Advantage, Quality Control and Application of a Plant-Mix Asphalt Modifier on Porous Asphalt and Steel Deck Pavement

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ABSTRACT: Comparing with the pre-mix asphalt modifying method, less attention has been paid to the plant-mix method due to quality control issues . Herein a new kind of plant-mix asphalt modifier, RST (Road-Science-Technology, a trademark), will be introduced. RST provides an easy way to produce high viscous asphalt mixture, which has been widely used in porous asphalt and steel deck pavement. Shorter heating history of the binder ensures less aging tendency due to characteristic of the plant-mix method. By means of the microscopy techniques, the quality control progress is evaluated to be efficient, cheap and reliable.

KEY WORDS: Pre-mixing modifier, plant-mixing modifier, high viscous asphalt, RST.

As an asphalt modifier, SBS has been playing a very important role.Comprehensive modifying effect makes it a mainstream of asphalt modifier, and the manufacturing process of the pre-mixing SBS polymer modified binder (PMB), including swelling, milling and maturing, has been widely used as a standard process.

Some problems of pre-mixing SBS PMB have been exposed according to special demands. For example, the high viscous PMB (HV-PMB), has been widely used in porous asphalt. By Japan standard, its 60℃ viscosity is higher than 20,000 Pa·s[1], furthermore, an ideal porous asphalt properties needs the viscosity higher than 100,000 Pa·s. A common choice is adding more SBS to increase 60℃ viscosity. But, with increasing SBS content, the compatibility of asphalt and SBS will worsen, phase separation tendency will increase, and additives will be needed to keep phase stability, where cost and storing process will be dramatically influenced.

Other problems occur on steel deck pavements. The HV-PMB is used to satisfy high temperature properties of asphalt mixture under rigorous circumstance. According to previous reports [2,3,4],pre-mixing SBS PMB are used, where the 60℃ viscosity reaches 300,000 to 400,000 Pa·s. Correspondingly, the 135℃ viscosity remarkably exceeds target value of china standard, which is ruled by less than 3Pa·s[5]. The temperature of PMB and asphalt mixture has to be raised to satisfy pumping need of PMB and mixture compaction. In an extreme

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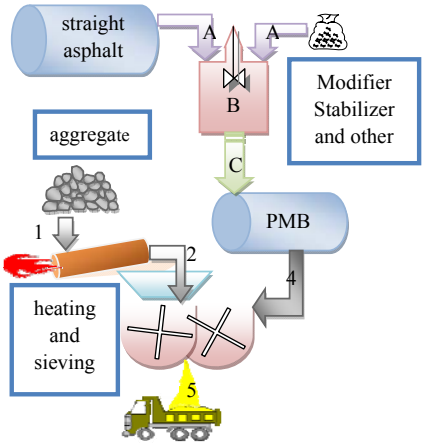
example, the temperature of mixture reaches 210℃ and the tracing of the project reports diseases relating to binder aging.

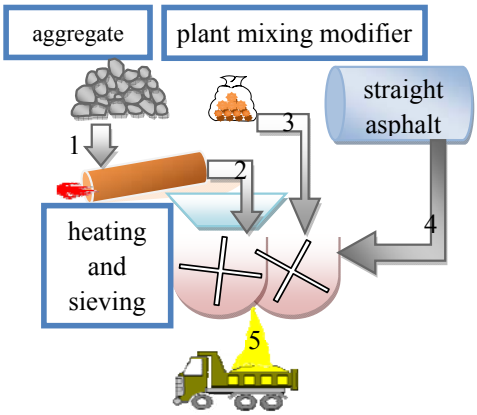
In brief, separation tendency,viscosity balance between higher temperature (135℃) and lower temperature(60℃) indicates shortcoming of SBS PMB, and effort and cost to resolve these problems shows a congenital defect of the pre-mixing modifying method.

Herein,a plant-mixing asphalt modifier, RST, will be reported, including its modifying mechanism, properties and application on porous asphalt and steel deck pavement.

1 INTRODUCTION

A typical manufacturing process of pre-mixing SBS modifying method is shown in Figure 1.The plant-mixing one is shown in Figure 2, where manufacturing, storing and shipping of PMB are omitted and the modifying process is completed in the mixer.





A. adding B. milling C. shipping, storing of modified asphalt
1. heating of aggregate 2. dry mixing of aggregate
3. adding and mixing of the modifier 4. wet mixing 5. loading

Figure 1: Pre-mixing modifying method Figure 2: Plant mixing modifying method

As a plant-mixing modifier, RST is a kind of thermal-plastic polymer, which is added into the plant mixer to modify the straight asphalt. Its properties is shown in Table 1.

Table 1: Properties of RST

Item	Properties	Signification
Appearance	well-distributed size	Separating properties within mixture
Density (g/cm^3)	0.95~1.02	
Smell	No irritant smell	Environmental and safety properties
Melt Index (g/10min)	>10	Separating properties within mixture

2 APPLICATION

Less attention has been paid to the plant-mix asphalt modifying method comparing with the pre-mix one since its birth. The reason might be that the existing quality control system corresponding to pre-mixing PMB can not evaluate the modifying effect at real time. On the other hand, there is still no effective measure to ensure and indicate modifying stability.

The modifying process of RST is demonstrated in Figure 2. RST is added into the mixer during dry mixing. Agitated by mixer, kneaded and heated by aggregate with high temperature, RST is melted and well distributed onto aggregate surface. During the course of wet mixing, straight asphalt is mixed with RST on the aggregate surface. Large contacting surface between asphalt and RST makes the modifying process complete quickly and PMB mixture is manufactured finally.

2.1 Indoor manufacturing method of RST PMB

To adapt to existing quality control system，an indoor manufacturing method of RST PMB is used as below：Mixing RST with small amount of straight asphalt (about 67 wt% of RST) and heating to about 150℃, RST will be partly melted in asphalt as mushy mixture. Then agitating and heating to 180℃, adding straight until corresponding amount completed. Finally, after milling for 3 minutes,the RST PMB is produced.

2.2 Properties of RST PMB

Using Esso straight asphalt 60/80, RST content is 8 % (asphalt:RST=92:8),10 % (90:10),12% (88:12),14% (86:14) (wt%), respectively, as shown in Table 2.

Table 2: Main properties of RST modified asphalt

Item	Unit	Esso 60/80	Esso +8%RST	Esso +10%RST	Esso +12%RST	Esso +14%RST	Target value*
Penetration (25℃,100g)	0.1mm	77	61	56	49	45	>40
Softening Point (R&B)	℃	46.3	74.2	81.9	92.1	95.8	>80
Ductility (5℃)	cm	/	32.71	35.29	40.47	28.44 (failed)	≥30
Toughness	N·m	/	13.88	26.12	32.71	38.65	>20
Tenacity	N·m	/	10.53	15.99	21.56	27.31	>15
Viscosity (60℃)	Pa·s	180	26,150	192,600	300,463	497,000	≥20,000
Viscosity (135℃)	Pa·s	/	2.01	2.41	2.90	3.40	-

*partly from JMAA.

Based on Table 2,some results can be summarized as follows:

1) RST PMB shows excellent high temperature stability by increasing RST content.
2) Addition of RST greatly improves low temperature properties of binder (5℃ ductility), which endows mixture with good fatigue and anti-cracking properties.

3) The 60℃ viscosity dramatically increases with RST addition, 8% content reaches higher than 20,000 Pa·s and 10% content could satisfy all demands of HV-PMB.
4) The proper content of RST should be from 10 to 12 % according to comprehensive factors,such as construction and cost.

2.3 Comparison with pre-mixing modifying method

2.3.1 Properties

Esso straight asphalt 60/80 is used to produce HV-PMB, the SBS content is 0 %,4 %,5 % and 8 %(wt%),respectively,main properties is shown in Table 3.

Table 3: Main properties of pre-mixing SBS PMB

Item	Unit	0% SBS	4% SBS	6% SBS	8% SBS	Target
Penetration (25℃)	0.1mm	77	52.7	49.2	43.1	>40
Softening point(R&B)	℃	46.3	73.4	81.3	101.3	>80
Ductility(5℃)	cm	0	33.7	34.7	55.3	≥30
Viscosity(60℃)	Pa·s	180	9,300	18,200	38,200	≥20,000
Viscosity(135℃)	Pa·s	-	2.17	3.17	3.57	≤3.0

Based on Table3,some results can be summarized as follows：

1) The comprehensive modifying effect of SBS has been clearly demonstrated.
2) The 60℃ viscosity is very small. When adding 8% SBS,the 60℃ viscosity is only 38,200 Pa·s, and at the same time the 135℃ viscosity has reached 3.57 Pa·s. A 60℃ viscosity higher than 100000 Pa·s could be anticipated by adding more SBS, but the pumping of PMB and compaction of mixture will be greatly affected.

Two kinds of pre-mixing SBS HV-PMB A and B are chosen to compare with RST HV-PMB.

Table 4: Comparison between pre-mixing SBS HV-PMB and RST HV-PMB

Item	Unit	pre-mixing A	pre-mixing B	Esso60/80 +12%RST	Target value
Penetration (25℃)	0.1mm	44	47.6	49	>40
Softening point (R&B)	℃	92	87.4	92.1	>80
Ductility (5℃)	cm	70	35.2	40.47	≥30
Viscosity (60℃)	Pa·s	109,300	48,200	300,463	≥20,000
Viscosity (135℃)	Pa·s	4.96	3.21	2.90	≤3.0

Based on Table4, conclusions could be drawn that:

1) All of the three kinds of PMB satisfy target values.
2) Considering 60℃ viscosity, all of them could be defined as HV-PMB.
3) The HV-PMB with 12% RST has a better viscosity balance.

2.3.2 Modifying Effect

The microscopy is often used to analyze micro-state of PMB and evaluate modifying effect.

The micro-state of every stage could be clearly demonstrated in Figure 3. Through mixing, milling, swelling and maturing process, the mixture of SBS and asphalt will be eventually turned into a homogeneous state. SBS has a density less than 1 g/cm^3, which is a little less than the density of straight asphalt.And the average molecular weight is higher than 100,000 and about 1000, respectively. The PMB can be considered as an energetically unstable mixture due to the density and molecular weight difference between SBS and asphalt. To prevent SBS PMB from separating, stabilizer and agitation are needed during storing stage. The microscopy of RST HV-PMB is shown in Figure 4.

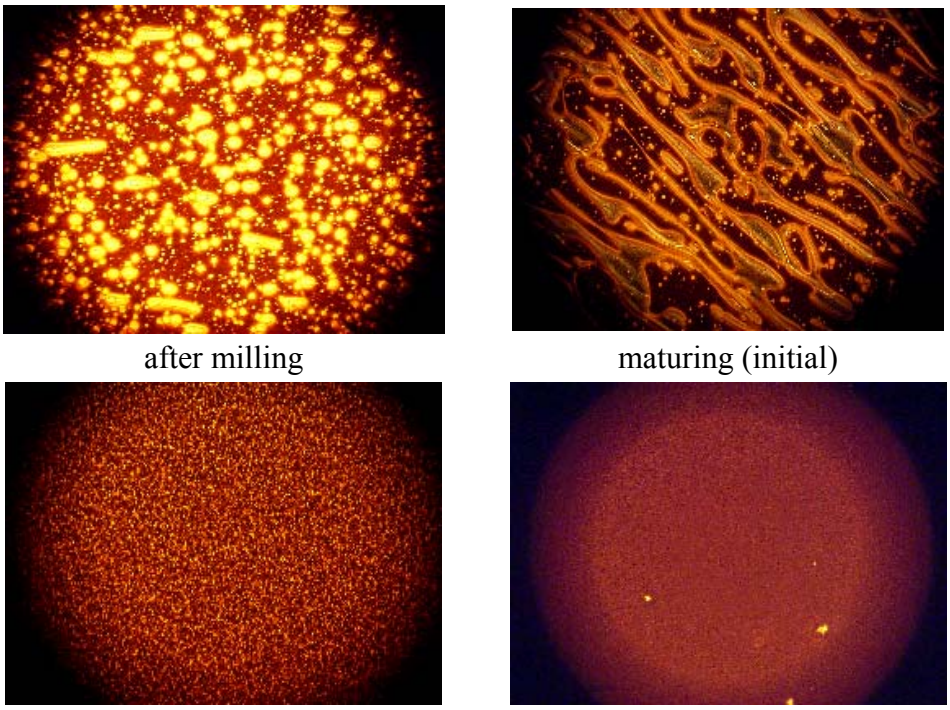


Figure 3: Microscopy of pre-mixing SBS PMB (×100)[6]

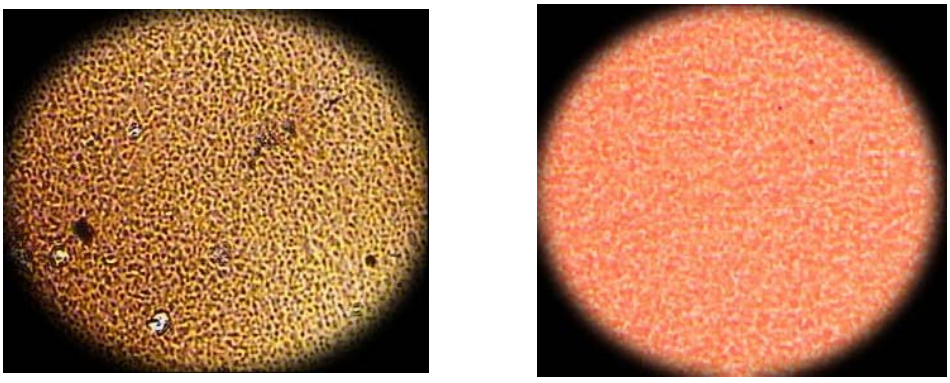


Figure 4: Microscopy of plant mixing RST PMB (×400)

Figure 4 shows that a clear and homogeneous modifier network has been formed and a

stable PMB can be produced with RST.

2.3.3 Summary

Briefly speaking, PMB with excellent and stable properties could be produced with RST. According to special cases,the RST HV-PMB has excellent high temperature properties and well-balanced viscosity, and has unique advantage comparing with pre-mixing SBS HV-PMB.

Additionally, a shorter heating history due to the omission of milling, maturing and storing process endows HV-PMB with a lower aging tendency, which will remarkably contribute to low temperature and fatigue properties of asphalt mixture.

3 APPLICATION CASES

3.1 A case of porous asphalt

Since 2002,about 1,500 thousand square meters porous asphalt road has been paved in Pudong District, Shanghai city. The plant mixing modifying method is used to produce HV-PMB mixture, in which over 95% of them used RST modifier.

3.1.1 Introduction

HuanNan Rd.1 expressway belongs to Outer Ring A20. It runs across Pudong District, connecting with Pudong airport expressway (A1) and Luchao harbor expressway (A2). In October 2006,the maintenance project of HuanNan Rd.1 was carried out, in which about 2.7 km porous asphalt overlay was paved with 4 cm liftness.

3.1.2 Materials

RST content of 14% was chosen due to heavy duty of HuanNan Rd.1. Properties of RST HV-PMB is shown in Table 5.

Table 5: Properties of RST HV-PMB

Item	Penetration (25℃, 100g)	Softening point (R&B)	Ductility (5℃)	Toughness	Tenacity	Viscosity (60℃)	Viscosity (135℃)
Unit	0.1mm	℃	Cm	N·m	N·m	Pa·s	Pa·s
14%RST +shell70#	42	94.3	32.6	35.1	27.4	366,400	2.96
Target value	>40	>80	>30	≥20	≥15	≥20,000	≤3.0

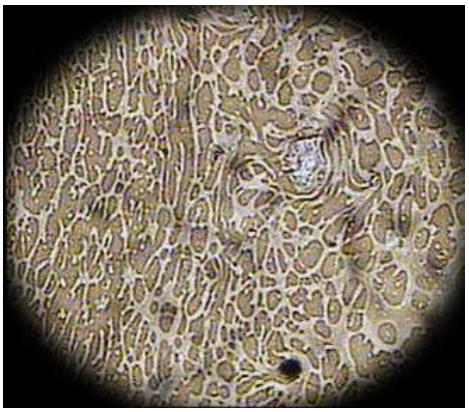
3.1.3 Quality control

1) Manufacturing process parameters

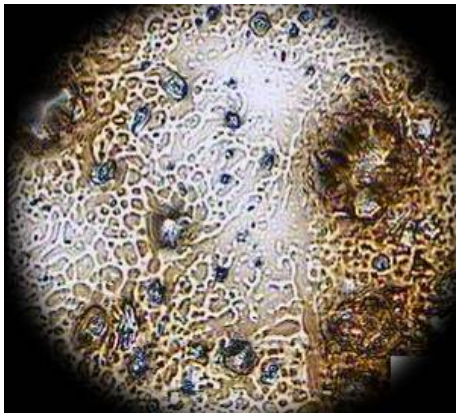
According to a plant mixing modifying method,more attention should be paid to controlling mixture manufacturing parameters. Key points are RST content, temperature of aggregate and asphalt, and mixing time. RST content can be controlled with automatic loading instrument. The temperature of aggregate and dry mixing time is related to whether RST can be melted

and well distributed onto aggregate surface or not, and the wet mixing time controls whether straight asphalt can be modified sufficiently or not.

Herein,a microscopy technique is used to control and evaluate main parameters of mixture manufacturing process.

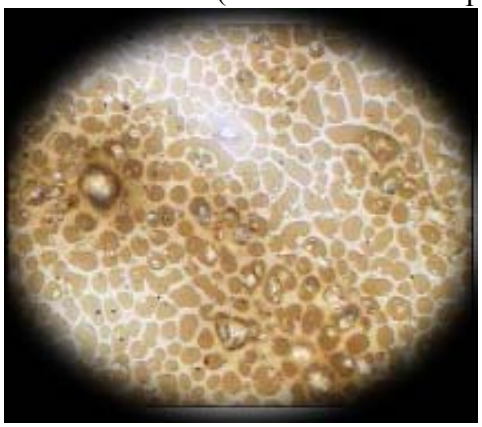


RST PMB (indoor)



RST PMB mixture (from marshall sample)

Mixture mortar (insufficient mixing time)



Mixture mortar (sufficient mixing time)

Figure 5: Microscopy of RST PMB and mixture mortar (×1000)

As indicated in Figure5, corresponding to indoor test, every mixture production process and the adjustment of parameters, the micro-state of RST PMB and mixture are clearly demonstrated. A finer and homogeneous modifier network under proper parameters ensures stable mixture properties. With microscopy,optimized parameters are listed in Table 6.

Table 6: Optimum parameters of manufacturing process

Item	Temperature(℃)		Time(s)		
	Aggregate	Straight Asphalt	Dry mixing	Wet mixing	Total mixing
Target	190-195	165-175	≥15	≥45	≥60

2) Mixture properties

The mixture properties are listed in Table 7.

Key parameters of manufacturing process are verified to be rational in accord with stable mixture properties.

Table 7: Properties of mixture

Binder	Marshall sample				Dynamic stability (time/mm)
	Air void (%)	Stability (kN)	Cantabro loss (20℃, %)	TSR (%)	
14%RST +shell60/80	21.8	5.57	13.8	92.16	7,310
Target	18-25	≥3.5	<20	≥80	≥3,000

3.2 A case of steel deck pavement

Double layer SMA is used on steel deck pavements. In china,it has been carried out at Humen Bridge, Xiamen Haicang Bridge , Wuhan Baishazhou Bridge, and so on.

The rigorous circumstance of steel deck pavement makes HV-PMB a natural choice in double layer SMA. But as above-mentioned, the balance between 60℃ viscosity and 135℃ viscosity of pre-mixing SBS HV-PMB can not be well kept, leading to a series of construction problems, such as binder aging and insufficient compaction.

As an instance, a double layer SMA with RST HV-PMB on RenMin Rd. Overpass Bridge, Suzhou City,which was constructed in September 2008,will be introduced.

3.2.1 Introduction

The schematic diagram of double layer SMA on steel deck is shown in Figure 6.

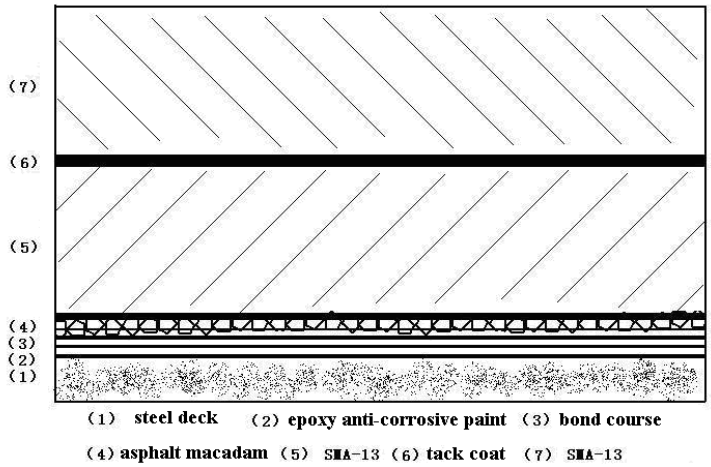


Figure 6: Schematic diagram of steel deck pavement

3.2.2 Key materials

The properties of shell 60/80 straight asphalt is shown in Table 8 and 8.2 wt % content of RST is chosen, which shown in Table 9.The viscosity of 135℃ is a precondition that ensures SMA mixture could be well compacted, and a higher viscosity of 60℃ endows mixture with excellent high temperature stability.

Table 8: Properties of Shell 60/80

Item	Unit	Value	Target
Penetration (25℃)	0.1mm	67.6	60~80
Softening point (R&B)	℃	47.35	≥46
Ductility (15℃)	cm	≥100	≥100
Ductility (10℃)	cm	19.2	≥15
Viscosity (60℃)	Pa·s	189.2	/

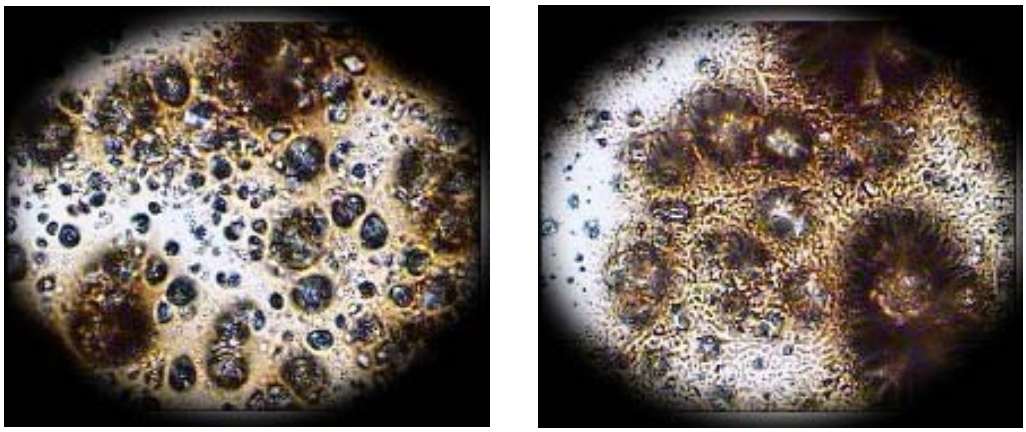
Table 9: Properties of RST HV-PMB

Item	Unit	Value	Target
Penetration (25℃)	0.1mm	49	>40
Softening point (R&B)	℃	81.05	≥80
Ductility (5℃)	cm	39.31	≥30
Toughness (25℃)	N·M	15.90	≥15
Tenacity (25℃)	N·M	11.32	≥10
Viscosity (135℃)	Pa·s	2.13	≤3.0
Viscosity (60℃)	Pa·s	26,870	≥20,000

3.2.3 Quality control

1) Manufacturing parameters

The microscopy technique is also used to control and optimize the manufacturing of RST HV-PMB mixture, in which optimum parameters are shown in Table 10. The mortar of RST PMB SMA has a homogeneous modifier network comparing with common SBS PMB SMA,as shown in Figure 7.



SBS PMB SMA mixture RST PMB SMA mixture

Figure 7: Microscopy of SMA mixture mortar (×1000)

Table 10.Key parameters of manufacturing process

Item	Temperature (℃)		Time (s)		
	Aggregate	Straight As.	Dry mixing	Wet mixing	Total mixing
Target	175-185	170-180	≥15	≥45	≥60

2) Mixture properties

The target air void is 4%,and the optimum asphalt content (OAC) is 5.8%. The mixture properties of SMA are listed in Table11, Table12, respectively.

Table 11: Volume properties

Mixture type	γ_m (g/cm^3)	VV (%)	VFA (%)	VMA (%)	VCA_{mix} (%)	VCA_{DRC} (%)
SMA-13	2.466	4.08	77.34	18.1	37.99	38.12

Table 12: Mixture properties

Mixture type	Stability (kN)	Flow (0.1mm)	Dynamic stability (time/mm)	Cantabro loss (%,20℃)	TSR (%)
SMA-13	6.59	32.38	6,750	1.32	97.80

3) Construction process

The balance between 135℃ viscosity and 60℃ viscosity is a typical characteristic of RST HV-PMB, making a static compaction possible, which is very important on steel deck pavements due to its vibration during compaction course. Finally, a static compaction process is carried out with static and tire rollers, and a well compacted pavement is completed.

4 CONCLUSIONS

1. The plant-mixing asphalt modifying method has its unique characteristic and advantage comparing with the pre-mixing one.
2. As a novel plant mixing modifier, RST behaves well on porous asphalt and steel deck pavements.
3. By means of the microscopy techniques, the manufacturing process of plant-mixing modified asphalt mixtures could be efficiently controlled.

REFERENCES

[1] Japan Road Association, 1992.*The Guideline of drainage asphalt pavement*.

[2] Tang, Z., Liang, C., Chen, X., *Design and Con struction of Steel Deck SMA Mixture of Haicang Large Bridge in Xiamen* [J]. HIGHWAY Jan. 2001 No1.

[3] Yang, X., Sheng, S., *Reasons and treatment of high temperature disease of Humen Bridge steel deck pavements* [J].Guangdong Gonglujiaotong, 2000(66).

[4] Liu, G.,Pan, X.,et al. *Pavement process of Baishazhou steel deck Bridge* [J].Transportation Science & Technology No. 5 O ct. 2000.

[5] *Technical Specification for Construction of Highway Asphalt Pavements (JTG F40-2004)*, The People's Republic of China Industry Standard.

[6] Uesaka, K., Yan, G.J., Sugiura, M., *Development and Manufacture Method of the High Viscous Polymer Modified Binder Used in Cold Regions*, Japan-China 2nd Workshop on Pavement Technologies, November 11-14, 2003, Tokyo, Japan.