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Rutting resistance property of warm recycled asphalt mixture

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Abstract: Warm recycled asphalt mixture can reuse the waste asphalt mixture via warm technology. In this paper, the waste mixture was reclaimed and analyzed. Warm recyclings with different propotion of reclaimed mixtures were designed. With the standard rutting test and Hamburg rutting test, the hot temperature stability of the warm recycling was evaluated. Conclusions on rutting resistance stability of warm recycling are drawn.

Introduction

Warm mix asphalt (WMA) is a newly developed technology. It is researched and applied throughout the world in recent years. The mixing temperature of WMA is 30°C lower than hot mix asphalt (HMA) and the performance of WMA is satisfying [1]. WMA has such advantages as energy-saving and low emission; it has received more and more attention throughout the world.

Reclaimed asphalt pavement (RAP) technology can use large amount of reclaimed pavement materials. After reclaiming, breaking, and screening, RAP can be mixed with virgin binder and aggregate, then recycled to produce hot asphalt mixture for pavement construction. There is important social significance for RAP technology because of the saving of bitumen and mineral aggregate resource. However, RAP percentage is limited for batch plant because of hot screening. So far, the maximum percentage is 30% at most, which will restrict the utilization of RAP technology [2, 3]. The combination of WMA and hot recycling is a new technology and it can effectively increase the percentage of RAP in recycled mixture.

As we all know, rutting is the most common distress of asphalt pavement especially in the condition of larger traffic volume and heavy axle duty. An important reason of rutting is the deficiency of high temperature stability of the pavement. With the coupling of high temperature and wheel loading, flow deformation may appear and the accumulation of the deformation will turn into rutting distress, when the shear stress surpasses the resistant ability of the mixture. Evaluation of high temperature property of asphalt mixture is the most important step for mixture design and evaluation. This paper investigates the rutting resistance of warm recycled mixture and analyses the feasibility of warm recycled mixture by comparing with hot recycled mixture.

Materials

In warm recycling, the reclaimed asphalt mixture is mixed with virgin aggregates and bitumen. The materials were tested respectively.

RAP. In this study, RAP came from Miyun region of Beijing. There were two types of RAP, 0~3mm and 3~15mm. They were tested individually, the results is listed in table1 and Table2.

Table 1 Grading and asphalt ratio of RAP

Sieve size (mm)	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	Asphalt ratio (%)
3-15mm (%)	100	99.4	93	70.6	46.3	31.1	25.3	16.5	11.1	7.3	4.29
0-3mm (%)	100	100	100	99.3	94.1	66.2	51.6	32.3	21	13.5	7.51

Table 2 Properties of Asphalt in RAP

Items	Unit	Requirement	Results
Penetration（5°C,5s,100g)	0.1mm	>20	20.9
Soft point (R&B)	°C	—	62.3
ductility@15°C	cm	—	1.1

As it shows in Table 2, the RAP was aged but it can meet the standard requirement [4]. The RAP can be recycled for engineering application.

Binder and Aggregate. Virgin binder and mineral aggregates are essential to recycled mixture besides RAP. In this study, pen70 virgin bitumen was used. The new mineral aggregates including coarse aggregate, fine aggregate and filler can all fulfill the technical requirement [5].

Mixture Design

Before investigating the high temperature property of warm recycling, the mixture was designed. In the mineral gradation, S-shape gradation was selected to improve the high temperature stability. At the same time, higher air void was adopted in this study for mineral skeleton structure.

Two RAP proportions were used for evaluating the influence of RAP on mixture performance, which was 45% and 50%. Table 3 shows the gradation of the recycled mixtures.

Table 3 Gradation of Warm mix

Sieve size (mm)	RAP 3-15mm	RAP 0-3mm	10-25 mm	10-15 Mm	5-10 mm	Filler	A (%)	B(%)	Range (%)
26.5	100	100	100	100	100	100	100.0	100.0	100
19	100	100	82.6	100	100	100	94.8	94.8	90～100
16	100	100	52	99.8	100	100	85.6	85.6	76～90
13.2	99.4	100	16.5	92.2	100	100	73.5	73.5	64～80
9.5	93	100	0.8	32.8	99.8	100	57.3	56.7	50～64
4.75	70.6	99.3	0.2	2.7	18.5	100	37.2	39.3	33～43
2.36	46.3	94.1	0.2	1.4	1.9	100	25.6	27.4	21～31
1.18	31.1	66.2	0.2	1.1	1.4	100	18.1	19.1	13～23
0.6	25.3	51.6	0.2	1.1	1.3	100	15.0	15.7	9～17
0.3	16.5	32.3	0.2	1	1.2	99	10.5	10.8	6～12
0.15	11.1	21	0.2	1	1.1	96.6	7.7	7.7	4～9
0.075	7.3	13.5	0.2	0.9	1	90.3	5.7	5.5	3～7
45%RAP	40	5	30	15	8	2	100	-	-
50%RAP	45	5	30	15.5	3	1.5		100	-

At the same time, hot recycled mixtures with 20%, 25% and 30% RAP were designed. The volumetric parameters were measured for comparison, which is in Table 4.

Table 4 Volumetric parameter results of warm and hot recycling

Mix type/ RAP ratio	A.A.R/Virgin binder content	Pmm	Psb	Va (%)	VMA (%)	VFA (%)	Stability (kN)	Flow Value (0.1mm)
WRAC-20/45%	4.4/4.20	2.632	2.519	4.4	13.9	68.7	9.77	27
WRAC-20/50%	4.4/4.19	2.630	2.518	4.3	13.9	69.0	10.13	29
HRAC-20/20%	4.4/4.35	2.626	2.516	4.2	13.8	69.7	10.27	27
HRAC-20/25%	4.4/4.31	2.629	2.515	4.4	13.9	68.6	9.90	29
HRAC-20/30%	4.4/4.26	2.631	2.518	4.3	13.8	68.7	10.19	28

Based on the same gradation, the virgin bitumen proportion reduces with the increasing of RAP. However, air voids of recycled mixture stay at the same level.

Rutting Resistance

Bituminous mixture is a kind of visco-elastic material and its properties are closely affected by loading duration and temperature. At higher temperature, the repeated action of wheel loading will lead to perpetual deformation. Rutting is the most common distress for asphalt pavement [6]. The strength and deformation resistance of bituminous mixture are required to improve, especially in higher temperature area.

There are many methods to evaluate the high temperature stability of asphalt mixture. In China, dynamic stability of wheel rutting test is generally applied [7]. Test conditions can be adjusted to simulate the actual loading and climate condition.

Hamburg wheel rutting test is used to simulate the deformation characteristics under action of heavy-duty vehicles. With the repeatedly action of steel wheel load, the growing and accumulating of rutting suggests the resistance potential. In Germany, this test is applied to evaluating the rutting resistance and the raveling with the extensive traffic volume [8].

Wheel Rutting Test. In this study, the wheel rutting test and Marshall Test were conducted to evaluate the high temperature stability. The tests were according to Chinese national standard [9], the results are indicated in Table5.

Table 5 Results of high temperature property of recycled mixture

Mix type/ RAP ratio	Marshall Stability (kN)	Flow Value (0.1mm)	Dynamic Stability@60°C, (cycles/mm)
WRAC-20/45%	9.77	27	2157
WRAC-20/50%	10.13	29	2269
HRAC-20/20%	10.27	27	2279
HRAC-20/25%	9.90	29	2367
HRAC-20/30%	10.19	28	2406
Standard Requirement(1-3-2)	≥8.0	20~40	≥1000

The Marshall Stability, Flow Value and Dynamic Stability of the warm recycling meet the national standard. For both hot recycling and warm recycling, with the increase of RAP, rutting resistance ability improves.

Wheel Rutting Test under special conditions. To simulate the high temperature stability of warm recycling under the actual temperature and load condition, the testing temperature was increased to 70°C and the contact pressure is 1.0MPa [10]. The results are illustrated in Table 6.

Table 6 Results of rutting at higher temperature and pressure

Mix type	Dynamic stability@70°C,1.0MPa(cycles/mm)
HRAC-20	713
WRAC-20	721
HMA AC-20	Destroyed

It shows that the rutting resistances of recycled mixtures are better than the hot mix. The warm recycling exhibits equivalently with the hot recycling.

Hamburg wheel rutting test. Hamburg wheel rutting test was carried out at 60°C to evaluate the high temperature stability. Rutting depth with 20000 cycles was applied as the criterion. The growing curve of the rutting depth is in Figure1, Figure 2 and Figure 3.

The Hamburg rutting depths of hot recycling and warm recycling was 2.85mm and 5.18mm respectively after 20000 repeated cycles, while the rutting was more than 12mm after 7000 cycles for HMA. It is clear that both warm and hot recycling exhibit better rutting resistance than HMA. RAP is beneficial to improve the high temperature stability of asphalt mixture. On the other hand, warm recycling is interior to hot recycling on rutting resistance because it is produced at a lower temperature and the binder is less aged.

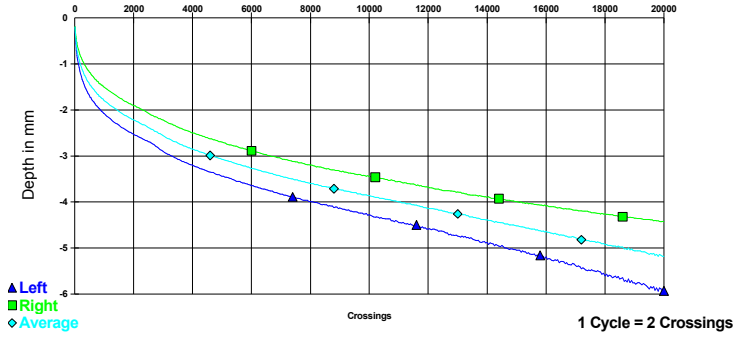

Figure 1 Hamburg rutting depth curve of warm recycling

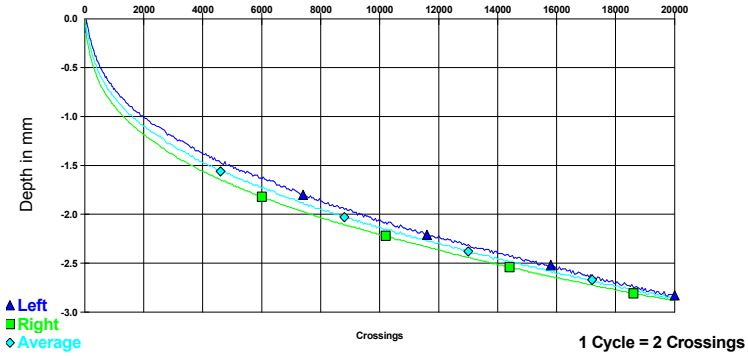

Figure 2 Hamburg rutting depth curve of hot recycling

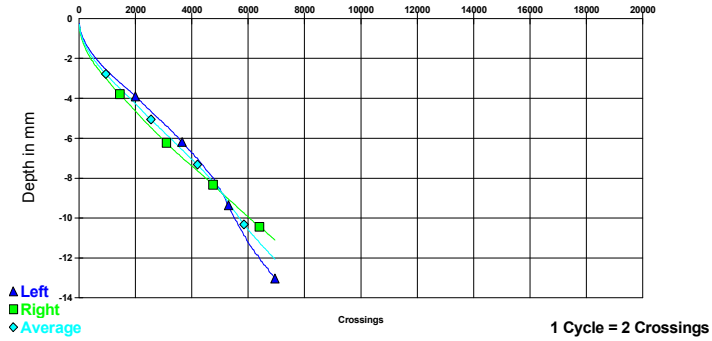

Figure 3 Hamburg rutting depth curve of HMA

Conclusions

The high temperature stability of warm recycling was investigated in this paper, and the following conclusions can be drawn:

1. The properties of warm recycling can fulfill the requiremengt if it is reasonably selected and designed.

2. Rutting test and Hamburg rut testing results illustrate that warm recycling exhibits well on high temperature stability, the increase of RAP in warm recycling is good for the improvement of rutting resistant ability.

3. Both hot and warm recycling are superior to HMA as far as rutting resistance ability is concerned, and warm recycling can't excel its hot counterpart.

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