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G+12 MULTISTORY BUILDING INTRODUCING WITH BELT TRUSS AND OUTRIGGER SYSTEM USING STAAD-PRO SOFTWARE

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Abstract: During the last few decades several buildings have been built utilizing belt truss and outrigger systems for the lateral load transfer (throughout the world). This system is very effective when used in conjunction with the composite structure, especially in tall buildings. The design of high-rise buildings is more often dictated by their serviceability rather than strength. Structural Engineers are always striving to overcome challenges of controlling lateral deflection and storey drifts as well as self-weight of structure imposed on the foundation. One of the most effective techniques is the use of an outrigger and belt truss system in Composite structures that can astutely solve the above issues in High-rise constructions. Multistorey structures are one of the most widely used to control the impact of overflow, efficiency, and durability when under horizontal forces acting on a structure similar to an outrigger system. During an earthquake or wind load, damage to non-structural forms can be trivialized. This paper examines a three-dimensional model of the G + 12-floor structure that should be available for analysis and design using Staad Pro software. This model analysis uses the linear static method and dynamic linear method. Features of efficiency and durability calculate integrated shifts, base shear, story drift, story strength, and critical real-time time of model of different types with outrigger system and of. The outrigger and belt truss system is commonly used as one of the structural systems to effectively control the excessive drift due to lateral load. During small or medium lateral load due to either wind or earthquake load, the risk of deflection can be minimized.

Index Terms - Storey Displacement, Base Shear, Base Moment, Axial Force, Bending Moment.

I. INTRODUCTION

In today’s modern era it has become a need to undertake development in tall structures to accommodate the present population as the cities are growing fast and land availability is becoming lesser for human beings, so there is a need for the r development of tall structures, but with development of tall structures there is need to tackle the problems related to it. Outrigger and belt truss structural system has proved to be an efficient and economical solution for the problems related to tall structure development. Earthquakes in general had a long history of deadly devastations in the past. Every year all over the world number of earthquake strikes the earth with low and high intensities. Earthquakes are the most unpredictable and devastating of all-natural disasters. Earthquakes are vibrations or oscillations of the ground surface caused by temporary disturbance of the elastic or gravitational equilibrium of the rocks above or beneath the surface of the earth. These disturbances and movements cause elastic impulses or waves. These waves are known as seismic waves and are classified as body waves- travel within the body of the earth and surface waves- over the surface of the earth. Earthquakes can be measured in terms of energy release i.e., by measuring amplitude, frequency, and location of seismic waves, and also by evaluating intensity i.e., considering the destructive effect of shaking ground on people, structures, and natural features. Intensity is measured on a Modified Mercalli intensity scale. Based on the peak ground acceleration or movement there are certain zones of the earth, named seismic zones. In India, there are four zones, II, III, IV, and V –the t one being the most devastating. The Indian subcontinent has a history of earthquakes. The reason for the intensity and high frequency of earthquakes is the Indian plate driving into Asia at a rate of approximately 47 mm/year.

The response of the structure due to ground motion is an essential factor to analyze and design any earthquake-resistant structure. The loads or forces which a structure subjected to earthquake motions are called upon to resist, the distortions induced by the motion of the ground on which it rests. The response (i.e., the magnitude and distribution of the resulting forces and displacements) of a structure to such a base motion is influenced by the properties of the foundations of the structure and surrounding structures, as well as the character of the existing motion. As the ground on which the building rests is displaced, the base of the building moves with it. However, the inertia of the building mass resists this motion and causes the building to suffer a distortion. This distortion wave travels along with the height of the structure in much the same manner as a stress wave in a bar with a free end. The continued shaking of the base causes the building to undergo a complex series of oscillations. When the ground shaking is at a much slower rate than the structure's natural oscillations, the behavior will be quasi-static; the structure simply moves with the ground with its absolute displacement amplitude, approximately the same as that of the ground. If the ground motion is much faster than the natural oscillations of the structure, then the mass undergoes less motion than the ground.

II. METHOD OF ANALYSIS

Most building structures were not designed to withstand large and moderate earthquakes by hand, in fact, usually, the force of gravity and lateral load makes it easier to attack the building during earthquakes. Its use, therefore, to appraise the severity of earthquakes through the STAAD-PRO software, is to improve the health and safety of crucial areas after earthquakes. The STAAD-PRO software also creates three-dimensional models and performs design and analysis The analysis method includes the following,

Vertical Line Route: - Vertical analysis is used to obtain equilibrium vertical loads to be commensurate to the action of variable earthquakes in buildings. The static method is adequate to analyze the properties using a formula as given in the Indian Code Of Distribution of removal, drift, and base shear calculations. So, this method is used to find the design of the lateral force known as the equivalent force method or the seismic coefficient method.

Strong Line Method: - This method is also known as the reaction spectrum method. The Spectrum method is to determine the behavior of structures during an earthquake such as a vibration problem using dynamic analysis, its calculation of the amplitude of deterioration. It establishes a spectrum of a single level of freedom in the elements of low movement. Also, this method is effective in designing and analyzing the spectrum of structural reactions that are abnormal, asymmetrical, etc. This method is also called modal mode.

III. PROJECT DESCRIPTION

3.1 Problem Statement

A G+12 storey building for a commercial complex has plan dimensions as shown in Figure 1. The building is Studied for all seismic zone on a site with medium soil. Design of building for seismic loads as per IS 1893 (Part 1): 2002.

3.2 General

1. The example building consists of a conventional concrete Building, a Building with a Belt truss of an Outrigger & Same Building with a Belt truss of an Outrigger including a Shear Wall caved in the center of the building in the outer periphery. Analysis and design are to be performed in Staad-pro Structural software.
2. The building will be used for exhibitions, as an art gallery or showroom, etc., so that there are no walls inside the building but for future expansion, we are taking an internal wall 115mm thick considering its load. External walls 230 mm thick with 12 mm plaster on both sides are provided and considered its load. For simplicity in analysis, no balconies are used in the building.
3. On the ground floor, slabs are not provided and the floor will directly rest on the ground. Therefore, only ground beams passing through columns are provided as tie beams. The floor beams are thus absent on the ground floor.
4. Secondary floor beams are so arranged that they act as Continuous beams and the maximum number of main beams gets a flanged beam effect.
5. The main beams rest centrally on columns to avoid local eccentricity.
6. For all structural elements, M30 grade concrete & Fe415 will be used.
7. The floor diaphragms are assumed to be rigid.
8. Centre-line dimensions are followed for analysis and design. In practice, it is advisable to consider finite-size joint width.
9. Preliminary sizes of structural components are assumed by experience.
10. For analysis purposes, the beams are assumed to be rectangular to distribute slightly larger moments in columns. In practice, a beam that fulfills the requirement of the flanged section in design behaves in between a rectangular and a flanged section for moment distribution.
11. Seismic loads will be considered acting in the horizontal direction (along with either of the two principal directions) and not along the vertical direction since it is not considered to be significant.
12. Plan aspect ratio is taken constantly for all the models which are (35m x 28m)
13. All dimensions are in meters unless specified otherwise.

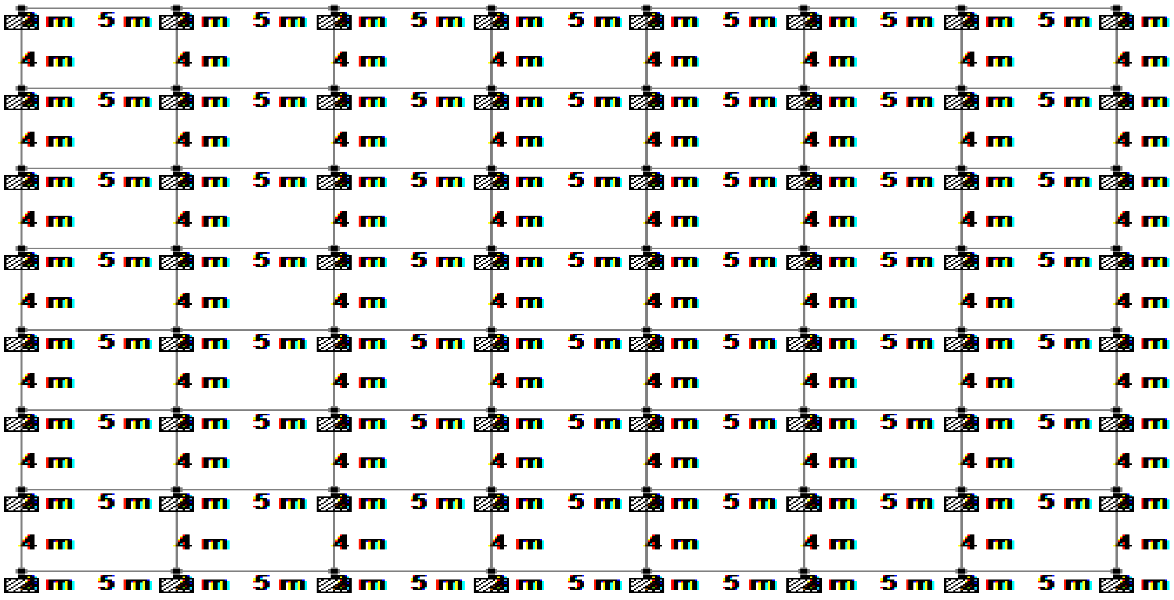

Figure 3.1. Plan of the building

Flow Diagram of Project

Conventional Concrete Building

Building with Outrigger and Belt Truss

Building using Outrigger and Belt truss Included Shear Wall

ZII ZIII ZIV ZV

ZII ZIII ZIV ZV

ZII ZIII ZIV ZV

Notation of Model

M1- CCBZII	M5-BUOBZII	M9- BUOBTSWZII
M2- CCBZIII	M6-BUOBZIII	M10-BUOBTSWZIII
M3- CCBZIV	M7-BUOBZIV	M11-BUOBTSWZIV
M4-CCBZV	M8-BUOBZV	M12-BUOBTSWZV

3.3 Description of Structure

General

The structure selected for this project is a simple Commercial building with the following description as stated below,

IS Code for Concrete: IS 456:2000
IS Code for Dead Load: - IS 875 Part 1
IS Code for Live Load:- IS 875 Part 2
IS Code for Seismic Load: - IS 1893:2002/2005 Part (1 to 4)

- Number of bays in the X direction and its width= 7 bays of 5 m each
- Number of bays in the Z direction and its width = 7 bays of 4 m each
- Story height = 3 m each
- Number of storeys = 13 (Excluding the plinth and substructure and including the Ground floor) (G+12)
- Depth of foundation from ground level = 2 m
- Plinth height = 800 mm
- Column size = 600 mm x 450 mm
- Beam size = 450 mm x 450 mm
- The thickness of the Slab =200 mm
- Density of concrete = 25 KN/m^3
- The brick wall on peripheral beams = 230 mm
- The brick wall on internal beams =120 mm.
- Type of wall= Shear wall & Masonry wall
- The thickness of the Shear Wall= 120mm
- Size of Outrigger Belt= 230 mm x 230 mm
- Material Used = Concrete M30 Grade

- The density of brick wall is 20 KN/m^3
- Internal Plaster 12mm
- External Plaster 12mm
- Density of Plaster = 18 KN/m^3

3.4 Data of the Example

- The design data shall be as follows for conventional concrete buildings:
- Live load: 4.0 KN/m2 at a typical floor
- Roof live load: 1.5 KN/m2 on the terrace
- Floor finish: 1.0 KN/m2
- Waterproofing: 2.0 KN/m2
- Terrace finish: 1.0 KN/m2
- Location: ZII, ZIII, ZIV & ZV.
- Wind load: As per IS: 875-part3 - Not designed for wind Load, since earthquake loads exceed the wind loads.
- Earthquake load: As per IS-1893 (Part 1) - 2002
- Depth of foundation below ground: 2 m
- Type of soil: Type II, Medium as per IS: 1893
- Allowable bearing pressure: 200 KN/m2
- Assume isolated footings with fixed joints.
- Storey height: Typical floor: 3 m, GF: 3 m & below plinths: 2m
- Floors: G.F. + 12 upper floors.
- Ground beams: To be provided at 100 mm below G.L.
- Walls: 230 mm thick brick masonry walls only at the periphery.

3.5 Material Properties

Concrete

All components unless specified in design: M30 grade all

Ec = 5 000 fck N/mm2
= 5 000 fck MN/m2
= 27 386 N/mm2 = 27 386 MN/m2.

Steel

HYSD reinforcement of grade Fe 415 confirming to IS: 1786 is used throughout.

A) For Conventional concrete Building:

Column Size: 600 x 450mm
Beam Size: 450mm x 450mm
X-type (Cross Bracing) as Outrigger belt truss: Size: 230mm x 230mm

3.6 Seismic design Parameters

General

For the present study following values for seismic analysis are assumed. The values are assumed based on reference steps given in IS 1893-2002 and 13920-1993 and IS 456:2000. Since Vidarbha is less vulnerable to earthquakes, this present study assigns all seismic *Zone* for moderate seismic intensity as stated in table 2 of IS 1893 – 2002.

- Zone factor for zone III – 0.16 (Table 2, P.16)
- Importance factor for office building = 1 (Table 6, P.18)
- Special Reinforced Concrete Moment resisting Frame (SMRF)
- SMRF is a moment-resisting frame detailed to provide ductile behavior and comply with the requirements of 13920-1993
- Response reduction factor for ductile shear wall with SMRF = 5
- Type of soil = Medium (Type II)
- Damping percent = 5 % (0.05)
- The thickness of the Shear wall = 230 mm
- Brick infill panel building type.

3.7 Design Seismic Load

The infill walls on upper floors may contain large openings, although the solid walls are considered in load calculations. Therefore, fundamental period *T* is obtained by using the following formula:

$T_a = 0.075\ h^{0.75}$ [IS 1893 (Part 1):2002, Clause 7.6.1]

$= 0.075 \times (44)^{0.75} = 1.28$ sec.

Zone factor,

- $Z = 0.1$ for Zone II
- $Z = 0.16$ for Zone III
- $Z = 0.24$ for Zone IV
- $Z = 0.36$ for Zone V

IS: 1893 (Part 1):2002, Table 2

Importance factor, I = 1.5 (public building)

Medium soil site and 5% damping

Ductile detailing is assumed for the structure. Hence,

Response Reduction Factor, *R*, is taken Equal to 5.0.

It may be noted, however, that ductile detailing is mandatory in Zones II, III, IV, and V.

3.8 Models Creations in Software

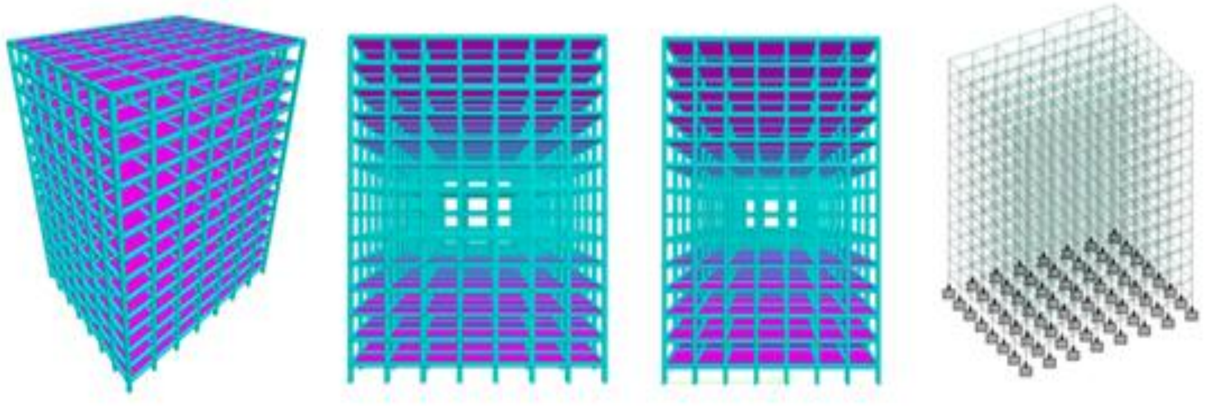

Figure 3.8.1. Conventional Concrete Structure

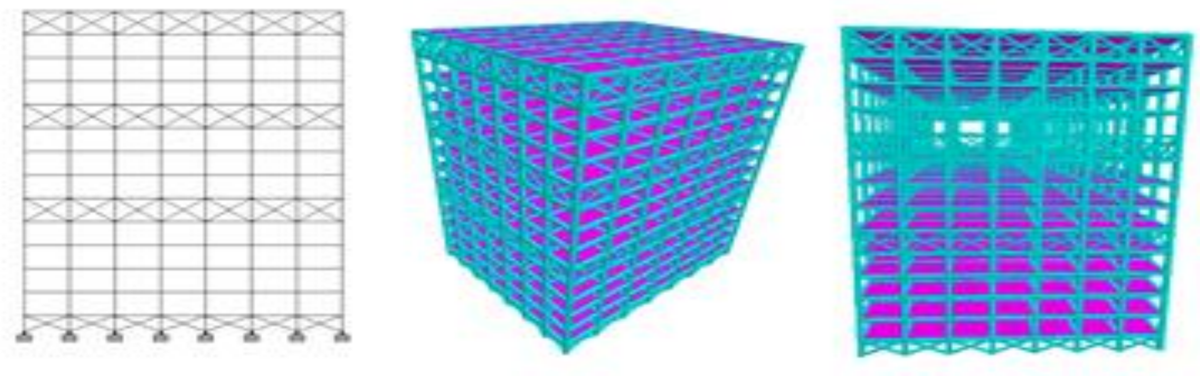

Figure 3.8.2. Structure with Belt Truss And Outrigger

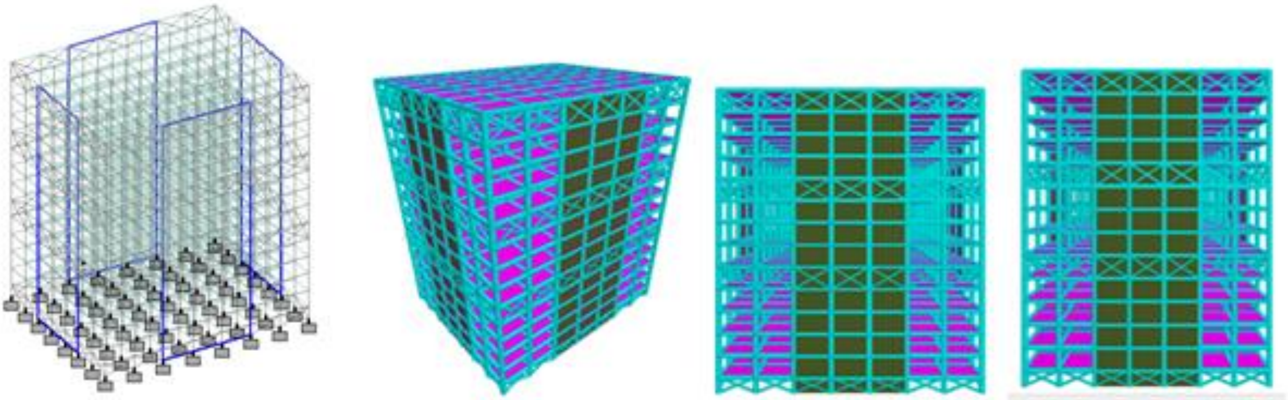

Figure 3.8.3. Structure With Belt Truss And Outrigger Introducing With Shear Wall.

IV. RESULTS AND DISCUSSION

A G+12 Multi-storied RCC building for all Seismic Zones is modeled using STADD-Pro software and the results are computed. The configurations of all the models are discussed in the previous chapter. Three types of models were created to analyze the structure of all seismic Zones. Model Type I - For the reference base model, a regular reinforced concrete moment resisting bare frame model is considered. Model Type II – In the base model introduce the Model with a belt truss as an outrigger. And Model Type III – Model with belt truss and outrigger introducing Shear wall. Equivalent Static Earthquake analysis is carried out to study parameter’s maximum storey displacement, Base shear, Base moment, Axial Force, and Bending Moment to compare the building with the application of a concrete outrigger at various positions varying with the height of the building and the software used for this analysis is Staad-pro V8i version. These models are analyzed and designed as per the specifications of Indian Standard codes IS1893, IS 13920, IS 875, and IS 456: 2000. The equivalent static method or seismic coefficient method had been used to find the design lateral forces along with the storey in X and Z direction of the building since the building is unsymmetrical.

4.1. Max. Base Shear & Base Moment

Elements or members of the buildings should be designed and constructed to resist the effects of design lateral force. STADD-Pro gives the lateral force distribution at various levels and each storey level. Lateral force of an earthquake is a predominant force that needs to be resisted for any structure to be earthquake resistant. The equivalent static method had been adopted to find out the lateral force in STADD-Pro. The Table No. 5.1 to Table No. 5.8 shows the distribution of the lateral force and the base shear & base moment at each storey level in X-direction & Z-direction.

Table 4.1 Lateral force or Base shear along X & Z direction.

Model	Base Shear	Base Shear
	X (KN)	Z (KN)
Model 2	95.332	95.132
Model 6	254.92	302.547
Model 10	2749.89	2348.815

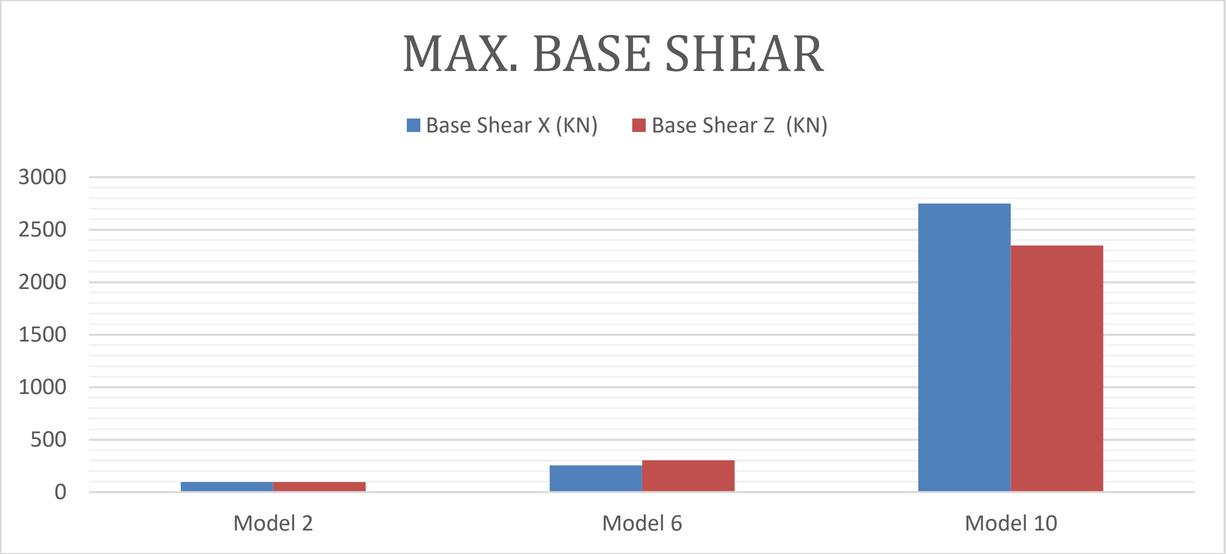

Figure 4.1 Lateral force or Base shear along X & Z direction.

4.2 Axial Force and Bending Moment calculation

Maximum Axial force and bending moment in any building are responsible for the stability of the members of any structure. The Axial force and bending moment are useful parameters for the design of any member of the structure. The least the moment the lesser will be the cost of the structure. Table 5.9 to Table 6.5 shows the Maximum Axial force and bending moment tabulated in X and Z direction for all the models.

Table 4.2.1 Axial force in X & Z direction for Zone III

Model	Axial Force	Axial Force
	X (KN)	Z (KN)
Model 2	9036.937	99.973
Model 6	9037.71	101.026
Model 10	9010.303	151.845

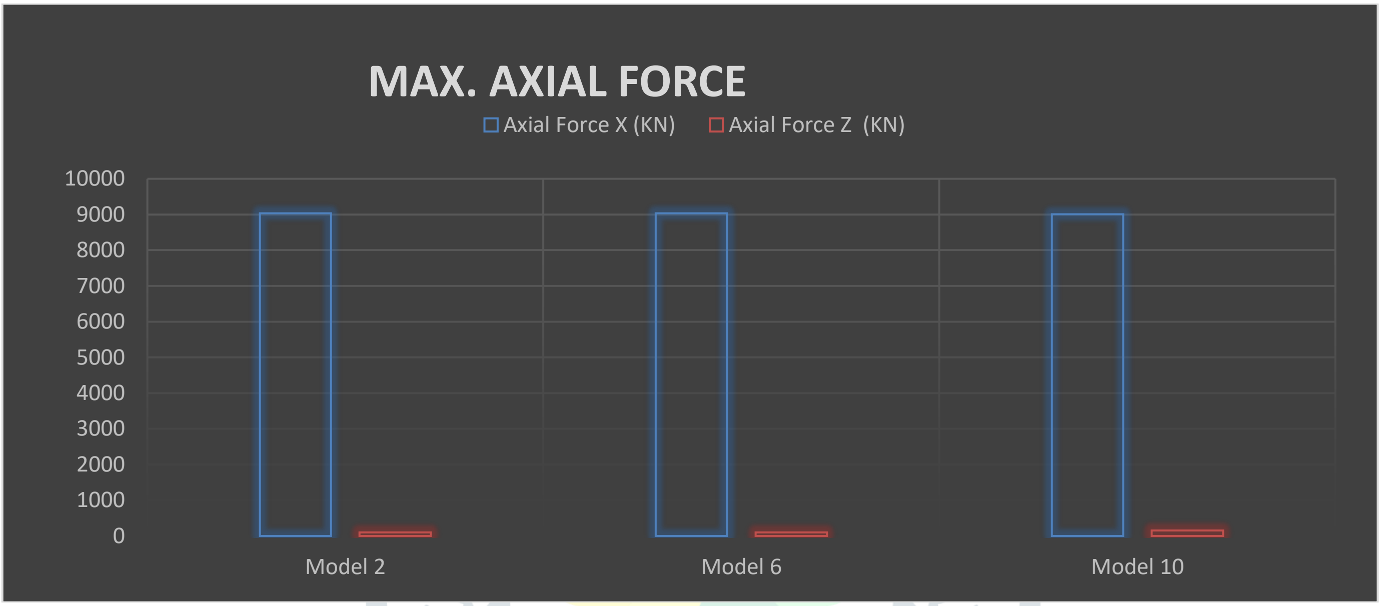

Figure 4.2.1 Axial force in X & Z direction for Zone III

Table 4.2.2 Bending Moment in X & Z direction for Zone III

Model	Bending Moment	Bending Moment
	X (KN-M)	Z (KN-M)
Model 2	1.392	159.764
Model 6	2.856	168.834
Model 10	11.035	270.133

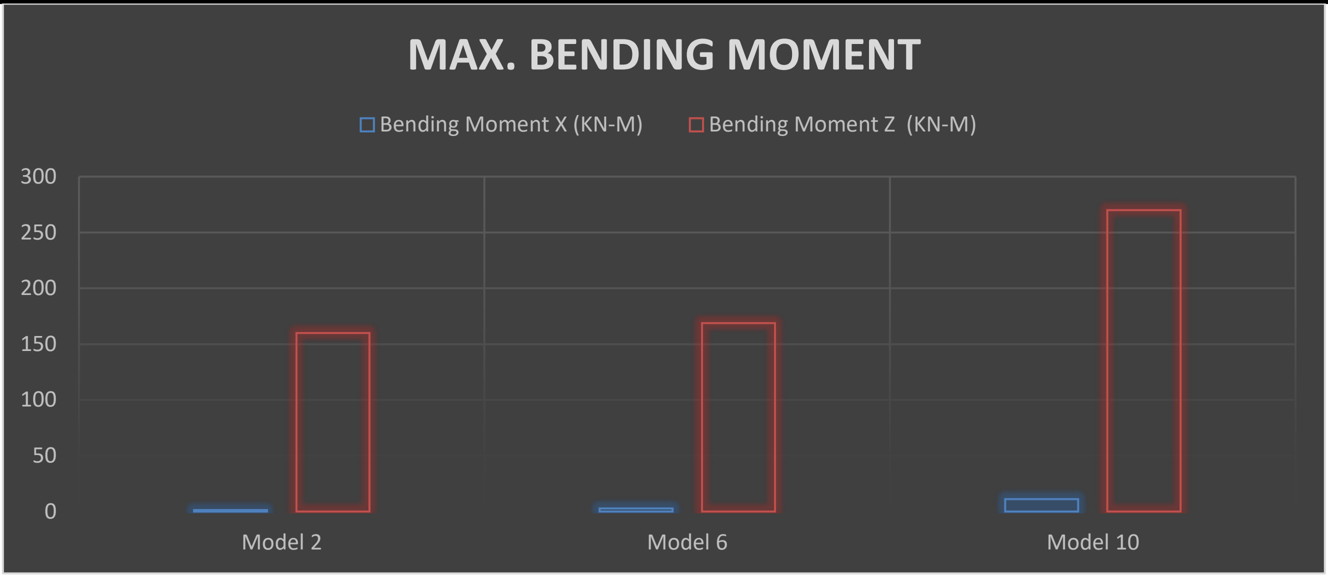

Figure 4.2.2 Bending Moment in X & Z direction for Zone III

4.3 Maximum Nodal Displacement

Node displacement of any structure represents the deflection of the structure whenever any load or load combination is applied to the structure. Since the building is analyzed for Earthquake resistance, displacements in horizontal directions are shown in table 5.8. Maximum displacements in X- Direction and Z- Direction for load combinations are stated in the table.

Table 4.3 Maximum Node Displacement for ZIII

Model	Displacement in	Displacement in
	X (mm)	Z (mm)
Model 2	37.945	44.444
Model 6	31.832	37.96
Model 10	20.326	27.168

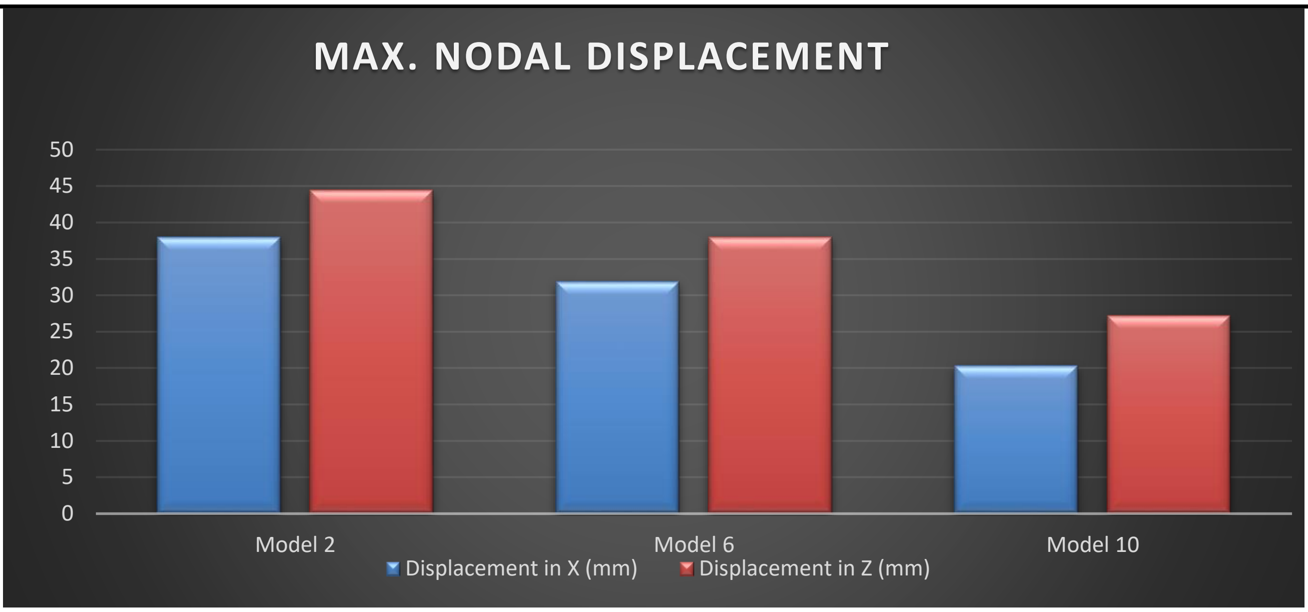

Figure 4.3 Maximum Node displacement for ZIII

V. CONCLUSION

[1] In very high-rise buildings, the outrigger system and belt truss provide maximum stiffness and increased efficiency when under air load or earthquake load.
[2] To use the outrigger system, the deviation or displacement is much smaller at the top of the level structure than outside the structural outrigger system.
[3] This slight deviation is due to the stated condition of the barber wall in the center of the building where an outrigger system is available to control the state of small maneuver.
[4] The instability of the use of a single level outrigger is better to control for a small shift than outside the outrigger system, but if more than one, two, three, four, or more is less of a reduction than all other structures.
[5] The model of 12-storey buildings under seismic side effects is approximately 10.5% reduced by vital side removal, and by 15% in storey drift.
[6] The architectural outrigger system can be used for up to 24 news plots.
[7] The load resistance capacity of tall buildings increases with the provision of an outrigger due to its strength factor.

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