International Journal of Engineering & Technology, 8 (1.2) (2019) 56-59

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Recycled Tire as Base Isolator for Low Rise Building in Malaysia

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Abstract

The main goal of isolation is to provide lateral flexibility to building foundation in order to mitigate horizontal movement resulted from earthquake event. Conventional seismic isolation system consists of elastomeric or sliding system which is costly. Recycled Tire Isolator (RTI) is a model designed to be installed at building foundations to resist earthquake forces. It is laterally flexible and has some similarities compared with commercial base isolators. RTI was fabricated using tread sections of recycled tires which are cut into pads of 300mm x 210mm and each pad has thickness of 10mm. Adhesive was applied on the cut tire pads before they were stacked on top of each other. Pressure was imposed on the RTI to ensure the layer of pads stick well. Static compression test and dynamic load test were conducted to examine the dynamic and mechanical properties of RTI. In static compression test, a controlled axial load of 380 kN (maximum capacity of the compression test machine) was applied on to the RTI. A displacement of 12.2mm was recorded. For dynamic load test, Servo Hydraulic MTS322 Testing Machine was used. The dynamic stiffness, damping ratio and damping coefficient were obtained and compared with the commercial isolator.

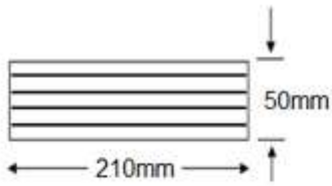
Keywords: *lateral flexibility; low rise buildings; recycled; seismic isolation.*

1. Introduction

Seismic isolation is a method adopted in engineering field to resist earthquake forces. Most structural engineers do not consider earthquake forces in their design especially for the low rise buildings. Hence, the conventional structures especially low rise residential buildings are subjected to inertia forces which lead to structural damages during earthquake. On 5th June 2015, an earthquake of magnitude 5.9 Richter Scale struck Ranau, Sabah in Malaysia causing damages to properties and has taken 18 lives. In February 2010, about 250,000 residence (mostly low rise buildings) and 30,000 commercial buildings were severely damaged when a magnitude of 7.0 earthquakes struck Haiti. Of all these past histories, it shows that it is urgent to identify a device or method to resist earthquake forces for low rise buildings. The damage resulted by earthquake is worldwide recognized to be a serious problem to important building structures especially hospitals, emergency management centers and all other structures which should remain fully functional during and after earthquakes [1]. The occurrence of earthquake is unpredictable. Malaysia is a country located outside the earthquake active region. However, earthquakes are expected in Sabah, which is considered as having a high level of seismicity than Sarawak and Peninsula Malaysia [2]. The fault zones in peninsular Malaysia are not very active compared to Indonesia and Philippines. The faults lines scattered across the peninsular are Temengor fault line, Kenyir fault line, Manjung fault line, Bukit Tinggi fault line and Kuala Pilah fault line. The AM5.9 earthquake on the Richter Scale that occurred in Ranau, Sabah, give an indication that Malaysia needs to take precautions to protect the buildings structures especially low rise buildings. Instead of increasing the capacity of the structure, it is more reasonable to reduce the seismic demand by modifying the dynamic response of the structure [3]. RTI as one type of rubber isolator is introduced to be installed at the foundation of the buildings to prevent them from collapse during earthquakes. Rubber isolators have been widely used in the field of vibration and noise control due to their characteristics as compact structure and high damping ratio [4]. The raw material used in fabricating RTI is recycled tire. Massive disposal sites of scrap tires are common in many cities and statistic shows that one scrap tire is produced per person every year [5]. Manufacturing of RTI can reduce the disposal problem of scrap tires. Isolation from the ground during a seismic excitation has been one of the challenging issues for researchers. The general principle is to decouple the building or structure from the horizontal components of the earthquake ground motion by interposing a layer with low horizontal stiffness between the structure and the foundation [6]. During earthquake event, a large interstory drift and floor acceleration will occur in the building. The only practical way of reducing interstory drift and floor accelerations concurrently is to use base isolation [7]. A Few studies have been conducted on steel laminated rubber bearing and fiber-reinforced elastomeric isolators to be used as earthquake resistance system at seismic regions of the world. However, these types of seismic isolator still unaffordable by poor families in the South Asian region. The main factor for the high cost of the conventional isolators is the process used in preparing the steel plates and bonding them to the rubber layers. Also, the high weight of the isolators is due to the same steel plates [8]. As a solution, an economical and sustainable base isolation using recycled tire pads is introduced and to be installed at the foundation of low rise buildings particularly residential houses [9]. RTI able to reduce the vertical and horizontal displacement of building caused by earthquakes [10]. It is proven that RTI is an effective and economical earthquake resistance system for low rise buildings in Malaysia. The aim of this paper is to determine the mechanical and dynamic properties of recycle tire isolator (RTI) through laboratory tests and the results were compared with the commercial isolator.

2. Methodology

Recycled tire was the main raw material in the fabrication of RTI. Only the tread section was used and cut into small pieces of tire pads. The dimension of RTI is 300 mm × 210 mm × 10 mm thick. The sectional view and plan view are shown in Figure 1(a) and (b) respectively. Dunlop contact adhesive glue was applied on the top and bottom of each tire pad. The samples were then tightened by using G-clip for approximately 72 hours to ensure a firm bonding between the tire pads. There were two types of RTI, four layers (RTI-4) and five layers (RTI-5). Figure 2 presented the servo hydraulic MTS322 testing machine used for compression test and dynamic load test.



(a) Section view

(b) Plan view

Fig. 1: RTI Samples

Fig. 2: Servo hydraulic MTS322 testing machine

3. Results and discussion

3.1. Compression test

RTI-4 and RTI-5 were tested under static compression using servo hydraulic MTS322 testing machine. The test was carried out based on British Standard. A controlled vertical force of 380 kN was applied on the samples for five cycles. A maximum displacement of 12.2mm was recorded as shown in Figure 3. The vertical effective stiffness of the samples were generated at fifth cycle based on the equation below,

$$K_{eff} = \frac{F_{max} - F_{min}}{\Delta_{max} - \Delta_{min}} \quad (1)$$

where F_{max} and F_{min} are the maximum positive and minimum negative shear forces, Δ_{max} is maximum positive shear displacement and Δ_{min} is the minimum negative shear displacement, respectively.

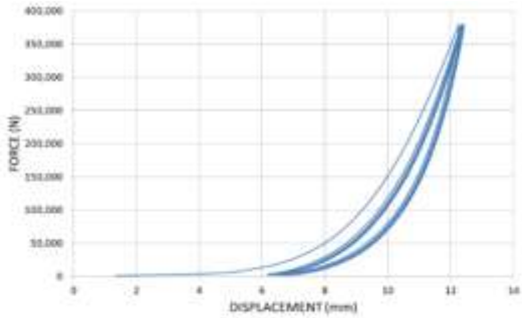


Fig. 3: Force vs displacement graph of RTI-5

The results of static stiffness for RTI-4 and RTI-5 were compared with fiber reinforced elastomeric isolator (FREI) and steel reinforced elastomeric isolator (SREI) as presented in Table 1.

Table 1: Static compression test results for RTI-4 and RTI-5

Sample	No.of Layers	Dimensions (mm)	Static Stiffness (N/mm)
RTI-5	5	300 (L) × 210 (W) × 50 (T)	41,307.95
RTI-4	4	300 (L) × 210 (W) × 40 (T)	123,637.02
FREI	1	43mm Dia x 11.75 (T)	34,813.00
SREI	1	43mm Dia x 60 (T)	94,143.00

Based on the results in Table 1, RTI sample with lesser layer will have higher value of static stiffness. The static stiffness of RTI-4 is 123,637.02 N/mm which is about three times the static stiffness of RTI-5. This explains well that the more the number of layers of rubber pad, the vertical flexibility will increase. By experiment, the static stiffness of commercial steel-reinforced elastomeric isolator (SREI) is 94,143.00 N/mm [8]. The static stiffness of RTI-4 is quite close to SREI. Therefore, RTI-4 has great potential to be used as base isolator replacing SREI. However, the vertical stiffness of FREI is only 34,813.00 N/mm which is quite similar to RTI-5. Vertical stiffness indicates the rigidity of the sample and its capacity to resist vertical deformation. RTI-5 deformed vertically about 12.5mm when a maximum axial load of 380 kN was applied on top of it. Whereas RTI-4 deformed only 10.4mm when maximum axial load of 339 kN was applied. Again it shows that RTI-4 can resist vertical load better compared to RTI-5 because RTI-4 deforms lesser.

3.2. Dynamic load test

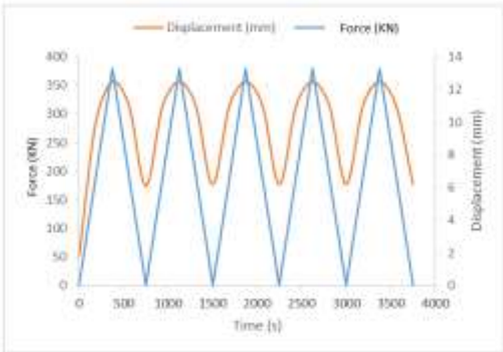


Fig. 4: Displacement vs time graph for RTI-5

Figure 4 show the displacement versus time graph obtained from dynamic load test which was conducted using servo hydraulic MTS322 testing machine with amplitude of ±0.5mm at frequency of 5Hz through displacement-controlled loading. The maximum displacement was recorded as 12mm with axial force of 380kN. Dynamic parameters such as dynamic stiffness, damping coefficient and damping ratio were determined as presented in Table 2.

Table 2: Dynamic test results for RTI-5 and RTI-4

Sample	Maximum Axial Load (kN)	Dynamic Stiffness (N/mm)	Damping Ratio	Damping Coefficient
RTI-5	60.4	40,357.28	8.89	224.94
RTI-4	105.0	83,101.17	7.18	941.19

From the results of dynamic load test, RTI-4 has a higher value of dynamic stiffness compared to RTI-5. The number of layers of rubber pad is one of the important factor contribute to dynamic stiffness. Damping coefficient is a material property that indicates whether a material will bounce back to its original form or return energy to a system. RTI-4 has a damping coefficient of 941.19 which is about four times the damping coefficient of RTI-5. This means that RTI-4 is more efficient in terms of energy dissipation and able to return better to its original form compared to RTI-5. The damping ratio of RTI-4 and RTI-5 is 7.18 and 8.89 respectively. These values have a close agreement with the experimental value obtained by the researcher, Bayezid Ozden [3], on low cost scrap tire pads with various brands. The optimum range of damping ratio for rubber bearing is between 7% and 14%. Therefore, RTI-4 and RTI-5 have a great potential to be used as a low cost base isolator.

4. Conclusions

In this research, recycled tire which is sustainable material is used to prepare the earthquake base isolator. This recycled tire isolator or RTI was tested under vertical compression and dynamic load. The mechanical properties and dynamic properties of different layer of RTI were obtained and compared within each other and also with the commercial elastomeric isolator. RTI is proven to have great potential to be used as base isolator for family in poor country due to its economical value and simple installation method.

Acknowledgement

This project is part of the research grant by AP-2015-011 on Development of Affordable and Innovative Earthquake Resistance (AIER) System for Low Rise Residential Buildings”. Special thanks to Dr Anuar and Assoc.Prof Dr Siti Aminah for giving their supports.

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