The Application of Grouting Sealing Material in the Treatment of Pavement Reflective Cracking

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Abstract. Grouting sealing technique was applied for the treatment of pavement reflective cracking in HengDe expressway and the treatment effect which evaluated by the portable falling weight deflectometer was demonstrated in this paper. Analysis considers that grouting sealing technique could effectively improve the bearing capacity of the pavement where distress happened by reducing the deflections of the pavement up to 5%-25%.

1. Introduction
Reflective cracking is one of the major type of distresses for semi-rigid type base asphalt pavements which has been adopted as a popular highway pavement structure in China. Reflective cracking left untreated is known to contribute to a rougher and noisier ride and to hasten the premature failure of the surface material at or near joints[1]. Over the years, several methods have been developed for mitigating reflective cracking[2]. For newly-built pavements, techniques including better mix design procedure and interlayers system have certain effects for preventing reflective cracking. For existing reflective cracking, commonly used treatments are joint sealing and milling rehabilitation, which however have their own shortcomings that cannot be ignored. This paper introduces grouting sealing technique as a new direction for the treatment of reflective cracking and briefly presents the application of grouting sealing material in the treatment of reflective cracking in the road maintenance project of HengDe expressway.

2. Reflective Cracking
The semi-rigid base usually consists of cement stabilized macadam or lime fly-ash stabilized macadam which is hard and brittle, and it is easy to produce shrinkage cracking due to the change of temperature or humidity. Cracking that rise from semi-rigid base will eventually propagate to the surface of asphalt pavement, leading to a reflective cracking on the overlay[3]. Reflective cracking is one of the major type of distresses in semi-rigid base pavement[4]. It destroys the integrity and continuity of pavement structure, and to some extent leads to the weakening of structural strength. Moreover, with the immersion of rain or snow, bases and sub-bases will be gradually deteriorated under cyclic traffic loading, and eventually, along with the emergence of pumping distress, as well as the breakage of overlay on the both side of cracking joint, the quality and service life of pavement will be seriously affected.

For existing reflective cracking, currently treatments are joint sealing and milling rehabilitation. Although milling rehabilitation can eliminate reflective cracking distress efficiently, this method will consume lots of time and finance under the construction period, leading a negative impact on traffic safety and efficiency. The objectives of joint sealing are water blocking on the surface and structural repairing of the interior, by injecting sealing materials into fracture itself. Nevertheless, traditional
sealing materials including emulsified asphalt or cement slurry, which are usually characteristic as poor durability and low service life, can hardly penetrate into the depth of the crack, leaving an 85% failure rate within one year after crack sealing. Compared with these two traditional treatment modes, grouting sealing technique provides a new direction for the treatment of reflective cracking. Taking the advantages of high permeability and cohesion of grouting material, crack sealing can be carried out from base bottom to pavement surface thoroughly and effectively, saving a lot of maintenance costs at the same time. Present market is full of various types of grouting sealing materials with different effectiveness and practicability in treating reflective cracking. Among them, the superiority of polyurethane grouting sealing material lies in its better performance in cohesion, fluidity, impermeability, mechanical strength as well as aging resistance, which certainly makes polyurethane leads all other materials.

3. Polyurethane Grouting Material

Polyurethane grouting sealing material can be divided into waterborne and oilborne according to its properties. Generally, waterborne polyurethane grouting material has good hydrophilic property which makes it suitable for grouting or plugging works under humid condition; while oilborne polyurethane grouting material behaves high mechanical strength after consolidation, which is mostly used for both foundation reinforcement and waterproof projects [5]. Most of the time, different types of polyurethane material will be mixed under appropriate proportion for grouting construction according to specific needs. Polyurethane slurry contains a lot of polar groups such as carbamate or urea, etc. These polar groups will form a strong adhesive force between the soil and mineral particles, which will cement the original fracture structure into an integrated reinforcement system.

Combined with the treating requirements of reflective cracking and the relevant technical requirements in CJJ/T 260-2016 "Technical specification for trenchless treatment of road deep diseases", this paper designs a two-component polyurethane reactive grouting material and its technical performance is listed below (Table 1). And the summary of construction technique and evaluation of distress treatment effect for reflective cracking are carried out on the basis of this material.

| No. | Subject                        | Result | Requirement |
|-----|--------------------------------|--------|-------------|
| 1   | Viscosity(25°C), mPa·s         | A component 223 | ≤600 |
|     |                                | B component 617 | ≤1000 |
| 2   | Density(25°C), g/cm³           | A component 1.26 | 1.22~1.25 |
| 3   | Curing time, min               | 12     |             |
| 4   | Compession strength(25°C), MPa | 5.0    | ≥0.6 |
| 5   | Tensile strength(25°C), MPa    | 3.1    | ≥0.4 |
| 6   | Osmotic pressure,MPa           | 0.6    | ≥0.2 |
| 7   | Chemical resistance            | 10% sodium chloride insoluble |
|     |                                | lime suspension insoluble |
|     |                                | 5% sulphuric acid insoluble |

4. Application

4.1. Overview

The pavement structure of this trial section is semi-rigid base with AC graded asphalt overlay. Over the years, distress had emerged under the influence of long-term heavy traffic and rainwater damage. Several transverse crackings through the lanes can be observed on the spot. In 2018, sealant filling had been carried out on the surface of crackings and small-scale patching treatment had been applied for separate deteriorated joint section. One year later, pumping distress has occurred right at the original surface sealing position as well as the patching area, some of which even appeared local subsidence.
4.2. Detection and Analysis
The deflection of pavement around the area of pumping was measured by portable falling weight deflectometer. The detection positions and the corresponding deflection values at these points are shown in the following diagram.

From the detected data, it can be seen that the deflection around the pumping and patching area is significantly higher than that of the area without distress. The increase of deflection indicates that the pavement structure has lost its original strength due to the present of distress. For this type of structural distress, surface sealant filling can only suppress the symptom but without treating the condition. Rainwater will continuously scour and destroy the structure at joint under the dynamic load of wheels over time, causing the pavement maintenance work to fall into a dilemma.

4.3. Distress Treatment
The pavement structure of this trial section is semi-rigid base with AC graded asphalt overlay. Over the years, distress had emerged under the influence of long-term heavy traffic and rainwater damage.
**4.3.1 Scheme Design.** In view of this type of structural distress, it can be effectively treated by the combination of grouting sealing and surface covering techniques. The water and air in the crack are squeezed out of the original position where the polyurethane grouting material replaces. The consolidation of saturated polyurethane material gives birth to a new integrated structure whose bearing capacity has been restored. The following surface covering is to emplace a crack resistant layer on the top of joint, for the sake of further prevention of water immersion.

**4.3.2 Drilling Layout.** According to the deflection shown in Figure 2, the drilling layout can be roughly determined as follows:

![Figure 3. Drilling layout at K61+050.](image)

The basic principle is to ensure that the drilling location is in the area of distress, and the drilling depth should runs through the total pavement structure.

The mud accumulated in the reflective cracking or the pumping distress shall be squeezed out before the actual grouting sealing carried out. Therefore, the distribution of grouting holes should be arranged within 30cm around the reflective cracking in a zigzag or rectangular pattern (depending on the trend of the crack on site). As for the grouting holes at patching area, they shall be arranged in tetragonal alignment at the same distance along with each other. While ensuring the above conditions, extra grouting holes should be pre-planned at the place where deflection is obviously raised.

A grouting pipe with specific outlets will be inserted in the grouting hole after drilling, and the top of the pipe is closely connected to a grouting cap with an anti-overflow valve.

**4.3.3 Grouting Sealing.** The mud or water accumulated in the distress shall be removed out through high-pressure air pump for the purpose of preventing the excessive humid environment from affecting the solidification quality of sealing material. The drainage time shall be determined according to the actual situation on site.

The grouting pressure should be controlled at about 2 MPa. Insufficient pressure is not conducive to the full dispersion of the sealing material into small cracks, while excessive pressure will easily lead to pavement arching or other structural damage.

The grouting sequence follows the order from the core of distress to other directions. Intermittent grouting with appropriate frequency shall be adopted for each hole. Meanwhile, it is crucial to take note of the changes of the horizon of pavement around the cracks at all time during the grouting process. Once there is slurry emerging from the cracks or partially lifted of the pavement, immediate stop should be executed without hesitate.
Figure 4. Mud Squeezed during Processing.

There are many factors affecting the total amount of grouting, which are primarily determined by the crack space, internal structure of the crack and the permeability coefficient of the slurry. It is generally considered that the ending signal of each grouting operation is that the slurry can no longer be injected under appropriate grouting pressure, followed by excess slurry discharged freely from the grouting hole after the detachment of the pipe and the cap.

4.3.4 Recheck and Finish. Redundant slurry left on the road surface shall be removed with all grouting holes being sealed after grouting process. Deflection re-detection will be conducted at the previous position once the consolidation of polyurethane material has accomplished. According to the changes of the deflection data before and after treatment, holes or areas that did not meet the requirement will be re-arranged for refilling. An accomplished treatment picture with crack resistant layer covering on the top of joint is shown below.

Figure 5. Treatment Accomplished.

4.4. Evaluation of Treatment
The comparison of deflection before and after the grouting treatment in K061+50 ~ K778 + 200 (upward direction) section of HengDe expressway is shown in the following table (Due to the large amount of measurement data, only values from four angles of reflective cracking (as shown in Figure 5) are selected for the comparison).
Table 2. Deflection Comparison.

| Stake      | Measurement of Deflection (0.01mm) | Average Decline |
|------------|-----------------------------------|-----------------|
|            | A       | B       | C       | D       |                 |
| k62+200    | Before  | 11.5    | 10.6    | 12.9    | 12.0             | 20.6%            |
|            | After   | 8.7     | 8.8     | 10.1    | 9.7             |                  |
| k62+660    | Before  | 17.1    | 20.2    | 13.2    | 14.7             | -5.4%            |
|            | After   | 18.9    | 23.9    | 10.9    | 16.2             |                  |
| k64+720    | Before  | 14.5    | 21.9    | 12.3    | /                | 10.0%            |
|            | After   | 14.1    | 19.7    | 10.2    | 16.5             |                  |

Particular tested points cannot be measured accurately due to the roughness of surface.

| Stake      | Measurement of Deflection (0.01mm) | Average Decline |
|------------|-----------------------------------|-----------------|
|            | A       | B       | C       | D       |                 |
| k64+040    | Before  | 13.1    | 14.8    | 12.3    | 11.8             | 6.5%             |
|            | After   | 13.3    | 11.0    | 12.8    | 11.1             |                  |
| k65+530    | Before  | 25.9    | 17.4    | 10.2    | 16.7             | 16.7%            |
|            | After   | 21.9    | 10.4    | 10.1    | 15.0             |                  |
| k66+630    | Before  | /       | 13.7    | 15.6    | 18.6             | 15.4%            |
|            | After   | 18.8    | 12.6    | 12.1    | 15.7             |                  |
| k67+440    | Before  | 12.0    | 12.0    | 15.6    | 23.8             | 27.4%            |
|            | After   | 8.8     | 9.5     | 9.4     | 18.5             |                  |
| k67+275    | Before  | 12.7    | 11.0    | 15.1    | 13.3             | 19.1%            |
|            | After   | 10.5    | 10.7    | 10.2    | 10.1             |                  |
| k68+525    | Before  | 16.3    | 13.2    | 11.3    | 16.2             | 6.5%             |
|            | After   | 13.1    | 14.8    | 12.3    | 11.8             |                  |

It should be noted that the reason for the rise of deflection at k62+660 has been speculated that the distress occurs at the tested point is relatively close to the surface, therefore, to a great extent, the deflection we measured here represent the modulus of consolidated material which has smaller modulus of resilience than the integrated pavement structure.

From the test data, it can be seen that the magnitude of deflection measured by portable falling weight deflectometer exhibits a few fluctuation, some of which even show a trend of weak increase. This is because that factors affecting the accuracy of results will become more diverse when it comes to the measurement of asphalt pavement rather than fine-grained soil or stabilized soil base which are the normally measured objects of portable falling weight deflectometer. Factors including the bearing plate of the instrument, the smoothness of the pavement surface or the specific causes of the distress will lead to fluctuations in the measurement. Nevertheless, the deflection at the same location has decreased apparently after grouting treatment in view of the overall changes, which can be explained that the sealing slurry fills the original cracks and consolidates the previously damaged structure as a whole.

5. Conclusion
(1) Combined with the effect required for treating reflective cracking and relevant technical requirements, this paper designed a two-component polyurethane reactive grouting material which was later applied to the distress treatment work on HengDe expressway. By means of deflection detection, the treatment effect of polyurethane grouting sealing technique towards the reflective cracking of semi-rigid base pavement was evaluated. Results show that grouting sealing technique can effectively reduce the deflections of the pavement where distress happened as well as improve the bearing capacity of the pavement.
(2) In order to evaluate the effect of treatment of distress thoroughly, it is wisely to consider the combination of multiple non-destructive detection methods such as high-precision ground penetrating radar, since there are some fluctuations in the detection data when it comes to usage of portable falling weight deflectometer.
6. References

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