Effect of Base Isolation in Multistoried RC Regular and Irregular Building using Time History Analysis

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***Abstract*—** *Base isolation (BI) is a technique that has been used around the world to protect the building structures from the damaging effects of earthquake. The installation of isolator in building at base level considerably increases the time period of the structure, which means it reduces the possibility of resonance of the structure giving rise to better seismic performance of the building. The analysis is performed to compare the effectiveness of base isolation in regular and irregular multi-storied RC frame building. For this study, 15 storied R.C frame building has been considered and Time History analysis is carried out using ETABS software version 2013. The Lead Rubber Bearing (LRB) is designed by considering the maximum gravity load coming on the column at the base and the same has been used for analysis. The results obtained from the analysis are compared in terms of time period, base shear, story displacement and story acceleration. Time period for the base isolated structures are higher than that of the fixed base structure. Due to the presence of isolator, base shear and story acceleration are significantly reduced in each direction (X and Y direction) as compared to fixed base building. When compared to base isolated regular building the plan irregular (re-entrant corner) and vertical irregular (vertical geometric irregular) base isolated building gives better performance.*

***Keywords*— Base Isolation, Time History Analysis, lead rubber Bearing, UBC 97 code, ETABS 2013, Base shear.**

I. INTRODUCTION

An earthquake is a sudden and transient motion of the earth's surface. According to geologists, the earth has suffered earthquakes for hundreds of millions of years, even before humans came into existence. Because of the randomness, the lack of visible causes, and their power of destructiveness, ancient civilizations believed earthquakes to be supernatural phenomena – the curse of God. In terms of the geological time scale, it is only recently (the middle of seventeenth century) that an earthquake has been viewed as a natural phenomenon driven by the processes of the earth as a planet. Thus subsequent work, especially in nineteenth century, led to tremendous progress on the instrumental side for the measurement of earthquake data. Seismological data from many earthquakes were collected and analyzed to map and understand the phenomena of earthquakes [1]. Causes of earthquakes: Movement of the tectonic plates relative to each other, both in direction and magnitude, leads to an accumulation of strain, both at the plate boundaries and inside the plates. This strain energy is the elastic energy that is stored due to the straining of rocks, as for elastic materials. When the strain reaches its limiting value along a weak region or at existing faults or at plate boundaries, a sudden movement or slip occurs releasing the accumulated strain energy. The action generates elastic waves within the rock mass, which propagate through the elastic medium, and eventually reaches the surface of the earth. Most earthquakes are produced due to slips at the faults or at the plate boundaries [1]. In most earthquakes, the collapse of structures like houses, schools, hospitals, historic and public buildings results in the widespread loss of lives and damage. Earthquakes also destroy public infrastructure like roads, dams and bridges, as well as public utilities like power and water supply installations. Past earthquake shows that over 95% of the lives were lost due to the collapse of buildings that were not due to earthquake. Though there are building codes and other regulations which make it mandatory that all structures in earthquake-prone areas in the country must be built in accordance with earthquake-resistant construction techniques, new constructions often overlook strict compliance to such regulations and building codes. A large number of buildings in India have been constructed without due consideration to earthquake loads. Further, the earthquake loads are also under continual revision in successive revisions of codes. Buildings also deteriorate with time and get damaged due to earthquake, flood, fire, blast, etc. All these circumstances require evaluation and retrofitting of existing building. From the past earthquake it was observed that, during earthquake most of the buildings were collapsed due to their irregular configuration in plan and elevation. In regular building earthquake force will be transfer uniformly from bottom to top of the building but in irregular building it distribute non-uniformly throughout the building. In traditional earthquake design it is compulsory that structure should have regular configuration. Base isolation is a recent and new earthquake resistance technology; in this system earthquake force induced to the structure is reduced at base level of the structure and avoids the transfer of load to the super structure. So that any type of building configuration can be constructed over the isolation system. For the present work regular and irregular buildings have been taken to study their performance using isolation system and without using isolation system during an earthquake.

1.1 Structural irregularities

In the past, several major earthquakes have exposed the shortcomings in buildings, which lead to damage or collapse. It has been found that regular shaped buildings perform better during earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. There are various types of irregularities in the buildings; they are divided into two groups, plan irregularities and vertical irregularities.

Plan irregularity: It comprises following types of irregularities

1. Torsion irregularity
2. Re-entrant Corners
3. Diaphragm Discontinuity
4. Non parallel Systems

Vertical irregularity: It comprises following type of irregularities

1. Stiffness Irregularity
2. Mass Irregularity
3. Vertical Geometric Irregularity
4. In Plane discontinuity in vertical elements resisting lateral force
5. Discontinuity in capacity-weak story

In this study, regular, plan irregular (Re-entrant corners) and vertical irregular (Vertical Geometric Irregularity) buildings are considered for the isolated and non-isolated buildings.

1.2 Base Isolation

The isolation technique decouples the structure from the horizontal components of the ground motion by interposing structural element with low horizontal stiffness between the structure and the foundation. This gives the structure a fundamental frequency that is much lower than its fixed base frequency of the ground motion. The first dynamic mode of isolated structure involves deformation only in the isolation system, the structure above being to all intents and purposes rigid. The higher modes that produce deformation in the structure are orthogonal to the first mode and, consequently, to the ground motion. These higher modes do not participate in the motion, so that the high energy in the ground motion at these higher frequencies cannot be transmitted into the structure [4].

1.3 Objectives of the work

1. To compare the response of the building such as base shear, time period, displacement and acceleration with and without base isolation. Following are the different types of building for the earthquake analysis.

   a. 15 storied RC regular building.

   b. 15 storied RC plan irregular building.

   c. 15 storied RC *vertical irregular building.*

2. To find out the response of buildings with and without base isolation by considering the time history analysis using Bhuj earthquake data.

3. To design the lead rubber bearing using UBC 97 code.

II. LITERATURE REVIEW

Abrishambaf and G. Ozay [2010] [6], has briefly described the “Effects of isolation damping and stiffness on the seismic behavior of structures”. In this paper his intention was to study the earthquake performance and optimization of bearing by considering 3,6, and 9 storied seismic isolated building using LRB, high damping and friction pendulum system bearing. The parameters like acceleration, maximum displacement and seismic coefficient was compared with fixed base and base isolated structure. The results concluded that LRB represents minimum seismic coefficient, acceleration and maximum displacement compared to friction pendulum and high damping rubber bearing.

Athamnia Brahim and Ounis Abdelhafid [2011] [7], has been studied “Effects of seismic isolation in the reduction of the seismic response of the Structure” by considering the 8 story plan irregular building using lead Rubber bearing. A nonlinear time history analysis was carried out using ETABS version 9.7.0 software. The results obtained concluded that lead rubber bearing minimizes the seismic response of the building

Mehmet Komur et. al. [2011] [8], for his study he was considered fixed-base and base isolated 4 and 8 storey reinforced concrete buildings. The LRB was taken as an isolation system. In base-isolated buildings large reduction is detected in base shear, acceleration values, and relative storey displacements as compared to fixed base buildings. In addition to this, the displacements and time period of isolated buildings are increased when compared with non-isolated buildings.

Shirule P.A. et. al. [2012] [9], used an 18-storey symmetrical R.C.C. building as a test model. Lead Rubber Bearing (LRB) and Friction Bearing (FB) was used as isolation system in this study. Nonlinear Time history analysis was 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, Koyana and Lacc T.H. Finally, base shear, displacement and acceleration are compared from 3 times histories 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.

III. BASE ISOLATION

3.1 Introduction

A large proportion of the world’s population lives in region of seismic hazard, at risk from earthquake of varying severity and varying frequency of occurrence. Earthquake cause significant loss of life and damage to property every year. Various a seismic construction designs and technologies have been developed over the years in attempts to mitigate the effect of earthquakes on buildings, bridges and potentially vulnerable contents. Seismic isolation is relatively recent and evolving technology of this kind. Seismic isolation consists essentially of the installation of mechanism which decouples the structure, or its contents, from potentially damaging earthquake-induced ground, or support, motions. This decoupling is achieved by increasing the flexibility of the system, together with providing appropriate damping. In many, but not all, applications the seismic isolation system is mounted beneath the structure and is referred to as “BASE ISOLATION”.

Isolation may often reduce the cost of providing a given level of earthquake resistance. The New Zealand approach has been to design for some increase in earthquake resistance, together with some cost reduction, a typical target being a reduction by 5% of the structural cost.

3.2 Types of base isolators

The most common types of base isolators used in buildings are:

a. Elastomeric rubber bearing.

b. High damping rubber bearing.

c. Lead rubber bearing.

d. Friction pendulum system bearing

IV. RESULTS

4.1 Time period

Comparison of time period for different models.

TABLE 1
TIME PERIOD FOR DIFFERENT MODELS

No. of modes	Time period (sec)					
	Model 1A	Model 1B	Model 2A	Model 2B	Model 3A	Model 3B
1	3.10	3.94	3.09	3.94	2.83	3.68
2	3.03	3.87	2.97	3.82	2.49	3.38
3	2.78	3.62	2.84	3.69	1.84	2.85
4	1.01	1.25	1.00	1.25	0.95	1.18
5	0.97	1.20	0.95	1.18	0.94	1.17
6	0.91	1.13	0.92	1.16	0.82	0.97
7	0.58	0.68	0.57	0.67	0.55	0.66
8	0.54	0.65	0.52	0.64	0.54	0.65
9	0.52	0.62	0.52	0.62	0.50	0.61
10	0.40	0.46	0.39	0.45	0.40	0.44
11	0.36	0.42	0.35	0.41	0.36	0.43
12	0.35	0.41	0.34	0.41	0.36	0.41

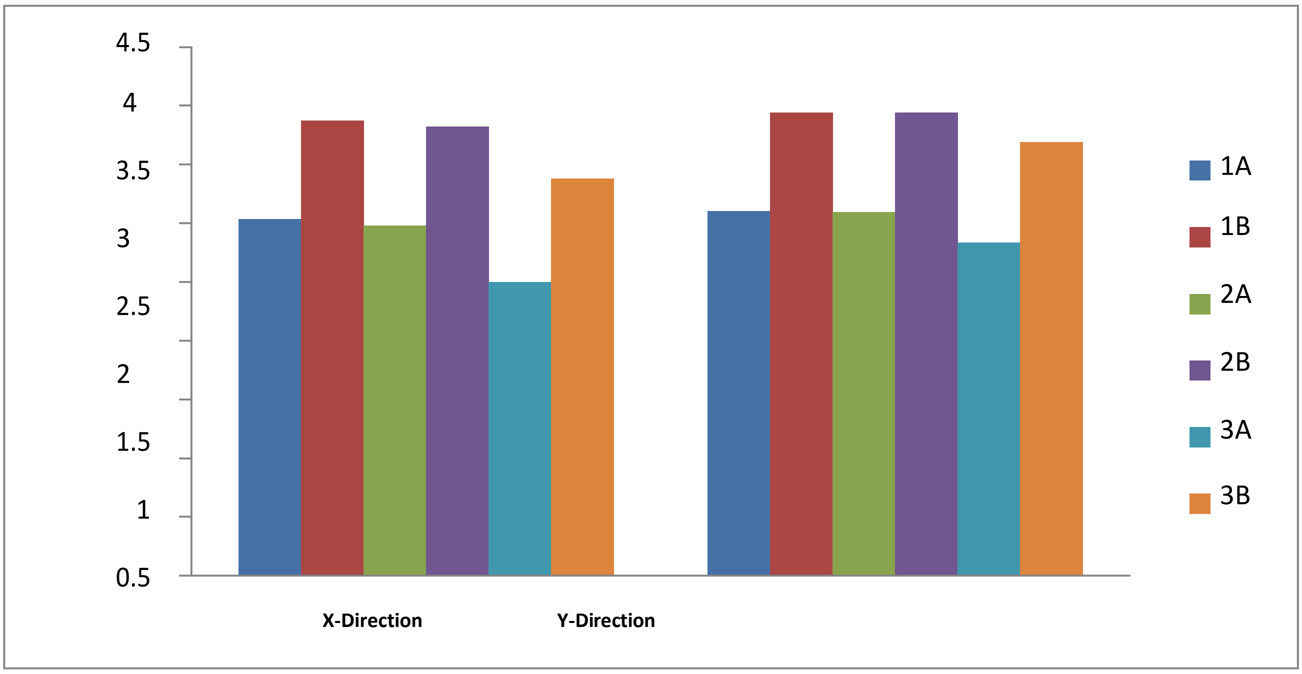

FIG. 1: TIME PERIOD FOR DIFFERENT MODELS

From the figure 1, it is observed that, time period decreases with increase in mode number. As result of the increased flexibility of the system, natural period of the structure is also increases. This shows flexibility is directly proportional to natural period.

TABLE 2
TIME PERIOD FOR DIFFERENT MODELS CONSIDERING FIRST THREE MODES

Models	Time period (sec)		
	X-X direction	Y-Y direction	Torsion
1A	3.03	3.10	2.78
1B	3.87	3.94	3.62
2A	2.97	3.09	2.84
2B	3.82	3.94	3.69
3A	2.49	2.83	1.84
3B	3.38	3.68	2.85

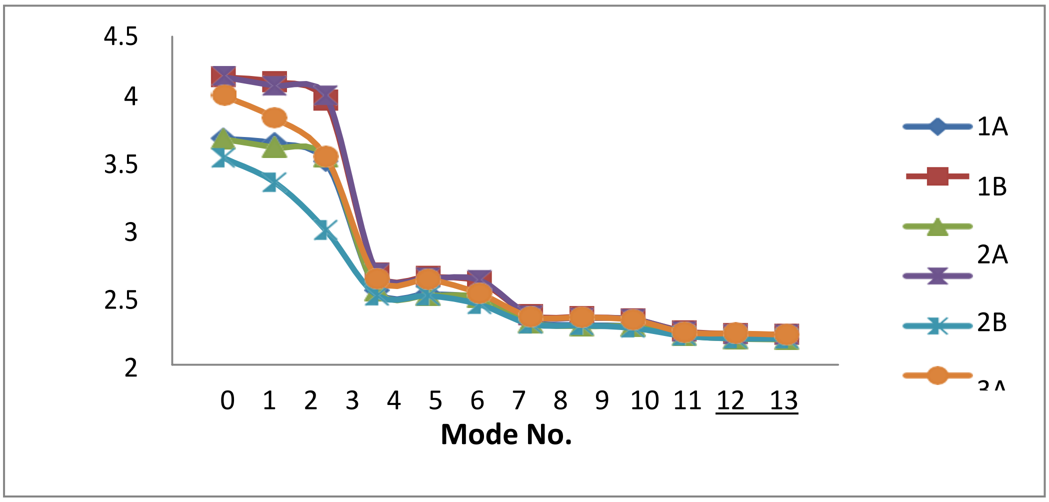

FIG. 2: TIME PERIOD FOR DIFFERENT MODELS ALONG X AND Y DIRECTION

Figure 2, shows that, in the modal analysis the time period of the structure is found to be 3.10sec, in Y-direction and the time period as 3.03sec, in X-direction for model 1A (Regular building with fixed base).

The time period of the structure is found to be 3.94sec and 3.87sec in Y and X direction respectively for model 1B (Regular building with base isolation). The time period in model 1B is 27% more than the model 1A both in Y and X direction.

The time period of the structure is found to be 3.09sec, in Y-direction and the time period as 2.97sec, in X-direction for model 2A (Plan irregular building with fixed base).

The time period of the structure is found to be 3.94sec and 3.82sec in Y and X direction respectively for model 2B (Plan irregular building with base isolation). The time period in model 2B is 27% more in Y and 28% more in X-direction than the model 2A. The time period of the structure is found to be 2.83sec, in Y-direction and the time period as 2.49sec, in X-direction for model 3A.

The time period of the structure is found to be 3.68sec and 3.38sec in Y and X- direction respectively for model 3B (Vertical irregular building with base isolation). The time period in model 3B is 30% more in Y and 36% more in X-direction than the model 3A.

4.2 Base shear

4.2.1 Comparison of base shear for different models

TABLE 3
VARIATION OF BASE SHEAR (KN) ALONG X AND Y DIRECTION FOR DIFFERENT MODELS

Models	Base shear (kN)	
	X-direction	Y-direction
1A	4810.02	3753.21
1B	2680.25	2723.46
2A	3629.20	2793.13
2B	1988.94	1921.50
3A	5739.24	3596.05
3B	2312.51	2362.89

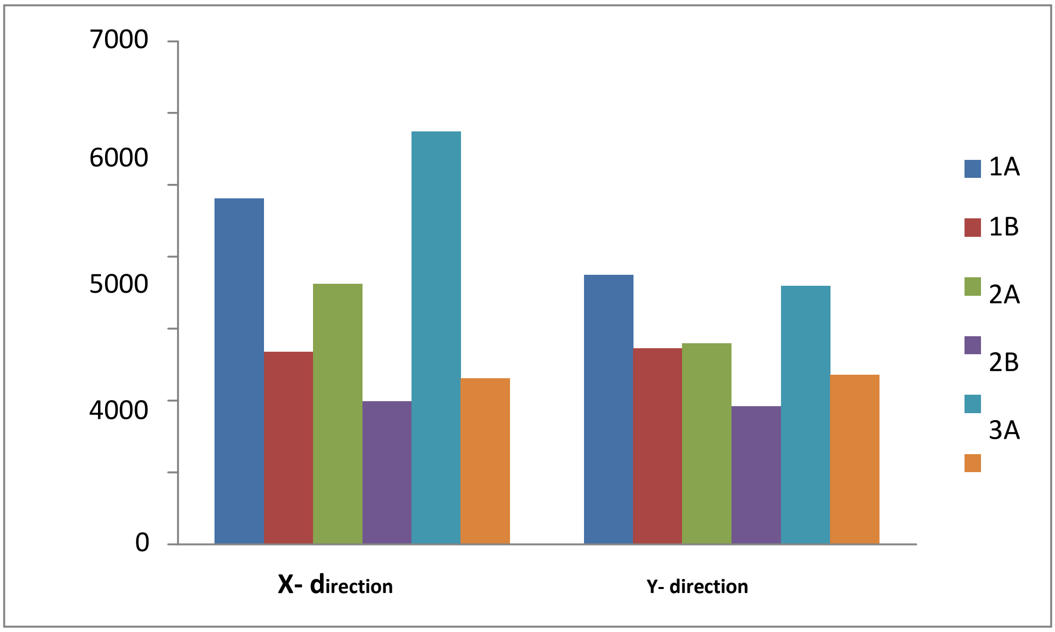

FIG. 3: BASE SHEAR (KN) ALONG X AND Y-DIRECTION

From the figure 3, it is observed that, the base shear in model 1B is decreases by 44% as compared to model 1A in X-direction.

The base shear in model 2B is decreases by 45% as compared to model 2A in X- direction. Similarly, it is decreases by 60% in model 3B as compared to model 3A in X- direction.

The base shear in Y-direction for model 1B, 2B and 3B are decreases by 27%, 31% and 35% as compared to model 1A, 2A and 3A respectively. This shows isolator gives better performance compared to fix base building.

4.2.2 Story displacement

➢ **Comparison of story displacement for different models.**

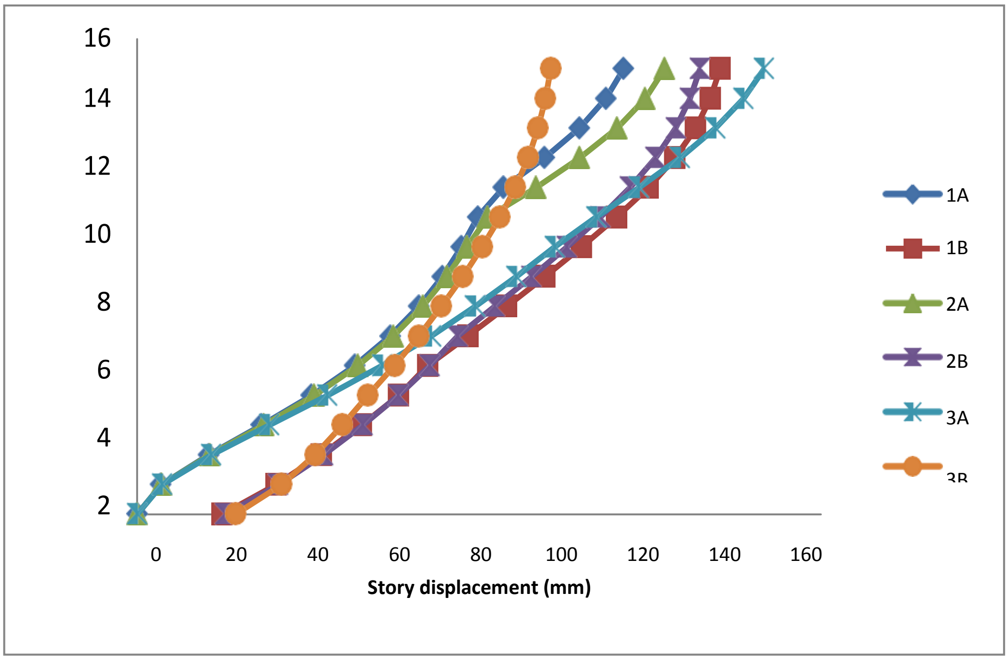

FIG. 4: STOREY DISPLACEMENT ALONG X-DIRECTION

TABLE 4
VARIATION OF STORY DISPLACEMENT (MM) ALONG X-DIRECTION FOR DIFFERENT MODELS

No. of Stories	Story displacement (mm)					
	Model 1A	Model 1B	Model 2A	Model 2B	Model 3A	Model 3B
15	113.8	136.4	123.4	131.7	146.7	96.8
14	109.7	134.1	118.9	129.4	141.9	95.5
13	103.5	130.7	112.3	126	135.3	93.8
12	95.3	125.8	103.5	121.3	127	91.5
11	85.7	119.6	93.3	115.3	117.4	88.5
10	79.7	112.2	82	108.4	107.4	84.9
9	75.9	104	77.2	100.6	97.7	80.8
8	71.4	95.4	72.4	92.3	88.7	76.2
7	65.9	86.5	66.8	83.7	79.1	71.2
6	59.2	77.4	60	75	68.8	65.9
5	50.9	68	51.6	68.5	57.3	60.2
4	40.8	61.2	41.4	61.1	44.5	54
3	29.1	52.5	29.6	52.8	30.9	48
2	16.8	43.1	17	43.6	17.4	41.7
1	5.6	32.5	5.7	33.1	5.8	33.8
0	0	19.9	0	20.6	0	23

TABLE 5
VARIATION OF STORY DISPLACEMENT (MM) ALONG Y-DIRECTION FOR DIFFERENT MODELS

No. of Stories	Story displacement (mm)					
	Model 1A	Model 1B	Model 2A	Model 2B	Model 3A	Model 3B
15	102.6	138.6	106.6	133.8	180.8	138.4
14	99.4	136.3	103	131.2	176.2	136.5
13	94	132.8	97.1	127.7	168.3	133.4
12	86.4	128	89	123	157	129.1
11	82.2	121.8	79.1	105	142.9	124.1
10	77.6	114.7	75	110.5	126.7	118.7
9	74.3	106.8	69.9	103.3	109.4	113.2
8	70.7	98.8	66.1	96	93.4	107.3
7	65.4	90.9	61.1	88.6	84.3	101.2
6	58.1	83	54.3	81	73.4	94.7
5	49.3	74.7	46	72.9	60.9	87.8
4	39.2	65.9	36.6	64.5	48.1	80.1
3	28.3	56.9	26.5	55.7	35.3	71.5
2	17.2	47.6	16.4	46.6	21.6	61.8
1	6.5	37.2	6.3	36.5	8.2	49.9
0	0	21.5	0	21	0	29.5

Figure 4 and 5 shows that, fixed base building have zero displacement at base of the building whereas in case of base isolated model appreciable amount of lateral displacement is observed at the base.

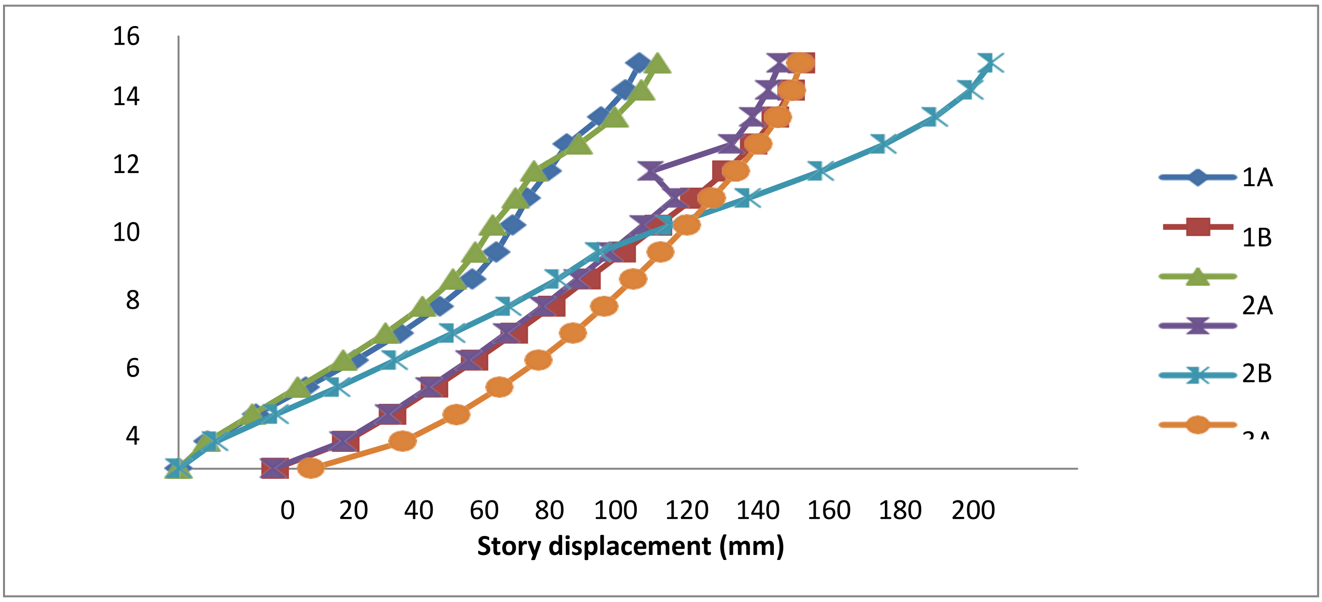

FIG. 5: STOREY DISPLACEMENT ALONG Y-DIRECTION

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