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Mid-Storey Isolation In Vertical Irregular Buildings

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Abstract: Practical, technical and economical difficulties in adopting base isolation created interest in study of mid-storey isolation, in which flexible isolators are installed at any intermediate storey of a building. Since vertical irregularities are increasing in the present architecture, a study to understand structural behaviour of these buildings under seismic loading is essential for proper design and better performance. This paper presents the time-history analysis of a stiffness and mass irregular building of G+20 stories and their seismic responses when incorporated with isolators at intermediate stories. The effect of change in isolation level in the seismic performance of the building is studied. The structural analysis software SAP2000 is used for the analysis process. Base shear, storey shear deviation and energy absorption of the high rise structures are plotted.

Keywords: High rise structures, Mid–storey isolation, SAP2000, Seismic isolation, Vertical irregularity

I. INTRODUCTION

Seismic isolation method was developed to prevent injury to the occupants and other components by isolating the building, thereby reducing the earthquake forces acting on it. Mid-storey isolation is a type of partial isolation in which only a part of the total building mass is isolated at an intermediate storey level, unlike isolating the total mass as in base isolation. These isolation devices absorb energy thus reducing the energy input on structures.

Irregular buildings are a major concern as it is becoming common now. According to IS 1893 (Part 1): 2016, a soft storey is one which has the lateral stiffness less than the storey above; while a mass irregularity occurs when the seismic weight of a floor increases to more than 150 percent of the floors below [10]. Here, this study consists of time history analysis of two buildings, a stiffness irregular and a mass irregular building, on both fixed and middle storey isolated conditions. Variation in results on changing the level of isolation has also been checked. Change in base shear, storey shear, energy dissipation, occurrence of peak values of storey shear and acceleration are compared and plotted. SAP 2000 software has been used for the study.

II. AIM

To find the effect of mid-storey isolation in the seismic responses of vertical irregular high rise buildings.

III. MODEL DESCRIPTION

Building model used is of G+20 stories with plan dimension 30 x 16 m. Each story is of 3.5m height. Beams used are 0.35 x 0.4 m and columns are 0.4 x 0.6 m. Stiffness irregularity is created in the second model by increasing the bottom storey height to 4.5m. Mass irregularity is created by increasing the seismic weight of storey 10 to about 181% than the adjacent storeys. This is done by increasing the weight of structural components and an addition of a superimposed dead load of 10 kN/m2.

Isolator used in common is high damping rubber bearing with an effective horizontal stiffness of 3.27 kN/mm and vertical stiffness 2796 kN/mm. It has a maximum vertical load capacity of 9596 kN, which is larger than the maximum axial load occurring in the considered structures. There are a total of 35 bearings installed, each with a height of 136 mm and 10% damping. The properties of isolators used in this study are taken from actually developed isolation devices. These are installed in the middle of columns in different storey locations to study the effect of varying the isolation interface along the height of the building. The 1940 El Centro earthquake is used for the time history analysis.

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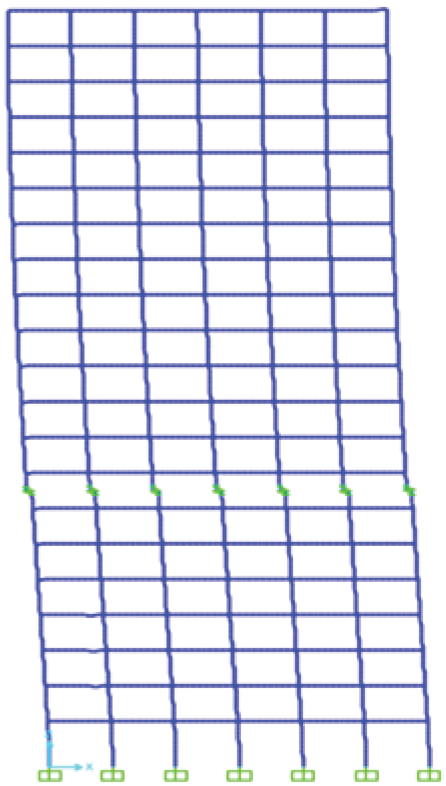


Fig. 1. Stiffness irregular model with isolation at storey 7

IV. RESULTS AND DISCUSSIONS

A. Modal Time Period

Seismic isolation basically increase the time period of the building to protect it from the resonance period range of earthquakes. Table I and Table II shows the comparison of time periods of stiffness irregular and mass irregular building respectively. Results shows an increase in modal periods of primary modes in X, Y and rotational directions as the isolation level is lowered.

Table I. Comparison Of Time Period Of Stiffness Irregular Building In Fixed And Isolated Condition

MODE	FIXED	MSI - 14	MSI - 7
X	3.23	3.32	3.47
Y	3.53	3.61	3.75
Rotational	3.02	3.1	3.24

TABLE II. COMPARISON OF TIME PERIOD OF MASS IRREGULAR BUILDING IN FIXED AND ISOLATED CONDITION

MODE	FIXED	MSI - 14	MSI - 7
X	3.12	3.2	3.37
Y	3.42	3.49	3.65
Rotational	2.92	3	3.15

B. Base Shear

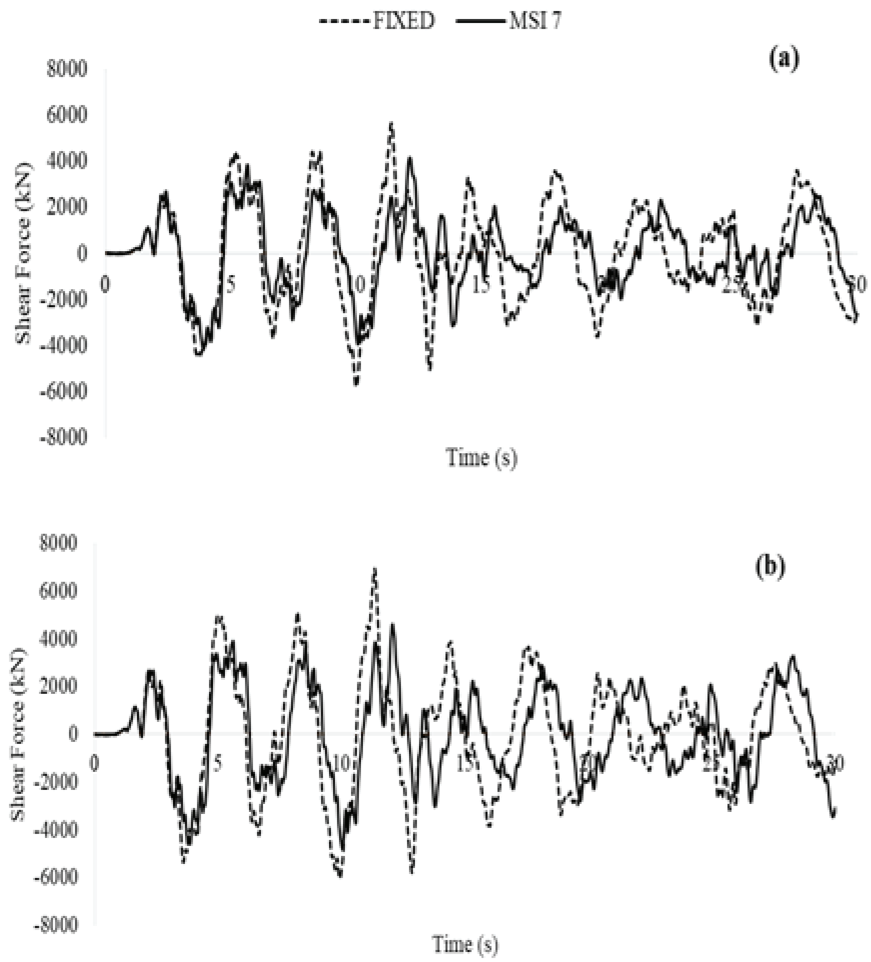
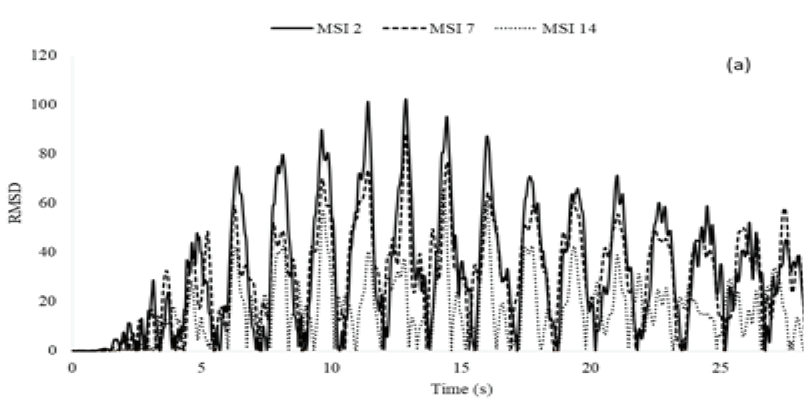


Fig. 2. Comparison of base shear on isolating storey 7 in (a) stiffness irregular (b) mass irregular buildings

Fig 2 shows the change in base shear time history in the two buildings on isolating storey 7. Peak base shear of the stiffness irregular building is reduced by about 28% and that of the mass irregular building is reduced by about 31% on isolating storey 7.

C. Storey Shear



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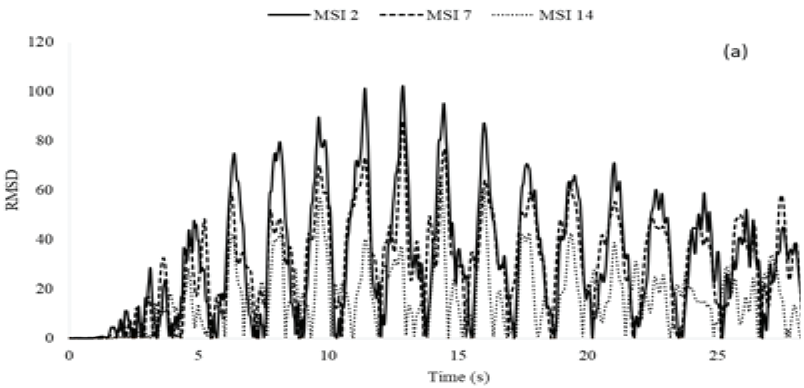

Fig. 3. Comparison of root mean square deviation of storey shear on isolating various storeys in (a) stiffness irregular (b) mass irregular buildings

Root mean square deviation plot of the two models are shown in fig 3. Storey shear time history of storey 1 which had peak value in fixed condition, is considered for calculations. Maximum deviation is obtained for second storey isolation in the two buildings which shows that maximum reduction of storey shear occurs on reducing the height of isolation.

D. Energy Dissipation

Variation in energy dissipation capacity of different storey isolations in both buildings are shown in fig 4. It can be observed that lower level isolations have more energy dissipation capacity. Energy plot of higher level isolated building almost coincides or only slightly vary from that of a fixed building. It even increases at some points in the case of mass irregular building model.

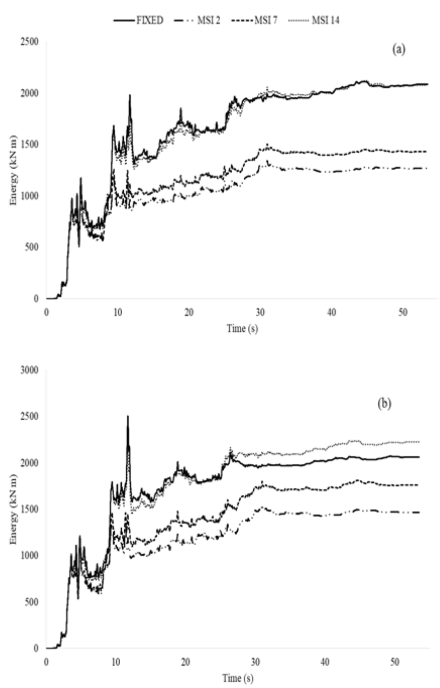

Fig. 4. Comparison of energy dissipation on isolation of various storeys in (a) stiffness irregular (b) mass irregular buildings

E. Maximum Storey Shear And Acceleration

TABLE III. MAXIMUM STOREY SHEAR

BUILDING TYPE	ISOLATION STOREY	STOREY SHEAR (kN) Max	At Storey	% Reduction
Stiffness Irregular	Fixed	193.4	1	-
	14	168.3	1	12.9%
	7	155.7	6	19.5%
Mass Irregular				
	Fixed	222.3	1	-
	14	193.2	9	13.1%
	7	163.9	6	26.3%

It is seen from table III that reduction of peak storey shear is more for mass irregular model than the stiffness irregular model. Maximum storey shear occurred below the isolation interface for both the models.

TABLE IV. MAXIMUM ACCELERATION

BUILDING TYPE	ISOLATION STOREY	ACCELERATION (m/s2)		
		Max	At Storey	% Reduction
Stiffness Irregular	Fixed	3.77	18	-
	14	3.57	19	5.3%
	7	3.36	5	10.8%
Mass Irregular				
	Fixed	4.42	Roof	-
	14	3.59	Roof	18.7%
	7	3.48	7	21.3%

Table IV shows that on comparing the maximum acceleration values of the models in various conditions, effectiveness of isolation is found more for mass irregular model, as it has more reduction of acceleration in the structure. Maximum acceleration occurred above the isolation level for higher level isolation and occurred below isolation level for lower level isolation.

V. CONCLUSION

- Modal time periods in X, Y and rotational directions increase on application of mid-storey isolation. It increases as the isolation level is moved down.
- Base shear is decreased by 28% and 30% for stiffness irregular and mass irregular buildings respectively.
- Root mean square deviation of storey shear showed maximum decrease in shear for isolation at lower stories.
- Input earthquake energy of the structure is minimized by mid-storey isolation. Energy dissipation is more when the isolation interface is located at lower stories.
- Effectiveness of storey isolation decreases with increase in isolation height in both buildings. It is more seen in the mass irregular building model than the stiffness irregular model.
- Max storey shear and acceleration occurs below the isolation layer for lower level isolation and max acceleration occurs above the isolation layer for higher level isolation.

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