

Seismic Base Isolation System using Scrap Old Tyres

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Abstract: Enfeebling the effects of vibration caused by the movement of tectonic plates has been the major topic of research in the field of Structural Engineering. Base isolation is a technique used to counteract the effects of seismic vibration and ensuring the safety of the superstructure. Even though, the strategy of base isolation has been used in interminable number of structures, there is a need for economized, effective base isolation technique. India has been recycling and reusing waste tyres for four decades, it is estimated that 60% are disposed of through illegal dumping. India, being the second largest manufacturer of rubber after China, there is a menace of rubber disposal in the country. Despite the numerous efforts of technologists of recycling and utilizing the scrap rubber tyres, 17% of the scrap rubber tyres are diverted to landfill creating disposal problem. Therefore, there is a need for utilizing the used scrap rubber tyres in an innovative way instead of dumping it.

Scrap Rubber tyres, being elastic in nature serve to be a potential shock absorber of seismic vibrations. In the present study, an attempt is made to utilize the recycled scrap rubber tyre in seismic isolation of structure. This technique proves to be a low- cost earthquake mitigation technique which can potentially reduce the damage caused by seismic shock propagation into the structure and hence ensure overall safety of the structure. An experimental analysis is done to evaluate the properties of assembly of rubber tyres and utilization of the same for isolating base of structures to check for the effectiveness in enfeebling the shocks produced by seismic vibrations. Furthermore, using the properties of scrap rubber tyres obtained from the experimental results, performance of the scrap tyres as a base isolation system for a multistoried building and stability of the structure was studied using Finite element analysis tool.

Keywords: Base Isolation, Scrap Rubber Tyres, Shock absorber, Damping, Vibration

I. Introduction

Nowadays several techniques are used for reducing the effect of earthquake, but the most commonly and widely used technique is Base isolation technique. Base isolation is the method or technique in which the superstructure is isolated from the substructure by introducing a deferral system between the foundation and the main structure, to decrease the seismic demand on the structures as an alternative of increasing the load resistant ability of the structure. Base isolation is the method which eliminates the effect of seismic demand by essentially separating the structure from potentially harmful ground motions, where the building superstructure is most affected. Base isolation can be achieved by providing devices of certain flexibility having low horizontal stiffness.

Presently the base isolators used are large, heavy and expensive such as steel laminated rubber bearings, lead rubber bearings, high damping rubber bearings etc. Seismic isolation system includes the installation of isolators under the supporting points of the structure. Usually, the isolators are located between the superstructure and foundations of the buildings. Over past few years, much importance is given on a better and cost-efficient method to decouple the building itself from the effects of seismic demand like vibration through base isolation techniques and the system that can prove to be economical is base isolators using scrap tyre rubber pads (STRP). The volume of the scrap tyres

generated are increasing in large amount due to increase in the number of vehicles. It is estimated that almost 1.5 billion tyres are expiring their uses as vehicle tyres in every year. Scrap tyre rubber pads (STRP) are easy to apply as well as low of cost. Its usage results in more dampness than the conventional ones. It is simple to make shear stiffness adjustments and its weight is comparatively less.

Introduction of the flexible layer that is STRP's; increase the deflection of the structure thereby increasing the durability of the structure and decreasing the lateral force occurring due to seismic ground motion at the base of the structure. The eco-friendly scrap tyre rubber pads (STRP) provide several advantages like low cost, easy to handle and also the shear stiffness adjustments are simple that is, by changing the number of layers. Various experimental and analytical studies are conducted on the STRP sample. Scrap tyre rubber pads (STRP) act as elastomeric bearing, causing decoupling of movements between superstructure and foundation. In scrap tyre rubber pads (STRP's) the steel reinforcements within the rubber sample have high stiffness and the rubber between them have lower stiffness. Automobile tyres have in built steel fibres or chords within it which acts as steel plates. Frequency of the superstructure is much lower than that of the foundation, due to which a very small vibration occurs thus saving the structure from the collapse.

Day by day, there is large increase in the population of India and also the less availability of land area, there is a requirement of design and seismic analysis of multi-storeyed buildings before the construction work starts. Multi-storeyed buildings are shelter for all the human beings and are designed for the basic needs of the people. Earthquake has turned dangerous to the human progress due to reasons of losing human lives, property and man-made structures. Hence the design of the multi-storey buildings in the earthquake prone area with reduced seismic effect is the need of the hour. A seismic design of high-rise multi-storeyed buildings is assumed as considerably important in the recent years. Seismic design in the traditional method was adopted based on the fundamental mode of the structure and distribution of the earthquake loads as static forces in various floors of the small height buildings, subjected to low intensity earthquakes. But as the number of the floors increase or height of the building increases, the seismic design is done with extremely thorough care.

II. Literature Review

Huma Kanta Mishra et al. ^[1] performed a study on the examination of the STRPs that consist of steel reinforcing cords which can be used as seismic isolation assembly. Steel plates used in conventional laminated rubber bearings can be substituted with the chords from the STRPs as they serve the identical principle. Stiffness, damping values and an eventual instability of the isolation unit are results from various tests and finite element analysis administered on bonded and unbounded STRP isolators. The results show that the damping in natural rubber bearings is comparatively a subordinate than the evaluated isolators.

Suhasini N Madekaret al. ^[2] conducted experiments as well as performed analytical study on implementing specified amount of flexibility in the structure to curtail the seismic influence on the building that can be accomplished by establishing low horizontal stiffness devices. Reduction of base shear can be achieved by establishing a flexible layer which enhances the deviation of the structure. Axial compression test and horizontal shear tests are administered. G + 8 storey structure is evaluated using ETABS software, employing the characteristics of STRPs concluded from the analysis. Introduction of STRPs causes abatement in storey movement and base shear of the structure. For low rise building, STRPs can thereby designated as base isolators.

Boominathan A et al. ^[3] have acclaimed from their study that the greater influence of seismic shock can be abbreviated by use of scrap tire pads as base isolation. It is economical earthquake alleviation approach. Flexible volume substructure method using SASSI 2010 was used to conduct the finite element analysis. Bhuj earthquake, India (2001) is considered as the index project for the evaluation. Damping ramification due to soil-rubber tire isolators minimizes the peak ground acceleration results drastically.

Mukesh Chauhan et al. ^[4] have carried out study to ameliorate base isolation as economic, reduce the weight and protect the building from earthquake. An explicit armor for the structure against the earthquakes is the base isolation, on which numerous studies have been carried out. Rubber portion amidst reinforcement sections deliver low horizontal stiffness, whilst the fiber reinforcement in the elastomeric isolator provide high vertical stiffness for the seismic base isolation.

M.SMashiri et al. ^[5] have investigated the properties and performance of Sand-tyre chip mixtures. Further, the backfill material can be substituted with sand-tyre chip (STCh) mixtures which can be used in numerous

geotechnical applications. The STCh can solve the geotechnical issues related to the low soil shear strength and high elasticity; simultaneously fix the issues governing to the environmental factors. The elastic characteristic and shear strength of the STCh mixtures are being evaluated. Various trials of monotonic triaxial tests have been conducted on sand mixed with numerous quantities of tyre chips. The results have concluded that tyre chips naturally dominate shear strength and the elasticity behaviour of the STCh behavior. The results of restriction and relative density of shear strength, dilatancy and initial tangent modulus of STCh mixtures has been evaluated. Furthermore, an experimental result has been used to endorse the elasticity model for STCh mixtures.

Anastasios Tsiavoset al.^[6] have executed a study which probes on the viability of considering a sand-rubber deformable granular as low-cost seismic isolation blueprint for developing countries. Evaluation of mechanism inside the sand-rubber sheet for the deficiency of the mechanical behavior. To calibrate the angle of friction of ternary sand-rubber mixtures is applied to distinctive vertical stress level through direct shear test. The experimentally derived mechanical characteristics are compared to the corresponding values for pure rubber and pure sand samples. The frictional characteristics amidst sand rubber layer and a timber interface are determined. A uniaxial shaking table experiment is carried out for the investigation of the fluctuation of a rigid sliding block and the quantification of the kinetic friction of different sliding interfaces for two different sand-rubber layer heights. The rigid sliding block which is fabricated to slide against the sand rubber layer is imposed to both a harmonic ramp loading and earthquake ground excitation. The conclusion of this static and dynamic experimental investigation is the determination of the optimum grain size and the height of the sand rubber layer that resemble to the lower friction coefficient between the sand rubber layer and the foundation. The evaluation of this integral framework paves the way for an integrated layout of a response modification strategy for mitigating seismic devastation in developing countries.

Ashish R. Akareet al.^[7] have analyzed and performed experimental study on hospital structure. Among the other structures buildings, hospital should be given the higher priority for safety measures during the calamities such as earthquake. The structural and non-structural components should remain operational and safe after earthquake. Hence, structural and non-structural elements need to persist the functions aftermath the disaster. Base isolation system serves as the perfect alternative as an vibration resisting armor system. It revolves around the concept of diminishing the inertial forces brought out by the earthquake, coaxed to extending epoch of the structure. The study utilizes SAP2000v14 software to grasp the applicability of high density and Rubber Bearing (HDRB) and friction pendulum system (FPS) as an isolation device. It is then examined in contrast among discrete criterions such as fixed base condition and base isolated condition. (G+12) storey hospital building is considered as the analysis model. Fixed base and base isolated structure are evaluated using non-linear time history analysis. The result obtained shows the reduction in base shear in both direction and increase in the displacement and time period for the base isolated structure. The receding of base shear in twain direction and increment in the displacement as well as time period for the base isolation structure is achieved from the outcome.

III. Methodology

This paper depicts the seismic response of a building in an earthquake prone region coupled with base isolator made up of scrap rubber tires affixed to the bottom of it. The intrusion of the rubber tires between the superstructure and the foundation alters the damping property by increasing the dissipation of energy. The capability of STRP as base isolators to undergo the movements imposed during the ground vibration and in addition to it, the ability to carry the gravity loads from the superstructure to the ground are well analyzed to check its efficiency. Much emphasis is given to better and cheaper method to decouple the building itself from the effects of vibration using STRP.

The building or the structure is decoupled from the horizontal component of earthquake ground motion by imposing a layer with low horizontal stiffness between the superstructure and foundation. The intrusion of the flexible layer between the superstructure and the foundation increases the deflection of the structure, thereby increasing the time period of the structure and decreasing the base shear.

Since it is required for the isolators to carry large vertical loads and deform to significant lateral displacement, the isolator should be capable of withstanding extreme conditions. STRP isolators provide immediate occupancy performance levels following the strong seismic events. The methodology for the research work is carried out as shown in Figure 2.

STRP as Base Isolator

One of the predominantly used material to function as the base isolator throughout the world is elastomeric bearing. Steel reinforcements present inside the isolators made from elastomeric bearings yields high vertical stiffness and the rubber segments between the reinforcement layers yields low horizontal stiffness. The automobile tires have interleaved steel reinforcing cord in various layers encompassed between the rubber layers. The tires of automobile which is used to produce STRP have similar effect like that of the steel plates or the fibers inside the conventional *elastomeric base isolators*.

Generation of STRP specimen

Elastomeric based isolators may be mimicked using pads made out of scrap rubber pads procured from automobile workshops considered as waste, which are called as scrap tire rubber pads. Automobile tires are made by vulcanizing steel mesh and cords with the rubber. When the tread part of the tires are removed and piled on the top of each other as rectangular rubber sheets, they form scrap tire rubber pad as shown in Figure 1 [1]. The tire bend is produced by cutting the tire ring in the transverse direction. The layers forming a scrap tire rubber pad can be stucked together using resin [4].



Figure 1 . Bounded STRP Specimen [1]

Detection of properties of STRP

The various performance objectives which defines the requirements for practical isolation system are

1. Flexibility
2. Damping
3. Resistance to loads

The flexibility of the isolator can be defined in terms of stiffness. The concept of flexibility and stiffness is complementary. The more the stiffness of the material implies that the material is less flexible.

The vertical stiffness as well as the maximum vertical load carrying capacity can be procured from the axial compression test of the specimen. The horizontal stiffness, horizontal load carrying capacity and damping can be procured from the horizontal shear test [2].

Evaluation of the efficiency of STRP as base Isolator

The structural and non-structural components of the building should remain operational after the earthquake. The basic idea of STRP as base isolation is to reduce the earthquake induced inertia forces by increasing the fundamental period of the structure. After procuring the properties of the STRP specimen, it is checked for its efficiency applied to building in seismic zone. It can be analyzed using the STAAD-PRO software. Non-linear time history is carried out for both fixed base and base isolated structures. The various aspects such as time period, base shear, storey drift, storey displacement and storey acceleration are analyzed and efficiency of the STRP's as base isolators scrutinized [7].

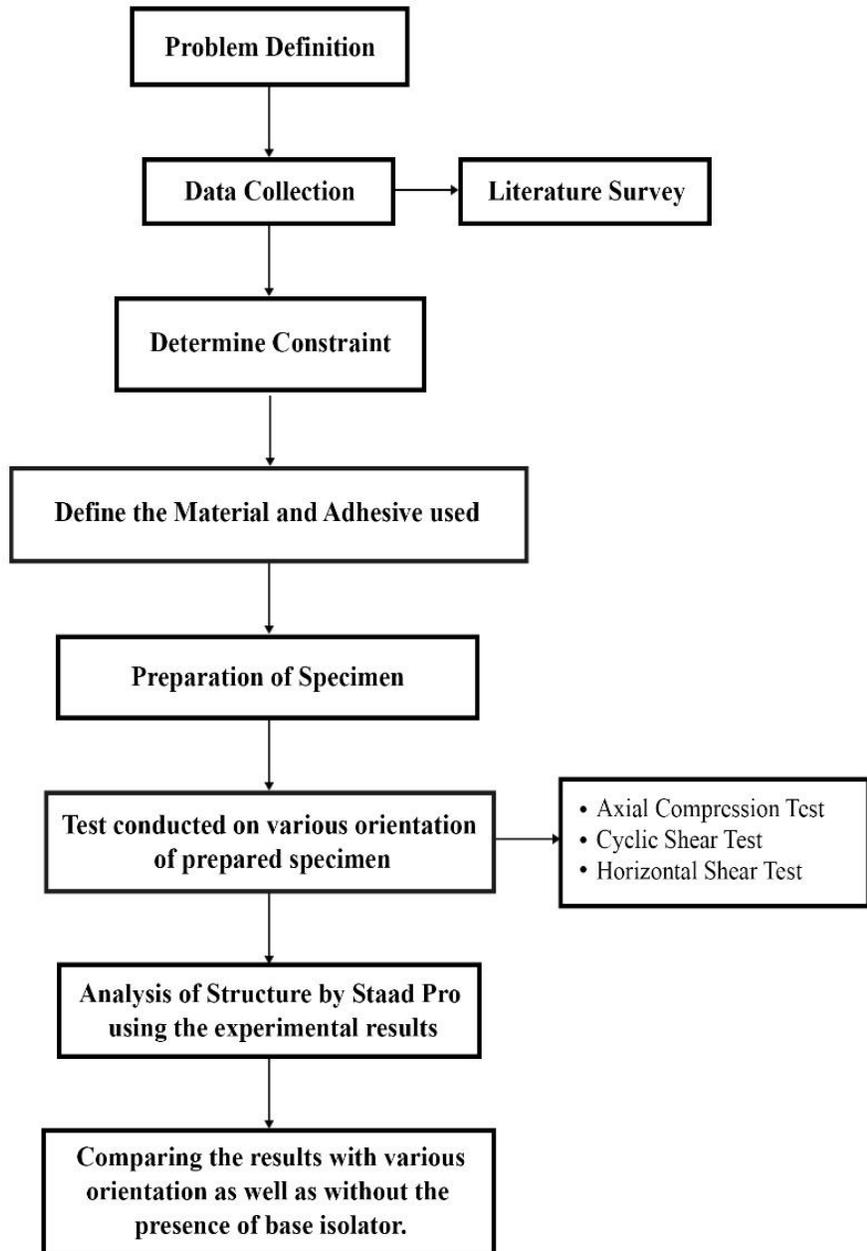


Figure 2: Methodology Flowchart

IV. Conclusion

Base isolation using Scrape Tire Rubber pads will replace the presently used techniques which are very costly such as lead rubber bearing, laminated rubber bearing, etc. Scrap Tire Rubber Pads (STRP) are used as base isolation material to mitigate the effects to structural building due to seismic movements in earthquake prone regions. Scrap Tire Rubber Pads (STRP) is low in cost and commercially affordable for the building in an earthquake prone severe zone. STRP's are simple to affix on a building and remain firm against earthquake. An attempt was made to study the action of STRP's in static compression and in cyclic shear loading. In the course of shear displacement, bonded specimen did not display any trace of layer separation. Mean time same test on unbonded specimen shows layer separation before accomplishing 100% shear deformation. This will ensure that application of bonding agent is adequate in the transfer of the shear forces. To rise the shear deformation capacity as well as to establish the stability STRP isolator needs to be bonded. The transfer of base shear force to the superstructure is decreased to 50% of that for the fixed base building [2]. This concludes that base isolation system employing STRP's is a appealing substitute to commercially accessible isolation systems. The fraction between vertical and horizontal stiffness greater than 150 in several case so that STRP isolator can be advised as an advantageous base isolation device [1]. These types of base isolation is advised to used for low axial pressure application such as residential buildings in developing countries.

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