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Effectiveness of Base Isolation System with Respect to Plan Irregularity in Multistorey RC Building

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ABSTRACT

In this work an analytical study is performed to find response of an irregular structure located in severe earthquake zone. Analysis is carried out by taking 5 story building by static and dynamic methods using ETABS-v16.0.0 software and IS code 1893-2002 (part1). The seismic response of the (RC) building, base isolated by lead rubber bearings (LRBs) is compared with the seismic response of the same structure which does not have base isolation system. The main objective is to check the performance of plan irregularity for base isolation system, to check effectiveness of base isolation system for plan irregularity specially for diaphragm irregularity which is one of the types of plan irregularity and to find story displacement, story drift and base shear.

Keywords: Plan Irregularity, Base Isolation, Lead Rubber Bearing, Base Shear, ETABS.

I. INTRODUCTION

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 relating to the passive structural vibration control technologies. It is easiest to see the principle at work by referring directly to the most widely used of these advanced techniques, known as base isolation. A base isolated structure is supported by a series of bearing pads, which are placed between the buildings and building foundation.

The concept of base isolation is explained through an example of building resting on frictionless rollers. When the ground shakes, the rollers freely roll, but the building above does not move. Thus, no force is transferred to the building due to the shaking of the ground; simply, the building does not experience the earthquake.

Now, if the same building is rested on the flexible pads that offer resistance against lateral movements, then some effect of the ground shaking will be transferred to the building. If the flexible pads are properly chosen, the forces induced by ground shaking can be a few times smaller than that experienced by the building built directly on ground, namely a fixed base building. The flexible pads are called base-isolators, whereas the structures protected by means of these devices are called base-isolated buildings.

The main feature of the base isolation technology is that it introduces flexibility in the structure. As a result, a robust medium-rise masonry or reinforced concrete building becomes extremely flexible. The isolators are often designed, to absorb energy and thus add damping to the system. This helps in further reducing the seismic response of the building. Many of the base isolators look like large rubber pads, although there are other types that are based on sliding of one part of the building relative to other.

Principle of Base Isolation System:

The basic principle behind base isolation is that the response of the structure or a building is modified such that the ground below can move without transmitting minimal or no motion to the structure above.

The response of a base isolated structure and a structure without base isolation can be illustrated as shown in the figure below. The displacement and acceleration are controlled by base isolation.

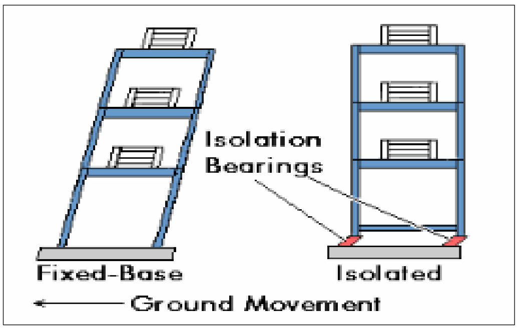

Figure 1. Structure with and without base Isolation System.

Types of Base Isolators:

There are a few practical isolation mechanisms which are widely used in the field of earthquake engineering. Which means that these systems can reduce the seismic demand of the structure.

1) Lead Rubber Bearing (Figure 2).
2) High Dumping Rubber Bearing (Figure 3).
3) Elastomeric Rubber Bearing (Figure 4).
4) Flat Friction pendulum (Figure 5).
5) Curved/spherical Friction pendulum (Figure 6

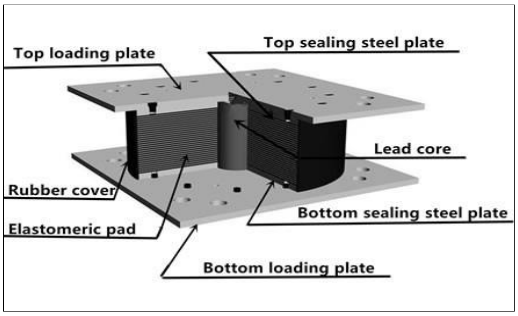

Figure 2. Lead Rubber Bearing

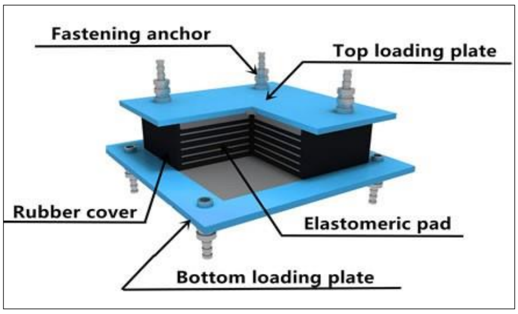

Figure 3. High Dumping Rubber Bearing

Figure 4. Elastomeric Rubber Bearing

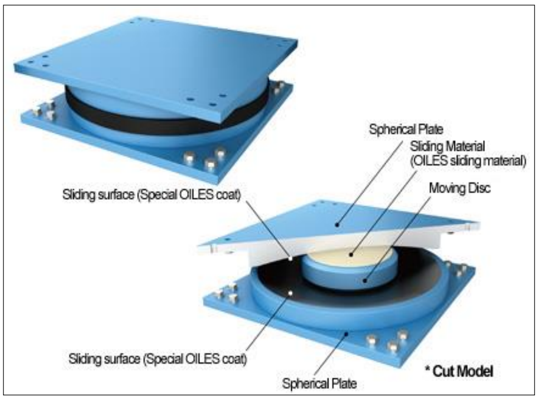

Figure 5. Flat Friction pendulum

Figure 6. Curved / spherical Friction pendulum

Plan Irregularities in buildings:

1) Torsion Irregularity:

Torsional irregularity shall be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsional irregularity is considered to exist when the maximum story drift computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure.

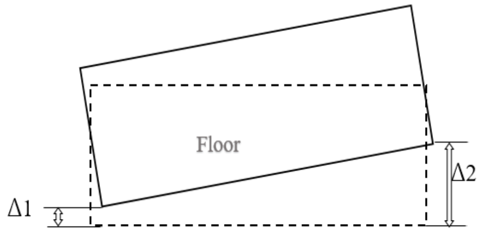

Figure 7. Torsional irregularities with stiff diaphragm

2) Re-entrant Corners:

The re-entrant, lack of continuity or "inside" corner is the common characteristics of overall building configurations that, in plan, assume the shape of an L, T, H, + or combination of these shapes occurs due to lack of tensile capacity and force concentration.

Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction.

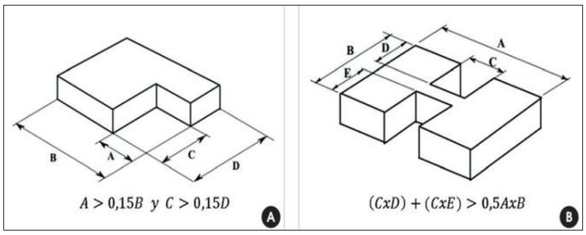

Figure 8. Re-entrant Corners Irregularity

3) Diaphragm Discontinuity

Diaphragms with abrupt discontinuities or variations in stiffness in the building, including those having cut-out or open areas greater than 50% of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50% from one story to the next story.

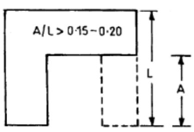

Figure 9, a) Diaphragm Irregularity condition according to IS-1893-Part1

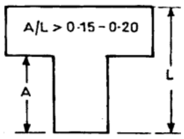

Figure 9. b) Diaphragm Irregularity condition according to IS-1893- Part1

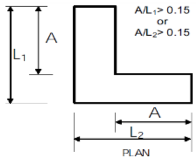

Figure 9 c) Diaphragm Irregularity condition according to IS-1893- Part1

4) Out-of-Plane Offsets

This irregularity exists where an in-plan offset of the lateral force resisting element is greater than the length of those elements.

Since there is no offset of the lateral force resisting element, no irregularity was found.

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements.

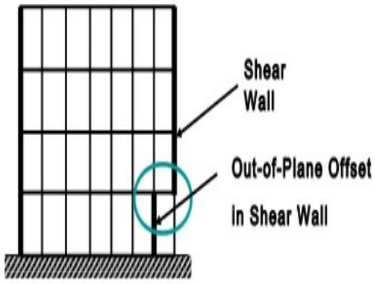

Figure 10. Out of Plane Offset

5) Non-parallel Systems

The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting system.

This condition results a high probability of torsional forces under a ground motion, because the centre of mass and resistance dose not coincide.

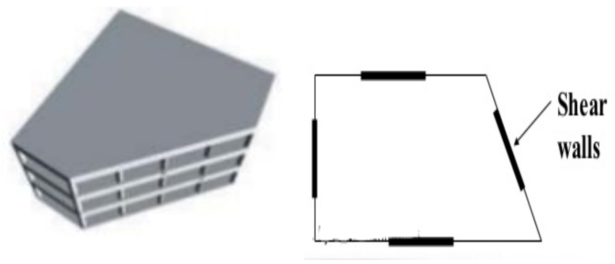

Figure 11. Non-Parallel System

II. INPUT DATA

To check the effectiveness of base isolation with LRB dampers a G+5 storey building having diaphragm irregularity with the following data is considered.

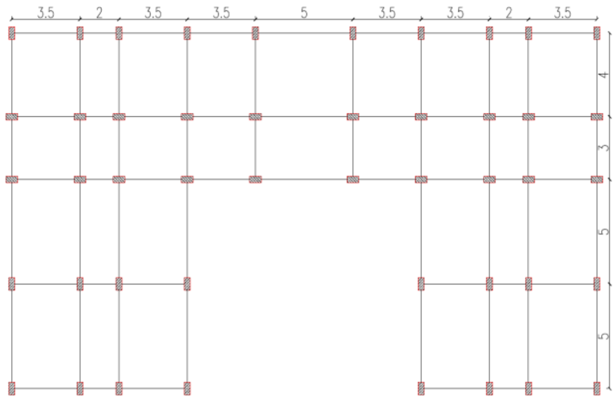

Figure 12 Plan of c-shaped G+5 storey building

Material Properties and Service Loads:

1. Grade of concrete used is M20 and grade of steel used is Fe 415.
2. Floor to floor height is 3*m*
3. Parapet height is 1*m.*
4. Slab Thickness is 150*mm.*
5. External wall thickness is 230*mm* and internal wall thickness is 150*mm.*
6. Size of columns is 300*mm* X 600*mm* and size of beams 300*mm* X 600*mm.*
7. Live load on floor is 3kN/m^2 and Live load on roof is 1.5kN/m^2.
8. Floor finishes is 1 kN/m^2.
9. Site located in Seismic Zone IV.
10. Building is resting on rock soil.
11. Density of concrete is 25 kN/m^3 *and* Density of masonry wall is 20 kN/m^3

Data has been collected from the book (Earthquake Resistance Design of Structures) Pankage Agrawal, Manish Shrikhande.

III. ANALYSIS AND RESULT

Considering the data above, the data is put in ETABS software, the following results will be given:

Table 1. Resultant table of base reactions of the building without BI

Load Case/Combo	FX kN	FY kN	FZ kN
Dead	0	0	35244.93
Live	0	0	6405
External Wall	0	0	3052.56
Internal Wall	0	0	5234.4
Parapet Wall	0	0	338.1
Floor Finish	0	0	2135
Roof Live	0	0	585
EQx	5858.09	0	0
EQy	0	3267.84	0
Comb1	0	0	79492.48
Comb2	7029.7	0	63593.98
Comb3	0	3921.408	63593.98
Comb4	8787.13	0	69007.48
Comb5	0	4901.76	69007.48
Envp Comb Max	8787.13	4901.76	63593.98

In following graph, the maximum story displacement of the building has been shown.

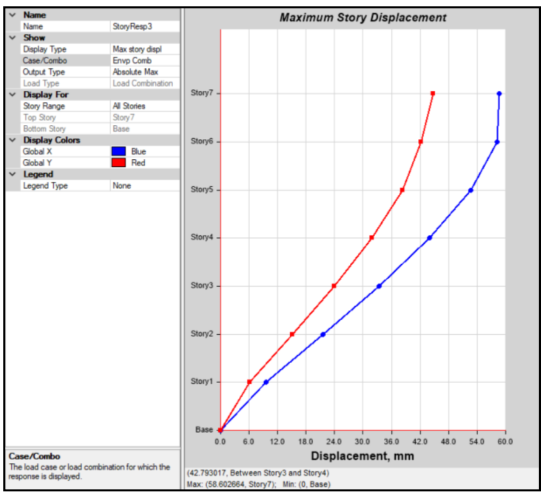

Figure 13. Maximum storey displacement of the building without base isolation system.

Table 2. Values of maximum storey displacement of each storey in the building without base isolation.

Story Data	Storey Displacement of Building *without* Base Isolation System.	
	X-direction	Y-direction
	mm	mm
Storey-1	10	6
Storey-2	22	15
Storey-3	34	24
Storey-4	43	31
Storey-5	53	38
Storey-6	58	42
Storey-7	58	44

In following graph, the maximum story displacement of the building has been shown.

Table 3. Values of maximum storey drift of each storey in the building without base isolation.

Story Data	Storey Drift of Building *without* Base Isolation System.	
	X-direction	Y-direction
	mm	mm
Storey-1	0	0
Storey-2	12	9
Storey-3	12	9
Storey-4	9	7
Storey-5	10	7
Storey-6	5	4
Storey-7	0	2

To perform the analysis of the same building layout with base isolation system, Lead Rubber Bearings (LRB) have been chosen and its mechanical properties have been collected from a research in which cyclic test had been done on Lead Rubber Bearings in different percentages of shear strain according to UBC-1997 (Volume2).

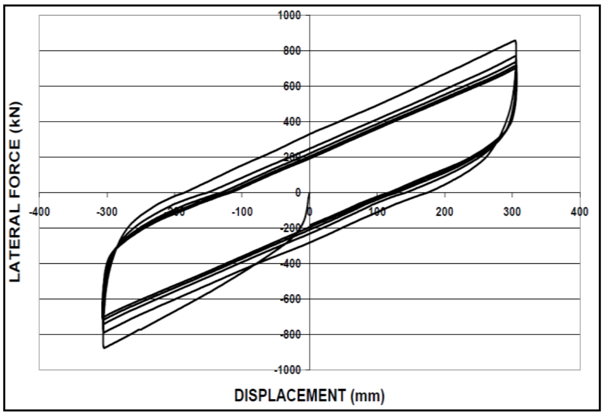

Figure 14. Force-displacement loops of a large-scale lead rubber bearing

Table 4. Mechanical properties of large scale lead rubber bearing obtained from the test.

Cycle	Effective Stiffness (kN/mm)	Energy Dissipated Per Cycle (kN-mm)	Effective Damping	Effective Yield Stress of Lead (MPa)
1	2.83	358825	0.22	12.2
2	2.54	298218	0.20	9.6
3	2.41	263190	0.19	9.2
4	2.33	245162	0.18	7.9
5	2.28	232491	0.17	7.2

The isolators which have been considered for the mentioned shape are assigned from "Assign >> link>>Link Properties" in ETABS.

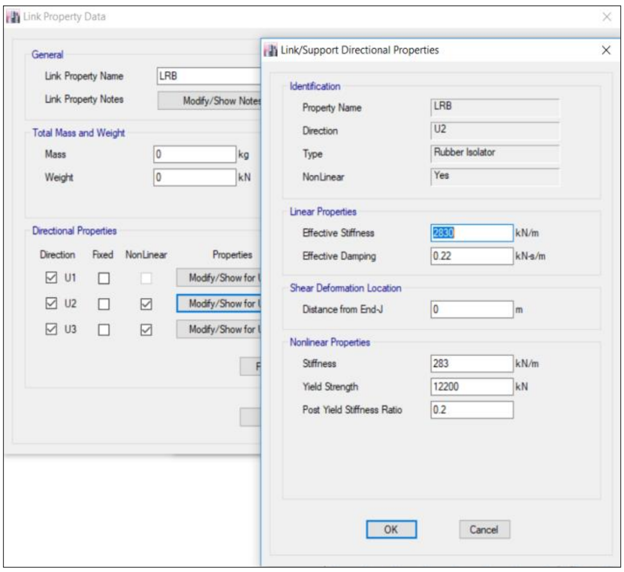

Figure 15. Base Isolator Properties in ETABS

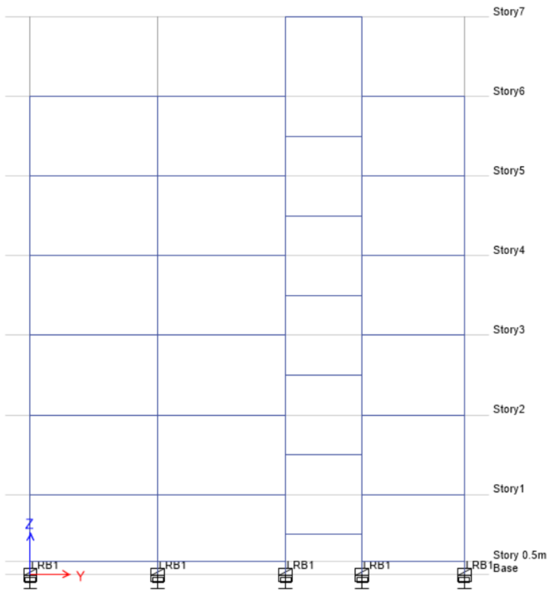

Figure 16. Side Elevation of the building with LRB isolators

After assigning the isolators and analysis of building, the following result has obtained:

Table 5. Resultant table of base reactions of the building with base isolation system.

Load Case/Combo	FX kN	FY kN	FZ kN
Dead	0	0	40322.2
Live	0	0	7452
External Wall	0	0	3655.34
Internal Wall	0	0	6249.6
Parapet Wall	0	0	338.1
Floor Finish	0	0	2484
Roof Live	0	0	585
EQx	678.65	0	0
EQy	0	378.55	0
Comb1	0	0	91629.36
Comb2	814.38	0	73303.49
Comb3	0	454.26	73303.49
Comb4	1017.97	0	79573.86
Comb5	0	567.83	79573.86
Envp Comb	1017.97	567.83	73303.49

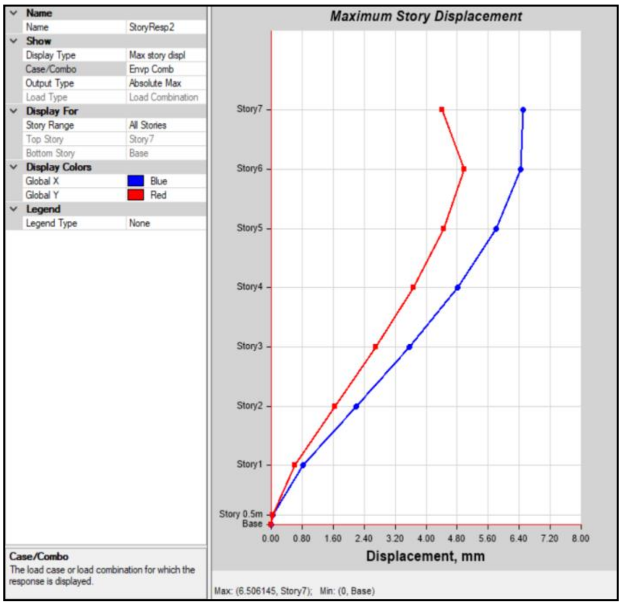

Figure 17. Maximum storey displacement of the building with base isolation system.

Table 6. Story Displacement comparison of the building *with* and *without* base isolation.

Storey Data	Storey Displacement of Building ***without*** Base Isolation System.		Storey Displacement of Building ***with*** Base Isolation System.	
	X-direction	Y-direction	X-direction	Y-direction
	mm	mm	mm	mm
Storey -1	10	6	0.75	0.5
Storey -2	22	15	2.25	1.55
Storey -3	34	24	3.7	2.7
Storey -4	43	31	5.75	3.7
Storey -5	53	38	5.8	4.5
Storey	58	42	6.4	4.9

-6				
Storey -7	58	44	6.5	4.5

Table 7. Story Drift comparison of the building *with* and *without* base isolation.

Story Data	Storey Drift of Building *without* Base Isolation System.		Displacement of Building *with* Base Isolation System.	
	X-direction	Y-direction	X-direction	Y-direction
	mm	mm	mm	mm
Story-1	0	0	0	0
Story-2	12	9	1.5	1.05
Story-3	12	9	1.45	1.15
Story-4	9	7	2.05	1
Story-5	10	7	0.05	0.8
Story-6	5	4	0.6	0.4
Story-7	0	2	0.1	-0.4

IV. CONCLUSION

The analysis of fixed base and base isolated G+5 Storey building is performed in this paper.
The base shear reduced around 88% in base isolated building compared to fixed base building.

The average reduction of maximum story displacement of base isolated building is 90% compared to fixed base building.

The average reduction of maximum story drift of base isolated building is around 85% compared to fixed base building.

V. ACKNOWLEDGMENT

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