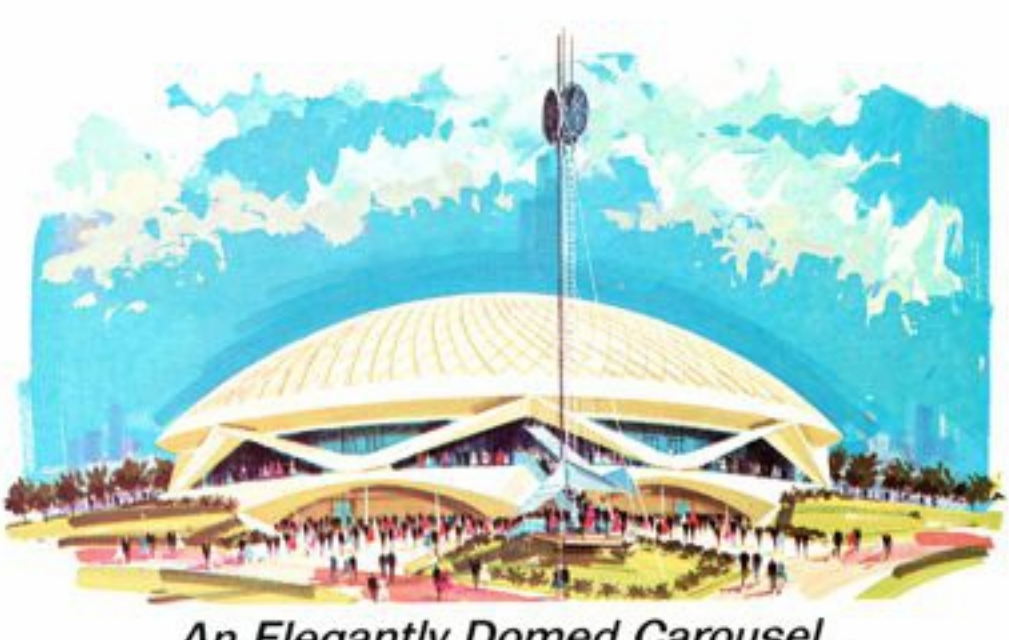


An Elegantly Domed Carousel...

A Colossal "Floating Wing"...

World's Fair Preview

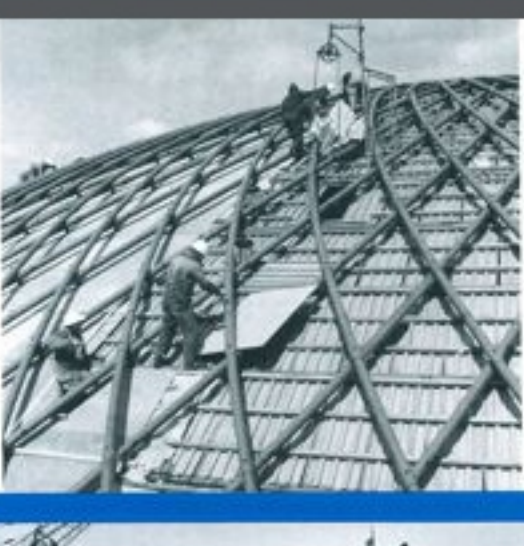
OCTOBER, 1963

A "Hovering" Hollow Square...

A New Concept in Space Structures...

...all described on the following pages

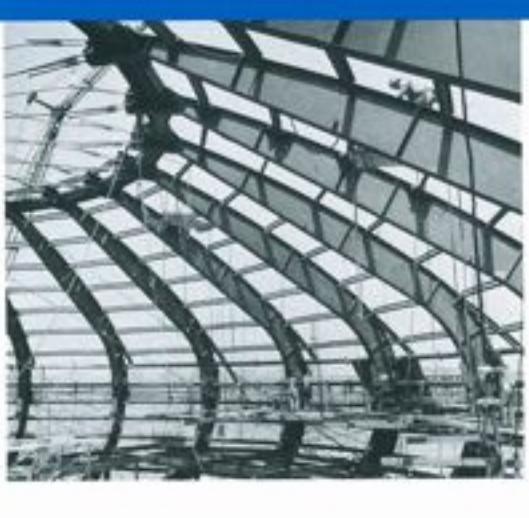
BETHLEHEM STEEL



A lamella steel pipe dome crowns the General Electric Company Pavilion

Steel U-frames connected to curving trusses frame the ride for the Bell System Exhibit

Lofty steel towers support eight giant trusses for the United States Pavilion



All-welded steel ribs, unique space structure, highlight The Travelers Insurance Pavilion

Four remarkable structures ... all framed with steel ...

fabricated and erected by **BETHLEHEM STEEL**

THE TRAVELERS INSURANCE COMPANIES PAVILION

A New Concept in Space Structures

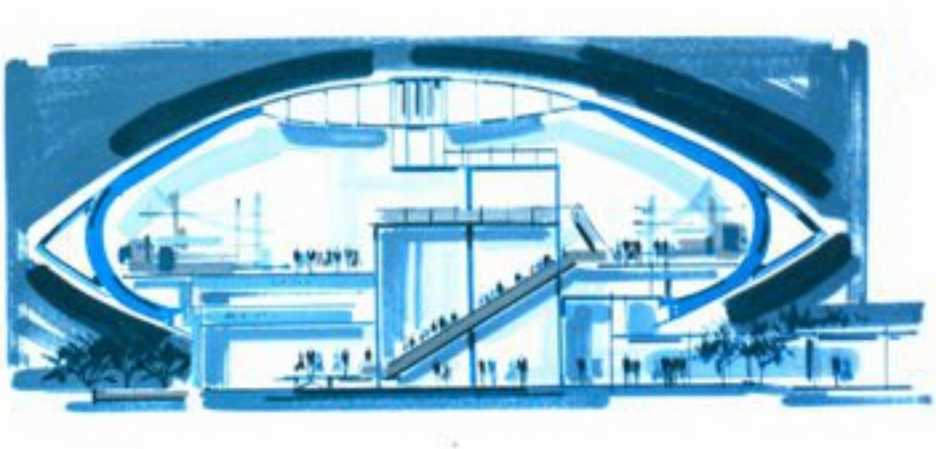
Bethlehem's crew first erected the lower halves of the ribs and the connecting purlins.

Here is a case where ingenuity in engineering design was required to produce, economically, a structure whose unusual shape was determined by promotional considerations.

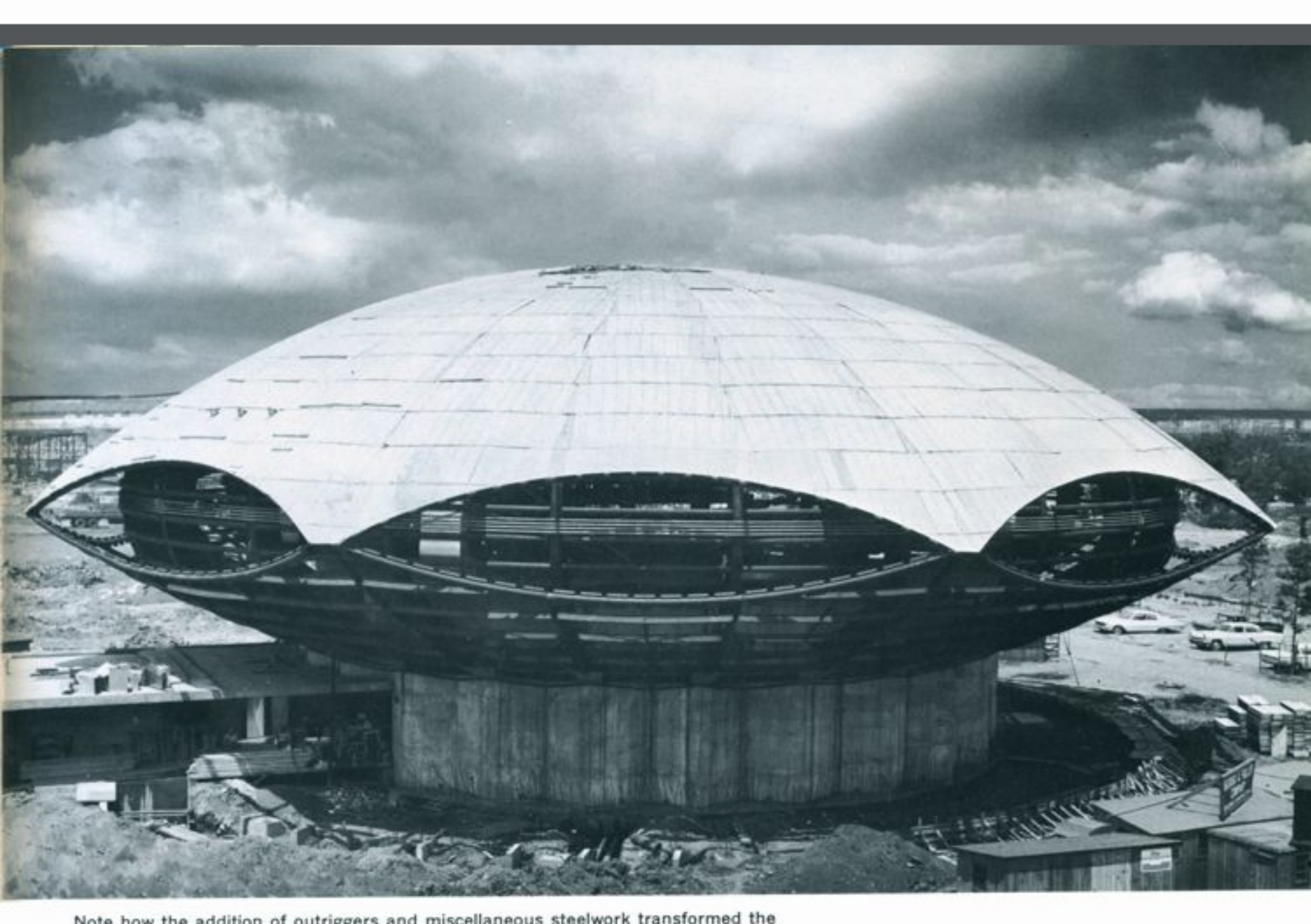
The Travelers' symbol is an umbrella, so it was essential to base design of their exhibit building on this shape. The final result was an abstract adaptation of the umbrella, mirrored by a similar form below, resulting in a scalloped-edge saucer which appears to be floating above a continuous wall of water jetted up from a circumferential pool.

Actually, the main structure is an oblate spheroid in elevation, with light outriggers added to establish the umbrella "points." It springs from abutments appended to a 23-ft-high, scalloped-edge (in plan) masonry wall which encloses the ground floor of the exhibit building. Twenty-four welded-plate ribs, shaped like boomerangs, curve up and out, then inward, leaving a 66-ft-diameter opening at the apex. Diameter of the spheroid at its equator is 132 ft. Total height above grade is 63 ft.

Next step was to erect the upper halves of the ribs (welded splices), and install purlins. Meanwhile, the tension ring was positioned on falsework. When all cables were tensioned, the basic structure was complete.



This sectional view greatly simplified, gives some idea of the interior. It does not show a free-standing, steel-framed stairwell at the approximate center of the structure. Visitors enter, ascend ramps through exhibits to an escalator, rise to the next level, and walk through additional display areas spiraling around the building, then descend to the exit. Administration and VIP offices are in the main building, with mechanical equipment in a 100 ft-long one-story wing.



Note how the addition of outriggers and miscellaneous steelwork transformed the basic spheroidal shape into that of an umbrella mirrored by a similar shape below.

Closure at the pole is accomplished with a remarkable space structure which, essentially, is a tension "hub" of steel plates, to which the outward thrust of the ribs is transmitted by steel cables.

Finally, the ribs are girded at the equator by four post-tensioned steel cables positioned in saddles fastened to the outer flanges of the ribs.

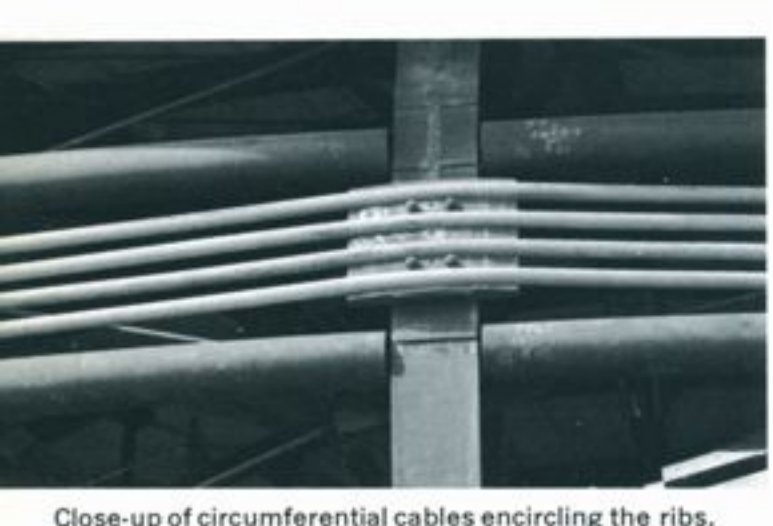
TENSION RING AT APEX

The tension plates are ¾-in. thick (upper) and 1-in. thick (lower), each equipped with twelve grooved saddles to receive the cables. The plates and saddles are held 8 ft-5 in. apart, c-c, and braced by hub framing which consists primarily of steel pipe and channels.

The cable structure uses 1¼-in. galvanized bridge strand for the top course, and 1⅝-in. strand at the bottom. Each individual length of strand, top and bottom, extends from sockets on one rib, through the saddle, and back to a neighboring rib and again socketed. The cables are spaced vertically with 3-in.-diameter pipe, the upper connections of which receive wide-flange purlins which support the roofing material.

Interior view during construction gives a better idea of the large volume of space created by this ingenious design.

The ribs extend upward and inward, and tie into a compression ring. Each cable of galvanized bridge strand is socketed to the top of one rib, runs through a saddle connected to a tension plate, and returns to an adjoining rib. Purlins atop the cable structure are solely for support of roofing material.



Close-up of circumferential cables encircling the ribs.

THE RIBS AND PURLINS

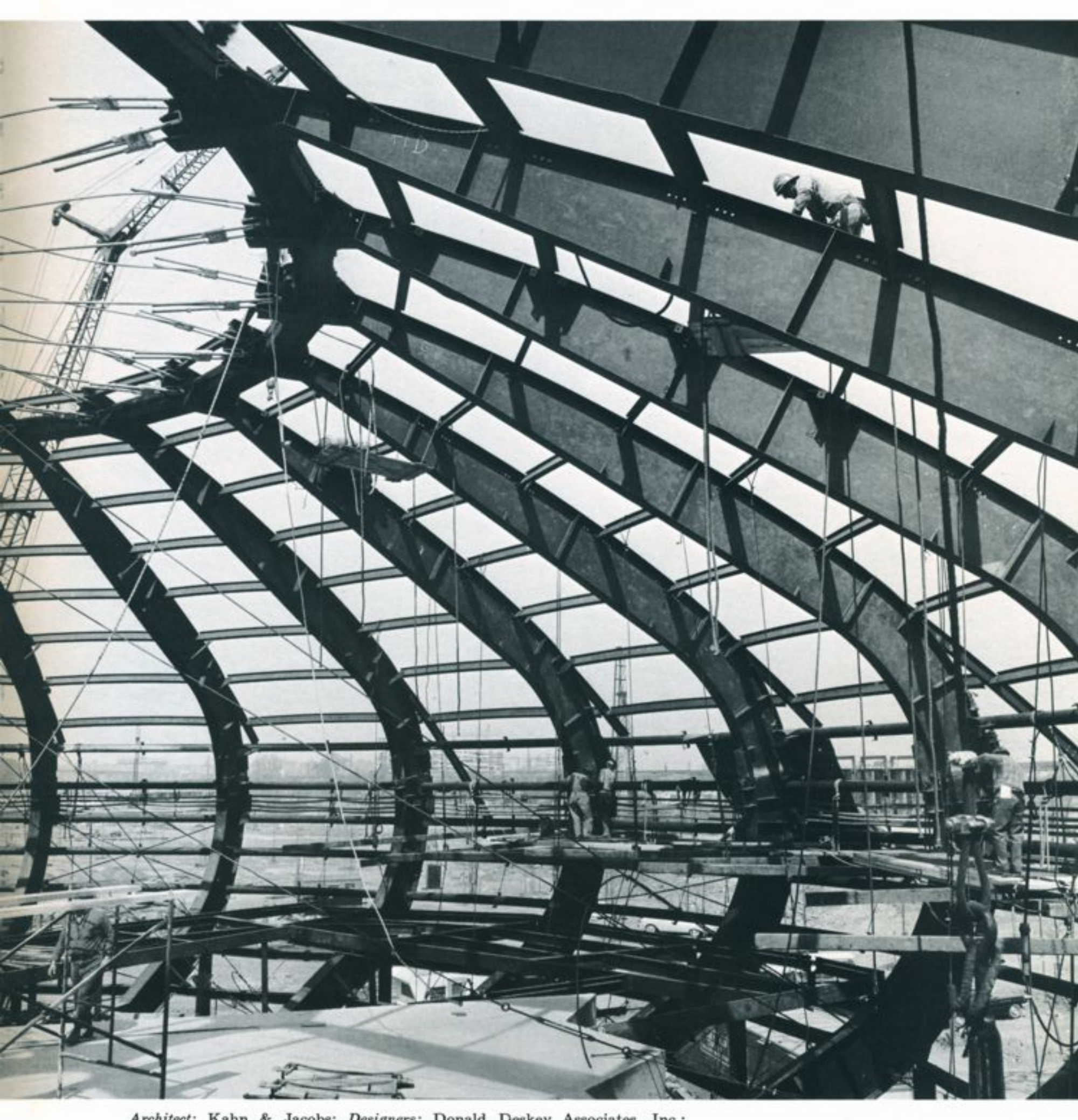
The welded-plate ribs have ¾-in. webs and 12-in.-wide flanges (thickness varies) to the height of the welded field splice, at which point the web plate changes to ⅜ in. It can be seen that the depth of the rib is only 36 in. at the "neck" of the base connection, increases to a maximum of 42 in., and measures only 16 in. at the top. Purlins are, typically, 10 B 19, on 6-ft centers, except for five courses of 8-in. pipe purlins at the equator, and edge purlins which form the sweeping curves for the "fringe" of the umbrella. All bays are braced with diagonal, 1⅛-in.-diameter tie rods.

Each rib is equipped, at the equator, with a four-grooved saddle to receive 2½-in.-diameter galvanized bridge strand cables. These cables were post-tensioned, and were designed for a working stress of 200 kips per cable. Result: avoidance of non-uniform distortions of the structure due to unsymmetrical loads.

The result is a structural system which utilizes three-dimensional prestressing, resulting in a stress pattern the opposite of what would be expected in a "conventional" clearspan structure. In a more prosaic solution the dome would be in compression and thick at the apex, as would be the junction of the ribs with the pedestals. In fact, in the very early stages, thought was given to achieving the double-umbrella shape by cantilevering trusses out from the supporting wall, and spanning the top with trusses; total weight of steel would have been about 40 psf, in comparison with the new system, which used only about 9 psf.

In addition to economy, this scheme resulted in a stable structure with an advantageous distribution of material throughout, and with a shallow space frame at the apex, allowing ample headroom. Also, it provides a maximum of usable interior space with eye-appeal and pleasing proportions. Obviously, such a system has considerable potential for arenas and auditoriums.

Note the extremely light structure of the footings and lower portions of the ribs.



Architect: Kahn & Jacobs; *Designers:* Donald Deskey Associates, Inc.; *Structural Engineer:* Lev Zetlin & Associates; *Mechanical and Electrical Engineer:* Jansen & Rogan; *Landscape Architect:* Clarke & Rapuano; *General Contractor:* George A. Fuller Company; *Steelwork:* Bethlehem Steel Company