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Mechanical characterization of waste-rubber-modified recycled-aggregate concrete

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A R T I C L E I N F O

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A B S T R A C T

A waste-rubber-modified recycled-aggregate concrete (RMRAC) intended for road construction was produced by adding granulated waste rubber to recycled-aggregate concrete (RAC). The impact mechanical properties of the RMRAC were studied using a variable cross-section 74-mm-diameter split-Hopkinson pressure bar (SHPB). The dynamic mechanical properties and the toughness of the RMRAC were studied at four strain rates, corresponding to four different input pressures, and were compared to those observed in the static condition. The effects of the rubber particle size, rubber content, and strain rate on the dynamic compressive strength and toughness of the RMRAC were analysed. Test results show that the RMRAC exhibits an enhanced strain rate effect and has good impact resistance relative to RAC.

1. Introduction

Concrete is among the most widely used construction materials in civil engineering. The performance of a concrete building or structure depends on the performance of the concrete used for construction. It is inherently brittle and, in higher-strength concrete, the brittleness is increased. Cracks may occur in concrete under loading, particularly in applications such as airport runways and roads; the cyclic loading from the take-offs and landings of aeroplanes and passing vehicles causes cracks to form gradually in the pavement. The presence of cracks causes severe degradation of the operational performance and service life of the concrete pavement.

Meanwhile, the growing prevalence of automotive transportation has created increasing amounts of waste rubber as a by-product, posing a great burden to the environment. Incorporating rubber into concrete can reduce environmental pollution and conserve resources (Blessen and Ramesh, 2015). Research has shown that rubberized concrete, produced by incorporating granulated rubber into a concrete mix, can display reduced brittleness and enhanced ductility and toughness relative to conventional concrete (Hernández-Olivares et al., 2002). Some studies have investigated the addition of rubber to increase the dynamic load resistance of concrete used for pavement (Batayneh et al., 2008; Li et al., 2004; Shu and Huang, 2014; Siddique and Naik, 2004). Rubberized concrete has excellent ductility, crack resistance, impermeability, frost resistance, fatigue resistance, impact resistance, and shock absorption properties, and it provides superior sound insulation and noise reduction as well as excellent wear resistance (Eldin and Senouci, 1993; Khaloo et al., 2008; Liu et al., 2013; Richardson et al., 2015; Son et al., 2011; Topçu, 1995; Toutanji, 1996; Wang et al., 2011). Experimental studies have shown that the compressive, bending, and splitting tensile strengths of rubberized concrete mixtures are lower than those of ordinary concrete. The strength and elastic modulus of rubberized concrete are decreased as the rubber content is increased (Iqbal, 2016). However, the greater friction between the rubber particles and concrete causes increased energy absorption because of the elasticity of the rubber, thereby significantly enhancing the damping capacity of concrete (Gabr and Cameron, 2012; Ganjian et al., 2009; Liu and Pan, 2011; Liu et al., 2012; Reda et al., 2008; Zheng et al., 2008). Therefore, rubberized concrete should also exhibit better performance under seismic loads than conventional concrete.

With recent rapid increases in urban construction and increases in the demolition of ageing buildings, the management of waste

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Table 1
Technical standards of rubber powders used.

Mesh number	Size (mm)	Cumulative passed (%)	Ash content (%)	Acetone extract (%)	Tensile strength (MPa)	Elongation at break (%)
5	4.04	≥90	≤8	≤8	≥15	≥500
20	0.86	≥90	≤8	≤8	≥15	≥500
60	0.22	≥90	≤8	≤8	≥15	≥500

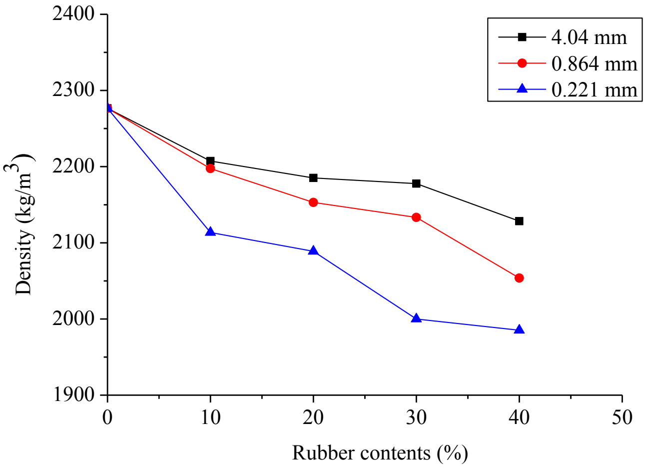

Fig. 1. Specimen density vs. rubber contents.

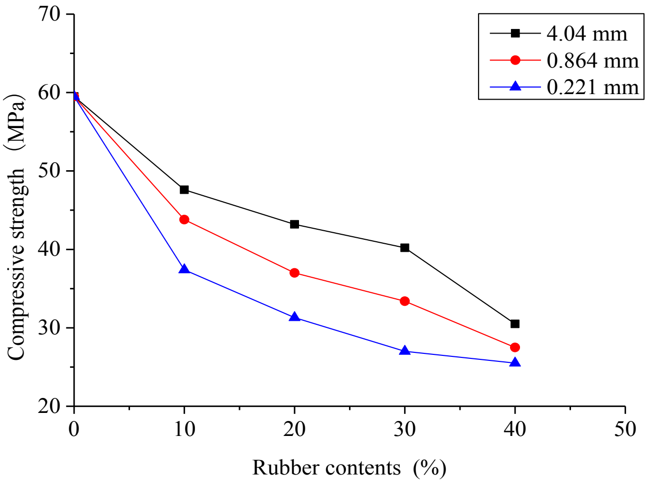

Fig. 3. Compressive strength vs. rubber contents.

concrete has become an important environmental problem. Recycling waste concrete as either concrete blocks (Teng et al., 2015) or coarse aggregate has received increased attention in recent years (Shi et al., 2016). Extensive research has been conducted on the mechanical properties of recycled aggregate concrete (RAC), including studies on recycled concrete members and structures. The combination of recycled concrete materials with polymeric materials, such as fibre sheets or rubber, in structures has been proposed by multiple researchers (Guo et al., 2014; Liu et al., 2015). In structures such as fortifications, highways, airport runways, and nuclear power plants, the dynamic mechanical properties of RAC significantly affect service life and safety (Epps, 1994; Li et al., 2014; Meddah et al., 2014).

To promote economic development and improvement in quality of life, many roadways requiring significant amounts of concrete must be constructed, especially in developing countries. The application of recycled aggregates and scrap rubber to road concrete could reuse these materials effectively in a manner benefitting both economic development and environmental protection.

In this study, a Split-Hopkinson pressure bar (SHPB) device (Liu et al., 2012) is utilized to investigate the impact behaviour and compressive performance of rubber-modified recycled-aggregate concrete (RMRAC). Coarse aggregate from recycled concrete is used to prepare the concrete mix; granulated waste rubber is added to

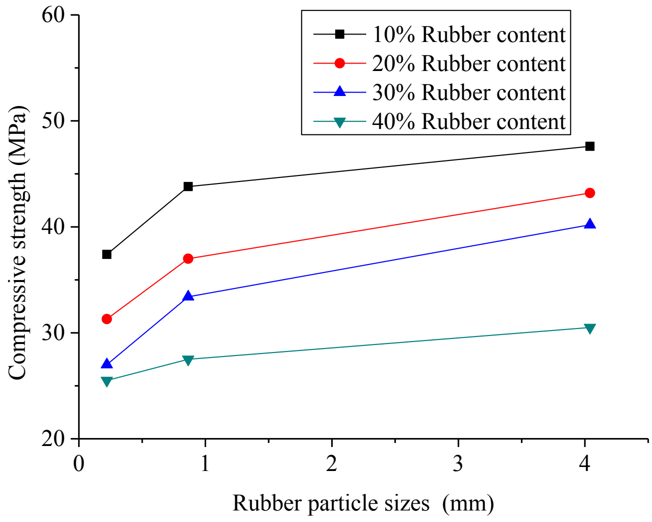

Fig. 2. Compressive strength vs. rubber particle sizes.

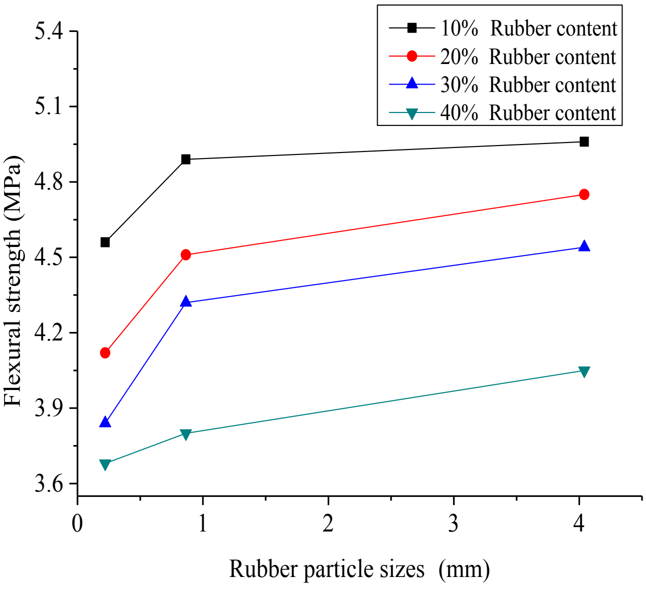

Fig. 4. Flexural strength vs. rubber particle sizes.

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