

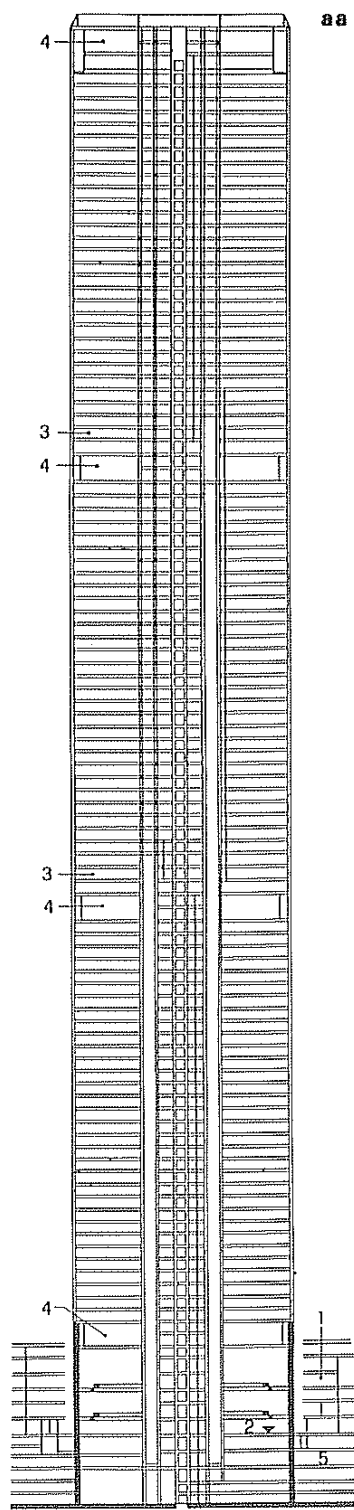
**World Trade Center,
New York, USA**

Structural design: M. Yamasaki and Associates, Troy, Michigan; E. Roth and Partners, New York.
Architectural design: Skilling, Helle, Jackson, Inc.
Completed: 1966/1973.

Function
The complex comprises two tower office blocks, each 110 storeys high, together with ancillary and 10-storey ancillary buildings arranged around the towers and a plaza. The complex provides for a capacity of 50 000 people but it also accommodates up to 80 000 visitors daily. It accommodates the premises of business insurance companies, banks and public utilities and includes a hotel.
The 110 upper floors contain open-plan offices free from internal supports, each with a net effective floor area. On five of the 110 floors are stations served by subway and rapid-transit lines, and ground parking space for 2000 cars, and facilities of various kinds. Below the ground floor and in four levels are air-conditioning and other technical services.
Each of the tower blocks has 100 passenger lifts and four goods lifts. A lobby on the 4th floor and two skylobbies, on the 44th and 104th floors respectively, subdivide the tower into three circulation zones. Each zone is connected by eleven or twelve elevators to the ground floor. From each of the skylobbies 24 local lifts give access to the office floors. Furthermore, five express lifts stop from the ground floor to the 110th floors. As three local lifts, and five the other, can operate in the same shaft, only 56 shafts are needed to accommodate the 104 lifts in the building. The shafts occupy 13% of the area of each floor. Maximum transit time, including waiting time of lift, is 2 minutes. In an emergency, an occupied tower block (assuming it to contain 55 000 people, including visitors) can be evacuated in 5 minutes.

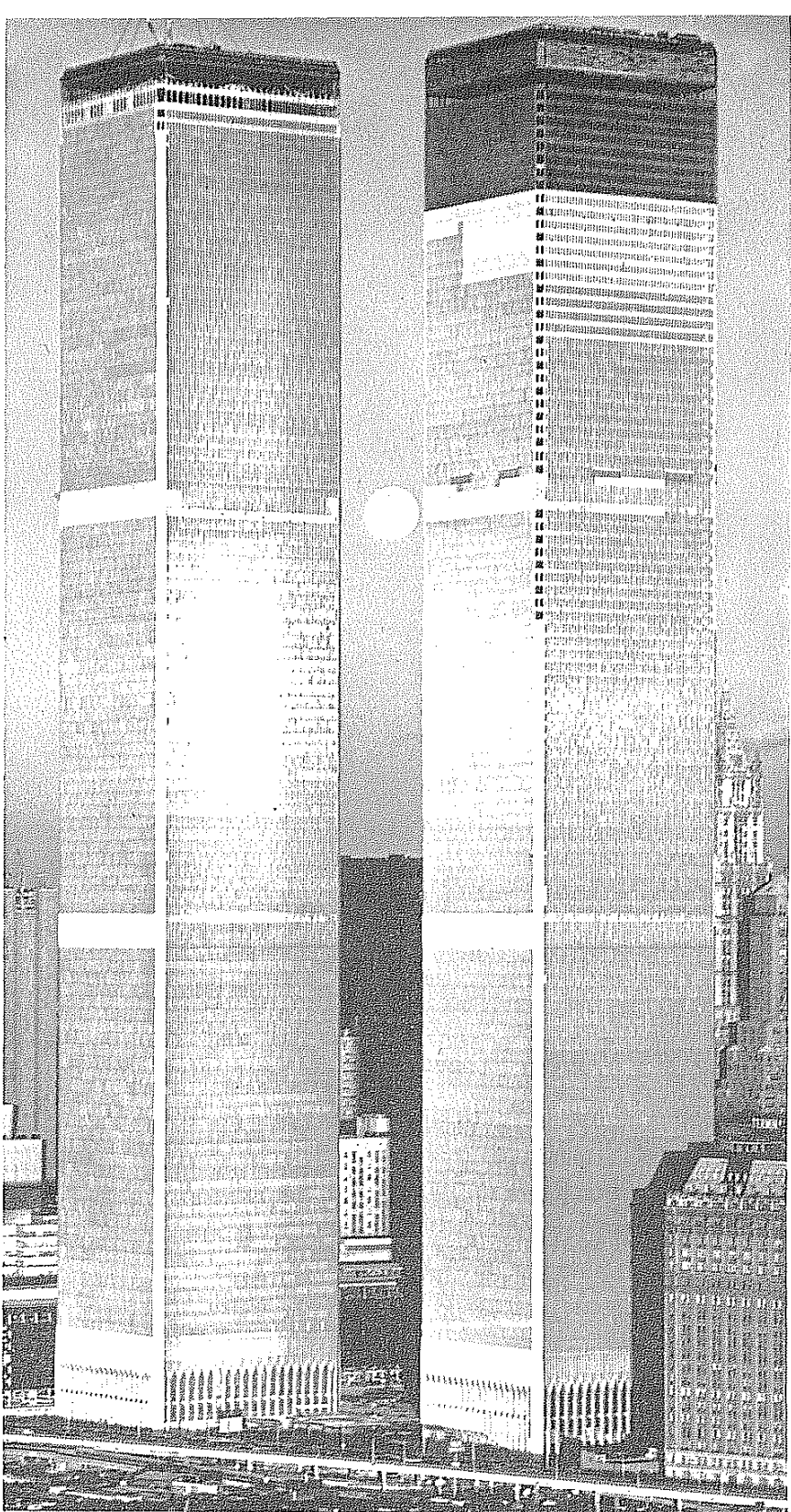
Dimensions
The towers, each 411 m high, 63.5 × 63.5 m on plan, core 24 × 42 m. Storey height 2.66 m, ceiling height 2.62 m. Height to top of antenna 447 m. Height to top of antenna hall 22.3 m.

Structural features
The structural design of the two towers is based on the method of absorbing and resisting the wind forces. On each of the towers a Vierendeel girder type wall is formed by 59 box-section columns (spaced at 3.05 m centres) which are rigidly connected by floor panels at each floor level. At the top of the building these walls are connected to transmit shear, so that, together with the floors of the building, they form a torsionally rigid framed tube which is supported by the foundations and transmits all loads. The floors span without intermediate columns between the external columns and the core, the 44 box-section columns of which have to carry vertical



Vertical section through a tower block
1 Ancillary building 2 Plaza level
3 Skylobby 4 Technical services
5 Underground car park

loading only.
External framework and façade: The external columns are of constant overall cross-section, 450 × 450 mm. The spandrel panels interconnecting them comprise steel plates, 1.32 m deep. 12 m above the entrance level the columns are combined in groups of three to form single base columns, spaced at 3.05 m centres and with an overall cross-section of 800 × 800 mm.
The wall thickness and grade of steel in the external columns are varied in successive steps in the upward direction: wall thickness decreasing from 12.5 to 7.5 mm, yield point of the steel from 70.0 to 29.5 kg/mm². To ensure that the floors remain plane, i.e., free from warping distortion, the external columns are so designed that the stresses, and therefore the strains, produced in them by vertical loads are equal to those produced in core columns (mild steel with yield point of 24 kg/mm²). The reserve stress capacity in the external columns which is provided by the progressively graded qualities of steel serves to absorb wind load. The design value adopted for wind pressure over the entire height of the building is 220 kg/m². The



The tower blocks viewed from the Hudson River

calculated maximum deflection at the top of the building is 28 cm.
The external framework was erected using prefabricated three-storey units, each comprising columns interconnected by spandrel panels. These units, ranging in weight from 22.3 to 6.0 t, were fitted together, alternately staggered in one-storey heights, and spliced with high-strength friction-grip bolts.
The external cladding to columns and spandrels consists of aluminium sheet. The window openings, 1.98 × 0.48 m, are infilled with bronze-tinted solar-heat rejecting glass fitted into aluminium frames and sealed with Neoprene gaskets. Automatic window cleaning is by means of rotating brushes guided along rails fitted on the column cladding.
● Floors: Composite floors comprise 900 mm deep bar joists (spaced at 2.04 m centres and braced transversely by secondary joists) and a 10 cm thick lightweight concrete slab laid on steel trough decking as permanent formwork. Composite action between the concrete and the steelwork is ensured by extending the diagonal web members of the