Structural System in Architecture
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Lecture No -39
Structural System for High-rise Buildings-II

Welcome to the NPTEL online certification course on Structural Systems in Architecture. This is the 39th lecture and this is the pen-ultimate lecture of the module 8 or the week 8 and also the course per se. And this lecture's topic is Structural System for High-rise Buildings-II.

Concepts Covered

- Introduction
- Exterior System
- Frame Tube System
- Braced Tube System
- Tube-in-tube System
- Bundle tube system

Learning Objectives

- Outlining the structural concept of Exterior System.
- To discuss the development of tubular structural system.

Introduction

Fazlur Rahman Khan (1929 -1982) born in Dhaka, a Bangladeshi-American Structural engineer is regarded as Father of Modern Skyscrapers.

Figure 1 Fazlur Rahman Khan (1929-1982)

According to Khan, the relation between the height of the building, loading and the average weight of structural steel can be given by the following graph.

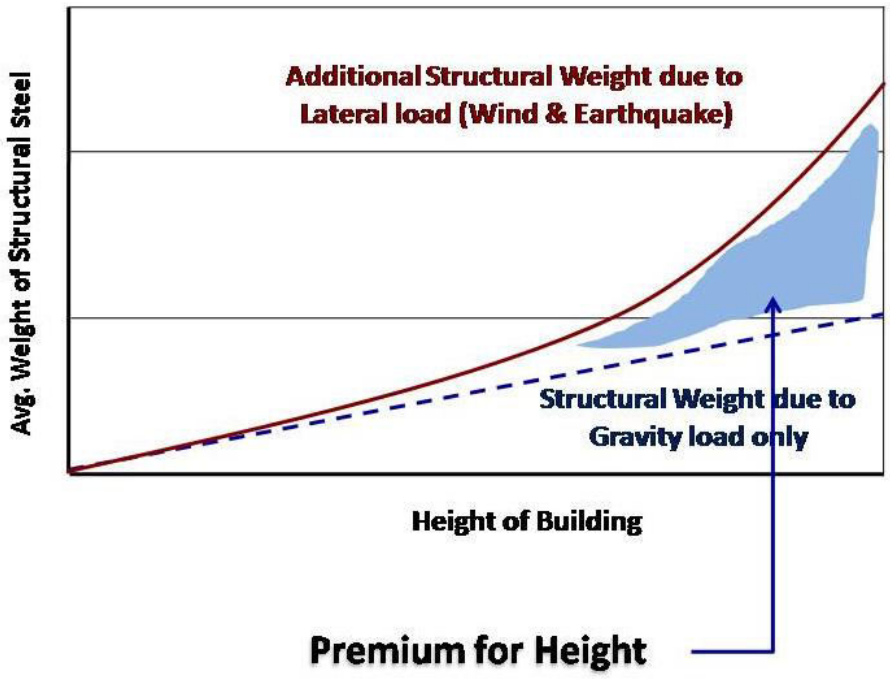


Figure 2 Graph showing the relation between height of building, loading and the average weight of structural steel

Exterior System

If the major part of the lateral load-resisting system is located at the building perimeter, a system is categorized as an exterior structure.

It is desirable to provide lateral load-resisting system components as far as possible on the perimeter of tall buildings to increase their structural depth. Tubes are known as basic exterior structures. It can be defined as a three-dimensional structural system utilizing the entire building perimeter to resist lateral loads.

Classification of Exterior System

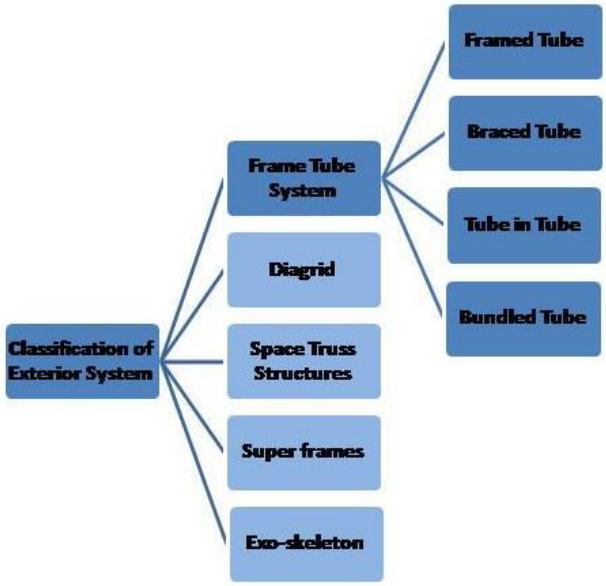


Figure 3 Classification of exterior system

Frame Tube System

In a frame tube system a building has closely spaced columns and deep spandrel beams rigidly connected together throughout the exterior frames. Depending upon the structural geometry and proportions, exterior column spacing should be from 5 to 15ft (1.5 to 4.5m). Practical spandrel beam depths should vary from 24 to 48in (600 to 1200mm). Resulting structural organization is the lateral load resisted by the whole tube.

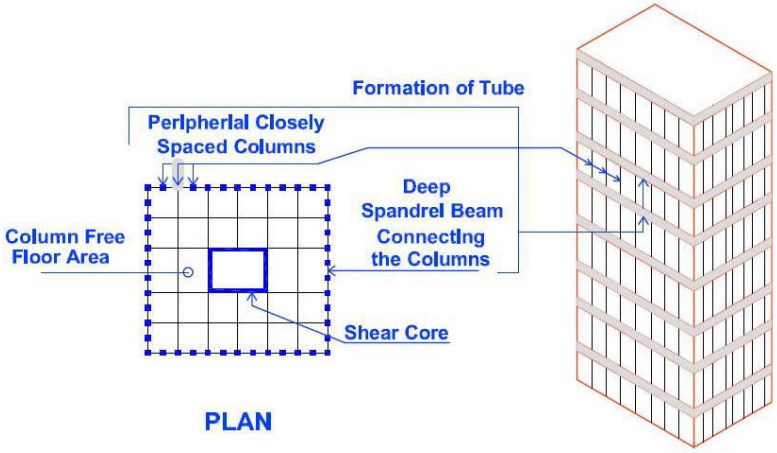


Figure 4 Frame Tube System

Water Tower Place (1975), Chicago, 262 m, 74 stories

Aon Center (1973) Chicago, 346 m, 83 stories

WTC(1971) New York, 417m, 110 storied

Figure 5 Examples of Frame Tube System

Braced Tube System

It is possible to stiffen the building Structure by introducing diagonal braces. Introduction of Diagonals also increases the spacing of columns in frame tube. The diagonals participate in dual role action as it collects gravity loads from floors as inclined columns also act as a stiffener in case of lateral loads.

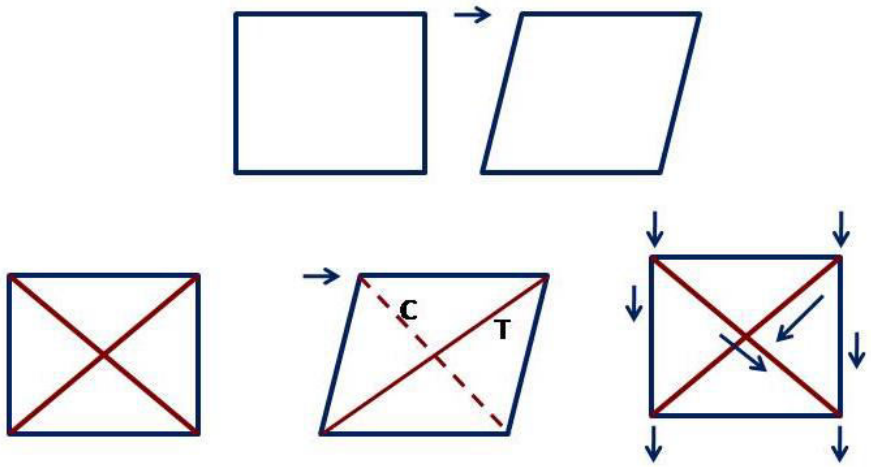


Figure 6 Impact of load action on bracing

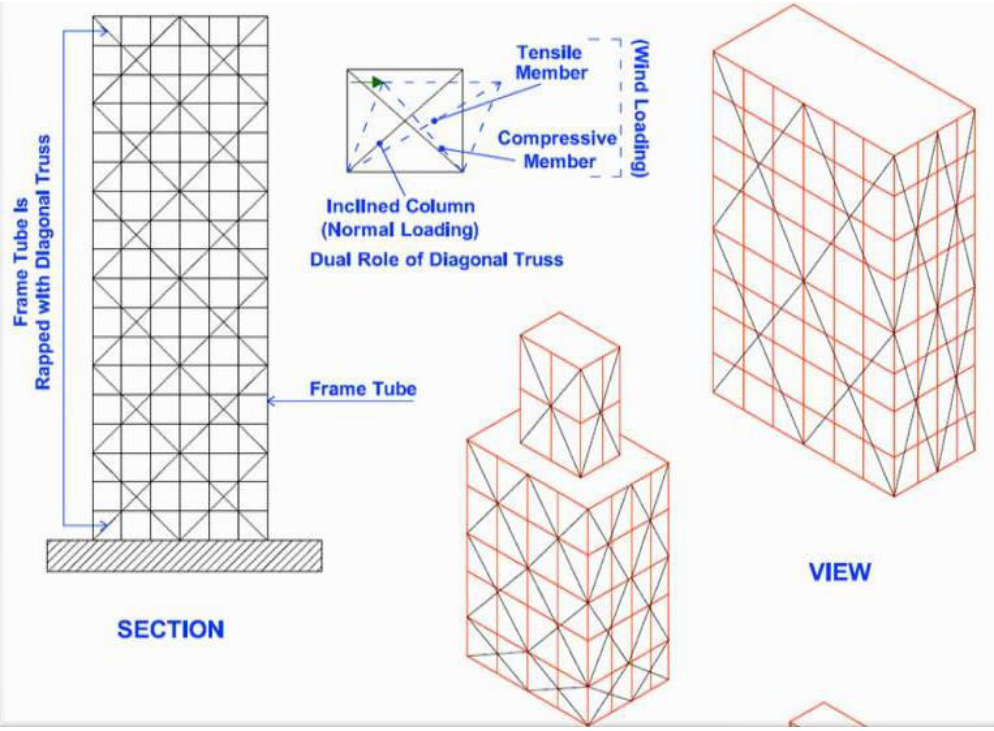


Figure 7 Braced Tube System

John Hancock Center (1970), Chicago, 344 m ,100 stories

Onterie Center (1986), Chicago, 174 m ,58 stories

Figure 8 Examples of Braced Tube Structure

Tube in Tube System

The stiffness of a Framed Tube can be further enhanced by using a core tube to resist part of the lateral load resulting in a tube-in-tube system. The floor diaphragm connecting the core and the outer tube transfer the lateral loads to both the systems. It is also possible to introduce more than one tube inside the perimeter tube.

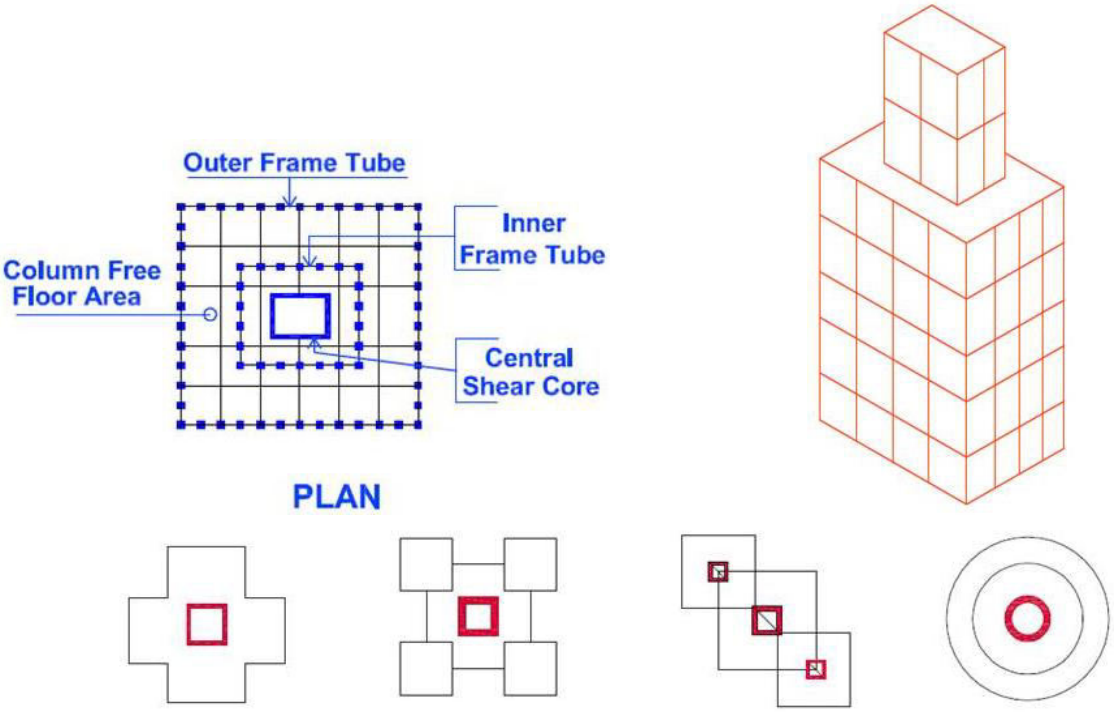
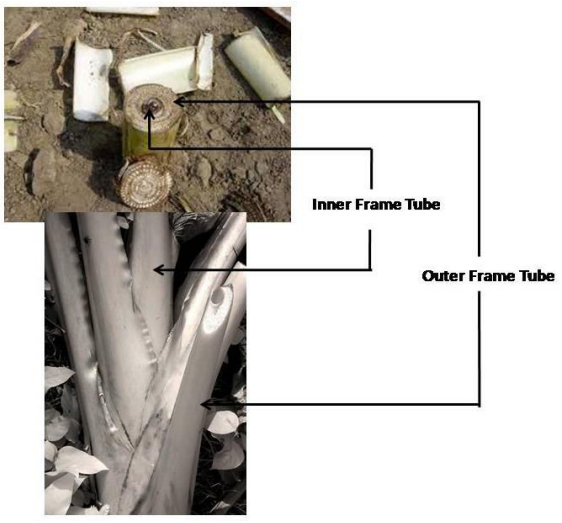


Figure 9 Tube in tube system

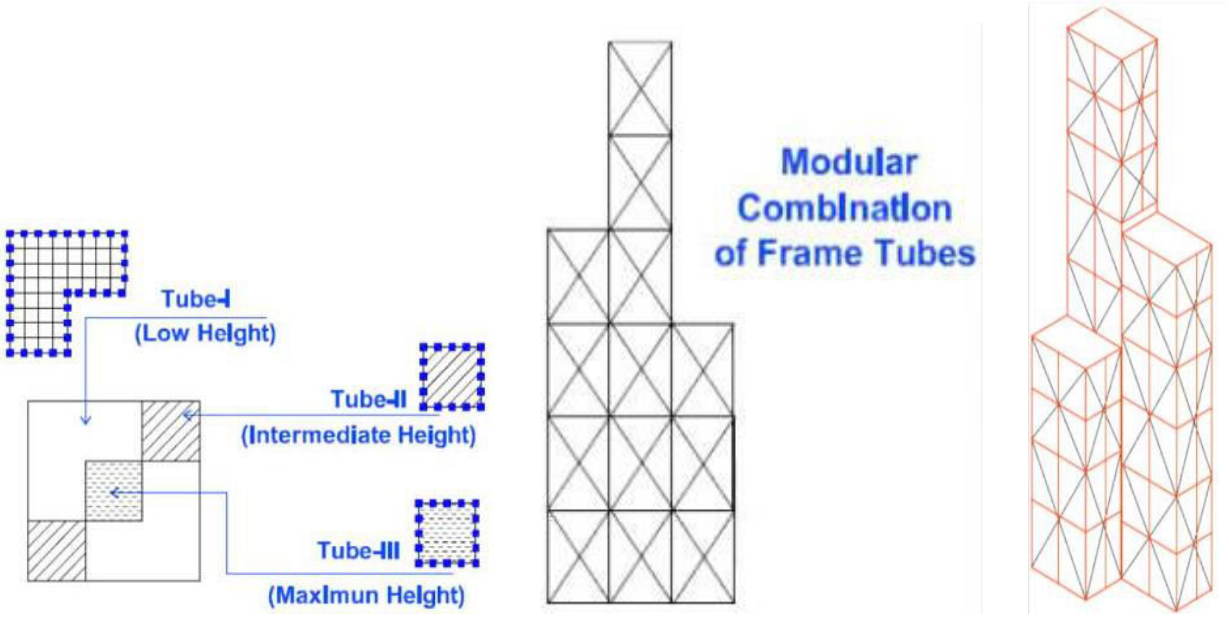


181 West Madison Street (1990)
Chicago, 207 m , 50 stories

Figure 10 Example of Tube in Tube System

Bundled Tube System

In tall buildings with larger floor areas, simple frame tube system becomes a very uneconomical structural solution. To overcome this, many frame tubes are symmetrically grouped together to create larger floor space. Further, these grouping of frame tubes (called bundled tubes) actively participate to transmit the super-structure load to the ground as well as provide the lateral stability against the transverse loading.



PLAN **SECTION** **VIEW**

Figure 11 Bundled Tube System

Sears Tower (1973), Chicago, 442 m,108 Stories

Burj Khalifa (2010), Dubai, 828m, 163 habitable floors plus 46 maintenance levels

Figure 12 Examples of Bundled Tube System

Diagrid

Almost all the conventional vertical columns are eliminated. This is possible because the diagonal members in diagrid can carry gravity loads as well as lateral forces. The distribution of load is possible in uniform manner due to the triangulated configuration.

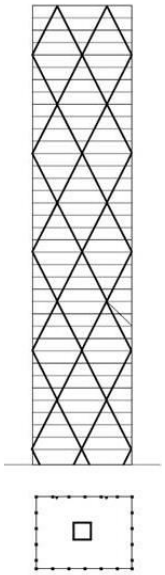


Figure 13 Diagrid

Hearst Building (2006), New York, 182m, 46 Stories

Swiss Re Building (2004), London, 181m, 41 Stories

Figure 14 Examples of Diagrid

Exo-skeleton

In exoskeleton structures, lateral load-resisting systems are placed outside the building lines away from their facades. The system is associated with other conventional types. Due to the system's compositional characteristics, it acts as a primary building identifier.

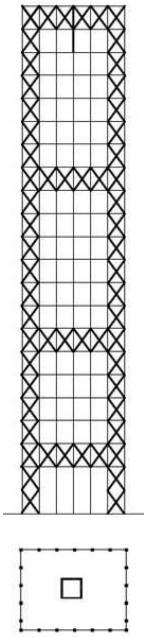


Figure 15 Exo-skeleton

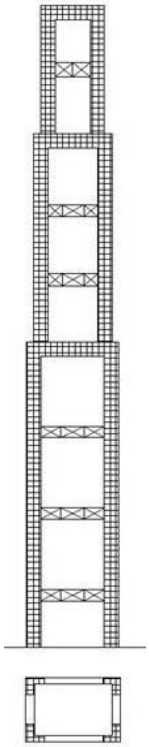
Hotel de las Artes, Barcelona, Spain

Burj Al Arab, Dubai

Figure 16 Examples of Exo-skeleton

Super Frames

A super-frame is composed of mega columns comprising of braced frames of large dimensions at the corners of the building. Like Exo-skeleton, the system is also associated with other conventional types. The mega columns are usually linked by multi-storey trusses at about every 15 to 20 storeys.



Parque Central Tower (1979)
Caracas, Venezuela, 221 m ,56 stories

Figure 17 Super Frames

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Conclusions

In conclusion, I'd like to state that in a high-rise building structural system, structural intensity in terms of material use is increased with the increase in its height. Exterior system of structure is mainly dependent upon tubes.