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Warm Mix Asphalt Mixture Performance Using Recycled Asphalt

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Abstract

Sustainability is a term that is at all times met with high approbation from society. Asphalt paving business is a prime candidate in the field of sustainability. Currently, Recycled Asphalt pavement (RAP) and Warm mix asphalt (WMA) are inspiring the knowledge of sustainability in the field of asphalt construction. A massive financial savings could be achieved when adding reclaimed asphalt pavement (RAP) to the production of warm mix asphalt (WMA). Also, it is an environmentally friendly substitute as it cuts down gas emissions when using WMA and a decrease in the need for new materials when using RAP. Twelve different mixtures were planned as a blend among WMA and RAP. RAP was added at rates of 20% and 40%. The same for WMA additive (Sasobit), it was added at contents of 1.5%, 2.5%, and 3.5%. Tensile Strength Ratio (TSR) and Wheel tracking tests were conducted to evaluate asphalt mix performance with different contents of Sasobit and RAP. Results have shown that the integration of RAP and WMA improves tensile strength by 280% for the conditioned mixes and 85% for the unconditioned mixes. The higher the RAP or Sasobit content the better improvement in rutting resistance.

Keywords: *HMA; WMA; Sasobit; Moisture susceptibility; TSR; Rutting*

1. Introduction

Sustainability is an expression that is always met with high approbation from society. Asphalt paving industry is a front-runner in the field of sustainability. Nowadays, Recycled Asphalt pavement (RAP) and Warm mix asphalt (WMA) are encouraging the idea of sustainability in the field of asphalt construction. WMA is an innovative technology that was first applied in Europe at the late 1990’s. The technology mainly depends on using additives like chemical additives, water, or organic additives which in turn allows for notable reduction in production temperature. WMA has many benefits like asphalt binder reduced oxidation, lower gas emissions, paving season extension, and increased RAP contents for usage [4]. WMA technology is gaining acceptance around the world, in 2014, USA production reached 113 million ton, this production represents one-third of USA production from asphalt [5].

RAP is widely used around the whole world. Mixtures containing RAP could achieve a similar performance to the traditional hot mixtures with an enhancement to rutting resistance and a respectable performance due to moisture damage [1]. Rap takes up an average of 47% from asphalt production in Japan, while the USA takes up an average of 20% of RAP from asphalt production [2]. Lately, USA and Europe are growing the production of WMA mixtures containing RAP in both sides, the research, and for the production. RAP contents could be improved when added to the warm mixes compared to hot mixes because of reduced production temperatures [3].

Even though, the varied variety of benefits offered by the usage of WMA additives or RAP within mixtures, some difficulties due to performance might show. WMA could be more susceptible to the moisture, whereas, RAP might rise asphalt mixture stiffness due to aged binder. According to that stiffness and that the mixture could be more sensitive to moisture due to the WMA additives. Therefore, a combination of RAP and WMA is essential to

produce a high-performance asphalt mixture with satisfactory levels of mixture stiffness and low moisture susceptible mixtures.
The following research aims to evaluate the differences between WMA and HMA while containing different contents of WMA additives and RAP. Specimens were produced in the laboratory using materials found in Egypt and from a local contractor to validate with a large scale in plant production the effectiveness of the mix design.
The detailed objectives of this research were to:

- Assess the performance of the warm mixes compared to the traditional hot mixes for the Egyptian asphalt industry.
- Ensure performance of RAP aggregates compared to virgin aggregate.
- Evaluate the effect of Sasobit and RAP on the rutting resistance and moisture damage according to materials found in Egypt.

2. Materials and Mix design

Materials used in this study were supplied from the local resources available across the country. They are classified to the following four resources: Virgin aggregate, Asphalt binder, RAP, WMA additive.

1.1 Virgin Aggregate

Two types of aggregate were used in this study, coarse and fine aggregate. Coarse aggregate was composed of two sizes while the fine was composed of natural and crushed sand. All aggregates were supplied by a local contractor. Aggregates gradation are presented in table 1.

Table 1. Different types of aggregate gradation

Sieve Size (mm)	% Passing			
	Natural sand	Crushed sand	Agg. 1	Agg. 2
25	100	100	100	100
19	100	100	100	93.1
12.5	100	100	97.3	20.2
9.5	100	100	75.1	8.6
4.75	100	100	7.0	1.1
2.36	98.4	75.1	2.3	0
0.6	81.4	33.1	2.1	0
0.3	53.6	26.9	2.1	0
0.18	16.2	24.0	2.1	0
0.15	8.4	23.1	2.0	0
0.075	3.9	19.7	1.9	0

1.2 Asphalt bitumen

Bitumen 60/70 were used in this study, a production of Suez plant placed in Suez governorate, Egypt. Properties and Egyptian specification limits of the used binder are shown in table 2.

Table 2. Selected bitumen Properties and specification

Property	Sample	Egyptian Code Limits	
		L.L	U.L
Penetration at 25° C (ASTM D5) [1]	70	60	70
Softening Point (ASTM D36) [2]	45	45	55
Viscosity at 135 ° C (ASTM D 4402) [3]	440	320	-

1.3 RAP

RAP is a result of cold milling using the specified machine for that work. Ten samples were sampled from a transportation truck. After that it was processed inside the laboratory to define its properties. First, a solvent extraction process is taking place to clean aggregates from binder to determine its content in RAP. The binder content was calculated to be 6.47%. Second, a RAP aggregate gradation was calculated and presented in table 3. Finally, specific gravity was calculated for the Rap aggregate according to ASTM standards [4] [5]. The calculated result was found to be 2.61.

Table 3. Sieve analysis results for RAP aggregates

Sieve Size (mm)	19.5	12.5	9.5	4.75	2.36
% Passing	100.0	96.8	94.1	80.3	61.5
Sieve Size (mm)	0.6	0.3	0.18	0.15	0.075
% Passing	35.3	18.7	10.5	8.8	5.0

1.4 Sasobit (WMA Additive)

"Sasobit is a Fischer-Tropsch or synthetic wax that is formed during the coal gasification process and that has been used as a compaction aid and a temperature reducer" [6]. This progression produces an additive with a low melting point that could alter the binder viscosity-temperature relationship. Sasobit turns to a liquid at a temperature of nearly 100°C which directs to a noticeable decrease in binder viscosity.

In addition, it is able to advance mixture resistance to rutting during the normal operating conditions without disturbing other properties of binder even it is compared to a conventional mixture [6]. Another benefit from using Sasobit is the better compaction of mixtures. Other studies show that using Sasobit achieves lower mixture air voids by up to 0.9 percent. As a result of its benefits, the production of asphalt mixture containing Sasobit reached 10 million tons around the world [6].

1.5 Mix Design

All the above resources were mixed and proportioned to produce a dense graded asphalt concrete mixture. Marshall mix design procedure will be followed to prepare mixtures for this study. Aggregate mix design for asphalt mixture will follow specifications for the Egyptian code (Part 9) [8]. Mixture design will be carried out for three mixtures, one control mix and two other mixes (20% RAP and 40% RAP). Aggregates mix design are planned to fulfill the required specification to meet requirements of a surface layer 4C gradation. Mixtures gradation is presented in table 4.

Table 4. Mixtures composition and grading limits

Sieve Size (mm)	HMA	20% RAP	40% RAP	Egyptian Code Limits (Mix – 4C)	
				L.L	U. L
25	100	100	100	100	100
19	97.9	98.3	98.6	80	100
9.5	66.9	72.2	75.9	60	80
4.75	51.7	57.4	59.3	48	65
2.36	42.7	46.4	47.0	35	50
0.6	26.6	28.3	28.3	19	36
0.3	19.2	19.1	17.7	13	23
0.15	9.0	9.0	8.2	7	15
0.075	7.1	6.6	5.6	3	8

Table 5 shows Marshall mixtures various properties. The calculated Optimum Binder Content (OBC), Marshall flow, Marshall stability, mixture density, air voids, VMA, and VFA are all presented in table 5. The resulted OBC will be applied for WMA mixtures assuming that WMA additive do not have considerable consequences on the volumetric properties for the asphalt mixture. Marshall quotient is also calculated and presented in table 5 [9] [10].

Table 6. Comparison of Marshall Properties

Asphalt Mix Characteristics	Control	20% RAP	40% RAP	Egyptian Code Limits For Wearing layers	
				Min	Max
Optimum AC%	5.37%	5.77%	5.23%	-	-
New AC%	5.37%	4.39%	2.46%	-	-
Bulk Density (ton/m3)	2.40	2.40	2.40	-	-
Stability (Kg)	1120	1270	1850	900	-
Flow (mm)	2.5	2.7	2.6	2	4
Marshall Quotient (kg/mm)	448	474	718	200[1]	-
Air voids %	3.60%	2.80%	2.80%	3	5
VMA %	14.40%	14.40%	13.40%	14	-
VFA%	73%	80%	80%	-	-

3. Methodology

A 12-different mixture were prepared and analyzed for this study. An assessment for mixtures will be applied to study to the performance of WMA against HMA and Recycled asphalt against the virgin aggregates. Three groups of mixtures will take place in this study with two different RAP contents inside the mixtures (40% and 20%). Each group will include four mixes, the first mix will have no WMA additive added. The second through the fourth mixture will contain a WMA additive (Sasobit) added as a percentage of 1.5, 2.5, and 3.5% from bitumen weight.

Mixtures will be evaluated according to moisture susceptibility and rutting performance. A major performance characteristic related to moisture failure is recognized as loss of bond in the asphalt mix. This issue occurs when water vapor or water gets in between aggregates and asphalt binder thus breaching the bond between the bitumen and aggregates [7]. Evaluation of moisture susceptibility for asphalt mixture will be inspected through the Tensile Strength Ratio (TSR) test procedure. ASTM D 4867 is the followed procedure for calculating TSR. The test requires six Marshall briquettes to be prepared and then divided to two groups. A group is kept inside water for a specified time while the other group is kept dry and then all briquettes are exposed to the indirect tensile test.

Another performance index in this study is the rutting. A Wheel Tracking Device (WTD) will take place to evaluate rutting resistance. The test could be summarized in few steps, first a slab with standard dimensions will be prepared. After that the slab is left inside a closed temperature controlled

[1] Western Australia Specification

compartment, then a loaded wheel is applied over the slab to encourage

4. Results and Analysis

Figures 1 and 2 show an outline about the outline Tensile Strength (ITS) values for the unconditioned and the conditioned mixes arranged for this research. Figure 1 show the ITS values for the conditioned mixes while figure 2 shows the ITS of the unconditioned mixes. From Figures 1 and 2 show that adding WMA additive and RAP to the mix achieves a great enhancement to the ITS values by80% for the unconditioned mixtures and 133% for the conditioned mixtures. Minimum requirements for ITS values according to Nevada DOT is 689 Kpa. Figures show that all mixes have agreed with the specifications [16].

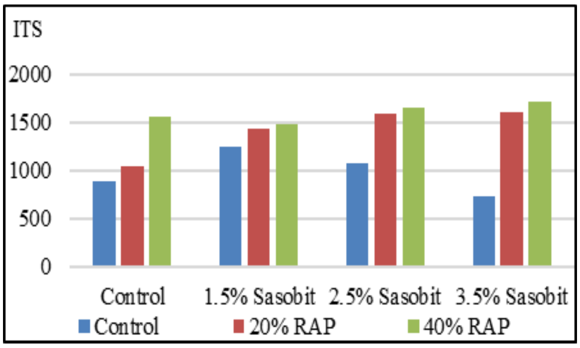

Figure 1: Tensile strength for conditioned mixtures

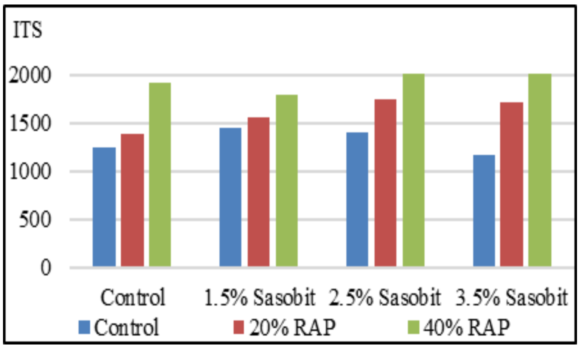

Figure 2: Tensile strength for unconditioned mixtures

Figure 3 shows an outline about the Tensile Strength ratio (TSR) values for mixes arranged over this study. Specifications restriction vary from organization to another, according to Nevada DOT limit is 70% [16]. Figure 3 present TSR values for the 12 mixes prepared through this study. Also, adding 20% RAP shows the best performance for most of Sasobit contents.

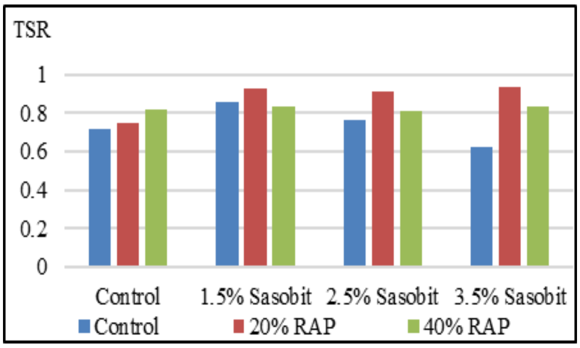

Figure 3: TSR for mixtures

Figures 4 shows an outline about rutting resistance results for the prepared slabs in this study. Figure 4 shows values for all mixes together in the same graph. It can be seen that Sasobit has a significant result about the rutting resistance for the virgin aggregate mixes. Results shown for rut depth are after 1500 pass from the loaded wheel. For the control mix group, the non-modified bitumen mix recorded a 2.5 mm rut depth while the 3.5% Sasobit mix recorded 1.4mm rut depth. These results mean that Sasobit improved mixture rutting resistance by 55%.

The same behavior can be seen also while increasing the RAP content but with a much lower improvement in values for the HMA. The 40% RAP recorded 2.2mm rut depth with an improvement in rutting resistance over the control HMA by 10%. Inversely, when combining Sasobit and RAP aggregate together in the same mixture, a huge increase in rut depth is recorded as shown in figure 4.

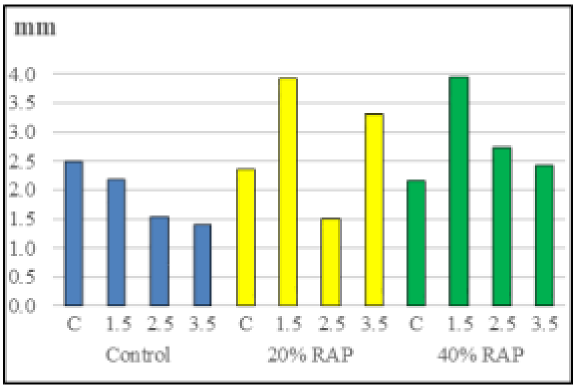

Figure 4: Rut depth for all mixtures

5. Conclusions

In this research, performance tests were applied to study the feasibility of using WMA additive and RAP with asphalt mixes and evaluate the outcomes from adding them. A list of important fallouts, conclusions, and recommendations based on this study are listed in the following sections.

Moisture Susceptibility Tests

- Using Sasobit and/or RAP has a high positive effect on mixture performance after comparison with the traditional HMA.
- The higher the RAP content or Sasobit Contents added to the mix the higher the Marshall stability values recorded.
- The high values of stability could lead to more brittleness of the mix; thus, care should be taken in consideration.

Wheel Tracking Test

- Adding RAP or Sasobit to the mix has an encouraging performance results.
- A combination of RAP and Sasobit together effected mix performance inversely at low contents of Sasobit but when the Sasobit content increased the performance has recovered again.

Finally, this study was projected to determine the applicability of using RAP and Sasobit; however additional study is required to cover these findings in the successive areas:

- More studies and examinations are needed for bitumen specially Superpave testing series as it contains several properties considered through the examination procedure.
- More WMA additives and technologies are required to be tested and evaluated to have a wider view about the WMA mixtures.
- Rejuvenators could be used to lower the amount of new binder added to the mix.

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