METHODOLOGY OF NON-DESTRUCTIVE EVALUATION OF THE CEMENT TILES ROOF USING ULTRASONIC METHOD

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1. INTRODUCTION

A sharp increase in demand for housing has been observed in recent years. The demand was satisfied by developers or by individuals using the services of small construction firms. As a result of the rapid increase in the number of houses built, the demand for building materials increased dramatically. Trying to meet the market demand the manufacturers reduced the production stages to minimum. Consequently, low quality materials, often produced not in conformity with the manufacturing technology requirements, appeared on the market.

This paper deals with problems relating to cement tile roof coverings on new residential buildings in Central Europe. Nondestructive methods of testing roof tile cracks and paint coat thickness are presented. Also a methodology for such tests, based on the experience gained from the nondestructive testing of roof tile cracks and paint coat thickness, is proposed.

2. PROBLEM

The considered buildings are mainly low residential buildings (mostly up to a few floors high) with gable roofs covered with cement tiles. The condition of the roof coverings was assessed through site visits on a dozen or so buildings and through observations, detailed inspections, visual examinations, exposures and macroscopic measurements and examinations made in their course. The close inspections of the roofs in the buildings revealed the following recurring defects and damage:

- Some of the tiles were improperly secured – they did not fit tight in the interlocking joints (fig. 1a) and were loose. According to the tile manufacturer manual, they should fit tight in the interlocking joint, as shown in fig. 1b.
- Due to the improper fixing, clearances between tiles were visible from beneath.
- Some of the tiles were mechanically damaged. Most of the damage had the form of chips, small fractures and fine cracks, as shown in fig. 2. According to [7-10], “Roof tiles (…) should not fracture, disintegrate or crack”.
- The roof coverings did not form a uniform plane, some of the tiles jutted out and some roof areas sagged.
Fig. 1. Way of fixing tiles in interlocking joint [3]: a) on one of buildings, b) according to manufacturer manual.

Fig. 2. Mechanically damaged tiles [3]: a-e) chips, f) cracks.
3. CRACK TESTS AND THEIR RESULTS

In order to test the quality of roof tiles one can use standard tests and nondestructive tests. The latter are divided into tests without the use of nondestructive equipment (visual inspections during site visits) and with the use of nondestructive equipment.

Through the use of the standard tests [10] one can determine: suspension length, tiling width, flatness, weight, strength, water resistance, frost resistance and fastenings. But such comprehensive testing is not often used since it requires the use of laboratory equipment. Visual testing (nondestructive without the use of nondestructive equipment) [4] is commonly used to locate roof tile chips, small fractures and fine cracks (under good lighting conditions and from a small distance), as shown in fig. 2.

The depth of cracks can be determined using the ultrasonic method [5, 6]. First, a crack with known parameters, i.e. length, opening and depth of opening (fig. 3), was modelled in a tile taken from one of the roofs in order to calibrate the method. Nondestructive equipment, i.e. an ultrasonic concrete tester CT1 with 100 kHz exponential heads [1], was used for the tests. First, the head ends were placed on the part of the roof tile free of cracks to determine the average ultrasonic pulse travel time needed to calculate surface acoustic wave velocity $C_p$ and longitudinal wave velocity $C_L$. Then the cracked areas were tested. Figure 4 shows the results obtained for the modelled crack while the way of testing the crack is shown in fig. 5. Knowing the ultrasonic wave velocity (4500 m/s on the average) in concrete, one could calculate the crack opening depth [2, 6].

![Fig. 3. Roof tile with modelled crack and crack close-up.](image1)

![Fig. 4. Results in particular measuring point for modelled crack: a) ultrasonic pulse travel time, b) crack opening depth.](image2)
Fig. 5. Testing depth of cracks in roof tiles: a) surface arrangement of ultrasonic heads[3], b) crosswise arrangement of ultrasonic heads [3], c) testing shallow crack, d) testing through crack.

T – transmitting ultrasonic head, 
R – receiving ultrasonic head,
\( C_L \) – longitudinal ultrasonic wave velocity, 
\( C_p \) – surface ultrasonic wave velocity.
In the author’s opinion, during checking in-situ tests on site there is no need to calculate the ultrasonic wave velocity in each case or to precisely calculate the crack depth. It is enough to compare the ultrasonic pulse travel times for the same base (the distance between the heads) to determine whether the crack is superficial (pulse travel time about 25.0 µs), deep (pulse travel time about 28.1-28.5 µs) or a through one (pulse travel time above 35.0 µs). Shallow cracks (about 2-4 mm deep), similarly as ceramic tiles, could not be tested because the surface wave would pass through them with no noticeable change in velocity.

4. PAINT COAT THICKNESS TESTS AND THEIR RESULTS

The thickness of the paint coat on the roof tiles was tested using an ultrameter thickness gauge and additionally, a micrometer screw (for checking purposes). The way of testing the thickness of the paint coat on the tiles is shown in fig. 6. In order to determine what coat thickness should be obtained from the paint used for painting cement tiles a standard tile sample was made in a laboratory and 1-4 paint coats were applied to it. The test results are shown in table 1.

Table 1. Paint coat thickness results for standard sample.

<table>
<thead>
<tr>
<th>No.</th>
<th>Number of paint coats [-]</th>
<th>Paint coat thickness [µm]</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>44</td>
</tr>
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<td>89</td>
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<td>4</td>
<td>4</td>
<td>120</td>
</tr>
</tbody>
</table>

When one does not know what the paint coat thickness should exactly be, one can qualitatively assess whether the paint coat is uniform over the whole investigated area of roof tiles and determine the average paint coat thickness. Then it is enough to compare the measured paint coat thickness values with the average to indicate the places where the paint coat thickness is much below the average. In the considered case, the average paint coat thickness was 28 µm and in the places where paint coat thickness was below the average it amounted to 8-18 µm. Such places predominated in the tested roof. The laboratory tests showed that two paint coats (as required for the tiles) should add up to a thickness of about 44 µm.

Fig. 6. Testing of roof tile pain coat thickness: a) standard sample, b) roof tile.
5. DESCRIPTION OF PROPOSED TEST METHODOLOGY

On the basis of the experience gained and conclusions drawn from the tests, a methodology for testing the opening of cracks in cement roof tiles is proposed. The methodology is illustrated with the chart shown in fig. 7.

Fig. 7. Chart illustrating methodology for testing opening of cracks in cement roof tiles.

In order to test the depth of opening of cracks in cement tiles one should visually locate a crack in a roof tile. Then prepare the surface for testing, by cleaning the tile’s surface and blowing the crack through with compressed air. The head ends should be placed first on the tile’s part free of cracks and the average pulse travel time should be determined in order to calculate surface wave velocity $C_p$ and longitudinal wave velocity $C_L$. Then the time it takes the ultrasonic pulse to travel a measuring distance of 20 mm is registered at every 10 mm along the crack. Analyzing the data after each pulse registration one calculates the ultrasonic wave velocity and determines the crack opening depth defined as: zero opening crack, superficial crack (pulse travel time about 25.0 µs), deep crack (pulse travel time of about 28 µs), through crack (pulse travel time above 35 µs).
On the basis of the experience gained and conclusions drawn from the tests, a methodology for testing coat paint thickness was developed. The proposed methodology is illustrated with the chart shown in fig. 8.

In order to test paint coat thickness on cement roof tiles one should prepare their surface by removing impurities. A standard sample, to which respectively one, two and three paint coats will be applied, should be prepared. Thanks to the sample it will be possible to determine the proper thickness of a given paint coat. Then the paint coat is measured in at least five points, the data are analyzed and the paint coat thickness and its average value are calculated. The test is continued in ten to twenty more measuring points. The results are compared with the ones obtained from the standard sample and the paint coat thickness is determined as: one paint coat, two paint coats and three and more paint coats. If no standard sample is available, the average thickness of the coat paint is determined and the latter is qualitatively inspected to determine whether it is uniform in the whole tested area. Thereby one can find the places where paint coat thickness is much below the average and thus indicate the inadequately painted areas.
6. CONCLUSION

Problems relating to roof tile coverings have been presented using as an example new residential buildings. The problems were due to the use of low-quality cement roof tiles which when laid on the roof did not form a uniform plane, were incorrectly secured, mechanically damaged and inadequately painted.

It would seem that cement roof tiles fabricated in steel moulds should be free of defects connected with firing, have a uniform colour and a proper shape ensuring their proper laying on the roof. However, as practice shows this is not the case. In order to check the quality of cement roof tiles one could use the standard tests, but the latter are not very useful since the manufacturers do not reveal any details about their products, providing instead documents obtained from certified laboratories. It seems that nondestructive methods with or without the use of nondestructive equipment – and above all the ultrasonic method – are highly suitable for this purpose.

Also nondestructive methods of testing cracks and paint coat thickness in roof tile products have been presented. They are particularly useful in cases where no laboratory testing is available and no specifications of the products can be obtained from the manufacturer. On the basis of the experience gained in such testing a methodology of nondestructive testing of roof tile cracks and paint coat thickness has been developed.

REFERENCES