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# WATER DAMAGE RESISTANCE OF LOW-TEMPERATURE MODIFIED ASPHALT MIXTURE

XiaoPeng Tong
*Ezhou Highway Development Center, Ezhou 436000, Hubei, China.*

**Abstract:** This paper analyzes the influence law of water damage on the strength and stability of low-temperature modified asphalt mixture, and discusses the action mechanism of raw material characteristics, mix proportion design, construction technology and environmental factors on water stability. The research shows that the water damage of low-temperature modified asphalt mixture is mainly caused by asphalt film peeling, aggregate softening and internal structure damage due to water intrusion; the addition of modified components such as rubber powder and polymer resin can significantly improve the water damage resistance of the mixture; optimizing the asphalt-aggregate ratio, improving the aggregate gradation and adopting reasonable construction temperature control measures can effectively reduce the risk of water damage.
**Keywords:** Low-temperature modified asphalt mixture; Water damage resistance; Anti-stripping; Prevention and control measures; Water stability

## 1 INTRODUCTION

With the advancement of the "carbon peak and carbon neutrality" strategy, the demand for energy-saving and environmentally friendly materials in the road construction field has become increasingly urgent. As a new type of road material, low-temperature modified asphalt mixture reduces the production and construction temperature by more than 35℃ through physical and chemical composite modification technology, which significantly reduces energy consumption and carbon emissions, and the emission of harmful gases such as asphalt fume is close to zero, showing outstanding advantages in energy conservation and emission reduction. Its excellent high-temperature stability, low-temperature crack resistance and construction adaptability have made it widely used in special scenarios such as cold regions and urban central areas [1]. However, in humid and rainy areas or road sections with high groundwater levels, the pavement of low-temperature modified asphalt mixture is prone to water damage diseases such as water seepage, peeling, raveling and potholes, which seriously affect the service life of the pavement and driving safety [2]. The traditional water damage prevention and control technology for hot mix asphalt mixture can no longer be fully applied to the low-temperature modified system, and its unique modification mechanism and construction characteristics make the water damage problem present new laws and characteristics [3]. Therefore, the systematic study on the water damage resistance and prevention measures of low-temperature modified asphalt mixture has important theoretical and engineering significance for promoting the sustainable application of this technology.

## 2 MECHANISM OF WATER DAMAGE IN LOW-TEMPERATURE MODIFIED ASPHALT MIXTURE

### 2.1 Essence of Water Damage

The water damage of low-temperature modified asphalt mixture is a physical and chemical process in which the internal structure of the mixture is damaged under the combined action of traffic load and temperature change after water intrusion. Its essence is that water damages the adhesion between asphalt and aggregate, leading to the peeling of asphalt film from the aggregate surface. At the same time, water generates freeze-thaw cycles, osmotic pressure and other effects inside the mixture, which aggravate the generation and expansion of internal cracks, and ultimately lead to the loss of strength and stability of the mixture [4].
Compared with traditional hot mix asphalt mixture, the water damage of low-temperature modified asphalt mixture has particularities: first, low-temperature construction reduces the thermal aging of asphalt, retains the flexibility and adhesion of asphalt, which is conducive to improving the potential of water damage resistance; second, the fluidity of asphalt film decreases at low temperatures, and insufficient compaction during construction is prone to form connected pores, providing channels for water intrusion [5].

### 2.2 Main Forms of Water Damage

The main forms of water damage of low-temperature modified asphalt mixture include asphalt film peeling, aggregate softening and deterioration, freeze-thaw damage, and pore water pressure damage.

### 2.3 Influence Mechanism of Water Damage

The destructive effect of water on low-temperature modified asphalt mixture is mainly realized through physical and chemical mechanisms:

On the one hand, in terms of the physical mechanism, the infiltration of water increases the internal humidity of the mixture, reduces the viscosity and adhesion of asphalt. At the same time, the flow of water in the pores will erode the aggregate surface and damage the integrity of the asphalt film. Under the action of temperature change and load, the phase change and dynamic water pressure of water will further aggravate structural damage [6].

On the other hand, in terms of the chemical mechanism, water will react with the polar components in asphalt, leading to the deterioration of asphalt performance; for mixtures containing mineral powder, water will dissolve some components in mineral powder, reducing the filling and stabilizing effect of mineral powder. In addition, harmful substances in water will accelerate the aging of asphalt and the corrosion of aggregate, indirectly reducing the water damage resistance of the mixture [7].

## 3 FACTORS INFLUENCING WATER DAMAGE RESISTANCE OF LOW-TEMPERATURE MODIFIED ASPHALT MIXTURE

### 3.1 Influence of Raw Material Characteristics

#### *3.1.1 Type and content of asphalt modifier*

The type and content of modifier directly affect the adhesion, flexibility and anti-aging performance of low-temperature modified asphalt, and thus determine the water stability of the mixture. Low-temperature modified asphalt adopts composite modified components such as rubber, polymer resin and surfactant. Among them, the elasticity of rubber powder and the cohesiveness of polymer resin can significantly improve the adhesion between asphalt and aggregate, and reduce the peeling caused by water intrusion. Test data show that the freeze-thaw splitting residual strength ratio of composite rubber modified asphalt mixture reaches 86.7%, which is significantly higher than 79.3% of ordinary hot mix asphalt mixture.

Different modifiers have different effects on improving water stability: SBS modifier mainly improves the high-temperature stability and flexibility of the mixture, but has a limited effect on improving water damage resistance; rubber modifier enhances the bonding between asphalt film and aggregate through the "bridging" effect of elastic particles, and the hydrophobic property of rubber particles can reduce water adsorption, resulting in a better water damage resistance effect [8]. In addition, the content of modifier should be controlled within a reasonable range; excessive addition may lead to a decrease in the compatibility between asphalt and aggregate, which instead reduces water stability.

#### *3.1.2 Aggregate characteristics*

The properties of aggregate are the key factors affecting the water stability of the mixture, mainly including the mineral composition, surface characteristics, particle shape and cleanliness of aggregate.

The mineral composition of aggregate determines its hydrophilicity: alkaline aggregates such as limestone are rich in calcium ions on the surface, which can chemically react with the acidic components in asphalt to form stable chemical bonds, with strong adhesion and excellent water stripping resistance; acidic aggregates such as granite have strong hydrophilicity on the surface, weak adhesion with asphalt, and are prone to water damage [9]. Low-temperature modified asphalt can improve the adhesion performance between acidic aggregate and asphalt by adding anti-stripping agent, so that the immersion Marshall residual stability of the mixture is increased to more than 90%.

The surface characteristics and particle shape of aggregate also affect water stability: aggregate with rough surface and multi-edge can form a mechanical interlocking effect with asphalt, enhance the bonding force and reduce water intrusion; while aggregate with smooth surface and round shape has poor bonding effect. In addition, impurities such as dust and soil on the aggregate surface will reduce the adhesion between asphalt and aggregate, which need to be thoroughly cleaned before construction.

#### *3.1.3 Mineral powder performance*

As a filler of asphalt mixture, the hydrophilicity, specific surface area and chemical activity of mineral powder have an important impact on water stability. Alkaline mineral powder such as limestone mineral powder can adsorb with asphalt to form a stable asphalt mastic, improving the water damage resistance of the mixture, while acidic mineral powder or mineral powder containing impurities will reduce the stability of asphalt mastic and accelerate water damage.

Excessively large or small specific surface area of mineral powder is not conducive to water stability: an excessively large specific surface area will cause the mineral powder to adsorb a large amount of asphalt, resulting in insufficient effective bonding asphalt; an excessively small specific surface area will lead to poor filling effect and increased porosity of the mixture. Tests show that when low-temperature modified asphalt mixture uses ground limestone mineral powder and the content of mineral powder is controlled at 3%~5%, the water stability is the best.

### 3.2 Influence of Mix Proportion Design

#### *3.2.1 Asphalt-aggregate ratio*

The asphalt-aggregate ratio is the core parameter affecting the water stability of the mixture. When the asphalt-aggregate ratio is too low, the asphalt cannot completely cover the aggregate surface, forming a discontinuous asphalt film, and water is easy to intrude from the voids, leading to asphalt film peeling; when the asphalt-aggregate ratio is too high, free asphalt will be generated inside the mixture, which is prone to bleeding under the action of water and temperature. At the same time, excessive asphalt will reduce the internal friction angle of the mixture and affect structural stability. Taking AC-20 as an example, when the asphalt-aggregate ratio of low-temperature modified asphalt mixture is 4.2%, the immersion Marshall residual stability reaches 93.6% and the freeze-thaw splitting residual strength ratio is 83%, showing excellent water stability [10]. This is because low-temperature modified asphalt retains light components with better dispersibility, and a small amount of asphalt can form a complete asphalt film while reducing the presence of free asphalt.

***3.2.2 Aggregate gradation***

Aggregate gradation determines the pore structure of the mixture, and thus affects the intrusion and discharge of water. A good gradation should make the mixture form a dense skeleton-dense structure, which not only ensures sufficient compactness and reduces connected pores, but also provides an appropriate amount of closed pores to alleviate the damage of freeze-thaw cycles. Research shows that when the porosity of the mixture exceeds 6%, water is easy to intrude and stay, and the risk of water damage increases significantly; when the porosity is lower than 3%, the air permeability of the mixture is poor, and the internal water is difficult to discharge, which also aggravates water damage. In addition, the continuity of the gradation curve is also important; gap-graded mixture is prone to local pore concentration, providing channels for water intrusion.

***3.2.3 Coordination of modifiers and additives***

In low-temperature modified asphalt mixture, the reasonable coordination of modifiers has a significant impact on water stability. The addition of anti-stripping agent can improve the adhesion performance between asphalt and aggregate. Especially in acidic aggregate, adding an appropriate amount of amine or amide anti-stripping agent can improve the water stripping resistance of the mixture by more than 30%.

The type of modifier also affects water stability: warm mix agent based on surfactant may increase the hydrophilicity of asphalt, which will reduce water stability if used improperly; the composite additive system adopted by low-temperature modified asphalt realizes the coordinated improvement of energy conservation and emission reduction and water stability.

### 3.3 Influence of Construction Technology

***3.3.1 Temperature control***

The construction temperature control of low-temperature modified asphalt mixture directly affects its compaction quality and pore structure, and thus affects water stability. When the construction temperature is too low, the fluidity of asphalt is poor, the mixture is not easy to compact, and it is easy to form a high-porosity structure, which facilitates water intrusion; when the construction temperature is too high, it will lead to thermal aging of asphalt, reduce the adhesion and flexibility of asphalt, and is also not conducive to water damage resistance. The construction temperature of low-temperature modified asphalt mixture must strictly follow the technical specifications. Tests show that when the paving temperature is 10℃ lower than the design requirement, the compaction degree of the mixture decreases by 3%5%, the porosity increases by 2%3%, and the water stability decreases significantly.

***3.3.2 Compaction quality***

Compaction is a key process to ensure the compactness of the mixture. Insufficient compaction will lead to excessive porosity of the mixture and form connected pores, making water easy to intrude; over-compaction will damage the particle shape of the aggregate, lead to damage to the internal structure of the mixture, and also affect water stability.

***3.3.3 Joint treatment***

Pavement joints are high-incidence areas of water damage. Improper joint treatment will form gaps, which become channels for water intrusion. In addition, the construction quality of tack coat and prime coat also affects water stability. The tack coat should use modified emulsified asphalt compatible with low-temperature modified asphalt, the spraying amount should be controlled at 0.30.5L/m² to ensure uniform spraying; the prime coat should penetrate 510mm into the base course to form an effective bonding layer and prevent water accumulation between the surface course and the base course.

### 3.4 Influence of Environmental Factors

***3.4.1 Climatic conditions***

The influence of climatic conditions on the water damage of low-temperature modified asphalt mixture is mainly reflected in rainfall, temperature change and the number of freeze-thaw cycles. The greater the rainfall and the longer the rainfall duration, the greater the depth and range of water intrusion into the mixture, and the more serious the water damage; in areas with severe temperature changes, the thermal stress inside the mixture will aggravate the generation of cracks, providing convenience for water intrusion; the more the number of freeze-thaw cycles, the more significant the destructive effect of water on the mixture.

In alpine and high-altitude areas, although low-temperature modified asphalt mixture has good low-temperature crack resistance, the long-term effect of freeze-thaw cycles will still lead to a decrease in water stability. Tests show that after 5 freeze-thaw cycles, the freeze-thaw splitting residual strength ratio of low-temperature modified asphalt mixture decreases by 10%15%, while that of traditional hot mix asphalt mixture decreases by 20%25%.

***3.4.2 Hydrological conditions***

Hydrological conditions such as groundwater level and groundwater quality also affect the degree of water damage. For road sections with complex hydrological conditions, effective drainage measures should be taken, such as setting drainage base course and edge drainage system, to discharge the water in the pavement structure layer in time and reduce the water retention time.

## 4 PREVENTION AND CONTROL MEASURES FOR WATER DAMAGE OF LOW-TEMPERATURE MODIFIED ASPHALT MIXTURE

### 4.1 Raw Material Optimization Measures

#### *4.1.1 Selection of high-quality modifiers and asphalt*

Select modifiers with good water damage resistance, and prioritize the use of rubber powder and polymer resin composite modified asphalt, such as low-temperature composite rubber modified asphalt and low-temperature composite SBS modified asphalt. Such asphalt not only has excellent high and low temperature performance, but also can enhance the adhesion between asphalt and aggregate through the synergistic effect of modified components, reducing the peeling caused by water intrusion.

#### *4.1.2 Optimization of aggregate selection and treatment*

Prioritize the use of alkaline aggregates such as limestone and dolomite, which have strong adhesion with asphalt and excellent water stripping resistance. If acidic aggregates such as granite and basalt are used, surface treatment should be carried out, such as brushing anti-stripping agent, lime slurry, etc., or anti-stripping agent should be added to the mixture to improve the adhesion performance between asphalt and aggregate.

#### *4.1.3 Rational selection of mineral powder and additives*

Select ground limestone mineral powder, the specific surface area of mineral powder should be controlled at 300~400m²/kg, and the water content should not exceed 1% to ensure that the mineral powder has a good filling and stabilizing effect. For areas with frequent freeze-thaw cycles, an appropriate amount of fiber stabilizer can be added to the mixture.

### 4.2 Mix Proportion Design Optimization Measures

#### *4.2.1 Determination of optimal asphalt-aggregate ratio*

Determine the optimal asphalt-aggregate ratio through Marshall test to ensure that the asphalt can completely cover the aggregate surface and form a continuous and uniform asphalt film. The determination of the optimal asphalt-aggregate ratio should comprehensively consider water stability indicators, such as immersion Marshall residual stability and freeze-thaw splitting residual strength ratio, to ensure that the water stability of the mixture meets the design requirements.

For humid areas, the asphalt-aggregate ratio can be appropriately increased by 0.1%~0.3% to increase the thickness of the asphalt film and enhance the water stripping resistance, but the asphalt-aggregate ratio should not be too high to avoid bleeding.

#### *4.2.2 Optimization of aggregate gradation*

Adopt skeleton-dense gradation to ensure that the mixture has sufficient compactness and good drainage performance. Adjust the proportion of coarse and fine aggregates to make the gradation curve smooth and continuous, avoiding gap gradation. In the process of mix proportion design, volume index verification should be carried out to ensure that the porosity, voids in mineral aggregate, saturation and other indicators of the mixture meet the specification requirements.

#### *4.2.3 Optimization of modifier and additive content*

To balance the high and low temperature performance and water stability of the mixture, the content of low-temperature modifier should be determined according to the construction temperature requirements, and the water stability of the mixture should not be affected while reducing the construction temperature.

### 4.3 Construction Quality Control Measures

Consistent with hot mix asphalt (HMA), strict construction temperature control, improved compaction quality, strengthened construction quality control of joints, tack coat and prime coat, and improved design and construction of drainage systems should be adopted.

## 5 ENGINEERING CASE ANALYSIS

### 5.1 Project Overview

The municipal road project of Chezhan North Street in Baiyun District, Guangzhou is located in a humid southern area with an annual rainfall of 1200~1500mm and a high groundwater level. This project adopts low-temperature modified asphalt mixture to pave the surface course with a thickness of 4cm. The mixture type is AC-13C, the modifier is rubber powder and SBS composite modification, the aggregate is limestone, and the mineral powder is ground limestone mineral powder.

### 5.2 Test Results of Water Stability

In the mix proportion design stage, the water stability of the mixture was systematically tested, and the results are shown in Table 1.

**Table 1** Test Results of Mixture Water Stability

| Test Item | Technical Requirement | Test Result | Compliance |
|---|---|---|---|
| Immersion Marshall Residual Stability (%) | ≥80 | 91.2 | Compliant |
| Freeze-Thaw Splitting Residual Strength Ratio (%) | ≥75 | 86.7 | Compliant |
| Water Permeability Coefficient (ml/min) | ≤120 | 38 | Compliant |

The test results show that all the water stability indicators of the mixture meet the specification requirements and are significantly higher than those of traditional hot mix asphalt mixture.

### 5.3 Application Effect

The project has been in service for 3 years after completion. After many rainy season tests, the pavement has no obvious water damage diseases, with good flatness and skid resistance. The immersion Marshall residual stability of the mixture remains above 88%, and the freeze-thaw splitting residual strength ratio remains above 83%, showing excellent water stability.

## 6 CONCLUSIONS

The essence of water damage of low-temperature modified asphalt mixture is that water intrusion damages the asphalt-aggregate adhesion, leading to the damage of the internal structure of the mixture, which is mainly manifested in four forms: asphalt film peeling, aggregate softening, freeze-thaw damage and pore water pressure damage.

Raw material characteristics, mix proportion design, construction technology and environmental factors all have an important impact on the water stability of low-temperature modified asphalt mixture. Among them, the type and content of modifier, aggregate characteristics, asphalt-aggregate ratio, compaction quality and drainage system design are the key influencing factors.

The water damage of low-temperature modified asphalt mixture can be effectively improved by selecting high-quality raw materials, optimizing mix proportion parameters, strictly controlling the construction process and establishing a normalized maintenance mechanism.

After adopting the prevention and control measures proposed in this paper in the case, the water stability indicators of the low-temperature modified asphalt mixture meet the specification requirements, and no obvious water damage diseases occur during service, showing a good application effect.

## COMPETINGINTERESTS

The authors have no relevant financial or non-financial interests to disclose.

## REFERENCES

[1] Luo B, Peng W B. Research on the application of low-temperature environmental protection modified asphalt in urban roads. Shanxi Architecture, 2022, 48(12): 93-95.

[2] Zhong W M, Wang Y, Liu P. Study on the influence of different viscosity reducers on the performance of modified asphalt and its mixture. Western Traffic Science & Technology, 2022(4): 66-69.

[3] Wei D, Zhao F, Wu H, et al. Study on road performance of warm mix rubber composite modified asphalt mixture. Technology and Economy of Changjiang Communications, 2017, 19(4): 54-58.

[4] Huang X M, Zhao Y L. Mechanism and Prevention Technology of Asphalt Pavement Water Damage. Beijing: China Communications Press, 2019.

[5] Li H B, Sun L J. Analysis of factors influencing water stability of warm mix asphalt mixture. Journal of Highway and Transportation Research and Development, 2020, 37(5): 1-7.

[6] Wu S P, Liu Z F. Study on micro-mechanism of water damage of asphalt mixture. Journal of Wuhan University of Technology, 2019, 41(6): 1-6.

[7] Zhao Y Q, Li M J. Study on evaluation method of water stability of asphalt mixture. Highway, 2021, 66(8): 1-6.

[8] Huang W R, Han C L. Study on water damage resistance of rubber modified asphalt mixture. Highway Transportation Technology, 2020, 36(3): 26-30.

[9] Li L H, Zhang N L. Adhesion between asphalt and aggregate and its evaluation method. Journal of Tongji University (Natural Science Edition), 2019, 47(4): 521-526.

[10] Luo B. Study on mix proportion design of low-temperature environmental protection modified asphalt mixture. Municipal Technology, 2022, 40(5): 174-176.