Typical Structural System of Tall RCC Buildings in India

Sumit Ghangus[1], Prof. Sangeet Kumar Gupta[2]

[1]*M.Tech (Structural Engineering) National Institute of Technology, Silchar, Assam, India*
[2]*Dean and Director, ASAP, Amity University Haryana*

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ABSTRACT – *The present analysis for every under developing and developed countries is somewhere based on its infrastructure development. In this 20th century there are many such remarkable examples of skyscrapers in front of world by many of the countries. This is a trend in building construction and going to be increase in future. The thoughts of Engineers and Architects are not stuck off to some limited designs and practices and this is giving birth to the changing scenario in construction. The high price of land in metro cities and home for everyone both can be fulfilled with vertical city concept. These building are not restricted to only tall but the typical structural systems. These structural systems which are described by IS 16700:2017 are explained in this study.*

Key words: Indian Standard, vertical cities, diagrid, fault, outrigger, core, seismic, framed, tube in tube, bundled tube.

1. INTRODUCTION

In the older practice of structural design the priority is given to the vertical loads, which results to strengthen the beams and columns for the safe transfer of loads to the foundation. These designs are restricted to low raised floors and any of the shapes either regular or irregular. The change is need of time; the buildings are now kept in same structural design for vertical loads only but the height was raised and a very important load was neglected. The load which was not in common practice for buildings was the lateral load, which results to a huge damage of life and property in Bhuj earthquake in year 2001. After this earthquake governing bodies brings the amendment in IS 1893 in years 2002 and kept it mandatory for the structural design practices. Based on the magnitude and intensity of repetition of earthquake, IS 1893 part 1 divides India in 5 earthquake zone. The zone 1, 2 are further merged as zone 2, considering zone 1 with very low intensity of earthquake or no earthquake zone.

The second most important lateral load is the wind load. The IS 875 Part 3 describes the wind load, looking on to the matter of increased requirement of high rise and tall buildings recent amendment is made in IS 875 part 3 in year 2015. The codes used in present Structural design practice is not limited to IS 456 and IS 875 but the IS 1893 and IS 16700:2017 are also mandatory to use. The building should be good enough to transfer safely the vertical load and the lateral load. The buildings must be designed for the lateral loads, considering the building like a cantilever which is stronger enough to resist the wind loads, earthquake loads or blast loads. .

The shapes of buildings is very important for its aesthetic view like the Shukhov tower in Russia, CCTV headquarter China, MyZeil in Germany etc. but these buildings cannot be designed by sticking up with the old design practices. New concept introduced in the design practice is the diagrid structural systems. Similarly, the IS 16700:2017 provides the path to some RCC tall buildings, with height less than equal to or greater than 50m and less than 250m. The buildings above the height 250m are the super tall buildings are not covered in this code. The building must not exist in 10KM shortest distance of seismic fault and the regular people density must be less than 20000 in the building.

The typical structural systems in tall building are as follows: structural wall, moment frame, moment frame- structural wall, structural wall with flat slab floor, core and outrigger, belt wall, framed tube, tube in tube, multiple tube systems. As per the Council of tall buildings and Urban Habitat (CTBUH) the structural systems are of four different types which are as follows: Shear frames, Interacting systems, Partial tubular systems and tubular systems. According to Mir M. Ali and Kyoung Sun Moon the structure are classified as interior and exterior.

2. CLASSIFICATION

The classification below is made based on the four major structural systems i.e. Frame, Wall, Core and Tube. The further classification for the structure is a mixed combination of these four main structure types. The detailed structure classification is shown in figure.1. The height of each structural system is restricted with its type. If a building is designed with, rigid frame will go up to height 60m to 70m, shear wall and core height up to 100m, outrigger structure with combinations of core and belt trusses goes up the 500m. Similarly with the combinations of core, tube, wall, diagrid and super frame structural systems the height of super tall buildings and skyscrapers can be achieved.

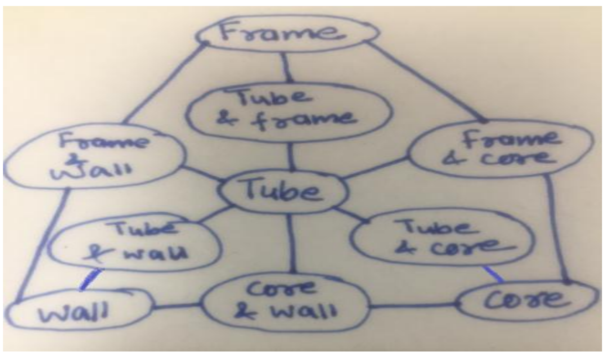

Fig-1: Classification of Structural Systems

As per the clause 3.12 of IS 16700:2017, the classification of the structural system are explained below.

2.1 Structural Wall System- This system is having the shear walls and the floors are directly with the system. This type of structure system is able to resist the lateral loads, vertical loads and the moments generated in the system. As shown below in figure in 2.1.

2.2 Moment Frame System- This is a normal moment resisting frame having beams and columns to resist the lateral and vertical loads. As shown below in figure 2.2.

2.3 Moment Frame – Structural Wall System- This system is a combination of shear walls and moment resisting frame. This structural system is more rigid then moment frame due to shear wall in this system, also it can better resist the lateral and vertical loads. This structural system is very common in present design practice, due to its high stiffness and better seismic resistance. As shown below in figure 2.3.

2.4 Structural Wall System with Flat Slab Floor System- This building type is designed with shear walls and flat slabs only. In this system slabs are designed without the beams. This system is having good lateral stiffness. As shown below in figure 2.4.

2.5 Core and Outrigger Structural System- Core is an internal structural system provided to the building either at the center or at the corners or at one side. The core can be designed like a wind tunnel and can also be used for the services. The spaces in the building will be more due to this core. The core can be of connected shear walls or of columns. The core is good to resist the lateral and vertical loads. Outrigger structural element is the columns placed at the perimeter of the building. The role of these outrigger columns is to increase the stiffness. The role of outrigger column is to transfer the axial load only. These outrigger columns are connected to the core with the help of outrigger beam, this combination is able to resist the flexural stiffness of the core and outrigger elements and axial stiffness of outrigger column. This structural system is as shown below in figure. 2.5.

2.6 Core, Outrigger and Belt Wall System- This structural system is similar to the core outrigger system but to increase the lateral stiffness the outrigger columns are connected with each other with the help of deep beams or belt wall/truss. These deep beams will transfer the vertical load from main columns to other columns for counteracting the tension loads induced due to the lateral loads. These deep beams will also increases the axial stiffness of the building. As shown below in the figure 2.6.

2.7 Framed- Tube System- This structural system is designed with closely spaced columns and the deep beams at the perimeter frame of the building to increase its stiffness. The entire vertical load of the building is resisted by the central core of the building. This system is suited for the very tall buildings. As shown below in figure 2.7.

2.8 Tube in Tube System OR Multiple Tube System- This system is similar to the core system but in this system the outer core will act as outer tube and inner core will act as inner tube. These tubes can be more than two based on the requirement of the building. These tubes will increase the stiffness of the building and suited for the very tall structures. As shown below in figure 2.8.

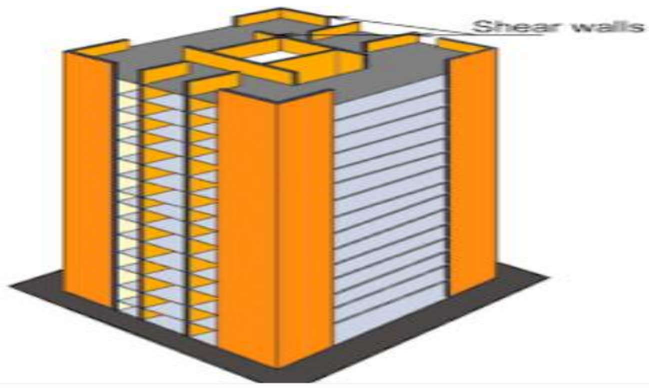

Fig-2.1: Structural Wall System

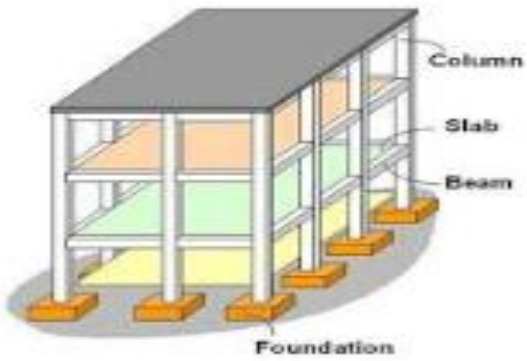

Fig-2.2: Moment Frame System

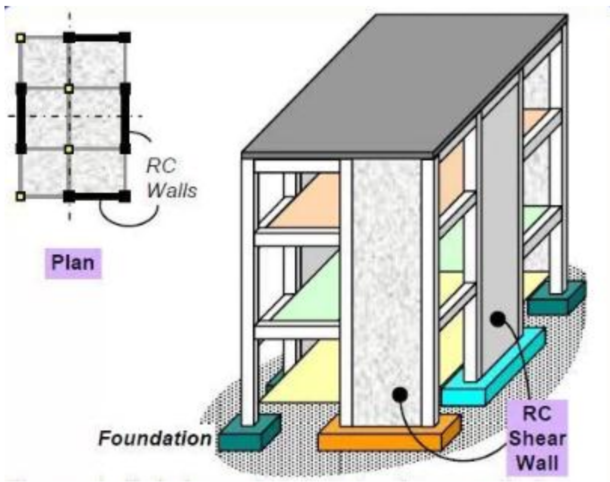

Fig-2.3: Moment Frame – Structural Wall System

Fig-2.4: Structural Wall System with Flat Slab Floor System

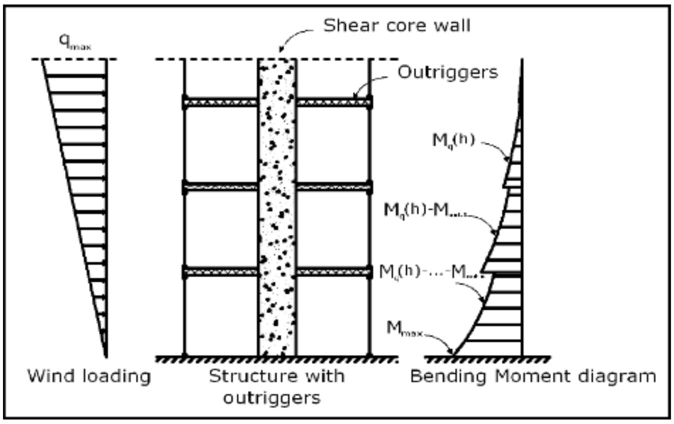

Fig-2.5: Core and Outrigger Structural System

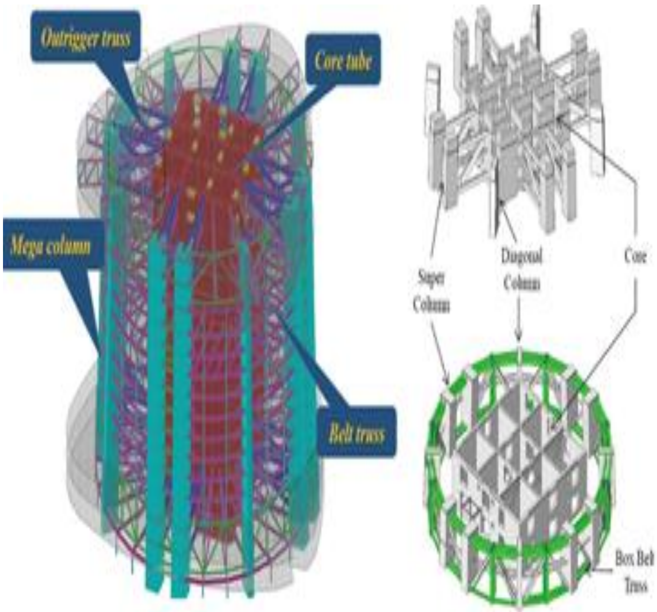

Fig-2.6: Core, Outrigger and Belt Wall System

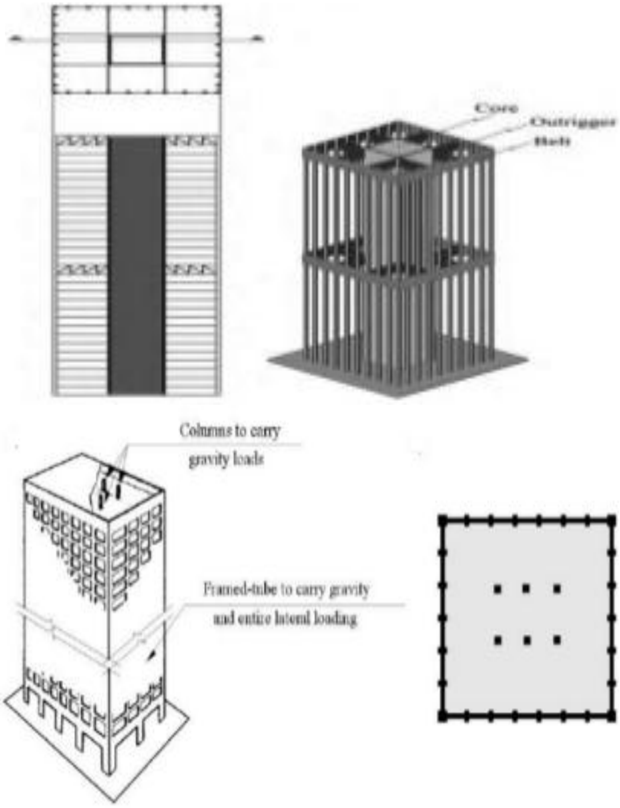

Fig-2.7: Framed- Tube System

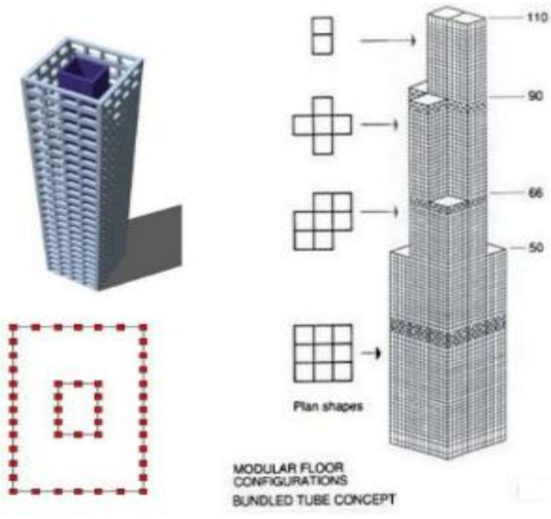

Fig-2.8: Tube in Tube System OR Multiple Tube System

3. ADVANTAGES OF TALL BUILDINGS TYPICAL STRUCTURAL SYSTEM CONCEPT

1. Keeping the shear walls face to face at the core of building will keep area of centroid of vertical section at the same position.

2. Simple framing systems.

3. No effect of shear-lag on shear wall due to the parallel placing of these walls.

4. The outrigger columns will take the gravity load only and the lateral load is entirely taken by the core of the building.

5. The effect of the perpendicular walls will be to stiffen the structure in torsion, to reduce the twist, and, in doing so, to influence the contributions to the parallel wall shear and moment that result from the structure's twisting.

6. Shear wall construct in building are effective in both the terms of cost and resisting seismic loads.

7. The framed tubes create more usable floor spaces by allowing fewer interior columns.

8. It can take different floor plan spaces like circular, square, rectangular and free forms.

4. BASIC CONCEPT FOR TALL STRUCTURAL BUILDINGS

These tall building will act like a cantilever when interacted with the lateral loads. The base of the building is kept broad and the ratio which is followed in general for height and base is 10:1. Higher the height of building, more will be the base shear. This is similar to design a cantilever beam, where maximum bending moment is at fixed end and minimum bending moment is towards the free end. Due to this reason the base of building is kept stronger and large in size and as the height of building rises the size of building perimeter is reduced to increase stability and reduce the surface interaction with the wind. The behavior of building is shown in figure 3. This is similar to a slender column with one end fixed and other end free.

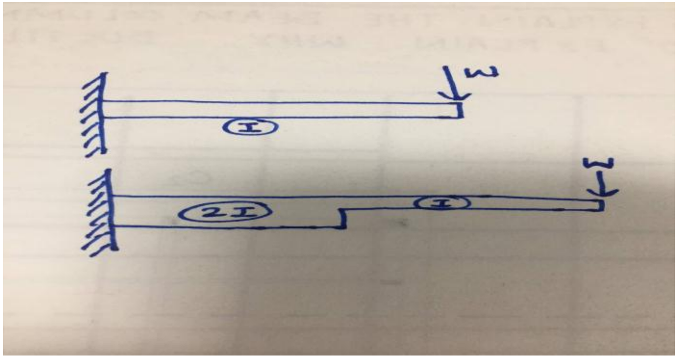

Fig-3: Cantilever action based on size of building base

5. CONCLUSIONS

It is found that the trend is changing very fast, which is due to both the reasons of locating people in metro cities and the lack of land spaces. The development of these vertical cities will resolve this problem. The height of each building will be decided based on the technique used for the design of that building. Each design technique have certain requirements based on which it can be decided that the particular technique is suitable or not suitable for the building type. The height in ascending order based on the structural systems of the buildings are: structural wall system, moment frame, moment frame - structural wall system, core and outrigger system, core- outrigger and belt wall system, frame tube system and tube in tube system and multiple tube system. It is found that moment frames are restricted to height up to 90m, moment frame - structural wall system up to 120m, core- outrigger and belt wall system up to 180m, frame tube system up to 240m, tube in tube up to 300m and bundled or multiple tube structural system up to 330m height. In Asia, during year 1982 there are 700 tall buildings and in year 2006 these building reach to 35000 which are highest among the world.

The scope in this area of research is larger; it can be further worked on the plan of building with its orientation and the shapes in elevation. These shapes can analyze and compared for particular buildings with different combination of these typical structural systems.

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This work is achieved with advice, support and endless effort of Prof. S.K Gupta. I am benefited from his wisdom and great experience. This idea of tall buildings will remain in our common discussions from the last many days but remains untouched due to the lack of Indian standards for tall Reinforced building. Publishing of IS 16700:2017 brings the clarity on this topic and the basics are discussed in this study.

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AUTHORS PROFILE

Mr. Sumit Ghangus
Structural Engineering,
M.Tech(Structural Engineering)
National Institute of Technology, Silchar, Assam, India

Prof. S K Gupta
Dean & Director
ASAP, Amity University
Haryana