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ANALYSIS OF THE BITUMEN BINDING MODIFICATION SYSTEM FOR COLD PAINTING MIXTURES (CPMS)

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Abstract
This article analyzes the modification methods used for binders in Cold Patch Mixes (CPMs) to enhance their strength and durability. The study examined the composition and mechanisms of action of traditional polymers such as Styrene-Butadiene-Styrene (SBS) and Styrene-Butadiene Rubber (SBR), as well as new composite modifications, including Microcapsules, Water-Soluble Epoxy Resin (WER), and Hybrid binders. The analysis demonstrates that modification significantly increases resistance to rutting at high temperatures and cracking at low temperatures, thereby extending the service life of CPMs in various weather conditions.

Keywords: Bitumen, modification, cold patch mixtures (CPMs), polymer bitumen, SBS, WER, hybrid binder, viscoelasticity, low temperature.

Introduction

Cold Patch Mixtures (CPMs) play an important role as a quick and effective solution in the repair of defects and potholes that occur on road surfaces. The strength and durability of CPMs largely depend on the quality of the binder used. Therefore, binder modification is the most important practical way to increase the efficiency of CPM. The main goal of modification is to improve the properties of traditional bitumen, i.e., to increase the resistance of the binder to plastic deformation at high temperatures and to maintain the property of flexibility (brittleness) at low temperatures, as well as to increase fatigue resistance. This study analyzes various methods of CPM binder modification, advanced and innovative technologies, their mechanisms, and road surface results.

Types and Technologies of Modified Conjunctions

According to the method of reducing the viscosity of binders, modified binders are divided into two main types:

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Modified molten bitumen (Cutback Bitumen): Bituminous binder with reduced viscosity by adding a solvent and subsequently modified.

Modified bitumen emulsions: This type of binder can be prepared in two ways: by modifying the emulsified asphalt or by emulsifying the modified asphalt.

Mature and most commonly used polymers

Currently, the following are recognized as the most widely used and mature modification technologies:

Styrene-Butadiene-Styrene (SBS) Copolymer and Styrene-Butadiene Rubber (SBR): These polymers are widely used in the modification of natural molten bitumens or bitumen emulsions. They significantly increase the elastic properties of the binder; when SBS is added to bitumen, it swells and forms a continuous three-dimensional polymer network within the bitumen [16]. This network provides resistance to high-temperature stain formation and low-temperature cracking.

Plastomeric Binders (P-Classes): Primarily Ethylene Vinyl Acetate (EVA) polymers. They give the bitumen hardness and increase the softening point, but do not provide as high elasticity as SBS. They are mainly used to improve high-temperature performance.

Rubber Crumb Modified Binder (CRMB)

Crumb-rubber (CRM), usually obtained from old tires

Mechanism: Rubber particles swell in hot bitumen and absorb light bitumen fractions. This increases the volume of bitumen, sharply increases its viscosity, and provides the ability to absorb a high level of internal stress [16].

Difficulty: A large amount of rubber crumbs leads to high viscosity, which requires an increase in the mixing temperature and limits its use.

Analysis of innovative and special composite modifiers

Recent research suggests new modifiers to overcome the shortcomings of traditional CPMs:

Microcapsules and Polymer Strength (New Composite Modifier)

This new modifier combines polymer strengthening and microcapsule techniques.

Advantages: Provides high low-temperature performance and adhesion strength compared to traditional CPMs. It has been confirmed to be suitable for road patch repair, especially in cold and humid weather, with rapid hardening at low temperatures.

Water-soluble epoxy resin (WER) Modification

The use of modified bitumen emulsion WER eliminates such drawbacks as poor adhesion and temperature sensitivity in traditional emulsified asphalt.

Mechanism: Strength and stability arise through physical and chemical interactions between the WER and the asphalt matrix. The hardening reactions of WER resins in the presence of epoxy and hydroxyl groups lead to the formation of a uniformly distributed network of three-dimensional interconnections in the asphalt emulsion.

Results: WER-CPMs demonstrate excellent indicators in terms of high-temperature stain resistance, low-temperature crack resistance, resistance to moisture damage, and adhesion strength.

Modified Discyclopentadiene (DCPD) Resin with Grubbs Catalysts

Properties: Inexpensive material, relatively low viscosity in the initial stage, extremely high strength after hardening. Has a curing profile that can be adjusted using catalysts.

Application: With the help of special catalysts, patches can be used for repair work in all weather conditions.

Magnesium Phosphate Cement (MPC) - Emulsified Asphalt (EA) Composite

Advantages: Improves viscosity, strength, adhesion strength, and conductivity.

Disadvantages: Due to the release of water from emulsified asphalt, a decrease in compressive strength, flexural strength, and wear resistance has been observed.

Fundamental Mechanisms of Modification (Rheological Analysis)

The advantages of modified binders affect not only the temperature, but also the internal structure of the bitumen.

Formation of the polymer network

1-Table

Main Feature	Mechanism	Result
High Temperature Hardness	Increasing the softening point of the binder.	Significantly reduce the risk of rooting.
Low Temperature Flexibility	Polymers form an elastic matrix in bitumen.	Increasing resistance to cracks occurring at cold temperatures.
Elastic recovery	Increasing the ability of the binder to return to its original shape after loading.	Extension of fatigue resistance and coating life.
Adhesion Property	Improvement of bitumen viscosity and binding to the aggregate.	Reduction of separation (stripping) of the aggregate under the influence of water and moisture.

Reological Assessment Using the Black Diagram

The Black Diagram (Phase Angle vs. Complex Module) is an important tool for a complete assessment of the viscoelastic properties of the binder.

PMB Concept: PMBs leave the traditional bitumen field and show high modules at low phase angles (high elasticity). This indicates the presence of an elastomeric network and the preservation of elasticity under load.

Superpave Restrictions: Studies have shown that binders of the same class of PG (e.g., PG 76-28) but chemically differently prepared showed different properties on the Black Diagram. This means that it cannot fully predict the actual performance of the PG class.

Hybrid Modification Technology

Hybrid modification aims to obtain the advantages of both modifiers by combining post-consumption polymers such as traditional polymers (SBS) and used tire rubber (GTR).

Objective: to achieve high efficiency by combining the elasticity of breast cancer with the high volume and low cost of GTR.

Stability: Terminal blended hybrid binders must maintain stability for a long time without aggregation and separation during storage (e.g., up to 21 days).

Practical advantage: Due to its low viscosity, it can be easily pumped and used in asphalt concrete plants.

Modification Problems in Cold Climate (Swedish Experience)

In countries with a cold climate, special requirements are established for PMB, such as not only the PG class, but also high elastic recovery (70-90% of examples) and resistance to de-icing chemicals.

Dual Wax Additive Effect (WMA)

Benefits: Wax additives In warm mixed asphalt (WMA) technology, Polymer Modified Bitumen (PMB) reduces mixing and compaction temperatures by reducing its viscosity at high temperatures. This serves to save energy.

Negative effects: Adding wax can negatively affect the binder's resistance to low-temperature cracking. Wax crystallizes in the cold and increases the brittleness temperature of the binder (the temperature limit LmT deteriorates).

2-Table

Feature (PMB 32)	Regular PMB 32	PMB 32 + 6% Wax
LST (Low Temperature Limit)	-20°C	deteriorated to -17°C
LmT (M-value Low Temperature Threshold)	-20°C	deteriorated to -12°C

Conclusion

Significant progress has been made in the field of modification of bituminous binders for cold patch mixes (CPMs). Elastomeric polymers such as SBS and SBR provide high elasticity and fatigue resistance, while plastomeric polymers such as EVA provide high-temperature hardness.

New composite modifiers, such as WER and DCPD, play an important role in the development of materials that meet special requirements, such as high temperature, humidity, and especially rapid hardening in cold weather.

It should be noted that additional rheological analyses, such as the Black Diagram and Elastic Recovery, are necessary for a correct assessment of the quality of modified binders (for example, different performance despite the same PG class).

The use of modified binders is one of the most promising solutions for improving the quality of road surfaces, reducing repair costs, and ensuring the stability of transport infrastructure.

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