

BASE ISOLATION STRUCTURES UNDER SEISMIC EXCITATION: A REVIEW

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Abstract: Seismic isolation systems are one of the most important modern methods in designing earthquake-resistant buildings. These systems separate the building from the ground using flexible devices, reducing the transmission of seismic motion into the building and thus reducing potential damage. These systems include lead-reinforced rubber bearings (LRB) and sliding bearings such as the Frictional Pendulum Bearing System (FPS). Recent studies have shown the high effectiveness of seismic isolation systems in reducing base shear forces and reducing enterer floor displacement during earthquakes, which improves the safety and security of the building. Seismic isolation systems face several challenges, including the effect of soil-structure interaction (SSI), which can affect the effectiveness of the system, especially in soft soil conditions. Research shows that soil quality plays a high role in system performance, as soft soil requires special designs to achieve the desired performance. In addition, 3D seismic isolation systems have been developed to counter horizontal and vertical vibrations. These systems are vital for critical facilities such as nuclear plants, bridges, hospitals, important buildings, etc. where vertical vibrations can significantly affect the building's non-structural components and its overall stability. Although seismic isolation systems effectively reduce seismic risks, there is a continuing need for more research to develop more efficient and applicable systems in various geological and constructional conditions. The future requires a deeper understanding and development of advanced materials, adaptive control systems, and comprehensive 3D isolation solutions.

INTRODUCTION

Base isolation is one of the most effective methods of earthquake-resistant design; this method attempts to shield structures from the damage caused by earthquakes by preventing the superstructure from being displaced by the ground. This idea began to emerge in the early 1900s and has experienced significant development in recent decades, which has led to its becoming an integral part of modern seismic design, particularly in areas that have a high degree of seismic activity. These systems used flexible bearings or dampers between the foundation and superstructure to absorb and dissipate seismic effects [37]. This technology was popularized in New Zealand in 1974, followed by the US in 1984 and Japan in 1985. Since then, it has been employed in many large projects like high-rise buildings, bridges, etc., and its performance has been demonstrated. The major purpose of use it is to reduce the damage caused by seismic loads and protect the lives of people [2]. There are many types of base isolation exist, each having its own features and special use. The most famous types of these systems contain rubber-base bearings

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like high-damping rubber bearings (HDRBs) and rubber lead bearings (LRBs), which are associated with their high performance in damping. Other types of sliding bearings, like the friction pendulum bearing (FPB), are also united into hybrid systems have both involve elasticity and damping performance. So, these techniques are very effective in decreasing earthquake response [1].

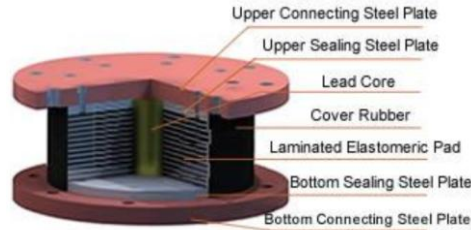


Figure 1: Cross Section of the Lead Rubber Bearing System.

The function of base isolation is to shift the natural period of isolated structure in percentage away from periods of the earthquake at the base of the structure by providing elastic and damping to the foundation to have less drift, decreased acceleration of storey, and reduced damages of structures and save lives, all of these effects for increasing the performance of structures at the seismic effect [30]. Base isolation design and its performance depend on the comprehensive understanding of the seismic loads, characteristics of structures, and materials used to manufacture it. Numerical and finite element modelling used in the analysis has a significant impact on the prognosis of the isolated structure's performance. Studies have proven that isolated buildings have a lower tendency to show a higher degree of seismic response than fixed structures, particularly regarding forces of shear and surface acceleration [25]. Many case studies have recommended that the use of base isolation is effective in real-world applications. For the case, use of HDRBs in a six-storey building in Vietnam reduces the roof's acceleration and the foundation's shear force during the effect of a seismic load, in comparison to the restrain of fixed base design. Also, the used of rubber lead base bearings in a high-rise building in India increased the resistance of structures against seismic effects, shows that their performance in dissipating seismic energy and noting the decrease of structural damages [6]. In spite of all these advantages of base isolation, there are some subjects to take into consideration: the initial cost may be high, the materials to manufacture it, and their durability under repeated and cyclic loading of conditions to be evaluated. Also, the interaction of soil underneath and isolated structures, known as soil-structures interaction (SSI), can affect the structure response for seismic, so it should be considered at the design stage. SSI is effective on the response of buildings [19]. Future research will concentrate on developing more effective methods of isolating. So, future research will focus on discovering more effective methods for isolating systems, increasing their long-lasting nature and the accuracy of numerical models. The discovering of automatic control systems and smart materials will help to develop base isolation methods, controlling or reducing seismic damage because it provides the solution to protect structures from seismic damage [33]. By effectively isolating building structures from the ground motion, base isolation systems reduce the probability of failure and increase the safety of users at structures. Future research and technological development will require addressing the current issues and expanding the base of isolation in different structural environments.

REVIEW OF LITERATURE

In the study “Earthquake Resistant Structure Using Base Isolation Technique” by Mhatre, et al. [23], the performance of buildings with base isolation technology was compared with buildings have fixed foundation. The results showed that the use of this technology significantly to reduces base shear and displacement and increases the time period of the isolated building as a result of seismic ground motion. They used rubber bearing as the primary isolation system, and 3D non-linear analysis was performed on residential reinforcement concrete buildings by using SAP 2000 software. The study showed that buildings with base isolation have greater flexibility and 20% fewer displacements at the top floor compared to buildings with a fixed foundation, resulting in a 30% reduction in shear forces and 25% bending forces required, thus reducing reinforcement needs. The study advised the use of base isolation to develop the seismic response of buildings in areas prone to seismic. The use of base isolation causes an increase in the oscillation period of isolated buildings and decreases the impact of earthquakes on the building. The use of rubber bearings also provides good stability and a positive seismic response.

In the study “Seismic Response of Base-Isolated Buildings with High Damping Rubber Bearings” by Deringöl and Güneyisi [11], the performance of high-damping rubber bearings (HDRB) with different design parameters in reducing earthquake effects on steel buildings was investigated. 18- different HDRB models were constructed and studied on low (3 storey's), medium (6 storey's), and high (9 storey's) steel structures. It showed that using a high isolation period and effective damping ratio increases the dissipated energy and reduces the relative isolation displacement and inter-storey displacements. For the case of the maximum displacements of the isolators were 28.19 cm, 29.22 cm, and 28.34 cm for the low, medium, and high structures, respectively, when the $T_3\beta_{15}\lambda_3$ system ($T=3$, $\beta=15$, $\lambda=3$) was used. The results showed that an HDRB with suitable design characteristics could reduce the inter-storey drift ratio, absolute acceleration, shear forces, and fundamental moments while providing an equal distribution of displacement across the building height. The study recommends the HDRB use different design systems to improve the earthquake performance of steel structures. *isolation period T , effective damping ratio β , and post-yield stiffness ratio λ characteristics of HDRB that used

Nguyen, et al. [26] studied the effect of using a base isolation system in improving the earthquake resistance of multi-storey buildings was analyzed in areas with moderate seismic activity, such as Vietnam. The results showed that the use of high-damping rubber bearings significantly reduces base shear and inter-storey displacement, increasing the basic oscillation period of the building by between 36% and 56%, reducing the acceleration of the upper floors by 58%, and reducing relative displacement by up to 79%. A 3D model of an eleven-storey building was analyzed using EtabsV17. The analysis showed that the isolated foundation significantly reduced the impact of seismic damage than to fixed buildings. Also advises using isolated foundation techniques when designing multi-storey buildings in areas prone with seismic activity to improve their seismic response and reduce the costs of repair after earthquakes.

In Fauzan, et al. [14], building with base isolation was analyzed to study their response during seismic activity. A model of high-damping elastomeric bearings (HDRB) used for a twelve-storey hotel building, and the performance compared between a fixed and a base-isolated building by using spectral response analysis and historical time analysis. The analysis showed that for isolated foundations, the internal shear forces and bending moments in columns are lower than in structures

with a fixed foundation, with shear forces reduced by nearly 70.72% and bending moments by 71.82%. Also, base isolation techniques reduced the relative displacement between floors by 56.53%. The study advises use of isolation for foundation in medium and high-rise buildings in Padang City, Indonesia, especially soft soil areas, to develop seismic performance and reduce damage caused by it.

In Haqbin [17], the base isolation reinforced concrete building was analyzed and designed to reduce the impact of earthquakes. SAP2000.v16 software was used to analyze a building containing of a basement and four floors above ground. The study showed that the base isolation oscillation period of the building with an isolated foundation increased by about four times compared to the building with a fixed foundation. Shear forces when using high- Damping Rubber Bearings (HDR) also decreased by up to 65%. The displacement at the base of the building reached 25.97 mm, while no displacement was recorded in the fixed case. Floor drift at the fourth storey also change from 10.49 mm to 0.53 mm when base isolation is used. The study advises using a base isolation system in building design to improve their seismic performance and decrease damage from seismic activity, which leads to improving the stability of buildings and ensuring safety.

In 2020, Radkia, et al. [29] analyzed asymmetric steel buildings to investigate the effect of seismic isolator taking into consideration the effect of the soil-structure interaction. The results significantly showed that the use of seismic isolators decreased inter-storey displacement and inter-storey acceleration. These effects were more cleared in single-story buildings than in other buildings. The study also showed that no effect on dynamic response for asymmetry in the structure, including displacement and acceleration. When converting type II soils to types III and IV, the displacement and sliding velocity decreased for all the structures studied. The study advised taking soil quality into consideration when designing seismic isolators to ensure suitable performance of the structure during earthquakes, especially in medium- and high-rise buildings, which helps significantly reduce damage caused by earthquakes.

Mmulti-storey buildings (G+10) with base isolation technology analyzed to investigate their performance for earthquake resistance. High-damping rubber bearings (HDRB) and lead rubber bearings (LRB) were used as isolation systems, non-linear historical time analysis was performed using ETABS 2016 software. The study showed that the period of the isolated buildings increased by up to 2.5 times compared to buildings with a fixed foundation, which Reduces seismic forces affecting the building. The study also showed that when use of base isolation increases the displacement between floors and reduces the rigidity of it, which increases the flexibility of the building and reduces the possibility of its collapse. The use of base isolation has been shown reduce in base shear by up to 60.78% when using HDRB and 62.53% when using LRB. The study advice to use of base isolation techniques for multi-storey buildings to improve their seismic performance and reduce damage, quickly reuse the buildings after earthquakes and provide protecting for sensitive equipment inside the buildings.

In 2018, Sahoo and Parhi [32], Analyzed multi-storey residential buildings using lead rubber bearings (LRB) base isolation to investigate their response under seismic activity. The study showed that the use of base isolation in the building foundation lead to increase the basic oscillation period of it by up to double, which decreases the seismic forces in the building. The analysis done by ETABS 2016 software, the study showed that the use of base isolation reduces base shear by up to 60% and increases storey displacement by up to 25%. For example, the oscillation period for a G+10 isolation foundation was 3.723 seconds while 2.622 seconds for a building with a fixed foundation. It recommends the use of base isolation techniques

in multi-storey buildings to improve seismic resistance, decreasing earthquake effects, quickly reused the buildings after seismic activity and provide protecting to sensitive equipment inside the building.

In 2018, Mazza, et al. [22], analyzed reinforced concrete buildings equipped with base isolation systems to study their response under exposed to earthquakes. The study used non-linear analysis models for a six-storey building and the performance of different base isolation systems such as high-damping rubber bearings (HDRB), steel-Teflon sliding bearings (SB) and friction pendulum bearings (FPB) were analyzed. The results showed that the use of isolation foundation systems certainly decrease the shear and bending forces on the columns, which increases the oscillation period for the isolated building and reduces the effect of earthquakes. It showed that foundation isolation techniques increase building flexibility by between 25% and 70% and develop the performance of buildings when exposed to earthquakes. For case of the used isolation system type HDRB reduced shear forces by 60% and horizontal displacement by 30%. The study recommends using base isolation systems in reinforced concrete buildings, especially in areas with high seismic activity, to develop seismic performance and reduce damage caused by earthquakes, which increases the safety of buildings and reduces repair and maintenance costs after earthquakes.

Fayaz and Patil [15] studied the performance of using a base isolation system on irregular multi-storey buildings in severe earthquake areas was analyzed. ETABS software was used to do static and dynamic analysis on a five-storey building, and the seismic performance for the building with lead rubber bearings (LRB) was compared with the same building with fixed base. The results showed that the use of base isolation significantly decrease base shear, displacement and drift between floors. For example, base shear is reduced by up to 88%, while maximum floor displacement is reduced by up to 90%, and drift is reduced by up to 85%. The study advises the use of a base isolation system in irregular multi-storey buildings to develop their seismic performance and reduce damage caused by earthquakes. Base isolation increases the flexibility of the building and reduces the seismic forces affecting it, which greatly improves its stability and safety.

In 2018, Fayaz and Patil [15] studied the performance of isolation system using frictional pendulum bearings (FPB) for refurbishment of reinforced concrete (RC) buildings against earthquake activity. The response of the existing building before and after refurbishment was evaluated by using non-linear model to analyze seismic activity. The study showed that the isolated foundations system significantly reduces the rate of drift between floors by up to 60% compared to fixed foundations, which reduce the structural damage during seismic activity. Also it showed that the isolated structures have good response the oscillation movements of earthquakes, as seismic forces were significantly reduced, increasing the oscillation period to approximately four times for isolated structures. The study recommended using(FPB) in refurbishment buildings in high seismic region to achieve significant development in structural response.

In Amrutkar, et al. [4], the response of asymmetric buildings located on slopes using base isolation Lead Rubber Bearings (LRB) was analyzed. it was designed and used in accordance with UBC 97 and IS 1893 Part 1, and the response between the buildings with base isolation at foundation and without was compared with using SAP2000 software. The study showed that when using base isolation the flexibility of the building increases and greatly reduces base shear and drift between storey, improving seismic response. For example, the base shear is by nearly 60%, and the base oscillation time is doubled, reducing the effect of earthquakes on the building. The study recommended using base isolation techniques in the design of buildings located

on slopes and in seismic areas to develop seismic response and reduce damage caused by earthquakes, which provide more stability and safety for the building.

In 2017, Nithin and Varma [27], studied the use of seismic base isolators on multi-storey buildings singularly and combined. The study use two types of isolators rubber lead bearings (LRB) and friction pendulum system (FPS). It showed that the use of base isolation greatly decrease the drift between storey and acceleration, develop the performance of buildings from seismic activity. For case of using LRB system decreasing base shear forces by nearly 60-70%, and for FPS system decreasing displacement by 20-30%. It also showed that the use of both types of isolator, like the combination of LRB and FPS, improve significantly protection than the use of one because of each systems have energy-absorbing or dissipation and vertical load-bearing characteristics, that provide more stability for building and decreasing damages from seismic activity. The study advise using both systems of base isolation as combined in the design of multi-storey buildings to develop seismic response and ensure the safety for buildings such as hospitals and disaster management centers.

In 2017, Ambasta, et al. [3] analyzed of conventional buildings and base-isolated buildings using lead elastomeric bearings (LRB) to investigate their seismic response. An eight-storey building (G+8) was modelled in a high seismic region (Zone V) in India, and the response was compared between buildings with base foundation isolation and with fixed foundation. The study showed that the use of foundation isolation greatly decrease displacement and drift between floors, with drift reduced by up to 70% compared to buildings with a fixed foundation. Shear and overturning forces also decreased by a same percentage, which boosts the stability of the building during seismic activity. The study advise the use of base isolation systems in multi-storey buildings in high seismic region, as it can reduce structural damage and provide safety for buildings during seismic activity. Also, it is advisable to analyze the costs and economical that effects of using these systems to ensure their compatibility with the ' financial and structural objectives of the project.

In 2017, Reddy, et al. [31], analyzed of multi-storey reinforced concrete buildings by using a base isolation system to study their performance under earthquake. which included modelling and analysis of two building the first have 5 storey plus ground floor the second have 17 storey plus ground floor, using two types of isolation, friction pendulum system (FPS) and lead rubber bearings (LRB). The study showed that the oscillation period of the building with isolated foundation increased greatly than to the buildings with a fixed foundation, reduced the shear forces by 70% in both directions X and Y. It obvious that the use of base isolation a significantly reduce displacement between floors, as the displacement of the 4th floor in the v of 17+G reduced from 10.49 mm to 0.53 mm when using LRB. The study recommended for multi-storey buildings in regions with high seismic activity to use base isolation systems to improve their performance and reduce damage caused by seismic activity, which provides more stability and safety for these buildings and reduces repair costs after earthquakes.

In 2017, Titiksh [36] analyzed of asymmetric mid-rise structures by using ETABS software to investigate their performance under seismic activity. The study involved 4-models: regular, irregular mass, irregular rigidity, and the model with prominent angles (Re-entrant). The study showed that the base shear and displacement increased similarly to the increase of seismic activity from seismic zone II to zone V, and the maximum base shear was in the model with angles that prominent in zone V. Also, displacement was largest in the same model, reaching 116 mm in the V-zone, and it was less in the regular model. The period of fundamental oscillation was the longest in the regular model, at 3.13 seconds. The study recommends that designs consider irregularities in mass and stiffness to develop seismic resistance.

Also, special management should be given to irregular structures in regions with high seismic activity to make sure provide suitable stability and safety of buildings and to decrease damage caused by the action earthquakes.

In the study “Seismic Response of Symmetrical and Asymmetrical Structure with Base Isolators” by Suthar and Noval [34], Symmetrical and asymmetrical structures using two types of base isolation lead friction pendulum (FPB) and rubber bearings (LRB) system was evaluated to get their performance under earthquake action. The analysis models for buildings of five stories high (G+5) by ETABS software. The study showed increases in the oscillation of isolated foundation period, reducing foundation shear by up to 70% than buildings without an isolation system. Also, horizontal displacement and storey drift are greatly increased by using base isolation. The drift was reduced by nearly 80% in asymmetric buildings. It recommends using base isolation techniques for regions with high seismic activity to develop seismic performance and decrease potential damage. So, a base isolation system helps to get more flexibility of the building and decrease the seismic effects, which boosts the safety and stability of the buildings and decreases the costs of repair after earthquakes. In 2017, Tafheem, et al. [35] analyzed multi-storey reinforced concrete buildings to study the response it was using base isolation under the action of seismic load. Two six-storey identical buildings were modelled and analyzed using ETABS software, one fixed base and the other isolated at the base of the columns of the building. The study showed that the fundamental period of oscillation of the insulated building magnifies by 28% than to the ordinary building, the base shear reduced by 69%, and the top storey acceleration reduced by 75%. The study recommends the use of base isolation systems to improve the seismic performance of buildings and reduce damage resulting from earthquakes. The system reduces seismic forces acting on the building and increases the flexibility of the structure, which enhances building safety and reduces post-earthquake repair.

Güneyisi and Deringöl [16] studied the behavior of structures equipped with lead rubber insulators under earthquakes was investigated using non-linear time history analysis. Steel frames five stories high and three columns equipped with lead rubber isolators (LRB) were used. The effect of isolation durations and isolation strength-to-weight ratio on the performance of structures was studied. Three natural ground kinematic recordings were used for analysis. The results showed that increasing the isolation period and strength-to-weight ratio leads to reducing the upper displacements of the frame, as the maximum displacement ratio decreased by 154.3% when exposed to the Tapas earthquake. The best isolation ratio was a period of 2.5 seconds and a strength-to-weight ratio of 0.04, which showed the greatest reduction in relative displacements and deformations between floors by 67.4% and 58.6%, respectively. The study recommends the use of lead-based rubber isolators with an isolation period of 2.5 seconds and a strength-to-weight ratio of 0.04 to achieve the best performance in reducing earthquake effects on structures. These results contribute to the design of more effective seismic isolation systems to improve the safety of buildings under the influence of earthquakes.

Darshale and Shelke [10] analyzed the response of base-isolated fixed-base reinforced concrete structures under earthquake action using ETABS software. The study examined three types of vertical decentralization: mass decentralization, solidity decentralization, and geometric decentralization. The results show that base isolation increases the initial structural period from 1.762 seconds to 4.343 seconds and reduces horizontal displacement by 60-65%, shear forces by 20-30%, bending moments by 25-35%, and base forces by 40-50%. , floor acceleration by 45-55%, and floor shift by 50-55%. The conclusion of the study demonstrates the effectiveness of

foundation isolation in reducing the response of structures to earthquakes and recommends its use as an effective means of controlling the impact of earthquakes on buildings with irregular structures.

In 2015, Cardone and Flora [8] proposed a new approach to the rehabilitation of buildings with low lateral strength or substandard detailing, using seismic isolation while accepting limited plastic deformations in the superstructure during strong earthquakes. Building with four storey reinforced concrete frame building. The approach was applied to it. Time history non-linear model analyzes showed that the use of seismic isolation can greatly increases the seismic response of buildings and decreasing establish and future maintenance costs. The study had found that using seismically isolated for buildings can protect them from damage without the need for significant reinforcement of concrete for the superstructure, decreasing initial costs by 30-40%. Also recommends the use of seismic isolation and approved with plastic deformations in acceptable limits as an effective and cost-saving strategy for refurbishment of existing reinforced concrete buildings after an earthquake.

Noorzai, et al. [28], Buildings analyze using base isolation technology to improve their resistance to earthquakes. A model of a 25-story building was used to analyze seismic activity with a base isolation foundation and fixed foundation to compare. The study showed that the use of base isolation decreases horizontal displacement by nearly 100% at the highest storeies, and decreases the forces and overturns by a greater percentage than to a fixed foundation. It also shows that it increases the fundamental oscillation period and decreases the effect of seismic activity on the building with an isolated foundation It. Recommendations refer to the use of base isolation as a suitable and active method to decrease seismic effects in high-rise buildings for the condition that the soil and location are suitable. The use of base isolation can provide suitable protection for buildings by decreasing forces developed from seismic activity and develop the building performance to lateral loads.

Barmo, et al. [5], the performance of isolated buildings using a hybrid system consisting of flat sliding bearings (FSB) with the addition of friction dampers Rotational (FD) and lead rubber bearings (LRB) was analyzed. The results showed that using a hybrid isolation system reduces displacements and fundamental shear forces while increasing the building height. However, the study noted that the hybrid system increases deflection, resulting in increased deflection as the building's flexibility increases. Compared to buildings with conventional foundations, the hybrid system provides improved performance in reducing displacements and foundation shear forces but causes increased deflections. The study recommends the use of a hybrid isolation system with rotational friction dampers at the base of the structure to improve seismic performance, especially in tall buildings, while cautioning against its negative impact on deflections. These results contribute to the design of more earthquake-resistant buildings using hybrid insulation techniques.

Cardone and Flora [8], the study includes a detailed evaluation of improving the seismic performance of buildings with reinforced concrete frames using seismic isolation. A real four-storey building in L'Aquila, Italy, was chosen as a case study. Non-linear historical time analyzes (NLRTHA) have shown that the use of seismic isolation can significantly reduce structural damage compared to the traditional approach. The results show that accepting limited plastic deformations in the superstructure can lead to significant initial cost savings (30-40%) compared to conventional methods, while the potential repair costs are reasonable and comparable to those required to strengthen the superstructure to prevent structural damage. The study recommends using a behavior factor greater than 1.5, and suggests a factor of up to 2.0 in the rehabilitation of existing buildings using seismic isolation. These

results are in line with the revisions of the Italian seismic code and indicate that the proposed alternative approach could be economically feasible for the rehabilitation of low-rise buildings with regularly reinforced concrete frames. However, the study emphasizes the need for additional case studies to confirm the applicability of this alternative strategy on a larger scale.

Ma, et al. [21] analyzed the response of base-isolated high-rise buildings using the pseudo-excitation method and the equivalent linearization method, and the accuracy of the results was verified using the Monte Carlo method. The results show that using the finite element (FE) model is more accurate than the multiple degrees of freedom (MDOF) model in calculating the maximum displacements and accelerations of the structure. The study showed that neglecting the effect of the higher mode in calculations reduces the accuracy of the results by up to 60% for displacements and 7% for accelerations. The results also show that the number of modes involved in the calculations has a small effect on the base deflection but significantly affects the absolute acceleration of the base. The study recommends using an FE model considering higher modes to improve the seismic response accuracy of basally isolated high-rise buildings.

Keerthana, et al. [20] analyzed the performance of multi-storey buildings using base isolation. An isolation system using laminated rubber bearings was designed and its properties were studied. The results showed that the use of base isolation significantly increases the natural vibration period of the building, reducing the seismic response. Three-storey building was analyzed, noted the oscillation period increased from 0.235 s to 2.554 s with use of base isolation. The study showed that foundation isolation decrease the lateral displacements in the storey by high percentage, that develop the building's response under the influence of seismic activity. The study prompts the use of foundation isolation technology in regions with high seismic performance to develop the resistance of the buildings and decrease damages caused by seismic activity.

Farissi and Budiono [13], the performance of multi-storey buildings using base isolation technology systems like rubber lead bearings and high-damping rubber bearings was analyzed. The study was performed on a twenty-storey building to match the response of fixed-foundation and base-isolated structures. The study showed that base isolation increases the fundamental oscillation period of the building from 1.94 seconds to 4.24 seconds while using lead rubber bearings and to 4.95 seconds while using high-damping rubber bearings. Also, the study showed that isolated structures obtain a great decrease in forces of base shear forces nearly 71.8% in the case of design earthquakes and 63.5% in the case of maximum earthquakes. The study prompts the use of base isolation technology to mend seismic response and decrease structural and non-structural damage of high-rise buildings.

Cardone, et al. [9], the response of isolated structures was analyzed using isolation systems involving high-damping rubber bearings (HDRB), lead rubber bearings (LRB), and pendulum bearings Frictional (FPB). The result of the study prompts the use of seismic isolation because it greatly decreasing inelastic deformation cycles than structures with fixed foundations. The study also found that isolated seismic structures show different response in management of damping capacity, decrease the reliance of the superstructure on hysteretic damping and plastic deformations of structures. For example, structures supplied by lead rubber bearings with a post-yield stiffness and equivalent damping ratio of 20% showed a decrease in ductility demands of 15% to 25%. Than systems using friction pendulum bearings with a damping ratio of 25% may experience a boost in ductility demands in low-storey buildings by nearly 30%. The study prompts the use of seismic isolation in buildings with reinforced concrete frames to improve seismic performance, with attention paid to designing

isolation systems to suit the building characteristics and avoiding heavy reliance on the internal damping capacity of the structure.

Di Sarno, et al. [12], the reliability of linear and non-linear dynamic analyses of irregular buildings equipped with base isolation systems (BIS). The study used a 3D model of a large, multi-storey hospital building foundational isolated using high-damping rubber bearings (HDRBs). The results showed that the values of the largest inter-storey deviation (d/h) calculated using spectral analyses on the 3D model ranged between $1/6$ and $1/10$ of the limit allowed in the code ($d/h = 0.33\%$), which indicates that the isolated buildings basically you need more stringent limits in design codes. Also, the maximum floor acceleration is reduced by approximately 70% compared to the ground acceleration. The study showed that spectral analyses provide less conservative values for motions and deformations than time history analyses, highlighting the need to carefully select natural ground motions to match the fundamental period of vibration of the structural system. The study recommends using simplified analytical models for preliminary analyses and selecting natural ground motions that match the fundamental vibration periods of basally isolated buildings to achieve accurate results.

In Mohamed [24], the response of base-isolated and fixed buildings under the action of earthquakes was studied. The results refer to base isolation greatly decreased the response seismic activity of buildings it showed a decrease in maximum displacement by nearly 23.7% than to fixed buildings. Also, the impact of the collision between adjacent isolated buildings is decreased by 12.1%, contributing to decreased structural damage. While the collision impact of fixed buildings increased to 18.29%, which increases the risk of damage to structures. The study prompts to increasing the isolated distances between adjacent buildings and using viscous dampers to decrease the energy transmitted from one building to another one during seismic activity. It is also prompt to conduct experiments on built models to ensure the effectiveness of these methods and get suitable designs to provide good performance to protect buildings during earthquakes.

Islam, et al. [18] developed a procedure to simplify the design steps of buildings with the use of lead rubber bearings (LRB) and high-damping rubber bearings (HDRB) in multi-storey buildings. The performance of these systems for isolating structures was studied in Bangladesh. The results showed that the use of LRB and HDRB can increase the performance of buildings against seismic activity and decrease lateral forces by up to 71.8% and greatly develop for structural system response.

In Cardone, et al. [7], a approach is displayed to give an accurately evaluation for the horizontal force distribution of base-isolated (BI) buildings by linear static analysis (LSA). This method is based on a factor that will measures the degree of nonlinearity of the base isolation system (BIS) and the ratio of the effective fundamental oscillation period of the isolated building (T_{is}) to the fixed foundation (T_{fb}). The results demonstrated that the proposed distribution of lateral forces has a significant effect on the accuracy of LSA predictions, NTHA demonstrated that the new distribution of forces outperforms the traditional distribution in predicting the ground shear load. For instance, the maximum lateral forces in buildings with lead rubber bearings (LRB) have been reduced by as much as 30% compared to the conventional distribution.

DISCUSSION

The previous research papers discussed a review of what studied the use of seismic isolation systems in the design of buildings to resist seismic activity. The review provides a detailed analysis of the different types of isolators used, the analysis

method, the variety of structures in terms of height and regularity, and the similarities and differences between different researches.

Types of Isolators Used

One of the main points addressed in the studies is the types of insulators used in seismic isolation systems. The most prominent insulators mentioned include:

Lead Rubber Bearings (LRB)

These bearings provide high elasticity and damping capacity, making them effective in absorbing and dissipating earthquake energy.

High Damping Rubber Bearings (HDRB)

It is characterized by its high damping capacity and flexibility, which reduces the transmission of seismic forces to the building.

Frictional Pendulum Bearing Systems (FPS)

These systems reduce the effect of seismic vibrations through a pendulum-bearing mechanism that allows horizontal movement.

Hybrid Isolation Systems

Combines the active and elastic properties of isolators, providing improved seismic control performance.

Analysis Method

Different researchers have used various analysis methods to evaluate the performance of seismic isolators. The main methods include:

Linear static analysis (LSA)

This analysis provides initial estimates of lateral force distributions in foundationally isolated buildings.

Non-linear Time Analysis (NTHA)

This analysis is more accurate in predicting the response of fundamentally isolated buildings under earthquakes, as it takes into account non-linear interactions between the structural system and the insulators.

Response Spectral

It is used to evaluate the performance of buildings by comparing the response of different models to earthquake frequencies.

Diversity of Facilities in Terms of Height and Regularity

The reviewed papers include a wide variety of structures in terms of height and 3-geometric regularity:

Low-Rise Buildings

Research has shown that foundation isolation significantly reduces displacement and shear forces in low-rise buildings.

Mid-Rise Buildings

Isolation systems provide significant improvements in seismic performance while reducing shear forces by up to 30%.

High-Rise Buildings

Base isolation effectiveness is slightly lower due to the height of the structure but it still provides noticeable improvements in vibration reduction.

Similarities And Differences Between Research

The studies were similar in several aspects, including:

Effectiveness of Isolators

All research has shown the effectiveness of seismic isolators in reducing the seismic response of buildings.

Analysis Methods

Research has used non-linear time analysis and response spectral methods to provide accurate estimates of the performance of isolators.

The Main Differences are

Type of Isolators

While some research has focused on rubber lead bearings, others have used high-damping rubber bearings, friction pendulum bearing systems, and hybrid systems.

Focus on Different Types of Buildings

Some research focused on multi-storey residential buildings, while others dealt with vital facilities such as nuclear power plants.

CONCLUSION

This review provides a comprehensive view of seismic isolation applications in improving the performance of buildings under earthquakes. The diverse use of isolators and advanced analysis techniques play a major role in developing safer and more sustainable buildings. While challenges regarding cost and the interaction between buildings and soil remain, future developments in smart materials and advanced control systems promise to bring significant improvements in this area

RECOMMENDATIONS

Choosing Suitable Materials for Isolators

Lead Rubber Bearings (LRB): Lead rubber bearings are prompt to use in areas with high seismic performance because of their high ability to dissipate the energy of seismic forces and develop the stability of structures. LRB should be selected with suitable mechanical characteristics to ensure have optimum reduction of shear forces and storey drift

High Damping Rubber Bearings (HDRB): suggest use in regions with ordinary seismic activity. HDRBs can be used to improve seismic response. The HDRB must be designed with appropriate design properties to get the optimum distribution of displacement across the building height and reduce absolute acceleration.

Using Developed Analysis Techniques for Seismic

Non-linear Seismic Analysis: to get an accurate and optimum understanding of the performance of structures under high and repetitive loads. This method can develop the design method of structures and get suitable resistance to the strongest seismic.

Responses: Response spectral analysis is used initially as a fast and effective evaluation method. This method should be used besides the non-linear analysis to ensure cover all predicated cases of all seismic activity.

Use Accurate Models to Get a Suitable Design

3D Models: It prompt to use 3D models to more suitable analyze seismic response. These models must be accurately designed to make suitable incorporation for all structural members and materials that are used.

2D models: They can be used for make the design simple for preliminary analysis, but make sure to study the results using 3D models for high accuracy.

Ensuring Stability and Safety by Suitable Criteria

Stability and Safety Criteria: It is prompt to use criteria like maximum displacement and damping ratio to estimate the seismic response of structures. Isolators should be designed with properties to ensure that these criteria are decreased to the lowest allowable level.

Standards of Functionality: It should take in consideration that structures with isolated foundations be able to still be in use after seismic activity. This can be checked by the optimum use of materials, technologies and characteristics that ensure functional continuity after active seismic activity.

The Depend on Suitable Techniques of Base Isolation

Multi-storey Buildings: It is prompt to use base isolation techniques in multi-storey buildings to develop seismic response and decrease damages. Isolation systems should be designed to suitable the height of buildings and the type of soil under isolated structures.

Buildings Located on Slopes: Base isolation techniques should be use to

develop the stability and decrease the effects of seismic activity. These techniques can be useful for greatly decreasing base shear and storey drift.

Integration of Different Types of Isolation Systems

Hybrid Isolation System: A hybrid isolation system that use more than one type of isolation in the same base. Lead-rubber bearings (LRB) and steel-Teflon slide bearings (SB) are prompt to get for maximum seismic resistance for the structure. This system can offer a developed response through the absorption of energy and the characteristics of bearing vertical load.

Use The Isolationsystemwithanenergy Dissipation Device

Use base isolation with other dissipation or absorption devices like dampers to improve structure performance in safety, stability, and damages.

Continuous Training, Development, and Practice of Implementation

Developing Engineering Staff: Continuous training should be offered to engineers and designers on the updated seismic isolation technology and updated analysis methods. This training will be useful in developing design accuracy to ensure the safety of structures.

Research and Development: It is prompt to continuity investment in investigation and development to develop materials characteristics and technologies that used in seismic isolation. Research can contribute to the improvement of new effective methods to develop the response of structures against earthquakes. By applying these recommendations, the design and response of isolated structures under the effect of seismic activity can be developed, contributing to the safety of the structures and decreasing potential deforms. The main aim must be to design structures able to be stiff of the strongest seismic loads and save their function of stability and operation.

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