# REVIEW ON PERFORMANCE AND AGING KINETICS OF CRUMB RUBBER MODIFIED ASPHALTS

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The present article gives an overview on performance and aging kinetics of matrix and crumb rubber modified asphalts. Three types of asphalts such as crumb rubber modified asphalt, AH-70 and AH-90 have been introduced. Equations related to aging kinetics have also been used in crumb rubber modified asphalt system. The experimental results show that the aging process of two types of asphalts (crumb rubber modified asphalt and AH-70) are of first order kinetics, and the anti-aging performance of crumb rubber modified asphalt is found to be better than that of AH-70.

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## Introduction

Nowadays a large number of vehicles are required due to rapid growth of the *Chinese* economy; therefore, road material pavement faces serious challenges with respect to *Chinese* upcoming regulations such as rutting, cracking, stripping and decreasing anti-slipping. *Chinese* scientists have been working on improving the performance of road materials in order to meet road development in *China*. Most of asphalts in *China* belong to multi-wax W grade asphalts. Its performance is supposed to be very poor in respect of low adhesive property, high temperature sensitivity, poor heat stability, low thermal crack resistance, easily flowing under the condition of high-temperature and rapidly hardening to become solid under the condition of low-temperature, therefore, it is very difficult for this type of asphalt to meet *Chinese* road design standard. [1] Crumb rubber is added into asphalts to improve its performance, such as needle penetration, elasticity, ductility and anti-deformation. Its high-temperature stability, anti-cracking and anti-fatigue performance are increased.[2]

In the present paper, the thermal performance of matrix asphalt and crumb rubber modified asphalt has been compared. Three types of asphalts (crumb rubber modified asphalt, AH-70 and AH-90) have also been studied. Further, aging kinetics equations have also been applied.

## Discussion

### Comparing the thermal performance between matrix asphalt and crumb rubber modified asphalt [3]

Three types of asphalts (No.1, No.2 and No.3) were synthesised by the addition of AH-70 as matrix asphalt and crumb rubber as a modified agent. Its properties were presented in Table 1. The experimental results showed that the performance of asphalt was improved by the addition of crumb rubber. The properties of crumb rubber modified asphalt satisfied *American* standard. On the other hand, matrix asphalt (AH-70) did not meet American standard under the condition of the reaction temperature (163 °C) and the reaction time (5 hours). This proved that crumb rubber improved the performance of asphalt.

Table 2 showed effects of thermal sensitivity on matrix asphalt and crumb rubber modified asphalt. Chen Huiming[4] introduced the relationship between penetration and temperature. Eqn. (1) was written as follows:

$$\lg P = k + AT \quad (1)$$

where

| | |
|---|---|
| $P$ | Penetration, 0.1 mm |
| k - | Constant |
| $A$ | Heat penetration coefficient |
| $T$ | Temperature, °C |

Based on below experimental data, heat penetration coefficient ($A$) was obtained by using the linear regression method, but its regression coefficient ($R$) could not be lower than 0.997. $T_{800}$ and $T_{1.2}$ meant equivalent softening point and equivalent brittle point, respectively. The higher $T_{800}$ value was, the higher stability of asphalt can be occurred. Eqn. (2) ($T_{800}$) and (3) ($T_{1.2}$) were listed as follows:

$$T_{800} = \frac{\left[2,903 - k\right]}{A} \quad (2)$$

$$T_{1.2} = \frac{\left[0.072 - k\right]}{A} \quad (3)$$

$A$ and k values taken from Eqn. (1). The experimental results presented that when crumb rubber was added into asphalt, the performance of crumb rubber modified asphalt was improved such as penetration (15 °C and 25 °C), $T_{800}$, $T_{1.2}$, elastic range and penetration index, however penetration values of No.2 and No.3 at 30 °C were lower than that of matrix asphalt. Furthermore, all $R$ values are more than 0.997.

**Table 1.** Properties of modified and matrix asphalts

| **Properties** | **Matrix asphalt** | **Modified asphalts** | | | **American Standard** | | |
|---|---|---|---|---|---|---|---|
| | **AH-70** | **No.1** | **No.2** | **No.3** | **ABR-1** | **ABR-2** | **ABR-3** |
| Penetration (25°C,100g, 5s)/0.1 mm | 69 | 67 | 64.5 | 91.5 | 25-75 | 50-100 | 75-150 |
| Penetration,( 4°C, 200 g, 60 s)/0.1 mm | 34 | 36 | 33 | 51 | >15 | >25 | >40 |
| Softening point, °C | 45.4 | 54.2 | 51.5 | 45.6 | >54 | >49 | >43 |
| Elastic recovery (25°C,10 cm)/% | 30 | 75 | 70 | 50 | >20 | >10 | >0 |
| Ductility (4°C)/cm | 3 | 22.5 | 16.2 | 21.3 | >5 | >10 | >20 |
| | | *After 5 hours at 163 °C* | | | | | |
| Penetration (4 °C), % | 60 | 81 | 83 | 77 | >75 | >75 | >75 |
| Ductility (4°C), % | - | 68 | 63 | 59 | >50 | >50 | >50 |

**Aging kinetics of AH-70 and crumb rubber modified asphalt**

Shi Hongbo [5] used AH-70 and crumb rubber modified asphalt as feedstocks and studied effects of the aging time on the yields of asphaltene. Two types of aging kinetics parameters and models were obtained. Table 3 presented the relationship between the aging time and the content of asphaltene. The content of asphaltene for No.1 and AH-70 gradually increased with an increase in the aging time at the same reaction temperature.

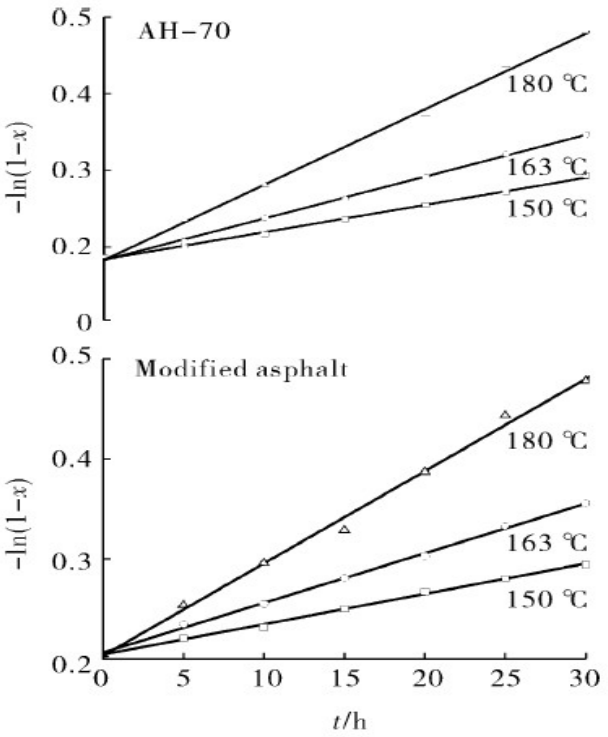


**Figure 1.** The relationship between -ln(1-*x*) and the aging time

Furthermore, the content of asphaltene for No.1 was more than that of AH-70 at the same aging time and reaction temperature. On the other hand, the content of asphaltene for No.1 and AH-70 slowly increased with an increase in the reaction temperature at the same aging time. This proved that the performance of No.1 was better than that of AH-70.

It was supposed that the aging process of asphalt was first order reaction, so –ln(1-*x*) was linearly related with the aging time shown in Figure 1. k was the slope of the line. It was very clear that –ln(1-*x*) had a significant correlation with the aging time. Furthermore, k value was 0.99762. It was proved that the aging process of asphalt was first order reaction.

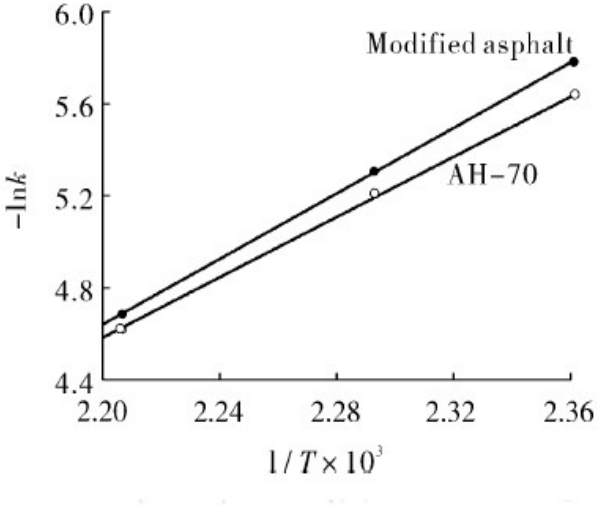


**Figure 2.** The relationship between –ln k and 1/*T*

Based on Arrhenius Eqn. (4) and the above experimental data, kinetics parameters of crumb rubber modified asphalt and AH-70 shown in Table 4 were obtained. Figure 2 presented the relationship between –ln k and 1/*T*.

$$\ln k = \frac{E_a}{RT} + \ln A \qquad (4)$$

Aging kinetics Eqn. (5) (crumb rubber modified asphalt) and (6) (AH-70) were written as follows:

**Table 2.** The effect of thermal sensitivity on matrix and crumb rubber modified asphalt

| Asphalt | Penetration/ $10^{-1}$ mm | | | *R* | $T_{800}$ | $T_{1.2}$ | Elastic range | Penetration index |
|---|---|---|---|---|---|---|---|---|
| | 15°C | 25°C | 30°C | | | | | |
| No.1 | 28.0 | 91.5 | 148.1 | 0.9988 | 44.77 | -13.24 | 58.02 | -1.26 |
| No.2 | 20.6 | 64.5 | 98.0 | 0.9976 | 49.50 | -12.17 | 61.67 | -0.88 |
| No.3 | 22.5 | 62.5 | 98.0 | 0.9995 | 51.10 | -14.79 | 65.89 | -0.45 |
| Matrix asphalt | 16.1 | 61.5 | 119.0 | 0.9999 | 44.20 | -4.36 | 48.56 | -2.32 |

**Table 3.** The relationship between the aging time and the content of asphaltene

| Aging time, h | Content of asphaltene | | | | | |
|---|---|---|---|---|---|---|
| | 150 °C | | 163 °C | | 180 °C | |
| | No.1 | AH-70 | No.1 | AH-70 | No.1 | AH-70 |
| 0 | 0.185 | 0.170 | 0.185 | 0.170 | 0.185 | 0.170 |
| 5 | 0.198 | 0.183 | 0.209 | 0.187 | 0.224 | 0.210 |
| 10 | 0.207 | 0.195 | 0.225 | 0.212 | 0.256 | 0.245 |
| 15 | 0.221 | 0.211 | 0.245 | 0.231 | 0.280 | 0.275 |
| 20 | 0.235 | 0.225 | 0.262 | 0.253 | 0.321 | 0.312 |
| 25 | 0.245 | 0.238 | 0.283 | 0.275 | 0.358 | 0.354 |
| 30 | 0.255 | 0.254 | 0.299 | 0.293 | 0.380 | 0.382 |

$$\ln(1-x) = -0.205 - 6.08 \cdot 10^4 e^{\frac{-7116}{T}} t \quad (5)$$

$$\ln(1-x) = -0.186 - 1.82 \cdot 10^4 e^{\frac{-6542}{T}} t \quad (6)$$

where

k the slope of the line

*R* the correlation

*T* the reaction temperature,

K the pre-exponential factor

$E_a$ the activation energy

## Conclusion

Based on the above results and discussion, a comparison of thermal performance of matrix asphalt and crumb rubber modified asphalt has been done. The experimental results showed that he performance of crumb rubber modified asphalt was improved, but penetration values of No.2 and No.3 at 30 °C were lower than that of AH-70. Furthermore, all *R* values are more than 0.997.

The content of asphaltene for No.1 and AH-70 gradually increased with an increase in the aging time at the same reaction temperature. On the other hand, the content of asphaltene for No.1 and AH-70 slowly increased with an increase in the reaction temperature at the same aging time. The aging process of two types of asphalts (crumb rubber modified asphalt and AH-70) were of first order kinetics reaction.

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