Construction and Building Materials 38 (2013) 491–496

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

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

Experimental investigation on fibre-reinforced cement-treated materials using reclaimed asphalt

A. Grilli [a,*], M. Bocci [b], A.M. Tarantino [c]

[a] Università degli Studi della Repubblica di San Marino, Department of Economics and Technology, Salita alla Rocca, 44, San Marino 47890, San Marino
[b] Università Politecnica delle Marche, Department of Civil Engineering and Architecture, via Brecce Bianche, Ancona 60131, Italy
[c] Università degli Studi di Modena e Reggio Emilia, Department of Mechanical and Civil Engineering, via Vignolese 904, Modena 41100, Italy

HIGHLIGHTS

- ▶ The use of PF can prevent the premature failure of CTM.
- ▶ The PF can reduce fracture tendency of CTM.
- ▶ CTM using PF and selected RA join eco-sustainable and long-lasting characteristics.

ARTICLE INFO

Article history:
Received 12 April 2012
Received in revised form 31 July 2012
Accepted 14 August 2012
Available online 8 October 2012

Keywords:
Cement treated mixtures
Reclaimed asphalt
Polymer fibres

ABSTRACT

Cement treated materials (CTMs) are used as base or subbase courses for heavy-traffic highway.

CTMs are characterised by high strength and stiffness ensuring a good support for the upper bituminous layers and by a uniform stress distribution on the lower layers. However, high stiffness of CTM can be self-defeating when the brittle behaviour becomes critical. In this case, CTM become typically prone to shrinkage cracking, which can lead to premature failure of the overall pavement. The use of polymer fibres, such as polypropylene fibres (PFs), can avoid the CTM weakening due to shrinkage phenomenon and it can prevent crack propagation with remarkable benefits in terms of service life of the road pavement.

CTM were originally produced using natural or crushed aggregates but, currently, also recycled aggregates, such as reclaimed asphalt (RA), have been more and more used to preserve natural resources and to reduce the disposal of materials coming from the demolition of civil constructions.

Although recycled aggregates could affect CTM mechanical characteristics, an accurate mix design and material selection allow appreciable performance to be reached.

This paper is a part of an overall research project and it investigates the influence of PF dosage and RA content on CTM properties. In particular, 3-point bending tests and ultrasonic pulse velocity tests were carried out on CTM employing a combination of different PF dosages and RA contents.

1. Introduction

The traffic loading cycles induce tensile stress at the bottom of bound layers of road pavements. The type of binder significantly influences the number of loading cycles that the bound layer can bear before cracking.

Cement treated materials (CTMs) for base or subbase courses have been used for more than 50 years to improve the bearing capacity of road pavements. CTM are produced by mixing aggregates and cement (using a dosage ranging between about 2% and 5% of aggregate weight). Cement treated layers can be used to replace or, as often happens, to integrate unbound granular foundation layers. The significant increase of stiffness and strength of the pavement structure allows a better distribution of the traffic-induced stress at the subgrade and a reduction of tensile strain at the bottom of bituminous layers [1]. For these reasons, the so-called semi-rigid pavement is the most used type of pavement structure for highways or heavy-traffic roads.

However, the excessive stiffness and the tendency to shrinkage of CTM may have negative effects on pavement life. On the one hand, the high stiffness makes the material inclined to a brittle behaviour enhancing the tensile state of the layer and leading to

---

* Corresponding author. Tel.: +378 0549 888111; fax: +378 0549 888113.
E-mail addresses: andrea.grilli@unirsm.sm (A. Grilli), m.bocci@univpm.it (M. Bocci), angelomarcello.tarantino@unimore.it (A.M. Tarantino).

0950-0618/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2012.08.040

premature cracking. On the other hand shrinkage cracking can appear just some days after construction, causing the origin and subsequent propagation of cracks up to the pavement surface.

Discrete fibres of different nature (glass, steel, plastic, carbon) can be used to improve the mechanical behaviour of cement materials [2].

The technique of fibre integration is worldwide diffuse to enhance strength, toughness, durability, prevent premature cracking and growth in cement concrete [3,4].

Likewise discrete fibres can be employed to improve CTM ductility and to reduce the tendency to brittle failure and shrinkage cracking. The discrete fibres can also contribute to tensile resistance, reduce the cracking tendency and its rate of propagation.

CTM have a rather poor cement matrix if compared to that of cement concrete, thus it does not need high performance fibres which could cause a non-sustainable increase of mixture cost.

A new political and social awareness on eco-sustainable constructions have encouraged, both researchers and technicians, to develop and to apply cost-effective techniques with low environmental impact. In this contest, CTM seem to meet the social and technical expectations since it allows the following advantages:

- Working at ambient temperature with no heating of materials, reducing energy consumption and fume emissions [5].
- Relative low cost if compared with others stabilization methods [6].
- Using simple and quick procedures and equipments since the in-plant production does not need any equipment for heating and reselecting aggregates nor filtration or exhaust extraction systems, while the in situ production does not require additional tank for bitumen spreading [6].
- Improving mechanical characteristics (strength, cohesion and durability) of granular materials even if the most effectiveness is achieved treating coarse graded mixtures with low plasticity index [1,6,7].
- Using several kind of recycled aggregates such as crushed concrete [8], crushed masonry [8,9], foundry sand [10], reclaimed asphalt [10–13], reclaimed aggregates [7,14].

The use of reclaimed asphalt (RA) as constituent material in CTM is one of the most interesting methods for preserving natural resources, reducing disposal of RA and production cost. However, RA could imply a reduction of mechanical performance of CTM.

In this case discrete fibres, acting as reinforcement, can compensate the weakness generated by RA, whereas the increase of cost due to fibres can be compensated by a convenient use of RA in place of expensive virgin aggregates.

In this study, polypropylene fibres (PFs) were selected as reinforcing material for CTM. In particular the PF were produced by recycling waste materials.

In order to determine the constituent materials for CTM which can match eco-sustainable, high-performance and long-lasting characteristics, the fibre reinforced CTM using RA seems to be the most viable choice.

2. Objective

The objective of this experimental study is to define the constituent materials for the production of CTM, which joins eco-sustainable, cost effectiveness and high-performance characteristics.

To achieve this target a selected RA was used in place of virgin aggregates and the addition of PF was intended to reduce shrinkage cracking and the typical brittle behaviour of CTM resulting in improved mechanical properties.

CTM using different RA content (50% and 80%) and PF dosage (2.5 and 4 kg/m^3) are compared with the respective reference CTM using no RA or no PF.

Table 1
Experimental program.

RA content (%)	Fibre dosage (%)	Series code	3-PBT	UVPT (before 3-PBT)	UVPT (after 3-PBT)
0	0	3C00RA	3	12	12
	2.5	3C00RA2.5F	3	12	12
	4	3C00RA4F	3	12	12
50	0	3C50RA	3	12	12
	2.5	3C50RA2.5F	3	12	12
	4	3C50RA4F	3	12	12
80	0	3C80RA	3	12	12
	2.5	3C80RA2.5F	3	12	12
	4	3C80RA4F	3	12	12

The mechanical properties of CTM were evaluated in terms of bending resistance, cracking distribution and ultrasonic pulse velocity tests to find the appropriate combination of RA content and PF dosage.

3. Experimental program

A preliminary study on CTM established the gradation, the dosage of cement (3% for all mixtures) and the optimum water content (5.5% for all mixtures) to comply with Italian specification.

Three kinds of granular mixtures, produced with respect to the same selected gradation, were treated with 3% (by aggregate weight) of cement. For the three granular mixtures the same gradation was obtained using different RA content: the first one containing 80% of RA, the second one containing 50% of RA and the third one, used as reference mixture, with no RA content (100% calcareous crushed aggregates).

These mixtures were combined with two dosages of PF, 2.5 and 4 kg/m^3. Once again the reference mixture had no PF. By adding PF, the proportion of other constituent materials was not changed.

Slabs (30.5 cm wide, 30.5 cm long, 8.0 cm thick) were compacted by means of a roller compactor. The 3-point bending tests (3-PBTs) were carried out on 7-day cured slabs to determine the tensile strength of mixtures.

Ultrasonic pulse velocity tests (UPVTs) were performed before and after 3-PBT to evaluate stiffness reduction and cracking distribution.

Table 1 reports the details of the experimental program in terms of materials, series code, kind of test and number of repetitions. In particular three slabs for each series were produced and tested. Each slab was tested by means of UPVT before (undamaged condition) and after 3-PBT (damage condition) in both directions (parallel and transversal to the cracking path). The ultrasonic pulse velocity was measured considering two paths per slab side by placing the two transducers on opposite faces (direct transmission).

4. Materials

4.1. Aggregates

The RA and aggregates were characterised in terms of gradation (EN 13043), apparent specific gravity ρ_a (EN 1097-6), water absorption WA_{24} (EN 1097-6), flakiness index FI (EN 933-3), shape index SI (EN 933-4), percentage of crushed surfaces

Table 2
Designation and characteristics of granular material used.

Designation	ρ_a (Mg/m^3)	WA_{24} (%)	FI (%)	SI (%)	C (%)	LA (%)
25 RA 0/12.5	2.50	0.5	7	8	–	–
0/4 G_F 90	2.73	1.8	–	–	–	–
6/10 G_C 85/15	2.69	1.1	9	15	100	–
10/16 G_C 90/10	2.69	0.9	9	3	100	22