

Stability Analysis of multistory building with different safety methods

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ABSTRACT

In today's world there is here huge demand for housing in big cities, there is a growing need for high-rise and multistory buildings. High rise buildings are wanted for big cities where space is limited. The development of these buildings has not kept pace with the development of many other systems in society. Objective is to produce a report about the effectiveness of the mega frame which can be used in marketing and/or further research of the concept. The report should also work as a basic guide on high-rise systems and design.

1. Introduction

According to new developed idea for improving the existing models of multistory buildings in the form of a new elevator system with a completely new structural system called the "mega frame". What makes the mega frame unique is that all the load is carried down through the giant pillars of the building's outer edge instead of as in many of today's high-rise buildings where a big part of the load is carried down through a central core. However, this system is only in an initial idea state and therefore needs more investigation before it is fully applicable.

First describing the historically most widely used systems for stabilization of tall buildings, wind dynamics and structures natural frequencies. These will be based on literature studies and the related works.

Then the report will move on to calculations in the form of modeling and analysis, using finite element method programs like Frame Analysis (Strusoft), SAP2000 and ETABS (CSI). A further study and comparison will be made on used structural systems before moving on to the mega frame concept.

Finally, the report ends with results and a comparison between the Colossal mega frame, Outrigger and Tube in a tube system.

High-rise Buildings

There is no specific definition and illustration for Multistory buildings. But, according to Indian Standard Codes a multi-story building should have one of the following elements:

Height relative to context: when a building is distinctly taller than an urban norm

Proportion: a building that is slender enough to give an appearance of a tall building or multistory building.

High-rise building technologies: the building contains technologies that are a product of the buildings height, such as specific vertical transportation technologies and structural wind bracing.

From a structural engineer's perspective, a building would be considered tall when lateral loads, i.e. wind or earthquakes, play a significant part in the buildings structural design.

2. The appraisalment of high-rise buildings

A lot of discoveries helped make the high-rise buildings functional, such as the telephone and the elevator. Earlier it had been difficult to rent out space above the fifth floor because of the tiresome walk up and down staircases. When Elisha Otis invented a self-braking elevator vertical transportation was possible. However, this transportation was very slow until improved by Werner von Siemens in 1880 with his electrically powered elevator. The telephone, invented by Alexander Graham Bell, made it possible for people to communicate without talking face to face, in turn making office jobs more stationary.

The biggest contribution for the structure itself came perhaps from Gustave Eiffel who had demonstrated iron as a useful building material. Soon after, the iron skeleton concept was born. As seen in one of the first high-rise buildings, the Monadnock in Chicago from 1891, the use of masonry in such a building is not very effective in terms of the floor space it inhabits with the masonry being six feet thick. The change actually came earlier when constructing the Home Insurance Building five years earlier, also in Chicago.

The Home insurance building used an iron skeleton in collaboration with masonry walls to create the world's first skyscraper. The Home Insurance building was never the tallest building in the world but considered the first skyscraper because of its iron skeleton. The iron frame was something that people didn't think was possible and the building had to shut down for a while during its construction. In this building the iron was used to handle the gravitational loads but today it's well-used for horizontal loads as well. Intentional or not, the masonry was the construction material handling horizontal loads in the Home Insurance Building.

It was perhaps the Monadnock that was the first tall building recognizing the effects of wind loads with its iron portal frame between the east and west side of the house. Iron, then steel, and its development led to new heights in

construction possibilities. New York soon took over as the capital for high-rise buildings in the early 20th century with buildings like the Singer tower, Woolworth building and later Empire State Building.

Even though steel was the material of choice in the beginning of the 20th century concrete was evolving to become a viable candidate because of its cheaper construction cost, better fire resistance and better mass dampening. In 1903 the first reinforced concrete high-rise building was built as the Ingalls Building in Cincinnati, Ohio, USA. Concrete was not often used as part of the structural system in high-rise buildings because of its weakness in tension along with non-developed calculations for reinforcement. It was not until the second half of the 20th century that it was being used as the primary part of a buildings structural system. This was because of earlier high-rise structures used the steel frame for stability until Fazlur Rahman Khan invented the tubular design.

Khans tubular design didn't only allow for concrete as being a profitable option, it also made for less material needed even in steel high-rise buildings. With the new design buildings like the John Hancock Center, Willis- (formerly Sears) Tower and World Trade Center showed up in the US, these new buildings set the record for tallest buildings on earth at the time.

Later developed structural systems like the outrigger and the buttress core has allowed for even higher buildings such as the Petronas Towers, Taipei101 and current tallest on earth; BurjKhalifa.

Acting loads

A building is subjected to a large number of different loads. They can be static or dynamic, come from outside or inside of the building. Simple categorization of them may be based on its direction; vertically or horizontally. Vertical loads, also known as gravity loads, generally consist of self-weight, live load and snow loads. Horizontal, or lateral loads, may occur in the form of wind load, tilt and seismic responses. Generally, the size of all these loads increases somewhat linearly with number of stories. The growth of the wind load on the other hand evolves differently and its effect intensifies rapidly with an increase in height. It is also the one which in most cases will be essential in the design of tall buildings - wind load as the main load.

A noticeable effect of the horizontal towards the vertical loads is illustrated in Figure 1. The need for material used in stabilizing the acting horizontal load increases dramatically as the number of floors reaches above 40-70. The amount of material for stabilization of the gravity loads, however, is proportional to the number of floors.

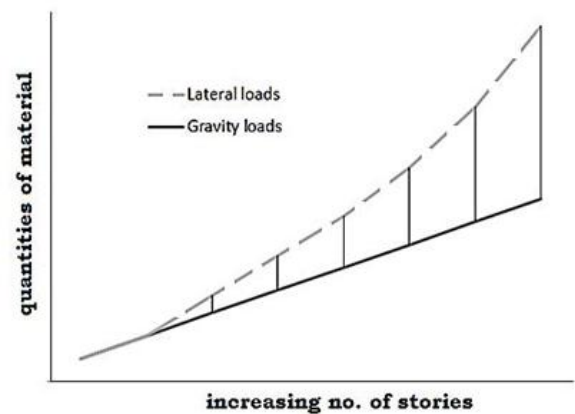


Figure 1: Cost of height diagram

While action of lateral loads is orthogonal to the building, which effect negatively on the building's stability as lateral displacement, overturning and twisting, gravity loads appear in the building's own direction and in that way to some extent, have a positive effect on the stability.

In all cases, regardless of the direction of the loads the building's main job is to transfer these loads to the ground. On the way down, different scenarios in the form of instability or breakage can occur in parts. Where exactly these instabilities occur depends a lot on the selected stabilization system.

3. Tubed Colossal Frame

Essentially, the articulated funiculate is vertical trains capable of switching between vertical and horizontal alignment. Having a vertical alignment when going up and down the structure and horizontal when on and off loading at stations.

The trains follow a continuous loop throughout the whole building, following the tracks that snake from one side to the other, stopping at every station, shown in Figure 2. All the funiculate trains follow the same tracks and use the same cables, shafts and motors, which add efficiencies.

Stations are separated by a fixed height, i.e. 250 meters, with conventional elevators making people able to go to specific floors, similar to that of a sky lobby.

When a train is going down bound the energy from its motion when braking is to be saved and used for up bound transportation, making the articulated funiculate sustainable.

The trains and train cars are to be designed so that the passengers are to be standing upright during transportation. By having a carriage frame inside the train car that pitches when switching between vertical and horizontal alignment the passengers remain standing. Current design shows that the articulated funiculate elevators needs space of 3,5 meters by 3,5 meters.

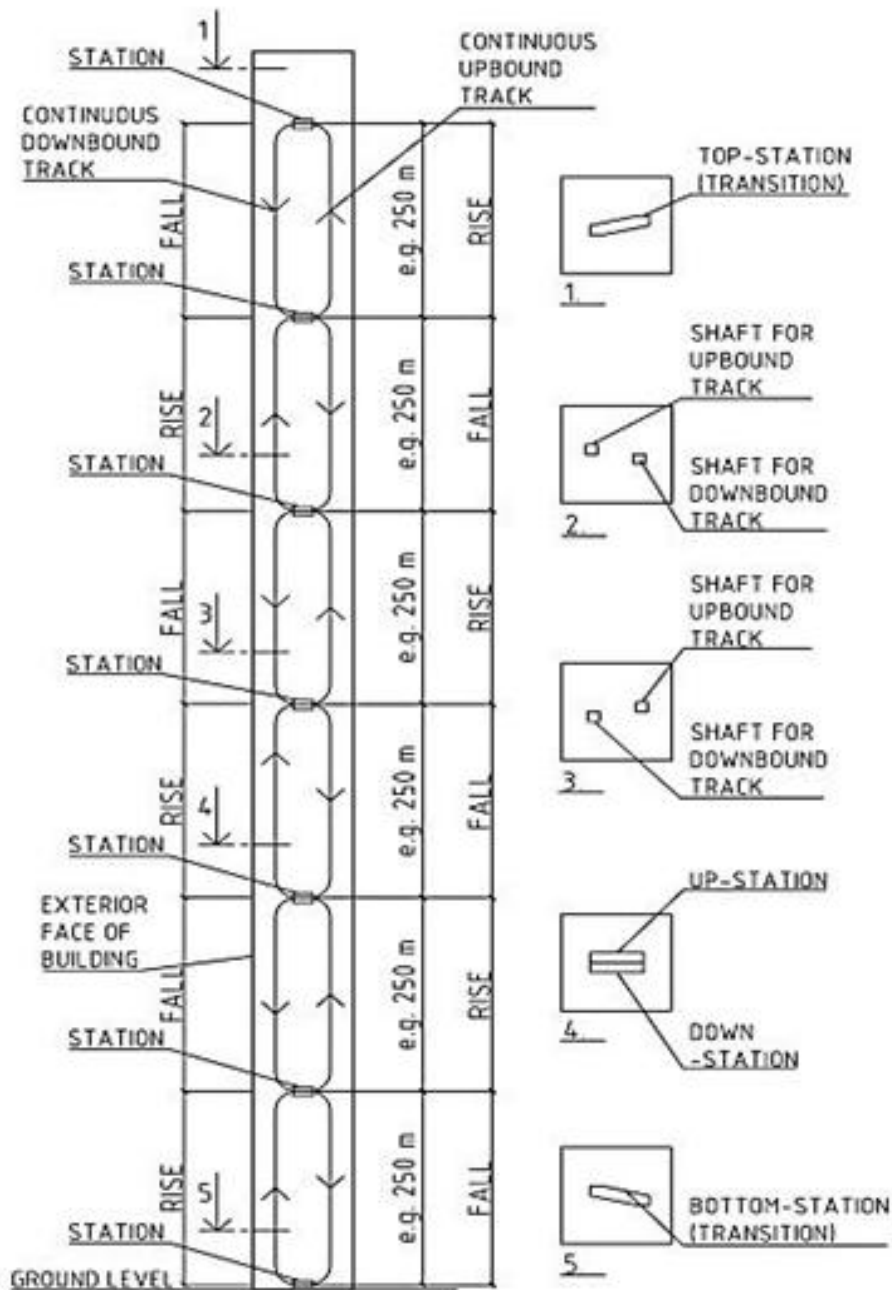


Figure 2: The trains follow a continuous loop throughout the whole building, following the tracks that snake from one side to the other, stopping at every station

Structural design

The Colossal frame structure utilizes the vertical corridors housing the articulated funiculate as reinforced concrete Colossal columns. These are designed according to the tubular concept mentioned in Chapter 2.5.5 making them achieve good stiffness. To improve the stiffness even more the Colossal columns are to be placed at the perimeter to

achieve maximum length of the lever arm. Similar to the outrigger system the legs are connected by horizontal tubes at certain floors; directly above and below the funiculate stations and at the top. The floor loads are carried through columns down to diagonals at outrigger levels which transfer the load to the Colossal columns, seen in Figure 3.

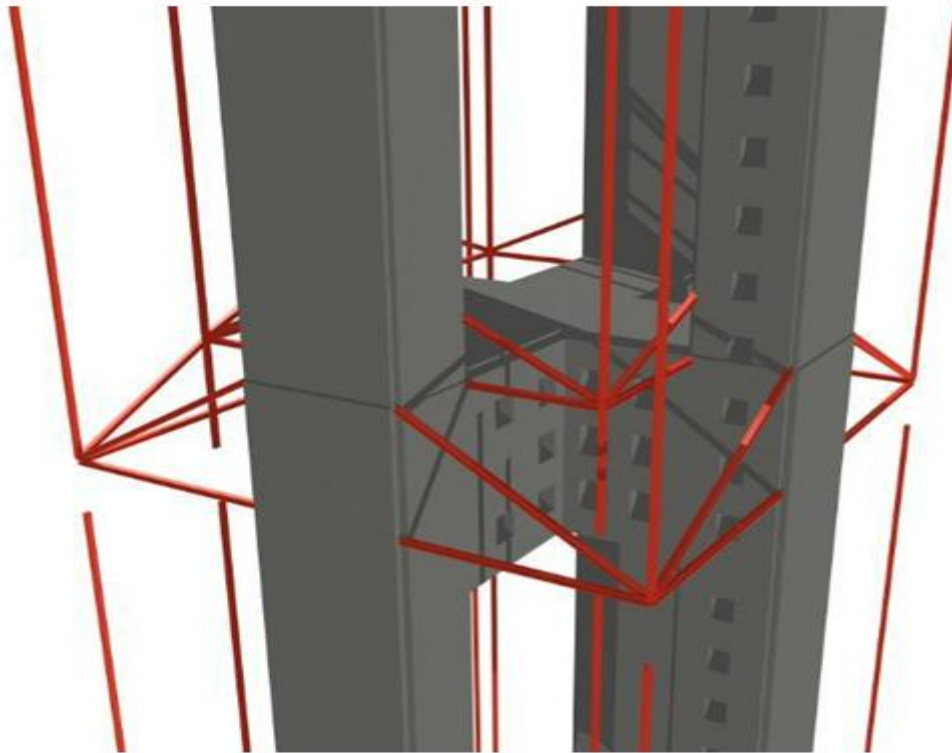


Figure 3: Floors around station, showing the framework connecting to Colossal columns via diagonals and the horizontal tubing connecting the legs

4. Result and analysis

The first result of the analysis of V1-V5, with no consideration of designing the walls, is expressed as buildings equivalent stiffness in different directions; X, Y and rotational stiffness R in Table 1 and Table 2. Based on the first result V5, which represents the TMF model used, is about as stiff as

the other models, besides the V1, in all directions. The V1A – V1C generally inherits much greater stiffness but also contains more material, about 34%, than in the V1-V5 due to the geometry of the tubes.

Table 1: Equivalent stiffness (EI) for V1-V5

	Stiffness Y	Stiffness X	Stiffness R
V1	3,93E+10	6,57E+10	1,77E+11
V2	7,30E+10	1,21E+11	4,15E+11
V3	7,29E+10	1,21E+11	4,75E+11
V4	6,38E+10	1,17E+11	4,75E+11
V5	6,41E+10	1,15E+11	4,54E+11

Table 2: Equivalent stiffness (EI) for V1A-C

	Stiffness Y	Stiffness X	Stiffness R
V1A	8,52E+10	1,21E+11	4,01E+11
V1B	1,18E+11	1,46E+11	5,50E+11
V1C	1,20E+11	1,29E+11	6,21E+11

As the V1 does not seem to be a stiffer version than V5, which was expected a different analysis is done. The tubes in models V1-V5 is connected at every other floor. The results

are illustrated in Table 3. In this case the V1 becomes stiffer than V5.

Table 3: Stiffness (EI) for V1-5 with Outriggers connected at every other floor

	Stiffness Y	Stiffness X	Stiffness R
V1	1,88E+11	3,55E+11	2,34E+12
V2	2,12E+11	4,08E+11	1,17E+12
V3	2,16E+11	4,15E+11	3,05E+12
V4	1,35E+11	2,56E+11	1,98E+12
V5	1,37E+11	2,53E+11	1,35E+12

In view of the results five promising models have been selected for the design of walls with the requirement that the tubes shall withstand the forces which have occurred by increasing wall thickness. From Table 4 it can be seen that V1 has the lowest stiffness while V1C has greatest stiffness but

uses more material. All of these models succeed in meeting the requirements for the highest allowed drift and deflection which is 0.25%. In this case V3 cope with the requirements using least material.

Table 4: Designed Tubed mega frame models, displaying stiffness (EI) and weight

	Stiffness Y	Stiffness X	Stiffness R	Weight [kN]	
				Walls	Total
V1	4,56E+10	7,59E+10	1,97E+11	54,1E+3	156,6E+3
V1A	8,76E+10	1,21E+11	4,06E+11	68,2E+3	162,9E+3
V1C	1,21E+11	1,32E+11	6,32E+11	66,9E+3	161,7E+3
V3	7,90E+10	1,27E+11	4,92E+11	52,4E+3	146,5E+3
V5	6,84E+10	1,21E+11	4,79E+11	52,4E+3	147,1E+3

5. Conclusions

It is not a simple task to determine which of the stabilization system that is most effective because there appears to be no universal solution to meet all possible requirements that may arise. Some systems are best suited taking into account certain factors, but has disadvantages over others. In the ETABS analysis of the 40 story building the three different systems each seem to have their respective benefits and disadvantages. Whereas the Outrigger system displays great stiffness its drawbacks are the amount of steel it uses and the extra number of stories the outrigger arms inhabit. The Tubed mega frame demands a high amount of concrete, more because of its geometry than the handling of loads. As with the Outrigger system some floors are sacrificed

to make room for the outriggers. The TMF does however use less steel and still has good stiffness, especially in the structures weak direction that is of outmost importance. Perhaps the most effective system at 40 stories is the Tube in a tube which does not require that much more steel than the TMF and the least amount of concrete, still being able to meet the requirements for deflection and drift. The tube in a tube system also has the benefit of not having to use outriggers, taking up space at certain floors, but has a drawback in that it uses a lot of room at the façade. Geometry is one of the most important aspects when it comes to the TMF. With other systems the geometry is often more static, not changeable other than with a wider or thinner core.

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