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Comparison of Different Types of Structural Systems in Tall Building Under Lateral Load

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Abstract

This study is aims to investigate the performance of multi-storey high rise concrete structures by linear static methods. The code suggests a different approach of analysis for asymmetric structures. The main objective of the study is to carry out the lateral load analysis to obtain performance levels of buildings. According to the load nature and structure behaviour method of liner static method be selected from storey drift, displacement, and Base shear. The study focuses on concrete structures located in seismic Zone IV, which is characterized by rocky soil conditions, according to the earthquake load specifications outlined in IS 1893 Part 1:2016. For the linear analysis G+25, G+30 and G+35 storey configuration are employed. The E-tabs software is utilized to conduct the analysis. The study compares various structural maximum response parameters to assess the performance of the structures. These parameters include displacement in the X- and Y-directions, storey drift, and base shear. In research, total 12 models with in addition to regular moment resisting frame model, moment resisting frame with shear wall, tube in tube model, and tube in tube with shear wall are considered for evaluation. Furthermore, the paper aims to compare the results obtained from the linear static methods for all the assessed parameters.

Keywords: *Compare The Maximum Displacement, Drift, Base Shear; High Rise Concrete Building; Linear Static Method; Seismic Load Analysis.*

1 Introduction

In last few years high rise concrete structure plays an important role for strong structure and the construction industry. Shear capacity of a structure can increased with shear wall system in the structure. Design of the structure must have good ductility to work well under lateral load. For getting max performance, required to understand linear static analysis. It is very essential to aware the performance base study for such buildings. Structural system and its elements are analyzed by linear static to get the satisfactory knowledge on seismic demands imposed by the ground motion. We can obtain load carrying capacity of the structure and different performance range of the structure by liner static analysis. computer-based linear static analysis is technique for performance-based design of building frame subject to lateral loading. The present study calculating attraction and displacement curve for different concrete frames with and without shear wall designed according to Indian standers general construction in concrete & steel, IS-456:2000 & IS-800:2007.

1.1 Concrete

Concrete, a widely used building material, consists of aggregate bonded together by fluid cement, which cures over time. It's composed of aggregate mixed with dry Portland cement and water, forming a fluid slurry. Through hydration, where cement reacts with water, this mixture hardens over hours into a durable stone-like material. Concrete's versatility allows it to be molded into various shapes and undergo tooled processes. The hydration process is exothermic, influenced by ambient temperature, which affects the setting time. Mortar, on the other hand, is a bonding agent used for masonry units, unlike concrete, which serves as a standalone building material.

1.2 Seismic analysis

Earthquake load is a lateral force occurring during seismic events, necessitating thorough consideration of a building's seismic behavior. Seismic analysis calculates how buildings respond to earthquakes, crucial for structural planning and engineering in quake-prone areas. Early seismic regulations, like the 1927 UBC appendix, mandated shear forces proportional to building weight on all floors. The evolution of seismic engineering has led to sophisticated designs incorporating specialized components in foundations or throughout structures. Modern analysis uses advanced finite element methods, simulating complex structures with precision akin to physics engines in video games.

1.3 Scope of the present study

Modelling of the multi-storey concrete building with various types of structural system under the lateral load using Etabs software and the results so obtained has been compared like as, lateral displacement, story drift, and base shear. Tushar B. Bambhaniya's study on Response Spectrum Analysis for high-rise concrete structures suggests that moment frame systems (M.F.S) and flat slab (F.T) systems are equally effective up to 20 storeys due to similar section sizes. However, beyond 20 storeys, tube systems offer superior resistance to lateral loads despite using smaller sections. Tube-in-tube structures, in particular, exhibit significantly reduced top storey movements and minimal storey drifts compared to traditional tube, shear wall, and moment frame systems. These findings underline the advantage of tube systems in enhancing structural stability and performance in taller buildings subjected to seismic forces. [1] Bipin H Naik's study on steel moment resisting frames and concrete tube structures shows that steel tube structures offer greater adaptability with longer periods and lower frequencies compared to traditional steel moment resisting frames. External bracing reduces the time period. Base shear increases with closer column spacing in steel tube configurations (steel tube-2, steel tube truss-2). However, steel tube structures exhibit larger displacements and drifts due to reduced stiffness compared to conventional moment resisting frames. [2] Syed Musthafa Khadri's study on wind and seismic analyses of various tube-in-tube and framed tube models reveals significant differences in displacements and storey drifts. Wind analysis indicates that models without shear walls experience higher displacements, reduced by 13.48%, 30.37%, and 78.93% in X and Y directions for framed tube, bundle tube, and tube in tube with shear wall models respectively compared to tube in tube without shear wall. Similarly, seismic analysis shows maximum displacements are highest for tube in tube without shear wall, decreasing by 2.66%, 18.71%, and 67.71% in X and Y directions for framed tube, bundle tube, and tube in tube with shear wall models respectively. Model 2 consistently exhibits the least storey drift across both wind and seismic analyses. [3] Hamid Mirza Hosseini's study emphasizes that reducing overall building drifts involves enhancing the stiffness of flange and web frame members. Increasing column depth significantly affects both overall building and storey drifts. Larger beam depths reduce overall building drifts, with critical storey drifts impacted more than overall drifts. However, increasing beam depth shifts axial forces away from ideal states in corner columns. Increasing interior wall thickness in models with high lateral stiffness increases overall building drifts, while enhancing middle column forces and balancing axial force distribution. [4] Mrunal P. Kawade's study on the Response Spectrum Method concludes that selecting the most effective stabilization system depends on specific project requirements, as no universal solution exists. Rigid frames exhibit high base shear under seismic loads, whereas systems incorporating central core walls (tube in tube, tubed mega frame, suspended structure) show decreasing base shear. Tubed mega frame and suspended structures have longer natural periods but experience high axial forces, shear forces, and moments in columns and beams. Adding central core walls improves lateral load efficiency in rigid frames and tube in tube structures. [5]

1.4 Objective

- To investigate a comparative study between Rigid Frame (RF), Rigid Frame with Shear Wall (RFSW), Tube in Tube (TT), Tube in

Tube with Shear Wall (TTSW).

- To evaluate the maximum result in Base Shear, Story Shear and Displacement, and compare those all.

2 Methodology

The primary role of structural elements in buildings is to support gravity loads. However, buildings also face lateral forces from wind and earthquakes, which become more critical with increasing height. Different structural systems respond differently to seismic forces due to factors like configuration, symmetry, mass distribution, and vertical regularity. Strength, stiffness, and ductility are crucial for ensuring structures can withstand these forces effectively. The initial task for structural designers is selecting a suitable system that meets seismic performance requirements while aligning with architectural needs, shown in Table 1, Table 2 & Table 3. Early collaboration between architects and structural engineers helps avoid unfavorable geometries that complicate design. Irregularities in buildings, such as abrupt geometry changes, interrupted load paths, and variations in strength and stiffness, can lead to complex structural behavior, potentially causing unexpected damage or collapse. Recognizing and addressing these irregularities requires a deep understanding of structural behavior.

2.1 Details of the Building

A symmetrical building of plan 40m X 40m located with location in zone IV, Jamnagar is considered. Eight bays of length 5m along X and Y direction are provided. Shear wall is located at the center of the building. All support is fixed at base.

Table 1 Details of The Building

General properties of Building	Details
Building plan	40m X 40m
Number of storey	G+25,30,35
Length of span in X-direction	5m
Length of span in Y-direction	5m
Floor height	3.0 m
Live load on floor	4 kN/m^2
Floor finish	1.25 kN/m^2
Periphery wall load	5.52 kN/m
Thickness of slab	200 mm
Grade of concrete	M45
Grade of steel	Fe500

Table 2 Size of The Member

Member	Size of the member
Column	1100 mm × 1100 mm(G+25 RF, G+35 RFSW) 1200 mm × 1200 mm(G+30 RF, G+35 TTSW) 1400 mm × 1400 mm(G+35 RF) 650 mm × 650 mm(G+25 RFSW) 1000 mm × 1000 mm (G+25 RFSW, G+30 TTSW) 700 mm × 700 mm(G+30 RFSW) 1050 mm × 1050 mm (G+30 RFSW) 800 mm × 800 mm(G+35 RFSW) 1800 mm × 1800 mm(G+25 TT) 1900 mm × 1900 mm(G+30 TT) 2000 mm × 2000 mm(G+35 TT) 900 mm × 900 mm (G+25 TTSW)
Beam	600 mm × 775 mm(G+25,30 RF) 450 mm × 600 mm(G+25,30 RF) 700 mm × 700 mm(G+25,30 RF) 300 mm × 450 mm(G+25,30,35 RFSW) 1500 mm × 900 mm(G+25,30 TT) 1500 mm × 950 mm(G+35 TT) 450 mm × 530 mm(G+25,30 TTSW) 650 mm × 600 mm(G+35 TTSW)
Thickness of shear wall	300 mm(G+25,30,35 RFSW), 380 mm (G+30 RFSW)

Table 3 Details of Seismic Parameters

Seismic parameters	Details
Seismic zone	IV
Importance factor(I)	1.2
Response reduction(R)	5
Types of soil	Rocky soil(Type-1)
Time period of G+25	1.110 sec.
Time period of G+30	1.323 sec.
Time period of G+35	1.537 sec.

3 Modeling of Building

3.1 Model Design

One of the objectives of this model generation is to accurately represent the distinctive characteristics of residential buildings. High-rise structures vary significantly in shape, height, and functionality, resulting in each building possessing unique characteristics. While there are established standards for different types of high-rise buildings (such as residential, office, and commercial), this study primarily focused on essential factors for model generation. In residential buildings, it is typical for all floors to share the same floor plan, which simplifies the modelling process, shown in Figure 1, Figure 2, Figure 3 & Figure 4. Therefore, the buildings in this study were modelled with identical floor plans across all levels. Additionally, shear walls of uniform section were implemented consistently throughout the building's height, strategically positioned at the central core of the structure. The modelling work was conducted using the software ETABS, a widely used tool for structural analysis and design in high-rise buildings.

3.2 Layout of the Buildings

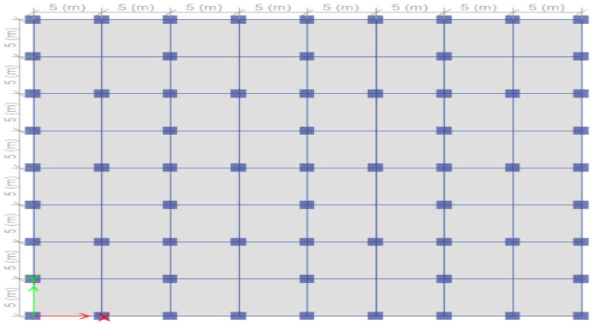

Figure 1 Plan of Rigid Frame

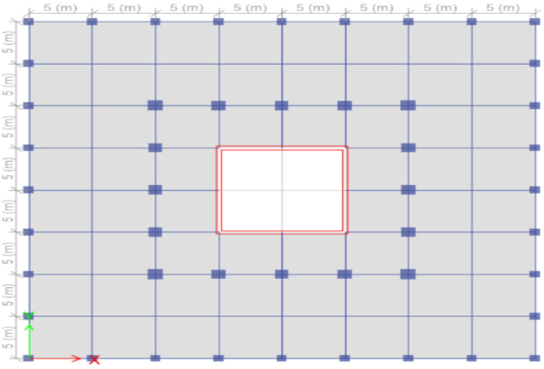

Figure 2 Plan of Rigid Frame with Shear Wall

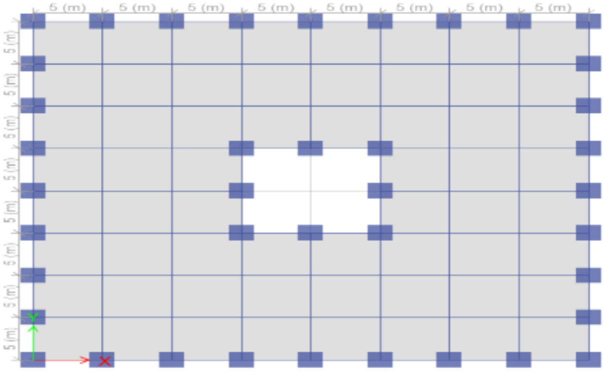

Figure 3 Plan of Tube in Tube Frame

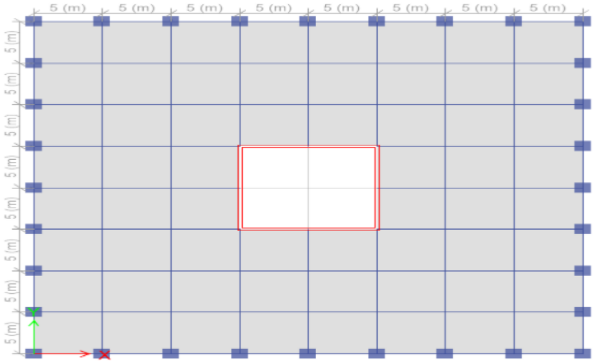

Figure 4 Plan of Tube in Tube with Shear Wall

3.3 Load Combination

As Per IS 456: 2000 Table 18 Cl. 18.2.3.1, 36.4.1, and B-4.3 limit state of collapse. The following load cases used in modelling, shown in Table 4.

Table 4 Load Combination

Name of Combination	Load Combination
Comb-1	1.5 (DL+LL)
Comb-2	1.5 (DL+EQX)
Comb-3	1.5 (DL-EQX)
Comb-4	1.5 (DL+EQY)
Comb-5	1.5 (DL-EQY)
Comb-6	1.2 (DL+LL+EQX)
Comb-7	1.2 (DL+LL-EQX)
Comb-8	1.2 (DL+LL+EQY)
Comb-9	1.2 (DL+LL-EQY)
Comb-10	0.9DL+1.5EQX
Comb-11	0.9DL-1.5EQX
Comb-12	0.9DL+1.5EQY
Comb-13	0.9DL-1.5EQY

4 Result and Discussion

4.1 Results

The behavior of each model is studied and the results are tabulated. The variation of controlled parameters like base shear, displacement, Storey drift has been studied for linear static method.

4.2 Results of Maximum Displacement in Various System

Figure 5 shows the comparison of maximum displacement for all four models. It shows that displacement is maximum in rigid frame without shear wall and minimum in rigid frame with shear wall. By adding shear wall displacement is reduced up to 15% to 40%.

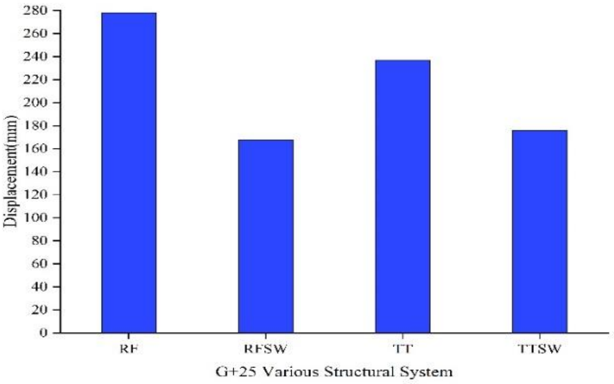

Figure 5 G+25 Displacement in Various System

Figure 6 shows the comparison of maximum displacement for all four models. It shows that displacement is maximum in rigid frame without shear wall and minimum in rigid frame with shear wall. By adding shear wall displacement is reduced up to 7% to 28%.

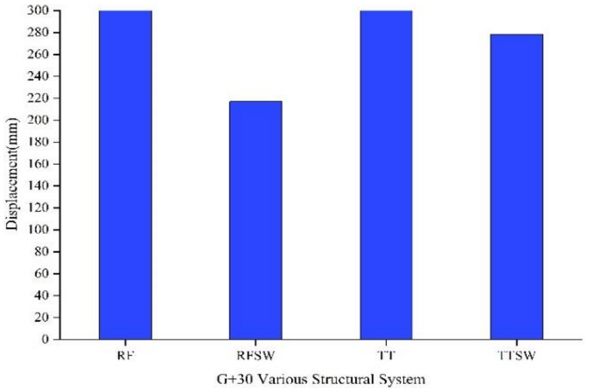

Figure 6 G+30 Displacement in Various System

Figure 7 shows the comparison of maximum displacement for all four models. It shows that displacement is maximum in rigid frame without shear wall and minimum in rigid frame with shear wall. By adding shear wall displacement is reduced up to 4% to 35%.

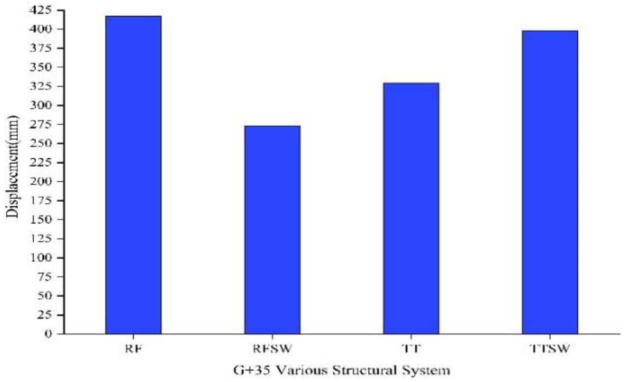

Figure 7 G+35 Displacement in Various System

4.3 Results of Story Drift in Various System

Figure 8 shows the comparison of story drift for all four models. It shows the maximum story drift in rigid frame without shear wall and minimum in rigid frame with shear wall. By adding shear wall story drift is reduced up to 16% to 46%.

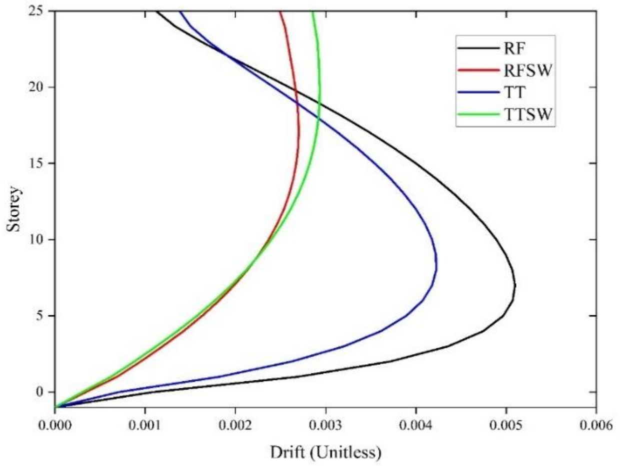

Figure 8 G+25 Story Drift in Various System

Figure 9 shows the comparison of story drift for all four models. It shows the maximum story drift in rigid frame without shear wall and minimum in rigid frame with shear wall. By adding shear wall story drift is reduced up to 16% to 46%.

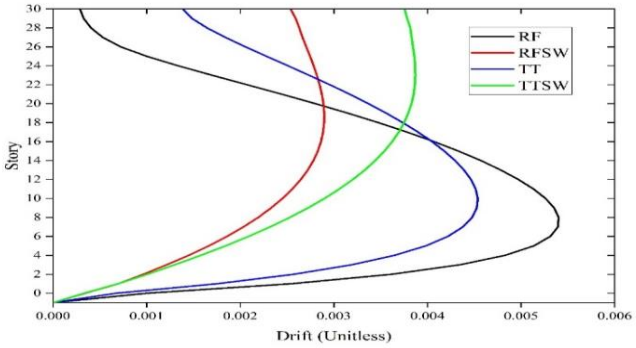

Figure 9 G+30 Story Drift in Various System

Figure 10 shows the comparison of story drift for all four models. It shows the maximum story drift in rigid frame without shear wall and minimum in rigid frame with shear wall. By adding shear wall story drift is reduced up to 16% to 44%.

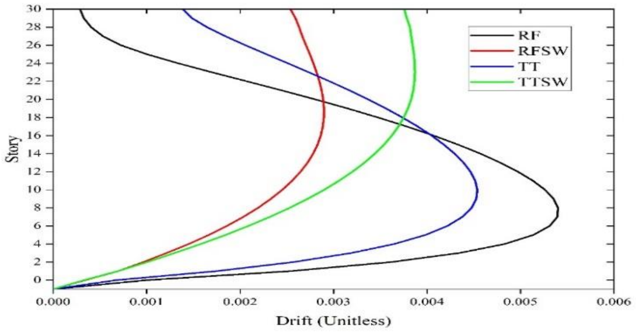

Figure 10 G+35 Story Drift in Various System

4.4 Results of Base Shear in Various System

Figure 11 shows the comparison of base shear for all four models. It shows the maximum base shear in Tube in Tube without shear wall and minimum in rigid frame with shear wall. By adding shear wall base shear is reduce for RFSW and TTSW up to 18% to 24%, and increased in TT up to 72.51%.

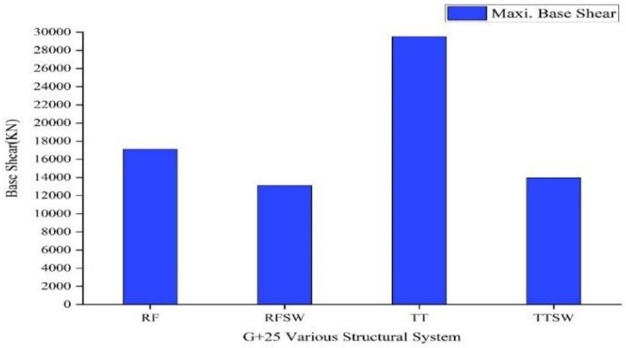

Figure 11 G+25 Base Shear in Various System

Figure 11 shows the comparison of base shear for all four models. It shows the maximum base shear in Tube in Tube without shear wall and minimum in rigid frame with shear wall. By adding shear wall base shear is reduce for RFSW and TTSW up to 20% to 30%, and increased in TT up to 68.60%.

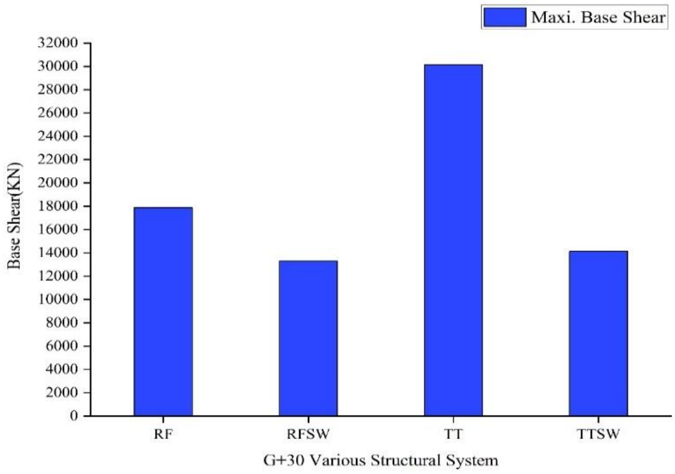

Figure 12 *G+25* Base Shear in Various System

Figure 12 shows the comparison of base shear for all four models. It shows the maximum base shear in Tube in Tube without shear wall and minimum in rigid frame with shear wall. By adding shear wall base shear is reduce for RFSW and TTSW up to 20% to 40%, and increased in TT up to 48%.

Conclusion

- By analysis of the G+25 storey building the maximum displacement is carried out in the Rigid Frame 279 mm and the minimum displacement is carried out Rigid Frame with Shear Wall 168 mm. The displacement reduces by 39.78 %.
- By analysis of the G+30 storey building the maximum displacement is carried out in the Rigid Frame & Tube in Tube is 300 mm ands 8 the minimum displacement is carried out Rigid Frame with Shear Wall 217 mm. The displacement reduces by 27.66 %.
- By analysis of the G+35 storey building the maximum displacement is carried out in the Rigid Frame 417 mm and the minimum displacement is carried out Rigid Frame with

Shear Wall 273 mm. The displacement reduces by 34.53 %.

- By analysis of the G+25 storey building the maximum drift is carried out in the Rigid Frame 0.0050 and the minimum drift is carried out Rigid Frame with Shear Wall 0.0027. The drift reduces by 46.00 %.
- By analysis of the G+30 storey building the maximum drift is carried out in the Rigid Frame 0.0054 and the minimum drift is carried out Rigid Frame with Shear Wall 0.0029. The drift reduces by 46.30 %.
- By analysis of the G+35 storey building the maximum drift is carried out in the Rigid Frame 0.0055 and the minimum drift is carried out Rigid Frame with Shear Wall 0.0031. The drift reduces by 46.64 %.
- By analysis of the G+25 storey building the maximum Base Shear is carried out in the Tube in Tube structural system 29517 kN and the minimum Base Shear is carried out Rigid Frame with Shear Wall 13102 kN. Base Shear Compare to Rigid Frame 72.51 % increase in Tube in Tube structural system.
- By analysis of the G+30 storey building the maximum Base Shear is carried out in the Tube in Tube structural system 30148 kN and the minimum Base Shear is carried out Rigid Frame with Shear Wall 13293 kN. Base Shear Compare to Rigid Frame 68.60 % increase in Tube in Tube structural system.
- By analysis of the G+35 storey building the maximum Base Shear is carried out in the Tube in Tube structural system 31527 kN and the minimum Base Shear is carried out Rigid Frame with Shear Wall 13808 kN. Base Shear Compare to Rigid Frame 47.61 % increase in Tube in Tube structural system.

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