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Design & Comparative Analysis of Application in Earthquake Resisting RC Structures & LRB Structure

Varshs B. Kare[1], Dr. Munesh Kumar[2], Dr. Sachin C. Deshmukh[3]
[1] Research Scholar, Department of Civil Engineering, Shri Jagdishprasad Jhabarmal Tibrewala University Churela, Jhunjhunu, Rajasthan(vsbere08@gmail.com)
[2] Assistant Professor, Department of Civil Engineering Shri Jagdishprasad Jhabarmal Tibrewala University, Churela, Jhunjhunu, Rajasthan(kumarmunesh687@gmail.com),
[3] Assistant Professor, Department of Civil Engineering, Walchand Institute of Technology, Solapur, Maharastra (scdeshmukh@witsolapur.org)

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Abstract:

Adherence to building codes prescribed by the government for specific regions, especially in earthquake-prone areas like Japan, Indonesia, and California, is vital for ensuring structural safety. Techniques such as lead rubber bearings (LRB) have been employed to minimize seismic vibrations by enabling the foundation or load-bearing structure to move in response to ground motion. Additionally, reinforced concrete (RCC) frameworks, with prescribed designs for transmitting loads to foundations through interlinking, have significantly improved earthquake resistance in modern structures. This study focuses on analyzing, designing, and estimating high-rise structures across various seismic zones, comparing traditional earthquake-resistant structures with those incorporating LRB technology. A comparative analysis of construction costs between these two methods will be presented, with the aim of determining the most economical and structurally safe approach. Base isolation, a key method discussed, involves the installation of support mechanisms that decouple the building from earthquake-induced ground motion, filtering seismic forces and reducing structural acceleration. This method has been proven highly effective over the past several decades, as it allows the structure to experience minimal movement despite significant ground motion during an earthquake.

Keywords: Seismic protection, base isolation, lead rubber bearing, earthquake-resistant structure, RCC framework, construction cost comparison, structural safety.

1. Introduction

Base isolation was first developed as a strategy to decrease the damage that earthquakes have on structures. Over the course of the last several decades, it has been shown to be one of the most successful strategies for earthquake mitigation. The construction of a support system that effectively isolates the structure from seismic ground vibrations is the technique that is being taken here. Through the process of detaching the building from the ground in the event of an earthquake, base isolation helps to limit the transmission of seismic forces, which in turn enables the structure to experience a considerable reduction in movement. The input forces that were created by the earthquake are filtered as a consequence, which results in the acceleration forces on the structure being reduced to a minimum. In essence, even while the ground is subjected to severe motion during an earthquake, the structure itself continues to be relatively stable, which considerably reduces the likelihood of damage occurring.

A natural occurrence that is marked by the shaking of the ground is known as an earthquake. It is because of the movement of the Earth's crust, which is caused by activities that take place deep inside the interior of the planet, that this phenomenon takes place. When molten material, also known as lava, reaches the surface of the Earth, it cools down and helps to the construction of new land. The core of the Earth is incredibly hot throughout this process. This continual process necessitates the migration of landmasses, which eventually results in the formation of new material. According to the idea of plate tectonics, the surface of the Earth is composed of a number of massive plates that are in a state of continual motion. At the boundary of these plates, earthquakes take place whenever these plates contact with one another or glide past one another. As a consequence of this, places that are closer to plate borders are more likely to suffer seismic activity, whilst those that are farther away experience lower levels of an earthquake. In addition to being caused by natural factors, earthquakes may also be caused by human actions, such as explosions that occur underground or other types of disturbances that occur on a huge scale.

Rather than being built to be earthquake-proof, buildings are constructed to be earthquake-resistant in structural engineering applications. During an earthquake, the motion of the ground creates inertia forces in both directions. These forces are the consequence of the mass of the structure as well as the acceleration of the ground that is induced by the seismic disturbance. In order for a structure to be able to withstand these forces, it is essential for the structure to have adequate strength and stiffness to survive the lateral stresses that are precipitated by an earthquake.

Building experts say that making a building stronger over and over again is not a good idea. In places where there is a lot of seismic activity, the accelerations caused by earthquakes can be more than one or even two times the acceleration due to gravity. This makes the structure's inertial forces much stronger. To fix this problem, base separation methods are often used to lessen the effects of seismic forces and make the building stronger during earthquakes.

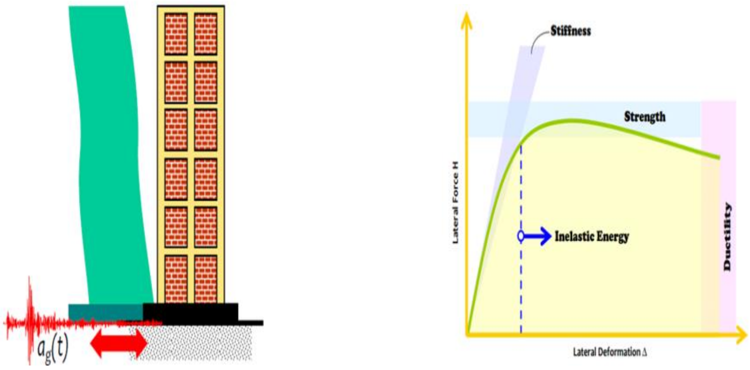

Figure 1: Purpose of the base isolation and Demand during ground motions

The core principle of base isolation is to alter a building's response to seismic activity, allowing the ground to move beneath it without transferring these movements to the structure itself. Ideally, this would result in a complete separation between the building and the ground; however, in practice, there is always some degree of contact between the structure and the ground surface.

In buildings with a completely rigid diaphragm, the natural period is effectively zero. As a result, the building experiences the same acceleration as the ground during seismic events, with no relative displacement between the building and the ground. In this case, both the structure and the substructure move together as one. On the other hand, a building with a fully flexible diaphragm would have an infinite natural period. Here, when the ground moves, the building remains unaffected by acceleration, and the relative displacement between the building and the ground mirrors the ground's movement. In this scenario, the building remains stationary while the substructure moves in response to the ground motion.

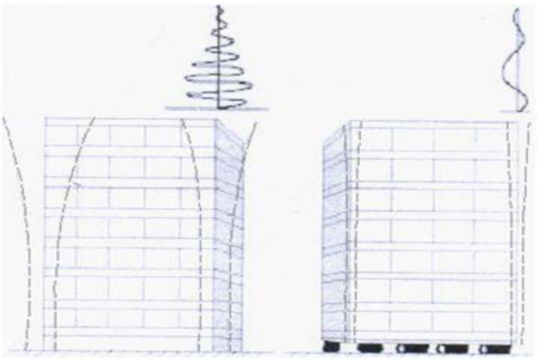

Figure 2: Principle of the base isolation

The design incorporates a lead plug that is tightly fitted into a pre-formed hole within an elastomeric bearing. “This lead core provides stability during regular service loads and helps dissipate energy when subjected to high lateral forces. The bearing's structure is reinforced with thicker steel plates on the top and bottom, which are sturdier than the internal shims, to support the mounting hardware. The entire bearing is enclosed in a protective rubber cover to shield it from environmental conditions.

When exposed to low lateral loads, the lead-rubber bearing maintains its rigidity both laterally and vertically. The lateral stiffness is attributed to the high elastic stiffness of the lead plug, while the vertical rigidity is due to the steel-rubber construction. At higher load levels, such as during an earthquake, the lead yields, causing a significant reduction in lateral stiffness, resulting in a characteristic period shift of the base isolation system. During large displacements, like those seen in moderate to severe earthquakes, the lead undergoes plastic deformation, which absorbs energy through a process called hysteretic damping. The level of viscous damping produced by this process is dependent on the displacement and typically ranges between 15% and 35%”.

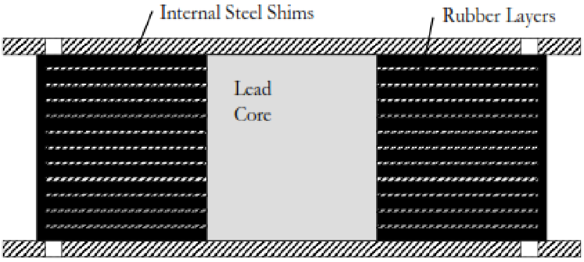

Figure 3: Lead rubber bearing section

One of the key advantages of the Lead-Rubber Bearing (LRB) system is its ability to provide rigidity under regular service loads, elasticity during seismic activity, and effective damping, all within a single compact unit. These features make LRBs the most widely used isolators, particularly in cases where high damping or structural rigidity under normal operating conditions is crucial. Moreover, the elastomeric materials used in high-damping rubber (HDR) bearings are equally suitable for LRB designs.

In traditional seismic design, the structure's strength is adjusted to resist earthquake forces. However, base isolation takes a different approach by separating the building from seismic ground movements. This is achieved by installing isolation devices between the building's foundation and its superstructure. The main purpose of these devices is to minimize the horizontal acceleration that reaches the building during an earthquake. All base isolation systems share common attributes, such as flexibility and the capacity to absorb energy. The core principle of base isolation is to shift the structure's fundamental period away from the frequency range where earthquake energy is most intense, while also improving the building's ability to absorb energy and reduce damage.

“Currently, base isolation techniques are categorized into three main types:

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

Implementation of Base Isolation in Buildings

A key concern for structural engineers is deciding when to implement base isolation in a building. The simple answer is that base isolation should be considered when it provides a more efficient and cost-effective solution for earthquake protection compared to other methods. If the design requirements for withstanding seismic loads demand a level of strength or detailing that is difficult to achieve with traditional techniques, base isolation becomes a practical and viable alternative.

To assess whether base isolation is appropriate for a particular structure, it is essential to review a set of factors that determine its effectiveness. This involves evaluating whether the building meets the necessary criteria for base isolation, ensuring it will enhance seismic performance and provide long-term safety and stability.

Weight of the Structure: Base isolation works best in structures with a large mass, as it enhances the building's ability to resist seismic forces. This effectiveness comes from leveraging the structure's long natural period of response. The natural period is a fundamental property of a building, which increases with the square root of its mass (M) and decreases with the square root of its stiffness (K). By adjusting these factors, base isolation systems can significantly improve a building's ability to absorb and mitigate earthquake energy, reducing damage and enhancing safety.

Period of the Structure: Buildings with a fundamental natural time period of less than one second are typically the best candidates for base isolation. For instance, structures that are less than 10 stories tall, or flexible designs like steel moment frames with fewer than five stories, are particularly well-suited for base isolation. These types of buildings can benefit significantly from the technique, as base isolation helps to effectively reduce the impact of seismic forces, ensuring greater safety and structural integrity.

Seismic Conditions with Long Period Waves: In certain areas, the path between an earthquake's epicenter and the building site can lead to long-period ground motion. This phenomenon is commonly seen in alluvial basins and may cause resonance in isolated structures, which can actually intensify the building's response instead of reducing it. Such occurrences have been documented in cities like Mexico City and Budapest, where these specific conditions have negatively impacted the performance of base-isolated buildings during earthquakes.

Subsoil Conditions: Base isolation is most effective when implemented on rock or stiff soil sites. Soft soil, much like in basin conditions, can amplify long-period ground motions, making it less ideal compared to more rigid sites. Although base isolation can still be used on soft soil, its overall effectiveness and efficiency may be diminished in such conditions, as the amplified ground motion can reduce the benefits of the isolation system.

Near-Fault Effects: One of the most discussed challenges of base isolation is its effectiveness in areas close to fault lines. In these regions, a phenomenon called "throw" can occur, marked by a high-velocity, long-duration pulse in the ground’s acceleration. While base isolation is used in near-fault locations, it often comes with increased costs and a more intricate evaluation process. Any structure built near a fault line must be carefully assessed for the "fling" effect, which is a consideration for all seismic designs, not just base-isolated systems.

Aspect Ratio of Structural Systems: Most isolation devices are engineered to operate effectively under compression loads. Sliding systems may lose their effectiveness when vertical loads generate tension, and elastomeric-based systems must handle tension through the elastomer material itself. Under low-stress conditions, tension can lead to cavitation, which decreases the stiffness of the isolator. As a result, isolation systems are typically not suitable for structures that depend on tension elements to counter lateral forces.

Contribution of Research work

The objective of this study is to analyze the influence of various base isolation systems on the linear dynamic characteristics of symmetrical and asymmetrical structures subjected to lateral earthquake forces. This will be achieved through response spectrum analysis in ETABS and experimental testing of both fixed base and base-isolated structures using a shake table.

- Study different types of base isolators and their constituent elements.
- Focus on the impact of various base isolation systems, such as lead rubber bearings, on the seismic performance of structures.
- Perform a comparative analysis between base-isolated and fixed base structures using ETABS software, evaluating factors such as columns and footings.
- “Conduct a parametric study to examine the linear dynamic characteristics of structures, considering different isolation systems using the response spectrum method”.

- Design and evaluate the effectiveness of base isolation systems within ETABS, contributing to the understanding of how these systems can improve seismic performance.

Scope Of the Study

The current study focuses on an analytical investigation of the impact that different base isolation systems have on the seismic response of structures subjected to lateral seismic loads. This research involves a detailed analysis of various types of base isolators, along with their constituent components. The study specifically examines the influence of base isolation systems, such as lead rubber bearings and friction pendulum bearings, on the seismic performance of both symmetrical and asymmetrical structures.

A comparative analysis is conducted between base-isolated and fixed-base structures through both experimental and analytical methods. Furthermore, a parametric study was performed to investigate the linear dynamic characteristics of these structures, utilizing different isolation systems through the response spectrum method. Additionally, the research focuses on designing and evaluating the effectiveness of lead rubber bearings and friction pendulum bearings as base isolation systems, with an aim to enhance the overall seismic performance of structures.

Limitations of study

Conducting experimental work for all cases is not feasible, as constructing models of base-isolated buildings would be prohibitively expensive. Therefore, reliance on software-based analytical studies becomes essential.

Performing manual calculations for a 3D frame building would be highly time-consuming and complex, making it impractical for large-scale analysis.

Seismic Zones

“India is currently divided into four earthquake zones based on seismic risk: Zone 2, Zone 3, Zone 4, and Zone 5. Although the classification once included Zone 1, no region in India is currently designated as Zone 1 in the latest seismic zoning maps. Zone 5 represents the areas with the highest seismic risk, while Zone 2 is considered to have the lowest risk. This updated classification helps guide building design and safety measures in accordance with the seismic activity specific to each region.

Figure 4: Zone in India

Zone 5: Zone 5 is the region with the highest seismic risk, prone to earthquakes of intensity MSK IX or greater. According to the Indian Standard (IS) code, a zone factor of 0.36 is assigned to this area, which structural engineers use for designing earthquake-resistant structures. This factor represents the intensity of ground shaking for an earthquake at the zero-period level. Zone 5 is classified as a Very High Damage Risk Zone and includes areas like Kashmir, the western and central Himalayas, North and Middle Bihar, the northeastern parts of India, and the Rann of Kutch. Additionally, regions with trap rock or basaltic rock formations are more vulnerable to seismic disturbances, further elevating the risk in these areas.

Zone 4: Zone 4 is classified as a High Damage Risk Zone, where regions are susceptible to earthquakes with an intensity of MSK VIII. The Indian Standard (IS) code assigns a zone factor of 0.24 to this area, which is used for designing buildings to withstand seismic forces. Zone 4 includes the Indo-Gangetic basin, Delhi, and Jammu & Kashmir. Additionally, the Patan area near Koynanagar in Maharashtra is part of this zone, as is the northern region of Bihar, including Raksaul, near the India-Nepal border. In Delhi, around 80 percent of the structures are vulnerable to collapse in the event of a major earthquake. A catastrophe of this scale would devastate key areas such as Lutyens' Delhi, the iconic Connaught Place, and the historic Walled City, potentially causing widespread damage in the political and commercial heart of India.

Zone 3: Zone 3, classified as a Moderate Damage Risk Zone, includes regions like the Andaman and Nicobar Islands, parts of Kashmir, and the Western Himalayas. These areas are prone to earthquakes with an intensity of MSK VII and a magnitude of up to 7.8. The Indian Standard (IS) code assigns a zone factor of 0.16 to Zone 3, which is used by engineers to design structures that can withstand seismic forces in these regions. While the risk is lower compared to higher zones, the potential for significant damage still exists, and proper precautions are essential for ensuring the resilience of buildings in these areas.

Zone 2: Zone 2 is classified as a Low Damage Risk Zone, where regions are vulnerable to earthquakes of intensity MSK VI or lower. According to the Indian Standard (IS) code, this zone is assigned a zone factor of 0.10. This indicates that the maximum horizontal acceleration a structure in this zone might experience is 10% of gravitational acceleration. Although the seismic risk is relatively low in Zone 2, ensuring that buildings are designed with this factor in mind helps safeguard structures against potential damage from minor earthquakes".

2. Literature Review

This literature survey synthesizes insights from various studies to explore the effectiveness of different structural systems and design methodologies in improving seismic performance. The focus is on RC framed structures with shear walls, viscous dampers, framed tube systems, and base isolation techniques, among others.

Saxena et al., (2024), The integration of shear walls in RC structures significantly enhances their seismic resistance. A study using ETABS software demonstrated that optimal placement of shear walls, particularly near the building core, reduces story displacement and improves overall structural performance Another comparative study found that while shear walls are effective, framed tube systems exhibit superior seismic resistance, with reduced displacements and enhanced ductility, making them a viable alternative for tall buildings in seismic areas

Sima, S., Ijmulwar et al (2024), The purpose of this work is to provide a simpler performance-based seismic design technique for buildings made of reinforced concrete (RC) that use fluid viscous dampers (FVDs) in order to improve their resistance to earthquakes. Through the selective positioning of dampers in floors that have large drifts, it focuses on limiting maximum displacement as well as floor acceleration. The research examines the effectiveness of this technology in comparison to both practical and conventional installation options, revealing that dampers enhance seismic behaviour in reinforced concrete buildings. In addition to demonstrating the efficacy of the suggested design approach, this study provides structural engineers with significant insights that can be used when constructing earthquake-resistant RC structures using FVDs.

Badri, Prasad et.al. (2023), A comprehensive evaluation of seismic analysis techniques for reinforced concrete and steel structures is presented in this study, with a particular emphasis on linear and non-linear static analysis. A comparison is made between the Equivalent Lateral Force Method and the Response Spectrum Method for the construction of multi-story structures in areas that are prone to earthquakes. It is standard practice to use the seismic coefficient approach and the response spectrum method when designing for seismic activity. Through the discussion of modern principles in the process of developing earthquake design response spectra, the research intends to be of assistance to engineers working in places that experience low to moderate seismic activity. Additionally, it offers insights into a variety of seismic analysis approaches that have been used in previous literature, with a particular focus on RCC structures.

A., Mishra et.al (2022), In this study, a comparative examination of the earthquake resistance of RCC buildings and energy dissipation devices such as Lead Rubber Bearings (LRB) is presented and discussed. The results of this study demonstrate the efficacy of base isolation systems, such as LRB isolators, in mitigating seismic reactions such as lateral displacement, shear pressures, and interstorey drift. The research highlights the significance of implementing base isolation as a means of controlling seismic reactions in buildings that have a variety of vertical irregularities via its findings. The use of LRB structures as a feasible method for strengthening earthquake resistance in building structures is the primary emphasis of the study as a whole.

Rakhesh J Ghante. et al. (2022), The research paper provides a comparative study on seismic analysis of RC structures with and without floating columns, including various lateral load resisting systems. It discusses the impact of different design elements such as floating columns, bracing systems, shear walls, and shear cores on the seismic performance of multi-story buildings. The study highlights that introducing a single bracing/strut contributes significantly to reducing shear force and bending moment. Additionally, the shear core structure demonstrates the highest resistance to seismic loads among all models analyzed. Overall, the paper emphasizes the importance of incorporating effective seismic design strategies in earthquake-resisting RC structures.

Ion, Sococol et al. (2022), Reinforced concrete (RC) frame systems that withstand moments and have decreased beam sections are the subject of this paper's seismic response analysis. It offers a mathematical analysis of the dissipation of seismic energy in marginal beam regions and the concentration of plastic hinges. Results show that by decreasing beam sections, seismic response is improved and the "Strong Columns-Weak Beams" mechanism is partially formed. This study contributes to enhancing the ductile behavior of RC structures under seismic actions, offering insights for designing earthquake-resistant RC structures with optimized beam configurations for improved performance during earthquakes.

The paper discusses the comparative analysis of RCC structures with energy dissipation devices like Lead Rubber Bearings (LRB) for earthquake resistance. It highlights the effectiveness of base isolation systems, such as LRB isolators, in reducing seismic responses like lateral displacement, shear forces, and interstorey drift. The study emphasizes the importance of incorporating base isolation to control seismic responses in structures with various vertical irregularities. Overall, the research focuses on the application of LRB structures as a viable solution for enhancing earthquake resistance in building structures.

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Rongtian Zhang. (2023), The research paper focuses on the concept of earthquake-resilient structures, emphasizing the shift from traditional seismic design to resilient structure design. “It discusses the problems with conventional seismic design, lays out the goals of resilient structure design, and sorts resilient buildings into types such as rocking buildings and those with self-cantering braces”. The paper also discusses the principles, research progress, and practical applications of resilient structures. While it doesn't specifically mention a comparative analysis between earthquake-resisting RC structures and LRB structures, it provides valuable insights into the advancements and principles of earthquake-resilient structures.

Edisson, Alberto et al. (2023), Rapid post-earthquake damage identification in RC resisting-moment frame structures is the main emphasis of this work, which employs Machine Learning. Based on the characteristics and intensity measurements of structural parts' behavior, it suggests an approach that uses ML algorithms to forecast the damage status of RC buildings. Random Forest and Gradient Boosting techniques, particularly acceleration-based intensity measurements, are shown to be beneficial in the research. Accurately diagnosing structural damage situations in RC structures using ML approaches is provided by the study, which also highlights the significance of improving earthquake data for future studies.

Gap Analysis

As the aspect ratio of a structure grows, the moments in the column considerably decrease for wind load situations, but the moments stay basically constant throughout varying aspect ratios under gravity loads.

Nonlinear time-history analysis, which incorporates various site-specific ground vibrations, is essential in the design of base-isolated structures.

In low-rise structures, an elevation in height leads to increased moments in the columns, but in medium-height buildings, the moments often stay stable.

Column moments are a crucial consideration in the construction of tall structures to ensure structural integrity.

3. Methodology

For the purpose of this investigation, the finite element program ETABS is used to model structures. All of the components that have an effect on the mass, strength, stiffness, and deformability of the structure are included into the analytical models. Beams, columns, and slabs make up the building's structural system. Non-structural elements, which do not substantially impact the behavior of the structure, are not included in the model even if they are not considered to be structural components. In order to analyze these models, modal analysis and response spectrum analysis are carried out. In particular, the emphasis of this study is on three-dimensional reinforced concrete (RC) structures that are at least twelve stories tall, have aspect ratios that vary by increments of half, have a total area of four hundred square meters, and are located in seismic Zone III. In this research, a comparison is made between two different cases: one has a fixed base, and the other includes base isolation that is accomplished using Lead Rubber Bearings (LRB).

3.1 Modelling & Design

Loads Acting on Buildings

Gravity Loads

“Gravity loads in the analysis include the self-weight of the building”, a floor finish load assumed to be 1.5 kN/m², and a live load of 2 kN/m², as specified in IS 875 (Part II) for residential structures during their operational phase. In addition to these, wall loads are considered as imposed loads, with internal beams carrying a load of “7.5 kN/m² and external beams carrying 13 kN/m²”. These loads ensure that all significant forces affecting the building's performance are accurately accounted for in the structural design.

Lateral Loads

Lateral loads, in contrast to vertical loads, may have a far more dramatic effect on structures, and this effect becomes more pronounced with increasing building height. The most common kind of live load is the lateral load, which consists mostly of horizontal forces acting on the structure. Wind loads, seismic pressures, and ground pressure on buildings like seashore retaining walls are typical instances of lateral loads. The location of the structure, the structural materials employed, the building's height and form, and other variables all have a role in the magnitude of these lateral stresses. To make sure the structure can withstand such kinds of pressures, these things need to be thought about thoroughly while designing it.

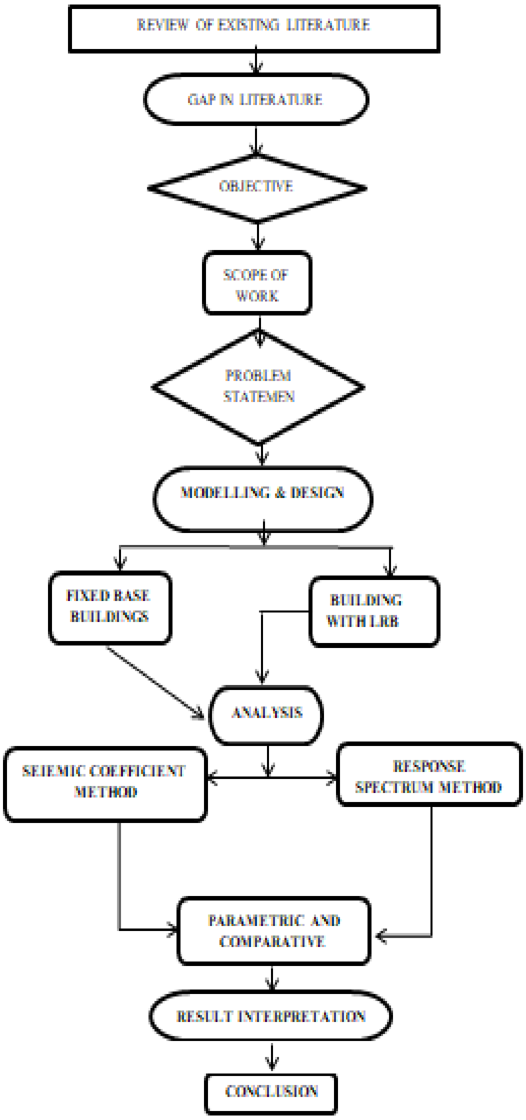
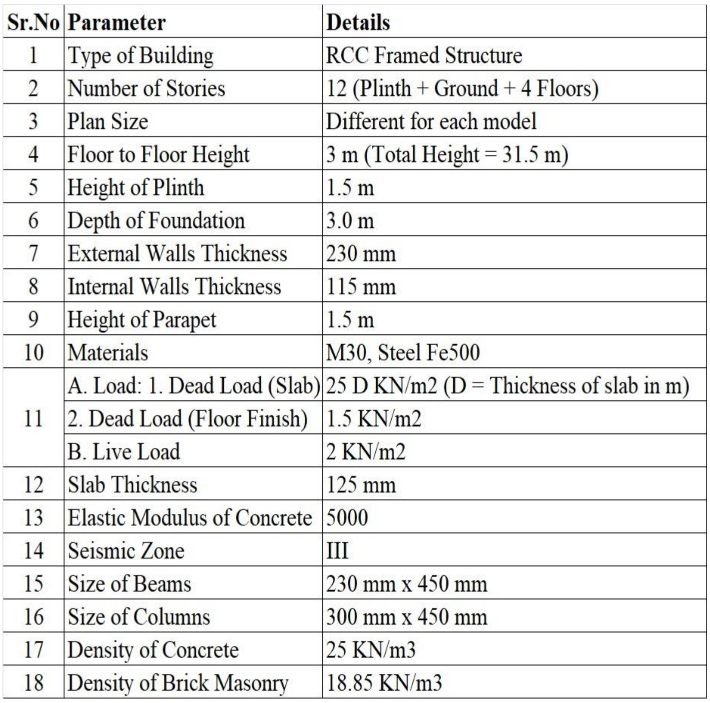


Figure 4: Flowchart of Methodology

Earthquake Load

The dynamic reaction of the building to ground shaking causes earthquake loading. “Another kind of lateral live load is earthquake loads. In addition to being more dangerous than wind loads, they are also very complicated and unpredictable. Thankfully, they don't happen very often. Earthquakes cause what people call "shakes," "rattles," and "rolls" on the ground. All buildings in an earthquake zone need to be resilient enough to endure these three distinct types of loads. The foundation of a building may move in any direction, although analysis typically only takes into account the horizontal components of such movement. Factors such as building mass, structural stiffness, and ground acceleration determine the strength of horizontal inertia forces caused by earthquakes”.

Table 1: Analysis Data for All Models



Sr.No	Parameter	Details
1	Type of Building	RCC Framed Structure
2	Number of Stories	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
6	Depth of Foundation	3.0 m
7	External Walls Thickness	230 mm
8	Internal Walls Thickness	115 mm
9	Height of Parapet	1.5 m
10	Materials	M30, Steel Fe500
11	A. Load: 1. Dead Load (Slab)	25 D KN/m2 (D = Thickness of slab in m)
	2. Dead Load (Floor Finish)	1.5 KN/m2
	B. Live Load	2 KN/m2
12	Slab Thickness	125 mm
13	Elastic Modulus of Concrete	5000
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/m3
18	Density of Brick Masonry	18.85 KN/m3

Table 2: Structural Details

Parameter	Details
Number of Stories	10
Floor to Floor Height	3 m
Type of Building	Commercial
Size of Beams	230 mm x 450 mm
Size of Columns	600 mm x 600 mm
Slab Thickness	150 mm
External & Internal Walls Thickness	230 mm
Height of Parapet Wall	1.2 m

Table 3: Loading Details:

Parameter	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	KN/m^2

Table 4: Seismic Details

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

G+12 FIXED BASED MODEL

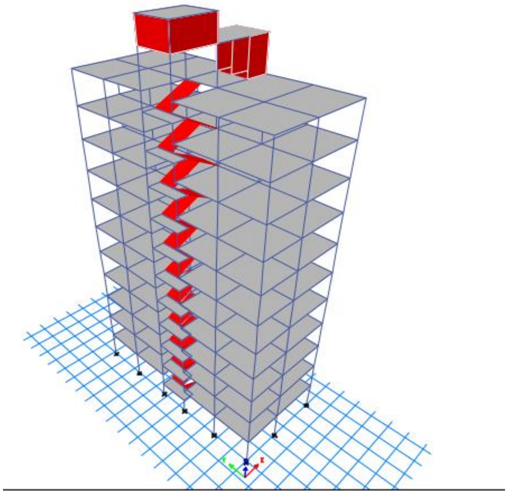


Figure 5: G+12 Fixed Based Model

G+12 LRB MODEL

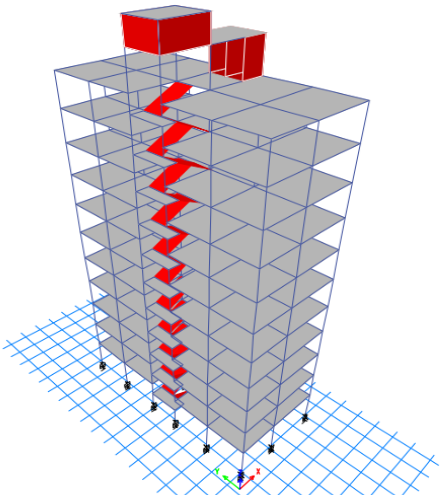


Figure 6: G+12 LRB Model

Table 5:

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
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	3.53	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	2.75	2.45

Table 6:

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
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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	3.53	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	2.75	2.45

Table 7:

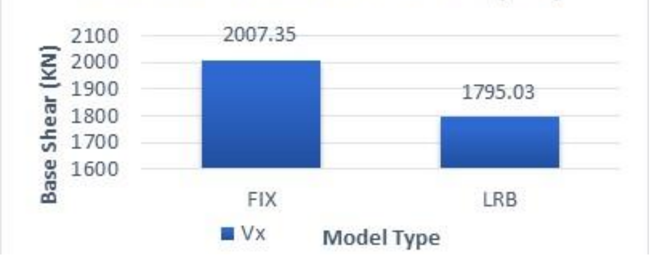
		TYPE OF MODEL	
MODE NUMBER	MODE DIRECTION.	**FIXED**	**LRB**
MODE1 IN SEC	Y DIRECTION	0.827	1.757
MODE 2 IN SEC	X DIRECTION	0.773	1.01
MODE 3 IN SEC	TORSION	0.667	0.865

4. Results & Discussion

Base Shear

Base Shear In X-X Dire (Kn)

BASE SHEAR	FIX	LRB
	2007.35	1795.03

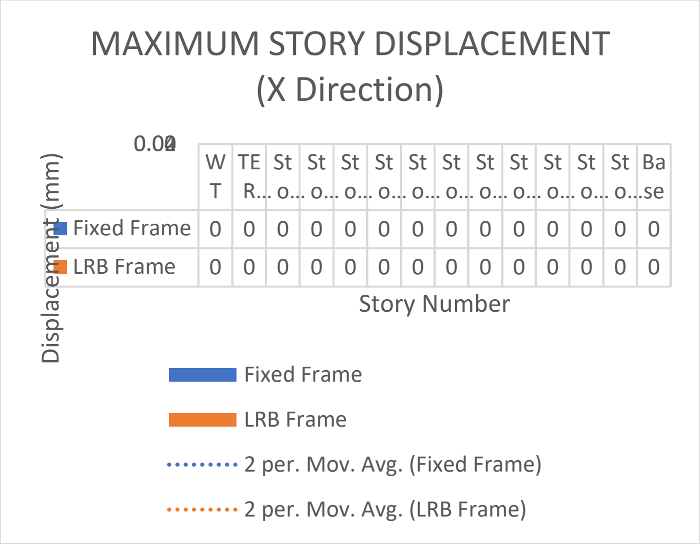


MAXIMUM STORY DISPLACEMENT

a) Maximum Story Displacement (X Direction)

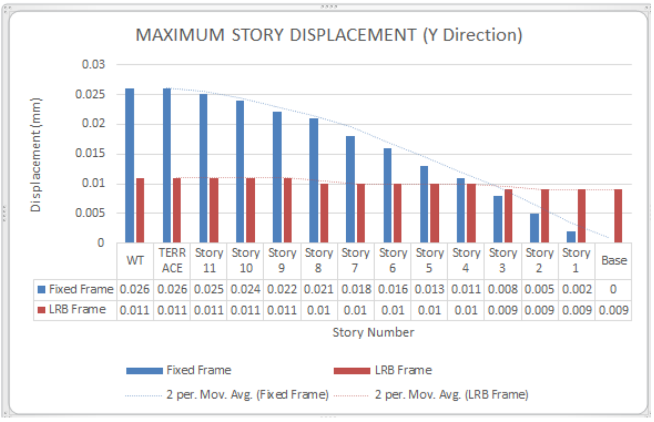
STORY	ELEVATION	Fixed Frame	LRB Frame
WT	41	0.003	0.004
TERRACE	39	0.003	0.004
Story11	36	0.021	0.023
Story10	33	0.02	0.022
Story9	30	0.019	0.022
Story8	27	0.018	0.022

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



a) Maximum Story Displacement (Y Direction)

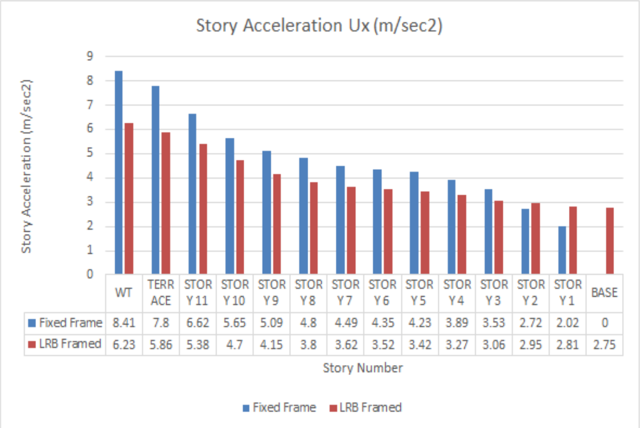
STORY	ELEVATION	Fixed Frame	LRB Frame
WT	41	0.026	0.011
TERRACE	39	0.026	0.011
Story11	36	0.025	0.011
Story10	33	0.024	0.011
Story9	30	0.022	0.011
Story8	27	0.021	0.01
Story7	24	0.018	0.01
Story6	21	0.016	0.01
Story5	18	0.013	0.01
Story4	15	0.011	0.01
Story3	12	0.008	0.009
Story2	9	0.005	0.009
Story1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



Story Acceleration

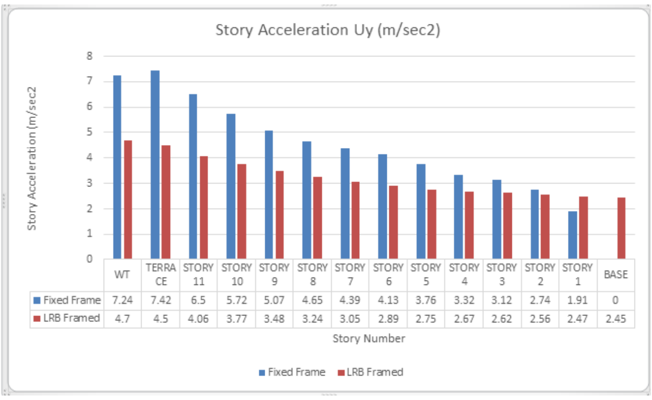
A) Story Acceleration Ux (M/Sec2)

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



a) Story Acceleration Uy (m/sec2)

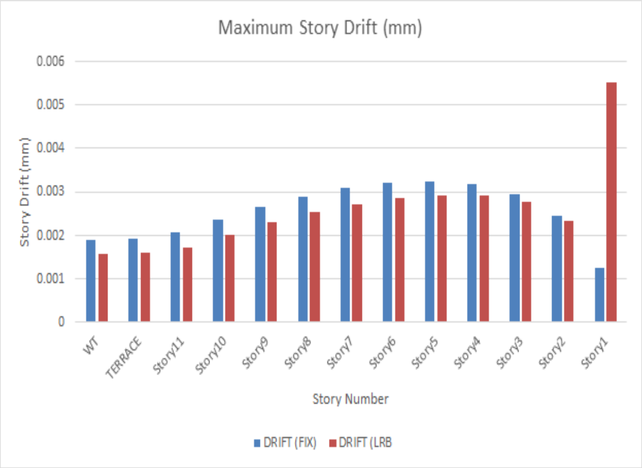
STORY	Fixed Frame	LRB Framed
WT	8.41	6.23
TERRACE	7.8	5.86
STORY 11	6.62	5.38
STORY 10	5.65	4.7
STORY 9	5.09	4.15
STORY 8	4.8	3.8
STORY 7	4.49	3.62
STORY 6	4.35	3.52
STORY 5	4.23	3.42
STORY 4	3.89	3.27
STORY 3	3.53	3.06
STORY 2	2.72	2.95
STORY 1	2.02	2.81
BASE	0	2.75



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

RESP SPECTRUM U1 FIXCED		
MODE	**PERIOD SEC**	**U1 ACC**
1	0.827	3.89
2	0.773	4.2
3	0.667	5
4	0.229	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

5. CONCLUSION

The purpose of this research was to investigate the effect that different base isolation systems, such as Friction Pendulum Bearing and Lead Rubber Bearing (LRB), have on the seismic response of structures that are exposed to lateral seismic stresses. This was done in contrast to buildings that have a permanent basis. Through the use of the response spectrum approach, an assessment was made about the performance of symmetrical and asymmetrical structures under a variety of base circumstances. The results demonstrate that the use of LRB as a base isolation system significantly reduces story shear, base shear, and story drift, particularly in higher stories, thereby enhancing the building's stability during an earthquake. Additionally, point displacements increased, which adds flexibility to the structure during seismic events. Overall, incorporating LRB improves structural stability, reduces reinforcement requirements, and makes the building more economical. It is concluded that the design of LRB is not only safe but also highly effective in mitigating seismic effects.

Discussion

- The shake table experiments revealed that Base Isolated Structures experience significantly less movement and acceleration compared to fixed base structures.
- When an external frequency was applied during the shake table test, the Base Isolated Structure demonstrated greater stability than the fixed base structure.
- The separation of the base allows the floors to move more freely and with less acceleration, in contrast to a fixed structure, and this was observed for both symmetrical and asymmetrical buildings in all directions.
- In all scenarios, the floor movements and deformations remained within the permissible limits outlined in IS 1893:2016.
- Linear dynamic analysis showed that the fixed base system has a much shorter natural time period than the base-isolated system across all models. These findings align with the empirical relationships provided by IS 1893:2016.
- The base shear was found to be significantly higher in fixed base structures compared to base-isolated structures in both the x and y directions.
- One and two-story symmetrical and asymmetrical buildings were analysed, and it was observed that structures with Friction Pendulum System (FPS) models exhibited lower storey displacements, accelerations, base stresses, and drifts compared to Lead Rubber Bearing (LRB) models.
- In conclusion, the base isolation system effectively protects buildings from both moderate and severe seismic ground motions.

REFERENCES

[1]. Manoj, Saxena., Ms., Anushka, Dehariya., Abhay, Kumar, Sharma. (2024) Seismic analysis of rc framed structure considering l-shaped shear wall and hollow core shear wall using etabs. Indian Scientific Journal of Research in Engineering And Management, doi: 10.55041/ijsrem36482

[2]. Sima, S., Ijmulwar., Sanjaya, Kumar, Patro. (2024). Seismic design of reinforced concrete buildings equipped with viscous dampers using simplified performance-based approach. Structures, doi: 10.1016/j.istruc.2024.106020

[3]. Badri, Prasad, Niraula., Nirav, Patel. (2023), A Review on Seismic Analysis of RCC and Steel Structures using Linear and Non-linear Static Analysis. International Journal for Research in Applied Science and Engineering Technology, doi: 10.22214/ijraset.2023.55972

[4]. A., Mishra., D., R., Singh. (2022), A Review Paper on Comparative Analysis on RCC Structure with Energy Dissipation Device and Composite Structure. International Journal For Science Technology And Engineering, doi: 10.22214/ijraset.2022.47835

[5]. Rakhesh, J, Ghante., Manjunath, B, V. (2022), Comparative Study on Seismic Analysis of RC Structure with and Without Floating Column Including Lateral Load Resisting Systems. International Journal of Innovative Research in Science, Engineering and Technology, doi: 10.15680/ijirset.2022.1110013

[6]. Ion, Sococol., Petru, Mihai., Tudor, C., Petrescu., Florin, Nedeff., Valentin, Nedeff., Maricel, Agop. (2022), Analytical Study Regarding the Seismic Response of a Moment-Resisting (MR) Reinforced Concrete (RC) Frame System with Reduced Cross Sections of the RC Beams. Buildings, doi: 10.3390/buildings12070983

[7]. A., Mishra., D., R., Singh. (2022), A Review Paper on Comparative Analysis on RCC Structure with Energy Dissipation Device and Composite Structure. International Journal For Science Technology And Engineering, doi: 10.22214/ijraset.2022.47835

[8]. Rongtian, Zhang. (2023). Research Review on Earthquake Resilient Structures. Highlights in Science Engineering and Technology, doi: 10.54097/hset.v52i.9186

[9]. Edisson, Alberto, Moscoso, Alcantara., Taiki, Saito. (2023). Machine Learning-Based Rapid Post-Earthquake Damage Detection of RC Resisting-Moment Frame Buildings. Sensors, doi: 10.3390/s23104694

[10]. Rajesh Kumar, Y. (2018). Comparative study of base isolators and viscous fluid dampers on seismic response of RC structures. *International Journal of Civil Engineering and Technology (IJCIET)*, 9(8), 798–806.

[11]. Baruwala, M. M., Darji, A. R., & Parikh, K. B. (2017). Seismic performance of buildings with base isolation, damper, and braced systems: A review. *International Journal of Innovative Research in Advanced Engineering (IJIRAE)*, 4(11).

[12]. Heysami, A. (2015). Types of dampers and their seismic performance during an earthquake. *Current World Environment*, 10(Special Issue 1), 1002-1015.

[13]. Islam, A. B. M. S., Hussain, R. R., Jumaat, M. Z., & Rahman, M. A. (2013). Nonlinear dynamically automated excursions for rubber-steel bearing isolation in multi-storey construction. *Automation in Construction*, 30, 265–275.

[14]. Islam, A. B. M. S., Hussain, R. R., Jameel, M., & Jumaat, M. Z. (2012). Non-linear time domain analysis of base isolated multi-storey buildings under site-specific bi-directional seismic loading. *Automation in Construction*, 22, 554–566.

[15]. Choudhury, S., & Singh, S. M. (2013). A unified approach to performance-based design of steel frame buildings. *Journal of the Institution of Engineers (India) Series A*, 94(2), 73–82. https://doi.org/10.107/s40030-013-0037-8

[16]. Tehaseen, S. K. G., & Kumar, J. D. C. (2017). Effect of change of storey drift and storey height in multi-storey building with varying seismic zones. *International Journal of Civil Engineering and Technology (IJCIET)*, 8(1), 583–590.

[17]. Mishra, M. P., & Dubey, S. K. (2017). Possibility of drift control in soft-storied RCC buildings in higher seismic zones. *International Journal of Civil Engineering and Technology (IJCIET)*, 8(9), 1100–1110.

[18]. Sullivan, T. J., Calvi, G. M., Priestley, M. J. N., & Kowalsky, M. J. (2018). The limitations and performances of different displacement-based design methods. *Journal of Earthquake Engineering*, 7(Special Issue 1), 201–241.

[19]. Sabeer, M., & Peera, D. G. (2015). Comparison design result of RCC building using STAAD and ETABS software. *International Journal of Innovative Research in Advanced Engineering (IJIRAE)*, 2(8), 92–97.

[20]. El-Shaer, M. A. A. (2015). Seismic load analysis of different R.C. slab systems for tall buildings. *International Journal of Current Engineering and Technology*, ISSN 2277-4106.

[21]. Sathawane, A. A., & Deotale, R. S. (2011). Analysis and design of flat slab and grid slab and their cost comparison. *International Journal of Engineering Research and Applications (IJERA)*, 1(3), 837-848.

[22]. Sharma, M., & Maru, S. (2014). Seismic load analysis of RCC building. *IOSR Journal of Mechanical and Civil Engineering*, 11(1), Ver. II, Jan 2014.

[23]. Bureau of Indian Standards. (2002). IS 1893-2002 (part-1) "Criteria for earthquake-resistant design of structures" (5th revision). Bureau of Indian Standards, New Delhi.

[24]. Bureau of Indian Standards. (2000). IS 456-2000: Plain and reinforced concrete code of practice (4th revision). Bureau of Indian Standards, New Delhi.

[25]. Bureau of Indian Standards. (1987). IS 875-1987 (part-1): Code of practice for design loads (other than earthquake) for buildings and structures – Dead loads. Bureau of Indian Standards, New Delhi.

[26]. Bureau of Indian Standards. (1987). IS 875-1987 (part-2): Code of practice for design loads (other than earthquake) for buildings and structures – Live loads. Bureau of Indian Standards, New Delhi.

[27]. Bureau of Indian Standards. (1987). IS 875-1987 (part-3): Code of practice for design loads (other than earthquake) for buildings and structures – Wind loads. Bureau of Indian Standards, New Delhi.

[28]. Bureau of Indian Standards. (1993). IS 13920-1993: Ductile detailing of reinforced concrete structures subjected to seismic forces. Bureau of Indian Standards, New Delhi.