Research on the Anti-Skid Performance of Asphalt Pavement under the Coupling Effect of High Temperature and High Humidity

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Abstract: With the rapid development of asphalt pavement construction projects, driving safety has attracted attention. There is a certain correlation between the anti-skid ability and environmental factors. To conduct experimental research on the anti-skid performance of asphalt pavement in high temperature and high humidity environments, the anti-skid ability of four types of asphalt mixtures was quantitatively studied in temperature, humidity, water accumulation, and high temperature and high humidity coupled environments. Research has found that the anti-skid performance of high-temperature and high humidity asphalt pavement rapidly decreases. As the humidity increases, the anti-skid performance continues to decrease but at a slower rate. The degree and speed of anti-skid performance decrease between SMA-13 and SSAM-13 are basically equivalent. The results of this study can provide theoretical basis for the optimization design of anti-skid performance in road engineering in high temperature and high humidity areas.

Keywords: Asphalt pavement; Mixture; Anti slip; BPN; Temperature and humidity

1. Introduction

For a long time, road traffic accidents have been a major challenge around the world. Traffic accidents are influenced by many factors, including driver behavior, vehicles, climate and environmental factors, and their coupling effects [1-4]. Anti slip performance refers to the measurement of frictional force obtained under standardized conditions. Good anti slip performance helps drivers control the parking distance and trajectory of their vehicles [5-7].

Hu Liqun et al. used AC and OGFC to study the mechanism of action with temperature and wear frequency. Through analysis, it was found that the anti-skid ability of the three asphalt mixtures decreased with increasing temperature and wear frequency. Under the influence of temperature and wear, SMA-13 and OGFC-13 mixtures had better anti-skid ability. As the temperature increases, the decrease in adhesion friction of AC-13 asphalt mixture also increases accordingly [8]. Zheng Dong et al. used epoxy asphalt mixture (EA-10) to analyze the changes in BPN of asphalt mixture under extreme climate factors such as sand, rain, and freezing. The research results show that the BPN value of EA-10 decreases by 23% to 44% under dry sand and dust climate conditions. The BPN values of EA-10 decrease by 20% and 30% under low and high rainfall conditions, respectively. The BPN values of road surfaces in ice crystal, ice film, and water accumulation states in frozen climate decrease by 10%, 70%, and 30%, respectively [9]. Hu Liqun et al. studied the impact of urban road pollutants on anti-skid performance, screened out pollutants collected by urban vacuum cleaners, and measured the friction coefficient of pollutants on AC-13 asphalt pavement using a continuous friction coefficient tester (T2GO system). It was found that when pollutants increased, the friction coefficient of the pavement would correspondingly decrease in dry environments; In humid environments, different pollutants have varying effects on the anti-skid performance of urban roads, and the impact is greater than in dry environments [10]. Through analyzing the changes in SMA friction coefficient in domestic and foreign engineering projects, Zhi Yufeng et al. found that the friction coefficient showed a significant short-term increase. After completion, the anti-skid performance shows a short-term decrease followed by an increase, and the friction coefficient shows an upward trend around 3-6, then tends to stabilize and then decrease [11].

At present, there are many studies on the anti-skid performance of asphalt pavement [12-15], focusing on the effects of asphalt mixture grading, aggregates, anti-skid performance evaluation methods, environment, and other factors on the anti-skid performance of asphalt pavement, as well as the anti-skid degradation law of asphalt pavement. However, there is still limited research on the mechanism of anti-skid performance degradation. This article selects four types of asphalt mixture vehicle track plate specimens, namely AC-13 AC-16, SMA-13, SSAM-13, Using a pendulum instrument to test the pendulum values under different temperature, humidity, water accumulation, and high temperature and high humidity environmental conditions, in order to study the anti-skid performance and anti-skid performance degradation of asphalt pavement in high temperature and high humidity coupled environments.

2. Experimental Methods

Select four grading types of mixtures, AC-13, AC-16, SMA-13, and SSAM-13, for comparative experiments.

2.1 Temperature Control Methods

This paper tests the BPN values of track plate specimens at different temperatures using a pendulum apparatus. Select a range of 126mm × 80mm between the rutting plate specimens of four types of asphalt mixtures for marking, ensuring that each rutting plate specimen undergoes pendulum testing at the same position at each temperature. Select temperatures of 10 ℃, 20 ℃, 30 ℃, 40 ℃, and 50 ℃ respectively. Before conducting the pendulum test, place the four types of asphalt mixture specimens and the slider on the pendulum instrument into a constant temperature chamber for 1 hour of insulation. Within 1-2 minutes, measure the surface BPN of the corresponding specimens using the pendulum instrument.

2.2 Humidity Control Methods

This paper tests the BPN values of track board specimens under different humidity levels using a pendulum apparatus. Select a standard temperature of 20 ℃ and a humidity range of 40RH to 100RH. For every 10RH increase in humidity, measure the BPN of four types of asphalt mixtures at this humidity using a pendulum. Before conducting the pendulum measurement, mark a range of 126mm × 80mm on each rut plate specimen to ensure that each measurement is at the same position. At the beginning of the test, place the formed rut plate specimens and the slider on the pendulum instrument into a programmable constant temperature and humidity insulation box for 1 hour of moisture retention. Then, measure the corresponding BPN of the specimens using the pendulum instrument for 1-2 minutes，as shown in Figure 1.

Figure 1. Programmable Constant Temperature and Humidity Insulation Box

2.3 Temperature and Humidity Coupling Control Method

This paper takes different humidity as variables and uses a pendulum instrument to test the BPN values of the corresponding temperature and humidity pavement specimens under constant temperature control. The relationship between the temperature and humidity composite environment and the BPN values of asphalt pavement is explored. This article selects temperatures of 40 ℃ and 50 ℃, and humidity of 70RH, 80RH, 90RH, and 100RH. Before the swing test, place the specimens and the slider on the swing tester into a programmable constant temperature and humidity chamber for 1 hour of insulation and moisture retention. Within 1-2 minutes, use the swing tester to test the BPN of the specimens at the corresponding temperature and humidity.

3. Experimental Results and Analysis

3.1 Effect of Temperature on the Anti-Skid Performance

As shown in the results of Figure 2, it was found that as the surface temperature of the specimen increased, the BPN of the asphalt pavement showed a downward trend. Excessive temperature caused a significant decrease in the anti-skid performance of the asphalt pavement, indicating that temperature has a significant impact on the anti-skid performance of the asphalt pavement. The BPN of the four types of asphalt mixtures showed an inverse proportional relationship with temperature, and the downward trend was basically the same. The temperature dependent curve of BPN for four types of asphalt mixtures can be divided into two stages. In the initial stage, it shows an approximately linear downward trend, and in the later stage, it gradually tends to be flat and approximately straight. When the temperature rises from 10 ℃ to 50 ℃, the BPN of the four types of asphalt mixtures in the initial stage shows SSAM-13>SMA-13>AC-16>AC-13; When the temperature rises from 10 ℃ to 40 ℃, the BPN of AC-13 decreases by 8.89%, 10.98%, and 12.23%, respectively, while the BPN of AC-16 decreases by 9.42%, 13.29%, and 8.0%, respectively; The decrease in BPN of SMA-13 was 7.24%, 11%, and 11.88%, respectively, while the decrease in BPN of SSAM-13 was 8.22%, 10.44%, and 11.67%, respectively. When the temperature rises from 40 ℃ to 50 ℃, the BPN values of AC-13, AC-16, SMA-13, and SSAM-13 decrease by 6.97%, 4.3%, 2%, and 5.6%, respectively.

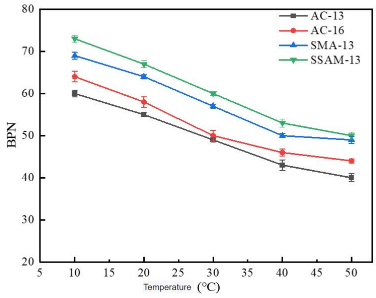
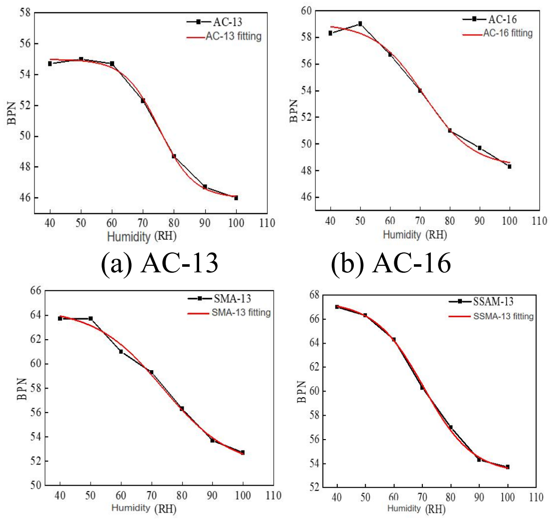


Figure 2. Changes in BPN Values at Different Temperatures

3.2 The Influence of Humidity on the Anti-Skid Performance of Asphalt Pavement

As shown in the results of Figure 3, it is found that as the humidity increases from 40RH to 60RH, the BPN value of asphalt pavement gradually decreases, and the decrease is relatively low, indicating that low humidity has little effect on the anti-skid performance of asphalt pavement; When the humidity is higher than 60RH, the deceleration rate and magnitude of BPN decrease on asphalt pavement suddenly increase, and the anti-skid performance of asphalt pavement deteriorates faster; When the humidity is greater than 90RH, the rate of decrease in BPN value of asphalt pavement decreases, and the BPN value gradually becomes flat, indicating that the anti-skid performance of asphalt pavement no longer deteriorates. When the humidity is between 40RH-60RH, the BPN values of the four types of asphalt mixtures decay within 3%; When the humidity is between 60RH-90RH, the BPN values of AC-13, AC-16, SMA-13, and SSAM-13 sharply decrease by 11.45%, 15%, 15.70%, and 14.93%, respectively; When the humidity exceeds 90RH, the BPN values of all four types of asphalt mixtures decrease by less than 2%.



(a) AC-13 (b) AC-16

(c) SMA-13 (d) SSAM-13

Figure 3. Changes in BPN Values under Different Humidity Conditions

3.3 The influence of Different Water Accumulation Levels on Anti-Skid Performance

After the above experimental process, the BPN were measured under different temperature and humidity conditions, as shown in Figures 4 and 5. When the temperature is 40 ℃ and the humidity increases from 70RH to 100RH, the BPN are lower compared to the BPN values at

40 ℃ mentioned earlier; compared with the previous study, the BPN slightly increased and the rate of decrease increased within the same humidity growth range. When the temperature is 40 ℃ and the humidity increases from 70RH to 100RH, the surface BPN of all four types of asphalt mixtures shows a downward trend. The BPN decrease by 11.94%, 11.72%, 8.5%, and 7.2%, respectively. When the temperature is 50 ℃ and the humidity changes from 70RH to 100RH, the BPN decrease by 22%, 19.8%, 21.2%, and 20.8%, respectively. When the temperature is at 40 ℃ or 50 ℃ and the humidity is between 70-80RH, the BPN decrease between 1-2%; When the humidity is between 90-100RH, the BPN values of AC-13 and AC-16 decrease by about 8%, while the BPN of SMA-13 and SSAM-13 decrease by between 3% and 4%. When the temperature is 50 ℃, the humidity increases from 70RH to 100RH. At the same humidity of 40 ℃, the BPN of asphalt mixtures decrease to varying degrees. When the humidity is between 70-80RH, the BPN of asphalt mixtures decrease by 3% to 5%. When the humidity is between 90-100RH, the BPN values of asphalt mixtures decrease by 12% to 15%. It can be found that in the same high humidity environment, temperature will significantly increase the decrease in BPN values of asphalt mixtures, indicating that in the same high humidity environment, temperature has a greater impact.

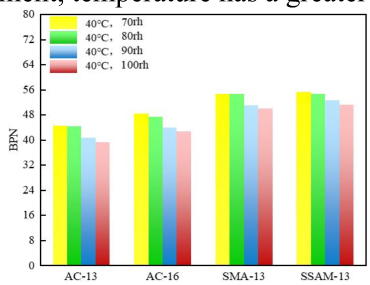


Figure 4. BPN Values in Different Humidity Environments at 40 ℃

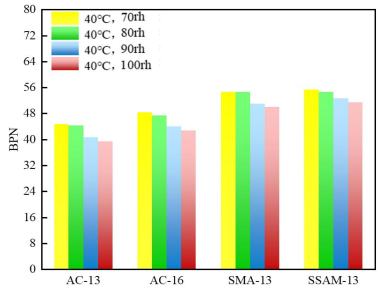


Figure 5. BPN Values in Different Humidity Environments at 50 ℃

When the specimen is subjected to extreme conditions of high temperature and high humidity, the decrease in BPN value of the asphalt mixture specimen is significantly greater than that under the single factor of temperature or humidity. When the asphalt mixture specimens are at the same temperature and the humidity is not greater than 80RH, the influence of humidity on the BPN values of the four types of asphalt mixtures is relatively small; When the humidity is greater than 90RH, the humidity has a significant impact on the BPN values of the four types of asphalt mixtures, and the rate of BPN value decrease increases. When the humidity is between 90RH-100RH, the decrease in BPN value of asphalt mixture caused by temperature increase is greater than that caused by humidity increase. Due to the insufficient amount of liquefied water on the asphalt pavement, it plays a lubricating role between the swing and asphalt pavement, and the macroscopic structure is not completely covered by water. Therefore, continuing to operate in a high humidity environment will cause the BPN of the specimen to continue to decrease. In high temperature and high humidity environments, two environmental factors do not have a positive impact on the anti-skid performance of asphalt pavement, and temperature leads to a higher degree of BPN value attenuation in asphalt pavement. Under high temperature conditions, asphalt pavement will soften and its skid resistance will actually be worse.

4. Conclusion

This article studies the changing trends of BPN values of four types of asphalt mixtures under temperature, humidity, and high temperature and high humidity composite environmental factors, revealing the mechanism and changing rules of the anti-skid performance of asphalt pavement affected by the above environmental factors, and fitting the asphalt pavement with environmental factors. The following conclusions are drawn:

(1) Temperature has a direct impact on the anti-skid performance of asphalt pavement, and as the temperature increases, the anti-skid performance of the four types of asphalt mixtures shows a decreasing trend. When the temperature rises from 10 ℃ to 50 ℃, the BPN of AC-13, AC-16, SMA-13, and SSAM-13 decreases by 33.3%, 31.3%, 28.7%, and 31.5%, respectively.

(2) Humidity has a negative impact on the anti-skid performance of asphalt pavement. As humidity increases, the anti-skid performance shows a small initial decrease, followed by an increase in the decrease, and finally the decrease rate slows down and gradually stabilizes. SMA-13 and SSAM-13 have stronger ability to resist anti-skid performance changes compared to AC-13 and AC-16.

(3) In a high-temperature and high humidity composite environment, all four types of asphalt mixtures show a slow decrease in their anti-skid performance in the early stage. As the humidity increases, the rate of anti-skid performance decline does not show a slowing trend. Due to the insufficient amount of liquefied water in asphalt pavement, there is still a trend of further decline. Compared to the high-temperature and high humidity composite environment, both SMA-13 and SSAM-13 have a smaller degree and slower decay rate of anti-skid performance compared to AC type asphalt mixtures in a single environment. There is not much difference in the degree and speed of anti-skid performance decay between SMA-13 and SSAM-13.

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