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INVESTIGATION OF CHANGES IN HIGH TEMPERATURE PERFORMANCE OF ASPHALT CONCRETE UNDER ULTRAVIOLET RADIATION

ДОСЛІДЖЕННЯ ЗМІН ВИСОКОТЕМПЕРАТУРНИХ ХАРАКТЕРИСТИК АСФАЛЬТОБЕТОНУ ПІД ДІЄЮ УЛЬТРАФІОЛЕТОВОГО ВИПРОМІНЮВАННЯ

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In recent years, asphalt concrete pavement in being a large number of applications, and gradually appeared a number of pavement damage problems, especially in the strong ultraviolet and high temperature environment of asphalt concrete pavement, because of long-term exposure to ultraviolet radiation, resulting in high-temperature durability of the pavement deteriorated year by year. In this paper, the number of UV aging cycles, aging temperature and UV radiation intensity on the rutting depth and dynamic stability are investigated through high temperature rutting test. The test results show that: for asphalt concrete, the number of UV aging cycles has a more pronounced effect on dynamic stability and rut depth compared to aging temperature and UV radiation intensity.

З постійним розвитком транспортної інфраструктури та збільшенням попиту на перевезення, асфальтобетон отримав широке застосування як основний дорожній матеріал. Його експлуатаційні характеристики в умовах високих температур мають значний вплив на довговічність і безпеку доріг. У багатьох регіонах спекотна погода та інтенсивне ультрафіолетове випромінювання є поширеними кліматичними характеристиками, які впливають на довговічність асфальтобетону. В умовах високих температур асфальтобетонне покриття схильне до появи тріщин, деформацій та руйнування, що безпосередньо впливає на довговічність дорожнього покриття та безпеку дорожнього руху.

З метою вивчення впливу ультрафіолетового випромінювання на високотемпературні властивості асфальтобетону, за допомогою проведення високотемпературного випробування на утворення колії, було встановлено залежності між кількістю циклів ультрафіолетового витримування, температурою витримування та інтенсивністю ультрафіолетового випромінювання на глибину колії та динамічну стійкість за допомогою проведення високотемпературного випробування на утворення колії.

Результати випробувань показують, що за умови постійної інтенсивності

УФ-випромінювання і температури випробувань, при збільшенні кількості циклів ультрафіолетового випромінювання глибина колії на поверхні зразка асфальтобетону збільшується зі збільшенням кількості циклів ультрафіолетового випромінювання, натомість динамічна стійкість - зменшується. Результати експериментів підтверджують, що при поступовому збільшенні інтенсивності УФ-випромінювання його вплив на глибину колії на поверхні асфальтобетонного зразка поступово зменшується Для асфальтобетону кількість циклів УФ-витримування має більш виражений вплив на динамічну стійкість і глибину колії порівняно із зміною температури при випробуванні та інтенсивністю УФ-випромінювання.

Key words: asphalt concrete, high temperature performance, ultraviolet radiation, dynamic stability, temperature.

Ключові слова: асфальтобетон, високотемпературні характеристики, ультрафіолетове випромінювання, динамічна стійкість, зміна температури.

Introduction. With the intensification of climate change and the increase in transportation demand, asphalt concrete, as one of the main pavement materials in road construction, is subjected to increasingly severe environmental tests[1][2]. In the process of road service, asphalt concrete experiences the influence of various natural climatic conditions, among which high temperature environment is a factor of great concern. Under high-temperature weather, asphalt concrete pavement is prone to face problems such as cracking, deformation and damage, which directly affects the service life of the road and traffic safety[3][4].

Ultraviolet (UV) radiation is an important influence in high-temperature environments, and its energy intensity and frequency make it a major factor in the high-temperature performance of asphalt concrete[5][6]. Prolonged exposure to UV light may cause aging and photo-oxidation of asphalt in asphalt concrete, which may lead to the degradation of pavement performance[7][8]. However, in-depth studies on the changes in the high-temperature properties of asphalt concrete under UV radiation have been relatively limited to date.

Raw materials and gradation. The experiment was conducted with SBSI-C modified asphalt, and the relevant technical specifications are shown in Table 1.

Table 1

SBS modified asphalt specifications and requirements

Index	Test Result	Requirement
Penetration (25 °C, 100 g.5s)/0.1 mm	66	60~80
Extensibility (5 °C)/cm	47	≥30
Softening Point/°C	78	≥55
Density (15 °C)/(g·cm^{-3})	1.027	—

SMA-13 asphalt concrete was utilized for the experiment, and the gradation is shown in Table 2.

Test methods. In this paper, ultraviolet radiation intensity, ultraviolet radiation cycle times and temperature of the three factors to analyze the impact of ultraviolet radiation on the high temperature performance of asphalt concrete. Respectively selected 0, 100 W/m^2, 200 W/m^2, 300 W/m^2 of these ultraviolet radiation intensities; ultraviolet radiation cycle times in order to simulate the actual road surface as far as possible and selected the radiation time of 12 ~ 13h, non-radiation time of 11 ~ 12h; at the same time, the temperature selection of 15 ~ 40 °C and 25 ~ 50 °C of the alternating transformation.

Table 2

Gradation of SMA-13 asphalt concrete

SMA-13		Lower limit	Ppper limit	Graduate median	Synthetic gradation
Percentage of mass passing through the following sieve pores (mm), %	16	100	100	100	100
	13.2	90	100	95	96.4
	9.5	50	75	62.5	60.7
	4.75	20	34	27	27.3
	2.36	15	26	20.5	21.4
	118	14	24	19	17.9
	0.6	12	20	16	15.8
	0.3	10	16	13	13.7
	0.15	9	15	12	11.1
	0.075	8	12	10	10.6

The indoor ultraviolet light accelerated aging test chamber: the test chamber includes temperature automatic regulator, the timer, and has a double wall. The light source of the accelerated UV aging test system takes 1000W straight tube high-pressure mercury lamp, the control temperature of the high-pressure mercury lamp is 40-60 °C, the main peak of the UV energy spectrum is 365 nm, and the acquisition of different UV radiation intensities is realized by adjusting the position of the transformation conversion layer.

The prepared specimens are firstly placed in 40°C or 50°C UV accelerated aging tester, and kept under the specified radiation intensity for 12 ~ 13h, then the specimens are removed and placed in 15°C or 20°C environment for 11 ~ 12h, and this process is treated as a complete UV aging cycle, and then 5, 10, 15 and 25 UV aging cycles will be carried out next.

Referring to the specification requirements, the high temperature performance of SMA-13 asphalt concrete was evaluated by the rut depth and dynamic stability in the rut test.

Analysis of test results. According to the above test method, different test conditions are adopted for asphalt concrete to carry out the test of UV aging cycle. Among them, the same temperature were taken 4 kinds of UV radiation intensity and 4 kinds of cycle times, a total of 16 groups of tests, in which each group of tests need to carry out 6 parallel tests, and the average value of these 6 tests as the results of the group. Meanwhile, a group of specimens not treated with the UV aging cycle was taken as a control group with the rut depth of 1.596 mm and the dynamic stability of 4841 cycles/mm. The changes of rutting depth of asphalt concrete under different UV aging cycle conditions are shown in Figure 1.

Along with the increase of the number of UV aging cycles, the rut depth of asphalt concrete gradually increased. In the case of UV radiation intensity of 200 W/m^2, the rut depth of asphalt concrete increased by 31.1%, 41.8%, 53.3%, and 65.3% when the temperature is 15 ~ 40°C, after 5, 10, 15, and 25 UV aging cycles, respectively. While the rut depth increased by 36.8%, 51.4%, 61.4%, and 75.6% when the temperature is 25 ~ 50°C. The data show that when the number of UV aging cycles increases, other conditions remain unchanged, the rut depth of asphalt concrete is also gradually increasing, and the increasing trend is more and more obvious, indicating that the high temperature resistance to deformation of asphalt concrete is the worse.

When the intensity of UV radiation increases, the rut depth of asphalt concrete also increases gradually. Take the case of 10 times of UV aging cycle as an example, when the temperature is 15 ~ 40 °C, the UV radiation intensity of 0, 100 W/m^2, 200 W/m^2 and 300 W/m^2 conditions, after 10 times of UV aging cycle, the rut depth of the asphalt concrete is respectively increased by 14.5%, 33.2%, 41.8%, 49.0%. The rutting depth of asphalt concrete increased by 20.1%, 37.9%, 50.3%, and 61.3% when the temperature was 25 ~ 50°C. The rutting depth of asphalt concrete increased by 20.1%, 37.9%, 50.3%, and 61.3%, respectively. This set of data can show that the rutting depth of asphalt concrete is significantly increased with the intensity of UV radiation, and its high temperature deformation resistance is getting worse and worse, of which, when the temperature interval is 25 ~ 50 °C, the rut depth of the increasing trend is more obvious.

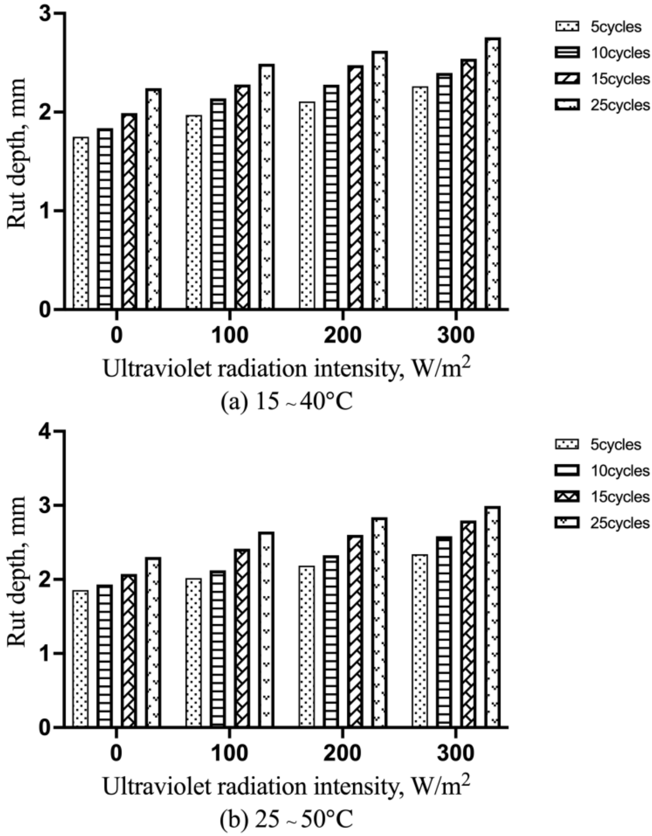

Fig. 1 Variation of rut depth of asphalt concrete under different ultraviolet aging cycle conditions

And from the selection of different test temperatures, it can be seen that the rut depth increased by 15% - 20% when the UV radiation intensity was from 0 to 100 W/m^2, about 10% when the UV radiation intensity was from 100 W/m^2 to 200 W/m^2, and about 8% when the UV radiation intensity was from 200 W/m^2 to 300 W/m^2. These experimental results show that when the intensity of

UV radiation increases gradually, its effect on the rut depth of asphalt concrete is gradually reduced. These experimental results show that when the intensity of UV radiation increases gradually, its effect on the rutting depth of asphalt concrete is gradually reduced. The reason for this phenomenon is mainly in the same number of UV aging cycles, asphalt concrete is only affected by the temperature; and when there is the intensity of UV radiation, the mixture is subjected to temperature and UV light, UV radiation makes the asphalt in the mixture aging, resulting in a reduction in the aggregate cohesion in the mixture, which in turn causes the rut depth of the asphalt concrete to occur more significantly.

The variations of dynamic stability of asphalt concrete under different UV aging cycle conditions are shown in Fig. 2.

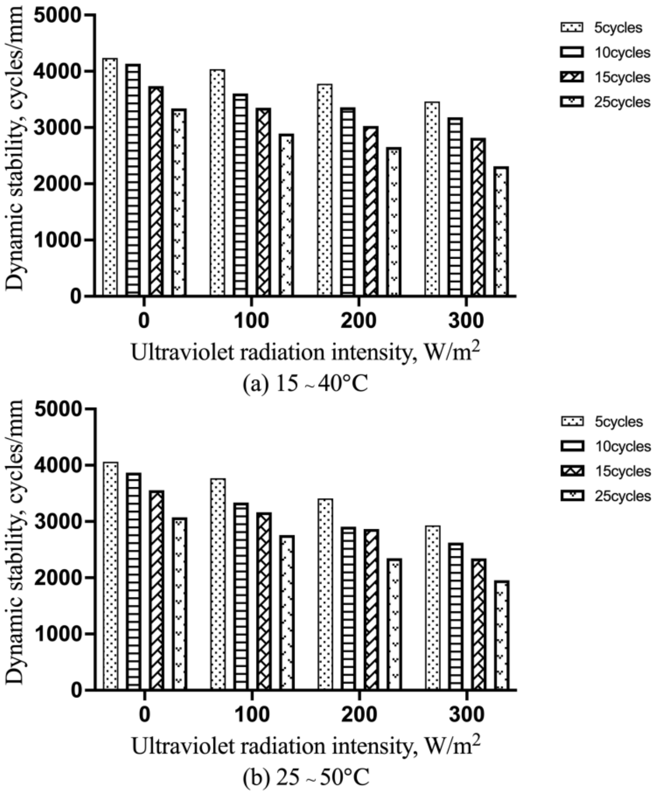

Fig. 2 Variation of dynamic stability of asphalt concrete under different ultraviolet aging cycle conditions

The dynamic stability of asphalt concrete decreased by 29.2%, 34.1%, 42.1%, and 52.1% after 5, 10, 15, and 25 UV aging cycle tests at temperature of 15 ~ 40°C with 300 W/m^2 UV radiation intensity, respectively. The dynamic stability of asphalt concrete decreased by 37.4%, 45.0%, 51.4%, and 59.3%, respectively, when the temperature was 25 ~ 50°C and the same UV radiation intensity was maintained. This indicates that the dynamic stability of asphalt gradually decreases with the increase of the number of UV aging cycles, while its attenuation shows an increasing trend, and the high temperature performance of the mixture is a little worse when the temperature is 25 ~ 50°C.

When the temperature interval was 15 ~ 40°C, the dynamic stability of asphalt concrete decreased by 22.6%, 30.5%, 36.7%, and 42.1% after 15 UV aging cycles when the UV radiation intensities were 0, 100 W/m^2, 200 W/m^2, and 300 W/m^2, respectively, while when the temperature interval was 25 ~ 50°C, the dynamic stability of asphalt concrete decreased by 26.3%, 34.2%, 40.4%, and 51.6%, respectively. The data show that the dynamic stability of asphalt concrete is related to the intensity of UV radiation, and the dynamic stability tends to decrease with the gradual increase of radiation intensity.

Conclusion. In this paper, the rutting test was used to study and analyze the effect of UV radiation aging on the high-temperature performance of asphalt concrete, and systematically analyzed the changes in dynamic stability and rut depth of asphalt concrete with the changes in the intensity of UV aging radiation, the temperature of the UV aging cycle, and the number of cycles, and the following conclusions were drawn:

1. Under the condition of keeping the intensity of UV radiation and the cycle temperature unchanged, and increasing the number of cycles of UV aging, the rut depth of asphalt concrete increases with the increase in the number of cycles of UV aging, while the dynamic stability is a consequent decrease.

2.Experimental results show that when the intensity of UV radiation increases gradually, its effect on the rutting depth of asphalt concrete is gradually reduced.

3. The dynamic stability of asphalt concrete is related to the intensity of UV radiation, and the dynamic stability tends to decrease with the gradual increase of radiation intensity.

4. For asphalt concrete, the number of UV aging cycles has a more pronounced effect on dynamic stability and rut depth compared to aging temperature and UV radiation intensity.

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