Title	ENGINEERING PROPERTIES OF CONCRETE INCORPORATING SCRAP RUBBER TIRE AS AGGREGATE REPLACEMENT WITH PALM OIL FUEL ASH AS PARTIAL REPLACEMENT OF ORDINARY PORTLAND CEMENT
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Engineering Properties of Concrete Incorporating Scrap Rubber Tire as Aggregate Replacement with Palm Oil Fuel Ash as Partial Replacement of Ordinary Portland cement

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ABSTRACT

One of the most popular fields of concrete research is a modification of concrete properties by substituting waste materials. In this research, the feasibility and performance of using tire-rubber particles incorporating 5%,10% and 20% as replacement of mineral aggregate and 20% Palm oil fuel ash (POFA) as cement replacement is investigated. Two different types of tire-rubber were applied in this study; the first type was fiber rubber with 0.84 to 3.36 mm particle size, and the second was granule rubber of 1-4 mm particle size. The research was considered to develop information about the effect size and shape of tire-rubber particles on mechanical properties of rubberized concrete. Selected standard mechanical test were performed and the result was analysed based on ASTM standard. The mechanical properties include compressive strength, indirect tensile strength and flexural strength. The result showed that the mechanical properties of rubberized concrete have considerably changed by the increase in replacement ratios further than 5% in both types.

Keywords: Rubberized Concrete; Engineering Properties; Palm oil fuel ash, Scrap Rubber Tire; Shape and Size

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1. Introduction

Recently, worldwide growth of the automobile industry and increase of car use has tremendously boosted production of tire. For example around 285 million scrap-tires are produced in the United States each year ("U.S. Environmental Protection Agency". 2009), Also France produces over 10 million scrap-tires per year (Siddique & Naik, 2004).

Tires are almost immune to biological degradation (Ganjian et al. 1996). Scrap tire is composed of non-degradable ingredients (Khalilitabas et al., 2011). They usually produce environmental mal-effects.

Modification of concrete properties by the addition of appropriate materials is a popular field of concrete research and several studies have been conducted to facilitate the use of new material in Portland cement (Najim et al., 2010; Khaloo et. al 2008; Pelisser et al., 2010).

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During the last 20 years researchers have conducted studies to investigate the potential and properties of plane rubberized concrete (PRC). Rubberized concrete is defined as concrete with coarse and/or fine rubber aggregate replacement. Topcu (Topcu, 1995) investigated the change of the properties for the rubberized concrete in term of both size and amount of the rubber chips. He reported compressive strength decreased by adding rubber in concrete. Eldin and Senouci (1993, 1994) used tire–rubber particles as concrete aggregates; elucidating rubberized concrete properties, and proposed an analytical approach to predict the strength in rubberized concrete. Mechanical behaviour under static and dynamic loads of specimens made of concrete filled with small volumetric fractions of crushed tyre rubber and polypropylene short fibre was investigated by Hernandez-Olivares et al. (2002). He observed engineering properties of rubberized concrete is reduced by adding more rubber. Li (Li et al, 2009) investigated the development of waste tire modified concrete by using different types of waste tire. For the waste tire chip modified concrete, surface treatment by saturating the NaOH solution and physical anchorage by drilling a hole at the centre of the chips were also investigated. The result showed pre-treatment could improve compressive strength of rubberized concrete. Mechanical properties of concrete containing high volumes of tire-rubber particle and the feasibility of using elastic and flexible tire–rubber particles as aggregate in concrete was investigated by Khaloo (Khaloo et al. 2008). The whole of previous research showed that utility of rubber particles affected the concrete by reducing the compressive strength by adding more rubber particles.
This article presented a comparative analysis of mechanical properties of rubberized concrete incorporating crumb rubber particle in two different type replacements to fine aggregate and showed the effect of type and size of rubber particles in properties of rubber concrete. Whole data were compared to the normal control concrete mix. The mechanical properties investigated included the compressive strength, indirect tensile strength and flexural strength beside fresh properties of rubberized concrete.

2. Experimental work

2.1 Materials

Natural aggregate consisted of coarse aggregate with maximum nominal size of 12.5 mm, and the fine aggregate was natural river sand used for this research which confirms to ASTM C33/C33M–11. The figure 1 illustrates the composition of natural river sand. The physical properties of the natural aggregate and rubber particles are shown in table 1

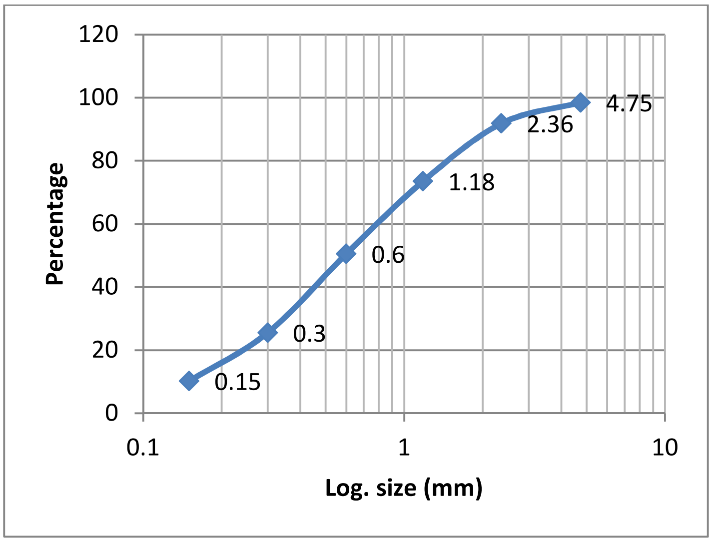

Figure 1: Fine aggregate grading

Table 1: Physical properties of aggregate

Aggregate	Fine aggregate	Coarse aggregate	Fiber rubber shredded (0.85-3.35mm)	Rubber granules (1-4 mm)
Specific gravity	2.68	2.65	0.884	1.337
Water absorption (%)	3.38	1.07	1.38	1.73
Fineness modulus	2.5			

Tire–rubber particles provides by scrap tire. The rubber particles used were two;

I. Fiber Rubber shred, replaced as a fine material with grading from 0.84 mm to 3.36mm.
II. Rubber granules, with size from 1 to 4 mm which it replaced as fine aggregate.

Ordinary Portland cement (OPC), Type I, based on ASTM C150 requirement was used. Palm oil fuel ash (POFA) used in this research as 20% replacement of OPC to enhance the compressive strength of concrete. 99.6% of particles size was less than 45 µm.

2.2 Mixture proportions

There were two basic mixtures designed according to ACI-318 method. The water/cement ratio was kept constant at 0.43 and super plasticizer, 1% by weight of cement, was taken for both mixtures and control batch as well. The POFA replaced at 20% of the total weight of OPC for both mixtures.

In the first mixture, 5%, 10% and 20% by volume of total fine aggregate were replaced by fiber tyre rubber shred. The mixtures were designed as R_1X CP20 and R_2X CP20, which X representing the percentage of replacement rubber, R_1 stands for fiber rubber shred and R_2 representing rubber granules. Concrete mix proportion specifications are shown in Table 2.

Table 2. Concrete mixture proportions

Mix	Cement (Kg/m^3)	POFA (Kg/m^3)	Super Plasticizer (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)	Fiber Rubber (Kg/m^3)	Rubber Granules (Kg/m^3)	Coarse Aggregate (Kg/m^3)
Control	530.23	-	5.30	228	720.8	-	-	885.5
$R_1$5CP20	424.2	106.05	5.30	228	684.76	12.02	-	885.5
$R_1$10CP20	424.2	106.05	5.30	228	648.72	24.05	-	885.5
$R_1$20CP20	424.2	106.05	5.30	228	576.64	48.09	-	885.5
$R_2$5CP20	424.2	106.05	5.30	228	684.76	-	18.2	885.5
$R_2$10CP20	424.2	106.05	5.30	228	648.72	-	36.4	885.5
$R_2$20CP20	424.2	106.05	5.30	228	576.64	-	72.8	885.5

2.3 Casting and testing

For each batch, cylindrical sample by 200 mm height and 100 mm diameter used for compressive strength test and indirect tensile strength test. The compressive strength and indirect tensile strength were determined according to ASTM C39/C39 M-12 and ASTM C496/C496M–11 respectively. Prism mould by 100×100×400 mm used for flexural strength test. The Flexural strength test was also carried out according to BS188: part

118:1983. All concrete samples were covered with wet burlap in the laboratory, then samples were de-moulded after 24 hours of casting, and were kept in water curing tank for 28 days base on ASTM / C192M-06 standard practice. Totally 7 batches were prepared in this study and this included 84 cylindrical (200×100) mm samples for compressive and indirect tensile strength, 63 samples of beam (100×100×500) mm for flexural test. 3 samples of cylinders were tested for compressive strength and indirect tensile strength after 7 and 28 days, and the 3 beam samples were tested on flexural test at age 7, 14 and 28 days of curing.

3. Experimental results and discussion

3.1. Compressive strength

The result of 7 days and 28-days compressive strength tests for rubberized concrete are shown in Figure 2 and 3. The average of three samples appearance on the bar chart containing both types of concrete was reduced by the increase in percentage of rubber particles. In general, the granule rubber showed better results in the early stage of strength in comparison to fiber rubberized concrete.

The 7days granules rubberized concrete, decreased from 14.56% to 38.28% by increasing the amount of rubber aggregate, and 7 days compressive strength of granules particles drop from 5% to 20%. In contrast the fiber rubberized concrete had better result in 28day.

It is observed that there was reduced only about 3.5% in 5% replacement of rubber.

The result showed obviously that fiber and granules concrete can used in the structural component by 10% replacement. Generally, the granules showed higher potential for utility in concrete.

The reduction of compressive strength is due to a lack of proper bonding between the cement past and rubber particles in comparing to aggregate and cement paste in control batch. In addition, lower stiffness of rubber particles compare to aggregate is another reason to reduce the concrete mass stiffness and lowers its load bearing capacity.

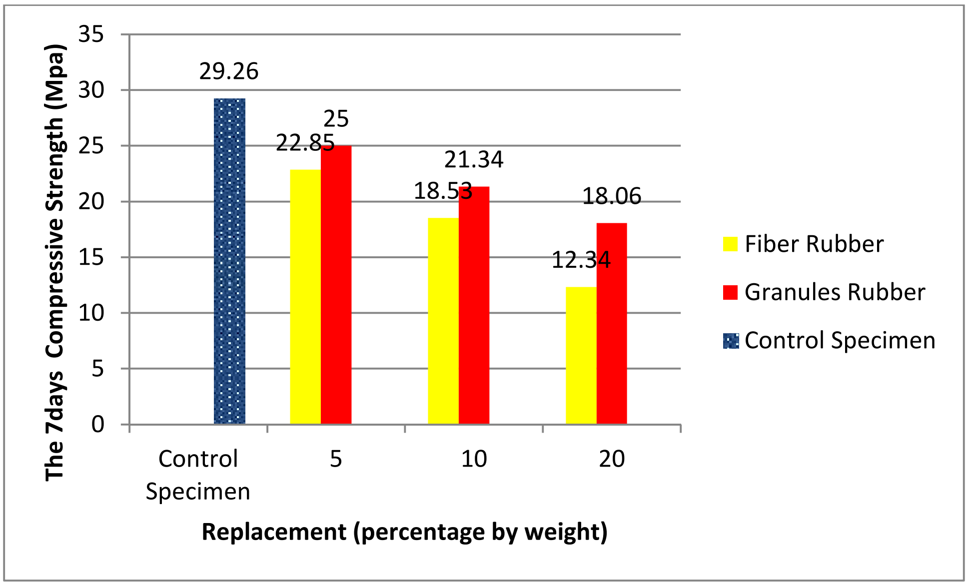

Figure 2: Results of 7-day compressive strength test.

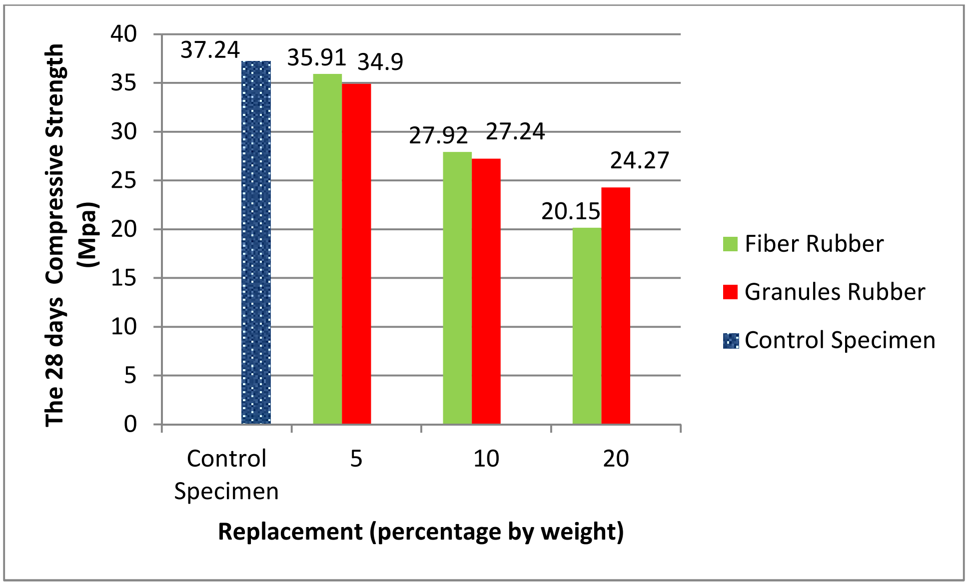

Figure 3: Results of 28-day compressive strength test.

3.2. Tensile strength

The results of tensile strength tests are presented in Fig.3 and 4. The splitting tensile strength tests were tested at the age of 7-days and 28-days. Tensile strength of fiber rubberized concrete showed approximately 9.4% higher strength in comparing to normal concrete. The results of 28-days showed that normal concrete had better strength than both rubberized batches. The outcomes obviously showed that there is no significant reduction in value when fine aggregate replaced with fiber rubber and granule rubber with maximum amount of 10%. This reduction can be explained by the lack of strong bonding between cementitious paste and rubber particles. It was observed that it was hard to separate the failed samples with higher amount of rubber in comparison to lower percentage of rubberized concrete because the rubber particles were bridging the crack and keep connected two concrete parts.

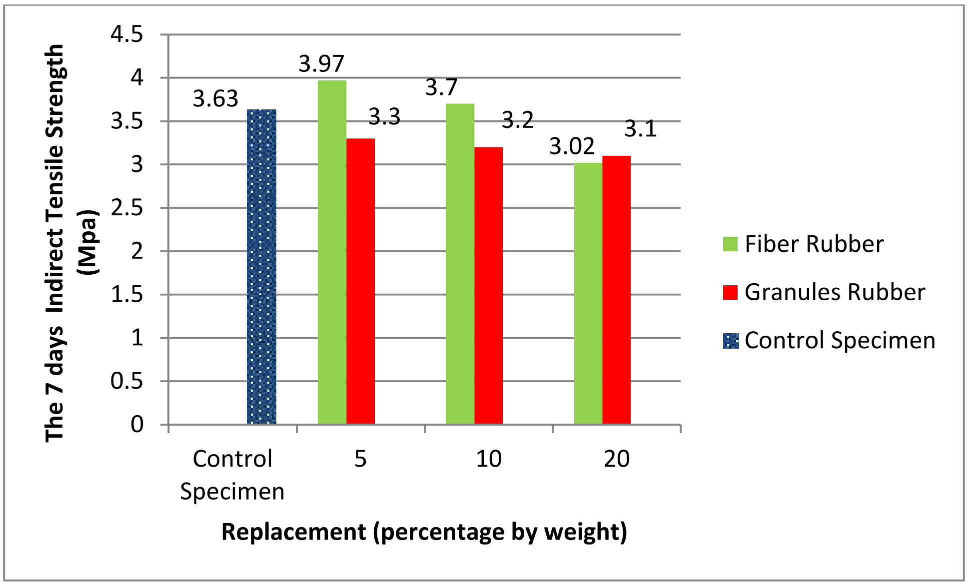

Figure 4: Results of 7-day tensile strength test.

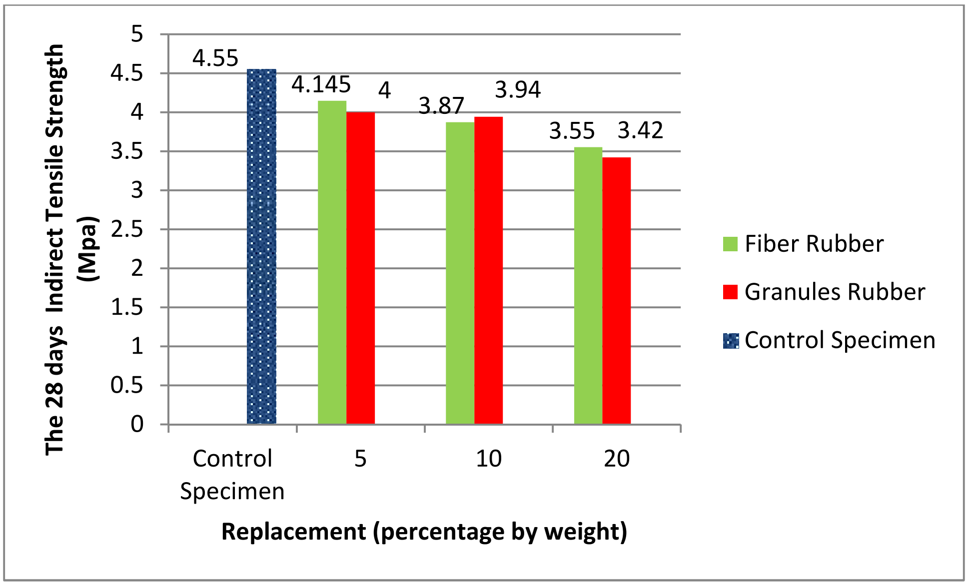

Figure 5: Results of 28-day tensile strength test.

3.3. Flexural strength

The flexural test was tested at age of 7, 14 and 28-days. The results of flexural strength tests are shown in figure 6, 7 and 8. Each value on the bar chart is the average of three prismatic specimens. The reduction in flexural strength observed in both types of rubberized concrete, and only the rates were different. The reduction of 19.5% and 7.5% was observed with substitute the fibre rubber aggregate and granules rubber particles respectively. The best result obtained with 10% of granules rubber replacement.

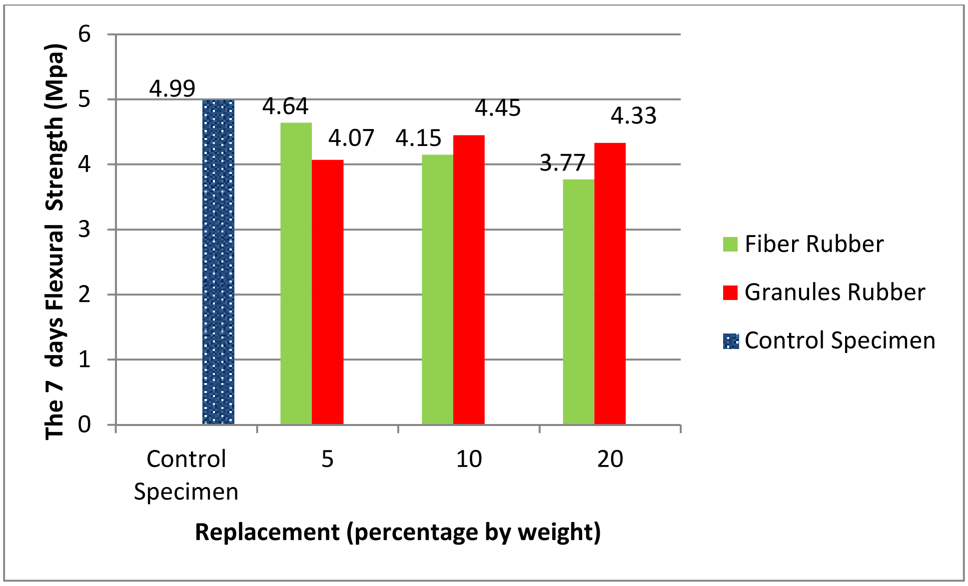

Figure 6: Results of 7-day flexural strength test.

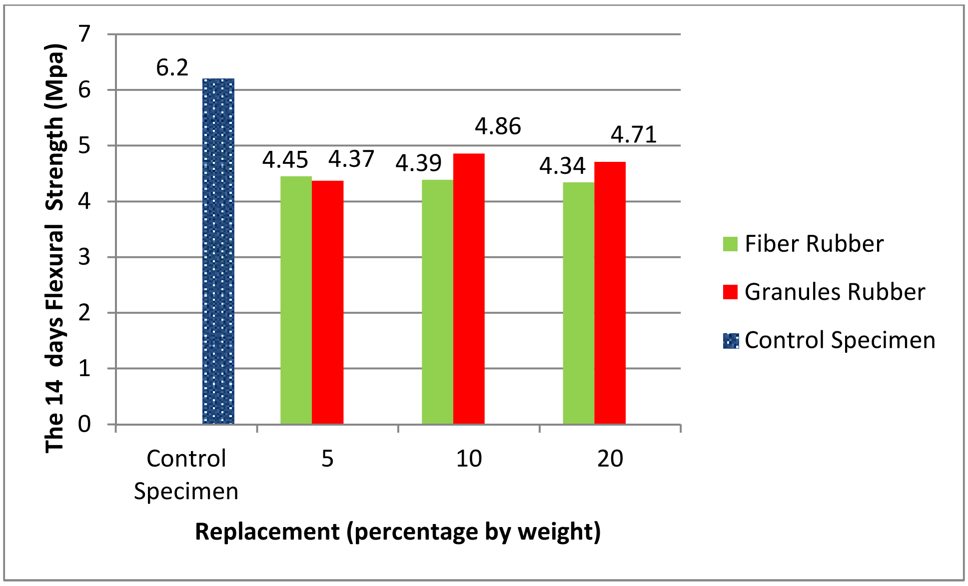

Figure 7: Results of 14-day flexural strength test.

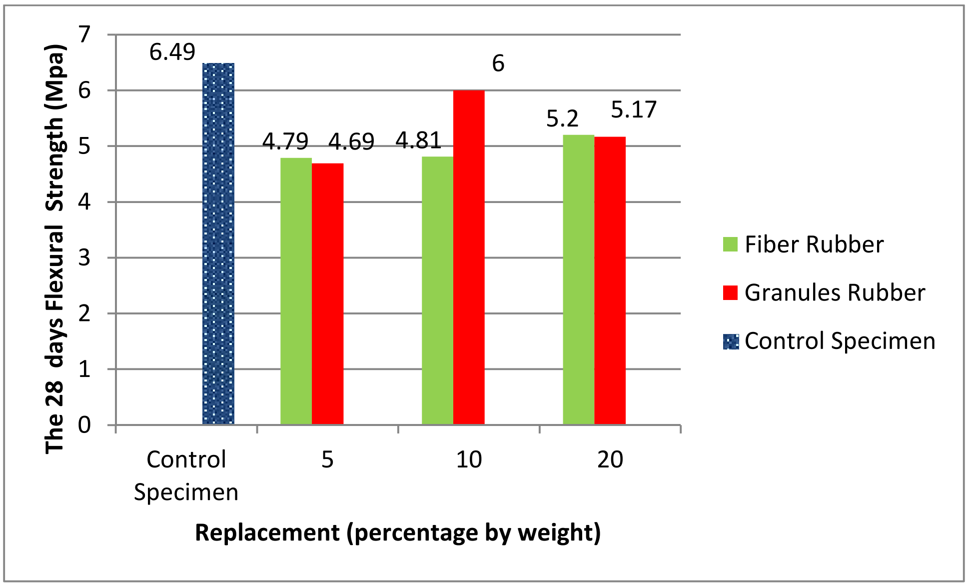

Figure 8: Results of 28-day flexural strength test.

4. Conclusions.

- Compressive strength of rubberized concrete depended on two factors is ; grain size and shape of replacing rubber and percentage added. In general, it was observed that compressive strength was reduced with increasing the amount of rubber particles in concrete. In addition, according to the experimental result, in line with the finding of other researchers, the maximum amount of replacement should limited not exceed to 10% of total volume of natural fine aggregate.
- Flexural strength and tensile strength were reduced with the increasing of rubber replacement in concrete. Although the loss of strength due to using rubber aggregate

on flexural strength and tensile strength were less than compressive strength. The rubber granules aggregate showed better results in flexural strength, but there was no observed significant difference in tensile strength for both rubber aggregate types.

- Replacement of rubber particles showed larger displacement and deformation in compared to plain concrete. It was due to the fact that rubber aggregate known as materials withstand a bigger ability to deform under carrying loads than natural aggregate.

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