

Research on design and performance of sasobit warm mixed reclaimed asphalt mixture

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Abstract: In order to evaluate road performance of Warm mixed reclaimed asphalt (WMRA), the tests are carried out. Different blended ratio(10%, 30%, 50%) of RAP(recycled asphalt pavement) is selected, and WMRA and Hot mixed reclaimed asphalt mixture (HMRA) are designed respectively. Through the test analysis, the method to determine WMRA optimal mixed temperature, molded temperature and heated temperature of new aggregate is established. Marshall test, rutting test, low temperature bending test, residual stability test and freeze-thaw splitting test are conducted, and Marshall indicators and road performance of HMRA and WMRA are finally evaluated.

1.Introduction

Pavement recycling technology can realize cyclic recycling of RAP utilization. As a green transportation technology, it has been widely applied^[1-2]. At present, a relatively complete design, evaluation and construction methods have shaped internationally, have achieved standardization level, but some technical problems still need to be solved. Considering the secondary aging of asphalt, the blended ratio of RAP in HMRA is severely restricted^[3]. However, WMA technology can make mixture mixed and compacted in a relatively low temperature, which is 30-50°C lower than the temperature of HMA^[4]. Therefore, if warm mix and reclaimed technologies are applied together, the proportion of RAP utilization will increase greatly, and mixing and compaction at a low temperature can be achieved, finally to realize the objective both RAP recycling utilization and energy saving.

2.Objectives

This main research aims to: (1)to determine the ratio of new asphalt and reclaimed modifier in reclaimed asphalt mixture that RAP blended ratio is 10%, 30%, 50%, respectively, for the final result to get 70# reclaimed asphalt. (2)to propose the method how to determine optimal mixed temperature, molded temperature and heated temperature of new aggregate. In the process of this, the temperature of specimen is determined for five kinds of HMRA and WMRA. (3)to evaluate Marshall indicators and road performance.

3.Material and gradation design

The asphalt content of RAP is 4.7% measured by centrifugal extraction method, and old aggregate is separated from RAP, technical characters as shown in Table 1. Asphalt in RAP is recycled using Abushen method, and new asphalt is Karamay unmodifier asphalt binder90# and110#, technical indicators as shown in Table 2. New aggregate is basalt coarse aggregate and limestone fine aggregate. Filler is limestone slag.



Warm mixed agent Sasobit is used. Sasobit is a synthetic straight-chain aliphatic carbon hydrogen mixture, has an important property that could decrease asphalt viscosity at high temperature and increase asphalt viscosity at low temperature, so Sasobit could not only reduce mixture construction temperature, but also improve mixture rutting resistance. Usually blended ratio is 3%(asphalt quality). Reclaimed agent(Type A) is produced by Xi'an huajin.

In order to analysis the influence of RAP blended ratio on reclaimed mixture performance, tests including three kinds of AC-20 gradation are designed (RAP blended ratio is 10%,30%,50%, numbered R1,R3,R5). The gradation is designed as shown in Table 3.

Table1. Technical properties of recycled aggregate

Relative apparent density		Flakiness content/%($\geq 4.75\text{mm}$)
$\geq 4.75\text{mm}$	$\leq 4.75\text{mm}$	
2.654	2.578	12.3

Table2. Technical properties of asphalts

Asphalt type	Penetration (25°C,100g,5s) /0.1mm	Ductility(5cm·min ⁻¹ ,15 °C) /cm	Dynamic viscosity(60°C) /(Pa.s)	Softening point/°C	Density(15 °C) /(g/cm ³)
Recycled asphalt	21.3	3.4	11960	67.6	1.083
90# virgin asphalt	87.5	>150	198.1	45.3	0.985
110# virgin asphalt	113.1	>150	176.5	40.7	1.017

Table3. Design gradation of reclaimed mixtures

Sieve size/mm	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Passing percentage/%	100	98.1	87.9	75.2	55.8	37.3	29.2	23.9	19.6	13.0	8.0	6.1

4.Blended ratio scheme of new asphalt and regenerant

Reasonably evaluate whether reclaimed asphalt technical property meets the requirement of target asphalt, and determine whether special regenerant needs to be added, the following method could be used:

(1) to predict optimal asphalt content P_{mb} of reclaimed asphalt mixture

On the basis of RAP blended ratio, material properties, climate, traffic volume and technical experience, optimal asphalt content could be evaluated. If relevant datais lack, it is evaluated according to Eq.(1).

$$P_{mb}=0.035a+0.045b+Kc+F \quad (1)$$

Where: P_{mb} —predicted asphalt content of reclaimed mix,%; $K=0.18$, when the passing percentage of 0.075mm is 6~10%; $K=0.20$, when the passing percentage of 0.075mm $\leq 5\%$; a —the aggregate proportion above 2.36mm, %; b —the aggregate proportion between 0.075mm and 2.36mm, %; c —the aggregate proportion below 0.075mm, %; $F=0\sim 2.0$, depending on water absorption of aggregate.

(2) to calculate the ratio of new and old asphalt

The ratioof new and old asphaltis calculated according to Eq.(2) and Eq.(3).

$$\frac{x_n}{x_0} = \frac{P_{mb} - P_{ob}P_i}{P_{ob}P_i} \quad (2)$$

$$x_n + x_o = 1 \quad (3)$$

Where: x_n , x_o —the proportion of new and old asphalt;

P_{ob} —asphalt content in RAP,%;

P_i —blended ratio of RAP,%;

(3) to predict reclaimed asphalt grade

In Chinese, the penetration grading system is usually chosed to evaluate asphalt performance, so reclaimed asphalt number is predicted through penetration grading,such as Eq.(4)

$$\ln(P_m) = x_n^a \ln P_n + x_o^a \ln P_o \quad (4)$$

Where: P_m, P_n, P_o —penetration of reclaimed asphalt, new asphalt and old asphalt, respectively, 0.1mm;
 a —viscosity deviation index, $a=1.2$ (reclaimed agent), $a=1.02$ (new asphalt).

(4) to calculate blended ratio of regenerant

The proportion of regenerant is determined according to Eq.(4), finally to meet the penetration grading requirements. According to above steps, reclaimed asphalt content, old and new asphalt and reclaimed asphalt penetration are predicted, respectively, the results are shown in Table 4.

Table 4. Reclaimed scheme

Gradation	asphalt content $p_{mb}/\%$	x_n/x_o		Reclaimed asphalt penetration $P_m(0.1\text{mm})$		Meet the requirement of asphalt binder #70	Accept (Yes/No)	serial
R1	4.62	0.90	0.10	90#	74.1	Y	Y	R1-1
				110#	93.2	N	N	
				90#	54.4	N	N	
				110#	64.5	Y	N	
R3	4.62	0.71	0.29	90#+4% reclaimed agent	71.2	Y	Y	R3-1
				110#+2% reclaimed agent	70.5	Y	Y	R3-2
R5	4.62	0.48	0.52	90#	40.1	N	N	
				110#	45.8	N	N	
				90#+7% reclaimed agent	71.4	Y	Y	R5-1
				110#+5% reclaimed agent	69.3	Y	Y	R5-2

5. Mixed and molded of reclaimed mix blended sasobit modifier

In China, Marshall design method is still the main design method in asphalt mixture. It is required that mix specimens are compacted with Marshall compactor and are needed double-sides compaction for 75 times each.

When 3% blended ratio of Sasobit of WMRA is tested, the optimal mixed temperature and molded temperature of mixture should be determined theoretically through viscosity-temperature curve of reclaimed asphalt, the corresponding temperature of 170cp and 280cp viscosity is optimum mixed and molded temperature. In addition, when batch-up mixing equipment is used, preheating temperature of RAP is usually 110°C. The target mixed temperature needs to be reached through heat conduction from new aggregate to RAP, so the blended ratio of RAP and moisture content would affect heated temperature of new aggregate. Therefore, a reasonable determination of mixed temperature and heated temperature of new aggregate is the key part for WMRA.

Referring to relevant research results, the method to determine mixed temperature, heated temperature of new aggregate of WMRA is proposed.

Step1: to determine mixed and molded temperature of WMRA

For five kinds of reclaimed program, because the penetration value is close to 70, For 145-165°C is selected as mixed temperature, 135-155°C is selected as molded temperature.

Step 2: to determine the optimal mixed and molded temperature of WMRA

There is stable cooling ratio ΔT for any warm mixed agent. The optimal mixed temperature and molded temperature of WMRA are determined according to Eq.(5) and Eq.(6).

$$T_{wm} = T_1 - \Delta T \quad (5)$$

$$T_{wc} = T_2 - \Delta T \quad (6)$$

Step3: to determine heated temperature of new aggregate

The mixed temperature is reached through conducting heat from new aggregate to RAP. This means the higher RAP blended ratio is, the higher heated temperature is. Heated temperature of new aggregate is calculated using Eq.(7).

$$T_a = T_m + \frac{C_R P_R (T_w - T_R) + C_f P_f (T_w - T_f)}{(0.0078r + 0.504)C_a P_a} \quad (7)$$

Where: T_a —heated temperature of new aggregate, °C; P_a, P_R, P_f —the proportion of new aggregate, RAP, slag, %; C_a, C_R, C_f —the specific heat of new aggregate, RAP, slag, kJ/kg. °C; T_R, T_f —the beginning temperature of RAP, slag, °C; r —blended ratio of RAP, %.

The final results of heated temperature, mixed and molded temperature of new aggregate is shown in Table 5.

Table 5. Mixed and compacted temp of mixtures and heated temperature of new aggregate

Mixture	Serial	Mixed Temp /°C	Compacted Temp/°C	heated temperature of aggregate/°C
HMRA	R1-1-H	155	145	176
	R3-1-H	155	145	196
	R3-2-H	155	145	196
	R5-1-H	155	145	227
	R5-2-H	155	145	227
WMRA	R1-1-W	140	130	156
	R3-1-W	140	130	169
	R3-2-W	140	130	169
	R5-1-W	140	130	193
	R5-2-W	140	130	193

6. Marshall indicators and performance evaluation

After asphalt mixture is mixed and molded, Marshall indicators and road performance tests are measured.

Marshall Indicators

After Marshall specimens are molded, relative bulk density (γ) were tested, void volume(VV), voids in mineral aggregate and voids filled with asphalt(VFA) are calculated. (1)When blended ratio of RAP is 10%, heated temperature of aggregate is very low, the VV of HRAM and WRAM are 3.9% and 3.8%, indicating that both have the same density, the cooling ratio of Sasobit is about 15°C. (2)With the increase of RAP blended ratio, the VV of HRAM and WRAM raises simultaneously, especially the VV of HRAM, the reason is that with the increase of heated temperature of new aggregate, the asphalt aging degree is much higher, affecting the workability of mixture. (3)When RAP blended ratio is the same, the VV of HRAM is much higher than WRAM, the reason is that heated temperature of HRAM is much higher than that of WRAM, leading to much higher aging degree, thereby affecting more workability.

Road Performance Evaluation

Mixture rutting test, low temperature bending test, residual stability test and freeze-thaw splitting test are conducted for the above six kinds of mixture, in order to evaluate high-temperature performance, low temperature performance and water stability performance.

(1) rutting test

In China, Loaded Wheel Testers(LWTs) is used to conduct asphalt mixes high-temperature performance test, test temperature is 60°C, wheel pressure is 0.7MPa, test time is 60min, loading rate is 43 times/min. The performance of asphalt mixtures is assessed by calculating the dynamic stability¹, test results shown in Figure 1, Figure 2. The results suggests that: (1)With the increase of RAP blended ratio, DS of HRAM and WRAM slightly increases. In the same case of reclaimed asphalt grade for HRAM and WRAM, this phenomenon is caused by asphalt aging. (2)the average value of DS for HRAM and WRAM is 1786.2 and 2540.2(times/mm), respectively, and DS for WRAM is 30.1% higher than DS for HRAM, indicating that Sasobit can improve the high temperature performance of mixture; (3)DS value of all mixtures are higher than 1000(times/mm),to meet the Chinese specification requirement.

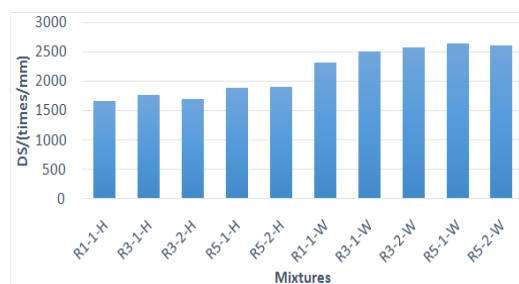
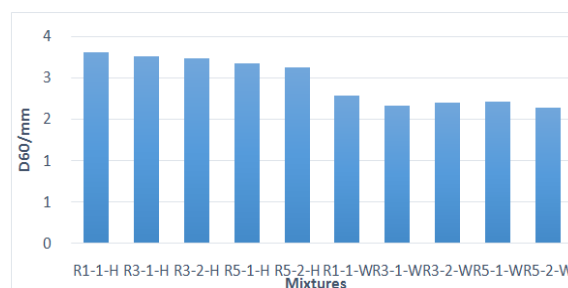


Figure1. DS Results of Mixtures.

Figure 2. D_{60} Results of Mixtures.

(2) low temperature bending test

Low temperature performance is the ability to resist shrinkage cracks at low temperature. Flexural tensile strength R_B , blending strain ε_B and stiffness modulus S_B are used to evaluate low temperature performance. Low temperature performance of mixture is tested by Material Testing System (MTS), the test temperature is -10°C , the loading ratio is 50mm/min. According to the sample size, when the trabecular was destroyed, flexural tensile strength R_B , blending strain b and stiffness modulus S_B can be calculated. The results suggest: (1) with the increase of RAP blended ratio, maximum failure strain of HRAM and WRAM decreases, and flexural tensile strength increases slightly. In the same case of reclaimed asphalt grade for HRAM and WRAM, this phenomenon is caused by asphalt aging. (2) the average value of flexural tensile strength for HRAM and WRAM is 9.81MPa and 10.75 MPa, indicating that Sasobit can improved flexural tensile strength mixture.

(3) water stability

Water stability of asphalt mixture is the ability to resist aggregate loose and shedding under the action of water. Residual stability (MS_0) and freeze-thaw splitting strength ratio (TSR) are used to evaluate water stability performance in Chinese specification. The results suggests, the MS_0 and TSR value between different reclaimed mixture do not vary remarkable, but all the values of mixture can meet $MS_0 \geq 80\%$ and $TSR \geq 75\%$ of specification requirements.

7. Summary and conclusions

(1) A calculation method about heated temperature, mixed and molded temperature of new aggregate for HMRA and WMRA is proposed.

(2) When the RAP blended ratio is low, the VV between WMRA and HMRA is very close, indicating that cooling ratio of Sasobit is 15°C .

(3) With the increase of RAP blended ratio, heated temperature of new aggregate for WMRA and HMRA is gradually raising, asphalt aging degree increases, leading to performance changes of mixture: VV and DS increases, low bended strain decrease.

(4) After Sasobit is blended into mixture, the new aggregate can reduce the heated temperature, weaken the asphalt aging degree, thereby reduce the VV of mix, and improve low temperature performance; Otherwise, Sasobit itself can improve the low temperature viscosity of asphalt, and then improve the high temperature performance. Sasobit materials are paraffinic, which can decrease low temperature property.

(5) High temperature performance and water stability performance of all WMRA meet Chinese specification requirements, and low temperature performance of partial mixture is slightly lower than the specification requirement.

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