Construction and Building Materials 59 (2014) 204–212

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Strength, abrasion and permeation characteristics of cement concrete containing discarded rubber fine aggregates

Blessen Skariah Thomas [a,*], Ramesh Chandra Gupta [a], Pawan Kalla [a], Laszlo Csetenyi [b]

[a] Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur, Rajasthan, India
[b] Concrete Technology Unit, University of Dundee, United Kingdom

HIGHLIGHTS

- Waste tyre rubber (a solid waste material) is used in cement concrete as a partial replacement of natural river sand.
- M30 grade of concrete was used with water/cement ratio 0.4. w/c ratios 0.45 and 0.5 were also studied.
- Aim was to dispose the solid waste material, and to find an alternate to natural sand in concrete construction.
- 0–20% substitution of fine aggregates, in multiples of 2.5% was done with crumb rubber.
- Crumb rubber may be utilized for the replacement for fine aggregates up to 7.5% without enough reduction in its desired strength.

ARTICLE INFO

Article history:
Received 26 December 2013
Received in revised form 27 January 2014
Accepted 28 January 2014
Available online 27 March 2014

Keywords:
Discarded tyre rubber
Sorptivity
Water permeability
Abrasion

ABSTRACT

Solid waste disposal is a worldwide problem. If not properly disposed, these materials become sources of environmental pollution and the problems related to it. Various studies are done worldwide to dispose these solid waste materials by using them for partial or complete replacement of aggregates in cement concrete. Discarded tyre rubber is an important solid waste material that destroys the ecological environment. This paper investigates the suitability of waste tyre rubber in cement concrete as a partial replacement for natural river sand. M30 grade of concrete is designed as per IS 10262: 2010, with water/cement ratios of 0.4. Water–cement ratios of 0.45 and 0.5 were also studied. 0–20% substitution of fine aggregates, in multiples of 2.5% was done with discarded tyre rubber (crumb rubber). The specimens with 0% discarded tyre rubber were taken as control mix. Tests were done to determine the compressive strength, flexural strength, abrasion resistance, micro-structure, water permeability, and Sorptivity in concrete specimens. It was observed that discarded tyre rubber may be utilized for the partial replacement for natural fine aggregates up to 7.5% without enough reduction in its desired strength.

1. Introduction

Concrete is a mixture of cement, aggregates and water. Aggregates constitute about 70% by weight of the concrete. There is a great demand for natural aggregates as the construction activities are increasing every day. As the natural resources are decreasing every day, some alternative materials that will serve the purpose of the natural aggregates should be introduced [4].

Due to the increase in the numbers of vehicles, lots of tyres are ending up as waste. Disposal of waste tyres has been a major environmental issue in cities all around the world. Billions of tyres are being discarded and buried all over the world, representing a serious ecological threat. It is estimated that 1000 million tyres reach the end their useful life every year. By the year 2030, the number can reach up to 1200 million tyres representing almost 5000 million tyres (including stock piled) to be discarded on a regular basis. Waste tyres also provide a breeding habitat for various pests. Moreover, tyre burning results in serious fire hazards [14,15,20,25].

Considering the average life of the tyres used in the vehicles as 10 years after retreading twice, the total number of waste tyres will be in the order of 112 million per year (in India). Such a growth, apart from causing noise and air pollution, has begun to cause pollution in terms of stock piles of discarded tyres. The previous common practice of use as fuel is now prohibited by the Government of various countries, as it causes environmental degradation [5,16,24]. Therefore, it is essential to consume or dispose the discarded tyre rubber by any other means to save health and to prevent environmental pollution.

* Corresponding author. Address: MSH-16, MNIT Jaipur, Rajasthan, India. Tel.: +91 9414180915.
E-mail address: bstblessen@yahoo.com (B.S. Thomas).

http://dx.doi.org/10.1016/j.conbuildmat.2014.01.074
0950-0618/© 2014 Elsevier Ltd. All rights reserved.

Eldin and Senouci [11] were the first to study on aggregates derived from used tyres, in 1993. They replaced fine aggregates by discarded tyre rubber (1 mm) and coarse aggregates by discarded tyre rubber (6 mm, 19 mm, 25 mm and 38 mm). They found that the particular concrete had lower workability, lower compressive and tensile strength, etc. The decrease in mechanical properties was attributed to loss of adherence between the surface of rubber particles and the cement matrix. They also observed that the loss of compressive strength increased with the size of the tyre derived aggregated (TA). Segre and Joekes [21] has observed that the treatment of rubber particles with NAOH enhances the adhesion of rubber to cement paste, improves the mechanical properties, abrasion resistance and decreases the water absorption of the rubberized concrete. Eldin and Senouci [18], Ling and Poon [23] made similar observations.

Ganjian et al. [12] studied on the performance of concrete mix incorporating 5%, 7.5% and 10% of discarded tyre rubber as aggregate and cement replacement. They observed that the addition of tyre particles in concrete has reduced the compressive strength, flexural strength, tensile strength, and modulus of elasticity. The water permeability increased with increasing percentages of rubber as aggregates, but it decreased when the rubber is used for cement replacement. Toutanji [22], Yilmaz and Degirmenci [1], Fattuhi and Clark [13] has made similar observations.

Bravo and de Brito [17] have replaced natural aggregates in concrete with 5%, 10% and 15% tyre derived aggregates and explained that the compressive strength reduced by 50% for 15% substitution, shrinkage and water absorption of rubberized concrete increased, carbonation resistance and chloride resistance decreased with increasing rubber content in concrete. Oikonomou and Mavridou [19] used tyre rubber granules for the partial replacement of sand in concrete and reported that there is a reduction in the mechanical properties, while the chloride ion penetration resistance has been improved than that of control mix.

Azevedo et al. [3] studied on the properties and durability of high performance concrete with partial replacement of sand with tyre waste. Flyash and metakaolin were used for partial cement replacement. They reported that, the increase of rubber wastes leads to serious compressive strength loss. The mix with 5% rubber waste and a partial replacement of cement by 15% fly ash and 15% metakaolin has almost the same resistance to sulphuric acid attack of the reference mix. The mixes with 45% fly ash and 15% metakaolin show a much higher resistance to sulphuric acid attack than the reference mix independently of the rubber waste content.

So, it is clear that the discarded tyre rubber should be disposed without causing any harm to the environment. One of the emerging fields is in the production of concrete, where tyre rubber may be used as a partial replacement to natural aggregates. This has the additional advantage of saving in natural resources. Hence, the reuse of this material in concrete could have both environmental advantages and at the same time ensure economic viability. In this regard, an attempt may be done to control the environmental pollution and to save the natural resources by using the discarded tyre rubber (crumb rubber) for partial replacement for fine aggregates in cement concrete.

2. Material properties and preparation of test specimens

2.1. Raw materials

Ordinary Portland Cement of grade 43, conforming to IS 8112: 1989 was used (specific gravity 3.15, normal consistency 34%, initial setting time 99 min, final setting time 176 min). Natural river sand confirming to zone II as per IS 383: 1970 (void content 34% as per ASTM C 29/C 29M: 2009, specific gravity 2.63, free surface moisture 1%, fineness modulus 2.83). Coarse aggregates, 10 mm size was used 40% (fineness modulus 5.573) and 20 mm size was used 60% (fineness modulus 7.312) crushed stone were used as coarse aggregates with an average specific gravity 2.63. Discarded tyre rubber was grinded into three sizes (powder form of 30 mesh, 0.8–2 mm, 2–4 mm). The specific gravity of rubber powder was 1.05 and that of the other two sizes were 1.13. The three sizes of crumb rubber were mixed in definite percentages (2–4 mm size in 25%, 0.8–2 mm size in 35% and rubber powder in 40%) to bring it to zone II as per IS 383: 1970. The particle size distributions of aggregates are shown in Fig. 1, chemical composition of crumb rubber is given in Table 1, physical properties of cement in Table 2, and chemical properties of cement in Table 3.

2.2. Preparation of test specimens

To investigate the suitability of discarded tyre rubber as a substitute for fine aggregates in concrete, M30 grade concrete was designed (as per IS 10262: 2010) with water–cement ratio 0.4. Other water–cement ratios of 0.45 and 0.5 were also studied. The ratio of cement, fine aggregates and coarse aggregates are 1:1.8:3.1. Crumb rubber was replaced for natural sand from 0% to 20% in multiple of 2.5%. The mixture proportions are given in Tables 4–6. Super plasticizer was used as the admixture to arrive at the desired workability (C.F. above 0.91). In these mixes 6 cubes of size 100 mm × 100 mm × 100 mm were casted for compressive strength test (7 and 28 days), 3 cubes each for abrasion test and Sorptivity test, 6 beams of size 100 mm × 100 mm × 500 mm were casted for flexural strength test (7 and 28 days). 3 cubes of size 150 mm × 150 mm × 150 mm were casted for water permeability test. The mixtures were prepared and casted at indoor temperature of 25–30 °C. Compaction factor tests were done on fresh concrete to determine its workability. Moulds were covered with plastic sheets, soon after casting and de-moulded after 24 h. Curing was done in water tank, with controlled temperature of 25–27 °C. Compression test, flexural strength test and abrasion test were done on the cured specimens as per IS specifications [6–10], Sorptivity test as per ASTM specifications and water permeability test as per DIN 1048.

3. Laboratory testing program

3.1. Density, setting and hardening of rubberized concrete

Workability of fresh concrete was tested in a compacting factor apparatus as per IS 1199: 1959 [10]. Density of fresh concrete mixtures was also measured as per IS 1199: 1959. The workability and density of concrete with different percentages of crumb rubber were compared with those of control mix. The results of the workability and density of fresh concrete are given in Tables 4–6 for

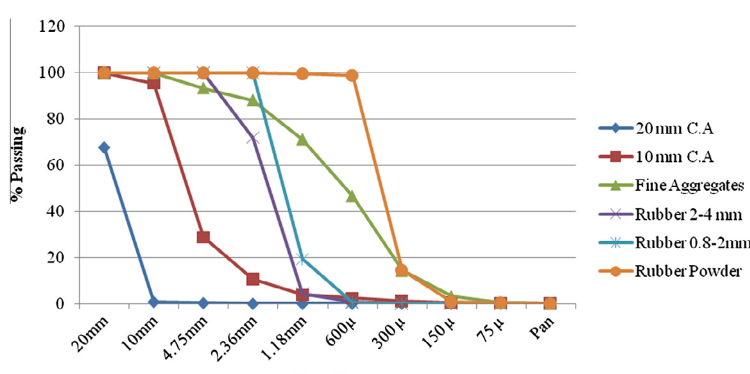

Fig. 1. Particle size distribution of aggregates (coarse aggregates, fine aggregates and crumb rubber).