

METHODOLOGY FOR EVALUATING THE RESISTANCE TO REFLECTIVE CRACKING OF ASPHALT MIXTURES UNDER HEAVY VEHICLE LOADING IN GUANGDONG, SOUTH CHINA

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ABSTRACT

Reflective cracking is one of the common problems faced with the asphalt overlay on an existing concrete road. The key to prevent reflective cracking is mainly depending on the performance of asphalt mixture. But now there is not still a simple and facile method and an index to evaluate reflective cracking resistance of asphalt mixture. This paper brings forward impact tenacity as an index and validates it by the simulating test. According to this principle we can design FAC asphalt mixture that is feasible and validated by trial road.

Keywords: reflective cracking, asphalt overlay, asphalt mixture, evaluation

INTRODUCTION

Asphalt overlay is often one of the simple and effective means of improving the performance of existing concrete pavements, but the main problem commonly encountered with this measure is reflective cracking in the asphalt overlays. But until now all measures only can leave reflective cracking happen and grow. There is not a measure that can prevent reflective cracking at all. The cause of reflective cracking can be marked off two types---temperature reflective cracking and load reflective cracking. In the most situations reflective cracking begins at the bottom of asphalt overlays except that temperature reflective cracking may happen from the top to bottom of asphalt overlays. With the economic development, the traffic increased and the proportion of overloading vehicle enhanced. So, the reflective cracking comes out accelerative. In the past, many measures, such as geotextile, fabrics etc., have been testified that those can prevent reflective cracking at a definite level. Therefore, if wanting to enhance the ability of asphalt overlay to resist reflecting cracking, the key is still to improve the performance of asphalt mixture and design with fatigue of asphalt mixture as a main index. So we need an amiable method to evaluate reflective cracking resistance of asphalt mixture.

IMPACT TENACITY OF ASPHALT MIXTURE

When a force is loaded, material will have stress and strain. The strain and stress curve of micro-units in viscoelastic material goes through different routes and forms a ring as loading and unloading, as showed in Figure 1. The area of ring can be thought as the whole energy loss in the loading process. We call the ring as lag ring. In the repeated loading process, the energy as the area of lag ring will transform into heat energy partly or completely. The heat energy will lead the material to plastic deformation and fatigue failure. So we can draw the conclusion that the less the area of lag ring is, in one loading and unloading process, the stronger fatigue resistance is. It can be used the equation $N_f = a(1/W_0)^b$ to explain the fatigue of material under repeating load. N_f means fatigue life. A , b mean material modulus; W_0 means the energy saved in the first loading process.



Figure 1. Lag curve.

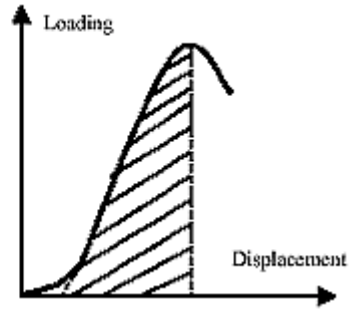


Figure 2. The curve of impact tenacity.

On the other hand, the wheel run cross the cracking on the concrete immediately and the instant force is considerable large. Therefore if we can draw the load-deformation curve when the asphalt concrete sample breaks under the high speed load, the area of lag curve means the energy that material need when sample break. We can call it impact tenacity and use I to symbolize it. The typical curve is showed as Figure 2. It is apparent that impact tenacity and reflective cracking resistance are in a direct proportion.

Using the “HongdaE5” electrical tensile test machine tests the bend impact tenacity of some kinds of asphalt mixtures. The size of beam is 25cm-3.5cm-3.5cm and the speed of loading is 500mm/min.

Experimental materials

The experiment adopts 70# bitumen and SBS modified bitumen, whose main performance is listed in Table 1 and Table 2.

Three types of gradation have been chosen: asphalt macadam (AM), continuous dense-graded asphalt concrete (AC) and full asphalt content asphalt concrete (FAC), and list in Table 3.

Table 1. The performance of 70 # bitumen.

Test Index	Scope	Result	Test Method
Penetration 25°C	60-80	71.5	T0604-2000
Ductility 25°C, 5cm/min ,cm	>100	>100	T0605-1993
Softening point $T_{R\&B}$ (°C)	44-54	50.2	T0606-2000

Table 2. The performance of SBS modified bitumen.

Test Index	Scope	Result	Test Method
Penetration index PI	≤ -0.2	0.043	T0604-2000
Ductility 5°C, 5cm/min ,cm	≤ 30	33	T0605-1993
Softening point $T_{R\&B}$ (°C)	≤ 55	90.7	T0606-2000
Segregation: 165°C, 48hr, the difference of softening point °C	$\neq 2.5$	0.8	T0661-2000
Viscosity (N·m)	----	25.8	T0624-1993
Tenacity (N·m)	----	21.5	T0624-1993
Elastically recovering 25°C, %	≤ 65	95	T0662-2000
Viscosity (PaS)	135°C	$\neq 3.0$	T0625-2000
	165°C	----	0.73
Segregation: 165°C, 48hr, the difference of softening point °C	$\neq 2.5$	0.8	T0661-2000
Viscosity (N·m)	----	25.8	T0624-1993

Table 3. The gradation of mixture.

Size (mm)	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	Content of Asphalt
AC-20	100	97.5	82.5	71	62	48	37	27	22	15	10	6	5.0%
FAC-20	100	96.4	70.1	58.8	46.0	26.0	21.8	17.4	13.6	9.8	7.8	6.2	5.6%
AM-20	100	95	72.5	62.5	52.5	27.5	13.5	9	6.5	5	4	2.5	3.8%
AC-25	97.5	82.5	71	63	53	42	33.5	25	19	13	9	5	5.0%

Test result:

Table 4. Impact tenacity of different mixture at different temperature.

Temperature	Kind of AC	1	2	3	4	5	6	Average (N·m)
15°C	AC20	3.123	1.134	1.334	----	1.365	2.066	1.475
15°C	AC25	1.404	1.363	0.531	1.841	----	1.495	1.327
15°C	AM20	0.739	1.547	----	0.902	0.418	0.476	0.568
5°C	AC20	0.746	0.951	0.592	0.393	0.954	0.487	0.746
5°C	AC25	0.410	0.419	0.972	----	0.816	0.791	0.609
5°C	AM20	0.173	0.267	0.213	0.337	0.319	0.158	0.243

Table 4 shows some results of impact tenacity. We can draw the conclusion that the type of mixture is the key to confirm impact tenacity. Although AC20 and AM20 are designed with the same maximum size of aggregate, impact tenacity is different. When a force works on asphalt mixture, one part of the force is borne by the main aggregate and the other is borne by asphalt mortar. It is considerably different that the stiffness of aggregate compares with the stiffness of asphalt mortar. The strain caused by a force can be 85 times than the whole strain of mixture and be 4.3 times in average. So according to the Load – Displacement curve, the area of AC20 is more than that of AM20. In the same type of mixture, the impact tenacity of AC25 is less than that of AC20. Therefore it can be explained that the size of aggregate affects the impact tenacity of mixture, especially fine aggregate do much.

THE SIMULATIVE TEST OF REFLECTIVE CRACKING RESISTANCE

In order to research the relationship of impact tenacity and reflective cracking resistance, the simulative test simulates reflective cracking happening and developing.

APA (Asphalt Pavement Analyzer) tester is designed according to the research of Georgia Institute of Technology, and can be used to test rutting resistance, water damage resistance and fatigue resistance. In order to simulate with the actual condition, test model as followed in Figure 3 is adopted.

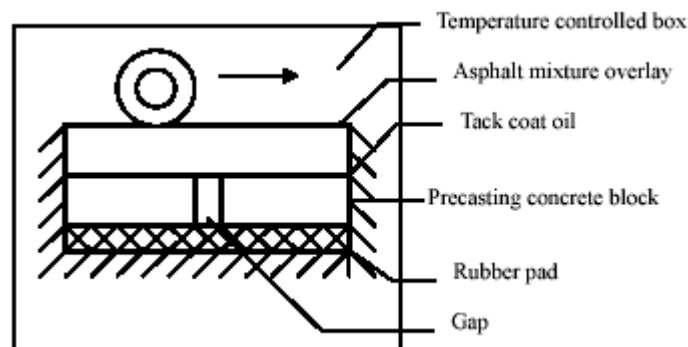


Figure 3. The sketch map of test.

The asphalt concrete is compacted and cut in rectangular size 30cm·12.5cm·3.5cm. The height of precast concrete specimens is 4.5cm. Put the precast specimens into the oven for preheating, then take them out and put them into the mold, making sure that there is a 3mm-wide cracking between the two precast specimens. The constraint of both sides and bottom of specimens is shown as Figure 3. There should have shown tack coat between the precast specimens and asphalt overlay. A rubber pad should be put under the precast specimens, which is 27.5cm·12.5cm·21.4cm in size, and its modulus of elasticity is 30-40kg/cm²/cm. The fabricated specimens should be cooled for four hours in room temperature (25±3°C), then put them into APA tester conserves for four hours under best temperature before conducting the test.

APA tester can finish three parallel trials in the same step. The conditioning temperature can be controlled in 10-60°C. The simulative load is steel wheel, whose back-and-forth moving frequency is 60 times per minute and the contact stress with specimen can be adjusted. In the experiment, load is 123kg and temperature is 15±1°C. Data measured is transferred into computer by sensor and the record is given by the form of curve and data. By the model analysis, fatigue cracking has been visible on the top of the asphalt mixture specimen when the difference of adjacent deflection of the precast specimen is more than 0.2mm. Comparing the result of the simulative fatigue test with the result of impact tenacity, the relationship between them can be seen in Figure 4.

From Figure 4, it can be seen that the more impact tenacity asphalt mixture has, the more fatigue life it has, and it can prevent reflecting cracking validly. The correlation between impact tenacity and fatigue is well and the variance of regression curve is R²=0.983. As a result we can use impact tenacity as an index to evaluate and forecast the reflective cracking resistance of asphalt mixture.

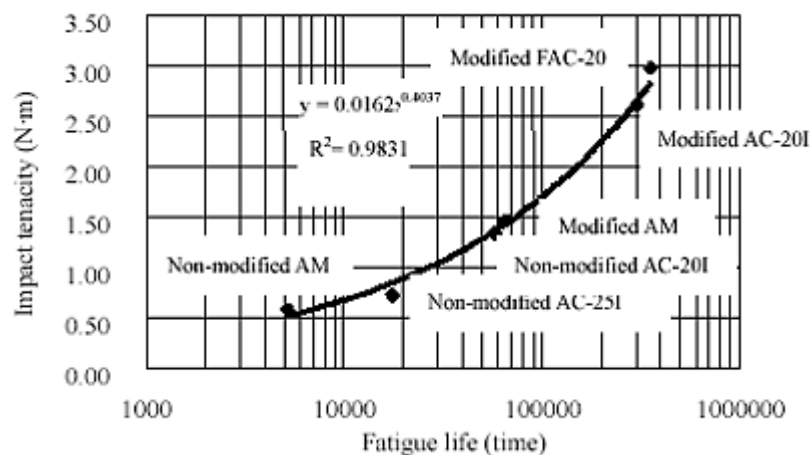


Figure 4. The relationship of fatigue life and impact tenacity.

FULL ASPHALT CONTENT ASPHALT CONCRETE

In order to apply impact tenacity to design asphalt overlay on the cement concrete road and improve the resisting reflective cracking and expand the life in use of asphalt overlay, we can design full asphalt content AC (FAC) with SBS modified asphalt by coarse aggregate voids filling method (CAVF).

CAVF emphasizes the role of interlock among the coarse aggregate (≥ 4.75 mm). It requires the Void of coarse aggregate measured in fact is less than the VCA_{des} , which is void of coarse aggregate with elected gradation in compact state. According to formula that followed, after deciding asphalt content, mineral powder content and designed void ratio, the content of coarse aggregate and fine aggregate can be worked out.

$$\frac{q_c}{100\rho_{ic}}(VCA - V_{vs}) = \frac{q_f}{\rho_{ff}} + \frac{q_p}{\rho_{fp}} + \frac{q_a}{\rho_a}$$

where:

- q_c, q_f, q_p, q_a : weight percent of coarse aggregate, fine aggregate mineral powder and bitumen,
- $\rho_{tc}, \rho_{tf}, \rho_{tp}$: apparent density of coarse aggregate, fine aggregate and mineral powder,
- ρ_a : density of bitumen,
- V_{vs} : design void ratio of asphalt mixture.

CAVF not only design the gradation of mixture, but also design with asphalt content, void, and VMA etc. index together. For example, a kind of coarse aggregate, VCA is 37.3. Assumed that asphalt content is 5.5%, the content of mineral powder is 6%, designed void ratio is 4%, so that the percent of coarse aggregate worked out is 74.8, the percent of fine aggregate worked out is 19.2. In the end the designed gradation of FAC20 asphalt mixture is listed in Table 6 and the result of Marshall Test is listed in Table 7.

Table 6. Component of the gradation of asphalt mixture.

Size (mm)	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
FAC-20	100	96.4	74.8	58.3	45.4	25.2	21.2	16.9	13.3	9.6	7.7	6.2

Table 7. The result of Marshall test (the content of asphalt is 5.5%).

Asphalt content	Density (g/cm ³)	Maximum Density (g/cm ³)	Void ratio (%)	VMA (%)	VFA (%)	Stability (N)	Flow (0.1mm)	VCA (%)
5.50%	2.330	2.458	5.223	17.01	69.3%	12372	35.9	38.8
	2.345	2.458	4.582	16.45	72.2%	10422	34.0	38.4
	2.321	2.458	5.558	17.31	67.9%	9147	39.8	39.0
Average	2.332		5.121	16.92	69.7%	10647	36.6	38.7

Comparing with the continuous dense-graded asphalt mixture AC20I, the optimum asphalt content chosen by Marshall test improves 0.5 percent. So if the chosen void is 5%, which is one percent more than that of the continuous dense-graded asphalt mixture AC20I, we can work out that VMA is 17% and VFA is 70.5%. The dynamic stability of this kind of asphalt mixture is 3324 times per mm in the rutting test. It can show that if the gradation is designed in reason, the rutting resistance of mixture is still strong, because the asphalt mortar play an important role - it bonds the coarse aggregate and fills in the void of coarse aggregate, making the skeleton of asphalt mixture strong to bear load. In addition, the water-damaged resistance of FAC asphalt mixture is similar to the common dense-graded mixture.

Many studies on the fatigue of asphalt mixture show that the fatigue life is related with the asphalt content. The more the asphalt content is, the longer the fatigue life is. In a conclusion, FAC asphalt mixture has the most impact tenacity. The fatigue life of FAC asphalt mixture resisting reflective cracking is 4.5 times than that of AM20 asphalt mixture, and improves 20 percent than that of AC20 asphalt mixture, according to the analyses on the comparison of simulative test with APA (Figure 4).

THE EXAMPLE

We apply this technology of FAC asphalt mixture overlay in order to improve the impact tenacity and reflective cracking resistance of asphalt mixture in Guangdong province. For example, FAC asphalt mixture designed with CAVF is used as liner layer of the overlay on old PCC road ($K_{4+400} \sim K_{4+800}$) in the project of reconstruction of north-ring highway in Guangzhou. The layer is 5cm in height and SMA13 is paved on it, the total height is 9cm. SBS modified asphalt is in use. According to the criteria of SHRP road performance, SBS modified asphalt is PG70-28 in gradation, its penetration is 61 and softening point is 83°C. The daily traffic on the whole highway is nearly amount to 0.19 millions vehicles per day. The most traffic in one

section is about 8,000 vehicles per day and overloading is very severe. The project is finished by the end of December 2000. The test overlay is in a good use and no damage is found, although during this seven months there are rainfall, which the historical record, and the higher summer average month temperature and the lower winter average month temperature in the past 50 years.

Another example, FAC asphalt mixture overlay is used as the material of the main express in Baoan district, Shenzheng. The overlay is 5 cm in height and the asphalt content is 5.7 percent, and the total area is up to 12 thousands square meters. FAC asphalt mixture is also taken place of asphalt macadam as the adjust layer in the Guangyuanzhong road of Guangzhou. Of course those trial roads are in use only some months, it is necessary to observe and study the actual ability of FAC asphalt mixture to resist reflective cracking for a long time. Now our study is going on.

Above all, we can draw some conclusions that is important to the project paving asphalt overlay on the old concrete road:

- The impact tenacity of asphalt mixture can be get by the bending test in the condition of 15°C, 500mm/min;
- The impact tenacity is in a good correlation with the reflective cracking resistance, so it can be regarded as an index to design the asphalt mixture overlay;
- Improving the asphalt content in some proper scope, the reflective cracking resistance of asphalt mixture can be enhanced;
- Using modified asphalt in the adjacent overlay on the old concrete road can improve the reflective cracking resistance of asphalt mixture.

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