Sears Tower, Chicago, Illinois (USA)

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7. Sears Tower, Chicago, Illinois (USA)

Owner: *Sears, Roebuck & Company*
Architects & Engineers: *Skidmore, Owings & Merrill, Chicago, Illinois*
Contractor: *Diesel Construction*
Completion date: *1974*

Sears Tower is the world's tallest office structure with 109 stories and a height of 1,450 ft. (442 m) above ground. It encloses 3.9 million gross sq. ft. (362,000 m²) of office space.

The non-prismatic building profile (Fig. 1) is the direct result of two different space requirements. First, Sears, Roebuck & Co. required large floor areas for their operations; and second, smaller floor areas were required for rental purposes. A logical solution to satisfy both requirements was to use a modular approach consistent with the bundled-tube concept in which an integrated cluster of framed tubes act together as one overall tube. The bundled-tube concept provided an organization of modular areas, which could be terminated at various levels to create floors of different shapes and sizes. The basic shape is composed of nine "mega-modular" areas 75 ft. (22.9 m) square, for an overall floor dimension of 225 ft. (68.6 m) square, up to the 50th floor (Fig. 2). These larger floors are suitable for Sears' occupancy. Step-backs provided by termination of megamodular areas occur at floors 50, 66 and 90, creating a variety of floor configurations ranging from 41,000 to 12,000 sq. ft. (3,800 to 1,100 m²) in floor area (Fig. 3). Such modulation of rental space maximizes rental revenue.

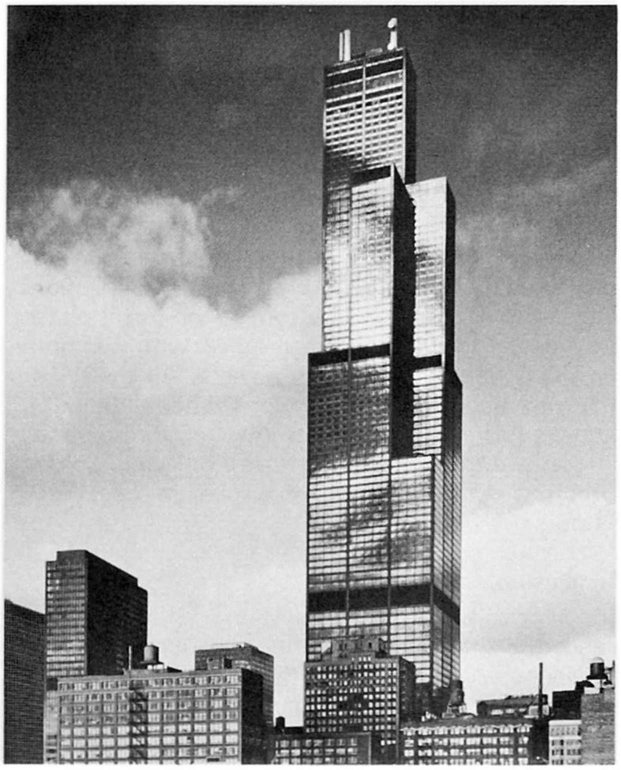

Fig. 1 Sears Tower, Chicago, Illinois

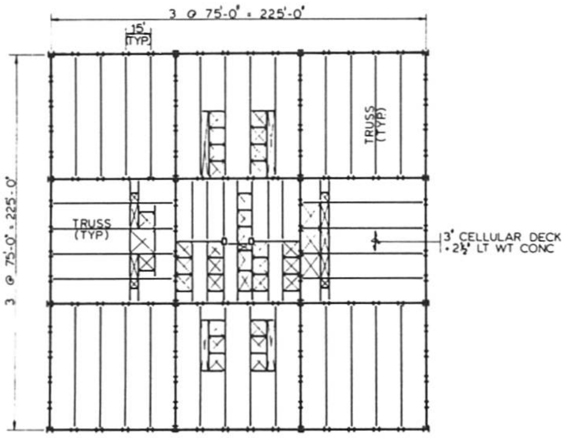

Fig. 2 Typical framing plan (levels 1 to 50) — Sears Tower

Structural System

The structure acts as a tube or vertical cantilever fixed at the ground in resisting wind loads. Nine square tubes of varying heights are bundled together to create the larger overall tube. The wall of each tube is composed of columns at 15 ft. (4.58 m) centers and deep beams at each floor; beams and columns act together as a "perforated tube" to resist wind load. Two adjacent framed tubes share one set of columns and beams. The basic character of the frame is maintained typically throughout for all floors and framed-tube lines. All beam-column connections are fully welded. At floors where floor area is reduced, setback is accomplished by termination of columns pertaining to the particular tube while the other columns continue up. Trussed levels, consisting of diagonal members between columns, are provided at three intermediate mechanical levels — two immediately below the setbacks at the 66th and 90th floors, and the third at the 29th—31st floor mechanical level.

Sears Tower's structural system, by providing the interior framed-tube lines, connects opposing façade frames at two intermediate points between the ends of the building. The two interior frames parallel to wind act as additional vertical transverse shear frames, reducing the shear lag effect in the flange frame (Fig. 4). This action reduces premium for height considerably as shown by the low unit structural steel quantity of 33 lb. per sq. ft. (161.1 kg/m²). The wind sway is about 0.3 in. (7.62 mm) per story for the design wind pressure; the fundamental natural period is 7.8 seconds. Caissons to rock are used for the column support. The caisson diameters vary from 7 to 10 ft. (2.1 to 3.0 m) and average 65 ft. (19.8 m) in length. A 5 ft. (1.5 m) thick mat was used to connect caisson tops.

Steel Fabrication and Erection

Built-up I-sections were used for beams and columns, with 39 and 42 in. (0.99 and 1.07 m) depth respectively. Column flanges vary in cross-section from 24 x 4 in. (609 x 102 mm) at the bottom to 12 x 3/4 in. (305 x 19.1 mm) at the top and that of the beams from 16 x 2-3/4 in. (406 x 69.9 mm) to 10 x 1 in. (254 x 25.4 mm). A total of 76,000 tons (69 Gg) of structural steel was used in the project consisting of A588, A572 and A36 grades.

Steel structure was systematized into shop-prefabricated modules. Each module consisted of a two-story column with shop-attached half-length beams on either side (Fig. 5). The column-beam modules are 26 ft. (7.9 m) high and 15 ft. (4.6 m) wide, and typically weight 15 tons (14 Mg). The shop fabrication eliminated 95% of field welding, and contributed to a lower price per ton of steel in place. Each modular unit was fabricated in a jig under controlled conditions to maintain close tolerances. An automatic Electroslag welding process was used for the butt welds of beams to columns. At the column-beam joints the continuity plates were fillet welded by the Innershield process. Absence of site storage space for modules dictated delivering modules to site in trucks exactly when needed. Frame module were then lifted into place (Fig. 6). Except for column splices all field connections were bolts (A490 friction bolts) for shear only. Exterior columns were insulated to limit average temperature variation in the columns.

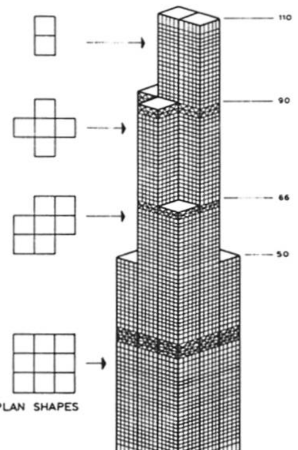

Fig. 3 Modular floor configuration – Sears Tower

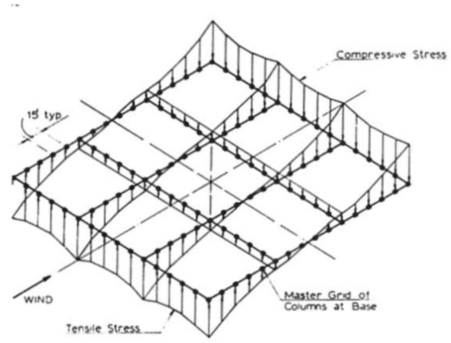

Fig. 4 Stress distribution due to wind load

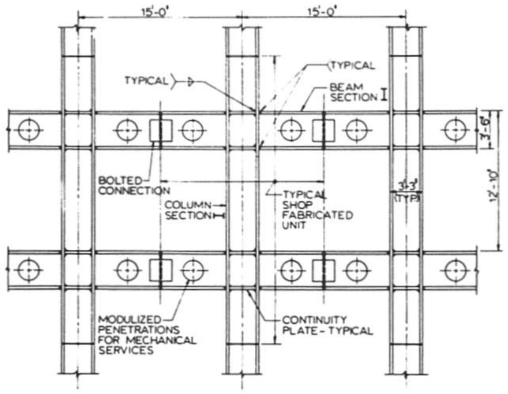

Fig. 5 Prefabricated beam – Column modules

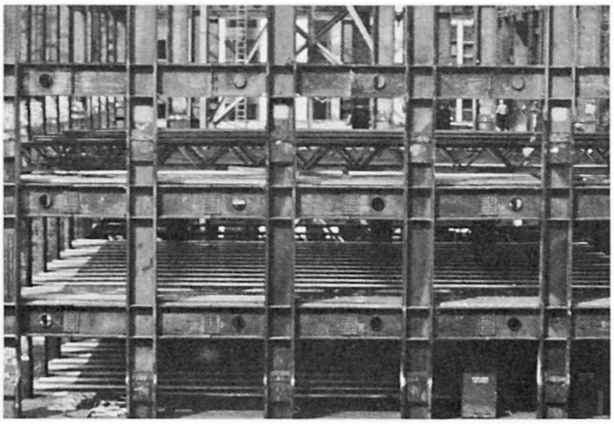

Fig. 6 Beam-column modules after erection

Floor System

The 75-ft. sq. megamodular floor areas were typically framed by one-way trusses of 75-ft. span at 15-ft. center (Fig. 2). Each truss frames directly to a column by means of high strength friction bolts designed for shear only. The span direction of these trusses were alternated every six floors to equalize the gravity loading on the columns. The trusses are 40 in. (1.02 m) deep and utilize all the available depth in the space between ceiling and floor slabs above. A 3 in. (76 mm) deep cellular metal deck with 2-1/2 in. (63 mm) lightweight concrete as used to span 15 ft. between trusses. Access for mechanical distribution ducts is provided by the triangulations in the trusses which allow a 21 in. (533 mm) diameter duct to pass through.

Conclusion

The bundled-tube system used in the Sears Tower represents a powerful concept for ultra-tall buildings. Its geometric logic allows flexibility with respect to shape and floor size modulations. The bundled-tube concept has established a new form which can be used with different clustering and different shapes for the basic module, thereby permitting considerable freedom in massing and site planning.