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Araştırma Makalesi / Research Article

Effect of Bitumen Grade, Bitumen Percentage and Mineral Binders on Mixture Properties in Foam Bitumen-Stabilized RAP Materials

*[1]Kemal Muhammet ERTEN, [2]Serdal TERZİ, [3]Hüseyin AKBULUT

[1]*Afyon Kocatepe University, Dazkırı Vocational School, Construction Inspection Department, Afyonkarahisar, Turkey, kmerten@aku.edu.tr, ORCID ID: http://orcid.org/0000-0001-5181-4109*
[2]*Süleyman Demirel University, Faculty of Enginering, Civil Engineering Department, Isparta, Turkey, serdalterzi@sdu.edu.tr, ORCID ID http://orcid.org/0000-0002-4776-824X*
[3]*Afyon Kocatepe University, Faculty of Enginering, Civil Engineering Department, Afyonkarahisar, Turkey, hakbulut@aku.edu.tr, ORCID ID: http://orcid.org/0000-0003-4504-4384*

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Abstract

The rates of using reclaimed asphalt pavement (RAP) materials in road construction work depend as much on the quality of the recycled material as on the effects of the additives blended with these materials to the mixture. For asphalt cold recycling, which can be made with different methods and additives, the optimum amount of water in the mixture and the cure that develops accordingly, the correct compaction of the mixture is two important aspects in terms of pavement performance. For this reason, different bitumen grades, different bitumen percentages and mixtures with different mineral binders were prepared for cold recycle with foam bitumen and optimum water requirement, bulk specific gravity values of the productions and variation of the heights of the Marshall briquettes were investigated. Productions made with cement, lime and fly ash, which are used as mineral binders, change of California Bearing Ratio values were observed. In the productions, 4 types of penetration bitumen (50/70-70/100-100/150-160/220) and the effect of using different percentages of them were revealed. Results showed that decreased bitumen penetration, increased bitumen percentage and increased RAP material percentage

*[1]Sorumlu yazar / Corresponding author

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made it difficult to compact the material and the optimum water percentage was directly affected by mineral binders.

Keywords: *RAP, Mineral binders, Foam bitumen, Optimum mixture water, CBR.*

Köpük Bitümle Stabilize RAP Malzemelerde Bitüm Sınıfı, Bitüm Yüzdesi ve Mineral Esaslı Bağlayıcıların Karışım Özelliklerine Etkisi

Öz

Geri kazanılmış asfalt kaplama (RAP) malzemelerin yol yapım çalışmalarında kullanım oranları, kazınmış malzemenin niteliğine bağlı olduğu kadar bu malzemelerle harmanlanan katkı maddelerinin karışıma olan etkilerine de bağlıdır. Farklı yöntemler ve katkı maddeleriyle yapılabilen asfalt soğuk geri kazanımı için, karışım optimum su miktarı buna bağlı olarak gelişen kür olayı ve karışımın uygun sıkıştırılması kaplama performansı açısından önem arz eden iki husustur. Bu nedenle çalışmada RAP malzemenin köpük bitümle soğuk geri kazanımı için; farklı bitüm sınıfları, farklı bitüm yüzdeleri ve farklı mineral esaslı bağlayıcılar ile karışımlar hazırlanmış, üretimlere ait optimum su ihtiyacı, hacim özgül ağırlığı değerleri ve üretilen Marshall briketlerinin yüksekliklerinin değişimi araştırılmıştır. Çalışmada mineral esaslı bağlayıcı olarak kullanılan çimento, kireç ve uçucu külle yapılan üretimlerde CBR (kaliforniya taşıma oranı) değerlerinin değişimi gözlenmiştir. Yapılan üretimlerde 50/70-70/100-100/150 ve 160/220 olmak üzere 4 tip penetrasyon bitümü ve bunların farklı yüzdelerinin kullanılmasının etkisi ortaya koyulmuştur. Ayrıca RAP malzemenin bitümden ayrıştırılmış agregasının farklı oranlarda kullanımı için 4 adet üretim yapılmış ve RAP malzemedeki bitümün karışıma katkısı araştırılmıştır. Elde dilen sonuçlar; bitüm penetrasyonunun azalmasının, bitüm yüzdesinin artmasının ve RAP malzeme yüzdesinin artmasının malzemenin sıkışmasını zorlaştırdığı ve optimum su yüzdesinin mineral esaslı bağlayıcılardan doğrudan etkilendiğini göstermiştir.

Anahtar kelimeler: *RAP, Mineral esaslı bağlayıcı, Köpük bitüm, Optimum karışım suyu, CBR.*

1. Introduction

Due to energy savings, raw material (bitumen and aggregate) savings and environmental gains, efforts to use reclaimed asphalt in pavements have accelerated in recent years.

Reclaimed asphalt pavements (RAP) material is reusable in new asphalt mixes because it is still valuable. Although aggregate and bitumen, which are components of the mixture, are recycled (McDaniel & Anderson, 2001; Yan et al., 2014).

However, because the RAP material is not heated in cold recycles, the mixture homogeneity and compaction difficulties can be encountered in the mixture application.

Therefore, to eliminate these negative effects, such as bitumen emulsion, foam bitumen, high penetration bitumen, cut-back bitumen, cement, fly ash and lime (Wang et al., 2018) additives have been used.

The purpose of application of foam bitumen, one of these additives, is to increase the surface area of bitumen and decrease its viscosity. In this way, homogenous mixing with cold and moist material is possible (Muthen, 1998; Wirtgen, 2012).

Mineral binders such as portland cement, hydrated lime and fly ash, which help improving the rap material usage rate and mix quality, improve the mechanical properties of cold-recycled mixtures, allowing them to open the road to early traffic in the short term. In the long term, they increase the strength of the pavement (Brown & Needham, 2000; Dolzycki et al., 2017; Graziani et al., 2018). However, mineral binding percentage is usually limited to 1% in cold mixtures because the use of these materials in high proportions results a brittle structure in the mixture. Such mineral binders, through their fine grain structure, help reduce voids in cold mixtures with high void content (Wirtgen, 2012), while it should be taken into consideration that they can increase the water requirement of the mixture.

If the mixture has an insufficient water content, the workability is reduced and the binding agent is not uniformly dispersed in it, while too much water extends the curing time, reduces the strength and density of the compacted mixture and may reduce the bitumen coating of aggregates (Muthen, 1998). Therefore, determination of optimum water content in the mixture is an important consideration in terms of mixture quality.

Determination of optimum water content is widely made by Proctor testing, developed by R.R. Proctor in the early 1930s. In the experiment, optimum mixture water is determined to find the maximum dry unit weight of the sample with the help of a standard free-falling hammer (Izquierdo et al., 2011).

For 100% RAP materials in literature; %3,73 (Seferoğlu et al., 2015), %4,1 (Cliatt et al., 2016) %5,5 (Wen, 2010) as a wide range of optimum water needs values are encountered. This is due to variability in recycled materials such as the percentage of bitumen, the amount of filler.

In the study, in mixtures made using different materials or different ratios of the same materials, the effect of materials on compactibility of the mixture, was determined by bulk specific gravity and briquette heights.

The CBR (California bearing ratio) experiment, which is used as another assessment criterion, can be done in two ways: wet CBR and dry CBR. The aim of the wet CBR experiment applied in the study was to determine the lowest bearing power in which the voids were completely filled with water (Demirel et al., 1999). In literature, for wet CBR values of 100% RAP material with no additive; very low values such as %26 (Seferoğlu et al., 2015), %19,85 (Saha & Mandal, 2017) were encountered but Seferoğlu et al. (Seferoğlu et al., 2018) stated that the addition of 1% cement to 100% RAP material increases CBR value more than approximately 2 times.

2. Materials and Method

In the study, the optimum water requirement used in the production of mixtures, bulk specific gravity values of the production and height values of Marshall brickets prepared for mixtures were used as evaluation criteria. In addition, the CBR (TS 1900-2) test was performed to evaluate the bearing capacity of the rap material of the mineral binders used in the study. Due to the difficulty of compaction in recycled materials in practice, it has been tried to understand that RAP material can be compacted better with which variables. That is to say, optimum mix values have been investigated for cold mixes in order to obtain mixes with low mixing water requirement, which can be compacted better and have high bulk specific gravity (high workability).

The RAP material used has the gradation given in Table 1. The gradation was not changed by using an additional material and the gradation effect was eliminated by making evaluations on the given single gradation. Although no new aggregate substitution was performed in the experiments, 4 different mixtures (0%-20%-70%-100% RAP) were prepared for a production series by extracting the RAP material bitumen and mixing the RAP+bitumen extracted rap aggregate in different proportions so the efficiency of the RAP material ratio on the productions was evaluated.

Table 1. Rap material gradation.

Sieve Size (mm)	RAP gradation (% passing)
25	100
19	96
12,5	87
9,5	79
4,75	58
2	33
0,425	9
0,18	4
0,075	1,6

In order to examine the effect of bitumen on the mixture, it was compared by taking the averages of the bulk specific gravity and briquette height (h) values of 5 samples made with foam bitumen percentages of 1.9-2.2-2.5-2.8-3.1% in all bitumen grades.

Also, in order to see the effect of the foam bitumen percentage sprayed on RAP material, in different foam bitumen percentages for the 70/100 bitumen grade (1.3-1.9-2.2-2.5-2.8-3.1-3.7%) mixtures were prepared and the results were evaluated.

Finally, the effect of the mineral binder was determined by preparing the mixture with lime, fly ash, cement mineral binders and without mineral binder in 70/100 bitumen grade and 2.5% bitumen percentage. Table 2 shows the codings for the productions.

Table 2. Sample coding for productions.

Sample Code	% Bitumen	% RAP	Bitumen Grade	Mineral Binder Type
2,5C070	2,5	0	70/100	Cement
2,5C2070	2,5	20	70/100	Cement
2,5C7070	2,5	70	70/100	Cement
2,5C10070	2,5	100	70/100	Cement
1,3C70	1,3	100	70/100	Cement
1,9C70	1,9	100	70/100	Cement
2,2C70	2,2	100	70/100	Cement
2,5C70	2,5	100	70/100	Cement
2,8C70	2,8	100	70/100	Cement
3,1C70	3,1	100	70/100	Cement
3,7C70	3,7	100	70/100	Cement
C50	2,2	100	50/70	Cement
C70	2,5	100	70/100	Cement
C100	1,9	100	100/150	Cement
C160	1,9	100	160/220	Cement
2,5HL70	2,5	100	70/100	Hydrated Lime
2,5FA70	2,5	100	70/100	Fly Ash
2,5-70	2,5	100	70/100	-

In productions, firstly, the optimum amount of mixing water is determined by using Modified Proctor (TS 1900-1) test without foam bitumen. Then, according to these optimum water amounts, foam bituminous mixes were prepared with the procedure determined by Wirtgen (2012) and standard Marshall briquettes with a diameter of 4 inches were produced with Marshall compactor for each mixture, with 75 blows on both sides. The briquettes were removed from the molds the next day of production and size measurements were taken (Figure 1 and Figure 2). In cold mixtures prepared with foam bitumen, a cure procedure is applied for weight determination in the air due to the use of water for workability. After the briquettes were kept in a 40°C drying oven for 72 hours, their weight in the air was determined and then their weighed in saturated surface and water were determined and their bulk specific gravities (Dp) were determined according to Equation 1.

$$Dp = \frac{Sample\ weight\ (in\ air)}{SSSDW - SWIW} \quad (1)$$

Where; SSSDW is sample saturated surface dry weight and SWIW is sample weight in water.

Figure 1. Briquette size measurement.

Figure 2. Briquette weighing.

3. Results and Discussion

As can be seen from Figure 3, in general the bulk specific gravity value tends to decrease and the briquette heights tend to increase with the increase in RAP material percentage. The decrease in briquette height is indicative of better compaction of the material and accordingly increase in bulk specific gravity. With the increase in RAP material percentage, the optimum amount of mixture water needed for the material's workability has also increased. As the amount of bitumen-coated material increases, the angularity and roughness of the material decreases, and while it is expected that less water is needed for workability, it is thought that the cracks in the aged bitumen in the RAP material absorbed the mixture water as a result of the opposite situation. Keeping the RAP content as low as possible seems more appropriate in terms of mixture compactibility and optimum water demand. However, it should be observed how the results will change if RAP material is replaced with a new aggregate other than its own aggregate extracted from bitumen.

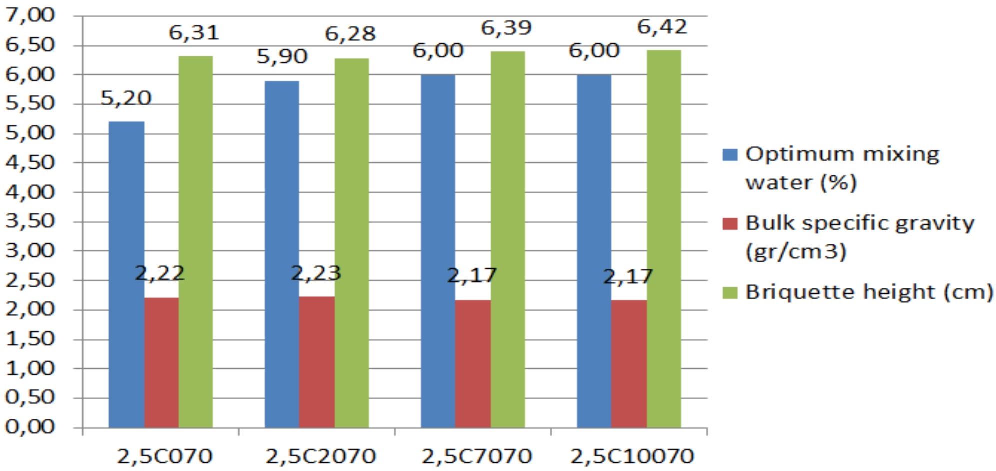

Figure 3. Comparison of productions for different RAP percentages.

Sample coding for Figure 3:
2, 5C070.

Where: 2.5 - bitumen percentage, C - cement, 0 – RAP percentage, and 70 – bitumen grade (70/100).

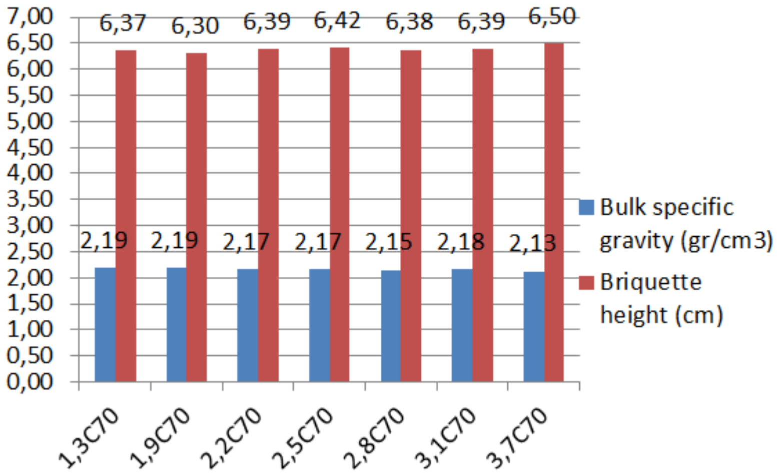

Figure 4. Comparison for different bitumen percentages in 70/100 bitumen grade.

Sample coding for Figure 4: 1, 3CH70.

Where: 1,3- bitumen percentage, C- cement, 70 – bitumen grade (70/100).

As can be seen from Figure 4, there has been a decrease in bulk specific gravity values in general with the increase in bitumen percentage. It is thought to be trend to increase, although no clear interpretation can be drawn for briquette heights. Since the evaluation for different bitumen percentages was made only for the 70/100 bitumen grade, the ideal bitumen percentage of the 70/100 bitumen grade was found to be 1.9% with the best compaction properties.

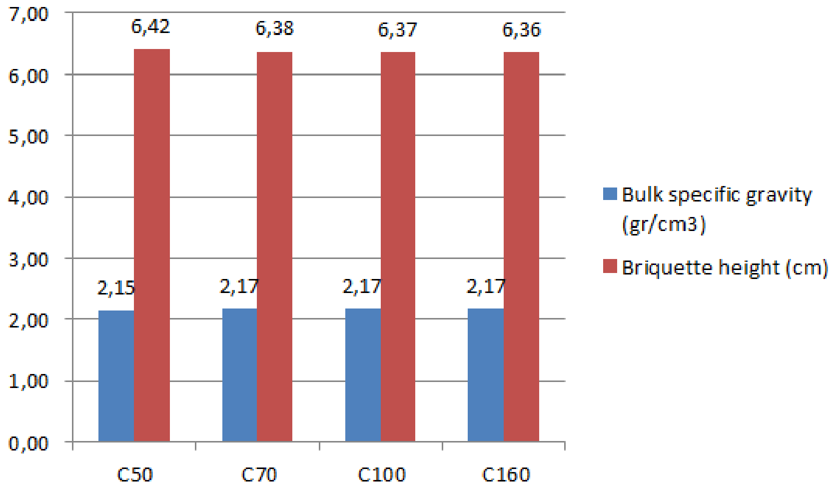

Figure 5. Comparison of the productions for different bitumen grades.

Sample coding for Figure 5: C50

Where: C - cement, 50 – bitumen grade (50/70).

As can be seen from Figure 5, the increase in bitumen penetration level decreased the briquette heights and increased the bulk specific gravity values, although not creating a significant trend.

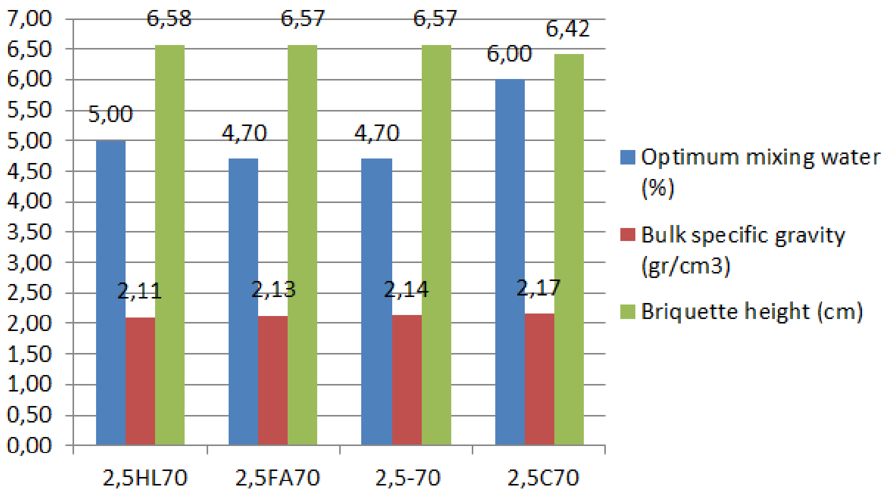

Figure 6. Comparison of production for different mineral binders.

Sample coding for Figure 6: 2, 5HL70 Where: 2.5 - bitumen percentage, HL – hydrated lime, 70-bitumen grade (70/100).

As can be seen from Figure 6; hdyrated lime (HL), fly ash (FA), cement (C) and without mineral binder (-) production with the lowest mineral binder density of lime yielded the lowest bulk specific gravity. The production of cement with the highest mineral binder density yielded the highest bulk specific gravity. While the lowest percentage of mixture water was obtained from fly ash that contribute positively to workability with global particul shape and without mineral binder productions, the most need for mixture water was found in cemented mixture which needed water for hydration event. The briquette height values measured in the productions were inversely proportional to the bulk specific gravity values. This again shows that the density of the well compactible material has increased.

In addition, CBR values for these productions are given in Figure 7. It is observed that the highest CBR result is obtained from cemented production and the lowest CBR result is obtained from production without mineral binder. The addition of mineral binder, regardless of the type, has increased the bearing power of the material. This finding, in Part 1 Seferoğlu et al. (2018) it is parallel to that stated by.

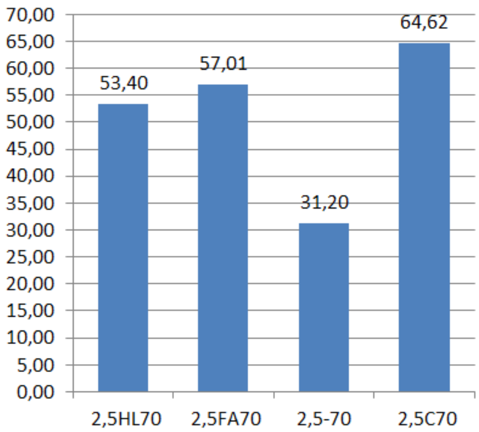

Figure 7. CBR values for different mineral binders.

Sample coding for Figure 7: 2, 5FA70
Where: 2.5 - bitumen percentage, FA – fly ash, 70-bitumen grade (70/100).

4. Conclusion

The study has aimed of evaluation of foam bitumen stabilized RAP materials by producing Marshall briquettes for different bitumen grades, different bitumen percentages, different RAP percentages, and different mineral binders in order to evaluate the optimum water percentage required for the workability of the mixtures and the control of the compaction difficulty that may be encountered in the application. The following results could be emitted by using optimum water content, bulk specific gravity and briquette height values to evaluate the mixtures;

- When all productions are considered, the bulk specific gravity tends to decreases as the height of the briquette increases.
- Mineral binders have caused of increasing the need for optimum mixture water and the bearing power of the mixtures.
- Decreased bitumen penetration has made the compaction of the material difficult.
- The increase in bitumen percentage leads the compaction of the material difficult.
- The increase in RAP material percentage in the mixture increased the optimum mixture water requirement and briquette height and reduced bulk specific gravity. As a result, the increase in RAP percentage has also made it difficult to compaction the material.

This study aimed of conducting to investigate the workability problems that may occur due to the RAP material contained in the foam bituminous mixtures, different materials in the mixture and how these materials can be overcome according to the usage percentages. According to the results; mixtures made with higher penetration but low bitumen percentage appear to be advantageous in terms of compactibility of the material. The addition of mineral binder to the RAP material should be considered according to the quality of the layer formed with the recovered material.

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