Research on Reasons for Repeated Falling of Tiles in Internal Walls of Construction

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Abstract. In view of the quality problem of repeated falling of facing tiles in some construction, the essay had a comparative trial in laboratory on cement mortar which is often used to paste tiles, special tile mortar and dry-hang glue, and measured durability of tile adhesive mortar through freezing and thawing tests. The test results indicated that ordinary cement mortar cannot meet standards due to reasons like big shrinkage and low adhesive. In addition, the ten times of freezing and thawing tests indicated that ordinary cement mortar would directly shell and do not have an adhesive force, and moreover, adhesive force of special tile mortar would reduce. Thus, for tiles of large size which are used for walls, dry-hang techniques are recommended to be used.

1. Introduction
As a decorative material, tiles are widely used in decoration engineering, but there are quality accidents due to hollowing and falling. Although there are many reports on relevant issues in China, they just talked in generalities and were not strongly targeted [1][2]. Entrusted by a construction company, the writer analyzed reasons for repeated falling of tiles for internal decoration of a building constructed by the company. The construction company suspected the tilts had problems with the reason that although it had been repaired several times, the phenomenon would appear again in the next year. Through filed investigation, the following phenomena were discovered: ① falling tilts were in staircases and elevators which had a bigger temperature difference; ② the tiles had a big size- 600mm*600mm*10mm, thus they were heavy; ③ tiles fell down in blocks and the back side of the tiles hardly had mortar; ④ the bonding mortar was cement mortar which was modulated by workers according to their experience and rebound strength of entity mortar was bigger than 30MPa.

According to the investigation, the writer planned to adopt ordinary cement mortar, special tile mortar and dry-hang glue to have put-off tests for comparison, and moreover, he measured durability of bonding effects of tiles through freezing and thawing so as to analyze reasons for falling of tiles.

2. Test raw materials and methods

2.1. Test raw materials
Cement: PO.32.5 cement, 28d compressive strength: 40.8MPa
Sand: river sand, fineness module: 2.8
Special tile mortar: homemade and constituted by cement, superfine compound powder, quartz sand (below 1mm), water reducing agent, retarder, super absorbent polymers (re-dispersible latex powder) and admixture according to certain ratio
Dry-hang glue: two-component AB dry-hang glue, produced by Shenzhen Jiajiehe Building Materials Co. LTD.

2.2. Test methods
Considering that tiles of the project fell down in blocks, workers in the construction progress might wet up back side of the tiles and then smeared mortar, or directly smear mortar. Thus, technically, the following three working conditions should be considered: ① directly smear mortar in the back side of tiles; ② directly smear mortar in the back side after soak tiles in water for 24h; ③ drain tiles after soaking them in water for 24h and then smear mortar in the back side, and the detailed testing program can be seen in Table 1. Have mixing ratio experiment according to materials provided by the construction party, and the proportion of cement, sand and water is 3:1:0.9. After molding, smear them in processed small tiles (size of test piece: 95mm*45mm*10mm) and have pull-out test 28d later.

| Number | Mixing proportion | Wetting of tile surface |
|--------|-------------------|-------------------------|
| J1 (common mortar) | 1500 | 500 | 450 | Dry smear |
| J2 (common mortar) | 1500 | 500 | 450 | Directly smear mortar after soaking in water |
| J3 (common mortar) | 1500 | 500 | 450 | Drain surface after soaking in water, and then smear mortar |

| Number | Special tile mortar | Wetting of tile surface |
|--------|---------------------|-------------------------|
| T1 (special mortar) | 1000 | 450 | Dry smear |
| T2 (special mortar) | 1000 | 450 | Drain surface after soaking in water, and then smear mortar |

| Number (dry-hang glue) | Proportion (A:B) | Wetting of tile surface |
|------------------------|------------------|-------------------------|
| S1                     | 1:1              | Dry smear |

In addition, the field investigation indicated that main positions where tiles fell down were staircase and elevator with significant temperature changes. Therefore, the essay selected whole pieces of tiles as experiment objects and smear mortar in the back side of tiles. After standard curing of 28d, it had 10 times of freezing and thawing cycle tests: low temperature: -5 degree; freezing: 8h; thawing: 16h.

3. Test results and discussion

3.1. Adhesion comparison of different materials to tiles
According to the requirements of Adhesive for ceramic tiles and investigation JC/T 547-2005, anti-pulling strength of cementitious adhesive is bigger than 0.5MPa. According to the testing program in Table 1, the test results are as shown in Table 2.

| Number | Pulling damage load (KN) | Average value (KN) | Anti-pulling strength |
|--------|--------------------------|--------------------|-----------------------|
| J1     | 1.248                    | 1.664              | 0.37                  |
| J2     | 1.160                    | 1.072              | 0.28                  |
| J3     | 1.072                    | 2.400              | 0.53>0.5              |
| T1     | 3.432                    | 2.752              | 0.86>0.5              |
| T2     | 2.752                    | 3.600              | 0.76>0.5              |
Analysis by analyzing results of pulling tests:

① For anti-pulling strength of ordinary mortar, through dry smear and directly smear after soaking in water, adhesive force of mortar cannot meet standard requirements and the reasons include: water retention of ordinary mortar is weak. Tiles will absorb a small quantity of water after dry smear, causing decline of adhesion between mortar and tiles; after soaking in water, if smearing mortar when there are water in surface, there will be a “weak layer” between tiles and mortar. After soaking in water, if smearing mortar after draining tile surface, adhesive force will be improved, which is also proved by the test. To sum up, construction technology has a big influence on cohesive force of tiles and ordinary mortar.

② For anti-pulling force of special mortar, both dry smear or (smear after draining surface of soaked tiles) can meet standard requirements, and moreover, anti-pulling strength of dry smear is higher. Cause analysis: special mortar often has admixtures like Dispersible adhesive powder which can enhance adhesive force and water retention capacity of special mortar without wetting tile surface. If tile surface is wet, there will be a “weak layer”, thus reducing adhesive force of special mortar.

③ Comparison of whole pieces of tiles in adhesive force: binding force of dry-hang glue > binding force of special tile mortar > binding force of ordinary mortar.

④ According to the pulling damage test (see in table 3), we can know that common mortar hardly adheres to tiles and it directly crack in bonding parts of tiles; a little special mortar adheres to and cracks in the mortar layer; while adhesive force of dry-hang glue is relatively strong and parts of damages are structural adhesive which is used in later pulling damage test.

Table 3. Adhesion of different materials to tiles.

| Number | Picture | Description |
|--------|---------|-------------|
| 1      | ![Image](image1.png) | Cracks of ordinary mortar and tiles are in binding parts of mortar and tiles. The back side of tiles hardly has mortar. |
| 2      | ![Image](image2.png) | Cracks of special mortar are in mortar layers. The back side of tiles has mortar. |
Although strength of ordinary mortar which is made by field workers is higher (rebound strength of mortar reaches to 30MPa), its shrinkage and transformation are big. After molding, there will be cracks in surface of molded small test pieces (see in figure1), causing a weak binding force between mortar and tiles. However, since special tile mortar is added with water and additives such as thickening agent, the adhesive stress will be strengthened and there will be no cracks (see in figure1).

3.2. Influence of freezing and thawing test on adhesive force

Hollowing and falling of tiles often happen in places which have big temperature differences such as corridor and elevator, and they are not thoroughly solved through repeated repair, thus the writer designed a freezing resistance test for adhesive force. The test results are as shown in table 4.

![Figure 1. Adhesion comparison of ordinary mortar and special mortar to tiles.](image)

| Number | Pulling damage load (KN) | Average value (KN) | Anti-pulling strength (MPa) |
|--------|--------------------------|--------------------|-----------------------------|
| DJ1    | 1.400                    | 1.352              | 1.38                        | 0.32                        |
| DJ2    | /                        | /                  | 0.45                        | 0.11                        |
| DJ3    | 0.888                    | 2.456              | 1.67                        | 0.39                        |
| DT1    | 2.792                    | 1.720              | 2.41                        | 0.56>0.5                    |
| DT2    | 2.856                    | 3.112              | 2.824                       | 0.69>0.5                    |
| DS1    | 4.312                    | 4.544              | 3.851                       | 4.24                        | 0.99                        |

Note: / stands for that mortar directly falls down from tile surface, which cannot be measured.

According to table 4, we can see that after freezing and thawing cycles, adhesive force of common mortar has a sharp drop, and some even fall on its own, which is in line with actual problems in engineering. Although adhesive force of special mortar also declines, it can still meet standard requirements. In addition, adhesive force of dry-hang glue also declines, but its freezing resistance will not be assessed considering that it belongs to organic products.
In addition, since mortar and density and drying shrinkage of tiles are different, the writer selected whole pieces of tiles after adhered with mortar for freezing and thawing tests, and the test results are as shown in table 5 and figure 2.

**Table 5. Test results of big tiles.**

| Number | Pulling damage load (KN) | Average value (KN) | Anti-pulling strength (MPa) |
|--------|--------------------------|-------------------|---------------------------|
| J1     | /                        | /                 | /                         |
| J2     | /                        | /                 | /                         |
| T1     | / 0.288                  | 0.288             | /                         |
| T2     | 1.040 0.656 0.576 0.757 0.18 | 0.576             | 0.757 0.18 |

![Common mortar](image1) ![special mortar](image2)

**Figure 2.** Adhesion of mortar and tiles (whole pieces of tiles).

Compared with small test pieces, when using whole pieces of tiles, adhesive force of mortar will have a big drop – common mortar will directly shell and the back side of tiles hardly has mortar; and special tile mortar also shells. Cause analysis: there are big differences in transformation of mortar and tiles. When temperature has fierce changes, transformation differences will cause rapid decline of adhesive force of mortar.

4. Conclusion

Conclusions through comparative tests:

1. Common mortar can meet demands of tiles on adhesive force in earlier stages by adopting proper construction technology (smear mortar when tile surface gets wet and the water is not drained), but its long-term performance cannot be guaranteed.
2. Since special tile mortar is added with water retention and tackifying components, it can realize ideal adhesion effects by dry smear in construction.
3. For tiles with a big size, it is suggested to use dry-hang technology to guarantee durability of adhesive effects of tiles.
4. Since falling of tiles is a long process and that the writer adopted the method of freezing and thawing to measure adhesive effects of mortar and tiles will have a certain regularity in earlier stages, a large number of tests are needed to verify.

References

[1] Zhang Q H 2017 *Inner Mongolia Sci. Tech. Econ.* 3 146.
[2] Liu F L 2004 *Inner Mongolia Coal Econ.* 1 46-7.

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