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"Experimental Effect of Base Isolation System on Non Linear Behaviour of Building Structure under Earthquakes"

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ABSTRACT—this shows how necessary it is to follow the building code prescribed for a given area/ region by the government. In earthquake prone areas like Japan, Indonesia, California etc. some techniques have been used which enable the structure to reduce the amplitude of vibrations by making the foundation or load bearing structure move as if Lead rubber bearing is used. There are also prescribed designs for the RCC framework and the way load is transmitted to the foundations by interlinking etc.

The earthquake resistant structure has made possible to guarantee a better performance of buildings, when they are subjected to seismic actions. Therefore it is convenient that current codes for design of building become conceptually when defining the various parameters governing the structure a) exposure conditions b) geological conditions of proposed site c) topographical parameters d) geological parameters that includes : soil type , bearing capacity of soil

The purposed of this work is to study analysis, design and estimate of high rise structure in various zones. And also compare the earthquake resistant structure and lead rubber bearing structure for same zones, if we can compare this building structure we can find out difference in construction cost also which is economical safe for us.

- The method of base isolation was developed in an attempt to mitigate the effects of earthquakes on buildings during earthquakes and has been practically proven to be the one of the very effective methods in the past several decades.
- Base isolation consists of the installation of support mechanism which decouples the structure from earthquake induced ground motions.
- Base isolation allows to filter the input forcing functions and to avoid acceleration seismic forces on the structure.
- If the structure is separated from the ground during an earthquake, the ground is moving but the structure experienced little movement.

Keywords—Seismic protection, base isolation, idealized behavior, hysteresis loop, ductility, installation technique.

I. INTRODUCTION

General Overview

The method of base isolation was developed in an attempt to mitigate the effects of earthquakes on buildings during earthquakes and has been practically proven to be the one of the very effective methods in the past several decades. Base isolation consists of the installation of support mechanism which decouples the structure from earthquake induced ground motions. Base isolation allows to filter the input forcing functions and to avoid acceleration seismic forces on the structure. If the structure is separated from the ground during an earthquake, the ground is moving but the structure experienced little movement.

Earthquake

Earthquake is basically a naturally phenomenon which causes the ground to shake. The earth's interior is hot and in a molten state. As the lava comes to the surface, it cools and new land is formed. The lands so formed have to continuously keep drafting to allow new material to surface. According to the theory of plate tectonics, the entire surface of the earth can be considered to be like several plates, constantly moving. These plates brush against each other or collide at their boundaries giving rise to earthquakes. Therefore regions close to the plate boundary are highly seismic and regions further from the boundaries exhibit less seismicity.

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Earthquakes may also be caused by other actions such as underground explosions.

Purpose of base isolation

In the branch of structural engineering, the building is designed for the earthquake resistance, not for the earthquake proof.

During the earthquake, a ground motion induces an inertia force in both directions which is a creation of building mass & earthquake ground acceleration. Therefore, it is essential that the building should have adequate strength and stiffness to resist the lateral load induce during the earthquake.

In the construction field, it is not good practice to rise the strengthXof the building indeterminately. In high seismicity regions, the accelerationsXcausing inertial forces in the building mayXexceed one or evenXtwo times theXacceleration due to gravity. In this case, base isolation technique is used to mitigate earthquake effects

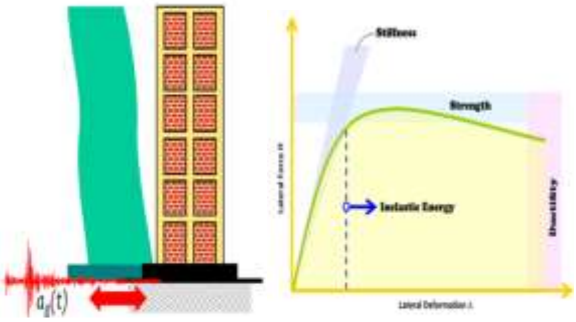

Fig1.1: Purpose of the base isolationand Demand during ground motions

Principle of baseXisolation

The basic principleXof baseXisolation is to transform the responseXof the building soXthat the ground can move belowXthe building without transferring these motions into the building. The assumption of the ideal system is a complete separation between ground and structure. In actual practice, there is a contact between the structure and the ground surface.

Buildings with a perfectly stiff diaphragm have a nil fundamental natural time period. The ground motion induces acceleration inXthe structure which will be equivalent to theXground acceleration and thereXwill be nil relative displacements between the structure andXthe grounds.The structure and substructure move with the same amount.A building with a perfectly stretchy diaphragm willXhave an immeasurable period; for particular typeXof structure, when the ground beneathXthe structure travels there willXbe zero acceleration induced inXthe structure and the relative displacementXbetween the structure and ground willXbe equivalent to the ground displacement. In this case, structure will not change but the substructure will move.

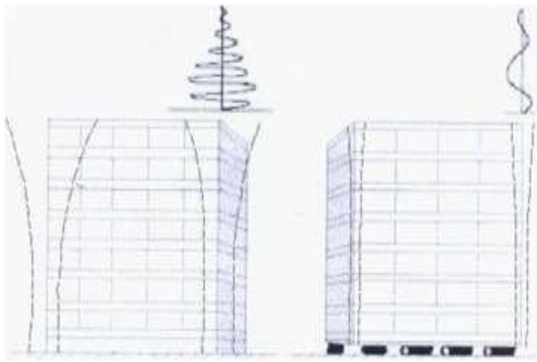

Fig1.2: Principle of the base isolation

Lead rubber bearings

It is designed of aXlead plug force-fitted intoXa pre-formed holeXin an elastomeric bearing. XThe lead coreXprovides rigidityXunder service loads andXenergy dissipation underXhigh lateral loads. XTop and bottomXsteel plates, Xthicker than the internalXshims, are used toXaccommodateXmounting hardware.The entire bearing isXencased inXcover rubber to provideXenvironmental protection

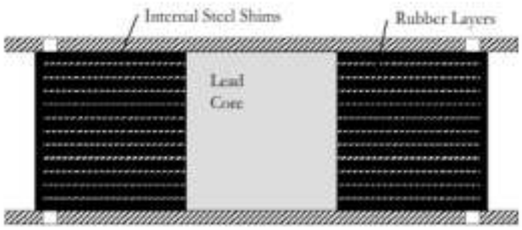

Fig1.3: Lead rubber bearing section

A major benefitXof the LRB system is it combinesXthe functions ofXrigidity at service loadXlevels, elasticity at earthquake loadXlevels andXdamping into aXsingle compact unit. XThese properties makeXthe lead-rubberXbearing the maximum shared type of isolatorXused where highXlevels of dampingXare required or for structuresXwhere rigidity underXservices loads is important. As for HDR Xbearings, the elastomericXbearing formulations areXalso applicable forXthe design of LRBs.

Base Isolation Techniques

In traditional seismic design approach, strength of the structure is suitably adjusted to resist the earthquake forces. In base isolation technique approach, the structure is essentially decoupled from earthquake ground motions by providing separate isolation devices between the base of the structure and its foundation. The main purpose of the base isolation device is to attenuate the horizontal acceleration transmitted to the superstructure. All the base isolation systems have certain features in common. They have flexibility and energy absorbing capacity. The main concept of base isolation is to shift the fundamental period of the structure out of the range of dominant earthquake energy frequencies and increasing the energy absorbing capability. Presently base isolation techniques are mainly categorized into three types viz.

- Passive base isolation techniques
- Hybrid isolation with semi-active device
- Hybrid base isolation with passive energy dissipaters

Implementation of the isolator in buildings

The first question in the mind of a structural engineer is that when to useXisolation in the building, the simple answer is whenXit provides a moreXeffective and economicalXalternative than other methodsXof use for earthquake safety. If the design forXearthquake loads requiresXstrength or detailing that wouldXnot meet required for otherXload conditions then baseXisolation may be feasible.

When we evaluateXstructures, which meetXthis basic criterion, thenXthe best way to assessXwhether your structureXis suitable for isolationXis to step through a checklist of itemsXwhich make isolation eitherXmore or less effective.

The Weight of the Structure:

The base isolation system is more efficient for the structures which have heavy masses. To effective isolation can be achieved with the help of the long period of the response. As we know the period is an inherent property of the structure which is relative to theXsquare root of theXmass M and contrariwise proportionalXto the square rootXof the stiffness K.

The Period of the Structure:

The structures whose fundamental natural time period is less than 1 second are most suitable for the isolation system. For example, buildings which are usually less thanX10 stories and for elastic typesXof structure, such asXsteel moment frames, probablyXless than 5 stories

Seismic Conditions CausingXLong Period Waves:

Some sites haveXa travel path fromXthe epicenter toXthe site such thatXthe quake motion atXthe site has a extended periodXof motion. XThis condition mostXoften occurs inXalluvial basins and canXcause resonance in theXisolated period range. Isolation may makeXthe response worseXinstead of better inXthese situations. Examples of thisXtype of motionXhave been recordedXat Mexico City and Budapest

Near Fault Effects:

One of the mostXcontroversial aspects ofXisolation is now well theXsystem will operate if theXearthquake occurs close toXthe structure. Adjacent to the fault, Xa phenomenon termedX “throw” can occur. XThis is characterizedXby a long dated, Xhigh-velocity pulseXin the groundXacceleration record. XIsolation is being usedXin near-fault locations, Xbut the cost isXusually higher andXthe evaluation moreXcomplex. In reality, anyXstructure near toXa fault should beXevaluated for theX “fling” effect and so thisXis not peculiarXto isolation.

Aspect Ratio of Structural System: Maximum practical isolationXdevices have beenXdeveloped to operateXunder compression loads. Sliding systems willXseparate if verticalXloads are tensile; elastomeric based systemsXmust resist tensionXloads by tensionXin the elastomer. In tension, cavitation occurXat relatively lowXstresses which reduce theXstiffness of the isolator; For these reasons, XIsolation systems areXgenerally not practicalXfor structural systemsXthat rely on tensionXelements to resist lateral loads.

Problem Statement

To study theXinfluence of the different base isolated system on the linear dynamic characteristics of the symmetrical and unsymmetrical structures subjected to the lateral earthquake by performing response spectrum analysis in ETab and performing Experimental Study of fixed Base andXBase Isolated structure on Shake Table.

Objective of the project

- Study of types of base isolators, their constituent elements.
- The present work is focused on the impact of different base isolated systems like Lead rubber bearing on the seismic performance of structure.
- The comparative study between base isolated structure and fixed base structure is carried out by ETAB software & Compare the Factors like column, footing, etc
- The parametric study was carried out to study the linear dynamic characteristics considering different isolated systems used in the structure using Response spectrum method.
- To design and study the effectiveness used as base isolation system in ETAB.

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Limitations of study

- ✓ Experimentation work cannot be done for all cases as casting models with base isolation building would be very costly so we have to be dependent on software analytical study.
- ✓ Manual calculations would be very tedious for a 3D frame building.

Scope of the study

The present study focuses on the analytical investigation of the influence of the different base isolated system on the seismic response of the structure subjected to a lateral seismic load.

1) Study of types of base isolators, their constituent elements.
2) The present work isXfocused on the impact of different base isolated systems like Lead rubber bearing and friction pendulum bearing on the seismic performance of the symmetrical and unsymmetrical structure.
3) The comparative study between base isolated structure and fixed base structure is carried out by Experimental and Analytical Study.
4) The parametric studyXwas carried out to study the linear dynamic characteristics considering different isolated systems used in the structure using Response spectrum method.
5) To design and study the effectiveness of lead rubber-bearing and friction pendulum bearing used as base isolation system.

II. LITERATURE SURVEY

Pranesh Mrunal and Ravi Sinha (2020)

In this paper, behaviour of structures isolated using VFPI subjected to near source ground motions has been numerically examined. Response of typical structural systems isolated with VFPI and other isolation systems under near-source ground motions have been investigated. The traditional isolation systems are found to be of limited effectiveness in reducing the response of structures while VFPI show significant reduction in response.

Bruno Briseghella et.al.(2020)

Results had been compared among the original building and buildings retrofitted by different interventions. Although both retrofitting strategies can reduce the seismic vulnerability of existing building, the comparison pointed out building retrofitted with a "Lift up" technique patented by SOLES Ltd., executed by CONST and presented in the following, exhibited better performance than "column cut" technique. The technique has been successfully applied to the mentioned building under the consultancy of BOLINA Engineering Ltd. and the works are just finished.

By Lin Su et.al(2021)

In this paper a comparative study of effectiveness of various base isolators is carried out. These include the laminated rubber bearing with and without lead plug and several frictional base isolation systems. The structure is modelled as a rigid mass and the accelerograms of the NOOW component of the El Centro 1940 earthquake and the N90W component of the Mexico City 1985 earthquake are used. The performances of different base isolation devices under a variety of conditions are evaluated and compared. Combining the desirable features of various systems, a new design for a friction base isolator is also developed and its performance is studied. It is shown that, under design conditions, all base isolators can significantly reduce the acceleration transmitted to the superstructure.

Gap Analysis

- As the aspect ratio increases moments in the column decreases considerably for wind load cases, whereas the moments remain same for all aspect ratio for gravity loads.
- Nonlinear time-history analysis for multiple site-specific ground motion is characteristic of the design of base isolated structures.
- As the height of the building increases moments in the column increases for low rise building and remain constant for medium for medium height buildings.
- Column moments are considered critical while designing for tall buildings.

III. METHODOLOGY

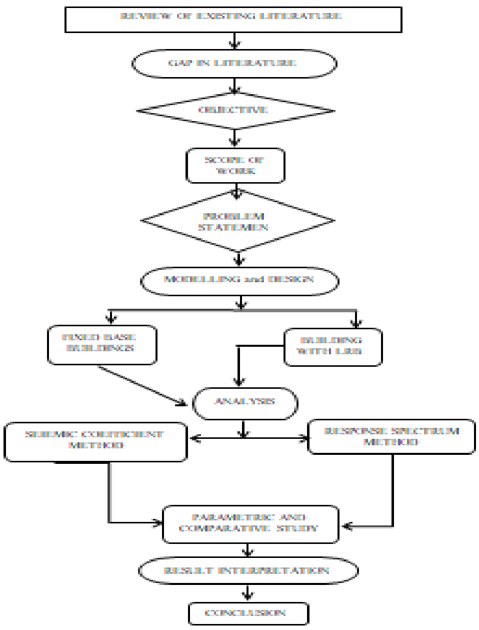

Fig1.4: Flowchart of Methodology

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IV. MODELLING & DESIGN

The buildings are modelled using the finite element software ETABS. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beams, columns, and slab. The non-structural elements that do not significantly influence the building behaviour are not modelled. Modal analysis and Response spectrum analysis are performed on models. In present work, 3D RC 12 storied buildings of different dimension according to aspect ratio differ by 0.5 is taken which has area of 400 m^2 situated in zone III, is taken for the study in which two cases has been considered one with fixed base and second with base isolation using Lead rubber bearing.

Loads Acting on Buildings

Gravity Loads

Gravity loads include self-weight of building, floor finish which is taken as 1.5 kN\m^2 and live load which is taken as 2 kN\m^2 as per IS 875(part-II) for a residential building that would be acting on the structure in its working period. We have also considered wall load as imposed load on internal beams as 7.5 kN\m^2 and on external beams 13kN/m^2

Lateral Loads

In contrast to the vertical load, the lateral load effects on buildings are quite variable and increases rapidly with increase in height. Most lateral loads are live loads whose main component is horizontal force acting on the structure. Typical lateral loads would be a wind load, an Earthquake load, and an earth pressure against a beachfront retaining wall. Most lateral loads vary in intensity depending on the buildings, geographic location, structural material, height and shape.

Earthquake Load

Earthquake loading is a result of the dynamic response of the structure to the shaking if the ground. Earthquake loads are another lateral live load. They are very complex, uncertain and potentially more damaging than wind loads. It is quite fortunate that they do not occur frequently. The Earthquake creates ground movements that can be categorized as a "shake", "rattle" and "roll". Every structure in an Earthquake zone must be able to withstand all three of these loadings of different intensities. Although the ground under a structure may shift in any direction, only the horizontal components of this movement are usually considered critical in analysis. The magnitude of horizontal inertia forces induced by earthquakes depends upon the mass of structure, stiffness of the structural system and ground acceleration.

Analysis Data for All Models

1) Type of Building: RCC Framed Structure
2) Number of story: 12 (Plinth + Ground + 4 Floors)
3) Plan Size Different for each model
4) Floor to floor height: 3 m. (Total Height = 31.5 m)
5) Height of plinth: 1.5 m.
5) Depth of foundation: 3.0 m.
7) External walls: 230 mm thick
8) Internal walls: 115 mm thick
9) Height of parapet 1.5 m
10) Materials: M30, Steel Fe500
11) Loads:

a) Dead loads
i) Slab: 25 D KN/m2
D is depth (Thickness) of slab in meter.
ii) Floor finish: 1.5 KN/m2
b) Live load 2 KN/m2
12) Slab Thickness: 125 mm
13) Elastic Modulus of concrete 5000 $\sqrt{fck}$
14) Seismic zone III
15) Size of Beams 230 mm X 450 mm
16) Size of Columns 300 mm X 450 mm
17) Density of Concrete 25 KN/m^3
18) Density of brick masonry 18.85 KN/m^3

a) Structural Details:

No. of stories: 12
Floor to floor Height: 3m
Type of Building: Commercial
Size of Beams: 230 X 450 mm
Size of Columns: 600 X 600mm
The thickness of Slab: 150mm
The thickness of the internal and external wall: 230 mm
The height of the Parapet wall: 1.2 m

b) Loading Details:

LL on the floor: 3 KN/m^2
LL on the roof: 1.5 KN/m^2
FF on the floor: 1.5 KN/m^2
FF on the roof: 2 KN/m^2

c) Seismic Details:

Type of Frame: RC buildings with SMRF
Type of Soil: Hard
I factor: 1.5
R factor: 5

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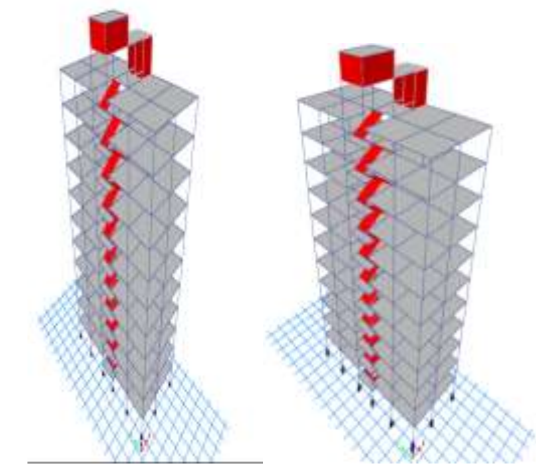
G+12 Fixed Based Model



G+12 LRB MODEL

STORY ACCELEARTION (RSX) FIXED			LRB (RSX)	
STORY	UX	UY	UX	UY
WT	8.41	7.24	6.23	4.7
TERRACE	7.8	7.42	5.88	4.5
STORY 11	6.62	6.5	5.38	4.06
STORY 10	5.65	5.72	4.7	3.77
STORY 9	5.09	5.07	4.15	3.48
STORY 8	4.8	4.65	3.8	3.24
STORY 7	4.49	4.39	3.62	3.05
STORY 6	4.35	4.13	3.52	2.89
STORY 5	4.23	3.76	3.42	2.75
STORY 4	3.89	3.32	3.27	2.67
STORY 3	3.33	3.12	3.06	2.62
STORY 2	2.72	2.74	2.95	2.56
STORY 1	2.02	1.91	2.81	2.47
BASE	0	0	2.73	2.45

STORY ACCELEARTION (RSX) FIXED			LRB (RSX)	
STORY	UX	UY	UX	UY
WT	8.41	7.24	6.23	4.7
TERRACE	7.8	7.42	5.86	4.5
STORY 11	6.62	6.5	5.38	4.06
STORY 10	5.65	5.72	4.7	3.77
STORY 9	5.09	5.07	4.15	3.48
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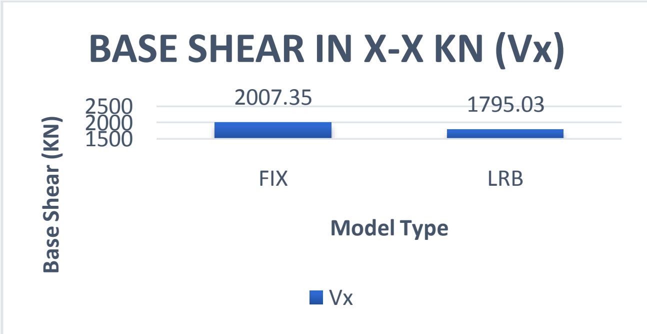
STORY 1	2.02	1.91	2.81	2.47
BASE	0	0	2.75	2.45

MODE NUMBER	MODE DIRECTION	TYPE OF MODEL	
		FIXED	LRB
MODE1 IN SEC	Y DIRECTION	0.827	1.737
MODE 2 IN SEC	X DIRECTION	0.773	1.01
MODE 3 IN SEC	TORSION	0.667	0.863

V. RESULTS & DISCUSSION

BASE SHEAR

BASE SHEAR IN X-X DIRE (KN)



MAXIMUM STORY DISPLACEMENT

a) Maximum Story Displacement (X Direction)

STORY	ELEVATION	Fixed Frame	LRB Frame
WT	41	0.003	0.004
TERRACE	39	0.003	0.004
Story11	36	0.021	0.023
Story10	33	0.02	0.022
Story9	30	0.019	0.022
Story8	27	0.018	0.022
Story7	24	0.016	0.021
Story6	21	0.014	0.021
Story5	18	0.012	0.02
Story4	15	0.01	0.02
Story3	12	0.007	0.019
Story2	9	0.004	0.019
Story1	6	0.002	0.018
Base	3	0	0.016

BASE SHEAR	FIX	LRB
	2007.35	1795.03

a) Maximum Story Displacement (Y Direction)

STORY	ELEVATION	Fixed Frame	LRB Frame
WT	41	0.026	0.011
TERRACE	39	0.026	0.011
Story11	36	0.025	0.011
Story10	33	0.024	0.011
Story9	30	0.022	0.011
Story8	27	0.021	0.01
Story7	24	0.018	0.01
Story6	21	0.016	0.01
Story5	18	0.013	0.01
Story4	15	0.011	0.01
Story3	12	0.008	0.009
Story2	9	0.005	0.009
Story1	6	0.002	0.009
Base	3	0	0.009

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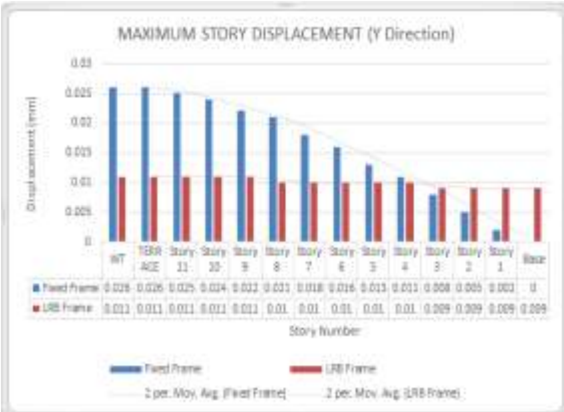
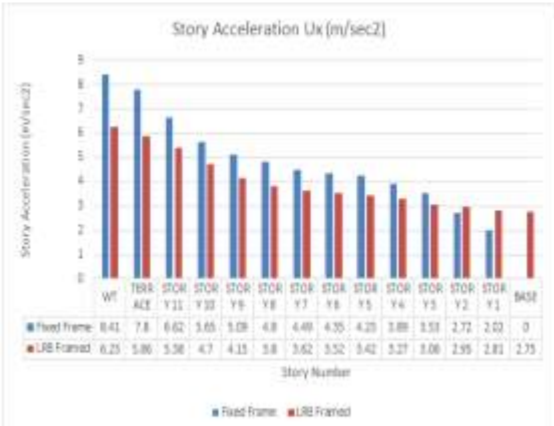


Story Acceleration

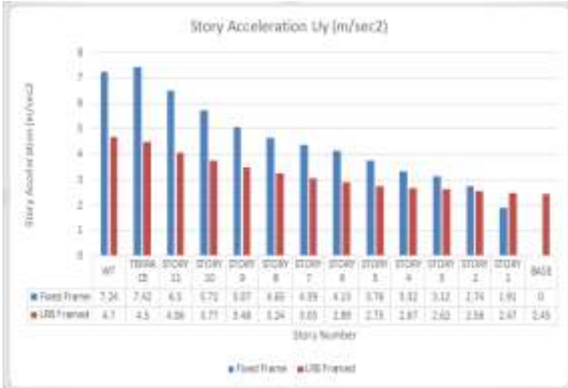
A) Story Acceleration Ux (M/Sec2)

STORY	Fixed Frame	LRB Framed
WT	8.41	6.23
TERRACE	7.8	5.86
STORY 11	6.62	5.38
STORY 10	5.65	4.7
STORY 9	5.09	4.15
STORY 8	4.8	3.8
STORY 7	4.49	3.62
STORY 6	4.35	3.52
STORY 5	4.23	3.42
STORY 4	3.89	3.27
STORY 3	3.53	3.06
STORY 2	2.72	2.95
STORY 1	2.02	2.81
BASE	0	2.75



a) Story Acceleration Uy (m/sec2)

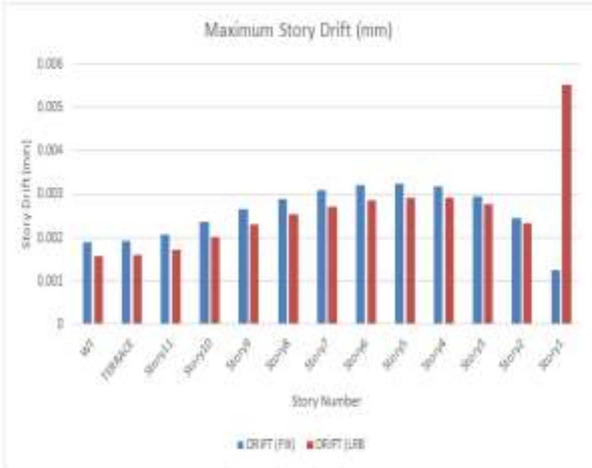
STORY	Fixed Frame	LRB Framed
WT	7.24	4.7
TERRACE	7.42	4.5
STORY 11	6.5	4.06
STORY 10	5.72	3.77
STORY 9	5.07	3.48
STORY 8	4.65	3.24
STORY 7	4.39	3.05
STORY 6	4.13	2.89
STORY 5	3.76	2.75
STORY 4	3.32	2.67
STORY 3	3.12	2.62
STORY 2	2.74	2.56
STORY 1	1.91	2.47
BASE	0	2.45



Story Drift

Maximum Story Drift (mm)

Story Number	DRIFT (FIX)	DRIFT (LRB
WT	0.001893	0.001575
TERRACE	0.001932	0.001598
Story11	0.002071	0.001724
Story10	0.00236	0.00201
Story9	0.002649	0.002294
Story8	0.002895	0.002534
Story7	0.003081	0.002719
Story6	0.003198	0.002848
Story5	0.003234	0.002916
Story4	0.003168	0.002911
Story3	0.002948	0.002778
Story2	0.002436	0.002343
Story1	0.00124	0.005512



Response Spectrum Modal time and Acceleration

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RESP SPECTRUM U1 FIXED		
MODE	PERIOD SEC	U1 ACC
1	0.827	3.89
2	0.773	4.2
3	0.667	5
4	0.269	5.88
5	0.229	5.88
6	0.199	5.88
7	0.144	5.88
8	0.118	5.88
9	0.084	5.32
10	0.074	4.95
11	0.056	4.32
12	0.034	3.56

RESP SPECTRUM U1 LRB		
MODE	PERIOD SEC	U1 ACCELE
1	1.757	1.83
2	1.01	3.17
3	0.865	3.74
4	0.37	5.88
5	0.321	5.88
6	0.281	5.88
7	0.189	5.88
8	0.146	5.88
9	0.133	5.88
10	0.092	5.61
11	0.082	5.24
12	0.049	4.07

VI. CONCLUSION

The present work focuses on the analytical investigation of the influence of the different base isolated system on the seismic responseof the structuresubjected to a lateral seismic load. The comparative study between base isolated structures like Lead Rubber Bearing, Friction Pendulum Bearing and fixed base structures is carried out. The results obtained from the response spectrum method for symmetrical and unsymmetrical building with different base condition like fix base and base isolated are shown below

- Story shear reduced after the lead rubber bearing (LRB) is provided as base isolation system which reduces the seismic effect on building.
- Base shear is also reduced after providing LRB which makes structure stable during earthquake.
- Story drift are reduced in higher stories which makes structure safe against earthquake.
- Point displacements are increased in every story after providing LRB which is important to make a structure flexible during earthquake.
- Finally it is concluded that after LRB is provided as base isolation system it increases the structures stability against earthquake and reduces reinforcement hence make structure economical.
- Hence, it is to conclude that we have got the desired outcomes thus the design of LRB is safe

VII. DISCUSSION

- From the Experimental Study using Shake Table the displacement and Acceleration of the Base Isolated StructureXare much less than the fixedXBase structure.
- The Base Isolated Structure is more stable for External frequency applied during Shake Table Test as compared to fixed Base Structure.
- Storey displacement, Storey acceleration, base shear and drifts are reduced considerably in case of the base isolated structure than the fixedXbase structure for symmetrical and unsymmetrical building in both directions. In all the case storey displacement and drifts are within permissible limit as per codal provision of IS1893:2016.
- From the linear dynamic analysis, the fundamental natural time period of the fix base is much less as compared base isolated system for all models considered. The time period obtained from the analysis is in comparison with the empirical expression given by the IS 1893:2016.
- The base shear is much greater for fix base structure as compared base isolated structure for all models in both x and y-direction.
- From the linear dynamic analysis for multi storey symmetrical and unsymmetrical structures, the Storey displacement, storey acceleration, base shear and drifts are considerably less in case of the FPS models than the LRB models.
- Finally it is concludedXthat base isolationXsystem is significantlyXeffective to protectXthe structures againstXmoderate as well as strongXearthquake ground motion.

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