International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 04 | Apr 2019 www.irjet.net p-ISSN: 2395-0072

A Study on Seismic Performance of Reinforced Concrete Frame with Lead Rubber Bearing Base Isolation System

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Abstract - *In the present work, an analytical study on seismic performance of G+10 storeyed Reinforced Concrete (RC) frame with various lateral force resistant systems like base isolation system and X-bracings was carried out using ETBS software. The Lead Rubber bearing (LRB) system was designed for the frame and their properties were used in the modelling of LRB for the RC frame. Static analysis, Linear Time History analysis (El-centro) and push over analysis were carried out for the frame. Maximum storey displacement, storey drift and maximum base shear were found out to find the effect of LRB used for the base isolation system. From the Time history analysis, the maximum drift for the RC frame with fixed base, X bracing and base isolation are found out 26.62mm, 1.914 mm and 0.415mm respectively. From the Time history analysis, the maximum displacement for the RC frame with fixed base, X bracing and base isolation are found out 163.03mm, . 13.344 mm and 2.504mm respectively. The base shear for the RC frame with fixed base, X bracing and base isolation are found out as 2294.3kN, 2606.7kN, 32.935 kN respectively. From the analytical study it is observed that, provision of base isolation has enhanced the seismic performance of the RC frame to a great extent. The results of Static and push over analysis also exhibit the similar trend in the performance of the frame.*

Key Words: Lead Rubber Bearing, Time History analysis, Pushover analysis, X-bracing, storey displacement

1. INTRODUCTION

Earth quake is a shaking of the ground caused by movement of the tectonic plates relative to each other, both in direction and magnitude. A large part of the world people lives in area of seismic hazard at risk from earthquake of varying harshness and varying frequency of existence. Earthquake cause significant loss of life and destruction to property every year. During past earthquake most of the irregular buildings collapsed due to the non-uniform distribution of the load compared to regular buildings. The earthquakes in the recent past have provided enough evidence of performance of different type of structures under different earthquake conditions and at different foundation conditions as a food for thought to the engineers and scientists. This has given birth to different type of techniques to save the structures from the earthquakes effects. Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements (like glass facades) and to some structural members in the building. This may render the building non-functional after the earthquake, which may be problematic in some structures, like hospitals, which need to remain functional in the aftermath of the earthquake. Two basic technologies are used to protect buildings from damaging earthquake effects. These are Base Isolation Devices and Seismic Dampers. Base isolation is also known as 'seismic base isolation' or 'base isolation system'. Seismic isolation separates the structure from the harmful motions of the ground by providing flexibility and energy dissipation capability through the insertion of the isolated device so called isolators between the foundation and the building structure.

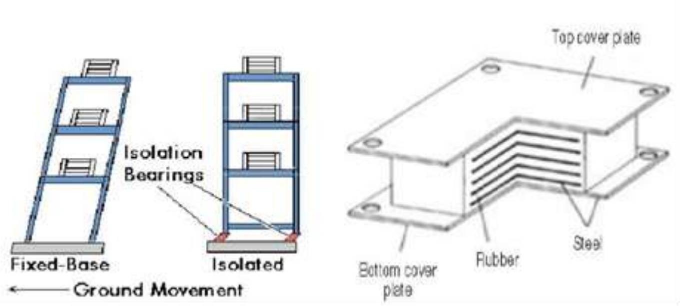

Figure1: Behaviour of Fixed base & isolated base buildings.

Donato Cancellara, et al. (2016) have studied the dynamic nonlinear analysis of different base isolation systems for a multi-storey RC building irregular in plan. **Athanasios et al. (2016)** have conducted a study onresponse simulation of hybrid base isolation systems under earthquake excitation .Investigated the response of a hybrid base isolation system under earthquake excitation. **J. C. Ramallo1, et al. (2008)** have presented an innovativebase isolation strategy and showed how it can effectively protect the structures against extreme earthquakes without sacrificing performance during the more frequent, moderate seismic events. **Minal Ashok Somwanshi et al. (2015)** carried out a studyon Seismic Analysis of Fixed Based and Base Isolated Building Structures. The work deals with modelling and analysis of 13-storey rigid jointed plane frame for two cases. First case is fixed base and second case is base isolated. Modelling and analysis is done using E-TABS software for Bhuj earthquake ground motion records. **Tremblay et al. (2003)** performed an experimental study on the seismic performance of concentrically braced X bracing and single diagonal bracing steel frames with cold-formed rectangular tubular bracing system. The loading sequences used were a displacement history obtained from nonlinear dynamic analysis of typical braced steel frames. Results were obtained for different cyclic loading and were used to characterize the hysteretic response, which includes the energy dissipation capabilities of the frame.

1.2 Seismic Resistant Systems

The types of lateral resistant Systems Such as base isolation systems, seismic damper systems were reviewed and finally bracing systems and base isolation system were fixed for the study purpose.

1.2.1 1BASE ISOLATION

In base isolation technology during earthquake, separating the superstructure or reducing the lateral movements of building superstructure from the movement of ground or foundation. The bearings of base isolation are designed in such a way that they are stiff vertically and flexible horizontally to allow for the difference in lateral movement while still supporting the superstructure. The base isolated structures are different than that of fixed base structure, in which the connection between the superstructure and the foundation are rigid and the superstructure translation in all direction is constrained.

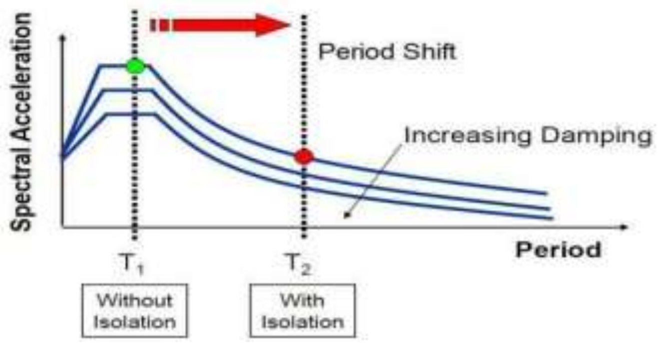

Figure 2: Effect of Seismic Isolation on Spectral Acceleration

The main aim of base isolation is to reduce the earthquake force produced on building superstructure. To some extent by reducing the superstructure's spectral acceleration, the reduction in seismic force at superstructure is achieved. By increasing the base isolated structure fundamental period and through damping caused by dissipation energy within bearing the accelerations are reduced.

1.2.2 Bracing Systems

A Bracing is a system that is provided to reduce the lateral deflection of the structure. The use of braced frames has become more effective in high rise structure and also in seismic design of structure. A Braced Frame is designed primarily to resist wind and earthquake forces in and a structural system. These braced frames are made of steel members. Similar to a truss a braced frame is designed to work in tension and compression.

2. OBJECTIVES OF THE RESEARCH

A G+10 storey reinforced concrete building was designed in accordance with IS 1893:2002 provisions; Three types of frames with lateral resistant systems were considered in the study. One with fixed base, other is base isolated and the third one was a braced frame. By analysing the fixed base buildings, we get maximum reactions under each column. For these maximum values Lead Rubber Bearings (LRBs) were designed manually in order to isolate the superstructure from substructure. And for braced system the X bracings are provided along the periphery walls. Response Spectrum Analysis, Push over Analysis are done and the Time History Analysis (THA) is carried out by taking El-Centro earthquake ground motion records.

The objectives of the present work are as follows:

1. To carry out modelling and analysis of fixed base, braced and base isolated buildings by using E-TABS software and study the effects of earthquake ground motions on these models.
2. To design and study the effectiveness of lead rubber bearing used as base isolation system.
3. To compare the fixed base, braced and base isolated building on the basis of their vital dynamic properties such as base shear and drift etc.

2.0 MODELLING AND ANALYSIS OF THE STRUCTURE

The current study involves the actual modelling of the G+10 RC Building using ETAB software and performing the analyses such as RSA, THA and POA. The building is modelled and designed as per IS 456:2000 in ETABS software version 2016. Structural responses are compared using Response Spectrum, Time History Analysis and Push Over Analysis.

Materials properties and section properties are defined and assigned. Reinforced concrete frame elements are modelled as beam and column element. Slab is modelled as area element. The design of isolators is done as per UBC 97 and suitable values are incorporated in ETABS software for modelling of base isolated structure.

Models considered for analysis:

The G+10 Storied RC building is taken for analysis and various models are created.

Model A : Fixed Base Model
Model B : Braced Structure Model

Model C : Base Isolated Model

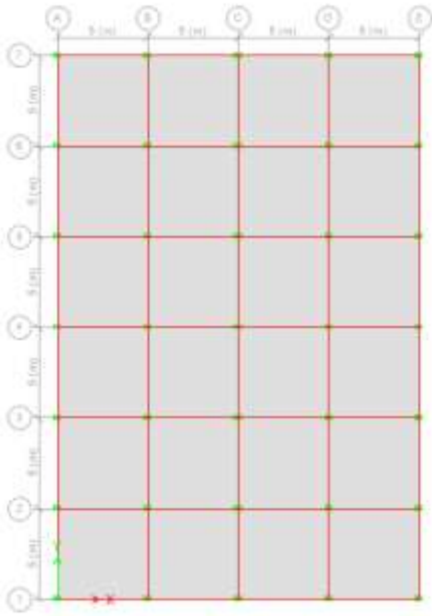

Figure 3: Plan – Model A, B, C

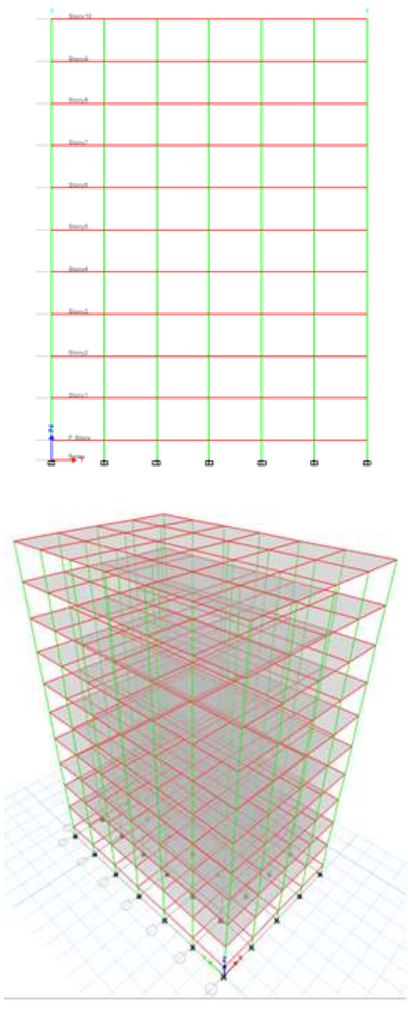

Figure 4: Elevation and 3D View – Model A

Following are the elevation and 3d view of braced model and base isolated model of the G+10 RC building.

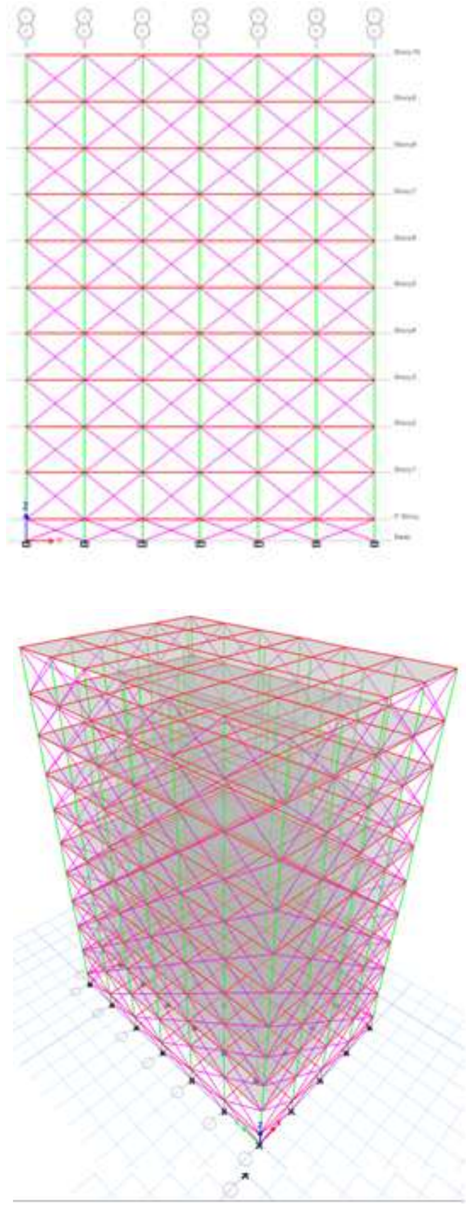

Figure 5: Elevation and 3D View – Model B

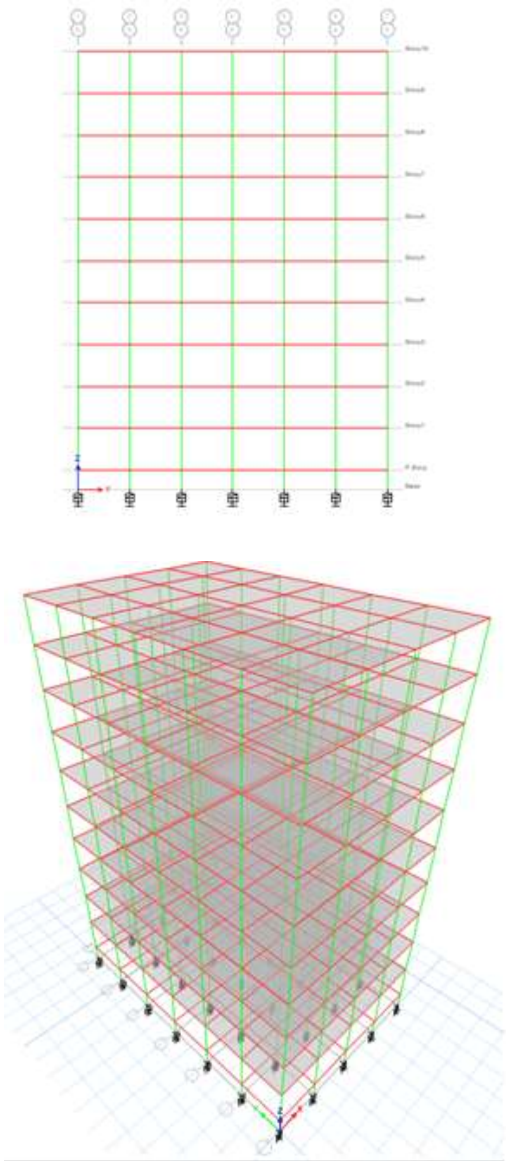

Figure 6: Elevation and 3D View – Model C

2.1 Details of The RC model frame

Following are the data given for modelling of the structure :

Table 2: Building Specifications

Grade of Concrete for Beam	M25
Grade of Concrete for Column	M30
Grade of Steel	Fe415
Story Height	4 m
Beam Size	310 x 610 mm
Column Size	310 x 460 mm
Slab Thickness	150 mm
Wall Thickness	230 mm
Live load on floor	3 kN/m^2
Live load on roof	1.5 kN/m^2

2.2 Seismic Properties

Table 3: Seismic Properties

Zone	III
Importance Factor	1
Type of Soil	Medium
OMRF	R = 3
Earthquake loads are taken as per IS 1893(part 1):2002	

2.3 Modelling of LRB Isolator

A variety of isolation devices including elastomeric bearings (with and without lead core), frictional/sliding bearings and roller bearings have been developed and used practically for a seismic design of buildings during the last 25 years. Among the various base isolation system, the lead rubber bearing had been used extensively. It consists of alternate layers of rubber and steel plates with one or more lead plugs that are inserted into the holes. Due to lateral forces the lead core deforms, yields at low level of shear stresses approximately 8 to10 Mpa at normal (200c) temperature, so the lead bearing lateral stiffness is significantly reduced. Due to this period of structure increases. One of the features of lead core is that it can recrystallize at normal temperature and will not encounter the problems of fatigue failure under cyclic loadings.

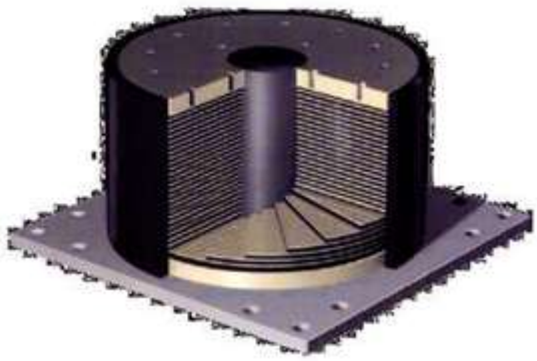

Figure 7: Lead Rubber Bearing with Layers of Rubber and Steel and Lead Core

3.0 RESULTS AND DISCUSSIONS

Both fixed base and isolated bearing models were analysed and designed in ETABS 2016 software. The models were designed as per IS456:2000 and found that the selected sections are safe under given loading and seismic condition and thus the study was further proceeded. The main seismic parameters selected for the comparison of models are story drift, story displacement, shear and acceleration. These analysis results are compared separately with each other.

3.1 Time History Analysis (THA) results

3.1.1 Story Drift

Table 4: Drift Comparison THA

Story	Max Drift in mm		
	MODEL A	MODEL B	MODEL C
Story10	3.485	0.899	0.09
Story9	6.362	1.003	0.132
Story8	9.352	1.024	0.152
Story7	12.372	1.243	0.187
Story6	15.16	1.365	0.243
Story5	18.125	1.419	0.332
Story4	20.981	1.537	0.415
Story3	23.7	1.67	0.407
Story2	26.622	1.672	0.299
Story1	26.114	1.914	0.171
P Story	3.537	0.7	0.061

The variation of drift with respect to various models is shown. It is observed that the Model C ie,. Base Isolated model exhibits very small value compared to Model A ie,. Fixed Base model.

3.1.2 Story Displacement

Table 5: Displacement Comparison THA

Story	Max Displacement in mm		
	MODEL A	MODEL B	MODEL C
Story10	140.448	13.344	2.504
Story9	159.892	12.445	2.416
Story8	153.895	11.443	2.285
Story7	144.808	10.419	2.146
Story6	132.725	9.39	1.989
Story5	117.897	8.275	1.766
Story4	100.396	3.383	1.438
Story3	79.955	5.427	1.027
Story2	56.255	3.81	0.622
Story1	29.634	2.215	0.323
P Story	3.537	0.7	0.17

Similar to drift values here also the base isolated Model C showed minimum displacement rather than other models.

3.1.3 Story Shear

Table 6: Shear Comparison THA

Story	Max Shear in kN		
	MODEL A	MODEL B	MODEL C
Story10	420.6981	239.4552	6.5402
Story9	745.3428	460.4168	9.7818
Story8	935.3044	680.4854	10.9434
Story7	998.7036	910.1322	13.4481
Story6	1306.2672	1117.8037	17.6732
Story5	1597.8748	1343.3374	24.756
Story4	1822.2565	1561.0872	31.8546
Story3	1929.8354	1766.6139	31.4968
Story2	2214.194	2010.9969	22.6512
Story1	2592.4333	2169.5289	10.749
P Story	2606.7375	2172.7263	9.512

Here it is observed that the shear values do not vary much between Model A and Model B, while the Model C showed major variation.

3.1.4 Story Acceleration

Table 7: Acceleration Comparison THA

Story	Acceleration in mm/sec^2		
	MODEL A	MODEL B	MODEL C
Story10	498.19	325.27	6.03
Story9	319.08	292.72	4.71
Story8	446.58	313.88	5.52
Story7	509.23	298.31	5.38
Story6	369.14	314.09	4.94
Story5	455.69	328.2	5.36
Story4	540.87	297.1	5.18

Story3	421.34	333.3	4.83
Story2	476.05	317.72	5.07
Story1	500.43	436.94	4.8
P Story	731.14	724.07	7.43
Base	769.64	769.64	8.75

Here again it is observed that the acceleration values do not vary much between Model A and Model B, while the Model C showed major variation. Hence based on the THA results the base isolated model – Model C is effective in seismic performance criteria.

3.2 Response Spectrum Analysis (RSA) Results

3.2.1 Story Drift

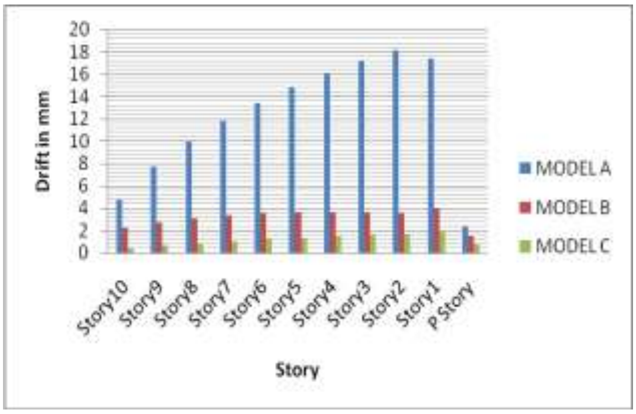

Figure 8: Drift Comparison RSA

The variation of drift with respect to various models is shown. It is observed that the Model C drifts lesser compared to Model A and B.

3.2.2 Story Displacement

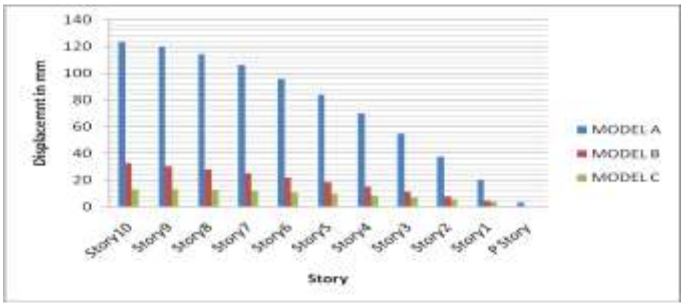

Figure 9: Displacement Comparison RSA

Here both Model B and C showed great reduction in displacement.

3.2.3 Story Shear

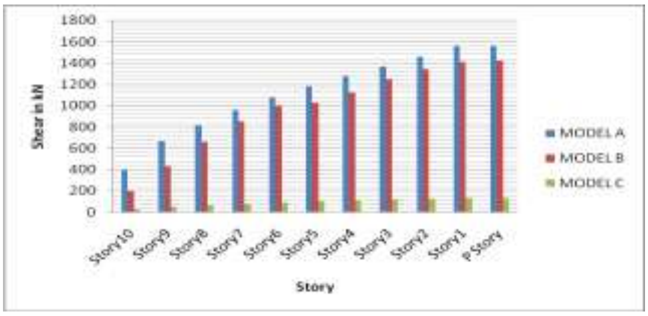

Figure 10: Shear Comparison RSA

Here it is observed that the shear values do not vary much between Model A and Model B, while the Model C showed major variation.

3.2.4 Story Acceleration

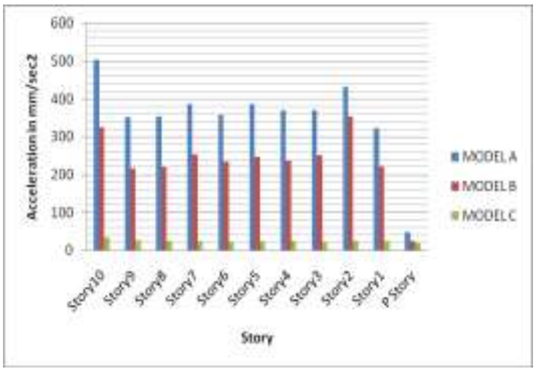

Figure 11: Acceleration Comparison THA

Here again it is observed that the acceleration values do not vary much between Model A and Model B, while the Model C showed major variation. Hence based on the RSA results the base isolated model – Model C shows high seismic performance.

3.3 Push Over Analysis (Poa) Results

3.3.1 Story Drift

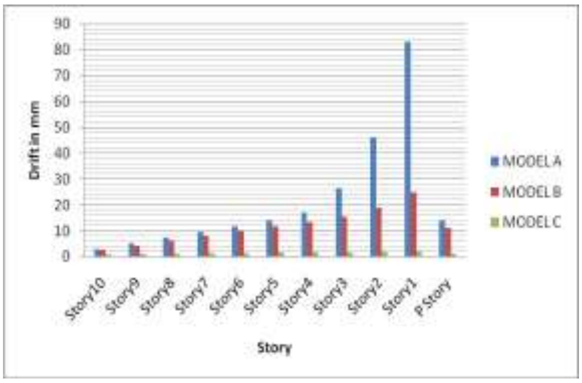

Figure 12: Drift Comparison POA

The variation of drift with respect to various models is shown. It is observed that the Model C drifts lesser compared to Model A and B.

3.3.2 Story Displacement

Table 13: Displacement Comparison POA

Story	Max Displacement in mm		
	MODEL A	MODEL B	MODEL C
Story10	226.421	124.656	9.09
Story9	223.484	122.174	8.56
Story8	218.471	117.972	7.955
Story7	211.26	111.951	7.26
Story6	201.845	104.107	6.475
Story5	190.219	94.447	5.604
Story4	176.287	82.979	4.658
Story3	159.247	69.687	3.65
Story2	132.948	54.367	2.601
Story1	86.719	35.622	1.513

Here C showed greater reduction in displacement with respect to A and B.

3.3.3 Story Shear

Table 14: Shear Comparison POA

Story	Max Shear in kN		
	MODEL A	MODEL B	MODEL C
Story10	400.2501	198.5654	24.1258
Story9	658.2547	410.7158	45.1474
Story8	814.5987	687.7694	63.5548
Story7	950.2248	841.0248	75.0017
Story6	1072.7711	998.5641	87.7779
Story5	1178.5853	1024.2563	98.0334
Story4	1281.5471	1125.23	107.5778
Story3	1364.439	1247.326	116.16
Story2	1459.0221	1341.231	123.8953
Story1	1555.1459	1410.265	131.7208
P Story	1556.2547	1435.528	132.547

Here it is observed that the shear values do not vary much between Model A and Model B, while the Model C showed major variation. Hence based on the POA results the base isolated model again showed maximum performance in withstanding seismic forces.

4.0 COMPARISON OF SEISMIC PARAMETERS

The following table shows the result comparison of all the three analysis methods.

Table 15: Drift Comparison

Type	Max Drift in mm		
	THA	RS	POA
Fixed Base	26.622	18.13	83.234
Braced	1.914	3.963	24.809
Base Isolated	0.415	1.815	2.344

Table 16: Displacement Comparison

Type	Max Displacement in mm		
	THA	RS	POA
Fixed Base	163.03	123.36	226.42
Braced	13.344	32.689	124.66
Base Isolated	2.504	13.165	9.09

Table 17: Shear Comparison

Type	Max Shear in kN		
	THA	RS	POA
Fixed Base	2294.3	1557.7	2310.5
Braced	2606.7	1883.9	2209.5
Base Isolated	32.935	132.67	1912.3

From this comparison it is clearly concluded that the base isolated model shows high seismic performance when compared to fixed base model and braced model. And the result is validated by doing three different types of analysis that yields same kind of observation.

5. CONCLUSIONS

In this project the fixed base model, braced model and base isolated model base isolated model by providing lead rubber bearing were analyzed by time history analysis (El-centro), response spectrum analysis and push over analysis. From these Analysis results following conclusions can be made.

- Story shear reduced greatly after the lead rubber bearing (LRB) is provided as base isolation system when compared to braced system and hence LRB isolators reduces the seismic effect on building more effectively.
- Also the max storey shear is also reduced after base isolation is introduced, which makes structure more stable than braced system during earthquake .
- Story drift are also minimized especially in higher stories which makes structure safe against earthquake.
- And overviewing all comparison the base isolation technique is found to improve the performance of the building by about 98%.

Therefore, it is concluded that the base isolation technique is superior in reducing the seismic response of the structure thus enhancing the performance of the building subjected to earthquake loads.

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