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Determination of Resistance to Creep Permanent Deformation of Hot Mix Asphalts Prepared with Various Additives

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Abstract

In this study, the resistance of hot mix asphalts containing different additives to the creep permanent deformation was investigated by the dynamic creep test. Four different additives were used in the study. Styrene-butadiene-styrene (SBS), American Gilsonite (AG), and Iranian Gilsonite (IG) were used for modifying the bitumen. Additionally, the same mixtures were prepared by using 2% hydrated lime as filler. The samples were subjected to dynamic creep test at 50°C under 500 kPa stress level. As a result of the tests performed, it has been determined that all of the additives used in the study improve the resistance to the creep permanent deformation. It has also been determined that the use of bitumen additives is more effective than the use of lime. Furthermore, it has been determined that the most effective additive is IG while the least effective additive is SBS, and hydrated lime use is more effective compared to the mixtures prepared with a neat binder.

Keywords: Creep Permanent Deformation; Hot Mix Asphalt; Modification; Styrene-Butadiene-Styrene; American Gilsonite; Iranian Gilsonite; Hydrated Lime.

1. Introduction

Hot mix asphalt (HMA), is a type of highway flexible pavement material, formed by mixing of aggregate and bitumen at certain ratios and compacting the resulting mixture at a certain temperature [1]. Hot mix asphalts consist of solid (aggregate), liquid (bitumen) and gas (air void) phases. The behavior of asphalt mixtures depends on the loading rate, temperature, aging of the binder, and air void content of the mixture [2]. Depending on the traffic loads and climatic stresses, various deteriorations occur in hot mix asphalts [3].

Rutting, which is one of the most common types of deterioration, is defined as the increased deformation in each layer of pavement under constant traffic load [4]. The most significant layer in terms of permanent deformation is the pavement layer, which is directly exposed to the traffic load [5]. Permanent deformations can occur during various periods of the pavement's service life. Mainly, there are three occurring mechanisms of permanent deformation (Figure 1). The first is the consolidation permanent deformation that occurs in the first years of the pavement's service life. Such deformations generally result from the consolidations, which occur due to lack of sufficient compaction during the construction of the asphalt layers. The second type of permanent deformation is called creep permanent deformation. It was determined that the permanent deformations observed on site are generally creep permanent deformations. The creep permanent deformation of asphalt layer is caused by a combination of consolidation (volume change) and shear deformation (no volume change) resulting from the dynamic pressure of traffic loads. The shear deformation of properly constructed (compacted) pavements – caused primarily by large shear stresses in the upper portions of asphalt layer(s)

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– is dominant [6]. The third type of this deterioration, structural permanent deformation, is rutting on the upper layer, which occurs due to rutting on the lower layers. In the first and third type of deformation, the deformed part descends from the first layer to a lower layer while the deformed surface ascends from the side of the wheel track [7].

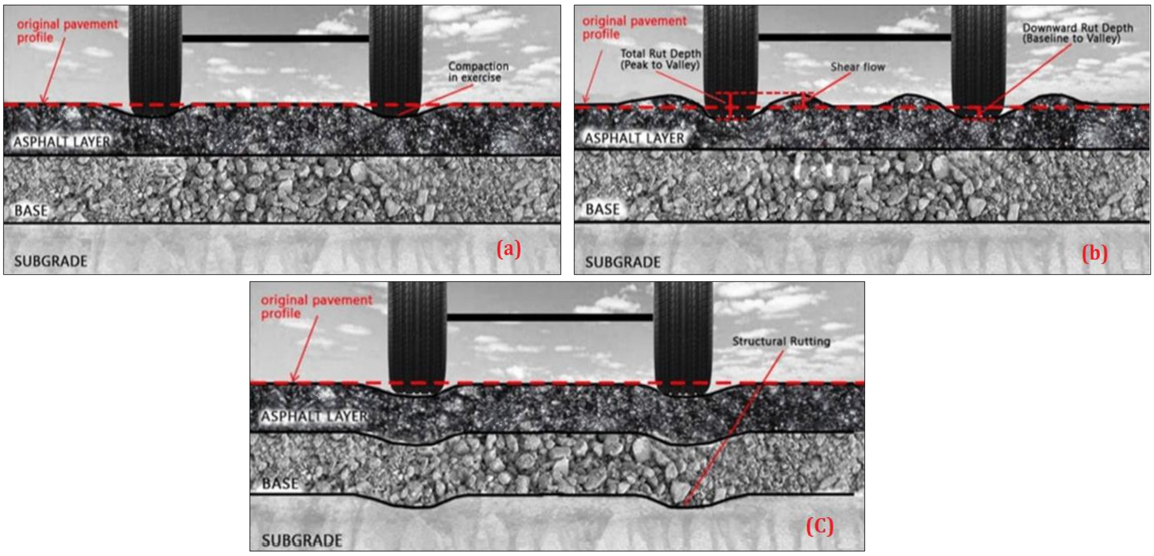


Figure 1. Consolidation (a), creep (b) and structural (c) permanent deformation [8]

In order to prevent or delay the deformations in hot mix asphalts, the most frequently used method is the use of additive [9]. Modified bitumen can be obtained by adding the additives to the bitumen, as well as the modification of the mixture can be achieved by adding the additives to the mixture at a plant. The bitumen additives can be divided into two main groups as natural or synthetic. The most frequently used synthetic additive is styrene-butadiene-styrene (SBS), which is an elastomer polymer [10].

In the study conducted by Bayekolaei et al., the effects of SBS structure and base binder type on rutting behavior of polymer–nanocomposite asphalt binders and mixtures were investigated. It was reported that binder type could significantly affect the rutting behavior of modified binders and mixtures containing polymers. Although softer asphalt binders had higher rut depth and rut depth rate values as a result of higher maltene phase in its base binder, it demonstrated higher enhancement ratio for polymer-nanocomposite-modified binders compared to conventional asphalt binders. Asphalt mixtures and binders modified with linear SBS nanocomposites demonstrated higher values of resilient modulus and $G^*/\sin\delta$ [11].

Li et al. investigated the high temperature stability of SBS modified asphalt mixtures. Different gradations of mixture, temperature and contents of SBS modifier were measured by the Wheel Tracking Test. Mixing SBS modifier in common asphalt mixtures, the resistance to rutting of the coarser aggregate mixture was superior to that of the finer aggregate mixture. The coarse aggregate could enhance friction of skeleton structure and mechanical interlocking force among mineral granule. The optimum contents of SBS modifier to the continuous-graded mixture was controlled at 5%~6% during asphalt mixture design. The high-temperature stability of mixtures was mostly influenced by the softening point of SBS modifier, and then the softening point of SBS modifier becomes one of the evaluation indexes on high-temperature stability of mixture [12].

Cao et al. prepared their mixtures by adding by styrene–butadiene–styrene (SBS) and anti-rutting additive (ARA) composite to bitumen as additives to improve the rutting resistance of the hot-mix asphalt (HMA) surface layer. The wheel-tracking test, bending test and indirect tensile test were conducted to evaluate the effects of three dosages of ARA on the high-temperature performance, low-temperature performance, and moisture susceptibility of SBS-modified asphalt mixture. Then, the high-temperature rutting-resistance performance of composite-modified AC mixtures was investigated by the dynamic modulus test and uniaxial creep test. The results indicated that the high-temperature performance of composite-modified asphalt mixture was significantly improved compared to that of the only SBS modified mixture. In conclusion, SBS and ARA composite-modified mixture had excellent high-temperature stability [13].

Alataş and Kizirgil investigated the effects of combined utilization of Styrene-Butadiene-Styrene (SBS) in bitumen modification and fly ash in mixture modification on the mechanical properties of hot mix asphalts. Within the scope of this study, 12 different mixtures were obtained by combining three different proportions of SBS additive relative to the total bitumen mass (0, 3 and 6 wt.%) with four different proportions of fly ash replacement relative to the total aggregate mass (0, 2, 4 and 6 wt.%). It was determined that the individual utilization of SBS and fly ash improved the stability of the mixtures, resilience at normal temperatures, resistance against moisture-induced damage, fatigue life and strength against permanent deformation. In addition, it was concluded that using only SBS in bitumen modification at 3 wt.% without using fly ash and the use of only fly ash as filler at a proportion of 6 wt.% with pure bitumen yielded similar results [14].

Gilsonite is the most frequently used natural additive. Gilsonite is a type of natural asphalt and it is most commonly found in Iran and the United States in the world. Hamidi investigated effects of Gilsonite use on the rheological properties of bituminous binders and mechanical properties of hot mix asphalts. The Marshall Immersion test, the wheel tracking test and the indirect tensile stiffness modulus tests were applied on hot mix asphalts prepared at optimum binder content. The results of the binder tests indicated that the addition of Gilsonite changed the characteristics of the binder. Increasing the proportion of Gilsonite causes a decrease in penetration, an increase in softening point and a reduction in temperature susceptibility. The results of the mixtures investigation indicated that the addition of Gilsonite significantly increased the Marshall stability, by 10 % and 19 %, respectively, tests results show the rate of deformation to reduce by 43 % and 71 %, respectively, with the addition of 4 % and 8 % Gilsonite. The modulus of bituminous mixtures is very dependent on temperature and the addition of Gilsonite is most significant at a testing temperature of 25°C; modulus increases by 45 % and 77 %, respectively, with the addition of 4 % and 8 % Gilsonite [15].

Zhong et al. obtained the rock asphalt (RA) from Xinjiang China and they used RA to modify the petroleum bitumen. RA with five different dosages were added into petroleum bitumen: at the rates of 0%, 5%, 10%, 15% and 20% by weight. A comprehensive performance of the RA modified bitumen binders and mixtures were evaluated, including the high temperature performance, low temperature performance, moisture susceptibility, tensile strength, and fatigue performance. It was determined that the addition of RA improved the high temperature performance of petroleum bitumen binders and mixtures. With the addition of RA, the moisture damage resistance, tensile strength and fatigue performance of petroleum mixture were enhanced as well [16].

Li et al. analyzed the performance of the Qingchuan rock asphalt–modified asphalt based on modified asphalt index tests, the dynamic shear rheometer test and the bending beam rheometer test. Performance verification of the Qingchuan rock asphalt–modified asphalt was conducted using the rutting, mechanical property, small-beam bending, freeze-thaw split, indirect tensile fatigue, and small-sized acceleration loading tests. The results indicated that the temperature sensitivity of rock asphalt–modified asphalt was decreased, and the temperature stability and water stability were strengthened. The rock asphalt modifier can obviously improve the anti-fatigue performance and high-temperature stability of its asphalt mixture. The dynamic stability of AC-20 with an 8 % rock asphalt content is 4,769 times/mm, which is 3.05-fold higher than the dynamic stability of the base asphalt. Small-sized acceleration loading tests confirm that the anti-fatigue performance and anti-rutting performance of a 10 % rock asphalt–modified asphalt mixture increase by 120 % and 233 %, respectively, over those of its base asphalt. Additionally, the anti-fatigue and anti-rutting performances exceed those of the styrene-butadiene-styrene–modified asphalt mixture [17].

Jahanian et al. used Iranian Gilsonite as bitumen modifier and common functional performance-based tests of bitumen were performed on specimens by adding Gilsonite at 0, 2, 4, 6, 8, 10 wt.% rates to bitumen specimens. Marshall Stability and flow, indirect tensile strength and moisture sensitivity, as well as dynamic creep, and resilient modulus tests were conducted on the mixtures prepared with neat and Gilsonite modified binders. The research proposed that adding Gilsonite to bitumen in hot mix asphalt considerably increased Marshall Stability and resilient modulus parameter in asphalt specimens. Moreover, increasing the flow number obtained from the dynamic creep test indicated an increase in rutting resistance [18].

Hydrated lime is the most commonly used filler material. Hydrated lime is generally used for improving the resistances of HMAs to moisture damage [19] as well as contributing to HMAs' resistances to permanent damage [20, 21]. Hydrated lime is generally used at a rate of 2% in place of filler [22].

In a study conducted by Yılmaz and Yalçın, 2% hydrated lime was used as filler and SBS, AG and IG was used in the bitumen modification. As a result of the study, it has been reported that all of the additives improve the Marshall stability, resistance to moisture damage, stiffness and resistance to rutting [23]. In another study conducted with the same materials, it has been determined that the additives improve the fatigue lives of HMAs [24]. Distinctly in this study, the resistances of mixtures were determined by conducting dynamic creep test on the mixtures that include neat bitumen, SBS, AG, IG modified bitumen, and mixtures with same binders along with 2% hydrated lime.

2. Materials and Methods

In this study, the binder and mixture volumetric design were made according to the Superpave method. The performance grade of modified binders should be minimum PG 70-22, in compliance with the traffic and climatic conditions of the city of Elazığ, Turkey, which was selected as the area of application.

PG 52–28, the asphalt cement obtained from Turkish Petroleum Refineries, was used as a neat binder. The neat binder was modified with American Gilsonite (AG), Iranian Gilsonite (IG), and SBS. The SBS polymer (Kraton D-1101), AG, and IG were obtained from Shell Chemicals Company, American Gilsonite Company, and Aydin Trade Company, respectively. Used modifiers was shown in Figure 2.

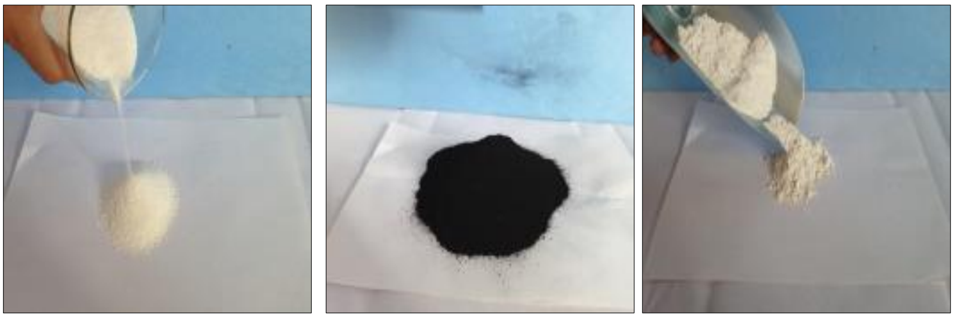


Figure 2. Used SBS (a) Gilsonite (c) and hydrated lime

For the purpose of preparing the modified binders, the neat bitumen and additives were mixed for 60 minutes at a temperature of 180ºC inside a mixer with a rotating rate of 1,000 rpm. At the end of the dynamic shear rheometer (DSR) experiments, it was decided that 11.0% of AG ($MB_{11\%AG}$), 10.0% of IG ($MB_{10.0\%IG}$) and 4.0% of SBS ($MB_{4.0\%SBS}$) should be used. DSR and bending beam rheometer (BBR) test results of neat and modified bitumens are presented in Table 1. As seen in Table 2, the modified bitumen performance level is PG 70-22, which meets the necessary level for the area of application [23]. Viscosity values were increased due to use of additives, which in turn increased the mixing and compaction temperatures.

Table 1. Binder test results [23]

DSR test results				
Temp.(°C)	G*/sinδ (kPa) (specification limit min. 1 kPa)			
	PG 52-28	$MB_{4.0\%SBS}$	$MB_{11.0\%AG}$	$MB_{10.0\%IG}$
52	1.803	-	-	-
70	-	1.279	1.334	1.291
	G*/sin δ (kPa) RTFOT residue (specification limit min. 2.2 kPa)			
52	14.460	-	-	-
70	-	7.318	8.163	8.769
	G*.sin δ (kPa) PAV residue (specification limit max. 5000 kPa)			
16	2578	-	-	-
28	-	1158	1754	1746
BBR test results				
Temp.(°C)	m-value (specification limit min. 0.300)			
	PG 52-28	$MB_{4.0\%SBS}$	$MB_{11.0\%AG}$	$MB_{10.0\%IG}$
-12	-	0.310	0.310	0.305
-18	0.514	0.278	0.405	0.723
-24	0.587	0.258	0.250	0.531
	Creep stiffness (Mpa) (specification limit max. 300 MPa)			
-12	-	80.4	134.0	86.0
-18	182.6	125.1	389.9	359.3
-24	364.3	228.6	433.7	599.0
	Performance grades (PG)			
	52–28	70–22	70–22	70–22
Rotational viscosity test results				
Viscosity (cP, 135°C)	250.0	1038.0	662.5	700.0
Viscosity (cP, 165°C)	87.5	325.0	187.5	200.0
Mixing temperature range (°C)	146–154	171–173	165–168	166–168
Compaction temperature range (°C)	124–135	166–168	157–161	159–162

The limestone aggregate was used for the asphalt mixtures. The properties of aggregate are given in Table 2 and the gradation of the aggregate mixtures is given in Figure 3. A crushed coarse and fine aggregate with a maximum size of 19 mm was selected for a dense graded asphalt mixture.

Table 2. Physical properties of the aggregate

Properties	Standard	Specification limits	Coarse	Fine	Filler
Abrasion loss (%) (Los Angeles)	ASTM D 131	Max 30	25.4	-	-
Abrasion loss (%) (Micro deval)	ASTM D 6928	Max 15	13.3	-	-
Frost action (%) (with Na_2SO_4)	ASTM C 88	Max 10	4.9	-	-
Flat and elongated particles (%)	ASTM D 4791	Max 10	3		

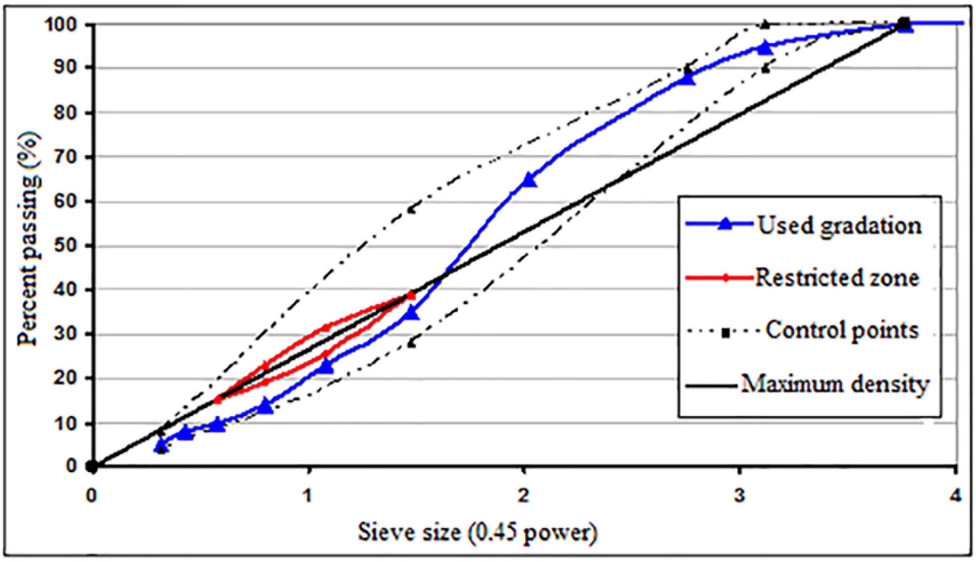
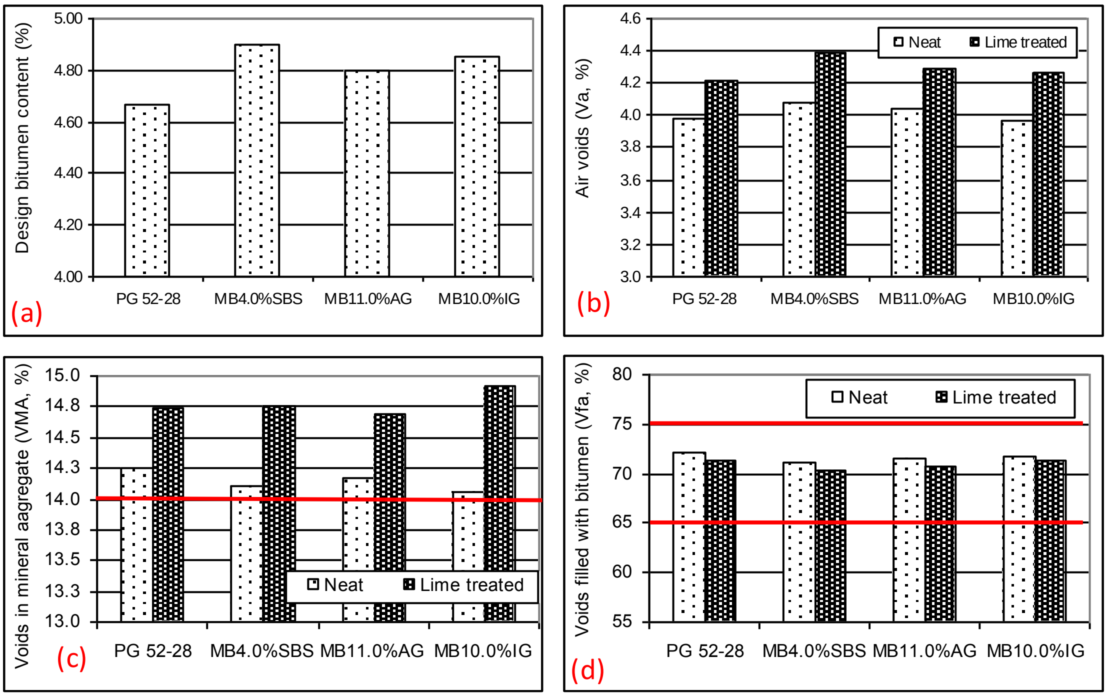


Figure 3. Combined aggregate gradation

The aggregate gradation was kept constant for all mixtures by using hydrated lime instead of 2% limestone filler in the hydrated lime containing mixtures. The design bitumen contents (DBC) of the singly limestone containing mixtures were determined in accordance with the Superpave mix design method. In the hydrated lime containing mixtures, the same bitumen contents which were specified for the singly limestone containing mixtures were used. The volumetric properties and specification limits of the control and modified mixtures are indicated in Figure 4. It was ensured for all of the mixtures to be within the Superpave specification limits.



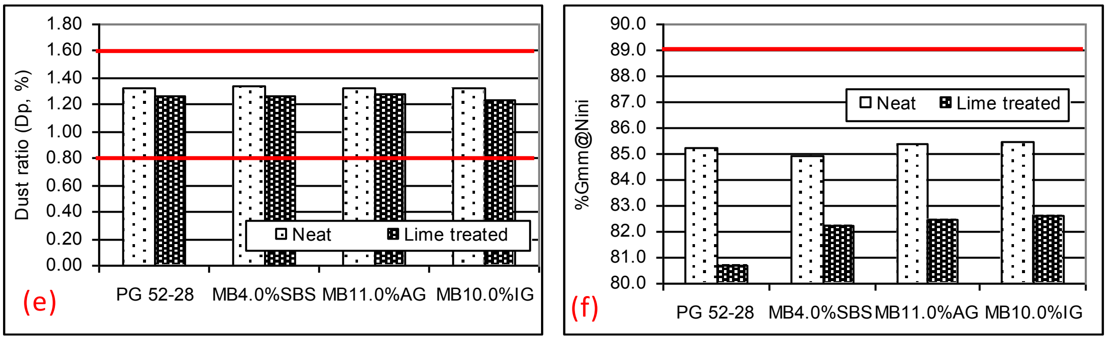


Figure 4. Volumetric properties of mixtures

2.1. Dynamic Creep Test

One of the most commonly used tests to determine the resistance of hot mix asphalt to the formation of permanent deformations is dynamic creep test. One of the reasons why this test is preferred is its convenience in the application and its consistent relationship with the formation of permanent deformations [25]. Thus, a constant rate of load is repetitively applied within certain periods on the surface of the cylindrical sample, which is either manufactured in a laboratory or obtained on site (Figure 5). With the help of the LVDTs placed vertically on the metal plate placed on the sample, the plastic and elastic deformations that occur after each repetition of load can be determined. The test can be conducted with various loads at various temperatures. By using the following formulas, the creep and resilient modulus can be calculated [26].

$$\varepsilon_c = (L3_n - L1)/G \tag{1}$$

$$\varepsilon_r = (L2_n - L3_n)/(G - (L3_n - L1)) \tag{2}$$

$$\sigma = F/A \tag{3}$$

$$E_r = \sigma/\varepsilon_r \tag{4}$$

Here, ε_c represents the total plastic (permanent) axial unit deformation, while ε_r represents the total elastic axial unit deformation. E_r represents the resilient modulus (toughness). G is the initial height of the sample (mm). L1 represents the initial reference displacement (mm), while L2n represents the maximum displacement (mm) at n impact number (elastic + plastic), and L3n is the (n+1) displacement before applying an impact (mm) (plastic). σ is the maximum vertical stress (kPa) while F is the maximum vertical load (N) and A is the area of cross-section (cm^2). As can be seen in Formula 4, the elastic unit deformation is inversely proportional to the resilient modulus value. With the increasing elastic unit deformation, the resilient modulus decreases. Thus, the hot mix asphalt with a high resilient modulus value exhibits less elastic behavior.

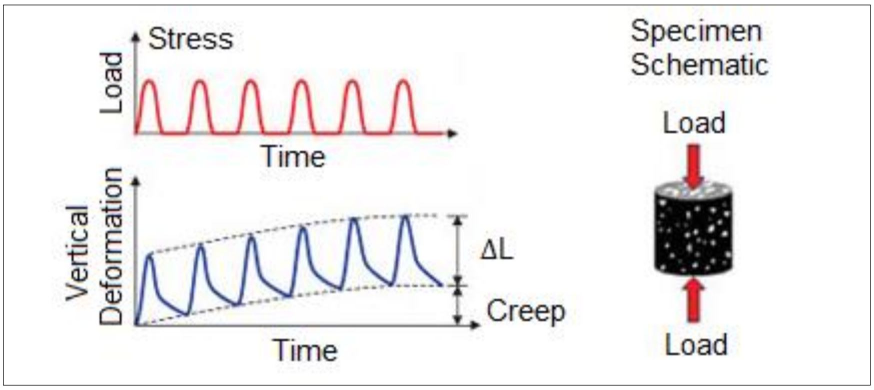


Figure 5. Relationships between the Load-Time and the Deformation-Time [27]

The dynamic creep test is conducted by using UMATTA test device. The test setup can be seen in Figure 6. The test system consists of a climate chamber, a loading frame, the software and a computer. The test can be conducted at the desired temperature thanks to the climate chamber. Before the test is conducted, samples are kept at the testing temperature at least for 4 hours in order to ensure that the temperature completely penetrates in the sample. The properties of the samples such as sample's height and diameter, the load to be applied, pre-load time, pre-load stress, loading period and increasing load time are entered into the software. Then, the sample is placed on the loading frame and the LVDTs, which will measure the vertical deformation, are configured before the test is initiated. During the test, it is first aimed to perform the initial rutting by applying the pre-load with the determined value of time and stress. At the end of the pre-load time, the test is proceeded on the normal stress level by applying dynamic loads until the desired load cycle is achieved or the sample is deformed.

Figure 6. Dynamic creep test setup

3. Results and Discussion

In this study, SBS, Iranian Gilsonite, and American Gilsonite were used for the bitumen modification. In addition, mixtures with neat and 3 distinct modified bitumen were prepared by using 2% hydrated lime. A total of 8 distinct types of mixtures were obtained. Three samples were prepared for each of these 8 distinct mixtures by using the gyratory compactor, which can be seen in Figure 7.

Figure 7. Gyratory Compactor

3.1. Results of Dynamic Creep Test

In this study, dynamic creep tests were conducted on 8 distinct mixtures by using the UMATTA test device. In these tests, the pulse period was set to be 1000 ms, while the pulse period was set to be 500 ms. The test loading stress was set to be 500 kPa, while the testing temperature was set to be 50 °C. All of the mixtures were subjected to the test under the same conditions.

All of the samples were subjected to 10,000 load cycles. The deformation-load cycle graph of the lime-free neat mixtures and the mixtures with modified bitumen was presented in Figure 8(a) while the load-deformation graph of mixtures without lime and with modified bitumen was presented in Figure 8(b).

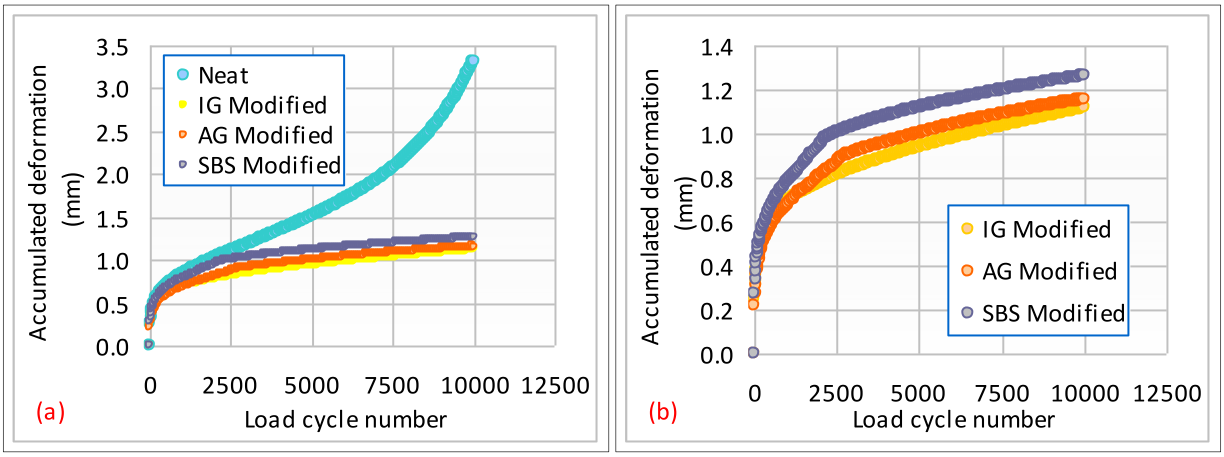


Figure 8. Load-deformation curves of mixtures prepared with neat and modified bitumen (a) and only modified bitumen (b)

As can be seen in Figure 8(a), the permanent deformation values significantly decrease with the use of SBS, IG, and AG in the bitumen modification compared to the mixtures prepared with a neat binder. It was determined that the permanent deformation values of mixtures prepared with a neat binder following the 10,000 load cycles were 2.63, 2.87 and 2.97 times higher than the mixtures prepared with SBS, AG, and IG following the same number of load cycles, respectively. As can be seen in Figure 8(b), the most effective additive is IG, while the least effective additive is SBS. The permanent deformation values of the mixtures modified with AG and IG following 10,000 load cycles were 8.48% and 11.41% lower, respectively, compared to the mixtures modified with SBS. The deformation-load cycle graph of the mixtures prepared with lime, neat and modified bitumen following 10,000 load cycles is given in Figure 9(a) while the deformation curves of the mixtures prepared with lime and modified bitumen are given in Figure 9(b).

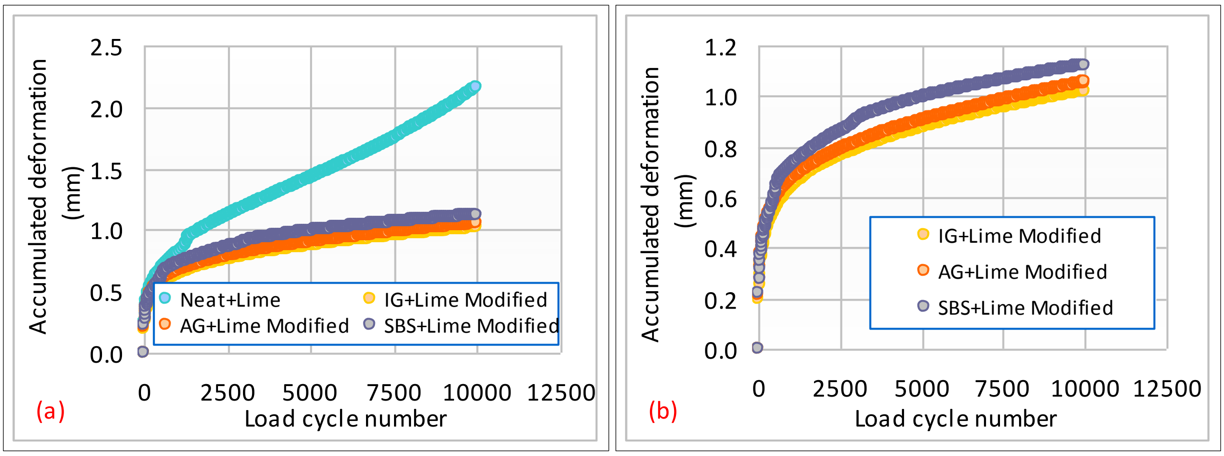


Figure 9. Load-deformation curves of mixtures prepared with 2% hydrated lime as filler, neat and modified bitumen (a), and only with modified bitumen (b)

The mixtures without lime, it has been determined that the mixtures with lime also have significantly lower deformation values following the 10,000 load cycles, compared to the mixtures prepared with a neat binder (Figure 9(a)). The deformation values of mixtures prepared with 2% lime as filler and a neat binder were 1.92, 2.05 and 2.12 times higher compared to the mixtures prepared with 2% lime as filler and the bitumen modified with SBS, AG, and IG, respectively. As can be seen in Figure 9(b), considering the modified bitumen, the most effective one was IG again, while the least effective one was SBS. The deformation values of the mixtures prepared with 2% hydrated lime as filler and bitumen modified with AG and IG following 10,000 load cycles had 6.22% and 9.24% less deformation, respectively, compared to the mixtures prepared with bitumen modified with SBS. The deformation-load cycle number graph of the mixtures prepared both with lime, without lime, and with neat bitumen is given in Figure 10(a). The deformation-load cycle number graphs of the mixtures prepared with SBS, AG, and IG modified bitumen are given in Figure 10(b), Figure 10(c) and Figure 10(d), respectively.

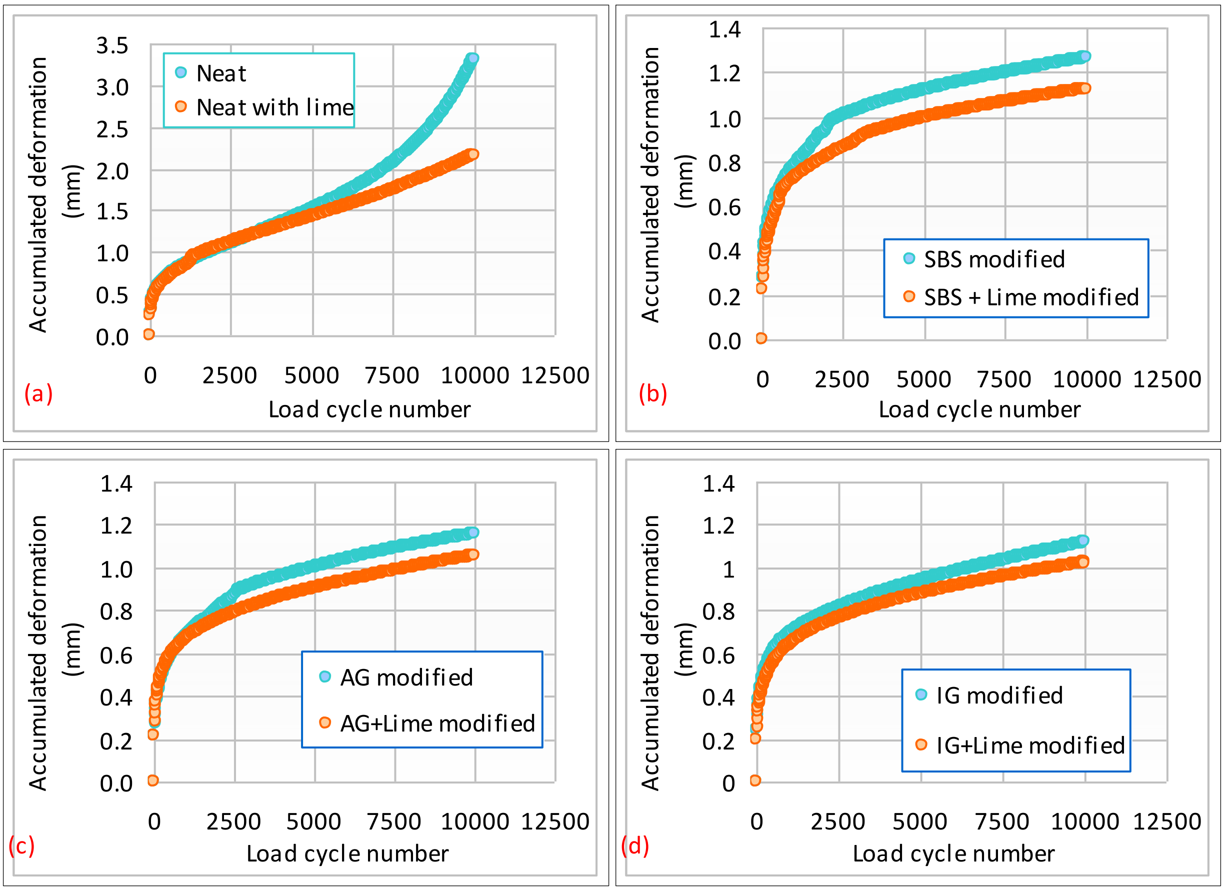


Figure 10. Accumulated deformation-load cycle number variations of mixtures prepared with neat bitumen (a) and SBS (b), AG (c) and IG (d) modified bitumen, as well as with lime and without lime

As can be seen in Figure 10, the permanent deformation values of all mixtures decreased with the use of lime. The deformation values of the mixtures prepared with neat bitumen and 2% hydrated lime as filler following 10,000 load cycles decreased by 34.88%. The deformation values of mixtures prepared with SBS, AG, and IG modified bitumen, and 2% hydrated lime as filler following 10,000 load cycles decreased by 10.86%, 8.66%, and 8.68%, respectively. Of these values with lime use, the permanent deformation value decreased the most for the mixtures prepared with a neat binder followed by the mixtures prepared with the SBS, IG, and AG modified bitumen, respectively. According to the results obtained, it has been determined that the use of hydrated lime as filler is most effective when used in mixtures prepared with neat bitumen for resistance to permanent damage, while the efficacy is similar for mixtures prepared with the AG and IG modified bitumen, but less effective compared to mixtures prepared with the SBS modified bitumen. The resilient modulus variances of the mixtures without lime up to 10,000 load cycles are given in Figure 11(a), while the resilient modulus variances of the mixtures with lime up to 10,000 load cycles are given in Figure 11(b).

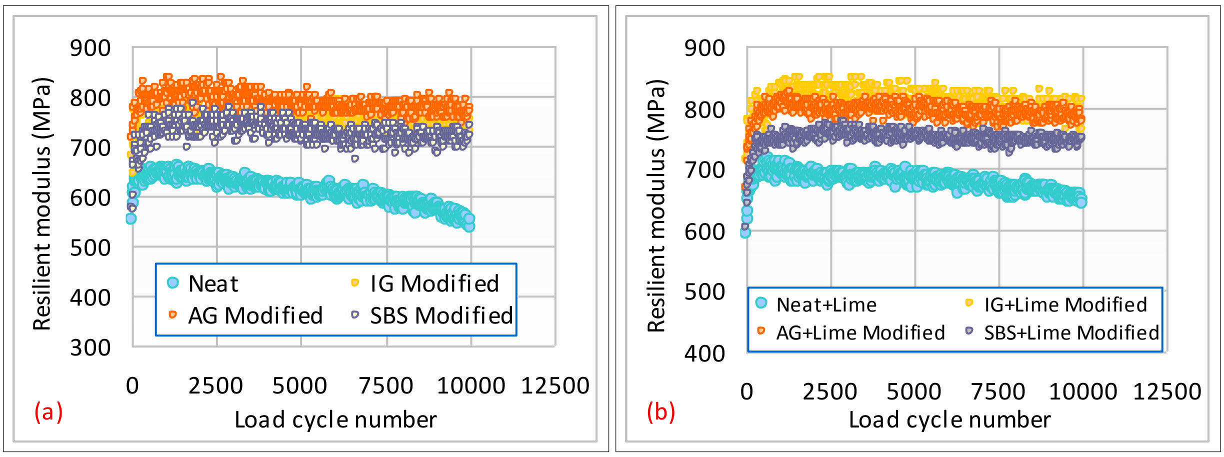


Figure 11. Resilient modulus variances of mixtures without lime (a) and with lime (b) with load cycle number

As can be seen in Figure 11, which demonstrates the resilient modulus variances with load cycle, it has been determined that the resilient modulus value increases up to first 1,000 cycles for all mixtures. However, it has also been determined that a constant decrease occurs with the increasing number of cycles. Khodaii and Mehrara reported that permanent deformations of HMAs that occur due to consolidation affect the resilient modulus [5]. In addition, they reported that during the dynamic loading, the increase in the resilient modulus is caused by the compaction that occurs in the mixture. In this study, the increase in resilient modulus up to the first 1,000 cycles was caused by a decrease in elastic unit deformation due to consolidation. After the first 1,000 cycles, the decrease in the resilient modulus of all mixtures was caused by the increase in elastic unit deformation due to a decrease in stiffness. Thus, the fact that the decrease in resilient modulus is low indicates that mixtures conserve their stiffness. Furthermore, among all mixtures with and without lime, the fact that neat bitumen had the lowest resilient modulus value indicates that the highest elastic deformations were those of the mixtures prepared with neat bitumen. For the mixtures prepared with modified bitumen, it has been determined that the most elastic behavior is exhibited by the mixtures prepared with SBS modified bitumen, while mixtures prepared with the AG and IG modified bitumen exhibit similar variations. The variations in resilient modulus with load cycles for mixtures prepared with and without lime are given in Figure 12.

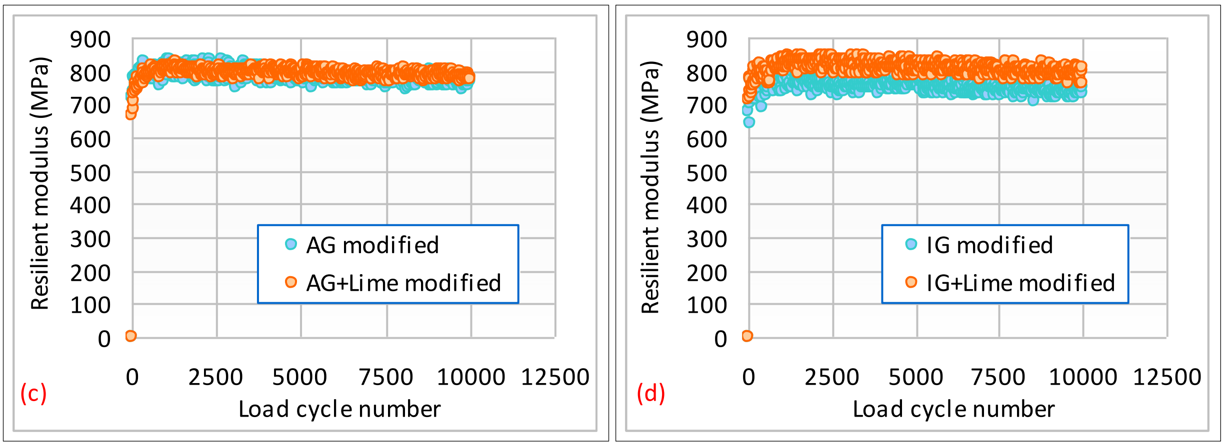


Figure 12. Variations in resilient modulus with load cycles for HMAs prepared with neat bitumen (a) and with SBS (b), AG (C) and IG (d) modified bitumen

As can be seen in Figure 12(a), the resilience module in the lime-free mixture prepared with a pure binder decreased significantly as a result of 10.000 load cycles, while it exhibited a more stable behavior with the use of lime. This situation was caused by the improvement in stiffness of the mixture with lime use. Furthermore, following the load cycle, there was no significant decrease in the resilient modulus value of the mixtures prepared with the modified bitumen. For the mixtures prepared with the SBS and IG modified bitumen, the resilient modulus values of the mixtures with lime were determined to be higher than those without lime. Thus, the use of lime in these mixtures decreases the elastic deformation. For the mixtures prepared with the AG modified bitumen, there was no significant change in the resilient modulus value with the use of lime. After 10,000 load cycles, the resilient modulus difference between those with and without lime was determined to be 13.62% for the mixtures prepared with a neat binder. For the mixtures prepared with the AG, IG and SBS modified bitumen, the resilient modulus value differences with the use of 2% hydrated lime were determined to be 1.8%, 1.46%, and 4.27%, respectively.

In a previous study conducted, the effects of additives and lime use on rutting formation were investigated by using the wheel tracking test method [23]. The results obtained in this study were found to be similar to the results of the previous study, indicating that the most effective additive in terms of resistance to permanent deformation is AG, while the least effective one is SBS and lime use is not as effective as the additive use.

4. Conclusion

In this study, the use of three different additives (AG, IG, and SBS) in bitumen modification and 2% hydrated lime use as filler were investigated in terms of their effects on the hot mix asphalts' resistances to permanent damage by using the dynamic creep test. The effects of the additives were determined by applying the dynamic creep test on 8 distinct mixtures prepared with the designed bitumen contents.

For the mixtures with and without lime, it was determined that the mixtures prepared with neat bitumen have the least resistance to creep permanent deformation, while the mixtures prepared with the IG modified bitumen have the highest resistance. Even though the resistance to creep permanent deformation improved with the use of lime, it was determined that the use of 2% hydrated lime as filler was not as effective as the use of additives for bitumen. Also for the mixtures prepared with modified bitumen, it was determined that hydrated lime use improved the resistance to creep permanent deformation.

Considering the resilient modulus values, it was determined that lime was most effective in the mixtures prepared with neat bitumen. Especially for the mixtures prepared with AG modified bitumen, it was determined that 2% hydrated lime use had no significant effect on the resilient modulus values.

According to the results obtained, it is concluded that even though the use of hydrated lime in the mixtures prepared with a neat binder results in an improvement in terms of resistance to creep permanent deformation, it is seen that the lime use has no significant effect in the mixtures prepared with modified bitumen. Thus, it can be suggested that, in terms of resistance to creep permanent deformation, it would be better if lime is not used together with the modified bitumen.

6. References

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