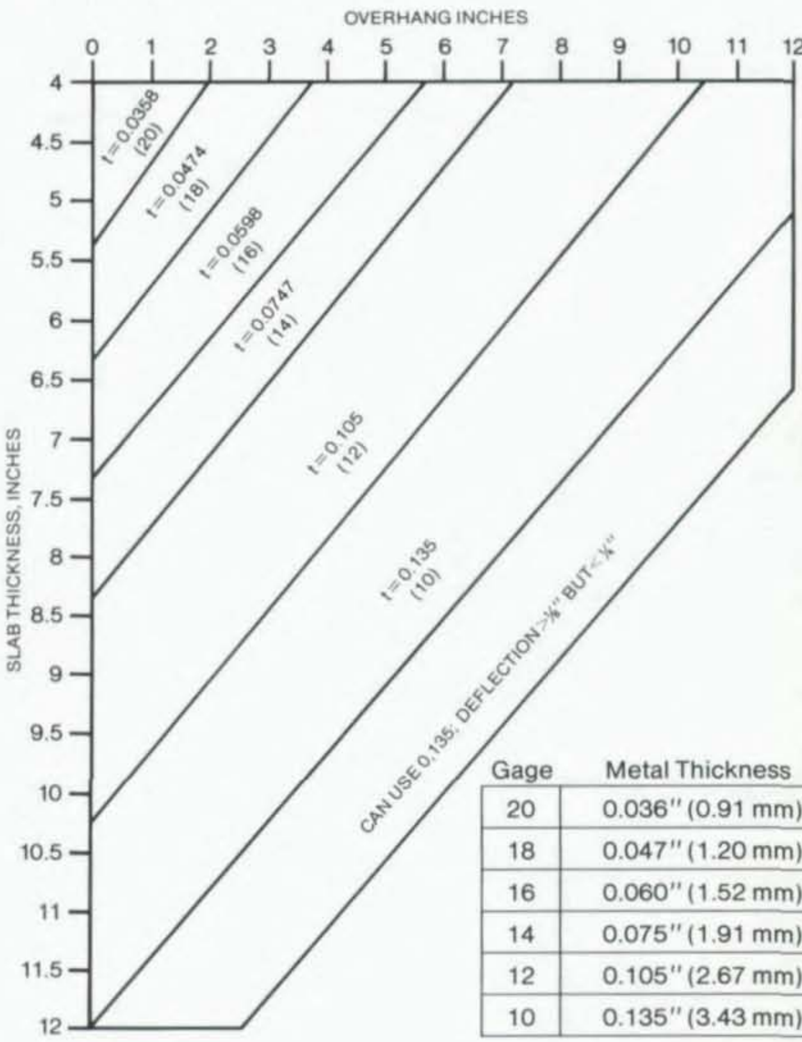
DECK DESIGN DATA SHEET

NO. 1

POUR STOP SELECTION CHART

The chart shows the thickness (gage) of the steel pour stop angle recommended by Nicholas J. Bouras, Inc. for the various slab thickness and overhang combinations. Two inches of bearing and one inch long welds at 12" O.C. are required. In determining these recommendations the steel stress was limited to 20000 psi and the deflection to ⅛".





Gage	Metal Thickness
20	0.036" (0.91 mm)
18	0.047" (1.20 mm)
16	0.060" (1.52 mm)
14	0.075" (1.91 mm)
12	0.105" (2.67 mm)
10	0.135" (3.43 mm)

Any time you need information on deck design, delivery, budget pricing, or bidding—call on us, your deckhands. Reprints of this chart are available on request.

*Return lip available on order.

MODERN STEEL CONSTRUCTION

Published by

American Institute of Steel Construction
The Wrigley Building
400 North Michigan Avenue
Chicago, Illinois 60611

REGIONAL OFFICES

NORTHEAST REGION	
New York, NY (Hdq.)	212/695-4291
Boston, MA	617/329-7417
Philadelphia, PA	609/858-9354
Pittsburgh, PA	412/443-8840
NORTH CENTRAL REGION	
Chicago, IL (Hdq.)	312/372-8957
Detroit, MI	313/352-5558
Minneapolis, MN	612/888-3791
SOUTHEAST REGION	
Atlanta, GA (Hdq.)	404/458-7679
Charlotte, NC	704/375-6547
Tampa, FL	813/879-0429
SOUTHWEST REGION	
Dallas, TX (Hdq.)	214/630-5236
Houston, TX	713/529-5564
St. Louis, MO	314/721-1332
WESTERN REGION	
Los Angeles, CA (Hdq.)	213/444-4519
Denver, CO	303/831-4622
San Francisco, CA	415/495-3550
Seattle, WA	206/624-5460
AISC HEADQUARTERS	
Chicago, IL	312/670-2400

VOLUME XXII NUMBER 4/FOURTH QUARTER 1982

CONTENTS

1983 ENGINEERING CONFERENCE MEETS MARCH 3-4

The 35th annual AISC NEC in Memphis, Tenn. will meet around the theme "Designing in Steel for Efficiency and Economy." Over 500 engineers are expected to attend the streamlined two-day conference, which will meet in the famous, and newly renovated, Peabody Hotel, now listed in the National Register of Historic Places.

For the first time, an exhibit area will be open to demonstrate products and services of special interest to structural engineers.

Main attraction of NEC is the presentation of technical papers which make the conference a major source of information on state-of-the-art structural steel engineering. Plus, a full program for spouses gives an overview of cultural, social and economic forces of Memphis both yesterday and today.

Registration is already underway, with substantial savings for early registration—$160 for those postmarked on or before Jan. 28, 1983; $100 for professional members. After Jan. 28, $200 and $125. For further information and/or registration forms, contact AISC Convention Services, 400 N. Michigan Ave., Chicago, IL 60611. 312/670-2400.

STILL TIME TO APPLY FOR 1983 FELLOWSHIP AWARDS

A maximum of eight graduate study Fellowships of $4,750 will be awarded in 1983. Awards go to graduate civil or architectural engineering students who propose study toward an advanced degree related to fabricated structural steel. The awards are designed to encourage expertise in the imaginative use of structural steel for bridges and buildings, and to motivate recipients to pursue new ideas that improve the technology of steel construction.

Awards are made on the basis of a student's proposed course of study, achievement and recommendation by college faculty. Applications are available from: AISC Education Foundation, 400 N. Michigan Ave., Chicago, IL 60611. Deadline is Feb. 1, 1983.

Spaceship Earth:
EPCOT Center's Gateway to Tomorrow

by John P. Grossman
and
Glenn R. Bell

EPCOT Center is Disney's newest entertainment world at Walt Disney World in Florida. Developed by WED Enterprises, the design arm of the Disney organization, it has two parts: Future World, a collection of exhibits of the new ideas and technologies which are emerging from the creative centers of America; and World Showcase, a meeting place to display the cultures of many nations. The focus of the entry courtyard is a 160-ft diameter geodesic sphere, raised 14 ft above ground and covered with faceted aluminum panels. Conceived as a symbol of EPCOT Center and the global impact of the technoloy of the future, the sphere was appropriately named Spaceship Earth. Because EPCOT Center is an entertainment complex, the exterior design tends towards a "show" facade while simultaneously presenting Disney's vision of the technology of the future.

"We wanted to create an atmosphere for our guests that raises their spirit and kindles an excitement for the human experience in the future," stated Gordon Hoopes, WED's project designer for Spaceship Earth. "We knew that having the entire sphere raised above the ground would cause substantial engineering problems but the psychological uplift for our guests would be worth it."

Underneath the geodesic-patterned metallic skin of Spaceship Earth is a complex steel structure carefully tailored to satisfy the varied requirements of WED's show designers and engineered to transfer the various loads to the foundations with the greatest economy consistent with the other program requirements.

Early WED Concepts

In early 1979, WED Enterprises retained Simpson Gumpertz & Heger Inc. (SGH), structural engineers, and Wallace, Floyd, Associates Inc. (WFA), architects, to develop the design of the Spaceship Earth pavilion from WED's concept sketches.

Through many studies over several years, WED's concept designers had determined the size of sphere they wanted at the entry to EPCOT Center. They had also established the concept for a support system that would be aesthetically desirable and which could be integrated into the surrounding facilities. Their early sketches showed three pairs of legs rising from ground level to support a patterned sphere of approximately 160-ft diameter.

Development of Sphere Enclosure

Because Spaceship Earth was intended as

John P. Grossmann is an associate of Wallace, Floyd, Associates, Inc.

Glenn R. Bell is a senior staff engineer at Simpson Gumpertz and Heger Inc.

Sleek monorail circles pavilions of Future World. Spaceship Earth looms high above EPCOT Center, kindles excitement for vision of future. Photos courtesy Walt Disney Productions

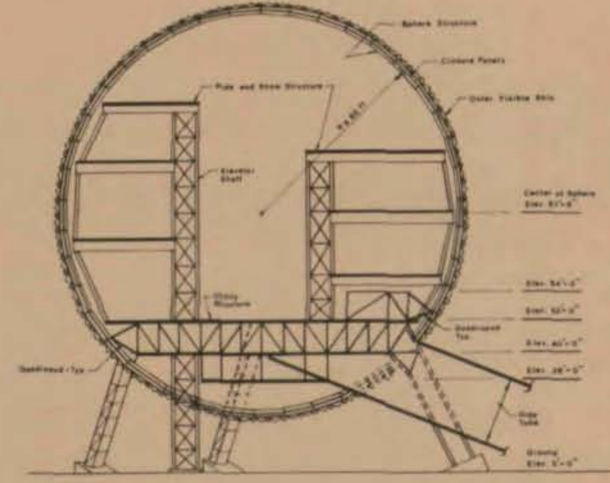


Figure 1—North-south section through Sphere

the main focal point and the "logo" pavilion of EPCOT Center, appearance of the sphere was of extreme importance. WED's designers initially indicated a preference for a geodesic pattern similar to that used for the Expo '67 dome in Montreal. But a final pattern for the exterior could not be determined until a preliminary structural design for the sphere had been developed.

The selection of the material for the sphere's enclosure involved several essential, but seemingly conflicting considerations. Reliable waterproofing was necessary to protect the costly ride equipment and show set; fire-resistive construction was essential for protection of the building occupants; and, of course, the selected material had to be appropriate aesthetically.

No single material satisfied all of these requirements. Sheet neoprene, for example, was deemed to provide the best water resistance, but its appearance was considered entirely inappropriate. This quandary led to the "double-skin" solution for the sphere enclosure. An inner shell, covered by a waterproofing neoprene sheet, was attached directly to the sphere structure. At a radius approximately two feet greater than that of the inner skin, a purely cosmetic cover was erected. This separation permitted the visible outer shell to be fabricated from more aesthetically desirable material.

The exterior panels do not need weatherproof joints, and the only structural requirement is that they be capable of resisting wind load perpendicular to their surfaces. The outer skin is supported from the hub points of the inner structure by aluminum pipe outriggers or standoffs. The two-foot space between skins provides access for maintenance of the waterproofing and the inside surface of the cosmetic skin.

The double-skin solution solved another problem: excessive runoff of rainwater to the pedestrian circulation below. By means of open slots between facets of the outer cosmetic panels, rainwater percolates to the inner waterproof skin where it is collected and carried away by a hidden gutter system at the sphere's equator.

Primary Structural Systems

A key design task during the conceptual phase was to devise a structure to support the interior ride track and show sets (the Ride and Show Structure; see Figure 1) that was independent of the structure of the geodesic sphere (the Sphere Structure). This was done to avoid concentrations of force in the sphere and interruption of its natural shell action, in an effort to keep the Sphere Structure members as light as possible. This structural separation also afforded WED's designers more flexibility in locating the ride tracks and show platforms, and it allowed the design of the sphere to proceed concurrently with, but independent of, the development of the ride and show.

The requirement that the Sphere Structure be totally elevated above the ground posed an unusual engineering challenge. To support all of the Sphere Structure loads directly on the legs would have created discontinuities and concentrations of force in the sphere, and would also have destroyed the shell behavior. The solution was to support the Sphere Structure as uniformly as possible at a ring of sphere hubs at the approximate elevation of the tops of the six legs. Ultimately, the Sphere Structure was kept entirely independent of the legs.

It was necessary to develop a major steel structure to transfer all of the loads from the Sphere Structure and most of the loads from the Ride and Show Structure to the six legs. Most of the mechanical equipment space from Elevation 28 to Elevation 52 was available for this purpose, but a major penetration for the ride entrance to the sphere (the Ride Tube) allowed only limited space between Elevation 52 and Elevation 64 at the southern part of the sphere. The structure provided in this space, designated the Utility Structure, developed into something akin to a huge six-legged table, on top of which was supported the Ride and Show Structure, and from which was suspended the Sphere Structure at the utility levels.

Sphere Structure

Although the Disney organization had developed its own EPCOT building code for Walt Disney World, the wind loading criteria that it contained were not applicable to a structure as unusual as Spaceship Earth. Preliminary structural design was based on wind-loading data derived from prior experience with spherical structures. Later, wind-tunnel studies were performed on a $\frac{1}{16}$ in. = 1 ft scale model of Spaceship Earth and its surroundings at the Wright Brothers Memorial Institute of the Massachusetts Institute of Technology. In addition to establishing pressure coefficients for the design of the Sphere Structure, the study was used to determine pedestrian level wind pressures. Design wind velocities for application of the wind-tunnel pressure coefficients were derived from the EPCOT Building Code, from American National Standards Institute data and from historical meteorological data for central Florida.

Several considerations bear on the selection of the geodesic geometry type and frequency for a geodesic structure:

- To minimize bending moment and buckling effects, the lengths of members should be limited.

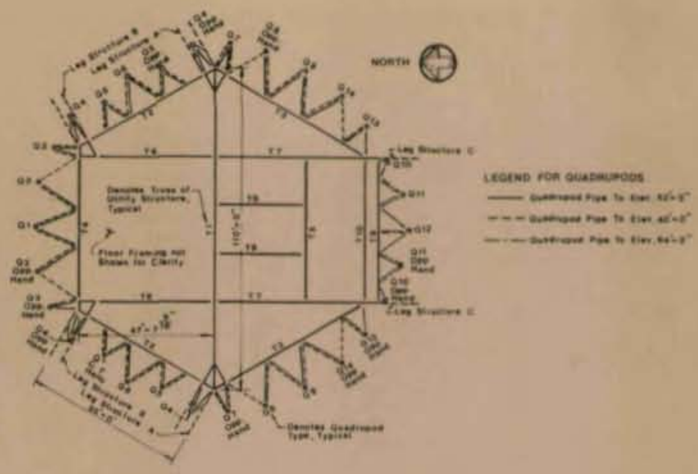


Figure 2—Key plan for utility structure, elevation 52 ft

- For economy of fabrication and erection, as few members and as few differing lengths of members should be used as possible.
- For efficiency, the difference between the maximum length of member and the minimum length of member should be minimized and member forces should not vary over too great a range.
- Since the geometry of the visible shell is related to that of the supporting structure, the selected geometry should be aesthetically pleasing.

After various structural studies by SGH and various pattern studies by WFA, and in consultation with WED, an eight-frequency "triacon" geodesic geometry was selected. This resulted in eight fundamental sphere-strut lengths and four (with opposite-hand complements) panel types. The struts range in length from 12-16 ft.

Steel wide-flange shapes were the natural choice for the Sphere Structure members. They are easily connected at their ends, and their strong bending axes can be oriented to efficiently resist dead loads and wind loads perpendicular to the sphere surface.

The struts were fabricated from A572 Grade 50 steel in three sizes: W10x45, W10x33 and W10x22. From the level of the supported hubs to the top of the sphere, these struts occur in three bands, the weights of the sections decreasing with increasing elevation. Most of the struts below the level of the support hubs, where the structure is essentially hanging, are W10x22, but heavier members were required at the structural discontinuities created by the penetrations for the legs, the elevator and the Ride Tube.

At hub locations, the struts are connected at their top and bottom flanges by circular steel plates which are stamped to a conical shape. This simple and economical type of connection is now commonly used in geodesic domes.

Prefabricated metal panels (closure panels), which fit into the triangles created by the struts, form the inner shell to which the waterproof membrane is applied. These panels support rigid-board insulation on their interior surfaces and they also participate with the outer visible skin in the resistance of wind loads perpendicular to the sphere surface. Their only structural function, in addition to resisting wind loads, is to laterally brace the wide-flange struts. These panels are formed from standard 3-in. deep 20-ga. metal roof deck with an 18-ga. flat outer sheet which provides a smooth surface for the neoprene waterproofing. Cold-formed, light-gage steel edge rails and structural tee clips provide attachment to the outer flanges of the wide-flange struts.

In total, the Sphere Structure is composed of 1,339 struts, 467 hubs, and 954 closure panels. The total weight of structural steel, excluding the closure panels, is 400 tons.

Utility Structure, Legs and Foundations

The key task in the design of the Utility Structure was to develop a structural system which would support the sphere as uniformly as possible while it transferred the sphere loads to the six legs. Candidates for rings of sphere hubs to be used as support hubs were identified. The hub elevations necessarily undulate because of the geodesic sphere geometry and because the Ride Tube penetration requires a rise in the level of the adjacent sphere support structure.

Essential considerations in the development of this system were economy of fabrication and simplicity of erection. It was desirable to shop-fabricate to the greatest extent possible, but shop-fabricated assemblies were restricted to a 12-ft wide shipping envelope. A number of early schemes examined employed box-type plate girders or three-dimensional trusses spanning between the six legs. These members were curved in plan to follow the perimeter of the sphere, and the schemes required them to carry substantial torsional loads because the sphere support points were outboard of straight lines struck between adjacent legs.

A major simplification and savings over these schemes was achieved by using the floor structures at Elevations 40 and 52 to carry the torsional loads by means of resistive couples developed by diaphragm forces in these floors. This solution was based on a hexagonal pattern of 12-ft deep trusses, designated T2, T3, T4 and T10 on Figure 2. The top chord of each truss is located at the floor at Elevation 52 and the bottom chord is located at the floor at Elevation 40. These trusses carry only vertical loads.

The sphere's support hubs are attached to these trusses by a system of four-legged assemblies called quadrupods. Extending from a common working point at the sphere support hub, two legs of the quadrupod attach to adjacent panel points of the upper chord of a truss, and two legs attach to adjacent panel points of the lower chord. The horizontal component of force in these members is carried by the 12-ft deep truss at the edge of the hexagonal platform. An exception to this system occurs at the southern area of the sphere, where the usable space between floor levels is inter-

Spaceship Earth from north

rupted by the Ride Tube. Here, a box-type space truss, *designated* T5, T9 *and* T10 *on* Figure 2, carries vertical and torsional loads.

Some of the columns of the Ride and Show Structure are also supported by this hexagonal pattern of trusses; outriggers are used to transfer loads from outboard columns back to the hexagonal trusses. Interior trusses T1, T6, T7 and T8 support other columns of the Ride and Show structure.

Legs Type A and Type B (see Figures 1 and 2) are box-type truss members. Legs Type C, *very restricted in width to fit within* the Ride Tube, are planar-type trusses with web plates covering their two sides.

Foundations are end-bearing, concrete-filled steel pipe piles, approximately 100-ft long. Reinforced concrete grade beams tie the pile caps and carry horizontal thrusts from the inclined legs.

Quadrupod Support System

The quadrupods carry the sphere loads to the Utility Structure and make the critical transition from the geodesic sphere geometry to the geometry of the hexagonal trusses. Each quadrupod typically consists of four pipe struts (6XX, 8STD or 8X), which connect a sphere hub to four panel points on a hexagonal truss. Some of the quadrupods are actually tripods because of pipe strut interferences with other structural components. Some of the quadrupod pipe struts attach directly to the leg structure rather than to the hexagonal trusses. There are 30 quadrupods in all, shown in plan on Figure 2.

Because of symmetry of the structure about the north-south axis, however, there are only 14 quadrupod types. Three additional hangers, similar to quadrupods but with only one strut, provide additional support for the sphere at the Ride Tube penetrations. The inner ends of the quadrupod pipes connect to the Utility Structure by means of compact weldments, which are bolted to the upper and lower chords of the trusses and are field-welded into slots at the ends of the quadrupod pipes. The outer ends of the quadrupod pipes connect to the sphere with a set of complex weldments, each based on a six-legged spider of steel plates; these are also field-welded into slots at the end of the quadrupod pipes.

An essential consideration in the design of the quadrupod support system was practicality in erection and fitup. The design allowed for field alignment of the sphere support hub points during erection by the use of erection bolts in slotted holes at each end of the quadrupod pipes. These connections allowed independent adjustment during erection of each support hub working point in each Cartesian coordinate direction. Once the support hubs were precisely set, these connections were welded off.

Additional horizontal adjustment was provided by shims between the truss chords and the previously described compact weldments at the inner ends of the pipes. Thus, accumulated fabrication and erection tolerances and the dead-load deflections of the sphere support system could be adjusted out of the system to obtain the precise alignment of the support hubs required for sphere erection.

Development of Outer Skin Panels

WFA performed the early pattern studies. They were concerned principally with the scale and geometry of the facets because the support points of the outer skin panels were determined by the geometry of the inner steel structure, and by the triangular sections thus defined. WFA studied possible patterns within these basic triangles by constructing cardboard mockups. The alternatives considered included a pattern that emphasized the accumulation of six triangles around a hub, resulting in an overall surface pattern of hexagons; a pattern which reflected the basic triangle and scale of the underlying steel structure; and a pattern that subdivided these triangles into smaller triangles of approximately eight feet on a side.

The final pattern, chosen by WED's John Hench, senior vice president for creative development, was a subdivision of the flat triangular facet of the structural steel geometry into four smaller triangles. Each smaller triangle is covered by a triangular pyramid of approximately one foot in altitude. A ⅛-in. scale mockup of the entire sphere was constructed with this pattern for final approval by WED's designers.

Concurrently with the pattern studies, color, material and lighting investigations

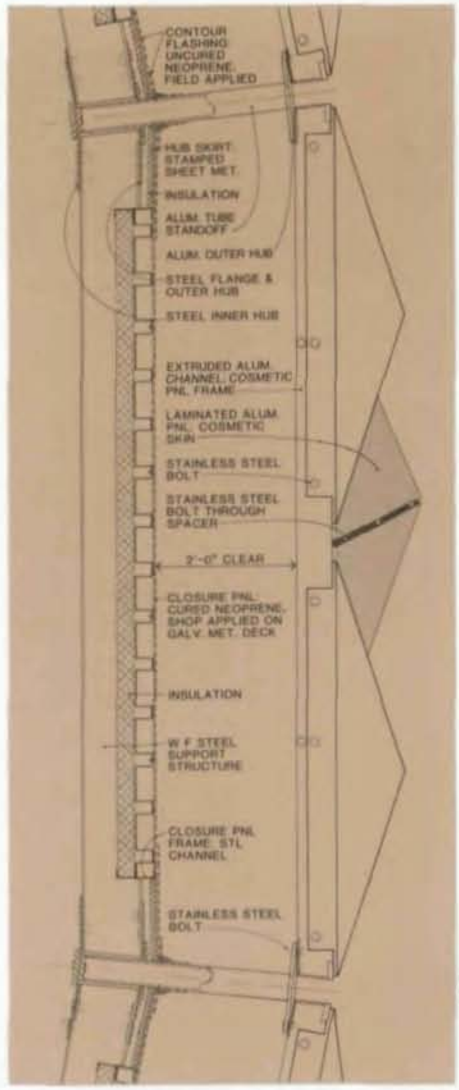


Figure 3—Cosmetic skin and closure panel

were undertaken. WFA investigated several different materials, placing particular emphasis on the program requirement for a color-fast coating and the dramatic effects which might be achieved with exterior lighting. The three generic types of materials considered were metal panels, fiberglass panels and glass.

Through several early study models, WED had investigated an exterior covering of reflective glass. WED asked WFA to investigate the possibility of backlighting a skin of reflective glass to create a glowing sphere at night. Although it appeared that a reflective glass enclosure backlit with long-life sodium bulbs was feasible, this solution was considerably more expensive than either of the others, and it would have involved long-term maintenance requirements. In addition, a similar effect could be achieved at night by using special exterior floodlights.

A wide choice of colors could be obtained from the formed fiberglass or metal panels coated with a high-performance coating.

WFA performed several color studies for review by WED designers. Of particular interest was an attempt to simulate the appearance of the earth as photographed from satellites by NASA. The intent was to outline the general features of the earth as one would see them from space without actually building a replica similar to a globe. Tinted aluminum sheets with transparent dyes for the various colors were proposed. This would have allowed the metallic quality of the material to register at the same time as the overall desired image.

As the design of the triangulated substrate developed, WED indicated a preference for a machinelike metallic look. The ease of forming aluminum and its ability to accept a wide variety of high-performance finishes made it a natural choice. Eventually, WED's designers selected a clear anodized aluminum as the desired finished appearance. Several composite panels with aluminum facings, equal to aluminum plate in finished appearance, were also considered.

WFA and SGH recommended that a performance specification be used for the panel material, and that, where the aluminum structure interfaced with the steel sphere structure, details and member sizes be included in the bid documents. In addition, profiles of the faceted panels and the critical geometry for the pattern were developed. The performance specification was written to ensure that the design would meet critical environmental conditions without any permanent change in appearance. Because the sphere would be one of the most visually prominent features of Epcot, the performance specification also included quality control requirements. (Figure 3 illustrates the final design for the visible exterior panels and substructure.)

Fabrication and Erection

The steel fabricator used the repetitive nature of the sphere system geometry to maximum advantage by fabricating the sphere struts and hub plates on computer-controlled punching and cutting machines.

To minimize the effects of the deflections of the hexagonal trusses on the Sphere Structure, it was necessary to ensure that a certain amount of dead load was applied to the Utility Structure before erection of the Sphere Structure. Thus, after the legs and trusses of the Utility Structure were erected, the steel and concrete floors at Elevations 28, 40 and 52 were placed, and most of the steel of the Ride and Show Structure was erected.

Next, the quadrupods were erected with a full interconnecting ring of sphere struts. The support hub working points were approximately set by level survey, and the adjustable connections of the quadrupods were temporarily fastened by erection bolts. Erection of the struts continued until three full sphere rings of the sphere were complete. The quadrupods were further adjusted during this stage as the struts drew the support hubs to the precise geodesic geometry. When the erection of three full sphere rings was complete, the geodesic geometry was considered set, and the adjustable quadrupod connections were welded off.

The erector worked upward from this support-hub level. Units of two, three or four struts were assembled on the ground and erected on the sphere in circumferential rings. This procedure was used up to approximately 50 ft in diameter, was assembled on the ground and hoisted into position to complete erection of the upper portion of the sphere. Next, the sphere components below the support-hub level were erected. No scaffolding or other temporary support of the sphere was required during erection.

The steel closure panels of the inner skin were erected with cable slings. Contract documents prescribed that erection of these panels closely follow the erection of the sphere struts so that the necessary lateral bracing of the struts would be provided before substantial loads were applied to the sphere. Next, the aluminum standoff pipes used to support the aluminum outer shell were erected. Flashing around the standoff pipes was installed, and the application of neoprene strips at the joints between closure panels completed the waterproofing. □

Owner/Architect/Engineer of Record
WED Enterprises, Inc.
Glendale, California

Consultants

Architect
Wallace, Floyd, Associates, Inc.
(formerly Wallace, Floyd, Ellenzweig, Moore, Inc.)
Cambridge, Massachusetts
San Francisco, California

Structural Engineer
Simpson Gumpertz and Heger, Inc.
Cambridge, Massachusetts
San Francisco, California

Construction Manager
Tishman Construction Corporation of Florida, subsidiary of Tishman Realty and Construction
New York, New York

General Contractor
Darin and Armstrong
Detroit, Michigan

Mechanical/Electrical Engineer
Syska & Hennessy
San Francisco, California

Steel Fabricator
Tampa Steel Erecting Company
Tampa, Florida

Westminster-Canterbury: Steel-Healthy Approach to New Markets

Nationwide, the census for senior citizens 65 and older grows by leaps and bounds. Now 11.2% of the nation's population, by the year 2,000 A.D. nearly 32 million, are expected to be in that bracket. Which means a whole new market in senior housing.

To meet the need in the Lynchburg, Va. area, the state's Episcopalians and Presbyterians formed a non-profit corporation to construct a new and innovative life-care retirement community—Westminster-Canterbury. The $12.7-million, 8-story structure provides 240 independent living units within its 280,000-sq ft steel framework. Two building wings house living units, a third provides for health care services.

Steel—for High Speed, Low Cost

The architectural/engineering firm chose a steel frame for the retirement structure because they believe they were able to estimate the owner's costs more accurately—and keep construction projections on schedule. They had a number of reasons for doing so:

- Quick erection time
- Flexibility of framing that can be modified easily in future renovations
- Economics of reduced construction time and finance costs
- Reduced foundation costs from relatively small loads steel framing imposes

Structural steel roof and floor beams are non-composite and conform to ASTM A36. Floor slabs are lightweight concrete on 2-in. composite metal deck (5¼ in. total thickness). To achieve required fire ratings, steel beams were spray-fireproofed, but composite metal deck was not. The structural steel columns, W10 sections conforming to ASTM A36 or A572 Grade 50 where required, were also spray-fireproofed.

The structural steel framing, founded on reinforced spread footings, resists lateral wind loads with Type 2 construction. The wind moments are distributed to selected joints of the framing with beam-to-beam column connections assumed flexible under gravity loads.

Designed with Elderly in Mind

The master plan developed for the 21-acre site accommodates the residents and a range of associated services—yet avoids the institutional character common to many retirement communities. A health-care service system provides home care, outpatient care, 120 beds for in-patients, physical therapy and support facilities.

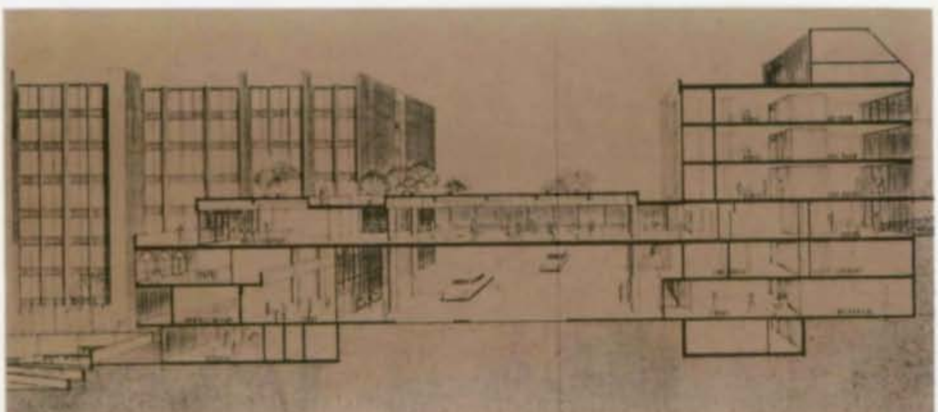
While site topography dictated the main entrance road bisect the site, the design solution was to provide two residential buildings and the service structure. An elevated, enclosed bridge spans the en-

trance road to interconnect all buildings. It also provides a weather-protected entrance and serves as a social nerve center as residents move from apartment to dining, to recreation and service areas.

The facility includes a wide range of common recreational, hobby, social and meeting facilities. Small, semi-private social spaces function as an extension of the dwelling units and serve as a substitute for the family room they previously had in their homes. Intermediate scale activities have larger rooms within residence buildings and along pedestrian ways. This variety of spaces responds to the diverse needs of the senior population.

The AIA Honor Award-winning Westminster-Canterbury was designed to maintain a health environment, rather than emphasize health care, and to encourage residents toward a healthy, productive life in their retirement years. □

Spacious activity bridge area is social nerve center for residents.



AIA award-winning Westminster-Canterbury House (far l.), Roanoke, Va. represents new markets to meet needs of burgeoning retirement-age population. Cross-section (l.) details interesting "activity bridge" interconnection of buildings and location of various facilities.

Steel framework was architect's choice for fast erection, flexibility of framing, reduced construction and financing costs.

Architect/Structural Engineer
Sherertz, Franklin, Crawford, Shaffner
Roanoke, Virginia

General Contractor
English Construction Co., Inc.
Alta Vista, Virginia

Owner
Westminster-Canterbury of Lynchburg
Lynchburg, Virginia

At Second Glance . . . Staggered Trusses Filled the Bill

by Robert DeBruin

M*innesota's severe winter cold . . . a* tight construction schedule . . . economic efficiency. Admittedly abbreviated, these are the primary reasons a steel staggered-truss framing system was chosen for a new Holiday Inn in Bloomington, Minn.

Early planning had clearly drawn specific design parameters for the 13-story, 300-room hotel. However, the selection of a framing system was delayed until two Ellerbe companies: Finance/Design/Construct, Inc., a design/build subsidiary, and Ellerbe Associates, Inc., the company's architectural/engineering subsidiary, were able to complete an in-depth analysis of the relative advantages of three separate framing methods.

Systems Ellerbe considered were:

- A cast-in place, post-tensioned flat-plate system.
- A conventional steel-framed system with beams, girders and columns.
- A conventional steel system for the lower two stories, combined with a steel staggered-truss system for the upper 11 stories.

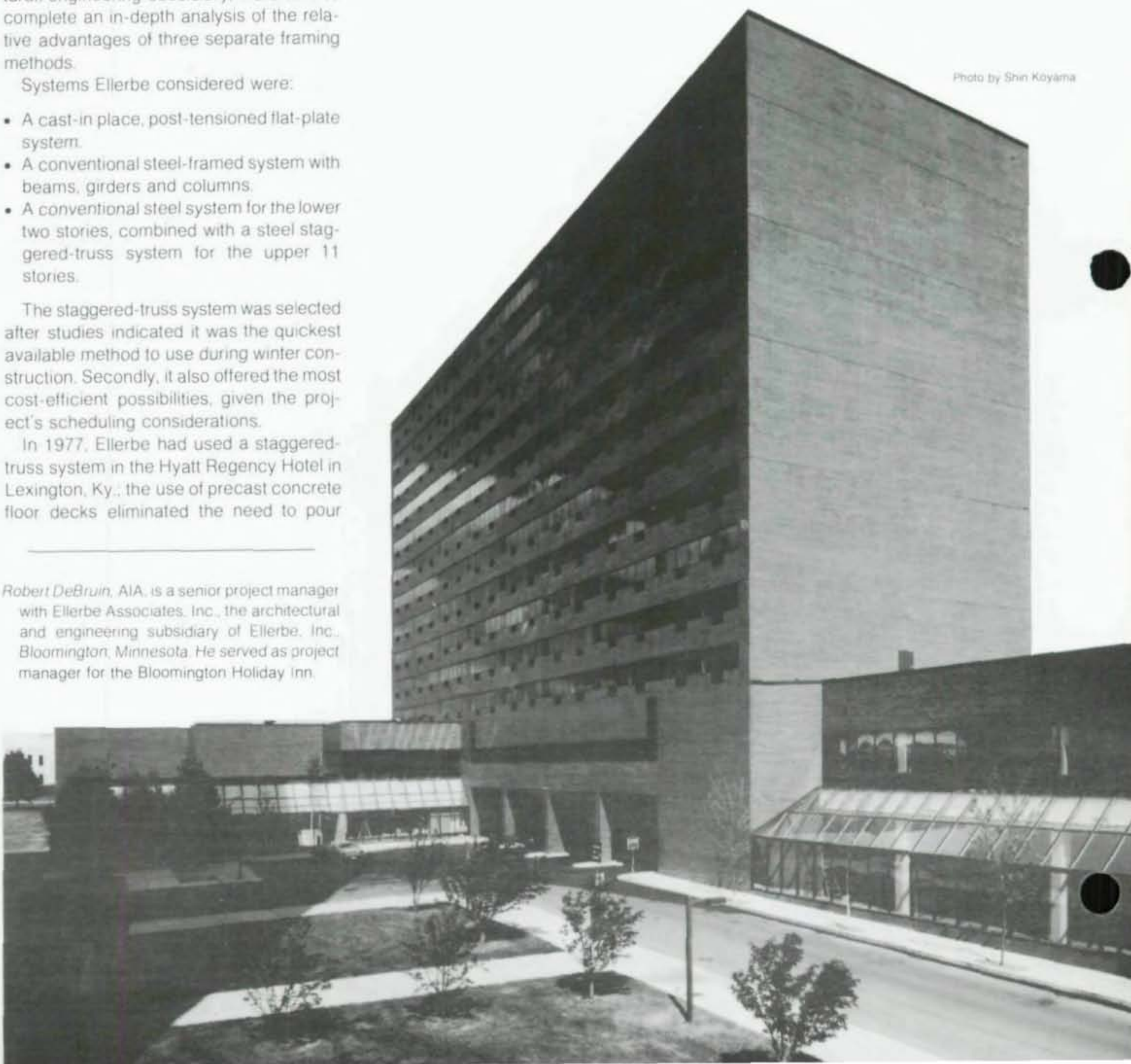
The staggered-truss system was selected after studies indicated it was the quickest available method to use during winter construction. Secondly, it also offered the most cost-efficient possibilities, given the project's scheduling considerations.

In 1977, Ellerbe had used a staggered-truss system in the Hyatt Regency Hotel in Lexington, Ky.; the use of precast concrete floor decks eliminated the need to pour concrete during the cold weather. The erection of a masonry load-bearing building during Minnesota's severe winter season would have required costly weather protection. Another important factor was that, with a more conventional system, interior walls would have to be carried through all public spaces to the hotel's foundations to provide efficient structural support. The winter cold would have made this particular process difficult, and added potential construction delays and budget problems to the project.

The selection of the steel staggered-truss system proved an excellent decision. The hotel foundation was started Nov. 16, 1979 and first steel was set on Jan. 24, 1980. Fifteen weeks and one day later, May 9, steel erection was completed. Estimates indicate the steel staggered-truss method reduced the construction schedule by at least a month.

Robert DeBruin, AIA, is a senior project manager with Ellerbe Associates, Inc., the architectural and engineering subsidiary of Ellerbe, Inc., *Bloomington, Minnesota*. He served as project manager for the Bloomington Holiday Inn.

Photo by Shin Koyama



In addition, factors normally considered to be limitations in the use of the steel truss system became positive elements in the design of the Holiday Inn.

The site presented certain inflexible restrictions. The most influential one was the size of the site. With a building program of 205,000 sq ft and an allowable site area (due to zoning setbacks) of only 30,000 sq ft, the space available for the public areas was extremely limited. Yet, it was important these public spaces provide a feeling of spaciousness and light to hotel visitors.

The column-free characteristics of the steel truss system allowed the architects to create an open, airy feeling in the public spaces, even though those areas are not all that spacious. This was accomplished by using sloped glazing at the building's front which facilitates flooding of the lobby, cocktail lounge and commercial space with sunlight.

The airy feeling in the lobby continues on to the second floor. Here, an open staircase leads visitors up to meeting space, retail stores and a walkway to an existing parking structure through the hotel's two-story recreational area—a swimming pool, whirlpool, sauna and game room. Retail space in the hotel is also column-free, which provides store owners with greater flexibility in merchandising and displays in what is, again, restricted space.

In the guest tower, the staggered-truss system permitted creation of double-width rooms in certain areas. These rooms, used for small meetings during the day, can be converted to sleeping rooms at night. They also give hotel management the opportunity to maximize both meeting and sleeping space in a very efficient manner.

One potential problem with the staggered-truss system involves distribution of electrical and plumbing systems. Because of the depth of the system's beams (10 in. below precast floors) and the desire to maintain an efficient floor-to-ceiling height, horizontal placement of plumbing and electrical systems was not feasible. The plumbing and electrical systems have been distributed in a vertical fashion. Since the Inn's opening in July, 1981, these "birdcage" mechanical and electrical systems have functioned very effectively.

In addition, the depth of the staggered-truss system's bottom chords prompted design of an innovative lighting technique for the hotel. By simply extending fireproofing of the bottom chords of the truss system, indirect lighting coves were created in the hotel corridors. Here again, what might normally be considered a limitation of the system was used in an innovative way to add to efficiency and aesthetics to the hotel.

The steel staggered-truss system is a particularly good example of a structural method which, on initial analysis, appears to present certain restrictions to the overall design process. However, in the case of the Bloomington Holiday Inn, the innate characteristics of the system turned into major advantages in creating a functional, aesthetically pleasing facility. □

Photos courtesy U.S. Steel Corp

Holiday Inn Hotel (l.), Bloomington, Minn. employed staggered-truss system in its construction. Steel-framed structure (top two photos) proved best for winter construction schedules and cost-efficiency.

Closeups detail K-bracing (l.) and spandr end plate design (below).
Photos courtesy L.L.Le Jeune Co.

Architect/Structural Engineer
Ellerbe Associates Inc.
Bloomington, Minnesota

Designer/Builder
Finance/Design/Construct Inc.
Bloomington, Minnesota

Steel Fabricator
L. L. Le Jeune Co.
Minneapolis, Minnesota

Owner
Seymour N. Logan Associates
Chicago, Illinois

NEW FROM AISC: THE MANUAL OF STEEL CONSTRUCTION, POCKET EDITION. (ALMOST).

Now you can order the structural steel standards of the industry—unabridged, complete in every detail—in a volume that's half the weight, half the thickness of the standard library edition. Printed on finest opaque "Bible" paper, with lightweight but tough vinyl cover. Won't quite fit in your coat pocket but it's a great traveling companion.

Order now: Your choice, $36.00

Library Volume: Standard 8th Edition Manual, 832 pages based on 1978 AISC Specifications.

Field Volume: Same number of pages, identical material but just 7/8" thick, weighs only 1 lb. 5¼ ozs.

Please ship immediately the following order for the 8th Edition AISC Manual of Steel Construction at $36.00 each: ___ copies of Library Volume ___ copies of Field Volume

$______ total payment enclosed

Name & Title ____________

Company ____________

Address ____________

City ________ State ____ Zip ____

Please enclose remittance. No C.O.D. orders. In New York, California, and Illinois add sales tax. Shipping charges prepaid in U.S.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC.

Dept. MS P.O. Box 4588, Chicago, IL 60680

World-famous Children's Hospital: Architect's Diagnosis was Steel!

The Alfred I. duPont Institute Children's Hospital was designed with an eye toward its inevitable future expansion. The world-famous Institute provides in-patient and out-patient tertiary care in a long-term treatment of children's diseases. It has served over 50,000 children since 1940 in its present facility, without regard to payment.

Since treatment emphases change, and new medical technologies are continuously being developed, it was of primary importance for the architect to create a design which gives the hospital clear-span space for maximum interior flexibility.

At the same time, it was equally important to plan for the best possible fire safety and patient access expected in any hospital—particularly in a pediatrics facility with an an international reputation for orthopedic surgery.

The massive use of steel—some 7,500 tons, including over 70,000 lineal feet of 8-ft trusses—permitted the architect to plan for the desired features, and to use an economical, fast-track approach to construction.

A four-story design (three patient floors and a basement) was chosen ultimately for the $100-million-plus hospital under construction in Wilmington, Del. The limestone-clad building, enclosing 750,000 sq ft, covers nearly five acres of land on a 320-acre site adjacent to the existing 50-year-old hospital. The $11-million first phase includes site work, foundation and steel erection. Site preparation included the removal of some 180,000 cu. yds. of rock and earth to accommodate the foundation, a combination of drilled caissons and spread footings.

Built-in Flexibility

To provide the flexibility for any future medical programs—which could not even be guessed during the early structural design phases—the architect designed column-free floors which could accommodate high loads. As a result, the Institute lays claim to the first interstitial space design in Delaware.

The concept uses special steel trusses up to 68-ft long to create the interstitial spaces which provide full access, and permit construction of column-free treatment and patient areas. The interstitial spaces also accommodate the various building systems, in effect creating mechanical service floors between patient floors.

Ceiling and floor spaces of the interstitial areas are supported by an efficient modified Warren truss system to maximize available open space. The split-channel design permits penetration of plumbing, electrical and mechanical systems, ductwork and wiring.

Building plans called for 650 68-ft floor trusses, each weighing 4.6 tons, and 209 59-ft floor trusses, 3.3 tons each, for construction of the interstitial and floor areas. For fireproofing, the architect chose a composite floor of 16-ga. steel and 7¼ in. of concrete, reinforced to provide an overall floor load capacity of 100 psf. The floor has a fire rating of three hours.

Walking Access to Services

The interstitial space has a 3½-in. poured gypsum deck with a two-hour fire rating. The architect notes this is one of the first installations of a gypsum deck interstitial system. It was consistent with his desire to provide total walking access within the interstitial space. In addition to its fireproofing characteristics, the gypsum deck also serves as the floor of the interstitial areas. The gypsum system, ideal for this

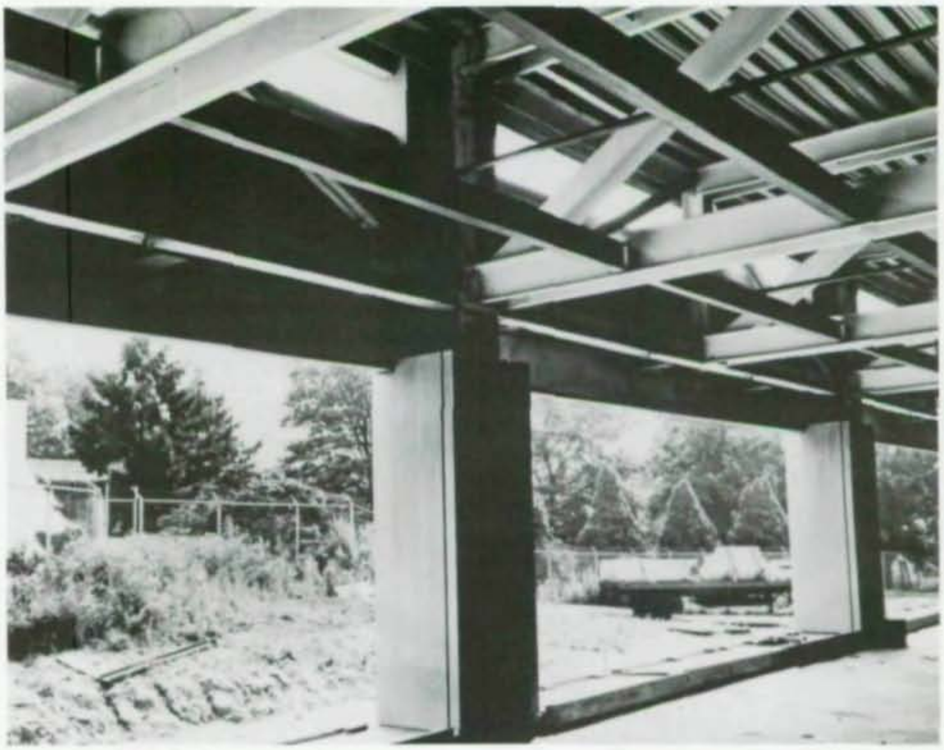
Unique design feature of new Alfred I. duPont Hospital is open-air child life courtyards. Completely surrounded, they provide sheltered environment for children. Steel's flexibility was important factor in special design.

purpose, is easily penetrated for future building modifications. As a walking surface, its sound-deadening properties does not readily transmit sounds created by service personnel above the patient floors.

Since the building was constructed with fast-track procedures, the outside truss was designed as a unit to accept any exterior wall system which may have been chosen later. As a result, steel construction could begin before the final interior and facade plans were completed. Typical column spacing is 28 ft o.c., with intermediate trusses supported by 528 38-ft long split-T king trusses. The steel used on the project was exposed to the weather for 2½ years before it was painted with duPont Corlar Enamel Hi-Build White. White was selected to maximize reflections in the interstitial spaces after the hospital was enclosed. The exterior skin of the hospital and a matching utilities building is clad with 86,000 sq ft of limestone, attached to the steel frame with stainless steel chips.

Completed, the building will have five landscaped courtyards as part of the emphasis to provide a special environment for the emotional as well as physical needs of patients. The facility, the first totally sprinklered hospital in Delaware, will have an ambulatory care center with the capacity to treat 75,000 children annually.

The 180-bed Institute building is designed to accommodate an additional 50-60 inpatients after it is fully operational. □



Modified Warren trusses (l.) support interstitial spaces, permit column-free patient areas and full access for service lines. Bottom of steel flooring (above) is visible above interstitial area framed by network of steel girders.

Architect
Saxelbye, Powell, Roberts & Ponder
Architects/Planners
Jacksonville, Florida

Structural Engineer
Smith, Hardaker, Huddleston & Collins, Inc.
Jacksonville, Florida

General Contractor
Huber, Hunt & Nichols, Inc.
Indianapolis, Indiana

Steel Fabricator
Montague-Betts Company, Inc.
Lynchburg, Virginia

Owner
Nemours Foundation
Jacksonville, Florida

New hospital wing covers five acres. Existing facility is on upper right; new utility building at lower right.

Hillier Headquarters: Steel "Reflects" an Architect's Choice

Setting the pace for a Princeton, N.J. *area being transformed from agricul*tural use to a corporate office/hotel center, a new headquarters building "reflects" the latest in architecture and energy-conservation design. It is the sleek glass headquarters of The Hillier Group, Architects, Planners and Interior Designers.

In the two-story circular lobby, complete with circular skylight, a right-angle free-standing stairway rises to the second floor. The stairway, constructed of steel, is framed with steel, with a banister of steel tubing. Complete with fountain and goldfish, a pool fills the area underneath the stairway.

Designed by the architect/owner, J. Robert Hillier, the reflective glass exterior addresses the problem of heat-gain during the summer months by reflecting solar heat away from the building. In designing an office building, summer heat-gain is more important as a conservation measure than winter heat loss. By reflecting solar heat away from the building, cooling costs have been reduced.

The all-glass exterior also represents a unique application. The glass is used as a veneer over gypsum sheathing mounted on steel studs. The glass is attached to the gypsum and the steel substructure by horizontal mullions. The glass is inserted into the horizontal mullions with buttglazing at the vertical joints, eliminating the need for vertical mullions.

Design of the building also fully utilizes natural lighting in the work stations to reduce energy costs. Horizontal bronze-tinted vision panels encircle the building, permitting every employee a view of the outside. Vision panels on the north side of the third-story clerestory admit natural lighting to the library of the space occupied by the second floor tenant.

A unique feature of the 31,000-sq ft building is the 90-ft sloped wall which has a southerly exposure of 46°. The angle was computed precisely to take maximum advantage of winter heat gain for the building's specific latitude. Below this wall, hot water solar collectors are hung on the interior of the building to avoid an unsightly exterior installation. The solar collector panels, attached directly to the exposed steel infrastructure and covered by fabric acoustical panels, heat all of the domestic hot water for the building.

The exposed steel infrastructure of the sloped wall forms the southerly side of a high-bay area that extends up to the third-story clerestory. It was painted to blend with the interior finishes of the building. This high-bay functions as a focal point and, with its exposed-steel appearance of modern sculpture, is of great interest to visitors.

The horizontal vision panels mounted in the sloped wall, which permitted the interior installation of the solar panels, permit the high-bay area to act as a greenhouse to collect passive solar heat, partially heating this part of the building.

The building also utilizes earth berming to conserve energy. Three and one-half feet of the building's height are bermed. Horizontal vision panels on the first floor are just above the berm level. The addition of stones along the top of the berm reduces erosion and drainage problems. A 3-ft overhang shades the interior of the building from the glare of direct sunlight.

Open office planning has been used throughout the first floor of the building. The interior space planning was designed around the exposed steel support columns which serve as cornerstones for all floor planning which often double as the delineation points of specific areas.

The Hillier Group chose steel framing for construction of its headquarters building for its speed and economy. Also, steel permits the concept of the high studio bay as a light, airy space—one that would have been difficult to implement with other construction mediums. The sloping roof and clerestory, which carry the active solar collectors, are

Photos by Norman McGrath

Spacious interiors under sloping wall and expansive stairwell lend open feeling to architect's new offices.

articulated very gracefully by using steel.

Cost studies proved steel to be the most economical system for the structure's design. By using steel, Hillier was able to construct an award-winning building from its original design concept.

The Hillier Group, which has occupied its section of the building for a year, has found it a delightful working environment. Energy efficiency in design has also proven to be energy efficiency in application. President J. Robert Hillier reports that energy usage is less than 50% of the energy needs of a similar, more traditional building.

Their new building sets the pace for expected growth in the immediate vicinity. At the same time, it serves as a case-in-point that energy efficiency and good design can be compatible. Unique usages of steel were an integral part of that accomplishment. □

Architect/Owner
The Hillier Group
Princeton, New Jersey

Structural Engineer
Blackburn Engineering
Princeton, New Jersey

Construction Manager
Lehrer/McGovern, Inc.
Philadelphia, Pennsylvania

Sloping, energy-efficient glass facade lends air of distinction to new Hillier Group headquarters building (far l.) in Princeton, N.J. North-facing windows permit indoor daylighting. Steel frame (l.) was architect's choice for its economy and speed of erection.

Amherst Campus: Pyramidal Truss Key to Clear-Span System

by Arnold A. Bitterman

A two-way pyramidal space truss is the key to a unique roof framing system designed for the 288-ft x 264-ft Amherst Campus field house. The new 10,000-seat structure is part of the first phase of the $31.5-million Health, Physical Education and Recreation (HPER) facility on the State University of New York at Buffalo's Amherst Campus.

The field house promises to be the finest athletic facility of any college or university in the East. Other elements of Phase I of the new facility include a two-level lobby, locker rooms, office space, mechanical equipment spaces and six handball courts.

Truss System Selection

At the outset of the project, the structural engineer investigated alternative framing systems for the field house roof, including both one and two-way truss systems. An important initial consideration was to minimize the depth of the truss for maximum head room and clearance within the structure, and to reduce building cubage. Since a standard one-way truss requires more depth than a two-way system, the engineer's cost studies indicated the two-way system to be the more economical framing method.

The space-truss is constructed of a series of interconnected pyramids, each with a 24-ft square base. The truss contains 239 structural steel beams in its top chord, 193 steel beams in the bottom chord and 432 diagonals. The system was designed with a SAGS computer program to compute the forces in each member, facilitating member design.

Connections Are Crucial

These connections, or hubs, are all-important to the space-truss system. Eight members come together in each hub. And these had to be especially designed so that forces would all intersect in a common point, to preclude any eccentric forces within the connection (see Figure 1).

A cruciform design was chosen for the diagonal members, each composed of four 90°-steel angles laid against each other. The cruciform shape facilitates connection within the hub, and makes for greater stability. The diagonals are each made up of four 5x5x⅝-in. angles. Top and bottom chord members are 14-in. wide-flange steel beams.

The design of the hub connections was complicated by the fact that the angles at which the various diagonals come into the hubs vary throughout the roof. This was necessary because the roof slopes ¼-in. per foot in four directions down from the roof center to achieve proper positive drainage. Consequently, the depth within the truss from center line of the top chord members to center line of the bottom chord, varies from 14 ft at the perimeter of the field house to 17 ft-6 in. at the center of the span.

The hub had to be designed not only to ensure a stable connection, but also to accommodate the use of standard high-strength bolts for field erection. The connections are fastened with A490 high-strength bolts. Because of the varying angles at which the diagonals enter the hubs, the engineer constructed a full-scale hub model to demonstrate that the bolts could actually be installed and tightened properly.

A unique feature of the space-truss design is that the bottom chord stops 12 ft short of the support columns located at the perimeter of the field house. The truss is supported at the perimeter columns by a typical top chord hub.

Arnold A. Bitterman, P.E., is a partner and chief structural engineer in the architectural/structural engineering firm of Sargent-Webster-Crenshaw & Folley, Syracuse, New York.

Amherst Campus fieldhouse at Buffalo, N.Y. promises to be one of finest collegiate athletic facilities in East. Steel framing played vital role in clear-span system.

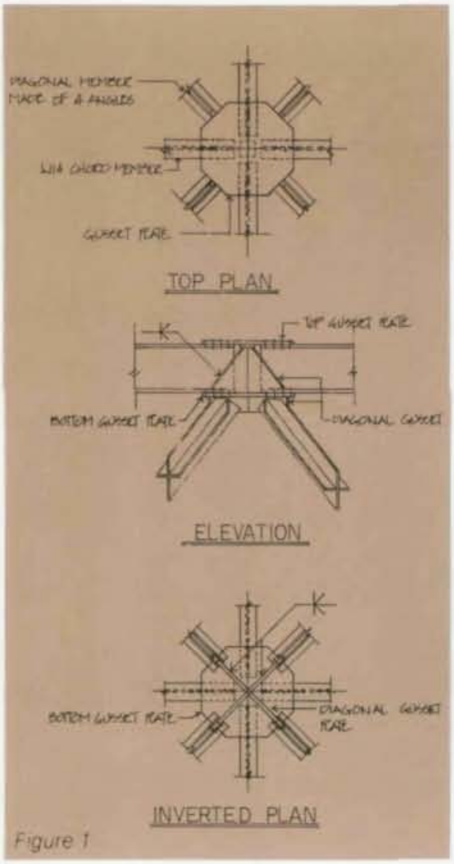
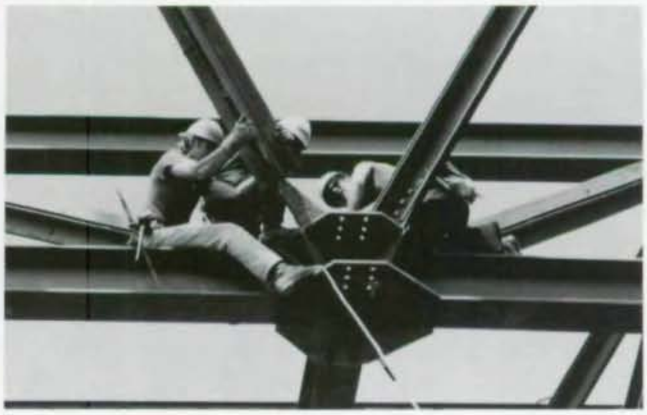


Figure 1



Unique roof framing system of 264 x 288-ft fieldhouse employs two-way pyramidal truss and special design hub connections.

Erection Carefully Monitored

Because proper erection of this geometrically complex construction is as important to the structure's success as its design, a consulting engineering firm, which also reviewed the original design, served as a special consultant to monitor the erection process on a full-time basis.

Roof construction began from the center of the field house space, working from a temporary platform of 36-in. dia. steel pipe, which shored the truss while it was erected (see Figure 2). The space-truss erection was accomplished by cantilevering the truss out from the central temporary platform, until it reached the field house perimeter support columns. The diagonals and the top chord members were pre-assembled on the ground in sections and lifted into position. All members were checked for accuracy of alignment, and for vertical and horizontal position. As erection of each section was accepted, final tightening of all bolts was done and tested by AISC standards.

Special Problems in Ventilation

To heat and ventilate a space as large as the field house presented special problems. Those services are provided by the combination of radiation for heating, and a duct system for ventilating and tempering air.

A 72-in. dia. supply duct was fed through the space truss, all around the octagonal field house perimeter. Air distribution cannon-type diffusers project air into space, at angles chosen so the air will not blow directly on spectators. Air is supplied to the system from triangular-shaped fan rooms at building corners. The system, which can be run using two or four fan rooms, is unique in its capacity to match the air change rate to the requirements of occupancy and/or use.

Sound attenuation is designed into the mechanical systems by sound-proofing in the heating, ventilating and air conditioning systems. Vibration isolation materials minimize or eliminate transmission of vibrations to structural elements and occupied spaces. □

Truss system provides ample room for large duct system to feed through it, reduces building cubage and gives maximum head room for athletic events.

Architect
Robert T. Coles, Architect
Buffalo, New York and Washington, D.C.

Structural/Mechanical Engineer
Sargent-Webster-Crenshaw & Folley
Syracuse, Buffalo and Watertown, New York; South Burlington, Vermont; Bangor, Maine

Structural Consultant
Lev Zetlin Associates
New York, New York

General Contractor
Siegfried Construction Co.
Buffalo, New York

Owner
New York State University Construction Fund
Albany, New York

Rehabbing Steel Bridges in Maine

by Theodore H. Karasopoulos

Ted Karasopoulas is bridge design engineer for the Maine Department of Transportation, Augusta, Maine. His remarks were presented at the 1982 National Engineering Conference in Chicago.

Most of you are probably aware there has been a shift by many highway departments towards rehabilitation in all phases of their work. Rehabilitation constitutes one of the R's of the so-called 3R Program of Restoration, Resurfacing and Rehabilitation. This shift in operations certainly includes bridges.

This discussion concentrates on the rehabilitation of small-to-medium-size steel bridges, which constitute the majority of bridges we deal with, and is typical in most states. In Maine, a large percentage of these smaller structures are maintained by municipalities, rather than by the State Department of Transportation. Because of the lack of funds and expertise, these structures were not maintained to adequate standards and now need considerable attention.

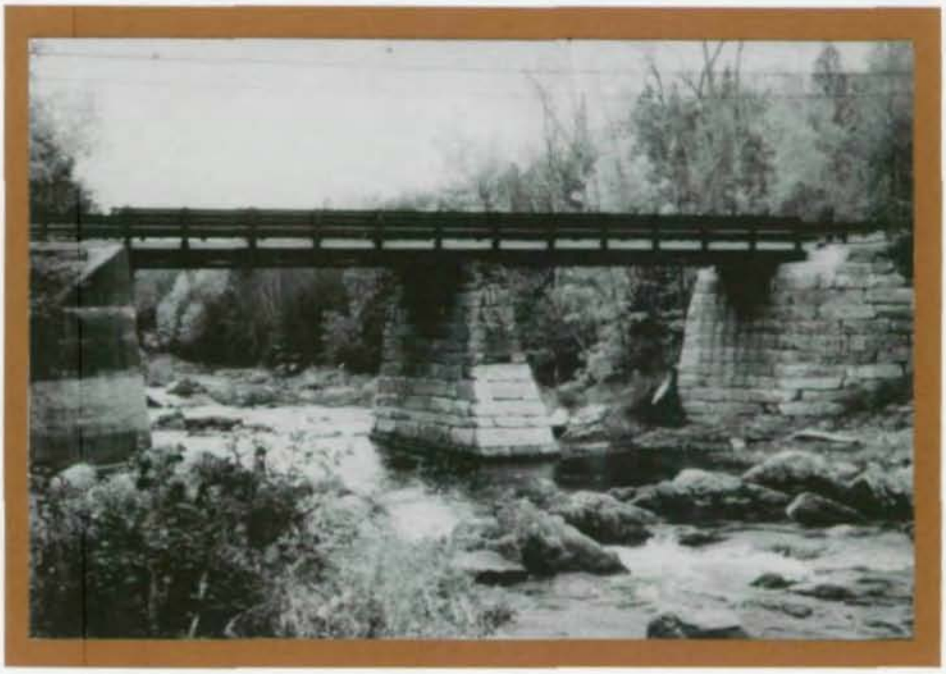
There are three primary reasons why we are presently concentrating more on rehabilitation than on building all new structures:

First, the realization of the magnitude of the bridge problem across the country. The bridge rating process now required by the Federal Highway Administration results in the systematic appraisal and rating of all structures. The fact that serious bridge problems exist has become well documented.

Second, there is a realization of the ever-growing lack of funds on the state level to address this problem.

The third reason is the fairly recent availability of federal funds for rehabilitation of bridges. Not very long ago such work was considered to be of a maintenance nature, and no federal funds were available. Therefore, the decision-making process by many agencies favored new construction with federal funds rather than rehabilitation, completely financed with local funds.

The bridge design process is normally divided into two major categories. The preliminary design, or the bridge type recommendation stage, followed by the final design stage, which includes preparation of plans and specifications.



Rural one-lane bridge in Cornville, Me. Complete superstructure, with new weathering steel and rail system, was built for $51,000.

The preliminary stage is a value engineering approach that systematically analyzes and evaluates all logical alternatives in solving a specific bridge problem. This phase of bridge engineering has undergone the biggest changes as rehabilitation came into prominence.

Several years ago, this process investigated complete replacement or new construction alternates and ignored, or superficially covered, rehabilitation. The reason for this, as previously stated, is that the decision-making process favored new construction.

A typical study would evaluate relative substructure and superstructure costs to determine the most economical span lengths. It would probably look into different materials such as concrete or steel. As long as all new construction was involved, this was a fairly routine process, especially for the agencies that maintain good statistical cost figures.

Presently, a whole range of additional alternatives must be considered, ranging from minor to major rehabilitation. This expands the process and certainly makes it much more complex. It now demands more judgmental and qualitative decision-making on the part of engineers. There are no formulas for determining the adaptability or acceptability of old parts of bridges for new and extended uses. Many parts are not accessible for inspection, and cannot be tested easily. Ingenuity and sound engineering judgment must be exercised to save and economically adjust and improve what is salvageable, discard what is not.

The findings of the preliminary engineering studies enable top management to select what is considered the most cost-effective solution, depending on funding and other current restraints. At the present time, rehabilitation rather than new construction seems to be considered as the most cost-effective solution in many of these instances.

However, a word of caution is needed at this point. Because of lack of funds, it is possible the pendulum for rehabilitation may swing too far—to the point that it does not result in economic solutions to bridge problems. The temptation will be to specify *rehabilitation without thorough investigations.* To propose and perform cost-effective rehabilitation improvements, a thorough survey and appraisal of the condition of the structure is a must. Major surprises during the construction of a project that result in costly change orders may render a rehabilitation project more costly than a replacement structure.

Needless to say, our department has been heavily engaged in rehabilitation work in recent years. And, in performing this work, we have found structural steel to be very versatile and adaptable material for such work. It is relatively light in weight and it can be altered easily for varied uses. It can be shortened with a cutting torch, lengthened by splicing and strengthened by welding. It can be salvaged from a structure that functionally has outlived its usefulness, and reused in another location.

It is very useful material for our rural town road bridges. Recently, we have constructed several bridges on rural roads with "used" steel beams and local labor at very reasonable costs. In view of the limited finances available to most of our small towns, this is practically the only way bridge construction can be affordable.

These rural bridges used either reclaimed steel members or new corrosion-resistant steel beams and rail systems. The accompanying photos show examples of such bridges up to about 100-ft long that have been constructed by Force Account procedures for $35,000 to $60,000. Some of these projects have been built with our own maintenance forces, but many others were constructed with semi-skilled town labor under our supervision.

The majority of the rehabilitation work we perform on bridges involves either wearing surface replacement or complete concrete deck replacement. The wearing surface work is performed on bridges about 20 to 30 years old. But, by far, most of our rehabilitation work involves the complete deck replacement of multi-beam steel bridges, which normally occurs for bridges more than 40 years old.

Before—one-lane bridge at Carthage, Me. prior to reconstruction (top);
After—bridge was reconstructed with reclaimed steel beams and timber floor for $33,000.

One of the advantages of a multi-beam or multi-girder steel bridge with a concrete deck is that by replacing the deck 40 to 50 years later, a substantial bridge is in place and ready to serve for another similar period before another deck replacement is required. Multi-beam structures also have the flexibility to accommodate maintenance of traffic during construction on the structure itself, since the deck can be replaced in halves.

Two of the primary and obvious problems we face in rehabilitating bridges that are 40 or 50 years old are functional and structural.

Most of the functional problems relate to the width of the facility. In the majority of cases, we can gain a few feet on the new deck without the expense of widening the substructure, and thus provide an adequate facility at a very reasonable cost.

On structures that now carry heavy traffic, we have redecked the existing bridge and provided additional width by adding new steel beams and widening the substructure units.

The structural problem is bridges of that vintage were not designed for the load-carrying capacities required today. We have been able, by a couple of methods, to upgrade these structures for modern design loads at relatively small costs.

We find that in a great number of these bridges we can increase the load to an HS20 capacity just by adding shear connectors on the top flange. Shear connectors are fairly easy and inexpensive to add without an excessive amount of welding. We take pains not to weld cover plates or other attachments that require a considerable amount of field welding and have a great potential for adding discontinuities and stress risers that tend to reduce the fatigue life of the structure.

If we find that adding shear connectors does not upgrade the loading to the desirable level, then the second step in our process is to take steel samples. We test these samples to find out whether higher allowable stresses than the ones specified in the AASHTO Specifications can be used for existing structures.

We have found, consistently, we can increase allowable stress considerably. Note, these higher allowable stresses are not in violation of the specifications. The code allows the use of values other than the standard ones, if proven by testing.

By using these two methods, we have been able, to date, to upgrade practically all of our multi-beam bridges without welding cover plates.

Reviewing the bridges we have rehabilitated and/or reconstructed in the last few years, we can generalize the following:

U.S. Route 1 bridge, Woolwich, Me. was originally built in 1934. New concrete deck was placed on existing steel and structure widened 19 ft by extending existing substructure, adding new superstructure.

- Steel trusses and through girders require expensive rehabilitation, unless their original load-carrying capacity is adequate. And, of course, it is not feasible economically to widen them.
- Concrete slab and T-beam bridges can be rehabilitated and widened, providing their concrete decks are in good condition. If not, they require complete replacement.

- Timber bridges are expensive to rehabilitate to the point where they can handle modern loads. In all but a very few cases, they require complete replacements.
- The most versatile structures for economical rehabilitation are the multi-beam or girder steel bridges with concrete decks. We have many such structures built since the 1920s. These bridges can be economically adapted to handle modern loads even when they were originally designed for lower capacities. They can also be widened where needed.

In summary, this type of construction constitutes the majority of our rehabilitation work. We are redecking 45-year-old bridges, maintaining traffic on half the bridge and upgrading the structure to modern standards. We can accomplish this work for about one-third the cost of a complete replacement structure.

As a matter of fact, looking back at a period of four years, we find we had only three multi-beam bridges we did not rehabilitate. These bridges needed complete replacement when a part of the Maine Turnpike was widened from four to six lanes. This would have placed the existing abutments within the new roadway. So, while other types of bridges of the same age require complete replacement to meet present standards, multi-beam steel bridges provide practical and cost-effective rehabilitation alternatives. □

SMALL RURAL BRIDGES

When a small rural bridge is beyond rehabilitation, it is replaced. We have developed a fairly simplified steel design, one that requires minimum contractor expertise, and has a fast, simple construction sequence. Abutments are kept considerably above streambed, so cofferdams are not required, riprap slopes are placed in front of the abutments, and corrosion-resistant steel is used for the beams to minimize maintenance costs. A concrete slab with an integral wearing surface is placed in a one-pour operation without any curbs and, of course, without any separate wearing surface. A combination corrosion-resistant steel rail and curb system is bolted at the fascia of the bridge and corrosion resistant beam type guard rail is continued on the approaches. These are fairly inexpensive and aesthetically pleasing structures that blend well in the rural environment so common in our state. We have received considerable plaudits for their simplicity and aesthetics.

These bridges normally replace old, single-span pony trusses and concrete T-beam structures.

Deteriorated deck (top) was reconstructed (bott.) using half of bridge width to maintain traffic.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
The Wrigley Building, 400 North Michigan Avenue
Chicago, IL 60611

Address Correction Requested

BULK RATE
U.S. POSTAGE
PAID
WHEATON, ILL.
Permit No. 1786

AMERICAN INSTITUTE OF STEEL CONSTRUCTION INC. AISC FOUNDED 1921

Steel