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Investigating properties of pervious concretes containing waste tire rubbers

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HIGHLIGHTS

- Rubberized pervious concretes were produced.
- Fine and coarse aggregates were replaced with crump rubber and tire chips.
- Permeability significantly reduced with tire rubbers.
- Effect of tire rubbers on mechanical properties was negative.
- Tire rubber enhanced fracture energy of the concretes.

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ABSTRACT

Objective of the work: To study the properties of rubberized plain pervious concrete in terms of the mechanical properties and the permeability.

Materials and methods: Three types of rubber were used in the production of rubberized plain pervious concrete mixtures which obtained by partially replacing the aggregate with rubber. One water-cement (w/c) ratio, one moist curing period, and four designated rubber contents by total aggregate volume were considered as experimental parameters. The results compared with non-rubberized pervious concrete (control) mixture.

Results: The use of rubber significantly aggravated the pervious concrete mechanical properties and its permeability but in different degrees according to the rate and type of rubber used. However, replacement of natural aggregate with rubber particles resulted in a significant increase of toughness and ductility of concrete as well as better damping capacity.

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1. Introduction

Disposal of waste tires has been a major issue to the cities all around the world. Generally, the cheapest and easiest way to decompose the used tires is by burning them. However, the pollution due to enormous amount of smoke makes this method so unacceptable that it is prohibited by law in many countries. Therefore, recycling of the waste tires seems to be necessary by means of innovative techniques [1–3]. Also, the other waste materials, such as steel fibers recovered from post-consumer tyres and aggregate obtained from construction and demolition waste are necessary to be recycled [4–6]. Innovative solutions to meet the challenge of the tire disposal problem involve the use of waste materials as additives to cement-based materials [3,7–9] and the production of rubber-powder incorporated asphalt or bituminous materials [10,11].

Conventional concrete pavement has lack of water and air permeability which had a negative impact on environment. The conventional concrete cannot capture stormwater and also cannot allow it to be filtered underground, causing some problem such as the phenomenon of hot island in city, water erosion and degradation in the quality of water. Utilization of conventional concrete in pavement construction consumes more efficient land use by need of retention ponds, swales and other stormwater management devices. Therefore, a new type of concrete, namely pervious concrete was developed and used in parking areas, walk ways, light traffic roads, and shoulders. Such types of pavements have seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater and minimize storm water runoff [12]. Pervious concrete has been used more frequently due to its benefits in reducing the runoff water, improving water quality, enhancing pavement skid resistance during storm events by rapid

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Table 1
Physical properties and chemical compositions of Portland cement.

Chemical analysis (%)	Portland cement
CaO	62.58
SiO_2	20.25
Al_2O_3	5.31
Fe_2O_3	4.04
MgO	2.82
SO_3	2.73
K_2O	0.92
Na_2O	0.22
Loss on ignition	1.02
Specific gravity	3.15
Blaine specific surface area (m^2/kg)	326

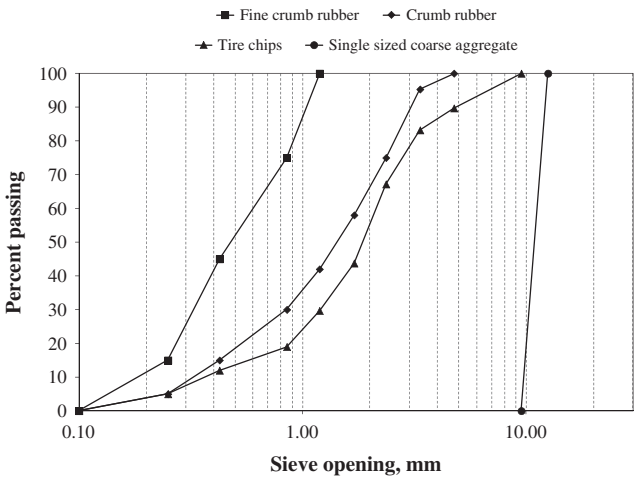

Fig. 1. Gradation curve of aggregate, tire chips, crumb rubber, and fine crumb rubber.

drainage of water, reducing the self-weight of the structure and the on-site noise level [13]. These properties made pervious concrete became an environmental friendly material in paving application [14]. To produce another environmental friendly material from waste material is concrete produced with recycled aggregate and such concretes can be used in both structural buildings and pavement applications [15].

Normally, pervious concretes (PC) are produced with water-to-cement ratio of 0.25–0.35 (mostly 0.27) and with no fine materials or not more than 10% of the maximum single sized coarse aggregate [16]. They have a porosity of 15–25%, a compressive strength of 3–30 MPa and a permeability of 0.025–0.61 cm/s. Moreover, PC has a unit weight of as low as 70% of the conventional concrete. Aggregate appeared to be much more effective on the mechanical and the durability behavior of the former than those of the latter since they occupy a marked volume of as high as 80% in the concrete [17]. Therefore, the growing interest on the use of rubber particles as concrete aggregates has encouraged the researchers to explore the performance of the rubberized pervious concretes. Moreover, the mechanical properties of pavement concretes can be improved by reinforcing with steel fibers [18].

This paper reports an experimental study on the properties of pervious concretes containing waste rubber. Pervious concretes were produced with an ordinary Portland cement of 450 kg/m^3 in a constant water–cement ratio of 0.27. The waste rubbers were used in three different particle sizes (very fine, fine, and coarse) with four different replacement levels (0%, 5%, 10%, and 20%) by total aggregate volume. The hardened properties of the concretes were tested for compressive strength, splitting tensile strength, modulus of elasticity, water permeability, and fracture energy.

2. Experimental study

2.1. Materials

CEM I 42.5R Portland cement with Blaine fineness of 326 m^2/kg and specific gravity of 3.15 was used to produce the pervious concretes. Physical and chemical properties of the cement are given in Table 1. A single sized natural river coarse aggregate (passing 12.5 mm, retained on 10 mm sieve) was used to provide the adequate permeability. Its specific gravity is 2.72. Two types of scrap tire rubber came from used truck tires castaway after a second recapping, namely crumb rubber and tire chips. Crumb rubber is a fine material while tire chips are produced by mechanical shredding thus containing coarser particle sizes. The waste rubbers were used with three different particle sizes, namely very fine, fine, and coarse. Tire chips (TC) with specific gravity of 1.02 were used as coarse rubber aggregates. However, two types of crumb rubber (CR) with nominal particle sizes of 4 mm and 1 mm (fine)

Fig. 2. Rubber materials and natural aggregates used in this research.

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