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MODERN STEEL CONSTRUCTION

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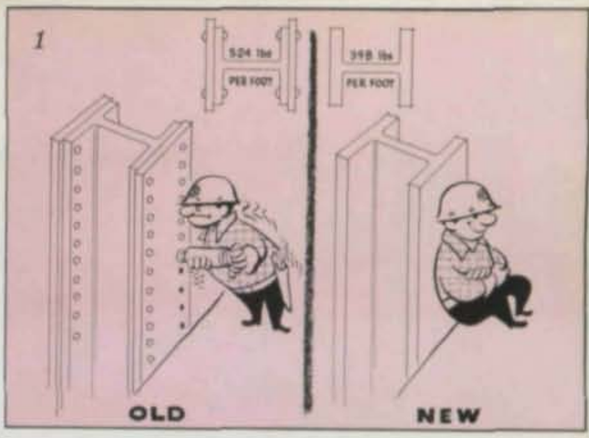

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EDITORIAL

Publication of this issue of **Modern Steel Construction** *coincides with the announcement and distribution of the 1961 "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings."*

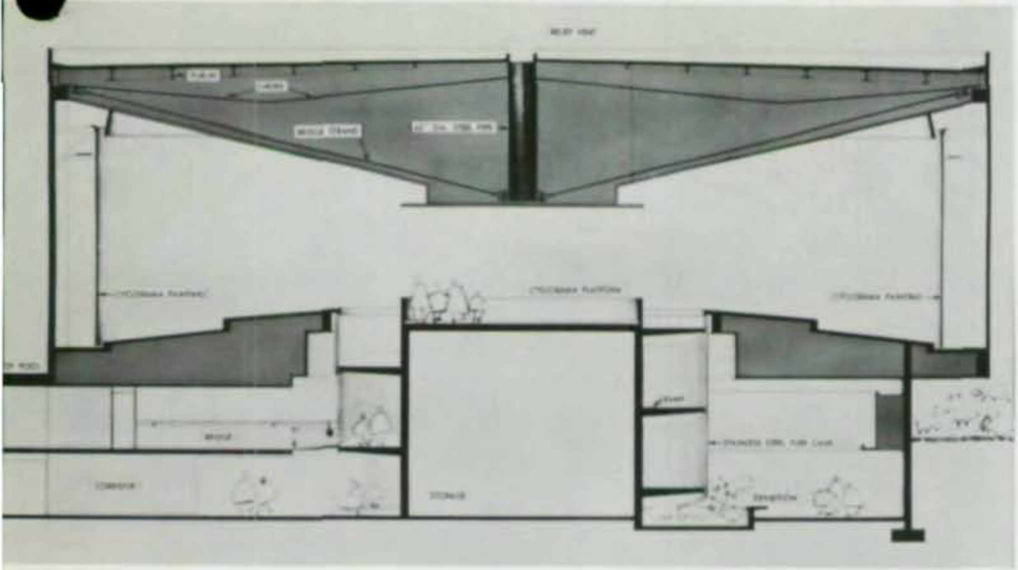
It is a completely revised Specification that puts to use every pound of steel with no sacrifice in safety or strength and provides opportunities to enhance the beauty and utility of steel-framed buildings.

It is the result of a quiet revolution in structural thought, the logical and consistent application of research developments and practical building experience.

Hence it is a proven document, more sophisticated, more realistic, yet encouraging the designer to take advantage of the most advanced methods of analysis to obtain freedom of expression.

A thorough knowledge of its provisions will mean less time and effort for the solutions of framing techniques, thus stimulating designers to explore a greater range of alternates in a given time.

With its accompanying Commentary, the Specification and Appendix now becomes the backbone of modern steel construction. Architects and engineers will create simpler, more interesting structures; contractors and building code officials will have a clear guide to safe, sure construction; and owners will be guaranteed dependable and economical steel buildings designed for their specific needs.



Cross section shows how the roof gives visitors an unobstructed view of the huge cylindrical painting of Pickett's charge. An acoustical plaster ceiling controls sound focus.

Here's where thousands of Americans will be

REFIGHTING THE CIVIL WAR

No engineer worth the name will give his undivided attention to the same things as the average American visiting the Cyclorama Building at Gettysburg (Pa.) National Military Park. Emerging from a ramp onto the Cycloramic platform, most viewers will concentrate on the 253-ft-long, 26-ft-high oil painting of Pickett's doomed charge toward Cemetery Ridge, which envelops them in a 360-degree circle. As the sounds of firing muskets and bursting shells come realistically at them from the scene of the battle, they will all but take part from the beginning of the attack until the smoke lifts, the fighting is over and Lincoln's immortal Gettysburg address is heard.

Meanwhile, however, engineers will probably try to determine how this unusual structure permits a completely unobstructed view of the whole painting.

Done in the 1880's, the huge picture has toured the country as a commercial enterprise and been shown in movies and on TV–but never so effectively as in this uniquely designed building. The painting demanded a climate-controlled space in which it could be viewed from a central platform and approached without interfering with canvas or view.

Architects Neutra & Alexander with structural engineers Parker, Zehnder and Associates, both Los Angeles firms, wanted an economical means of spanning the 347½-ft-diameter structure without interior columns. A simplified form of steel trusses in an inverted conical plane was chosen, for ease of fabrication and erection, and elimination of secondary stresses.

Five 122-ft-long radial trusses frame into a 3½-ft-diameter, 18-ft-high cylindrical center post, hub of the hung roof. The bottom chords of each truss are bridge strand assemblies, the upper chords are two tapered girders. Steel purlins extend from girder to girder to give the roof continuity.

During construction, the center post was supported by a temporary column while all steel was erected. With the center post plumb, the strands were equally tightened to lift the post just free of the temporary support. The initial position of the center post had been calculated to be about six inches higher than the final elevation desired. All subsequent loads – gypsum deck, roofing and acoustical plaster ceiling – caused equal stress increases in all truss members, which dropped the post to its calculated final elevation.

The structure was designed for the National Park Service of the Department of the Interior. Orndorff Construction Company, Inc., New Cumberland, Pa., was general contractor on the million-dollar facility, completed in December during this first year centennial celebration of the Civil War. Dedication will be July 1, 2, & 3, 1962, anniversary dates of the famous battle. Cumberland Bridge Company of Camp Hill, Pa., was the structural steel fabricator.

Much like the lid on a frying pan, the cable-suspended roof of the Cyclorama building is a separate structural entity, created by the unique interaction of steel girders, king post, strand and purlins. The structural system is in the shape of an inverted cone.

NEW RULES FOR STEEL CONSTRUCTION

by D. E. Stevens
Senior Regional Engineer, AISC

Much as modern meat packers boast the use of "everything but the squeal," the new AISC Specification packages more liberal techniques for utilizing every ounce of steel's full strength. Based on extensive research into the behavior of steels under load, and recognizing advances in structural design methods, this Specification will mean greater economy and efficiency with no sacrifice of structural integrity.

The first Specification for structural steel was issued in 1923 and quickly became a design bible. In 1936 it was revised to reflect the ASTM-authorized increase in A7's minimum yield point from 30,000 to 33,000 psi, and in 1946 the Specification was revised to include welding standards and to reflect design refinements resulting from research.

In the past few years, supplementary rules to the Specification have been issued to cover such new developments as plastic design and ASTM A36 steel.

The 1961 revision is the most comprehensive change ever made to the AISC Specification. Many significant advances in materials, design and fabrication are recognized, and criteria for their use are established. Underlying many of the improved provisions is the recognition that **proven strength** is the soundest engineering approach. This concept makes possible the fuller utilization of steel's inherent strength with no reduction of well-established factors of safety.

For the first time, the Specification provides rules for design with a whole spectrum of new steels with different properties applicable to specific needs. In addition to the well-known A7 and A242 grades, the Specification presents the design criteria for:

A373 (32,000 psi): low carbon and manganese for controlled weldability, especially in thicker members.

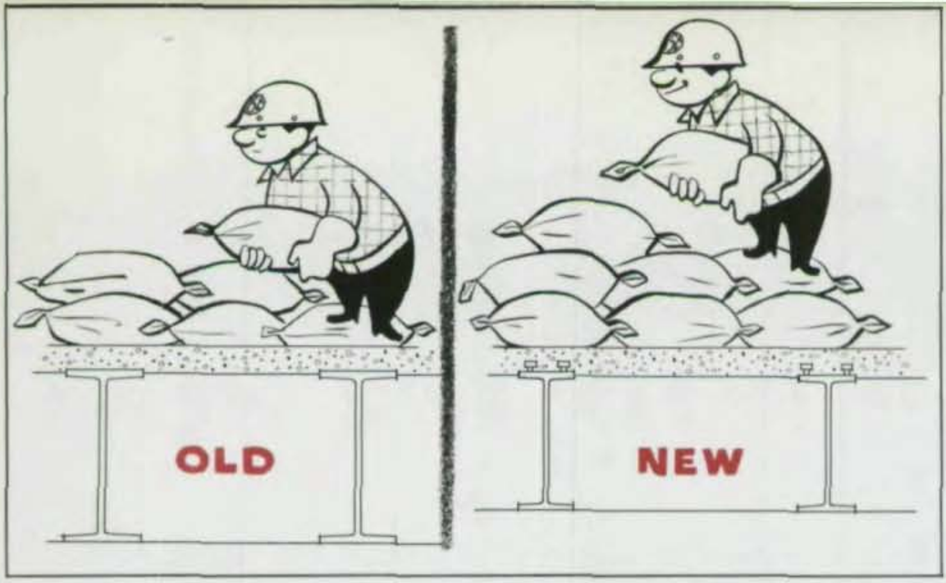
A36 (36,000 psi): higher strength with controlled weldability.

A440 (50,000 psi): still higher strength for riveted and bolted construction.

A441 (50,000 psi): equal to A440 with excellent weldability and improved impact properties.

The Specification also reflects the post-war advances in fastening methods. While the old Spec recognized only one grade of rivet steel, the 1961 revision has three. New provisions for E60 and E70 electrodes are included; there's a new standard for automatic welding, and two grades of steel for high strength bolts are allowed.

The two column sections shown have the same load-carrying capacity, but the new high-strength member weighs 24 per cent less than the carbon steel (old). There are additional savings in fabrication cost through the elimination of cover plates.



Joining concrete and steel in composite design results in an integral structural unit with much more strength than given by the sum of the two parts.

New Formulas for Working Stresses

To simplify the use of these steels, new formulas are presented that express working stresses in terms of specified minimum yield-point stress. The working stresses reflect more refinements based on actual behavior of steel structures under load. More recognition is given to factors such as compactness, plasticity, the presence or absence of lateral support, symmetry and shape.

Savings Through Composite Design

Another area of savings is in the use of composite design – the joining of steel beams and concrete deck into an integral floor system. The new combination can support as much as 35 per cent more load than the same elements in older designs, or the same load can be supported by lighter steel sections.

Shear connectors – continuous spirals, steel channels or studs – are welded to the top flanges of beams to be embedded in the concrete slab when the deck is poured. The slab by extension then becomes the flange of a composite T-beam. The Specification includes the latest results of research which requires fewer shear connectors. The required number can be computed on the total shear for uniform spacing along the beam flange. This means reduced detailing, fabrication costs and faster erection.

Economical Plate Girder Design

Research pay-dirt panned out a rich reward on AISC-supported inquiries into economizing plate girder design for buildings as well as bridges. "Without sacrificing structural safety, more efficient and more economical plate girders can now be designed," says Swiss engineer-scientist Konrad Basler who pioneered the work at Lehigh University.

According to Dr. Basler, "Earlier design specifications assumed that the limit of structural usefulness in a plate girder was reached when the intensity of shear stresses in the web reached a theoretical buckling stage. While such a stage does measure the strength of a column, analysis and experiments clearly demonstrate that the plate girder web is capable of carrying loads far in excess of those producing the theoretical 'buckling stage.'"

"This added capacity is due to the formation of 'tension fields,' long recognized in aircraft design. Under the new theory, transverse stiffeners act as compression struts in conjunction with tension fields functioning as diagonals to form a Pratt truss."

Other Provisions

This article has briefly discussed the alterations which will affect the main members of the structure, but there are also many new provisions which make possible new economies in details:

The 1956 plastic design rules have been updated and revised to include the requirements for the use of A36 steel.

Higher allowable bearing stresses for steel-on-steel and steel-on-concrete; more effective use of fasteners in connections.

New column formulas based on the latest recommendations established by the Column Research Council provide more accurate column design.

More liberal requirements as to minimum thickness of material.

New column formulas for the design of compression members.

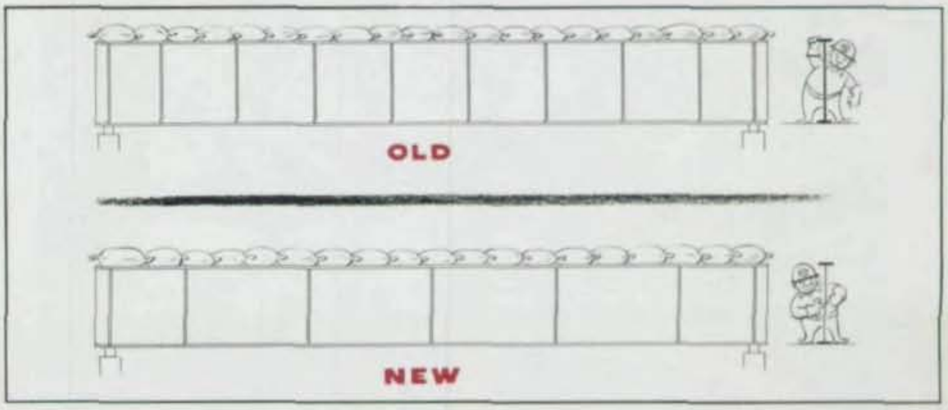
New interaction formula to cover combined bending and compression stresses.

New reduction formula for members subject to lateral buckling which gives a better appraisal of the buckling strength of deep beams and girders.

More realistic provisions relating to the use of built-up members such as box girders.

T. R. Higgins, AISC director of engineering and research, who has shepherded the Spec through its many drafts, summarizes it as "permitting a more economical and more imaginative use of steel than has ever been possible before. The physical research on the behavior of steels under load has given us clearer insight into its intrinsic strength. Now, the designer is free to create a simpler, cleaner, more interesting structure, far enhanced in beauty and utility, yet achieved at lower cost."

New Specification rules for plate girder design permit thinner webs, fewer transverse stiffeners, and less costly fabrication. The combined savings can reduce the cost of girders by as much as 20 per cent.



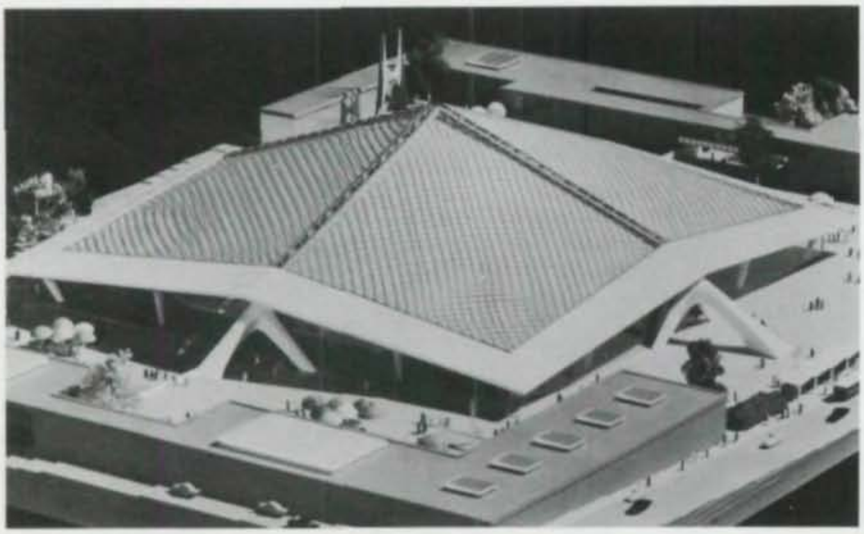
For a big problem of Man in the Space Age, structural steel provides down-to-earth answers.

STEP INTO THE NEXT

That's the invitation of the World's Fair of 1962 in Seattle, Wash. To help their designers achieve a fitting setting, the Fair's planners allowed free choice of suitable building materials. Result: the two most significant structures are built with steel.

The choice is particularly appropriate, for the Century 21 Exposition, as the Fair is called, takes as its theme "Man in the Space Age." Steel is not only cutting a swath in outer space, but it is also the material best suited to solve that pressing space problem closer to home: accommodating the population explosion.

The gigantic coliseum demonstrates one of steel's answers: it encloses a three-acre area 11 stories high without a single interior column to eat up space. With the Fair's keynote building, the Space Needle, steel offers another dramatic answer to the question of where —and how—you go when the ground gets crowded: Up.



COLISEUM CENTURY 21

During the Fair (April 21-Oct. 21, 1962), Coliseum 21 (below) will feature a "floating city" showing how man will live, work and play in the coming century. It will later be converted into a giant sports-convention facility. The sweeping roof with clear span of 360 ft in each direction is supported by steel compression trusses springing from sculptured concrete abutments at the middle of each of the building's four sides.

Trusses intersect 115 ft above the floor at the center point. Each truss is about ten feet deep, eigth feet wide at the top and four feet wide at the bottom. An inner walkway permits servicing of lighting fixtures and mechanical equipment, and provides access to a radio-TV platform at the roof's apex. Roofing is supported by prestressed steel cables held taut in a laced hyperbolic paraboloid formed by the trusses and prestressed concrete edge beams.

Paul Thiry, FAIA, designed the building. Peter Hostmark was the structural engineer; Howard S. Wright Construction Co. was the general contractor; and Isaacson Iron Works fabricated and erected the trusses. All are Seattle firms.

Some champions of steel have rightly pointed out that if buttresses, too, had been of steel, the Coliseum's ratio of space-enclosed to ground-space-consumed would have been even more impressive.

CENTURY

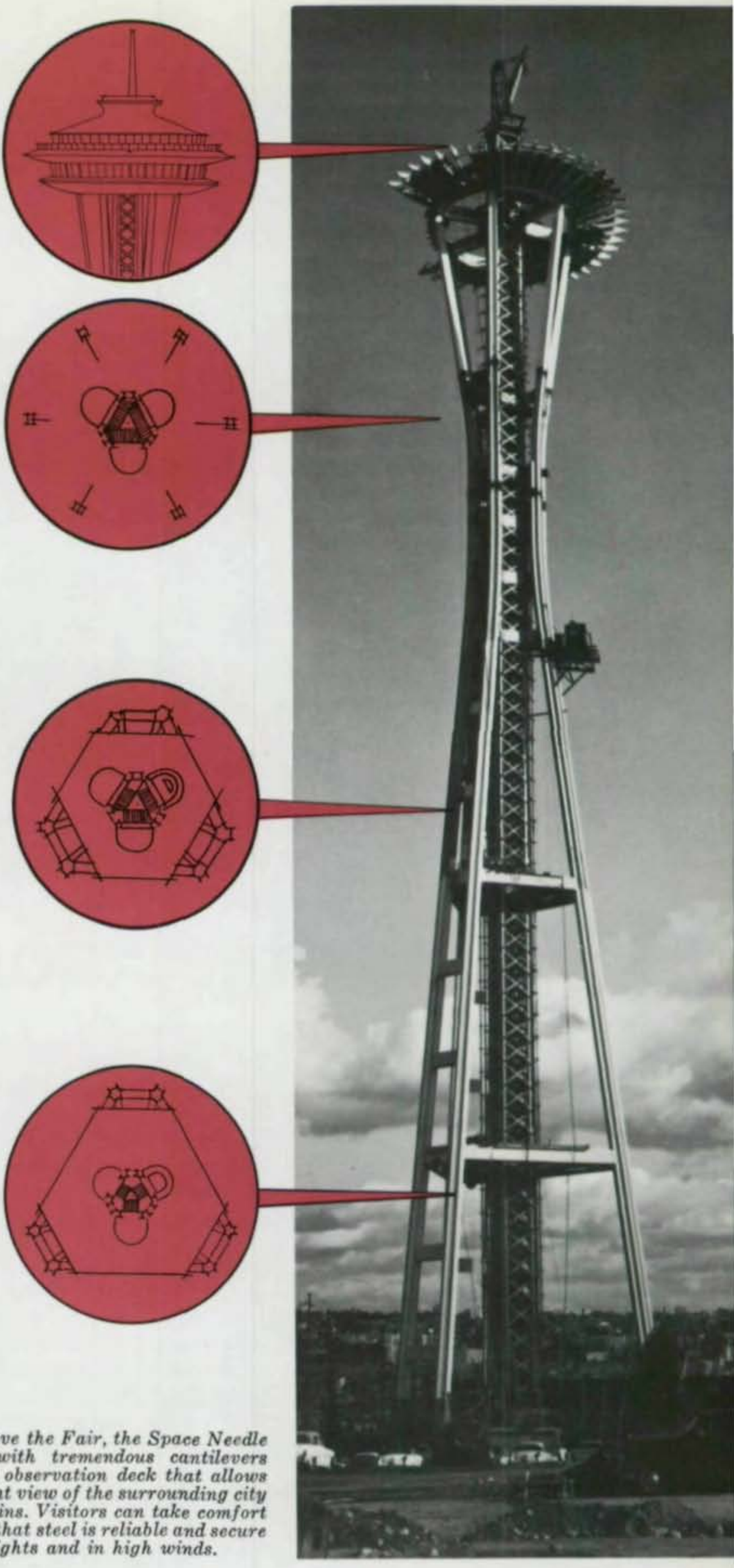
SPACE NEEDLE

The Space Needle (right), at 600 ft, is the tallest free-standing structure west of the Mississippi and the first tower of its kind in the world.

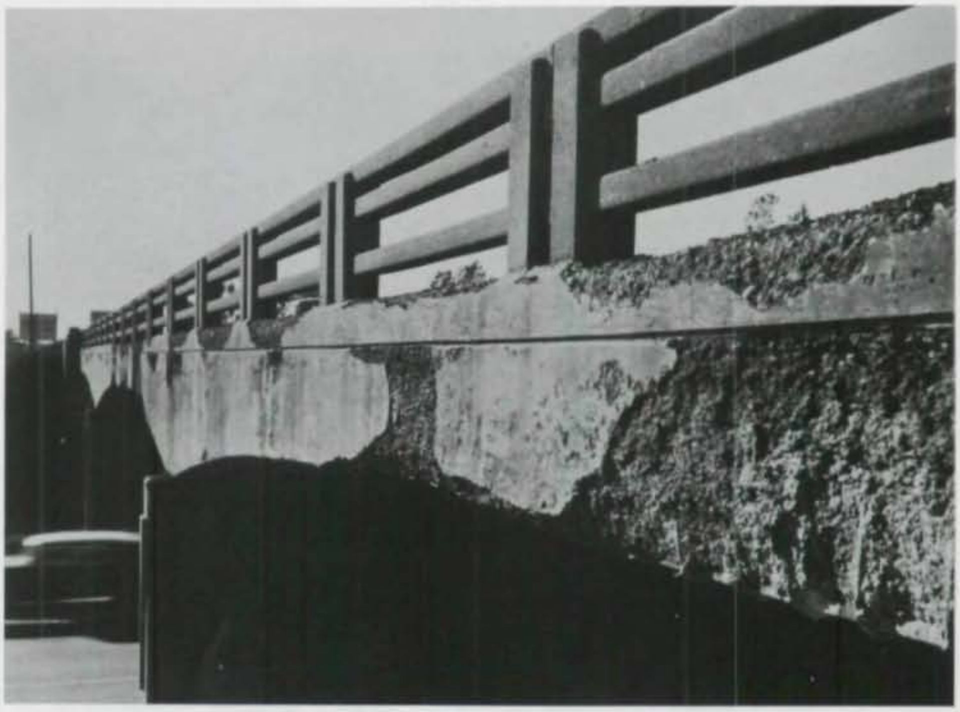
It is made up of a central utility core and three sets of tapered "legs," each composed of two steel columns. Up to the 400-ft level, each of the six columns is formed from three 36 WF300 sections. From that point, each is made up of two 36 WF300 sections. Columns throughout the full length of the Needle are joined by high tensile bolts. Between the 260- and 420-ft levels, each *pair of columns has a steel plate shirt*waist giving the effect that the columns are one piece.

The girders forming the intermediate platforms are topped with shear lugs. Concrete is poured over all, and the subsequent composite construction forms a diaphragm between the tower legs and the core. Use of A36 steel allowed increased design stress in the tower.

A unique feature of the tower construction was the upward progress through the central core of a 35-ton derrick crane which literally crawled its way to the top. Developed especially for this job, by Pacific Car and Foundry Co., fabricator and erector of the steel, it will also have practical application for building construction by doing its job from elevator shafts. Three elevators outside the core ride on rails extending out from the sides of the core and are lifted by overhead cables. Two stairways and all utilities go up inside the core. Architects and engineers for the Needle were John Graham & Co. of Seattle and New York; consulting structural engineer, John K. Minasian of Pasadena, Calif. They chose steel because of its lighter weight and speed in assembly.



Soaring above the Fair, the Space Needle is topped with tremendous cantilevers forming an observation deck that allows a magnificent view of the surrounding city and mountains. Visitors can take comfort in knowing that steel is reliable and secure at great heights and in high winds.



As may be seen 20 years of de-icing chemicals have taken a toll on this concrete bridge. Severe spalling has created hazards for motorists when chunks of concrete have fallen unexpectedly into the streets below.

STEEL SOLVES DETROIT'S

When the Michigan State Highway Department engineers decided to rebuild 17 deteriorating concrete bridges on the Detroit Industrial Expressway, they specified steel and cut construction time by over five months.

The Expressway, which is elevated over heavily travelled north-south streets, was built in 1941 to speed Detroit war workers to the Willow Run bomber plant. Because of the shortage of construction materials, particularly steel, the Bureau of Public Roads instructed the Highway Department to build with low-strength concrete, which created a number of design problems. It limited the length of spans and restricted roadway width beneath the bridges. The restrictive design also required large vertical and horizontal supporting members for the bridges.

While the condition of the expressway bridges made immediate repairs necessary, the drastic decision to demolish and completely rebuild the bridges was also affected by the crush of today's mounting highway use. The Traffic Department reports that traffic flow over this heavily travelled section of the expressway, renamed Michigan Interstate 94 Freeway, has increased 76 per cent since 1952; the daily average is 24,276 cars. Also, bridges at four intersections had to be increased from two to four lanes for both east- and west-bound traffic to provide for future expansion of the freeway to carry eight lanes of traffic. The need for building the bridges as fast as possible influenced the Department's selection of structural material.

Since both concrete and steel were in plentiful supply, the engineers had free choice for replacement in today's competitive market. Despite numerous advances of entraining and high strength that have improved concrete in recent years, structural steel was chosen.

Through the close cooperation of the fabricators, steel for both the structural members and the deck forms was made immediately available as soon as the old bridges were completely demolished and new piers built. This meant faster construction time. Prefabrication was another factor influencing the use of steel, because it meant minimum interference to normal traffic flow on the expressway and intersecting streets. Although the expressway itself had to be cut down to one lane in each direction during reconstruction, lanes of the intersecting heavily travelled streets beneath could be kept completely open.

As an example of steel's advantage of speed in construction, one bridge on the Oakwood Boulevard intersection is being rebuilt in concrete. This was done because the bridge was widened recently, and at that time the original construction was duplicated. Economics dictated that the remainder of the structure be concrete so that the new widening would not have to be removed.

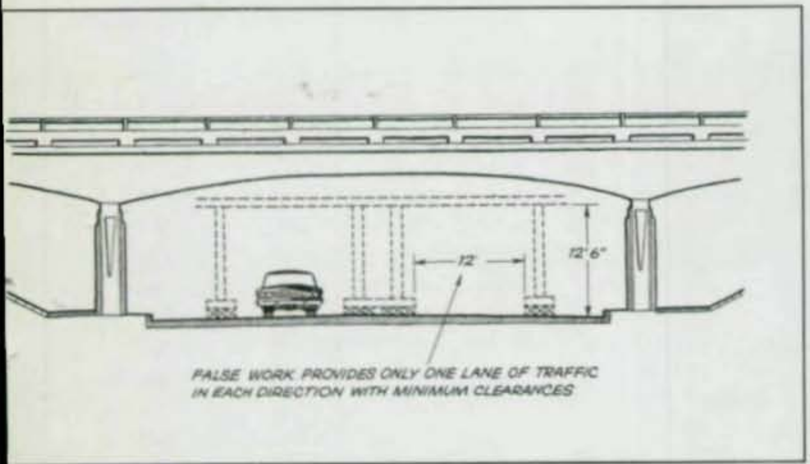
However, as shown in the diagram, the construction process at this point required the building of special, temporary piers to support the weight of the forms and fresh concrete of the 58 ft-3 in. center span. It was necessary to construct these piers in the center of Oakwood Boulevard, so that traffic flow both north and south under the expressway bridge was restricted to two, 12-ft-wide by 12½-ft-high openings. This compares with the minimum horizontal clearance on the steel spans of 49 ft allowing full use of all four lanes of the road beneath.

The design of the project is under the direction of Nelson C. Jones, Engineer of Bridge and Road Design for the Michigan Highway Department, and the construction is under the direction of P. A. Nordgren, Bridge Construction Engineer. The sections under reconstruction are on a 15-mile stretch of the Expressway between Dearborn and Ypsilanti. Unit Steel Corporation, Dearborn; Yeager Steel, Port Huron and Calsico, Chicago, fabricated the steel bridges. L. A. Davidson, R. E. Daily, and Darin & Armstrong are the general contractors.

Demolition and reconstruction started in July 1961 and will be completed by mid-January 1962. According to Highway Department officials, projects of this type are normally scheduled over a 12-month period.

The cost for the newly named Michigan Interstate 94 Freeway is budgeted at $3,100,000. The difference in first cost between the steel and concrete design is considered negligible by the Michigan State Highway Department. Long-run cost certainly was a major consideration in terms of time saved by the state, driving time and tempers of the Detroit drivers, and future maintenance costs of the actual bridges. Someday the concrete wearing surface may have to be replaced, but the bridges will long outlive the highway itself.

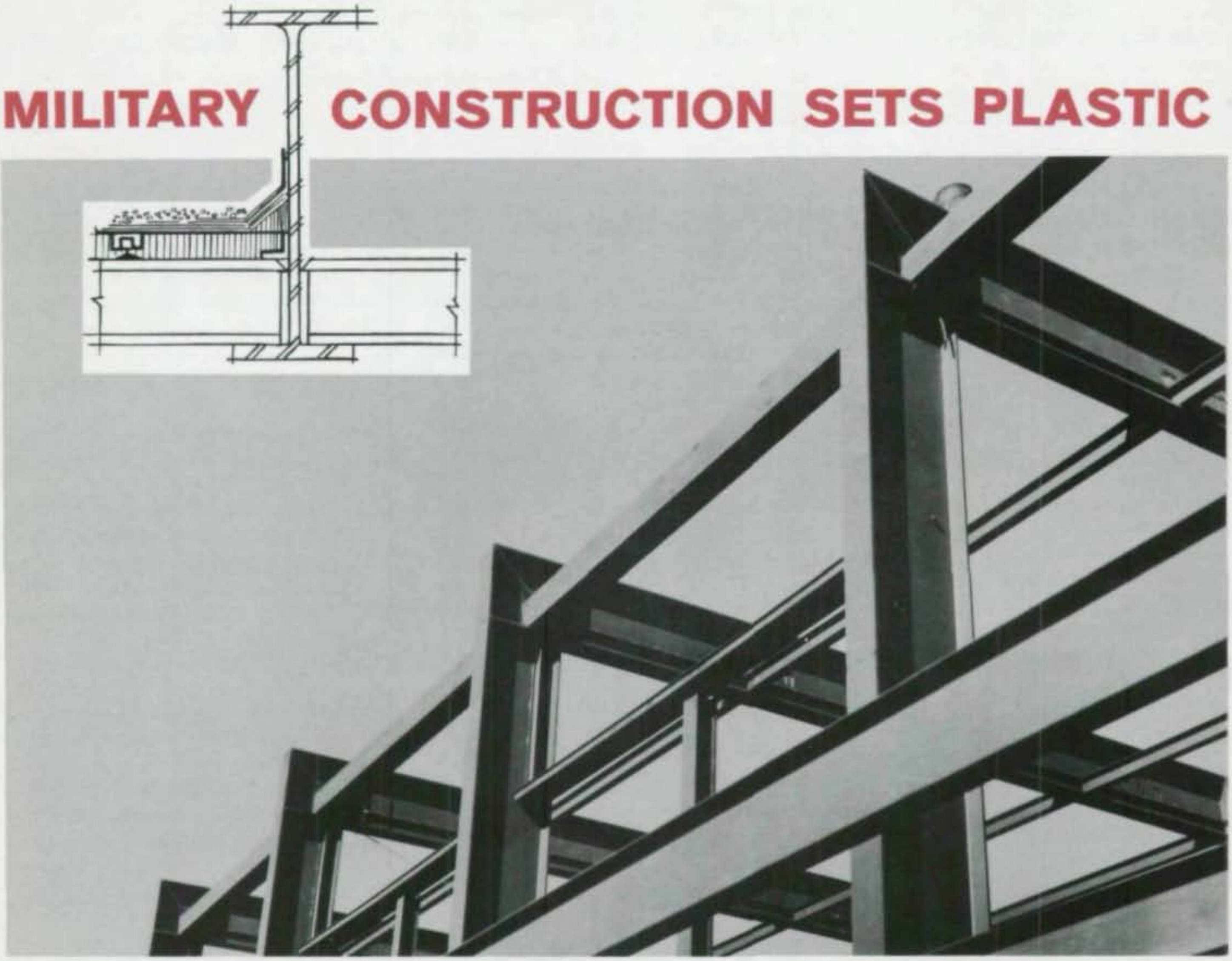
BIGGEST TRAFFIC JAM



Artist's sketch is taken directly from a section of a print of the one bridge being rebuilt in concrete. Sketch shows temporary falsework needed to support the forms and freshly poured concrete.

With structural steel, no form work is necessary. A major factor in the decision to use steel is the minimum interference to traffic permitted during construction and much speedier erection.

MILITARY CONSTRUCTION SETS PLASTIC



Seven rigid-frame bents span the Armory's drill hall and Sports Arena. Each bent weighs 15 tons and spans 120 ft.

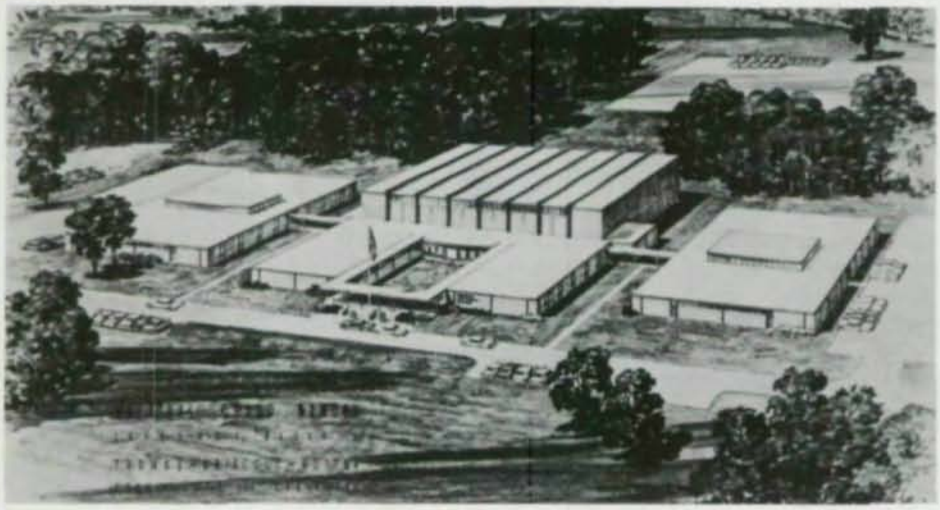
by Earl Bodron, Lieutenant Colonel, CE, Ga. ARNG

Two "firsts" are prominent in the National Guard Armory, Savannah, Ga. For one thing, plastic design had never been used previously in military structures—at least as far as those of us involved in this project knew. Then, too, the rigid-frame bents that span the 120-ft drill hall are among the longest steel spans ever erected in plastic design.

By using the theory of plastic design, architects Thomas, Driscoll, & Hutton of Savannah were able to reduce by 15 per cent the amount of structural steel required, as compared with the steel requirements of the conventional elastic theory of design.

In planning the Savannah Armory, structural steel designed by the plastic theory was selected over competitive materials for several reasons: The relative lightness of the steel frame minimized difficulties created by poor subsoil conditions and saved on foundation construction costs. The architects were permitted a wide flexibility of design, resulting in a column-free span over the drill hall without the usual deep-truss or

DESIGN RECORD



The Armory is a complex of three buildings linked by covered walkways. The flanking buildings each contain four company-sized units.

ponderous superstructure. A lightweight steel frame proved to be best suited to military needs, municipal requirements and a limited budget.

The central structure of the Armory contains two headquarters and administration wings, and a drill hall which will seat 5000 when used as a sports arena. Seven 120-ft-long rigid-frame bents, 20 ft center-to-center, span this arena, with a clear height of 30 ft. Each weighs 15 tons. Designed under the plastic theory, these bents were fabricated of 33WF125 sections, resulting in a depth-span ratio of 1:44.

Eight-inch purlins are framed into the bottom of the wide-flange section, with the result that the major portion of the frame is exposed outside the building.

By exposing the steel in the central structure, and in the flanking buildings as well, the designers were able to derive an aesthetic as well as a functional character from the steel frame.

In the words of the architect: "Steel offered itself as an integral part of the architectural expression of the project."

The flanking buildings each contain four company-size units. That portion of the steel framing adjacent to the exterior walls of these two lower buildings has also been placed outside the building and free of the walls. The exterior columns support 12-in. channels which act as a fascia, and also carry the 12-in. light beams for the roof framing system.

Construction of the Armory is characterized by the extensive use of steel, not only as a structural system, but also as frames for windows, canopies and glass curtain walls. The masonry walls and the windows are non-load-bearing, and merely act as opaque and transparent screens.

Cost for the 66,000-sq-ft project is $624,500 or $9.47 per sq ft. This included necessary parking facilities. Construction was started in August, 1960, and was completed this past summer.

The Armory certainly represents a landmark in military design, and it is interesting to speculate about the probable savings in weight had A36 steel been available when the design was made. It probably would have amounted to an additional seven per cent.

SIMPLIFIED DEFLECTION CALCULATIONS

BY IRA HOOPER

The present trend to long, slender spans in buildings requires the frequent computation of beam deflections. This article, by an Associate of Seelye, Stevenson, Value & Knecht, Consulting Engineers, New York, develops rapid methods for determining the deflections of simple-span beams of constant section, with several types of loading. Beam materials considered are steel, aluminum, wood, reinforced concrete, and composite steel-concrete; effects of creep and shrinkage in concrete are also included. (Effect of end-fixity will be the subject of a subsequent article.) For purposes of this discussion, it should be noted that high precision is not usually required for a deflection calculation, since it is a check after the strength of a member has been established.

As an example of the simplified method, consider the following formula for the deflection of a simply supported beam, uniformly loaded, designed for 20,000 psi. The formula will be derived after the example.

$$\Delta = \frac{L^2}{100c}, \text{ where} \qquad (1)$$

Δ = deflection (in.)
L = span (ft)
c = distance from neutral axis to extreme outer fiber (in.)

For a 14 WF 34, spanning 25 ft, designed for 20,000 psi:

$$\Delta = \frac{(25)^2}{100\text{x}7} = \frac{625}{700} = 0.89 \text{ in.}$$

The computation is simple and can be done mentally; the basic formula can be memorized easily.

Basic Formula

The derivation of formula (1) follows. For a simple span with uniform load:

$$\begin{aligned} M &= \frac{wl^2}{8} \\ s &= \frac{Mc}{I} = \frac{wl^2c}{8I} \\ \Delta &= \frac{5wl^4}{384EI} = \left(\frac{wl^2c}{8I}\right)\left(\frac{5l^2}{48Ec}\right) \\ &= \frac{5}{48}\left(\frac{s}{E}\right)\left(\frac{l^2}{c}\right) \\ &= 15\left(\frac{s}{E}\right)\left(\frac{L^2}{c}\right) \qquad (2) \end{aligned}$$

Formula (2) is general and can be applied to any material by the proper choice of s and E. For A7-type steel:

$$\Delta = 15\left(\frac{20{,}000}{30{,}000{,}000}\right)\left(\frac{L^2}{c}\right) = \frac{L^2}{100c}$$

For other materials (Table I):

$$\Delta = K_{\text{Mat'l}}\left(\frac{L^2}{100c}\right) \qquad (3)$$

$$K_{\text{Mat'l}} = \left(\frac{s}{E}\right)\left(\frac{30{,}000}{20}\right) = 1500\left(\frac{s}{E}\right)$$

Steel, wood, and aluminum beam sections are generally symmetrical and c is equal to one-half of the depth. Concrete beams are usually critical in the steel reinforcement that is designed to resist moment with a stress of 20,000 psi, assuming c as 0.60 d for balanced design and assuming E for 3000 psi concrete as 3,000,000 psi. For composite beams, the designer usually prepares tables of section properties of typical members including values of S and c. ("Composite Construction," JULY 1960 P/A.)

Effect of Nonuniform Loading

Deflection of a beam is a function of the area of the moment diagram. A moment diagram can be chosen (Table II) that closely approximates most actual conditions.

Creep

For concrete beams, the use of c as 0.60 d in formula (3) will result in the deflection for short-term loading; under long-term loading, creep will reduce E, for 3000 psi concrete, from 3,000,000 psi to about 1,000,000 psi, which accordingly will increase the beam limberness by about 50 per cent (Appendix A). Allowance for increased deflection due to creep is obtained by multiplying the proportion between long-term load and total load by 50 per cent:

$$\begin{aligned} \Delta_{\text{Creep}} &= 0.50\Delta\left(\frac{DL+\frac{1}{2}LL}{DL+LL}\right) \\ \Sigma\Delta &= \Delta + \Delta_{\text{Creep}} \\ &= \Delta\left[1+.50\left(\frac{DL+\frac{1}{2}LL}{DL+LL}\right)\right] \\ &= \Delta K_{\text{Creep}} \qquad (4) \end{aligned}$$

It is apparent that $1.25 < K_{\text{Creep}} < 1.50$.

For composite beams, the designer prepares tables of typical sections that give values for S and c for both values of E—3,000,000 psi for short-term loading and 1,000,000 psi for long-term loading. Deflections for long- and short-term loads are calculated separately and added.

Shrinkage

Concrete shrinks about 0.00045 times its length. In a simple reinforced-concrete beam, or a simple composite-steel beam, the deflection caused by shrinkage is similar to the deflection caused by a uniform moment for the full length of the beam, so that the unit shortening of the concrete plus the unit lengthening of the steel equals 0.00045. This deflection is shown (Appendix B) to be about

$$0.48\,\frac{L^2}{100c};$$

therefore, for the rest of this article $K_{\text{Shrink}}=0.48$.

Effect of Overdesign

Formula (2) shows that deflection, Δ, varies directly as unit stress, s. If a beam is oversized, the unit stress will be reduced in the proportion of S_{Req} divided by S_{Furn}, and the deflection will be reduced by the same proportion.

Example 1

Find the deflection of a 12-in. deep aluminum beam. Alloy 6061-T6, which has been designed to span 18 ft with a concentrated load at midspan, simply supported.

$$\begin{aligned} \Delta &= \frac{L^2}{100c}\,(K_{\text{Mat'l}})\,(K_{LD}) \\ &= \frac{(18)^2}{100\text{x}6}\,(2.25)\,(0.8) = 0.97 \text{ in.} \end{aligned}$$

Example 2

Find the deflection of an 18-in. deep concrete beam that has been designed to span 25 ft with equal loads at its third points, simply supported. Include the effects of creep and shrinkage; dead loads equal the live loads.

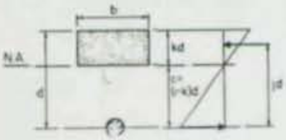
$$\begin{aligned} \Delta &= \frac{L^2}{100c}\left[K_{LD}\left(K_{\text{Creep}}\right)+K_{\text{Shrink}}\right] \\ &= \frac{(25)^2}{100\text{x}.60\text{x}16} \\ &\quad \times\left[1.02\left(1+\frac{.50\text{x}3}{4}\right)+.48\right] \\ &= 0.65\text{x}1.88 = 1.22 \text{ in.} \end{aligned}$$

Legend

c = distance from neutral axis to extreme outer surface (in.)
d = depth of concrete beam to center of steel area (in.)
E = modulus of elasticity (psi)
I = moment of inertia (in.^{4})
K = factors defined in text
l = span (in.)
L = span (ft)
M = moment (in. lb)
S = section modulus (in.^{3})
s = maximum stress due to bending (psi)
w = uniform load (lb per in)
Δ = deflection (in.)
ϵ = unit strain

Appendix A: Effect of Creep in Reinforced-Concrete Beams

As creep occurs in a concrete beam of balanced design, the neutral axis moves closer to the reinforcing steel, reducing c and j.



$$f'_c = 3000 \text{ psi}$$
$$f_s = 20{,}000 \text{ psi}$$
$$\Delta = 15\frac{sL^2}{Ec} = \frac{15ML^2}{cjdA_sE}$$
$$s = \frac{M}{jdA_s}$$
$$\frac{\Delta_{30}}{\Delta_{10}} = \frac{c_{10}j_{10}}{c_{30}j_{30}} \qquad \text{(Table IV)}$$

Appendix B: Effect of Shrinkage in Reinforced-Concrete Beams

For a beam designed for uniform moment at balanced design:

$$\Delta = 1.2\left(\frac{L^2}{100c}\right) \qquad \text{(Table II)}$$
$$\Sigma\epsilon = \epsilon_s + \epsilon_c = \frac{20 \text{ ksi}}{30{,}000 \text{ ksi}} + \frac{1.35 \text{ ksi}}{3000 \text{ ksi}}$$
$$= 0.00067 + 0.00045 = 0.00112$$

By proportion, the deflection due to shrinkage is:

$$\Delta_{\text{Shrink}} = \frac{0.00045}{0.00112} \times 1.2\left(\frac{L^2}{100c}\right)$$
$$= 0.48\left(\frac{L^2}{100c}\right)$$
$$= K_{\text{Shrink}}\left(\frac{L^2}{100c}\right) \qquad (5)$$

TABLE I: **BASIC FORMULAS;** $\Delta = K_{\text{Mat'l}}\frac{L^2}{100c}$

Beam Material	s_{ksi}	E_{ksi}	$K_{\text{Mat'l}}$
Steel, A7	20	30,000	1.0
Steel, A36	22	30,000	1.1
Wood	1.5	1,760	1.28
Glued laminated wood	2.4	1,800	2.00
Aluminum 6061-T6	15	10,000	2.25
Aluminum 2014-T6	22	10,600	3.11
Reinf. concrete	20	30,000	1.0
Composite steel-conc.	20	30,000	1.0

TABLE II: **EFFECT OF LOADING ON** Δ; $\Delta = K_\Delta\left(\frac{s}{E}\right)\left(\frac{L^2}{c}\right) = K_{LD}(15)\left(\frac{s}{E}\right)\left(\frac{L^2}{c}\right)$

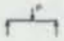
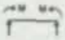
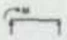
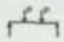
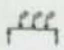
Load	Load diagram	Moment diagram	M_{max}	Δ	K_Δ	K_{LD}
1 Uniform			$\frac{wl^2}{8}$	$\frac{5\,wl^4}{384\,EI}$	15	1.00
2 Conc.—midpt.			$\frac{Pl}{4}$	$\frac{Pl^3}{48\,EI}$	12	0.80
3 Uniform moment			M	$\frac{Ml^2}{8\,EI}$	18	1.20
4 Moment 1 end			M	$\frac{Ml^2}{16\,EI}$	9.25	0.62
5 Conc.—⅓ pts.			$\frac{Pl}{3}$	$\frac{23\,Pl^3}{648\,EI}$	15.3	1.02
6 Conc.—¼ pts.			$\frac{Pl}{2}$	$\frac{19\,Pl^3}{384\,EI}$	14.3	0.95
7 Conc.—⅓ pt.			$\frac{2\,Pl}{9}$	$\frac{Pl^3}{56\,EI}$	11.6	0.77
8 Conc.—¼ pt.			$\frac{3\,Pl}{16}$	$\frac{Pl^3}{69\,EI}$	11.1	0.74

TABLE III: **SUMMARY OF FORMULAS**

Beam Material	Combined Formula
Steel, aluminum, wood	$\Delta = \frac{L^2}{100c}\left[K_{\text{Mat'l}} \times K_{LD} \times \frac{S_{\text{Req}}}{S_{\text{Furn}}}\right]$
Concrete	$\Delta = \frac{L^2}{100c}\left[K_{LD} \times K_{\text{Creep}} + K_{\text{Shrink}}\right]$
Composite	$\Delta = \frac{L^2}{100c}\left[K_{LD} \times K_{\text{Creep}} \times \frac{S_{\text{Req}}}{S_{\text{Furn}}} + K_{\text{Shrink}}\right]$

TABLE IV: **EFFECT OF CREEP**

$p = \frac{A_s}{bd}$	$n = \frac{E_s}{E_c}$	K	$c = (1-K)d$	$j = 1 - \frac{K}{3}$	cj	$\frac{c_{10}j_{10}}{c_{30}j_{30}}$	Remarks
.0136	10	.403	.597d	.866	.517d		Assume 1.50 as conservative average
(balanced)	30	.585	.415d	.805	.334d	1.55	
.0068	10	.31	.69d	.90	.62d		
(half of balanced)	30	.47	.53d	.84	.45d	1.38	

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HOW GLOBE-UNION GOT THE MOST FOR ITS MONEY

Structural steel framework for Globe-Union is wide-flange exterior columns, five-inch pipe interior columns, wide-flange beams, and open webbed joists five feet on center.

Basic bay system is 25 x 40 ft with the joists spanning the entire 40 ft. The sizes of steel joists and their spacing was determined by the span of the metal deck

For its branch factory and office building in Geneva, Ill., Globe-Union, Inc. of Milwaukee, Wis., got just what it wanted – for only $11.74 per square foot. The key to success: structural steel used in the most up-to-date way.

The foremost building requirement of this battery-producing company was maximum flexibility, not only for the present but for future use when processes or even products may change. The minimum safe structure installed now made use of plastic design with cantilevers every other bay and simple beams between the cantilevers. The structure could readily and easily be strengthened to meet any future need. Meanwhile, the large spans permitted by steel framing offer maximum versatility in the use of present space.

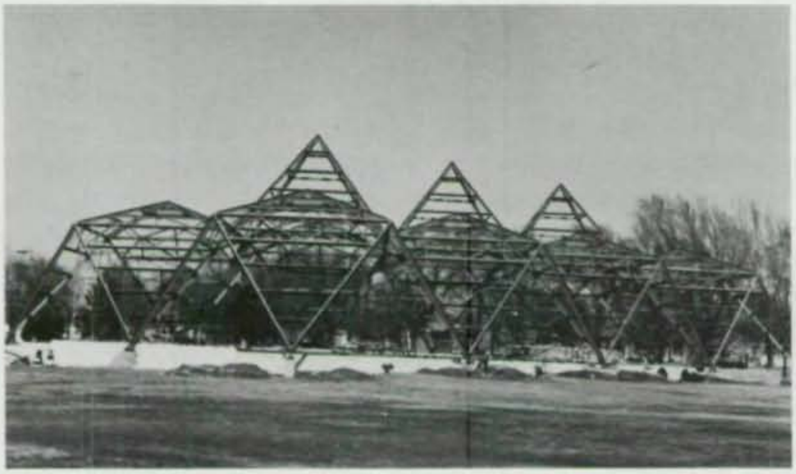
The building is as attractive as it is functional. Exposed steel in the architectural design inexpensively and effectively expresses the clear statement of structure. Aesthetic pleasure is derived from the proper proportioning of the simple structural elements.

Putting the framework outside the exterior walls not only created this ordered, well-detailed effect, but also provided a clean, straight, uninterrupted surface on the inside wall to facilitate easy housekeeping, an important consideration in the manufacturing process.

Other plusses the company appreciated in its new building: fast erection (no structural material goes up so quickly as steel); a man-made lagoon in front of the building; 300-degree hot water heating and ventilating system in conjunction with the extensive exhaust suction system for the manufacturing process.

Total cost of the 107,875-sq-ft building, excluding only fees, land and landscaping, was $1,266,340. Architect was Charles H. Harper Associates, and structural engineer was Robert J. Strass, Inc., both of Milwaukee. Henry C. Beck, Inc., Atlanta, Ga., was the general contractor, and steel fabricator was B. L. Montague Co., Inc. of Charleston, S. C.

PYRAMIDAL SPACE FRAME GLAMORIZES SWIMMING POOL



After the structural steel frame was in place (above), the three high pyramids were covered with triangular sections of translucent white plastic and the remainder of the structure was sheathed in corrugated aluminum (below). The interior beams were painted boat-blue and left exposed.

The roof over a swimming pool is usually a very plain structure. However, when the Whitaker State Orphans Home at Pryor, Okla. decided to put a roof over its swimming pool, the design of the other buildings at the Home required this structure to be modern and different. And different it is!

The roof, designed to cover the pool and adjacent dressing areas, is 68 ft wide, 136 ft long and 35 ft-2 in. from the pool surface at its highest point. Because of its location over the pool, the structure forms both the walls and the roof and is supported entirely at the outside edges.

The structure was designed and constructed as a space frame in pyramidal sections of varying heights, all built on a 34-ft module. Principal beams were anchored with a rigid joint at 12 points about the perimeter of the pool on a 45-degree angle to form the three high pyramids. The beams forming the eight low pyramids intersect the high pyramids at the mid-point. All connections are fully welded. Cross beams spaced down the sides of each triangular section act as purlins for the attachment of the skin.

In conventional construction, purlins and girts are necessary to support sheathing and siding, but contribute nothing to the spanning ability of their supporting structure. In this unique design, however, purlins and girts do double duty, serving also as components of a three-dimensional system of trusses within trusses. The efficiency of this concept is demonstrated by the fact that, even though spanning 68 ft, the largest member is an 8WF13 beam.

Due to a tendency toward four-hinged arch action under wind or other unsymmetrical loading, knee bracing was required at six critical points. All other members are in the planes of the surfaces.

With as many as eight members in six different planes meeting at a single joint, exacting calculations were made in the preparation of detailed shop drawings to maintain the close tolerances required for field welding. Prior to shipment to the field, a mock-up section of each typical panel was assembled in the shop to check fabrication and assembly methods.

Architects Bailey, Bozalis, Dickinson & Roloff chose the geometric module of a clear span to fit the low job budget. By combining wall framing with roof framing the results save money and usually produce a structure of striking appearance. Contract price for the entire project was $95,762.

Architects and structural engineers, McDonald & Floyd, are both Oklahoma City firms.

Steel fabrication and erection were by Patterson Steel Company, Tulsa. General contractor was Williams Construction Co. of Pryor, Oklahoma.

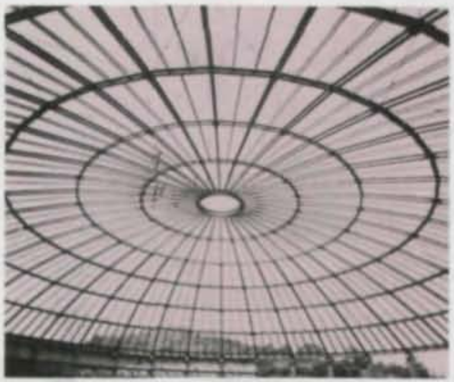
newsbriefs

BOX GIRDER ON A CURVE

A two-span continuous curved box girder will be part of the new overhead ramp complex leading from the Lincoln Tunnel to new parking levels at New York's Port Authority Bus Terminal. The eight-foot-wide box sections, which are subjected to a combination of bending, shear and torsional forces, are built of ¾-in. flange plates and ⅜-in. webs. Angle sections are provided at each corner, and tee beams are welded to the flange plates to provide stability. One span, 111 ft in length, has a 4 ft-6 in. depth. The other is 75 ft long and has a varying depth to provide headroom for a lower roadway. Radius of curvature is 67 ft. A 20-ft wide concrete slab secured by shear connectors forms a 14-ft roadway and two 3-ft wide sidewalks.

ALTERNATE DESIGN NO. 1

The 300-ft diameter domed roof for the George Leroy Manley Field House for Syracuse University provides column-free floor area for the multi-purpose building. Steel framing — 721 tons in the dome — was $194,000 cheaper than thin shell concrete. Architects: King & King; engineers: Eckerlin & Klepper; fabricators: American Bridge Division and Syracuse Engineering Co., Inc.



1961 SPEC COPIES AVAILABLE

Copies of the 1961 Specification and Commentary have been mailed to all architects and Engineers who regularly receive AISC publications. Additional copies are available free of charge through headquarters or regional offices listed on the inside front cover of this issue.

Following announcement sessions in Chicago, New York, San Francisco and Dallas, regional seminar meetings will be held in other cities for architects and engineers interested in a briefing on the provisions contained in the new Specification.

ALTERNATE DESIGN NO. 2

Engineers Severud-Elstad-Krueger saved eight percent in steel tonnage by using composite design with shear connectors for the new American Red Cross Operations & Service Center in NYC. This was accomplished without shoring requirements. The original design called for a conventional steel frame, but careful investigation showed composite design to be the most favorable. Architects: Skidmore, Owings & Merrill; steel fabricator: Bethlehem Steel Company.