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Assessing the effects of recycled asphalt pavement materials on the performance of roller compacted concrete

Chafika Settari [a], Farid Debieb [a,*], El. Hadj Kadri [b], Othmane Boukendakdji [a]

[a] LME Laboratory, University of Medea, Algeria
[b] L2MGC Laboratory, University of Cergy-Pontoise, France

HIGHLIGHTS

- Recycled asphalt pavement (RAP) materials are used in roller compacted concrete.
- Increasing RAP in roller compacted concrete decreases its density.
- Increasing RAP in roller compacted concrete increases its tensile strength.
- 50% max of RAP materials are recommended to be used in roller compacted concrete.

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ABSTRACT

In some countries of the world, for economic and environmental reasons, recycled asphalt pavement (RAP) materials comes from old bituminous road pavements are increasingly investigated. In Algeria particularly, a huge quantity of this type of waste is produced every year but rarely quantified and rarely reused. This paper evaluate the effects of various RAP sizes as substitute of coarse and fine natural aggregate (NA) on the mechanical properties and durability of roller compacted concrete (RCC). The RAP and NA materials are characterized and compared. The mechanical properties and durability of RCC with RAP materials are analyzed and compared to the RCC with 100% of NA. The experimental results showed that it is possible to manufacture RCC with a maximum of 50% of RAP materials. In addition to that, it may be more environmentally efficient to valorise this type of waste in concrete, because this helps to remove in general some parts of wastes and protects the environment.

1. Introduction

The quantity of waste produced each year in the European community is estimated at 3.0 billion tons of which 40% comes from construction and demolition waste (C&DW); they are composed in major part, of concrete, asphalt and masonry [1,2]. In Algeria particularly, a huge quantity of waste is produced every year but rarely evaluated. The construction industry generates approximately 2.2 million tons per year including 15% of C&DW while other large quantities of waste are coming from old bituminous road pavements but rarely quantified and reused [2,3]. In the environmental consideration and according to the new classification of the waste, the aggregates without bituminous are non-dangerous waste (classification 17 03 02) [2]. The aggregates with coated bituminous waste are considered as admissible in the category of the inert waste [4]. Using RAP materials in RCC has several advantages, like it possible to contribute to the resolution of waste storage problem, the reduction of the environmental pollution, the safeguarding of natural resources, the reduction of construction cost and the increase of supply in sand and gravels. Recent successful studies on the use of recycled aggregates in RCC have been reported in some countries [5–7]. However, they are mainly devoted to experiences with RAP materials as coarse aggregates, only a few of them describe RCC made with the fine fraction or coarse and fine aggregates [8–10]. Therefore, the main objective of this research is to investigate the effects of fine, coarse or both fine and coarse RAP particles on the mechanical performances (compressive strength, tensile strength and elastic modulus) and the durability (characterized by capillary absorption) of RCC mixtures. To achieve these objective, different RCC mixtures with RAP materials are made, analyzed and compared to a referential RCC with 100% of NA.

* Corresponding author.
E-mail addresses: debieb.farid@univ-medea.dz, f_debieb@yahoo.com (F. Debieb).

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2. Roller compacted concrete

RCC is a dry mix concrete laid down and compacted like soil. The same constituents than for ordinary concrete are used but cement content is lower (250 kg/m^3) [11] and slump is close to Zero [12] (Fig. 1). Moreover, this type of concrete is rapid setting and especially used in road and dam construction. The RCC is quite economic (low cost production and rapid installation) [13] suitable for covering road ways [13,14].

3. Research program

3.1. Materials and tests

An industrial Portland cement type CEM II 42.5 N from Algeria, with a density of 3100 kg/m^3 and an average compressive strength at 28 days of about 42.5 and 62.5 MPa, was used for all concrete mixtures. Three limestone crushed NA fractions (coarse NG 3/8, NG 8/15 and fine NS 0/3) coming from MontGorno region and three other RAP fractions (coarse RG 4/10, RG 10/14 and fine RS 0/4) coming from bituminous road pavements are used for RCC mixes. RAP materials are used at virgin state (without bitumen extraction). The different tests realized on aggregates and concrete are summarized in Table 1.

3.2. Identification and formulation of the RCC mixtures

3.2.1. Identification of mixtures

Five concrete mixtures were made. Either natural sand, coarse natural aggregates or both were partially replaced (50% and 100%) with RAP Materials. Literary codes identify each mixture in a precise way. $RCC_{G/S}$ indicates the roller compacted concrete with the percentage of substitution in coarse (G) and fine (S) RAP materials:

- **RCC 0/0:** RCC with 100% of coarse and fine NA (reference concrete).
- **RCC 50/50:** RCC containing 50% of coarse and 50% of fine RAP materials.
- **RCC 0/100:** RCC with 100% of fine RAP materials.
- **RCC 100/0:** RCC with 100% of coarse RAP materials.
- **RCC 100/100:** RCC with 100% of coarse and 100% of fine RAP materials.

3.2.2. Optimization of mix by Rene-LCPC software

The optimized granular skeleton of different mixes is given by Rene-LCPC software. The RCC mix is based on the requirements of minimal porosity (Fig. 2) [15] and the water content (W) corresponding to the highest compactness (γ_d) with the modified proctor test procedure (Fig. 3).

Fig. 1. Zero slump of RCC.

Table 1
Identification of tests realized on aggregates and concrete.

Tests	Specimen (mm)	Standard
Aggregates		
Grain size distribution	–	NF P18-560
Density	–	NF P 18-554
Water absorption	–	NF P 18-555
Sand equivalent	–	NF P 18-598
Los Angeles	–	NF P 18-573
Concrete		
Compressive strength	Cylinder (Φ160× h 320)	NF P 18-455
Tensile strength	Cylinder (Φ160× h 320)	NF P 18-434
Elastic modulus	Cylinder (Φ160× h 320)	NA 437
Capillary absorption	1/2 core (Φ160× h 100)	EN 13057

After calculating the quantity of efficient water for compaction, an optimal RCC should include the quantity of necessary dough to fill the emptiness of the granular skeleton and to get the wanted workability. The RCC mixing procedure (6 min) used [3] is summarized in Table 2.

At the end of mixing, the concrete is put in two layers in the mould fixed on the vibrating table, vibrating each time during 1 min. Specimens are compacted through an experimental procedure and device [16] developed in the Building Materials Laboratory (LMC) of the University of Liege in Belgium (Fig. 4). The main advantage of this method is the possibility of reuse of the cylinder prepared by compaction (non-destructive technique). This device allowed the optimization of the compactness of RCC by a vibratory compaction energy applied on cylinders to be used for concrete characterization. The compactness is evaluated on samples of about 7.5 kg. A weight of 20 kg is inducing a pressure of 10 kPa during the vibration (150 Hz). The volume of concrete really cast is measured and compactness is deduced from the relation Vsolid/Vtotal. The principle is illustrated in Fig. 4b. This will reduce the pores volume and increases the compactness.

4. Experimental results and discussions

4.1. Aggregates

4.1.1. Grain size distribution

The grain size distribution of NA and RAP particles used is presented in Fig. 5. Recycled sand (fine particles of RAP) appears coarser than natural sand; it is predominantly composed of small gravel and a small proportion of medium sand. According to Fig. 5, it appears that coarse recycled aggregates may be similar to coarse natural aggregates; this result was confirmed by other researchers [8,16–19].

4.1.2. Properties of aggregates

By visual analysis, we find that the surface of the coarse RAP particles is rough and includes some micro fissures, but it is smooth for natural aggregates. The fine RAP fraction includes a significant amount of fine particles due to crushing gravels

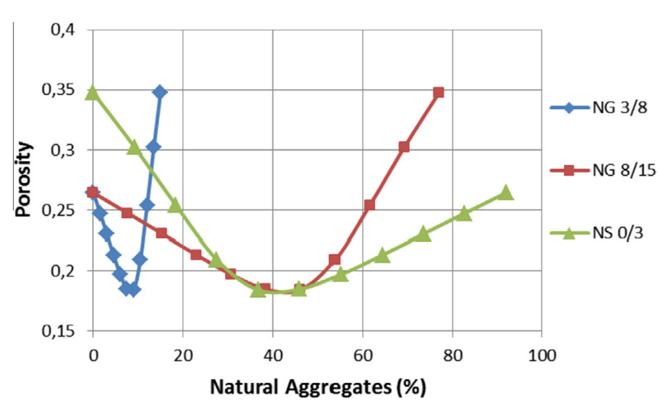

Fig. 2. Variation of the minimal porosity of the reference concrete (RCC 0/0).