Evaluating and Modeling of Modified Asphalt Binder at Elevated Temperatures

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Abstract. Many regions in Iraq with high weathering temperature suffer from very hot climate during a long summer season continue to more than 5 months with temperature rise to more than 50°C. Also, increasing road traffic and axial loads causing a permanent deformation that leads to decrease pavement performance and reducing its life. Asphalt binder is considered one of the most significant keys in flexible pavement and its characteristics have a great impact on asphalt mixtures so choosing the suitable type of asphalt binder may improve its performance and control on permanent deformation failures. In this research, Daurh and Basrah asphalt binders were chosen to be characterized and enhanced their properties by using some modifiers. Three types of modifiers were selected with different percentages, styrene-butadiene-styrene (SBS), butyl rubber (BR) and BG plus anti-stripping agent. The results showed Multi Stress Creep and Recovery (MSCR) test is a suitable technique to evaluate the improvement of asphalt cement. The degrees of improvement in the percent of recovery %R and the non-recoverable compliance Jnr values and percent of reduction accumulated strain at 0.1 and 3.2 kPa after asphalt modification is higher for the SBS followed by BR then BG plus and Durah asphalt binder has better rutting resistance than Basrah asphalt cement. The behavior of modified asphalt cement modeled as viscoelastic materials and predicted the sigmoidal model as a suitable mechanical model to represent this behavior.

Keywords: Asphalt cement; MSCR; recovery percent R; non-recoverable compliance Jnr; sigmoidal model

1. Introduction
Rutting distress in flexible pavements appears due to the repeated traffic loading as a result of the accumulation of permanent deformation and significantly influenced by asphalt binder’s rheological
properties (Cooper et al., 1985 and Sousa et al., 1991). Due to the viscoelastic behavior and thermal susceptibility of asphalt binder, permanent deformation is greatly increased at high temperatures and in the existence of heavy and slow-moving vehicles. In general, the rutting phenomenon reduces the comfortable and safety envisaged by the users of roads, therefore using asphalt cement with good rheological properties will increase the resistance of pavement to this phenomenon. To attain this aim, construction materials in flexible pavement need to be thoroughly selected by indicating the results of authoritative laboratory testing, that able to assess their irreversible strain response under repeated loading and yielding actual performance that related to ranking.

This would force the researchers to develop more advanced ways to enhance the asphalt pavement to resist the high temperatures and loads and also to enhance the evaluating methods of those materials. The main goal of these improvements is to provide asphalt pavement material with higher durability and last longer which results in cost-effective material. One of the common ways to achieve such improvements is to add some polymer modifiers to the asphalt cement to reduce rutting and cracking (D'Angelo, 2007).

When asphalt cement used as construction materials of roads, it should be tested in a series of tests to evaluate its strength and capability to resist rutting and cracking phenomena. The elastic recovery test is the main test used to evaluate the existence of elastomers in the modified asphalt cement. Increasing the percentage of elastomers improves the rutting resistance of flexible pavement. However, the state Department Of Transportation (DOT) experts were not satisfied with this test because the test needs a long time to finish (4-5 hours) and most agencies do not follow (AASHTO) standard guidelines to conduct the test (D'Angelo, 2007 and Abedali, 2017).

The traditional SHRP parameter (G*/sin(δ)) (Anderson et al., 1994) certified in performance grading proved to be inappropriate in assessing the actual potential of asphalt cement to anti-rutting, particularly in the case of products of polymer-modified asphalt binder (Bahia et al., 2001). The limits of the SHRP approach are essentially connected to the fact that the (G*/sin(δ)) is identified by using small-strain oscillatory loading within the linear-viscoelastic range, away from real conditions of damage. Many studies have been conducted by (Bahia et al.,(2001), Masad et al.,(2009) and Saboo and Kumar, (2016)) to get over these limitations, resulting in developing of several standard methods used to evaluate the rutting properties of asphalt binders. among these tests, the Multi-Stress Creep and Recovery Test (MSCR) had a prominent role because of its ability to simulate the discontinuous traffic loading nature and material dependence on stress (AASHTO TP 70,2013).

To replace (G*/sin(δ)), the current parameter of Superpave at a high temperature of asphalt cement, a new test, named Multi Stress Creep and Recovery (MSCR), was studied extensively (D'Angelo, 2009). In this test, a series of shear creep and recovery is used. In its current form, the MSCR test composes of 1 second of creep loading followed by 9 seconds of recovery over multiple stress levels of 0.1kPa and 3.2kPa at 10 cycles for each level of stress (Wasage et al., 2011).

MSCR is considered a new test method that has been introduced to evaluate the resistance of asphalt mixture to permanent deformation. According to Saboo and Kumar (2016), the MSCR test method was introduced as a part of the new Superpave grading system (AASHTO MP 19-10) and accepted as a standard. The MSCR test output used to determine non-recoverable creep compliance (Jnr) and recovery percent (%)R for identifying the susceptibility of different types of asphalt cement to permanent deformation. The experimental results showed that there is a good correlation between the unrecoverable creep compliance (Jnr) at 3.2 kPa and the actual field performance (Kumar et al., 2017). The (Jnr) parameter determining at high values of used stresses and at non-linear material characteristics have is more accurate because the strain in asphalt binder film on aggregate surfaces is much greater than the strain that happens in asphalt mixtures (Subhy, 2017).

Eventually, (MSCR) test was created as an alternative for the presence AASHTO M 320 test at high temperature for asphalt cement. The output results obtained from the MSCR test can also be used as a replacement for the different SHRP tests. Also, to demonstrate the essential properties of the MSCR test likes an easy to use in the performance-related test. According to Golalipour, (2011), both base and modified asphalt cement were evaluated in the developed a new asphalt cement test to identify the
permanent deformation property at high temperatures for asphalt cement. Equipment that used in the testing of the asphalt cement was the existing dynamic shear rheometer (DSR) which is widely accepted equipment by highway agencies that used in identifying the rheological properties of asphalt cement in specifications that related to the stress-strain response of viscoelastic materials and is very appropriate to assess asphalt types of cement (Golalipour, 2011). This study will focus on the following objectives:

1. Quantify the percent recoveries (%R) and non-recoverable compliance (Jnr) of the base and modified asphalt cement by using the Multiple Stress Creep and Recovery (MSCR) test.
2. Examine the viscoelastic behavior of asphalt cement before and after using modifiers and the effect of modification on an elastomeric response and the recovery rates.
3. Simulate the behavior of asphalt cement as viscoelastic materials.

2. Experimental work

2.1. Materials

Two types of modified and unmodified asphalt types of cement were collected to perform the (MSCR) and frequency sweep test. To cover a wide range of viscoelastic properties of asphalt cement, ten samples of asphalt cement (base and modified) were used in this experimental work included two samples of AC 40-50 base asphalt binder from two different refineries (Al-Basrah and Al-Durah). Their physical properties are presented in Table 1, the other samples included modified asphalt cement with radial styrene–butadiene styrene (SBS) with different percentages (5% and 7% by weight of asphalt cement) mixed with asphalt cement for 2 hours and 180 °C as a mixing temperature (Kareem, 2016), one percentage of Butyl rubber (BR) (9% by weight of asphalt cement) mixed at a temperature of 165 °C for 60 minutes (Liu and Weilong, 2003), and one modified asphalt cement with 0.075% (by weight of asphalt cement) of a liquid anti-stripping agent (BG plus), the product from Sika IRAQ L.L.C that mixed at a temperature of 150 °C and for 30 minutes. The properties of BG plus and SBS are presented in Tables 2 and 3 respectively. All samples were prepared using a blending machine with 500 rpm and subjected to DSR and MSCR tests to measure the rheological properties and evaluate of non-recoverable creep compliance parameters of Jnr0.1 and Jnr3.2 correspondent to 0.1 and 3.2 kPa stress levels respectively.

| Table 1. Physical and rheological properties of base asphalt cement (AC). |
|-----------------------------------|-------------------|-------------------|
| Property                          | Basrah asphalt cement | Durah asphalt cement |
| Penetration                       | 41                 | 43                 |
| Rotational viscosity (c.P)        | 527.1              | 479.01             |
| Softening point (˚C)              | 52                 | 51                 |
| Penetration Index (PI)            | -1.2               | -1.3               |
| Complex modulus G*(Pa) at 40˚C and 10 Hz | 5.5*10^5          | 5.43*10^5          |
| Phase angle (δ°)                  | 60.79              | 61.13              |

| Table 2. Properties of BG plus anti-stripping agent. |
|-----------------------------------------|------------------------|
| Property                                | Requirement            |
| Chemical Base                          | Nanotechnology, Silane based |
| Form                                    | Liquid                 |
| Appearance                              | Pale yellow            |
| Density                                 | 1.0 Approximately @ 27° C |
| pH Value                                | Approx. 9.00           |
| Consumption / Dosage                    | 0.02% to 0.1%, By weight of |
Table 3. Properties of SBS modifier.

| Property          | Unit | Requirement |
|-------------------|------|-------------|
| Density           | Kg/m³| 1240        |
| Specific gravity  | -----| 0.95        |
| Tensile Strength  | MPa  | min.32      |
| Melting point     | °C   | 170-190     |
| Elongation        | %    | 880         |
| Molecular structure| -----| Radial     |

2.2 Laboratory Tests

2.2.1 Multiple Stress Creep and Recovery Test

RHEOTEST model RN4.3 dynamic shear rheometer (DSR) as shown in Figure 1(Abed and Al-Haddad, 2020) was used to establish a creep and recovery test concept to assess the potential of asphalt binder to rutting for both base and modified asphalt cement. Asphalt binder can be represented as a sandwiched between the DSR’s parallel plates (25mm) with a 1mm gap setting, ten cycles of creep and recovery are conducted at two levels of stress as suggested in AASHIO (0.1 and 3.2 kPa). The test is conducted according to ASTM D7405–15 specifications at 64°C. The new test procedure allows two stress levels of 0.1 (to describe asphalt cement’s behavior within the linear viscoelastic region) and 3.2 Kpa (represent a binder’s behavior within a non-linear viscoelastic region) for both base and modified asphalt cement as shown in Figure 2, to be applied for 1 second and allow recovery for analysis of Multiple Stress Creep and Recovery(MSCR) for Iraqi modified asphalt cement followed 9 seconds for 10 cycles and no time lag between cycles are applied as shown in Figure 3. The parameters that are obtained from the MSCR test are:

\[ R_{0.1} = \frac{\sum (\varepsilon_r(0.1,N))}{10} \]  \text{ for } N=1 \text{ to } 10 \hspace{1cm} (1)

\[ R_{3.2} = \frac{\sum (\varepsilon_r(3.2,N))}{10} \]  \text{ for } N=11 \text{ to } 20 \hspace{1cm} (2)

Non-recoverable creep compliance between 0.1 kPa and 3.2 kPa are determined using Equations (3) and (4) below:

\[ J_{nr}(0.1) = \frac{\sum (J_{nr}(0.1,N))}{10} \]  \text{ for } N=1 \text{ to } 10 \hspace{1cm} (3)

\[ J_{nr}(3.2) = \frac{\sum (J_{nr}(3.2,N))}{10} \]  \text{ for } N=11 \text{ to } 20 \hspace{1cm} (4)

\[ J_{nr} \]: non-recoverable creep compliance and \[ R \]: percent of Recovery.
Figure 1. RHEOTEST model RN4.3 dynamic shear rheometer (DSR).

Figure 2. A typical plot of the MSCR curve for modified Durah binder with a 7% SBS modifier.

Figure 3. A typical one cycle of creep-recovery for Daurah binder modified by 7% SBS
2.2.2 Frequency Sweep Test

Rheological testing was performed on an RHEOTEST model RN4.3 dynamic shear rheometer (DSR) to evaluate the rheological behavior of modified and base asphalt binder from Durah and Basrah refineries and using parallel plate geometry based on ASTM (D7175 – 08) “Determining the Rheological Properties of Asphalt Binder Using DSR” Plates diameter was 8 mm with gap 2mm between them and plate with 25 mm diameter and 1 mm gap, depending on test temperatures.

The frequency sweep test is considered as a useful way of measuring the viscoelastic properties of asphalt cement in DSR. The procedure of this test composes of applying constant low-level load amplitude to avert asphalt specimen damaging overloading frequencies rang (typically from 0.1 to 10 Hz due to equipment limitations).

To assure results repeatability, all tests were performed at least twice. Viscoelastic behavior of asphalt cement was considered linear when the modulus value had not deviated more than 5% from its initial value and the results of complex modulus are used to predict a mathematical model to describe the rheological properties of binders. In this study, the rheological tests were conducted under the controlled-stress conditions at low and intermediate temperatures (4, 16 and 28) °C using plate’s diameter 8 mm with 2 mm gap opening and at a higher temperature (40, 55 and 70) °C using 25 mm diameter plate to plate, and 10 rad/s of frequency and 1 mm gap opening.

3. Results and Discussion

MSCR test was carried out to study the behavior of the materials at higher stresses level in regions exceeded the linear viscoelastic limits. The output data of the MSCR test is utilized to determine the nonrecoverable creep compliance (Jnr) and recovery percent (%R) for identifying the susceptibility of asphalt cement to permanent deformation or rutting. Non-recoverable creep compliance (Jnr), is calculated by dividing non-recoverable shear strain by the shear stress and used to assess the rutting potential of the asphalt cement. The results presented in Figure 3 and Figure 4 showed that the addition of the modifiers provides a high reduction in strain values compared with base asphalt binder, which is an improvement to the performance.

At both stress levels, 0.1 and 3.2 KPa, it can be noticed that the reduction of the accumulated strain is more than 4.5 times for 9% BR, 13 times for 0.075% of BG Plus, 14.31 times for 5% SBS and 66.5 times for 7% SBS when compared them with base Basrah asphalt cement at 0.1 KPa stress level.

While the effect of modifiers on Durah asphalt cement was better than Basrah asphalt cement, the reduction in accumulated strain is more than 6.5 times for 9% BR, 6.1 times for 0.075% of BG Plus, 58.43 times for 5% SBS and 116 times for 7% SBS when compared them with base asphalt binder.

3.1 Percent of Recovery (%R)

Using the modifiers with base asphalt cement of Durah and Basrah refineries increased elastic recovery of the binders to maximum values between (21.2-36) at stress level 0.1 KPa and between (52.93 – 64.45) at stress level 3.2 KPa compared to the base binders indicating a superior polymer network in the binder as shown in Tables 4 and 5 and Figures 5 and 6. The highest values of recovery percent at the 7% SBS modified asphalt binder, followed by asphalt binder modified with 5% SBS, then asphalt binder modified 9% BR and, as the last one, the base asphalt cement. In general, the unmodified asphalt binder would suffer a lower percentage of recovery than those modified with modifiers. Interestingly, the results show that at 0.1 KPa the addition of 7% SBS to the base binder for both types of asphalt binders recorded a high percentage of the recovery. However, it reduced between (33- 49) % when increasing the stress to 3.2 KPa for both types of asphalt cement. On the other hand, adding %7 of SBS to the base binder increases the recovery percent by 21.2 and 52.93 times compared to the base binder at 0.1 and 3.2 KPa respectively for Durah asphalt binder and by 36 and 64.45 times compared to the base binder for Basrah asphalt cement.
Table 4. The MSCR parameters at the two stress levels for Durah asphalt cement (AC).

| Binder type           | MSCR Parameters | Different percentage in Jnr |
|-----------------------|-----------------|-----------------------------|
|                       | at stress level 0.1 kPa | at stress level 3.2 kPa
|                       | R (%)   | Jnr (1/kPa) | R (%)   | Jnr (1/kPa) |
| base                  | 4.381   | 3.012       | 0.894   | 4.166       | 38.346      |
| AC with 5%SBS         | 73.535  | 0.047       | 43.139  | 0.134       | 183.263     |
| AC with 7%SBS         | 92.801  | 0.013       | 47.32   | 0.124       | 857.360     |
| AC with 9%BR          | 29.839  | 0.460       | 27.028  | 0.629       | 36.862      |
| AC with 0.075%BG      | 4.561   | 2.665       | 0.965   | 3.819       | 43.311      |

Table 5. The MSCR parameters at the two stress levels for the Basrah asphalt cement (AC).

| Binder type           | MSCR Parameters | Jnr Percent difference |
|-----------------------|-----------------|------------------------|
|                       | at stress level 0.1 kPa | at stress level 3.2 kPa |
|                       | R (%)   | Jnr (1/kPa) | R (%)   | Jnr (1/kPa) |
| base                  | 2.532   | 4.059       | 0.942   | 5.203       | 28.209      |
| AC with 5%SBS         | 41.799  | 0.254       | 17.198  | 0.475       | 86.557      |
| AC with 7%SBS         | 91.344  | 0.027       | 60.719  | 0.176       | 555.390     |
| AC with 9%BR          | 22.859  | 0.843       | 21.878  | 1.203       | 42.670      |
| AC with 0.075%BG      | 8.743   | 3.084       | 0.675   | 2.136       | 44.382      |

Figure 4. Accumulated strain for base and modified binders at 3.2kPa stress level.

Figure 5. Accumulated strain for base and modified binders at 0.1kPa stress level.

Figure 6. Variations in percent recovery at 0.1kPa and 3.2 kPa stress level for modified and pure Durah asphalt binder.

Figure 7. Variations in percent recovery at 0.1kPa and 3.2 kPa stress level for modified and pure Basrah asphalt binder.
3.2 Non-recoverable creep compliance (Jnr)

The improvement of modified asphalt cement can be estimated by the non-recoverable compliance (Jnr); which is sensitive to the applied stress and measured by 1/kPa. In this study, Jnr was calculated for the base and modified asphalt cement, and two kinds of asphalt binders, Figures 7 to 9 presents the variation of creep compliance at 0.1kPa and 3.2 kPa stress levels of asphalt binder with and without additives at 64°C. Decreased the non-recoverable compliance Jnr values of modified asphalt binder at the typical highest pavement temperature of 64°C in both stress levels, indicates that all modified asphalt cement are less susceptible to rutting than the base material because of the lower the Jnr value the stiffer the binder.

For both types of binders, Jnr was calculated for the base and modified binders as shown in Figures 7 and 8. It can be showed that increasing the stress from 0.1 to 3.2 Kpa did not make significant performance change in most of the binders especially those modified with elastomers as shown in Tables 2 and 3 for both types of asphalt cement. The Jnr results confirm the findings that the binder modification by 7% SBS resulted in the lowest value of Jnr which means that it has the best performance among the other modified binders in this study. The addition of SBS to modify asphalt cement achieved good behavior and approximately sustained that behavior with the increase of the applied stress followed by 5%SBS, 9% BR then 0.075% BG Plus when comparing them with base asphalt binder. Therefore, it could be mentioned that SBS modification is a good option for both local base binders. Depends on the results presented in Figure 10, Durah asphalt cement has better rutting resistance than Basrah cement.

![Figure 7: Variations in creep compliance at 0.1kPa and 3.2 kPa stress levels of Durah asphalt binder with and without additives at 64°C.](image1)

![Figure 8: Variations in creep compliance at 0.1kPa and 3.2 kPa stress levels of Basrah asphalt binder with and without additives at 64°C.](image2)
4. Modeling of Experimental Data

This research investigates the use of one mathematical model namely the sigmoidal model, to describe the rheological properties of asphalt cement. Mathematically, the sigmoidal model can be presented in Equation 5:

\[ \log|G| = \delta + \frac{\alpha}{1 + e^{\beta \gamma \log(f_r)}} \]  

Where: \( G^* \) is the complex shear modulus of the asphalt cement, \( \delta \) is a minimum value of \( G^* \), \( \alpha \) is a difference between the maximum and minimum value of \( G^* \), \( f_r \) is the reduced frequency (Hz) and \( \beta, \gamma \) are S-shaped function parameters based on asphalt cement properties and characterizes the shape of sigmoidal functions. \( \beta \) presented the point of the turning curve halfway between the maximum and minimum value of \( G^* \) and \( \gamma \) represent the curve slope; the standard value of \( \gamma \) is 1.0; if \( \gamma \) is more than 1.0 the curve is steeper and if less than 1.0 then the curve is shallower. In this research, the sigmoidal model is used for characterizing the master curves of complex modulus for asphalt cement. The four-parameter sigmoidal model is used for fitting the complex modulus of asphalt mixtures (Pellinen et al., 2003). However, this model has been modified to be used for asphalt cement (base and modified) data. Four fitting parameters, \( \alpha, \beta, \delta, \) and \( \gamma \), are estimated by using the non-linear least square fitting method as shown in Tables 6 and 7. The fitting process is carried out with the assist of Graph Pad Prismver.8 Software.

### Table 6. The average parameters of the sigmoidal model of different types of Durah asphalt binder.

| Parameter     | \( \beta \) | \( \alpha \) | \( \delta \) | \( \gamma \) |
|---------------|-------------|-------------|-------------|-------------|
| Base          | 3.744       | 21.544      | -1.603      | 0.6216      |
| 5% SBS        | 2.597       | 11.350      | 1.439       | 1.052       |
| 7% SBS        | 2.447       | 15.271      | 1.624       | 0.8852      |
| 9% BR         | 3.385       | 8.678       | 1.492       | 0.8021      |
| 0.075% BG plus| 3.739       | 23.915      | -1.489      | 0.6686      |
Table 7. The average parameters of the sigmoidal model of different types of Basrah asphalt binder.

| Parameter | \(\beta\) | \(\alpha\) | \(\delta\) | \(\gamma\) |
|-----------|-----------|-----------|------------|-----------|
| Base      | 3.683     | 10.546    | -1.552     | 0.7879    |
| 5% SBS    | 2.433     | 7.286     | 1.135      | 0.8929    |
| 7% SBS    | 3.855     | 8.179     | 1.116      | 0.7983    |
| 9% BR     | 2.814     | 7.865     | 1.540      | 0.8359    |
| 0.075% BG plus | 3.421 | 10.870    | -1.087     | 0.6225    |

Based on the results of the analysis process by Pad Prismver.8 Software:

1. At a given type of asphalt binder, the magnitude of \(\delta\) for base and 0.075% BG plus are negative. The negative \(\delta\) pointed out the value of complex shear modulus \(G^*\) of asphalt cement is very small at low frequencies and high temperatures.

2. The values of \(\delta\) through the analysis process are small because asphalt cement (base and modified) are acting like a viscoelastic liquid and the \(\delta\) values reduce with the addition of modifiers comparing with base asphalt cement because the modifiers enhanced the elastic response at the high temperatures and/or low frequencies due to the polymer network.

3. The addition of modifiers reduces the values of \(\beta\), \(\delta\), and \(\alpha\) values and increase \(\gamma\) values for both types of asphalt binders comparing with base asphalt binder. This indicates that \(G^*\) values are too small at low frequencies and high temperatures.

4. The \(\gamma\) values are observed to be steady for the base and modified asphalt binders, indicating that the value of \(\gamma\) did not play an essential role in affecting the slope of the master curve in the range from intermediate temperatures to high temperatures.

5. Conclusions

Several conclusions can be gain from this work and are listed below:

1. Both MSCR parameters: non-recoverable creep compliance and percentage of elastic recovery are improved as a result of adding modifiers to asphalt cement and increase with increasing modifier percent.

2. Using modifiers with base asphalt cement of Durah and Basrah refineries increased the elastic recovery of the binders to maximum values between (21.2-36) at stress level 0.1 KPa and between (52.93 – 64.45) at stress level 3.2 KPa compared to the base binders indicating a superior polymer network in the binder.

3. Decreasing the non-recoverable compliance \(J_{nr}\) values of Durah and Basrah modified asphalt cement at the typical highest pavement temperature of 64°C at both stress levels indicates that the modified asphalt cement is less susceptible to permanent deformation (rutting) than the base asphalt cement because of the lower the \(J_{nr}\) value, the stiffer the asphalt cement.

4. Regardless the asphalt type, ranking the formulations in terms of higher values of \(R\) and lower values for \(J_{nr}\), i.e. higher rutting resistances, at the regular creep and recovery at the first cycle, the 7% SBS modified asphalt binder is the best, followed by asphalt binder modified with 5% SBS, the 9% BR modified asphalt binder and, then the addition of BG Plus anti-stripping agent didn’t affect significantly on values of \(R\) of asphalt binders and the last one, the base AC. With increasing cycles number, the general effect observed is the reduction of \%R and increase of \(J_{nr}\), (i.e a lower rutting resistance), but the ranking is the same.

5. The best performance of the modified binder can be attained by mixing 7% SBS with base asphalt binder from the two sources and keep sustained with an increased level of stress to 3.2 Kpa. The modified binder was improved by 21.2 and 36 times compared to the neat Durah and Basrah asphalt respectively binders.
6. Based on the results of non-recoverable compliance Jnr, Durah asphalt cement has better rutting resistance than Basrah asphalt binder.

7. The effect of modifiers on Durah asphalt cement was better than Basrah asphalt cement. Maximum reduction in accumulated strain is more than 116 times for Durah asphalt cement modified with 7% SBS while for Basrah asphalt cement modified with 7% SBS is 66.5 times comparing with base asphalt cement.

8. The stiffness of asphalt cement increase with adding modifiers to asphalt cement and improve the properties of asphalt cement within the viscoelastic range at stress level 3.2 Kpa.

9. The addition of SBS to asphalt binder achieved good behavior and approximately sustained with increasing the applied stress. Therefore, it could be mentioned that SBS modification is a good option for both local base binders.

10. For a wide range of service temperatures between 4 °C to 70°C, using the function of the sigmoidal model to build the master curve appears to be in a good fitting with the data because it follows the physical form of measured data.

11- The addition of modifiers reduces the values of $\beta$, $\delta$, and $\alpha$ values and increase $\gamma$ values for both types of asphalt binders comparing with base asphalt binder. This indicates that $G^*$ values are too small at low frequencies and high temperatures.

Acknowledgments
The authors acknowledge Mustansiriyyah University, College of Engineering, Highway, and Transportation Department for supporting this work. https://uomustansiriyah.edu.iq.

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