EVALUATION OF ASPHALT PAVEMENT PERFORMANCE FOR DIFFERENT DIATOMITE CONTENT

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Keywords

Asphalt Pavements,
Diatomite,
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Repeated Creep

Abstract

The majority of steel and reinforced concrete bridges are produced with asphalt pavement. The reason for this is to protect steel and concrete structures from the effects of water and degrading salt additives and to increase their durability. Asphalt bridge superstructures are mostly manufactured with four layers. These layers are the primer bonding layer, waterproofing layer, protection layer and surface asphalt wearing layers. The superstructure must protect the supporting substructure. It should protect the life of the structure and ensure the integrity of the structure against permanent deformation, aging, raveling, water damage and chemical effects. Diatomite additive is used as a performance enhancer in various aspects. It is generally preferred in the region of 5%-15% according to the bitumen mass. The granulometric size and chemical properties of the diatomite additive are other effective factors. In this study, the rutting resistance of conventional and diatomite-modified asphalt pavement for 5% and 10% ratios for selected diatomite additive gradation is investigated. The rutting resistance of the pavements is investigated by repeated creep tests for two different additive ratios on water-damaged and control mixtures. In unconditioned samples, 5% diatomite-modified mixtures; in conditioned samples, 10% diatomite-modified mixtures showed the greatest deformation resistance.

FARKLI DİATOMİT İÇERİĞİ İÇİN ASFALT KAPLAMA PERFORMANSININ DEĞERLENDİRİLMESİ

Anahtar Kelimeler

Asfalt Kaplamalar,
Diatomit,
Tekerlek İzi,
Tekrarlı Sünme

Öz

Çelik ve betonarme köprülerin çoğunluğu asfalt kaplama ile üretilmektedir. Bunun nedeni çelik ve beton yapıları su ve bozundurucu tuz katkılarının etkilerinden korumak ve dayanıklılıklarını arttırmaktır. Asfalt köprü üst yapıları çoğunlukla dört katlı olarak imal edilmektedir. Bu tabakalar astar yapıştırma tabakası, su yalıtım tabakası, koruma tabakası ve yüzey asfaltı giydirme tabakalarıdır. Üst yapı destekleyici alt yapıyı korumalıdır. Kalıcı deformasyona, yaşlanmaya, sökülmeye, su hasarlarına ve kimyasal etkilere karşı yapının ömrünü korumalı ve yapının bütünlüğünü sağlamalıdır. Diatomit katkı maddesi çeşitli yönlerden performans arttırıcı olarak kullanılmaktadır. Genellikle bitüm kütlesine göre %5-15 aralığında tercih edilir. Diatomit katkı maddesinin granülometrik boyutu ve kimyasal özellikleri diğer etkili faktörlerdir. Bu çalışmada, seçilen diatomit katkı gradasyonu için %5 ve %10 oranlarında konvansiyonel ve diatomit-modifiyeli asfalt kaplamanın tekerlek izi direnci incelenmiştir. Kaplamaların tekerlek izi direnci, su hasarlı ve kontrol karışımları üzerinde iki farklı katkı oranı için tekrarlı sünme testleri ile araştırılır. Koşullandırılmamış numunelerde %5 diatomit-modifiyeli karışımlar; koşullandırılmış numunelerde, %10 diatomit ile modifiye edilmiş karışımlar en yüksek deformasyon direncini göstermiştir.

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1. Introduction

Bridge pavements can operate under very different load conditions. It is exposed to the loads of traffic vehicles and climatic conditions. Multidirectional forces act on the pavement. Also, different temperatures, water and deicing salts create additional stresses. The embankment load on bridge decks is much higher than the pavement on the sand. Wheeled vehicles cause compressive and tensile stresses in the outer layer of the pavement. They can cause permanent deformation and fatigue cracks in asphalt pavements. The stress and strain in the bridge pavement are greater than in the ground. Therefore, it poses more risk (Pokorski et al., 2016). In Europe, waterproofing is applied on bridge asphalt pavements. Asphalt pavement on bridges consists of a protective layer and a wear layer. These two layers are usually made of mastic asphalt (MA), asphalt concrete (AC), and stone mastic asphalt (SMA). Due to the special conditions of the loads on the bridge deck, asphalt mixtures with a high mastic content and a closed structure are preferred. A mixture of MA and SMA is used as a protective layer (EAPA, 2013).

The thickness of the asphalt layers in the soil is approximately 10 - 30 cm. In the typical superstructure layer above the soil, there are horizontal tensile stresses at the bottom of the asphalt pavements. Asphalt pavements on bridge decks are much thinner than pavements on the ground. Their thickness is approximately 8 - 12 cm. Due to the different stiffness values of stress and strain, concrete and asphalt slabs should be considered separately. The stress and strain in the bridge pavement vary depending on the deck type (Pokorski et al., 2016). Bridge deck pavements must resist permanent deformation. The pavement depth should be at the desired level. It should meet the requirements such as skid resistance, rigidity and smoothness. It should be resistant to heavy traffic loads and bad weather conditions (BPG, 2003). The deck should absorb the traffic loads and transfer them to the supporting structures.

It must be resistant to deformation and form an anti-skid floor for vehicles. In addition, it should protect the bridge structure from surface waters containing deicing salts that cause corrosion in winter. Due to the different conditions of the pavement structure in a bridge deck, these functions are often not fulfilled by a single material. A functional distinction can be made for the layers that make up the floor covering, it consists of several layers. This system consists of asphalt pavements. However, it can also include primer, membrane, and binder pavements (HBEBES, 2022). In general, asphalt bridge pavement systems can be divided into four different layers: Sealing/binding layer (primer), waterproofing layer, protective layer and surface layer (asphalt). Because the steel slab is more flexible than the concrete slab, the surface pavement must have high abrasion resistance and meet the rigidity requirements without cracking.

In steel structures, large deformations occur in the bridge deck. Therefore, fatigue in the asphalt layer is a more important issue for steel bridges than for concrete bridges. Therefore, optimum values must be found in resistance to permanent deformation, rutting resistance and resistance to fatigue cracks. In some cases, epoxy asphalt can be used on steel bridges. In general, steel plate thicknesses vary between 10 - 14 mm and asphalt layer between 35 - 80 mm. In order to minimize dead loads, the weight of the bridge deck steel and cladding should be kept to a minimum. For concrete bridge pavements, low adhesion between the waterproofing membrane and asphalt pavement, moisture saturation in the asphalt pavement are the most important issues. Inappropriateness of these factors poses great problems. Premature deformation occurs if the asphalt pavement is not thick enough and the primer coat is not applied properly (EAPA, 2013). Repetitive loads, vibrations in the bridge deck, thin layers and severe weather conditions cause deformation of the pavement. In addition, such deformations reduce the service life of bridge systems and increase repair costs. The basic functional requirements in asphalt pavements are water tightness in all conditions, mechanical stability/strength that can withstand shear forces, especially during braking and acceleration in bends, and resistance to cracking and stratification under the influence of temperature changes and traffic loads. Ensuring and maintaining mechanical and chemical resistance between normal loads, weathering and deicing salts is very important (EAPA, 2013). Various applications can be made to increase the life of bridge deck pavements and reduce life cycle costs. One of these applications is the use of modified asphalt mixtures (Widyatmoko and Elliott, 2005; Park et al., 2009).

One of the asphalt modifiers used in the world is diatomite sedimentary rock. Diatomite is a naturally occurring, soft, siliceous sedimentary rock. It is a building material that can be easily turned into fine powder. The main chemical components of diatomite are silica, alumina, and iron oxide (Tan et al., 2012; Cong et al., 2016; Cong et al., 2012). Diatomite is widely used as an asphalt conditioner with its low cost, large reserves and high absorption ability and large storage area properties (Tan et al., 2012; Cong et al., 2016).

Diatomite is abundant in our country (Cubuk, 1998). It is generally used as a filtration material and the usage areas of diatomite have been rapidly investigated recently. It is mostly seen in the waste category, and with the use of diatomite additive in the construction industry, it has an important place for an economic and sustainable future. It is known that diatomite additive improves the performance of asphalt mixtures against water damage, fatigue, rutting and aging problems. It is stated that it offers a healing mechanism with a physical mixture, not a chemical reaction, and is used as a bitumen stabilizer (Omur et al., 2021).

Constructive advantages in terms of production and recycling conditions because diatomite can be used as filler, added to bitumen, improved performance problems, suitable for multiple additive options, versatile function in storage stability in plants, homogeneous protection of bitumen film thickness, mixing regulation feature, and improving aging problems. Diatomite modified asphalt is considered to be an important current perspective for Turkey due to its convenience and prevalence in Turkey (Omur et al., 2021).

Diatomite modified asphalts have bitumen drainage preventive properties in mixtures, form a foam-like structure, can be used at rates up to 15% by weight of bitumen, provide adhesion by significantly increasing the specific surface area, strengthen adhesion to wet (moist) aggregates, low-temperature performance in use in cold areas. It can also be used with modifiers that form fiber structure, it functions in terms of preventing icing, increases fatigue performance and is advantageous in terms of long-term performance, due to its feature, it contributes to the improvement of production conditions-plant conditions-site conditions and to increase the quality of the asphalt industry, refinery and field. Diatomite-modification reduces the aging problem of asphalt mixtures under application conditions. In this way, diatomite additive strengthens recycling strategies, increases the homogeneity of the mixture with inorganic physical effect, and can be easily mixed with bitumen. Its effects on water damage, rutting and fatigue performance are being investigated (Omur et al., 2021). In the mixture gradation, instead of filler, porous asphalt mixtures containing 0%, 5%, 10% and 15% diatomite by weight were prepared and microstructure analysis and performance tests were carried out. It was stated that the porous asphalt mixture containing diatomite showed higher optimum asphalt content due to the low bitumen drainage property caused by the high specific surface area of the diatomite. Compared to normal mix, porous asphalt mixes prepared with diatomite provided better particle loss resistance, moisture damage resistance, rutting resistance and low-temperature cracking resistance (Huang et al., 2010). Diatomite is gaining increasing attention as a new source material as it has the potential to be a viable alternative to mineral fillers in asphalt pavement construction. Uniaxial fracture test, repeated creep test and low-temperature cracking test were applied to determine the mechanical properties, limestone dust content and optimum addition ratio content of sand-asphalt composites containing various proportions of diatomite. When the results were examined, it was revealed that the compressive strength, deformation properties and low-temperature cracking resistance of asphalt composites were improved by the use of diatomite (Cheng et al., 2018).

In a study, diatomite and glass fiber were used as a performance enhancing additive in asphalt mixtures at the rates of 0.1%, 0.2% and 0.3% compared to the total asphalt mixture weight. The relationship between the rutting resistance property and the modifiers developed linearly when the amount of additives was low. It was also found that when diatomite is used in small proportions, it reduces the low-temperature tensile strength. The addition of diatomite may be the main cause of the decrease in the stiffness modulus. Diatomite is a light and elastic material, but asphalt is a viscoelastic material, the modulus of elasticity of asphalt depends on temperature. The modulus of elasticity of diatomite modifiers is less than that of asphalt at low-temperature. Therefore, the diatomite particles in asphalt are flexible, and these flexible particles cause the modulus of the diatomite-modified asphalt binder to drop. Ultimately, this result leads to a decrease in the modulus of stiffness of the modified asphalt mix (Qinglin et al., 2015).

In a study investigating the antifreeze performance effects of diatomite and SBS additives in ground rubber (CR) added stone mastic asphalt (SMA) mixtures, air gap, indirect tensile strength, indirect tensile stiffness modulus values were questioned. It was observed that the air void values increased, the indirect tensile strength and indirect tensile stiffness modulus values decreased with the increase of freeze-thaw cycles. The addition of diatomite and SBS decreased the air gap in the CR modified mixtures and increased the indirect tensile strength and stiffness modulus. By forming a thicker asphalt film and an anchored structure around the CR particles and aggregates, the diatomite is stated to absorb lower molecular groups and lower aromatic molecules and reduce air voids. Thus, the cohesion between aggregates increases and the internal resistance of the mixture increases (Wei et al., 2017). The viscosity of the asphalt binder increases significantly when diatomite powder is added. Dynamic shear rheometer test results indicate that the increase in the percentage of diatomite at high temperatures causes the value of the complex shear modulus to increase and the phase angle to decrease, which shows the effect of diatomite in reducing permanent deformations (Cong et al., 2012). The physical properties, dynamic rheological behavior, storage stability and aging criteria of asphalt binders modified with 4% diatomite by weight were investigated; It was observed that both the viscosity and modulus of elasticity of the bituminous binders increased rapidly with the addition of diatomite at high-temperatures. Compared with pure asphalt binders, positive results were obtained in the resistance of modified asphalt binders to high-temperature deformation and low-temperature cracking (Cong et al., 2012), moreover, the anti-icing performance of diatomite-modified asphalt mixtures, improved fatigue life, is expressed (Wei et al., 2016; Chen et al., 2007). Diatomite has high absorption capacity and stability. It produces a low-cost solution and is a widely used mineral with significant storage. Widely used for asphalt modification in China (Tan et al., 2012; Song et al., 2011; Kietzman and Rodier, 1984; Tan et al., 2009).

The effect of diatomite/basalt fiber on the performance of asphalt mix was investigated through rutting test, low-temperature indirect tensile strength test, moisture damage susceptibility test, four point bending fatigue test and F-T loop test. The addition of basalt fiber and diatomite to the asphalt increased the high-temperature rutting, low-temperature cracking, freeze-thaw cycle damage and moisture damage resistance of the asphalt mixture in seasonal frozen regions. It also increased the fatigue life of the asphalt mixture (Cheng et al., 2018).

The OH^- group is found in diatomite. It is an important parameter for the surface activity and absorptivity of diatomite. The porous structure of diatomite increases its adherence and wetting ability with asphalt. Small particle size, large number of mesopores, and large specific surface area increase the adsorbability of asphalt for lightweight components. The properties of diatomite also allow it to form a strong physical bond with asphalt additives. They provide a possible reason to improve asphalt mix performance. Moreover, due to its low cost and simple modification process, the economic benefits of diatomite-modified asphalt mixture have great advantages over conventional modified asphalt mixture (Cheng et al., 2018).

From the literature summary given above, it can be seen that the rutting resistance of diatomite-modified asphalt mixtures increases significantly. However, it can be seen that there is no consensus in the literature regarding the most appropriate diatomite ratio. It is stated that significant performance decreases are observed at usage rates greater than 13%, and good results can be obtained between 6% and 13%. The aim of this study is to investigate the usability of low and medium dosage diatomite-modified asphalt mixtures in terms of deformation resistance in bridge pavement layers. For this purpose, the deformation resistance of bituminous asphalt mixture samples modified at 5% and 10% usage rates were investigated by repeated load creep tests.

2. Materials and Method

2.1. Material

In this study, asphalt cement with a penetration grade of 50-70 whose properties are presented in Table 1 and limestone aggregate whose properties are shown in Table 2 were used. According to the Highways Technical Specification (HTS, 2013), the aggregate granulometry suitable for the production of dense graded asphalt concrete has been determined. The aggregate granulometry curve is given in Figure 1.

In the study, diatomite materials, from Bentas Bentonit company, were used. XRF (X-Ray Fluorescence) main oxide analysis results of diatomite additives are shown in Table 3 and granulometry curves are shown in Figure 2. In addition, XRD (X-Ray Diffractometer) graph and SEM image of diatomite are given in Figure 3. EDS (Energy Dispersive Spectrometry) layered image of diatomite and EDS Map sum spectrum of diatomite additive are given in Figure 4.

Table 1. Pure bitumen properties

Test	Method	Value	Specification limits
Specific gravity (25°C)	ASTM D-70	1.011	
Softening point (°C)	TS EN 1427	52	46-54
Flash point (°C)	TS EN ISO 2592	240	Least 230
Penetration (25°C) 0.1mm	TS EN 1426	63	50-70
Ductility (25°C)	ASTM D-113	100+	

Table 2. Aggregate properties used in the experiment

Properties	Test method	Results	Specification limits
Specific gravity (coarse aggregate)	ASTM C 127		
Bulk		2.707	
Apparent		2.733	
Specific gravity (fine agg.)	ASTM C 128		
Bulk		2.763	
Apparent		2.776	
Specific gravity (grain)		2.242	
Los Angeles abrasion (%)	TS EN 1097-2	26.70	
Flakiness, (%)	BS 812	9.71	≤25
Stripping resistance (no additive) (%)	ASTM D-1664	60-65	≥60
Clay lumps and friables, %	ASTM C 142	negative	will not be found
Plasticity index for sandy aggregate	TS-1900-1	NP	NP
Organic matter for sandy aggregate	TS EN 1744-1	Negative	Negative

Table 3. Main oxide analysis results of diatomite additive

	Unit	Value
SiO_2	%	73.955
Al_2O_3	%	8.989
Fe_2O_3	%	2.899
MgO	%	2.485
CaO	%	2.270
Na_2O	%	0.207
K_2O	%	1.256
TiO_2	%	0.511
P_2O_5	PPM	0.206
MnO	%	0.102
SO_3	%	0.014
Cl	PPM	94
BaO	%	0.032
CuO	%	0.194
NiO	%	0.227
SrO	%	0.038
V_2O_5	%	0.0739
ZnO	%	ND
ZrO_2	%	0.028

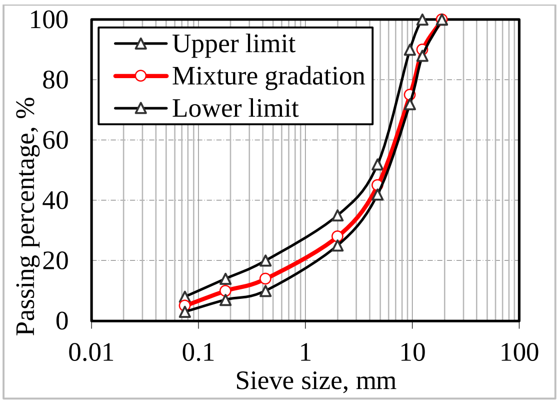


Figure 1. Aggregate granulometry curve

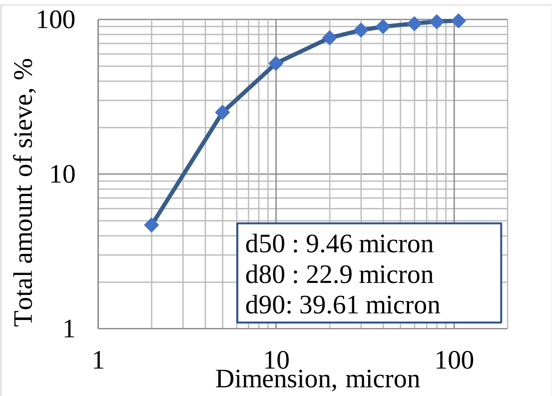
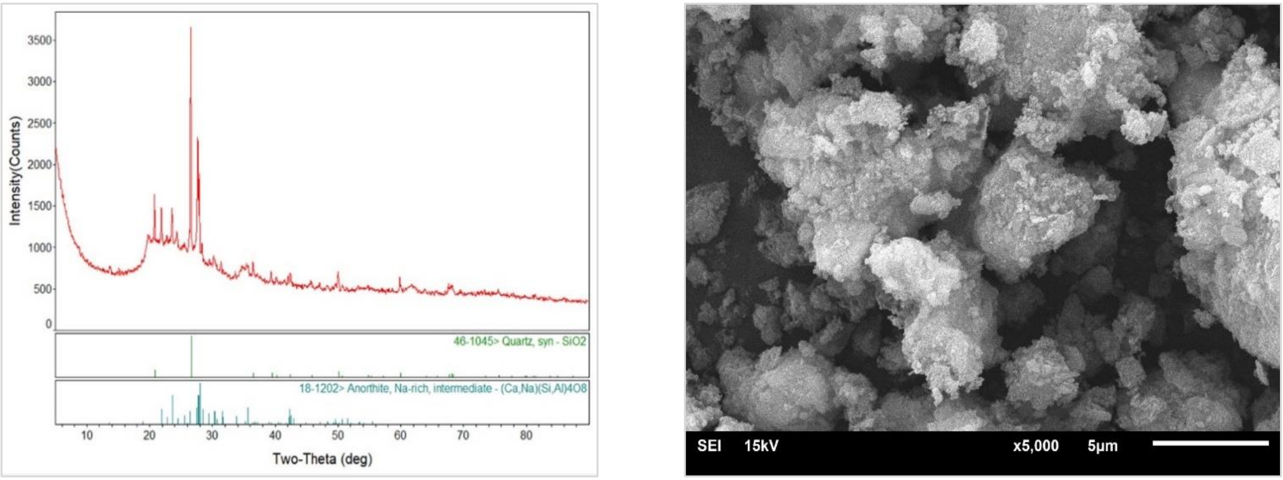
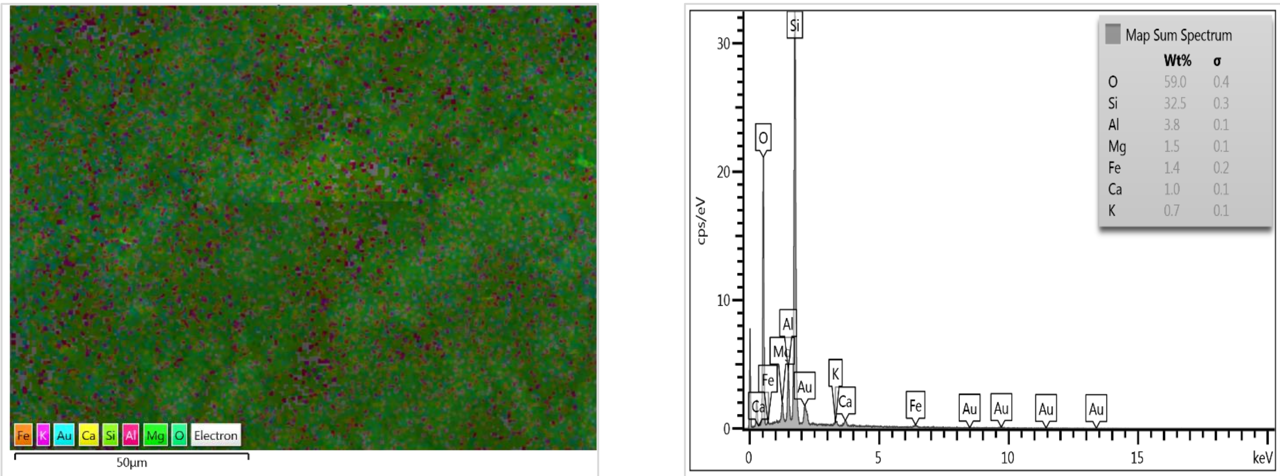


Figure 2. Granulometry curve of diatomite additive



a) b)

Figure 3. For diatomite: a) XRD graph b) SEM images



a) b)

Figure 4. Diatomite additive: a) EDS layered image b) EDS map sum spectrum of diatomite additive

2.2. Mix Design

In accordance with the Highway Technical Specification (HTS, 2013), the dense graded asphalt concrete design was made with pure bitumen according to the Marshall method. The bitumen content, which gives 4% air voids, was taken as the optimum bitumen content and calculated as 5.10%. It was observed that other mixture properties in the calculated bitumen content also met the specification limits (Table 4). Control mixtures and diatomite-modified mixtures were produced in the same bitumen content.

Table 4. Asphalt concrete design results

Design parameters	Specification limits	Mixing values
Number of blows per face	75	75.00
Density, gr/cm3		2.44
Marshall stability, kg	Least 900	1189
Blank, Vh, %	3-5	4.00
Space filled with asphalt, Vf, %	65-75	71.64
Flowing, mm (mm)	2-4	3.48
Bitumen content, (%)	4-7	5.10
VMA, %	14-16	14.37

2.3. Method

Direct (dry) and indirect (wet) methods can be used to prepare the diatomite-modified asphalt mixture. When using the direct modification method, diatomite is added as a mineral powder to the asphalt and aggregate mixture. In the indirect method, it is important to prepare the asphalt binder to be modified with diatomite before the preparation of the mixture (Zhou, 2008). It is stated that the two mixing methods give approximately the same effect in view of mechanical performance. The bentonite addition rate was determined based on the studies in the literature (Yin, 2012). Bentonite additives of 5% and 10% by weight were added to the bitumen and diatomite-modified bitumen and asphalt mixtures were prepared. The wet method was used. The modification processes were decided by using the studies in the literature. In a study in the literature, a shearing temperature of 150°C, a mixing speed of 3000 rpm and a mixing time of 120 minutes were selected for the preparation of diatomite-modified asphalt (Cong et al., 2012). In another study, the shearing temperature was 150°C, the shearing speed was 4000 rpm, and the shearing time was 40 minutes (Guo et al., 2015). In another study, the shearing temperature is 160°C, the shearing speed is 5000 rpm and the shearing time is 40 minutes (Tan et al., 2012). In this study, diatomite- modified bitumen was prepared at 4000 rpm shearing speed at 160 °C. It was mixed during 40 minutes. Repeated creep testing can be used to determine the rutting resistance of asphalt mixtures. The test can be performed under different temperatures, loading stresses, loading times, test times and various loads (Aksoy and İskender, 2008). In the repeated creep test, the relationship between the cumulative permanent deformation and the number of load repetitions is read. As the amount of deformation increases, the rutting resistance decreases. In this study, repeated creep tests were carried out on conditioned and unconditioned asphalt mixtures within the scope of EN-12697-25 (A) (BS EN 12697-25, 2016), test standard. Conditioning was performed using the AASHTO T 283 (AASHTO T 283, 2021), method. The tests were carried out at 40 °C, 95 kPa loading, 0.5 Hz frequency and 20000 loading cycles. Three identical asphalt briquettes were used for each experimental condition.

3. Test Results and Evaluations

Repeated creep curves of unconditioned asphalt mixture samples are shown in Figure 5 and conditioned ones in Figure 6. For the same mixture type, the area between the creep curves of the unconditioned samples was smaller than that of the conditioned samples. In other words, the difference between permanent deformations in the conditioned samples was higher than that of the unconditioned samples. This situation reveals that in the performance questioning, conditioned samples are more distinctive in the observed experimental method. In unconditioned mixtures, a distinction was made between control and 5% diatomite-modified mixtures; all of the modified mix samples showed smaller deformations than the control mix samples. However, when the modification dosage was increased (10%), the standard deviation between the deformations of identical samples increased and higher differences were observed between the results. Respectively; for control mixtures, 5% diatomite-modified mixtures and 10% modified mixtures, the standard deviation values of the unconditioned and conditioned mixtures were 0.024; 0.023; 0.044 and 0.062; 0.054; 0.058 was found

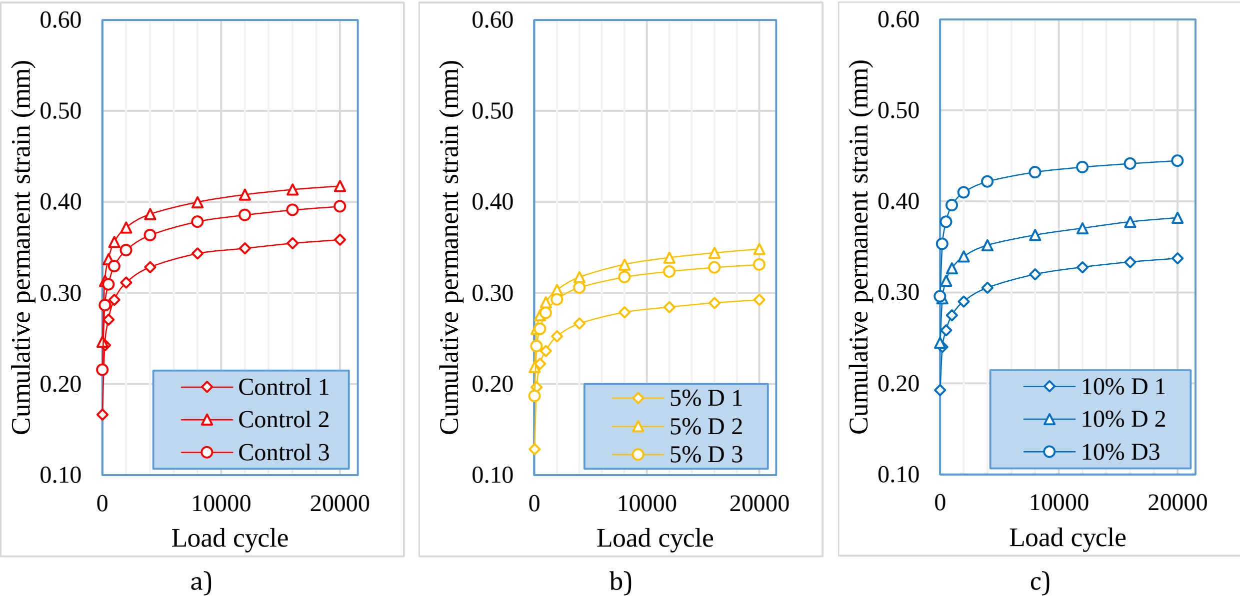


Figure 5. Deformation curves of unconditioned asphalt mixes: a) control mixtures b) 5% diatomite-modifiate mixtures c) 10 % modifiate mixtures

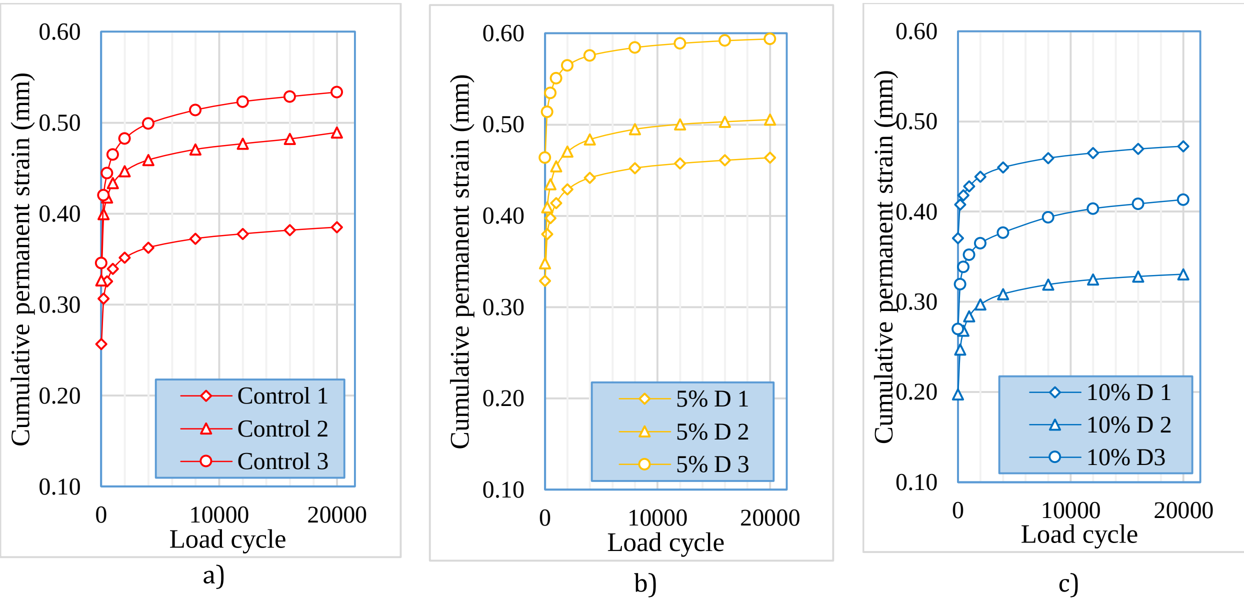


Figure 6. Deformation curves of conditioned asphalt mixes: a) control mixtures b) 5% diatomite-modified mixtures c) 10 % modified mixtures

The average deformation curves of unconditioned and conditioned asphalt mixture samples are shown in Figure 7. According to the test results, while 5% diatomite-modified asphalt mixtures showed the highest deformation resistances in unconditioned mixtures, there was no significant difference between the deformation resistances of control and 10% diatomite-modified mixtures. It was determined that the amount of deformation observed as a result of the test increased and the deformation resistance decreased when conditioning was applied to the samples. On the other hand, 10% diatomite-modified mixtures showed the highest deformation resistance and 5% diatomite-modified mixtures showed the lowest deformation resistance in conditioned mixtures.

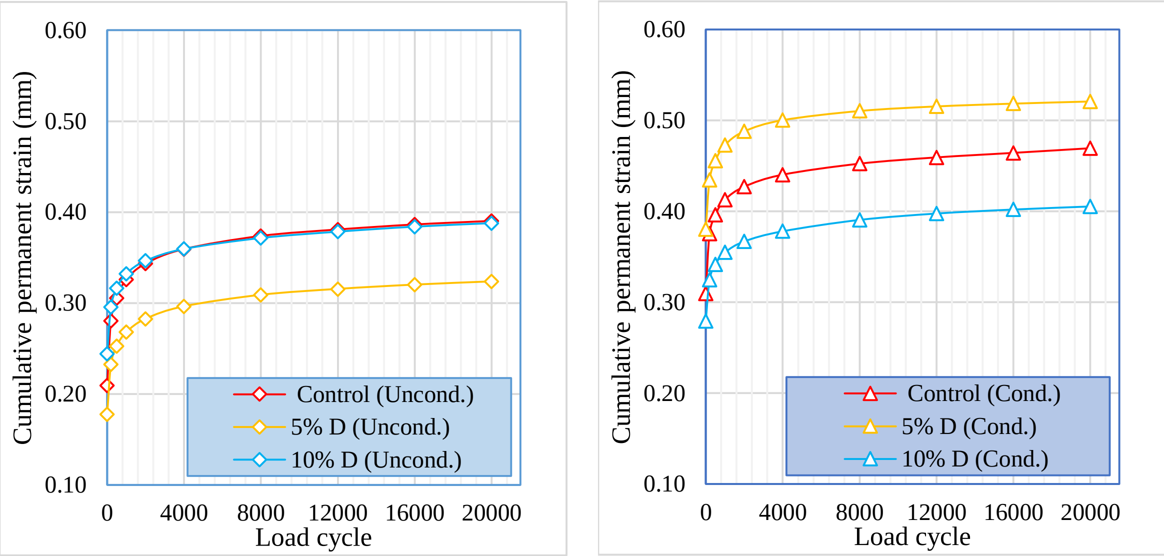


Figure 7. Comparison of deformation resistance of asphalt mixes

In a study conducted by Yang et al. (2018), 12% diatomite was modified by bitumen weight and it was observed that diatomite modification caused a significant increase in the high temperature performance of the asphalt mixture compared to reference samples. In a study by Chen et al. (2014), the high temperature performance and dynamic stability of asphalt mixtures produced with 6% diatomite modification by weight of bitumen increased significantly compared to samples without additives. In a study conducted by Luo et al. (2016), diatomite additive was used at the rates of 0-9-11 and 13% according to the weight of the bitumen, and the dynamic stability of the prepared samples compared to the reference samples increased by up to 13% at high temperatures and reached the maximum value at 13%. It has dropped significantly by 15%.

Du et al. (2022), the diatomite content (mass fraction) of the asphalt mixture was used at 10%, 13%, 20%, 23% and 25% ratios and a rutting test was performed. When the active diatomite content is less than 20%, the dynamic stability of the asphalt mix gradually increases with the increase of the content. However, when the ratio exceeds 20%, the dynamic stability decreases. For this reason, the most appropriate diatomite ratio was suggested as 13%. Chen et al. (2007), in a study, determined that the optimum content of diatomite modified bitumen is 10%. Zhang et al. (2011), in a study concluded that the optimum dosage of diatomite is 13% by analyzing the low temperature performance of binders and blends. Therefore, 10-13% was a reasonable dosage range. Diatomite significantly improves the high temperature performance of asphalt mixes, but some studies reveal that the improvement in low-temperature performance of asphalt mixes is negligible, while others note poor behavior in low-temperature cracking resistance (Yue et al., 2019). Asphalt mixes modified with single additives cannot improve the overall properties of asphalt mixes. Dual modification technology in asphalt mixes is the best alternative to reduce low-temperature cracking and high-temperature rutting. To improve the overall performance of asphalt mixtures under environmental conditions, it is recommended to use asphalt mixtures modified with two types of additives (Yue et al., 2019).

In the studies in the literature, it is seen that there are various small cavities in the outer layer shell of the diatomite. This special structure of diatomite not only provides a large diatomite surface area on the asphalt mixture, but also facilitates the adsorption and wetting of the asphalt (Bao and Jiang, 2010; Yang et al., 2018). Studies have shown that the pore size of diatomite is mainly distributed by condensation between 1 nm and 8 nm. The average pore diameter of diatomite is 5.4895nm. The mesoporous structure can increase the capacity to absorb light components of asphalt, resulting in increased viscosity and high-temperature performance of asphalt (Bao and Jiang, 2010; Van Garderen et al., 2012).

One of the most important parameters in the evaluation of diatomite quality is SiO_2 content (Li, 2008). In particular, the surface of the diatomite has a very strong bonding strength due to the presence of this amorphous SiO_2. In addition, the inert nature of SiO_2 reduces the transmission rate in the pavement and imparts thermal insulation functions to the pavement (Bao, 2005). This issue is attributed to the superior compatibility properties between asphalt and diatomite. High compatibility reduces the mixing time and aging of the modified asphalt (Li, 2008).

This study confirms the optimum diatomite ratio of 10% - 13% for diatomite modified asphalt mixtures in the literature. When the diatomite ratio was chosen as 10%, a significant increase in resistance for rutting was achieved, while higher deformations were observed in the conditioned mixtures at the 5% incorporation ratio. The low diatomite ratio is thought to be a worthwhile issue with binary modifications, especially fiber type additives. At moderate usage rates, diatomite-modified mixtures show high mechanical properties. It is considered that diatomite/fiber modified asphalt mixtures may be a suitable option in areas such as bridge pavements where temperature changes are rapid and freeze-thaw cycles are high.

4. Conclusion and Recommendations

In this study, the deformation properties of diatomite-modified asphalt mixtures were investigated for low (5%) and medium (10%) usage rates of diatomite additive. Unconditioned and conditioned asphalt mixture samples were utilized. In unconditioned mixtures, 5% diatomite-modified mixtures demonstrated higher deformation resistances than control and 10% diatomite modified mixtures. Diatomite has the ability to trap heat due to the high silica content in it. It is also known to be used in thermal insulation materials. Therefore, as the diatomite content in bitumen increases up to a certain rate, the resistance to rutting at high temperatures increases. This is why 10% diatomite content is more successful than 5% diatomite modification. On the other hand, in the conditioned samples, the highest deformation resistance occurred at 10% modification rate. The 10% lower usage limit stated in the literature was confirmed in this study. According to the literature review, when 10% diatomite-modification made with fiber as basalt or lignin seems to be effective in terms of deformation resistance in bridge pavements where freeze-thaw cycles are frequent and severe and the effect of extreme climatic conditions is felt. In future studies, low usage rates of diatomite additive will be investigated with different fiber options and ratios. In addition, it is recommended to investigate diatomite-modified asphalt mixtures in terms of resistance to anti-icing additives and sulfate effects.

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Declaration of Ethical Code

The authors declare that all of the rules stated to be followed within the scope of the “Higher Education Institutions Scientific Research and Publication Ethics Directive” were followed, and none of the actions specified under the title of “Actions Contrary to Scientific Research and Publication Ethics” have been carried out.

Author Contribution

In this study; Mustafa Taha ASLAN, Erol ISKENDER in the article's concept, design, data collection and preparation, literature review; Erol ISKENER, Atakan AKSOY, Mustafa Taha ASLAN data analysis, at the stage of evaluating the results; Mustafa Taha ASLAN, Erol ISKENDER, Dundar AYYILDIZ, Atakan AKSOY, C. Ensar SENGUL contributed to the writing of the article and converting it into the template.

Conflicts of Interest

“The authors declare that there is no conflict of interest.”

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