ANALYSIS OF SEISMIC BEHAVIOUR OF RCC BUILDING FRAME USING FREI

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Abstract- The base isolation system is a passive system in which reductionin transmission of earthquake energy is obtained by lengthening the fundamental horizontalperiod of the structural system, which plays an important role in reducing seismic vulnerabilityof a structure in high seismic prone areas.A laminated isolator consists layer of elastomeric material as rubber and interleavedwith thin steel reinforcing layers and known as steel reinforced elastomeric isolator (SREI). In this work, the heavy weight of steel layers isreplaced by thin layers of bi-directional fiber fabric which is known as fiber-reinforcedelastomeric isolators (FREI).In present work the effectiveness of the fixed base and isolated base (FREI) with different storeyRC frame building are concerned with controlling the vibrations of the structure. The presentresearch work of G+6 and G+8 story buildings situated in zone V are analyzed under thevarious loadings such as dead load, live load, and earthquake load. Free vibration analysis andresponse spectrum analysis have been carried out for these models building with a fixed base andBase Isolation Device (FREI). It is observed that story storey drift and maximumbase shear in response spectrum is significantly reduced at top stories with the base isolatedbuilding and even when critical load combination are observed.

Keywords – Response Spectrum Analysis, FREI, Storey Drift, Lateral Displacement.

I. INTRODUCTION

The Earthquake is one of the major natural hazards to the life on the earth and has affected countless cities and villages of almost every continent. Therefore, it is necessary to design structures that are earthquake resistant. Now a day uncountable high-rise building has been constructed all over the world and the numbers are increasing day by day. Construction of this Low-rise, Medium-rise, High rise building the major task is to determine the performance of building under different types of loading i.e., Earthquake and wind force (wind force is considered in High-rise buildings only).

Earthquake generally defined as perceptible shaking and vibration of the earthquake resulting from sudden release of energy in form of seismic wave. Wind force is defined as a body or a structure such as building a tower or a chimney when placed in where the flow of air will experience pressure and forces.
Base isolation is one of the most popular means of protecting a structure against earthquake forces. It is one of most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. A base isolated structure is supported by a series of bearing pads, which are placed between the buildings and building foundation.

In this research paper, the seismic response behavior of RCC building frame of (G+6), and (G+8) are taken as fixed base structure and base isolated structure have been studied and also comparison between maximum storey drift and base shear with different load combination are being carried out.

II. DESIGNING OF FREI

Fiber reinforced elastomeric isolators (FREI) is the composition of neoprene rubber and fiber material which are combined together as one by vulcanization process. The dimension of FREI is being calculated by taking maximum service load acting on column at the base of structure under fixed condition. The design of FREI is very complex and therefore, the researchers prefer the same design method as that of Lead rubber bearing (LRB). The design code ASCE 7-10 guide to analyze the equivalent static forces. The design of FREI is done according to ASCE 7-10, Cl. No. 17.4. The following steps are followed to get the design parameters:

Step 1: Evaluate the located spectral response of structure at a period of 1 second, $S_1 \leq 0.60g$.
Step 2: Select site soil profile category, determine site coefficient F_v from table 11.4-2
Step 3: Determine seismic coefficient S_{M1} and S_{D1}.
Step 4: Select type of isolation bearings and the damping coefficient B_D.
Step 5: Select a desired period of the isolated structure at the design displacement, T_D.
Step 6: The effective horizontal stiffness of isolator is obtained as
Step 7: Estimate the design horizontal displacement D,
Step 8: Estimate the total rubber thickness required T_r:
Where, γ = maximum shear strain
Step 9: Determine the plan dimension of FREI,
Step 10: Find the number of rubber layers n_e and total thickness of isolator, h for a chosen thickness of rubber and fiber layer.
Step 11: Recalculate the actual values of effective horizontal stiffness of the FREIs).

The procedure for calculating the effective stiffness and damping are as follows:

- The effective horizontal stiffness of FREI is given by equation;

$$K_{eff} = \left(\frac{W_i}{g}\right).\left(\frac{2\pi}{T_D}\right)^2$$

- Design Displacement D_D;

$$D_D = \left(\frac{g}{4\pi^2}\right)\left(\frac{S_D T_D}{B_D}\right)$$

- The Damping ratio β is calculated as;

$$\beta = \frac{W_d}{2\pi * K_{eff} * (D_D)^2}$$

- Vertical Stiffness K_v;

$$K_v = \left(\frac{E_c A}{t_r}\right)$$

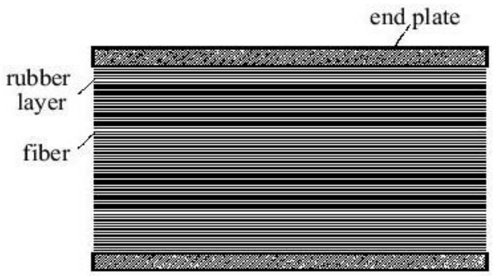

Fig. 1 Model of Fiber-Reinforced Elastomeric Isolator

The fig 1 represented the cross section of FREI consisting of end plate (either rubber or thick steel plates), fiber fabric material layer and rubber layer.

III. MODELLING OF BUILDING

In this analysis work, the three-dimensional RCC frame building model of different stories, such as G+6, G+8 storey is being used with fiber reinforced elastomeric isolator (FREI) and without base isolation system. These stories are unsymmetrical in plan area of about 1080m^2. The RCC Frame Building are being designed and analyzed according to IS 456:2000 and IS1893:2002 by using ETABS. And nonlinear static analysis performs on the asymmetrical R.C.C. Frame Building model without any isolators and with stable fiber reinforced elastomeric isolators(FREIs). The Behavior of buildings is studying in term of maximum storey displacement, story drift, story shear by placing FREI on the Building.

Table 1: Height of Storey

Storey	Height (in m)
G+6	23.3
G+8	29.9

The RCC frame building of storey G+6, G+8 are modelled with their base fixed and also with their base isolated by FREI. Total four model are analysed using ETABS v17 commercial software.

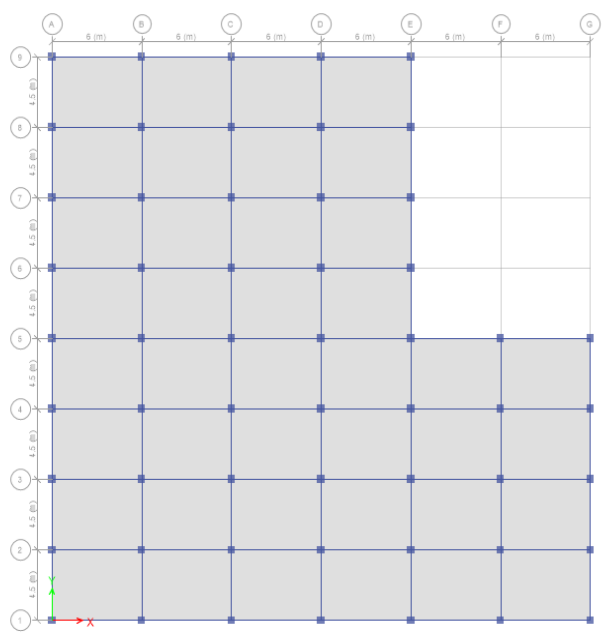

Fig. 2 Plan view Storey

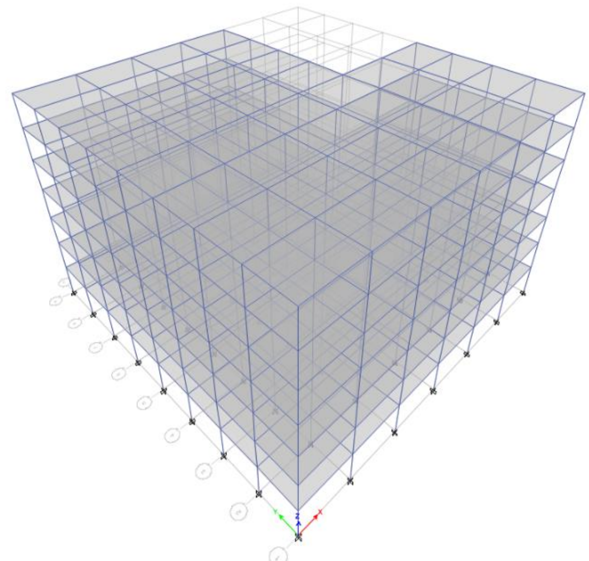

Fig. 3 Three Dimensional view of G+6 Fixed base RCC Frame Building

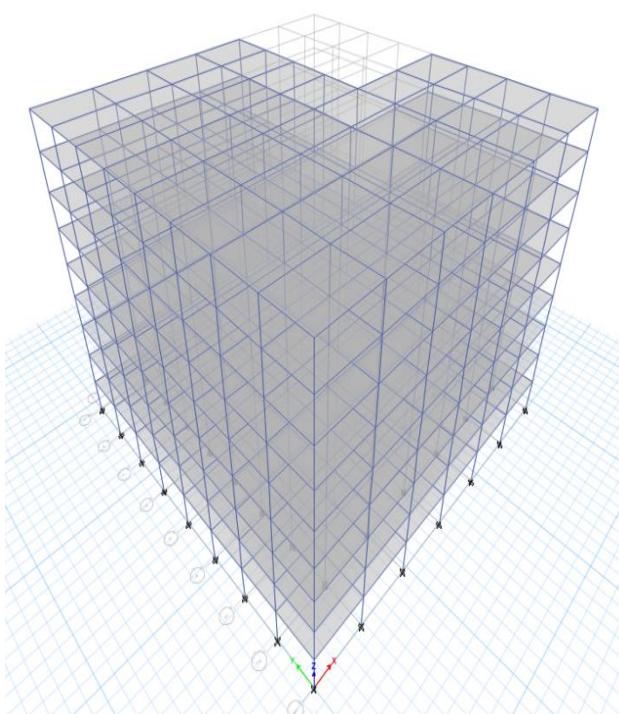

Fig. 4 Three Dimensional view of G+8 Fixed base RCC Frame Building

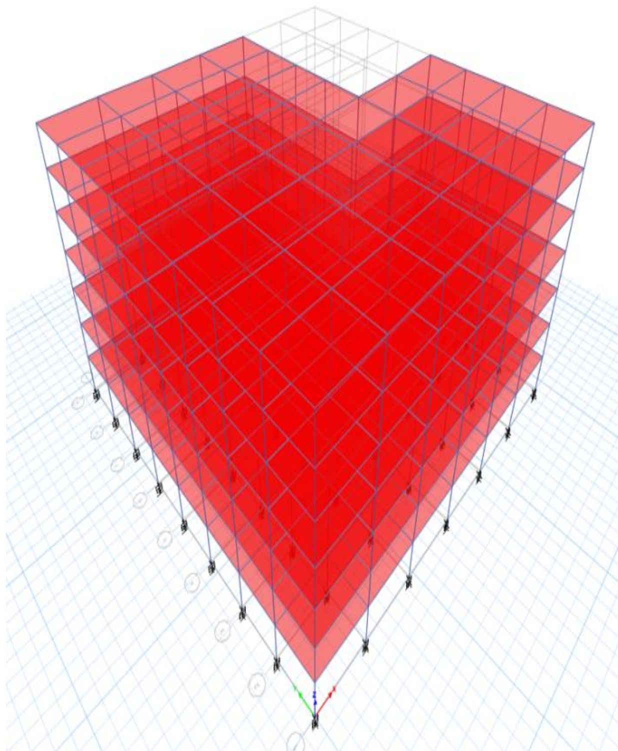

Fig. 5 Three Dimensional view of G+6 RCC Frame Building Using FREI

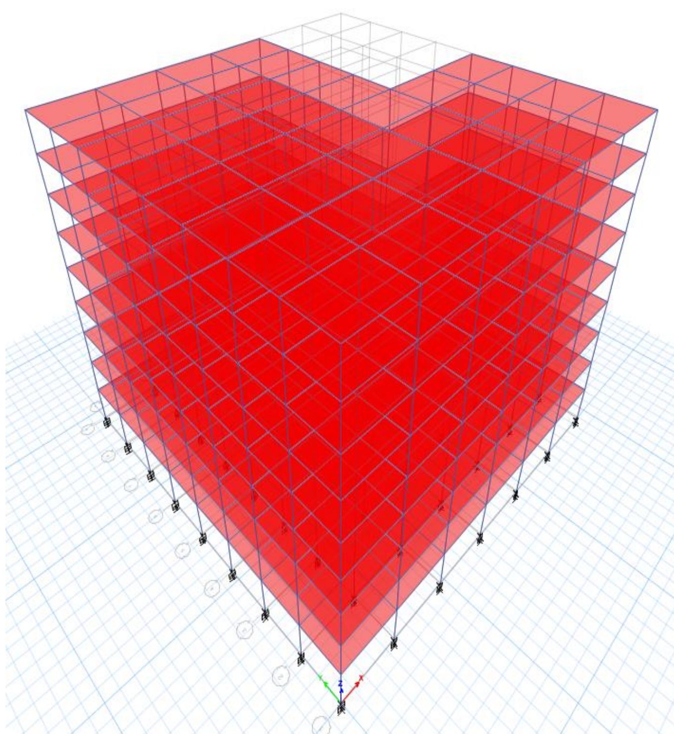

Fig. 6 Three Dimensional view of G+8 RCC Frame Building Using FREI

A. Structural Modeling

Table 2: Structural properties of Concrete

Particular	Model Data
Grade of Concrete	M-20
Weight per unit volume (KN/m^3)	25 kN/m^3
Modulus of Elasticity, E_c (MPa)	27386.12
Poison's Ratio μ	0.2
Coefficient of Thermal Expansion, α $\left(\frac{1}{°C}\right)$	5.5×10^{-6}
Shear Modulus, G (MPa)	11410.89

Table 3: Structural properties of Steel

Particular	Model Data
Grade of Steel	Fe-500
Weight per unit volume (KN/m^3)	78.5 kN/m^3
Modulus of Elasticity, E_c(MPa)	2×10^5
Coefficient of Thermal Expansion, α $\left(\frac{1}{°C}\right)$	5.5×10^{-6}

Table 4: Dimension of RCC Frame Building

Particular	Model Data
Slab Thickness (mm)	125
Size of Beam (mm)	250×450
Size of Column for G+4, G+6, G+8 resp. (in mm)	500×500
	600×600
	750×750
Floor Finishing Load (Dead Load)	1.25 KN/m^2

Live Load	2.5 KN/m^2
Wall Load (on Each Beam)	11.4 KN/m

Table 5: Seismic Parameters

Particular	Model Data
Seismic Zone	IV
Seismic Factor (Z)	0.24
Response Reduction Factor, R	5
Importance Factor, I	1
Soil Type	II
Damping Ratio	0.05

B. FREI Properties

The dimensions and various other properties such as effective horizontal Stiffness, effective vertical stiffness, design displacement and damping ratio has been calculated, to analyze the behavior of structure under seismic forces. The above parameter has been calculated by the formula given in chapter II of this paper. The modeling of FREI depends on

- The total weight of the structure.
- Fundamental Natural Time Period
- Maximum Load on acting on the column
- Damping Factor
- Design Horizontal Spectral Acceleration Coefficient.

*B1. Dimensions of FREI for **G+6 Storey** Building*

1. Effective Horizontal Stiffness = 1390 KN/m
2. Effective Damping = 0.05
3. Effective Vertical Stiffness = 22.8065 KN/m
4. Dimension of FREI = 465×465×161 mm
5. Aspect Ratio = 2.9
6. Shape Factor = 15.5

*B2. Dimensions of FREI for **G+8 Storey** Building*

1. Effective Horizontal Stiffness = 1323.53 KN/m
2. Effective Damping = 0.05
3. Effective Vertical Stiffness = 2139991.54 KN/m
4. Dimension of FREI = 500×500×192 mm
5. Aspect Ratio = 2.62
6. Shape Factor = 15.5

IV. RESULT AND DISCUSSION

The static and dynamic analysis is conducted for six different model condition using ETABS v17. The results so obtain are discussed in this chapter further, in detail. Indian Standard Code is utilized for the static and dynamic analysis of three different storey. These two different stories medium-rise building is analyzed in two conditions, one with fixed base and other with fiber-reinforced elastomeric isolator as base isolation. Therefore, total four model are used for knowing the parameter and responses of the buildings. The result of Lateral drift and Base Shear of six different modal in both X-direction and Y-direction are compared by Response spectrum analysis. Hereby, the results are displayed in form of graph or by tables shown below.

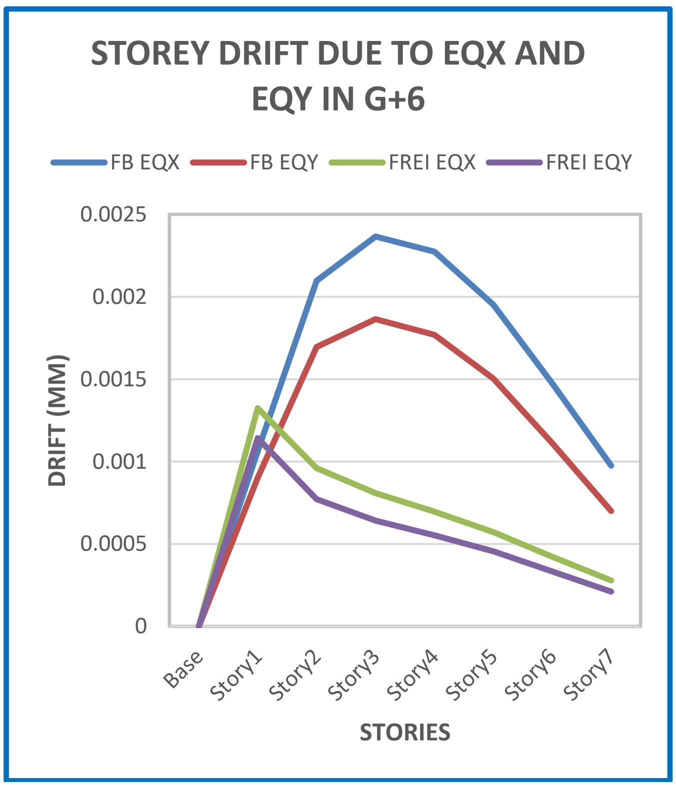

Fig.7STOREY DRIFT DUE TO EQX AND EQY IN G+6

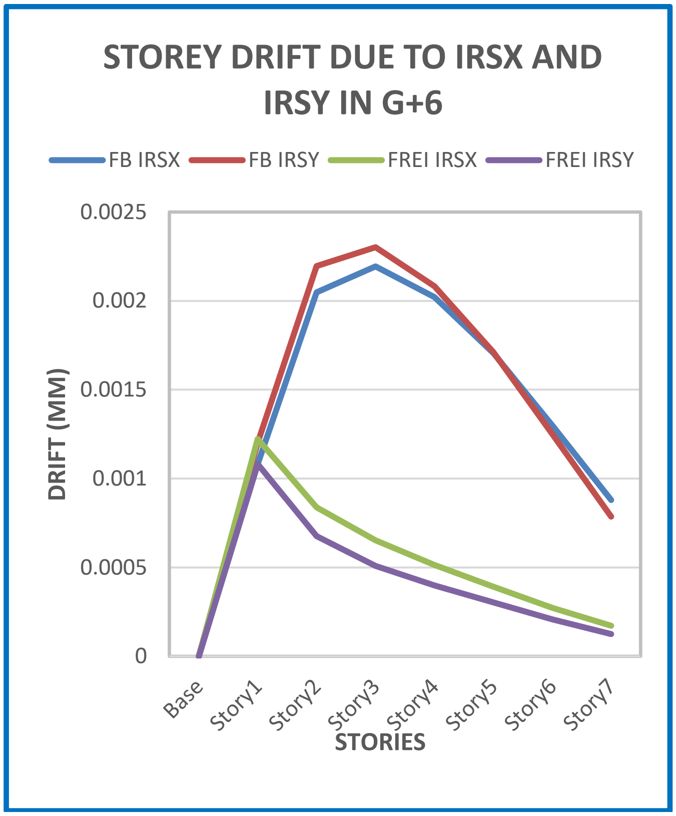

Fig.8 STOREYDRIFTS DUE TO IRSX AND IRSY IN G+6

The Graph display in Fig.7 and Fig 8 are showing the storey drift ratio of G+6 story in X and Y direction due to static and response spectrum analysis. The lateral loads applied on structure in X and Y direction, when the RC building has its base fixed or isolated with FREI. Therefore, storey drift ratio of some storey is as, in case of static analysis in X direction, storey 1 is 0.0010 in fixed base condition and 0.00132 when FREI mounted. Storey 7, 0.00098 when base is fixed and0.00028 in case of FREI. Similarly, in Y direction, storey 1 is 0.00090 in fixed base condition and 0.00114 when FREI mounted. Storey 7, 0.00070 when base is fixed and 0.00021 in case of FREI. The storey drift ratio in case response spectrum is also somewhat similar to static analysis storey drift ratio. The graph also shows that, for FREI building there is sudden increase in storey drift from base to storey 1 and then the drift is reduced gradually. Similarly, in case where response spectrum is applied on G+6 RC building to check the storey drift in X and Y direction the somewhat same curves are displayed in the graph. The sudden increase in storey drift from base to storey 1 and then the drift is reduced gradually as shown in figure 7 and Figure 8. So, we can say that the storey drift ratio is reducing, when the FREI is used as a base isolation in G+6 RC Building.

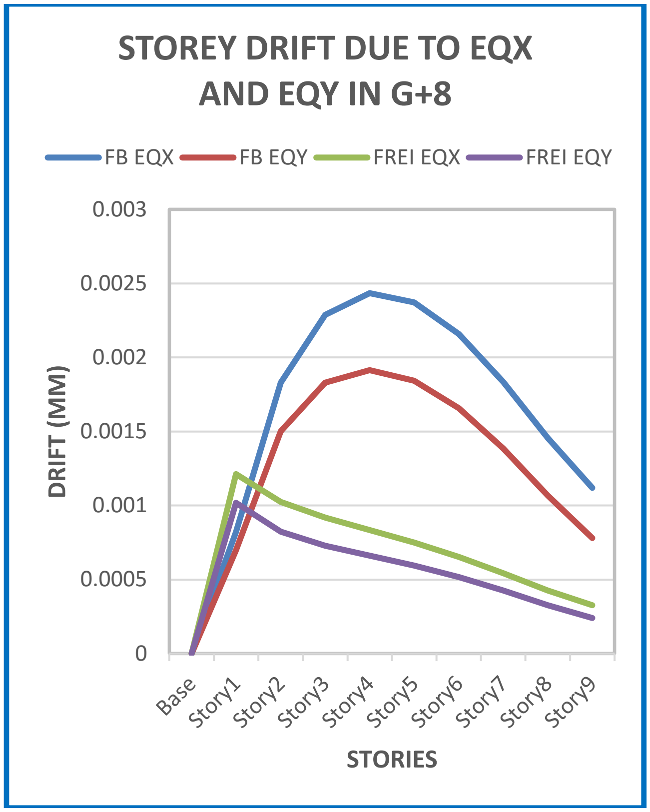

Fig.9 STOREY DRIFT DUE TO EQX AND EQY IN G+8

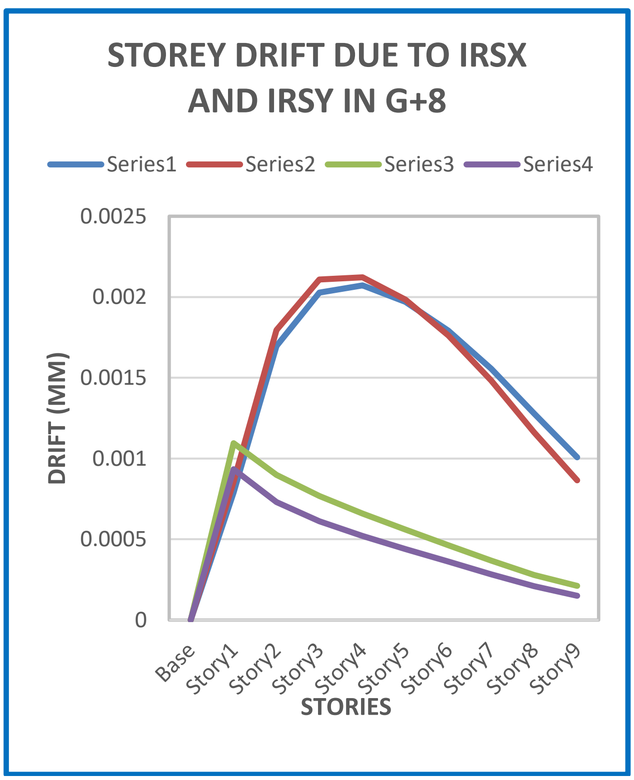

Fig.10 STOREY DRIFT DUE TO IRSX AND IRSY IN G+8

The Fig.9 and Fig.10 represented the storey drift ratio of G+8 in X and Y direction due to static and response spectrum analysis. The lateral loads applied on structure in X and Y direction, when the RC building has its base fixed or isolated with FREI. Therefore, storey drift ratio of some storey is as, in case of static analysis in X direction, storey 1 is 0.00082 in fixed base condition and 0.00121 when FREI mounted. Storey 9, 0.00112 when base is fixed and 0.00033 in case of FREI. Similarly, in Y direction, storey 1 is 0.00070 in fixed base condition and 0.00102 when FREI mounted. Storey 9, 0.00078 when base is fixed and 0.00024 in case of FREI. The storey drift ratio in case response spectrum is also somewhat similar to static analysis storey drift ratio. The graph also shows that, for FREI building there is sudden increase in storey drift from base to storey 1 and then the drift is reduced gradually. Similarly, in case where response spectrum is applied on G+8 RC building to check the storey drift in X and Y direction the somewhat same curves are displayed in the graph. The sudden increase in storey drift from base to storey 1 and then the drift is reduced gradually as shown in Fig.9 and Fig.10. So, we can say that the storey drift ratio is reducing, when the FREI is used as a base isolation in G+8 RC Building.

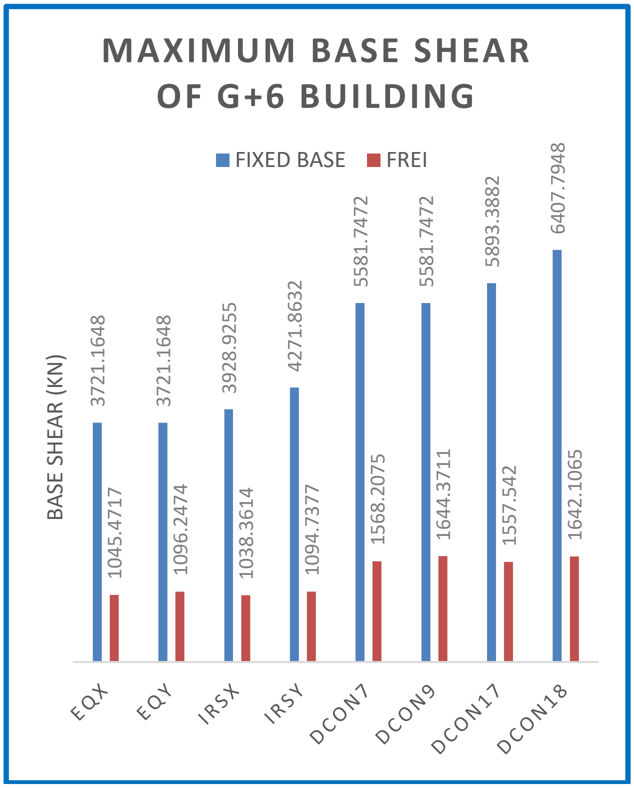

Fig.11 MAXIMUM BASE SHEAR OF G+6 BUILDING

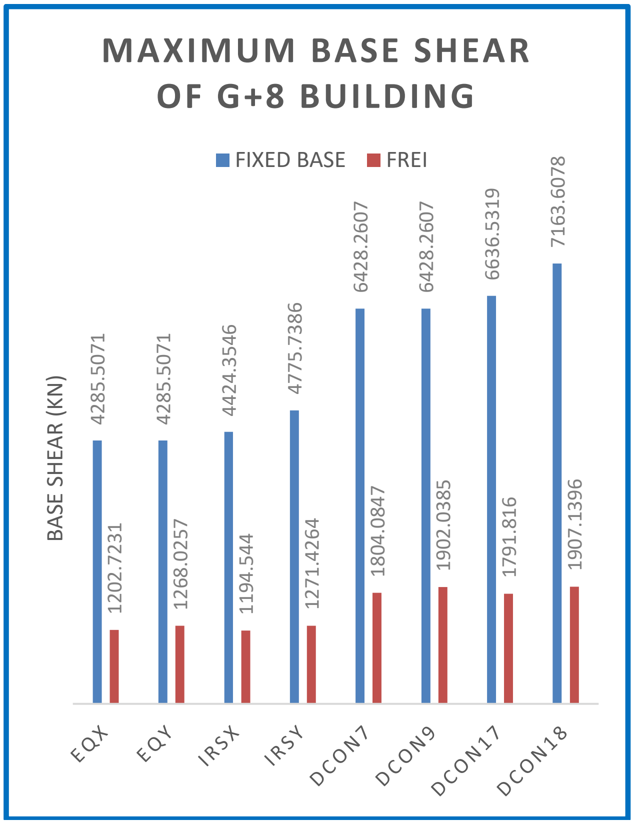

Fig.12 MAXIMUM BASE SHEAR OF G+8 BUILDING

The values of Base Shear in X and Y direction for G+8 RC building are compared in Fig.11 and Fig.12. The value of base shear depends on the seismic weight and the arrangement of mass and isolators. From table Fig.11, it can be seen that, the value of base shear of G+8 building in static condition with fixed base was 4285.51 KN in both direction and with FREI was 1202.72 KN in X direction and 1268.03 KN in Y direction. The reduction can be seen by response spectrum analysis also, as in fixed base 4424.35 KN is base shear in X direction and 4775.74 KN in Y direction and it reduces to 1194.54 KN and 1271.43 KN when FREI is used as base isolators.

Similarly, from Fig.11 where the base shear in critical load combination is also reduced while using FREI as an isolator. The four-load combination are chosen to see the behavior of G+8 RC building in critical conditions. Therefore, the value of base shear in Dcon7 and Dcon9 is 6428.26 KN under fixed base, while using FREI the Dcon7 and Dcon9 reduces to 1804.08 KN and 1902.04 KN respectively. Another load combination is Dcon17 and Dcon18, in fixed base the base shear is 6639.53 KN and 7163.61 KN respectively while in FREI is 1791.82 KN and 1907.14kN.

V. CONCLUSION

The study describes the behavior of fiber-reinforced elastomeric isolators on structural system under the execution of dynamic load, from which various conclusion can be drawn based on results:

- The storey drift ratio in static and response spectrum analysis shows the allover reduction. Thus, lateral displacement of each storey will reduce and minimize the damage caused due to seismic forces.

- Maximum Base Shear of static analysis in X & Y-Direction is fall down up to 71% approx. all the stories.

- The analysis of base shear was done by response spectrum analysis, when FREI is mounted on structure and comparison is done with Fixed Base Structure. It is being observed that there is a reduction of about 72% in the base shear by using response spectrum as per Indian Standard in X- direction.

- There is a decrement in base Shear of about 73.5% in Y direction, by taking response spectra as per IS code.

- Critical Load Combination also shows the decrement in base shear while using FREI about 3.5 times when compare with fixed base structures.

- Finally, it can be said that the fiber-reinforced elastomeric isolators can be used as an isolator in case of low-rise and medium-rise buildings.

The above conclusion can simply be stated as, that the FREI can be the better option in developing countries because of its similar properties as conventional isolators. Also because of FREI is light in weight and manufacturing cost is ten times low as conventional once.

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