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EFFECT OF MANUFACTURING TECHNOLOGY ON QUALITY OF CERAMIC FLOOR TILES

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Abstract

Products manufactured for the building industry undergo inspection thanks to which they achieve better and better quality. However, there are situations in which inspection as stipulated in a standard provides incomplete information. The currently presented example of ceramic tiles pressed from the ‘dry’ input material illustrates the circumstance of poor matching between the standard inspection method and evaluation of actual product quality. It has been shown by the example of an industrial floor under regular operating conditions destroyed quite quickly even though the tiles were regarded by the inspecting persons as the items of the very good quality. In order to examine the homogeneity of material in tiles ultrasound method has been used. It allowed to prove that the quality of these products differs significantly from the standard evaluation which assessed them with respect to flexural strength in only one, middle cross-section. Pressing technology doesn’t ensure uniform input concentration along the entire surface and the standard inspection method provides an answer about its repeatability in only one cross-section. The ultrasound inspection of a large number of tiles enables immediate response to and correction of any variances in pressing technology. In case of a stationary inspection with workstation based on the ultrasound method, even segregation of manufactured tiles into various classes characterized by the different quality would be possible. Highest quality tiles could be used in structures with the higher loads, and tiles of relatively lower quality, but sufficient strength in other ones.

Key words

Ceramic tiles; Industrial floor; Compression Strength; Non-destructive Test Method; Ultrasound method

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1 INTRODUCTION

Control tests of manufactured products are aimed at ensuring their good quality. The method of testing depends on which product feature has an essential influence on their quality. In the manufacture of machine elements, important features usually include geometric dimensions controlled with appropriate accuracy using devices for linear measurement. The strength features of the material must be also controlled in an appropriate way, usually based on standard guidelines.

The subjects of interest in this study are ceramic tiles for industrial floors manufactured using a pressing method. Their strength, and as a consequence possible applications, depend both on the composition of ceramic substance, and on the effectiveness (degree of homogeneity) of substance compaction during the pressing process. Therefore, the method of controlling tile strength should be based on evaluating this feature in various cross-sections [1]. As it is stipulated in [2], such measurements are very important because mechanical properties of the tiles are not uniform across the whole surface. Standard control tests are not compliant with this requirement because they anticipate only destructive methods, consisting in breaking tiles in a strength testing machine. Using method given in [3], product strength is checked always in the same cross-section, over half of its length. Obviously the question arises whether there are any examples indicating that this testing method, as stipulated by the standard, is not sufficient?

2 EXAMPLES OF FLOOR TILES WEARING IN FACTORY HALLS

Floors in two industrial halls were tested. In one of the halls, a new floor was made using gres type ceramic tiles. This hall had not yet been used for production purposes. Only fork lift trucks without load had driven on the floor. In the other hall, the floor had been used for several years. Driving fork lift trucks were transporting large loads according to their destination. In addition, the floor was thermically loaded, rapid cooling occurred after opening of the gates through which fork lift trucks with manufactured goods were leaving.

The tile floors in both halls became damaged. To a smaller but essential extent in the new hall, and to a very high extent in the old hall. In the new hall, none of the tiles broke, while their corners and sides were quite commonly chipping off (fig. 1).

Fig. 1: Typical damage of ceramic tiles in the new floor

The floor used for the period of approx. 3 years showed significant damage (fig. 2), however the places of damage were similar (corners or end fragments of the tiles).

Fig. 2: Typical damage of ceramic tiles in the old floor

3 PURPOSE OF TESTING

Preliminary observations of the floors highlighted the material heterogeneity of the tiles. Following Romagnoli et al. [4], bending strength control, compliant with requirements of the standard [3] (fig. 3), does not answer the question regarding the distribution of strength homogeneity in the tile.

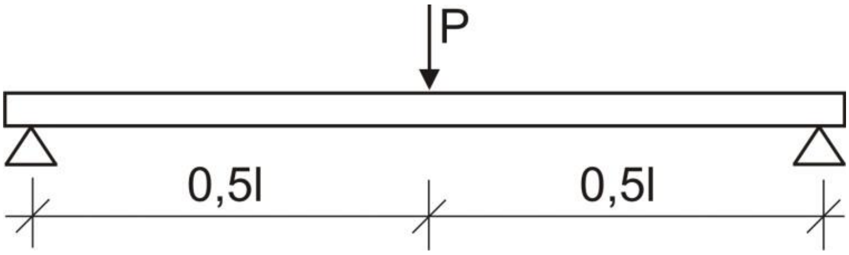

Fig. 3: Standard method of testing strength of ceramic floor tiles [3]

It was assumed that the main purpose of experimental tests was to determine strength of gres material in various tile cross-sections. Assuming that it is possible to answer the question formulated in this way, it would be also necessary to identify parameters which will allow qualifying of the product to the group of good or disqualified ones (to be rejected).

4 TESTING METHODOLOGY

When choosing the testing methodology, it was assumed that it should be possible to test tiles both in laboratory conditions on the producer's premises, as well as in the construction site when the tiles have been already built in the floor. Hence an ultrasound method was chosen with one-sided access to elements being tested, that is the surface ultrasound method [5, 6,7]. 12 measuring sections were marked on each test floor tile on which time of ultrasound impulse transfer was tested (fig. 4).

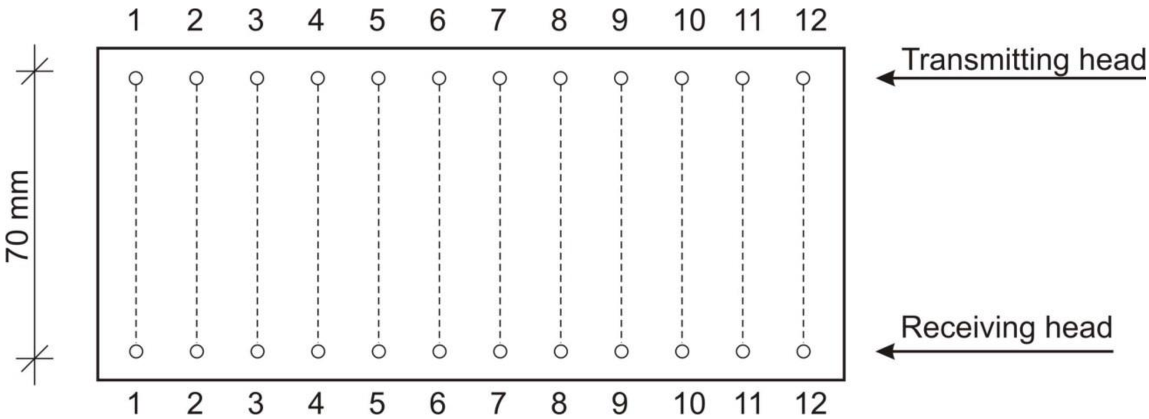

Fig. 4: Location of measuring sections in the pressed ceramic tile for surface ultrasound tests

'Spot' ultrasound heads, frequency of 40 kHz [7, 8, 9], were used for the measurements. The time of ultrasound wave transfer and ultrasound impulse velocity were determined along the constant route of l = 70 mm. Following the same principles, both tiles built in the floor (fig. 5) and purchased from the producer were tested.

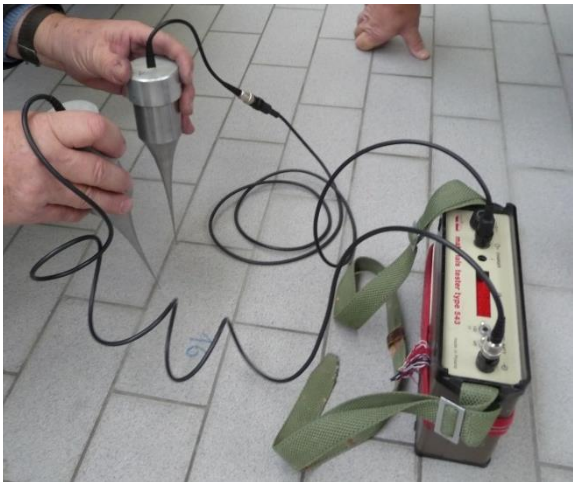

Fig. 5 Testing floor tiles in the industrial hall using ultrasounds

In total, 30 tiles in the floor and 6 purchased tiles (new) were examined. In the case of tiles built in the floor, only damages of corners and edges, shown in fig. 1 were visible. In the case of new tiles, it turned out that approx. 50% of elements in the package had other types of damages resembling stratification across the depth visible on their side edges (fig. 6).

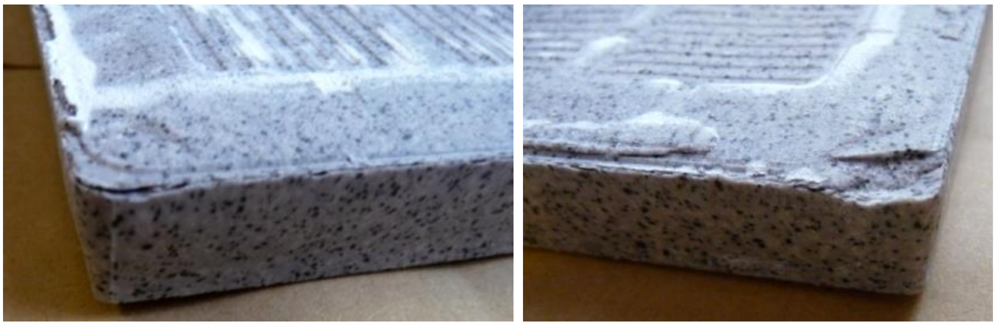

Fig. 6 Examples of new pressed 'gres' tiles with damages on side edges.

The damages shown were not regarded as defects by the manufacturer because they did not have any influence on the value of breaking force controlled according to the standard [3].

5 DISCUSSION REGARDING THE TEST RESULTS OBTAINED.

The conducted tests indicate that in tiles without damage, regardless of the fact whether they were built in or newly bought, change of surface wave velocity C_p in individual measurement sections was small. Figures 7 a and 7 b shows the examples of results of surface wave velocity tests in the measured sections of tiles without damage, that has been built in the floor. Figures 7 c and 7 d shows the examples of surface wave velocity in measured sections of the new, disused tiles without damage. Numbers of measurement sections along the tile lengths were shown on the vertical axis.

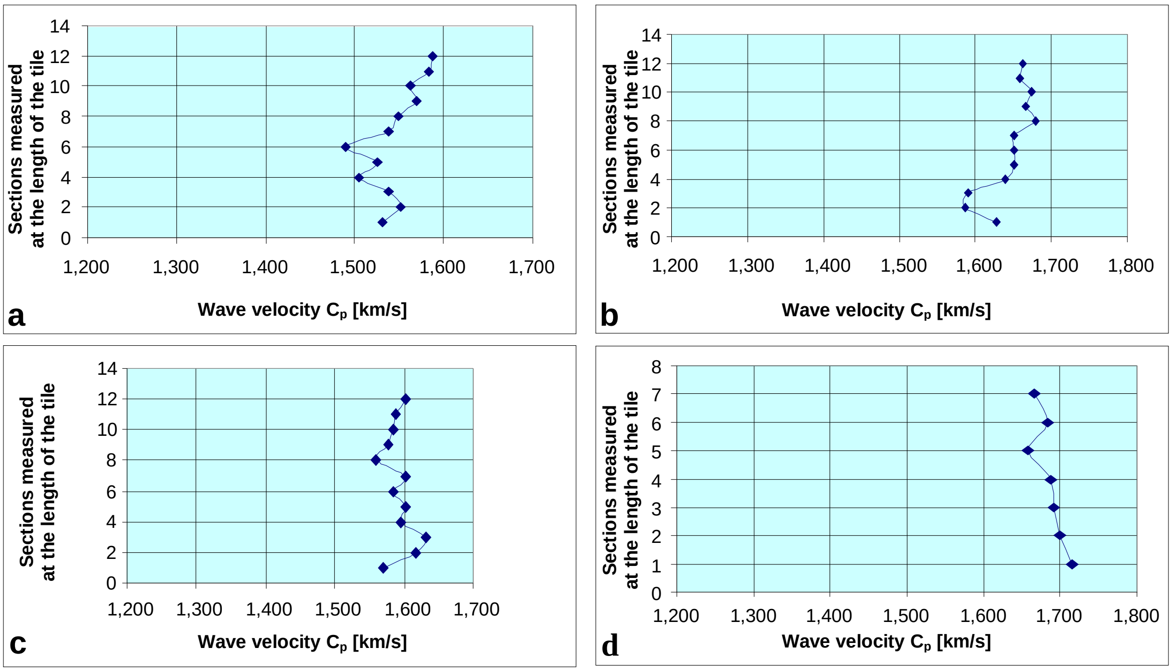

Fig. 7 Surface wave velocity C_P [km/s] in the 12 tested cross-sections along the length of 'gres' pressed tiles which did not have any damage: a, b – tiles built in the floor, c, d – new tiles. Standard deviation $S \leq 0,029$ km/s

The obtained charts indicate that these tiles have a relatively evenly compacted structure along their length. Even though velocities in each of them were not the same, the built in tiles did not get damaged. The tiles not built in also did not have any damage from the production stage. The difference of wave velocity C_p between the weakest and the strongest cross-sections (spread) did not exceed 100 m/s. Standard deviation didn't exceed the value of 0.029 km/s.

Figure 8 shows the examples of surface wave velocity in measured sections of built in the floor and new tiles with visible damages. Progress of velocity C_p that appears in tiles with damages is completely different than in tiles without damages. In tiles with damages there was always the tendency of change in wave velocity C_p coming from one end of the tile to the other end.

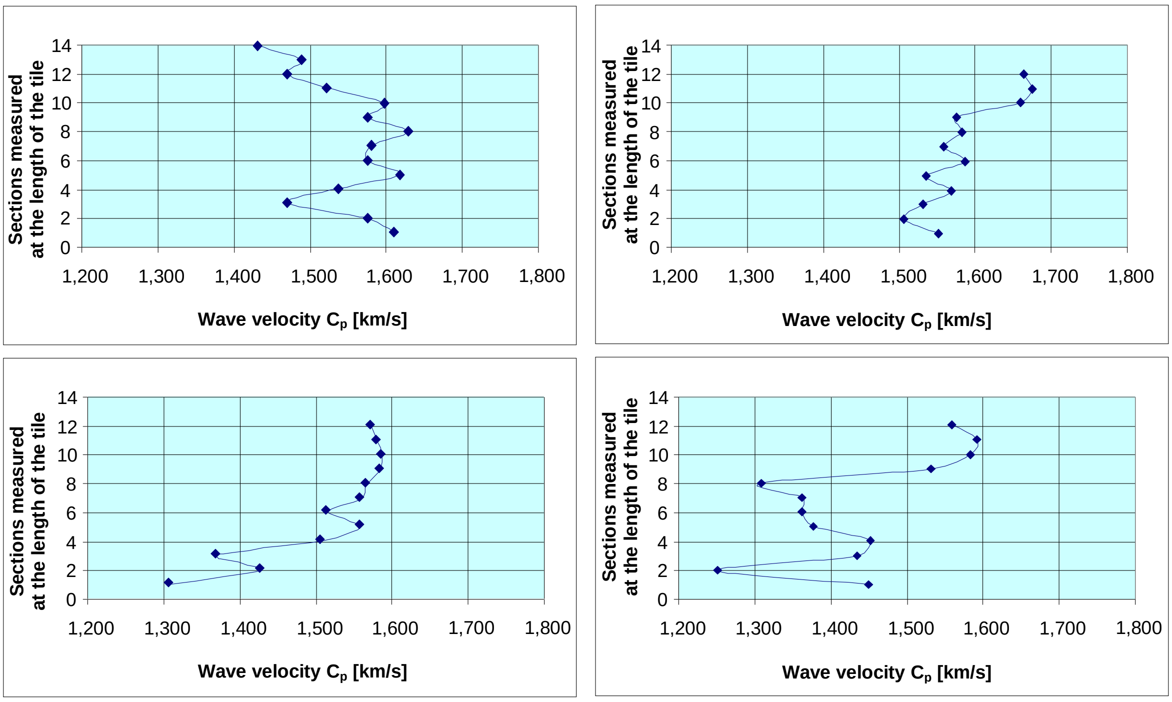

Fig. 8 Surface wave velocity C_p [km/s] along the length of pressed tiles in which damage occurred. S >> 0,03 km/s

The difference of velocity between the highest and the lowest value is much higher than in tiles without damage, it was 200 – 300 m/s. Standard deviation reached the value of 0.080 km/s. The nature of ultrasound velocity changes presented in fig. 8 indicates uneven pressing of ceramic substance in the mould which undoubtedly shows the need to improve the pressing method.

In some tiles another tendency was noticed, namely weakening of gres structure which appeared on their both ends. Chosen examples of wave velocity measurements in sections of that kind of tiles has been shown on fig. 9. Number of measuring sections on each tile has been lowered down to 7.

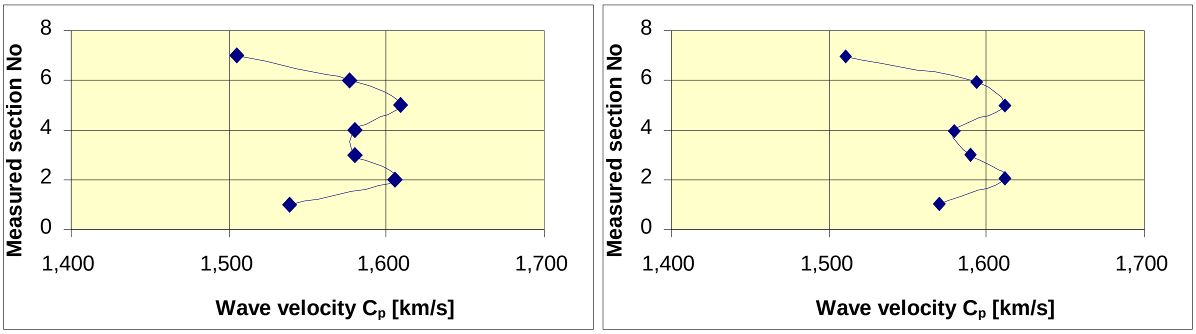

Fig. 9 Examples of tiles with less compacted areas near both ends.

Lower strength of gres in the final sections of tiles results with lower velocity of ultrasound waves near their edges parallel to the measurements direction. It can be assumed that lower compaction of the material on the ends was caused by higher susceptibility of the mould sides or smaller quantity of the material in these areas before pressing. The latter cause seems more probable. Elimination of it leads also to interference in the technological manufacturing process.

Undoubtedly, the most convincing interpretation of the results is obtained by graphic presentation of them in the charts (fig. 7- 9). Statistical parameters, such as: spread, arithmetic mean and standard deviation, also characterize well quality of the tested floor tiles.

6 SUMMARY AND CONCLUSIONS FROM THE TESTS

The presented ultrasound tests regarding quality of gres type floor tiles have the features of a universal method because they allow testing of these products both after manufacture and after building in. It was established in the described experiment that the tested products were of very good quality, if the spread of surface wave velocity ΔC_p did not exceed 100 m/s. In tiles with defects, the spread was in the order of 200 – 300 m/s. Standard deviation for very good tiles did not exceed the value of 0.029 km/s, for damaged tiles and tiles with defects it reached the value of 0.080 km/s that is it was almost three times higher. When correlation dependence is determined between ultrasound wave velocity C_p and strength of the tested materials $f_c = f(C_p)$, the strength of gres in the given cross-section as well as force breaking the tile can be established, if the purpose is to refer to the current standard. The test is very easy and non-destructive, after the test the tile can be qualified to an appropriate class or can be rejected, if it does not fulfil the requirements.

In [10, 11, 12] authors emphasises that nowadays, it has become increasingly evident that it is also practical and cost effective to expand the role of nondestructive evaluation to include all aspects of materials production and application. The presented control method allows revealing of material defects which are not detected using the conventional destructive method. When it is first used by the producer, production technology can be improved because it detects pressing defects. If used in the ongoing production control, it allows dividing of products into classes suitable for different values of loads. Such case as described in the study could not have happened, if the described test method had been used.

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