Journal of Southeast University (English Edition) Vol. 27, No. 1, pp. 61 –64 Mar. 2011 ISSN 1003—7985

Construction controlling and strength increasing characteristics of locally developed epoxy asphalt mixture

Chen Chun Qian Zhendong Chen Leilei

(Intelligent Transportation System Research Center, Southeast University, Nanjing 210096, China)

Abstract: The construction controlling elements, including construction performance at low ambient temperatures, reserved time ranges, and the strength increasing rule, for locally developed epoxy asphalt mixture (LDEAM) are studied through laboratory tests. Air void and Marshall stability are chosen as the performance measures for evaluating the construction quality. The wheel rolling test is used to simulate the actual construction situations, while the Marshall test and the Brookfield viscosity test are adopted to study the strength increasing rule. The experimental results reveal that the LDEAM can be constructed under a low ambient temperature condition of 10 ℃, and its longest reserved time is 70 min at a reserved temperature of 120 ℃. Test also shows that the strength of the LDEAM increases with time and temperature before cured. Finally, the theoretical reason for the strength increasing rule is analyzed on the basis of the organic chemistry theory.

Key words: construction characteristics; locally developed epoxy asphalt; strength increasing characteristics

doi: 10.3969/j. issn. 1003 –7985. 2011. 01. 013

The epoxy asphalt mixture (EAM) is composed of graded aggregates, fillers, and an epoxy asphalt binder. It is a mixture with high strength and rigidity which provides good corrosion resistance, high temperature stability, moisture susceptibility and anti-fatigue property[1-2]. Due to its excellent service performance, the EAM has been successively used in many long-span steel bridge deck pavement in China, and shows good performance[3].

To date, most of the EAM used in Chinese steel bridge deck pavement are imported from the USA which imposes strict requirements on an ambient construction temperature higher than 20 ℃ during construction. Besides, the imported epoxy asphalt material has very strict requirements on the reserved time and other construction controlling elements[4]. Moreover, the strength increasing rule of the material is not very clear. Consequently, the construction workability becomes an obstacle to the use of the EAM.

Under this situation, local epoxy asphalt has been developed and used in construction practices in China. Previous studies[5-7] proved that some of the pavement performances, e. g., moisture susceptibility, relative rutting performance, low-temperature performance, and relative fatigue performance, of the locally developed epoxy asphalt mixture (LDEAM) are up to or better than those of the EAM imported from the USA. In spite of this, the construction controlling elements and the strength increasing rule for the LDEAM are still unclear.

Focusing on these issues, this paper presents a laboratory program for experimentally investigating the construction controlling elements, including construction performance at low ambient temperatures, reserved time ranges, and the strength increasing rule of the LDEAM. The key elements of the construction controlling and influencing factors of the strength increasing rule for the LDEAM are investigated as well.

1 Materials

1.1 Raw materials

The locally developed epoxy asphalt binder consists of two cement components: component A (epoxy resin) and component B (base asphalt). Component A is used to modify the base asphalt. Basalt stone chips collected from Jurong in Jiangsu province in China are used as aggregates. The properties of the raw materials used in this paper all meet the required qualifications.

1.2 Aggregate gradation

The aggregate gradation used in the steel bridge pavement of the Second Nanjing Yangtze River Bridge is adopted for the research. The maximum aggregate diameter is 13.2 mm and the gradation curve is shown in Fig. 1.

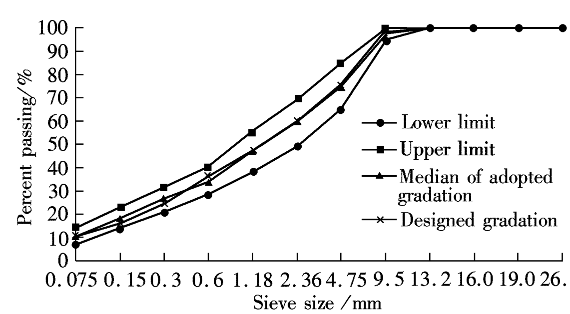

Fig. 1 Adopted and designed aggregate gradation in test

1.3 Optimum binder content

The Marshall mixture design procedure is employed to design the optimum binder content. The target air void of the mixture is 3% and the Marshall stability of the cured specimen is more than 40 kN. According to the test results, a binder content of 6.6% is found to be optimum for the LDEAM.

Received 2010-11-01.

Biographies: Chen Chun (1986—), male, graduate; Qian Zhendong (corresponding author), female, doctor, professor, qianzd@seu.edu.cn.

Foundation items: The National Natural Science Foundation of China (No. 50578038), the National Key Technology R&D Program of China during the 11th Five-Year Plan Period (No. 2009BAG15B03)

Citation: Chen Chun, Qian Zhendong, Chen Leilei. Construction controlling and strength increasing characteristics of locally developed epoxy asphalt mixture[J]. Journal of Southeast University (English Edition), 2011, 27(1): 61 –64. [doi: 10.3969/j. issn. 1003 –7985. 2011. 01. 013]

2 Controlling Elements

2.1 Allowable working ambient temperature

The air void and the initial strength of the asphalt mixture are chosen as the controlling indices to study the construction performance of the LDEAM at low temperatures. By controlling the ambient temperature, the wheel rolling method is used to simulate the real rolling effects under roller compaction construction at low temperatures, and the Marshall test method is used to study the initial strength for the LDEAM constructed at low temperatures. The ambient temperatures of 20, 10 and 5 ℃ are selected based on the actual situations of construction at low temperatures. Tabular specimens are shaped at these three ambient temperatures by the wheel rolling method. The dimensions of the tabular specimens are 300 mm × 300 mm × 50 mm. In order to make the tabular specimens cure rapidly, they are placed in an oven with a preserved temperature of 120 ℃ for 5 h. Then, five cores, four at the coffin corner and one at the center, are drilled from each tabular specimen. Based on this, the air voids of the cores are examined. Meanwhile, the Marshall specimens are shaped at ambient temperatures of 20, 10 and 5 ℃, and are placed in the corresponding ambient temperatures for 24 h. Finally, the initial Marshall strengths of the specimens are examined.

The air voids of the cores drilled from the tabular specimens are shaped at different ambient temperatures and the stabilities of the corresponding Marshall specimens are shown in Tab. 1.

Tab. 1 Construction quality of LDEAM at different ambient temperatures

Ambient temperature/℃	Air void/%	Stability/kN
20	1.7	8.3
10	2.1	6.9
5	3.2	5.3
Technical standard	≤3.0	≥5.0

From Tab. 1, we can find that the air void of the specimen that is shaped at 5 ℃ does not meet the requirements of the technical standards. Comparatively, the air voids shaped at 10 ℃ and 20 ℃ can meet the requirements. It is also observed that the stabilities of the specimens shaped at the three temperatures are all greater than 5.0 kN, indicating that the stability can meet the requirements of the technical standards. Therefore, it is proper to choose 10 ℃ as the lowest construction ambient temperature to obtain a good rolling effect and high initial strength for guaranteeing the construction quality.

2.2 Reserved time

The reserved temperature for the EAM is usually controlled at 120 ℃[4-7]. This reserved temperature is adopted in this study, and the Marshall test method is used to investigate the effects of reserved time on the air void and stability for the LDEAM with the goal of finding the longest reserved time to make sure that the air voids of the cured specimens are smaller than 3% and the strengths are greater than 40 kN. According to actual construction requirements, the range of the reserved time for EAM is set between 30 min and 110 min[8]. Therefore, the mixtures are placed in an oven with a reserved temperature of 120 ℃ for different reserved times between 30 min and 110 min. Then, the mixtures are taken out and shaped into Marshall specimens. Before examining the air voids and the Marshall stability, all the Marshall specimens are placed in a high temperature oven set for rapid curing.

The experimental results of the effects of the reserved time on the air void and stability are shown in Fig. 2.

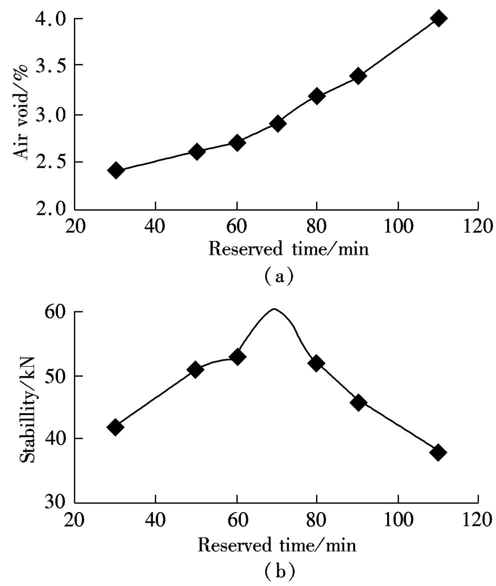

Fig. 2 Performance of LDEAM at different reserved times. (a) Air void-reserved time curve; (b) Stability-reserved time curve

From Fig. 2, it is observed that the longest reserved time to meet the requirements of air void(≤3%) is 70 min, and that the longest reserved time to meet the requirements of stability (≥40 kN) is 90 min. Therefore, 70 min is selected as the longest reserved time for the LDEAM to meet both the air void and stability requirements.

From Fig. 2(a), we can also see that the air voids of specimens increase with the increase in reserved time. The reason is that the viscosity of the epoxy asphalt binder increases with the increase in reserved time, which makes the fluidity of the asphalt binder decrease with the decrease in visual performance, i. e., air void increases with the increase in reserved time. Fig. 2(b) shows that the largest stability of the specimens occurs at the reserved time of about 70 min. The reason is that at the reserved time of 70 min, the target air void of 3%, as well as the optimal binder content, is obtained.

3 Strength Increasing Rule

The strength increasing rule of the EAM is different from that of the common asphalt and general modified asphalt mixtures. Therefore, it is necessary to study the strength increasing rule to determine the proper preserved time before the LDEAM is cured[9]. In this study, the viscosity-time curves at different test temperatures for the LDEAM are constructed, in which the viscosity is measured by a Brookefield rotational dial viscometer with a rotating speed of 100 r/min. Then, the Marshall specimens of the LDEAM are shaped and put in different preserved temperatures of 20, 120, 125, and 130 ℃. The Marshall stabilities of the specimens are measured every hour till they stop growing. Finally, the strength increasing rule for the LDEAM is investigated by comparing different preserved times of specimens when the strengths reach cured stability.

The viscosity-time curves at different test temperatures are shown in Fig. 3 and the results of the experiments on the strength increasing rule are shown in Fig. 4.

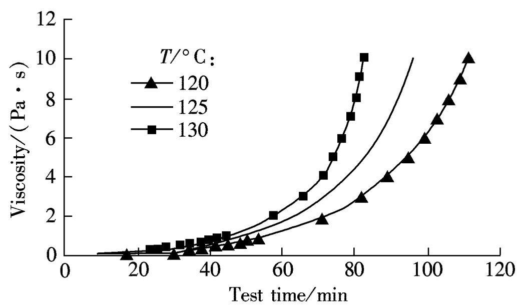

Fig. 3 Viscosity-time curves at different test temperatures

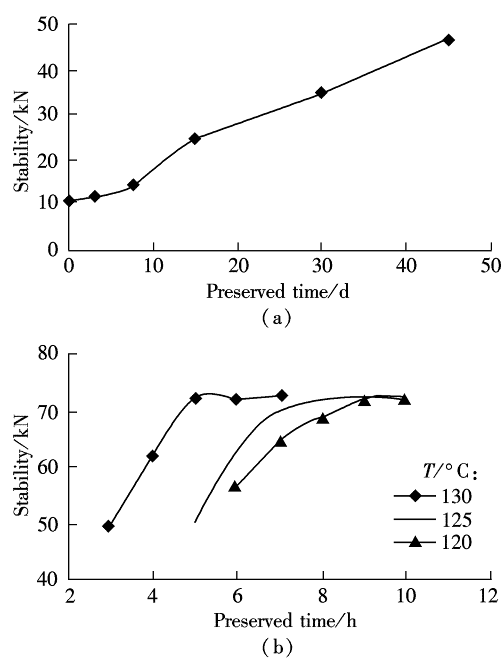

Fig. 4 Stability growth of LDEAM with the increase in preserved time. (a) Stability-time curve at preserved temperature 20 ℃; (b) Stability-time curve at different preserved temperatures

From Fig. 3, we can see that no matter which temperature it is at, the viscosity increases slowly at the beginning stage of the test, and then increases at a much faster speed. It is also observed that the higher the test temperature is, the faster the viscosity grows. This can be explained by the dual-Arrhenius model[8-9] as

$$\ln\eta(t, T) = \ln\eta_\infty + \frac{E_\eta}{RT} + At\exp\left(-\frac{E_a}{RT}\right) \qquad (1)$$

where $\eta(t, T)$ is the viscosity; η_∞ is the Arrhenius pre-factor; E_η is the flow activation energy; E_a is the reaction activation energy; R is the gas constant; T is the absolute temperature; t is the time; and A is the factor. By replacing the $\eta(t, T)$ with the strength of the epoxy asphalt mixture $P(t, T)$, Eq. (1) can be rewritten as

$$\ln P(t, T) = \ln P_\infty + \frac{E_\eta}{RT} + At\exp\left(-\frac{E_a}{RT}\right) \qquad (2)$$

where P_∞ is the Arrhenius pre-factor.

From Fig. 4(a), we can see that when the preserved temperature is 20 ℃, it takes about 40 d for the EAM specimen to achieve the stability of 40 kN as the requirement for open traffic. Although the preserved temperatures are different, the largest stabilities are almost the same with a value of about 73 kN. Therefore, 73 kN can be determined as the stability of the cured epoxy asphalt mixture specimen. Fig. 4 (b) also shows that the time for the specimen to achieve the largest stability becomes shorter and shorter when the preserved temperature increases. Hence, we can conclude that preserved time and preserved temperature are two significant factors of the strength increasing rule for the locally developed epoxy asphalt as shown in Eq. (2).

4 Conclusions

Based on the results of the experimental tests conducted for the locally developed epoxy asphalt mixture, the following conclusions can be drawn:

1) The range of construction ambient temperature for the locally developed epoxy asphalt mixture is wide, and the lowest construction ambient temperature for achieving good rolling effect and high initial strength is 10 ℃.

2) The longest reserved time for the locally developed epoxy asphalt mixture is 70 min at 120 ℃, which can provide more time to construct and solve the unexpected problems during construction.

3) Preserved temperature and preserved time are the main influence factors of the strength growth for the locally developed epoxy asphalt mixture. So it is necessary for close traffic to preserve the epoxy asphalt concrete after the construction is completed.

References

[1] Huang Wei. *Theory and method of deck paving design for long-span bridges*[M]. Beijing: China Construction Industry Press, 2006: 47 −62. (in Chinese)

[2] Çubuk M, Gürü M, Çubuk M K. Improvement of bitumen performance with epoxy resin[J]. *Fuel*, 2009, **88**(7): 1324 −1328.

[3] Wang Wenqiang, He Huayan. Study on performance of epoxy asphalt concrete applied in the deck pavement of Pingsheng Steel Bridge [J]. *Advanced Materials Research,* 2010, **150/151**: 470 −474,

[4] Huang Wei, Qian Zhendong, Chen Gang, et al. Epoxy asphalt concrete paving on the deck of long-span steel bridges [J]. *Chinese Science Bulletin*, 2003, **48**(21): 2391 −2394.

[5] Qian Zhendong, Luo Sang, Wang Jianwei. Laboratory evaluation of epoxy resin modified asphalt mixtures [J]. *Journal of Southeast University*: *English Edition*, 2007, **23**(1): 117 −121.

[6] Luo Sang, Wang Jianwei, Qian Zhendong. Research on the performance of locally developed epoxy asphalt mixture [C]//*Proceedings of the* 26*th Annual Southern African Transport Conference*. Pretoria, South Africa, 2007: 736 − 744.

[7] Li Guofen, Zhang Gaoqin, Chen Yan. Quality controlling of epoxy asphalt concrete in steel-deck surfacing [J]. *Forest Engineering*, 2007, **23**(3): 62 −64. (in Chinese)

[8] Min Zhaohui, Zhang Zhanjun, Qian Zhendong. Dependency of time-temperature of epoxy asphalt mixture strength [J]. *China Journal of Highway and Transport*, 2007, **20**(3): 1－4. (in Chinese)

[9] Yu Jianying, Cong Peiliang, Wu Shaopeng, et al. Curing behavior of epoxy asphalt [J]. *Journal of Wuhan University of Technology: Materials Science Edition*, 2010, **24**(3): 462－465.

国产环氧沥青混合料施工控制与强度增长特性

陈　春　　钱振东　　陈磊磊

(东南大学智能运输系统研究中心,南京 210096)

摘要:通过室内试验研究了国产环氧沥青混合料在低温环境条件下的施工和易性、容留时间范围,以及强度增长规律等施工控制特性. 选取芯样空隙率和试件马歇尔稳定度作为评价施工质量的性能指标;通过轮碾试验模拟实际施工过程中的碾压成型过程;选择马歇尔试验和布氏粘度试验研究强度增长特性. 试验结果表明:国产环氧沥青混合料可以在 10 ℃的低温环境条件下进行施工;混合料在 120 ℃的容留温度条件下最长容留时间达到 70 min;在国产环氧沥青混合料完全固化以前,混合料强度随着时间和温度的增长而不断增长. 最后,用有机化学理论分析了国产环氧沥青混合料强度增长规律的理论依据.

关键词:施工特性;国产环氧沥青;强度增长特性

中图分类号:U443.33