Discussion

A Prestressed Steel Space Frame

Paper presented by PAUL ROGERS (April 1967 Issue)

Discussion by **MANU SHAH**

The structural solution of the building is no less remarkable than the building itself. The use of prestressing and preloading techniques is very interesting.

The prestressing of tension ring after preloading the compression ring does not give any added strength or stability. It only compresses the tension ring to its unloaded shape. The author does not give the exact amount of outward movement in his paper. My estimate is that columns supporting tension ring move out by about ½-in. under full dead load. This movement is hardly perceptible in a 16-ft long column and should not constitute any structural or aesthetic problem. Besides, for this building, as the structural frame does not seem to be exposed to view, it would not present any aesthetic problem even if the movement were large enough to be perceptible. Another approach to control this movement is by detailing the columns to tilt inward such that they are pushed out of plumb under full load. The preloading technique alone, without prestressing can restrain any deformations from incremental loads if such deformations are to be eliminated. Hence, the writer feels that prestressing was not the structural necessity.

The central tower seems quite heavy and placing the tower prior to roofing would have reduced the preloading loads and perhaps made the preloading unnecessary. The writer would like to know the amount of these deformations and its adverse effect on the structure.

The use of triangular trusses for roof framing seems very interesting and economical. The writer feels that more details of this aspect would have been very helpful.

Manu Shah is Project Engineer, Skidmore, Owings & Merrill, Architects/Engineers, Chicago, Ill.

Discussion by **PAUL ROGERS**

Preloading and prestressing of the structure was carried out *simultaneously*. The procedure was as follows: The 30-ft diameter compression ring was supported on a substantial shoring. Then the eight large oil cans, including sand, were attached to the supported ring. Upon completion of prestressing, the compression ring *lifted* free from the shoring.

The author believes that prestressing was an absolute necessity. Let us assume, for discussion's sake, that prestressing was omitted.

The following are just samples of distress that could have occurred:

1. Peripheral horizontally curved beams would have elongated, at 22 ksi stress, a total of 4.12 in. This would have increased the diameter by 1.31 in., or would have tilted the columns by approximately ⅝-in.
2. The curved beams, under tension, would have had the tendency to straighten out. This would have pushed the columns further out, would have distorted the beams, and played havoc with the geometry of the roof structure.
3. The 32 space trusses were bolted together at the top chord. Near the periphery, the elongation of each bolt would have been ± 4.12/32 = 0.129 in. According to Hook's Law, using ¾-in. length for bolts:

$$
\begin{aligned}
f &= ALE/L \\
&= (0.129 \times 29 \times 10^6)/0.75 \\
&= 500{,}000 \text{ psi in tension.}
\end{aligned}
$$

The whole thing would have fallen apart!

4. With the exterior diameter increasing and the diameter of the compression ring decreasing, and the top chord of the space trusses under axial and flexural compression, the compression chord would have to drop substantially to satisfy geometry. This can not be permitted.
5. Without prestressing, all the secondary member, connections, roofing, etc., would be subject to undeterminable stresses and strains, unnecessarily weakening the total structure.
6. Such an imposing structure is expected to last a long time, perhaps centuries. It is conceivable that major additions be performed in the future. Removal of *any* peripheral curved girders would precipitate failure. No one is expected to cut through four heavy cables; thus future safety is guaranteed.

The author firmly believed that prestressing steel structures brings about safety with economy.

Paul Rogers is President, Rogers-Cohen-Barreto, Marchertas, Consulting Engineers, Chicago, Ill.