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Research on Structure and Properties of Embedded Gussasphalt

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Abstract: With its unique characteristics (such as anti-leaking, fatigue crack resistance, durability), Gussasphalt has been widely used in projects of steel deck pavement. However, its limitation is the overloading abilities in high temperature condition. In China, around Yangtze River and southward, the environmental temperature in summer usually exceeds 36 , along with high traffic volume and heavy-loaded vehicle. It's necessary to improve the high temperature stability of Gussasphalt to meet the severe application requirements of steel deck pavement, for solving the technical problems on steel deck pavement in high temperature and heavy load conditions. This study, which served the increase of anti-overloading ability of Gussasphalt in high temperature condition as the purpose, by adjusting the structures and construction technology of Gussasphalt, introduced a new type of Gussasphalt—Embedded Gussasphalt. Embedded Gussasphalt has a higher interlocking rate of aggregates framework, lower asphalt content and lower construction temperature. Test results of fluidity, rutting and fatigue life showed that the high temperature stability and fatigue performance of embedded Gussasphalt got remarkably improved without fluidity decreased.

Keywords: Embedded Gussasphalt; Steel Deck Pavement; Fluidity; High-Temperature Stability; Fatigue Cracking Resistance

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INTRODUCTION

Gussasphalt, abbreviated as GA, is originally known as Guβ in German, meaning "river". As its original meaning, Gussasphalt should be qualified with fluidity. And because of the automatically leveling capability of Gussasphalt, the roller compacted is generally not needed, but simple paving equipment is required to complete the entire construction.

In addition to possessing the properties of conventional asphalt concrete, Gussasphalt owns other properties like good water impermeability, excellent durability, high fatigue cracking resistance, good follow-deformation capacity and high overall performance etc because of its structural characteristics (high mineral powder content, high asphalt content and high mixing temperature).[1] It is just the special properties that meet the application requirements of bridge deck pavement, therefore, Gussasphalt has been widely used in the engineering of steel deck pavement, proven to be the most extensively used and most successful paving material in projects of steel deck pavement[2]**.** For instance, single-layer Gussasphalt structure was used in Forth Road Bridge of UK, whose service life was over 30 years; single-layer Gussasphalt was adopted in Hong Kong Tsingma Bridge, without distresses for 13 years from May 1997; Gussasphalt + SMA structure was applied in Japan's Akashi Kaikyo Bridge, and since it was open to traffic in 1998, the application effect is satisfied until now [2].

In some special application conditions, such as the long span bridge under high temperature and heavy traffic, high-temperature performance of steel deck pavement is not good enough because of the high asphalt content in Gussasphalt. Once Gussasphalt was used in China's Jiangyin Yangtze River Bridge. However, less than a year after it had been open to traffic, serious distresses such as rutting and longitudinal cracking occurred [3]. In the areas of Yangtze River and southward, where daytime temperature in summer exceeds 35 , even up to 40 , with the thermal storage effect of steel box-girder, the temperature of bridge deck pavement gets higher, over 60 [4]. At the same time, there are many heavy and overloaded vehicles passing through, which is more disadvantageous to Gussasphalt. According to pavement application characteristics, when Gussasphalt is used as the protective layer and high elastic modified asphalt SMA10 as the wearing layer, its overall performance of the structure has been improved remarkably [5], but some differences still exists between the service life and design life.

To improve the high-temperature stability of Gussasphalt under heavy load, the key point is to solve the contradiction between properties and construction fluidity of Gussasphalt. At present, two ways are adopted to coordinate and balance the two parts, while the actual result is the opposite.

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Increase Asphalt Content

Increasing the asphalt content to improve the fluidity of Gussasphalt, shall surely reduce its high-temperature stability. In order to compensate the high-temperature stability, it is necessary to improve the high-temperature performance of the modified asphalt (softening point) or increase the modifier content, in this way, viscosity of asphalt binder will be certainly increased and construction fluidity of Gussasphalt will get reduced(shown in Fig.1). Such a vicious circle has been always restricting the development and application of Gussasphalt.

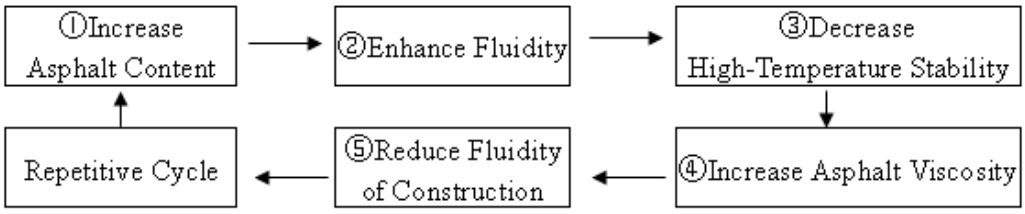

FIG. 1. Schematic diagram of vicious cycle of gussasphalt

Increase Mixing Temperature

In the case of high asphalt viscosity, to improve fluidity of Gussasphalt by increasing asphalt content shall issue in a vicious circle (Fig. 1). On the other hand, increasing mixing temperature shall have the same result as well. However, too high temperature will accelerate aging speed and aging degree of asphalt binder, and reduce fatigue cracking resistance and durability of Gussasphalt. In Japan or Germany, the mixing temperature of Gussasphalt is 180 ~ 220 in forced-mixing asphalt plant, and the paving temperature is 210 ~ 230 (heated in Cooler). In China, due to adoption of modified asphalt with higher viscosity and stronger high-temperature performance, the mixing temperature of Gussasphalt exceeds 230 , and paving temperatures exceeds 250 generally. The great differences existing in the temperatures of Gussasphalt during construction has a great impact on performances of concrete.

To illustrate the impact of the mixing temperature on performance of asphalt binder adopted in Gussasphalt, German type 20-1100 Asphalt Mix Analyzer was used to perform the performance tests on extraction-recovery asphalt binder of Gussasphalt, shown in Table 1 and Fig. 2.

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Table 1. Three Main Indicators and Viscosity of Asphalt in Three Aging Degree under Different Temperatures

Test Items	Original Sample		Short-Term Aging(163)		Extracted and Recovery 240	
	Test Value	Ratio	Test Value	Ratio	Test Value	Ratio
Penetration(25 ,0.1mm)	38.1	1.0	29.3	0.770	28.7	0.753
Softening Point( )	87.8	1.0	92.4	1.053	99.0	1.128
Ductility(10 ,cm)	52.5	1.0	21.3	0.406	6.3	0.120
Viscosity(135 ,mPa·s)	1995	1.0	2888	1.448	3657	1.833

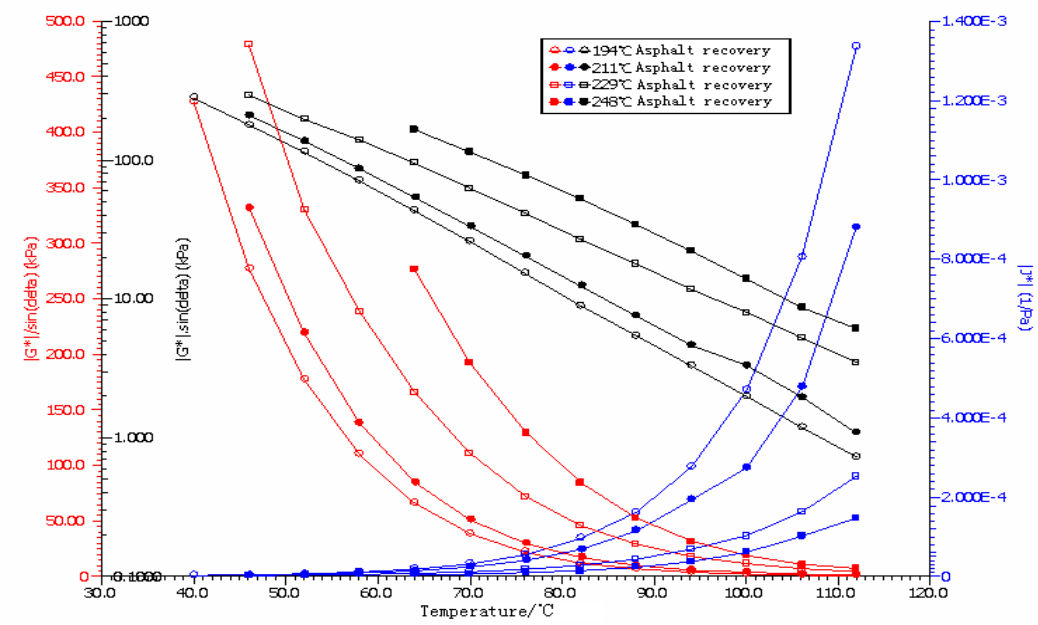

FIG.2. DSR scan result of asphalt recovery under different mixing temperatures

Test results of Table 1 and Fig. 2 show that relatively high producing temperature has sizable impact on the performance of concrete [6].

On the basis that the construction fluidity is ensured, improving Gussasphalt's high temperature stability without loss of other performances is a technical problem in study of steel bridge deck pavement. In order to solve this problem, embedded Gussasphalt is introduced in the preliminary study.

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STRUCTURE AND MATERIAL OF EMBEDDED GUSSASPHALT

Embedded Gussasphalt is the Gussasphalt with good high-temperature stability and fatigue cracking resistance performance, by adjusting the casting Gussasphalt structure, reducing mixing temperature and increasing the content of coarse aggregate (embedding rate).

Structure Formation Mechanism

Based on in-situ Gussasphalt gradation form [7] (shown in Table 2) and mixed proportion design (Structure A for short), the coarse aggregate in certain ratio was taken out to form Structure B before mixing. As the asphalt content is unchanged, the oil-stone ratio is relatively high, thus fluidity is relatively high when the temperature is lower than the conventional mixing temperature. After paving such Gussasphalt, spread two layers of gravel of bigger particle size and more content quickly, then compact it once using a combined wheel road-roller with lower limit position (with load-bearing wheels on both sides going on track) and vibrate, then asphalt mastic moves upwards to embed the bestrewed gravel into it, thus Structure C (embedded Gussasphalt) is formed. Compared with Structure A, structure C possesses lower oil-stone ratio and gravel embedding ratio, and the high-temperature stability has been enhanced. Because the temperatures during mixing and paving are decreased, the fatigue cracking resistance performance gets improved as well.

Table 2. Design Grading and Range of Gussasphalt（GA10）

Sieve Size(mm)	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Gradation Range(%)	100	80~100	63~80	48~63	38~52	32~46	27~40	24~36	20~30
Design Gradation(%)	100	92.6	69.5	53.1	46.5	39.2	33.7	30.1	27.1

Table3. Different Structural Material Composition of Gussasphalt (%)

Type of Structure	Mineral Powder	0~2.36mm Aggregate	2.36~4.75mm Aggregate	4.75~9.5mm Aggregate	9.5~13.2mm Aggregate	Proportion of Coarse Aggregate	Asphalt Content
A	**28**	30	10	28	4	32	7.9
B	31	33	8	24	3	28	8.4
C	27	29	7	28	12	39	7.5

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Structure and Material Composition

In this study, optimum asphalt content in Structure A of the ready-designed Gussasphalt (GA10) is 7.9%. Before the mixing producing, a certain ratio (10% of total amount of aggregate) of coarse aggregate is taken out. When the content of the aggregate is reduced, the oil-stone ratio is increased; meanwhile the asphalt content of the mixture is 8.4%. Accordingly, though the mixing temperature is only 190 ~ 210 , Structure B still be qualified with good fluidity. After paving fully mixed Gussasphalt Structure B, spread two layers of coarse aggregates of different specifications immediately, the amount of spread aggregate is 16% of the total aggregate of Structure A, namely, apart from the part which has been taken out, 6% more is spread. Finally, it is compacted once by a combined wheel road-roller with lower limit position (with load-bearing wheels on both sides going on track) and vibrated to form Structure C, which is the embedded Gussasphalt we need.

In the embedded Gussasphalt, proportion of coarse aggregate is increased to 39%, with a 7% increase compared with the original Structure A; asphalt content decreases to 7.5%, 0.4% lowered, thus increasing its high temperature heavy-load resistance performance in two aspects. Meanwhile, mixing temperature decreased to below 210 , which was affective for improving low-temperature cracking resistance and fatigue performance of the concrete.

Test and analysis were conducted to evaluate performance difference between embedded Gussasphalt (Structure C) and conventional Gussasphalt (Structure A).

PERFORMANCE TEST & STUDY on EMBEDDED GUSSASPHALT

In this study, hard and clean basalt gravel was used as aggregate and limestone powder as for mineral powder, all performances can meet relevant requirements in *Technical Specifications of Asphalt Pavement Construction* (JTG F40 - 2004). Composite modified asphalt is used as asphalt binder, and performance testing results shown in Table 4.

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Table 4. Test Results of Composite Modified Asphalt

Test Items		Test Results	Test Method
Penetration(25 ,0.1mm)		38.4	JTJ 052-2000 T0604
Softening Point( )		97.5	JTJ 052-2000 T0606
Ductility(5 ,cm)		20.9	JTJ 052-2000 T0605
Viscosity (mPa·s)	135	3878.0	JTJ 052-2000 T0625
	175	420.0	
Elastic Recovery Rate (25 ,%)		90.5	JTJ 052-2000 T0662
RTFOT (163)	Weight Loss (%)	-0.03	JTJ 052-2000 T0610
	Penetration Ratio (%)	76.7	JTJ 052-2000 T0604
	Ductility(5 ,cm)	10.1	JTJ 052-2000 T0605

From results in Table 4, it can be seen that modified asphalt used in Gussasphalt is relatively hard, with penetration less than 4mm and a relatively high softening point close to 100 . The viscosity is also relatively high, exceeding 3.0Pa·s at 135 , higher than SHRP technical requirements of the conventional modified asphalt (≤ 3.0 Pa·s). Therefore, the impact of asphalt content on performance of Gussasphalt is lower than other types of mixture.

Same modified asphalt is used to do contrast tests on various performances of Gussasphalt of two structures (Structure A and Structure C), as shown in Table 5.It can be seen from the results in Table 5: (1) In the case of mixing and paving under low temperature, embedded Gussasphalt possesses good fluidity. It is the lower production temperature of the mixture that makes great contributions to improvement of the low temperature performance and fatigue performance; (2) Compared with Structure A, the high-temperature overload resistance capacity of embedded Gussasphalt is significantly improved, particularly in rutting test, the dynamic stability is nearly doubled, it directly related to lower asphalt content and higher embedding rate of the coarse aggregate; (3) The low-temperature performance is significantly improved and the fatigue life is greatly enhanced, mainly due to lower production temperature of the mixture and enhancement of its strength. This is the main purpose of developing embedded Gussasphalt, and the biggest performance characteristic of embedded Gussasphalt as well.

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Table 5. Performance Test Results of Embedded Gussasphalt

Test Items	Gussasphalt Structure A	Gussasphalt Structure C	Test Methods
Construction Temperature( )	238	205	*Technical Guide on Design and Construction of Bridge Deck Paving of Highway Steel Box Girder*
Fluidity(S)	35	12	
Penetration(60 ,mm)	3.02	1.13	
Penetration Increments (60 ,mm)	0.26	0.18	
Dynamic Stability (60 ,mm/time)	610	1160	JTJ 052-2000 T0719
Maximum Bending Strain(-10 , micro-strain)	6260	8100	JTJ 052-2000 T0715
Fatigue Life (15 ,800 micro-strain, ten-thousand times)	52	86	AASHTO T321 (ex-TP8)

Note: The size of bending test specimen under low temperature is 300×100×50mm, fatigue test specimen is 385×50×65mm.

CONCLUSIONS

Relative to conventional Gussasphalt, the high-temperature stability, low-temperature cracking resistance and fatigue durability of embedded Gussasphalt are entirely enhanced on the basis of ensuring construction fluidity. As its excellent performance, this structure has been recommended to the project of Chongqing Egongyan Yangtze River Bridge Pavement and Across-Sea Xiamen-Zhangzhou Bridge Pavement, on the purpose of verifying its actual advantages of structure and performance by applying to solid projects.

The introduction of embedded Gussasphalt structure and great improvement of the performances of conventional Gussasphalt, making the adaptive and high-temperature overload resistance properties of Gussasphalt further developed , which plays an important role in perfecting Gussasphalt + SMA pavement system, solving the technical problems of steel deck pavement under special application conditions .

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