Construction and Building Materials 120 (2016) 473–481

Contents lists available at ScienceDirect

Construction and Building Materials

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

Performance evaluation of a resinous cement mortar modified with crushed clay brick and tire rubber aggregate

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HIGHLIGHTS

- Properties of a resinous mortar with rubber waste (RW) and brick waste (RW) were studied.
- Natural sand was replaced, in volume, by 10–30% of RW and 2.5–10% of BW.
- The composed mix (RW, BW) improves mechanical resistances, water absorption and shrinkage.
- The studied mortar constitutes a valuable addition in the range of rubber cementitious composites.

ARTICLE INFO

Article history:
Received 9 November 2015
Received in revised form 4 May 2016
Accepted 19 May 2016
Available online 26 May 2016

Keywords:
Clay brick waste
Rubber waste latex
Filler
Resinous mortar
Cementitious composites

ABSTRACT

This paper reports an experimental study that aimed to investigate the effect of two wastes, as partial replacement of natural sand (NS), on the performances of a cement mortar reinforced by a resinous latex. These are tire rubber wastes in fine aggregate form (RW) and brick waste as filler (BW). The volume of the RW aggregates contents was 10%, 20% and 30% while, the BW fillers contents were 2.5%, 5%, 7.5% and 10%. Ten mortars were designated for this purpose and evaluated on dry unit weight, water absorption by total immersion, compressive and flexural strengths, shrinkage and water absorption by capillary suction. The workability of all mixtures was maintained constant by use of a local Ether Polycarboxylate superplasticiser (Medaplast SP 40). Test results indicated that the combined incorporation of 20% RW with 5% and 7.5% BW leads to a decrease in water absorption and shrinkage at 28 days. The deterioration of the 28 days compressive and flexural strengths induced by the incorporation of the RW aggregates can be significantly minimised by the introduction of BW fillers due to their capacity to compact the mixtures and to their pozzolanicity. A viable alternative for producing environmental mortar by the use of two wastes has been proven by this study.

1. Introduction

More than 1.5 billion tires are produced worldwide every year [1] causing an increasing threat to human health and the environment at their end of life, when becoming waste. The generated waste tires are currently stockpiled in many countries around the world and their volume is rising due to the increasing world population, vehicle ownership and usage. Within the industrial world, research and development is continuously progressing towards finding new and innovative techniques in the recycling sector. In contrast, within developing countries, the use of these accumulated and non-degradable waste materials is still in its early phases, thus the problem is even more serious. This is the case of Algeria where nearly 26,000 tons of scrap tires are generated every year [2], however only timid studies to recycle them are currently being conducted, in the geotechnical area [3]. Some pilot projects have been started using pneusol (tyresol) technique developed by Nguyen Thanh Long [4]. An example of a typical use of this technique in the stability of an embankment road situated at kilometer point number $8+278 \pm 25$ m at Bousmail city (Department of Tipaza, northern Algeria) is well described by Benabdelouahab et al. [3].

On the other hand, natural sand (NS) is becoming rare due to its intensive use in construction. Recycling more waste material is now an unavoidable outcome.

Much research has been conducted worldwide revealing creative solutions to manage and reduce the volume of waste tires that is generated year after year [5–7]. Among the most investigated areas are the incorporation of granular rubber waste (RW) into cement-based materials [8–21] which has proven the viability of using granular RW as a replacement of fine and coarse

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http://dx.doi.org/10.1016/j.conbuildmat.2016.05.119
0950-0618/

aggregates in mortars and concretes, especially in circumstances where mechanical strengths, as well as densities, are not the main desired characteristics. In fact, the replacement of aggregates with RW reduces the compressive strength of concrete [8–11]. This decrease has been explained usually by the poor adhesion between the cement matrix and the rubber particles [13]. Many works have mentioned the use of pre-treatment of RW to improve this adhesion, thus to achieve better strength performances: immersion of RW in NaOH solution [13,22], coating with a thin layer of cement past [23], use of styrene butadiene rubber (SBR) [24], organic sulfur [25] and recently silane coupling agent with a chemically active coating [26].

Some other works have been carried out based on the incorporation of several fillers into basic mixtures such as limestone [27], fly ash [28,29] and silica fume (micro silica exactly) [30] to enhance the mechanical properties of the resulting composite materials. Promising results have been achieved. However, the incorporation of brick waste (BW) powder, as filler, in the replacement of natural sand (NS) had not been studied in spite of its pozzolanic reaction with hydrated lime [31]. The filler added to the basic composition will, also, correct the compactness of the aggregate mix (NS + RW). The new eco-material with two wastes represents a valuable addition to the range of rubber cementitious composites.

To improve some characteristics of this two wastes-cementitious mortar, it is proposed, in this study, to incorporate simultaneously RW aggregates and BW fillers, as a volume replacement for sand aggregates, into a matrix reinforced by a fixed amount of a resinous latex. According to [24], the introduction of this latter material improves the bonding between rubber aggregate and cement paste, which would deteriorate with the introduction of RW. Mechanical and physical properties of rubberised cement mortar are also improved.

The aim of the present paper is to report the results of experimental investigations on physical, mechanical and hydric properties of this resinous mortar where NS was replaced by RW aggregates, BW fillers or both. The amounts of replacement used were 10–20% and 30% for RW and 2.5–5.0–7.5 and 10% for BW. That of the resinous latex was fixed at 7% by weight of cement.

The workability of the studied mortar has been maintained constant by the use of an Ether Polycarboxylate Superplasticiser. The hardened mortar was characterised according to the following properties: dry weight unit (dry bulk density), water absorption by total immersion, compressive and flexural strengths, shrinkage and water absorption due to capillary action (sorptivity).

2. Materials and test procedures

2.1. Materials

2.1.1. Cement

A local Portland Cement (PC) type CEM I with strength class 42.5 complying with Algerian Standard NA 433-2002 was used for all the mortar mixes. The absolute density and specific surface area of the cement were 3.15 and 3200 cm^2/g respectively. Its chemical composition and its clinker mineralogical composition, as determined by Bogue calculation, are given in Table 1.

Table 1
Chemical and mineralogical compositions of the Portland cement.

Chemical composition	(%)	Clinker mineralogical composition	(%)
SiO_2	21.62	C_3S	52.48
Al_2O_3	4.49	C_2S	22.69
Fe_2O_3	5.37	C_3A	2.82
CaO	63.91	C_4AF	16.32
MgO	1.66		
SO_3	1.92		
Na_2O	0.08		
K_2O	0.25		
LoI[a]	0.81		

[a] Loss on ignition.

2.1.2. Natural sand

Siliceous sand collected from Oum Ali sandpit (Department of Tebessa, northern Algeria) with a maximum particle size of 4 mm was used to manufacture the reference mortar; its fineness modulus and absolute density were 2.36 and 2.56 respectively. Fig. 1 exhibits the particle size distribution of both natural sand (NS) and rubber waste (RW) particles. As can be seen in this figure, their distribution curves are continuous.

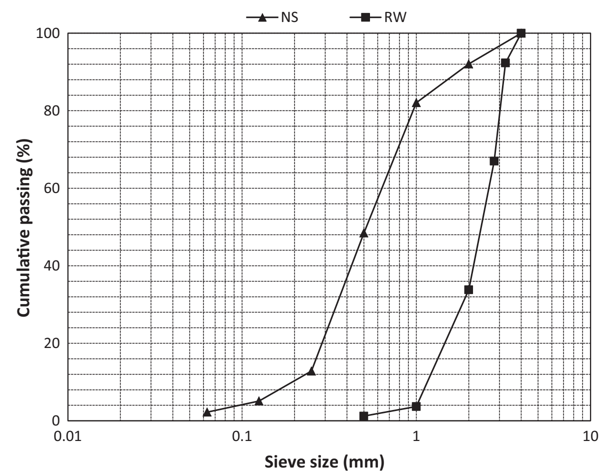

Fig. 1. Particle size distribution curves of NS and RW particles.

2.1.3. Rubber waste aggregates

RW aggregates used in this study were obtained by the mechanical grinding of worn tires from a local factory. Their size distributions are ranged from 0.5 to 4.0 mm (Fig. 1) and their absolute density was 0.94.

2.1.4. Brick waste filler

Brick waste (BW) filler for this study consisted of fragments of fired clay bricks that were calcined at about 850 °C and were discarded as waste in a brick-manufacturing factory located in the Bendjerrah municipality (Department of Guelma, northern Algeria). These were first crushed and then finely ground and screened in a sieve opening of 2 mm. 74% of the particles passed through the sieve of 0.063 mm allowing them to be classified as filler materials according to the usual classification of the French standard NF XP 18-540. These were initially homogenised, and then oven-dried at 105 °C for 24 h. The absolute density of the BW filler is 2.50 and its chemical composition is presented in Table 2.

2.1.5. Superplasticiser

The superplasticiser used in the mortar mixtures is an Algerian superplasticiser based on Ether Polycarboxylate, commercially named Medaplast SP 40. It was used at 1.4% of the cement weight to ensure the same workability with varied proportions of rubber particles, evaluated by means of mortar flow table test (EN 12350-5).

2.1.6. Stabiliser

Because of the important difference between specific densities of the NS (2.56) and the RW aggregates (0.94), and also because of the hydrophobic nature of the tire rubber particles, segregation has been observed when rubber particles were added. To ensure good dispersion, a stabiliser in powder form, commercially named Medacol BSE and manufactured by Granitex Algeria was used at 0.1% of cement weight. It is composed of colloidal agents and ultra fine silica. Its colour is grey and its density is ~0.01.

Table 2
Chemical composition of the BW used (%).

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_3	Na_2O	LoI
69.26	14.17	6.30	4.28	2.25	1.34	0.02	0.28	1.96