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Comparative Analysis of RCC Structure with Energy Dissipation Device and Composite Structure

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Abstract: ***The ground movement which occurred naturally and creates disaster to cause damage of the structures is called Earthquake. In the earth's crust seismic activities occur that creates waves. These waves transmit to structures through foundation. Thus, due to this earthquake movements, inertia force is invoked in structure resulting in damaging the whole or part of structure.***

Base isolation is the recent development for seismic resistant designs, this may not be totally controlling the ground movement but helps in minimising the impact of ground movement. Base isolation enables in reduction of earthquake forces by lengthening the period of vibration of structure. Also, the structural response accelerations are less than the ground acceleration because of Base isolation.

It helps in limiting the effects and after effects of earthquake and that's why it is widely accepted in the whole world as one of the most effective approaches in past few years. The response spectrum analysis is conducted on three different model using CSI ETABSv19, several values of all three models were found out from Structure. Structure is Located in Earthquake Zone IV. Three models are used for analysing the response of the building. The results of frequency, time period, displacement, drift, storey overturning moment and storey stiffness are compared for G+25 RC frame structure with shear wall, RC frame structure with base isolation and composite structures.

Keywords: Base isolation, composite structure, response spectrum, shear wall.

I. INTRODUCTION

This study examines the comparative analysis of the following three model i.e., RC frame structure with shear wall, RC frame structure with base isolation and composite structure. The main purpose of Shear walls to provide large strength and stiffness to building, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. In present work linear dynamic analysis of G+25 RC frame structure with shear wall, RC frame structure with base isolation and composite structures are analysed and compared. effect of all these structural components is calculated on structure having 25 Storey.

II. NEED OF BASE ISOLATION

1) Provides good flexibility to the structure.
2) Make building earthquake resistant.
3) Story become more serviceable.
4) Earthquake prone zones of developed countries are now making compulsory to have a isolated base in the building with higher importance.
5) Reduces steel reinforcement.
6) Reduces the base shear, and overturning moment of the structure.
7) Increases time period of the structure.

As compared to fixed base structure, Base isolated structure provides more ductility to the structure and now days use of base isolation structure is very common in earthquake prone areas.

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III. NEED OF COMPOSITE STRUCTURE

1) High flexibility in design and ease of manufacturing.
2) Ideal material in earthquake prone locations due to its high strength, stiffness and ductility.
3) The size of the elements can be reduced, thus increasing the strength-to-weight ratio.
4) Facilitate faster project construction.
5) Meet the demand for long span construction, a modern trend in architectural design.
6) Allows easy structural repair and modification.
7) Precisely designed concrete and steel composite members prevent brittle fracture of reinforced concrete members and have high ductility.
8) Encased steel frame can be used as a shoring system during construction process.

As compare to conventional RCC structure, composite structure is widely used in practice now-a-days because of better seismic performance. Hence these structures are demand in many countries which are seismic prone area irrespective of developed or under developed.

IV. OBJECTIVE

The objective is to perform the Linear dynamic analysis of G+25 RC frame structure with shear wall, RC frame structure with base isolation and composite structures and compare their results. effect of all these structural components is calculated on structure having 25 Storey which is Located in Earthquake Zone IV.

Analysis is done with the help of ETABSv19 software.

1) To compare the result for RCC and composite structure of G+25 storey.
2) To understand the behaviour of RCC and composite structure in Response Spectrum analysis.
3) To determine the effect of base isolation in time period, base shear, overturning moment, base shear, storey drift in high rise structure.
4) To determine the behaviour of composite structure in response spectrum analysis.
5) To determine the behaviour of structure base isolation and its comparison with composite structure and with RC frame structure with shear wall.

V. LINEAR DYNAMIC ANALYSIS

Linear dynamic analysis or Response spectrum Static procedures are appropriate when the effects of the higher mode are negligible. Thisis often true for short-term, conventional buildings. Therefore, for high-rise buildings, buildings with irregular or non-orthogonal torsion systems, a dynamic process is required.In the linear dynamics process, the building is modelled as a Multi Degree of Freedom (MDOF) with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input was modelled using either modal spectrum analysis or time series analysis, but in both cases the respective internal forces and displacements were determinedby linear elastic analysis. The advantage of these linear dynamic procedures over linear static procedures is that higher modes can be considered. However, they are based on a linear elastic response and, therefore, applicability decreases with increasing nonlinear behaviour, which is approximated by the overall force reduction coefficients. In linear dynamics analysis, the response of the structure to ground motion is calculated in the timedomain, so all phase information is retained. Only linear properties are assumed. The analytical method can use the decomposition method as a means to reduce the degrees of freedom in the analysis.

VI. MODELLING AND ANALYSIS

The linear Dynamic Analysis is conducted on three different model using CSI ETABS19, severalvalues of model were found out from RC with shear wall, RC frame with base isolation and Composite Structure. IS:1893-2016 guidelines are used for the Dynamic Analysis of G+25 story RC frame structure with shear wall, RC frame structure with base isolation and composite structure is done.
Different types of models used for analysis
Model 1: G+25 RC frame structure with shear wall. Model 2: G + 25 RC frame structure with base isolation. Model 3: G+ 25 Composite Structure.

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Table 6.1 data used for analysis of RC frame structure		
SN.	Particulars	Dimension / Value
1	Plan dimension	25 x 25 m
2	Height of the bottom storey	3.6 m
3	Total Height of building	75.6 m
4	Height of parapet	1.2m
5	Thickness of slab	200mm
6	Seismic zone Importance factor Zone factor Damping factor	IV 1.2 .24 5%
7	Floor finish Live load at all floor Wall load Parapet wall Density of concrete Density of steel Density of brick	2.0 KN/m^2 2.0 KN/m^2 12 KN/m 5.96 KN/m^2 25 KN/m^2 7850 KG/m^2 20 KN/m^3
8	Grade of Concrete Grade of reinforcing steel Soil condition	M30 HYSD500 Medium
9	Grade of beam and column Size of beam Size of column	M30 300 x 500 mm 1000 x1000 mm

Table 6.2 data used for analysis of composite structure		
S. No.	Particulars	Dimension/value
1	Plan Dimension	25x25 m
2	Total height of the building	75.6 m
3	Height of bottom storey	3.6 m
4	Height of each storey	3 m
5	Height of parapet	1.2 m
6	Thickness of slab Thickness of profiled deck Thickness of walls	200 mm 75-100 mm 230 mm
7	Seismic zone Importance factor Zone factor Damping ratio	IV 1.2 0.24 5%
8	Floor finish Live load at all floors Wall load Parapet wall Density of concrete Density of steel Density of brick	2.0 KN/m^2 2.0 KN/m^2 12 KN/m 5.96 KN/m 25 KN/m2 7850 KG/m3 20 KN/m3
9	Grade of concrete in column Grade of deck Grade of reinforcing steelSoil condition	M30 M20 HYSD500 Medium soil

A. Design Data For LRB

Table 6.3 data used for LRB design			
1	Seismic zone factor, Z	0.3	(UBC 97, Vol-2, Table 16-I & Zone Map)
2	Seismic Source Type	B	
3	Near source factor, Na	1	(UBC 97, Vol-2, Table 16-S)
4	Near source factor, NV	1	(UBC 97, Vol-2, Table16T)
5	ZN_v	0.3	
6	Maximum capable earthquake response coefficient, Mm	1.5	(UBC 97, Vol-2, Table A-16-D)
7	Soil Profile Type	SD	(UBC 97, Vol-2, Table 16-J)
8	Seismic coefficient, $CV = CVD$	0.54	(UBC 97, Vol-2, Table 16-R)
9	Seismic coefficient, Ca	0.36	(UBC 97, Vol-2, Table 16-Q)
10	Choose Response Reduction Factor, R for SMRF	8.5	(UBC 97, Vol-2, Table 16-N)
11	For SMRF/IMRF/OMRF Structural System Above the Isolation Interface, RI	2	(UBC 97, Vol-2, Table A-16-E)
12	Effective Damping (βd or βm)	0.15	15% Damping []
13	Damping coefficient, Bd or Bm	1	Interpolate (UBC 97, Vol-2, Table A-16-C)

B. Maximum Load Obtained after dynamic analysis on column is being taken for design of LRB

Table 6.4 Design Data for LRB OF G +25 for lateral load of 20500 KN		
Rotational Inertia	0.731550068	KN/m
For U1 Effective Stiffness	20624555.58	KN/m
For U2 & U3 Effective Stiffness	20624.5556	kN-m
For U2 & U3 Effective Damping	0.15	
For U2 & U3 Distance from End-J	0.00490	m
For U2 & U3 Stiffness	157650.0916	KN/m
For U2 & U3 Yield Strength	772.8317928	KN

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C. Descriptions Of Models

All three models which are considered for analysis, are shown below.

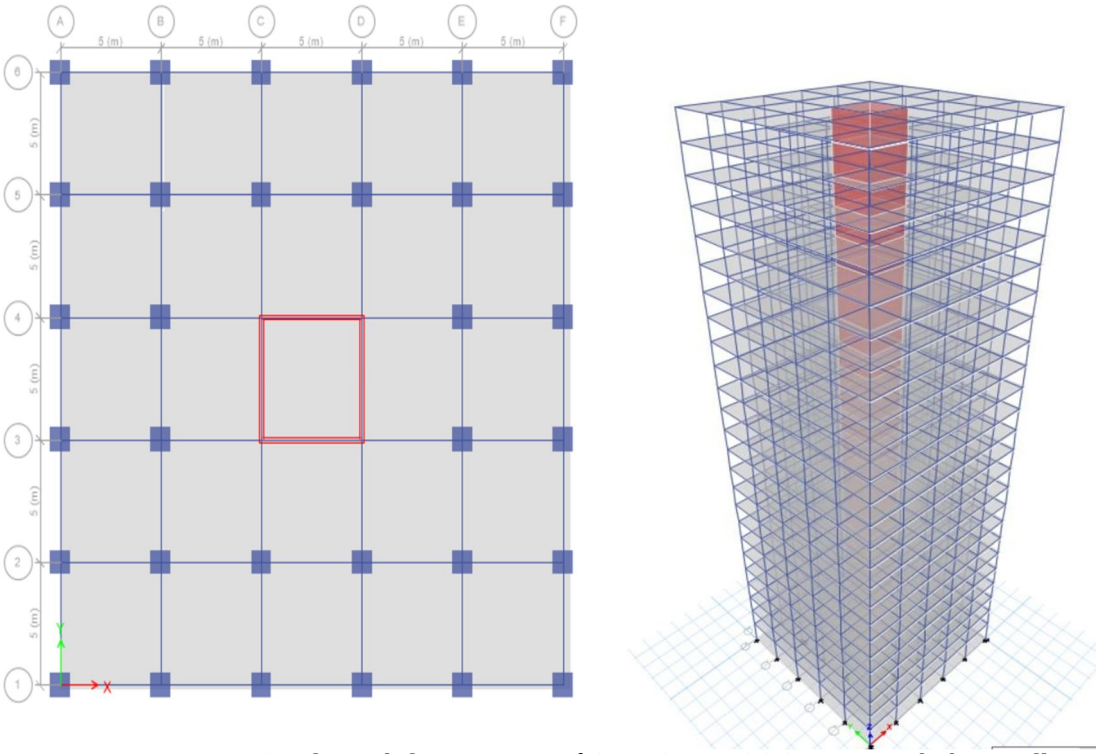


Figure 6.1 Plan and elevation view of G+25 Story RCC Structure with shear wall

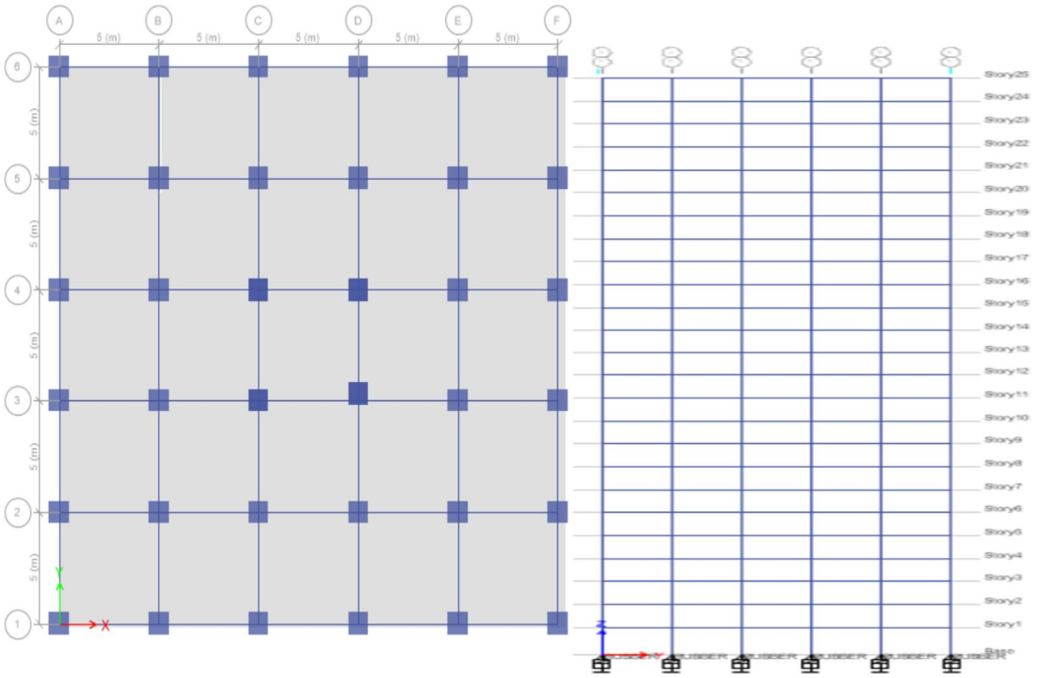


Figure 6.2 Plan and Elevation view of G+25 Story RC frame Structure with base isolation.

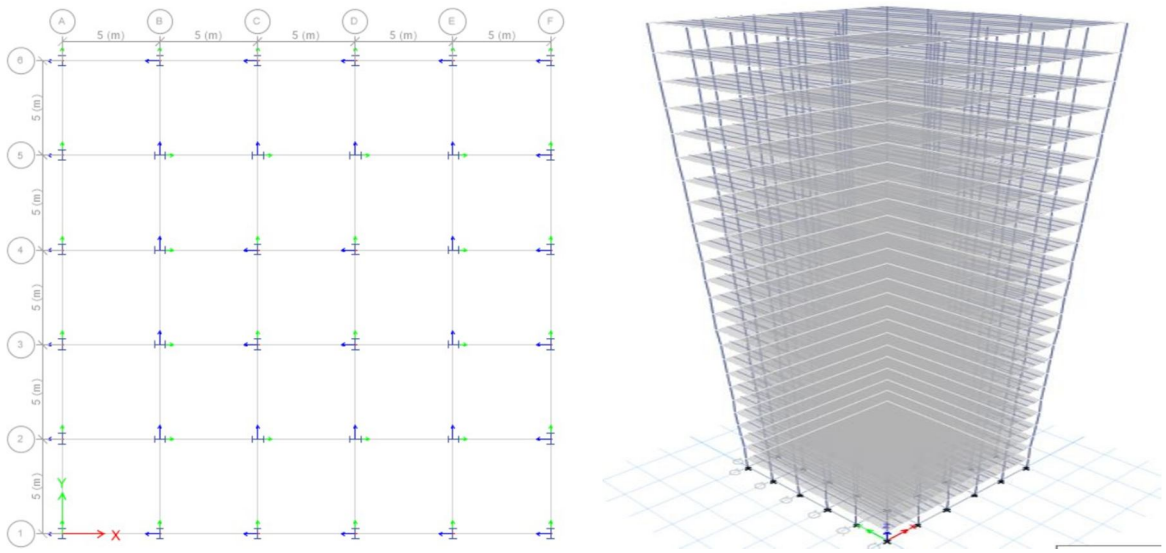


Figure 6.3 showing plan and elevation view of G + 25 story composite structure.

VII. RESULTS AND DISCUSSION

A. *Free Vibration Analysis*

Modal analysis is the study of the dynamic properties of system in the frequency domain. It is the field of measuring or calculating and analysis the dynamic response of the structure during exciting. In structural engineering modal analysis used the overall mass and stiffness of a structure to find the various periods at which it will be naturally resonant. These periods of vibration are essential in earthquake engineering. Modal analysis is the process of determining the inherent dynamic properties of a system in the form of natural frequencies, damping coefficients, and modal shapes, and usingthem to build a mathematical model of the behaviour. The mathematical model that is formulatedis called the modal of the system, and the information about the properties is called modal data. The free vibration analysis of G+ 25 storey RC frame structure with shear wall, RC frame structure with base isolation and composite structure are performed to get a dynamic structural behaviour.

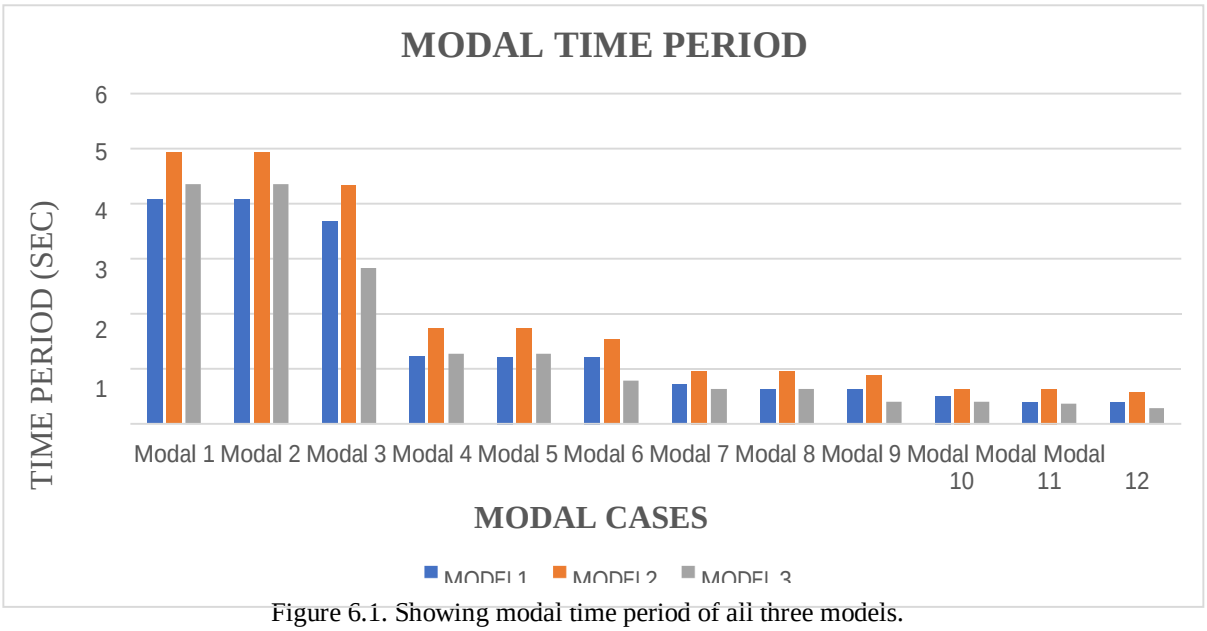


Figure 6.1. Showing modal time period of all three models.

The modal time period is maximum in model 2 which is 4.93 seconds and minimum in model 1 i.e., G +25 RC frame structure with shear wall at core is 4.08 seconds and Modal time period in model 3 is 4.356 seconds.

B. Response Spectrum Analysis (IS:1893-2016)

The Response Spectrum analysis is carried out as per Indian Standard and Story Displacement, Story Shear, Story Overturning Moment, Story Stiffness are discussed for all G+25 story model.

C. Storey Displacement

Story displacement is the lateral displacement of the story relative to the base. Response spectrum analysis of G+25 story RC frame structure with shear wall, RC frame structure with base isolation and composite structure are performed. Story displacement is the lateral displacement of the story relative to the base. story displacement is maximum in model 2 which is 72.481 mm and minimum in model 1 which is 58.956 mm. story displacement in model 3 is 64.12 mm.

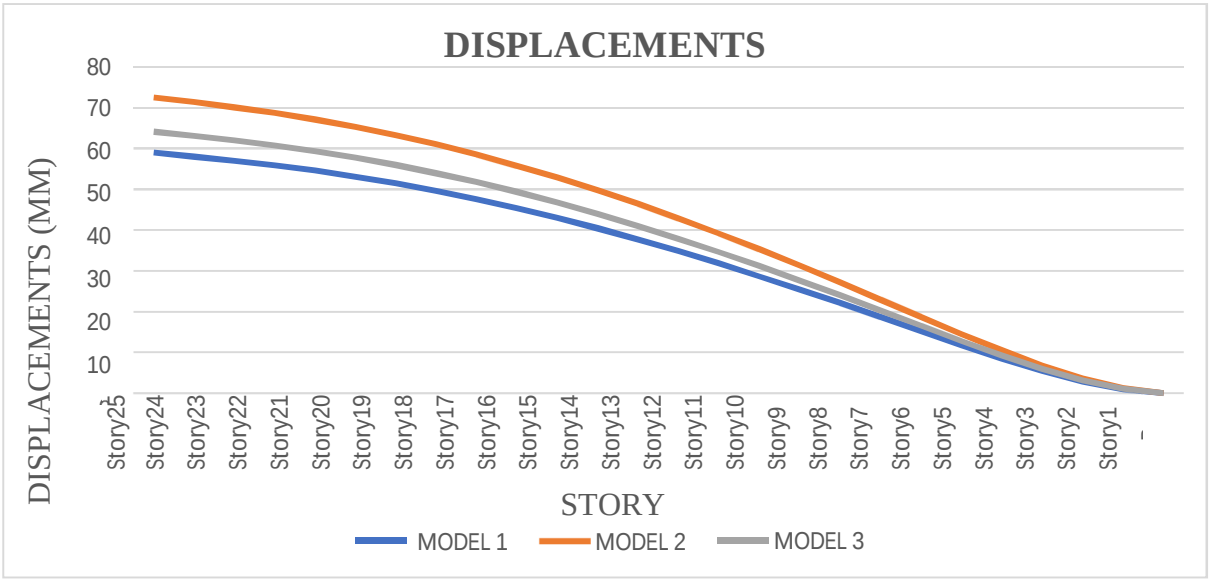


Figure 6.3. showing displacements of all three models.

D. Maximum Story Overturning Moment

The overturning moments are obtained by multiplying the story shear by the distance to the centre of mass above the elevation considered. story overturning moment is maximum in model 1 which is 130235.69 KN-M and minimum in model 2 which is 116373.34 KN-M. story overturning moment in model 3 is 124470.64 KN-M.

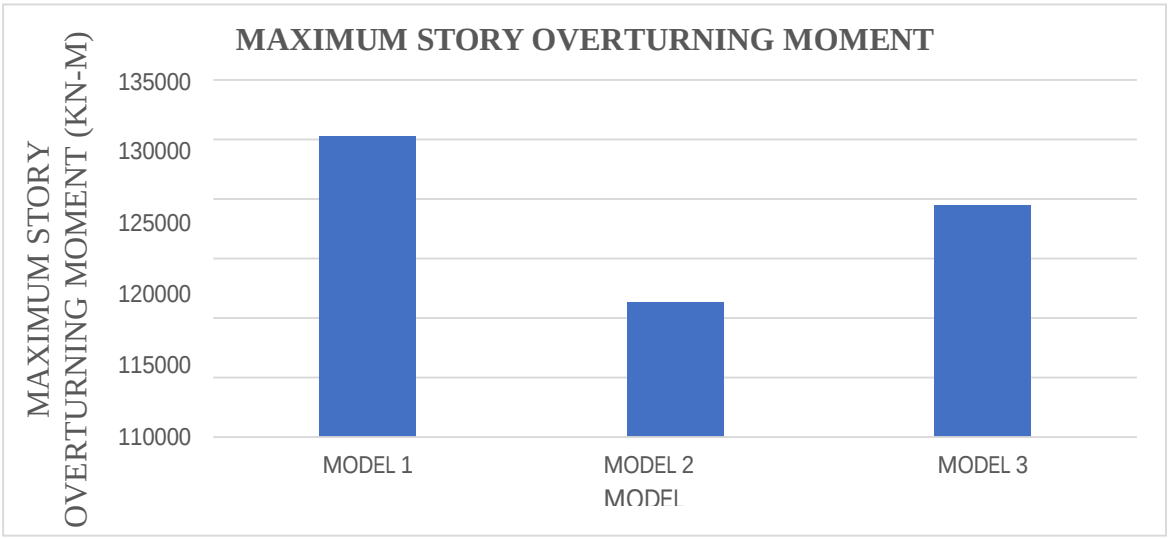


Figure 6.4 showing maximum story overturning moment for all three models.

E. Story Drift

Storey drift is the difference of displacements between two consecutive story divided by the height of that story and Story displacement is the absolute value of displacement of the storey under action of the lateral forces.

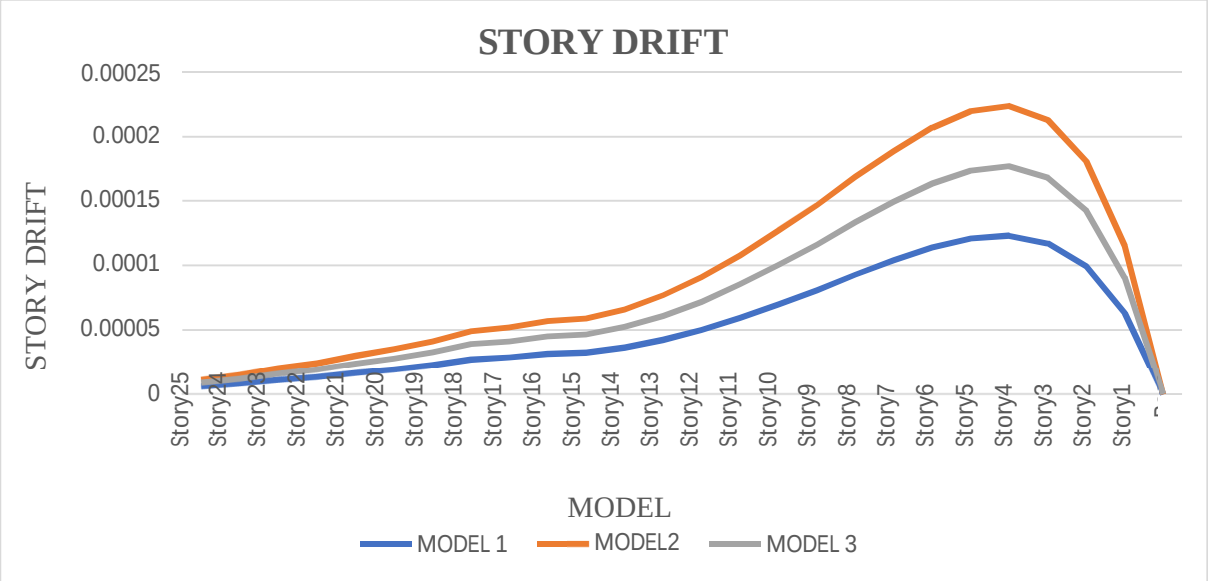


Figure 6.5 showing story drift for all three models.

Story drift is maximum in model 2 and minimum in model 1. After analysis and all design check as per IS: 1893 (2016), storey drift satisfies the design criteria and storey drift value is not exceeding 0.004 times storey height.

F. Base Shear

Base shear is the estimation of maximum expected lateral force which will occur at the base of a structure due ground motion during the earthquake. Due to seismic activities, the ground start moving. Due to the movement of ground, lateral force is developed in opposite direction of motion. That developed lateral force due seismic motion at the base of the structure is called base shear. base shear is maximum in model 1 which is 1514.36 KN and minimum in model 2 which is 853.66 KN. base shear in model 3 is 1366.87 KN.

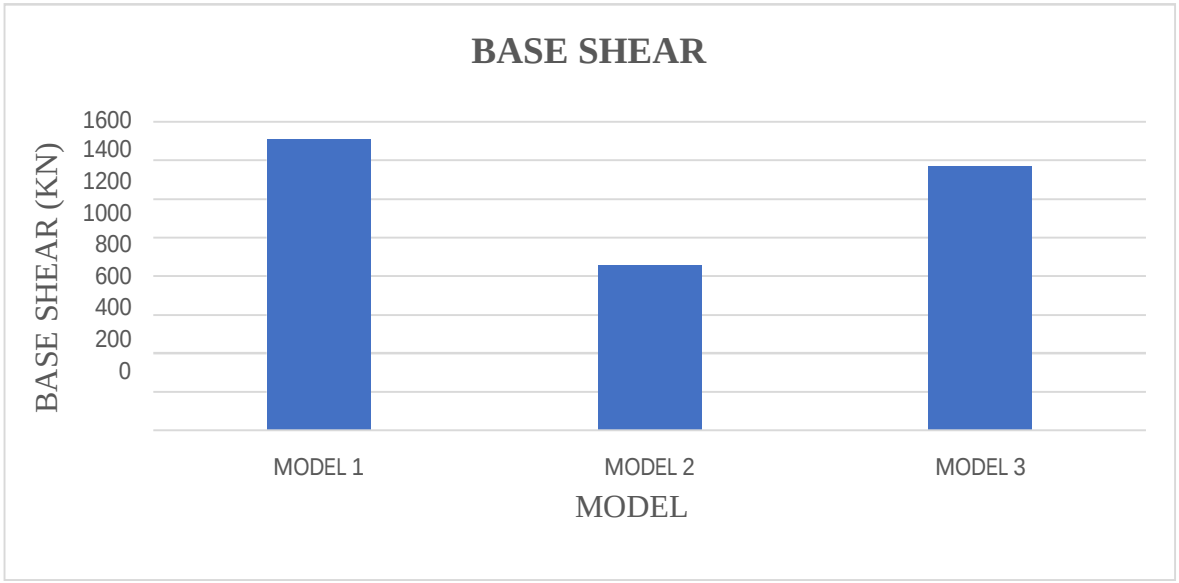


Figure 6.6 showing base shear for all three models.

G. Storey Stiffness

In structural engineering, the term'stiffness' refers to the rigidity of a structural element. In general terms, this means the extent to which the element is able to resist deformation or deflection under the action of an applied force.

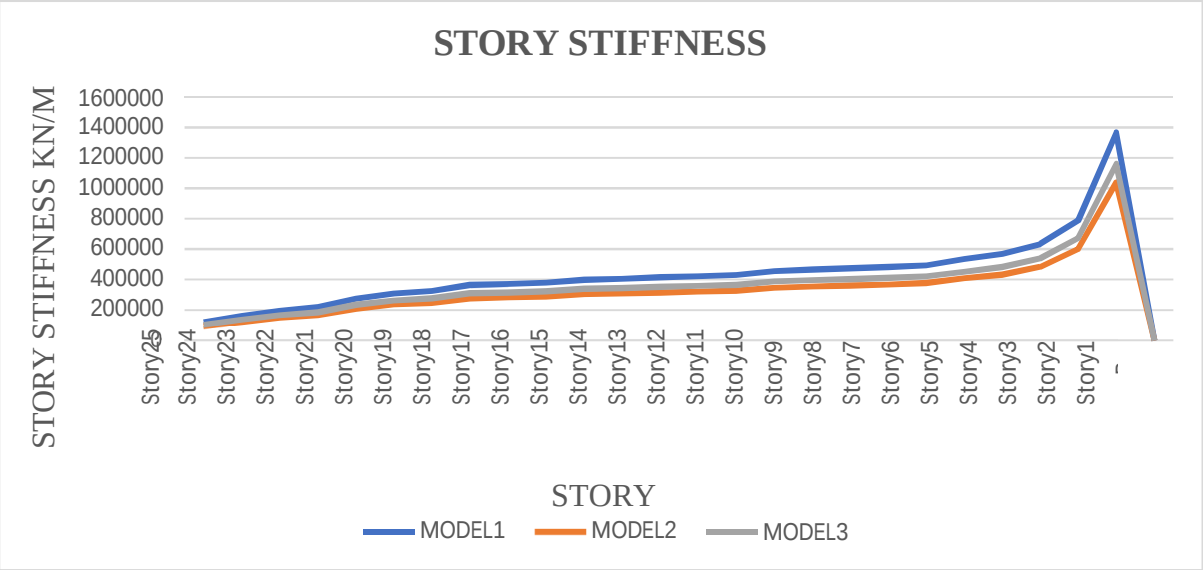


Figure 6.7 showing story stiffness for all three models.

Response spectrum analysis of G+25 story RC frame structure with shear wall, RC frame structure with base isolation and composite structure are performed. story stiffness is maximum in model 1 which comes out to be 120627.1 KN/M and minimum in model 2 which is 91676.5 KN/M. story stiffness for model 3 is 102533.5KN/M.

VIII. CONCLUSION

A. Time Period

1) The modal time period is maximum in model 2 which is 4.93 seconds and minimum in model 1 i.e., G +25 RC frame structure with shear wall at core is 4.08 seconds and Modal time period in model 3 is 4.356 seconds.
2) Modal time period in model 2 is 20.83 % more than that of model 1 and 13.17% more than that of model 3.
3) Because of base isolation in model 2 the ductility of structure increases significantly which leads to increase in time period and decrease in frequency.

B. Story Displacement

1) Story displacement is maximum in model 2 which is 72.481 mm and minimum in model 1 which is 58.956 mm. story displacement in model 3 is 64.12 mm.
2) Story displacement in model 2 is 22.94% more than model 1 and 13.04 % as compare to model 3 respectively.
3) As rigidity increases displacement decreases and vice-versa.

C. Maximum Story Overturning Moment

1) Story overturning moment is maximum in model 1 which is 130235.69 KN and minimum in model 2 which is 116373.34 KN. story overturning moment in model 3 124470.64 KN.
2) Maximum story overturning moment in model 1 is 11.91 % more than that of model 2 and 4.63% more than that of model 3.

D. Story Drift

1) Story drift is maximum in model 2 and minimum in model 1. After analysis and all design check as per IS: 1893 (2016), story drift satisfies the design criteria and story drift value is not exceeding 0.004 times story height.
2) As the stiffness of the structure increases the drift ratio decreases and vice-versa.

E. Base Shear

1) Base shear is maximum in model 1 which is 1514.36 KN and minimum in model 2 which is 853.66 KN. base shear in model 3 is 1366.87 KN.
2) Base shear in model 2 is reduced by 43.62 % as compare to model 1 and 37.54 % as compare to model 3 respectively.
3) As mass of a structure increases base shear also increases.

F. Story Stiffness

1) Story stiffness is maximum in model 1 which comes out to be 120627.1 KN/M and minimum in model 2 which is 91676.5 KN/M. story stiffness for model 3 is 102533.5KN/M.
2) Story stiffness in model 2 is 31.57 % less than model 1 and 11.84 % less than as compare to model 3.
3) As the ductility of the structure increases, stiffness of the structure decreases and vice- versa.

IX. FUTURE SCOPE

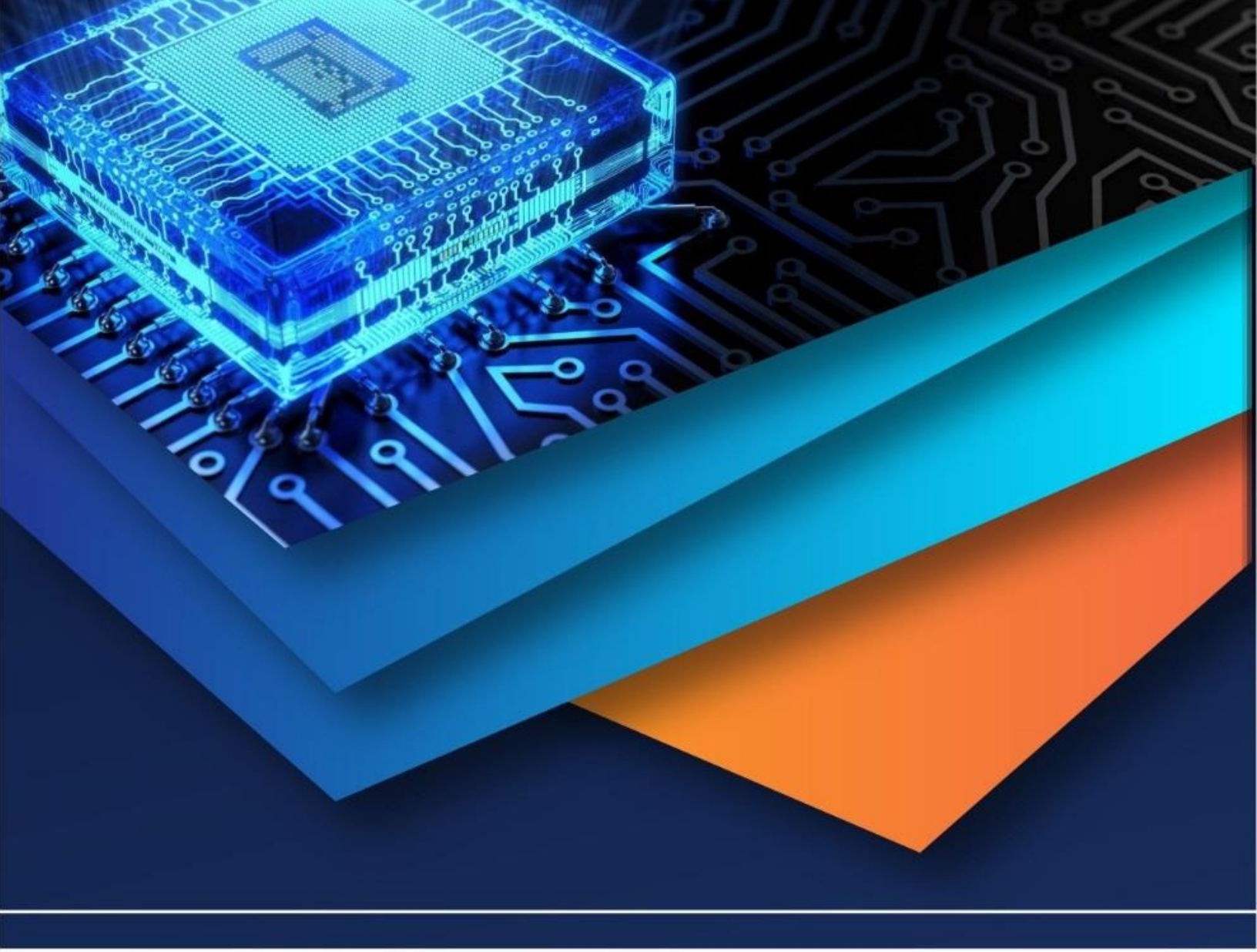
G+25 storey RC frame structure with shear wall, RC frame structure with base isolation and composite structure.

1) Performance based seismic analysis can be done and its performance criteria can be checked from FEMA 356.
2) Extension of this study on other RCC framed buildings. Performance of base isolation oversteel structure.
3) Similar analysis with varying the height of the structure.
4) Performance of similar structure can be checked with High Damping Rubber Bearing.
5) Cost comparison of 30,35 and 40 story structure can be done using LRB and other lateral load resisting system i.e., shear wall, bracings, etc.
6) Nonlinear dynamic analysis of RC frame structure with shear wall and the same structure with optimized section can be done.

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