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Investigation of the Usability of Foamed Bituminous Mixtures as Bituminous Base Course

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Anahtar Kelimeler
Foamed bitumen,
Triaxial cyclic compression,
Indirect tensile resilient modulus,
Asphalt recycling

Abstract: Materials recycled with foam bitumen are promising materials for pavements economically and environmentally. However, there are different opinions in the literature about how these materials are positioned in the pavement. It is clear that their performances will not be suitable for the wearing course, but that they are used for the plant mixture base course because they contain bitumen, and that these materials will be neglected in the evaluation of these materials. In the study, 4 different foam bituminous mixes prepared with a recycled pavement material and a standard bituminous base course mix were compared in terms of the resilient modulus obtained from the uniaxial indirect tensile resilient modulus test. Gradation is the same for three of the mixtures, two of them use cement as a mineral binder, but 70/100 grade bitumen in one of these two productions and 50/70 grade bitumen in the other. In the third mixture, 70/100 grade bitumen and hydrated lime (HL)+fly ash (FA) were used. In the final mixture, 70/100 grade bitumen and cement were used as mineral binders, but gradation was changed. In addition, permanent deformation control for the final production was carried out with a triaxial cyclic compression test. It was concluded that all these variables affect the results, but the resilient modulus values obtained for all were quite close to those obtained from the bituminous base sample. Considering that the foamed bituminous mixtures will be thicker than the bituminous base course in practice, it is considered structurally appropriate to use this layer instead of the bituminous base course.

Köpüklü Bitümlü Karışımların Bitümlü Temel Tabakası Olarak Kullanılabilirliğinin Araştırılması

Keywords
Köpük bitüm,
Üç eksenli döngüsel basınç,
Dolaylı çekme esneklik modülü,
Asfalt geri dönüşümü

Öz: Köpük bitümle geri kazanılmış malzemeler ekonomik ve çevresel anlamda üstyapılar için umut verici malzemelerdir. Ancak bu malzemelerin üstyapıda nasıl konumlanacağı ile ilgili literatürde farklı görüşler mevcuttur. Performanslarının aşınma tabakası için uygun olmayacağı ancak bitüm ihtiva etmeleri nedeniyle PMT (plent mix temel) tabakası için kullanılmasının da bu malzemelerin değerlendirilmesinde özensiz davranılmış olacağı açıktır. Çalışmada geri kazanılmış bir üstyapı malzemesi ile hazırlanan 4 farklı köpük bitümlü karışım ile standart bir bitümlü temel karışımı tek eksenli dolaylı çekme modülü testinden elde edilen esneklik modülü değerleri açısından kıyaslanmıştır. Karışımlardan üç tanesi için gradasyon aynı olup iki tanesinde mineral esaslı bağlayıcı olarak çimento kullanılmış ancak bu iki üretimin birisinde 70/100 diğerinde 50/70 bitüm kullanılmıştır. 3. karışımda ise 70/100 bitüm ve sönmüş kireç+uçucu kül kullanılmıştır. Son karışımda 70/100 bitüm ve mineral esaslı bağlayıcı olarak çimento kullanılmış ancak gradasyon değiştirilmiştir. İlave olarak son üretim için kalıcı deformasyon kontrolü, üç eksenli tekrarlı basınç testi ile yapılmıştır. Tüm bu değişkenlerin sonuçları etkilediği ancak hepsi için elde edilen esneklik modülü değerlerinin bitümlü temel numunesinden elde edilene oldukça yakın olduğu sonucuna ulaşılmıştır. Uygulamada, köpük bitümlü karışımların bitümlü temel tabakasına göre daha kalın olacağı da düşünüldüğünde bu tabakanın bitümlü temel yerine kullanılması yapısal olarak uygun görünmektedir.

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1. Introduction

Using natural resources more efficiently and sustainably, recycled materials are increasingly used to reduce environmental problems in road construction [1]. In case of using the old pavement as recycled materials, As stated by Yan et al. [2]; RAP (reclaimed asphalt pavement) material can reduce the stress-strain density in the aggregate and bitumen intermediate phase. Thus, it also helps to reduce the need for bitumen. Asphalt Recycling and Reclaiming Association; it has defined different recycling techniques such as Cold Planing, Hot Recycling, Hot In-Place Recycling, Cold Recycling, Full Depth Reclamation [3]. Considering the increase in greenhouse gas emissions by twice every 10 ° C in the production of bituminous mixtures [4], cold recycling from these methods undoubtedly stands out due to its environmental advantages [5], [6]. The main logic in recycling with foam bitumen, which is one of the recycling methods in the cold in place, is to increase the surface area of the bitumen to facilitate its mixing into recycled material [7]. However, one of the most important points to be considered here is the recycled material gradation.

ARRA [3], Thompson et al. [8] stated that the percentage passing through No.200 sieves should be between 5 and 15 of the recycled material. Thus, the bitumen will be distributed according to the material and no bitumen lumps will occur [9].

Active filler materials such as cement [10], [11], [12], [13] hydrated lime [14], fly ash [15] used in foam bituminous mixtures improve the mechanical properties of the mixture [10], [16], [17], [18].

Water is used instead of heating to place and compaction cold recycled materials [19]. This water used is an important factor in reaching suitable volumetric properties of cold recycled materials [19], [20]. However, since proper curing conditions cannot be achieved, if the water in the mixture is preserved after compaction aggregate-bitumen and active filler adhesion will not develop as expected [21]. Therefore, curing is one of the important points to be considered in such mixtures.

In determining the optimum bitumen percentage for cold mixtures with foamed bitumen, the ITS test (Indirect Tensile Strength), which is commonly determined according to the dry sample results, is used. The percentage of filler is generally kept low (around 1%) to prevent shrinkage cracks [12].

Adoption of foamed bituminous mixtures is still largely based on empirical studies and lacks universally accepted mix design procedures [22]

Resilient modulus, which is defined as the resistance of pavement materials to flexible deformation under applied loads [23] and a basic parameter for pavement design [24], is also used to evaluate foam bituminous mixtures. In the resilient modulus test, it is recommended to use a haversine load of 0.1s loading time and 0.9s rest time experimentally to represent the wheel load passing through the pavement in practice for loading [25], [26]. As a result of dynamic loads applied to the pavement, plastic deformation occurs. As the number of load repetitions increases, plastic strains decrease with each load repetition. Strain after 100 to 200 repetitions is practically fully recoverable (flexible) [25].

Because of the repeated wheel loads applied, small irreversible deformations accumulate over time to form a permanent deformation [27]. The main failure mechanism for FBSM (foamed bitumen stabilised materials) is permanent deformation under loading [10]. Especially, the use of high percentage (> 3%) foam bitumen will act as a lubricant between aggregates and reduces the friction angle, thereby increasing shear failure and consequently permanent deformation [12], [28].

Khosravifar et al. [28] has been stated that a layer of foam-stabilized material that is designed appropriately by the structure will be located between granular aggregate base and hot mix asphalt, whereas Wirtgen [12] can be used safely instead of bituminous base course.

In this study, based on the knowledge of the literature, in order to compare foam bituminous mixtures and bituminous base material; MR values were compared by making a uniaxial indirect tensile resilient modulus test on 50/70-70/100 grade bitumens, foam bituminous mixtures prepared using cement-hydrated lime and fly ash type active fillers and the bituminous base course sample prepared to compare them. In addition, for the production of a foamed bituminous mixture, permanent deformation control was performed with a triaxial cyclic compression test. In this study, it is aimed to investigate the usability of foamed bituminous mixtures instead of bituminous base course.

2. Material and Method

The main gradation used in the study is Type A gradation (Rap material gradation, which was also used in our previous studies) [29], [30], [31] seen in Table 1, which is the original gradation of the material scraped off the road (100% RAP). Type B gradation is the same as Type A gradation except for the part that passes through No. 40 sieve. In the foam bituminous mixtures, it is recommended to have a high percentage of fine material in order to spread the bitumen homogeneously into the mixture [3], [8], [12]. For this reason, the material passing through the No.40 sieve was made suitable for the gradation range recommended by Wirtgen [12] by adding new aggregates from outside and the performances of these two materials were compared. The purpose of using the new aggregate for substitution is that the shortage of fine materials that may occur in the application will be covered with the new aggregate from the outside.

Table 1. Material gradations used in experimental studies

Sieve Size		Gradation Type/Passing (%)	
mm	inch/No	Type-A	Type-B
25	1	100	100
19	3/4	96	96
12,5	1/2	87	87
9,5	3/8	79	79
4,75	No.4	58	58
2	No.10	33	33
0,425	No.40	9	11
0,18	No.80	4	7
0,075	No.200	1,6	4

In mixtures prepared for these two gradations, 70/100 bitumen grade and active filler type cement (1%), which is frequently used in foam bituminous mixtures, was used.

In addition, with Type A gradation, a production was made with 50/70 bitumen to see the effect of bitumen grade and 1% HL+1% FA to see the effect of active filler type.

The amount of mixing water used in the productions was determined by the Modified Proctor test.

Foam bituminous mixtures were prepared in accordance with the procedure for preparing foam bitumen stabilized material (Figure 1) recommended by Wirtgen [12]. The ideal foaming temperature and optimum foaming water of the bitumens used are presented in Table 2. [31]

The meanings of the abbreviations used for production codes are as follows.

2.5: Percentage of foam bitumen
A: Gradation Type
70: 70/100 bitumen grade
C: Cement
HL: Hydrated lime
FA: Fly ash

The reason why bitumen percentage varies in production was made for 5 different (1.9-2.2-2.5-2.8-3.1) bitumen per production code, and the optimum bitumen percentage of that production was determined according to the ITSDRY (Dry Indirect Tensile Strength) values obtained from these productions.

Reproductions were made according to these optimum values for resilient modulus test.

Table 2. Ideal foaming temperature and optimum foaming water for bitumen classes used in the study

Bitumen Grade	Bitumen Penetration	Foamed Temperture	Water Percent
50/70	53,6	170°C	3
70/100	85,2	170°C	2

Figure 1. Foam bitumen stabilized material mixture produced with cement in uncompacted state [31]

Foam bituminous mix samples were kept in the 24-hour mold and then 72 hours in a 40°C drying oven, as suggested by Wirtgen [12], before the resilient modulus test. Due to the active filler in it, the curing period was completed in 28 days by waiting for another 24 days in the laboratory.

2.1. Indirect Tensile Resilient Modulus Test

The test was carried out according to ASTM D7369-11 standard and uniaxially. The samples were loaded in the waveform of the haversine with a 0.1 second load and a 0.9 second rest period. The test was carried out at 25°C and 100 preconditioning was applied to the samples and then the average value of 5 loads was taken as the resilient modulus. The samples were prepared with gyratory compactor in 15cm diameter and 10cm height dimensions, and then cut into 15cm diameter and 5cm height (Figure 2).

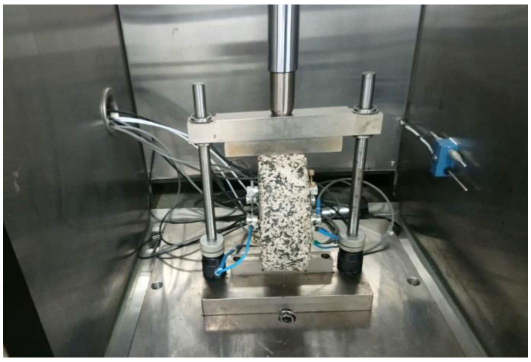

Figure 2. indirect tensile resilient modulus test application to foam bituminous mixture

2.2. Triaxial cyclic compression test

According to TS EN 12697-25 standard, this test was carried out to determine the creep properties of bituminous mixtures and permanent deformation control was performed for the 2.5A70C sample.

The test samples were prepared with gyratory compactor in 10cm diameter and 15cm height dimensions, and then cut into 10cm diameter and 10cm height. The test was carried out in a triaxial load cell at 40°C (Figure 3.). Samples were applied in the wave form of haversine, confining stress 100kPa and axial stress 300 kPa were used (Figure 4.). Total permanent strain obtained by 10000 loading was determined.

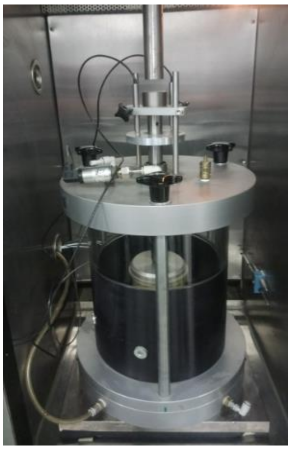

Figure 3. Triaxial cyclic compression test for foam bituminous mixture

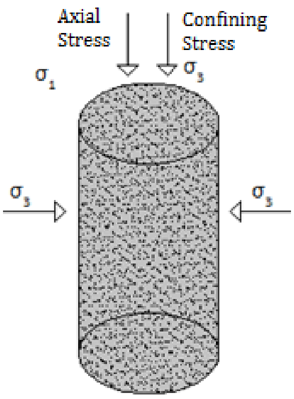

Figure 4. Stress state during permanent deformation test

3. Results and Discussion

According to the data obtained as a result of the test, the graphic shown in Figure 5. has been prepared.

As seen from Figure 5.; In the 1.9B70C production, more fines in the material gradation has decreased compared resilient modulus to the 2.5A70C production. However, since this situation may add flexibility to the mixture of aged bitumen in the RAP material [2], it may be thought that the required substitution was made with the new aggregate instead of the RAP material.

The use of bitumen with different penetration grades in the 2.5A70C and 2.2A50C productions did not make a significant difference in the resilient modulus.

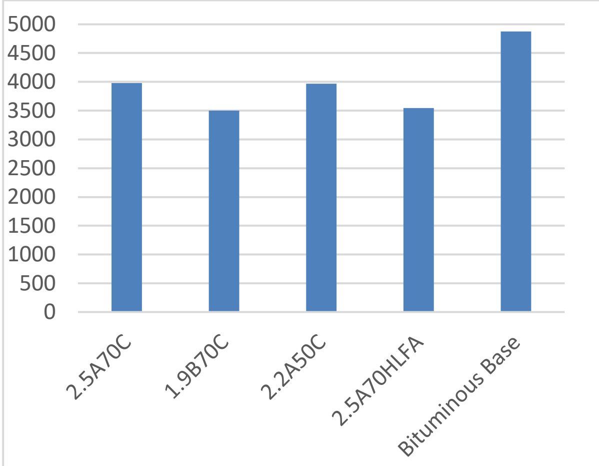

Figure 5. Resilient modulus values for all productions

The use of cement as active filler in the production of 2.5A70C was more positively reflected in the resilient modulus of the mixes than the HL+FA used in the production of 2.5A70HLFA. This situation is caused by the hydration that develops with the prolonged curing time of the cement. The fact that the resilient modulus of 2.5A70HLFA production is higher than that of 1.9B70C production indicates that gradation is more effective than the active filler type.

The result obtained from the bituminous base sample was higher than all foam bituminous mixtures. However, it is probable that the results of the foam bituminous mixtures are quite close to the bituminous base, resulting from the long-term curing strength increase [32].

While the resilient modulus was found with the Indirect Tensile Resilient Modulus Test, a value of 0.00422 mm was obtained as a recoverable vertical deformation. This value was obtained as a result of 105 repetitive loads. A permanent strain of 0.332 mm (2.2%) occurred in the sample after 10000 loading with the Triaxial cyclic compression test. As a result, both values are very low and this is an indication that it is not able to display a completely flexible behavior due to the active fillers and aged bitumen in the sample. Especially one of the main reasons for the result found with Indirect Tensile Resilient Modulus Test to remain at such a low level is the middle 5 cm part of the sample where the lvdt is located as seen in Figure 2. Since the active filler material in the sample rigidizes the mixture depending on the curing, there is no significant deformation especially in this middle section. Similarly, Iwanski and Kowalska [33] mentioned the effect of cement content on increasing the resilient modulus in their studies.

4. Conclusion

In this study; produced for foam bituminous mixtures for two different types of active filler; two different gradations, as 50/70 and 70/100 two different bitumen grades, two different active filler type as cement and hydrated lime (HL) + fly ash (FA), and produced a standard bituminous base mixture. For production the resilient modulus values of the samples were determined by indirect tensile resilient modulus test and the following conclusions were made according to the results obtained.

More fines of the material under No.40 sieve for gradation had a decreasing effect on the resilient modulus.

The changes made in the bitumen grade did not make a significant change in the results. However, only two different bitumen grades have been compared for this study and it is recommended to experiment with higher penetration bitumen.

Foam bituminous mixtures were subjected to a total of 28 days of curing before the experiment, and due to the increase in the curing time of the active filler products, the resilient modulus control is recommended for shorter curing time.

In this study, HL and FA active filler materials were used together, and this production was close to cemented production. However, it can also be investigated how the use of these materials individually will reflect on the results. It has been determined that foamed bituminous mixtures, especially made with suitable gradation and suitable active filler material, are products with a quality close to the bituminous base.

Considering that the recycle thickness of foam bitumen recycled materials in practice is around 1.5-2 times the average bituminous base course, it is considered structurally appropriate to use these mixtures instead of bituminous base and it is a promising situation for the use of these materials. However, crack behavior should be observed due to the active fillers in the products.

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