Comparative Study of Different Types of Base Isolators in Multistoried Building

Md Qurban Ali, Koyel Mandal, Diksha Navle, Tuba Shaikh, Professor Shweta Motharkar

***Abstract*—Base isolation (BI) is an effective strategy to protect building structures from earthquake damage. Placing isolators at the base of the building notably lengthens its natural period, which helps to mitigate resonance effects and enhance seismic performance. This research evaluates the efficiency of base isolation in both regular and irregular multi-story reinforced concrete (RC) frame buildings. A 15-story RC frame building was chosen for this study, and Time History analysis was conducted using STAAD PRO software version 2023. Lead Rubber Bearings (LRB), Natural Rubber Bearings (NRB), and a combination of NRB and LRB were designed based on the maximum gravity load on the base columns, and these designs were incorporated into the analysis. The results were compared in terms of natural period, base shear, story displacement, and story acceleration. The natural periods of base-isolated structures were observed to be longer compared to those of fixed-base structures. Isolators significantly reduced base shear and story acceleration in both the X and Y directions compared to fixed-base buildings, though the results varied with different types and combinations of isolators. When comparing base-isolated regular buildings to irregular ones (with re-entrant corners or vertical geometric irregularities), the irregular buildings showed better performance, with results differing depending on the type of base isolation employed.**

Keywords:- NRB(natural rubber bearing), LRB(Lead Rubber bearing), NRB + LRB (Combination of natural rubber bearing and lead rubber bearing) .

I. INTRODUCTION

Modern methods for seismic protection often involve separating the building from the ground, allowing horizontal movement via the foundations or the bearings of vertical structural elements. These systems are commonly known as base isolation systems. Because seismic isolators are installed between the superstructure and the ground, or to isolate specific parts of the building, this type of seismic isolation is also referred to as external isolation. Seismic isolation technologies, which have been extensively developed and utilized over the past decade, include passive control systems categorized as such.

Base isolation systems typically comprise bearings that permit horizontal movement, dampers that control displacements, and components that ensure rigidity under lateral loads. The bearing elements are sufficiently rigid to support vertical loads while maintaining horizontal flexibility. This behaviour alters the natural period of the base isolation system along with the superstructure, thus helping to reduce inertia forces. The reduction in inertia forces, compared to traditionally designed buildings, depends on the dynamic characteristics of the building and the shape of the response spectra curve in seismically isolated structures. The increased ductility, which modifies the first mode period, results in significant displacements within the superstructure relative to the seismic isolation system.

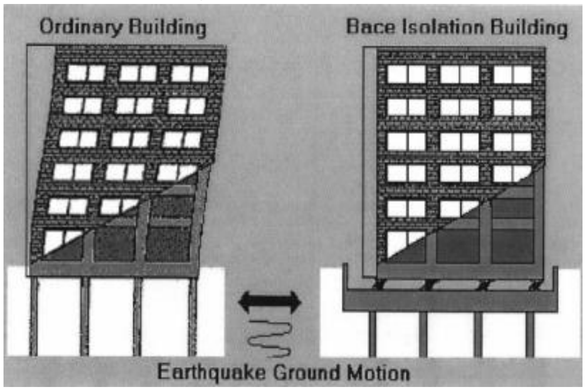

Fig. No 1

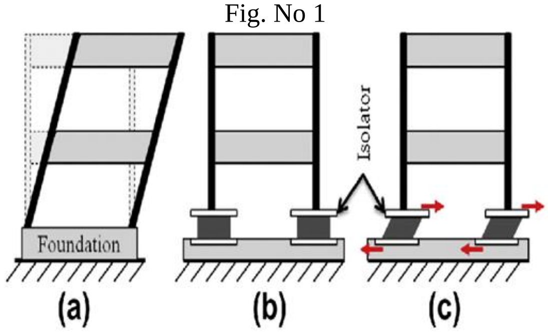

Fig. No 2

Base Isolators

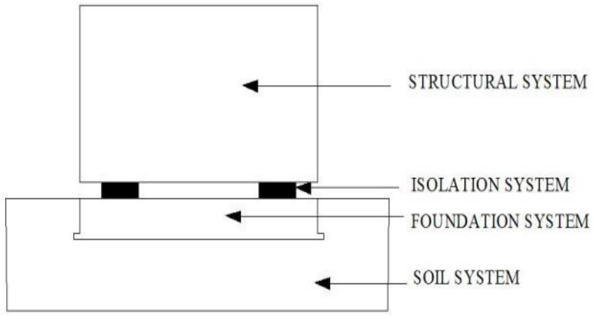

Fig. No 3

Components of base isolation system

1. Natural Rubber Bearing (NRB): A natural rubber bearing is a structural component used in construction and engineering to reduce the transmission of vibrations and absorb shocks between connected structures. Made from natural rubber and typically encased in metal plates or other materials, these bearings are designed to provide flexibility and isolate buildings or infrastructure from ground motion. This enhances their resilience to seismic activity and other dynamic forces. Natural rubber bearings are commonly used in the construction of bridges and buildings to enhance their safety and stability.

2. Lead Rubber Bearing (LRB)

A Lead Rubber Bearing (LRB) is a type of base isolator used in seismic engineering and structural design. It consists of layers of natural rubber and steel reinforcing plates, with a lead core. The lead core imparts unique characteristics to the bearing. Lead is a dense and malleable material, allowing the bearing to deform and absorb energy during an earthquake. This deformation helps reduce the transmitted forces to the structure it supports, enhancing the building's seismic performance.

3. High Damping Rubber Bearing (HDRB)

High Damping Rubber Bearings (HDRBs) are seismic isolation devices used in civil engineering to mitigate the effects of earthquakes on buildings and infrastructure. They are designed to provide both flexibility and energy dissipation, thus reducing the transmission of seismic forces to structures. HDRBs are commonly employed in the construction of critical infrastructure, such as hospitals, bridges, and emergency response facilities, to enhance their earthquake resilience. By minimizing the damaging effects of seismic forces, HDRBs help protect these structures and the people inside.

4. Friction Pendulum System (FPS) or Sliding Bearing

A Friction Pendulum System (FPS) is a type of seismic isolation device used in civil engineering to protect buildings and infrastructure from the destructive forces of earthquakes. It is designed to allow structures to move independently from ground motion during an earthquake while providing controlled damping and energy dissipation. FPS devices consist of a sliding mechanism that enables the structure to move with the seismic waves, thus reducing the forces transmitted to the building. This movement, combined with the frictional properties of the pendulum system, helps dissipate energy and maintain the stability of the structure during seismic events. FPS devices are particularly effective in protecting buildings from both large and small earthquakes, making them a versatile choice for seismic isolation. The system's ability to decouple the structure from ground motion significantly reduces the risk of structural damage and enhances the overall safety of the building’s occupants.

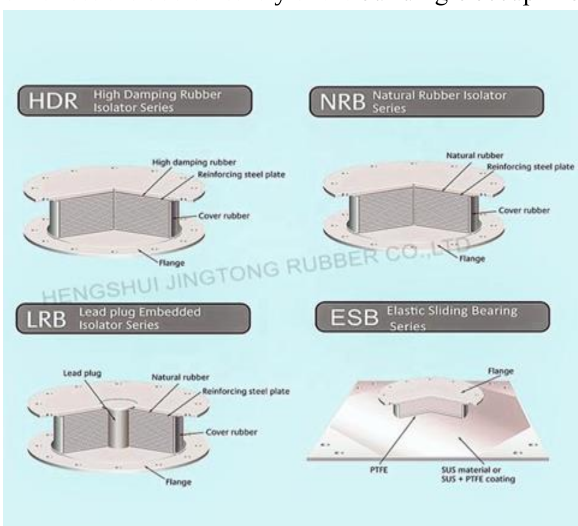

Fig. No 4 types of base isolator

Advantages of base isolators:-

1. Provide better stability
2. Neglects axial drift
3. Neglects axial accelaration
4. Avoid suddeen failure to the building
5. Isolating building’s foundation to the superstructure

Table. No 1 Comparison of two types of base isolators

Lead rubber bearing (LRB)	High damping rubber bearing (HDRB)
Consist of layers of rubbers and steelplates with a core of lead.	Consist of only layers of rubbersand steel plates.
Ability to dissipate energy duringearthquake.	Ability to allows for greater energyabsorption during earthquake.
Include the flexibility of the bearing.	Include high damping capacity.
Cost effectiveness of implementation.	Gives suitability for buildings forbuildings in high seismic zones.
Gives better stability to buildings.	Gives better stability to buildings.
Used in buildings and bridges toprovide better stability.	Used in buildings and bridges toprovide better stability.
Reduce impact of earthquake waves.	Reduce impact of earthquake waves.

LITERATURE SURVEY

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METHODOLOGY

EXECUTION OF WORK:

1. Site Assessment and Seismic Hazard Analysis: Conduct a thorough site assessment to understand the geological and geotechnical conditions. Perform a seismic hazard analysis to determine the potential ground motion the building may experience.
2. Structural Analysis: Perform a detailed structural analysis of the building to evaluate its current design, load-bearing capacity, and susceptibility to seismic forces.
3. Selecting Base Isolation System: Select the most appropriate base isolation system based on factors such as building size, weight, expected ground motion, and local building codes. Options include elastomeric bearings, sliding bearings, or hybrid systems.
4. Dynamic Analysis: Use computer-aided software to conduct dynamic analysis, such as finite element analysis, to simulate the building's response to seismic forces. Optimize the base isolation system design based on analysis results.
5. Detailed Engineering Design: Create a detailed engineering design for the base isolation system. This includes specifying the type, placement, size, and material properties of the isolators. Ensure the design complies with local seismic design codes and standards.

6. Foundation Preparation: - Adapt the building's foundation to accommodate the base isolators. This may involve excavation, construction, or retrofitting.
7. Installation: - Professionally install the chosen base isolation system components, ensuring correct placement and integration with the building's structure.
8. Quality Control and Inspection: - Implement a quality control plan to oversee the installation process. Conduct regular inspections to ensure that work meets design specifications.
9. Testing and Verification: - Perform rigorous testing to verify the effectiveness of the base isolation system. This may include shake table tests to simulate earthquake conditions and field tests to measure the system's actual performance during real seismic events.
10. Monitoring and Maintenance Plan: - Develop a long-term plan for monitoring and maintaining the base isolation system to ensure it remains in optimal condition.
11. Emergency Preparedness: - Create an emergency response plan for building occupants, including procedures for earthquake safety and evacuation.
12. Regulatory Approvals and Permits: - Secure all necessary permits and regulatory approvals from local authorities and agencies.
13. Documentation and Record Keeping: - Maintain comprehensive documentation of the entire process, including design, construction, testing, and maintenance records.
14. Training and Education: - Provide education and training to building occupants, maintenance staff, and emergency responders on the features and safety protocols of the base isolation system.

Selection and Survey of site

Selected site should be in high seismic zone as we know zone five in India is most seismic prone zone. The regions of Kashmir, the Western and Central Himalayas, North and Middle Bihar, the North-East Indian region, the Rann of Kutch and the Andaman and Nicobar group of islands fall in this zone.

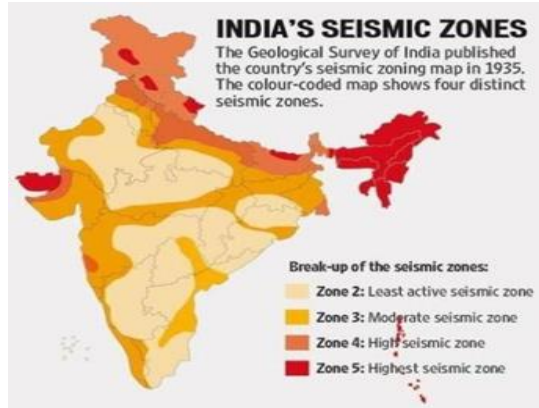


Fig. No 5 Siesmic Zones of india

Problem statement

The following are the basic data considered for analysis

1. Height of the typical storey = 3m
2. Height of the ground storey = 3m
3. Length of the building =30m
4. Width of the building = 30m
5. Height of the building =45m
6. Number of storey = 15 (G+14)
7. Slab thickness =150mm
8. Grade of concrete = M30
9. Grade of steel = Fe 600
10. Support = Fixed
11. Column sizes = 0.35*0.35
12. Beam size = 0.3*0.3
13. Live load = 3 kn/m2
14. Dead load = 3 kn/m2
15. Density of concrete = 25
16. Seismic zones = zone V
17. Site type = Type 2
18. Importance factor = 1.5
19. Response reduction factor = 5
20. Damping ratio = 5%
21. Structure class = C
22. Basic wind speed = 47 m/s
23. Risk coefficient (k1) = 1,08
24. Terrain size coefficient (k2) = 1.14
25. Topography factor (k3) = 1.36
26. Wind design code = IS 875: 2015
27. RCC design code = IS 456: 2000
28. Steel design code = IS 800: 2007
29. Earthquake design code = IS 1893: 2016 (part 1)
30. Type of soil =Loose soil
31. Location =Shimla

Rubber base isolator properties

1. Link type = Rubber isolator
2. Stiffness (NRB) = 800
3. Stiffenss (LRB) = 1300
4. Combined stiffness = peripheral columns (1300) and internal columns (800)
5. Effective damping = 0.05

III. MATH

Design of Lead Rubber Bearings (LRB)

Lead Rubber Bearings (LRB) are developed by integrating lead into standard rubber bearings, thus sharing common design parameters such as the bearing plane size and rubber layer thickness. The inclusion of lead, however, introduces unique design characteristics. The diameter and height of the lead insert directly influence the LRB's capacity to absorb and dissipate energy. Additionally, parameters such as the initial elastic stiffness, yield stiffness, and their ratio are critical in the seismic design of buildings and bridges.

Design Steps:

1.Vertical Load on Isolator:

Determine the vertical load on the isolator after analyzing the gravity loads, which include dead load, live load, and superimposed dead load (SIDL). Let this load be denoted as R kN.

2. Fixed Base Time Period:

The fixed base time period of the structure is T. For a base-isolated structure, consider a time period Tb which is three times T, thus Tb=3T.

3. Effective Stiffness:

Calculate the effective stiffness of the isolator using the vertical reaction R and Tb.

$$K_{eff} = \left(\frac{R \cdot 4 \cdot \pi^2}{g \cdot T_b^2} \right)$$

4. Maximum Displacement:

Using the response spectra for 10% damping as per IS 1893 (Part-I): 2002, compute the maximum displacement of the isolator Sd:

$$S_d = \left(\frac{S_a \cdot T_b^2}{4 \cdot \pi^2} \right)$$

5. Energy Dissipation per Cycle:

- Calculate the energy dissipation per cycle WD:

$$W_D = 2 \cdot \pi \cdot K_{eff} \cdot S_d^2 \cdot \varepsilon_{eff}$$

6. Short-term Yield Force:

Estimate QD as the first approximation for the short-term yield force:

$$Q_D = \frac{W_D}{4 \cdot S_d}$$

7. Post-yield Horizontal Stiffness:

Determine the post-yield horizontal stiffness Kd:

$$K_d = K_{eff} - \left(\frac{Q_D}{S_d} \right)$$

8. Displacement Calculation:

Calculate the displacement Dy.

$$D_y = \frac{Q_D}{9 \cdot K_d}$$

Adjust the estimate of QD for Dy, and compute the yield force Q.

$$Q = \frac{W_D}{4 \cdot (S_d - D_y)}$$

9. Geometric Design:

- Lead Plug Area: Calculate the lead plug area Ap.

$$A_p = \frac{Q}{f_{py}}$$

- Lead Core Diameter: Calculate the diameter dp.

$$d_p = \sqrt{\left(\frac{4 \cdot A_p}{\pi} \right)}$$

Rubber Layer Height: Determine the total height of the rubber layers H:

$$H = \frac{S_d}{\gamma_{max}}$$

where γmaxis the design shear strain, typically 50%.

Compression Modulus: Calculate the compression modulus of the rubber-steel composite Ec:

$$E_c = E(1 + 2K_s^2)$$

where K is the modification factor (0.57), and S is the shape factor (assumed to be 10).

10. Effective Area Calculations:

- Allowable Normal Stress Area A0.

$$A_0 = \frac{R}{\sigma_c}$$

Where σc is the allowable normal stress.

- Shear Strain Condition Area A1:

$$A_1 = \left(\frac{18 \cdot S \cdot R}{E_c \cdot \varepsilon_b}\right)$$

where εb is the damping constant (500%).

11. Rubber Stiffness:

Relate the stiffness of the rubber Kr to the final stiffness Kd.

$$K_r = \frac{K_d}{1 + 12\left(\frac{A_p}{A_0}\right)}$$

12. Area and Diameter:

- Calculate the effective area A and diameter d.

$$A = \left(\frac{K_r H}{G}\right)$$

where G is the shear modulus.

- Determine β

$$\beta = 2\cos^{-1}\left(\frac{S_d}{d}\right)$$

- Calculate the area A_{re}.

$$A_{re} = \left(\frac{d^2}{4(\beta - \sin\beta)}\right)$$

13. Single Rubber Layer Area:

- Determine A and d.

$$A = \max(A_0, A_1, A_{re})$$

14. Layer Thickness and Number:

- Calculate the single layer thickness t:

$$t = \frac{d}{4 \cdot S}$$

- Determine the number of layers N:

$$N = \frac{H}{t}$$

15. Steel Plate Thickness and Isolator Height:

- Assume the thickness of steel plates ts=2.5t_s = 2.5ts=2.5 mm.
- Calculate the total height of the isolator h.

$$h = H + N \cdot t_s + 2 \cdot (\text{cover plate thickness})$$

Assume the cover plate thickness as 25 mm, and ensure the cover plate diameter is greater than the rubber core diameter.

Models in staad

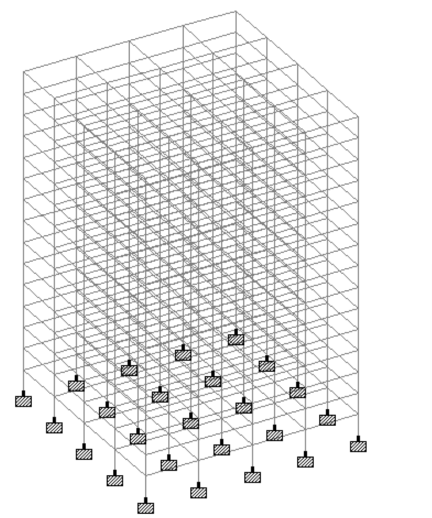


Figure.6 Fixed supports building

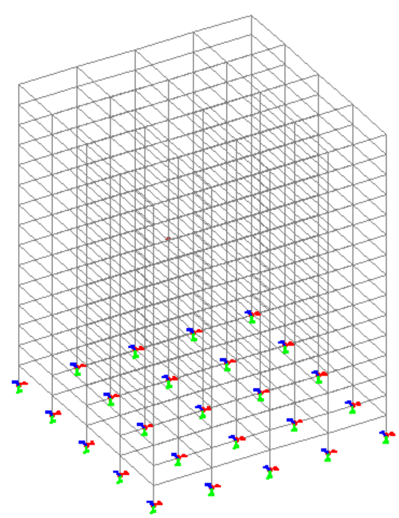


Figure.7 NRB supported building

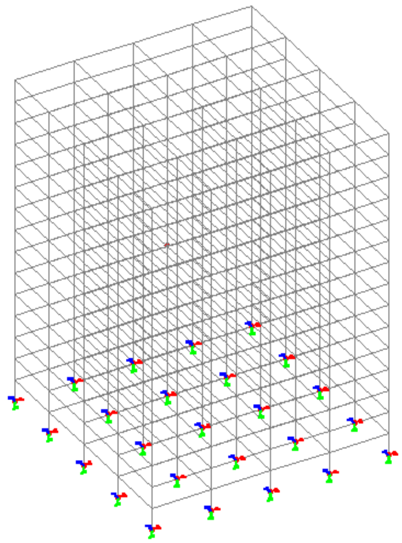


Figure.8 LRB supported building

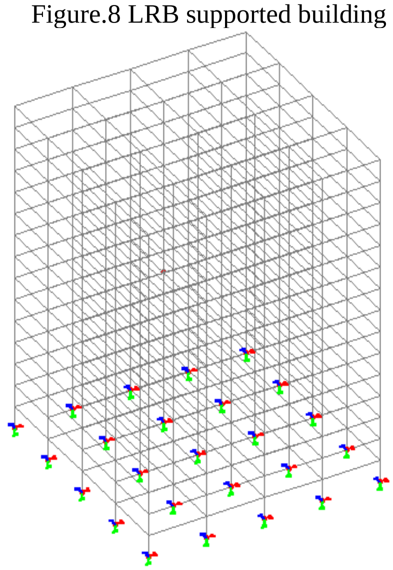


Figure.9 Combined supported building

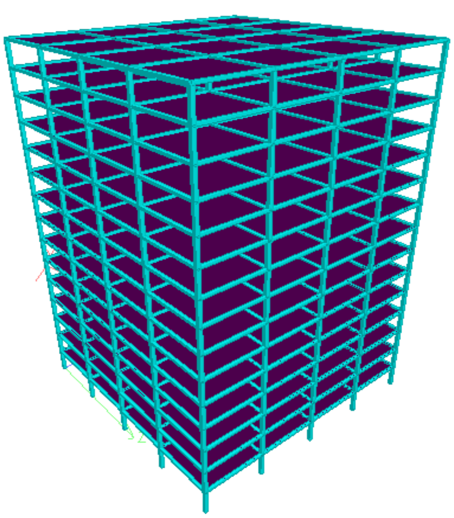
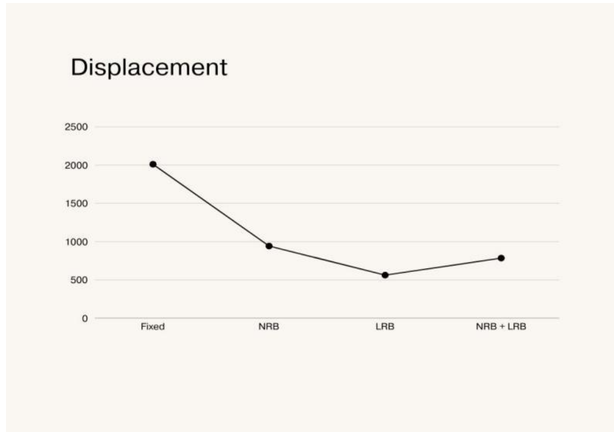


Figure.10 3D model

RESULTS AND ANALYSIS

Table. No 2 Nodal displacement

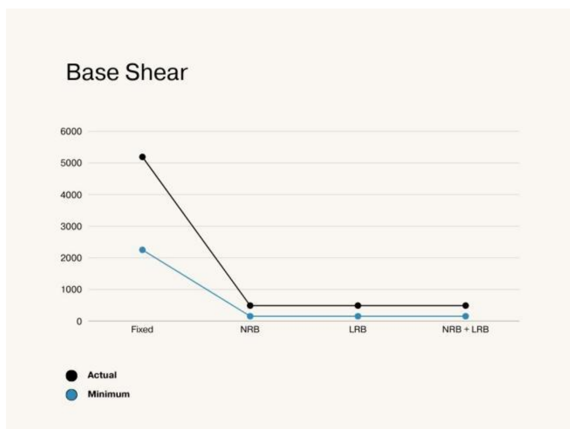
Support	Displacement
Fixed	2010.701
NRB	942.544
LRB	562.257
NRB + LRB	784.583



Graph no. 1

Table. No 3 Base Shear

Support	Base Shear (Actual)	Base Shear (Minimum)
Fixed	5192.61	2250.92
NRB	489.70	155.52
LRB	489.70	155.52
NRB + LRB	489.70	155.52



Graph. No 2

VII. CONCLUSION

Buildings in high seismic zones should be designed with flexibility by incorporating base isolators. A stiff and rigid reinforced concrete (RC) building tends to collapse suddenly during seismic events, leading to significant loss of life and property. This study proposes a model with base isolators, comparing different types such as Lead Rubber Bearings (LRB), Natural Rubber Bearings (NRB), and a combination of LRB and NRB, to determine the most effective type.Using STAAD Pro software, we compared base-isolated buildings to fixed-base buildings. The results show that base isolation significantly reduces story acceleration compared to fixed-base structures. Among the different types of isolators, LRBs were found to be the most effective, reducing both building displacement and story acceleration more than NRBs or the combined LRB+NRB setup. The study also found that as the period lengthens, story accelerations and story drift of the superstructure decrease. However, displacements increase with period in base-isolated buildings for all cases. Additionally, base shears in each direction are reduced with the use of base isolators. In conclusion, seismic base isolation technology, particularly with LRBs, enhances the seismic performance of buildings by reducing accelerations and displacements, thereby increasing safety during seismic events.

ACKNOWLEDGMENT

I used Chat Gpt to formulize my equations and attached the equation in my report in Screenshort format.

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[6] International Journal of Engineering Research & Science (IJOER) ISSN: [2395-6992] [Vol-4, Issue-5, May- 2018] Page | 30 Effect of Base Isolation in Multistoried RC Regular and Irregular Building using Time History Analysis Omkar Sonawane1,Swapnil B. Walzade2 1PG. Student, Department of Civil engineering, Trinity College of engineering and research, yevalewadi, pune 2Assistant Professor, Department of Civil engineering, Trinity College of engineering and research, yevalewadi, pune.

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with and without base-isolation comparative study of multi-storey rc building with and without base-isolation kothireddy akhil reddy, student, department of civil engineering, institute of aeronautical engineering, akhilreddy3043@gmail.com dr j s r prasad, professor, department of civil engineering, institute of aeronautical engineering, jsr.prasad@iare.ac.in dr. Venu malagavalli, professor, department of civil engineering, om

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