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Examination of Performance of Seismically Isolated and Non-Isolated RC Structure using Lead Elastic Bearing Isolators

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ABSTRACT

In Reinforced Cement Concrete structures lateral loads are first which will grow proportionally with growth in floor height of the structure as a result of which lateral loads more effective in the top story in contrast to the bottom story due to which the structures are likely to react as cantilever and that forces develop high stresses, produce sway movement leads to serious damages and hence at last results in failure of the structure. Each of these causes form the study of the effect of lateral loads very dominant. Column is the most critical member in the building subjected to earthquake loading because failure of a column can affect the stability of the whole building. Column may fails due to lack of ductility, strength and weak beam column joint. A model of a 14 storey structure is made on ETABS Software and analysis of reinforced concrete framed structure under earthquake excitation has been carried using the linear static analysis methods as per the guidelines provided in IS1893:2016 codes to simulate seismic analysis. In order to study the effect seismic force on LRB system zone II of India a multi-storey hotel building of G +13 of Square and L Shape configuration is taken in zone II with and without having a lead rubber bearing (LRB) at its base is analyses using linear static method. Supports has been removed at base and assigned as spring and different parameters like storey displacement, storey drift, base shear, and storey shear for all cases are evaluated and presented in the form of charts Based on results and comparing the parameters of different cases namely Asymmetric & Symmetric buildings with and without base isolation the conclusion can be made that Base isolation is very effective in reducing the storey drift in Symmetrical building & Asymmetrical building. For Asymmetrical building the base shear in X direction is reduced after the implementation of LRB system and in Y direction the same is reduced.

KEYWORDS: *RC structure, Base isolation, Lead Rubber Bearings, Base Shear, ETABS, Story displacement*

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1. INTRODUCTION

GENERAL

Now-a-days the demand of area for construction is going on increasing everywhere. The shortage of place in different regions has guided to the evolution of vertical growth restoring from low-rise to average-rise and high-rise or tall structures. For High-rise structures Reinforced Cement Concrete is preferred. R. C. C. structures are always subjected to gravity loads (i. e. vertical loads) and lateral loads (i. e. horizontal loads), gravity loads consider live load, dead load, superimposed load, and lateral loads consider earthquake load and wind load. Previously structures were designed and drafted for only gravity loads that may not have protection against lateral or horizontal loads due to low height of structure (Pallavi Badry, 2018).

In Reinforced Cement Concrete structures lateral loads are first which will grow proportionally with growth in floor height of the structure as a result of which lateral loads more effective in the top story in contrast to the bottom story due to which the structures are likely to react as cantilever and that forces develop high stresses, produce sway movement leads to serious damages and hence at last results in failure of the structure. Each of these causes form the study of the effect of lateral loads very dominant (Sohan Lal et al. 2018).

Buildings oscillate during earthquake shaking. The oscillation causes inertia force to be induced in the building. The power and term of swaying, and the measure of dormancy power actuated in a structure rely upon highlights of structures, called their dynamic qualities, notwithstanding the attributes of the seismic tremor shaking itself. The significant unique attributes of structures are methods of swaying and damping. A method of wavering of a structure is characterized by related Natural Period and Deformed Shape in which it sways.

SEISMIC BEHAVIOUR OF BUILDING

A seismic tremor is the fit of ground shaking brought about by unexpected arrival of energy in the world's lithosphere for example hull in addition to part of an Upper mental this energy emerges predominantly from pressure is developed during structural cycles which comprise of cooperation

between the Crust and the inside of earth in some portion of the world quake are related with volcanic movement. These functions are of Shallow concentration and cost significant harm with the sweep of around 30 kilometers from the focal point of the focal point. Structures waver during quake shaking. The swaying causes idleness power to be incited in the structure. The power and length of swaying, and the measure of dormancy power prompted in a structure rely upon highlights of structures, called their dynamic attributes, notwithstanding the qualities of the seismic tremor shaking itself. The significant unique attributes of structures are methods of wavering and damping. A method of swaying of a structure is characterized by related Natural Period and Deformed Shape in which it wavers. Section is the most basic part in the structure exposed to seismic tremor stacking on the grounds that disappointment of a segment can influence the dependability of the entire structure. Segment may bombs because of absence of malleability, quality and powerless shaft segment joint.



Fig. 1.1 Multiple-story collapse in a six-story building due to strong beam-weak column design in the 1999 Turkey earthquake



Fig.1.2 showing column damage during earthquake excitation



Fig 1.3 showing beam-column joint failure

SEISMICALLY-ISOLATED BUILDING

In India, Zone4 and Zone 5 is one of the most elevated seismic-hazard zones and has encountered numerous quake catastrophes from the most recent fifty years. Seismic segregation innovation developed from different early thoughts and types into what is regularly alluded to as "Base disengagement" as appeared in figure 1. 1. A base-disconnected structure has an "confinement level" between the establishments of the structure and the upper structure (generally alluded to as the superstructure). Isolators and dampers are introduced at the confinement level to decouple the structure from tremor ground movement.

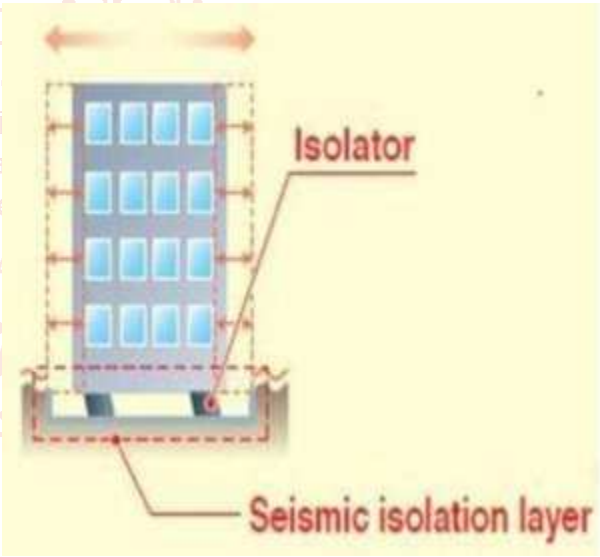


Figure 1.4 seismically-isolated building

LAMINATED RUBBER BEARINGS (LRB)

LRB are frequently use as isolators. Elastic heading have exceptionally low flat solidness, which permits level development of the superstructure and decrease of powers that are prompted in the structure by quakes. Seismic separation frameworks lessen the influencing of structures, by expanding the measure of even development at the base. Figure 1.1.1 shows this trademark by contrasting a seismically-disengaged working with a normal fixed structure and to a tall structure without seismic seclusion. This vertical firmness of most elastic bearing is like that of the establishment of regular structure. This implies that the vertical trademark and developments of seismically confined structure are basically equivalent to those of ordinary structures. Dampers are likewise remembered for the confinement framework: to assimilate tremor energy, in this manner and decrease even uprooting.

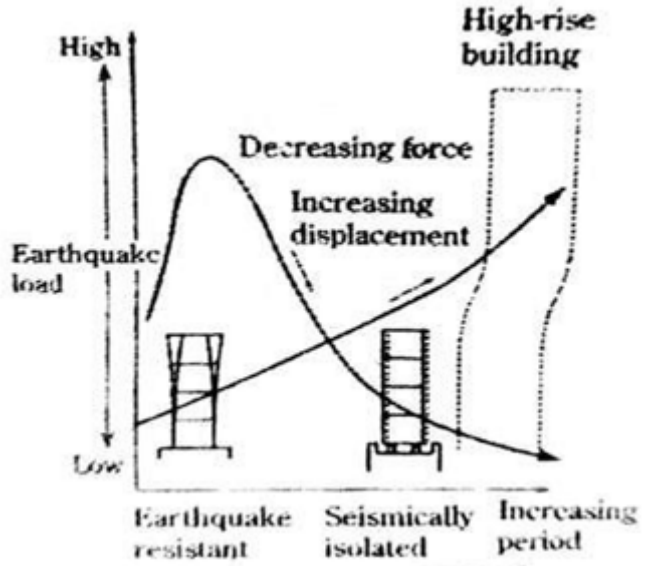


Fig 1.5 earthquake loads and periods of buildings during Earthquake

The delicate development of a seismically-separated structure offers security to the occupants and to the structure itself. It likewise limits harm to the non-auxiliary segments, for example, equipment's, window ornament dividers, and segment dividers, and the structure substance. These trademark recognize seismically-detached structures from normal fixed-based structures, consequently permitting the structure to remain completely operational during and after a solid quake. Hence, seismic seclusion innovation ought to be considered for any structure that cuts off fundamental capacities.

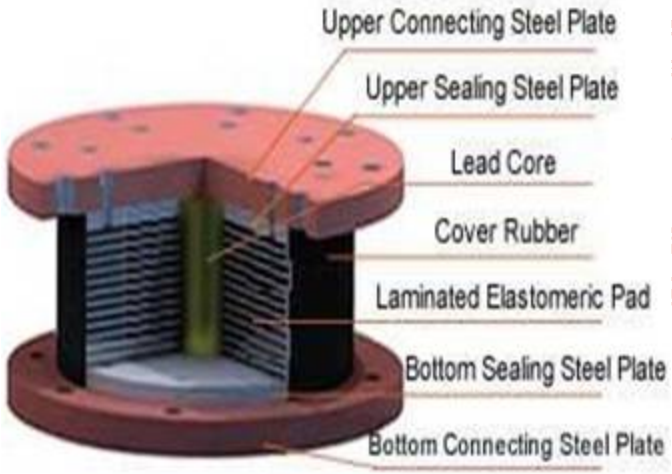


Fig 1.6 A Typical LBR

The seismic seclusion framework has gotten more far reaching as of late, including as retrofits of leaving building, and in wide range of utilization for new structure. The Table 1 show the seismically separated structure start worked by year by various nations.

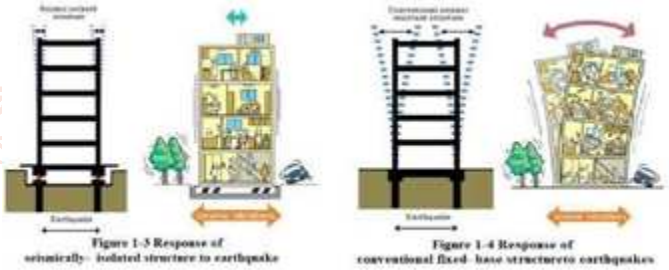
TABLE 1 SEISMICALLY-ISOLATED BUILDING STARTING BEING BUILT UP IN THE WORLD

S. No	Country	Year
1	New Zealand	1974
2	US	1984
3	Japan	1988
4	US (Bridge)	1982
5	India	2003

BEHIVIOUR OF SEISMICALLY-ISOLATED BUILDINGS IN EARTHQUAKE?

In spite of the pictures inferred by "disconnect", seismically-segregated structure move evenly at the separation level, which is between the superstructure and the establishment: by on a level plane adaptable confinement gadget. Most seismically-segregated structures move gradually even way, yet with long flat relocation, while the ground moves quickly and savagely underneath (Fig 1-3). The generally sluggish development of the superstructure brings about lower superstructure- disfigurement, accordingly assembling inhabitants don't feel the savage shocks of speeding up of the ground. The dampers in the disconnection framework ingest seismic energy, which keeps up the strength of the superstructure. Alongside the dampers and elastic direction, the quickening in the superstructure is significantly less than the increasing speed of the ground beneath.

Interestingly, customary fixed-base structures assimilate seismic energy by plastic twisting of their basic individuals, for example, radiates sections, or dividers, and the quickening increments all through stature of the structure. (Fig 1-4)



Many seismically-isolated building are equipped with strong-motion accelerometer to measure building response in earthquakes, and many of the record obtained from these accelerometers are published. Table 2 shows the maximum earthquake occurs observed in India.

TABLE 2 THE MAXIMUM EARTHQUAKE OBSERVED IN INDIA.

Date	Place	Magnitude
June 16, 1819	Kutch, Gujarat	8
Jan 10, 1869	Near Cachar, Assam	7. 5
May 30, 1885	Sopore, Jammu and Kashmir	7
June 12, 1897	Shillong Plateau, Meghalaya	8. 7
April 4, 1905	Kangra, Himachal Pradesh	8
July 8, 1918	Srimangal, Assam	7. 6
July 2, 1930	Dhubri, Assam	7. 1
Jan 15, 1934	Bihar-Nepal Border	8. 3
June 26, 1941	Andaman Islands	8. 1
Oct 23, 1943	Assam	7. 2
Aug 15, 1950	Arunachal Pradesh-China Border	8. 5

July 21, 1956	Anjar, Gujarat	7
Dec 10, 1967	Koyna, Maharashtra	6. 5
Jan 19, 1975	Kinnaur, Himachal Pradesh	6. 2
Aug 06, 1988	Manipur-Myanmar Border	6. 6
Aug 21, 1988	Bihar-Nepal Border	6. 4
Oct 20, 1991	Uttarkashi, up hills	6. 6
Sept 30, 1993	Latur-Osmanabad, Maharashtra	6. 3
May 20, 1997	Jabalpur, Madhya Pradesh	6
Mar 29, 1999	Chamoli District, Uttar Pradesh	6. 8
Jan 26, 2001	Bhuj, Gujarat	7. 7
Sept13, 2002	Andaman Islands, India region	6. 5
Dec 26, 2004	Nicobar Islands, India region	7. 1
Dec 14, 2005	Uttaranchal, India	5. 1
Feb 14, 2006	Sikkim, India	5. 3
Nov 6, 2007	Gujarat, India	5. 0
Feb 6, 2008	West Bengal, India	4. 3
Sept16, 2008	Maharashtra, India	5. 0
Aug 10, 2009	A ndaman Islands, India region, A ndaman Islands earthquake	7. 5
June 12, 2010	Nicobar Islands, India region	7. 5
Feb 4, 2011	Myanmar–India border region	6. 2
Sept 18, 2011	India–Nepal border region, Sikkim earthquake	6. 9
Oct 29, 2011	Sikkim, India	3. 5
May 1, 2013	Eastern Kashmir, India	5. 4
Jan 3, 2016	Manipur, India region, Imphal earthquake	6. 7
Jan 3, 2017	India–Bangladesh border region, Tripura earthquake	5. 5

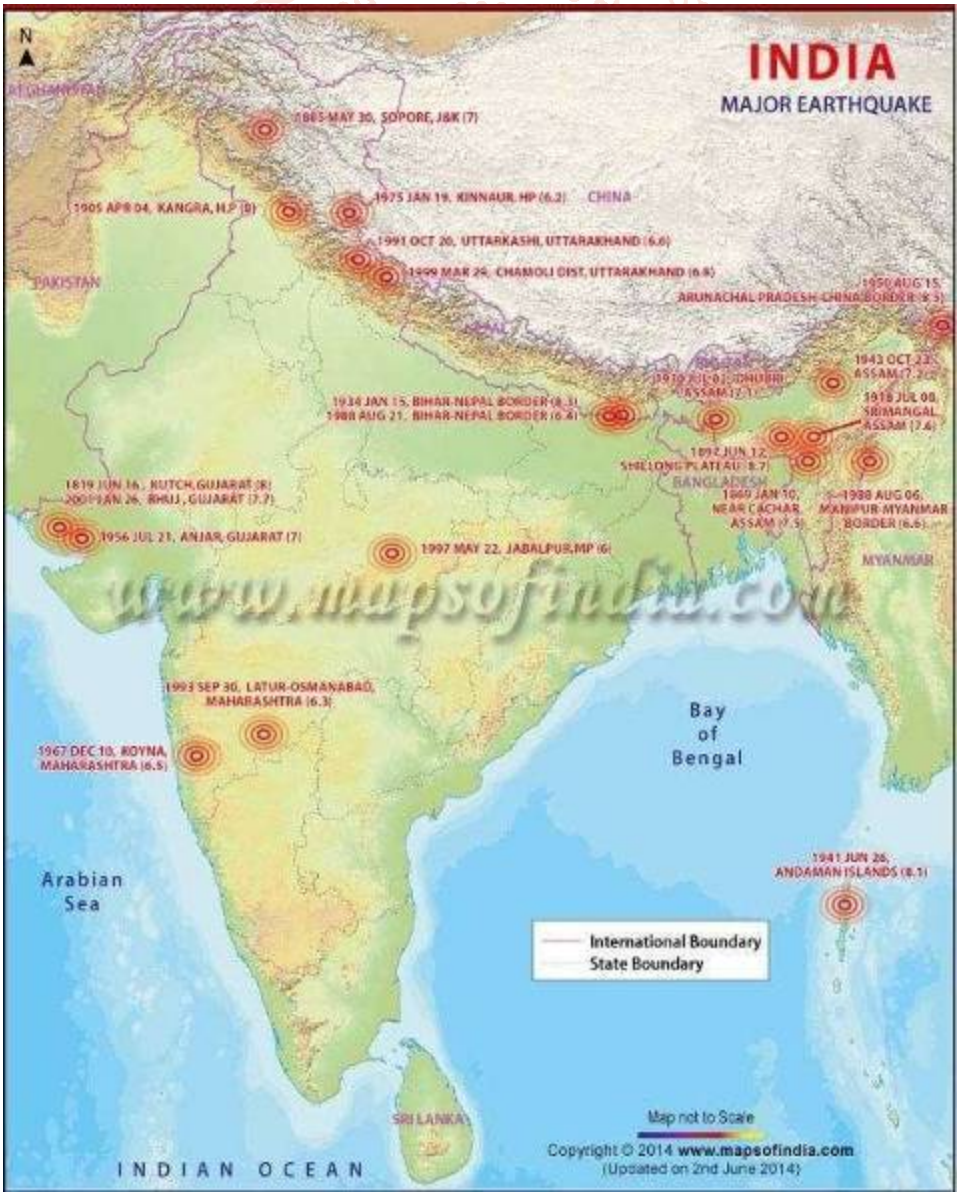


Figure 1.5 major earthquake in India (1985-2001)

THE DESIGN ADVANTAGE OF SEIMICALLY-ISOLATED BUILDING?

In seismically-separated structures, the seismic misshapening and energy assimilation are essentially communicated to the gadget that contain the seclusion framework. Contrasted and ordinary fixed-base structures, plan anticipating seismically-confined structure isn't as prohibitive with respect to the arrangement of seismic components, for example, shear dividers and supports. Also, it is easer to situate parcel dividers, permitting more adaptable designs for some kinds of structures, for example, business structures, clinics and galleries.

More-confounded setup of seismic components are regularly vital so as to diminish capriciousness, which is turn control solidness. Such is the situation of center kind structure with fortified solid dividers, that have their lifts and flights of stairs, or mechanical rooms found counterbalance in plan, or structures that are misfortune or lurched in plan.

In seismically-disengaged structures, superstructure unusualness can be constrained by changing the area of the Center of the mass of the superstructure comparative with the focal point of the solidness of the detachment framework.

SEISMIC ZONES

BIS categorizes Indian topography into 4 seismic zones i. e. zone II, III, IV and V where 5th zone has frequent tectonic plates movements while zone 2 has the least movement.

Broadly,

Zone – V includes the entire north-east zone of the country, Uttaranchal, Rann of Kutch in Gujarat, parts of J&K, Himachal Pradesh, a part of North Bihar and some part of Andaman & Nicobar Islands.

Zone – IV includes he rest over parts of J&K and Himachal Pradesh, Delhi, Sikkim, Northern areas of Uttar Pradesh, Bihar and West Bengal, some parts of Gujarat and minute portions of Maharashtra near the west coast and Rajasthan.

Zone – III includes Kerala, Gujarat and West Bengal, some Parts of Punjab, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, Goa, Lakshadweep islands, rest remaining parts of Uttar Pradesh, Chhattisgarh, Maharashtra, Orissa, Andhra Pradesh, Tamil Nadu and Karnataka.

Zone – II lefts with the remaining parts of country.



Figure 1.6: Map of India Determining States in Different Seismic Zones

SEISMIC CODAL PROVISIONS

1. IS 1893:2002 (Part 1): Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions - Fifth Revision.
2. IS 875 (Part 1 and 2): Code of Practice for Design Loads [Rather than Earthquake] For Buildings and Structures.
   - Part 1: Dead Loads - Unit Weights of Building Materials
   - Part 2: Imposed Loads by Bureau of Indian Standards (BIS)
3. IS 456:2000: Plain and Reinforced Concrete - Code of Practice.

COMPONENTS IN SEISMIC ANALYSIS:

Following features are observed in seismic analysis:

1. Zone Factor [IS 1893 (Part 1): 2002, Clause 6. 4]:

According to the Code, the term zone factor is defined for all seismic zones for the Maximum Considered Earthquake (MCE) in respective zones as, this is a factor used to obtain a design spectrum depending on the perceived seismic hazard in the zone in which the structure is located. It given in Table 2 of IS 1893 (Part 1):2002. It is denoted by Z and can also be determined from the seismic zone map of India, which is shown in figure 1 of IS 1893 (Part 1):2002. Seismic zoning assesses the maximum severity of shaking that is anticipated in particular region.

Zone Factor, Z (Clause 6. 4. 2)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0. 10	0. 16	0. 24	0. 36

2. Importance Factor [IS1893 (Part1):2002, Clause 7. 2]:

The importance factor is a factor used to obtain the design seismic force depending upon the functional use of the structure characterized by hazardous consequences of its failure. It is customary to recognize that certain categories of building and should be designed for greater levels of safety than the others, and this is achieved by specifying higher lateral design forces. Such categories are:

1. Building which are essential after an earthquake – hospitals, fire station, etc.
2. Places of assembly – schools, theatres, etc.
3. Structures will collapse which may endanger lives – Nuclear plants, dams, etc. (R. S. More et al. 2015)

Importance factor changes with change of occupancy also, which results in a structure being re- classified to a higher importance factor, the structure shall conform to the seismic requirements for a new structure with the higher importance factor. It is denoted by I.

importance Factors, I (Clause 6. 4. 2)

SI No. (1)	Structure (2)	Importance Factor (3)
1	Important service and community buildings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, tire station buildings; large community halls like cinemas, assembly halls and subway stations, power stations	1. 5
2	All other buildings	1. 0

3. Response Reduction Factor [IS 1893 (Part1):2002, Clause 6. 4]:

The fundamental principle of planning and designing a structure for solid ground movement is that the structure ought not crumple or collapse but rather harm to the auxiliary components (structural members) is allowed. Since a structure is permitted to be harmed if there should be an occurrence of serious shaking, the structure ought to be intended for seismic powers significantly less than what is normal under solid shaking, if the structure were to remain linearly versatile or elastic. Response reduction factor is the factor by which the real base shear power ought to be diminished, to get the design lateral force. Base shear constrain is the power that would be produced if the structure were to stay flexible amid its reaction to the plan premise quake (DBE) shaking. The estimations of response reduction factor arrived experimentally in view of building judgment and are demonstrated as follows:

Response Reduction Factor [1], *R*, for Building Systems

(Clause 6.4.2)

I No.	Lateral Load Resisting System	R
(1)	(2)	(3)
	Building Frame Systems	
i)	Ordinary RC moment-resisting frame (OMRF)[2]	3.0
ii)	Special RC moment-resisting frame (SMRF)[3]	5.0
iii)	Steel frame with	
	a) Concentric braces	4.0
	b) Eccentric braces	5.0
iv)	Steel moment resisting frame designed as per SP 6 (6)	5.0
	Building with Shear Walls[4]	
v)	Load bearing masonry wall buildings[5]	
	a) Unreinforced	1.5
	b) Reinforced with horizontal RC bands	2.5
	c) Reinforced with horizontal RC bands and vertical bars at corners of rooms and jambs of openings	3.0
vi)	Ordinary reinforced concrete shear walls[6]	3.0
vii)	Ductile shear walls[7]	4.0
	Buildings with Dual Systems[8]	
viii)	Ordinary shear wall with OMRF	3.0
ix)	Ordinary shear wall with SMRF	4.0
x)	Ductile shear wall with OMRF	4.5
xi)	Ductile shear wall with SMRF	5.0

A list of main cities of our country falling in various seismic zones, has enlisted by BIS and is given below:

According to a survey in January 2018, nearly 54% of the land in India is prone to earthquakes. India is separated in 4 seismic zones, which are Zone 2, Zone 3, Zone 4 and Zone 5. Out of these zones, zone 5 is the most prone to earthquakes whereas, zone 2 has the lowest seismic levels following cities are most prone to earthquake having tall structures-

- Guwahati
- Srinagar
- Delhi
- Mumbai
- Chennai

Guwahati
This city lies in the zone V of the seismic zones of India, making it inclined to quakes. This city has seen some overwhelming seismic tremors and tremors are very basic in the region.

Srinagar
J&K is another seismic tremor inclined city in India. It additionally goes under the seismic zone

5. Different territories of the Kashmir Valley, additionally go under this seismic zone. 85%of the state's part comes under seismic zone IV.

Delhi
The Capital City of India positioned 3rd in the most earthquake prone areas of India. On the sides of the River Yamuna and Chhatarpur basin are the two most earthquake prone locality in this region.

Mumbai
Mumbai additionally falls in the seismic zone III. The area of Mumbai, which is on a beach front line, expands the danger of a tidal wave. Since the most recent 20 years, most structures in Mumbai have been planned remembering the seismic zone.

Chennai
Previously, Chennai used to lie in zone II. Be that as it may, recently, the city has moved to zone After encountering solid tremors in September 2001, with a seismic tremor of 5. 6 size on the R scale (Richter scale), the city has become more prone to earthquakes.

According to the Seismic Zone Map of IS: 1893-2002, India is divided into 4 zones on the basis of seismic activities namely Zone II, Zone III, Zone IV and Zone V.

SEISMIC ISOLATION DEVIVE
Seismic disengagement gadget component that are introduced between the establishment and upper structure of a structure (ordinarily alluded to as the superstructure) to lessen the impacts of tremor ground movement on the structure. Seismic disconnection gadget have four capacity.

1. Decouple the structure starting from the earliest stage, limit the transmission of tremor movement to the structure (disconnection work).
2. Support the heaviness of the superstructure in a steady way consistently (load conveying capacity).
3. Reduce the abundance shaking brought about by tremor (damping capacity).
4. Ensure that the superstructure re-visitations of its unique situation after a seismic tremor (re- focusing capacity)

Contingent upon required capacities, seismic detachment gadgets are named either an "isolator "or a "damper": the previous fulfills the necessity of (1) and (2) (a few kinds of (3) and (4) and the last fulfills (3).

Isolators are intended to give low flat solidness consistent execution, for example, stable burden conveying capacity to help the structure weight. To lessen the degree of development to as handy reach, damping is additionally needed in the separation framework. Dampers ingest quake energy that outcomes from the speed of movement, and aid the decrease of relocation of the separation framework. In India, there are numerous kinds of isolators, for example, Laminated Rubber Bearing LRB, Flat sort Slider, Spherical slider and roller bearing. Some kind of isolators have damping capacity, for example, LRB, High-damping elastic bearing and slider. Dampers are normally metallic gadgets of steel or lead liquid dampers, utilizing delicate, clingy liquid, for example, oil and grating dampers.

METHODS OF SEISMIC ANALYSIS
Seismic investigation is a subset of basic examination and the figuring of the reaction of a structure exposed to a quake. A structure can possibly 'wave to and fro during a quake which is called major mode. Seismic investigation is grouped under the sort of burden applied remotely relying on the kind of development examination can be comprehensively named Linear investigation and Non-direct investigation. In direct investigation Equivalent Static Method is utilized and in non-straight examination Response range strategy and Time history technique is utilized. [S. K. Duggal].

EQUIVALENT STATIC METHOD:
An equal static technique is utilized to seismically plan the greater part of the low and medium-ascent building structures. In this strategy, plan powers are procured from flexible spectra that are diminished utilizing a reaction alteration factor. This strategy for discovering plan horizontal powers is otherwise called the static technique or the equal static strategy or the seismic coefficient technique. This strategy doesn't need dynamic examination; notwithstanding, it represents the elements of working in a surmised way. The static technique is the least difficult one it requires less computational exertion and depends on formulae given in the code of training. Identical static examination is typically satisfactory for the plan of such a framework except if its disappointment is considered to make urgent harm the auxiliary framework. Where dynamic examination isn't plausible, it is attractive to build up a reasonable identical static power and Equivalent Static Analysis is utilized.

RESPONSE SPECTRUM METHOD:
Reaction range examination is maybe the most well-known strategy utilized in configuration to assess the greatest basic reaction because of the seismic activity. In straightforward language, the word range in seismic designing methods that the reaction of structures having an expansive scope of periods is summed up in a solitary chart. A reaction range shows the pinnacle reaction of a SDOF structure to a specific tremor. Subsequently, a plot of the most extreme reaction (e. g., of relative dislodging, outright relocation, quickening, or spring power) against the time of vibration, or against the regular recurrence of vibration or the roundabout recurrence of vibration, is known as a reaction range. The reaction range idea along these lines gives a functional way to deal with apply the information on auxiliary elements to the plan of structures and improvement of parallel power necessities in construction laws. This technique is otherwise called modular strategy or mode superposition technique. The technique is pertinent to those structures where modes other than the central one fundamentally influence the reaction of the structure. By and large, the reactions should be resolved uniquely in the initial scarcely any modes on the grounds that the reaction to a seismic tremor is principally because of lower methods of vibration. [B. S. Taranat].

TIME HISTORY METHOD:
Time history investigation is a bit by bit examination of the dynamic reaction of a structure to a predetermined stacking

that may differ with time. Time history investigation is utilized to decide the seismic reaction of a structure under unique stacking of agent tremor (Wilkinson and Hiley, 2006). The computation of time-frame can be attempted by various methodologies. The impact of variety of each time span on seismic reaction boundaries for example base shear, dislodging, story float can be endeavored.

SCOPE

As per the past works done, above all else the postulation centers around the overall contemplations of seismic secluded structures which are overall utilizations of seismic separated structures, distinctive sort of isolators, the establishment cycle of them, their mechanical qualities, cost of confined structures and area. At last, the plan techniques for various kinds of isolators are examined to introduce straightforward, brief, and reasonable data and standards needed by specialists in seismic disengaged structures. In this manner G+ 10 stories working in zone 5 are examined by LRB isolators to concoct the ideal case as indicated by the seismic interest. Microsoft Excel bookkeeping page is used so as to configuration Lead Rubber Bearing isolators. At long last, a G+10 story building fixed-base and ideal confined structures are dissected so as to explain contrasts between the exhibitions of these two kinds of structures. In addition to what in particular have just been done, these two structures are planned and their materials are contrasted with uncover the distinctions.

As per the past works done, most importantly the theory centers around the overall contemplations of seismic separated structures which are overall utilizations of The extent of present investigation focuses on assessment of RC building (Designing as indicated by IS code 456:200 and IS 13920:2016 First amendment) utilizing reaction range examination. The exhibition based quake designing strategy known has Nonlinear reaction methodology has been viably utilized in this regard. The Response range has been done utilizing ETAB 2016, a result of CSI.

The results of examination are thought about as far as Base shear, Spectral Displacement in x heading, Spectral Displacement in y course, Story float proportion and so forth Decide the most ideal blend of fortification that would be practical, successful and must be restricted so as to empower quick inhabitance.

WORKING MODEL FOR VIBRATION ISOLATION USING LRB ISOLATOR

The present research work is predominantly concentrated around the vibration isolation of the multistoried building subjected to the seismic forces. For the purpose in this very investigation lead rubber bearing isolators has been provided at the foundation level and the bare frame is analyzed for the performance under the action of seismic forces**.**

The sole idea behind the investigation came long before the actual start of the dissertation, perhaps during my graduation when I have attended a national conference on "Friction Pendulum Seismic Base Isolator" held at **L. D. College of Engineering Ahmedabad, Gujarat (India).**



Figure 1. 6 The working model friction pendulum isolator

Further study about base isolation reported that although the first base isolator was used in KILKARI in 1981 but the use of base isolator in structures were not in the full flange mode in India. The most devastating and massive BHUJ earthquake of 2001 has taught the structural

Designers and researchers a lot itself, and after that seismic base isolator were used in more than thousands of the buildings, built across the length and breadth of the country.

The knowledge gained so far about base isolator thereafter developed the quest for the further investigation and research in this very area of seismic base isolation of structures in my mind. To fulfill my quest about, I have decided to work upon in this very area of research during my Master's dissertation and the more detailed study and research about the type of material being used for the base isolator have shown that LEAD RUBBER BEARING SEISMICALLY BASE ISOLATOR could be a near ideal solution for the seismic base isolation of the buildings. For the purpose a typical G+10 Storey building has been modeled in structural design package ETAB 2016 with and without the LRB isolator and the results obtained were as positive as assumed.

LAYOUT OF THE STUDY

This dissertation is divided into six chapters:

First chapter deals with the introduction of base isolation its modeling & advantages, Objective of the study.

Second chapter deals with the Literature survey of High rise structure under different seismic zones subjected to lateral forces.

Third chapter deals with the problem identification, in this the previous work and its research gaps is discussed with objectives of this work.

Fourth chapter deals with methodology in which the whole execution steps and the cases are described.

Fifth chapter deals with the result and discussion of structural frame analysis, where it is discussed in terms of Maximum Reaction, Maximum Story Displacement, Maximum Overturning Moments and Maximum Story Drift.

Sixth chapter deals with the conclusion of the analysis results and also the further scope of the study

2. LITERATURE REVIEW

INTRODUCTION

The literature on the topic of "**Examination of Performance of Seismically Isolated and Non- Isolated RC Structure Using Lead Elastic Bearing Isolators"** is reviewed in this chapter. Some papers dealing with related to the above topic are discussed in the present chapter. The literature review search has been performed for relevant publications using many Web based search engines and databases. The search was purposely restricted to articles published in refereed journals and containing the terms: isolation, earthquake resistance, linear static and nonlinear static analysis, LBR, displacement of structure etc. Any research paper with the key terms as mentioned above has been considered here and included in the database of this research. Thus the literature review provides a basic background and the ideas for the present work and is relevant for the present study.

LITERATURE REVIEW

To supplement automated search, a manual search was also done. The manual procedure involved searching the reference sections of the papers identified by the automated search and referring the text/reference books. Any relevant references within those papers/reference books were followed up on.

Yutaka Nakamura and Keiichi Okada (2019) this composition audits seismic confinement andreaction control strategies for structures, which can make structures strong against quakes and have gotten mainstream during the most recent thirty years in Japan. Seismic detachment is a technique for shielding a structure from serious quakes by introducing isolators and energy retaining gadgets under the superstructure. The composition portrays three sorts of covered elastic orientation and three sorts of damping gadgets. Seismic detachment gives basic wellbeing, yet in addition security and security for individuals and properties in the structure. Seismic confinement is additionally utilized for the retrofit of notable structures. Reaction control techniques use different sorts of dampers that are introduced into a structure and ingest vibration energy. The original copy clarifies three first reaction control dampers: the steel hysteretic damper, the viscoelastic damper and the thick liquid damper. The impacts of seismic confinement and reaction control strategies were checked through shaking table tests, auxiliary wellbeing observing and tremor reaction investigations.

Mohammad Ganji , Hossein Kazem (2017) seismic practices of a steel outline outfitted witheither gooey damper or lead-center elastic orientation (LRB) isolator were assessed and thought about under the impact of close shortcoming tremor records. For this reason, three structures of 5, 10, and 15 stories outfitted with horizontal bearing frameworks made out of steel second opposing edges were exposed to 7 close blame quake accelerogram sets at seismic tremor risk levels 1 and 2, to assess their reactions under three situations, to be specific with no energy dispersal framework, with thick damper, and with LRB isolator, utilizing dynamic investigation of time history using PERFORM 3D v5 programming. The outcomes were characteristic of upgrade in seismic execution of the gooey damper-prepared structures at tremor peril level 1, as the comparing execution level was improved from life wellbeing to continuous ease of use, while no critical seismic execution level upgrade was resolved at seismic level 2. Seismic isolator-prepared structures were additionally connected with seismic execution level improvement from life wellbeing to continuous ease of use at both quake danger levels. Relative parallel uprooting at floor levels in damper-prepared structures and seismic isolator-introduced structures were discovered to be about 29% and 68% improved over that of the structure with no energy dissemination framework. Aftereffects of circulation of shear powers inside structures furnished with thick damper and seismic isolator, as contrasted against that of the structures and no energy dispersal framework, arraigned expanded and diminished shear powers, separately.

REZA MIRZA HESSABI (2017) the dynamic impacts of base disconnection frameworks, diminishing the entomb story floats of the superstructure is regularly accomplished to the detriment of high base removal level, which may prompt unevenness of the structure or non- commonsense plans for the base isolators. To lessen the base removal, a few crossover basic control procedures finding the impacts of tuned mass dampers on the seismic exhibition of structures with nonlinear base detachment frameworks. Seismic plan reasoning and subtleties have advanced from just believing tremors to be equivalent to twist loads, to comprehend the marvel of the earthshaking that applies a structure reaction. This model clarifies cross breed vibration control of keen expressway connect structures exposed to seismic tremor stacking.

Esra Mete Güneyisi, Ahmet Hilmi Deringöl (2016) In this examination, the seismic conduct of the base detached edges was researched relatively through nonlinear time history investigation. For this, two-dimensional five-story and three-cove steel second casings outfitted with lead elastic bearing (LRB) isolators were utilized. The power twisting conduct of the isolators was displayed by the bi-direct conduct which could mirror the nonlinear attributes of the lead-plug course and adequately used to show all confinement frameworks. In the plan of LRB, two fundamental boundaries, in particular, segregation period (T) and proportion of solidarity to weight (Q/W) upheld by isolators were considered as 2. 0, 2. 5 and 3 s, 0. 04, 0. 07 and 0. 10, individually. The fixed base and base disconnected edges were demonstrated utilizing a limited component program. In the investigation, three diverse normal ground movements were utilized. The exhibition of the contextual analysis structures were estimated by the variety of rooftop dislodging, relative uprooting, interstorey float and hysteretic bend.

DEVI SREENIVAS (2016) this examination paper delineates the central questions identified with the insurance of the structure envelope against seismic powers. The plan and establishment of cladding frameworks needs incredible consideration on the grounds that fruitful presentation relies upon taking care of issue of the connection among cladding and building structure during a seismic function. All Seismic codes require hefty boards to keep up development either by sliding or malleable associations. In high seismic zones sliding associations are once in a while utilized, in view of the chance of erroneous changes when jolts are utilized, sticking or authoritative because of waste materials left after establishment and sticking because of mathematical variety of the basic casing utilizing level powers. As time is significant in a serious business climate, it is vital for the association that can be immediately introduced is a significant concern.

ALI YEGANEHFAR (2015), the exploration paper synopses Seismic (base) seclusion is agenerally experienced innovation for shielding structures from the impacts of moderate and serious tremor shaking. The article centers predominantly around the distinctive mathematical techniques utilized in the examination of base segregated structures. The standard type of unraveling the conditions of movement overseeing the seismic reaction of building structures with nonlinear base disconnection comprises of utilizing solid bit by bit reconciliation techniques. A successful elective static buildup and square iterative plans can be utilized. The significance of the conditions of movement of structures outfitted with different base detachment frameworks is depicted. The straight hypothesis of base detached structures is then performed. The investigation of the seismic reaction of structures with confinement frameworks are planned by fulfilling all the boundaries in the paper.

EVREN ERKAKAN (2014) The exploration displays the consequences of a broad arrangement of test tests to recognize the mechanical qualities of an as of late proposed seismic seclusion gadget. Innovative materials and non-conventional procedures, for example base disconnection and supplemental damping can be practical and dependable to ensure the authentic structures. A great deal of shaking table tests on scaled models of tall structures with numerous viewpoints proportion was directed to test the dynamic exhibition of the TLRB and the seismic reactions of base confined tall structures. The conditions overseeing the change of these two stages are given. Both the time history and the reaction range results demonstrate that the structure with both elevate and sliding systems is better than that with just the inspire component. This paper impacted vertical excitation on the general after effect of the structure in every arrangement, and presents a clarification for the even vertical coupling that intensified the level increasing speeds in 3D comparative with XY excitation.

O. E. OZBULUT (2014) the objective of this examination is to get ideal qualities for each plan boundary by performing affectability investigation of a scaffold disconnected by a S-FBI framework. Initial, a three range nonstop extension is demonstrated as two levels of opportunity with the S-FBI framework. A neuro-fluffy model is utilized to catch rate and temperature subordinate nonlinear conduct of the SMA gadget. At that point, a bunch of nonlinear time history investigations of the separated extension is performed. The variety of the pinnacle reaction amounts of interest is appeared as a component of plan boundaries of the S-FBI framework and the ideal qualities for every boundary are assessed. This basic control technique displays astounding execution, for example, quick calculation, nonexclusive constant control, quickening decrease, and high seismic energy dispersal and so on The general benefits of the coherence and switch control techniques are additionally thought about and examined. Three unique setups can be on the other hand considered dependent on the game plan of the SMA components in vertical, supporting, and flat headings.

DONATELLO CARDONE (2014) The examination manages significant parts of seismic danger assessment, methodical investigation of existing structures, tests for assessment of in-situ quality and degree of harm and disintegration in brick work and RC structures, numerical demonstrating of edges, outline tubes, shear dividers and casings with in fills, and different techniques for investigation for quake powers for seismic assessment, seismic assessment which requires information on auxiliary conduct, materials of development, standards of seismic intercession and conduct of altered structure, and different retrofitting materials. This incorporates execution levels of different kinds of structures. The meaning of these presentation levels has been taken from FEMA and ATC. It is trusted that this will give satisfactory data needed to compelling execution of seismic retrofitting. A contextual analysis introducing quickly an inventive method that can present base confinement on existing structures is furnished regarding the utilization of FPS.

T. Novo · H. Varum · F. Teixeira-Dias (2013) This paper is centered around the investigation of a tremor assurance framework, the tuned fluid damper (TLD), which can, if sufficiently planned, decrease quake requests on structures. This constructive outcome is refined considering the swaying of the free surface of a liquid inside a tank (sloshing). The conduct of a confined TLD, exposed to a sinusoidal excitation at its base, with various dislodging amplitudes, was concentrated by limited component examination. The effectiveness of the TLD in improving the seismic reaction of a current structure, agent of present day engineering structures in southern European nations was likewise assessed dependent on direct powerful investigations.

KHAN SHAZADA (2012) This paper presents the after effects of an exploratory examination completed to research the seismic presentation of a two story block workmanship house with one room in each floor. Un-strengthened Masonry (URM) is broadly utilized as a structure method all through the world, for example, seismically dynamic districts. The current paper centers around the investigation of exploratory outcomes regarding sidelong burden limit, firmness corruption, removal malleability limit, conduct variables and energy scattering limits. The disappointment modes watched were: sliding of block at mortar-unit interface; discrete shear breaks in workmanship dividers, pounding of brick work units and twisting of support in tie segments. The impact of angle proportion and pre-pressure levels on different boundaries used to evaluate seismic execution is analyzed. Trial work demonstrated that dividers with medium to high angle proportions fizzled in slanting elastic shear disappointment mode while squat dividers fizzled in inclining shear followed by bed-joint sliding. The askew pliable shear qualities of the dividers decided from exploratory work were then contrasted and Turnsek and Sheppard condition used to decide corner to corner pliable shear quality of URBM dividers.

T. Novo, H. Varum, F. Teixeira-Dias & H. Rodrigues (2012) this paper is centered around the investigation of a tremor insurance framework, the Tuned Liquid Damper (TLD), which can, if enough planned, diminish quake requests on structures. This constructive outcome is refined considering the wavering of the free surface of a liquid inside a tank (sloshing). The conduct of a disconnected Tuned Liquid Damper, exposed to a sinusoidal excitation at its base, with various uprooting amplitudes, was concentrated by limited component investigation. The proficiency of the TLD in improving the seismic reaction of a current structure, agent of present day engineering structures in southern European nations was additionally assessed dependent on direct powerful examinations.

S. L. CHAN, S. T. CHAN, C. K. LAU, ALDOWS TANG (2010) The point of this investigation is to dissect the straightforwardness of quake safe plan approach for structures by methods for a basic survey of the variables for quality change and removal enhancement. The objectives of this paper are: (I) to give a review of improvement and most applicable changes of tremor safe plan codes , and (ii) to look at and examine seismic-plan approaches determined by US and Mexican codes. The examination incorporates conversation of the main boundaries for seismic plan, for example, quality adjustment factors, relocation enhancement factor and float limits. The outcomes are introduced in a typical organization that permits a direct examination. Sensors will be set deliberately all through the structure to gauge how parts perform. For instance, 230 accelerometers will quantify how quick the structure and its nonstructural segments moved during the recreated quakes. What's more, 160 sensors, including high goal GPS gadgets, will quantify the general dislodging between two focuses, while 50 strain checks will gauge the twisting of the rebar that are covered in the structure's solid establishments.

KERI. L. RYAN (2010) The information assembled through this examination could help educate more powerful fire codes. Likewise, this investigation will give a special occasion to all the while watch the impacts of shaking and fire on building frameworks, which could prompt new multi-danger PC models that could support draftsmen and engineers plan more secure structures. Similar seismic locales in the two nations. The plan cycle is talked about from deciding the ground movement requests through companion survey and detachment gadget testing. Uncommon consideration is made to the code plan strategies for separated structure in the two nations with center around the dislodging requests for segregation gadgets. This plan strategy encourages the direct quadratic controller control calculation with yield input. For a different level of-opportunity structure, the shear power gave by seismic confinement can be isolated from the superstructure and framed as a control input. This control input is an element of the general dislodging and speed at the disconnection layer with a steady solidness amount and damping coefficient. This control calculation gives the chance of determining these two constants.

SAIRAM NARASIMHAN (2009) The investigation of a seismically disengaged working with anormal inelastic conduct of the superstructure might be done utilizing two elective examination strategies: nonlinear time-history investigation and Pushover examination. FEMA concedes utilizing the sucker examination additionally for base-confined structures. Taking everything into account, it must be identified that the base-segregated structures are typically nonlinear and non- traditionally damped frameworks. Accordingly, the standard direct modular examination dependent on a straight connection between damping, mass, and firmness and modular uncoupling can‟t be applied. Accordingly, as a choice to coordinate joining techniques, the dynamic harmony condition might be uncoupled in the troublesome modular space (precise complex-esteemed modular investigation) . Through fitting determinations of limits; this model was utilized to describe a wide assortment of hysteretic conduct, including relaxing, solidifying squeezing, and solidness/quality corruption.

WENDY TAIWANGSA (2002) The examination was led to investigate base isolators to be utilized in agricultural countries, where the use of customary elastomeric elastic orientation because of financial reasons is restricted. Many non-industrial countries have either embraced the means or are directing examination into reasonable neighborhood arrangements. Low-harm innovations appropriate for non-industrial nations should be straightforward, moderate, and solid. The least difficult method of improving new plug building reaction is to decrease seismic weight – utilize lighter materials increment auxiliary consistency and improve propping system‟s repetition develop on better ground – an inclination for rock destinations over delicate or recovered land locales utilize all the more normally pliable materials, for example, lumber or steel consider and take into account seismic development. The least complex method of accomplishing this is with the idea of base disconnection. This paper works best on generally firm, hefty, and low-ascent structures, where straightforward steel plate sliders, or lead elastic heading are presented.

RASHMI PALL (1993) The paper manages the insurance of structures by inactive control utilizing seismic separation. The seismic disconnection thinks the impacts of ground shaking in exceptionally planned gadgets executed in the structure. The standard of the technique, its belongings, and highlights are quickly introduced. The gadgets utilized are presented, giving a brief look to their past, present state and improvement. The utilization of erosion base isolators has been appeared to give a useful and compelling way to deal with planning low ascent structures to oppose tremors. Their minimal effort is engaging, so everybody, from governments to people, can manage the cost of them and advantage from this innovative headway. An intriguing element, on erosion base detached houses or different structures, is that their characteristic period fluctuates with the seriousness of the quake; hence the wonder of reverberation is kept away from. Different preferences of contact base isolators are, when enacted, grinding base isolators give damping and separation. The high damping is by energy dissemination in grating. The relocation in contact base disconnected structures is restricted to around 25 mm, in this way costly enumerating of administration associations isn't needed.

J. M. KELLY, S. B. HODDER (1981) The main perspective is the stamped decrease for the in-structure quickening spectra with significant ramifications for the upgraded security of optional structures and hardware. This article centers around the use of detached seismic disconnection for structures basically as is drilled in the United States, however frameworks utilized in different nations will be examined. The paper is coordinated into the accompanying significant areas: seismic segregation equipment, trial exhibit, past endeavors to accomplish 3D seismic seclusion, and exploration needs. This paper sums up current practices, portrays broadly utilized seismic segregation equipment, accounts the set of experiences and advancement of present day seismic disconnection through shake table testing of confined structures, and surveys past endeavors to accomplish three- dimensional seismic disengagement. The audit of flow rehearses and past examination are orchestrated with ongoing improvements from full-scale shake table testing to feature regions where exploration is expected to accomplish full seismic harm insurance of structures. The accentuation of this paper is on the use of uninvolved seismic seclusion for structures.

3. OBJECTIVES & PROBLEM IDENTIFICATION

PROBLEM IDENTIFICATION

The study on the topic of "**Examination of Performance of Seismically Isolated and Non- Isolated RC Structure Using Lead Elastic Bearing Isolators"** is reviewed in this chapter.

The following problems can be easily detected from the previous work done related to this domain

1. The structure subjected to Lateral Loads should be studied separately since in General design and analysis the structure is designed for the combination of dead load, live load and super dead load.
2. The impact assessment of the lateral load such as Earthquake load or Seismic load is much needed now for high rise buildings.
3. Impact analysis of the performance of individual story of a high rise building is very essential in case of lateral loading such as wind and Earthquake loads.
4. Study should include the effect of symmetry and asymmetry of the structures to get the optimum solution of destructive event during a wind load or any Disaster such as cyclone or Earthquake case.
5. In the previous work done only the Tuned mass damper and viscous damper very few study is done for the Asymmetric Building with Lead Rubber isolators.

The above problems are considered in this study to achieve the optimum conclusions for the design and analysis of a structure regarding the Seismic loadings.

For the study, **G+13** storey building with square and L shaped is considered. The building has the plan dimension of **24 m x 24 m** for **square shape** and **32 m x 24 m** for **L shaped** and story height of 3 m in typical story and 3 m in base storey. To study the effect under lateral force, building is kept Asymmetric in plan. The shape of the column in plan is kept square and size of the column is kept constant through the height of structure.

The building considered in the study is to be located in seismic **Zone II**, and intended for Commercial use (Hotel). Building is founded **medium strength soil**. The columns at base are assumed to be provided with Mat footing. Response reduction factor for the special moment resting frame has taken as 5. The finish load on the floor is taken as 1. 5 KN/m^2. Live load on the floor is taken as 3. 5 KN/m^2. The following cases has been considered for the analysis of work. Modeling has been carried out using ETAB 16. 2. 1.

Case (1) Symmetrical building subjected to Seismic forces in general condition (Without Isolator).

Case (2) Symmetrical building subjected to Seismic forces With Lead Rubber Bearing (LRB) Isolator at base.

Case (3) Asymmetrical (L shaped) building subjected to Seismic forces in general condition (Without Isolator).

Case (4) Asymmetrical (L shaped) building subjected to Seismic forces With Lead Rubber Bearing (LRB) Isolator at base.

OBJECTIVES OF THE STUDY

The primary objective of this current work is to study of the earthquake response of multi-storey Buildings using performance based seismic isolators. The effect of seismic response on G+13 storey building with the help of ETABS software 16. 2. 1 version, for LRB isolators has been investigated.

The main objectives of the present thesis are as follows;

1. To design a G+13 storey, reinforced concrete frame building using ETABS
2. To calculate the base shear, story shear, story displacement, Story drift to regular G+13 building.
3. To calculate the base shear, story shear, story displacement, Story drift to regular & L shaped G+13building with base isolation.
4. To examine the effectiveness of LRB under low frequency ground motion
5. To explore possibility of modification in LRB for increasing its effectiveness under all types of ground motion.

- The maximum storey shear is reduced by **53. 44%** after the implementation of LRB System in the symmetrical building while in case of asymmetrical building it is reduced by only **29. 92%** after using same LRB system.
- The effect of asymmetry is considerable in the seismic performance of a multistoried building with and without base isolation system although the presence of LRB system is responsible for better performance of the structure against seismic loads.

Future scope:

1. This study was done by considering the linear static analysis for G+13 storey buildings. This study can be further extended for taller buildings with dynamic analysis in future work.
2. Instead of using Lead Rubber Bearing Isolator a trial can be made by using dampers to increase the strength of members.
3. Redesigning the failed elements in flexure and shear is required to prevent the failure.
4. It is recommended that the alternative load paths in the form of load bearing bracings and through increase in the flexibility of the structure to minimize the Seismic attack on the building.

REFERENCES

[1] **S. Mohan Kumar, R. Jeyanthi 2016** – "Progressive Collapse Analysis of a Multi-storey RCC building using Pushover Analysis" - International Journal of Engineering Research & Technology (IJERT), Department of Civil Engineering MNM Jain Engineering College Chennai – 600 097, INDIA, March 2016, Vol. No. - 5, ISSN: 2278-0181.

[2] **Ali Yeganehfar 2015**. Comparing Nonlinear Static Analysis Methods In Predicting The Seismic Response Of Structures Isolated By Sliding Base Isolators. Canadian Journal of Pure and Applied Sciences Vol. 9, No. 3, PP. 3655-3671.

[3] **Arturo Teno-Colunga, M. EERI, and Miguel (2006**). Design Displacement for Base Isolators Considering Bidirectional Seismic Effects. Earthquake Spectra Volume 22, No. 3 page 803-825.

[4] **Bruno Palazzo 2014**. Seismic Reliability of Base-Isolated Structures with Friction Pendulum Isolators (FPS). Second European Conference on Earthquake Engineering and Seismology Istanbul.

[5] **C. Y. Wang, (1993).** Numerical Simulation of Seismic Response of a Base Isolated Building with Low Shear Modulus Rubber Isolators. ASME Pressure Vessel and Piping Conference July 25-29, Denver, Colorado.

[6] **Devi Sreenivas 2016**. Evaluation of Seismic Performance of Re-Entrant Cornered Buildings with Base Isolators. IJSTE - International Journal of Science Technology & Engineering Volume 3 Issue 03.

[7] **Donatello Cardone 2014.** Seismic Rehabilitation of Existing Reinforced Concrete Buildings with Seismic Isolation: A Case study. Earthquake Spectra Volume 30, No. 4 page 1619-1642.

[8] **Evren Erkakan 2014**. Experimental Investigation of Uplift on Seismic Base Isolators. Civil Engineering Dept. METU.

[9] **J. M. Kelly, S. B. Hodder (1981).** Experimental Study of Lead and Elastomeric Dampers for Base Isolation system. College of Engineering University of California Berkley California.

[10] **Keri. L. Ryan (2010).** Evaluation of Design Review Process and Requirements for Seismic- Isolated Buildings. Earthquake Spectra Volume 26, No. 4 page 1101-11

[11] **Khan Shazada 2012.** Experimental Seismic Performance of Unreinforced Brick Masonry Buildings. Earthquake Spectra Volume 28, No. 3 page 1269-1290.

[12] **L. M. Megget, (1978).** Analysis and Design of Base Isolated Reinforced Concrete Frame Building. Bulletin of the New Zealand National Society for Earthquake Engineering Vol No 11.

[13] **Murthy, C. V. R.,** "Earthquake tips, Learning earthquake design and construction", Building material and technology promotion council, Government of India, New Delhi, 2005. Available from http://www. ourvmc. org/Files/EQTips_Full. pdf

[14] **O. E. Ozbulut 2014.** Performance of Isolated Buildings With Superelastic-Friction Base Isolators Under High Seismic Hazard. Department of Civil and Environmental Engineering, University of Virginia Structures Congress 2014 ASCE 2014

[15] **Rashmi Pall, (1993)** Study of Friction Base Isolators for Seismic Control of Low Rise Buildings. Concordia University Montreal, Quebec, Canada.

[16] **Reza MirzaHessabi 2017** Exploring the effects of tuned mass dampers on the seismic performance of structures with nonlinear base isolation systems Earthquakes and Structures, Vol. 12, No. 3 (2017) 285-296.

[17] **Sairam Narasimhan (2009).** Principal Component Analysis for Predicting the Response of Nonlinear Base Isolated Building‟s. Earthquake Spectra Volume 25, No. 1 page 93-115.

[18] **S. L. Chan, S. T. Chan, C. K. Lau, Aldows Tang (2010).** Contemporary Seismic Engineering. Contemporary Seismic Engineering 2010, Hong Kong.

[19] **VojkoKilar (2009).** Seismic behavior of asymmetric base isolated structures with various distributions of isolators. University of Ljubljana, Faculty of Architecture, Zoisova 12, SI-1000 Ljubljana, Slovenia. Engineering Structures 31 (2009) 910-921.

[20] **Wendy Taiwangsa, (2002).** Seismic Performance of a Base Isolated Demonstration Building. Earthquake Spectra Volume 18, No. 4 page 777-793.

[21] **B. S. Taranath**, Reinforced Concrete Design of Tall Buildings. 2009.

[22] Bureau of Indian Standards, "IS 456 : 2000 - Plain and reinforced concrete - code and practice," Bur. Indian Stand. New Delhi, p. 144, 2000.

[23] Bureau of Indian Standards, "IS 1893 (Part 1):2002 Criteria for Earthquake Resistant Design of Structures," Bur. Indian Stand. New Delhi, vol. 1893, no. June, p. 27, 2002.

[24] Bureau of Indian Standards, "IS 875 (Part 1):1987 Code of Practice for Design Loads (Other than Earthquake) For Buildings and Structures," Bur. Indian Stand. New Delhi, vol. 875, no. Part 3, 1987.

[25] Bureau of Indian Standards, "IS 875 (Part 2): 1987 Code of Practice for Design Loads (Other Than Earthquake) for Buildings and Structures," Bur. Indian Stand. New Delhi, vol. 875, no. March 1989, 2003.

[26] IS 4326 - Earthquake Resistant Design and Construction of Buildings Code of Practice (Second Revision), publish by Bureau of Indian standard.

[27] BVN: 2012 – Bhumi vikash niyam, publish by Madhya Pradesh government, 2012.

[28] GSA: 2003 – General Service Administration, published by U. S., june,2003

[29] FEMA: 356 - Federal Emergency Management Agency, published by Washington, D. C., November, 2000.