STUDY ON MIXTURE DESIGN AND MECHANICAL PERFORMANCE OF WARM MIX ASPHALT CONTAINING RECLAIMED ASPHALT PAVEMENT

Nagaoka University of Technology

Mezatio Zebaze Mickel-Sadrack
19504081
Highway Engineering

1. INTRODUCTION

Nowadays due to the need of a low cost, good quality and eco-friendly asphalt pavement, many researches have been done on recycling of asphalt at high and medium temperatures. In other words the use of reclaimed asphalt pavement (RAP) has been increasing during the past years. RAP is a recycled aggregate which is produced by crushing old asphalt concrete and screening the particle size. Generally RAP in high proportions is often incorporated in new mixtures with the help of rejuvenator (T-RIBAIBU) which restore the original properties of aged (oxidized) asphalt binder in RAP.

Based on this perspective of environmental protection, warm mix asphalt (WMA) has been used in some developed countries, especially in European countries. WMA is hot mix asphalt (HMA) mixture that is produced at reduced temperatures of about 20 ℃ to 40 ℃ lower than that of conventional HMA mixtures. WMA has some advantages, such as less CO2 emissions, less energy consumption, less fumes, less bitumen ageing, and less wear on machines and resources.

When WMA is produced at HMA facilities, an additive is required to reduce viscosity of the asphalt binder. “Sasobit” is a typical additive of WMA and is a fine crystalline long chain aliphatic hydrocarbon. It is completely soluble in asphalt at 115 ℃. When it is added to asphalt, it helps to reduce the production and compaction temperatures. Sasobit is manufactured from natural gas using the Fisher Tropsch process of polymerization.

Depending on countries and states in Europe and America, RAP content in WMA mixtures are limited to about 30% and 20% respectively. In Japan many continue to use the conventional method of HMA, because little information is made available to recycle asphalt using the WMA approach which may offer better advantages than the conventional one. The objective of this research therefore was to produce WMA with Sasobit by adding RAP of different proportions to the Japanese dense-graded asphalt concrete of 20 mm maximum particle size, evaluate its performance and compare this to that of its equivalent HMA.HMA.

2. METHODOLOGY

Investigation of the research was done as shown on Table 1 below.

Table 1: Research investigations

Selected gradation and RAP% content	Hot Mix	Warm Mix (Sasobit)	Performance test	
	Prd: 154-162 ℃	Prd: 129-137 ℃	Wheel tracking test	Direct tensile test
	Com: 142-147 ℃	Com: 117-122 ℃		
	Binder type	Binder type		
0%	Grade 60/80	Grade 60/80+ Sasobit	Observations and Analysis	
10%	Grade 60/80	Grade 60/80+ Sasobit		
20%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU		
30%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU		
40%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU		
50%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU		
60%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU		

2.1 Selected gradation size

Excel sheet was used to calculate the percentage of RAP content of each mixture.

Table 2: Selected gradation size

Sieve size (mm)			Percentage Passed							Planned particle size
	Lower limit particle size	Upper limit particle size	RAP %							
			0%	10%	20%	30%	40%	50%	60%	
26.5	100	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0	95	100	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8
13.2	75	90	83.1	84.1	83.1	82.6	82.5	82.6	84.0	82.6
4.75	45	65	55.2	54.4	54.4	55.0	55.0	56.7	55.3	55.2
2.36	35	50	38.8	41.9	41.5	41.8	41.4	41.2	42.2	42.2
0.6	18	30	25.4	28.7	28.6	29.0	29.1	28.4	29.5	28.6
0.3	10	21	12.6	14.9	15.1	15.3	15.7	15.0	15.9	14.4
0.15	6	16	8.1	8.2	8.0	7.9	8.1	7.6	7.8	7.9
0.075	4	8	6.1	6.0	5.7	5.5	5.6	5.1	5.1	5.9

2.2 Determine the Designed asphalt content

The designed asphalt content was obtained to be 5.5% of the total mixture, using the standard procedure recommended by NAPA. At each RAP content the old asphalt presence in RAP, the percentage of Sasobit added (3% by weight of OAC obtained), and T-RIBAIBU added (20% by weight of old asphalt present in RAP) were taken considerations.

3. EXPERIMENTS AND RESULTS ANALYSIS

After producing the HMA and WMA mixtures at temperatures as shown in table 1 above the performance test were conducted and results obtained as follows;

3.1 Wheel tracking (WT) test

Wheel tracking test evaluate the permanent deformation of asphalt concrete (rutting resistance). It was carried out in the following conditions

Table 3: Condition for WT test

Items	Condition
Dimensions	300x300x50
Number of compactor rolling (time)	15
Temperature (°c)	60
Curing time (min)	360
Test time (min)	60
Number of round trips (time)	1260
Wheel load (N)	686
Wheel material	Solid rubber

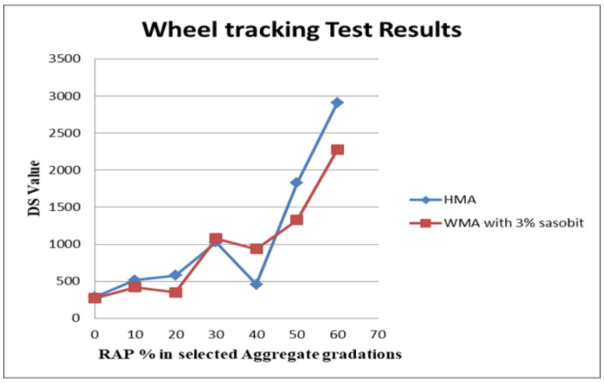

Fig 1: Wheel tracking test results

From these results, the DS values of both HMA and WMA mixtures increased as RAP content increased. In general the HMA mixtures had higher rutting resistance than WMA mixtures. However there were exception at 30%and 40% RAP content for WMA mixtures which performed better than HMA mixtures.

3.2 Direct tensile test

The direct tensile test shows the cracking resistance of asphalt concrete. This test evaluates the displacement of the specimen when it is subjected to force in the axial direction. The stress and strain of the sample are also obtained from this test.

Table 4: Condition for DT test

Item	Condition
Specimen Dimensions (mm)	40x40x240
Test temperature (°c)	20
Displacement ratio (mm/min)	1
Curing time	5hours or more

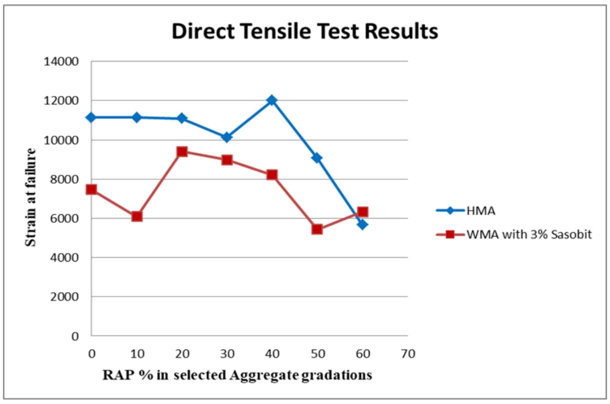

Fig 2: Direct tensile test results

From the direct tensile test results, the strain at failure shows higher cracking resistance for HMA than WMA mixtures at all RAP content. Also it was noticed that as the RAP content increased the cracking resistance（strain at failure） of both mixtures decreases.

Table 5: General Performance observation

Selected gradation and RAP% content	Hot Mix	Warm Mix (Sasobit)	Performance test	
	Prd: 154-162 ℃	Prd: 129-137 ℃	Wheel tracking test	Direct tensile test
	Com: 142-147 ℃	Com: 117-122 ℃		
	Binder type	Binder type		
0%	Grade 60/80	Grade 60/80+ Sasobit	HMA	HMA
10%	Grade 60/80	Grade 60/80+ Sasobit	HMA	HMA
20%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU	HMA	HMA
30%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU	WMA	HMA
40%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU	WMA	HMA
50%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU	HMA	HMA
60%	Grade 60/80+ 20% T-RIBAIBU	Grade 60/80+ Sasobit+ 20% T-RIBAIBU	HMA	WMA

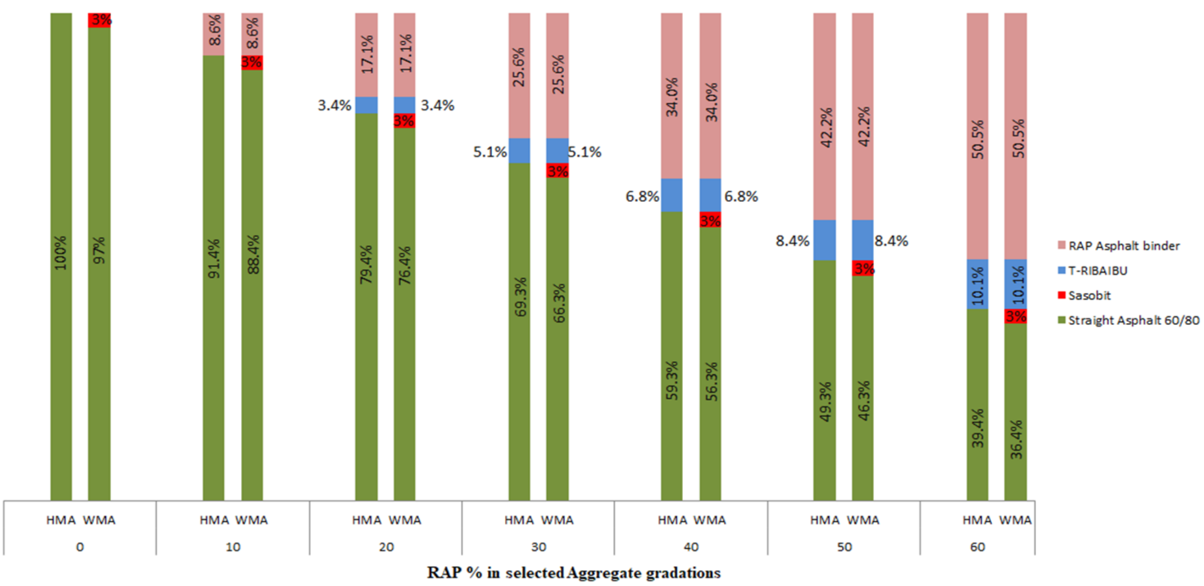

Fig 3: Mixtures binder contents

3.3 Analysis of mixtures binder physical properties

Table 6: Test performed to determine the mixtures binder physical properties

Test	Standards used	Properties determined
Penetration of bituminous materials	ASTM D5	Temperature susceptibility
Softening point of bitumen	ASTM D36	Hardness
Viscosity determinations of unfilled asphalts using the brookfield thermosel apparatus	ASTM D4402-87	Fluidity
Force ductility of bituminous materials	ASTM D113	Tenacity

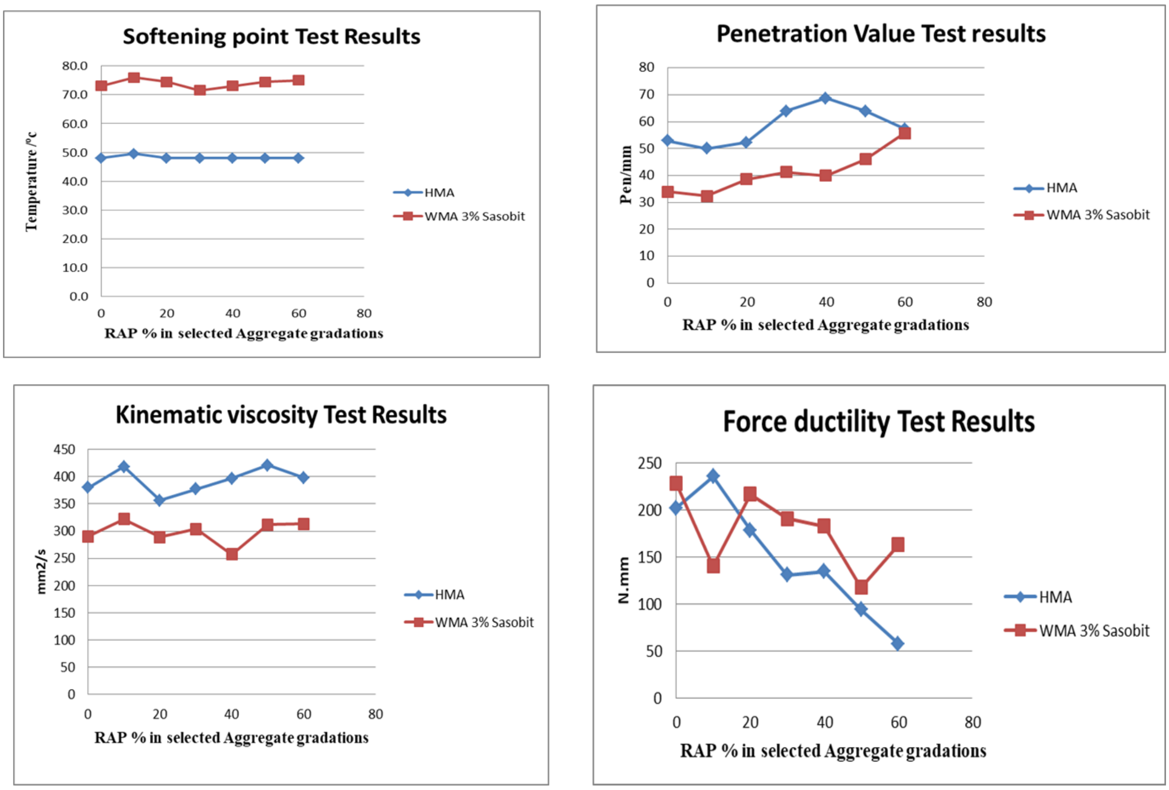

Fig 4: Results of mixtures binder physical properties

4. CONCLUSION

In a nutshell the main findings to this research were as follows

1) Up to 30% to 40% RAP content in the Japanese dense grade of 20 mm maximum size could be mixed with WMA mixture including Sasobit.

2) The rutting resistance and the cracking resistance of HMA mixture were generally higher than WMA mixtures due to the decrease in binder consistency.

3) Sasobit modified binder by increased the softening point and tenacity, while the penetration and viscosity grade decreased leading to increase in temperature susceptibility and stiffness of WMA binder.