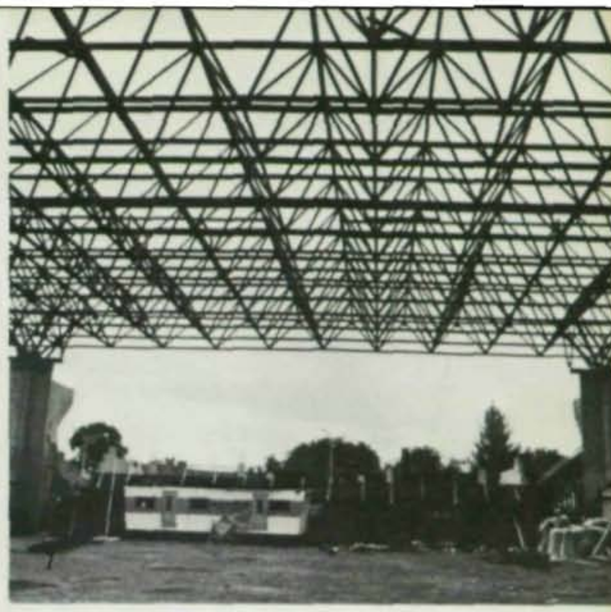
VOLUME XIII / NUMBER 4 / FOURTH QUARTER 1973

MODERN STEEL CONSTRUCTION



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Steel

MODERN STEEL CONSTRUCTION

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CONTENTS

KIMBROUGH MEDAL

The J. Lloyd Kimbrough Medal, established in 1940 in memory of AISC's first president, honors outstanding contributions to the use of structural steel.

In 1973 Dr. Fazlur R. Khan, a Partner in the Chicago office of Skidmore, Owings & Merrill, Architects-Engineers, was named by the AISC Board of Directors to receive the Kimbrough Medal, only the sixth time the medal has been awarded in its 33 year history.

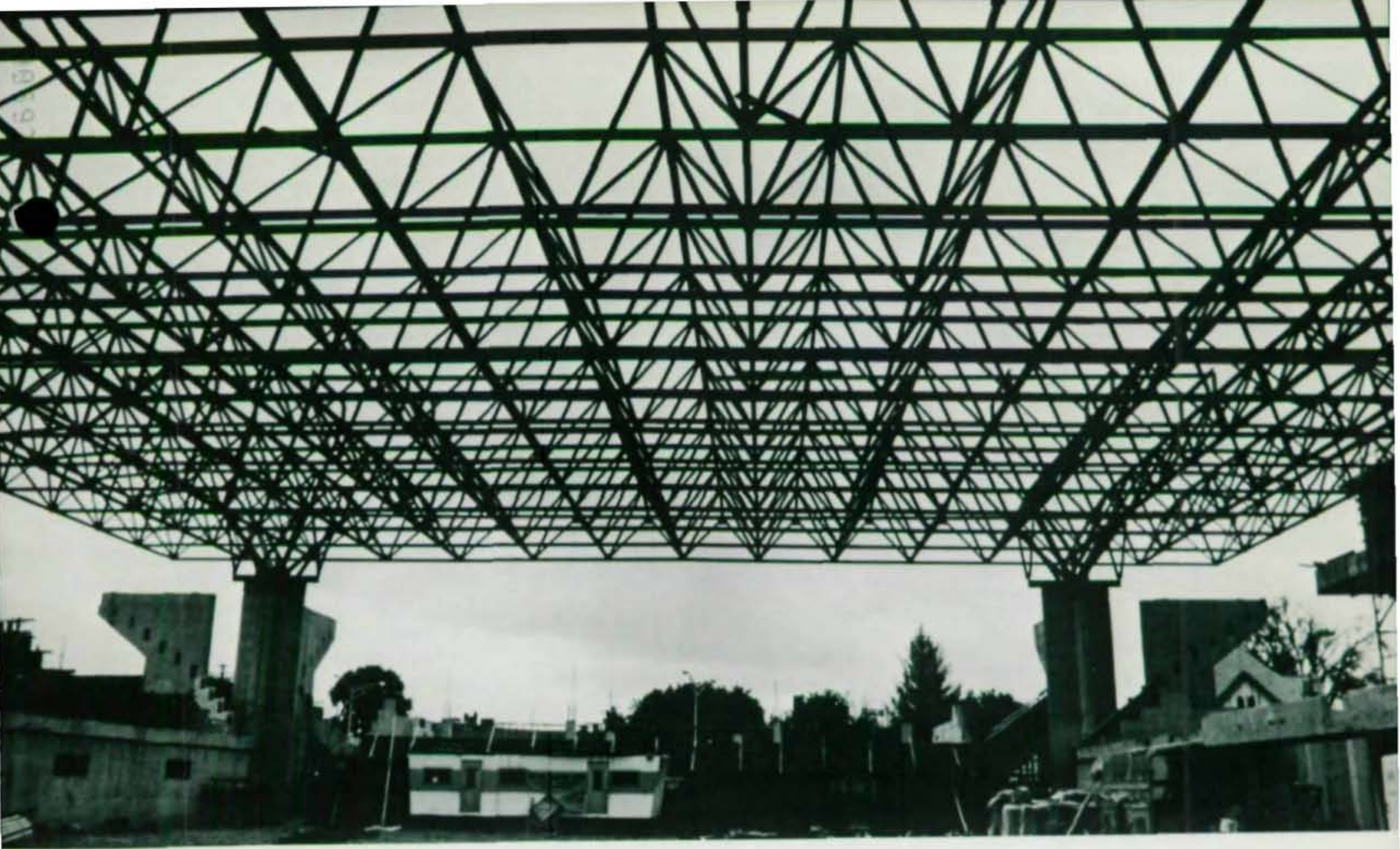
Dr. Khan was cited for his outstanding contribution to the development of steel framed construction, for his innovations in structural engineering that have created a bold new era of significant high rise buildings, for advancing the field of structural design and for stimulating its public understanding and appreciation, and for combining great aesthetic sensitivity with his engineering expertise.

1974 AISC NATIONAL ENGINEERING CONFERENCE

Leading authorities in the fields of steel design, research and construction will meet in Chicago on May 2 and 3 to exchange ideas and information. The engineer or architect who wishes to keep informed about the continuing developments in these fields will find this conference a valuable and exciting experience.

An outstanding group of speakers will discuss a wide variety of topics, such as economical connections, stability, unusual buildings, new design techniques, research developments and future specification changes. As a special feature, the winner of the 1974 T. R. Higgins Lectureship Award will make an oral presentation of his paper.

Contact AISC, 101 Park Avenue, New York, N. Y. 10017 for information about registration.



Space Frame Covers Arena

by P. R. Chakrabarti, Keith C. Thornton, and Ray P. Nardone

Architect:
Elbasani Logan and Severin
Berkeley, Calif.

Structural Engineer:
T. Y. Lin and Associates
New York, N. Y.

General Contractor:
E. L. Nezelek
Johnson City, N. Y.

Steel Fabricator:
Schenectady Steel Co., Inc.
Schenectady, N. Y.

Broome County Veterans Memorial Arena, Binghamton, N. Y., is a 7,000 seat multipurpose complex for activities such as hockey, basketball, boxing, ice shows, concerts, conventions, and trade shows. The 206 ft x 315 ft arena area is spanned by a three-dimensional steel space frame supported at four major and four minor points. A separate gallery structure, containing lobbies and meeting rooms, will eventually connect to a future performing arts theatre.

Design Modifications

The arena roof was originally designed as a 9-ft deep space frame, supported by four cross-shaped concrete columns, with a 28-ft deep skirt around the periphery. The skirt was an integral part of the structural design. Due to transportation, fabrication, and erection considerations, it became apparent that the cost of such a structure would exceed the approved budget.

To reduce these difficulties, two steel columns were added to each of the longer sides of the building; this technique not only eliminated the need for the skirt to act as a structural element of roof framing, but also reduced the average weight of the steel from 22 psf to 15 psf. Subsequently, the depth of the space frame was increased to 11 ft, with the 28-ft deep skirt supported by the main structure. Thus, the final form of the space frame was developed.

The structure covers nearly 65,000 sq ft, with a 40-ft overhang beyond the four cruciform columns. These columns support steel bases made of W sections and plates, also cross-shaped. In turn, these steel bases support inverted pyramid structural members which support the space frame.

A 13'-8" grid was chosen for geometrical reasons. Pyramidal elements were used throughout the structure.

Mr. Chakrabarti and Mr. Thornton are Senior Designer and Partner, respectively, at T. Y. Lin Associates, Consulting Engineers, New York, N. Y. Mr. Nardone is Regional Engineer, AISC, New York, N. Y.

Pyramidal trusses, each 204 ft long, were erected across the width of the structure in a carefully planned sequence, then joined to form a giant space frame.

Structural Theory

Several methods were considered to analyze and design the space structure: consistent deflection, finite differences, orthotropic grid, analogous flat plate with moment distribution, model analysis, and successive approximation with a computer program.

The method used in this project was a combination of analogous flat plate and successive approximation. In this design, the roof was considered as a flat plate supported on eight columns with column bands. In analyzing the slab for bending and shear, the top and bottom chords resisted bending stresses and the diagonals resisted shear loads. Members were proportioned according to these forces. Observing the possible shortest paths for loads to flow to the supports, forces in members were reduced or increased based on judgment. Forces thus obtained by hand analysis checked extremely well with the results obtained by computer analysis.

The Broome County Veterans Memorial Arena provides 7,000 seats for spectators and floor area for sports, shows, conventions, and other exhibitions. A separate adjacent gallery structure contains lobbies and meeting rooms.

Computer Analysis

The size and complexity of the frame precluded a hand analysis, and time and money made solution by a specially written computer program not feasible. With the preliminary design completed, it was most convenient to analyze the structure by the existing general problem-oriented program, ICES-STRUDL (Integrated Civil Engineering System Structural Design Language) because of its generality, flexibility, simplicity, and availability.

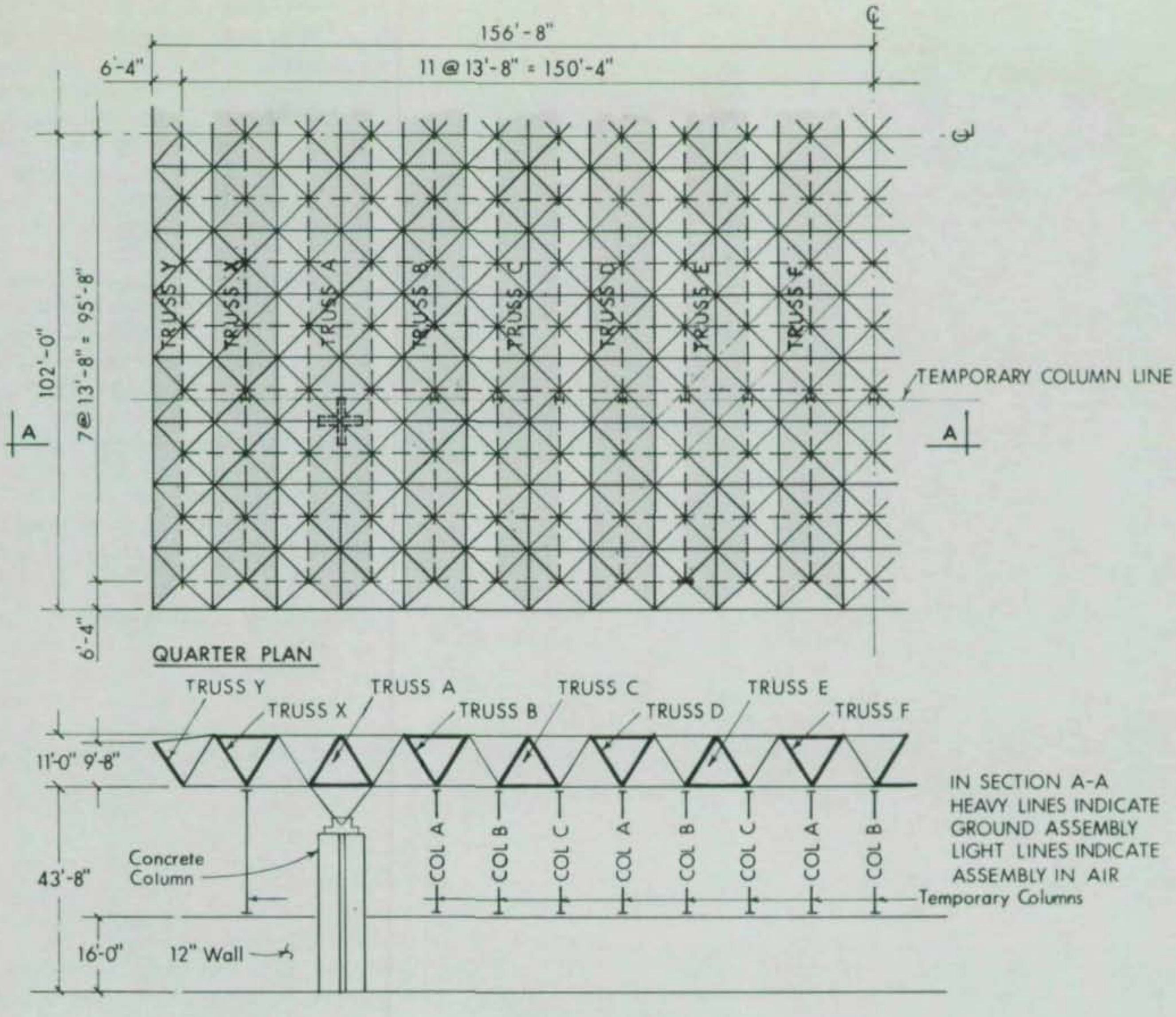
Due to symmetry, only one quarter of the structure required analysis. The analysis model had 212 structural joints, 2 actual support joints, 192 top chord members, 170 bottom chord members, 344 diagonal members and 8 support-related members. Three loading conditions were analyzed: (1) full uniform dead and snow loads, (2) mechanical equivalent concentrated loads, and (3) combination of the two. Since perfect rigid or pin connection is not possible in actual structures, one analysis was made assuming all joints pinned (i.e., space truss) and another analysis was made assuming all joints rigid (i.e., space frame).

Design Concept

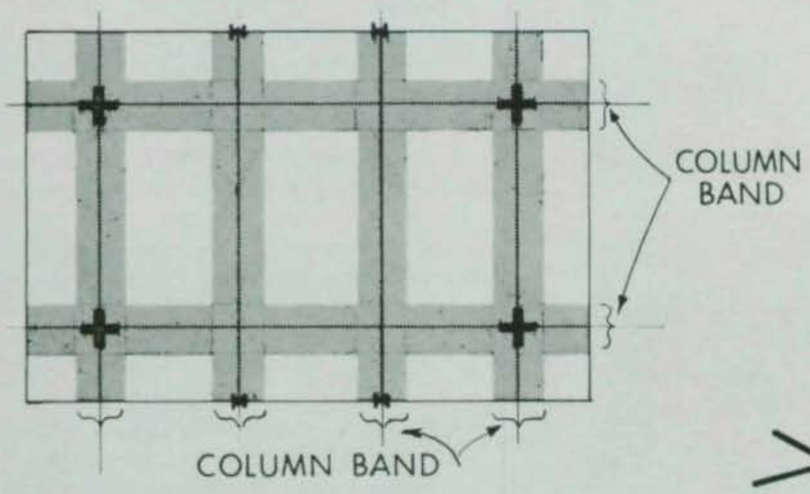
Selection of structural steel shapes for the members and the design of joints were the most critical decisions in regard to the overall design. The architect required a joint with a simple look. To achieve this while simultaneously considering ease of erection, a joint was developed by simply crossing two plates.

The following points were considered in choosing members of the space structure:

1. Typical joints were created by crossing two gusset plates, welded to the bottom flanges of top chords and the top flanges of bottom chords. These plates received double angle diagonals. Since the diagonals did not meet in the same plane as the top or bottom chords, the forces in the gusset plates could not reach the c.g. of the chords directly and local bending was a consideration at the joints.
2. Top chord members, though axially loaded, were also subjected to bending due to roofing and live load. Therefore, sections were chosen to satisfy both needs.

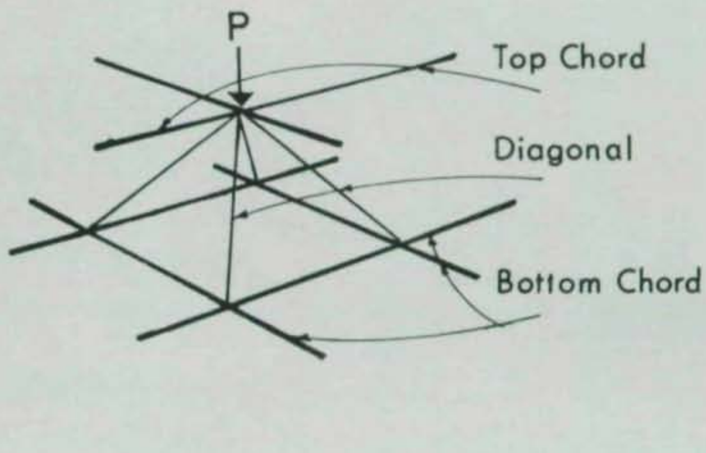


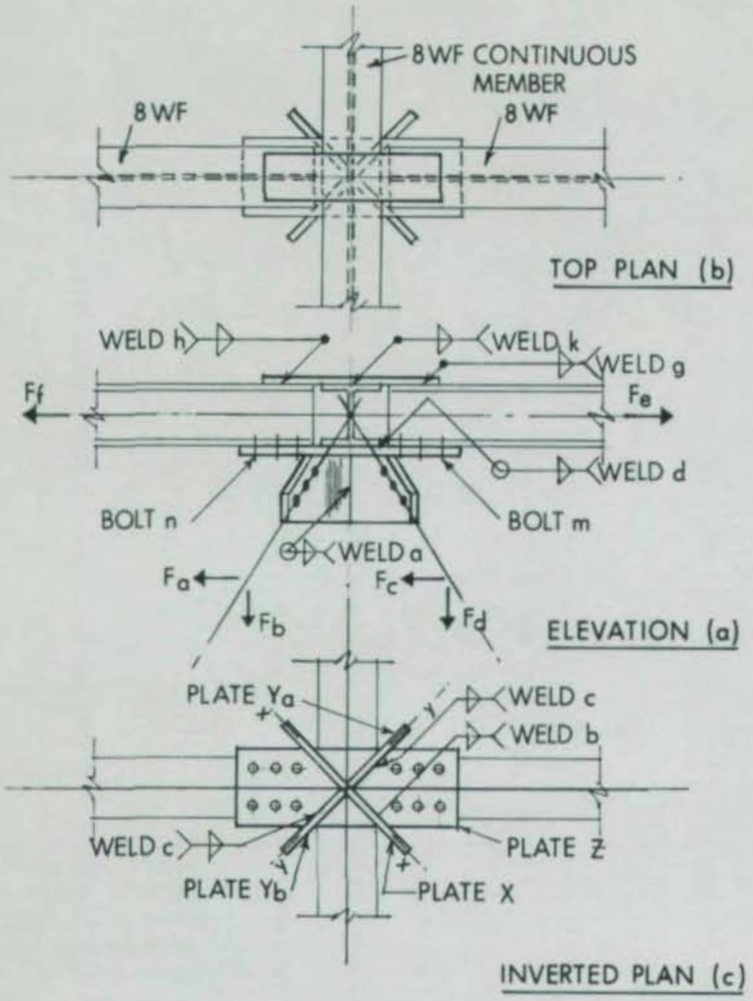
Plan and Erection Scheme



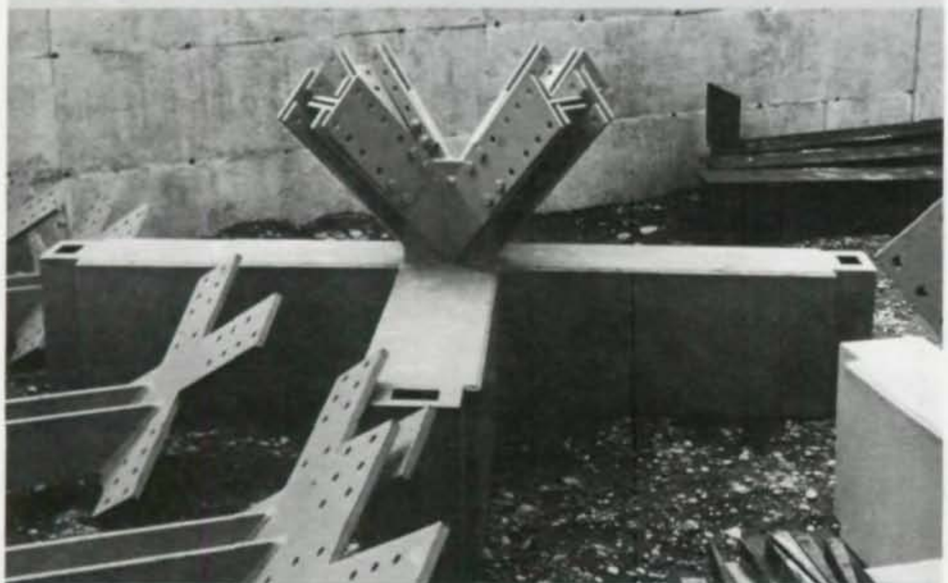
In the design, the steel roof was considered as a flat plate supported on eight columns, with column bands as indicated by shaded areas.

Pyramidal elements were used throughout the structure.





Detail of top chord joint. Gusset plates, aligned at 45 degrees to the chord, receive double angle diagonals.



Steel bases supporting the space frame were fabricated to the same cruciform shape as the concrete columns.

3. Bottom chord members usually had only axial forces. Therefore, T sections were used which have centers of gravity very close to the flanges, thereby reducing local moments. Corrugated sheets of #18 and #24 gage were used for the roof deck. These sheets spanned the top chords and were aligned in a checkerboard pattern so as to place almost equal loads at the node points. Limited rollers were assumed to be at the four concrete columns. This allowed the structure to move horizontally a certain amount prior to being stopped and applying a thrust at the column tops. To reduce weight, A572 (50 ksi) steel was used primarily. The diagonals, however, were A36 (36 ksi) steel. High strength ⅞-in. A325 bolts, and E70XX welding rods were used for connection requirements.

Fabrication and Erection

With the basic module measuring 13'-8" wide by 11'-0" deep, a large portion of the structure could not be assembled in the fabricating plant and then transported to the site. Consequently, the entire structure was designed as a shop welded, field bolted structure.

The erection procedure involved subassembling the space frame on the ground by connecting three chord units to form a triangle in cross section. Three of these subassemblies were then joined to make a 204'-0" long truss, equal to the width of the structure. Truss A (see drawing of Plan and Erection Scheme) was erected first and locked into position on the concrete columns. Two sets of Columns A (temporary) were then placed in position. Truss B was then hoisted by an 82 ton truck crane, tied into Truss A, and finally placed on temporary Columns A. The process was repeated by "leap-frogging" the columns until the last two concrete columns at the other end of structure were reached. Finally, roofing was placed and side skirts were connected to the space structure.

The structure was assembled and erected with no major problems. The weight of steel in the space frame, less the skirts, totaled 490 tons, averaging 15 psf. Design and development was completed in three months, fabrication took 5 months, erection one month.

A New Approach to Jumbo Jets

by Paul Wood and Eugene Fasullo

To provide a superior level of service to passengers entering or leaving the Boeing 747 and other wide-bodied aircraft at John F. Kennedy International Airport, the international air carriers, working with the Port Authority of New York and New Jersey, selected a three-door, one-sided enclosed walkway access to the aircraft.

Access to two of the aircraft doors is provided by movable walkways supported from the ground, typical of those found at many airports today. However, access to the last door, behind the aircraft wing, is provided by an innovative cantilevered movable bridge which is in turn supported by a cantilevered fixed structure.

This unusual structure, in its extended position, allows the passenger to exit directly from the rear of the aircraft to the terminal building, passing over the wing; yet, in its retracted and rotated position, it provides ample clearance for the aircraft to move in and out of its parking position.

To minimize weight and provide minimum wall thickness in the overlapping tubes, the designers chose to use a stressed-skin design for the movable walkway instead of the traditional truss structure. This all-welded structurally efficient box unit is made up of decking, plates, and angles. The walkway, consisting of two overlapping sections, has a rear anchor span of 55 ft and a cantilever span that can extend to 40 ft.

The cantilevered fixed structure, composed of two trusses, one at each side of the walkway, forms a fan at its cantilever end to allow the movable walkway to rotate away from the aircraft, To form this fan one truss must change direction at its support point, presenting a challenge in analysis and detailing that was sucessfully met by the use of sophisticated analysis and innovative design. This fixed structure has an anchor span of 90 ft and a cantilever of 60 ft. The tip of the cantilever is 34 ft above the apron.

Owner of the facility is the Port Authority of New York and New Jersey, who also developed the performance specifications and approved the final design concept. Designer and General Contractor for the overall project was Dortech, Inc., a subsidiary of Dorr-Oliver, Inc., Stamford, Conn. For the fixed structure, the General Contractor was Frank Briscoe Co., Inc., Newark, N. J., and the Steel Fabricator was Carew Corp., York, Pa. The movable walkways were designed, fabricated, and installed by St. Louis Car Co.

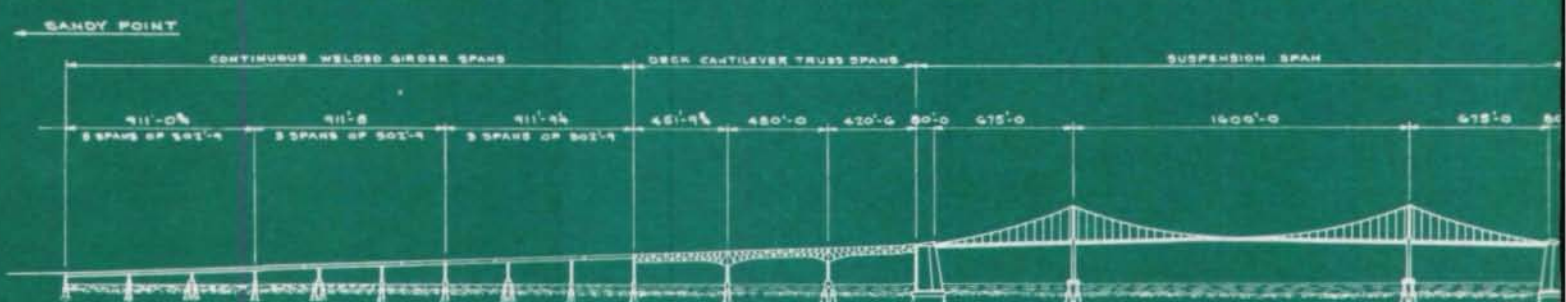
Mr. Wood and Mr. Fasullo are Supervising Engineer and Chief Structural Engineer, respectively, at the Port Authority of New York and New Jersey.

Four Bridges Combined into One

Designer:
Joseph E. Greiner Company, Inc.
Baltimore, Md.

General Contractor:
Raymond-Dravo-Langenfelder
Baltimore, Md.

Steel Fabricator:
American Bridge Div., United States Steel
Pittsburgh, Pa.



The recently opened Gov. William Preston Lane, Jr. Memorial Bridge, across the Chesapeake Bay to the Eastern Shore, combines four different types of bridge construction.

The 38-ft wide three-lane roadway bridge is located 450 ft north of a similar two-lane structure erected 21 years ago. Increasing beach travel and weekend traffic jams at both ends of the bridge called for the construction of the second parallel span.

Steel Superstructure

Four different types of steel superstructure comprise approximately two-thirds of the bridge's entire length.

Starting from the west side, there are nine 302-ft continuous welded girder spans, three deck cantilever truss spans at 451, 480 and 420 ft in length, a 2,950-ft suspension bridge consisting of two 675-ft side spans and a 1,600-ft main span, and nine more deck cantilever truss spans measuring from 420 to 600 ft in length.

Continuing from the truss spans is a 1,720-ft through cantilever truss bridge with two 470-ft anchor spans and a 780-ft center span; and finally, three more continuous welded girder spans, each 202 ft in length, complete the steel superstructure portion.

Two assembly points were used for the approximately 34,000 tons of structural and plate steel that went into the structure. Some sections were partially assembled in Baltimore and floated to the construction site; other sections were constructed on falsework near the western approach.

Erection Procedures and Techniques

Many of the spans were floated into place on barge platforms which were towed into place and partially flooded. As the barge "sank," the span settled into place on its piers.

Spans were put up in alternate sequence. After a span was set in place, one of two huge tower-derricks (one was 410 ft and the other 305 ft high) moved in to erect cantilever arms on the ends of the already placed truss spans. Then, other completed sections of truss span were barged into place below the bridge level and hoisted from the ends of the trusses, similar to two people standing on either side of a ditch and lifting someone out between them.

Enormous weight was involved in construction of the bridge. The heaviest float-in, a 1,400 ton through truss anchor arm span measuring 507 ft, was assembled in Baltimore, towed 25 miles to the bridge site (a four hour trip), and floated into place. The heaviest lift, an 1,100-ton, 390-ft long center section of the through truss span, was raised about 115 ft from the deck of the barge into final position.

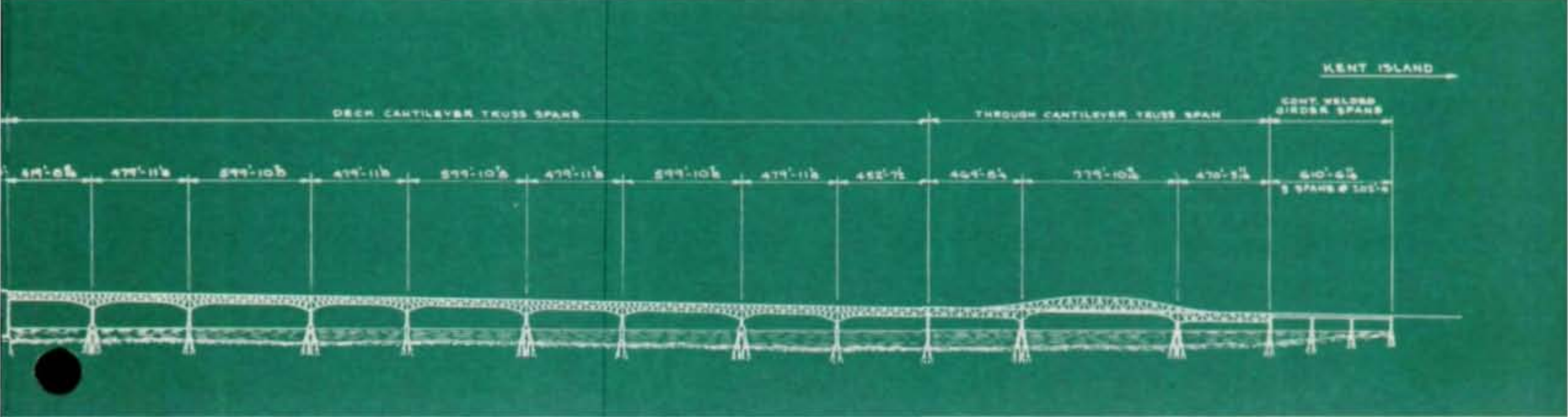
In addition to the massive structural steel work, some interesting "high wire" cable work took place. Each cable was fastened to the anchorages at each end of the suspension bridge and carried over the top of the 372-ft high bridge towers supporting the suspended spans. In addition, suspender cables or ropes were fastened to the cables and trusses. Each main cable is composed of 61 strands of steel, made up of 3,577 galvanized steel wires. The strands were pulled across one at a time. This method replaced the traditional cable-spinning method of assembling bridge cables.

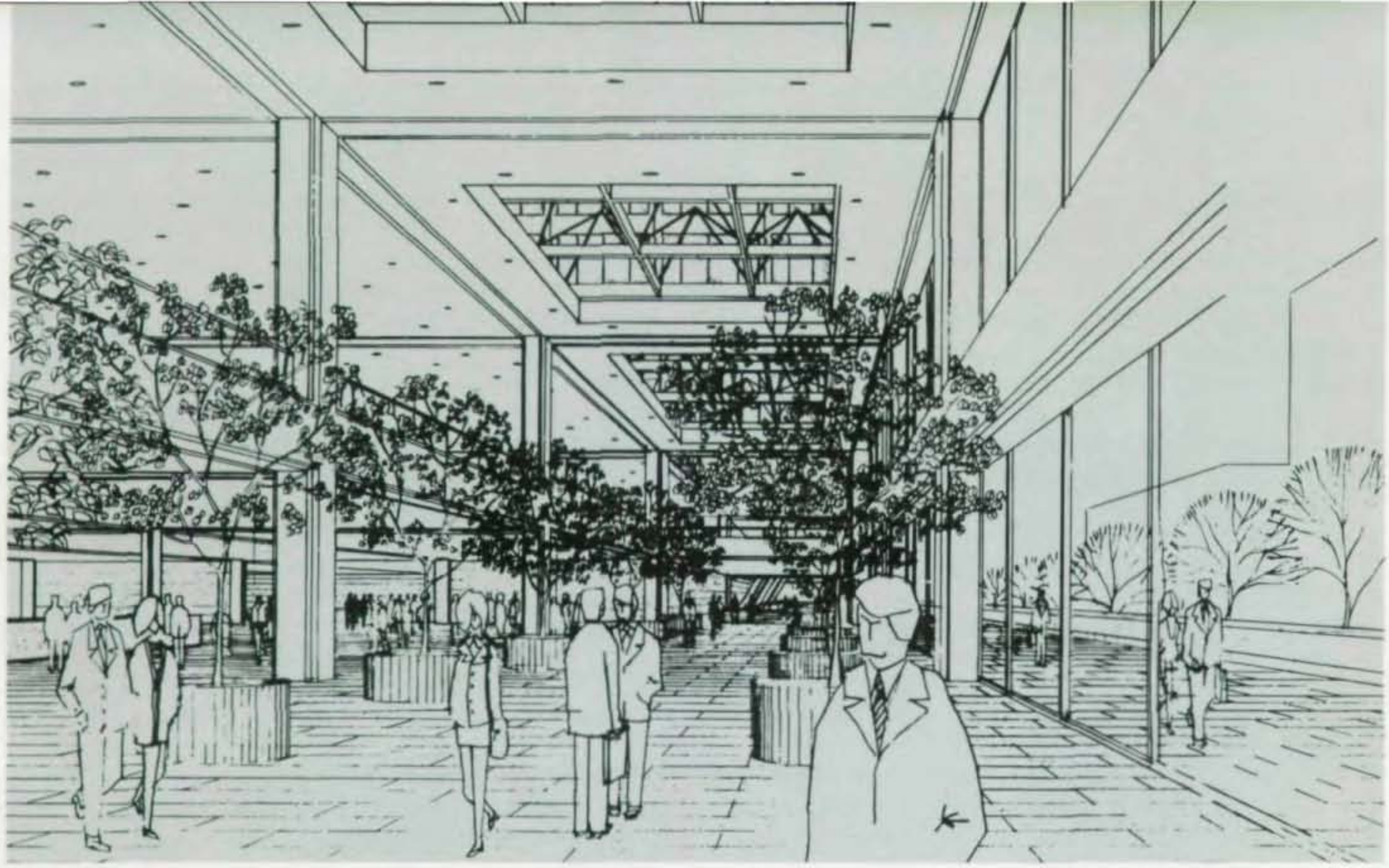
Other Features

Other notable changes in appearance and procedure from the days when the first Bay Bridge was erected include a different view for the motorist driving across the new bridge. The roadway sits atop the stiffening truss on the new bridge. In the older bridge, the roadway ran through the truss, obstructing the view. Welded deck girder spans, many of which are curved, have replaced many of the truss spans of the old bridge. The curved girders were made possible by higher-strength steels and advanced design technology.

In addition, the suspension towers appear completely different in the two bridges. The new towers have single horizontal members connecting the columns instead of the cross-braced effect on the older bridge. The new towers are heavier, since the roadway on the new bridge is one lane wider. The through truss cantilever span is more arch-like than the double peaked span of the first bridge.

Steel erecting methods have changed along with design techniques in the last two decades. The original bridge was put up with riveted construction and little welding, while the new project included a great deal of shop welding and field connections made with high-strength bolts.





Wisconsin Hits A New High

The First Wisconsin Center is the biggest thing to hit Milwaukee's skyline since the Indian Mound Builders left their handiwork on the city's wooded bluffs some 3,000 years ago. The 601-ft high structure is the tallest in the state and stands 251 ft over the next tallest building in Milwaukee.

The project is a 42-story, 1.3 million sq ft bank and office building, including a galleria commercial area. The office tower rises from a two-level, 200-ft wide glass enclosed plaza that covers the entire length of a city block. The first level includes the main banking floor and safe deposit area and features a landscaped garden. The second level, or galleria, includes the bank's commercial lending divisions, plus shops, boutiques, professional services, and restaurants. The galleria bridges the street into a structured parking area, with a capacity for 1,000 cars, providing a shelter for pedestrians throughout two city blocks.

Structural System

The framework of the Center comprises 24 steel columns. The welded and bolted skeleton of the building contains 16,500 tons of 36 ksi structural steel. The steel structure was worked in fifteen 40 x 40-ft modules per floor, using both a cellular and non-cellular deck system. Throughout most of the building, there are only two interior columns per floor. In the upper third of the structure, where the elevator core area is decreased, only four columns are exposed.

Lateral belt trusses at the bottom, middle, and top of the building stiffen the structure, permitting reduction in size and weight of the other steel members, and keeping the weight of the steel frame to a minimum. Mechanical floors are located at the truss areas.

Slurry Wall

Excavation required working 60 ft below street level and 30 ft below the level of Lake Michigan. A slurry wall retention system was used to keep side walls of the excavation system from caving in. The excavation around the three walls on the perimeter of the Center was surrounded by a mixture of bentonite clay and water. The slurry was pumped into the excavation as clam shells dug a 30-in. wide trench, which finally went 50 ft deep. With the slurry acting as a retaining wall, H-piles were driven through the slurry to 150 ft. As the pile driving neared completion, a rebar cage was set into the slurry wall, and then concrete was pumped into the excavation. After the concrete displaced the slurry into tanks, the slurry was strained and reused. Use of the slurry wall retention system resulted in savings of thousands of dollars and allowed excavation to proceed without delay.

Other Features

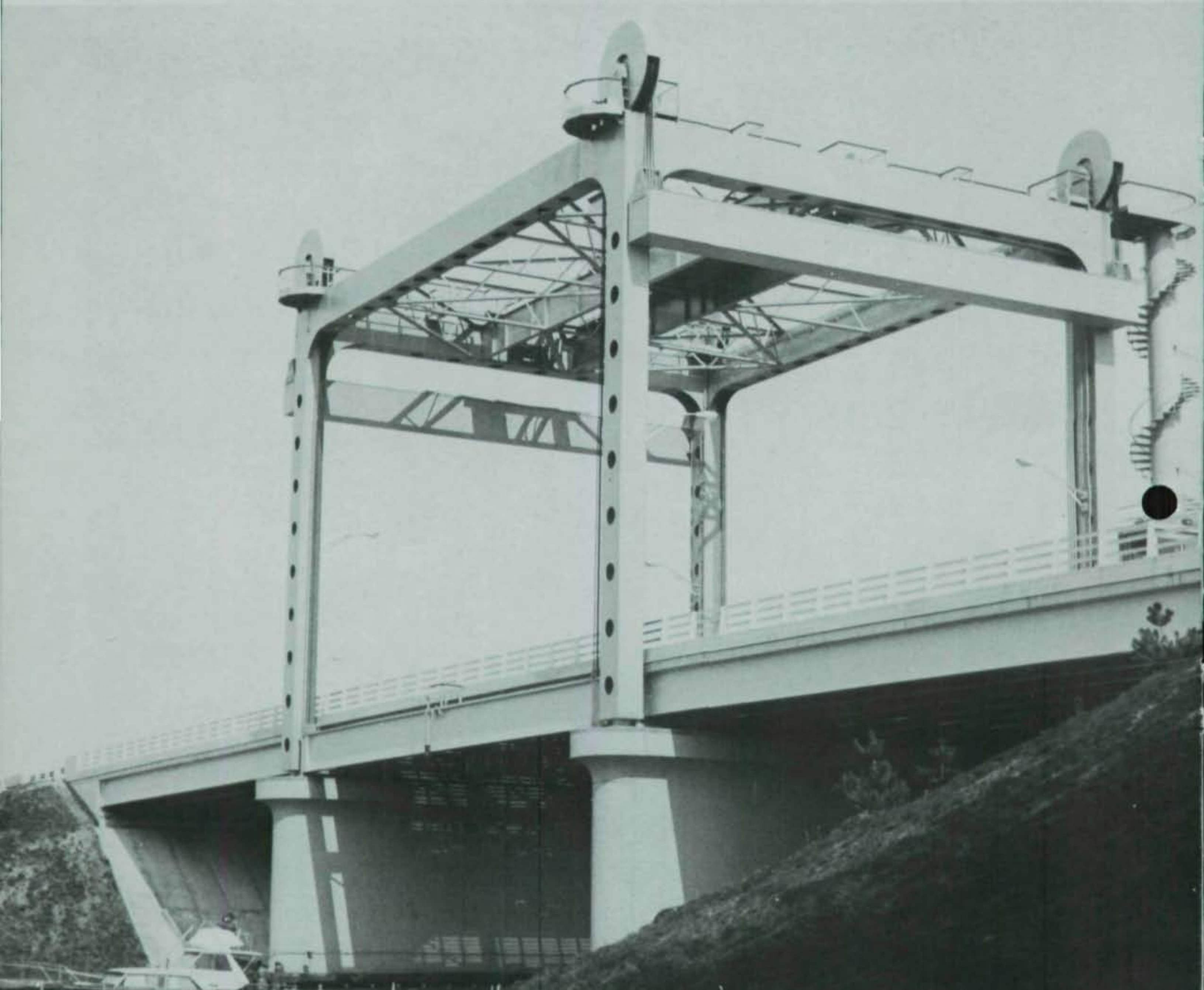
The skin of the Center is a curtain wall comprised of 66 percent glass, 34 percent aluminum and is electrostatically painted white.

The windows are fixed double-glazed insulating units with bronze, heat-absorbing, glare-reducing glass.

Architect/Engineer:
Skidmore, Owings & Merrill
Chicago, Ill.

General Contractor:
Carl A. Morse, New York, N. Y.

Steel Fabricator:
American Bridge Div., United States Steel
Pittsburgh, Pa.



VERTICAL LIFT BRIDGE

The Point Pleasant Canal crossing is a three span composite welded plate girder and vertical lift bridge. If not the first, it is one of two or three such structures of fully welded fabrication in operation in this country at this time. The bridge is unique in that the tower span, that is, the fixed structure from which the lift span is raised and lowered, is fundamentally a rigid frame with unbraced box-section columns seated on spherical bearings at the pier cap. This design was chosen to eliminate the conventional end portal bracing between columns and offers a pleasing "see-through" appearance to the public and nearby residents.

With the lift span in the "down" position, the vertical under-clearance above local Mean High Water is 30'-0". With the span "up", this clearance is normally 65'-0", but provisions have been made to raise the span an additional 3'-0" under emergency conditions. It takes slightly more than one minute to fully raise the span and an equal time to lower it.

All machinery, the motor, and motor controls are located on the top of the tower span. The shafts form an "H" leading to the four corners of the span where the sheaves are mounted. Located in the center of the "H" is the single operating motor (60 hp), which activates and controls the longitudinal shaft rotations. Right-angle gear reducers translate the rotation of the longitudinal shaft to the four transverse shafts. At the end of each transverse shaft is a pinion gear which engages the toothed rack on the periphery of the sheaves. Six lifting ropes connecting the counterweight to the lift span are draped across each sheave. With only one motor operating the entire system, no other synchronization is necessary.

No buffers were used in this design. The speed of the lift span movement is electrically controlled. About two feet above the pier-top, the span speed is reduced to 10% of its normal speed, and just before seating the torque is reduced to 50% of maximum.

The sheaves carry the lifting ropes which connect the lift span to the counterweight, and by rotating the sheave, the lift span moves up or down. The outside diameter at the gear rack is 10'-4". The sheave shaft is 13½ in. in dia.

At each of the four sheaves, there are six lifting ropes, each about 100 ft in length. The rope is 1½-in. dia. improved plow steel wire rope with hemp centers.

Each counterweight consists of a steel-framed box filled with concrete, except for five pockets which contain loose concrete blocks for weight adjustments. The pockets are designed to provide space to balance by 4½% over and under the weight of one counterweight.

The bridge carries a 4-lane, bi-directional roadway and is designed to carry a live load corresponding to AASHO HS20-44 or tandem 24,000 lb. axles at 4-ft spacing. The open steel grating can take 16,000-lb. wheels.

Designer:
Howard, Needles, Tammen & Bergendoff
New York, N. Y.

General Contractors: (A Joint Venture)
Mason-O'Connor, Inc.
Cinnaminson, N. J.
Thompson Construction Corp.
Albany, N. Y.

Steel Fabricator:
Cumberland Bridge Company
Camp Hill, Pa.

1973 ARCHITECTURAL AWARDS OF EXCELLENCE

▲ CONTEMPORARY RESORT HOTEL
Walt Disney World, Florida
Architect: Welton Becket and Associates

▲ OXFORD VALLEY MALL
Middletown Township, Pennsylvania
Architect: Cope Linder Walmsley

▲ GAZEBO
North Little Rock, Arkansas
Architect: Euine Fay Jones

FEATHER FACTORY
San Francisco, California
▼ Architect: Knorr-Elliott & Associates

FOURTH DISTRICT HEADQUARTERS METROPOLITAN POLICE DEPARTMENT
Washington, D.C.
Architect: McGaughan & Johnson

COLLEGE OF DU PAGE—INSTRUCTIONAL UNIT ONE
Glen Ellyn, Illinois
Architect: C. F. Murphy Associates

REGENCY HYATT HOUSE
San Francisco, California
Architect: John Portman & Associates

PINE KNOB MUSIC THEATRE
Independence Township, Michigan
Architect: Rossen/Neumann Associates

FIRST AND SECOND CHURCH IN BOSTON
Boston, Massachusetts
Architect: Paul Rudolph

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▲ **THE OMNI**
Atlanta, Georgia
Architect: Thompson, Ventulett & Stainback, Inc.