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Permanent deformation and deformation compliance of guss-asphalt for orthotropic steel deck plate surfacing

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Abstract: Indentation test and bending test were adopted to investigate permanent deformation and deformation compliance of guss-asphalt for orthotropic steel deck plate. Factors of mastic Epüre content, fine to coarse aggregate proportion, temperature and loading pressure were investigated. It is pointed out that mastic Epüre content, temperature and loading pressure are the main factors influencing permanent deformation of guss-asphalt; fine to coarse aggregate proportion influences its maximum bending strain and crack energy at low temperature. The results indicate that there exists an optimum mastic Epüre content, and a critical operation temperature as well as a critical loading pressure for guss-asphalt in operation.

Key words: permanent deformation; deformation compliance; guss-asphalt

Guss-asphalt, a low void asphalt surfacing rich of mastic Epüre, is widely studied and used in England, North Europe and Japan owing to its good deformation compliance[1-3]. In China, few studies[1] have been conducted until the construction of Jiangyin Yangtze River Bridge (JYYRB). Its deck plate surfacing is guss-asphalt introduced from England, paved in the summer and autumn of 1999. During its early operation time, rutting and cracking were observed. Severe overloading and lack of deformation resistance at high temperature were originally considered as the main causes; further investigation demonstrated that unbalanced properties between high temperature stability and deformation compliance were also direct factors[3].

Researchers[4,5] have focused on improving high temperature properties of guss-asphalt since the premature damage of JYYRB's deck plate surfacing. However, good deformation compliance is also required owing to its flexibility of long-spanned steel bridge. Therefore, when applying guss-asphalt to long-spanned steel bridges over Yangtze River, more attention should be paid to its deformation resistance without decreasing its deformation compliance[6]. To get a clear view of how these two properties influence each other and then make a balance, indentation test at high temperature and bending test at low temperature[7,8] are conducted. Factors of mastic Epüre content (MEC), fine to coarse aggregate proportion (FCAP), temperature (Temp) and loading pressure (LP) have been investigated.

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1 Test Program

1.1 Materials

Asphalt cement is a blend of styrene-butadiene-styrene (SBS) modified asphalt named Cariphalt from Shell Company and Trinidad Lake Asphalt (TLA) from Venezuela. The properties of Cariphalt, TLA, and asphalt cement are listed in Tab.1.

Tab.1 Properties of Cariphalt, TLA, and asphalt cement

	Property	Cariphalt	TLA	Asphalt cement
	Penetration (100 g, 25 ℃, 5 s) /0.1mm	68	1	24
	Soft point (R&B) /℃	84	95	60
	Ductility (25 ℃, 50 mm/min) /cm	37		51
	Flash point (COC) /℃	>300	>300	>300
	Specific gravity (20 ℃)	1.042	1.393	1.210
	Solubility (chlorine-ethylene) /%	99.9	55.4	71.3
	DSR (82 ℃, $G^*/\sin\delta$)/ kPa	1.502		1.386
TFOT	Mass loss /%	0.02	0.03	0.04
	Penetration rate /%	85		92
	Ductility (25 ℃) /cm	22		47
	DSR (82 ℃) /MPa	487		635

Coarse aggregate (CA, >4.75 mm) is basaltic, with abrading value 12.1%, polishing value 51, crushed value 9.6%, and compression strength 178 MPa. Fine aggregate (FA, 0.075 to 4.75 mm) is calcareous. Both CA and FA were from a highway aggregate manufacturer in Zhenjiang.

The mineral filler (MF, < 0.075 mm) is calcareous, with low hydrophilic co-efficiency and moisture content, passing rate over 95%, was from a highway MF manufacturer in Nanjing.

Guss-asphalt was designed based on relative specifications[7]. Its gradation along with specification limit is presented in Tab.2.

Tab.2 Gradation and specification for guss-asphalt

Sieve size/mm	Accumulated passing rate/%	
	Specification	Designed mixture
13.2	100	100
9.5	90 to 100	92
4.75	65 to 85	74
2.36	45 to 62	50
0.6	35 to 50	38
0.3	28 to 42	32
0.15	25 to 34	28
0.075	20 to 27	22.5

1.2 Mixing and casting procedures

Mixing and casting procedures are the same as Ref. [8] mentioned. Firstly asphalt cement and MF were blended together at 160 to 170 ℃ to make mastic Epüre. Then warmed-up FA was added to make fine aggregate mastic asphalt. Warmed-up CA was finally added to form guss-asphalt. Specimens could be prepared when the temperature reached 200 to 220 ℃.

1.3 Specimens

Marshall specimens with a size of 101.1 mm diameter and 63.6 mm height were made for Marshall stability test. Cubic specimens with a length of 70.7 mm were made for dimensional stability and indentation test. Beam specimens with a size of 30 mm × 35 mm × 250 mm were made for bending test. All specimens were made without any blow.

1.4 Test procedure

To examine the basic properties of these three types of guss-asphalt concrete mixtures, Marshall and dimensional stability tests were conducted on Marshall specimens and cubic specimens, respectively. The specimens for Marshall test were allowed to stay for 6 to 8 h at water attemperator of 60 ℃ before testing, while the cubic specimens was required to stay for 24 h at water attemperator of 60 ℃ before testing. Marshall test was carried out at a loading rate of 50mm/min at room temperature. Dimensional stability test was carried out with vernier caliper. Relative procedure of dimensional stability test is given in Ref.[9].

Indentation test (see Fig.1) was adopted to investigate guss-asphalt's high temperature deformation resistance according to Refs. [7, 8]. Apparent specific gravity of the specimens has been determined before test to calculate air voids. Influences of MEC, FCAP, Temp and LP were investigated. Their values are shown in Tab.3. To explore the influences of MEC and FCAP on deformation resistance, water attemperator is set to 40 ℃ and LP to 1.05 MPa. To explore influences of LP, the water attemperator is set to 60 ℃. For each indentation test, the stamp area is a solid circle with 25.2 mm diameter.

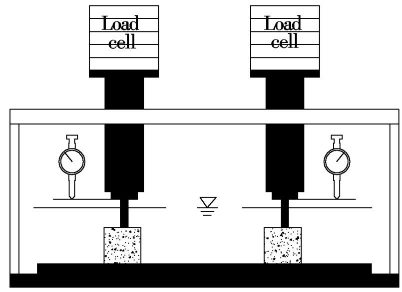

Fig.1 Loading frame and test setup for indentation test

Tab.3 Factors and their levels at indentation test

Level	Factors			
	MEC/%	FCAP	Temp/℃	LP/MPa
High	31.8	2.50 (FG)	60	1.32
Middle	29.6	2.03 (NG)	50	1.05
Low	28.5	1.75 (CG)	40	0.80

Deformation compliance of guss-asphalt has been investigated by a three-point bending test at −15 ℃. The loading rate of bending test is 1 mm/min. The test was carried out on MTS810 with conditioner. Maximum strain ε_{max} and crack energy J have been calculated according to Eqs.(1) and (2). Only material factors were investigated.

$$\varepsilon_{max} = \frac{6hd_{max}}{L^2} \tag{1}$$

$$J = \sum R_t \varepsilon_t \tag{2}$$

where h is the height, d_{max} is the crack displacement of mid-span, L is the span of the two rest points, R_t and ε_t are the simultaneous bending strength and the strain before crack, and can be calculated by

$$R_t = \frac{3LP_t}{2bh^2} \qquad t = 0 \text{ to } t_{max} \tag{3}$$

$$\varepsilon_t = \frac{6hd_t}{L^2} \tag{4}$$

where P_t is the simultaneous load force, and b is the width of the beam.

2 Results and Analyses

2.1 Basic properties of three mixtures

Basic properties of the three mixtures are shown in Tab.4. The results show that the three mixtures are well designed to meet the target.

Tab.4 Basic properties of the three mixtures

Property	Mixture		
	NG	CG	FG
Apparent S. G.	2.531	3.523	2.531
Air void/%	1.26	1.26	1.20
Marshall stability/kN	11.5	10.6	11.8
Marshall flow/0.1mm	84	91	73
Dimensional stability/%	2.92	3.74	2.48

2.2 Influences of material factors

The indentation curve with MEC is shown in Fig.2. The curve compares well with rut test results. Therefore, the indentation test is suitable for describing permanent deformation resistance at high temperature of guss-asphalt.

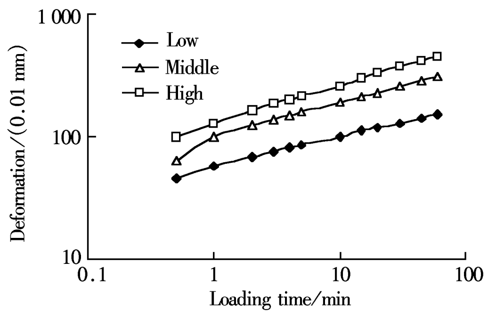

Fig.2 Indentation curves of guss-asphalt with MEC

Fig. 3 compares statistical results for different MECs and FCAPs. MEC has more remarkable influence on deformation resistance than FCAP. The more the mastic Epüre, the worse the deformation resistance. The relationship between FCAP and indentation value is not so clear. Therefore, it can be concluded that deformation resistance at high temperature of guss-asphalt is mainly related to mastic Epüre, not content of aggregates, which is distinguished from normal asphalt concrete mixture.

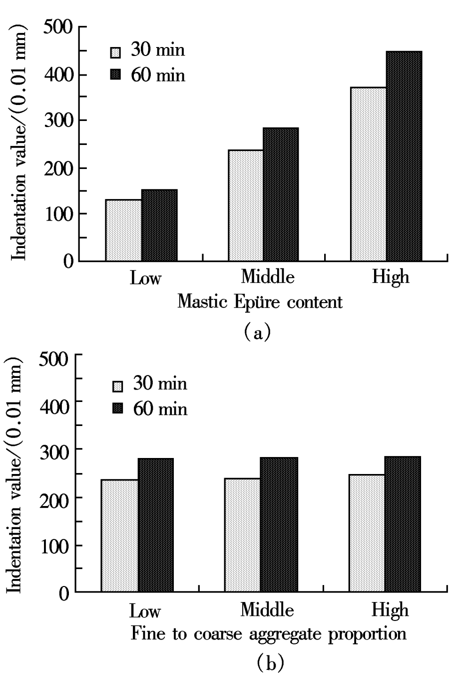

Fig.3 Indentation test results of guss-asphalt with different MECs and FCAPs

As shown in Tab. 5, both MEC and FCAP have visible influences on deformation compliance. The curve shape of MEC to maximum strain or crack energy is convex quadric polynomial, while the curve shape of FCAP to maximum strain or crack energy is half left-side trapeze form. It implies that there is an optimum MEC. Within the optimum content, improving FCAP may enhance mixture's low temperature ability.

Tab.5 Results of bending test at low temperature

Level	Mastic Epüre content		Fine to coarse aggregate proportion	
	Maximum strain/10^{-6}	Crack energy/J	Maximum strain/10^{-6}	Crack energy/J
High	3 019	37.7	3 509	61.8
Middle	3 442	51.1	3 442	51.1
Low	1 693	18.9	2 151	27.1

2.3 Properties of three mixtures

Influences of test conditions on permanent deformation of guss-asphalt with optimum MEC and properly designed FCAP were also studied. The results are shown in Fig.4. Both short term (30 min) and long term (60 min) indentation values are greatly influenced by temperature and loading pressure. There is a critical temperature with guss-asphalt's operation as

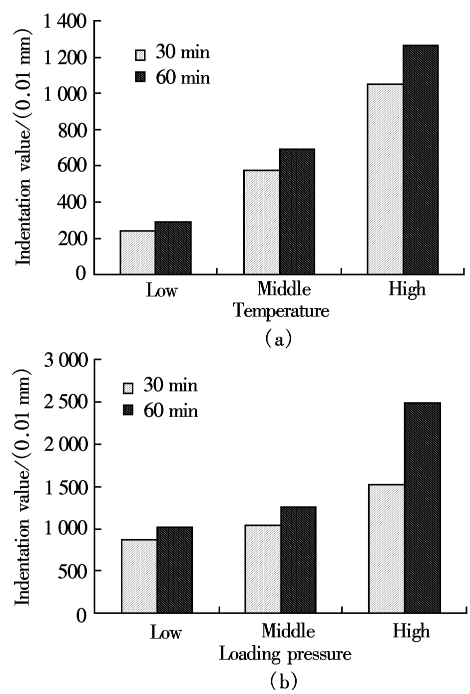

Fig.4 Indentation test results of guss-asphalt with loading conditions. (a) Different temperature conditions (middle pressure); (b) Different pressure conditions (high temperature)

well as a critical loading pressure. In the worst condition in which temperature and loading pressure are over their critical values, a large amount of irrecoverable plastic deformation accumulates which induces rut and shearing stream in mixture. Therefore, axle load limiting and measurement of decreasing temperature are necessary for guss-asphalt as steel deck plate in operation.

3 Conclusions

In this study, influences of mastic Epüre content, fine to coarse aggregate proportion, temperature and loading pressure on permanent deformation and deformation compliance of guss-asphalt have been investigated. It can be concluded from the results:

1) Mastic Epüre content, temperature and loading pressure have prominent influence on permanent deformation resistance of guss-ashpaht.

2) There is an optimum mastic Epüre content in guss-asphalt to balance its high and low temperature properties. Within the content, improving fine to coarse aggregate proportion may enhance mixture's low temperature ability.

3) There is a critical temperature with guss-asphalt's operation as well as a critical loading pressure. Axle load limiting and measurement of decreasing temperature are necessary for guss-asphalt surfacing in operation.

Further studies of mastic Epüre influences on guss-asphalt's deformation compliance and the critical operation temperature and loading pressure may be undertaken. The relationship and co-efficiency between indentation test and rut test can also be investigated.

References

[1] JYBCB, College of Transportation of Southeast University. Guss-asphalt and structure research for JYYR Bridge (final research report) [R]. Nanjing: Southeast University, 2000. (in Chinese)

[2] College of Transportation of Southeast University. Survey on steel deck with asphalt pavement for Runyang Bridge [R]. Nanjing: Southeast University, 2001. (in Chinese)

[3] College of Transportation of Southeast University. Project of partly rehabilitating pavement of Jiangyin Bridge's steel deck plate (final research report)[R]. Nanjing: Southeast University, 2003. (in Chinese)

[4] Deng Xuejun. Asphalt pavement stability at high-temperature for Jiangyin bridge in China[J]. *Journal of Traffic and Transportation Engineering*, **2002**, **2**(2): 1 −7. (in Chinese)

[5] Chen Xianhua, Huang Wei. Studies on high temperature stability of guss-asphalt as steel deck pavement [J]. *Journal of Chongqing Jiaotong University*, **2003**, **22**(1): 32 −35. (in Chinese)

[6] Chen Xianhua, Huang Wei, Li Hongtao, et al. Properties of guss-asphalt for orthotropic steel deck plate surfacing [J]. *Journal of Highway and Transportation Research and Development*, **2004**, **21**(9): 26 −29. (in Chinese)

[7] Germany Standart. Zusätzliche Technische Vertragsbedingungen und Richtlinien für die Herstellung von Brückenbelägen auf Stahl(ZTV-BEL-ST-92)[S]. 1992.

[8] Chen Xianhua. Structure research on steel deck plate with asphalt pavement for Runyang Bridge [D]. Nanjing: College of Transportation, Southeast University, 2003. (in Chinese)

[9] Edwards Ylva, Westergren Pereric. Polymer modified waterproofing and pavement system for high coast bridge in Sweden [R]. Sweden: Swedish National Road and Transportation Research Institute, 2001.

浇注式沥青混凝土铺装的永久变形与变形追从性

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摘要: 采用贯入试验与弯曲试验, 研究了沥青玛蹄脂含量、粗细集料的比例、试验温度与荷载压力等因素对浇注式沥青混凝土铺装的永久变形与变形追从性的影响. 结果表明: 沥青玛蹄脂含量、试验温度与荷载压力是影响浇注式沥青混凝土永久变形能力的主要因素, 而粗细集料的比例则影响混合料的低温极限弯曲应变与断裂应变能; 浇注式沥青混凝土中存在最佳沥青玛蹄脂含量, 而在实际运营过程中铺装存在临界温度与临界压力.

关键词: 永久变形; 变形追从性; 浇注式沥青混凝土

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