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# Study on High Temperature Behaviour of Gussasphalt

Yang Jun[1] Gharabaghy Cyrus[2] Steinauer Bernhard[2]

([1] Transportation College, Southeast University, 210096, China)
([2] Institut für Strassenwesen, RWTH AACHEN, D52074, Germany)

**Abstract:** Rutting is one of the most damages in the asphalt surfaces for the orthotropic steel bridge decks. With Hamburg wheel-tracking device, the suitable test conditions for Gussasphalt in Germany are pointed out, the high temperature behaviour of Gussasphalt with different binders are tested and compared. The polymer-modified binder has higher resistance stability to rutting. The retained time and mixed frequency have obvious effects on Gussasphalt behaviour during Gussasphalt retained period.

**Key words:** Gussasphalt, high temperature behaviour, Hamburg wheel-tracking test, polymer-modified binder

The problem of the surfaces for orthotropic steel decks, which is essential technology in the great span steel bridge construction, has not been solved well in the world. It is paid more attention to by international engineering and academic field. Surfaces lay down on the orthotropic steel plate directly, under driving load, wind load, temperature change and environment influence and steel deck partial deformation, their stress and deformation are far more complex than those of the highway and airport surfaces, thus to their intensities, deformation characteristics, temperature stability, durakility and so on, the higher requirements are necessary.

The good ductility and resistance characteristics to fatigue of Gussasphalt, the double-decked Gussasphalt structures are used mainly in Germany. The split is spread above the surfaces enhancing anti-skid resistance. The Gussasphalt design life is 15 – 20 years, the various problems of surfaces appeared after using 1 or 2 years, such as shove, rutting, blister, ravel, pothole, cracks, corrosion and so on[1,2]. Rutting is one of the main damages although the European climate is moderate. Reducing the rutting, the harder and polymer-modified binder are suggested to apply. The correlated reports of study on the high temperature stability behaviour of Gussasphalt with the Hamburg wheel-tracking device (HWTD), are not found. The paper presents the high temperature stability behaviour of Gussasaphalt of several polymer-modified binders with HWTD. The related material test methods are expounded.

## 1 Basic Materials and Related Check

Seven different binders are tested in accordance with DIN EN 12591[3] and TL PmB[4], related indices are in Tab.1.

**Tab.1** Binder related indices

| Binder | Needle penetration/mm | Softening point/℃ | Fraaβ breaking point/℃ | Elastic recover percent/% | Density/(g·cm$^{-3}$) |
|---|---|---|---|---|---|
| B30/45 | 3.60 | 57.0 | –9.30 | — | 1.038?7 |
| PmB45 | 4.70 | 60.0 | –17.0 | 69.0 | 1.030?9 |
| PmB25 | 3.30 | 69.0 | –12.0 | 65.5 | 1.030?8 |
| NV25 | 3.00 | 72.0 | –23.0 | * | 1.035?7 |
| SFB5–50 | 5.80 | 101.0 | –14.5 | 87.0 | 1.018?4 |
| Caribit 25 | 2.65 | 69.8 | –8.0 | 77.0 | 1.023?5 |
| Caribit 25S | 2.16 | 88.1 | –8.0 | 76.0 | 1.025?5 |

Note: * The sample wasn't pulled to demand length, it broke;— It hasn't been tested, because it is normal binder, the others are polymer-modified binders.

Based on RG Min StB 93[5] and TLM in StB 2000[6], the different fillers and basalt aggregate are tested, the related indices are in Tabs.2 and 3.

**Tab.2** Different fillers related indices

| Filler | Density/(g·cm$^{-3}$) | Void percent/% | Strengthening quality* /℃ | Water sensitivity** /% |
|---|---|---|---|---|
| HKW | 2.794 | 30.1 | 16.5 | 0.14 |
| Kue | 2.718 | 30.9 | 16.5 | 0.23 |

Note: * The different percent fillers mixed with fixed binder (B160/220)($w_F$ : $w_B$ = 0:1;1:1;1.5:1;1.86:1;2.3:1), test softening point change and find mix percent, with which softening point is improved 20?℃. Normally based on test results ($w_F$ : $w_B$ = 1.86 : 1) compare the filler quality and select better filler. Here are test results of softening point increase with mix ($w_F$ : $w_B$ = 1.86 : 1) compared basic binder[7].
** The asphalt Marshall samples are with 5% – 6% air voids, fixed binder and content. The volume change, Marshall stability and flow value of Marshall samples (sunk in water of 40?℃ for 48?h or not) are tested. The filler quality to water sensitivity is decided. Here are test results of volume change percent.

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** Born in 1968, female, associate professor, doctor.

**Tab**.3 Aggregate related indices

| | | |
|---|---|---|
| Los Angles abrasion value/% | | 10.5 |
| Apparent density/(g · cm$^{-3}$) | | 3.013 |
| Affinity | | Good |
| Grain form(Length:width ≥ 3 : 1)/% | 5/8 | 19.5 |
| | 8/11 | 16.5 |
| Impact test(Normal)* | | 13.0 |
| Impact test(FTW)** | | 13.0 |
| Impact test(Cook)*** | | 14.4 |
| Impact test(Heat)**** | | 13.9 |

Note: * The fixed size and percent aggregates are carried on the impact test. The crushed index of impact test is expressed with the average value of passing percents of five singles fixed analytical sieves after the impact test.

** FTW means frost-thaw-alternation. The fixed size and percent aggregates are carried on 10 fixed temperature cycles (20 to −20?℃) and then carried on the impact test.

*** The fixed size and percent aggregates are boiled for 36?h and carried on the impact test.

**** The fixed size and percent aggregates are put into fire of 700?℃ and be held 20?s and carried on the impact test.

## 2 Mineral Material Gradation and Mix Design

In accordance with ZTV Asphalt-StB 2001[8], the middle values of GA 0/11S are elected to mineral material and mix designs are carried out with the penetration tests at 40?℃, the optimal binder contents of each Gussasphalt are decided. The composited gradation and the required gradation in ZTV Asphalt-StB 2001[8] are in Tab.4. The penetration tests at 50?℃ and 60?℃ with the same samples of 40?℃ are tested and compared with different mixtures in Tab. 5.

**Tab**.4 Mixture of the grain groups for GA 0/11S

| Gradation Type | Passing percent of each sieve size/mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.09 | 0.25 | 0.71 | 2 | 5 | 8 | 11 |
| Composite gradation | 25.9 | 32.3 | 38.9 | 48.9 | 61.2 | 75.4 | 94.8 |
| Upper limit of ZTV Asphalt-StB 2001 | 20 | 24 | 32 | 45 | 58 | 70 | 90 |
| Low limit of ZTV Asphalt-StB 2001 | 30 | 40 | 48 | 55 | 70 | 85 | 100 |

Higher test temperature becomes, deeper the penetrations of Gussasphalt becomes. There is no homogenization in the same composite mixture. The elastic recovered ability of Gussasphalt should be paid attention to under the same test condition.

**Tab**.5 Gussasphalt penetrations at different temperatures

| Binder | Binder content/% | Density/(g · cm$^{-3}$) | Maximum density/(g · cm$^{-3}$) | Air void/% | Penetrations/mm | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 40?℃ | | 50?℃ | | 60?℃ | |
| | | | | | 30?min | Increase | 30?min | Increase | 30?min | Increase |
| B30/45 | 7.1 | 2.571 | 2.613 | 1.6 | 1.84 | 0.14 | 1.86 | 0.17 | 2.14 | 0.21 |
| NV25 | 7.4 | 2.553 | 2.614 | 2.3 | 2.02 | 0.18 | 1.99 | 0.2 | 3.01 | 0.23 |
| PmB25 | 7.5 | 2.559 | 2.584 | 1.0 | 1.98 | 0.21 | 2.39 | 0.26 | 2.64 | 0.18 |
| PmB45 | 7.2 | 2.563 | 2.578 | 0.6 | 1.74 | 0.2 | 2.78 | 0.28 | 3.14 | 0.43 |
| SFB5-50 | 6.9 | 2.567 | 2.606 | 1.5 | 1.71 | 0.08 | 2.39 | 0.1 | 2.82 | 0.13 |
| Caribit 25 | 7.1 | 2.612 | 1.7 | 2.17 | 0.31 | 2.67 | 0.38 | 3.93 | 0.48 | 2.568 |
| Caribit 25S | 7.1 | 2.566 | 2.619 | 2.0 | 1.81 | 0.28 | 2.7 | 0.31 | 4.11 | 0.47 |

Note: The value is the penetration increase from 30 to 60?min.

## 3 Hamburg Wheel-Tracking Tests

### 3.1 The HWTD and test method[9]

The Hamburg wheel-tracking device (HWTD) measures the combined effects of rutting and moisture damage by rolling a steel wheel across the surface of an asphalt concrete slab that is immersed in hot water. A. G. Esso of Hamburg developed the device in 1970s. The concept is based on a similar British device that has a rubber tire. The city of Hamburg finalized the test method and developed a pass/fail criterion that would guarantee mixtures with very low susceptibility to rutting. Now it is used as a specification requirement for some of the most traveled roadways in Germany to evaluate rutting and stripping.

Tests within the HWTD are conducted on a slab that is 260?mm wide, 320?mm long, typically 40?mm thick, also 80?mm, 120?mm or other thickness, required air voids using a linear kneading compactor.

Testing in HWTD is conducted under water or in air at 25?℃ to 70?℃, with 50?℃ being the most common temperature. Loading of samples in HWTD is accomplished by applying a 700?N or so force onto a 47-mm-wide steel or rubble wheel which has a diameter of 203.5?mm. The average contact stress given by the manufacturer is 203.5?MPa. Given that the contact area increases with rut depth, contact stress is variable. In accordance with the manufacture, a contact stress of 0.73?MPa approximates the stress produced by one rear tire of a double-axle truck. The average speed of each wheel is approximately 1.1?km/h. Each wheel travels approximately 230?mm before reversing direction, and the device operates at 53 ± 2 passes/min. Test samples are loaded for 20?000 passes or until deformation of 20? mm occurs.

During test period, the data collect system can record the rutting development process for one fixed test point and total cross section. Two parallel samples are tested. The system can calculate average value automatically and draw the figures of rutting development process.

### 3.2 Establish the suitable test conditions

The correlated reports on high temperature stability behaviour of Gussasphalt with HWTD haven't been found. Only for the mixture design of asphalt binder layer, there is a requirement[9] that the rutting depth should be not more than 3.5 mm under the following conditions: 50?℃, steel wheel and water bath. What test conditions are suitable for Gussasphalt should be found and decided. With PmB25 under different test conditions, the wheel-tracking tests are carried out. The test results are in Tab.6.

In test period, test temperature, wheel style and water factors are thought out. In accordance with test results in Tab.6, test temperature and wheel style have obvious effects on the high temperature behaviour of Gussasphalt. About other binder NV25, with wheel-tracking tests, the temperature effect is similar. The suitable test conditions for Gussasphalt in Germany are 50?℃, rubber wheel and air bath. Gussasphalt has little air voids, which is not more than 2% and can be adjusted by binder content. With the same test temperature and wheel style, Gussasphalt has low susceptibility to water. That is consistent with traditional idea of Gussasphalt. It is impervious and can protect the steel plate from water.

**Tab.6** Gussasphalts with different wheel-tracking test conditions

| Binder and content/% | | Plates parameters | | | Deformation at 20?000 cycles/mm | | | | Test conditions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Density/ (g·cm$^{-3}$) | Air void/% | Thickness/ cm | Fixed point value: Test | Fixed point value: Average | Section average value: Test | Section average value: Average | Temper-ature/℃ | Tire style | Bath |
| 7.7 | PmB 25 | 2.538 | 1.7 | 4.1 | 20.0 | 18.6 | 14.2 | 13.5 | 60 | Steel | Water/ 8?200* |
| 7.7 | PmB 25 | 2.541 | 1.6 | 4.1 | 17.2 | | 12.8 | | | | |
| 7.5 | PmB 25 | 2.565 | 1.0 | 4.0 | 15.5 | 17.8 | 14.7 | 17.1 | 60 | Rubber | Air/ 19?800* |
| 7.5 | PmB 25 | 2.558 | 1.3 | 4.1 | 20.0 | | 19.4 | | | | |
| 7.5 | PmB 25 | 2.561 | 1.2 | 4.1 | 5.9 | 6.2 | 6.9 | 7.3 | 50 | Rubber | Water |
| 7.5 | PmB 25 | 2.561 | 1.2 | 4.1 | 6.5 | | 7.6 | | | | |
| 7.5 | PmB 25 | 2.555 | 1.4 | 4.1 | 15.1 | 16.3 | 16.0 | 17.1 | 50 | Steel | Water |
| 7.5 | PmB 25 | 2.557 | 1.3 | 4.1 | 17.5 | | 18.1 | | | | |
| 7.5 | PmB 25 | 2.562 | 1.1 | 4.1 | 6.4 | 6.7 | 7.0 | 7.2 | 50 | Rubber | Air |
| 7.5 | PmB 25 | 2.557 | 1.3 | 4.1 | 7.0 | | 7.4 | | | | |
| 7.4 | PmB 25 | 2.545 | 1.9 | 4.1 | 5.3 | 5.2 | 5.8 | 5.7 | 50 | Rubber | Air |
| 7.4 | PmB 25 | 2.545 | 1.9 | 4.1 | 5.0 | | 5.5 | | | | |
| 7.4 | NV 25 | 2.561 | 0.7 | 4.2 | 2.9 | 3.3 | 3.5 | 3.8 | 50 | Rubber | Air |
| 7.4 | NV 25 | 2.555 | 0.9 | 4.1 | 3.7 | | 4.0 | | | | |
| 7.4 | NV 25 | 2.561 | 0.7 | 4.1 | 15.6 | 16.5 | 14.9 | 15.9 | 60 | Rubber | Air |
| 7.4 | NV 25 | 2.558 | 0.8 | 4.0 | 17.3 | | 16.8 | | | | |

Note: * The number is the load cycles, while the test rutting depth is 20.0?mm.

### 3.3 Test results

Normally, binder and mineral material finish the mixing, they can't be paved and compacted at once because of transport and others. There are some regulations to Gussasphalt about their retaining time in ZTV Asphalt-StB 2001[9]. At 240?℃, Gussasphalt mixtures can be retained for not more than 2?h; at 230?℃, they can be retained for not more than 6?h; the Gussasphalt mixtures in cooker must be constructed within 12?h. The regulations are too rough. In laboratory, Gussasphalt behaviour is influenced by the mixture retaining time and mixing frequency in retained period is found.

After mixing at 250?℃ for 1?min with 60?r/min, form the rutting plates at once, or retaining mixture 50?min to 250?℃ and with 8?r/min , or retaining mixture 1?h to 250?℃ and with 10?r/min. The wheel-track test conditions are at 50?℃, rubber wheel and with air bath. The test results are in Tab.7.

In accordance with Tab.7, the retained time and mixed frequency have obvious effects on high temperature behaviour of Gussasphalt. The behaviour of Gussasphalt influenced by time and temperature should be paid attention to. The polymer-modified binder has higher resistance to rutting than normal binder.

Compared with high temperature behaviour of

Gussasphalt with different binders, NV25 has lower susceptibility of retaining time.

**Tab.7** Gussasphalt with different retaining times

| Binder and content/% | | Plates parameters: Density/ (g · cm$^{-3}$) | Air void/% | Thickness/ cm | Deformation at 20?000 cycles/mm: Fixed point value Test | Fixed point value Average | Section average value Test | Section average value Average | Test conditions: Retainig time/min | Mix frequency/ (r · min$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 7.2 | PmB 45 | 2.562 | 0.6 | 4.2 | 16.5 | 18.3 | 14.9 | 16.5 | 0 | 11?400* |
| 7.2 | PmB 45 | 2.557 | 0.8 | 4.2 | 20.0 | | 18.1 | | | |
| 7.5 | PmB 25 | 2.536 | 1.9 | 4.2 | 18.7 | 18.7 | 19.3 | 19.2 | 0 | |
| 7.5 | PmB 25 | 2.537 | 1.8 | 4.1 | 18.7 | | 19.1 | | | |
| 7.1 | B 30/45 | 2.548 | 2.5 | 4.2 | 20.0 | 18.5 | 15.8 | 14.8 | 0 | 9?200* |
| 7.1 | B 30/45 | 2.560 | 2.0 | 4.2 | 17.0 | | 13.8 | | | |
| 6.8 | B 30/45 | 2.568 | 1.2 | 4.1 | 5.8 | 7.2 | 6.7 | 7.8 | 50 | 8 |
| 6.8 | B 30/45 | 2.574 | 1.0 | 4.1 | 8.5 | | 8.9 | | | |
| 7.2 | PmB 45 | 2.554 | 0.9 | 4.1 | 12.0 | 12.2 | 12.1 | 12.3 | 50 | 8 |
| 7.2 | PmB 45 | 2.555 | 0.9 | 4.0 | 12.4 | | 9.6 | | | |
| 7.5 | PmB 25 | 2.546 | 1.0 | 4.1 | 8.8 | 8.7 | 9.6 | 9.4 | 50 | 8 |
| 7.5 | PmB 25 | 2.554 | 0.7 | 4.0 | 8.5 | | 9.2 | | | |
| 7.4 | NV 25 | 2.561 | 0.7 | 4.2 | 2.9 | 3.3 | 3.5 | 3.8 | 50 | 8 |
| 7.4 | NV 25 | 2.555 | 0.9 | 4.1 | 3.7 | | 4.0 | | | |
| 6.9 | SFB 5 – 50 | 2.564 | 1.2 | 4.1 | 9.4 | 9.7 | 10.5 | 10.8 | 50 | 8 |
| 6.9 | SFB 5 – 50 | 2.570 | 1.0 | 4.1 | 9.9 | | 11.0 | | | |
| 7.1 | B 30/45 | 2.567 | 1.8 | 4.0 | 6.5 | 5.8 | 7.4 | 6.6 | 60 | 10 |
| 7.1 | B 30/45 | 2.558 | 2.1 | 4.2 | 5.0 | | 5.7 | | | |
| 7.2 | PmB 45 | 2.551 | 1.0 | 4.0 | 3.3 | 3.9 | 3.9 | 4.6 | 60 | 10 |
| 7.2 | PmB 45 | 2.550 | 1.1 | 4.1 | 4.5 | | 5.3 | | | |
| 7.5 | PmB 25 | 2.562 | 0.9 | 4.1 | 2.5 | 2.4 | 2.8 | 2.8 | 60 | 10 |
| 7.5 | PmB 25 | 2.582 | 0.1 | 4.1 | 2.2 | | 2.7 | | | |
| 7.4 | NV 25 | 2.567 | 1.8 | 4.1 | 2.8 | 2.8 | 3.2 | 3.1 | 60 | 10 |
| 7.4 | NV 25 | 2.564 | 1.9 | 4.0 | 2.7 | | 3.0 | | | |
| 6.9 | SFB 5 – 50 | 2.558 | 1.8 | 4.1 | 1.8 | 2.5 | 2.3 | 2.9 | 60 | 10 |
| 6.9 | SFB 5 – 50 | 2.557 | 1.9 | 4.1 | 3.2 | | 3.5 | | | |
| 7.1 | Caribit 25 | 2.584 | 1.1 | 4.1 | | 1.5 | 1.6 | 1.7 | 60 | 10 |
| 7.1 | Caribit 25 | 2.583 | 1.1 | 4.2 | 1.5 | | 1.7 | | | |
| 7.1 | Caribit 25S | 2.574 | 1.7 | 4.2 | 1.3 | 1.4 | 1.4 | 1.5 | 60 | 10 |
| 7.1 | Caribit 25S | 2.572 | 1.8 | 4.1 | 1.5 | | 1.6 | | | |

Note: * The number is the load cycles, while the test rutting depth is 20.0?mm.

## 4 Conclusion and Suggestion

With HWTD, the suitable test conditions for Gussasphalt in Germany are pointed out, the high temperature behaviour of Gussasphalt with different binders are tested and compared. The polymer-modified binder has higher resistance stability to rutting. The retained time and mixed frequency have obvious effects on Gussasphalt behaviour, so the study on Gussasphalt behaviour influenced by the retained time and temperature should be paid more attention to and carried out deeply.

There are more fillers, around 20% – 30%, in the Gussasphalt than normal asphalt mixtures. It is very important to elect the filler. Based on the change of softening points with fixed binder to search better filler and decide suitable percent of binder-filler in mixture, the authors think that test concept is clear and test method is simple. It can be used for reference in other countries.

The binder-filler mortar is core in asphalt mixture. Its property restricts behaviour of asphalt mixture. The study on behaviour of the binder-filler mortar should be paid more attention to.

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# 浇注式沥青混合料高温性能研究

杨 军[1] Gharabaghy Cyrus[2] Steinauer Bernhard[2]

([1] 东南大学交通学院，南京 210096)
([2] 亚琛工业大学道路研究所，亚琛 D52074，德国)

**摘 要** 车辙是正交异性钢桥面沥青混凝土铺装主要病害之一.采用汉堡轮辙试验机，提出了适宜于德国、考察浇注式沥青混合料高温性能的试验条件，测试和比较了不同浇注式沥青混合料的高温性能.聚合物改性沥青混合料具有较高的抗车辙能力.滞留时间和拌和频率对浇注式沥青混合料的性能有明显的影响.

**关键词** 浇注式沥青混合料，高温性能，汉堡轮辙试验，聚合物改性沥青
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