Research on Innovative Application Technology of Thin-layer Rapid Repairing Materials in Damaged Passageways of Yard Cranes

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Abstract The number and severity of the damaged yard crane passageways on the wharfs are increasing year by year. Based on the research results of thin-layer repairing of the damaged passageways of yard cranes at home and abroad in recent years, this paper analyzes the characteristics and hazards of thin-layer disease of concrete pavement and measures the mechanical properties and durability of thin-layer rapid repair materials through setting time test, mechanical test, abrasion resistance test and frictional coefficient test. It is concluded that its properties can meet the requirements of thin-layer repairing technology, and some engineering examples of thin-layer rapid repair are listed in this paper.

1. Introduction
There are various types of damage forms of yard crane passageways on the wharfs, and the causes of damage are not the same, among which the thin-layer damage is in the forms such as reinforcement exposure, peeling, polishing, potholes and slight cracks. This paper focuses on two main causes of the damage [2]:

(1) Surface voids and reinforcement exposure: The main reason for the surface voids and reinforcement exposure is the relatively high air content of the newly-paved repair material cement, or the unreasonable mix ratio that has been used. The air entraining agent is not used in cement concrete or the air entraining agent of low quality is used, which results in high air content of the cement. Furthermore, improper mix ratios such as too much cementing material, too much sand, and too small water-binder ratio will make the cement concrete too viscous and difficult to discharge bubbles. In addition, the poor maintenance in the later period will also lead to pockmarks on the hardened concrete pavement.

(2) Peeling: The cement paste or mortar layer of the cement concrete pavement peels off from the surface of the coarse aggregate, and segregation occurs when the concrete surface is vibrated excessively or the water cement ratio is too large; on the other hand, the concrete exposed to outdoor environment for a long time produces a small hole with a diameter of 2-5cm, which forms the peeling-off of the concrete pavement. The reason is that the construction soil pavement has suffered from the fatigue effects of corrosion, freezing-thawing and vehicle loads.

The surface of the thin-layer repair structure is subject to the impact and fatigue of the natural environment and tire loads for a long time. Therefore, the rapid repair material for thin-layer repairing needs to meet the following technical requirements:[3]

(1) To meet the working performance requirements, the initial setting time of repair materials shall meet the necessary operation time for workers’ construction;
(2) High strength and rapid hardening in the early stage. In order to recover the traffic as soon as possible, the compressive strength of the rapid repair material should reach 30MPa with a flexural strength not be less than 4.5MPa within one hour while its strength should reach C40 within 24 hours. Furthermore, its later strength must be stable without shrinking;

(3) Good compatibility with old concrete, that is, the newly paved repair layer has good adhesion with the old concrete layer, and the expansion coefficient and shrinkage of the repair material are not much different from those of the original concrete, and the color is similar;

(4) Good durability. Repair materials should have good abrasion resistance, corrosion resistance and fatigue resistance;

(5) The cement mortar repair materials should have certain fluidity, which should be greater than 180mm according to the specifications.

2. Research on Experimental Performance of Thin-layer Rapid Repair Materials

2.1. Setting time

Thin-layer rapid repair materials require a fast setting time to facilitate early opening of the traffic. However, the initial setting time should not be too short, which should meet the necessary construction time.

The operation method of our research team is as follows: first, pour 500g of thin-layer repair material into the mixing pot, then add the optimal mixing amounts of water, namely, 8%, start the mortar mixer to stir at low speed for 30s and at high speed for another 90s, and then pour it into the test mold with glass bottom plate, and test the initial setting time with a standard Vicat apparatus. It is stipulated in the specification that the time when all water is added to the mortar shall be taken as the start time of the setting time. When the test needle sank 4mm ± 1mm from the bottom plate, that is, when the penetration resistance was 3.5MPa, it reached the initial setting state, as shown in Figure 1, which was called the initial setting time. The measured room temperature was 15 °C and the water temperature was 20 °C. Three sets of experiments were performed according to the above test methods, and the initial setting time measured was 9min, 11min, and 10min, respectively.

![Figure 1 The initial setting state](image)

2.2. Mechanical properties

Compressive and flexural strength tests were conducted with reference to the test procedures of GB / T 17671-1999 test method for strength of hydraulic cement mortar.

Before the test, the indoor temperature should be kept at about 20 ± 2 °C, and the relative humidity should be controlled above 50%;

(b) Pour the thin-layer repair material into the mixing pot of the mortar mixer. After adding water, start the mixer to stir at low speed for 30s first, and then at high speed for another 90s until the rapid repair material was evenly mixed and had good fluidity and cohesiveness;

(c)After completing the stirring, a 40mm × 40mm × 160mm test mold was poured and quickly placed
onto the cement sticku and vibrating platform, and then it was smoothed out after 15 times of vibration. It is better to control the whole test process from adding water into the mixing pot to the completion of vibration within 3 minutes;

(d) After half an hour of curing, the specimen was demolded and continued to be cured in the natural environment until it reached the corresponding age;

(e) Finally, the compressive and flexural strengths of the specimen were measured by compressive and flexural testing machines, and the data were recorded and sorted.

The compressive and flexural strengths of seven different ages were tested, namely, 1h, 4h, 1d, 7d, 28d, 60d and 90d. Therefore, it was necessary to make seven groups of specimens, three in each group, with a total of 21 specimens and the corresponding ages were 1h, 4h, 1d, 7d, 28d, 60d, and 90d, respectively.

The specimens were shown in Figure 2.

![Figure 2 Specimens](image)

Take the average data of each group of specimens, and remove the data with too large difference in results to get the mechanical properties of magnesium phosphate rapid repair material, as shown in Table 1.

| Age  | 1h  | 4h  | 1d  | 7d  | 28d | 60d | 90d |
|------|-----|-----|-----|-----|-----|-----|-----|
| Flexural Strength (Mpa) | 5.1 | 5.7 | 7.1 | 7.9 | 9.2 | 9.9 | 10.0 |
| Compressive Strength (Mpa) | 34.5 | 38.6 | 41.1 | 63.1 | 69.4 | 73.0 | 74.5 |
| Ratio of flexural strength to compressive strength | 0.148 | 0.148 | 0.173 | 0.125 | 0.133 | 0.136 | 0.134 |
The compressive strength of the thin-layer rapid repair material had reached 34.5MPa in 1h, and the flexural strength had reached 5.1MPa, which met the technical indicators mentioned above, and could meet the requirements of open traffic in 1h. The compressive and flexural strengths of 28d were 69.4MPa and 9.2MPa respectively. The strengths tended to be stable, and no intensity shrinkage occurred when it reached 60d.

2.3. Abrasion resistance

There will be a certain amount of abrasions due to the direct exposure of thin-layer repair materials on the road surface, and the continuous expansion of these abrasions will result in tiny cracks. Therefore, the abrasion resistance of the repair material is very important.

The experiment was referenced to T0567-2005 “Test Method for Abrasion Resistance of Cement Concrete” in JTGE30-2005 “Test Specification for Cement& Cement Concrete for Road Project”.

The abrasion resistance index was expressed by the wear amount Gc per unit area of the worn side of the standard specimen of 150 mm*150 mm*150 mm. Take out the abrasion resistance specimen of the thin-layer repair mortar after curing in the outdoor dry air environment to the age of 27d, wipe its surface with a rag and maintain it in the indoor environment for 12 hours. After dying for another 12 hours in an oven at 60 ± 5 ℃ until it had a constant weight, place it in the fixture of a concrete abrasion resistance tester, grind it for 30 turns under the load of 200 N and weigh it as the initial mass m1 of the abrasion resistance specimen, and then continue grinding for another 60 turns and weigh it as the residual mass m2 of the abrasion resistance specimen of the magnesium phosphate rapid repair mortar. It should be noted that the fixture on the turntable must tightly clamp the specimen. The vacuum cleaner should be aligned with the wear surface, so that the debris could be cleaned away in time, and the blade should be replaced immediately during the whole test. Taking the average data of the abrasion of three specimens as the test results after the group, the specimens with a wear loss of more than 15% were removed and the average values of the remaining specimens were taken.

| Specimen No. | m1 (g) | m2 (g) | m1-m2 (g) | Gc (kg/m²) | Mean value |
|-------------|--------|--------|-----------|------------|------------|
| 1           | 7474.7 | 7445.7 | 29.0      | 2.320      |            |
| 2           | 7549.2 | 7520.5 | 28.7      | 2.296      | 2.283      |
| 3           | 7502.8 | 7474.9 | 27.9      | 2.232      |            |

It can be seen from Table 2 that the average wear amount of the repair material is 2.283 kg/ m², which meets the construction requirements for thin-layer repairing.

2.4. Frictional coefficient

Based on the Field Test Instructions of Highway Subgrades and Pavements, the frictional coefficient of the thin-layer repair material was measured by the test model of T0964 pendulum to measure the friction coefficient of pavement. As shown in Figure 3, the friction coefficient is about 0.6, which makes the tire have enough safe driving distance when braking.
3. Engineering innovation and application of thin layer repair materials

In terms of the damaged site of No. 58 Longmen Road at Hairun Container Terminal in Xiamen Port, the project team adopted innovative techniques and applied thin-layer repair materials for the patching. Figure 4 shows the passageway of yard cranes before and after repairing. The actual repair effect was fine, and the strength of smooth tire traffic could be achieved within one hour.

Due to the friction effect of the coarse aggregate, the running tire will be severely worn, and a lot of tire slag will fall on the driving track when the tire is driving on the damaged passageways of yard cranes. The surface of the repair materials is relatively smooth, and the repaired passageways play a better role in protecting the tires.

This application experiment has made a good practice exploration for the thin-layer repair of concrete. Attempts have been made on the methods of material mixing and coagulation treatment. At the same time, a real case has been carried out to verify the effect, which indicates that the technique and materials can solve the corresponding repair problem of the damaged passageways of yard cranes on the wharfs.
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