Research on Interlayer Bonding Treatment Technology of Ultra-Thin Whitetopping Material

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Abstract. Ultra-Thin Whitetopping has been studied and applied abroad as an emerging asphalt pavement overlay and pavement surface layer structure. UTW has the advantages of economy, durability and energy saving, and has broad prospects in urban road asphalt pavement maintenance, rural road surface, airport road surface and so on. For the UTW structure, the bonding condition between the board and the base layer has an important influence on the performance and life of the UW structure. The destruction of the interface between the layers is one of the important reasons for UTW damage. In this paper, the self-developed test piece forming mold was used to carry out the overlap test and the split test of the test piece to carry out the UTW interlayer adhesion performance test. The best interlaminar material and interlaminar treatment is obtained by drilling and engraving the interlayer polymer paste.

1. Introduction
With the rapid growth of traffic volume, overload, channelized traffic and the characteristics and defects of asphalt pavement itself, China's asphalt pavement is facing a severe challenge. Asphalt pavements continue to suffer from rutting, shifting, subsidence, aging, looseness, cracking and other problems, and the damage situation of low-grade township roads is particularly serious. Due to the low shear strength of asphalt pavement, a large number of road intersections, parking lot entrances, bus stops, trucks and bus lanes on urban roads are prone to deterioration, congestion, ruts, pits and other damages, which seriously affect the normal use of the road and the level of service. The way to add reinforcement to the old asphalt pavement is mainly asphalt concrete cover and cement concrete cover. Among them, cement concrete cover has the advantages of strong shear resistance, long service life, high surface reflectivity, low pavement temperature, high bearing capacity, low reflectivity of old roads, etc. It is very suitable for the maintenance of old asphalt roads in road junctions, parking lot entrances, bus stops, toll stations, trucks and bus lanes.

Generally, the pavement structure is divided into a surface layer, a base layer, and a cushion layer according to functions. The surface layer is exposed to the atmosphere and is in direct contact with the vehicle. It is well known that the base layer is the load-bearing layer of the pavement structure and is intuitive to the entire pavement structure. From a mechanical point of view, there is stratification, that is, there is interlayer bonding, and interlayer bonding means bonding between two different materials. In the case of external force, different performances may occur due to different mechanical properties
of different layers. If the integrity of the entire pavement structure is to be maintained, it means that the integrity and continuity of the layers can be maintained after deformed induced by external force.

2. Test raw materials and mix ratio

The cement concrete cover material can be divided into three parts, the upper layer cement concrete material, the middle layer interlayer bonding material, and the lower layer asphalt concrete material. Through such test piece forming form, the same structure as the actual engineering is achieved. In the test specimens prepared in the test, in addition to cement, sand and water, different admixtures were added to improve the performance of the concrete.

2.1. Test raw material

Polymer: The addition of polymer to mortar and concrete can significantly improve the workability, cohesion, adhesion and flexural strength. The butadiene-styrene copolymer emulsion is used in this paper.

Defoamer: After adding butadiene-styrene copolymer emulsion to cement mortar and concrete, the polymer modified mortar and concrete prepared can generate a large number of bubbles due to the strong air entrainment effect of butadiene-styrene copolymer emulsion, and the larger size of the can bubbles causes the concrete to increase in porosity, decrease in impermeability and in strength.

Water reducing agent: A concrete admixture that reduces the amount of water used for mixing while maintaining a constant slump in the concrete. After adding the concrete mixture, it has a dispersion effect on the cement particles, which can improve its workability, reduce the unit water consumption, improve the fluidity of the concrete mixture, or reduce the amount of cement used to save cement.

Early strength agent: can improve the early strength of concrete, and has no significant effect on the late strength. The main role of early strength agent is to accelerate the hydration of cement and promote the development of early strength of concrete; it has both early strength and certain water reduction enhancement functions. The early strength agent used herein is prepared by mixing 1:1 calcium nitrite and calcium chloride.

2.2. Cement concrete mix ratio

| Table 1. Mix ratio of cement concrete |
|--------------------------------------|
| Cement mix ratio (10L)              |
|--------------------------------------|
| cement (kg/m3) | Water cement ratio | Water (kg/m3) | aggregate (kg/m3) | Water reducing agent (%) | polymer (%) | Defoamer (%) | Early strength agent (%) |
|----------------|--------------------|---------------|-------------------|--------------------------|-------------|--------------|--------------------------|
| 2#: 3#: 4#     | 0.80%             | 15%           | 15%               | 0.94                      | 0.94        | 3‰           | 2%                       |
| 4.2            | 0.3                | 5             | 7.76:3.88:6.2     | 0.0336                   | 0.0336      | 0.63         | 0.012                    |
| 5              | 0.9                | 5             | 7.76:3.88:6.2     | 0.084                    | 0.084       | 6            | 0.084                    |

2.3. Interlayer bonding material mix ratio

| Table 2. Interlayer polymer cement paste mix ratio |
|---------------------------------------------------|
| Interlayer polymer cement paste                   |
|---------------------------------------------------|
| cement (kg/m3) | Water cement ratio | Water (kg/m3) | polymer (%) | Defoamer (%) | Early strength agent (%) |
|----------------|--------------------|---------------|-------------|--------------|--------------------------|
| 225            | 0.36               | 66            | 15%         | 7‰           | 2%                       |
| 225            | 0.5                | 112.5         | 15%         | 7‰           | 2.599                    |

| Table 3. Interlayer polymer cement mortar mix ratio |
|---------------------------------------------------|
| Interlayer polymer cement mortar                  |
|---------------------------------------------------|
| cement (kg/m3) | Water cement ratio | Water (kg/m3) | aggregate (kg/m3) | polymer (%) | Defoamer (%) |
|----------------|--------------------|---------------|-------------------|-------------|--------------|
| 225            | 0.5                | 112.5         | 675               | 33.75       | 2.599        |
There are four kinds of polymer interlayer binders: polymer cement mortar; polymer cement paste; only polymer latex; no treatment between layers. And the amount of only polymer latex added between the layers is 1.78.

3. Test process and result analysis

3.1. laboratory apparatus

Asphalt Mixture Performance Tester (AMPT): A direct continuous fatigue method for direct continuous fatigue damage measurement instead of traditional bending fatigue. Tests for the dynamic modulus, rheology and rheology of the mixture, repeated loading and static creep testing, and direct tensile fatigue testing can be performed. Load capacity: static load 15KN, dynamic load 13.5KN; actuator stroke: 30mm; temperature control range: 4-60 °C; confining pressure: 0-210kpa.

3.2. Experimental molding mold development

The molding die is applied to the overlay test of the AMPT tester, so the dimensional requirements are in accordance with the test operating platform. The dimensions of the test pieces on both sides of the interlayer bonding material are all 75mm*75mm*30mm. After the molding is completed, the maximum length, width and height of the whole test piece are 160mm*75mm*30mm. The intermediate layer bonding material has an adjustable thickness of 0 mm * 10 mm.

3.3. Experimental content

On the one hand, study the influence of different interlayer bonding materials on the bonding ability of the base layer and the surface layer; on the other hand, increase the surface roughness and effective contact area of the base layer to explore the effect of friction to enhance the performance of the pavement, and finally make the surface layer and the base layer Achieve inter-layer bonding to explore new ways to enhance inter-layer bonding capabilities.

3.4. Overlay test of specimen forming method

The test piece is made of three parts of concrete material in the horizontal fixture, and the asphalt concrete is placed on one side of the mold; the concrete concrete is reproduced on the other side, and the aggregates, water and cement of various specifications are weighed according to a certain ratio. Stir the aggregate evenly, then add the cement weighed in advance, continue to stir. After the dry mix is fully stirred, add a certain amount of water to maximize the uniform dispersion of water, cement and aggregate. Then placed on the vibrating table to make it evenly distributed, then compacted and smoothed to make it the same size as the asphalt concrete; finally, add the interlayer binder in the middle of the fixture, add the mixture and compact it. The configured interlayer polymer material should be used within 30 minutes. The whole test piece was placed in the mold and placed in the room for more than 12 hours, and the test piece was demoulded out; finally, the test piece was placed in a curing box for 28 days of maintenance.

After 28 days of curing, the overlay test was carried out using an AMPT test machine, and the test pieces were subjected to a fatigue test one by one. Three test pieces were made at a time for each layer of bonding material, and the same conditional parts are cured under the same conditions. The test was carried out at the same straight pull frequency, the same test temperature control, and the same tensile displacement.

3.5. Different interlayer bonding studies

3.5.1. Test plan. The inter-layer bonding performance test specimens are made of self-made fixtures, measuring 30mm×75mm×160mm, consisting of three parts, one of which is asphalt concrete, the other part is cast-in-place cement concrete, and the middle part is the joint material between cast-in-place layers. The degree of bonding of the different materials was evaluated using different interlayer bonding
materials. The test piece was repeatedly applied with a fatigue test, and finally the fracture occurred at the joint between the layers, thereby simulating the damage of the joint between the layers of the cement concrete cover material to evaluate the interlayer bonding performance.

The test control group was composed of different interlayer bonding materials and the same interlayer treatment. The test pieces are cement paste interlayer bonding materials; polymer cement mortar interlayer bonding materials; polymer cement paste bonding materials; polymer anhydrous pulp; no bonding between layers.

Table 4. Test piece material composition

| material type       | I          | II                      | III                    |
|---------------------|------------|-------------------------|------------------------|
| Asphalt concrete    |            | Cement paste            |                        |
|                     |            | Polymer cement paste    |                        |
|                     |            | Polymer cement mortar   |                        |
|                     |            | Polymer anhydrous paste  |                        |
| No treatment        |            | Cement Concrete         |                        |

According to the test specification Overlay Test test procedure, the test temperature is set to 20 °C, the maximum tensile displacement is 0.1 mm and 0.2 mm, the test frequency is 0.1 Hz, and the loading cycle is 60 times.

3.5.2. Analysis of test results.

Figure 1. (1 - cement paste; 2-polymer mortar; 3-polymer paste; 4- no additional water polymer paste; 5 - no binder)
Table 5. Section table

| Interlayer bonding material | Interface processing | Original test piece | Crack location | Crack legend | Fracture cross section |
|-----------------------------|----------------------|---------------------|----------------|--------------|------------------------|
| Polymer cement paste        | No treatment         | Interfacial junction | Interfacial junction |
|                             | groove               | Interfacial junction | Interfacial junction |
|                             | drilling             | Interfacial junction | Interfacial junction |
|                             | Grooving and drilling| Interfacial junction | Interfacial junction |
| Polymer cement mortar       | No treatment         | Interfacial junction | Interfacial junction |
| Cement paste                | No treatment         | Interfacial junction | Interfacial junction |
| Contains no added water polymer paste | No treatment | Interfacial junction | Interfacial junction |
| no                          | No treatment         | Interfacial junction | Interfacial junction |

Since the test instrument is in the trial pull phase at the beginning of each test, the tensile stress is large at the first stretch, and the data is stabilized by repeated loading of the data after the second stretch. It can be seen from the above figure that the trend of the five different interlayer bonding materials is the same. As the number of stretching increases, the stress is gradually decreased and tends to be stable, and the interlaminar materials with large to small tensile stress are polymer paste, no binder between layers, polymer paste without added water, polymer mortar, cement paste. By comparing polymer paste, polymer mortar, no added water polymer paste and cement paste, we can conclude that the addition of polymer can induce the filling of concrete aggregate more compact, so the polymer-containing material can better the bonding performance.
On the one hand, the maximum tensile stress of each material can reflect the properties of the material, and on the other hand, the rate of change of the tensile stress is also one of the reaction factors. At the same loading displacement and number of times, the interstitial material that first reaches the fatigue failure can be predicted by the rate of stress drop. The faster the tensile stress drops, the more likely the damage occurs. As can be seen, the cement paste has the slowest rate of decline, followed by the inter-layer polymer paste. Although there is no maximum tensile stress value between the layers, the rate of decline is also large, which means that the unbonded material between the layers will be destroyed first under multiple fatigue stretching; The rate of decline is the lowest, but it can withstand the minimum stress in combination with the maximum tensile stress.

3.6. Study on different interfacial interface treatment methods

3.6.1. Test plan. In addition to different inter-layer bonding materials, different inter-layer interface treatment methods are used to treat the asphalt concrete part, which can simulate the treatment of the old asphalt pavement, which is used to increase the roughness of the asphalt concrete part, inducing the increase in the degree of interlayer bonding.

| Interlayer bonding material | Interface processing          |
|-----------------------------|------------------------------|
| Polymer cement paste        | Groove drilling              |
| Polymer cement mortar       | Grooving and drilling        |
| Polymer latex               | No treatment                 |
| Cement paste                | No treatment                 |

In this scheme, the same interlayer bonding material and different interlayer treatment methods are adopted, so the asphalt concrete interface is treated, which is grooved, drilled, grooved and drilled, and no treatment; add polymer cement paste as interlayer bonding material. The asphalt concrete is cut according to the size of the test piece fixture, the size is 75mm×75mm×30mm; the groove size is 3mm and the interval is 1cm; the hole size is 1cm, the interval is 2cm, the diameter is 5mm.
3.6.2. Analysis of test results.

![Figure 3](image1.png)

**Figure 3.** (1-polymer paste drilling; 2-polymer paste groove; 3-polymer paste plus groove)

![Figure 4](image2.png)

**Figure 4.** (1-polymer paste drilling; 2-polymer paste groove; 3-polymer paste plus groove)

The analysis method of different bonding materials between layers before the experiment can be concluded that the interlayer processing method of the maximum tensile stress is polymer cleaning groove and drilling; the minimum stress drop rate is polymer pure slurry drilling. When the inter-layer bonding contact surface is simultaneously grooved and drilled, the area of the inter-layer bonding contact surface is increased, and the roughness of the inter-layer bonding surface is increased, thereby improving the interlayer bonding ability. Therefore, the best inter-layer treatment method is to add polymer drilling and drilling.
3.7. Direct split test results and analysis

Table 7. Fatigue test results

| Number | Interlayer material       | Maximum stress(KN) | Average maximum stress(KN) |
|--------|---------------------------|--------------------|---------------------------|
| 1#     | Polymer mortar            | 20.06              |                           |
| 2#     | Polymer mortar            | 20.13              | 20.07                     |
| 3#     | Polymer mortar            | 20.02              |                           |
| 4#     | Polymer paste             | 20                 |                           |
| 5#     | Polymer paste             | 23                 | 21.02                     |
| 6#     | Polymer paste             | 20.06              |                           |
| 7#     | Add polymer only          | 18.56              |                           |
| 8#     | Add polymer only          | 18.09              | 18.62                     |
| 9#     | Add polymer only          | 19.22              |                           |
| 10#    | No processing between layers | 18.86        |                           |
| 11#    | No processing between layers | 18.77        | 17.97                     |
| 12#    | No processing between layers | 16.27        |                           |

It can be seen from the test results in the above table that the split value of the interlayer polymer paste and the interlayer polymer mortar is large. Combined with the overlay test, the best interlayer bonding material is polymer paste. The best interlayer bonding treatment is grooving and drilling the polymer paste.

4. Conclusion

The inter-layer bonding ability has an important influence on the road performance and life of UTW. A large number of domestic and foreign studies have shown that the function of UTW remains largely dependent on the good adhesion to the old asphalt pavement. Based on this, the interlayer bonding properties of UTW were studied by overlay test and splitting test, and the following conclusions were obtained:

1. The best interlayer bonding material can be obtained as a polymer paste by different interlayer materials.

2. The best inter-layer bonding treatment method is grooving and drilling the polymer paste can be concluded through the different layers of material treatment.

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