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Comparative Study for Seismic Performance of Base Isolated & Fixed Based RC Frame Structure

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Abstract

A large proportion of world's population lives in regions of seismic hazards, at risk from earthquakes of varying severity and frequency of occurrence. Earthquake causes significant loss of life and damage of property every year. So, to mitigate the effect of earthquake on building the base isolation technique one of the best solutions.

Seismic isolation consists of essentially the installation of mechanisms which decouple the structure from base by providing seismic isolators. The seismic isolation system is mounted beneath the superstructure and is referred as 'Base Isolation'.

The main purpose of the base isolation device is to minimize the horizontal acceleration transmitted to the superstructure. Base isolation is very promising technology to protect different structures like building, bridges, airport terminals and nuclear power plants etc. from seismic excitation.

In this report, the G+14 storied frame structure is taken to compare the seismic effect of fixed base structure with respect to isolated structure. The (G+14) storied frame structure is design with base isolation by using the ETAB software. High Damping Rubber Bearing (HDRB) is used as an isolator having efficient results for frame structure over the fixed base structure than any other isolation system. The report concluded that the very less values come for lateral loads by using High Damping Rubber Bearing. It has high flexibility and energy absorbing capacity, so that during an earthquake, when the ground vibrates strongly only moderate motions are induced within the structure itself.

Keywords: Base isolation, Damping.

1. Introduction

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.

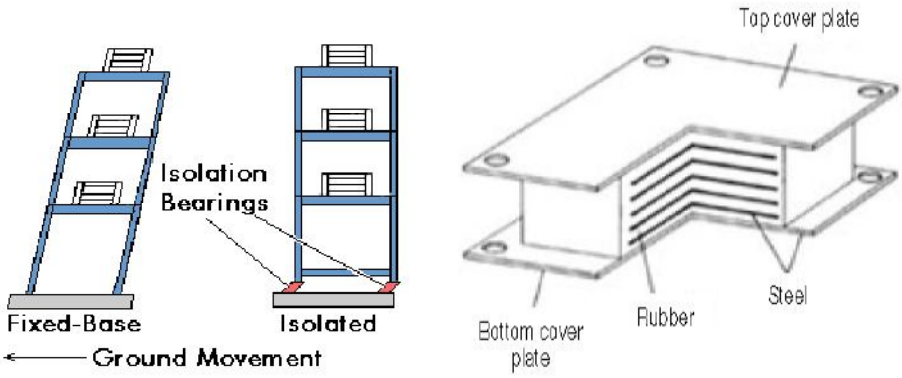

Fig. 1: Behavior of Fixed base & isolated base buildings.
Source: Ref. No. 6.

1.1 Purpose of base isolation

A design philosophy focused on capacity leads to a choice of two evils:

1. Continue to increase the elastic strength. This is expensive and for buildings leads to higher floor accelerations. Mitigation of structural damage by further strengthening may cause more damage to the contents than would occur in a building with less strength.
2. Limit the elastic strength and detail for ductility. This approach accepts damage to structural components, which may not be repairable. Base isolation takes the opposite approach, it attempts to reduce the demand rather than increase the capacity. We cannot control the earthquake itself but we can modify the demand it makes on the structure by preventing the motions being transmitted from the foundation into the structure above.

1.2 High damping rubber bearing (HDRB)

HDRB is one type of elastomeric bearing. This type of bearing consists of thin layers of high damping rubber and steel plates built in alternate layers. The vertical stiffness of the bearing is several hundred times the horizontal stiffness due to the presence of internal steel plates. Horizontal stiffness of the bearing is controlled by the low shear modulus of elastomeric while steel plates provides high vertical stiffness as well as prevent bulging of rubber. High vertical stiffness of the bearing has no effect on the horizontal stiffness. Rubber reinforced with steel plates provides stable support for structures. Multilayer construction rather than single layer rubber pads provides better vertical rigidity for supporting a building. With the help of HDRB earthquake vibration is converted to low speed motion. As horizontal stiffness of the multi- layer rubber bearing is low, strong earthquake vibration is lightened and the oscillation period of the building is increased. Horizontal elasticity of HDRB returns the building to its original position. In a HDRB, elasticity mainly comes from restoring force of the rubber layers. After an earthquake this restoring force returns the building to the original position.

2. Modeling Procedure in ETAB

The modeling procedure of fixed base and base isolated building in ETAB and design steps of isolators and linear static analysis using UBC 97 for isolated building has been carried out and seismic design procedure has been done using IS 1893:2002 (Part 1), for that the following data is used.

2.1 Building details and plan

- Grade of Concrete – M20, Steel Grade – Fe415
- Floor to Floor height is 3.5m, Plinth height above GL is 0.9
- Depth of Foundation is 0.6m below GL, Parapet height is 1m , Slab thickness is 150mm,
- External wall thickness = 230mm, Internal wall thickness = 150mm,
- Size of Columns = 230*450mm,Size of Beams = 230*380mm
- Live load on floor = 3 KN/m^2, Live load on Roof = 1.5 KN/m^2
- Site located in Seismic zone 4, i.e. Z= 0.24
- Building is resting on medium soil, Take importance factor as 1.
- Building frame type – SMRF, Density of Concrete = 25 KN/m^3
- Density of Masonry wall = 20 KN/m^3

Using the above plan in (G+14) RCC frame, the RCC G+14 frame has been analyzed & Designed for a fixed base & isolated base with High Damping Rubber Bearing for Earthquake forces by ETABS software.

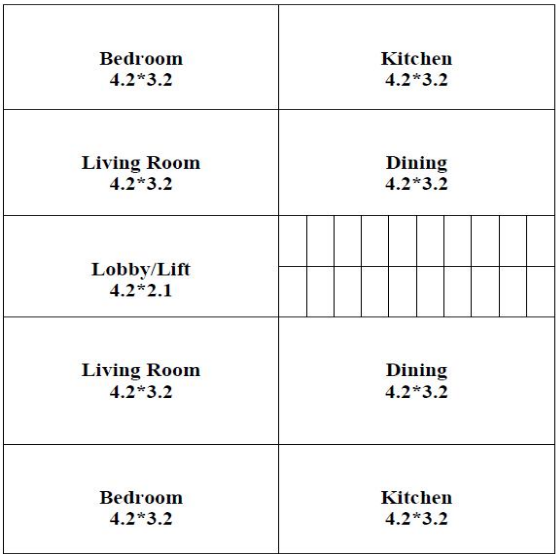

Figure 2: Plan for Design.

3. Result

It is compared for behavior of base isolated structure with fixed base structure under seismic load. From this it have been observed that structural effects like story displacement, story drift, story over turning moment & lateral load to stories of structure are reduced due to use of the isolators. The above results-parameters of structural effects like story displacement, story drift, story over turning moment & lateral load are represented in X & Y direction.

Table 1: Story displacement

Story No	Story Displacement (m)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	0.2782	0.00	0.1133	0.00
13	0.5397	0.00	0.2217	0.00
12	0.7660	0.00	0.3183	0.00
11	0.9749	0.00	0.3983	0.00
10	1.1534	0.00	0.4617	0.00
09	1.3057	0.00	0.5167	0.00
08	1.4232	0.00	0.5583	0.00
07	1.5233	0.00	0.5933	0.00
06	1.6058	0.00	0.6133	0.00
05	1.6643	0.00	0.6327	0.00
04	1.7229	0.00	0.6451	0.00
03	1.7620	0.00	0.6505	0.00
02	1.7961	0.00	0.6522	0.00
01	1.7961	0.00	0.1418	0.00
Base	0.0000	0.00	0.0000	0.00

Table 2: Story Drift in X & Y direction.

Story No	Story Drift (m)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	0.2782	0.0020	0.1133	0.0000
13	0.5397	0.0029	0.2217	0.0010
12	0.7660	0.0050	0.3183	0.0010
11	0.9749	0.0070	0.3983	0.0020
10	1.1534	0.0080	0.4617	0.0020
09	1.3057	0.0100	0.5167	0.0020
08	1.4232	0.0110	0.5583	0.0030
07	1.5233	0.0120	0.5933	0.0030
06	1.6058	0.0130	0.6133	0.0030
05	1.6643	0.0140	0.6327	0.0030
04	1.7229	0.0150	0.6451	0.0040
03	1.7620	0.0150	0.6505	0.0040
02	1.7961	0.0160	0.6522	0.0040
01	0.2977	0.0031	0.1418	0.0010
Base	0.0000	0.0000	0.0000	0.0000

Table 3: Story displacement.

Story No	Lateral Load To Stories (KN)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	59.84	0.37	95.74	0.37
13	58.70	0.37	91.84	0.37
12	55.93	0.37	87.15	0.37
11	47.48	0.34	73.89	0.34
10	39.84	0.31	61.92	0.31
09	32.52	0.28	49.95	0.28
08	25.85	0.25	40.07	0.25
07	20.16	0.22	31.22	0.22
06	14.96	0.19	23.67	0.19
05	10.73	0.16	16.65	0.16
04	7.32	0.13	11.45	0.13
03	4.39	0.10	6.75	0.10
02	2.28	0.07	3.64	0.07
01	1.14	0.04	1.56	0.04
Base	0.00	0.00	0.00	0.00

Table 4: Story Drift in X & Y direction.

Story No	Story Shear (KN)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	59.60	0.37	93.14	0.37
13	114.87	0.74	179.53	0.73
12	162.38	1.07	253.77	1.07
11	202.11	1.37	315.86	1.37
10	234.93	1.65	365.81	1.65
09	259.98	1.91	406.30	1.91
08	279.84	2.13	436.00	2.12
07	293.66	2.32	458.94	2.31
06	304.89	2.48	476.49	2.46
05	312.66	2.61	488.64	2.60
04	316.98	2.71	495.39	2.71
03	317.85	2.78	496.74	2.78
02	317.85	2.82	496.74	2.82
01	317.85	2.82	496.74	2.82
Base	317.85	2.82	496.74	2.82

4. Conclusion

1. Base isolation is very promising technology to protect different structures like buildings, bridges, airport terminals and nuclear power plants etc. from seismic excitation.
2. The variation in maximum displacement of stories in base isolated model is very low while compared with fixed base model. It is observed that when increasing the number of stories this variation of maximum displacement of stories will be somehow considerable.
3. The significant characteristic of base isolation a system affect the superstructure to have a rigid movement and as a result shows the relative story displacement & story drift of structural element will decrease and consequently the internal forces of beams and columns will be reduced.
4. Due to decrease in lateral loads to stories, the accelerations of the stories are
5. reduced. This results in the reduction of inertia forces.
6. Story overturning moment and story shear are also reduced in base isolated building resulting in making the superstructure above the isolation plane as rigid and stiffer.
7. From the above points, it is concluded that the performance of isolated structure is efficient in the Earthquake prone areas.

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