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Research Article

Investigation of the Effect of Recycled Asphalt Pavement Material on Permeability and Bearing Capacity in the Base Layer

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The purpose of this research was to investigate the effects of recycled asphalt pavement (RAP) and cement content on the permeability and bearing capacity characteristics of aggregate base courses. Mixtures containing untreated RAP ranging between 0 and 100 percent and 1, 2, and 3% cement-treated RAP were subjected to laboratory tests (bitumen content, sieve analysis, modified proctor, soaked California bearing ratio (CBR), and constant-level permeability tests). The results showed that, as the RAP percentage in the mixture increased, CBR values decreased considerably. Moreover, there is a linear increase in the CBR values with cement treatment. Optimum moisture contents (OMC) and maximum dry densities (MDD) showed a decreasing trend. Increasing the cement percentages in 100% RAP blend increases the OMC and MDD values. The permeability of RAP showed a decrease as the percentage of RAP and cement increased in blends. The study showed that the CBR value of the 20% RAP blend is also obtained in the 100% RAP/3% cement-treated blend. Thus, it has been understood that cement is a suitable material in order to increase the use of RAP. In addition, the increase in the percentage of RAP and cement made the base course more impermeable.

1. Introduction

Past experiences showed that milling asphalt paved area instead of simply repaving over the existing asphalt surface and then laying a new asphalt pavement is a much more efficient way for a long term performance. Since most of the RAP material is recycled back into hot-mix asphalt pavements, there is a general lack of data pertaining to the bearing capacity and permeability properties for RAP material in other possible applications, particularly pavement base courses.

Base course is significant for the road structure because it reduces the traffic load-generated stresses on the underlying subbase and subgrade courses. It is important to understand the drainage and strength characteristics of the aggregate base course. The permeability and CBR tests are used frequently to identify drainage and strength characteristics of base courses. Several authors have performed laboratory studies of RAP material, focusing on tests of interest to base course construction, including Proctor compaction, CBR, and resilient modulus to assess the suitability of RAP material as a base course material [1–3].

The bearing capacity of the base courses strongly depends on the RAP content mixed with the conventional virgin aggregate (VA). The percentage of RAP material in blends exceeds 20–25%, and the expected CBR value for the base course decreases as discussed by several authors [4–12]. Some researchers reported that the RAP content of the base mixtures should be limited to a maximum of 50% by weight [7, 8].

The permeability test takes a direct way to characterize the moisture susceptibility of a compacted material (saturated or unsaturated) by measuring the speed of water flow through pore spaces in the material. Moisture trapped between the particles in the base course can lead to base course destruction due to loss of support. In asphalt wearing courses, the water content can leak into the base course from surface cracks over time.

Some authors [13–15] have come to the conclusion that permeability decreases with the increases in the RAP content, while the opposite opinions and results are also given by the other researchers [3, 4, 16, 17]. This is because of the different bitumen contents, gradations, and fine content amounts of the RAP materials used.

The utilization of RAP as an alternative of virgin aggregate has gained more interest as a result of the availability of stockpiles of RAP materials. While past research has basically centered on the strength and durability properties of base course with RAP, this research investigates the bearing capacity and permeability properties.

2. Scope of the Study

The objective of this experimental study was to assess the bearing capacity and permeability characteristics of RAP material used as a base course when it is used at high percentages without any significant reduction in performance. The soaked CBR and constant head permeability tests were conducted on laboratory prepared samples of different RAP percentages, water contents, and dry densities. The effect on the test results of puzzolanic cement-treated 100% RAP material was also investigated.

3. Materials

The RAP material was obtained by cold recycling methods of degraded asphalt overlay in Trabzon, Turkey. Three different grades (0–7 mm, 7–19 mm, and 19–38 mm) of VA materials were taken from the quarry. Laboratory tests were carried out, and the results are presented in Table 1 for VA.

Table 1: Properties of virgin aggregates.

Loss of weather resistance (with Na_2SO_4), %	4.56
Abrasion, %	12.0
Absorption, %	1.18
Flatness index, %	13.0
Peeling strength, %	(i) 0.3% additive: 75–80 (ii) 0.5% additive: 80–85 (iii) Additive-free: 30–35

RAP materials were comprised primarily of two components: aged asphalt binder and basalt aggregates. Extraction tests were performed according to the AASHTO T 164, and it was found that bitumen content of RAP was 3.72% by weight.

Sieve analysis tests were performed according to AASHTO T 27. The results of sieve analysis test indicated that all gradations were uniform and fall within the ranges established by the AASHTO specification limits of ABC. Therefore, there was no need for the screening process. Aggregate size greater than 19 mm was eliminated since the recommended maximum aggregate size of the ABC design was 19 mm, and therefore, the aggregate gradation was adjusted accordingly. However, the significance of the gradation of RAP on the engineering properties and performance characteristic of a RAP blend (especially high RAP content blend) treated with cement has not been rigorously studied.

The used puzzolanic cement type is CEM IV 32.5R. Cement contents of 1%, 2%, and 3% by dry weight were used in the cement-treated 100% RAP blends. In this research, VA, RAP, RAP/VA blends, and cement-treated RAP blends were studied.

4. Experimental Methods and Results

4.1. Moisture-Density Characteristics. Modified proctor tests were carried out on blends according to AASHTO T 180 to determine the moisture-density relationships. The density of milled or processed RAP material depends on the type of aggregate in the recycled pavement and the moisture content of the stockpiled material. Although the available literature on RAP contains limited data pertaining to density, the MDD of milled or processed RAP has been found to range from 1.94 to 2.30 t/m^3, which is slightly lower than that of VA [15, 18, 19].

As shown in Figure 1, due to the bitumen surrounded the RAP aggregates which inhibit compaction, the compacted dry densities of RAP/VA blends tend to decrease with increase of RAP percentage (Figure 1).

A binding and/or agglomeration effect where residual asphalt binder within RAP causes finer particles to adhere to each other as well as larger particles, reducing the amount of water needed to achieve the required compaction level of the RAP blends. This factor has to be considered when the suitable moisture content of compaction is determined. It is observed that as the RAP fraction of the base course increases, the required OMC achieving the maximum compaction decreases [2, 20]. This trend was confirmed by a prior study, who found that the increase in RAP content leads to a decrease in the MDD and OMC values [21].

As the cement was added to the RAP material, the MDD and OMC values are increased [22]. It was considered reasonable for a material with high water absorption, such as cement, to produce this increase (Figure 2).

The typical OMC of a compacted RAP blended material was reported to be lower than that for VA [3, 23]. However, the OMC was reported to be higher for RAP blends treated with cement, due to higher fine content and the absorptive capacity of these fines.

4.2. Bearing Capacity. The soaked CBR tests were carried out in accordance with AASHTO T 193. The test samples were prepared in a mold with five layers, and each one was compacted with 56 blows. From the test curve, the applied forces corresponding to the 2.5 mm and 5 mm penetration were read. The greater CBR value in these penetrations is accepted as the CBR value of the sample.

The soaked CBR values of specimens containing different percentages of RAP material are presented in Figure 3. All specimens tested showed a decrease in the CBR values with an increase in the percentage of RAP material in blends. When Figure 3 is examined, it is seen that the RAP material has a CBR value of about 68% lower than that of VA. A similar trend of CBR results was reported by several authors [4, 5, 9].

The bitumen-coated aggregates in the RAP had a significant strengthening effect over time, such that RAP

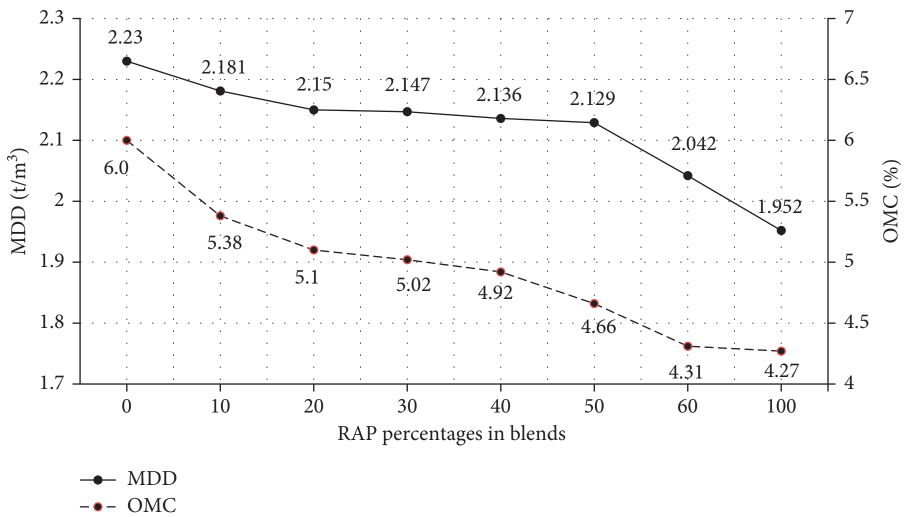

Figure 1: Modified proctor test results of RAP/VA blends.

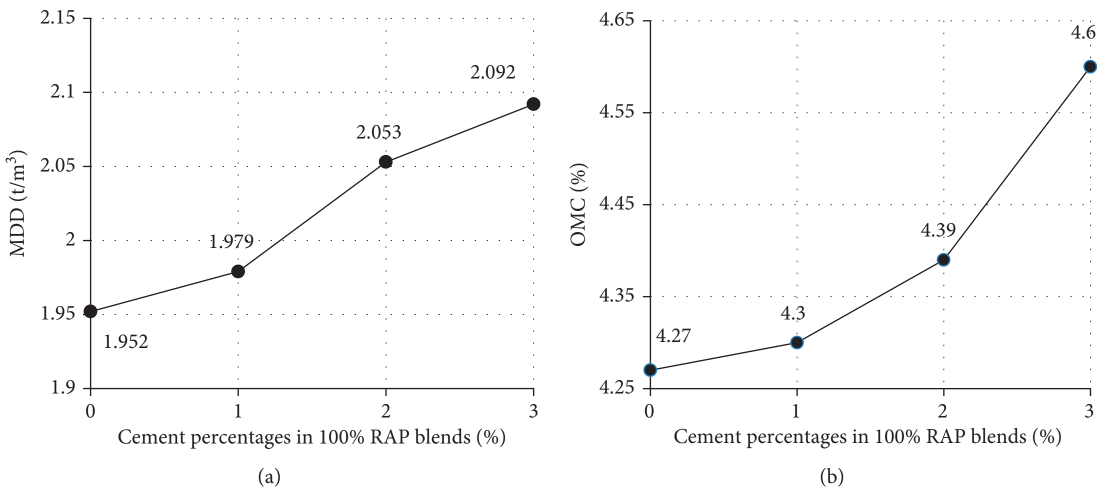

Figure 2: Modified proctor test results of cement-treated 100% RAP blends.

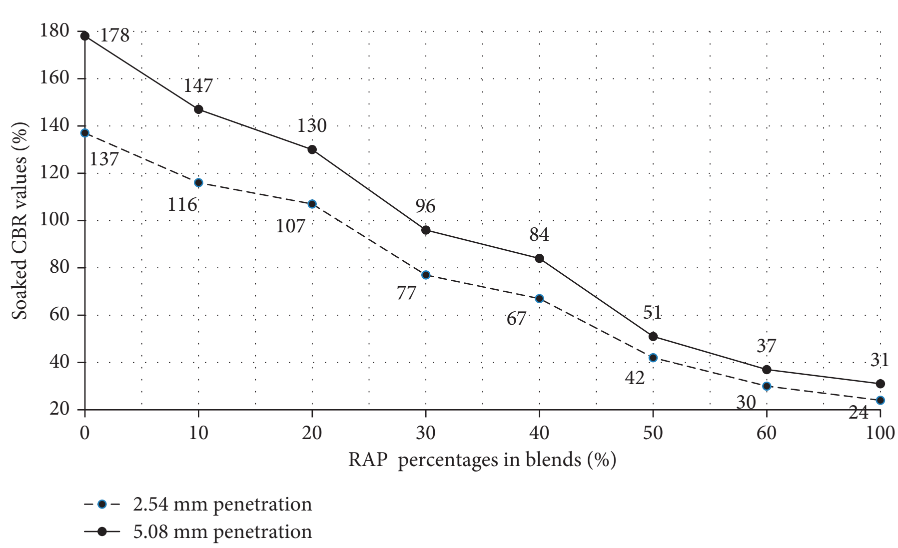

Figure 3: Soaked CBR test results of RAP/VA blends.

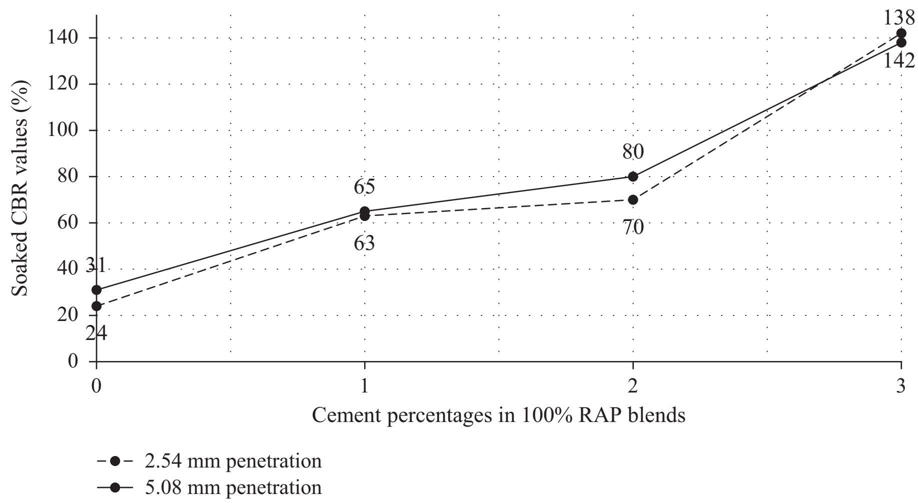

Figure 4: Soaked CBR test results of cement-treated 100% RAP blends.

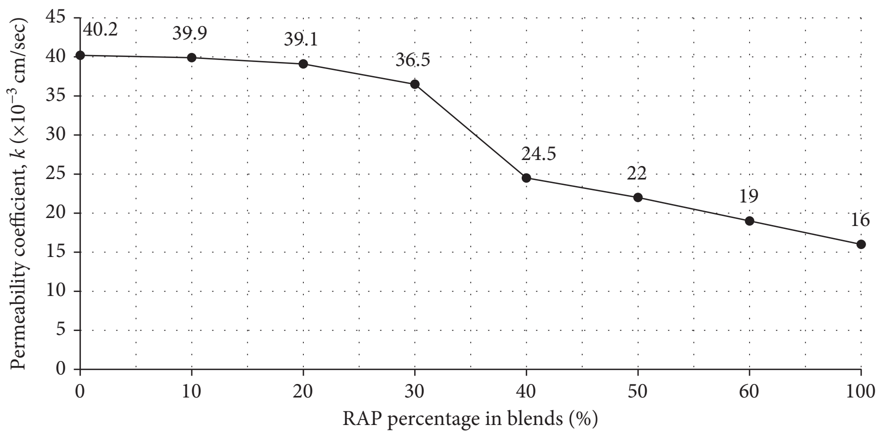

Figure 5: The permeability test results of RAP/VA blends.

specimens containing 3% cement produced CBR values exceeding 142% after a week (Figure 4). As the cement percentage increased from 0% to 3%, the CBR values increased from 30% to 138%. The bearing capacity of RAP blended material is strongly dependent on the proportion of RAP to VA and, in general, decreases with increasing RAP percentage [24].

4.3. Permeability Characteristics. Based on the typical gradations of RAP, less than 10% particles passed #200 sieve, constant head permeability test method was chosen for determining the value of permeability coefficient (k) in accordance with ASTM D 2434.

The diameter of 162 mm cylinder cells was used to measure the k of 100% RAP, 100% RAP/1% cement, 100% RAP/2% cement, and 100% RAP/3% cement blends while 213 mm diameter cylinder cells were used for 100% VA, 10%, 20%, 30%, 40%, 50%, and 60% RAP/VA blends.

In general, VA has high permeability values. The interlocking between the asphalt-coated aggregates in RAP and the VA particles decreasing the air voids caused aggregates to be impermeable. Therefore, as more RAP material was added to the blend, the k value decreased. The reduction of permeability might be due to the aggregation of RAP particles as a result of compaction. The asphalt in RAP could form a bond between particles.

As shown in Figure 5, the permeability of RAP blends increased as the percentage of RAP material in the blend decreased [13–15]. However, opposite results were obtained from some researchers [3, 4, 16, 17]. The differences can be attributed to the fact that experimental procedure and materials used were slightly different.

As shown in Figure 6, the k value of RAP material was 16×10^{-3} cm/sec while the permeability of cement-treated RAP material decreased with increasing cement percentages in 100% RAP blends. When cement was used as a treatment material, it is noteworthy that the permeability was close to zero, that is, an impermeable layer was obtained.

5. Recommendations

In this study, the RAP material was obtained from the milling of asphalt pavements for resurfacing in the cold recycling process of Trabzon, Turkey. The results may not

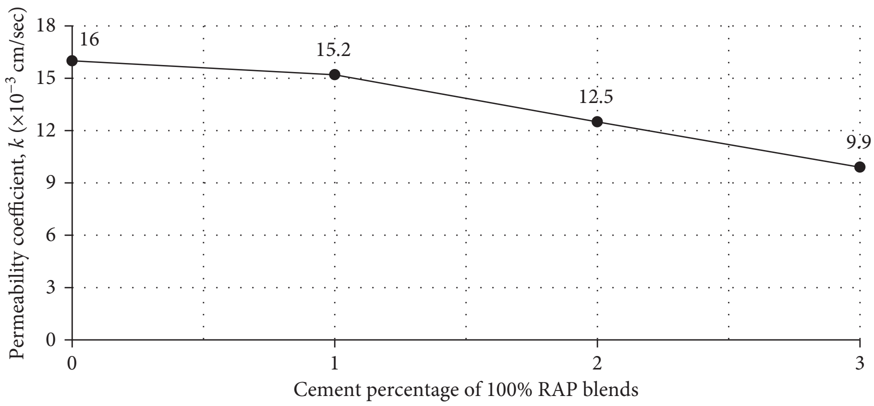

Figure 6: The permeability test results of cement-treated 100% RAP blends.

apply to RAP obtained from crushing methods because of the lower percentage of fine aggregates. Further research is needed on this subject. The fine aggregate has a significant effect on cement bonding and permeability. The gradation of milled RAP material is generally finer and denser than that of the VA. The milling does not cause as much degradation as crushing; consequently, the gradation of milled RAP is generally not as fine as crushed RAP.

6. Conclusions

Based on the results and discussions presented in this study, the following conclusions may be drawn:

(1) A certain replacement percentage of VAs with RAP can be used in ABC applications without detriment to the CBR and permeability potential.

(2) RAP is a poor material in terms of carrying capacity when used alone. For this reason, it should be mixed with VA or cement. Puzzolanic cement can be an effective solution to improve base course performance by means of bearing capacity and permeability. The cement used in the blend may be limited to 3%. The addition of more than 3% of cement to RAP material increases the fine content amount (below #200 sieve). The MDD and OMC decreased with the increasing RAP and cement percentage in blends.

(3) As the RAP content in the blend increased, the CBR value decreased considerably. A linear increase in the CBR values was observed by improving the bearing capacity with cement treatment. The CBR value of the 20% RAP in RAP/VA blend is also obtained in the 100% RAP/3% cement-treated blend. Thus, it has been understood that cement is a suitable stabilizing material in order to increase the use of RAP material. Increasing the percentage of RAP or cement made the base course more impermeable.

(4) CBR and k values found in this study can be considered as default design input values to be used by pavement designers when using RAP as a substitute material for aggregate base course (ABC).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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