STUDY, BEHAVIOUR AND COMPARISON OF BASE ISOLATED STEEL-CONCRETE-COMPOSITE STRUCTURES BY RESPONSE SPECTRUM ANALYSIS

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Abstract - *Base isolation technique is widely used to safeguard building structures from damaging effects of earthquakes. The installation of base isolators at base of a structure increases the time period and reducing resonance of structure providing safety of structure against seismic forces. The type of base isolator taken for this study is Lead rubber bearing. The base isolation system have to perform three functions, they are horizontal flexibility, energy dissipation and rigidity to ensure its performance to isolate the seismic forces to safeguard buildings from earthquakes. The Lead rubber bearing quite does it well than other isolators so mostly these isolators are used widely. The study is performed to compare steel-concrete-composite structures of fixed and base isolated conditions. Predicting the behaviour of steel concrete composite structures with varying storey heights under seismic loads using response spectrum analysis under fixed and base isolated condition will provide sufficient information and confidence to go in for steel concrete composite construction in India. For this study a 10 storey Steel-Concrete-Composite structures is considered and a Response spectrum analysis is carried out in ETABS2015. The Lead rubber bearing is designed as per UBC97 and was used in analysis of Base isolation systems. Time period of base isolated structures is comparatively higher than building under fixed condition and with the reduced base shear at base of the structures prove the efficiency of base isolated structures compared to fixed base structures and serves better during earthquakes. It is fount that Concrete structure with base isolation is more effective in seismic prone areas compared to other structures (Steel-SRC-CFT) considered in this study.*

***Key Words*: Steel – Concrete - Composite structures, Response spectrum analysis, Base isolation, Lead rubber bearing.**

1. INTRODUCTION

Steel and concrete structures are the structures in civil engineering practice all over the globe in huge and especially in India. Composite structures are developing in various countries and in India it is yet to be practiced. Therefore the performance of these structures of various storey heights with different seismic prone zones and loads are taken under this study to exhibit and find the best fit structure to serve the needs effectively for our criterion.

Steel-concrete composite systems have seen widespread use in recent decades because of the benefits of combining the two construction materials. Reinforced concrete is inexpensive, massive, and stiff, while steel members are strong, lightweight, and easy to assemble. In decks, composite systems eliminate the need for formwork. In columns, two systems are commonly used, steel reinforced concrete (SRC) where a steel section is encased in concrete, and concrete filled tubes (CFTs). One important advantage of composite systems is that construction is accelerated through separation of trades. Initially, a bare steel frame is erected to carry the gravity, construction, and lateral loads during construction. As erection of the building progresses, concrete is cast in lower-level columns to form the composite system that will resist the total gravity and lateral loads.

The inelastic behaviour of composite members and systems, which is particularly important in limit state calculations for earthquake resistant design, is not yet thoroughly understood. As a result, design provisions for composite structures have generally been extrapolated from provisions for traditional reinforced concrete or steel structures.

Nonlinearities in the response of steel-concrete structures stem from inelasticity of the materials or from changes in the geometry of the structure. The sources of material inelasticity are related to the components of a composite system, namely, concrete and steel. Concrete is a brittle material with distinctively different responses in tension and compression.

A response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes.

Lead rubber bearing (LRB) are the laminated rubber bearing containing one or more lead plugs to deform in shear. The lead in the bearing deforms physically at a flow stress of 10 MPa, providing the bearing with bilinear response. For that reason the lead must fit tightly in the elastomeric bearing, and this is achieved by making the lead plug slightly larger than the hole and applying force at the time of inserting it in the hole.

1.1 OBJECTIVE OF WORK

To compare the response of the building such as Time period, Maximum displacement and Base shear for 10 storied Steel-Concrete-Composite buildings with and without base isolation by considering the Response spectrum analysis.

1.2 SCOPE OF WORK

Steel-concrete composite structures are effective structural systems for high-rise buildings but these structures are mostly not employed in Indian conditions. Predicting the behaviour of steel concrete composite structures with varying storey heights under seismic loads using response spectrum analysis under fixed and base isolated condition will provide sufficient information and confidence to go in for steel concrete composite construction in India.

1.3 METHODOLOGY

- Analyze, design and comparison of results to arrive at an efficient structural alternative among steel, Concrete and composite structures (Fixed and Base isolated) for G+10 commercial building with moment resistant frames.
- Literature study
- Performing linear-dynamic statistical analysis (Response spectrum analysis).
- Carry out 3-D modeling of the structure using structural analysis software ETABS2015.
- By use of MS Excel program to carry out design of base isolated Steel-Concrete-composite structures.
- Validation of results obtained.

2. LITRETURE STUDY

Chandak N. R. [1] was presented the work reelected to Effect of Base Isolation on the Response of Reinforced Concrete Building. The six storey building is analyzed with rubber isolating device and by providing friction pendulum isolation device at its base. The analysis was done by using response spectrum analysis. Results obtained from the presented work shows that there is reduction of base shear, storey drift, storey shear, torque and increment in the storey displacement.

Santosh H.P. *et al.* [2] presented the work on seismic analysis of low to medium rise building for base isolation. The lead rubber isolator was used as an isolating device. The analysis was done by using STAAD Pro software. The six storey building were analyzed both by considering the base as fixed base structure and then by considering it as a base isolated by means of lead rubber bearings. The analytical results obtained show the reduction in storey acceleration and the storey shear in case of base isolated structure compared to non isolated structure.

Torunbalci N. *et al.* [3] presented the analytical study on mid-storey building by considering various seismic isolation techniques. For a case study, a six storey building was analyzed by using three dimensional nonlinear time history analysis. The analysis was done on the basis of various seismic isolation and energy dissipating alternatives. Alternatives which included rubber bearings, friction pendulum bearings, additional isolated storey and viscous dampers.

Dhawade S.M. [4] presented the comparative study for seismic performance of base isolated & fixed based RC frame structure. The high density rubber isolator used as a isolation device. The work presented by author was done on (G+14) structures using ETABS software. A linear static analysis was carried out on the given structure. The comparative study was presented hear between fixed base and base isolated structure. A result shows reduction in the storey drift, shear, acceleration and increment in the storey displacement.

Jerome Hajjar, (2002) has investigated and shown that concrete filled steel tube columns are used as super columns in high-rise structures, where they form the primary load-bearing members in the buildings gravity and lateral resistance systems. Steel lies at the outer perimeter, where it performs effectively in resisting flexure as well as axial tension and compression, while concrete forms an excellent core to help withstand compressive loading. The steel reinforced concrete beam-column has the potential to provide excellent strength and ductility relative to RC members.

Shirule et al, (2012) used an 18-storey symmetrical R.C.C building as a test model. Lead Rubber Bearing (LRB) and Friction Bearing (FB) is used as isolation system in this study. Nonlinear Time History analysis is used on both of fixed base and base isolated buildings. There are two portions; one is comparative study of performance of fixed base condition and base isolation (LRB and FB) condition and the comparative study of performance by three different time histories Bhuj, Koyna and Lacc T.H.Finally, base shear, displacement and acceleration are compared from 3 times history analysis between fixed base condition and base isolated condition. The base shears in each direction are decreased with LRB by 46% and with FB by 35% in base isolated building compared to the fixed base building

Panchal and Marathe, (2011) have brought out that steel option is better than R.C.C. But composite option for high-rise building is best suited among all three options. The reduction in the dead weight of steel framed structure is 32% with respect to R.C.C frame structure and composite framed structure. Total saving in the composite option as compared to the R.C.C results in 10% so as with steel it will be 6-7% and composite structure gives more ductility to the structure as compared to the R.C.C which is best suited under the effect of lateral forces.

Saatcioglu and Naumoski, (2005) developed the design response spectra for six functional buildings (5 , 10 and 15 storeyed) and each building was moment resisting frame buildings considered in Vancouver and Ottawa and a total of the fifteen accelerograms were used for the seismic analysis. Computer software called the DRAIN-2DX was used for the analysis. These graphs give the peak value of the load. The result they obtained was that the higher floors showed higher amplification due the earthquake load and the difference in spectra are more profound for the low rise building. The response amplification relative to the ground Volume 01, No.5, May, 2015 Page 2 excitations varied from floor to floor. The amplification was of the highest at the roof level and the amplification factor for roof is approximately 4.0 for 5 – storeyed buildings and, 3.0 for 10 storeyed buildings and 2.0 for 15-storeyed buildings. It decreases gradually going from roof level to the first storey level. Equations were developed in the project and they can also be used to generate floor design spectra from the UHS specified for a given location.

3. MODELING AND ANALYSIS

Modeling and Analysis is carried out using ETABS 2015. Response spectrum is carried out on all models. Beam and Column are considered as frame element and slab is considered as area element and its property varies based on the type of structures taken into this study.

3.1 MODELS CONSIDERED

Totally 8 models is been considered for this study below describes the details of it,

- **a-** Steel structure under fixed condition
- **b-** Concrete structure under fixed condition
- **c-** Composite structure(SRC) with fixed condition
- **d-** Composite structure(CFT) under fixed condition
- **e-** Steel structure with base isolation
- **f-** Concrete structure with base isolation
- **g-** Composite Structure(SRC) with base isolation
- **h-** Composite structure(CFT) with base isolation

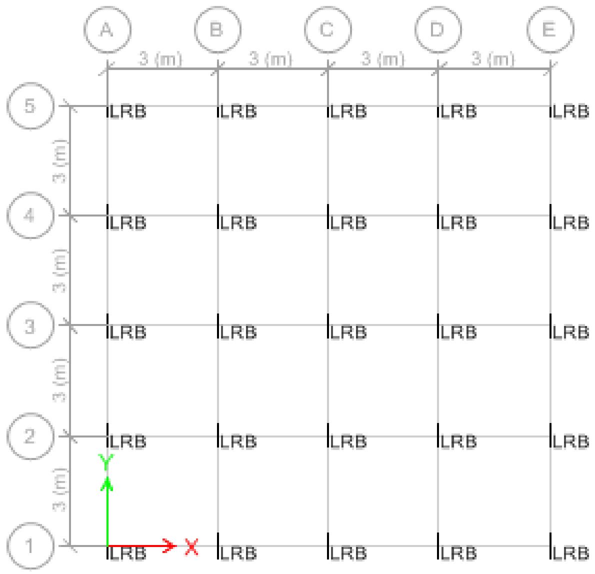

FIG. 1: Plan view of building for all models

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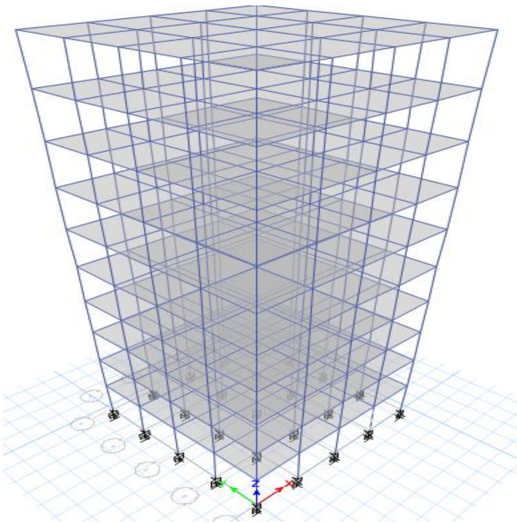

FIG 2: 3D view of Composite BI building

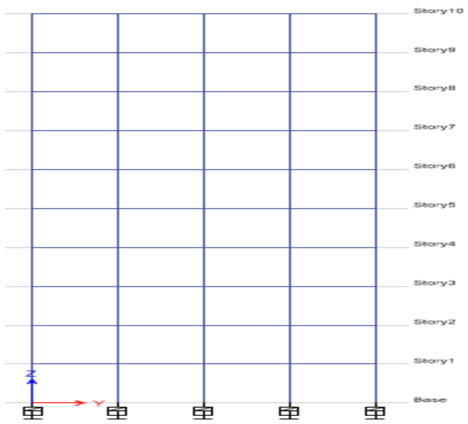

FIG 3: Elevation of Composite BI building

3.2 BASIC CONSIDERATIONS

Table-1 Building details

No. of storey	G+10
Storey height	3m
Slab thickness	150mm
Support conditions	Fixed, Base isolated
Soil type	class2, medium soil
Steel grade	Fe250
Grade of Concrete	M25 beam, M30 column
Parapet height	1.2m
Wall thickness	230mm

3.3 WORK DETAILS

Table-2 Section details

Structure	Column	Beam
Steel	WPB400	ISMB250
Concrete	600x600mm	400x300
Composite(SRC)	450x450(ISMB400)	ISMB350
Composite(CFT)	600x600mm Flange & Web thickness-25mm	ISMB350

3.4 LOADING DATA

Floor finish = 1.25 kN/m^2

Live load on roof = 1.5 kN/m^2

Live load on floor = 2 kN/m^2

3.5 EARTHQUAKE DATA

Zone (Z) = II

Response reduction factor (R) = 3

Importance factor (I) =1

Zone factor = 0.16

Damping ratio (DM) = 0.05

3.6 LRB LINK PROPERTIES

Nonlinear Link Type : Rubber Isolator

U1 Linear Effective Stiffness : 1500000 kN/m

U2 and U3 Linear Effective Stiffness: 800 kN/m

U2 and U3 Nonlinear Stiffness : 2500 kN/m

U2 and U3 Yield Strength : 80 kN

U2 and U3 Post Yield Stiffness Ratio: 0.1

4. RESULTS AND DISCUSSION

The Time period, Base shear and storey displacements for all type of structures with and without Base isolation are obtained in this study and are compared for its effective seismic behaviour.

4.1 TIME PERIOD

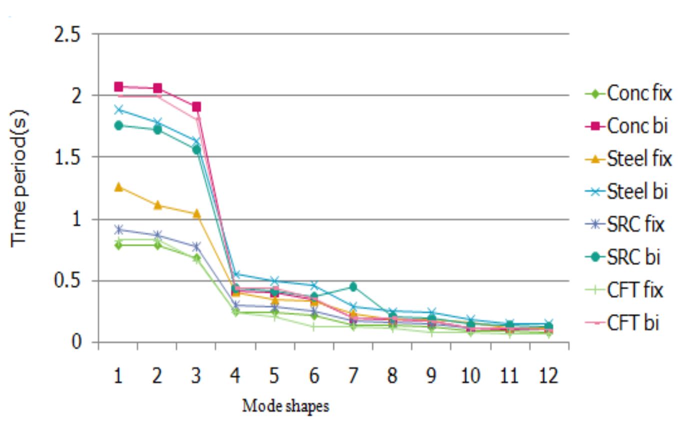

FIG.4: Time period V/s mode shapes

From fig.4 it is observed that, time period decreases with increase in mode number. As result of the increased flexibility of the system, time period of the structure is also increases.

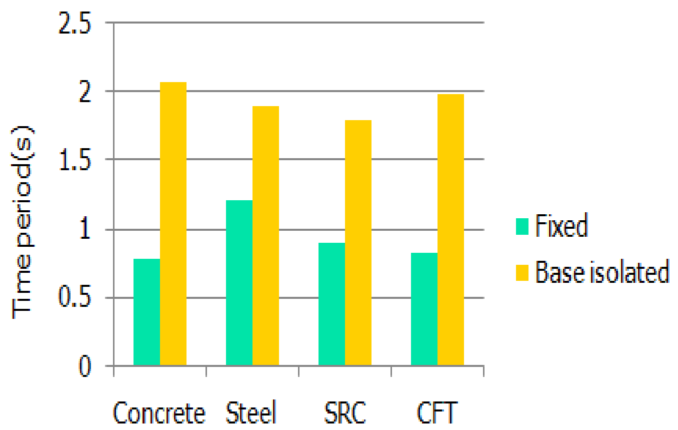

FIG.5: Time period V/s different models

The above graph shows the comparisons of time period V/s Concrete-Steel-Composite (SRC & CFT) structures of 10 storied building. From FIG.5: It is clear that, time period of base isolated structures increases compared to fixed condition structures. From the graph, percentage increase of the time period of base isolated structures compared to fixed conditions are (Concrete = +62%, Steel = +34%, SRC = +48%, CFT = +59%).

4.2 BASE SHEAR

The base shear is distributed along the height of the structure in terms of lateral force. The use of base isolation in a structure reduces the shear compared to fixed conditions. The results are plotted in figure 6.

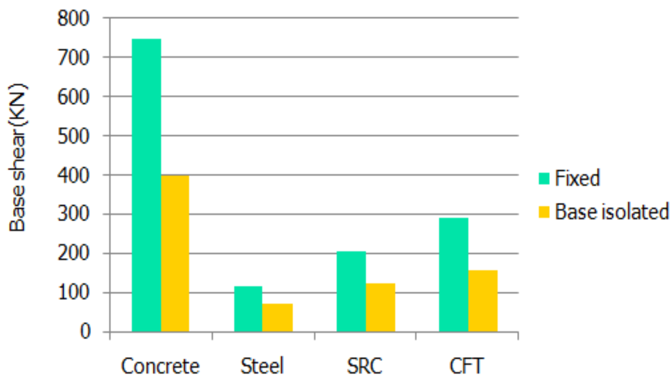

FIG.6: Storey shear V/s different models

From FIG.6: It is clear that, base shear of base isolated structures decreases compared to fixed condition structures. From the graph, percentage decrease of the base shear of base isolated structures compared to fixed conditions are (Concrete = -47%, Steel = -39%, SRC = -40%, CFT = -47%).

4.3 LATERAL DISPLACEMENT

The lateral displacement for all models under response spectrum analysis are shown in the below figure 7.

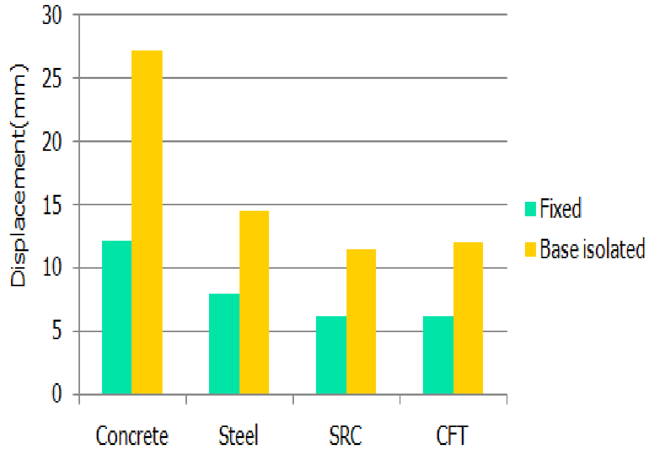

FIG.7: Maximum Storey displacement V/s different models

From FIG.7: It is clear that, displacement of base isolated structures increases compared to fixed condition structures. From the graph, percentage increase of the displacement of base isolated structures compared to fixed conditions are (Concrete = +54%, Steel = +37%, SRC = +41%, CFT = +50%).

5. CONCLUSIONS

1) The flexibility at the base of the building increases with the use of Lead rubber bearing isolators.

2) The transfer of lateral forces during earthquakes is reduced as the time period of the structure is increased by the use of base isolation (Lead rubber bearing).

3) The use of base isolation decreases the base shear, increases displacement and time period proves its efficiency over fixed condition and gives better seismic protection during earthquakes.

4) Among the 4 different structural models considered (Concrete-Steel-SRC-CFT) Concrete and CFT building structures gives better performance by the use of isolators at the base of the building as compared to other structures at higher seismic prone area.
5) Comparing the two types of composite column structures (SRC & CFT), CFT is found to be performing better than SRC in this study (CFT 10% increase compared to SRC base isolated structure)

6) Comparing 4 structures considered for this study Concrete base isolated structures performs better with following criterion percentage (Time period=+62%, Base shear=47%, Maximum storey displacement=+54%)

6) From this study it is clear that use of base isolation in a structure turns out to be promising as a seismic protector safeguarding human values and materials.

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