



OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

Design and Analysis of a Non-Conventional Tall Structure with Increasing Cross-Section Towards Higher Elevations Incorporating Environmental and Structural Challenges

SubhroJyoti Ghose¹, Prof. AnantBharadwaj², Prof. Ankita Agnihotri³

¹PG student of Civil Engineering , Sri Aurobindo Institute of Technology , M.P. , Indore

²Head of the Dept, Civil Enigeeering , Sri Aurobindo Institute of Technology , M.P. , Indore

³Professor, Civil Enigeeering , Sri Aurobindo Institute of Technology , M.P. , Indore

Abstract: It is difficult to distinguish the characteristics of a building which categorize it as tall. After all, the outward appearance of tallness is a relative matter. In a typical single-story neighborhood, a three-story building may appear tall. A 50-story building in a city may be called a high-rise, but the citizens of a small town may point proudly to their skyscraper of six stories. In large cities, such as Chicago and Manhattan, and now in United Arab Republic, with a vast number of tall buildings, a structure must pierce the sky around 100–120 stories if it is to appear tall in comparison with its immediate neighbors. A tall building cannot be defined in certain terms related to height or number of floors.

Tall Structure: A building of height greater than 50m. but less than or equal to 250m (Clause 3.14, pg. 3, IS 16700)

Key word : Tall structure, Load , Bending moment

I. INTRODUCTION

Development of engineering codes related to seismic analysis, wind load analysis also made it easier to construct the high risers. Geotechnical engineering is also coupled with structural analysis of tall structures because unless the soil condition is good enough to tolerate the heavy load in limited area the structure can not be constructed. Now a days several technologies are available like sand drain , preloading , mechanical compaction & etc. to develop the ground condition . Recently we are fortunate enough to have the guidance of IS 16700: 2023 for analysis of tall structure. The new materials allowed the development of light weight skeletal structures permitting building with greater height with reduced weight. The structures can be spacious enabling more people to dwell though the use of ground space is very less . Developers have seen the design of these two buildings, with their rectangular floor plates and central structural core, as representing the perfect office floor arrangement, due to flexibility and efficiency.

II. OBJECTIVE

We have already mentioned that research work is much done to design a tall structure with gradually increasing cross section towards higher elevation. It's design will be much more complex & challenging than other conventional structure tall structure with same cross section & gradually reducing cross section. The difficulties what we need to overcome for it's design are discussed below.

- Weight of slabs will be increasing towards higher elevation due to increased area. More mass will be accumulated in higher elevation. The center of mass for our proposed structure will be in higher elevation than conventional tall structure.
- In order to make the building environmental friendly we have proposed gardening in 5th floor, 7th floor & also in 9th floor. Total 32 no. of floors to be constructed above the ground level. The weight of soil to be considered in design. The slab thickness to be increased. Proper water proofing should also be considered to eliminate any harassed effect in structural members. Details of waterproofing including it's drawing are mentioned in later phase. Gardening is also considered in cantilever slab projected out from the building in peripheral area. The cantilever garden will make the building environmental friendly, will reduce heating effect inside the building but will also increase the weight of entire structure. The foundation should be able to support the load. Thus gardening is also another challenging factor to be considered to design the structure.

We have considered a swimming pool at the top floor of the building. Now a days swimming pool is available in several building, hotels.

III. METHODOLOGY :

The non-conventional structure will have increased cross section/ floor area towards higher elevation. Benefit of the structure: It will

be beneficial due to the following reasons as mentioned below

- A. After the construction will be over most of the ground area under same owner can be used as it was before.
- B. The ratio of ground occupied to constructed floor area will higher than conventional tall structures. [C] Considering the same ground area under same owner more dwellers, offices can be accommodated[D] Free land area of same owner can be increased in a crowded city with very dense population.

Soil improvement:

In comparison with conventional Tall Structures the ground will be subjected to immense pressure due to higher area constructed. So special soil improvement techniques to be implemented. There are several methods of soil improvement as mentioned below.

1. Mechanical compaction
2. Sand compaction piles & stone columns
3. Soil stabilization by use of admixtures
4. Soil stabilization by injection of suitable groups
5. Soil stabilization by electrical & thermal methods

Requirement of Foundation's stability: Foundation is the ultimate member to transfer the entire load of the building. The building what we are going to design is a special & nonconventional type. The area of the floors will be increasing with height. It's edges will follow a parabolic path of $Y = 5X^2$ But the size of foundation is limited to 17.5m. X 17.5m. Therefore it will be subjected to immense pressure. Stability of the structure depends upon the stability of the supporting soil. The foundation will be pipe cap. The foundation must be located with respect to any future influence which could adversely effect it's performance. For ex. In future there should not be any deeper excavation in the vicinity of the foundation. There should not be any leakage of any chemical which may cause reduction in bearing capacity.

Reduction of extreme weight:

1. To reduce the weight of the entire structure let us avoid using brick work for internal walls. Rooms with aluminum partition wall will reduce the weight. Unit weight of masonry brick work is 1920 Kg / Cu.M.. Unit weight of aluminium is 2710 kg/Cu.M.. But aluminium room are made of hollow section & thickness is much lesser than brick wall which is further followed by plastering.
2. The external wall in periphery can be constructed with toughen glass. As it will reduce the weight w.r.t. brick work. Unit weight of brick work is 1920 Kg / Cu.M. & that of toughen glass is 2.5 Kg/ Sq.M. per mm. So Considering 12 mm thickness we may have the dead load due to glass wall as 30 KG/Sq.M. But Brick wall will be minimum 100 mm thick so it will impose a weight of 192 kg / Cu.M (neglecting the weight of plastering) . Almost 6.4 times heavier than toughen glass wall.

Heavy material storage godown will NOT be allowed. Due to heavy weight point load (or heavy load in particular area) of stored materials to be considered . It may cause increased dead

load consideration for the entire structure & it may cause structural designing more challenging & uneconomic. Bearing capacity of soil may not be as high & required. Application of geotechnical engineering may cause the design uneconomic & practically not possible in different site conditions.

V. DESIGN:

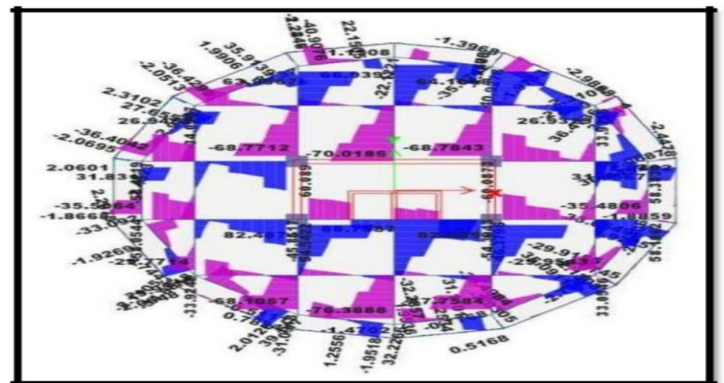
Application of Software

1. **ETAB** : The software stands for extended 3D structural analysis of building system . It is especially used for structural analysis of tall structures. It allows an engineers to define a grid system & create different structural elements like, beam, column, slab using different materials like different grades of concrete, steel & etc.
2. **STADD Pro**: The software is used for various structural analysis. It also enable us to determine the bending moment of structural elements.
3. **SAFE 22.7.0** : The software is used to analyze the foundation of the structure . Earlier we need to use ETAB to analyze the structural elements. The base reactions are found in ETAB & used in SAFE. It enables us to design the foundation of different size & shape.

Important notes

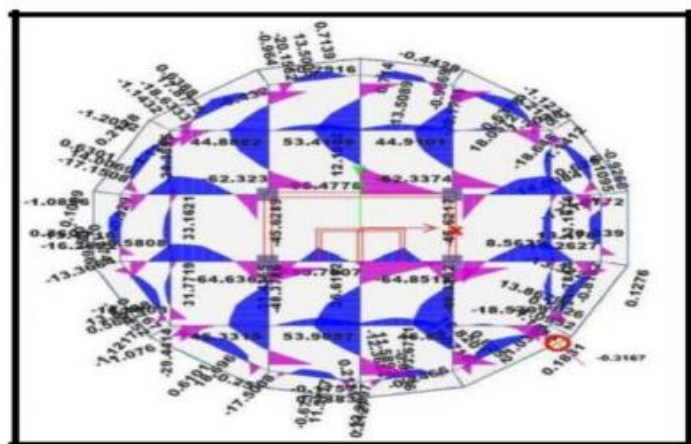
- [A] The structure will consist of total 36 floors. The floors will have gradually increasing cross section towards higher elevation.
- [B] [B] There will be a swimming pool in topmost floor (GF+32)
- [C] Gardens are proposed at GF=5 , GF+7 & G
- [C] Required Dead load, Live load, Earthquake load & Wind loads are applied through software
- [D] Toughen glass is used in external areas to reduce.
- [E] In garden area 400 mm soil filling will be done & waterproofing membranes will be applied.

Loads in design : The beams are designed through Etabs software . Dead load (1.5 kN/Sq.M.) , Live load (3Kn/Sq.M) , Earthquake load (Considering seismic zone V for location in North Sikkim , Mamring) , Wind load (As per location) is applied . Load of soil is separately considered in garden area , GF+5. GF+ 7 & GF+9 & cantilever projection of soil is considered for gardening. Load of water is also considered in swimming pool area in top most floor (GF+32) .



Generation of Shear force diagram , Bending moment diagram , Shear & longitudinal reinforcements are determined by Etab software . A few examples are mentioned

Shear Force diagram of beams @ GF+17 (Figure 1)

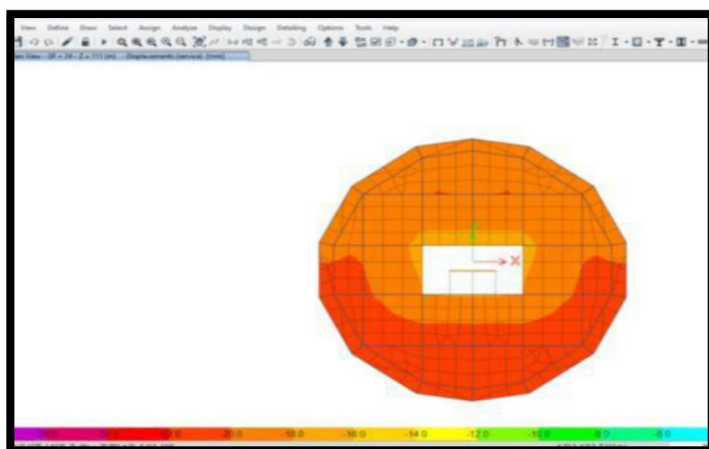


Bending Moment diagram of beams @ GF+17 (Figure 2)

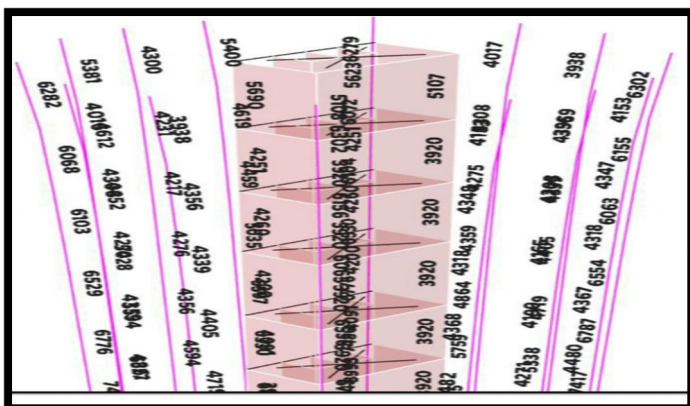
Similarly for all structural member it can be analysed through software.

Displacement of slab due to applied load can be checked.

One such example is mentioned below.



Max displacement found from colour scale is 22 mm < 25 mm (24th floor) (Figure 3)



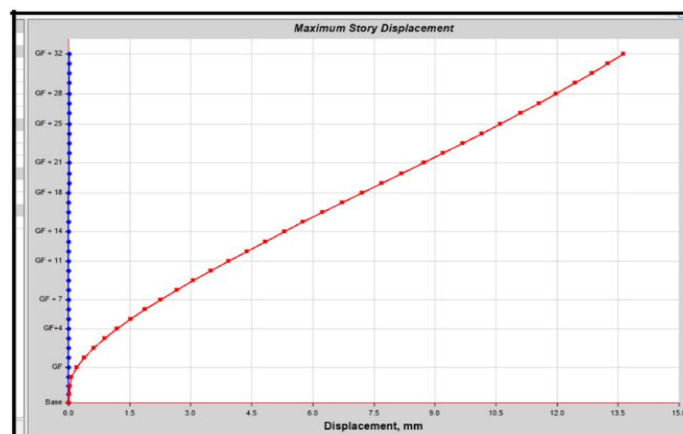
Longitudinal reinforcement of column (Figure 4) (Sq mm in cross section)

Foundation design: Due to immense pressure the ordinary raft foundation will not be possible. We need to create pile foundation. We tried with circular, polygonal & square pile caps. For every shape of pile caps we tried with different depths. Ultimately we found circular pile cap of 2 m. depth as most economic. Piles are designed with 0.6 m. dia. with 1.5 m C/C design . The group effect of piles are also considered. Efficiency of pile group (η_g) is calculated as mentioned below :

Calculation as per Converse Lambare formula- Gives the value $\eta_g = 0.567$

Calculation as per Sailer Kenny formula – Gives the value $\eta_g = 0.699$

P-Δ analysis

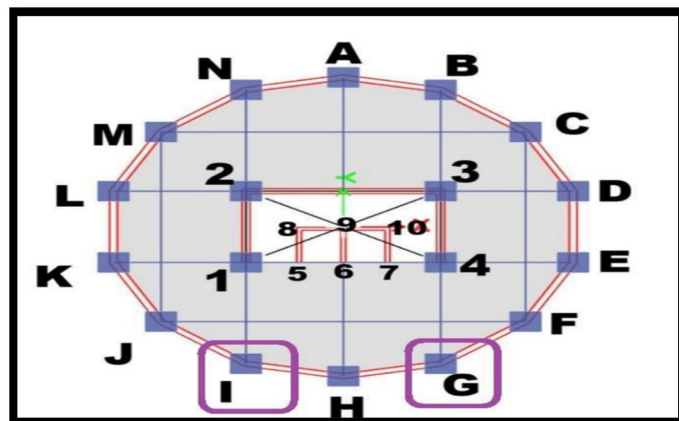


Pictorial presentation of graphical presentation of maximum displacement.

Q-

The analysis is done through Etab software

- The graph is generated through Etab software , maximum displacement found as 13.8 mm
- As per clause no 5.4.1, pg no. 5 of IS 16700: 2023 the total drift of topmost usable floor shall be limited to $H/500$.
- The height above soil level is 125m. Maximum allowable displacement for topmost floor will be $125/500 \text{ m} = 0.25 \text{ m} = 250 \text{ mm} > 13.8 \text{ mm}$ (the actual displacement of topmost floor)
- So we may conclude our structure is safe in P-Δ analysis.



Floor beam , column & wall layout (Figure 4)

Trial & experiments :

1.Size of Beam JF in GF + 32/ +130.00

a.Initially we considered the size of beam JF in above mentioned floor as 400 mm X 600 mm . But it failed in maximum deflection . Max. deflection found 28.75 mm > 25 mm.

b.We increased the size of the beam as 500 mm X 700 mm. Max. deflection reduced as 20.66 mm <25 mm . It is in permissible limit.

2.Slab thickness : Trial at GF + 31

1. Initially we tried to design the slabs with a thinness of 150 mm. But we found the maximum deflection as 28.70 mm > 25 mm.
2. We increased the thickness as 175 mm. All other parameters like size & layout of beams were same , loading conditions were also the same . The deflection reduced as 20.53 mm < 25 mm. It is in permissible limit.

3.Slab thickness : Trial at GF + 31

1. Initially we tried to design the slabs with a thinness of 150 mm . But we found the maximum deflection as 28.70 mm > 25 mm.
2. We increased the thickness as 175 mm . All other parameters like size & layout of beams were same , loading conditions were also the maintained as same . Deflection reduced as
3. 20.53 mm < 25 mm , in safe condition .

4. Attempt for reducing slab thickness at GF+32 [Swimming pool]

We took an attempt to reduce slab thickness at GF+32 (swimming pool area) to save concrete volume . But it failed in deflection. Deflection exceeds 25 mm (the permissible range) . All area failed in deflection excluding around opening.

5.Attempt for designing garden in higher elevation

We tried to design a garden in higher elevation at 29th floor. But the deflection of the slab exceed 25 mm . It's found as 27 mm . In practical situation there will be weight of water & trees which will increase the deflection. Increased size of beams or slab thickness could have reduced the deflection. But the weight of the structure will be increased. Already we have proposed pile foundation . Again increasing the load (also including the soil load) will create difficulty in design .

V.CONCLUSION

It is a great opportunity to go through the opinions of different wise & innovative persons like esteemed Professors, engineer / scientist & other people. Some of them have emphasized on wind load calculation, some on earthquake, some of them asked to strictly design the foundation. One theory is also developed regarding pile foundation in tall structure. Theories are also available regarding waterproofing & how the structures are affected due to harassed effect of soil. The intellectuals tried to analyses the tall structure with different shapes like rectangular, square, circular & etc. Different kind of frame work are also

proposed. We also have several IS codes as already mentioned. These codes also provide guidance for tall structure design. Now a days software like Etabs, STADD Pro are also available causing it much easier to expedite the design process. Earlier only manual design was possible & it was a long& time taking critical process.

VI.REFERENCES

- [1] IS 875 Part I : 1987
- [2] IS 875 Part II : 1987
- [3] IS 875 Part III : 2015
- [4] IS 1893 Part I : 2016
- [5] IS 456 : 2000
- [6] Tall Structure Design
By Bryan Smith & Alex Coull
- [7] Soil Mechanics & Foundation By P.N. Modi
- [8] Soil Mechanics By Amit Srivastava
- [9] Soil Mechanics & Foundation Engineering By K.R. Arora
- [10] Theory of Structures by S. Ramamurtham & S. Narayanan
- [11] Matrix Analysis of Structures By U.P. Wadge
- [12] Soil Mechanics & Foundation By B.C. Punmia