Construction and Building Materials 182 (2018) 580–587

Contents lists available at ScienceDirect

Construction and Building Materials

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

Experimental study on cement-treated and untreated RAP blended bases: Cyclic plate loading test

Ayşegül Güneş Seferoğlu [a,*], Mehmet Tevfik Seferoğlu [b], Muhammet Vefa Akpinar [b]

[a] Gümüşhane University, Civil Engineering Department, Gümüşhane, Turkey
[b] Karadeniz Technical University, Civil Engineering Department, Trabzon, Turkey

HIGHLIGHTS

- Virgin aggregate, RAP and pozzolanic cement mixtures are prepared for base courses.
- Permanent surface deformations are obtained using large scale cyclic plate loading test.
- High RAP rates have increased permanent deformations without cement treatment.
- A 1% increase in cement rate resulted in a 9–10% increase in material costs.

ARTICLE INFO

Article history:
Received 11 December 2017
Received in revised form 1 June 2018
Accepted 18 June 2018

Keywords:
Reclaimed asphalt pavement (RAP)
Plant-mix base course (PBC)
Cyclic plate loading test
Cement treatment
Permanent deformation
Cost Analysis

ABSTRACT

The asphalt surrounding the reclaimed asphalt pavement (RAP) aggregates decrease the performance characteristics of road layers. RAP material increases the permanent deformation potential of road layers under the traffic load. In this study, the performances of RAP-VA (Virgin aggregate) mixtures was tested using cyclic plate loading test by adding pozzolanic cement into mixtures in order to use RAP material at the rate of 100% and to minimize the permanent deformation in plant-mix base courses (PBC). The permanent surface deformations of base course were measured at different points throughout 100 loading cycles and all of the measurements were compared to that of base course prepared from 100% VA. The effect of RAP/cement rate of mixtures on the permanent deformations was examined and it was determined that the increase in RAP rate increased the permanent deformations but cement significantly decreased it. Moreover, considering the material costs of mixtures, the cost analysis was performed and the profit margins that using RAP and cement offers to constructors were computed.

1. Introduction

The experiences gained before indicate that the repaving the deformed asphalt surface after milling it is a very efficient method in terms of the long-term performance. The reclaimed asphalt pavement (RAP) that is obtained by milling the pavement and reused in roadway superstructure layers can be used as alternative to traditional virgin aggregate. In Turkish Roadways (Turkey/DOT), the RAP materials are used in hot-mix asphalt (HMA) layers. But, in foreign countries, it can be used in unbound base courses by many roadway corporations. The base courses decrease the stress created by traffic load on subbase and subgrade courses. It is important to successfully understand the strength characteristics of aggregate base courses. The California Bearing Ratio (CBR) tests are widely used in revealing these characteristics. Bearing capacity of RAP base layers strongly depends on the RAP content mixed with VA [1,2,3]. In specification of Turkey/DOT, the minimum soaked CBR value set for the plant-mix base courses (PBC) is 120% [4].

Thompson and Smith [5] defined the permanent deformations as a key factor for the pavement failure. For this reason, they specified it as an important characteristic in determining the pavement performance. Because of the presence of asphalt covering the RAP aggregates, 100% RAP material typically has low strength [6,7,8,9,10] and high permanent deformation potential [11]. The increase in RAP ratio in the mixtures was reported to increase the permanent deformations. Dong and Huang [12] reported that the permanent deformation of RAP materials are significantly more than VA and, thus, it is not suitable to use RAP material in unbound base courses solely. In order to increase the strength of RAP

Abbreviations: RAP, reclaimed asphalt pavement; DOT, department of transportation; VA, virgin aggregate; PBC, plant-mix base course; HMA, hot-mix asphalt; ESAL, equivalent single axle load; LVDT, linear variable differential transformers; TL, Turkish Lira.

* Corresponding author.
E-mail addresses: agseferoglu@gumushane.edu.tr (A.G. Seferoğlu), mtseferoglu@ktu.edu.tr (M.T. Seferoğlu), mvakpinar@ktu.edu.tr (M.V. Akpinar).

https://doi.org/10.1016/j.conbuildmat.2018.06.160
0950-0618/

material and to reduce the permanent deformations, RAP material can be mixed with VA and/or cement. Bleakley and Cosentino [2] added 2–3% cement into RAP material and then reported satisfactory strength and deformation characteristics.

The use of cyclic plate loading tests is very important in determining the effects, which the vehicles in traffic have on the roadway superstructure, under laboratory conditions. In this study, the changes in permanent deformation under cyclic loading of PBC prepared with cement-treated and untreated RAP offering sufficient CBR (120%) value and the effects of cement and RAP concentrations on these changes were examined.

2. Test materials and equipment

2.1. Virgin aggregate (VA)

In Turkey, the plant-mix base courses (PBC) are made of 100% VA material. The VA used here was procured from a stone quarry. The laboratory tests carried out on VA and also the results of these tests are presented in Table 1.

2.2. RAP material

The RAP material used in this study was obtained by milling the wearing course of an urban road in Trabzon-Turkey. RAP material consists of two main components: aged asphalt and basalt aggregate. Extraction test was carried out in accordance with AASHTO T 164, and the asphalt content of RAP material was found to be 3.72% in weight. The RAP materials larger than 25 mm were removed and the sieve analysis test was performed in accordance with AASHTO T 27. The gradation of RAP material was within the gradation limits set in Turkey/DOT specification for PBC [4]. The filler content (<0.075 mm) was found to be 3.3%. modified proctor tests were performed on RAP material according to the AASHTO T 180. The maximum dry density was 1.952 t/m^3, which corresponded to the optimum moisture content of 4.27%. And then, the soaked California Bearing Ratio (CBR) test was performed according to AASHTO T-193 and the soaked CBR value of 100% RAP mixture was found to be 31%.

2.3. Pozzolanic cement

The type of cement used was CEM IV 32.5R. In order to achieve minimum 120% CBR level set by Turkey/DOT for PBC, 1%, 2%, and 3% cement (by dry weight) were added into RAP and RAP-VA mixtures [4]. Adding cement significantly may improve the strength characteristics of RAP mixtures, but the use of cement at high concentrations may also cause weak fatigue performance and even cracks [13]. Some of the researchers used the cement in a wide range between 0% and 6% [13,14,15,16]. In this study, by considering the criterion of affordability, the maximum cement concentration was confined to 3%.

Table 1
Features of virgin aggregates (obtained from the manufacturer).

Tests	Test Results	Turkey/DOT Specification Limits	Standards
Loss of weather resistance (with Mg_2SO_4), %	4.56	≤20	DIN EN 1367-2
Abrasion (Los Angeles), %	12.0 (Type B)	≤35	AASHTO T 96
Flatness index, %	13	≤25	DIN EN 933-3
Absorption, %	1.18	≤3.0	DIN EN 1097-6
Liquid limit (LL)	N.P.	N.P.	AASHTO T 89
Plasticity index (PI)	N.P.	N.P.	AASHTO T 90

2.4. Mixture preparation

Sieve analysis tests were carried out on all the mixtures, except for the cement-treated ones, in accordance with AASHTO T 27. The results indicated that all the mixture gradations were uniform and within the range specified by Turkey/DOT for PBC. For all the untreated mixtures, the filler material content smaller than 0.075 mm was found to be less than 10% (maximum 10% is a criterion specified for PBC in Turkey/DOT specification [4]). In soaked CBR test curve, the CBR values corresponding to the load applied at 2.5 and 5 mm penetration levels are given. Among two penetration values, the penetration value yielding higher CBR value was found to be those at 5 mm, and the CBR values at this penetration were considered to be the CBR value. The bearing capacities of mixtures were observed to be significantly correlated with the RAP concentration of mixtures. As the RAP concentration increased, the CBR value decreased as stated by several researchers [3,5,17,18].

The RAP-VA-cement concentrations used in previous studies were limited in number, and no information was provided about if it is possible to use higher number of concentrations. In order to obtain more detailed information, RAP concentration was used at wider range in the present study. Eight different untreated mixture were prepared by using 0/100, 10/90, 20/80, 30/70, 40/60, 50/50, 60/40 and 100/0 RAP/VA rates. For the mixtures that are not suitable for PBC in terms of CBR value, 1%, 2% and 3% pozzolonic cement (by dry weight) was added. The cement addition significantly increased the strength characteristics of mixtures. The soaked CBR test results of untreated and cement-treated mixtures are presented in Fig. 1.

2.5. Plant-mix base courses

The untreated and cement-treated mixtures with maximum RAP concentration meeting the min. 120% CBR value specified in Turkey/DOT specification were chosen to be used in cyclic plate loading test, and the base courses prepared form these mixtures were subjected to the test. A PBC prepared traditionally with 100% VA was used as a reference in order to compare the results, and it was also subjected to the test.

The mixtures to be used for base courses were 20% RAP-80% VA, 60% RAP-40% VA-3% cement, 100% RAP-3% cement and 100% VA. The base courses that were prepared separately for each mixture were compressed at minimum 98% modified proctor compaction. The courses prepared in 20 cm total thickness consisting of 4 layers, each of which had 5 cm thickness, were placed in the cyclic plate loading test tank. The main characteristics of prepared test mixtures including maximum dry unit weight (γ_{dmax}), optimum moisture content (W_{opt}) and soaked CBR values are presented in Fig. 2.

2.6. Subbase course

The subbase course to be laid just below the base courses was prepared from 100% VA material. They were placed within test box by compressing at minimum 98% modified proctor compaction and prepared in 20 cm total thickness consisting of 4 layers, each of which had 5 cm thickness.

3. Method

In order to examine the effects of RAP and pozzolanic cement content of RAP course, which is placed over the subbase course, on the performance under cyclic loading, 4 cyclic plate loading tests were performed within a large-scale geotechnical test box