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Comparative Seismic Analysis of High Rise Buildings with Different Structural Framing

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ABSTRACT

Now a day it has been observed that modern trend is towards taller and slenderer structures both residential and commercial increasing rapidly. As the height of structure get increases, the building acts as cantilever and get deflected because of its slenderness. For such structure the effects of lateral loads like winds loads, earthquake forces have become more effective which increasing importance for every designer to face with the problem of providing adequate strength and stability against lateral loads with economic consideration. From the previous studies, it has been concluded that there was not much problem in drift failure particularly in lower seismic zones. But as we go to higher zones than the ordinary multistory buildings also face the problem of drift more than the prescribed by the IS code 1893-2002 which become critical limit causing sudden collapse during earthquake. This study focuses on the various provisions to reduce the drift of building and make it more stable. Some of them are providing shear wall, tube structural system and base isolation system. The analysis has performed using ETABS for G+42 multistoried building in zones III.

Keywords : Framing system, Lateral loading, Drift control, Base isolation, Shear wall

I. INTRODUCTION

The population is growing day by day, so we have a problem of limiting available land. Recently, a high rise building has become more popular due to increasing cost of land. In general, structures can be classify as low-rise buildings with less than six stories, mid-high-rise buildings with stories between six and fifteen, and high- rise buildings with more than fifteen stories. As the height of building increases, the lateral loads become predominant than the gravitation loads. Wind and earthquake load are the two types of lateral loads acting on high rise buildings. Lateral forces cause very high stresses and deflections. So that, structures should have the adequate strength to resist vertical forces together with required stiffness against horizontal loads.

During the structural design innovation period, many lateral load resisting models have been developed like the moment resisting frame system, shear wall system, brace frame system, outrigger braced structural system and many different framed tube models like tube, tube- in-tube, partially braced tube-tube, bundled tube models which provide an economical high-rise structure designs with different height width ratios.

The main aim in this project is to perform seismic analysis of high rise building with moment resisting frame system, shear wall system, brace frame system and tube-in-tube system using structural program ETABS.

II. LITERATURE REVIEW

Khan.R. , Shinde.S.B (2015) This paper represents the study of 20 storey diagrid structure in comparison with exterior braced frame structure. The analysis and design results of the two models are presented in the form of storey shear, displacement, drift, and summary of lateral and gravitational forces. However, the diagrid structure withstands about the same amount of lateral loads as compared to an exterior braced structure, since all vertical columns are eliminated along its periphery. As such, the diagrid structure has a higher efficiency than braced structures.

Patil.M.N., Sonawane.Y.N (2015) This paper investigates the earthquake response of a symmetric multistory building using manual calculations and ETABS 9.7.1 software In both manual and software analyses of seismic weights, the result is the same. Base shear values obtained by manual analysis differ slightly from those obtained by software analysis. The values obtained by manual analysis are slightly higher than those obtained by software analysis.

T.Subramani, M.Shanmuganandam (2018) The paper presents the analysis of a 4 storey reinforced concrete plan geometric abnormal and one with fixed base and different with base isolated approach using SAP 2000. An analysis of dynamic response spectrum is conducted for a building with four stories. Fixed base and base isolator are used to analyze the total structure. The conclusion of this work stated that base isolation is one of the most effective tools of engineering concerning the passive structural vibration control technologies.

N.H. Hamid, I.F. Azmi and S. Shin (2018), This paper explorer the day by day increasing demand of base isolation system in high seismic regions for building structures. The structures were modelled using the finite element software, SAP2000. As per the research there are basically three types of base isolation system which are passive base isolation system, active base isolation system and hybrid base isolation system. Among these the hybrid base isolation system is most effective type to reduce severe damages in structures. Also concluded that the lead rubber bearing elastomeric bearing isolator shows superb seismic performance under severe ground motions.

Dia Eddin Nassani, Kamiran Ali (2020) In this paper, structural analyses were performed to compare the structural response of different types of lateral load resisting systems (moment-resisting frame system, shear wall system, dual system and framed tube system) under effect of seismic and wind loads using the structural program ETABS. Each system that resists lateral loads was evaluated for its displacements on storeys.The main purpose of this paper was to prove that the changing in the type of structural system from the moment resisting system to the tube system had positive results in the performance of the structure behavior the results showed that the deflections were decreased with changing the type of structure from the first system (moment resisting) to the fourth system (tube).

III. PROBLEM DEFINITION

In tall building design, drift is a concern related to the dynamic characteristics of the building during earthquakes, which can result in the horizontal displacement of the building. Drift shall be caused by the accumulated definition of each member, such as a column, beam, brace and shear wall. Therefore, when we want to control the quantity of displacement by changing its design, we cannot figure out which member of the structure should be changed, only from one result of computer calculation.

The main objective of this paper is on drift control in structural design. Consequently present the effective earthquake protection system for drift control by comparing structural framing system and base isolation system.

The following methodology is adopted for the analysis of R.C. multistoried building:

1 Review of existing literatures by different researchers.
2 Selection of types of structures.
3 Modeling of the selected structures.
4 Selecting building areas for analysis.
5 Analysis is carried along for x-axis.
6 Performing static analysis on selected building models and comparison of the analysis results.
7 Determining parameters like drift values, deflections, storey shears are compared for all type of structural systems.

IV. MODELLING AND ANALYSIS

Every structure has to be designed for strength, limiting deformation and durability. On achieving this, the function and aesthetics of structures should keep in consideration. These may possible when structural engineer has got sufficient knowledge about architectural requirements. High-rise structures are subject to lateral loads, which can cause certain failures. The lateral loads are almost live loads, whose main horizontal force component acting on the different members of structure.

The basic model is replication of 'Palais Royale' in Mumbai, Maharashtra, India.

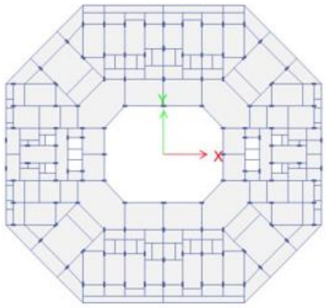

Figure 1: Plan View

Figure 2: Elevation View

TABLE I MODEL DESCRIPTION

Description	Value	Unit	Remark
Type of building	Residential		
Total height ofsuper structure	126	m	
Width of structure	32	m	
Length of structure	35	m	
No. of stories	42	Floors	
Floor Height	3	m	
Beam Size	230x700	mm	For all floors
Column Size	350x1000	mm	For all floors
Slab Thickness	150	mm	For all floors
Live Load	2	kN/m^2	For all floors
Floor Finish Load	1	kN/m^2	For all floors

A. Shear wall frame

Shear wall is a vertical R.C.C. plate continuous from foundation level up to roof. These are designed to resist the horizontal forces that are induced in the plane of wall. The shear walls are placed symmetric in plan layout to avoid the twist in building.

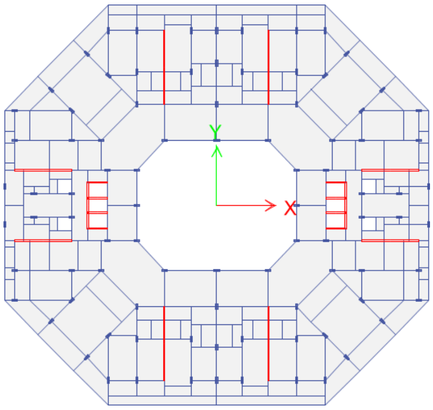

Figure 3 : Shear wall frame

B. Tubular system

This is the simplest form of a tube, consisting of closely spaced columns that are linked by deep spandrel beams. A rigid frame formed by columns and beams along the exterior of the building forms a dense and strong structural wall. It provides sufficient strength to resist all lateral loads on the building, so that the interior can be framed simply for gravity loads.

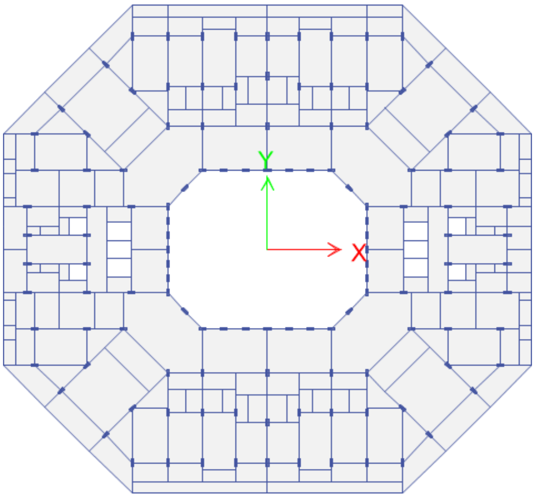

Figure 4: Tube frame

C. Base Isolation system

Base isolation systems are earthquake protection measures that separate the superstructure from the foundation. An elastomeric bearing is the most common form of base isolation. It is composed of mild steel plates sandwiched between layers of natural or synthetic rubber which act as single unit. During an earthquake, the steel plates stabilize the rubber layer so that it doesn'tbulge.

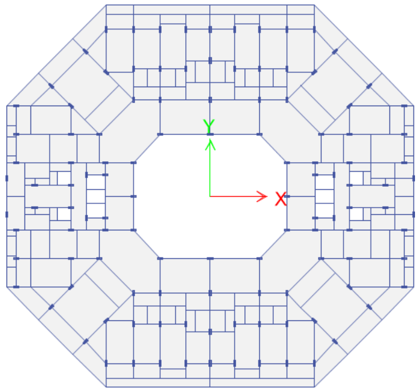

Figure 5: Base Isolation

Elastomeric Bearing Base Isolator Properties from 'Doshin Rubber Engineering' catalogue selecting 880mm diameter circular bearing for maximum column load at base

CIRCULAR SERIES T- Ø 880 mm

Part No.	Overall Height (mm)	Designed Compressive stiffness at zero shear (kN/mm) keff	Designed Shear stiffness (kN/mm) k	Shear Deflection Capacity (mm)	Total Rubber (mm)	Rated load at ZERO shear At Rotation : 0,003 rad (kN) Fz	Rated load at 70% shear At Rotation : 0,003 rad (kN)	Estimated Mass (kg)
INTERNAL RUBBER LAYER THICKNESS - 18 mm								
DC-1804-T-C	137	3921	7.60	50.4	72	14524	11172	346.10
DC-1805-T-C	160	3137	6.08	63.0	90	14524	11172	380.98
DC-1806-T-C	183	2614	5.07	75.6	108	14524	11172	415.86
DC-1807-T-C	206	2241	4.34	88.2	126	14524	11172	450.75
DC-1808-T-C	229	1961	3.80	100.8	144	14524	11172	485.63
DC-1809-T-C	252	1743	3.38	113.4	162	14524	11172	520.52
DC-1810-T-C	275	1569	3.04	126.0	180	14524	11172	555.40
DC-1811-T-C	298	1426	2.76	138.6	198	14524	11172	590.29
DC-1812-T-C	321	1307	2.53	151.2	216	14524	11172	625.17
INTERNAL RUBBER LAYER THICKNESS - 21 mm								
DC-2103-T-C	123	3520	8.69	44.1	63	12200	9385	317.18
DC-2104-T-C	149	2640	6.52	58.8	84	12200	9385	354.05
DC-2105-T-C	175	2112	5.21	73.5	105	12200	9385	390.92
DC-2106-T-C	201	1760	4.34	88.2	126	12200	9385	427.80
DC-2107-T-C	227	1508	3.72	102.9	147	12200	9385	464.67
DC-2108-T-C	253	1320	3.26	117.6	168	12200	9385	501.54
DC-2109-T-C	279	1173	2.90	132.3	189	12200	9385	538.42
DC-2110-T-C	305	1056	2.61	147.0	210	12200	9385	575.29
DC-2111-T-C	331	960	2.37	161.7	231	12200	9385	612.16

Figure 6: Doshin Rubber Engineering catalogue page no.26

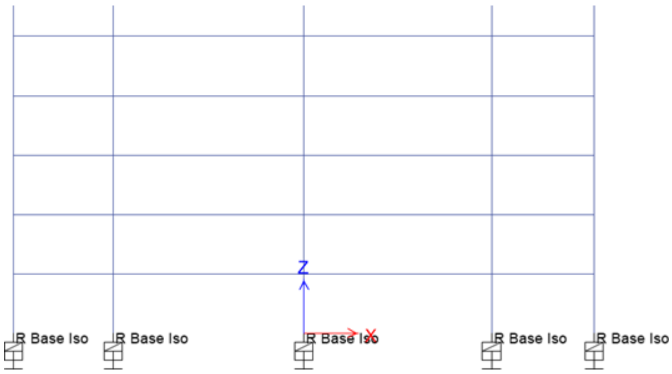

Figure 7: Base Isolation Properties Elevation View

V. DISCUSSION AND RESULTS

The results for following parameters are as given below for the comparative study only the case of earthquake force in x-direction i.e. 'EQX' earthquake is considered.

- Displacements X-direction
- Story Shear X-direction
- Story Drifts X-direction

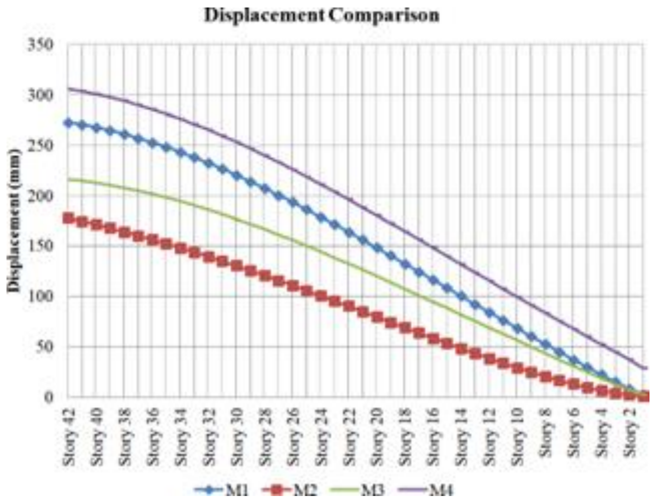

Figure 8: Displacement Comparison Graph

All graphs show the uniform increment of story displacement from bottom to top story. The maximum displacement is recorded for top stories. For the top floor displacements among every model, model with shear wall consideration shows minimum value of displacement, which is due to presence of shear wall. As compared with beam column frame, the story displacement in shear wall frame can be reduced upto 35% at top floor. On the other hand base isolated system shows increase in deflection as compared to beam column frame which is not acceptable.

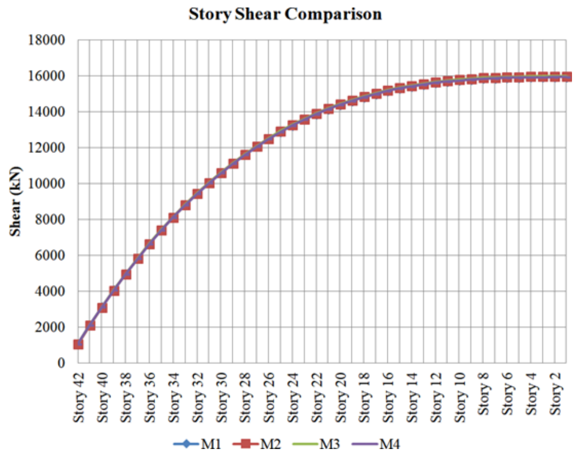

Figure 9: Story Shear Comparison Graph

The story shear is maximum at bottom and minimum at top story. For the top floor story shear among every model, model with shear wall consideration shows minimum value, which is due to presence of shear wall. As compared with beam column frame, the story shear in shear wall frame at top story can be reduced upto 1.43%.While there is no change in shear force in base isolated frame in comparison with beam column frame.

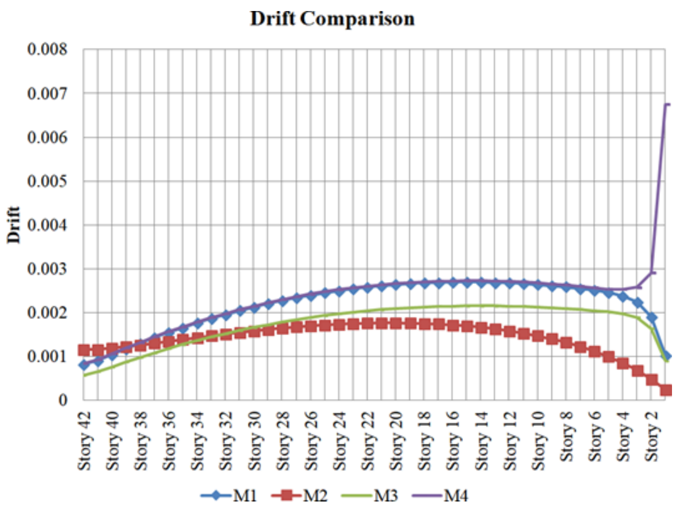

Figure 10: Drift Comparison Graph

The variations in drifts at every story are compared. It is observed that the lateral drift is maximum at middle portion of building. All drifts are within limiting value except M4 model at story 1. For model with shear wall shows minimum value of story drift. As compared with beam column frame, the story drift can be reduced upto 35%.

Whereas, the story drift can also be reduced by using base isolated, but should be controlled at lower story with other preventive measures.

VI. CONCLUSION

From the above discussions, the following considerations are concluded in beam column frame, shear wall frame, tubular frame and base isolated frame:

- Story displacements are observed for shear wall frame is less at top floor
- Story shear in shear wall frame shows lesser increment at bottom floor as compared to other frames.
- Story drifts are observed for frame at middle portion of frame is effectively reduced due to addition of shear wall.

Hence, from all above conclusions it is predicted that the incorporation of shear walls in the high-rise structure shows effective results as compared to all other structural framing combinations.

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