Effect of Building Height on Torsional Response of Lead Rubber Bearing Base Isolated Structures-A Study

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ABSTRACT

In this paper the effect of height variation of a base isolated building on torsional response has been investigated. For the study building are base isolated by lead rubber bearing (LRB). The height of the building is varied successively and subjected to bi-directional earthquake excitation. The torsional response of base isolated structure is studied for each increment in the story height and compared with fixed base structure. The result indicates that, base isolated structures reduces torsional rotation. Also, this reduction in response is more for buildings of ten to fifteen storeys, beyond which such reduction found to be less.

Keywords-angle of incidence, base isolation, lead rubber bearing, story increments, and torsional rotation.

I.INTRODUCTION

An earthquake is the natural occurring phenomenon which generates seismic waves resulting from sudden release of energy from earth’s crust causing vibration of the ground and structure on it. There is necessity to prevent severe damage to buildings when they are subjected to earthquake. Base isolation is a technique which prevents damage to the structures during earthquake by isolating the seismic energy [1]. The system which separates substructure from super structure is called base isolator. Elastomeric bearing and sliding bearing are two main classification of isolators.Elastomeric bearings are mainly classified in to three types as laminated/Low damping rubber bearing, lead rubber bearing, high damping natural rubber bearing. These isolators commonly have two thick steel end plates and alternate layers of rubber and steel shims. The steel shims prevent bulging of rubber providing high vertical stiffness. Laminated/Low damping rubber bearing exhibit low damping which arises resonance in severe earthquake. In high damping natural rubber bearing, increase in damping is achieved by adding extra fine carbon blocks, oils, resins to rubber. Lead rubber bearings contains one or more lead plugs in center to improve hysteretic damping [2]. For the study lead rubber bearing (LRB) is considered. Researchers have shown that, during earthquake the use of LRB as base isolator can reduce dynamic response of structures in terms of roof acceleration, base shear, and roof displacement and as compared to fixed base structures [3-4]. It is also shown that, Electricite-de-France (EDF) system is suitable for near-fault earthquakes rather than elastomeric bearings [5].

During an earthquake, torsional mode of the building might activate and can cause severe damage to structure. Due to non-uniform distribution of stiffness, strength in structures, mass, and torsional components of the ground movement etc. torsion is induced is structures. As per IS 1893 (Part 1): 2002, earthquake loads are considered only along the principal axesfor the design of a structure. However, torsion can be induced in the structure when earthquake act on any other axis of structure [6]. Usually the structures is designed for uni-directional seismic excitation. However, during an earthquake, structure may be subjected to bi-directional excitations as well [7].Thus, if a structure designed for uni-directional seismic excitation it might not respond well for a bi-directional seismic excitation [8].

Various researches have carried out in order to study the effect of torsional rotation in structure on elastomeric base isolation. It is observed that even in torsionally coupled structures base isolation is effective in reducing dynamic response of fixed base structures [9-10]. However, above studies are carried out by considering low rise building but the effect of torsional rotation on LRB base isolated structure in tall buildings is not observed. So in this study, the effect of torsional rotation of LRB base isolated structure on tall buildings is carried out by varying story numbers.

II.METHODOLOGY

Details of the building considered for the study are given in Fig. 1.The grade of concrete considered is M40 for column and M20 (as per IS 456: 2000) for beam and slab. The unit weight of RCC is 25 kN/m^3. The height of each story is 3.5 m. Beams and column are of dimensions 250 mm × 450 mm and 850 mm × 850 mm respectively. Thickness of slab is 150 mm. Live load of 3 kN/m^2 on all floors and 1.5 kN/m^2 on roof and dead load of 2 kN/m^2 on floors and 1 kN/m^2 on the roof is considered.

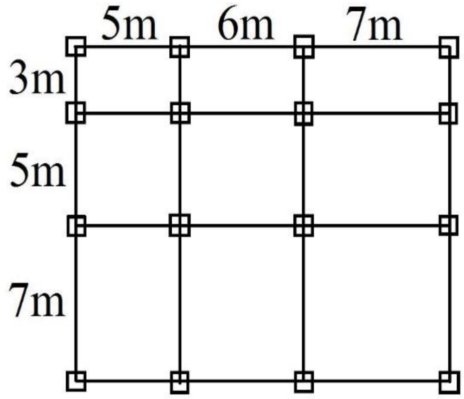

Fig. 1 Plan of the building

A 3 D model of the building is developed in ETABS software. Beam and column elements are modelled as frame elements and slab as shell element. Rigid diaphragm property has been assigned to all the floors. LRB is

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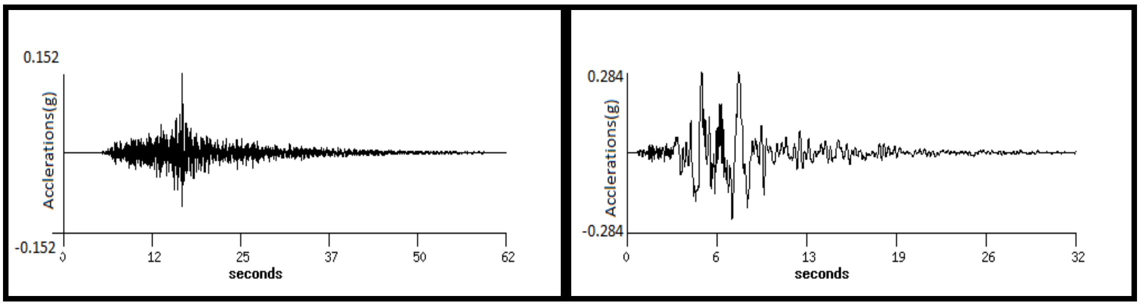
modelled as link/support element in the software. Various parameter of LRB like vertical stiffness, effective horizontal stiffness, yield force, post yield stiffness ratio are calculated based on the methods given in [11-13]. Table 1 lists typical LRB isolator property values for thirty story building.

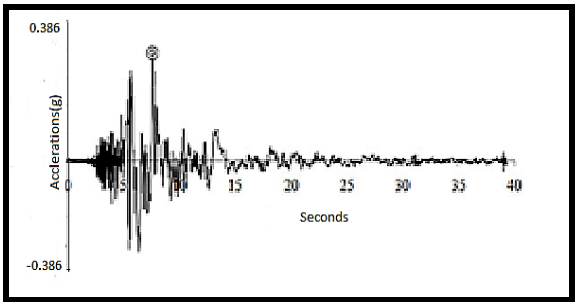
Table 1 LRB Isolator properties

Effective horizontal stiffness	1942 kN/m
Vertical stiffness	812322 kN/m
Yield force	175 kN
Post yield stiffness ratio	0.1
Effective damping	0.1

By considering three different earthquake records linear time history analysis is carried out for the study. As perguidelines of ASCE7-05 16.1.3 minimum three different previously recorded earthquake data should be considered for the design in dynamic analysis. Out of three earthquake records considered, El-Centro is near fault earthquake with peak ground acceleration (PGA) of 0.386g, Chi-Chi and Kobe are far field earthquakes with PGA of 0.152g and 0.284g respectively. Accelerograms of earthquake records considered are shown in Fig 2.



Chi-Chi Earthquake Kobe Earthquake



El-Centro Earthquake

Fig. 2 Accelerograms of three earthquakes

In order to capture effect of torsion on structures, for the study bi-directional seismic excitations have been considered by varying the angle of incidence of earthquake from 0^o to 180^o at an interval of 10^o. The torsional rotations are obtained by the rotation of diaphragms along vertical axis in terms of radians. In the study, torsional response of structures are investigated by increasing story numbers from six stories to thirty stories.

III.RESULTS AND DISCUSSIONS

Tables 3, 4 and 5 represent the percentage reduction in torsional rotation when fixed base structure is compared with base isolated structure for all buildings for various earthquake records. Since, the torsional response of buildings up to five storey heights is considerably less, the response for these structures have not been accounted for. It can be seen that, torsional rotation in structure increases with increase in stores. It is also seen that in all structures for all three earthquakes torsional rotation is effectively reduced by LRB base isolator. For all the three earthquakes, LRB isolator reduces torsional rotation, and this reduction is more for buildings of ten to fifteen storeys. This could be due to the phase lag which happens between earthquake and frequency of isolated structure. The maximum reduction in torsional rotation by LRB isolator is 92.315% for twelve story building for Chi-Chi earthquake. It is 91.625% for twelve story building in Kobe and 73.091% for eleven story building in El-Centro earthquakes respectively.

Table 3 Torsional response of fixed and base isolated structures for Chi-Chi earthquake

No. of Stories in the structure	Angle of incidence of the earthquake for maximum torsional rotation for fixed structure	Maximum torsional rotation (Radians) for fixed base structure	Torsional rotation (Radians) in base isolated structure corresponding to maximum rotation in fixed structure	% Reduction in torsional rotation
30	160	0.001776	0.000904	49.099
29	160	0.001686	0.000835	50.474
28	170	0.001456	0.000708	51.374
27	170	0.001296	0.000618	52.315
26	170	0.001255	0.000559	55.458
25	170	0.001218	0.000524	56.979
24	170	0.001152	0.000487	57.726
23	160	0.001166	0.000469	59.777
22	170	0.001058	0.000418	60.491
21	170	0.001017	0.000379	62.734
20	170	0.000995	0.000361	63.719
19	170	0.000982	0.000352	64.155
18	170	0.000868	0.000302	65.207
17	170	0.000895	0.000286	68.045
16	170	0.000865	0.000258	70.173
15	170	0.000862	0.000219	74.594
14	170	0.000763	0.000187	75.491
13	150	0.000706	0.000126	82.153
12	170	0.001393	0.000107	92.319
11	170	0.001237	0.000104	91.593
10	170	0.000943	0.000106	88.759
9	170	0.000636	0.000138	78.302
8	160	0.000317	0.000113	64.353

7	160	0.000394	0.000164	58.376
6	170	0.000269	0.000143	46.840

Table 4 Torsional response of fixed and base isolated structures for Kobe earthquake

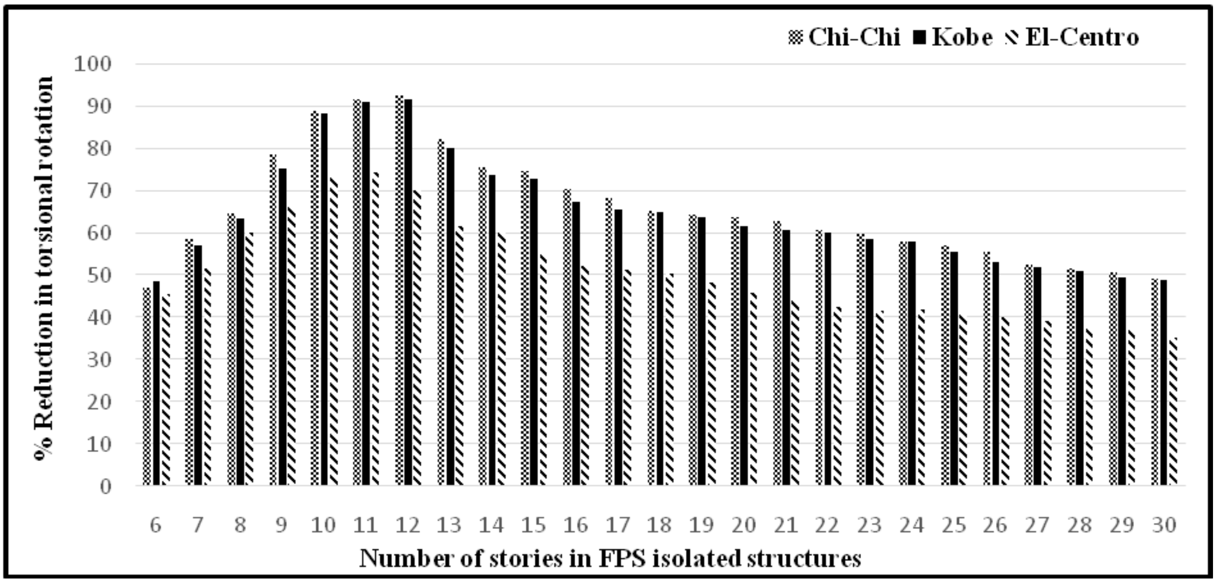
No. of Stories in the structure	Angle of incidence of the earthquake for maximum torsional rotation for fixed structure	Maximum torsional rotation (Radians) for fixed base structure	Torsional rotation (Radians) in base isolated structure corresponding to maximum rotation in fixed structure	% Reduction in torsional rotation
30	170	0.002765	0.001412	48.933
29	170	0.002715	0.001373	49.429
28	170	0.002696	0.001323	50.927
27	170	0.002636	0.001273	51.707
26	170	0.002611	0.001225	53.083
25	160	0.002594	0.001155	55.474
24	170	0.002556	0.001076	57.903
23	170	0.002437	0.001014	58.391
22	160	0.002332	0.000935	59.906
21	170	0.002252	0.000886	60.657
20	170	0.001904	0.000734	61.450
19	170	0.002195	0.000797	63.690
18	170	0.001901	0.000671	64.703
17	160	0.001711	0.000589	65.576
16	170	0.001593	0.000523	67.169
15	170	0.001346	0.000368	72.660
14	170	0.001168	0.000347	73.716
13	170	0.001555	0.000309	80.129
12	160	0.001803	0.000151	91.625
11	170	0.001549	0.000142	90.833
10	170	0.001038	0.000122	88.247
9	150	0.000703	0.000175	75.107

8	170	0.000686	0.000252	63.265
7	160	0.000407	0.000175	57.002
6	170	0.000305	0.000167	45.246

Table 5 Torsional response of fixed and base isolated structures for El-Centro earthquake

No. of Stories in the structure	Angle of incidence of the earthquake for maximum torsional rotation for fixed structure	Maximum torsional rotation (Radians) for fixed base structure	Torsional rotation (Radians) in base isolated structure corresponding to maximum rotation in fixed structure	% Reduction in torsional rotation
30	170	0.003511	0.002278	35.118
29	160	0.003512	0.002214	36.959
28	170	0.003115	0.001954	37.271
27	170	0.002919	0.001784	38.883
26	170	0.002765	0.001664	39.819
25	170	0.002682	0.001592	40.641
24	170	0.002498	0.001459	41.593
23	170	0.002355	0.001382	41.316
22	170	0.002209	0.001276	42.236
21	170	0.002034	0.001143	43.805
20	170	0.001788	0.000974	45.526
19	170	0.001567	0.000815	47.990
18	170	0.001506	0.000749	50.226
17	170	0.001336	0.000652	51.198
16	160	0.001121	0.000537	52.096
15	160	0.001073	0.000483	54.986
14	170	0.000882	0.000354	59.864
13	170	0.000747	0.000289	61.312
12	160	0.000693	0.000208	69.986
11	170	0.000799	0.000215	73.091

10	170	0.000975	0.000264	72.923
9	170	0.000864	0.000294	65.972
8	160	0.000699	0.000279	60.086
7	160	0.000443	0.000215	51.467
6	170	0.000294	0.000154	47.619



Reductions in torsional response for various earthquakes can be seen in Fig. 3. It can be seen that, for El-Centroearthquake, which is a near fault earthquake with peak ground acceleration (PGA) of 0.386g, reduction in torsional rotation by LRB isolator is least. For Chi-Chi and Kobe earthquakes which is a far field earthquakes with PGA of 0.152g and 0.284g respectively, reduction in torsional rotation by LRB isolator is more for Chi-Chi then Kobe earthquake with higher PGA.

IV.CONCLUSIONS

Effect of building height on torsional rotation of LRB base isolated structures is studied. Effectiveness of LRB base isolator in reducing torsional rotation is studied by considering buildings of different heights, subjected to bi-directional seismic excitations. For the study, one near fault and two far field earthquakes were considered. Based on the study it can be concluded that, LRB base isolator can successfully reduce overall torsional rotation in tall structures. However, its effectiveness in reducing torsional rotation reaches is maximum at a particular storey and reduces beyond that storey. Effectiveness LRB isolator in reducing torsional rotation was found to be more for far field earthquakes.

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