

FINITE ELEMENT MODELLING OF CRUMB RUBBER CONCRETE COLUMN  
SUBJECTED TO EARTHQUAKES

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## **DEDICATION**

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

## **ACKNOWLEDGMENT**

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## **ABSTRACT**

Production of sustainable concrete is the most crucial factor to be considered in construction fields. The utilization of waste treated crumb rubber and steel fiber can mitigate the problematic issues of Normal Concrete (NC) which is brittle, low tensile, and low damping performance. The purpose of this research was to compare the experimental results of Crumb Rubber Concrete (CRC) subjected to earthquake loading with finite element Modelling by using ABAQUS. Three-dimensional finite element analysis of concrete lumped mass column of 35 MPa and having base 275 mm x 80 mm; column 40 mm x 500 mm lumped mass column 120 mm x 190 mm is developed using ABAQUS and subjected to numbers of earthquake loadings. The test specimen was characterized, concrete mix (10%, of rubber particles content), The result of finite element analysis is validated using experimental data. Overall, this research demonstrates the potential use of treated crumb rubber as sustainable concrete that can enhance the damping performance of the concrete structure, and this could be a major benefit for structure in seismic areas where energy dissipation is needed.

## **ABSTRAK**

Pengeluaran konkrit lestari adalah faktor yang paling penting untuk dipertimbangkan dalam bidang pembinaan. Penggunaan getah serbuk dan gentian keluli yang dirawat sisa dapat mengurangkan masalah Masalah Konkrit Normal (NC) yang rapuh, tegangan rendah, dan prestasi meredam rendah. Tujuan kajian ini adalah untuk membandingkan hasil eksperimen Crumb Rubber Concrete (CRC) yang tertakluk kepada pemuatan gempa dengan pemodelan unsur terhingga dengan menggunakan ABAQUS. Analisis unsur terhingga tiga dimensi bagi lajur jisim lumped massa 35 MPa dan mempunyai asas 275 mm x 80 mm; lajur 40 mm x 500 mm lumped jisim 120 mm x 190 mm dibangunkan menggunakan ABAQUS dan tertakluk kepada jumlah beban gempa. Spesimen ujian dicirikan, campuran konkrit (10%, kandungan zarah getah), Hasil analisis unsur terhingga disahkan menggunakan data eksperimen. Secara keseluruhannya, penyelidikan ini menunjukkan potensi penggunaan getah serbuk yang dirawat sebagai konkrit yang dapat meningkatkan prestasi redaman struktur konkrit, dan ini boleh menjadi manfaat utama struktur di kawasan seismik di mana pelepasan tenaga diperlukan.

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## **LIST OF ABBREVIATIONS**

NC	-	Normal Concrete
CRC	-	Crumb Rubber Concrete
TDA	-	Tire Derived Aggregate

## LIST OF SYMBOLS

$\sigma_{exp}$	-	Experimentally measured stresses
$\varepsilon_{exp}$	-	strain
$\sigma_{true}$	-	True Stresses
$\varepsilon_{ln}$	-	Logarithmic Strain
$\Psi_{crc}$	-	Dilation Angle
$k_c$	-	The ratio of the second stress invariant on the tensile meridian to that on the compressive meridian
$f_{bo}$	-	Initial equiaxial compression yield stress
$f_{co}$	-	Initial uniaxial compressive yield stress

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background

Building structure in earthquake regions w designed with seismic design code for structure protection. However, the problem is properties are quasibrittle failure, offer less ductility and less damping performance. The nearly complete loss of loading capacity, once failure is initiated, and it could cause major damage or total collapse (catastrophic failure) of the structure, especially during a high-intensity earthquake event. Earthquake is sudden shaking of the ground caused by the passage of seismic waves through Earth's rocks. Seismic waves are produced when some form of energy stored in Earth's crust is suddenly released, usually when masses of rock are straining against one another suddenly fracture and "slip". Earthquakes occur most often along geologic faults, narrow zones where rock masses move about one another. The major fault lines of the world are located at the fringes of the huge tectonic plates that make up Earth's crust. The earthquake alters the shape of the earth with high intensity and damages the men made building and several losses of lives were observed in multiple times. There's a saying among seismologists: "Earthquakes do not kill people, Buildings kill people." It is not the enormous shock waves of energy released during an earthquake that causes most injuries and fatalities. It is how the structures in which people live, work and congregate react to those shock waves that can spell the difference between life and death. The following are biggest reasons buildings fail in an earthquake i.e soil fails, foundation fails and the reinforced concrete building fails subjected to an earthquake.

Mass of the building plays an important role to withstand against earthquake. Every building can withstand gravity loading include some lateral loads. Most of the buildings are not designed to resist, intense and side by side load during earthquake.



In such case when earthquake wave hit series of waves building foundation get fail which indicates that earthquake was not strong enough to damage the structure.

Concrete is one of the most vital construction material on earth because of its compressive strength, versatility, good durability and cost of construction. From last 20 years, research is undertaken to use recycle tires rubber as a replacement of concrete aggregate. It was noted that with the addition of recycle rubber, dynamic and tensile properties of concrete were improved. As concrete is weak in tension and strong in tension. Some material was needed to improve the tensile properties of concrete with addition of crumb rubber. It improves tensile and dynamic properties but that was a reduction in compressive strength of concrete. In the Meantime, 1.1 tires per person are disposed of per annum. In 2009, the number of disposed of scrap tires in the landfill was 594 thousand tons. Tires are difficult to landfill in one piece because they tend to float the surface. From last couple of years Over 3 million tons of wastetires were disposed of in EU states each year (ETRA, 2006; FISE-UNIRE, 2007) and approximately 600 hundred tons are stockpiled. Over the years there is a continuous increase in fees for disposing of tires and it became more expensive. This trend is likely to continue as landfill spaces become scarcer. Therefore, the need to manage scrap tires has become a necessity and these scrape tires dispose of in various legal or illegal manners (disposal of tires in the unpermitted area) and disposing of tire become more expensive over the years. Scrape tire continues to be a nuisance to the environment. Because of the bulky nature of tires 75% of tire space is void and the whole tire need large amount of space for landfill. Shredding process of tyre is expensive but overcome above problems.

Due to above mentioned problem and high-cost tire stockpils turned up across the country. Thus waste tire produces significant environmental, aesthetic and human health problems. In 1983, over seven million waste tyre was burned in virginia for nine months which cause pollution to nearby waste sources.[The United States Environmental Pn Agency, 1993].

The development of vehicle industry has created a huge problem in recent years known as “black pollution”. In some countries, landfill is not allowed to damp waste

tire. Reutilization of scrape tire is sustainable for development. Scrape tire has been suggested to use in asphalt for pavement and burning of energy in a cement kiln. Rubber can be used as a replacement of aggregate in concrete, as concrete is most widely used material in the world. Utilization of crumb rubber in concrete will overcome the utilization of waste tire.

Generally, crumb rubber has the capability to dissipate energy due to its elastic behavior. Past research has proved that the rubberized concrete from waste tires can absorb energy by delaying crack propagation thus helps to improve the damping performance, but the reduction in compressive strength caused by low bonding adhesion between cement paste and crumb rubber particles has become a main concern. Low bonding of crumb rubber in Interfacial Transition Zone (ITZ) can affect the concrete strength

A more recent study investigated that replacing up to 20% of fine aggregate with rubber will increase the damping capacity of concrete. There was a decrease in compressive strength which was reported by the author (Bowland, 2011). The main purpose of using rubber as aggregate is to enhance concrete impact resistance (Siddique and Naik, 2004). In general, these studies explain that the addition of rubber will only help to increase elastic behavior of concrete, on the other hand, it will reduce compressive strength studied by (Nehdi and Khan, 2001).

(Khaloo *et al.*, 2008) Investigated addition of tire chip, crumb rubber, and both tire and crumb rubber by replacing 12.5%, 25%, 37.5% and 50% of total volume of aggregate in concrete. It was noted that with the addition of all type of rubber, the toughness of concrete was increased till 25% replacement, beyond that there was a decline in toughness of concrete.

(Al-Tayeb *et al.*, 2013) It was observed that crump or chipped tire rubber aggregate increase impact resistance of concrete during impact test by 10Kg hammering from 60mm. (Kaloush *et al.*, 2005)achieve that there was a decrease in natural frequency and increase in damping ratio of a structural element using Rubberised concrete as compared to that normal concrete. (Batayneh *et al.*, 2008)

Several considerations, such as particle size of rubber, percentage, and replacement of fine, course and total aggregate with total aggregate will play an important role in properties on concrete.

Therefore, some modification in concrete properties by replacement of crumb rubber and the addition of steel fibers with modified water-cement ratio has been made in this research to overcome this problem. This research is different from previous works which are concerned about the mechanical properties of concrete containing crumb rubber, as this study is focused on the potential of CRC as seismic resistance structure. Lastly, CRC will increase the energy dissipation by increasing the damping coefficient under the various intensity of seismic loading under earthquake event.

## **1.2 Problem Statement**

Concrete is a brittle material which shows less damping performance and less ductile. Thus, concrete subjected to the earthquake will induce damage or collapse to the structure once failure is initiated in concrete. Which further cause the foundation failure and complete damage of the structure. To overcome this problem, a material with damping properties must be added to concrete. Previous literature concluded that concrete containing rubber from waste tires could absorb energy which will delay crack propagation thus improve damping performance. However, there was a reduction noted in compressive strength was observed because of low bonding between cement paste and crumb rubber. The experimental approach seems promising; however, the experimental test is time-consuming and costly. Consumption of energy cost is another problem to be solved using experimental methods. The error margin in experimental work without any analytical optimization is very high. It suggests investigating an analytical approach to optimize the energy cost using modeling techniques.

### **1.3 Research Objectives**

This study aims to numerically analyze treated crumb rubber from waste tire to improve the damping performance of concrete structure to be performed as seismic resistance structure in the earthquake region. In many cases, analytical methods are more economical than laboratory or field testing, and finite element model provides information. The development of reliable analytical model reduces the number of test specimens for the solution of the given problem. A laboratory test is time-consuming and costly. The main objectives of this research are as follows

1. To model the rubberized column using ABAQUS.
2. To investigate the capacity of the column.
3. To evaluate the damping ratio and analyze the response of normal concrete and crumb rubber concrete (column) subjected dynamic loadings (seismic ground motion).

### **1.4 Scope of Study**

The establishment of the scope of the study is to achieve the objectives from experimental works. All testing procedures followed the Malaysian Standard (MS), British Standard (BS), Eurocode Standard (BS-EN), American Society for Testing and Materials (ASTM), and some of the procedures were proposed by previous researchers.

4. The designed (mix) strength of concrete is 35 N/mm<sup>2</sup> at 28 days.
5. The maximum size of treated crumb rubber is 4.75 mm with 10% replacement of fine aggregates.
6. Addition of steel fibers as 1% by volume fraction.
7. Addition of 1% superplasticizer and Crumb Rubber Steel Fiber blended cement Concrete by cement density.

8. Analyzing the model in ABAQUS

### **1.5 Significance of Study**

The significance of this study is to compare the results of finite element modeling of column subjected to different earthquake loading excited with laboratory results which were done by Author. In laboratory test lamped mass column was tested for different earthquake loadings to check energy dissipation of column. From experimental results, it was noted that the use of treated crumb rubber would increase energy dissipation and delay crack propagation. Thus, crumb rubber from waste tire will benefit the construction industry in the earthquake region. Also, analytical modeling will help us to reduce time consumption and cost.

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