# NONLINEAR ANALYTICAL STUDY OF TALL BUILDING USING IS 16700-2017

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**Abstract -** *Tall buildings are emerging constructions in Indian cities due to urbanization. In comparison to low and mid-rise buildings the design criteria for tall buildings are different. National building code and other Indian standard codes are not sufficient to adequately address various issues related to tall building. Recently, BIS released the Code IS 16700: 2017 "Criteria for Structural Safety of Tall Concrete Buildings" under CED-38 committee. In present study various aspects studied for tall buildings with reference to IS 16700. In analysis for seismic loads few changes in comparison to IS 1893 part 1: 2016 are also reported. Modelling of the tall building and changes in the design considerations are listed.*

***Key Words***: Tall building, IS 16700-2017, P-delta, Stiffness Modifiers

## 1. INTRODUCTION

Shortage of land in cities to accommodate the huge population migrants due to rapid urbanization can be compensated by vertical developments of cities with tall buildings. Tall buildings are the emerging construction practice in the developing countries like India. The design criteria for the tall buildings are different I n comparison to low and medium rise buildings. When we check came to know that wind load isn't the governing case in the greater part of the low-ascent structures, yet for tall structures wind is the overseeing govern in the majority of the cases.

Urbanization's immediate impact was the enormous land scarcity that inevitably led to the construction of tall buildings, for both residential and business-related reasons, even more so in metropolises. More than half of Indian terrain is at a risk of earthquakes (~58.6%).

## 1.1 WHAT IS MEANT BY HIGH RISE STRUCTURE??

Tall structures all through the world are turning out to be mainstream step by step. With the appearance of advanced development innovation and PCs, the fundamental point has been to build more secure structures keeping in view the general financial matters of the task. A tall structure, condo tower, office tower, apartment block, or block of flats is a tall structure or structure utilized as a private and additionally office use. In specific zones they may be suggested as "Multi Dwelling Unit" or "Vertical metropolitan regions". They can possibly decongest the never-ending suburban on the ground level, and increment the metropolitan development, lodging higher number of families in lesser space. Advantages incorporate they go about as milestones; make special horizon and proficient land use. Despite the fact that there is no exact definition that is all around acknowledged, different bodies have attempted to characterize what high-rise means: The New Shorter Oxford English Dictionary defines a high-rise as "A building having many stories". The International Conference on Fire Safety in high-rise Buildings (IFSEC Global) defined a high-rise term as "Any structure where the height can have a serious impact on evacuation" Massachusetts, US General Laws characterize a skyscraper as being higher than 70 feet (21 m). The team of engineers, inspectors, architects and similar professions define a high-rise structure as a building that is at least 75 feet (23 m) tall.

## 1.2 HIGH RISE STRUCTURES IN INDIA

Indian urban communities are seeing massive development because of movement from encompassing towns, prompting endless suburban, housing interest, ascend in expense of land. Numerous residents all over India move to the urban areas for better positions and lifestyle. Enterprises, exchange and business exercises and number of institution focuses in urban areas pull in gliding populace from all their low populated towns and regions. This has extended the urban areas every which way and all parts of advancement. With an endless suburban of kilometres, these face the issues of clog, contamination, ordinary driving to work place, rivalry, deforestation and so forth.

## 2. IS 16700-2017 OVERVIEW

As India encounters fast turn of events, urban areas will keep on observing tremendous spray in the interest for reasonable lodging and business land, in the metro urban areas as well as in tier 2, 3 and 4 cities. Because of this need, the metropolitan advancement services of the states have expanded the reasonable developed region ashore by methods for increasing Floor Area Ratio (FAR or FSI). Most cities now typically have new buildings of 15 storeys and higher (50m+) to consume the available FAR. The structural engineering community across the country was not geared to the sudden increase in building heights and there were gaps in the conceptualization and design process of tall buildings. Unlike low-rise buildings, design of taller buildings is driven not by gravity loads alone; lateral loads such as wind and earthquake play a defining role in conceptualizing the design. A normalized plan convention to guarantee adequate execution of tall structures as far as security and functionality was required. Quite a Standard Code of Practice didn't exist in India for plan of tall structures. Consequently another Standard for Criteria for Structural Safety of Tall Concrete Buildings was created his standard gives prescriptive prerequisites to plan of RCC solid tall structures.

## 3. LITERATURE REVIEW

O. Esmaili and S. Epackachi et. al (2008) In recent decades, shear walls and tube structures are the most appropriate structural forms, which have caused the height of concrete buildings to be soared. So, recent RC tall buildings would have more complicated structural behavior than before. Therefore, studying the structural systems and associated behavior of these types of structures would be very interesting. Here in this paper; we will study the structural aspects of one of the tallest RC buildings, located in the high seismic zone, with 56 stories. In this Tower, shear wall system with irregular openings are utilized under both lateral and gravity loads, and may result some especial issues in the behavior of structural elements such as shear walls, coupling beams and etc. To have a seismic evaluation of the Tower, a lot of non-linear analyses were performed to verify its behavior with the most prevalent retrofitting guidelines like FEMA 356. In this paper; some especial aspects of the tower and the assessment of its seismic load bearing system with considering some important factors will be discussed. Finally after a general study of ductility levels in shear walls; we will conclude the optimality and conceptuality of the tower design. Finally, having some technical information about the structural behavior of the case would be very fascinating and useful for designers.

Rupali Kavilkar and Shweta Patil (2014) —High-rise structures are also called "vertical cities", having the potential to decongest urban sprawl. Indian cities are witnessing immense demographic expansion due to migration from surrounding villages, leading to urban sprawl, housing demand, rise in cost of land. Housing has developed into an economy generating industry. Given this demand, while high-rise residential structures have become a solution in the metropolitan cities, they remain eluded in tier II cities in India. Low-rise or mid-rise high-density dwelling types have developed in these cities. A study of Pune city's housing needs, demands, market, and type of structures being built, reveal that tall buildings of 11 floors are being developed on the city's urban fringe. Most of the high-rise projects remain as proposals. An investigation in this case study reveal that high rise structures are not preferred due to user perception of insecurity in case of fire and high cost of the building. The paper aims at studying the availability and use of fly ash in various proportions, which can be used in Indian high-rise residential buildings. The research paper indicates that fly ash concrete can be used to reduce the cost of construction and has the potential to minimize the damage caused due to high temperature.

Sunil S K, Mahesh Kumar C L et.al (2017) Tall building or Tallness, however, is a relative matter and tall buildings cannot be defined in specific terms related just to height or to the number of floors. The tallness of a building is a matter of a person's or community's circumstance and their consequent perception. From the structural engineer's point of view, however a tall building may be defined as one that. Because of its height, is affected by lateral forces due to wind or earthquake actions to an extent that they play an important role in the structural design. The influence of these actions must therefore be considered from the very beginning of the design process. In this Paper, considering the multi-storey building of G+30 floors. The various loads applied on the building such as Dead load, Live load and Earthquake load. Then analysing the behaviour of structure subjected to combination of the above-mentioned loads using E-tabs software. For the irregularity building considering the equivalent static method for different zones and soil types the clear visible that there is an increasing order in the values obtained for cumulative storey shear, displacement, storey drift and overturning moment are follows in the order of soil-I, soil-II and soil-III types in all zones in X direction. And also, it comes same in the order of zone II, zone III, zone IV, zone V in all soil types in X direction.

Sumit Ghangus, Prof. Sangeet Kumar Gupta (2017) 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.

Gangisetty Venkata Krishna and Ratnesh Kumar (2018) Tall buildings are emerging constructions in Indian cities due to urbanization. In comparison to low and mid-rise buildings the design criteria for tall buildings are different. National building code and other Indian standard codes are not sufficient to adequately address various issues related to tall building. Recently, BIS released the Code IS 16700: 2017 "Criteria for Structural Safety of Tall Concrete Buildings" under CED-38 committee. In present paper various aspects and issues related to tall buildings with reference to IS 16700 have been reviewed. The selection of structural system and plan dimension are specified based on structural configuration and seismic zone. In the design of tall building other parameters that need attention are; wind load analysis using wind tunnel test, P-Δ effect, secondary effect like creep & shrinkage, and temperature. In analysis for seismic loads few changes in comparison to IS 1893 part 1: 2016 are also reported. Modelling of the tall building and changes in the design considerations are listed. Criteria for selection of foundations are specified. The importance of non-structural elements is also specified and design guidelines based on the sensitivity of the elements are provided.

Khuzaim J. Sheikh Krutarth S. Patel et.al. (2018) Early structures in the medieval period of twentieth century were assumed to carry only the gravity loads. However, today with the increase in urbanization along with the scantiness of land availability and high price rise, the need of the vertical development arises for fulfilment of various needs of human activities. Owing to these situations, advances have been in the development for the use of high-strength materials, lightweight material along with changes in structural design and establishment of slender buildings. These innovative methods require critical analysis with consideration of lateral loads such as wind and earthquake loads. Presently, numerous structural systems are available which can be utilized for analysis of the lateral resistance of tall buildings. In this way, proper examination is required for undertaking the consideration of proper type of structural system, which can be used to fulfil all our Structural & Architectural parameters along with effective utilization of the material & technology that can be useful for sustainability of the future. The present work, studies the response of the various structural system used in the buildings and its comparison. Four different structural systems were investigated, which includes Structural Wall + Moment Resisting Frame, Structural Wall System, Core Structural Wall system and Outrigger Structural System (Belt Truss System). 39 storey building having typical height 3.65m was considered. Moreover, Response Spectrum analysis and Static wind analysis were also performed and comparison of different structural parameters such as Base Shear, Storey Drift, and Storey Displacement were accomplished.

M.Jesse Leo Pragnan, Anirudh Maddi (2019): The turn of the century saw urbanisation like never before, which has led to the obvious problem of land scarcity and thus, land price spike, among others. To address this inadequacy of space, tall buildings have become commonplace. However, the safety of multi-storied buildings diminishes greatly in areas of moderate - high seismic intensity. The design of such buildings must facilitate the accommodation of loads applied laterally on them. Following the recently released IS code, "Criteria for Structural Safety of Tall Concrete Buildings 1S16700:2017" will ensure the safety of these high rise structures even in zones of high seismic intensity. This latest code lays emphasis on using P-Delta analysis for high-rise buildings, alongside the other conventional seismic analyses (like Equivalent Static Analysis, Linear Dynamic Analysis (Response Spectrum Analysis), Nonlinear Static Analysis (Pushover analysis) and Nonlinear Dynamic Analysis) that were used hitherto. In this study, modelling, analysis and design of a Tall RCC building was done employing IS code16700:2017. ETAB software was used to execute Equivalent static analysis, Response Spectrum analysis and P-Delta analysis in seismic zone-V and medium soil conditions. A variety of seismic parameters, for example, self-weight, displacement, time period, storey drift, base shear and storey shear, were evaluated and analyzed for Response Spectrum analysis and P-Delta analysis making use o the IS16700:2017 code. Although the storey shear was same in both the analyses, the storey drift was considerably more in P-Delta analysis in comparison to Response Spectrum analysis.

Shesalu D. Vadeo | M. V. Waghmare (2019) Earthquakes in the past have shown that a strong mainshock is often followed by aftershocks forming mainshock-aftershock series type of ground motions or multiple earthquakes. Aftershocks could occur after days, months or even years and although they are normally smaller in magnitude, their intensity can be large with different energy content than mainshock and pose a seismic hazard after a mainshock. The general approach of seismic design of structures usually considers a single earthquake but recent studies have shown that the mainshock aftershock records and interaction between these two should be evaluated to determine the likely damage behavior and responses of structure.Due to successive shaking of the ground over a short period of time, the damages in the structure gets accumulated and the structure becomes vulnerable to collapse. To understand the behavior of structure under such repeated ground motions or multiple earthquakes, non-linear time history analysis is carried out. The present study considers a 12 storey reinforced concrete building. The building was analyzed for both linear and nonlinear time history analysis for 5-time history ground motions considering mainshock and mainshock-aftershock sequences. The material and geometric non linearities were accounted in terms of hinges and p-delta effects. It was found that the mainshock-aftershock sequence of ground motion has significant effect on the response of the structure in terms of top displacements and storey drifts. The analysis was carried out by ETABS 2016.

## 4. AIM AND OBJECTIVE OF PRESENT STUDY

Following are the objectives:

1) To understand the behaviour of structure linear equivalent static method is used.
2) To understand the behaviour of structure by Response spectrum analysis will be studied.
3) To compare structural performance in terms of Time Period, Storey Displacement, Storey Drift and Base Shear by Seismic Analysis.
4) To study the stiffness modifiers stated in IS 16700 & IS 1893 & its effect.

## 5. SCOPE OF WORK

Following are the scope of work:

1) The present study considers a 50 storey reinforced concrete building. The building was analyzed for both equivalent static linear and nonlinear response spectrum analysis.
2) The building will be analyzed according to the Indian Standards (IS 16700-2017& IS 1893-2016)
3) Only the superstructure is studied and the goal is to study the various clauses & codal provision stated in IS 16700.

## 6. PROBLEM STATEMENT

A regular symmetrical floor plan of 20-meter X 20 meter is considered with 50 Storey. Story height are kept 3m for all models. Nonlinear Response spectrum Analysis, P-delta analysis and Stiffness modifiers are studied.

## 7. METHODOLOGY

### 7.1 MODELLING STEPS

In this study, the Nonlinear Push over Analysis, P-delta analysis & Stiffness modifiers are studied in terms of storey displacement, storey drift, base shear and fundamental time period.

Following steps are adopted in this study.

Step 1: Selection of site condition and seismic zone.

Step 2: Selection of building geometry and modelling of structural system using ETABS 2017 software for the same plan.

Step 3: Application of loads and load combination to the structural model according to the Standard codes.

Step 4: Analysis of each building frame models.

Step 5: Comparative study of results in terms of time period, storey displacement, storey drift and base shear

Step 6: Analysis of each building frame models.

Step 7: Effect of Parametric changes on model will studied.

### 7.2 MODELLING DATA

Following data will be used for analytical model by ETABS 2019 to meet the objectives of this study.

Plan dimension 20 meter X 20 meter

Number of Storey 50 Storey

Grade of Concrete M40

Grade of Steel Fe500

Storey Height 3 meter

Size of beam 300mm X 600mm

Size of Column 650mm X 900mm

Shear wall 300 mm

Thickness of Slab 125mm

Dear Load 2KN/m^2

Live Load 3KN/m^2

Wall Load (Frame load) 12.42KN/m^2

Structure Utility Commercial

Seismic Zone III

Seismic Coefficient 0.16

Response Reduction Factor 5

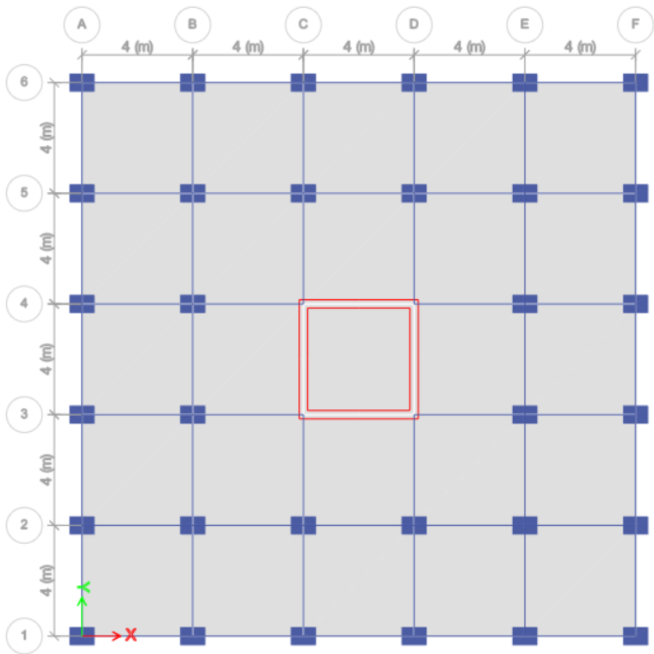
Importance Factor 1.2

Analysis Method Static Analysis

1. Linear Equivalent static method
2. Response spectrum analysis method.
3. Non Linear P-delta Analysis

IS Codes Used IS 456-2000
IS 1893 Part 1-2016,
IS 16700-2017

### 7.3 Bare Model




PLAN

Stiffness modifiers that are given in IS 16700-2017.

**Table 6 Cracked RC Section Properties**
(*Clause* 7.2)

| Sl No. | Structural Element | Un-factored Loads: Area | Un-factored Loads: Moment of Inertia | Factored Loads: Area | Factored Loads: Moment of Inertia |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| i) | Slabs | 1.0 $A_g$ | 0.35 $I_g$ | 1.00 $A_g$ | 0.25 $I_g$ |
| ii) | Beams | 1.0 $A_g$ | 0.7 $I_g$ | 1.00 $A_g$ | 0.35 $I_g$ |
| iii) | Columns | 1.0 $A_g$ | 0.9 $I_g$ | 1.00 $A_g$ | 0.70 $I_g$ |
| iv) | Walls | 1.0 $A_g$ | 0.9 $I_g$ | 1.00 $A_g$ | 0.70 $I_g$ |

## 9. RESULTS AND DISCUSSION

### 9. 1 Time Period

The time period which is obtained after static analysis is 5.492 sec.

| Case | Mode | Period | Frequency |
|---|---|---|---|
| | | sec | cyc/sec |
| Modal | 1 | 5.492 | 0.182 |
| Modal | 2 | 5.403 | 0.185 |

| | | | |
|---|---|---|---|
| Modal | 3 | 3.326 | 0.301 |
| Modal | 4 | 1.579 | 0.633 |
| Modal | 5 | 1.543 | 0.648 |
| Modal | 6 | 1.106 | 0.905 |
| Modal | 7 | 0.798 | 1.252 |
| Modal | 8 | 0.778 | 1.286 |
| Modal | 9 | 0.66 | 1.515 |
| Modal | 10 | 0.524 | 1.91 |
| Modal | 11 | 0.509 | 1.963 |
| Modal | 12 | 0.469 | 2.132 |

## 9. 2 Base Shear

As building is symmetrical hence we can see base shear value in both direction is equal.

RSX = 4231 KN
RSY= 4196 KN

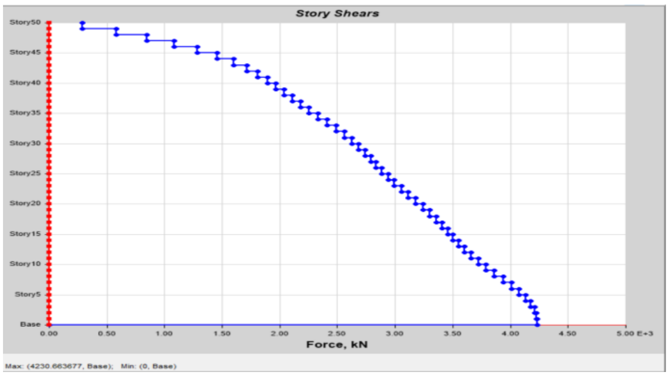



Figure 9.2.1 Base shear RSX dynamic Analysis for Structural wall and Moment frame

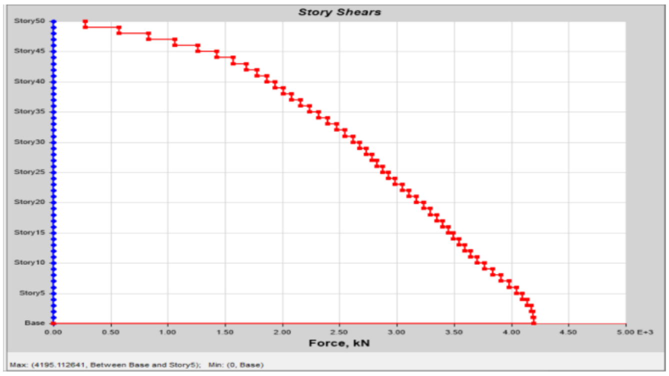



Figure 9.2.2 Base shear RSY dynamic Analysis for Structural wall and Moment frame

## 9.3 Lateral Displacement

Lateral displacement is maximum horizontal displacement that can be occur in the event of lateral load. The permissible lateral displacement should be (h/250),

Where,

h= Height of the building

i.e = 150000/250 = 600mm

Lateral displacement in X = 134.24mm

Lateral displacement in Y = 138.29mm

These values are less than permissible limit hence ok.

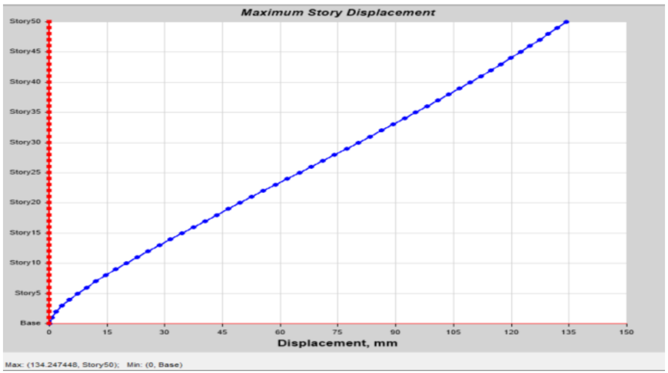



Figure 9.3.1 Lateral Displacement RSX dynamic Analysis for Structural wall and Moment frame

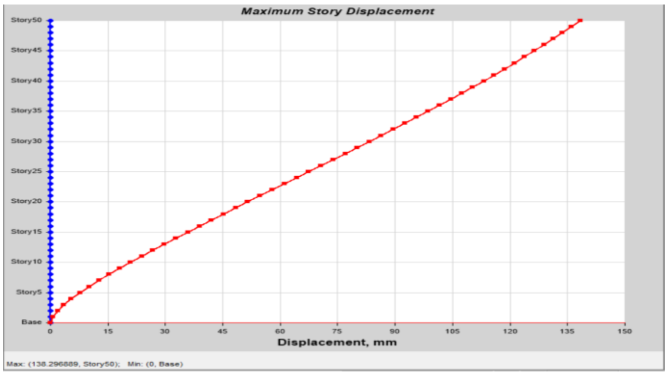



Figure 9.3.2 Lateral Displacement RSY dynamic Analysis for Structural wall and Moment frame

## 9.4 P-delta Analysis

P-delta analysis is the nonlinear analysis to tackle the secondary moments that will act on the structure. Here we consider the displacement that will occur due to weight of the structure. Generally this is very important in tall structure. Hence specifically IS16700-2017 suggest to carry out the p-delta analysis on the building.

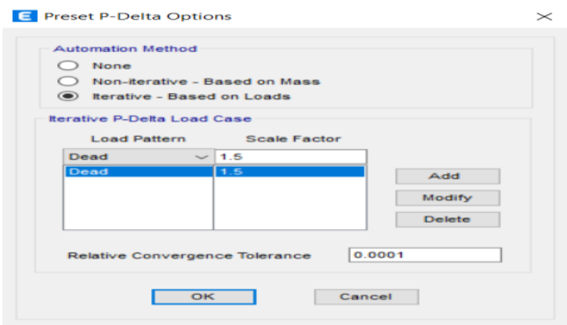



Figure 9.4.1 P-delta Analysis

**10. CONCLUSIONS**

Following are the conclusion.

1. Linear Static analysis gives Time period of 5.492 Sec. Dynamic analysis give Time period as 5.492 sec. Time period does not change with the change of seismic analysis method. For both the static and dynamic model time period remain unchanged. Hence we can conclude that time period value not affected when we change the method of analysis.

2. For linear static analysis first mode is in translation and second mode also in translation whereas third mode is found in rotation which is Ideal as per code requirements.

3. Base shear value is higher in dynamic analysis results compare to static analysis.

4. Lateral displacement is 182mm in X direction and 187 mm in Y direction. Which shows the stiffness contribution. Column orientation is in X-Y direction hence lateral deflection is less in X –direction comparatively in Y direction.

5. Moment resisting frame gives lesser value comparatively structural wall and moment frame for time period. As time period is inversely proportional to stiffness of the building. Time period is less when building stiffness is high. Structural wall contribute more stiffness towards the overall building compare to column. Hence this system is more reliable for high rise buildings.

6. When we compare the lateral displacement of the building with both the structural system then comes to know that structural wall are extensively resist the lateral load hence over all displacement is reduced. Here we found lateral displacement for Moment resisting frame as 173mm & 180mm in X & Y direction vice versa. When we compare it with structural wall system we get the lateral displacement as 134mm & 139mm in X & Y direction vice versa which is quite less. Hence we can conclude that this kind of system is more reliable and effective for high rise structures.

7. When we compare the inter storey drift of the building for the both the structural system then comes to know that structural wall system resist the lateral load effectively which results the lesser ratio of inter storey drift. Here we get the inter storey drift value for moment resisting frame system as 0.001357 & 0.001412 in X & Y direction vice versa. Whereas we get the inter storey drift value 0.001086 & 0.00118 in X & Y direction vice versa. Here we conclude that the structural wall system is most effective structural system for high rise buildings.

8. Base shear value for moment resisting frame is less compare structural wall system.

9. Time period value is increases when we use stiffness modifiers suggest in IS 1893-2016. This is happens because we are considering the cracked moment of Inertia. The gross capacity is reduced as suggested in code hence its stiffness also reduce which ultimately increase the time period.

10. Lateral displacement also found with increment when we applied the stiffness modifiers suggest in IS 1893-2016.

11. Inter storey drift also increase with modified stiffness given in IS 1893-2016.

12. When we compare the time period obtained from stiffness modifiers given in IS16700-2017 & IS1893-2016 then comes to know that IS 16700-2017 gives more time period value. More time period means less stiff. AS we are using the stiffness modifiers for wall and slab also which was missing in IS 1893-2016. Hence we can conclude that cracked moment of inertia should be followed for high rise building which is given in IS 16700-2017 as it is more reliable.

13. Lateral sway is much higher we are checking the displacement of the building with modified stiffness given in IS 1S 16700-2017. As we are considering the cracked moment of inertia. This value also higher than the stiffness modifiers based on IS 1893-2016. Hence we can conclude that for calculation of lateral sway of high rise buildings stiffness modifiers should be followed given in IS 16700-2017.

14. The same is happens with inter storey drift because we are dealing with cracked moment of inertia.

15. When we carried out the P-delta analysis then time period is increase as compare to structural wall dynamic analysis model. P-delta analysis encounter the secondary effect in the building which leads to differ the stiffness the building which ultimately increase the time period.

16. Lateral displacement after P-delta analysis is 150mm & 157mm in X & Y direction vice versa. This is higher than obtained value means for high rise building, P-delta analysis is quite important to ensure the secondary effect in the design.

### 10.1 Future scope of the study

Following points are considered as future study of this study.

1. Building with Geometrical Irregularity can be studied using IS 16700-2017.
2. Nonlinear seismic analysis can be carried for further results.
3. Time dependent of creep analysis can also be carried out.
4. Temperature analysis can also carried out.

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