Zeitschrift: IABSE structures = Constructions AIPC = IVBH Bauwerke

Band: 6 (1982)

Heft: C-23: Selected works of Fazlur R. Khan (1929-1982)

Artikel: Brunswick Building, Chicago, Illinois (USA)

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DOI: https://doi.org/10.5169/seals-17597

1. Brunswick Building, Chicago, Illinois (USA)

Owner:	*Washington-Dearborn Associates, Inc.*
Architects-Engineers:	*Skidmore, Owings & Merrill, Chicago, IL*
Contractor:	*George A. Fuller Company, Chicago, IL*
Completion date:	*1965*

The 38-story Brunswick Building (Fig. 1) is the first reinforced concrete building designed on the basis of frame-shearwall interaction concept. Building systems in reinforced concrete were then either shearwall of frame type. A combination of the two system types produced enormous benefits in terms of stiffness. Since the exterior frame is exposed, the Brunswick Building also addressed temperature problems concerning shortening of exterior columns in extreme cold temperatures. The building is rectangular in shape (Fig. 2) and provides a clear column-free space of 37 ft. It encloses approximately 800,000 sq.ft. of office space and rises 550 ft. above grade.

Fig. 1 Brunswick Building, Chicago, Illinois

Structural System

The Brunswick Building layout required a clear span of 35 to 40 ft. for office use. The structural system was organized into perimeter frames with closely-spaced columns and deep spandrels, and a central shearwall core housing various building service elements. The organization created a column-free space of 37 ft. 4 in., as shown in Fig. 2. The highly articulated character of frame can be seen in Fig. 1. The exterior frames and core shearwalls, connected by concrete floor framing, interact to resist wind pressure. The interaction behaviour is schematically shown in Fig. 3. Because of the different lateral deflection characteristics of the frame and shearwall, the frame tends to pull back the shearwall in the upper portion of the building and push it forward in the lower portion. As a result, the frame participates more effectively in the upper portion of the building where the wind shears are relatively less and the shearwall carries most of the shear in the lower portion of the building where the frame generally cannot afford to carry high lateral loads. The result is a considerably stiffer structure which minimizes premium for the height. In Brunswick Building, the cantilever deflection of shearwall acting alone was about 9 in. which reduced to 3 in. when the frame-shearwall interaction was considered.

Exterior frames are formed by spacing columns at 9 ft. 4 in. on centers along building periphery (Fig.2). Column dimensions are 1 ft. 10 in. by 3 ft. 5 in. at the third floor and reduce to 1 ft. 4 in. by 1 ft. 11 in. at the roof level. The columns are connected by 2 ft. deep spandrel beams. The continuity and rigidity is obtained through monolithic concrete joints. A perimeter transfer girder 24 ft. deep and 8 ft. wide, resting on 7 ft. square columns spaced at approximately 56 ft. apart, was provided at the third floor (Fig. 1). The core walls are 2 ft. thick at ground level and reduce to 1 ft. at roof level. A 5,000 psi concrete was used for columns, walls, and spandrels from ground level up to the 28th floor and a 4,000 psi concrete from the 28th level to roof. Fig. 2 shows the floor framing plan of a quarter of a typical floor. One-way ribbed joist type slab was provided between the interior wall and the exterior frame. At the corners, a two-way waffle system was used. This eliminated any further increase of structural depth in the corner area. The two-way waffle slab with its column strip and middle strip beams tended to load the exterior columns more at the column strip beams than at the remaining middle strip beams. The corresponding column sizes were, therefore, increased, though not expressed outside. A 4,000 psi lightweight concrete was used for floor framing.

The building foundation consists of circular concrete caissons founded on the rock located about 100 ft.

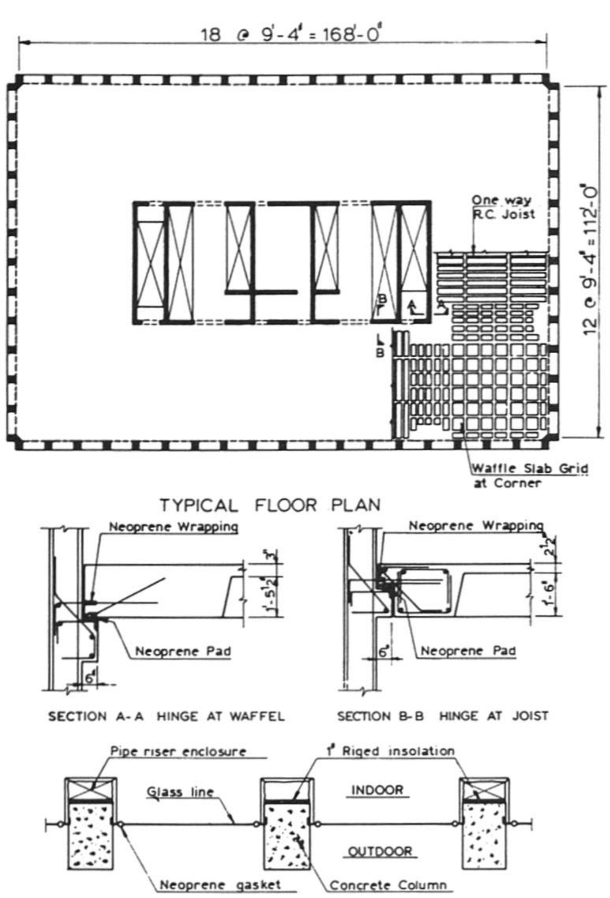

Fig. 2 Typical floor plan, hinge details, and glass line of Brunswick Office Building

(22.8 m) below grade level. The caissons were constructed using hand-dug method.

Large Temperature Movements

The articulated character of exterior frame is brought about by exposure of spandrels and columns. The columns also act as mullions and a single pane of glass is inset deep into the frame, exposing the columns by about 70% of the area. The simplicity of this detail creates a strong architectural expression. In Chicago, where the temperature may drop to −20° F in the winter and rise to 100° F in the summer, exposure of the exterior columns may cause considerable rotational movement of the upper floor in relation to the interior columns or shearwalls. Brunswick Building is the first building where special partition details and structural design were incorporated to account for the effect of column exposure. A detailed temperature analysis considering the heat flow through the column and the restraining effects of the floor slab system indicated a maximum movement of 1-1/4 in. (3.175 cm) at the top floor. Since the governing temperature effects caused by cold winter weather are cumulative from the base to the roof (Fig. 4), it was considered logical to hinge the upper floors (29th floor and up) around the shearwall. The decision to relieve the high bending stresses through hinging rather than to provide strength for their accommodation was made as a result of a study of economics and performance considerations. Hinging of these floors around the shearwall assumed proper functioning of the structural system even under severe winter exposures. Maintaining lateral restraint of columns or load bearing walls at hinges was achieved with dowels wrapped with an elastomeric material. Thus, the dowel did not restrain the slab from rotation, but provided lateral restraint of vertical elements at each floor level. Details used in Brunswick Building are schematically shown in Fig. 2. The details have been functioning in the building for the last 20 years. Observations indicate that the structure is performing as planned; no architectural or structural problems have been encountered.

Summary

Brunswick Building, by incorporating the exterior frame with the shearwalls, started a new type of system which is used even today. Structural studies on stiffness characteristics of the exterior frame done during design phases of Brunswick Building set the stage for newer framing systems, now referred to as tubular and tube-in-tube systems. These systems minimize frame racking and maximize cantilever action through optimal spacing and proportioning of columns and spandrels and have gained popularity in modern high-rise construction.

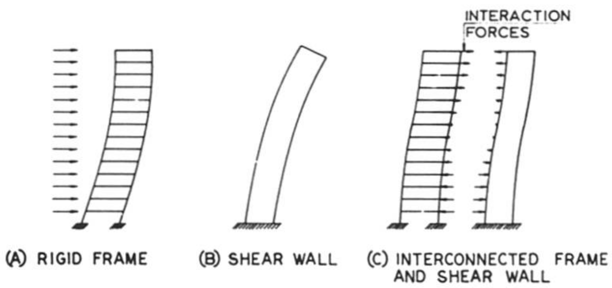

Fig. 3 Frame-shearwall interaction

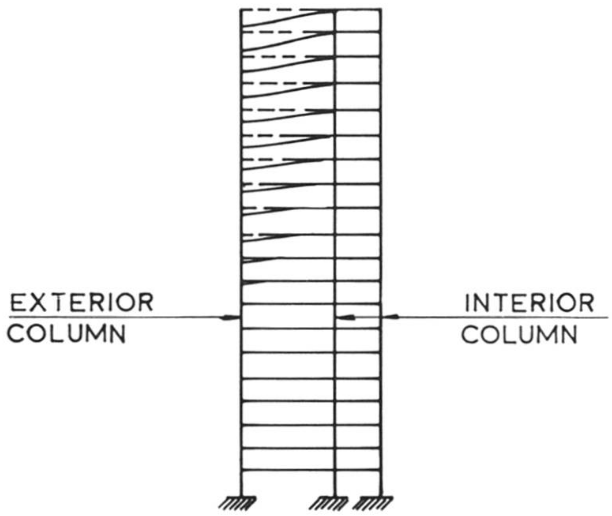

Fig. 4 Racking of floors due to temperature effect