Impact of various warm mixing agent on the characteristics of asphalt rubber

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ABSTRACT

Rubber modified asphalt enables the reuse of waste materials and promotes environmental protection, while effectively enhancing the road performance of materials. However, it also presents challenges in terms of high energy consumption and pollution. Warm mixing agent offers a viable solution to address these issues by significantly improving various aspects of rubber asphalt. In this study, three warm mixing agents with distinct action mechanisms were selected to investigate their effects on the properties of 30% rubber modified asphalt. The warm mixing agent exhibits minimal impact on the structural integrity of rubberized asphalt, maintaining its performance stability. The warm mixing agent exhibits a beneficial effect on the alteration of rubberized asphalt elongation post-aging, with EC120 displaying the most pronounced propensity to retard asphalt aging. However, the viscosity of rubber asphalt fortified with EC120 warm mixing agent demonstrated a rapid increase when exposed to high temperatures.

Keywords: Rubber asphalt, warm mixing agent, penetration, softening point, ductility, viscosity

1. INTRODUCTION

The construction of highway infrastructure involves significant investment in materials and energy consumption, as well as extensive disturbance to the ecological environment. This makes it an important area for green and low-carbon transformation within the transportation industry[1-4]. Asphalt rubber and its mixture not only facilitate the reuse of waste materials and environmental protection, but also effectively enhance material road performance, offering substantial economic and social value[5-7]. However, the production and construction processes are carried out in high-temperature environments, resulting in considerable energy consumption and emissions of toxic gases and greenhouse gases. Moreover, higher temperatures can lead to the deterioration of rubber asphalt, affecting its service life. Additionally, asphalt rubber mixture construction is more susceptible to insufficient compaction issues that affect pavement construction quality and durability[8-12].

Today, with the increasing focus on energy conservation and environmental protection, warm mixing technology has the potential to reduce the temperature of rubber asphalt mixture throughout production and construction. This allows for good workability at lower paving and compaction temperatures[13-17]. Warm mix asphalt mixture is expected to be the future direction of mixture technology. In this study, three types of warm mixing agents were added to asphalt rubber containing 30% rubber powder, and the changes in various performance indicators of asphalt were analyzed and compared.

2. EXPERIMENTAL MATERIALS AND METHODS

2.1 EXPERIMENTAL MATERIALS

The asphalt used is asphalt rubber with rubber powder content of 30%, and the main technical indexes are shown in Table 1.

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Table 1. Technical indicators of asphalt rubber.

Test	Values	Experimental method
Penetration (100 g, 5 s, 25℃)/0.1 mm	54	ASTM D5
Softening Point (R&B)/℃	72.5	ASTM D36
Ductility (15℃, 5 cm/min), cm	15.9	ASTM D113
Flexible recovery (%)	87.5	
Viscosity (180℃)/Pa·s	3.1	

There are three kinds of warm mixing agents selected. The code names are EW04, 1208 and EC120 respectively. The addition amount is 3% of the asphalt mass.

2.2 Test method asphalt performance experiment

Asphalt three indexes and viscosity of four kinds of asphalt were tested respectively, and the indexes after aging were studied to study the effects of various warm-mix agents on asphalt properties.

3. ANALYSIS OF INFLUENCE OF WARM MIXING AGENT ON ASPHALT PERFORMANCE

Preparation of warm-mixed asphalt: The warm mixing agent is directly incorporated into the pre-prepared rubber asphalt by heating the asphalt to approximately 160°C. Subsequently, the warm mixing agent is added in accordance with the optimal dosage and subjected to mechanical stirring for a duration of 10-20 minutes, resulting in a uniform and stable system.

3.1 Comparison of penetration before and after adding warm mixing agent

The variation in the penetration index of rubber asphalt before and after the addition of a warm mixing agent is depicted in Figure 1. The data presented in the figure indicates that the penetration of warm-mixed modified rubber asphalt experiences an improvement subsequent to the introduction of the warm mixing agent into the rubber asphalt, with the most notable change observed in the rubber asphalt supplemented with the 1208 warm mixing agent. This alteration is attributed to the capacity of the warm mixing agent to marginally enhance the internal structure of the rubber asphalt, thereby rendering it more pliable. Concurrently, it is evident from the figure that the penetration of the rubber asphalt exhibits a modest increase following the modification with the warm mixing agent, with the maximum increment being merely 5 units. This suggests that the softening effect elicited by the warm mixing agent is relatively subdued, consequently exerting an insignificant impact on the structural integrity of the rubber asphalt and preserving its overall performance stability.

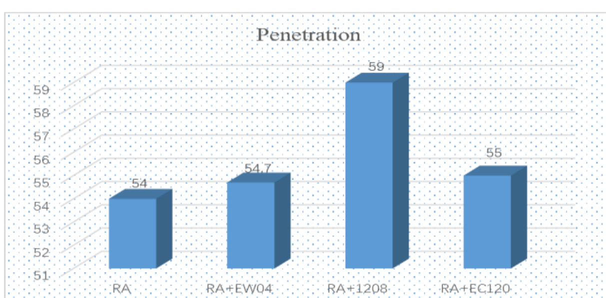

Figure 1. Influence of different warm mixing agents on the penetration of rubber-modified asphalt.

Figure 2 illustrates a comparative analysis of the penetration rates of asphalt before and after aging. The data indicates that the penetration of asphalt decreases to varying degrees post-aging. Notably, the penetration of rubber asphalt containing the EW04 warm mixing agent experienced the most significant reduction, with a post-aging penetration ratio of only 59%. This is followed by the rubber asphalt with the 1208 warm mixing agent, which exhibited a penetration ratio of 73% after aging. Both values are notably lower than the 85% penetration ratio of the control sample without any warm mixing agent. These observations suggest that both EW04 and 1208 have a detrimental impact on the penetration ratio of asphalt, leading to a pronounced change and subsequent hardening of the asphalt. Conversely, the penetration of rubber asphalt with the EC120 warm mixing agent showed the least decline, maintaining a penetration ratio of 87% after aging. This outcome implies that the addition of EC120 helps stabilize the components of rubber asphalt and can effectively postpone its aging process.

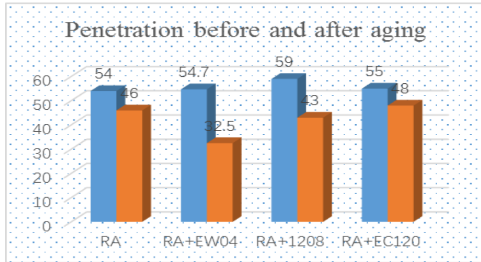

Figure 2. Impact of different warm mixing agents on the penetration of rubber asphalt before and after aging.

3.2 Comparison of the softening point before and after adding a warm mixing agent

The variation in the softening point of rubber asphalt before and after the addition of a warm mixing agent is depicted in Figure 3. Observations from the figure reveal that upon the addition of EW04 and 1208 warm mixing agents to rubber asphalt, there was a minor reduction in the softening point of the warm mix-modified rubber asphalt. Conversely, when the EC120 warm mixing agent was introduced to rubber asphalt, the softening point of the warm mix rubber asphalt ascended to 85℃, indicating a substantial enhancement. This suggests that EC120 has the potential to fortify the internal structure of rubber asphalt, enabling it to preserve an optimal asphalt space structure at elevated temperatures and consequently augment its softening point.

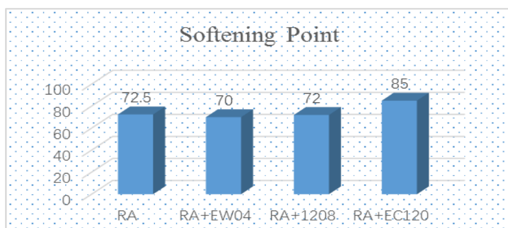

Figure 3. Influence of different warm mixing agents on the softening point of rubber-modified asphalt.

3.3 Comparison of the ductility before and after adding a warm mixing agent

The alteration in the ductility of rubber asphalt subsequent to the addition of a warm mixing agent is depicted in Figure 4. Evident from the figure, the incorporation of the warm mixing agent leads to a varied reduction in the ductility of the rubber asphalt. This indicates that the warm mixing agent exerts a moderate detrimental effect on the low temperature anti-cracking performance of the rubber asphalt; however, the diminution in ductility is marginal, and its impact on the overall performance of the rubber asphalt is relatively inconspicuous.

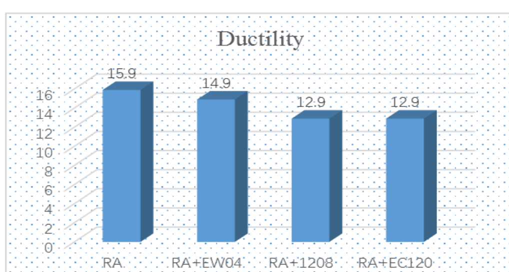

Figure 4. Influence of different warm mixing agents on the ductility t of rubber-modified asphalt.

Figure 5 illustrates the alteration in ductility experienced by the asphalt prior to and subsequent to aging. Observations from the figure indicate a varying degree of reduction in the ductility of aged asphalt. The rubber asphalt, when devoid of a warm mixing agent, exhibited the most significant decline in ductility. Conversely, the rubber asphalt incorporated with EW04 and 1208 demonstrated a comparable decrease, whereas the rubber asphalt combined with EC120 displayed the least reduction. This outcome suggests that the utilization of the EC120 warm mixing agent can protract the aging process of asphalt, a finding that aligns with the penetration analysis outcomes presented in the preceding paper.

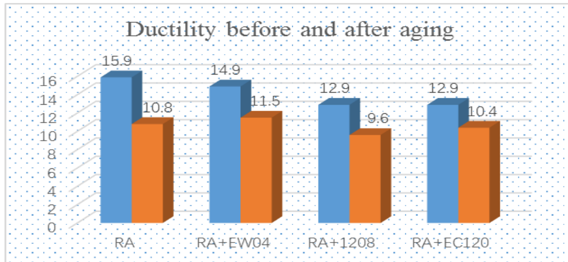

Figure 5. Influence of different warm mixing agents on the ductility of rubber asphalt before and after aging.

3.4 Comparison of viscosity before and after adding warm mixing agent

The alteration in the kinematic viscosity index of rubber asphalt at 180°C, before and subsequent to the introduction of a warm mixing agent, is illustrated in Figure 6. The graph indicates that, in contrast to the rubber asphalt devoid of any warm mixing agent, the viscosity of the asphalt containing EW04 as a warm mixing agent exhibited minimal variation. Conversely, the viscosity of the asphalt incorporated with the 1208 warm mixing agent experienced a reduction of 20%, and the viscosity of the asphalt with EC120 diminished by 50%. This discrepancy can be attributed to the distinct mechanisms of action among the warm mixing agents: EW04 and 1208 function as surface active agents, whereas EC120 is specifically designed for viscosity reduction. Consequently, the viscosity of the rubber asphalt supplemented with EC120 has noticeably decreased. By replicating the temperature conditions under which rubber asphalt is typically stored and transported at 163°C, an analysis was conducted on the viscosity changes of the rubber asphalt after durations of 24 hours and 48 hours. As observed in Figure 6, the viscosity of rubber asphalt without a warm mixing agent remained largely unchanged after 48 hours. In contrast, the viscosity of rubber asphalt with the EW04 warm mixing agent decreased after 24 hours and then slightly increased after 48 hours. The viscosity of rubber asphalt with the 1208 warm mixing agent showed no significant change after 24 hours but experienced a slight increase after 48 hours. Notably, the viscosity of rubber asphalt with the EC120 warm mixing agent rose slightly after 24 hours and markedly increased after 48 hours. This behavior indicates that the addition of surface active warm mixing agents to rubber asphalt results in minimal changes in viscosity and maintains relative stability under high-temperature conditions. However, when a viscosity-reducing agent is added, its effectiveness diminishes rapidly under elevated temperatures, leading to a loss of the viscosity-reducing benefits. Consequently, rubber asphalt containing viscosity-reducing warm mixing agents should be utilized promptly and not stored for extended periods.

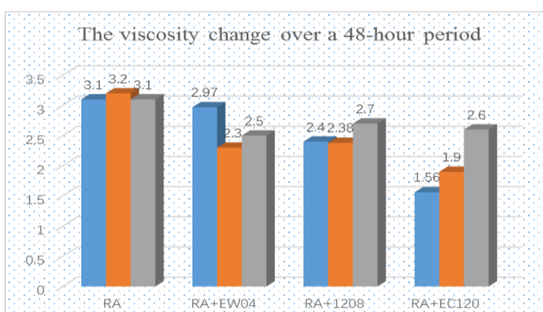

Figure 6. Influence of different warm mixing agents on the viscosity t of rubber-modified asphalt.

4. CONCLUSION

(1) The warm mixing agent exhibits minimal impact on the structural integrity of rubberized asphalt, maintaining its performance stability. Notably, EW04 and 1208 exert detrimental influences on asphalt aging, whereas EC120 contributes positively to the aging process of rubberized asphalt.

(2) When EW04 and 1208 warm mixing agents were incorporated into rubber asphalt, the softening point of the resulting warm mix modified rubber asphalt decreased. Conversely, upon addition of the EC120 warm mixing agent to rubber asphalt, there was a notable increase in the softening point of the warm mix rubber asphalt.

(3) The warm mixing agent exerts a detrimental influence on the low temperature anti-cracking performance of rubberized asphalt; however, the diminution in ductility is marginal, and its impact on the overall performance of rubberized asphalt remains subdued. Conversely, the warm mixing agent exhibits a beneficial effect on the alteration of rubberized asphalt elongation post-aging, with EC120 displaying the most pronounced propensity to retard asphalt aging.

(4) Upon the addition of EW04 and 1208, the viscosity of rubber asphalt exhibited minimal change and remained relatively stable under elevated temperature conditions. Conversely, the viscosity of rubber asphalt fortified with EC120 warm mixing agent demonstrated a rapid increase when exposed to high temperatures. Consequently, the interval between the preparation and application of rubber asphalt containing EC120 warm mixing agent should be minimized to prevent excessive viscosity build-up.

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