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MODERN STEEL CONSTRUCTION



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EDITORIAL

A new technical booklet "Steel Gables and Arches" is now available to architects and engineers. It includes easy-to-use tables and design examples of gables and arches designed in A36 steel.

The section on gables presents design data on single span pinned-base rigid frames fabricated of straight prismatic steel sections in a range of spans from 50 to 150 feet in steps of 10 feet. In each span, column heights are varied between 12 feet and 20 feet in increments of 2 feet. For each span and column height, data are given for flat roofs as well as slopes of 3 on 12, 6 on 12, and 9 on 12.

Arches which are two-hinged and circular are covered in the combination of spans, rise-to-span ratios and combination of loads which satisfy most building requirements.

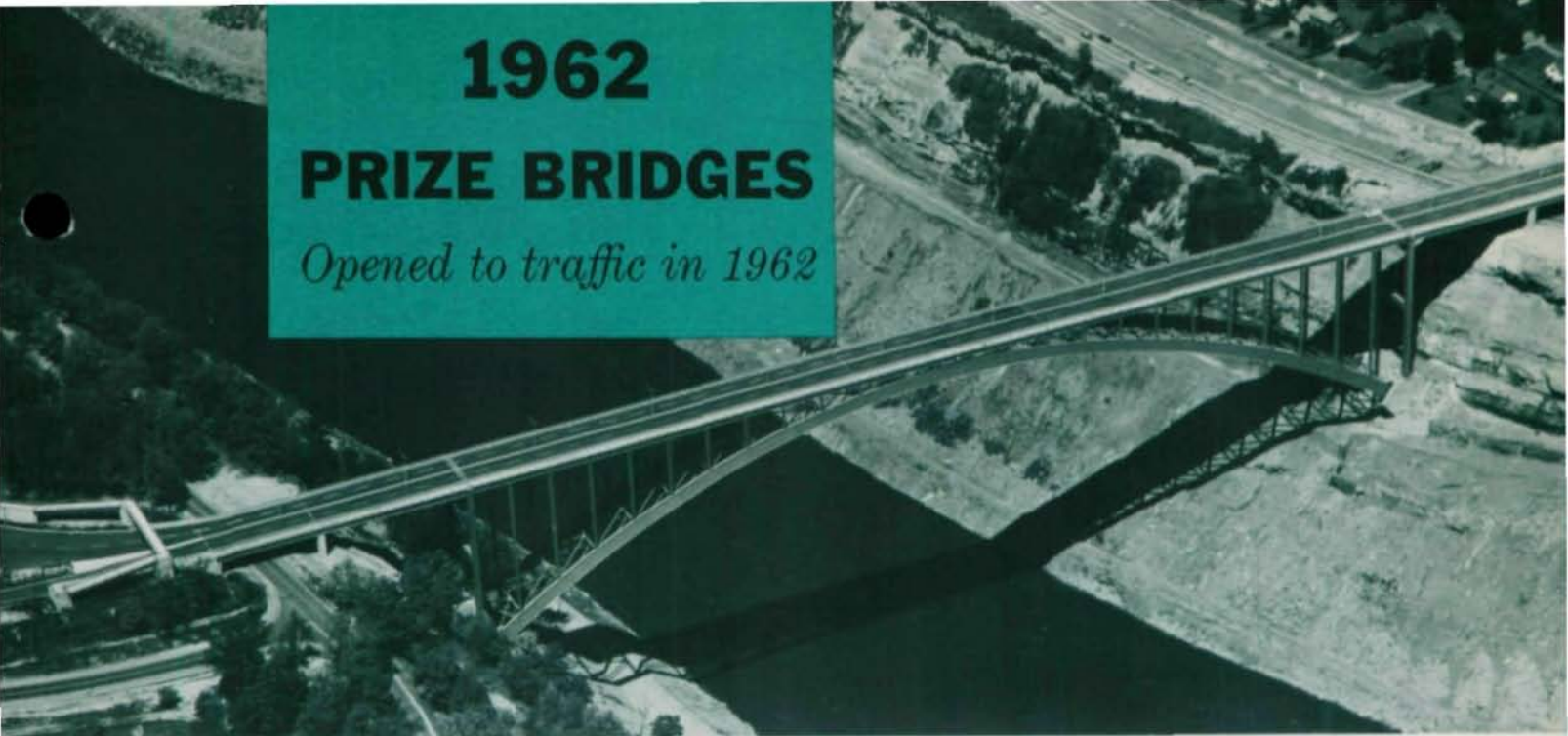
Your copy of this technical booklet is available, without cost to you, from your local AISC regional engineer or upon your written request to AISC headquarters, New York.

A CLARIFICATION:

The following clarification is made in the sketch entitled "Acceptable Defects" in the article "New Welding Specification Sets Radiographic Standards for Bridges" in the third quarter of 1963 issue MODERN STEEL CONSTRUCTION. The notation "Max." preceding the "2-1/4" Long Fusion Defects" and the "3/8" Long Fusion Defects" should be eliminated. Actually an individual defect of as much as 1/2" long could occur in a 1 1/2" plate."

1962 PRIZE BRIDGES

Opened to traffic in 1962



LONG SPAN PRIZE BRIDGE, FOR BRIDGES WITH SPANS 400 FEET OR MORE

Lewiston-Queenston Bridge, over the Niagara River between Lewiston, New York and Queenston, Ontario.
Owner: Niagara Falls Bridge Commission.
Designers: Hardesty & Hanover.
Fabricator: Bethlehem Steel Company.



MEDIUM SPAN PRIZE BRIDGE, FOR BRIDGES WITH FIXED SPANS UNDER 400 FEET AND COSTING MORE THAN \$500,000

South Fork Eel River Bridge at Meyers Flat, Humboldt County, California.
Owner: State of California.
Designer: State of California.
Fabricator: Independent Iron Works.

SHORT SPAN PRIZE BRIDGE, FOR BRIDGES WITH FIXED SPANS COSTING LESS THAN \$500,000

Parker Bridge, Yakima County, Washington.
Owner: Yakima County.
Designer: Homer M. Hadley, Consulting Engineer.
Fabricator: United Concrete Pipe Co.



Eleven steel bridges were honored as the most beautiful opened to traffic during 1962, by the American Institute of Steel Construction, the national association representing the structural steel fabricating industry.

The jury selected Prize Winners in each of four categories and seven Awards of Merit from the 75 entries received by the Institute in its annual Prize Bridge Competition.

The jury was composed of: William

J. H. Hough of Harbeson, Hough, Livingston and Larson, Philadelphia, Pennsylvania; Thomas C. Kavanagh of Praeger-Kavanagh-Waterbury, New York City; Harry R. Powell, Harry R. Powell and Associates, Seattle, Washington; Michael Rapuano, Clarke and Rapuano, Inc., New York City; and Perry Rathbone, Museum of Fine Arts, Boston, Massachusetts.

In commenting on the entries, the jury felt that prescribed bridge standards limit engineers in making full use

of steel's strength, aesthetic appeal and economy. Short and medium span bridges up to 400 feet are the most severely penalized by these limitations, some of which are outmoded.

Speaking as chairman of the jury, Thomas C. Kavanagh stated:

"There needs to be a relaxation of some mandatory bridge standards to allow more imaginative designs which are possible today with new,



MOVABLE SPAN PRIZE BRIDGE

Georgiana Slough Bridge,
Walnut Grove, California.
Owner: Sacramento County, California.
Designer: Sacramento County, Calif.
Fabricator: Kaiser Steel Company.



FIRST AWARD OF MERIT — LONG SPAN BRIDGES WITH SPANS 400 FEET OR MORE

Cart Creek Bridge, Daggett County,
Northeastern Utah.
Owner: Utah State Department of Highways.
Designer: Structures Division,
Utah State Department of Highways.
Fabricator: American Bridge Division,
U. S. Steel Corporation.



AWARD OF MERIT — LONG SPAN BRIDGES WITH SPANS 400 FEET OR MORE

Flaming Gorge Reservoir Bridge (pipeline),
Green River, Wyoming.
Owner: El Paso Natural Gas Company.
Designers: Matthews, Kenan and Eden.
Fabricator: Allison Steel Manufacturing
Company.

AWARD OF MERIT — SHORT SPAN BRIDGES WITH FIXED SPANS COSTING LESS THAN \$500,000

Middle Fork Smith River Bridge,
Crescent City, California.
Owner: State of California.
Designer: State of California.
Fabricator: Vinnell Steel Co.

advanced bridge concepts and new, higher strength steels."

The four Prize Bridges will have stainless steel plaques affixed to them as a permanent tribute to their designers for combining aesthetics and utility in graceful river crossings. The designers, owners, and fabricators of the Prize Bridges and Awards of Merit will receive certificates attesting to the selection of the bridges.

FIRST AWARD OF MERIT — MEDIUM SPAN BRIDGES WITH FIXED SPANS UNDER 400 FEET AND COSTING MORE THAN \$500,000

Interstate 64 Bridge, Frankfort, Kentucky.
Owner: Commonwealth of Kentucky.
Designer: Division of Bridges, Kentucky Department of Highways.
Fabricator: American Bridge Division, U. S. Steel Corporation.

AWARD OF MERIT — MEDIUM SPAN BRIDGES WITH FIXED SPANS UNDER 400 FEET AND COSTING MORE THAN \$500,000

Elysian Viaduct Bridge, Los Angeles, California.
Owner: State of California.
Designer: State of California.
Fabricator: Kaiser Steel Company.



FIRST AWARD OF MERIT — SHORT SPAN BRIDGES WITH FIXED SPANS COST LESS THAN \$500,000

South-to-West Ramp Milwaukee Stadium Interchange, Milwaukee, Wisconsin.
Owner: Milwaukee County Express Commission and Wisconsin State Highway Commission.
Designers: Howard, Needles, Tammen & Bergendoff.
Fabricator: C. Hennecke Co.

FIRST AWARD OF MERIT — MOVABLE SPAN BRIDGES

Bridge over South Branch of the Elizabeth River, about 3 miles south of Norfolk, Norfolk County, Virginia.
Owner: Commonwealth of Virginia Department of Highways, Richmond, Virginia.
Designers: Hardesty & Hanover.
Fabricator: American Bridge Division, U. S. Steel Corporation.



NEW BUILDING FOR TORRINGTON



Structural Steel Framing Facilitates 72,000 sq ft expansion.

By Marcel Breuer,
FAIA.

The Torrington Manufacturing Company, faced with the need to expand manufacturing facilities of its machine Division, last year purchased a densely wooded, sloping site of about 60 acres on the outer edge of Torrington, Connecticut.

The Machine Division, which makes strip and wire forming machinery, was bursting the seams of its flood-ravaged, turn-of-the-century quarters and constantly fighting a production line which more closely followed the flow of the river than that of orderly manufacturing operations. To design its new building, the Company turned to Marcel Breuer and Associates, who had previously built assembly plants for their Air-Impeller Division in Oakville, Canada; Van Nuys, California; Rochester, Indiana and Brussels, Belgium.

In choosing its site, the Company sought more than raw space for expansion and selected a forest setting of considerable beauty. The preservation

of trees and rocky landmarks was part of the program from the outset. The setting has been further enhanced since construction for the benefit of their staff by the addition of shade trees in the midst of the 160-car parking lot, picnic tables and boccei courts in a nearby clearing.

Siting 72,000 sq ft of single-level factory space on the gentle slope was dictated by the requirement to make provision for the possibility of a three-fold expansion with minimum earthwork and tree destruction. A large trucking yard is provided adjacent to one long side of the factory from which trailer trucks are able to choose between semi-sheltered dock delivery, complete pit entry under a crane (truck bed and factory floor at the same level), or entry at grade onto the floor itself.

The structure is completely framed of rolled steel members with height under beams and column spacing determined by an analysis of the shop opera-

tion and the economic use of standard steel sections. Height is 19 ft-5 in. under the lowest girder dictated by the required hook height of the cranes. The resulting overall height permits free movement of large machinery in all required directions with a margin to cover a possible increase in size of future products. Those spaces which do not require the factory height are grouped together under a lower roof, creating the front section of the building, and include administrative offices, laboratory space, engineering drafting rooms, staff washrooms and cafeteria.

Centrally located between the production floor and sales-engineering offices is a research laboratory outfitted for the confidential development of machines specialized to the needs of particular customers.

To sheath the basic structure, porcelain enameled aluminum siding was selected for its low maintenance cost and flexibility in connection with future

00123

expansion. The white finish provides a contrast to the darkness of the surrounding forest. The fluted siding has been used in continuous vertical sections throughout. Wherever openings were required, they are full height thus exposing the steel structure in combination with black brick, grey asbestos panels, aluminum sash and trim. The rather bizarre assembly of roof-mounted mechanical equipment has been painted a uniform lemon yellow producing a particularly brilliant silhouette against the blue sky.

Within the factory, against a background of black structural steel and machines in basic colors, the ceiling of galvanized corrugations and the natural concrete block partitions are enlivened by vari-colored utility lines. Industrial fluorescents provide the desirable level of illumination for shop operation. The company requested no windows in the manufacturing space itself – a decision based on previous experiences with other plants. A few panels of glass over pass-doors serve employee psychological needs to permit them to check weather and to keep in touch with the outside.

The interior of the office is lighted by large north windows with a view to the woods. Fluorescent units are mounted in a wooden grid floating below the level of air-conditioning ducts, utility pipes and conduits – all of which have been "painted out" in dull charcoal, including the sprayed-on, acoustic insulation which completely covers the interior steel frame and the underside of the roof deck. Office partitions, whether full or half-height, are bracketed between floor and grid with friction connections that do not mar when partitions must be removed. Partitions themselves are of natural wood and black pressed-wood paneling. Only the partition around the chief executive's office is carried to the structural ceiling. The furnishings are white, grey, and black. The cafeteria has a sky-blue wall; and filing cabinets are color-coded.

Designer: Marcel Breuer, FAIA, Architect
Robert F. Gatje, AIA, Associate

Engineering and Supervision:
Westcott and Mapes, Inc.

General Contractor: Oneglia and Gerrasini, Inc.,
Torrington, Connecticut

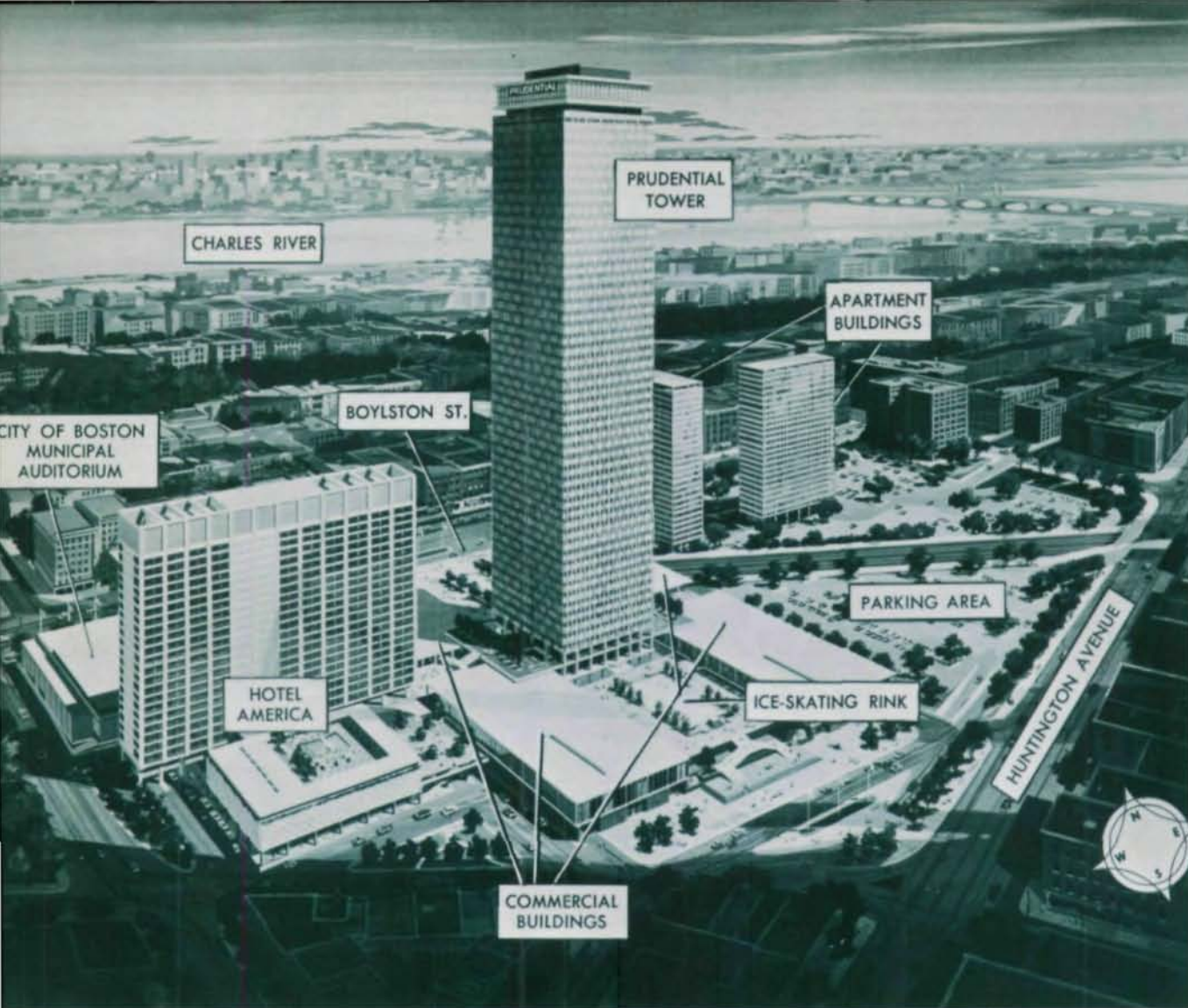
Structural Steel Fabricator: Berlin Steel Construction Co.,
Berlin, Connecticut



▲ *Free movement of large machinery in any direction is permitted by the more than 19 ft clear height.*

▼ *Exposed structural steel adds dignity and informality to the interior. Large north windows provide good light and a view towards the woods.*





THE NEW PRUDENTIAL C

Damned by some, praised by most, Boston's new Prudential Center may well create a building and business renaissance in a long-time blighted area. Dominating the 31.3-acre site is the 52-story, 750-ft Prudential tower, the tallest building in the U.S. outside Manhattan, surrounded by smaller structures much as the nobles' tombs huddled around the Pharaoh's large pyramids.

The area was for many years the unsightly yards for the New York Central-Boston and Albany Railroads. To the north is the fashionable Back Bay section of handsome brick and brownstone residences; to the east, commercial buildings; to the south a once-fashionable area, now a rundown slum; to the west, the Mother Church of Christ,

Scientist and a culture center composed of famous Symphony hall, Northeastern University; and beyond, the Museum of Fine Arts.

The site is mostly filled land where the water table rises and falls with the tide. Sheet piling forms a coffer-dam around the buildings to seal off the water during construction. The tower is supported by 144 drilled-in caissons driven to rock an average of 150 ft below grade. Sockets were drilled 16 to 24 ft into rock to receive the piling. Unit stress in end bearing at the bottom of the sockets is 70 tons per sq ft.

All the caissons consist of half-inch steel shells 30 inches in diameter. Within are 14WF column cores impacted with 4000-psi concrete. The caissons are

capped with 8½-ft-thick grid slabs to support the grillages of the huge columns.

The tower structure is completely isolated by expansion joints from the rest of the project. Of conventional steel frame design, it was shop-riveted and field bolted and was erected in just over six months. There are 20 and 21-ft bays in the east-west axis by five 35-ft bays in the north-south, to form a box 150 x 175 ft in plan.

Because the tower is not surrounded by any other high buildings such as in New York City, special attention had to be given to wind pressures, especially because of its squarish shape. In 1957 when the structural design was started, Edwards & Hjorth, New York



Structural Engineers Edwards and Hjorth possess the special background of knowledge and experience to design for the unusual wind loading problem on this 750 foot tower.

tion due to dead and live loads. Only 48 columns support the tower, so that with the magnitude of wind forces used for the design, a situation of fairly high wind moments had to be accommodated by a limited number of connections. The wind design for moment distribution is on the basis of the cantilever method.

In the north-south direction a slight modification from this system had to be made because the girders on the 35-ft span were controlled by the dead and live-load requirements rather than wind-load requirements.

Haunched beams were used in many instances on the first through 22nd floors. Their design maintained sufficient depths for connection requirements and building stiffness yet permitted maximum ceiling heights as well as passage of mechanical ducts without excessive holes in the girders. The beams were 24WF130's, cut just below the fillet of the bottom flange six feet from the end. Stiffener plates were added to avoid any tendency towards deformation.

The tower is sheathed with gray and green structural glass set in aluminum grills. The 10,000 fixed windows are cleaned from a 42-ft motorized platform swung from the 51st floor. From the 50th floor observation deck and the 52nd floor gourmet restaurant the viewer can see nearly 100 miles on a clear day. Mechanical floors are located at floors 12, 21, 31, 41 and 51.

A reflecting moat surrounds the tower. It is 25-ft wide, with 20,000 sq ft of water 18-in deep. To give the illusion of greater depth, the great tub is coated with deep blue ceramic tile. Beneath the pool are three subterranean levels of parking and services. Circulation and filtration of the water is provided for cleanliness, and, to allow for year-around operation, a hot water heating unit is included in the circulation system.

Four bridges cross the pool to connect the tower to spacious plazas and courts. Four commercial buildings surround the periphery. On the east and west, promenade decks are supported

ENTER

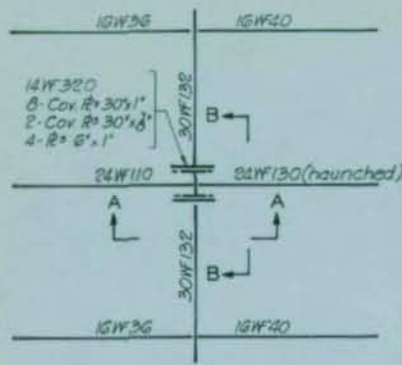
structural engineers, contacted the Boston weather bureau for a history of wind velocities and their frequencies. On the basis of this 24-year history and the use of seventh-root law for the variation of wind velocities with height above ground, design pressures were arrived at acceptable to the City and the engineers.

Boston's building code requires a 20-lb wind load, but because of the special problems for such a high tower, the steel frame was designed for a varying wind pressure starting at 36 psf at the roof and tapering to 20 psf at the ninth floor and below.

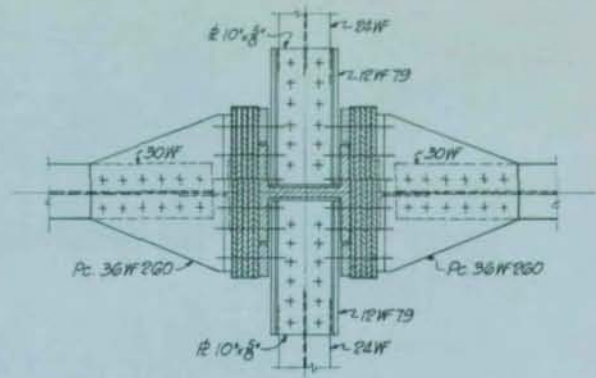
As the wind connections were of the split-beam type, the engineers realized a degree of fixity in the girder connec-

Topping-out nears as ironworkers swing final steel into place.

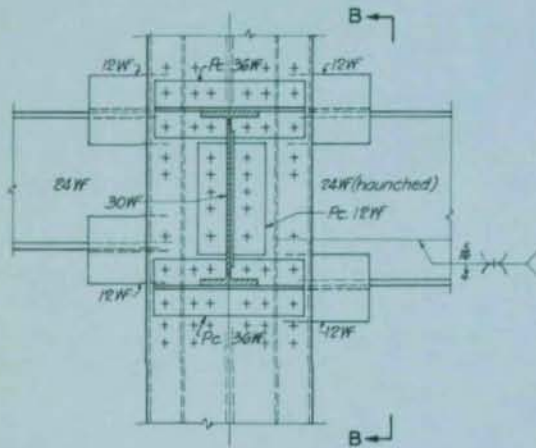




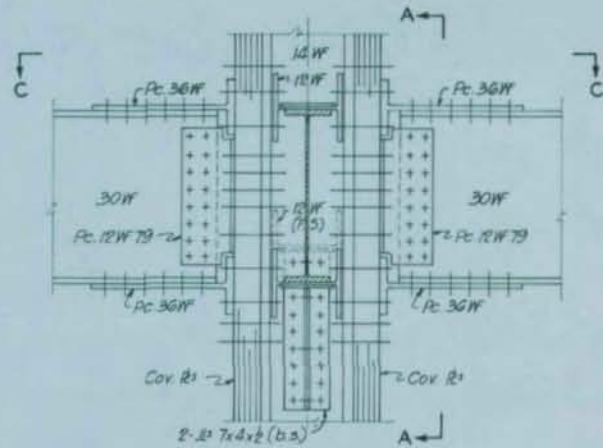
PART PLAN



SECTION C-C



SECTION A-A



SECTION B-B

Sketches of the unusual beam to column wind connections.

from the frames of these two-story buildings. An interesting feature is that the decks are cantilevered 30 ft to the tower around the light wells above the reflecting pool.

Also included within the 31 acres is the Boston War Memorial Auditorium which has facilities for convention and exhibits as well as facilities for grand opera and ballet. It boasts a 37-ton-capacity elevator to move trucks to the Convention floor unloading exhibits directly.

The Hotel America, a 1012-room hotel, is being built by Prudential but will be operated by the Hotel Corporation of America. Adjacent and connected is a four-story wing with ballroom, auditorium and other meeting rooms, as well as a full size rooftop swimming pool.

Building over the main line of the

Boston and Albany railroad posed some structural problems. The main line of the railroad runs diagonally beneath the north plaza of the Center in a 510-ft long x 132-ft wide right of way tunnel. Also running in the tunnel will be the extension of the Massachusetts toll road which has its terminus connecting with the southeast expressway at South Station one mile to the east.

The Center has its own ring road to handle local traffic which feeds from city streets and the turnpike exit into outside parking space and interior garages for 3000 cars.

Master planner for the 100 million dollar plus project is Charles Luckman Associates, New York. Hoyle, Doran & Berry, Boston, are associate architects on the tower, and prime architects for the City Auditorium. According to the

Luckman office, "The architectural thinking behind this use of land is not only to provide a proper setting for people but to enhance the visual impact of . . . New England's tallest and largest structure. . . . Of the 11-acre tower site, nearly five acres are reserved for beautification of the 200 x 1000 ft plaza."

To some Bostonians, the huge complex is out of place to the financial and physical scale of the city. Its very location away from the main commercial area is a calculated gamble on the future of the area. However, with the building more than 50 per cent occupied, the gamble seems likely to pay off. If the future is charted shrewdly by its business and political leaders, the huge tower can truly be a monument to careful planning.

The new municipal parking deck for Mount Vernon, New York is steel framed. Previously, prestressed and reinforced concrete were the acknowledged materials, since three of the recently built parking decks in nearby White Plains have been of this material. The engineer, Leo Zamory, of Mount Vernon found structural steel to be the best solution to this parking deck. Mr. Zamory found the new AISC Specifications and high strength steels cause for re-evaluating past cost studies.

Multi-decking the parking lot located in the center of Mount Vernon's Civic Buildings Complex had to be constructed quickly, economically, and be in keeping with the colonial character of the surrounding buildings. The use of structural steel columns, girders, and beams proved to be the most suitable. A construction schedule was arranged so as to present access to the site for excavation and foundation work until the structural steel was being shipped from the mill to the fabricator. Excavation and foundation work were scheduled to be performed concurrently with the fabrication of the structural members. By the time erection was started the foundation work

PARKING TRENDS REVERSED

had been completed, the area back filled and graded, and the crushed stone base placed and rolled with only the column anchor bolts projecting. Over three hundred tons of steel, which had been carefully detailed and fabricated were ready for immediate erection upon delivery to the site. The steel was erected within five days. By the end of the sixth week of actual field operation the 200' x 200' three level structure was completely framed and ready to receive the composite-form floor. With this composite-form there was no waiting time for the

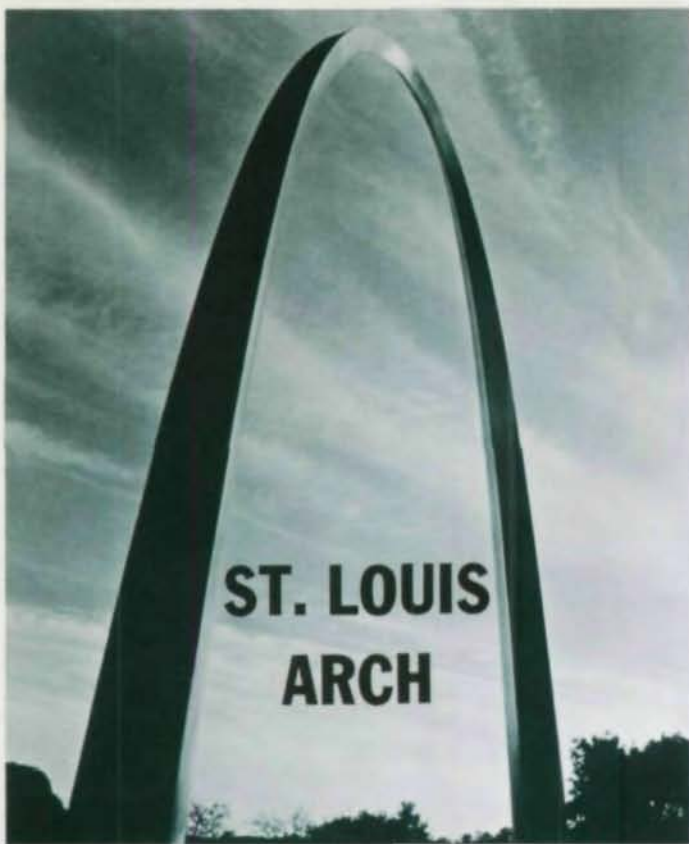
poured concrete to build up strength, no need for stripping forms and no need for reshoring structural members to permit continuity of operation as is the case with timber forms. Bethlehem's V-45 high strength steel was used permitting the use of an allowable working stress as high as 29,000 psi. Understandably, the cost per ton was higher but the savings in tonnage was considerable.

This parking deck provides parking for 316 vehicles with each parking stall nine feet wide with a cost per car of \$1,430. It is important to realize that this figure includes the cost of one thousand square feet of office space which includes ceilings and heating and also includes outside roadwork. Therefore, the actual cost per car is less than \$1,400. Note also the colonial appearance of the parking deck with its brick facade, cast stone sills, copings, wrought iron railings and work trim around the entrance.

This building also contained a unique method of snow removal. A two story high snow "bin" equipped with special heater coils at the ground floor is within the walls to melt the snow. The water flows through the floor drains.

Based on using new AISC specification and high strength steels past cost studies were reevaluated. Result - steel framing was selected and a trend was reversed.





Architect Eero Saarinen's model of Gateway Arch indicates how the full-sized, 630-foot-high steel monument will look when it is completed in late 1964.

Rising spectacularly on the bank of the Mississippi River is a gleaming steel arch to commemorate the westward expansion that helped to make America great. To be known as the Gateway Arch, the 630-foot-high steel structure is scheduled to be completed early in 1965.

Designed by the late Eero Saarinen as the theme structure for the Jefferson National Expansion Memorial in St. Louis, the arch will not only honor America's pioneers to an estimated 3,000,000 visitors a year but will stand as a tribute to the skill and ingenuity of modern pioneers in the construction, fabrication and materials industries.

The elegant Gateway Arch, shaped in 4,751 tons of various modern steels, will disclose to the viewer none of the complex engineering that gives the arch strength and permanence behind its sparkling stainless steel skin. For example, unlike the Eiffel Tower the arch has no structural skeleton because the steel skin is itself stressed to carry gravity and wind loads to the ground.

The arch takes its basic shape from an inverted, weighted catenary curve, which can be expressed mathematically.

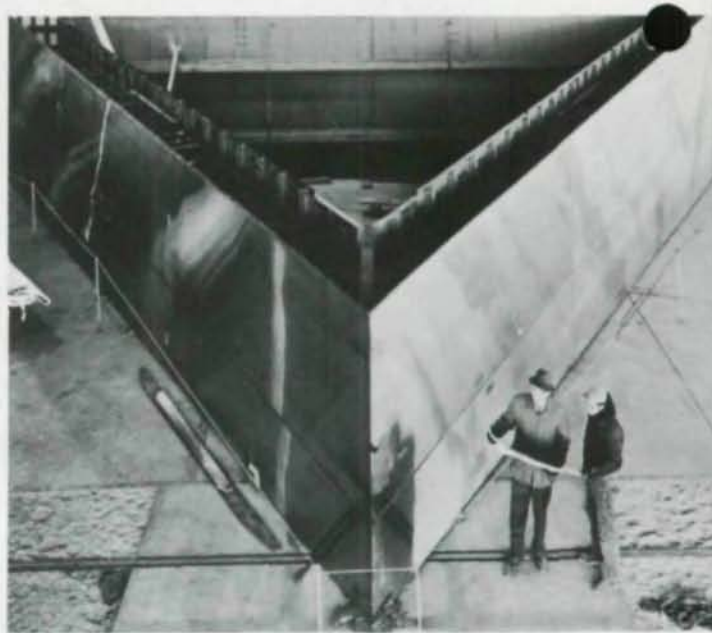
The arch legs are triangular in section to provide greater structural strength. Both the height and the span are 630 ft.

Given the arch's soaring curve, conventional elevator arrangements for sight-seers were impossible so an eight-capsule (car) train following a curved hatchway in each leg was developed. This will be supplemented by elevators in the relatively straight portion of each leg rising to a height of 370 ft.

Squeezing trains, elevators and stairs into the decreasing triangular cross section was a complex engineering problem. Not only was space a problem but the triangular leg sections had to be made strong enough to take gravity, transportation equipment and wind loads.

To this end, the arch has a double-skin steel wall with space between outer and inner skins varying from 36 in. at the base to 7½ in. at a height of 400 ft. From there to the top this spacing remains constant. The inner skin is ¾-inch-thick type A-7 carbon steel, except in the corners where 1¾-inch-thick steel is used for greater stiffness.

To sheathe the arch with its outer skin, the fabricators required the largest



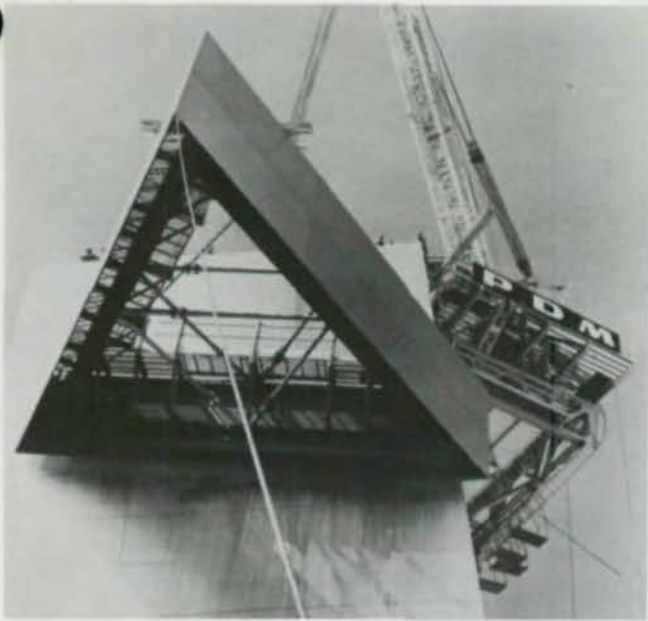
Test assembly of the first of 142 stainless steel sandwich sections that will form the Arch. Pittsburgh-Des Moines Steel Company is fabricating and erecting the structure.

quantity of stainless steel ever ordered for one job: 160,000 square feet of ¼-inch plate, the largest plates measuring 6 by 18 feet. The mills polished the type 304 stainless plates to a No. 4 finish.

To the 300-foot mark the space within the double-skin wall is filled with concrete, forming a composite section stiffening the arch against wind forces. Stiffness is especially critical in this lower half of the arch because a small movement here would result in a much larger movement at the top. Sway of the arch at the crown is calculated to be about 18 in. with a design wind load of 155 mph.

To prevent wind loads on the arch from generating tension stresses in the concrete, the core is post-tensioned in the outer corners of the arch. At ground level, 126 high-strength alloy steel bars tension each corner of the structure. This is stepped off and decreased to 76 tendons per corner at the top of the concrete core. In addition, post-tensioning bars are added in the intrados of the arch to overcome tension stresses induced by wind action parallel to the arch plane.

Incorporated in the arch's design are the results of wind tunnel tests undertaken by the late D. B. Steinman in 1948



Creeper derrick raises 12-foot-high section for placement on north leg of the arch.



Stifleg derrick rides on steel tracks attached to extrados face of the arch leg.

to identify the wind pressure and suction distribution over the length of the arch due to varying wind direction. Additionally, a wind vibration investigation was made by Severud-Elstad-Krueger, and was confirmed by a computer analysis undertaken by Fairchild Stratos Corp. The results showed that due to the continuous dimensional change of the arch section there is no wind velocity which can cause the arch to resonate over its total length. Because of its triangular cross section, the arch also has excellent resistance to torsion moments induced by wind.

In addition to vertical post-tensioning, high-strength steel bolts apply a squeezing force to the concrete core of the wall "sandwich," creating a friction bond. The bolts are attached to Z-shaped connectors held by studs welded to the inner face of the stainless steel outer skin. The bolts pass through holes in the carbon steel inner skin where they are held in place by nuts. For local bending, the outer and inner skins act as the top and bottom flanges of a beam, providing a stressed-skin action comparable to modern aircraft design.

From the top of the composite section to the crown of the arch all direct compressive loads are carried by the

outer stainless steel skin and the inner carbon steel skin. Vertical steel diaphragms on two-foot centers connect the two skins and serve as stiffeners to prevent buckling of the inner skin. Steel angles spaced halfway between each diaphragm stiffen the outer skin. The stiffeners and vertical diaphragms are interrupted at each field splice and do not contribute to arch action.

To handle the shop welding, the fabricator designed and built two house-size welding fixtures, one for butt welding carbon steel inner shell plates and filletting angles to them, the other — larger one — for butt welding stainless sheathing plates.

The stainless steel welding fixture has grooved copper backup bars and hydraulically powered copper holdowns to align and flatten the plates during welding. An automatic, consumable electrode head welds the longest joints full depth at 42 ipm with a 1/16 inch type 308 wire and a shielding mixture of 75% argon, 25% CO₂ gas.

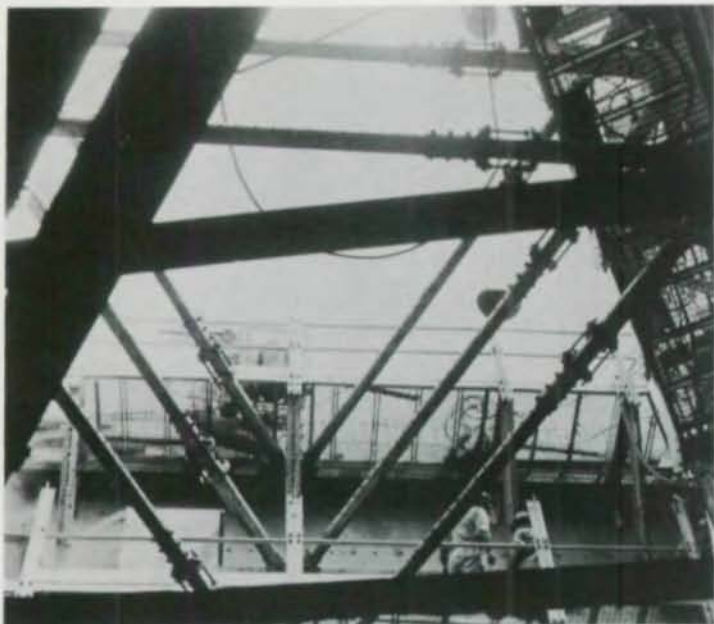
Workers handle plates easily in this welding fixture because the plates move on free-rolling steel balls spaced every 3 feet. To lift the limp plates after welding without kinking them, special sling yokes were made for the cranes. The

largest plates — for the base sections of the arch — measure 12 x 54 feet.

Welded plates are turned over and moved by crane to a work table where a specially designed friction saw accurately cuts them to size. This rig has a framework of structural steel carrying a 15-hp Stone abrasive saw mounted on tracks. At one end is a Graham variable-speed drive that pulls the saw along the tracks with a bicycle chain. An overhead crane lifts the center and aligns it with the layout marks. Once started by an operator the saw makes the cut automatically. It can make cuts as long as 27 ft or cut plates up to 4 inches thick.

While on this same table, the panel is laid out for the locations of Z-bars, and operators using templates weld rows of studs to the stainless steel. The Z-bars are fastened to the 5/16-inch stainless steel studs with carbon steel nuts tightened to 22½ ft-lb with a torque wrench. The finished arch will have 260,000 of these studs.

Inner and outer steel walls are then assembled with tie bolts extending from the Z-bars on the stainless panel through holes in the carbon steel panel. The bolts hold the two walls together and permit adjustments for flatness — the



Inside the leg of the steel Gateway Arch are temporary structures which are removed as sections are completed and new ones are added.



Model shows how crane with 100-foot boom will ride 42-by-32-foot platform up each leg to lift huge sections into place. This method was one of several developed by Pittsburgh-Des Moines Steel Company to build the giant stainless steel monument.

exterior surface has to be flat within $\frac{1}{8}$ inches in any 8 feet.

Completed sections are then loaded on gondola cars for the trip to St. Louis. Two sandwich wall sections ride side by side on a car, their stainless sides facing each other but held apart by steel uprights covered with wood and neoprene. To secure each section, steel rods are welded to wales on the carbon steel plates and to the steel sides of the cars. At the job site, cranes equipped with a tubular steel spreader bar place the arch sections upright in a specially constructed steel storage area.

For assembly, a crane moves three steel wall sections onto a 56 x 125-foot concrete welding pad nearby. To shield welding operations, the pad is equipped with a 20-foot-high, 56 x 60-foot steel framed shelter covered with corrugated galvanized sheets. Canvas tarps that can be raised and lowered protect the ends. The entire structure rides on wheels and shuttles back and forth over the welding pad as successive sections of the Arch are assembled.

Both legs of the arch, acting like free-standing cantilevers, are being erected simultaneously. The cantilever erection method eliminates scaffolding. To resist wind loads during erection, a steel stabilization truss will connect the free-standing cantilevers at approx. 530 ft.

Dominating the dramatic construction work are two specially designed creeper derricks with enough muscle to lift 50-ton loads, enough control to place them with a watchmaker's precision. Allowable tolerances are $\pm\frac{1}{8}$ in. The derricks lift themselves virtually by their own "bootstraps" up the curved arch. Special equipment maintains them on a level keel regardless of the height and curvature of their position.

As the arch rises, the derricks will be too high for workmen to climb down during the course of the day. Derrick platforms are therefore equipped with personnel facilities including space for lunch breaks as well as communications equipment.

Vertical tracks, made from 30-in. WF steel beams with cover plates on both sides, are spaced 24 feet apart and hold a "sled" that supports the derrick and platform. Each track is attached to the stainless steel skin of the arch with brackets held by four $1\frac{1}{4}$ -in.-dia. high-strength steel bolts. These brackets hold the tracks about 2 ft out from the arch surface.

Four $5\frac{3}{4}$ -in.-dia. high strength steel pins connect the sled to the tracks. Telescoping steel legs extend between the outer corners of the platform framing and the lower portion of the sled with pin connections at both ends. As the

arch rises, its curvature increasingly departs from the vertical and the legs are continuously shortened to keep the derrick platform level.

Sections of track are added in about 50-ft lengths, and the entire derrick creeps up after every four sections of the arch are erected. When the arch is completed, the derrick will climb down the tracks, lowering dismantled sections of the track above it as it descends. Bolt holes in the stainless steel surface will be plugged and ground smooth.

Lifting an arch section in place takes only about a half hour. When the section is high enough to clear the completed portion of the leg, the derrick swings it into position and places its corners on screw jacks which make final adjustments to position the section for welding. This is followed by installation of post-tensioning bars and concrete pouring, completing the section.

Subcontractor for fabrication and erection of the nearly 4,000 tons of structural and stainless steel plate is Pittsburgh-Des Moines Steel Co. The steel sandwich sections for the arch walls are fabricated in their Pittsburgh and Warren, Pa., plants. General contractor on the \$11.5-million monument is MacDonald Construction Co. of St. Louis. Completion of the arch is scheduled for early 1965.

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Two story structure is designed for an additional story in future.

By applying the principals of plastic design, we achieved significant savings in the building frame of the Health Study Shopping Center presently under construction in Adelphi, Md. The complex is composed of two sections: One is a two-story office building designed for the addition of another floor at some future date. The other section is one story and will be occupied by several shops. The whole complex is a medium size shopping center.

The two-story portion of the building is framed with steel beams and open web joists using plywood and K clips for the forming of a 2½-in. concrete slab. It is 150 ft long and 125 ft wide with 25 x 25-ft bays. The live load is 100 psf and the partition allowance is 20 psf.

A36 steel coupled with the use of plastic design would have saved 18 percent of the steel tonnage if the most economical sections in simple span and plastic design are compared — 24WF76 versus 21WF62; however, since the architectural requirements made it necessary to use an 18-in.-deep beam, the savings achieved were reduced to 15 percent.

It is interesting to note that reducing the depth of beam obtained by the time-honored formula $WL/8$ to an architecturally required 18-in. depth would raise the difference in weight of steel to 23 pounds per foot of beam or 27 percent of its weight — 18WF64 versus 18WF85. Further savings were realized by fabricating the beams in two-span lengths and setting the intermediate columns on the top flanges of the beams. In this manner the beams were continuous over two spans and simply supported at the outer ends. By using this system of framing, we were able to eliminate costly splices to provide for continuity and speed up the erection of the structural steel. The steel erector estimates that a little over eight days were saved in the erection by eliminating through plates at each concrete-filled pipe columns as well as providing a frame that could be



PLASTIC DESIGN SAVES STEEL

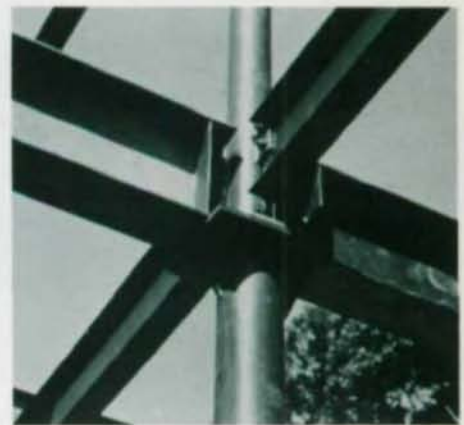
by Alexis Smislova,
Professional Engineer

more easily plumbed. In addition to a saving of 9½ tons of steel, further savings inherent in the steel frame because of speed in erection, fabrication and detailing amount to approximately \$30 a ton. All the main connections were made with ASTM A325 high strength bolts.

The method employed in forming the 2½-in. concrete slab consisted in using ¾-in. plywood two feet wide held in place by K clips.

Instead of the conventional two-foot center-to-center spacing for the joists, we chose a 2 ft-4 in. spacing to accommodate two-foot standard width plywood sheets. This also saved two joists per bay.

However, the net saving per bay was less than the full weight of two joists since the wide spacing made it necessary to use heavier joists. It is estimated that the tonnage of open web joists saved on the job amounted to three tons for the two floors.



Simple detail at interior pipe columns saves erection time and facilitates plumbing.

The K clips provided an easy way to strip the forms. Although it was not done on this job, the top row of bridging could be eliminated since the combination of plywood and K clip hold the top chord of the joists securely in place. The general contractor estimates that, based on four form uses, the savings in the forming of the slab to be 5½ cents per square foot as compared to the permanent type of forming material such as corrugated sheet metal.

In conclusion it is worthy to note that the overall poundage of steel ran a little over 7½ lbs. per square foot, including beams, joists and columns.

The architect for the project was Donald N. Coupard & Associates of Bethesda, Md., the structural engineers Smislova & Carcaterra, Silver Spring, Md. The general contractors are Adecco, Inc., Washington, D. C. Fabricating and erecting was done by B & M Welding and Ironworks, Inc. of Gaithersburg, Md.

BRIDGE DESIGNER KAVANAGH COMMENTS

Dr. T. C. Kavanagh served as a member of the AISC jury in selecting the 1962 prize bridges. He is a partner in the Engineer-Architect firm of Praeger-Kavanagh-Waterbury.

Since short-and medium-span bridges are generally viewed at close range, the continued recurrence of many standard but time worn details, not in consonance with architectural potentialities of steel yet in many cases insisted upon by the specifying agencies, points up a fertile area where the steel industry can do much to improve bridge architecture.

Massive concrete parapets, grossly distorting the depth of the structure; end pylons disproportionate in size, breaking the smooth flow of the bridge ribbon; handrails either blocking the motorists' view or lacking in balance; exposed stiffeners on fascia girders where not essential; a slavish repetition of curved "butterfly" or T-shaped concrete piers, which are really not as handsome as solid pier shafts with straight ends tapered inward toward the bottom; the weary and dangerous standardization of thruway bridges with vertical piers at side shoulders or in center mall, when the alternate of graceful inclined strut frames is available to eliminate these hazards completely; the continued use of straight, broken-chord fascia

beams on curved bridges, when curved fascias are available; the lack of recognition of wide box girders, which have done so much for concrete bridge architecture, and which blend so well with the substructure piers and single columns; the failure to incorporate prestress by tendons or externally induced restraints, to "slenderize" the structure . . . these are commonly observed evidences of the price we pay for standardization. Clearly, under such restrictions an imaginative bridge designer is hard put to give full expression to, or to make full application of new developments in theory and practice.

* * *

A remarkable illustration of the extent of development possible when freedom of aesthetic expression is encouraged, is in the field of long-span bridges in Europe during the period of reconstruction following the last war. The truly beautiful funicular bridge structures so indigenous to and so highly developed in America — namely, the long-span suspension bridge and steel arch—were not only "rediscovered" and refined by our European brothers, but new concepts were developed in the form of orthotropic plate construction; deck plate girders with spans up to 850

ft; cable stiffened girder bridges both with symmetrical towers or with a single tower, as at Cologne; box girders of long span; prestressed steel composite spans, and many others.

* * *

The six classical precepts of aesthetics set down by Vitruvius were ably restated many years ago by William J. Watson as they apply to bridge architecture, namely:

- Arrangement — or functionalism.
- Economy — as regards cost, efficiency and lack of superfluity.
- Order — or harmony of scale, material and detail, as regards elements and the whole.
- Symmetry — or balance of parts.
- Propriety — or honesty, lack of deception.
- Eurythmy — or element of beauty resulting from fitting adjustment of members. Sometimes enhanced by proper and significant ornamentation.

It is fortunate that bridge designers perhaps subconsciously incorporate these precepts in the ordinary design function. Nevertheless, they afford a handy checklist by which the finished design may be judged.