Seismic Response of Isolated Building With Different Height To Width Ratio

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Abstract- *Base isolation is an effective mean for protection of structure from earthquake damage. The basic concept of base isolation is to insert a flexible layer between foundation and superstructure thus decoupling the building from damaged cased due to ground motion. As building height increases it become flexible hence height to width of the building is an important character of building. This paper presents the seismic response of base isolated building with various heights to width ratio. The lead rubber bearing type isolator was considered for the study. The main aim is to decide proper height to width ration for application of base isolation to the building structure. The building frame with different height to width ratio ranging from 0.77 to 2.7 was studied and different parameters such as displacement drift, base shear and maximum forces in columns are compared and presented. The response of building with various aspect ratios was compared with fixed base. Linear response spectra and nonlinear time history analysis was carried out using finite element software SAP. The results obtained indicate that the base isolation will be effective up to the aspect ratio of 2.3.*

Keywords- Lead Rubber bearing, Base isolation, Height to width ratio, Nonlinear time history.

I. INTRODUCTION

In view of earthquake mitigation the three major classifications are Base isolation, Active energy dissipation devices and Passive energy dissipation devices. Base isolation is an effective mean for protection of structure from earthquake damage. The basic concept of base isolation is to insert a flexible layer between foundation and superstructure thus decoupling the building from damaged caused due to ground motion. In addition the damping properties provided by Isolation system helps to dissipate the energy imparted during an earthquake event. Seismic base isolation, which is now recognized as a mature and efficient technology, can be adopted to improve the seismic performance of strategically important building such as schools, hospitals, industrial structures, multi-storey buildings etc.

The present study is performed on buildings situated in high seismic zone to judge the effectiveness of base isolation techniques.

II. METHODOLOGY

The present paper aims to study efficient height to width of the building to implement base isolation system. The lead rubber bearing is considered as the isolation device. The lead in this system helps to impart stiffness where as rubber is a flexible material and provide damping to the structural element. Six different models are considered for the study with fixed base and isolated base. The properties of lead rubber bearing are calculated for each of the model based on the fundamental period and maximum base reaction. Following models are considered for the study.

Model M_1F: G+4 Fixed base building with height to width ratio as 0.779
Model M_1I: Base isolated G+4 Building with height to width ratio as 0.779
Model M_2F: G+7 Fixed base building with height to width ratio as 1.166
Model M_2I: Base isolated G+7 Building with height to width ratio as 1.166
Model M_3F: G+10 Fixed base building with height to width ratio as 1.554
Model M_3I: Base isolated G+10 Building with height to width ratio as 1.554
Model M_4F: G+13 Fixed base building with height to width ratio as 1.941
Model M_4I: Base isolated G+13 Building with height to width ratio as 1.941
Model M_5I: G+16 Fixed base building with height to width ratio as 2.329
Model M_5I: Base isolated G+16 Building with height to width ratio as 2.329
Model M_6I: G+19 Fixed base building with height to width ratio as 2.716
Model M_6I: Base isolated G+19 Building with height to width ratio as 2.716

For every model there are two types i.e. fixed base and isolated base, the idea is to track the performance difference between them and finally compare the performance difference between models 1 to 6. The building frame considered is symmetric in both orthogonal direction and hence unidirectional study will be sufficient to judge the performance. The building frame considered is shown in figure 1.

Seismic and other data used is shown in table I. The preliminary design is performed using combinations used for limit state of strength and serviceability. After fixing sizes of various members nonlinear modal time history analysis was performed for 3 different time history record. The time history record used for the study is shown in table II. The 3 dimensional FEM modelling of the building is carried out using finite element software SAP. The beams and columns are modelled as 2 nodded elements. The isolator is modelled using link element.

TABLE I
DATA USED FOR ANALYSIS

Frame type	Special moment resisting frame
Buildings considered	G+4,G+7,G+10,G+13,G+16, G+19
Height to width ratios	0.779,1.166,1.554,1.941,2.329 ,2.716
Storey height	3.1m
Depth of foundation	2.2m
Plan dimension	27mX27m
Unit weigh of RCC	25 KN/m²
Unit weight of masonry	18 KN/m²
Live load intensity on floor	3.0 KN/m²
Live load intensity on roof	3.0 KN/m²
Weight of floor finish	1.5 KN/m²
Water proofing load on roof	2.0 KN/m²
Thickness of External wall	200mm
Thickness of Internal wall	100mm
Height of parapet	1.0m
Seismic Zone	IV (Z=0.16)
Importance factor	1.5
Repose reduction factor	5
Soil type	Medium
Grade of Concrete	M30
Grade of Steel	Fe500

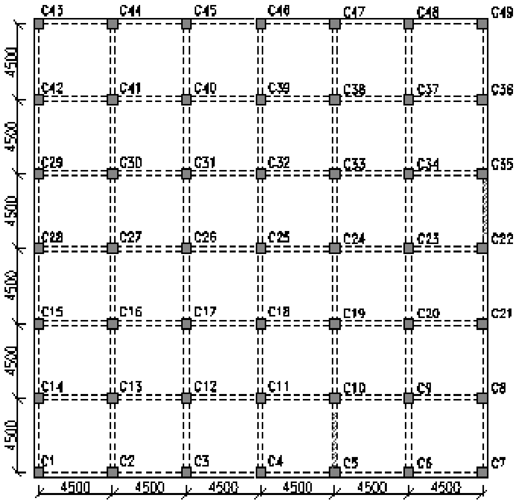


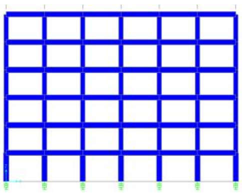
Figure 1 Structural plan for the frame consider for analysis

III. MODELLING AND ANALYSIS

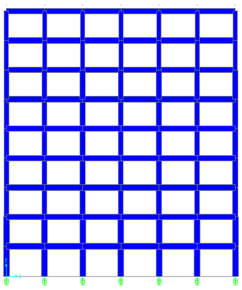
For modelling of plug lead rubber bearing type isolator first the properties are calculated for linear and nonlinear analysis from book titled "Design of seismic isolated structure" by F. Naeim and J. M. Kelly. The properties are calculated based on UBC-97.The lead rubber isolated is modelled by using nonlinear link element with single node and six DOF. All fixed base building are first design for most unfavourable effect of load combinations as per IS 1893 and IS 456. The lead rubber isolated is modelled by using nonlinear link element with single node and six DOF. All fixed base building are first design for most unfavourable effect of load combinations as per IS 1893 and IS 456. The design is carried out using software the purpose is to fix the sizes of members to represent proper stiffness, hence detail design is not carried out. Adopting the proper sizes will avoid any additional weight being considered in analysis. Equivalent static and response spectra dynamic analysis are being carried out and sizes are adopted based on the results obtained from these analysis. The response of the building in view of various response parameters are also determined using nonlinear time history analysis.

TABLE III
DETAILS OF TIME HISTORY DATA

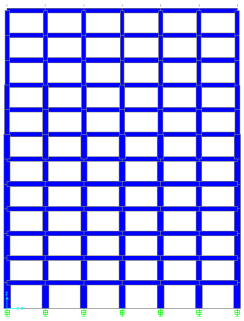
Earthquake	Recording station	Componen t	Duration in seconds	PGA
Bhuj earthquake 26 January 2001	Ahmadabad	N 78 E	133	1.0382



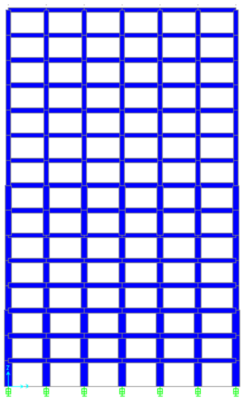
Model M1



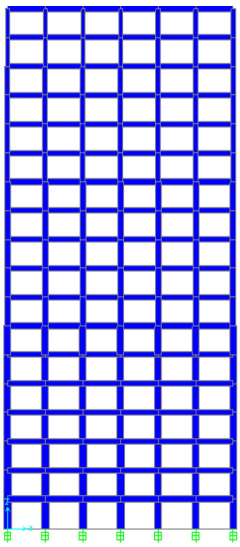
Model M2



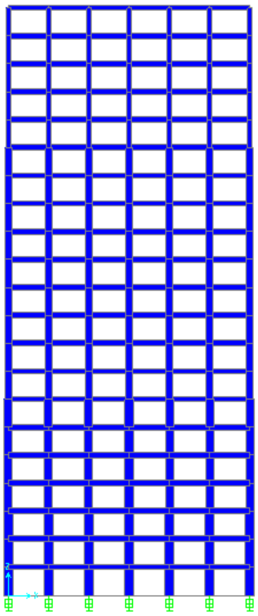
Model M3



Model M4



Model M5



Model M6

Figure 2 Building Mathematical Model

IV. RESULTS AND DISCUSSION

The results obtained from the analysis are presented in terms of various response parameters such as displacement, base shear and maximum forces in columns.

A. Modal Analysis

The modal analysis is carried out on the models using Ritz's vector. The total number of modes considered for analysis is 30. The first three models are considered to be governing mode and first mode will give the fundamental natural period of the building. The relative increase or decrease in time period for each of the mode is calculated for fixed base and isolated base building. The difference in time period for each of the height to width ratio is presented.

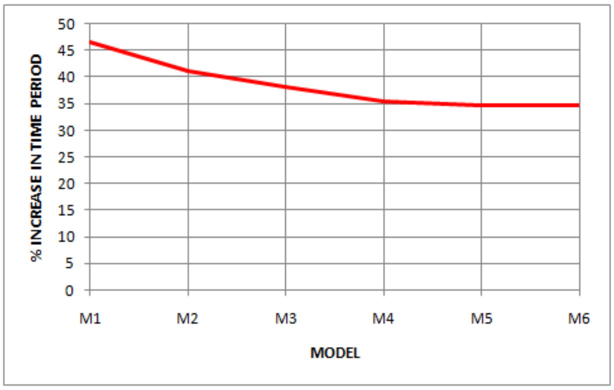


Figure 3 Percentage difference in Time period

It is expected that when isolators are provided for the building the time period tends to increase since the building becomes more flexible. The percentage increase in time period for each the model between fixed and isolated buildings is presented here. The graph mainly remains flat after model M5 (h/w= 2.32). This observation shows that the base isolation is not much effective after model M4 and is more effective for small and stiff building.

B. Response spectra analysis

The response spectra dynamic analysis is carried out and results are presented here.

1. Displacement

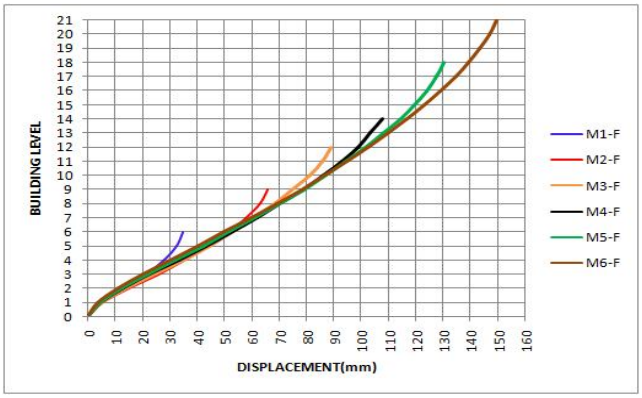


Figure 4 Displacement profile for isolated building

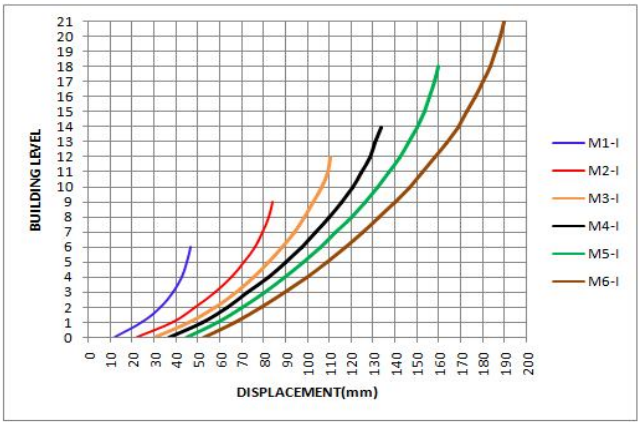


Figure 5 Displacement profile for fixed base building

As observed from the displacement profile it is very clear that displacement is more in case of isolated building. The displacement tends to be increase in isolated building because of the flexibility offered by isolator at base of the structure.

2. Storey Drift

For the fixed base building the storey drift from base to level 4 goes on increasing and then it decreases after level 4. For fixed base building the initial drift at level 1 is more and then it goes on decreasing towards top. The storey drift variation is smoother in case of isolated building. The storey drift profile for different models is shown in figure 6.

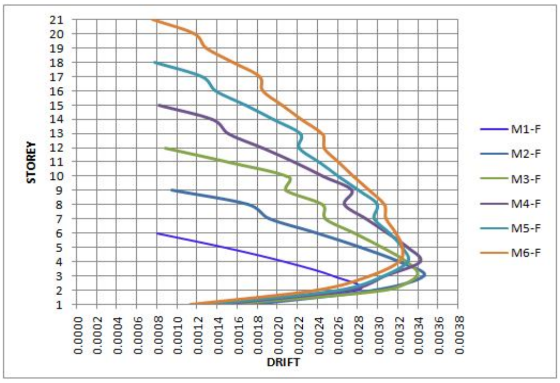


Figure 6 Storey Drift for Fixed base building

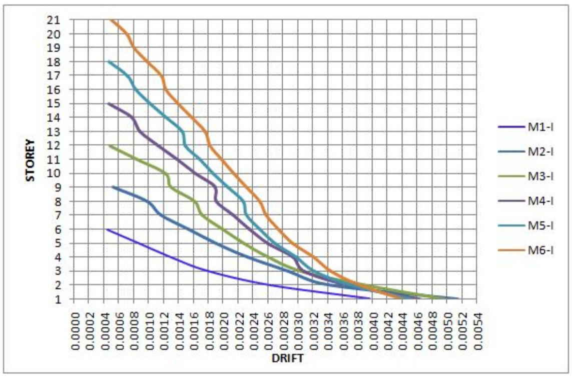


Figure 7 Storey Drift for Isolated base building

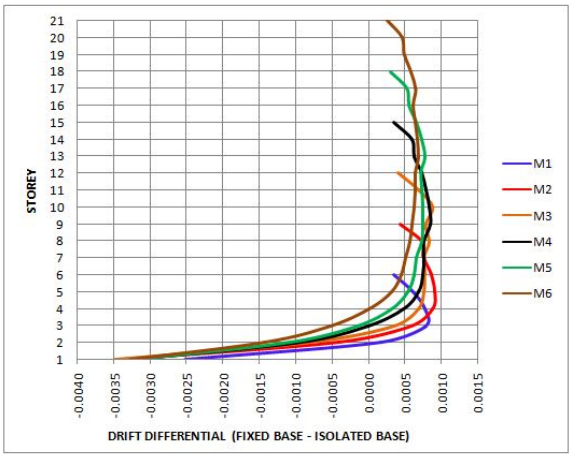


Figure 8 Drift differential

It is observed from the graph that the drift was more in isolated building for all models. As the height increases the graph is mostly become vertical after level 4 indicating that there is not much change in relative drift except for the top level. The graph thus indicates that the base isolation is more effective in short building. The graph mostly overlap for model M3, M4 and M5 from level 4 and after that there is slight tilt towards negative side and hence it can be stated that the response become stable after model M5, however the base isolation is most effective for model M2.

3. Base shear

The base shear is compared on the basis of the net values of base shear obtained from response spectra analysis and percentage decrease in base shear for isolated building when height of the building increases.

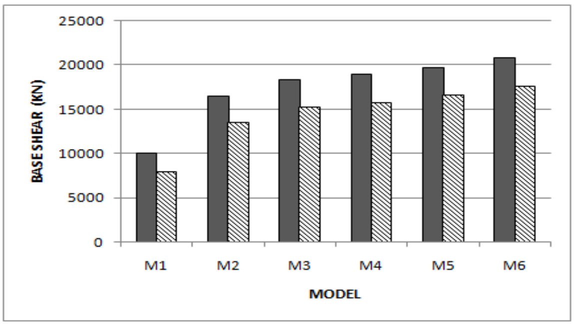


Figure 9 Maximum base shears

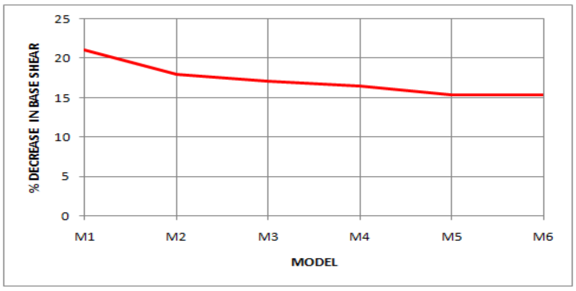


Figure 10 Percentage Decrease in base shear

It is observed form the graph there is maximum reduction of base shear for model M1 between fixed base and isolated base building.

4. Maximum forces in column

The maximum forces in column are observed for the entire model. One internal and one external column is selected for the study. The column C1 and C17 is selected to study the forces.

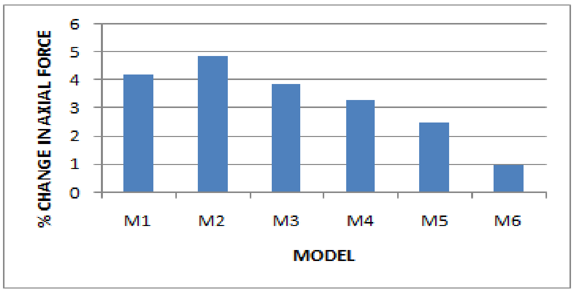


Figure 11 Percentage Change in Axial force (Exterior Column C1)

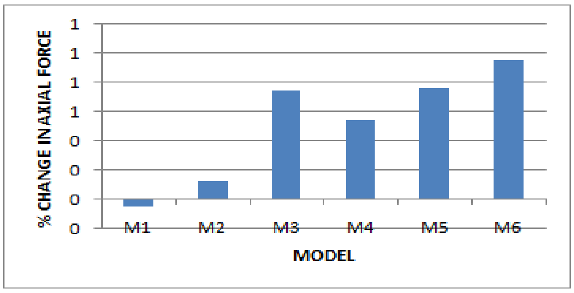


Figure 12 Percentage Change in Axial force Interior Column C17)

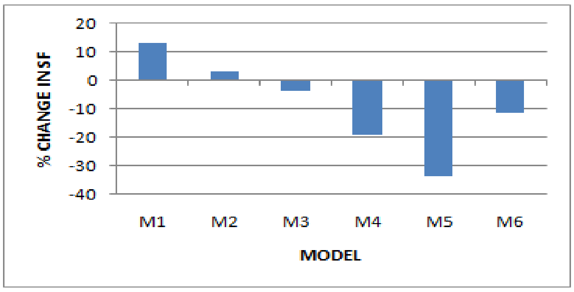


Figure 13 Percentage Change in Shear force (Exterior Column C1)

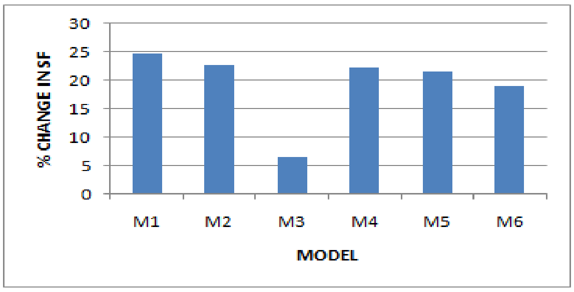


Figure 14 Percentage Change in Shear force (Interior Column C17)

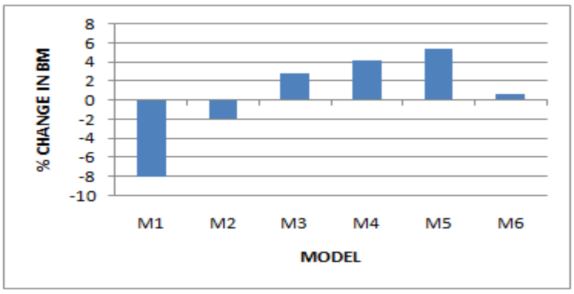


Figure 15 Percentage Change in BM (Exterior Column C1)

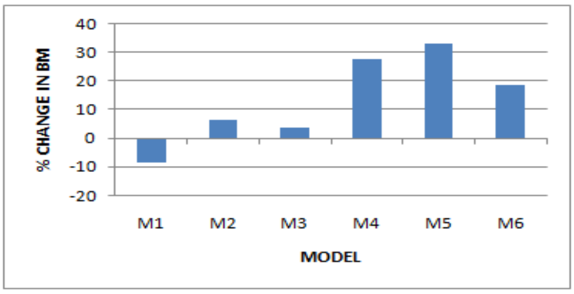


Figure 16 Percentage Change in BM (Interior Column C17)

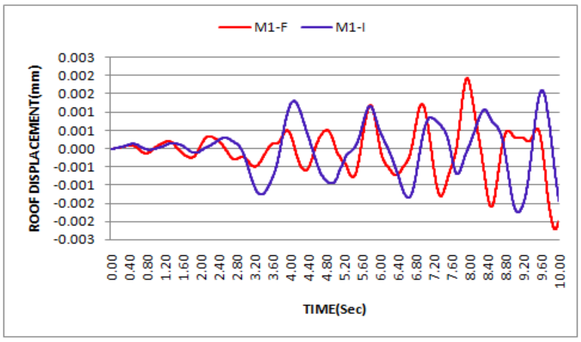
The column C1 was an exterior column and column C17 was an interior column, however instead of presenting Axial, SF and BM for the entire model to get a clear idea of variation of forces according to aspect ratio and percentage change in forces was presented in Figure 3.8 to 3.10 above. The positive change indicates that the column forces decreases where as negative change indicates increase in column forces.

As observed from the graph the positive difference reduces after model M5 for shear force and bending moment and hence the model M5 with height to width ratio of 2.32 will give the optimum performance as far as column forces are concern.

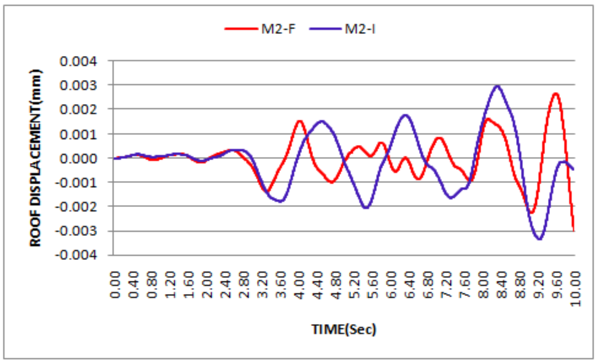
B. ***Time history analysis***

1. Roof displacement

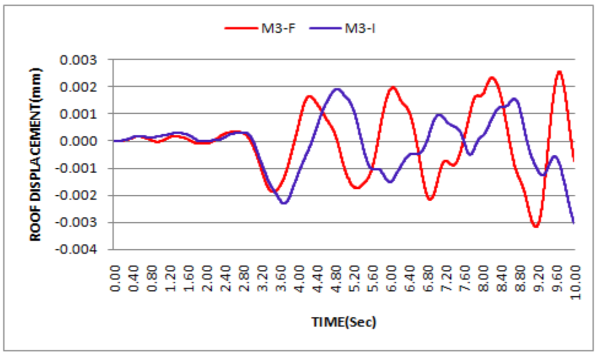
The roof displacement time history for Bhuj earthquake time history was presented for different values of height to width ratio for fixed and isolated base building.



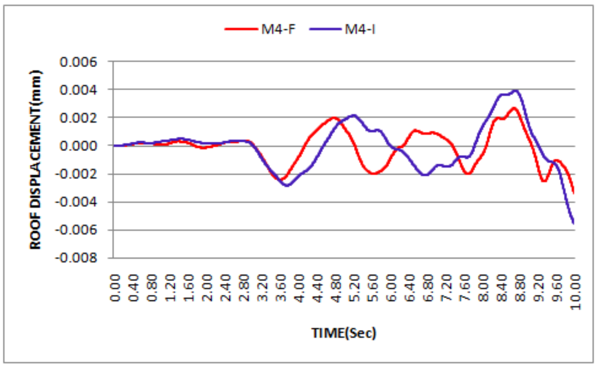
Model M1



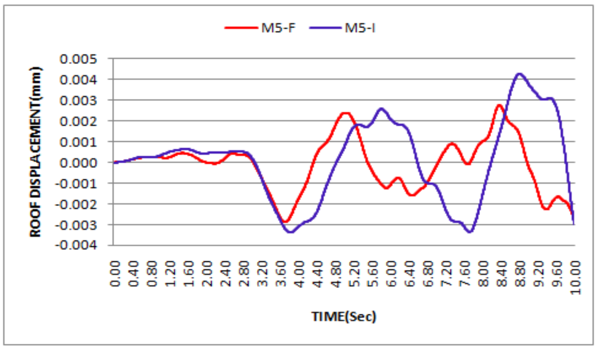
Model 2



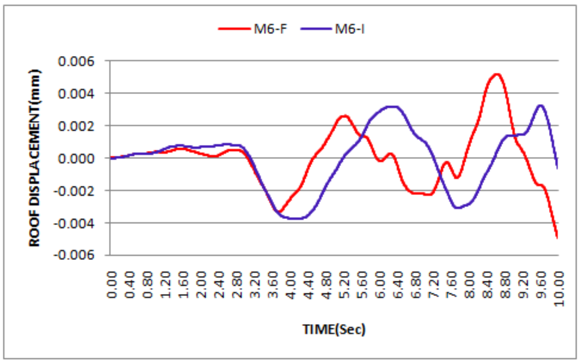
Model 3



Model 4



Model 5



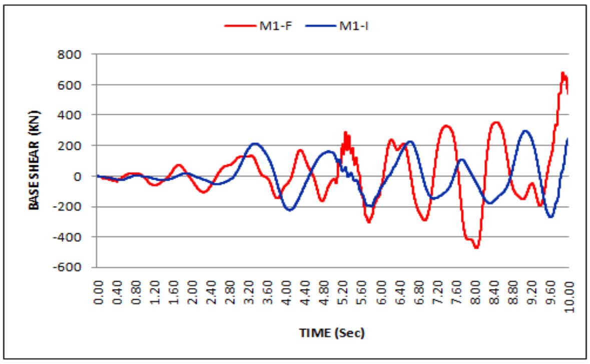
Model 6

Figure17 Roof Displacement time history (Bhuj) for different models

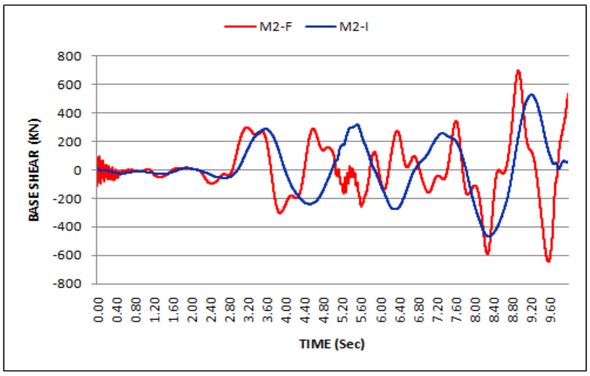
The roof displacement time history is plotted for models with different height to width ratio and presented above. The time history analysis is performed and presented for Bhuj earthquake record. For model M1 and M2 the displacement of isolated building is more than fixed base building. The roof displacement is found to be less in isolated building after model M4. Hence the good control over the roof displacement can be obtained in model M5 and M6 and M5 seems to be optimum.

2. Base shear

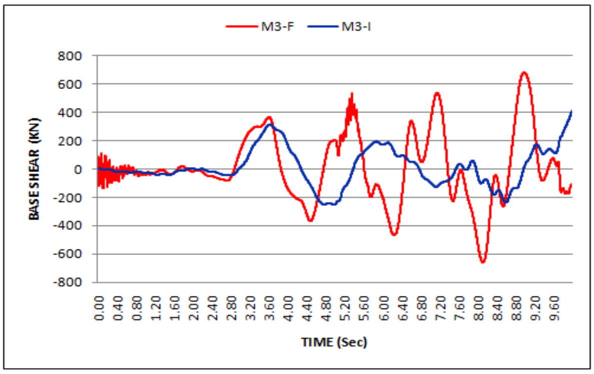
Base shear time history for Bhuj earthquake time history was presented for different values of height to width ratio for fixed and isolated base building.



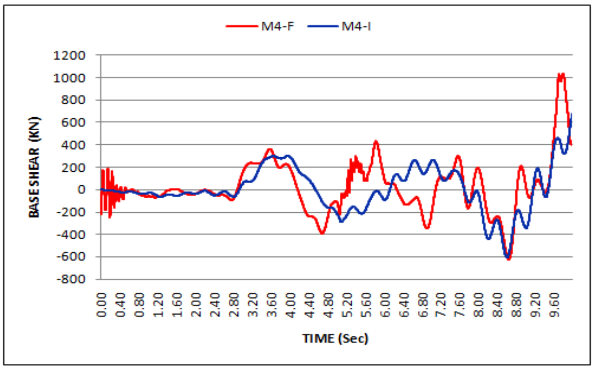
Model 1



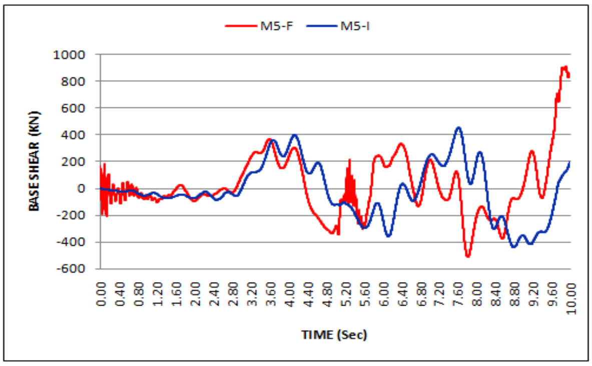
Model 2



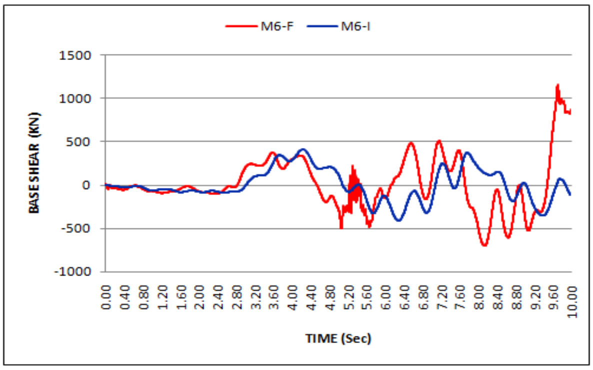
Model 3



Model 4



Model 5



Model 6

Figure 18 Base shear time history (Bhuj) for different models

As observed from the base shear history the isolated building responded well for the first model for the initial period of earthquake however for the entire earthquake of 10 sec the maximum reduction in base shear was observed for model M5 with height to width ratio of 2.32.

V. CONCLUSION

It is concluded from the results obtained that the base isolation system will be more effective for short buildings. The height to width ratio of 2.3 is found to be the maximum ratio after which the response of base isolated building will be stable compared to fix base building. Hence it is recommended that for the base isolation system maximum height to width ratio shall be maintained in the range of 2.3 to 2.7 for the most efficient results.

REFERENCES

[1] Radhikesh P. Nanda, Manish Shrikhande and Pankaj Agarwal, "Low cost base isolation system for seismic protection of rural buildings ", Practice periodical on structural design and construction, ASCE, ISSN 1084-0680/04015001(8)

[2] Panayiotis C. Roussis,, "Study on the effect of uplift-Restraint on the seismic response of base isolated structures", Journal of structural Engineering, ASCE, Vol. 135, No. 12, Dec.2009

[3] Lin Su, Goodarz Ahmadi and Iradj G. Tadjbakhsh, "Comparatice study of base isolation systems", Journal of Engineering Mehanics, ASCE, Vol 115, No.9, September 1989.

[4] A. N. Lin,, "Seismic performance of fixed base and base isolated steel frames", Journal of Engineering Mechanics, ASCE, Vol 118, No5, May1992

[5] Yu Chen and Goodarz Ahmadi, "Wind Effecct on base isolated structure", Journal of Engineering Mechanics, ASCE, Vol.118, ISSN 0733-9399/92/0008-1708,August 1992.

[6] IS 456-1964 (Reaffirmed 2000), Code of Practice for Plain and Reinforced Concrete (Second Revision), Indian Standard Institute, NewDelh