Base Control Of High Rise Buildings Using Fixed Isolators

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ABSTRACT:

Seismic isolation is counted among the most popular and effective means of protecting structures against earthquake forces. Base isolators, like Lead-Rubber Bearings (LRB), High-Damping Rubber Bearings (HDB) or Friction Pendulum Systems (FPS) are extensively used in practice in many earthquake-prone regions of the world. The present paper reports the results obtained from the numerical study on seismic response of a base-isolated 10 storey,20 storey & 30 storey building modeled with 4-node shell elements. The investigation aims to determine effectiveness of the Base Isolators in suppressing structural vibrations. The seismic response of the analyzed building, both fixed-base and base-isolated under the 2001 Bhuj earthquake was studied. The reduction in lateral response was measured by comparing the displacements and peak accelerations of both structures. The preliminary results of the study indicate that application of the Rubber Base isolators leads to a significant improvement of dynamic performance of the analyzed building during seismic excitations.

In the present case study a Building Structure of different storey levels that is 10 storey, 20 storey & 30storey buildings are analysed with fixed base and isolated base that is the base with base isolators

Results are compared in the form of Storey displacements, Storey Shear, Storey Over turning Moments with & without Base isolators in both Static and Dynamic Analysis. Also the Zone wise results & Storey wise results are compared using tables & graph to find out the most optimized solution.

IndexTerms:seismic isolation,damping,isolators

I.INTRODUCTION

The conventional approach to seismic-resistant design is to incorporate adequate strength, stiffness and inelastic deformation capacity into the building structure so that it can withstand induced inertia forces. This was with the presumption that during strong ground motion, whenever inertia forces exceed their design earth-quake levels, the structure will dissipate this excess energy through deformations at predefined locations scattered over the structural framework. It was observed that, even with members designed for ductility, the structures did not always perform as desired, which could be because of reasons such as:

• Strong-column weak-beam mechanism failed to develop as a result of stiffening effect of walls being present

• Creation of short columns because of changes in wall layout, introduced later

• Poor concreting at joints due to reinforcement congestion On experiencing failures during earthquakes, it was realized that a design based only on the principle of incorporating ductility as a safeguard against seismic effects needs a critical review. In their search for alternative design strategies to minimize magnitude of inertia forces, engineers came up with the innovative idea ofintroducing a flexible medium between supporting ground and the building, thereby decoupling the structure from energyrich components of seismic ground motion. This strategy came to be known as the base isolation method. This chapter covers a brief history of base isolation as well as basic concepts of such a system together with its principle benefits and limitations. Also described are the prevailing approaches for design of structures supported on both the elastomeric and sliding isolators. The purpose herein is to acquaint the reader with some of the principal facets of design of isolator supported buildings. The methodology of design is elaborated through illustrative examples. It should be recognized that the design and implementation of an isolator system is highly complex and calls for considerable practical experience and expertise.

1.1 CONCEPT OF BASE ISOLATORS

To diminish vulnerability of a building to damage during an earthquake, base isolation has emerged as a viable structural option. It is a sophisticated practical solution to improve seismic response of a building by minimizing the structural damage, which was earlier taken to be unavoidable during strong ground motion. Because of the low horizontal stiffness of this deformable medium, it alters the fundamental period of a stiff structure such that it is significantly higher than that of the high energy imparting ground motions. As a result, for its fundamental mode of vibration, the superstructure is subjected to much lower inertia forces with consequent reduction (Fig. 10.1) in base shear. On the flip side. if the founding stratum is soft, then there is a distinct possibility of the enhanced period due to base isolation being close to the period where an earthquake is likely to have considerable energy. Such a situation can lead to an increase in the response. Thus, it can be said that base isolation is best suited for buildings with a high natural fundamental frequency (T less than about I s) and preferably those supported on rock or stiff soils. Reinforced concrete moment (rained buildings up to about 8-10 storeys and those with shear walls up to 12-15 storeys are said to be ideal candidates for base isolation (Naeim 2001). If a framed structure were supported on hard strata, it would deform as in Fig. 10.2a. However, when supported on isolators, the lateral displacement in the first mode is concentrated at isolator level while the superstructure behaves almost like a rigid body (Fig. 10.2b). As a result, for buildings supported on base isolators, there is less need to provide ductile energy dissipating regions (e.g. near beam-column joints) as in conventional fixed based structures. However, in view of limited experience of such systems and as a matter of abundant precaution, codes recommend retention of the present form of ductile detailing. This is also to obviate possible brittle failure under a maximum credible earthquake (MCE) in the region or earthquakes with long period energy inputs. In addition, codes also call for rigorous testing of the proposed isolators and peer review of the design, since it is an emerging technology and failure of an isolator system could prove catastrophic.

Isolators should be located such that there is ample access to them for mainte-nance, repair and replacement, if necessary. A full diaphragm should be employed to distribute lateral loads as uniformly as possible to the isolators. Generally, isolators can be placed at the bottom of columns at basement slab level. This location has the advantage that no special treatment is required for elevator or service lines as they traverse the bearing level. On the other hand, if they are placed at top of basement, then elevator shaft and internal staircase and cladding details may require special treatment below first floor level. Isolators do substantially enhance the fundamental period of a stiff structure but at the expense of increased building displacements. The first mode deformation occurs at the isolation level only. The real challenge while designing a base isolated structure is the need to control displacements during a major earthquake while maintaining good performance for moderate level earthquakes. Since the superstructure will function essentially as linearly elastic, the structural framework is expected to remain undamaged even during a moderate-level earthquake.

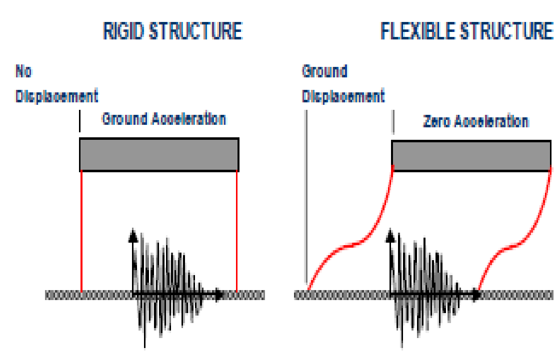
1.2 PASSIVE BASE ISOLATOR

Base isolation is a passive control technique against lateral vibrations. As discussed earlier, an isolation system should be able to support gravity loads (including those due to vertical seismic acceleration), be sufficiently stiff to minimize displacements under repeated small magnitude lateral loads such as those due to wind, be highly flexible to absorb the energy during strong motion earthquakes and possess capability to self-centre after an earthquake event. Passive isolators that meet these requirements are preferred. Quite clearly, this means that the isolator should possess non-linear stiffness characteristics. It should also possess adequate damping characteristics to assist dissipation of seismic energy and not have excessive lateral displacement across the isolator interface.

The successful base isolation of a building depends on the installation of mechanisms Which decouple the structure from potentially damaging earthquake-induced ground motions. Therefore, it is very important to have an adequate understanding of the influence of each parameter in the isolation system and the superstructure on the seismic performance of the base isolated buildings. The primary function of an isolation device is to support the super structure while providing a high degree of horizontal flexibility. This gives the overall structure a long effective period and hence lower earthquake generated accelerations and inertia forces. Many kinds of isolation systems have been developed to achieve this function, such as laminated elastomeric rubber bearings, lead-rubber bearings, yielding steel devices, friction devices (PTFE sliding bearings) and lead extrusion devices, etc ..

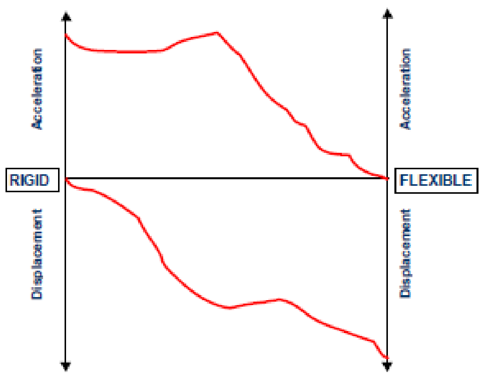
II. BASE ISOLATION:

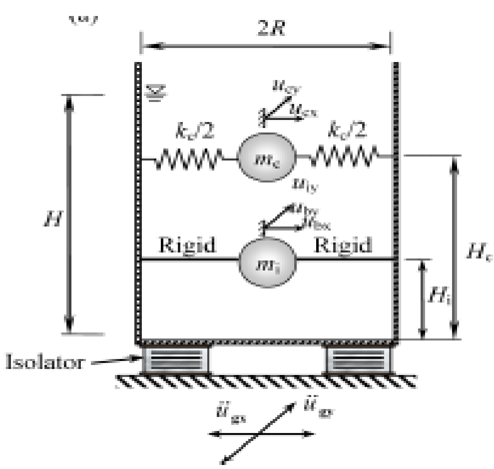
The fundamental principle of base isolation is to modify the response of the building so that the ground can move below the building without transmitting these motions into the building. In an
ideal system this separation would be total. In the real world, there needs to be some contact between the structure and the ground.
A building that is perfectly rigid will have a zero period. When the ground moves the acceleration induced in the structure will be equal to the ground acceleration and there will be zero relative displacement between the structure and the ground. The structure and ground move the same amount.
A building that is perfectly flexible will have an infinite period. For this type of structure, when the ground beneath the structure moves there will be zero acceleration induced in the structure and the relative displacement between the structure and ground will be equal to the ground displacement. The structure will not move, the ground will.

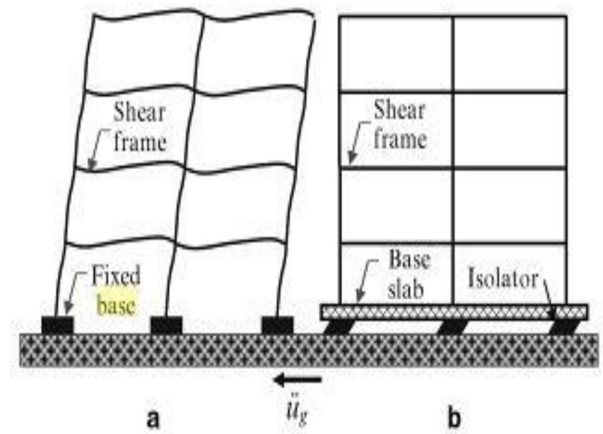


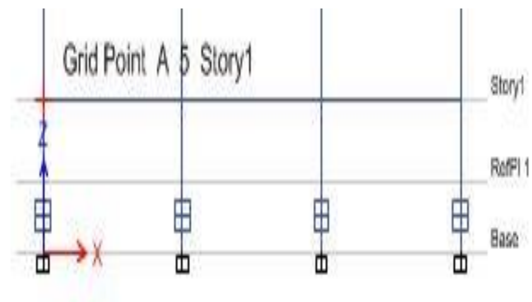
All real structures are neither perfectly rigid nor perfectly flexible and so the response to ground motions is between these two extremes, as shown in fig. For periods between zero and infinity, the maximum accelerations and displacements relative to the ground are a function of the earthquake, as shown conceptually.

For most earthquakes there be a range of periods at which the acceleration in the structure will be amplified beyond the maximum ground acceleration. The relative displacements will generally not exceed the peak ground displacement, that is the infinite period displacement, but there are some exceptions to this, particularly for soft soil sites and site which are located close to the fault generating the earthquake.

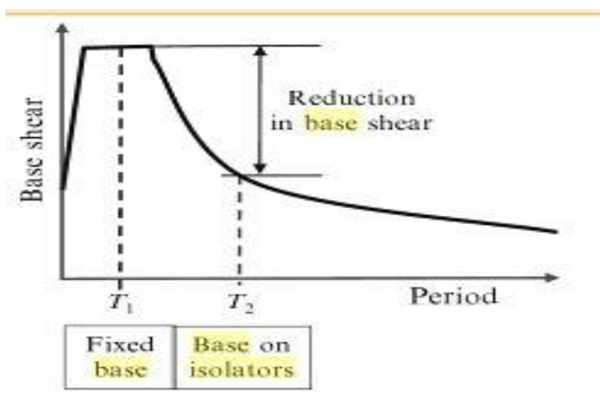








BASE ISOLATORS PLACED IN A BUILDING MODEL



III MATERIAL PROPERTIES

3.1 Loads

1. Live load

Live load from 1st floor to 14th floor = 3 kN/m^2

Live load on 14th floor
= 1.5 kN/m^2

2. Dead load

Dead load is taken as prescribe by the IS: 875 -1987 Code of Practice Design Loads (other than earthquake) for Buildings and structure.

Unit weight of R.C.C= 25 kN/m^3
Unit weight of brick masonry=19 kN/m^3

Floor finish= 1.5 kN/m^2
Water proofing=2 kN/m² on terrace roof
Wall load = 13.8 kN/m on all floors
expect terrace Roof =6.9 kN/m on terrace roof

3.Wind load

The basic wind speed (V_b) for any site shall be obtained from IS 875 it is 44 m/sec and shall be modified to include the following effects to get design wind velocity at any height (V_z) for the chosen the structure.

Risk level Terrain roughness, height and size of structure, and Local topography It can be mathematically expressed as follows:

Vz = Vb K1.K2.K3

Where,

Vz = design wind speed at any height **z** in m/s

K1 =probability factor (risk coefficient)

K2 = terrain, height and structure size factor

K3 = topography factor

Wind Exposure parameters
Wind direction angle = 0 Degree
Windward coff. Cp = 0.8
Leeward coff Cp = 0.5
Wind coefficients
Wind speed = 39 m/s
Terrain category = 4
Structure class = C
Risk coefficient (k1) = 1
Topography (k3) = 1

3.Seismic loading

In the present work the building is located in Hyderabad which comes under –zone-II, using the IS 1893 (Part-I) – 2002(1) the following are the various values for the building considered.

a. Zone factor (Z):

It is a factor to obtain the design spectrum depending on (lie perceived maximum seismic risk characterized by Maximum considered Earthquake (MCE) in the zone in which the structure is located. The basic zone factors included in this standard are reasonable estimate of effective peak ground acceleration.

Zone factor = 0.36 (Zone-V)

b.Response reduction factor I:

It is the factor by which the actual base-shear force that would be generated if the structure were to remain elastic during its response to the Design Basis Earthquake (DBE) shaking, shall by reduced to obtain the design lateral force.

Response reduction factor = 5.0

Importance factor (I):

It is a factor used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of post-earthquake functional need, historical value, or economic importance.

Importance factor (1) = 1 Soil type:

Soil site factor (1 for hard soil, 2 for medium soil, and 3 for soft soil) depending on type of soil average response acceleration coefficient Sa/g is calculated corresponding to 5% damping Refer Clause 6.4.5 of IS 1893-2002. In the present work three type of soil are used.

Soil type considered is medium soil, factor 2.

b. Damping:

The effect of internal friction, imperfect elasticity of material, slipping, sliding etc in reducing the amplitude of vibration and is expressed as a percentage critical damping.

Damping – 5%

3.2 Material properties:

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the condition of curing and age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive strength of concrete.

The modulus of elasticity of reinforced concrete members can be assumed as

$$E = 5000\sqrt{fck}$$

Where,

E = Short term static modulus of elasticity in **kN**/m^2

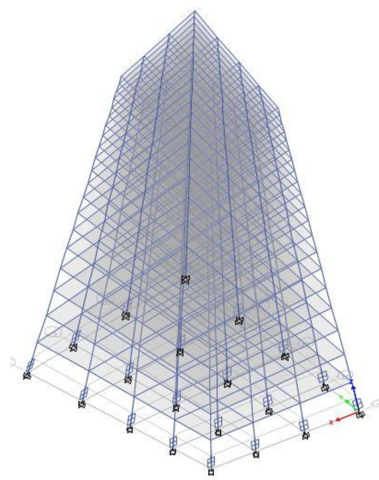
f_{ck} = Characteristic cube compressive strength of concrete in N/mm^2

The modulus of elasticity of reinforced concrete members for M40 grade concrete is

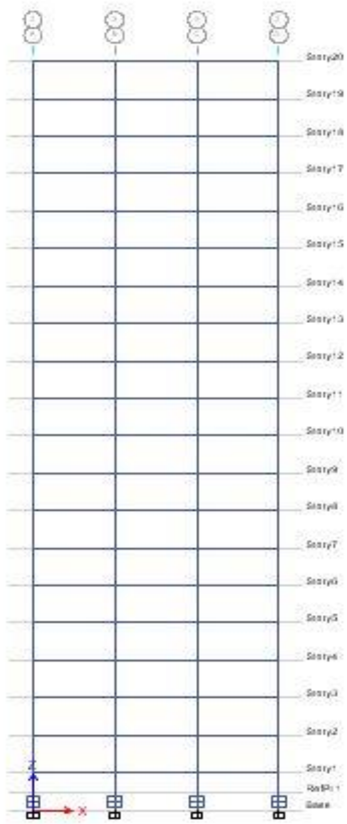
E= 27386127 **kN**/m^2.

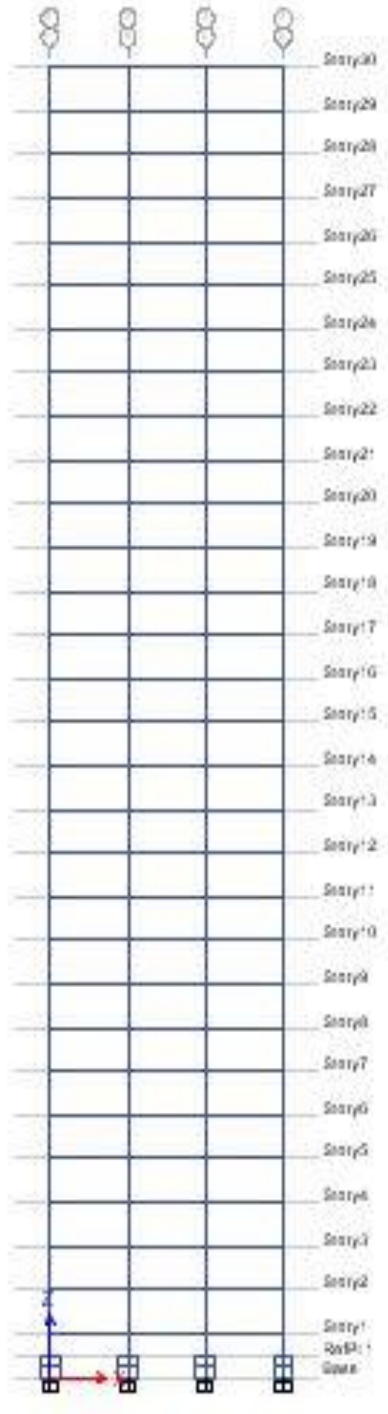
Poisson's Ratio:

Poisson's ratio is the ratio between lateral strains to the longitudinal strain. It is generally denoted by the letters for normal concrete the value of Poisson's ratio lies in the range of 0.15 to 0.20 when actually determined from strain measurement. For the present work Poisson's ratio is assumed as 0.2 for reinforced concrete.



3D MODEL OF BUILDING WITH BASE ISOLATORS





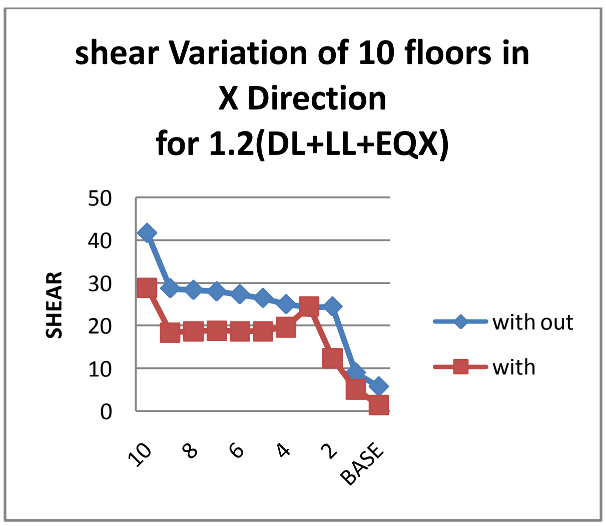
ELEVATION MODELS OF 10,20 & 30 STOREY BUINDING WITH BASE ISOLATORS

IV. RESULTS

Shear comparison along X & Y direction

Table 4.1 Showing shear values of 10 floors in x Direction

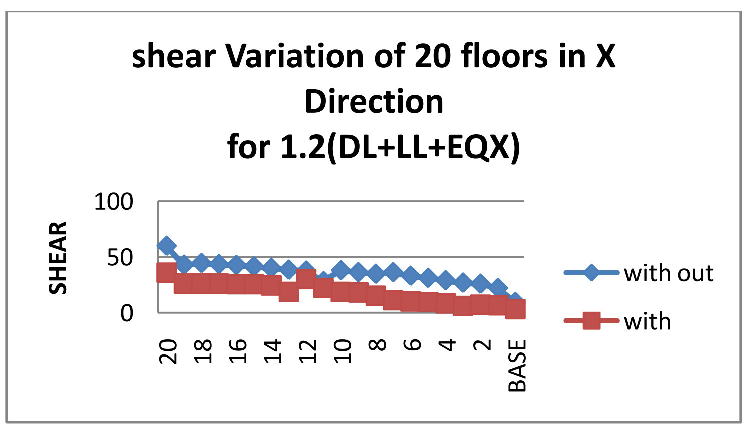
storey	with out	with
10	41.71	28.91
9	28.77	18.441
8	28.38	18.8
7	28.04	18.85
6	27.36	18.71
5	26.5	18.76
4	25.05	19.73
3	24.3	24.544
2	24.52	12.43
1	9.08	5.2
BASE	5.82	1.56



Graph 4.1 Showing shear variation for 10 floor building in X direction

Table 4.2 Showing shear values of 20 floors in x Direction

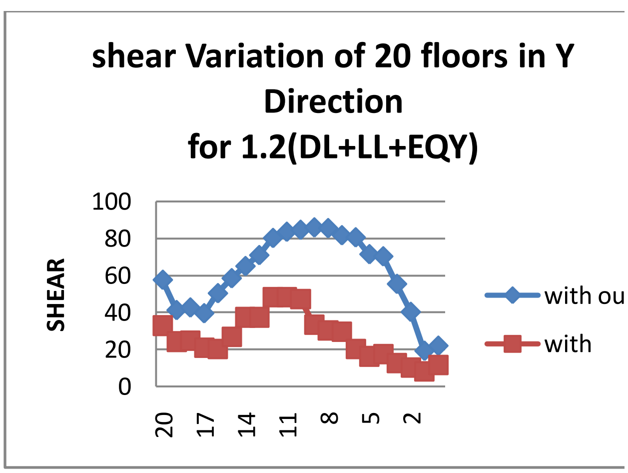
storey	with out	with
20	59.92	36.16
19	42.93	26.29
18	44.48	26.5
17	43.488	26.31
16	42.723	25.87
15	41.45	25.92
14	40.15	24.8
13	38.47	19.02
12	37.63	30.2
11	28.24	22.1
10	37.99	19.01
9	36.32	18.2
8	34.85	15.2
7	36.32	11.55
6	33.09	10.23
5	31.16	9.52
4	29.11	8.52
3	26.92	6.2
2	25.93	7.52
1	22.15	6.52
BASE	9.52	3.21



Graph 4.2 Showing shear variation for 20 floor building in X direction

Table 4.3 Showing shear values of 20 floors in y Direction

storey	with out	with
20	57.57	32.83
19	41.22	24.24
18	42.63	24.75
17	39.53	20.88
16	50.35	20.26
15	58.43	26.86
14	64.97	37.33
13	70.9	37.32
12	80.15	48.144
11	83.51	48.14
10	84.56	47.04
9	85.86	33.25
8	85.47	30.25
7	81.63	29.5
6	80.5	20.18
5	71.4	16.25
4	70.25	17.52
3	55.36	12.55
2	40.26	10.2
1	19.26	8.2
BASE	22.01	11.56

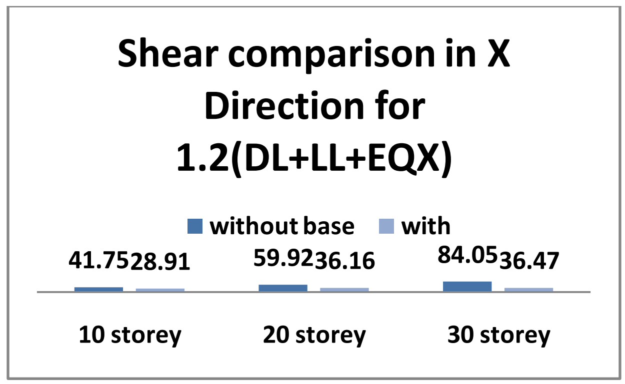


Graph 4.3 Showing shear variation for 20 floor building in y direction

Comparison graphs of Shear in Both directions direction

Table 4.4 Showing shear comparison values in x Direction

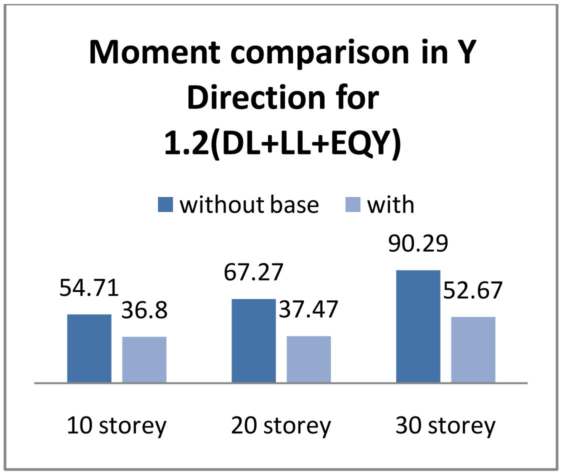
storey	without base	with
10 storey	41.75	28.91
20 storey	59.92	36.16
30 storey	84.05	36.47



Graph 4.4 Showing displacement variation for building in X direction

Table 4.5 Showing moment comparison values in x Direction

storey	without base	with
10 storey	54.71	36.8
20 storey	67.27	37.47
30 storey	90.29	52.67



Graph 4.5 Showing displacement variation for building in X direction

V.CONCLUSION

From analytical results, it is observed that base isolation technique is very significant in order to reduce the seismic response of both symmetric as well as asymmetric models as compared to fixed base building and control the damages in building during strong ground shaking. By comparing the dynamic properties of buildings following conclusions are made:

1. It has been observed that maximum Storey displacement was decreased of about 40% by providing Base Isolators, the displacement gradually decreases for top storey of base isolated building as compared with fixed base building model.

2. It has been observed that maximum Storey Shears and Base Shear was decreased of about 50% by providing Base Isolators, the Shear gradually decreases for top to bottom storey of base isolated building as compared with fixed base building model.

3. It has been observed that maximum Moment and Base Moment was decreased of about 50% by providing Base Isolators, the Moment gradually decreases for top to bottom storey of base isolated building as compared with fixed base building model.

4. From analytical study, it is observed that for both models of symmetric as well as asymmetric, fixed base building have zero displacement at base of building whereas, base isolated building models shows appreciable amount of lateral displacements at base. Also it has been observed that as floor height increases, lateral displacements increases drastically in fixed base building as compare to base isolated building. Due to this reduction in lateral displacement during earthquake damages of structural as well as non structural is minimized.

3. It is observed that for fixed base building have zero storey acceleration at base of building whereas, in case of base isolated building model appreciable amount of storey acceleration has been found out at base. Also it has been observed that as floor height increases, storey acceleration increases drastically in fixed base building as compared to base isolated building where it is almost constant.

4. From the study of symmetric building models it can be concluded that Shear force, Bending moment, Storey Displacement symmetric building model. Therefore it is concluded that symmetrical building with base isolation remains strong enough during earthquake.

5. In both of the models fixed base and base isolated there is reduction in bending moment. Thus it will require less reinforcement. Therefore cost is reduced considerably.

6. Finally it is concluded that base isolation system is significantly effective to protect the structures against moderate as well as strong earthquake ground motion.

VI.REFERENCES

[1] Kilar V. And Koren D., "Usage Of Simplified N2 Method For Analysis Of Base Isolated Structures," The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.

[2] Saiful Islam A. B. M., Jameel M., Ahmad S.I. And Jumaat

M. Z., "Study On Corollary of Seismic Base Isolation System On Buildings With Soft Storey," International Journal of the Physical Sciences Vol. 6(11), pp. 2654-2661, 4 June, 2011 ISSN1992-1950 ©2011 Academic Journals.

[3] Di Sarno, L., Cosenza, E.and Pecce, M.R., "Application Of
Base Isolation To A Large Hospital In Naples,
th

Italy,"10 World Conference on Seismic Isolation, Energy Dissipation and active Vibrations Control of Structures, Istanbul, Turkey, May 27-30, 2007.

[5] Nakashima M.,Chusilp P., "A Partial View of Japanese Post-Kobe Seismic Design and Construction Practices",Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto 611-0011, Japan.

[6] Ramallo J. C.,Johnson E. A.,Spencer B.F., Jr.,And Sain M.K,

"Semiactive Building Base Isolation", The 1999 American Control Conference, San Diego, California, June 2–4, 1999.

[7] Ramallo J. C.; Johnson E. A., A. M. Asce; and B. F. Spencer
Jr., M.Asce, "Smart Base Isolation Systems",

10.1061/ASCE/0733-9399/2002/128:10/1088.

[8] A. Jalali1 and P. Narjabadifam, "Optimum Modal Characteristics for Multi-Story Buildings Isolated with Lead rubber bearings", 4th International Conference on Earthquake Engineering, Taipei, Taiwan, October 12-13, 2006, Paper No. 187.

[9] Wen P. And Baifeng S., "Two Step Design Method For Base Isolation Structures", The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.

[10] Pradeep Kumar T. V. And D. K. Paul, "Force-Deformation

Behavior of Isolation Bearings", 10.1061/ASCE/1084-0702/2007/12:4/527.

[11] Indian Standard Criteria for Earthquake Resistant Design Structure 1839-2002

[12] Shrikhande M. and Agrawal P., "Earthquake Resistant Design structure", Tata McGra Hill Publication, 10th Edition 2004.

[13] Duggle S.K., "Earthquake Resistant Design Structure", Tata
McGra Hill Publication, 10th Edition 2004.

[14] Zanaica L., "Design of Storey-Isolation System in Multi-
Storey Building" MEEES programmed, May,2007.

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