Analysis of Construction Treatment Technologies for Asphalt Pavement Cracks in Municipal Road and Bridge Engineering

Guanghui Liu

Anhui Zhonglan Construction Co., Ltd., Hefei, Anhui, 230000, China

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Abstract: In the construction of municipal road and bridge engineering, cracks in asphalt pavements are one of the common defects. The formation of such defects not only affects the aesthetic appeal of the pavement but also reduces its functional performance, potentially leading to more severe pavement distress. With the increasing traffic volume, traditional pavement crack treatment technologies can no longer meet modern road standards and requirements. Against this backdrop, pavement construction technologies have gradually garnered attention. This paper provides a detailed analysis of construction treatment technologies for cracks in asphalt pavements in municipal road and bridge engineering, aiming to offer valuable reference suggestions to construction personnel and improve the construction quality of asphalt pavements in such projects.

1. Introduction

Municipal road and bridge engineering is a crucial part of urban infrastructure construction, playing a carrier role in ensuring smooth urban traffic and facilitating social and economic development. Asphalt pavement is widely used in municipal road and bridge engineering due to its advantages such as low maintenance costs and high driving comfort. However, influenced by factors like the natural environment and construction quality control, asphalt pavements are prone to crack diseases, which affect pavement smoothness and driving safety. Based on this, it is essential to study the formation mechanism of asphalt pavement cracks in municipal road and bridge engineering and analyze construction treatment technologies for these cracks. This is of great significance for ensuring the safe and stable operation of municipal infrastructure.

2. Formation Mechanism of Asphalt Pavement Cracks

2.1 Traffic Load

Traffic load is an important external force factor that causes asphalt pavement cracks. It leads to pavement damage through processes such as concentrated stress, material fatigue, and crack initiation. When vehicles travel on the pavement, they generate impact loads, horizontal loads, and vertical loads. The impact load is a severe impact load produced by heavy-duty vehicles, which can instantaneously increase local stress. The horizontal load refers to the intensified shear action between the surface layer and the base layer when vehicles turn or brake. The vertical load causes severe bending deformation of the pavement structural layer, with the bottom of the surface layer subject to tensile stress and the top of the base layer subject to shear stress. Under long-term repeated loads, micro-damage accumulates in the asphalt mixture due to its fatigue characteristics. Once the tensile stress exceeds the material's tensile strength, tiny cracks appear at the bottom of the surface layer and expand upwards as the load increases, forming transverse cracks.

2.2 Water Factors

Water is one of the important environmental factors that accelerate the initiation and expansion of asphalt pavement cracks. It damages the asphalt pavement through reactions such as infiltration, structural degradation, and crack induction, and shortens the pavement's service life when acting in

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conjunction with traffic loads. The damage of water to the pavement structure is mainly reflected in the following aspects: First, the stripping effect reduces the bond strength between asphalt and aggregates, causing the asphalt film to strip from the aggregate surface and generating tiny cracks under external forces. Second, the softening effect reduces the strength of the water-saturated base layer. Under repeated traffic loads, the base layer undergoes compressive deformation, increasing the tensile stress at the bottom of the surface layer. Third, freeze-thaw damage: When the water infiltrating into the pores freezes at low temperatures, its volume expands, generating frost heave stress and causing micro-cracks in the pavement structure. When it melts and infiltrates into the cracks again during thawing, repeated freeze-thaw cycles form network cracks.

2.3 Temperature Factors

In regions with large temperature differences, cracks caused by temperature account for more than 40%. Asphalt mixtures are highly sensitive to temperature, and their stiffness and strength change non-linearly with temperature. Once the temperature stress exceeds the material's limit, crack problems are induced. At low temperatures, if the diurnal temperature difference is greater than 15 °C, the volume of the mixture will shrink sharply, generating internal tensile stress. Transverse cracks will initiate at weak points such as construction joints, and the crack width will expand as the temperature decreases [1]. At high temperatures, the fluidity of the mixture increases, making it prone to rutting under loads. Shear stress is generated on both sides of the rut due to uneven forces, forming longitudinal cracks.

3. Construction Treatment Technologies for Asphalt Pavement Cracks in Municipal Road and Bridge Engineering

3.1 Crack Sealing Technology

Crack sealing technology is a commonly used technical support for repairing asphalt pavement cracks in municipal road and bridge engineering. Its core principle is to inject a bonding sealant with good adhesion into the cracks to prevent rainwater, snowmelt, etc., from entering the cracks, effectively alleviate the displacement and deformation of the pavement on both sides, thereby curbing the expansion of the crack area and increasing the service life of the asphalt pavement. The construction level of the crack sealing technology is an important factor affecting the repair effect of asphalt pavement cracks. When applying this construction technology, standardized procedures must be strictly followed.

Crack Slotting: Use a specialized slotting machine to cut a trapezoidal slot along the crack direction with a width of about 10 mm and a depth of about 13 mm. Ensure that the depth of the slot is greater than the depth of the crack and that the sealant can completely fill the entire crack. Note that during slotting, construction personnel should control the cutting speed within a reasonable range to prevent chip dropping, which may affect material adhesion.

Slot Cleaning: Use a high-pressure hot air gun to remove debris from inside the slot. If there is accumulated water inside the slot, increase the drying time appropriately to ensure that the moisture content of the slot wall is below 3%. After completing the cleaning work, construction personnel should use a flashlight to check whether there are hidden cracks at the bottom of the slot. If so, expand the slotting area to prevent leakage during sealing.

Material Injection: Select the appropriate sealing material based on the ambient temperature. Use a sealing machine to inject the material evenly along the slot at a constant speed, ensuring that the injection speed is consistent with the material's fluidity so that the material fills the slot and is 2 mm higher than the pavement surface. If the crack width is greater than 10 mm, multiple injections can be carried out. After each injection, wait for the material to initially cure before injecting the next layer [2].

Post-construction Maintenance: After the crack sealing construction is completed, construction personnel should set up warning signs in the corresponding area to prohibit vehicles from rolling over it. Under normal circumstances, the maintenance time for normal-temperature materials should be no less than 1 hour, and for high-temperature materials, it should be no less than 30 minutes to ensure that the material is completely cured and forms the specified sealing structure.

3.2 Seal Coat Technology

Seal coat technology serves both protective and reinforcing functions and is a key technology. Its core principle is to lay a wear-resistant and anti-permeable protective layer on the crack area of the asphalt pavement, which not only prevents dust, rainwater, etc., from entering the cracks and eroding the pavement structure but also seals tiny cracks on the pavement surface, slows down the crack expansion rate, and enhances the pavement's skid resistance. According to differences in construction materials and construction processes, seal coat technology is divided into fog seal coat technology and slurry seal coat technology. When applying this technology to treat asphalt pavement cracks, the following points should be achieved:

Pavement Pre-treatment: Use a high-pressure water gun, etc., to thoroughly clean oil stains and other debris from the pavement surface. If there is accumulated water on the pavement, use a hot air gun to blow-dry the water. If the asphalt pavement cracks are greater than 3 mm, first use the crack sealing technology for separate treatment to prevent the seal coat material from being unable to enter the cracks. Carefully check whether there are settlement and other diseases on the pavement and deal with them in a timely manner to ensure pavement flatness and firmness.

Material Preparation: When preparing fog seal coat materials, dilute emulsified asphalt and water in a ratio of 1:1.03. If enhanced anti-aging performance is required, add an appropriate amount of anti-aging agent, stir evenly, and let it stand for about 7 minutes to ensure the stability of the material properties. When preparing slurry seal coat materials, input each material into the mixing bin of the slurry seal coat machine according to the design mix ratio and use a forced stirring method until a slurry mixture is formed [3]. If the consistency of the mixture is too high, add an appropriate amount of water; if it is too low, add emulsified asphalt.

Spraying and Paving: During fog seal coat spraying, use a specialized spraying machine to uniformly spray the diluted emulsified asphalt onto the asphalt pavement surface in a foggy form. Adjust the spraying width according to the equipment model, and overlap the adjacent spraying widths by 7 cm to avoid missing spraying areas. At the same time, reasonably control the spraying pressure during spraying to ensure that the emulsified asphalt can fully and comprehensively penetrate into the cracks. During slurry seal coat paving, use a specialized slurry seal coat machine for paving. Adjust the paving thickness according to the designed thickness to ensure paving uniformity. Construction personnel should continuously observe the flow state of the slurry mixture during the entire paving process. If problems such as agglomeration or segregation occur, immediately stop the paving construction, check the rationality of the material mix ratio, and make appropriate adjustments.

Maintenance: For fog seal coat maintenance: After the spraying construction is completed, set up warning signs to prohibit vehicles and pedestrians from traveling on the pavement [4]. If the ambient temperature is between 20 °C and 25 °C, the maintenance time should be no less than 4 hours. If the ambient temperature is below 15 °C, increase the maintenance time appropriately to ensure that the emulsified asphalt is completely cured. For slurry seal coat maintenance: After the paving construction is completed, close the traffic. Under normal temperature conditions, maintain it for 1-2 days. When the surface of the slurry mixture is dry, traffic can be opened. If it rains during the maintenance period, cover it with a waterproof cloth in a timely manner to prevent the mixture from being washed away by rainwater. After the maintenance construction is completed, construction personnel should carefully check whether there are problems such as peeling on the seal coat surface and repair them in a timely manner if any are found.

3.3 Overlay Technology

The core principle of overlay technology is to repave a layer of asphalt mixture overlay with strong durability and high flatness on the surface layer of the asphalt pavement that has already developed crack diseases. This not only completely blocks the expansion of the original cracks but also repairs diseases such as rutting and wear on the pavement surface, enhancing the pavement's bearing capacity. This technology is suitable for road sections with wide distribution of asphalt pavement cracks, high traffic volume, and high requirements for pavement quality. It can extend the service life of the asphalt pavement as a whole and reduce later maintenance costs [5]. According to differences in overlay thickness, material characteristics, and construction purposes, overlay technology can be divided into ultra-thin overlay technology, medium-thick overlay technology, and thick overlay technology. These overlay technologies have certain differences in process details, and the core construction processes are divided into the following steps:

Original Pavement Pre-treatment: Use pavement detection equipment to detect the strength of the original pavement base layer. Excavate the areas where the deflection value exceeds the design requirements to the base layer and carry out reinforcement treatment. Use a milling machine to mill the original pavement surface layer. The milling depth is about 12 mm for ultra-thin overlays, about 35 mm for medium-thick overlays, and about 70 mm for thick overlays. Ensure that there are no loose aggregates on the milled pavement, that it is flat, and that there are no step-like height differences. Use a high-pressure blower to remove crushed stones, dust, etc., after milling. If there is oil stain on the surface, clean it with an asphalt cleaner and dry it with a hot air gun to ensure that the pavement moisture content is less than or equal to 3%.

Spraying Tack Coat: During construction, use a fast-breaking modified emulsified asphalt and spray it evenly with intelligent equipment. After the emulsified asphalt breaks and the surface turns black, the overlay layer can be paved.

Overlay Layer Paving: During ultra-thin overlay paving, use a high-precision paver to ensure good fluidity of the mixture. Avoid stopping the paver during the entire paving process. If stopping is necessary due to special circumstances, set up construction joints, cut vertically at the construction joints, apply tack coat, and then repave. During medium-thick and thick overlay paving, use a large paver equipped with a contact balance beam and reasonably control the paving speed. For thick overlays, use a layered paving process and scientifically set the paving interval between the upper and lower layers to prevent poor bonding due to layer cooling.

Rolling Compaction: Rolling is the core link to ensure the compactness of the overlay layer. During rolling construction, follow the principles of close following, slow rolling, high frequency, and low amplitude [6]. In the initial rolling stage, use a steel wheel roller for two rollings at a speed of 1.5-2 km/h. The main purpose is to ensure the stability of the mixture and prevent displacement. In the re-rolling stage, use a rubber-tired roller for about five rollings at a speed of 2-3 km/h. In the final rolling stage, use a smooth-wheel roller for two rollings at a speed of 2.5-3.5 km/h. The main purpose is to eliminate rolling marks and enhance pavement flatness.

Maintenance and Opening: After the rolling construction is completed, set up warning signs and close the traffic. Under normal circumstances, the maintenance time for ultra-thin overlays at room temperature is about 7 hours, and for medium-thick and thick overlays, it should be more than 12 hours. During the maintenance period, prohibit pedestrians from stepping on it. If there is precipitation, cover it with a waterproof cloth.

3.4 Reinforcement Technology

Reinforcement technology is a key technology for repairing cracks caused by insufficient strength of the base layer. Its main purpose is to fundamentally hinder the further expansion of cracks by repairing and enhancing the structure. This technology is widely used in the renovation of old roads and the treatment of diseases in heavy-load road sections, effectively solving the problem of repeated diseases caused by "only repairing cracks without reinforcing the structure." This technology is mainly divided into the following three categories: Grouting Reinforcement[7]: This technology has high construction efficiency, has little impact on traffic, and has low construction costs. Inject cement-based or chemical grouting materials into loose areas using high-pressure equipment. During actual construction, construction personnel need to accurately detect diseases and reasonably control the grouting pressure. For severely loose areas, take the upper limit of the pressure, such as 2.5 MPa for cement-based materials, and for slightly loose areas, take the lower limit of 1.5 MPa to avoid base layer cracking due to excessive pressure.

Fiber Reinforcement: Lay glass fiber grids between the base layer and the surface layer, with longitudinal and transverse tensile strengths of no less than 80 kN/m and a breaking elongation of no more than 3%. After spraying the tack coat, wait for about 20 minutes until the emulsified asphalt breaks before laying the reinforcing material, and ensure that the material is flat and wrinkle-free during laying.

Reinforcement Layer Paving: When the looseness of the base layer is greater than 100 mm, this technology must be applied to fundamentally repair the cracks. During the milling of the old structure, use precision milling technology to ensure the reasonable flatness deviation of the top surface of the milled base layer and prevent uneven thickness of the reinforcement layer due to insufficient flatness. During subgrade treatment, if the subgrade is found to be loose after milling, excavate it to the intact layer, backfill it with graded crushed stone in layers, and ensure a compaction degree of about 97% and a subgrade resilient modulus of no less than 30 MPa.

4. Conclusion

In the context of modern society, with the development of science and technology and the improvement of the economic level, the construction technology of asphalt pavements in municipal road and bridge engineering has received high attention from all walks of life. Relevant departments and construction personnel should reasonably apply corresponding construction treatment technologies for asphalt pavement cracks according to the characteristics of municipal road and bridge engineering and control the construction quality from different links, thereby fundamentally improving the construction quality of municipal road and bridge engineering and reducing the probability of crack problems.

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