Study of seismic performance of low-cost base isolation system using STRP in multistorey building

Anjana Das[1], Aparna K M[2], Rahila Beevi V J[3], Clydin P A[4]
[1 2 3 4] Department of Civil Engineering, Adi Shankara Institute of Engineering & Technology Kalady,India
[1] anjanadas212003@gmail.com ,[2] aparnakms676@gmail.com , [3] rahilabeevi497@gmail.com, [4] clydin.ce@adishankara.ac.in

Abstract-

Earthquakes are natural events that cause widespread destruction, loss of life, and economic devastation. They occur when seismic forces release energy stored in the Earth's crust, generating tremors that can last from seconds to minutes, and can trigger landslides, tsunamis, and fires. To mitigate earthquake damage, innovative solutions are necessary. Earthquake-resistant construction techniques have emerged as effective measures. Base isolation, which decouples a structure from the ground, reducing force transmission, is one such technique. Other methods include seismic retrofitting to strengthen existing structures, using reinforced materials like reinforced steel and fiber-reinforced polymers, and incorporating shock-absorbing systems such as viscous fluid dampers and lead-rubber bearings. Additionally, flexible foundations that allow structures to move with seismic forces, advanced framing techniques like special moment frames and buckling-restrained braced frames, are being utilized. Furthermore, a promising alternative for base isolation is the use of scrap tyre rubber pads (STRP), an eco-friendly, low-cost approach that repurposes waste materials, providing sustainable waste management and affordable seismic protection. By exploring these innovative solutions, helps in improving seismic resilience and saving lives. Effective adoption of these techniques can significantly reduce earthquake damage, protecting infrastructure, and ensuring public safety. In the present study the behaviour of STRP is analyzed using ETABS Software

Keywords: Earthquake-resistant, ETABS Software, low-cost, Scrap tyre rubber pads (STRP)
.

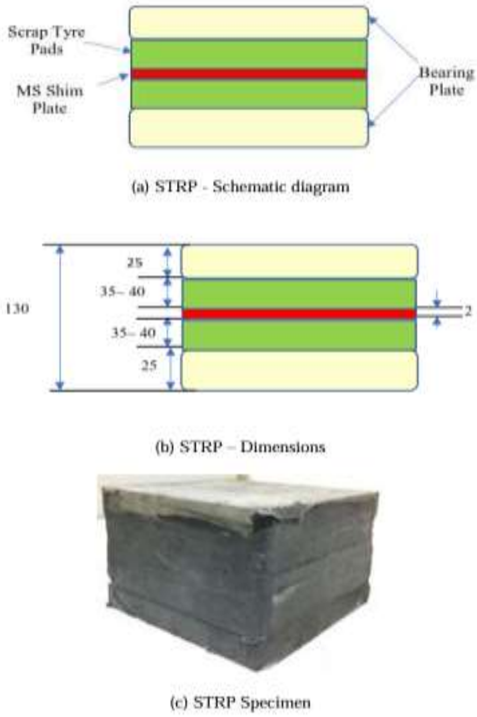
I. Introduction

Each year, earthquakes lead to significant casualties and property damage, with Asia experiencing over 300 earthquakes between 1990 and 2022. These seismic events contribute to an average of 20,000 global deaths annually. Although less frequent than floods, earthquakes often result in severe destruction, primarily due to structural collapses.

To mitigate earthquake damage, various engineering techniques can be employed, including structural reinforcement, bracing systems, damping devices, and base isolation methods. Base isolation is particularly effective, as it minimizes seismic forces by separating the structure from its foundation, as shown in “Fig.2”.This technique enhances flexibility, prolongs the building's natural period, and absorbs shocks. Common base isolation devices include elastomeric bearings, sliding bearings, and hybrid systems. Among these, elastomeric bearings—such as steel-laminated, lead-rubber, and high-damping rubber bearings—are widely used.

While traditional base isolation systems can be costly, an economical and eco-friendly alternative is the use of scrap tire rubber pads (STRPs). Manufactured from recycled tires, STRPs help absorb seismic energy, enhance structural resilience, reduce landfill waste, and enable controlled movement for stability. STRPs are produced using heavy vehicle tires, with test samples measuring 200 × 200 × 130 mm. A standard sample includes two 25 mm thick steel plates at the top and bottom, a 2 mm thick steel shim plate, and two rubber pads, each 39 mm thick, as illustrated in “Fig. 1.” The steel and rubber layers undergo vulcanization to function as a composite system. Compression and shear tests determine vertical and horizontal stiffness, while ETABS software is used to assess STRP behavior as a sustainable base isolation method.

This study considers a G+7 office building proposed for construction in Roorkee, Haridwar district, Uttarakhand. Situated in seismic zone IV, this region faces a high risk of earthquake-induced structural damage, emphasizing the need for effective earthquake-resistant solutions.



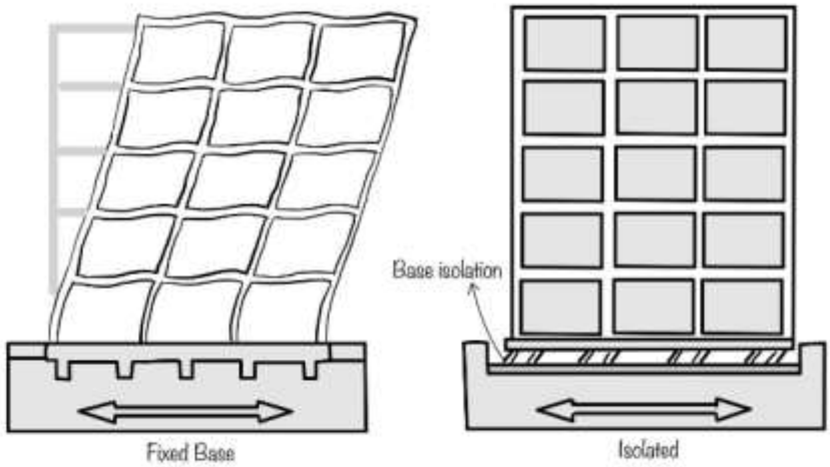


Fig. 1. Particulars of STRP sample for the study.

Fig.2 Base isolation system in buildings

II. NEED / MOTIVATION BEHIND THE STUDY

Base isolation is a crucial technique for safeguarding buildings against earthquakes by minimizing the impact of ground motion. Traditionally, flexible devices like rubber bearings are used to absorb vibrations and prevent structural damage. However, conventional isolators are often expensive and bulky.

A promising alternative is **scrap tire rubber pads (STRPs)**—a cost-effective and sustainable solution. With millions of tires discarded annually, STRPs repurpose waste material while offering easy installation and effective lateral force reduction. This innovation enhances building durability during seismic events.

As India's population grows, the demand for earthquake-resistant multi-story buildings increases. Taller structures require careful engineering, yet traditional methods can be financially restrictive. While base isolation is primarily used for critical infrastructure, making it affordable for homes, schools, and public buildings could significantly enhance safety in earthquake-prone regions.

III .OBJECTIVES

1. To evaluate the seismic performance of structure by using STRP as base isolator

2. Parametric study (Storey displacement, Storey drift, Overturning moment)
3. Comparison of base isolation systems (STRP, LRB)

IV .METHODOLOGY

The study uses ETABS software for analyzing and designing the multi-storey building. ETABS is a powerful tool known for handling complex structural models and performing dynamic analysis, making it ideal for such projects.

A. LITERATURE SURVEY

Papers related to analysis and design of a multi-storey building using ETABS were studied.

B. IDENTIFICATION OF OBJECTIVE

The main objective of study is to evaluate the seismic performance of structure by using STRP as base isolator.Then Parametric study is conducted for each fixed base, lead rubber bearing and STRP and then compared.

C. DEVELOPMENT OF BUILDING PLAN

The building plan is prepared for inputing to ETABS. The building plan of an office building(commercial) is prepared in AUTOCAD software

D. MODELING AND ANALYSIS

Model and analyze the building in ETABS software with a fixed base. Repeat the process for LRB and STRP isolators. Assign material properties, apply loads (dead, live, seismic, and wind) as per building codes, and perform dynamic analysis.

E. PARAMETRIC STUDY

Parameters -Story displacement, Story drift and overturning moment is studied for fixed ,LRB,STRP based structure.

F. COMPARISON OF BASE ISOLATORS

Building with scrap tire rubber pads are compared with building with fixed base and lead rubber bearing.

V .MODELING AND ANALYSIS

The floor plan was created in AutoCAD and imported into ETABS. Sectional properties were defined, and columns and slabs were modelled with assigned properties. The layout was replicated across floors with necessary adjustments. Dead, live, wind, and seismic loads were calculated as per IS 875 and IS 1893:2016. “Fig.3” shows 3d view of building

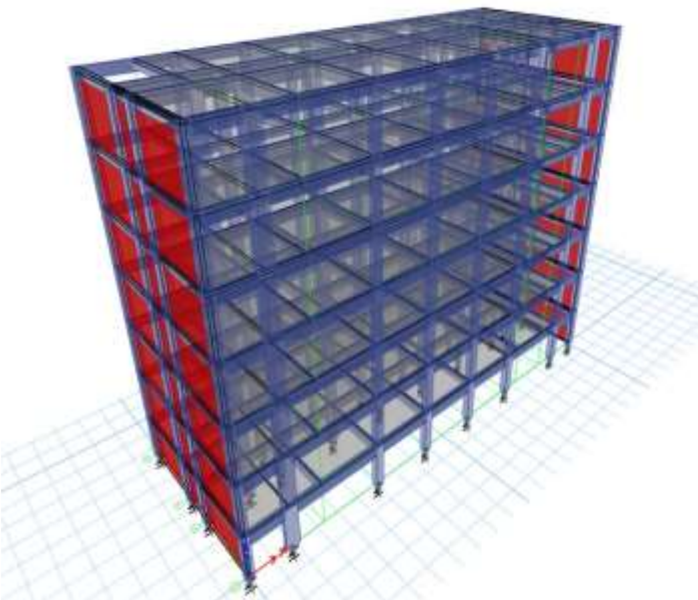


Fig. 3 Modelled 3d view of plan.

A. MEMBER AND BASE ISOLATOR PROPERTIES

The cross-section properties for the beams and columns were assigned and the member property is defined by choosing material as concrete. Various grades are assumed for members as in Table 1.

Element	**Concrete grade**
Beam	M25
Column	M30
Slab	M20
Shear wall	M25

Table 1

B. LEAD RUBBER BEARINGS

Lead Rubber Bearings (LRBs) are a widely used base isolation technique designed to protect buildings from earthquake damage. LRBs consist of **rubber layers and steel plates with a lead core**, which together provide flexibility and energy absorption. This system effectively reduces the transmission of ground vibrations to the structure, minimizing the impact of seismic forces.Table 2 shows the properties of LRB to be inputted in ETABS .[10]

Properties	**value**
U1 Effective stiffness	21442 KN/m
U2 &U3 Eff stiffness	438 KN/m
U2 & U3 non-linear Stiffness	410 KN/m
U2 &U3 Eff damping	0.05
Yield strength	41804 Mpa

Table 2

C. SCRAP TIRE RUBBER PADS

Scrap tyre rubber pads can be an effective solution for base isolation in seismic design due to their excellent damping and flexibility properties. By repurposing waste rubber from used tyres, this approach not only enhances a building's resilience to earthquakes but also promotes sustainability by reducing landfill waste. The inherent characteristics of rubber allow it to absorb and dissipate energy during seismic events, significantly minimizing the transfer of forces to the structure and improving overall safety.

Experimental investigations on isolation bearings, in order to identify the behavior of the proposed seismic isolator (STRP) with vertical compressive and shear loadings have been performed in many studies[7]and is used to formulate table 3

Properties	value
U1 Effective stiffness	21442 KN/m
U2 &U3 Eff stiffness	438 KN/m
U2 & U3 non-linear Stiffness	410 KN/m
U2 &U3 Eff damping	0.05
Yield strength	41804 Mpa

Table 3

VI. parametric study

Parameters such as Story displacement, Story drift and Overturning moment is studied for structure with STRP bearings.

A.MAXIMUM STORY DISPLACEMENT

Maximum story displacement refers to the maximum lateral movement experienced by a specific level of a building during events like earthquakes or strong winds. This measurement is important for evaluating a building's safety and performance. In ETABS, you can analyze maximum story displacement by first ensuring the structural model is correctly set up, including material properties and load conditions.

Maximum story displacement is observed to be reduced by more than50% when STRP Base isolation is provided.Story response is shown in Table 4 and graph is ploted as “Fig. 4”

Story	Displacement (mm)		
	Fixed	LRB	STRP
Story7	39.408	13.646	16.014
Story6	37.678	13.117	15.245
Story5	34.747	12.172	13.9
Story4	30.672	10.855	12.073
Story3	25.569	9.197	9.879
Story2	19.491	7.167	7.391
Story1	11.839	4.453	4.424
Base	0	0	0

Table 4

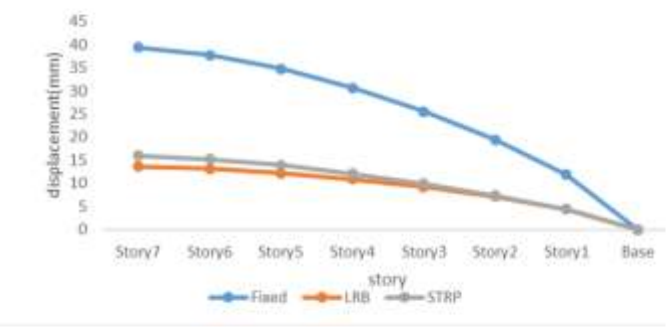


Fig.4 story displacement

B.MAXIMUM STORY DRIFT

Maximum story drift is the horizontal displacement between two adjacent floors during events like earthquakes or high winds. Excessive drift can cause structural damage and pose safety risks. It is measured as the displacement difference, typically as a ratio or percentage of the floor height.

Maximum story drift is observed to be reduced by more than 50% when STRP Base isolation is provided. Story response is shown in Table 5 and graph is ploted as “Fig. 5”

Story	Drift (unitless)		
	Fixed	LRB	STRP
Story7	0.000494	0.000151	0.00022
Story6	0.000837	0.00027	0.000384
Story5	0.001164	0.000376	0.000522
Story4	0.001458	0.000474	0.000627
Story3	0.001737	0.00058	0.000711
Story2	0.002186	0.000776	0.000848
Story1	0.003946	0.001484	0.001475
Base	0	0	0

Table 5

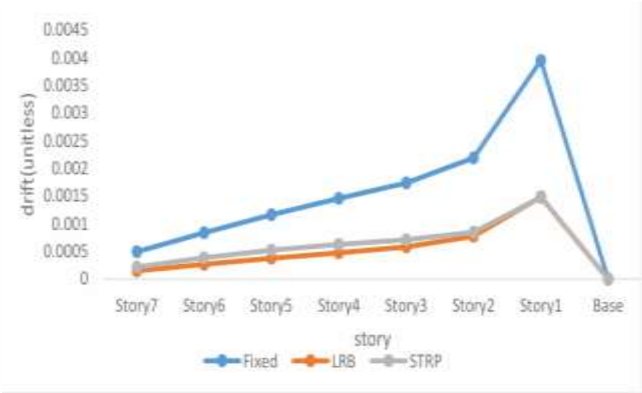


Fig.5 story drift

C. STORY OVERTURNING MOMENT

Story overturning moment refers to the rotational force acting on a specific floor or story of a building, typically caused by lateral loads such as wind or seismic activity. This moment is crucial for understanding how forces can affect the stability and safety of a structure, particularly in multi-story building

Story Overturning Moment is observed to be reduced considerably when STRP Base isolation is provided. Story response is shown in Table 6 and graph is ploted as Fig. 6

Story	Moment (KNm)		
	Fixed	LRB	STRP
Story7	6.80E-07	-42835.8	-43004.6
Story6	-2223.57	-101434	-100875
Story5	-6669.78	-160892	-159822
Story4	-13089.9	-221109	-219595
Story3	-21281.5	-282068	-279994
Story2	-31088.7	-343838	-340861
Story1	-42402.2	-406579	-402087
Base	-53319	-423608	-417943

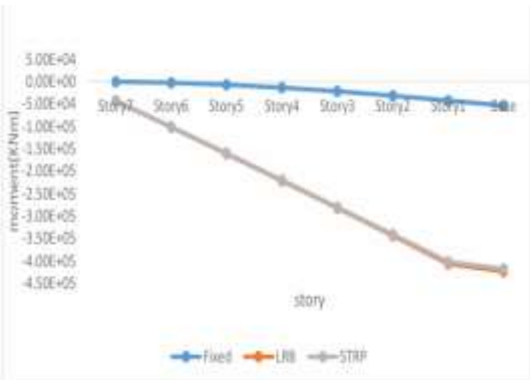


Table 6 Fig.6 story overturning moment

VII.conclusion

In the present study, an attempt has been made to study the behaviour of scrap tyre rubber pad isolator in a G+7 structure. Results show significant reductions in story displacements, story drifts and story overturning moments, making it suitable for low-cost alternative in seismic-prone regions. While the results are promising, further research is needed to refine the material properties and evaluate long-term performance. This approach offers a sustainable and economical alternative for seismic protection in buildings.

acknowledgement

The authors sincerely thank Ms. Clydin P. A, Assistant Professor, Civil Department, Adi Shankara Institute of Engineering and Technology, for her invaluable guidance and continuous support throughout this research. We also extend our heartfelt gratitude to Dr. K. Dhanasekar, Head of the Civil Department, and the Principal and faculty members of Adi Shankara Institute of Engineering and Technology for their encouragement and assistance, which greatly contributed to the successful completion of this work.

References

[1] Suhasini N Madhekar ,Harshwardhan Vairagade ; "Innovative base isolators from scrap tyre rubber pads " - Conference: UKIERI Concrete Congress, Concrete (March 2019)

[2] Prasoon Kumar Singh , Dr. Birendra Singh , Dr. Sudeshna Chakravarty –"Performance of Base Isolator from Scrap Tyre Rubber Pads on Building" International journal of engineering research &technology (IJERT) Volume 11, Issue 06 (June 2022)

[3] Ancy Mathew , Sajeeb R. "Seismic Performance of Multistoried Building Frames with Unbonded Scrap Tyre Pad Isolator"- http://www.ijert.org December 2022

[4] Huma Kanta Mishra ,Akira Igarashi, Hiroshi Matsushima ,Aiko Furukawaetal., "Experimental and analytical study of unbonded and bonded scrap tyre rubber pad as base isolation device" (2012)

[5] Mohammad Muzamil and Manish Kaushal ; "Seismic Protection with Base Isolation Method Using ETABS" International Journal of Innovative Research in Computer Science & Technology (IJIRCST) (May 2022)

[6] J. Cici Jennifer Raj , M. Vinod Kumar; "Nonlinear Modal Time History Analysis on RC framed buildings with scrap tyre as the base isolator for Past Indian earthquakes"-https://doi.org/10.1007/s41024-022-00162-5 January 2022

[7] Manish Kumar,Suhasini N. Madhekar and HarshavardhanVairagade"Low-cost Base Isolators from Scrap TyreRubberPads", https://www.researchgate.net/publication/333703518, June 2019

[8] Manthan H Vasani and Satyen D. Ramani," Comparitive study of effect of infill walls on fixed base and base isolated reinforced concrete structures" JETIR ISSN-2349-5162 Volume 4, Issue 0, April 2017

[9] Umer Bin Fayaz, Brahamjeet Singh; "A Study of Seismic Analysis of Building Using ETABS" International Journal of Innovative Research in Engineering and Management (IJIREM) December 2023 https://doi.org/10.55524/ijirem.2023.10.6.2

[10] S. Mallikarjun , A. Shruthi ;"A Study on Dynamic Response of High-Rise Buildings using Lead Rubber Bearing Isolator" CVR Journal of Science and Technology, Volume 23,December2022

[11] Adil Ziraouia, Benaissa Kissia , Hassan Aayab, Ilham Azdinea ; " Seismic behavior of base-isolated building structures with lead rubber bearings (LRBs)"- Procedia Structural Integrity 61 (2024) 171–179 , 2024