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Performance Analysis of Base Isolation & Fixed Base Buildings

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Abstract:— **The aim of the seismic design is to protect the important building such as museums, hospitals, official buildings etc.., and reduce the damages after a seismic event. Many researchers have done a lot of research to get the best solutions to resist earthquakes and protect survival. One of those solutions is base isolation, the main goal of seismic isolation is to shift the fundamental frequency of a structure away from the dominant frequencies of earthquake ground motion and the fundamental frequency of the fixed base-superstructure, the other purpose of an isolation system is to provide an additional means of energy dissipation, thereby reducing the transmitted acceleration into the superstructure. In the present study, a five-story RCC building has been designed and analyzed according to IS Code for seismic analysis by (ETABS-2015) software using time history analysis, the study considered two models one of the models represents conventional building and the second model represents base isolation (BI) building. Results show that the model of base isolation reduces meaningfully the moment and shear produced for the same mode and hence reinforcement required is lesser compared with the fixed-base model, the results also show that the modal period increases in BI model subsequently, displacement is higher in this model than fixed base model because of flexibility of base isolation building.**

Index Terms **- Earthquake, Nonstructural component, Base Isolation (BI), Fixed Base, Lead Rubber Bearing (LRB), Time history analysis, Time period, Story drift, Story acceleration, Base shear.**

I. INTRODUCTION

Seismic is the factor which generate a lateral forces applied on the base of structure, and should be considered during the design by structural engineer. The objective of the seismic design is to protect important facilities such as hospitals, museums and official buildings etc., to reduce damage after earthquakes. This has been done by many researchers who have a lot of research to get the best solutions for earthquake resistance and protection to survive[1].

The idea of base isolation has been found in historical buildings in some active regions of the world, who have used multi-layer stones which exhibit a less friction during earthquakes and ability to move in all the directions without damages[2].

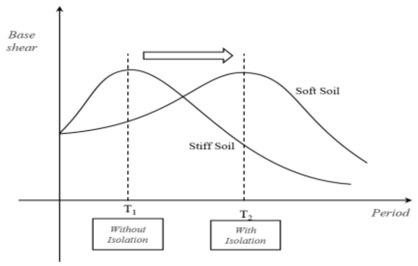

Fig. 1 Shifted of period in base isolation

In conventional buildings, when the building is subjected to earthquake motion, the building amplifies acceleration that results of seismic in peak floor acceleration(PFAs) higher than the peak ground acceleration(PGA) that causes a severe damage to non-structural components. The design of non-structural components to stand up after earthquake is important factor for safety and reduces the damages. In view of base-isolated structures, the energy due to earthquake is dissipated by isolators before traveling through the structure from base to roof. Thus, the lateral force resulting an earth quake which is applied on structural elements including non-structural elements are low in base isolation system compared to conventional system adopted in construction. Subsequently the chance of structural components to still stand up after seismic is higher[3].

One of the goals of seismic isolation is to shift the fundamental frequency of a structure away from the dominant frequencies of earthquake ground motion and the fundamental frequency of the fixed base superstructure. Seismic isolation advices are most effective when used in structures on stiff soil and structures with low fundamental period (low-rise building)[4].

Stiff structures are particularly well-suited to base isolation, since they move from the high acceleration region of the design spectrum to the low acceleration region. In addition, for very stiff structures, the excitation of higher mode response is inhibited, since the superstructure higher mode periods may be much smaller than the fundamental period associated with the isolation system[5],[6].

The other purpose of an isolation system is to provide an additional means of energy dissipation, thereby reducing the transmitted acceleration into the superstructure[4]. The aim of isolators to isolated the superstructure from the supporting ground in order to reducing the transmission of the earthquake motion to the structure[7]. Thus, base isolation decouples the structure from ground during seismic. The other purpose of an isolation system is dissipated the seismic energy[8].

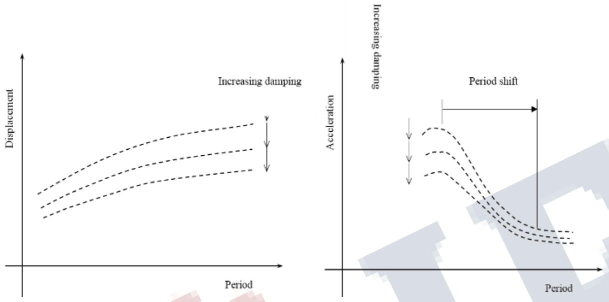

Fig. 2 Effects of base isolation on spectral acceleration & displacement

II. THE DESIGN AND CHARACTERISTICS OF LRBS

Lead Rubber Bearing (LRBs) are consisting of a standard elastomeric laminated rubber bearing. The rubber compound can be of natural rubber or chloroprene rubber. The shape can be either round or rectangular. In this study a round shape is chosen. The LRBs are generally constructed with low-damping (unfilled) elastomers with shear modules of 0.4 −1.2N /mm2 and lead cores with diameters ranging 15% and 33% of the bonded bearing diameter for round bearings. The minimum 0.4N /mm2 is selected for the study carried out. The elastomer provides the isolation and recanting, while the lead core offers the necessary energy dissipation or damping component. The maximum shear strain value is generally between 125% and 200%. The inner steel shims do not only grant for good load capacity, but also for a proper confinement of the lead core. The yield stress of lead core is depending on the temperature: 18MPa at 35°C, 10MPa at 75°C, 7MPa at 125°C and 4MPa at 225°C. Therefore, after one load cycle it can be assumed that the yield stress is 13MPa and after three it is 11MPa. The yield stress value of 11MPa is assumed for the testing[9],[10],[11].

The calculation of the LRBs properties is showing in the Table 1 which has been done according the UBC-97:

Table. 1 Results of isolator design

Design period [s]	T_{eff}	1.384
Effective damping	β	5.0 %
Design displacement [m]	d_{bd}	0.2163
Rubber shear modulus [KN/m^2]	G	1000
Axial load on the LRB [KN]	W_i	1964
Effective stiffness [KN/m]	K_{eff}	1975.93
Dissipated energy per cycle [kNm]	E_D	29.04
Short term yield force [kN]	F_0	33.56
Post-elastic tangent stiffness [KN/m]	K_p	115.35
Elastic stiffness [KN/m]	K_e	1153.5
Stiffness ratio	K_e/K_p	0.1
Yield displacement [m]	d_y	0.024
Yield force [KN]	F_y	11.249
Total bearing diameter [mm]	$D_{bearing}$	457
Lead-plug diameter [mm]	D_{pd}	62.33
Lead-plug stiffness [KN/m]	K_{pd}	155.2
Total rubber stiffness [KN/m]	Kr	1820
Single layer rubber thickness [mm]	t	10
Number of rubber layers	n	20
Steel plates thickness [mm]	ts	3
Top & bottom steel plates thickness [mm]	$t_{s.ext}$	30

III. MODELING & ANALYSIS OF BASE ISOLATION

Isolators can be modelled explicitly in analysis software such as ETABS, SAP2000 and LARSA. When software does not support an explicit isolator element, a spring element or a short column may be used to simulate the isolator.

A. *Structure data*

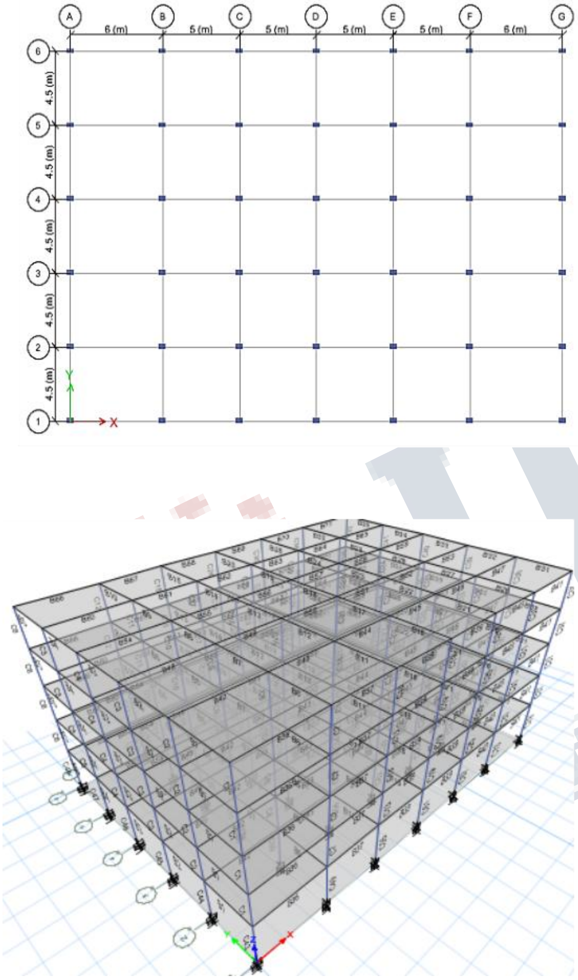

Fig. 3 Plan & 3D Views of structure

The (G+4) RCC building is taken for the case study and its structural details such as grade of concrete, grade of steel, beam sizes, column sizes and all the other parameters are assumed as per Table 2 according the IS code[12],[13]. For the analysis of fixed as well as base isolated building linear time history analysis and response spectrum method is used. To conduct time history analysis, LUCERNE ground motion records are used [14].

Table. 2 Data of structure

Grade of concrete	M 25	Seismic Zone (Z)	0.36
Grade of steel	Fe 415	Response Reduction Factor (R)	5.0
Floor to floor height	3.5 m	Importance Factor (I)	1.0
Ground floor height	4.5m	Site Type	II
Dead load	1.5 KN/m^2	ECC. Ratio (e)	0.05
Slab thickness	150 mm	Effective stiffness (K_{eff})	1975.9 KN/m
Wall partition on beams	2 KN/m	Force at 0 displacement (F_0)	33.56 KN/m
Internal wall	150 mm	Stiffness of rubber in LBR (K_r)	1820.74 KN/m
Columns	300× 450 mm	bearing horizontal stiffness(K_b)	436.2 KN/m
Beams	300 × 600 mm	Total bearing vertical stiffness(k_V)	223199.95 KN/m
Live load on all floors	3 KN/m^2		

B. *Results & Discussions*

Using ETABS software the fixed base and base isolated symmetric building are analyzed. The main objective of work is to reduce dynamic properties of structure by providing Base Isolation. Thus from above design of Lead Rubber Bearing data a Base Isolated symmetric building model is created and analyzed by using E-TABS-2015 software. The assumed preliminary data required for analysis of frame is shown in Table 2. After the modeling and analysis, the results out are follows:

1) *Displacement*

Table 3 shows the maximum displacement for both cases, the base isolated and fixed base, the results show that at top floor the base isolation produces (32.4) mm as compared to fixed base (18.5) mm. This gives us an evidence that the base isolation buildings are more flexible than fixed base buildings.

Table. 3 Max Displacements at each story

TABLE: Story Max Displacements

Story	Load Case	Direction	Base Isolation mm	Fixed-base mm
Base	Th	X	0	0
Story1	Th	X	27.9	7.3
Story2	Th	X	29.8	11.5
Story3	Th	X	31.1	14.4
Story4	Th	X	32	16.9
Story5	Th	X	32.4	18.5

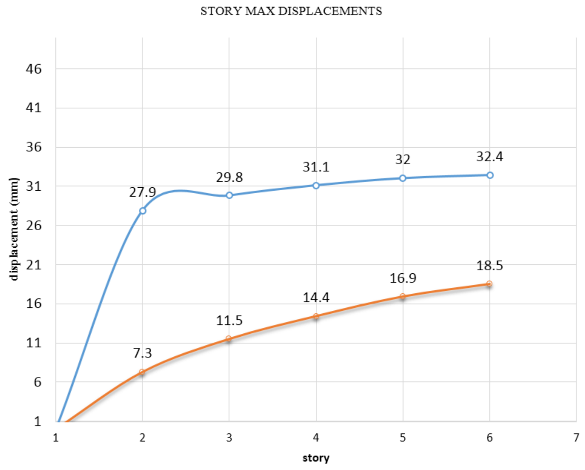

Fig. 4 Story Max Displacement

2) *Story drifts*

The floor level vs story drifts graph models of fixed and base isolated building for symmetric are as shown in Fig. 5 and Table 4. From Fig. 5, it is observed that in the base isolated building, story drift at the top floor significantly reduces with 58.5% as compared to the corresponding fixed base models.

Table. 4 Story drifts at each story

TABLE: Story Drifts

Story	Load Case	Item	Drift (m) Base Isolation	Fixed Base
Story1	Th	X	0.006195	0.001628
Story2	Th	X	0.000562	0.001197
Story3	Th	X	0.000365	0.001081
Story4	Th	X	0.000238	0.000835
Story5	Th	X	0.000118	0.000434

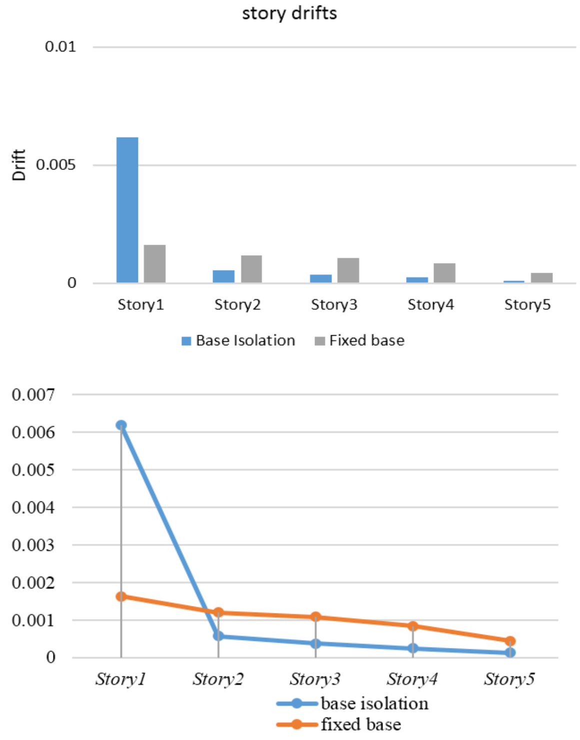

Fig. 5 Story drifts

3) *Time Period*

The aim of isolators is shifted and increasing the time period of earthquake. From the results in Table 5, and Fig. 6, it is observed that the time period increases in case of base isolated with 36.5 % for first modal (fundamental modal).

Table. 5 Modal periods of Base Isolation & Fixed-base

TABLE: Modal Periods

Case	Mode	Period (sec)	
		Base Isolation	Fixed base
Modal	1	2.18	1.384
Modal	2	1.9	1.034
Modal	3	0.52	0.45
Modal	4	0.41	0.335
Modal	5	0.32	0.266
Modal	6	0.28	0.195
Modal	7	0.21	0.195
Modal	8	0.2	0.165
Modal	9	0.16	0.138
Modal	10	0.14	0.113
Modal	11	0.1	0.073
Modal	12	0.1	0.071

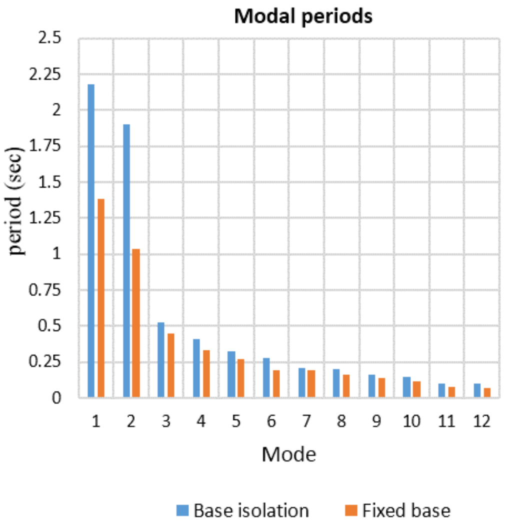

Fig. 6 Modal periods

4) *Time history Plot-Fixed base*

The analysis has done by Non-linear time history analysis. Figure 7 shows that the base shear vs time, it is observed that the base shear considerably reducing in case of base isolated with 48.56 % as compared to fixed base model.

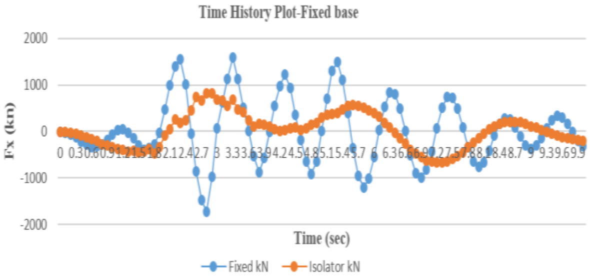

Fig. 7 Time history plot VS Fixed base

5) *Pseudo Spectral Acceleration, PSA*

The seismic energy dissipation and damage control of building structures can be done by isolators. The acceleration due to earthquake reduces with the isolators at the 1st floor as shown in Fig. 8, after that starts increasing slightly along with increasing the no. of stories but at the top floor it is still less than the acceleration at the base.

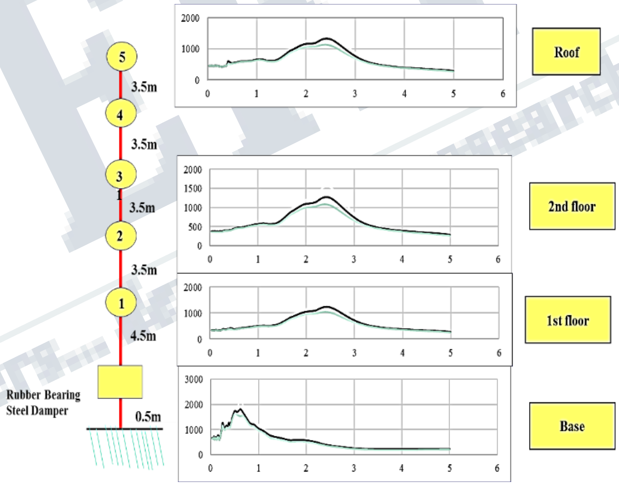

Fig. 8 Pseudo spectral acceleration, PSA

CONCLUSION

- After providing lead rubber base isolator (LRBs) the fundamental period mode of structure is increased by 37 % for G+4 stories building. It is concluded that the mode period is increased after providing rubber isolator due to the flexible property of the isolator.

- For time history analysis, the base shear for (G+ 4) stories building in X and Y direction for fixed condition is 1596 KN. After providing rubber isolator the base shear is 821.5 KN. It concluded that the base shear is decreased in base isolation model.

- When compared with fixed base structure, the base shear is reduced in base isolated structures, thus the response of building is good in base isolated structures than fixed base structures.

- The story displacement is more in case of base isolation by 73.8 % for G+4 stories building which is give us an evidence, it is more flexible than fixed base model.

- It observed that the energy of seismic dissipation by LBR isolators, i.e. acceleration is reducing in superstructure in base isolated case.

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