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# Laboratory investigation on the mechanical behavior of asphalt mixtures incorporating reclaimed asphalt pavement and Sasobit additive

Humam H. Mohammed[1]*
[1]Civil Engineering Department, University of Technology, Iraq; 40328@uotechnology.edu.iq (H.H.M.).

**Abstract:** The serious rutting problem faced by asphalt pavements requires authorities to create better-performing asphalt mixtures that address this issue. The research examines how adding Sasobit warm mix additive to asphalt mixtures, which combine 30% reclaimed asphalt pavement (RAP), affects their Marshall properties, moisture damage, and rutting resistance. Tests were conducted with Sasobit at three different addition rates: 1%, 2%, and 3%. Experimental results show that adding 2% Sasobit to a mixture containing 30% RAP resulted in the best Marshall characteristics, with a maximum stability measurement of 12.2 kN and better performance than the control mixture, which had 9.8 kN stability. The 2% Sasobit mixture displayed the lowest flow rate at 2.9 mm, while the control mixture flowed at 3.3 mm. The best rutting resistance performance appeared in the mixtures of 2% Sasobit with 30% RAP, reducing the unmodified mix's rut depth by 44%. Adding 2% Sasobit into mixture samples decreased moisture damage by 8.5% compared to the unmodified samples in moisture susceptibility tests. The results indicate that optimal Sasobit concentrations improve the durability, stability, and resistance of asphalt mixtures containing recycled asphalt pavement while extending their usefulness for road construction.

***Keywords:*** *Moisture susceptibility, Reclaimed asphalt pavement, Rutting resistance, Sasobit.*

## 1. Introduction

Asphalt pavements asphalt binder functions as a component which binds all other elements together. Almost all asphalt binders derive from crude oil manufacturing processes. Traditionally, asphalt systems are described as colloidal, where asphaltenes and micelles supported by polar resins stabilize each other in the continuous avalanche of maltenic oil. The binder's characteristics determine how pavements react under different environmental and loading scenarios and at warm and cold operating temperatures [1-4]. Asphalt binder performance receives detrimental effects from four types of pavement distresses, including high-temperature rutting, medium-temperature fatigue, moisture damage, and low-temperature cracking damage, making pavements less durable. The properties of base asphalt binders require modification to achieve better performance standards, according to Julaganti, et al. [5]; Motamedi, et al. [6] and Yue, et al. [7]. The recycling process of asphalt pavements uses RAP materials combined with virgin asphalt or recycling agents (rejuvenators) to enhance features of RAP materials according to Yousefi, et al. [8] but experts remain undecided about HMA with RAP performance versus neat HMA. Different research studies evaluated the resistance to moisture damage of recycled mixes through performing multiple moisture susceptibility tests. When RAP content increases, stiffness increases, leading to superior Marshall stability values than neat pavement mixtures, according to research in Yousefi, et al. [8]; Martinho, et al. [9] and Panda, et al. [10]. Therefore, it is reasonable to conclude that higher RAP amounts reduce the moisture resistance capability and overall durability.

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* Correspondence: 40328@uotechnology.edu.iq

The improved workability of asphalt mixtures using warm mix technology occurs at lower temperatures though this process might facilitate water damage to asphalt pavements. Sah, et al. [11] studied the moisture resistance of foamed asphalt mixtures through investigations, which showed that water damage begins because asphalt weakly adhesives to aggregate materials. The study conducted by Gao, et al. [12]. Gao, et al. [12] and Liu, et al. [13] confirmed that CR-WMA containing E3G could be improved by adding an anti-stripping agent to enhance asphalt mixture water stability. Ji, et al. [14] and Varveri, et al. [15] proved that warm mix additive decreases bonding strength between asphalt and aggregate materials Mirzababaei [16]. Behnood [17] and Ghabchi, et al. [18] researched how EBS with polyethene (PE) affects water stability in warm mix asphalt mixtures while determining that EBS decreases asphalt pavement water damage. The asphalt mixture containing the organic wax additive of RH shows increased susceptibility to water damage, according to [19, 20]. Various countries have increased their focus on waste and recycled materials for use alongside WMA production attempts by pavement engineers. RAP products obtained from old asphalt pavement milling operations effectively decrease energy consumption and greenhouse gas emissions [21]. The use of RAP materials in asphalt pavements shows two beneficial effects: it decreases the need for virgin materials, and it raises pavement rutting resistance due to stiff aged asphalt binder found in RAP materials [22-26]. Asphalt mixture performance matches or exceeds the performance of RAP-free mixtures when RAP makes up 30% of the mixture, according to research findings [23, 27]. RAP leads to better resistance against moisture damage, according to specific studies [28], while contradictory results show the opposite effect [29]. Various researchers have identified concerns about RAP blended mixtures' thermal and fatigue cracking resistance [30, 31]. Using soft binders with rejuvenators and WMA technologies may reduce the negative outcomes of RAP entering asphalt mixtures [19, 26]. Research revealed that 2% of Deurex provides performance results comparable to Sasobit's. High-temperature performance delivers good results from modified asphalts Sasobit and Deurex. Research indicates that Deurex working at 2% must be combined with 2% or 3% Sasobit additives [19]. WMA creates lower binder viscosity at lower production temperatures thus helping to decrease emissions during asphalt mix processing and slowing down the aging process of aged RAP binders. Some additives used in WMA actively serve as rejuvenators and deliver adequate coating [8, 32]. Research conducted by previous authors studied the behaviour patterns of WMA mixtures that included RAP materials. Reviews by Ameri, et al. [20] and Shiva Kumar and Suresha [26]. Varveri, et al. [15] have compiled crucial research outcomes about how RAP influences WMA mixture behaviour. The addition of RAP into WMA mixtures results in environmental impact reduction between 10–15%, according to Guo, et al. [22] while RAP blended WMA mixture behaviour depends strongly on properties of constituent materials, including aggregate, asphalt binder, RAP content and WMA additive choice [8]. The research studies how Sasobit, a WMA additive, and reclaimed asphalt pavement materials affect asphalt mixture mechanical properties and durability characteristics. According to this research, an evaluation of WMA additives at intermediate temperatures became part of this research despite insufficient investigation in existing studies.

## 2. Description of the Materials

The research uses four basic materials for producing asphalt mixtures: asphalt cement (binder), Aggregate, RAP, and warm additive. A 40-50 penetration grade binder type obtained from the Dourah refinery serves as the main composition of the binder. Aggregate materials consisting of limestone obtained from AL-Nibaie quarry show the characteristics shown in Table 1.

**Table 1.**
The physical appearance of aggregates

| Property | Results | ASTM Standard |
|---|---|---|
| **Fine aggregate** | | |
| Bulk specific gravity | 2.574 | C128 |
| Apparent specific gravity | 2.617 | |
| Water absorption (%) | 0.72 | |
| **Coarse aggregate** | | |
| Bulk specific gravity | 2.615 | C127 |
| Apparent specific gravity | 2.630 | |
| Water absorption (%) | 0.88 | |
| Los Angeles abrasion | 18.0 | C131 |
| Angularity (%) | 96 | D 5821 |
| Soundness (%) | 3.1 | C88 |

Sasobit constitutes a major synthetic wax-based additive for improving the workability, compaction properties, and performance of asphalt mixtures within WMA technology. Fischer-Tropsch synthesis produces this additive, which decreases asphalt mixture viscosity, thus enabling lower production and compacting temperatures equivalent to 20–30°C below standard hot mix asphalt. Production temperature reduction enables considerable energy conservation, reduced air emissions, and enhanced sustainable environmental outcomes. Sasobit improves the stiffness and rutting resistance properties through its features, which benefit mixtures prepared with reclaimed asphalt pavement (RAP). High Sasobit dosages produce brittle mixtures that may reduce the fatigue resistance of the material. Achieving optimal Sasobit addition requires careful balance to obtain proper workability, excellent durability, and mechanical strength of asphalt pavements. The dose of additive (Sasobit_) determined were1%, 2% and 3% by weight of asphalt. The supplier supplied the chemical properties of Sasobit according to Table 3.

**Table 2.**
The Sasobit ® properties

| Property | Results |
|---|---|
| Appearance | solid |
| Odour | odourless |
| Flash point | > 250 °C |
| Boiling point/boiling range | > 370 °C |
| Water solubility | insoluble |
| Density @ 25 °C, | 0.9 gm/cm$^3$ |
| Viscosity, dynamic | 6 - 12 mPa.s |
| Melting point/range | > 75 °C |

A surface layer of RAP was obtained from the Mayoralty of Baghdad project office through milling operations. Testing with a centrifuge extractor according to ASTM D2172 yielded 3.9 % asphalt content throughout the different RAP stockpile test samples. A comparison between the RAP aggregate gradation shown in Table 3 and the wearing mixture standards based on (SCRB/R9) is provided in the table.

**Table 3.**
Test Results of RAP Aggregate Gradation Extracted

| Sieve Size, | Gradation of Passing Percentages After Extraction | SCRB, Standards |
|---|---|---|
| ¾ | 100 | 100 |
| ½ | 93 | 90 – 100 |
| 3/8 | 86 | 76 – 90 |
| #4 | 59 | 44 – 74 |
| #8 | 45 | 28 – 58 |
| #50 | 16 | 5 – 21 |
| #200 | 7.8 | 4 – 10 |

## 3. Method for Sample preparation

The evaluation process for WMA additives included testing modified asphalt binder properties to determine the best WMA additives that would work during WMA mix production. A high shear mixer using a speed of 4000 rpm enabled the fluidification of 500 grams of base asphalt binder in its container until it reached fluidity. The WMA additive chemicals were added in weight percentages of 1, 2, and 3 at 150 ± 5 C for 20 minutes. The RAP ratio was incorporated into the neat HMA mix at 30% weight of the entire mix. The RAP requires two-hour heating at 110 °C for the process. The RAP aggregate received sieving to yield various aggregate sizes before replacing portions from every sieve. The research utilized compaction temperatures of 110 C as part of its approach. The study utilized temperatures which were 40 C below standard temperatures.

**Table 4.**
Blend of Aggregate Gradation

| Sieve Size, | ¾ | ½ | 3/8 | #4 | #8 | #50 | #200 |
|---|---|---|---|---|---|---|---|
| Gradation of Passing Percentages | 100 | 95 | 83 | 59 | 43 | 14 | 7 |

**Figure 1.**
Wet process modification of modified Asphalt with Sasobit

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**Table 5.**
Influence of addition of Sasobit on the physical characteristics of Asphalt Binder

| **Property** | **Test Results of modified binder with Sasobit** | | | |
|---|---|---|---|---|
| | 0.0% | 1.0% | 2.0% | 3.0% |
| Penetration | 47 | 54 | 60 | 65 |
| Penetration index | - 0.859 | - 1.546 | -1.574 | -1.957 |
| Ductility, cm | >100 | >100 | >100 | >100 |
| Viscosity @135 °C, Pa.s. | 510 | 410 | 380 | 369 |
| Softening point, °C | 52 | 47 | 44 | 43 |

## 4. Experimental Results and Discussions

The laboratory tests performed on original bitumen without additives and additive percentages ranging from 1% to 3% appear in Table 5. These additives produced effects which caused higher penetration and lower softening point results. The decreased PI value indicates that bitumen exhibits more sensitivity to temperature variations. An increase in WMA additive levels brings about enhanced resistance to temperature changes in all WMA samples when compared to basic bitumen, as observed in Table 5.

Figure 2 shows results from the Marshall test applied to mixtures containing 30% recycled asphalt pavement (RAP) and sasobit in different amounts (1%, 2%, and 3%). It demonstrates how Marshall's stability increased with more sasobit addition than the control mixture. Tests demonstrated that mixing the asphalt at 2.0% of Sasobit with 30 % RAP content resulted in the best mixture performance. The high flow value indicates that the asphalt mixture demonstrates lower resistance during traffic load applications. An elevated amount of asphalt cement produces a proportional rise in the Marshall flow measurement.

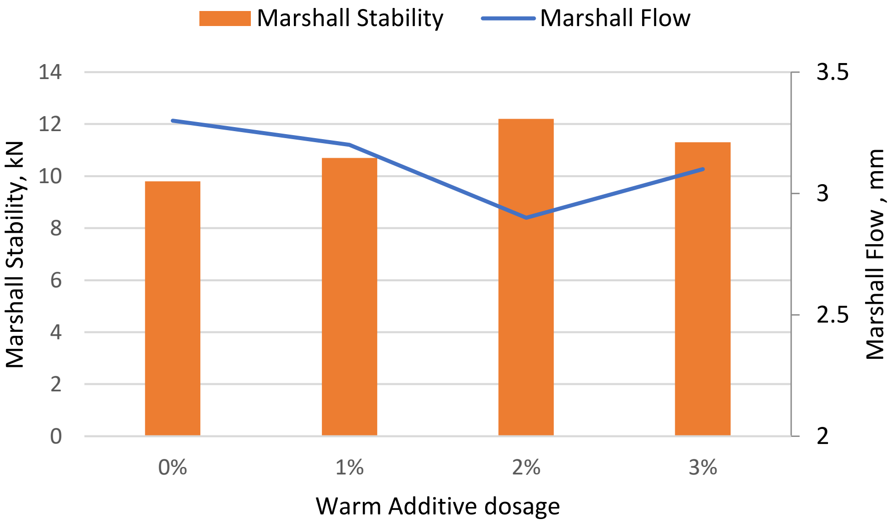

**Figure 2.**
The influence of Sasobit on Marshall stability and flow characteristics.

Figure 3 presents the TSR values for various asphalt mixtures. The use of 30% RAP in an HMA mixture produces enhanced ITS values across both unconditioned and conditioned specimens, mainly because of the increased stiffness from the mixture composition. The mixtures containing WMA additives demonstrated the maximum ITS value enhancement from RAP incorporation for unconditioned specimens among the tested mixtures. The standard criterion for identifying acceptable moisture susceptibility in mixtures is 0.8 as the minimum TSR value. All the mixtures show TSR values exceeding 0.8, indicating lower susceptibility to moisture damage. Additions of RAP in asphalt mixtures lead to elevated TSR values compared to asphalt mixtures without RAP, thus enhancing their resistance to moisture damage.

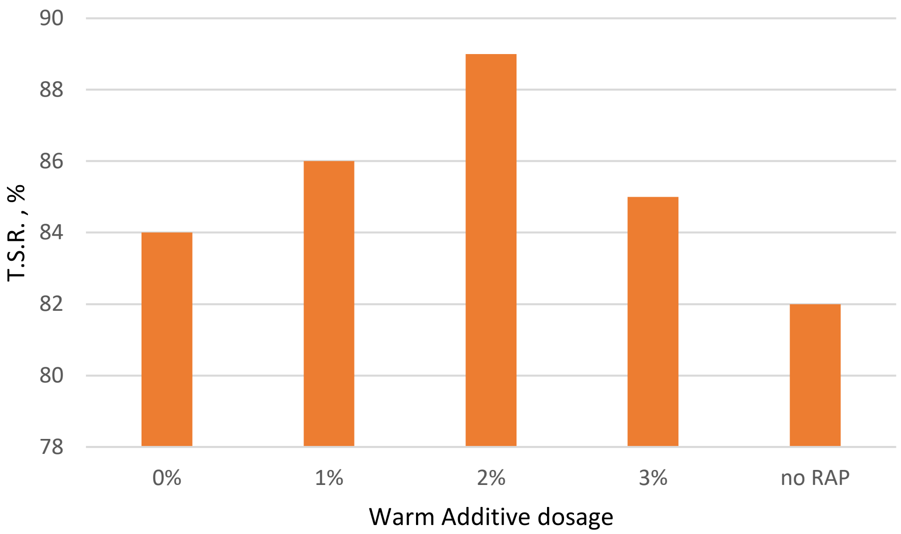

**Figure 3.**
The effect of adding Sasobit on TSR.

Figure 4 shows the impact of different warm additive dosages on the rut depth performance of asphalt mixtures. The experimental data show that rut depth reduces as the dosage of warm additive rises from 0% to 2%, indicating better permanent deformation resistance. Rut depth starts at approximately 8 mm when warm additives are not added but steadily drops to 4.5 mm when usage reaches 2%. Warm additives improve asphalt mixture stability when added to asphalt mixtures by strengthening binder bond strength and reducing load-induced deformation. When the dosage reaches 3%, a small increase in rut depth appears indicating a possible point after which additive excess might harm the performance. The data indicates warm additives enhance rut resistance until reaching an optimum dose, but applying greater amounts than necessary could potentially degrade mixture performance, possibly because of softened binders and weakened aggregate connection.

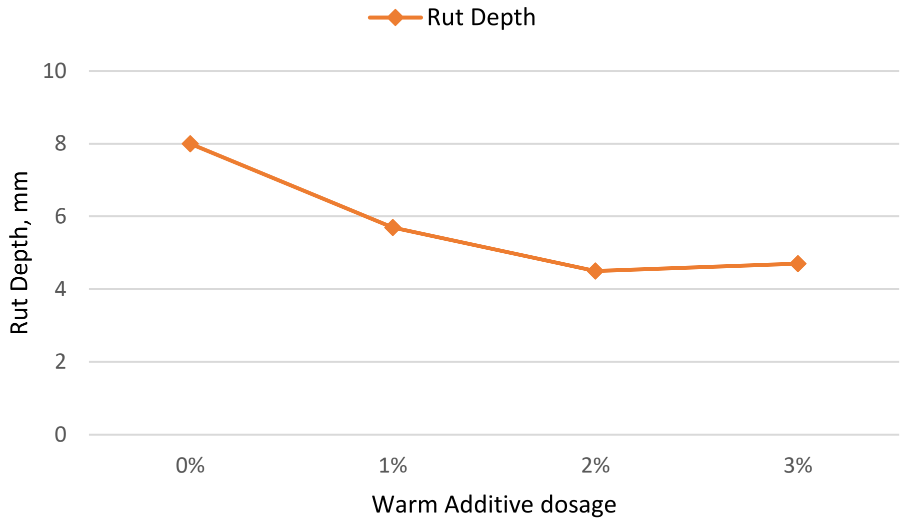

**Figure 4.**
The influence of Sasobit on rutting resistance

## 5. Conclusion

Asphalt pavement rutting presents a crucial challenge for road users and governmental authorities. The research gap demanding resolution stems from this significant problem affecting asphalt pavement users and authorities. Various amounts (1%, 2%, and 3%) of sasobit were added to asphalt mixtures that contained 30% RAP to enhance their rutting resistance. This research investigates how sasobit incorporated with RAP affects the Marshall properties and rutting resistance of asphalt mixtures. The main conclusions drawn are:

1. The incorporation of sasobit along with 30% RAP produced improved The Marshall characteristics in asphalt mixtures. Two percent sasobit incorporated with thirty percent RAP to asphalt cement AC (40/50) resulted in a maximum Marshall stability of 12.2 kN exceeding the control mixture stability of 9.8 kN. Among the mixtures combined with 1.0% sasobit and 30% RAP, the flow value in the Marshall test decreased. The addition of 2% sasobit and 30% RAP resulted in the greatest reduction of Marshall flow at 2.9 mm, while the control combination showed a corresponding reduction of 3.3 mm.
2. The combination of 2.0% sasobit and 30% recycled asphalt pavement (RAP) produced modified asphalt mixes with the best rutting resistance, demonstrating 44% more than the unmodified control mix.
3. Asphalt mixtures modified with 2.0% sasobit and 30% recycled asphalt pavement showed 8.5% less moisture damage than unmodified samples.

## Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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