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Design of Base Isolation Systems for a R.C.C. Building to Reduce the Earthquake Force on Structures

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Abstract: Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements and to some structural members in the building. This may render the building non-functional after the earthquake, which is not acceptable for important buildings, like hospitals, fire stations, etc. Special techniques are required to design buildings they remain practically undamaged even in a severe earthquake. Buildings with such improved seismic performance usually cost more than normal buildings. However, this cost is justified through improved earthquake performance. One of the technologies used to protect buildings from damaging earthquake effects is “Base Isolation”. The idea behind base isolation is to separate (isolate) the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least greatly reduced.
The work undertaken is an attempt to understand the fundamentals of Base Isolation, its design &behavior under seismic loading. A RCC building of Basement + GF +4 has been considered with basement constructed of RCC wall at its periphery. IBC 2000 recommendations were used. The basic types of base isolator namely High Damping Rubber Bearing (HDR) was designed. The base isolated RCC building was exposed to Design Spectrum seismic loading of IS 1893-2002 (Part I) to compute its response. The conclusions were drawn on the basis of analysis and design of base isolator along with comparison of displacement, storey drift and base shear for fixed base with RCC isolated building. A commonly available, widely used software SAP2000.v16 was utilized.
Keywords: earthquake force, confined displacement, control collapse of building, safety of building

I. INTRODUCTION

The field of seismic design is a subject directly concerned with both life safety and cautious and slow to innovate. Like other code-dominated issues, and like airplane safety, seismic safety has never been much of an important issue. In short, seismic safety is generally taken for granted. Improvements in seismic safety, Development of structural systems that perform reasonably well, and enable materials such as steel and reinforced concrete is necessary. The choices for lateral resistance lie among shear walls, braced frames, and moment resistant frames.

The codes have mandated steadily increasing force levels, in a severe earthquake a building, if it were to remain elastic, would still encounter forces several times above its designed capacity. This situation is quite different from that for vertical forces, in which safety factors insure that actual forces will not exceed 50% of designed capacity unless a serious mistake has been made. For vertical forces, this is easy to do. But to achieve similar performance for seismic forces, the structure would be unacceptably expensive. This disagreement between seismic demand and capacity is traditionally accommodated by reserve capacity, which includes uncalculated additional strength in the structure and often the contribution of portions and exterior cladding to the strength and stiffness of the building. In addition, the ability of materials such as steel to dissipate energy by permanent deformation—which is called ductility—greatly reduces the likelihood of total collapse.

Modern buildings contain extremely sensitive and costly equipment. These building contents are more costly and valuable than the buildings themselves. Furthermore, hospitals, communication and emergency centers, and police and fire stations must be operational when needed most immediately after an earthquake. Conventional construction can cause very high floor accelerations in stiff buildings and large interstorey drifts in flexible structures. These two factors cause difficulties in insuring the safety of the building components and contents. Hence, it’s necessary to incorporate a new design approach which will reduce the earthquake forces up to an extent and does not damage the structure.

II. METHODOLOGY

Design Methods
Following methods are used according to the design requirements for a given project.
• Static Analysis

For all seismic isolation designs it is necessary to perform a static analysis. This establishes a minimum level for design displacements and forces. The static analysis is also useful both for preliminary design of the isolation system and the structure when dynamic analysis is required and for design review; undercertain circumstances it may be the only design method used.
Dynamic analysis may be used in all cases and must be used if the requirements mentioned for adequacy of static analysis are not satisfied.

III. ANALYSIS

The conclusions were drawn on the basis of analysis and design of base isolator along with comparison of displacement, storey drift and base shear for fixed base with RCC isolated building. A commonly available, widely used software SAP2000.v16 was utilized. The result of the analysis drawn in graphs and charts in the following:

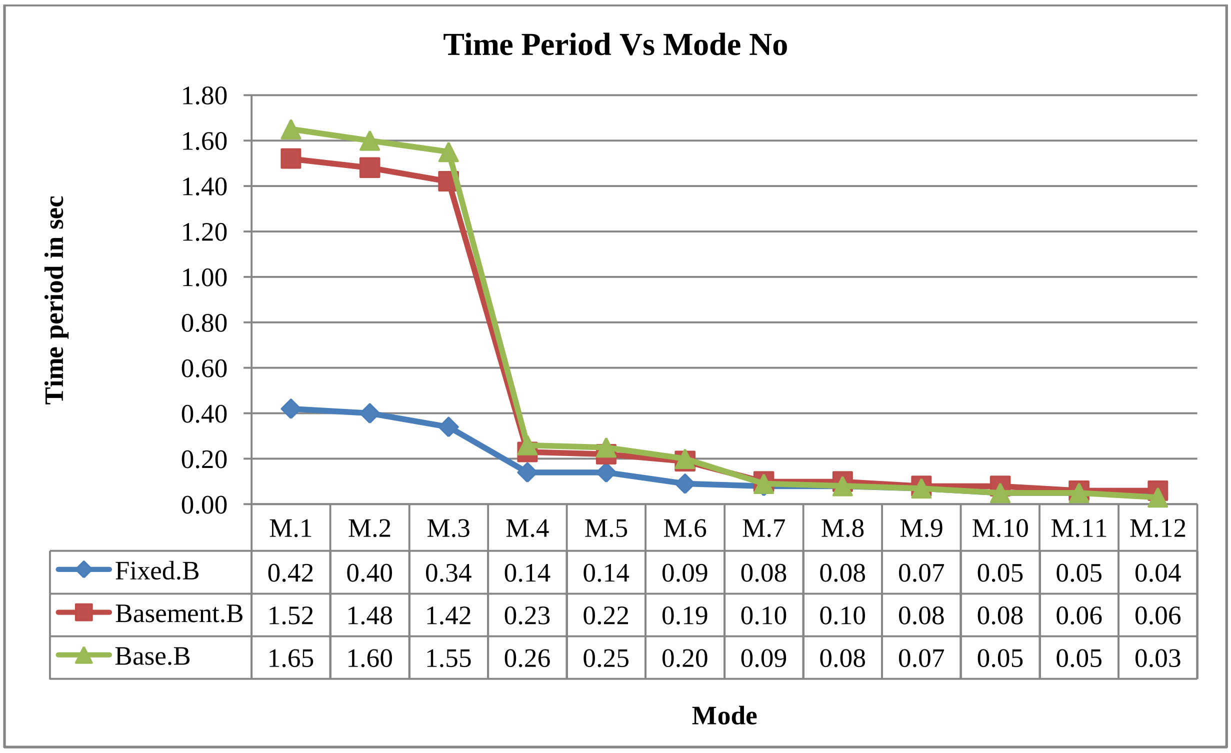


Figure1 Comparison of Time Period vs. Mode No

Figure1is a graphical presentation of time period vs. mode no for a fixed base and isolated base building. The graph clearly shows the period shift that we are able to achieve due to base isolation in the initial modes. We can see there is considerable period shift which is obtained because of the provision of flexibility at the base of the structure due to base isolation.

Table1. Comparison Of Modal Participation Mass Ratio In X Direction

Comparison of modal participating mass ratio in x direction			
mode	Fixed base	High Damping Rubber	
		Basement	Base
1	0.63	0.35	0.38
2	0.63	0.78	0.71
3	0.64	1.00	1.00
4	0.77	1.00	1.00
5	0.77	1.00	1.00
6	0.84	1.00	1.00
7	0.84	1.00	1.00
8	0.84	1.00	1.00
9	0.84	1.00	1.00
10	0.99	1.00	1.00

11	0.99	1.00	1.00
12	0.99	1.00	1.00

IS 1893-2002 Part I specifies that the number of modes to be used in the analysis should be such that the sum total of modal masses of all the modes considered is at least 90 % of the total seismic mass and missing mass correction beyond 33 %.

In Table1 we can see that the mass participation of 90 % as per IS -1893 takes part in the 10th mode. This is because of the presence of RCC wall all around the periphery and interior of the building. The RCC walls were modeled as solid walls around the periphery and interior of building at the basement level and due to the presence of RCC walls the building becomes very stiff at the basement level and hence higher frequency is required for the mass participation. While in case of base isolated the modal mass participation of 100% is achieved in 3rd mode because of the flexibility provided by the bearings.

Table 2 gives the comparison of modal participating mass ratios for fixed base and isolated base building in Y direction.

Table 2Comparison Of Modal Participating Mass Ratio In Y Direction

Comparison of modal participating mass ratio in y dir			
Mode	Fixed Base	High Damping Rubber	
		Basement	Base
1	0.00	0.25	0.15
2	0.64	0.82	0.82
3	0.66	1.00	1.00
4	0.66	1.00	1.00
5	0.77	1.00	1.00
6	0.77	1.00	1.00
7	0.80	1.00	1.00
8	0.81	1.00	1.00
9	0.82	1.00	1.00
10	0.82	1.00	1.00
11	0.99	1.00	1.00
12	0.99	1.00	1.00

In Table 2 the mass participation of 90 % or more is achieved in the 11th mode in Y direction and that is due to the provision of RC walls at the basement level.

In Table 1 and Table 2 we can see that mass participation of 90 % in case of base isolated structure is obtained in the third mode, and so as per IS 1893-2002 Part I we shall consider only first three modes for the response spectrum analysis of the building and hence results for displacement and storey drift for building is plotted for the first three modes respectively.

One other criteria for the effective working of the base isolation system is the reduction in the base shear that we must achieve in X and Y direction.

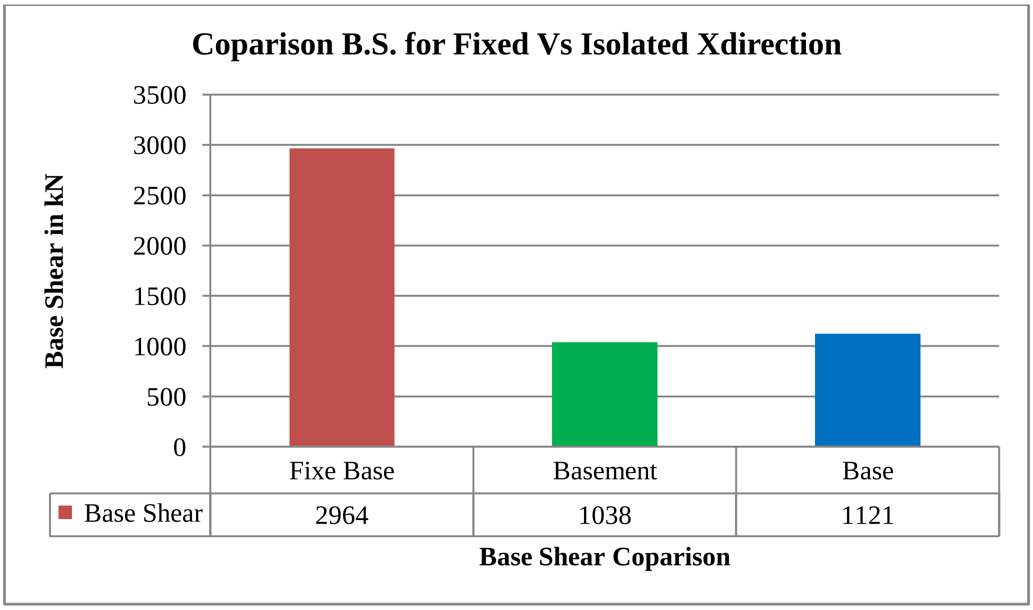


Figure2 Comparison of Base Shear in X Direction

Figure 2 shows the graphical comparison of base shear for a fixed base building with isolated building in X direction. We can see from the graph that the value of base shear for bearings at the base of the building is higher as compared to that of bearings placed at the top of the basement column. Base shear value coming higher in case of fixed base building is due to the rigid body action taking place. Even the percentage reduction of base shear in case of bearings at the top of the basement column is more.

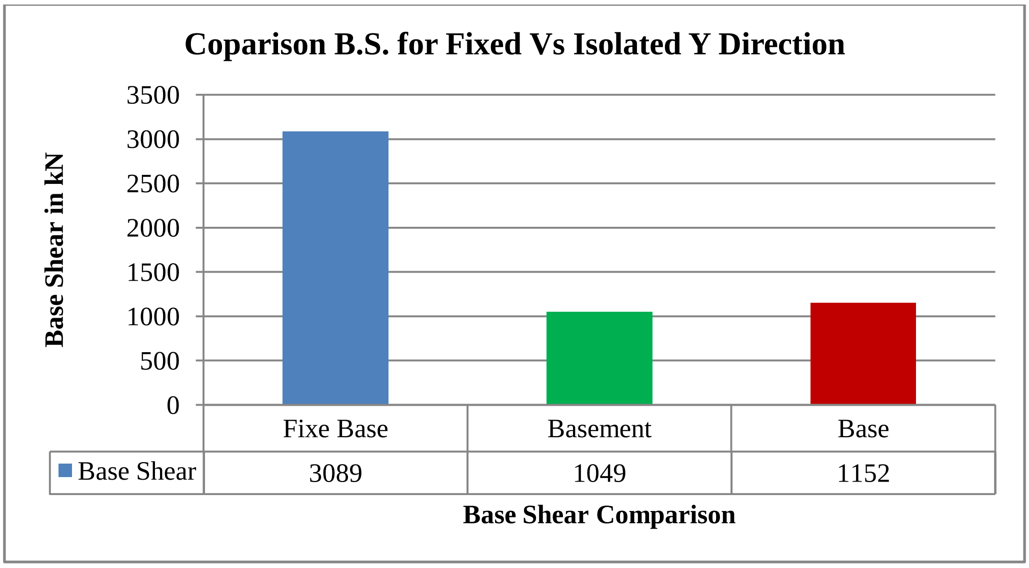
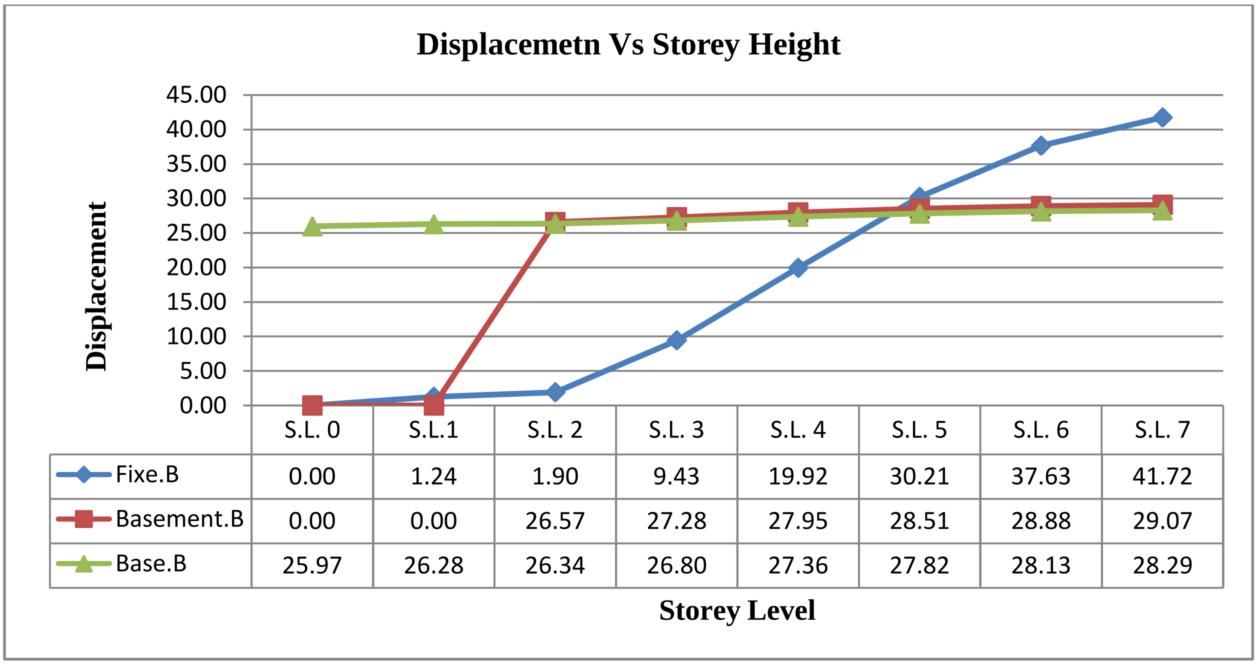


Figure3 Comparison of Base Shear in Y Direction

Figure3 gives the graphical presentation for comparison of base shear of fixed base RCC structure with base isolated structure along Y direction. We can see that almost similar results are obtained for the base shear as compared to that obtained in X direction.

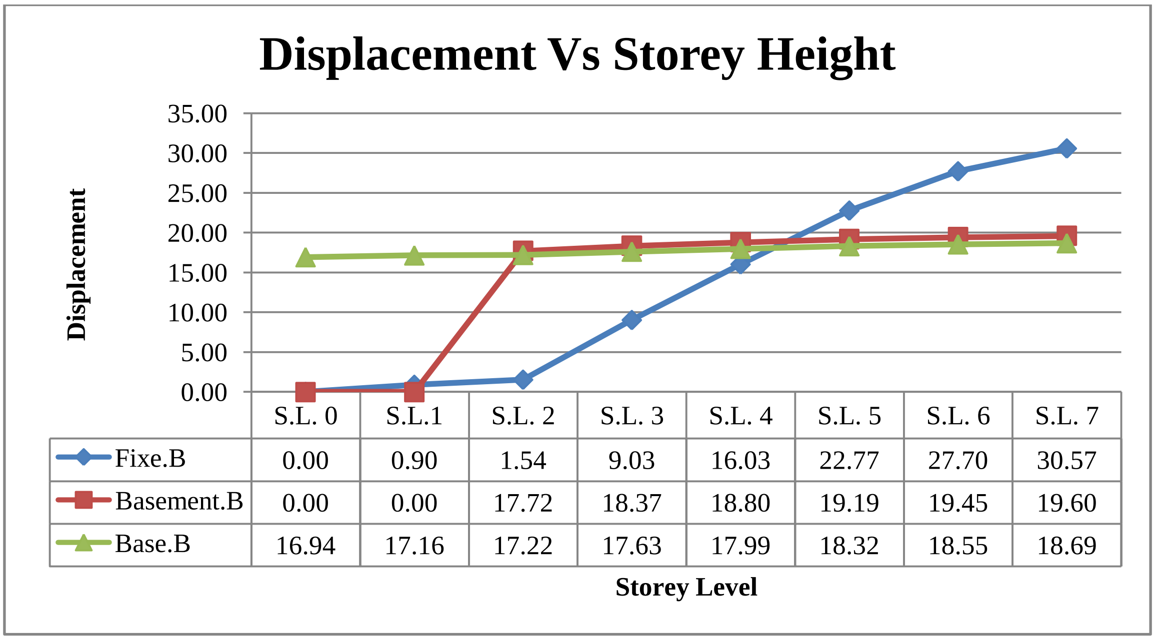
As we move from ground floor to the top floor in case of fixed base building the displacement values changes consistently, while in case of the base isolated building the displacement does not increase very much with the increase in height.



	S.L. 0	S.L.1	S.L. 2	S.L. 3	S.L. 4	S.L. 5	S.L. 6	S.L. 7
Fixe.B	0.00	1.24	1.90	9.43	19.92	30.21	37.63	41.72
Basement.B	0.00	0.00	26.57	27.28	27.95	28.51	28.88	29.07
Base.B	25.97	26.28	26.34	26.80	27.36	27.82	28.13	28.29

Figure4 Graph of Displacement Vs Storey Level for Mode 1 in X Direction

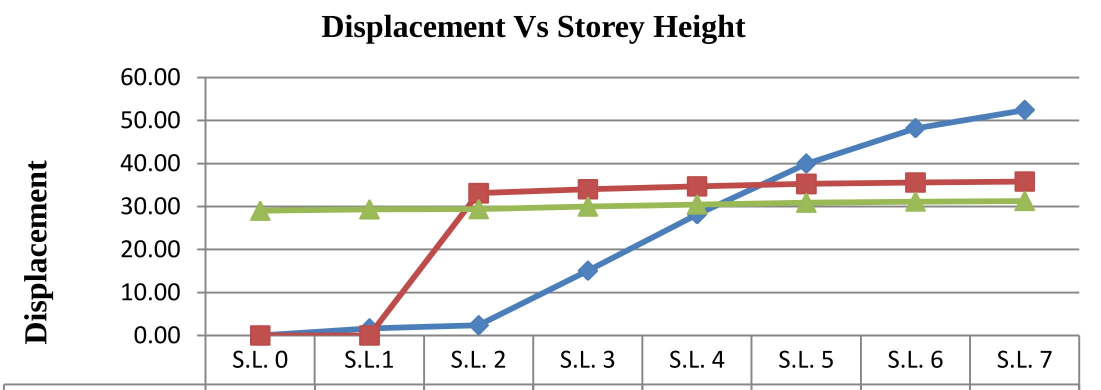
Figure 4 shows the graphical representation of the displacement vs. storey level for column no 1 for mode 1 in X direction. From the graph we can see that the value of displacement for fixed base building varies as the height of the building increases, while for a base isolated building the value of displacement doesn't increase much with the increase in the height of the building.



	S.L. 0	S.L.1	S.L. 2	S.L. 3	S.L. 4	S.L. 5	S.L. 6	S.L. 7
Fixe.B	0.00	0.90	1.54	9.03	16.03	22.77	27.70	30.57
Basement.B	0.00	0.00	17.72	18.37	18.80	19.19	19.45	19.60
Base.B	16.94	17.16	17.22	17.63	17.99	18.32	18.55	18.69

Figure5 Graph of Displacement Vs Storey Level for Mode 2 in Y Direction

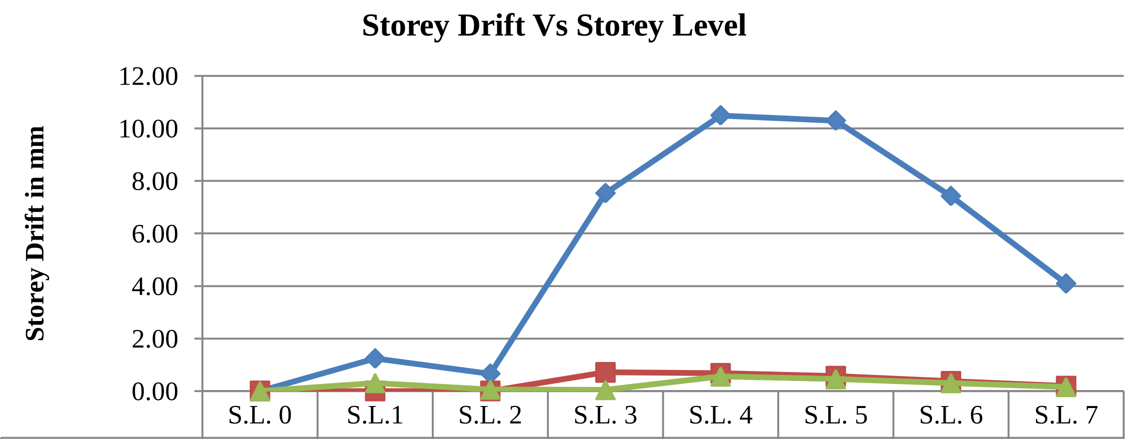
Figure 5 shows the graphical representation of the displacement vs. storey level for column no 1 for mode 2 in Y direction. We can see that even in the Y direction value of displacement for fixed base building varies as the height of the building increases, while for a base isolated building the value of displacement doesn't increase much with the increase in the height of the building. Hence similar results are obtained as in X direction for building with isolators.



	S.L. 0	S.L.1	S.L. 2	S.L. 3	S.L. 4	S.L. 5	S.L. 6	S.L. 7
Fixe.B	0.00	1.63	2.36	15.03	28.17	39.94	48.17	52.41
Basement.B	0.00	0.00	33.08	34.03	34.70	35.24	35.59	35.78
Base.B	29.00	29.32	29.37	29.97	30.47	30.87	31.14	31.28

Figure 6 Graph of Displacement Vs Storey Level for Mode 3 in Y Direction

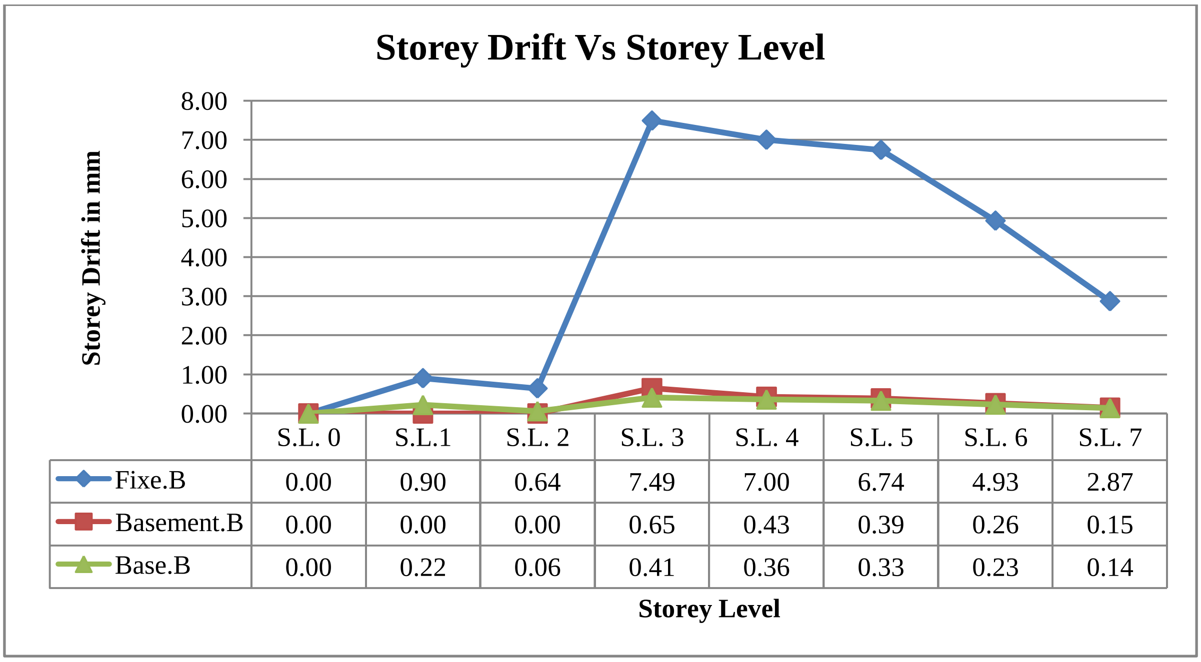
Figure 6 gives the graphical presentation of displacement vs. displacement for column no 1 for mode 3.One of the main criteria for effective working of the base isolation is the reduction in the storey drift. This will directly reduce the storey acceleration and hence the damage is reduced.



	S.L. 0	S.L.1	S.L. 2	S.L. 3	S.L. 4	S.L. 5	S.L. 6	S.L. 7
Fixe.B	0.00	1.24	0.66	7.53	10.49	10.29	7.42	4.09
Basement.B	0.00	0.00	0.00	0.71	0.67	0.56	0.37	0.19
Base.B	0.00	0.31	0.06	0.05	0.56	0.46	0.31	0.16

Figure7 Graph of Storey Drift Vs Storey Level for Mode 1 in X Direction

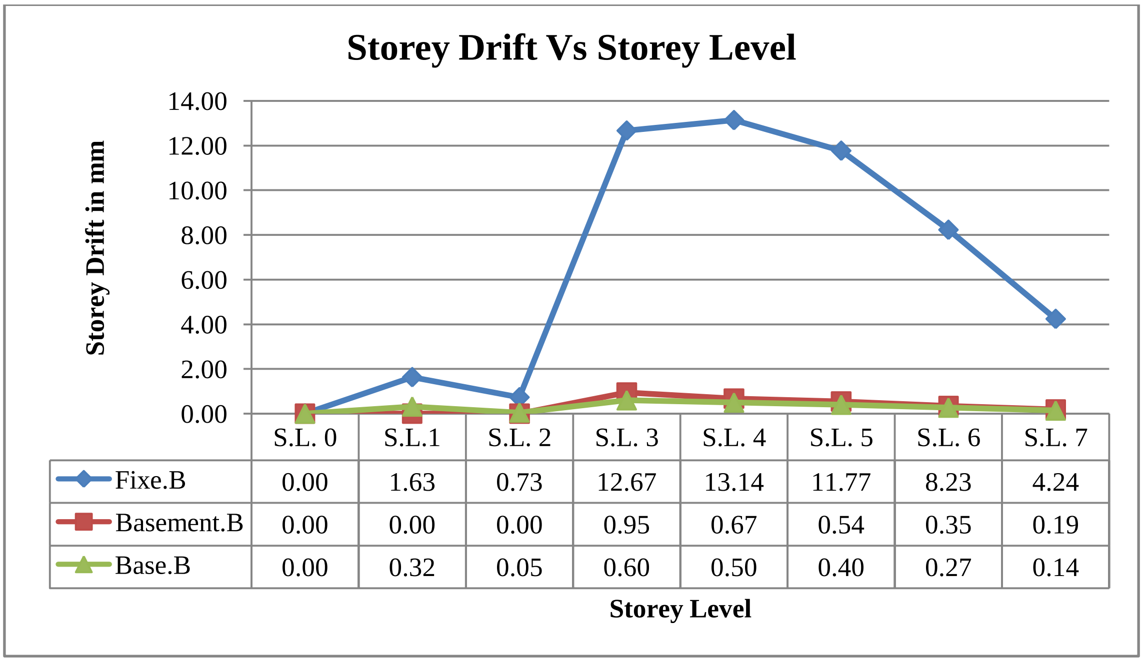
We can see the storey drift is not increase in case of base isolation building vs fixed base building.



	S.L. 0	S.L.1	S.L. 2	S.L. 3	S.L. 4	S.L. 5	S.L. 6	S.L. 7
Fixe.B	0.00	0.90	0.64	7.49	7.00	6.74	4.93	2.87
Basement.B	0.00	0.00	0.00	0.65	0.43	0.39	0.26	0.15
Base.B	0.00	0.22	0.06	0.41	0.36	0.33	0.23	0.14

Figure8 Graph of Displacement Vs Storey Level for Mode 2 in Y Direction

We can see the storey drift in Y direction is increased vs base isolation building.



	S.L. 0	S.L.1	S.L. 2	S.L. 3	S.L. 4	S.L. 5	S.L. 6	S.L. 7
Fixe.B	0.00	1.63	0.73	12.67	13.14	11.77	8.23	4.24
Basement.B	0.00	0.00	0.00	0.95	0.67	0.54	0.35	0.19
Base.B	0.00	0.32	0.05	0.60	0.50	0.40	0.27	0.14

Figure9 Graph of Displacement Vs Storey Level for Mode 3 in Y Direction

We can see the storey drift in Y direction is increased vs base isolation building.

IV. CONCLUSIONS

The primary aim of this work is to develop a 3D model that accounts for the essential dynamic behavior of a base-isolated building and allows predictions to be made of the isolation performance against ground-borne vibration. To achieve this aim, a number of specific objectives were set. These are now reviewed and consideration is given to the extent to which they have been met.

A 3D frame was modeled using SAP2000 with fixed base and base-isolated conditions. From the results presented in above parts of this topic, the following conclusions have been drawn.

After detailed study of work, following conclusions were made.

• The fundamental time period of base isolated structure is increased by almost 4 times as compared to that of a fixed base building.

• The base shear in X direction for High damping rubber bearings located at the top of the basement column was reduced by 65 %.
• Displacement obtained at the base of the building in mode 1 for HDR located at the base is 25.97 mm, while no displacement was obtained at the base in fixed condition.
• Storey drifts at the 4th level in mode 1 for LRB located at the base of the building was reduced to 0.53 mm from 10.49 mm.
Thus, Base isolation achieves the reduction in earthquake forces along with shift in the modal time period and decrease in the storey drift.

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