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Behavior of rubberized concrete under active confinement

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HIGHLIGHTS

- Effects of rubber content and confining pressure on the compressive behavior of concrete are studied.
- Four different batches of concretes with rubber replacement ratios of 0%, 6%, 12%, and 18% are tested under active confining pressures of up to 25 MPa.
- An increase in the rubber content results in a decrease in the compressive strength but an increase in the axial and lateral deformability of actively confined concrete.
- An increase in the rubber content leads to an increase in the lateral strain of concrete for a given axial strain and confining pressure.
- An increase in the confining pressure leads to an increase in the axial strength and strain of rubberized concrete with a similar trend to that in conventional concrete.

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ABSTRACT

This paper presents the results of the first experimental study on the axial compressive behavior of the rubberized concrete under active confinement. Four different batches of concretes with rubber replacement ratios of 0%, 6%, 12%, and 18% were prepared. The effects of the rubber replacement ratio and confining pressure on the compressive behavior of concrete were examined through the tests of unconfined and actively confined concrete cylinders. The active confinement was applied by a Hoek cell at different pressures, including 5, 7.5, 10, 15, 20, and 25 MPa. The results indicate that the rubber content significantly affects the compressive behavior of actively confined concrete. An increase in the rubber content results in a decrease in the compressive strength and an increase in the axial and lateral deformability of concrete. It is found that the axial strength and strain of rubberized concrete increase with the confining pressure following a similar trend to that in conventional concrete. On the other hand, the rubber content affects the descending branch trend of the axial stress-strain curves of concrete under active confinement, with more shallow branches seen in concretes with a higher rubber replacement ratio.

1. Introduction

Waste tire disposal is becoming a significant environmental concern due to the lack of landfills. Pacheco Torgal et al. [1] reported that about 5 billion tires will be discarded due to an increase of the motor vehicles by year 2030. In some countries, the tire rubber is burned to produce fuel, artificial reefs, and feedstock. However, these applications are not economical and result in an increase of contamination and health hazards [2]. Furthermore, the limited availability of landfills and increasing costs of waste disposal are the other problems associated with the disposal of waste tires [3].

Some characteristics of the rubber tires such as the high strength, durability, resistance to the fatigue, sound attenuation and vibration absorbency, and low weight, make them a useful material for use in subgrade insulation, pavement, lightweight fill material, drainage material, flowable fill, road embankment, and sound barrier. However, these applications utilize only a small proportion of the volume of the tire rubber that end in the landfills [4]. Recently, construction industry has placed significant attention to the use of eco-friendly and waste-based materials to lower the environmental impact of concrete. As one of the important applications of wastes in concrete, the use of rubber particles to replace sand in the concrete was suggested as a value-added use of waste tire rubber [5–8].

The use of tire rubber has been extensively studied in the highway asphalt mixes [9]. However, studies on the use of rubberized concrete for structural applications have been limited [10–12].

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Existing studies investigated the effect of the sand or coarse aggregate replacement with rubber particles on the mechanical behavior of the concrete. It was found that an increase in the rubber content results in a decrease in the strength and elastic modulus of concrete. However, more ductile behavior was observed in rubberized concrete compared to conventional concrete. Topcu [13] showed that the replacement of the sand and coarse aggregates with rubber particles results in an increased inelastic deformation capacity over that of the conventional concrete. Khatib and Bayomy [14] performed experimental compression and flexural tests on the rubberized concrete using two types of tire rubber, namely the coarse tire chips and fine crumb rubber. It was found that the rubber replacement ratio should be limited to 20% of the total aggregate volume to avoid large strength reductions.

The dynamic behavior of the rubberized concrete was investigated by Xue and Shinozuka [10], Topcu [15], Hernandez-Olivares et al. [16], and Zheng et al. [17]. Xue and Shinozuka [10] found that rubberized concrete can be used as a structural material to enhance the dynamic performance of concrete structures. The impact performance of the rubberized concrete was studied by Liu et al. [18], which revealed that the addition of rubber increased the energy absorption capacity of concrete. Guneyisi et al. [19] and Elchalakani [20] found that an inclusion of silica fume can improve the mechanical properties of rubberized concrete and decrease the rate of the strength reduction. Abendeh et al. [21] studied the behavior of crumb rubber concrete-filled steel tubes and found lower compressive strength compared to the conventional concrete. Duarte et al. [22] investigated the behavior of rubberized concrete-filled steel tubes under combined lateral cyclic loading and axial compression. Li et al. [23] and Dattatreya and Raghu [24] found that the ductility of fiber-reinforced polymer (FRP)-confined rubberized concrete was higher than that of the FRP-confined plain concrete under axial compression. Although existing studies have shown that the compressive strength of the rubberized concrete is lower compared to that of the conventional concrete, they also showed that addition of rubber can improve various characteristics of concrete (e.g. increased ductility and reduced weight) and the structural members manufactured with it (e.g. increased energy absorption and improved dynamic performance).

It is well established that the lateral confinement of concrete significantly enhances its ductility and compressive strength [25–40]. One of the methods for confining concrete is active confinement, where a constant confining pressure is exerted to concrete through a triaxial load cell. Studying actively confined concrete is important for understanding the behavior of concrete under constant confinement pressure condition, which is extremely useful for simulating the behavior of concrete under constant confining pressure (e.g. steel-confined concrete) as well as varying confining pressure (e.g. FRP-confined concrete) [41]. As discussed in detail in Lim and Ozbakkaloglu [42], a large number of studies have been conducted to understand the mechanical behavior of concretes of different grades under active confinement. However, no study has been reported to date on the behavior of rubberized concrete under triaxial compression. Such studies are needed to understand the behavior of rubberized concrete under confinement to determine the feasibility of the use of the material in structural applica-

Fig. 2. Hoek cell used for applying active confinement.

Fig. 1. Cored specimens from the concrete blocks.

Table 1
Mix proportions of the concrete.

Mix	Rubber content, RR (%)*	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Sand (kg/m^3)	Water (kg/m^3)	Rubber (kg/m^3)	ρ (kg/m^3)
RC0	0	400	1080	687	200	0	2311.2
RC6	6	400	1080	646	200	13.5	2298.3
RC12	12	400	1080	605	200	27.0	2266.7
RC18	18	400	1080	563	200	40.4	2230.1

* As volume replacement of sand.