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Non-Linear Time History Analysis of G+15 RC Frame Building with Shear Wall

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Abstract: The structure is vulnerable to ground movement during an earthquake and damages the structure. It is important to know the nature of the movement of the ground in order to prevent damage to the structure due to the movement of the ground. The main purpose of Shear wall is to counter the lateral forces acting on the structure and it act as a vertical cantilever beam. The time history method is used for nonlinear dynamic analysis. The nonlinear time history analysis is conducted on four different model using CSI ETABS19, several values of all four models were found out from Structure. IS:1893-2016 guidelines are used for the time history analysis of four model of G+15 storey. Hence, total four models are used to analyse the dynamic response of the building. The result of, story displacement, story drift, storey shear, storey overturning moment and base shear are calculated and compared for all four models.
Keywords: RC frame, shear wall, seismic damage, nonlinear time history analysis, dynamic analysis, ETABS.

I. INTRODUCTION

Understanding the behaviour of structures under such repeated ground movements for some earthquakes, a non-linear time history analysis is performed. Earthquakes are the result of the rapid release of stress energy stored in the crust and the generation of seismic waves. The most important dynamic characteristics of an earthquake are the peak ground acceleration, frequency component, and duration. These properties serve as the dominant rule in studying the behaviour of structures under seismic motion. Seismic analysis of multi-storey buildings is performed using linear and non-linear methods. The method of analyzing the response spectrum is linear dynamic analysis. 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 this study G+15 RC frame building with shear wall placed at different location is used. model is analysed using the nonlinear time history method. The commercial building models G+15 storey RC frame building with shear wall at various location are analysed using ETABS 19 software. The seismic codes are specific to the country. IS 1893:2016 used for the calculation of seismic design forces.

II. NEED OF NONLINEAR TIME HISTORY ANALYSIS

A. A nonlinear dynamic analysis is the only method to describe the actual behaviour of a structure during an earthquake.
B. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time, hence accurate method to analyse the structure.
C. Better structural strength, ductility, stiffness, can be ensured by performing maximum considered earthquake nonlinear time history analysis using expected strength.
D. Facilitate faster project construction.

III. OBJECTIVES

In this thesis nonlinear dynamic analysis of G+15 building, three models with shear wall at different location and one model without shear wall is done. this analysis (NLTHA) is done using CSI ETBAS v19 software.

The objectives of this thesis are to analyse the behaviour of the structure under dynamic loading, corresponding design criteria, methodology for the design of structure to meet the seismic demands by comparing to past earthquake ground motions record,

1) To understand the nonlinear behaviour of structure under dynamic loading.
2) To understand the seismic performance of structure under dynamic loading with shear wall at various locations.
3) To check the seismic performance of structure without shear wall.
4) To compare the behaviour of RC frame structure with shear wall and without shear wall under nonlinear dynamic loading.

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IV. NONLINEAR DYNAMIC ANALYSIS

Nonlinear dynamics analysis uses a combination of ground motion records with detailed structural modelling, and thus can produce results with relatively low measurement uncertainty. In nonlinear dynamic analyses, the detailed structural model subjected to ground motion recording generates estimates of the component strains for each degree of freedom of the model and combined modal responses. using schemes such as the square root of the sum of squares. In the nonlinear dynamic analysis, the nonlinear properties of the structure are considered as part of the time domain analysis. This approach is the most stringent and is required by some building codes for buildings of unusual configuration or of special importance. However, the calculated response can be very sensitive to the characteristics of the individual k ground motion used as seismic input; therefore, several analyses are required using different ground motion records to obtain a reliable estimate of the probability distribution of the texture response. Since the characteristics of the seismic response depend on the magnitude or severity of the seismic tremor, a comprehensive assessment requires multiple nonlinear dynamics analyses at different intensity levels to represent the seismic response. show different possible earthquake scenarios. This has led to the emergence of methods such as dynamic incremental analysis.

V. MODELLING AND ANALYSIS

This chapter explained that the 3D building model is analysed using the nonlinear time history method. The commercial building models G+15 storey RC frame building with shear wall at various location are analysed using ETABS 19 software. The seismic codes are specific to the country. In India, Indian Standard for Design of Seismic Structures IS 1893:2016 is the main standard that provides the outline for the calculation of seismic design forces.

A. Different Types of Models Used for Analysis

1) Model 1: G+15 Storey structure with shear wall at corner.
2) Model 2: G+15 Storey RCC frame Structure with shear wall at core.
3) Model 3: G+15 Storey structure with shear wall at edges.
4) Model 4: G+15 Storey structure without shear wall.

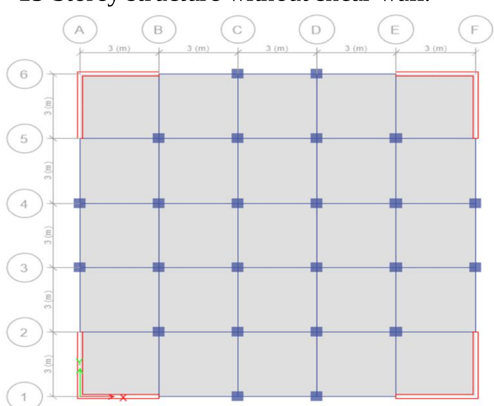

Fig. 5.1. Showing plan view of Model 1.

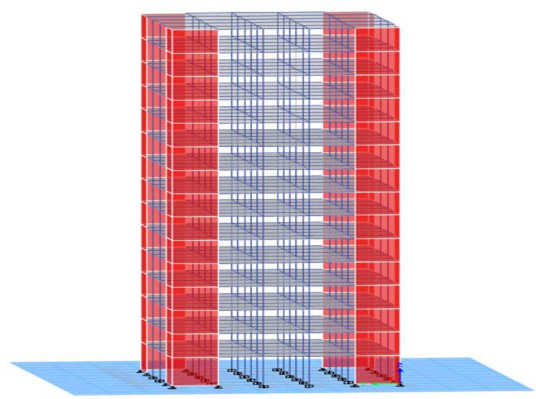

Fig. 5.2. Showing elevation view of Model 1.

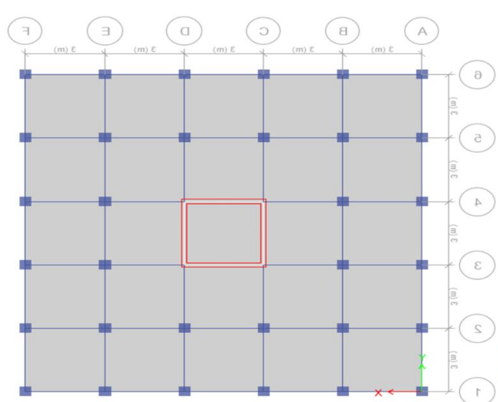

Fig. 5.3. Showing plan view of Model 2.

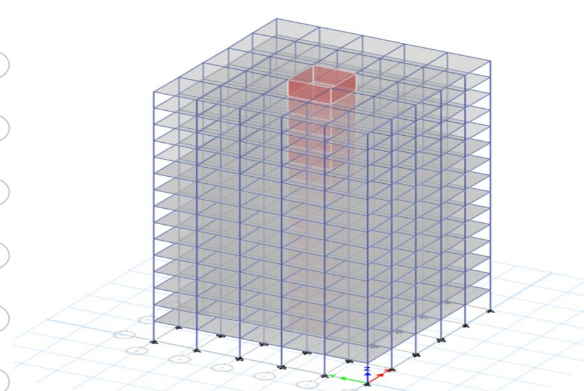

Fig. 5.4. Showing elevation view of Model 2.

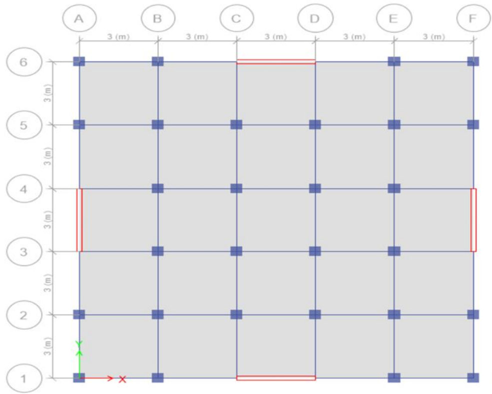

Fig. 5.5. Showing plan view of Model 3.

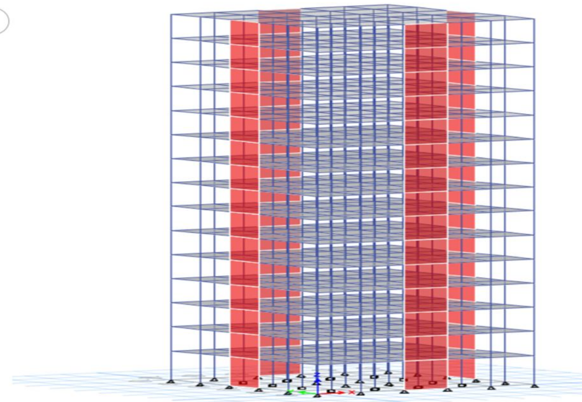

Fig. 5.6. Showing elevation view of Model 3.

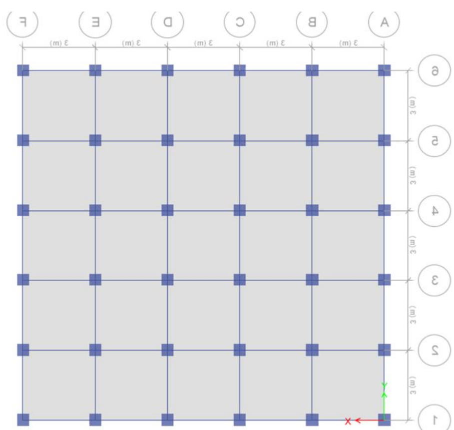

Fig. 5.7. Showing plan view of Model 4.

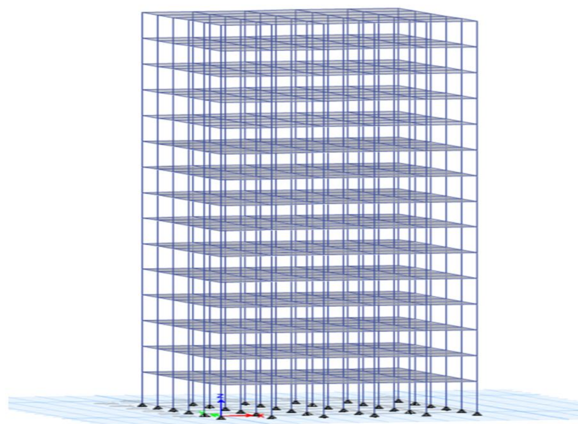

Fig. 5.8. Showing elevation view of Model 4.

B. Nonlinear Time History Analysis Steps

Time-history analysis is done using the process which follows:

1) Creating the model and assign support conditions to restrained joints.
2) Select Define > Functions > Time History to define a time-history function which characterizes load variation over time
3) Assign load conditions to the model through Assign > Joint Loads or Frame Loads.
4) Define either a modal or direct-integration time-history load case through Define > Load Cases.
5) Apply load cases.
6) Defining load type
7) Defining load name
8) Defining function and selecting time history from file, form the define section.

C. Types Of Time History Analysis

The time history analysis can be classified as

1) Fast Nonlinear Analysis (FNA)
2) Direct-integration time-history analysis
3) Progressive collapse analysis
4) Periodic time-history analysis for two applied loads with different frequencies In this paper faster nonlinear analysis is performed considering precondition
5) Be primarily linear-elastic.
6) Have a limited number of predefined nonlinear members.
7) Lump nonlinear behaviour within link objects.

Table 5.1. Sectional property of beams and columns			
s.no.	Model	Beam dimension (mm)	Column dimension (mm)
1.	I	300 X 400	500 X 500
2.	II	300 X 400	500 X 500
3.	III	300 X 400	500 X 500
4.	IV	From story 1 to 5 350 X 500	600 X 600
		From storey 5 to 10 300 X 450	600 X 600
		From storey 10 to 15 250 X 400	600 X 600

Table 5.2 data for analysis of RC frame structure		
S.NO.	PARTICULARS	DIMENSION/VALUE
1	Plan Dimension	15m x15m
2	Total height of the building	45.6m
3	Height of bottom story	3.6m
	Height of each storey	3m
	Height of parapet	1.2m
5	Thickness of slab Thickness of walls	150mm 230mm
6	Seismic zone	v
	Importance factor	1.5
	Zone factor	0.36
	Damping ratio	5%
7	Thickness of shear wall	150mm
	Grade of shear wall	M 35
8	Floor finish	1 kN/m2
	Live load at all floors	3 kN/m
	Wall load	12 kN/m
	Parapet wall load	5.5 kN/m
	Density of concrete	25 kN/m3
	Density of brick	20 kN/m3
9	Grade of concrete	M 35
	Grade of reinforcing steel	HYSD 500
	Grade of ties steel	Fe 415
	Soil condition	Medium soil (TYPE II)

VI. RESULTS AND DISCUSSION

A. Modal Time Period

The modal time period of G+15 RC frame building for shear wall at various location and without shear wall as shown in graph below. Maximum time period is in model 4 which is 1.645 seconds, whereas minimum time period is in case of model 2 which is 1.36 seconds. The time period for model 1 and 3 is 1.452 and 1.491 seconds respectively.

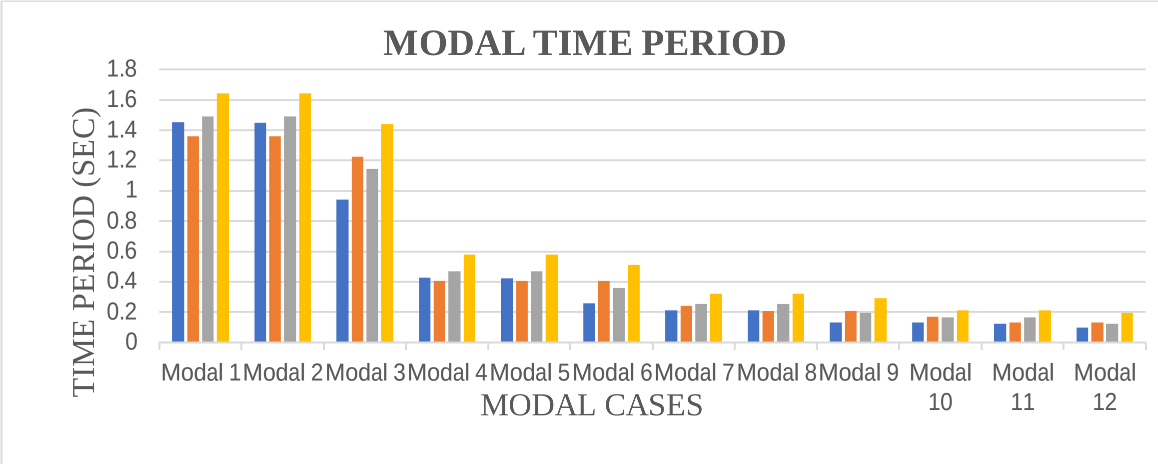

Figure 4.1. showing modal time period of all four models.

B. Time History Analysis (IS:1893-2016)

Nonlinear dynamic analysis is carried out as per Indian Standard considering nepal earthquake (2015, gorkha) time history data. story displacement, story drift, storey shear, story overturning moment and base shear are calculated for G+15 RC frame building and various results are compared for all four models.

1) *Story Displacement:* Story displacement is the lateral displacement of the story relative to the base. non-linear Dynamic analysis of G+15 RC frame building with three models with shear wall at various location and one model without shear wall are performed and story displacement values for all four models are compared. The storey displacement result shows that maximum storey displacement in model 4 i.e. structure without shear wall is 23.328 mm, where as its minimum in model 1 i.e., structure with shear wall at corner. By using shear wall, strength and stiffness of structure increases as a result structural lateral load carrying capacity increases. The above displacement values shows that story displacement is minimum in model 1 i.e., 19.625 mm. which is minimum as compare to shear wall at edges in which story displacement is 20.337 and shear wall at core is 20.161 mm. the story displacement is minimum in RC frame structure with shear wall at corner because it increases resistance against twisting.

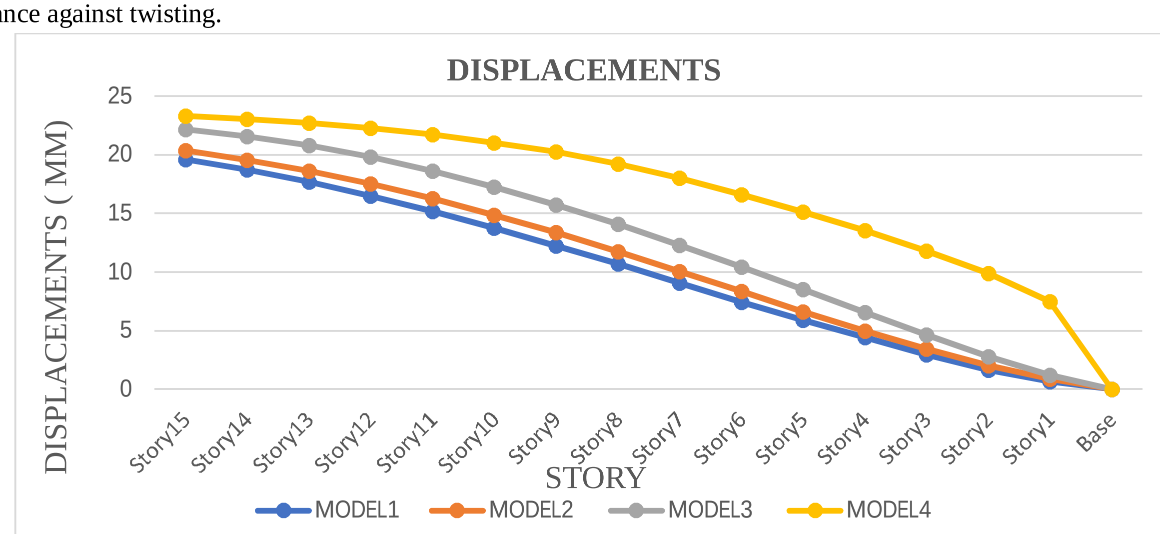

Figure 4.2. showing displacements of all four models.

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2) *Story Shear:* Story shear is the amount of lateral (horizontal) load, be it wind or seismic, is acting in each story. As the height of building increases story shear decreases and vice-versa. non-linear Dynamic analysis of G+15 RC frame building consisting of three models with shear wall at various location and one model without shear wall is performed. The story shear is minimum in case of model 3 which is 1002.309 KN and maximum in case of model 4 i.e., 1519.102 KN. the story shear in case of model 1 is 1048.395 KN and in case of model 2 is 1125.432 KN.

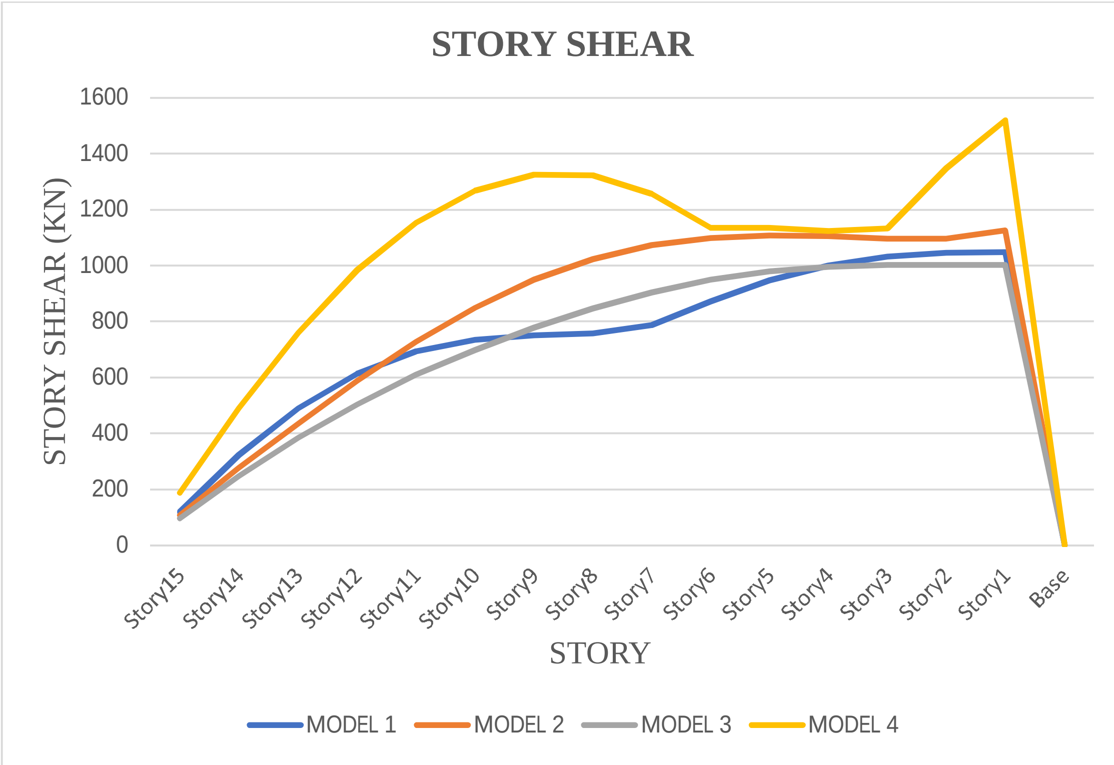

Figure 4.3. showing story shear of all four models.

3) *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. non-linear Dynamic analysis of G+15 RC frame building consisting of three models with shear wall at various location and one model without shear wall is performed. Story overturning moment is minimum in case of model 1 i.e., 30312.834 KN-M and maximum in case of model 4 which is 40428.817 KN-M. the values of story overturning moment in case of model 2 and 3 are 38445.382 KN-M and 33607.003 KN-M respectively.

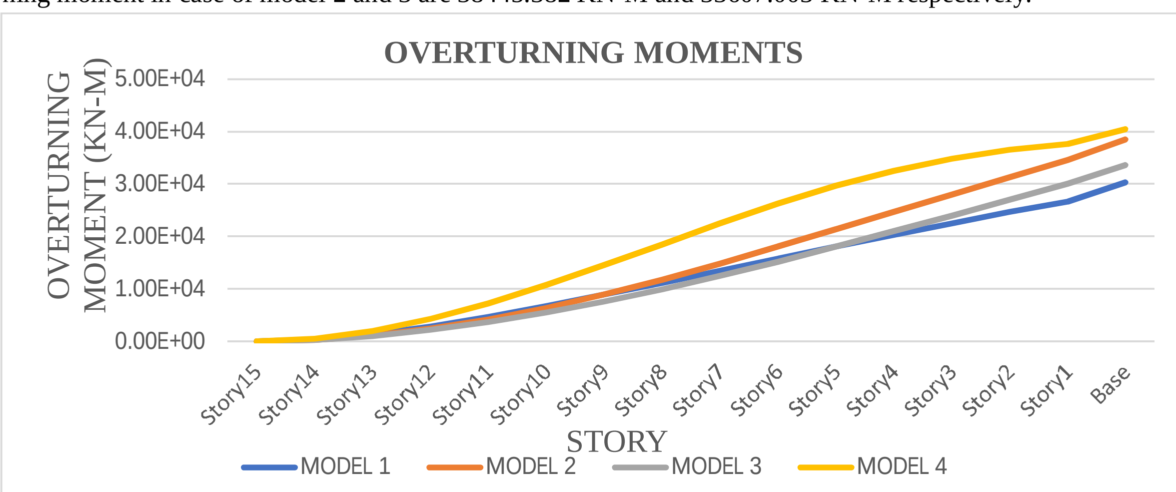

Figure 4.4. showing story shear of all four models.

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4) *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. 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.

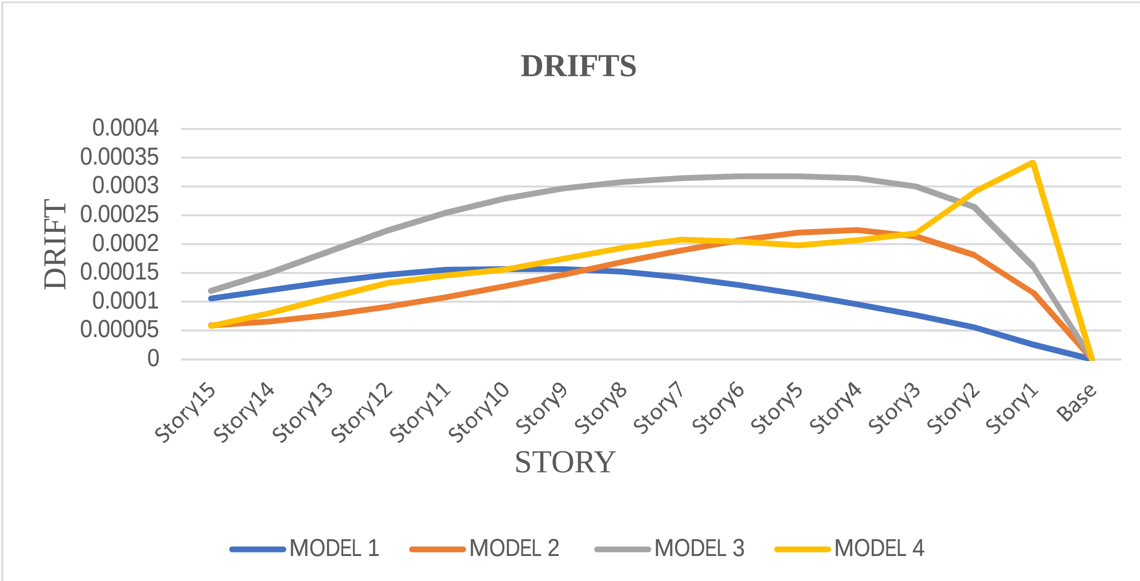

Figure 4.5. showing drift for all four models.

5) *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.

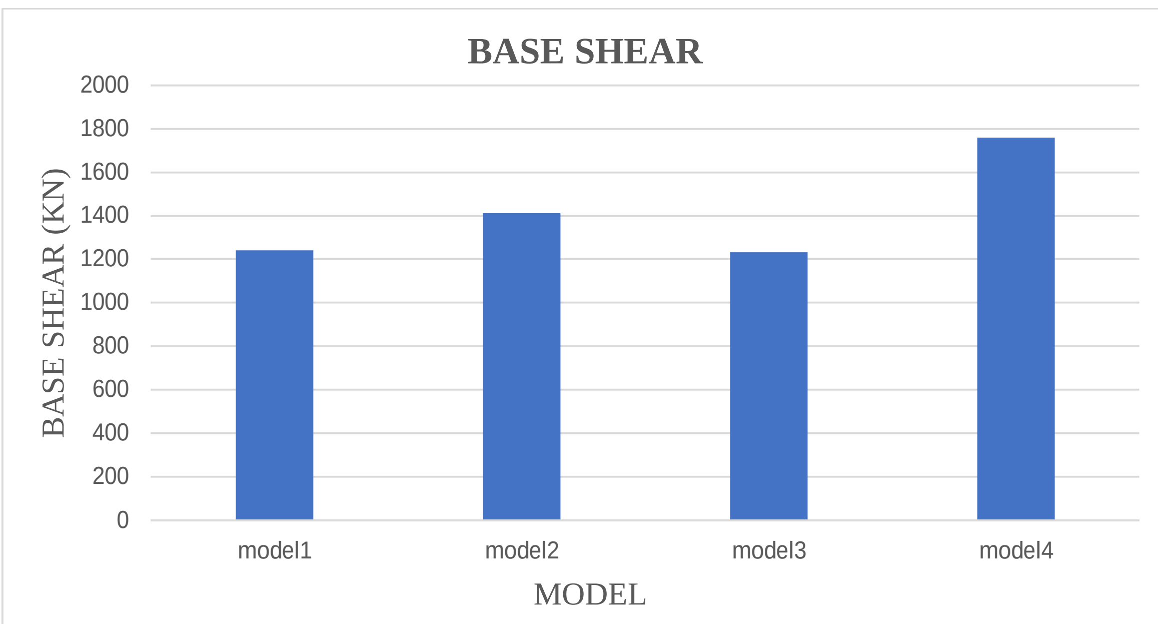

Figure 4.6. showing base shear for all four models.

The base shear is maximum in case of model 4 i.e., 1759.819 KN and minimum in case of model 1 which is 1241.308 KN. The values of base shear in case of model 2 and 3 are 1410.481 KN and 1233.565 KN respectively.

VII. CONCLUSION & FUTURE SCOPE

In the present study, an attempt has been made to compare the dynamic response of multi-storied building with shear walls placed at different locations and without shear wall. For this purpose, G+15 RC frame building is considered for the analysis. By placing the shear walls at different locations, the following conclusions are drawn

A. Conclusion

In the present study, an attempt has been made to compare the dynamic response of multi-storied building with shear walls placed at different locations and without shear wall. For this purpose, G+15 RC frame building is considered for the analysis. By placing the shear walls at different locations, the following conclusions are drawn

1) *Time Period*

a) For model 4 time period is 1.645 seconds which is maximum. Time period for model 2 is 1.36 seconds which is minimum and it is decreased by 11.73 % as compare to model 4. in a similar manner as compare to model 4 time period for model 1 and 3 is decreased by 17.32 % and 9.36% respectively.

b) In comparison among G+15 RC frame building with shear wall only, time period is maximum for model 3 which is 1.491 seconds. time period for model 1 and model 2 is decreased by 6.33 % and 8.80% as compare to model 3.

c) Due to increasing model time period in model 4, the frequencies are reducing and hence building becomes safer in earthquake hazards.

2) *Storey Displacement*

a) Story displacement is maximum for model 4 which is 23.328 mm. Story displacement is minimum for model 1 which is 19.625 mm and it is decreased by 18.87% as compare to model 4. The story displacement for model 2 and 3 is decreased by 12.32% and 3.63 % as compare to model 4.

b) In comparison among G+15 RC frame building with shear wall only, the story displacement is maximum in model 3 which is 22.161 mm. the story displacement is decreased by 11.44 % in model 1 and 8.23 % in model 2 as compare to model 3.

c) Hence it can be concluded that as rigidity increases displacement decreases and vice-versa.

3) *Storey Shear*

a) Story shear is maximum for model 4 and it is 1519.102 KN. Story shear is minimum in model 3 which is 1002.309 KN and it is decreased by 34.1 % as compare to model 4. Story shear is decreased by 30.98% in model 1 and 25.92% in model 2 as compare to model 4.

b) In comparison among first three models with shear wall only, the story shear is maximum in model 2 which is 1125.43 KN and minimum in model 3 which is 1002.309 KN. Story shear for model 1 and 3 is reduced by 6.84 % and 10.94 % respectively as compare to model 2.

c) Hence it can be concluded that by using shear wall story shear decreases. Among three models with shear wall at various location, model 3 i.e., shear wall at core found out best in terms of story shear.

4) *Storey Overturning Moment*

a) Story overturning moment is maximum in model 4 which is 40428.82 KN-M. Story overturning moment is minimum in model 1 which is 30312.83 KN-M and it is decreased by 25.02 % as compare to model 4.

b) In comparison among models with shear wall at various location, model 1 gives better results as compare to model 2 and model 3. story overturning moment is maximum in model 2 which is 38445.382 KN-M and minimum in model 1. story story overturning moment in model 1 and 3 is decreased by 21.15 % and 12.58 % respectively as compare to model 2.

c) So, it is clear that by using shear wall at corner story overturning moment decreases significantly as the stiffness of the structure increases.

5) *Drift*

a) Drift is maximum in story 1 of model 4 which is 0.0034 and minimum in model 1.the maximum drift in model 1 is at the story 10 which is 0.0016.

b) In comparison among G+15 RC frame building with shear wall placed at different location, maximum drift is in model 3.

c) So, it can conclude that as the stiffness of the structure increases the drift ratio decreases and vice-versa.

6) Base Shear

a) Base shear is maximum in model 4 which is 1759.819 KN and minimum in model 3 which is 1233.565 KN.

b) In comparison among G+15 RC frame structure with shear wall placed at different location. base shear is maximum in model 2 which is 1410.481 kn. As compare to model 2, base shear in model 1 and 3 is decreased by 12 % and 12.6 % respectively.

c) The base shear values are goes on increasing from model 3, model 1 and model 2 when compared with the structure without shear walls.

d) The dead load of the model 4 is maximum because of the larger thickness of beam and column as compare to other three models. So, it can be concluded that as the mass of a structure increases base shear also increases.

B. Future Scope

1) Analysis of multi-storied structures by using different software's by providing shear walls to certain height only at different locations in the building can be carried out. It is also recommended to analyse the same structure by considering soil structure interaction.
2) dampers, base isolation also have a vital role in structural stability against catastrophic event, hence nonlinear dynamic analysis along with base isolation and dampers can be done.
3) Performance based seismic analysis can be done and its performance criteria can be checked from FEMA 356.
4) Nonlinear dynamic analysis of RC frame building with ductile design of shear walls can be done.
5) Nonlinear dynamic analysis of RC frame structure consist of combination of bracing and shear wall can be done.
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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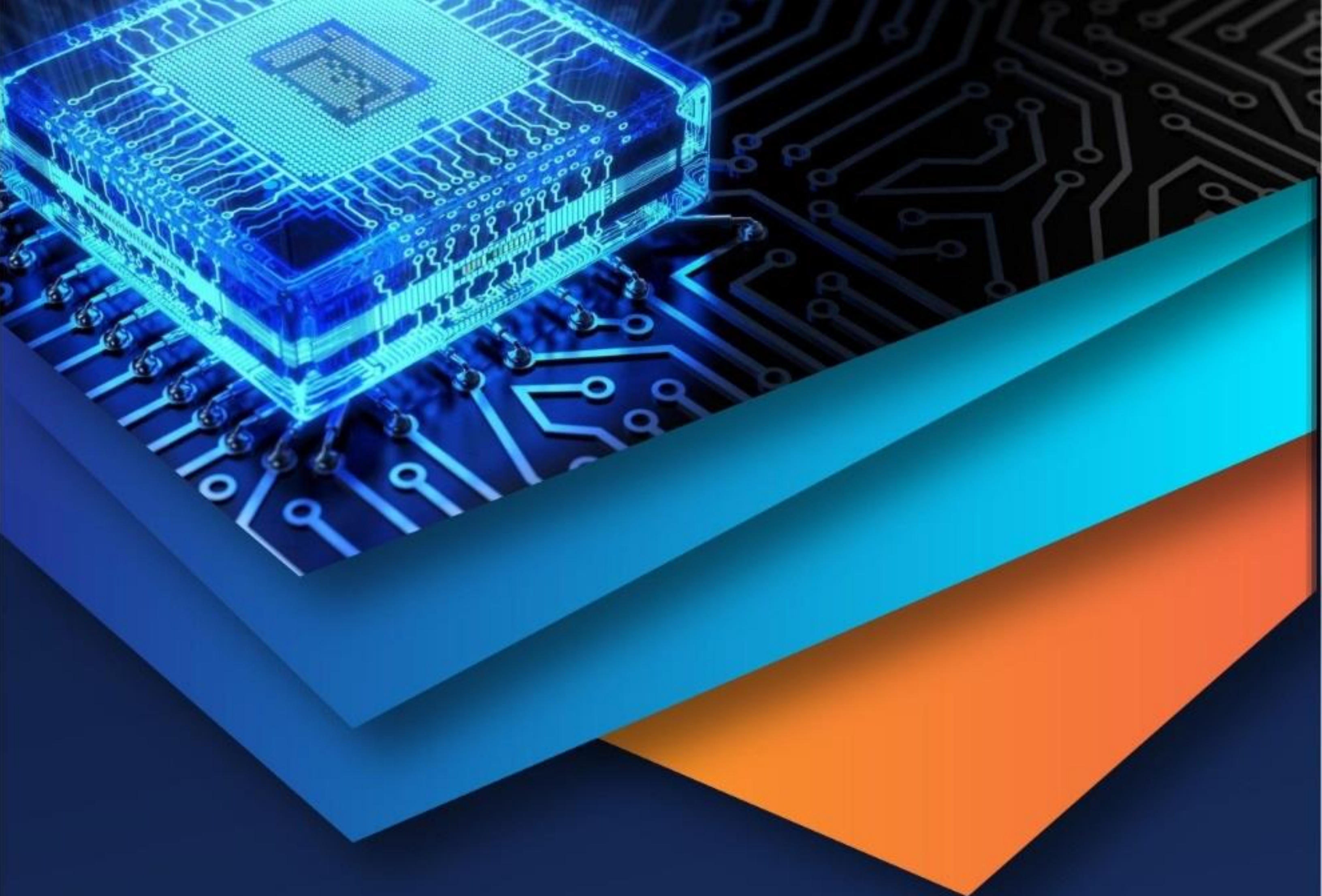

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