CHARACTERISATION OF FROST DAMAGE TO CERAMIC TILES IN SLOVENIA

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ABSTRACT

One of the important properties of building products is durability. Ceramic building products, including ceramic tiles for outdoor use, have to be frost resistant in order to have a long service life. Different types of laboratory tests can be performed to determine the frost resistance of ceramic tiles: at the Slovenian National Building and Civil Engineering Institute frost resistance tests on ceramic tiles are performed according to the standard EN ISO 10545-12. On the basis of the results of several years experience of performing frost resistance tests on ceramic tiles, an attempt has been made to characterize the frost damage occurring during these tests in relation to the manufacturing factors which influence the reaction of the material to frost action. Some cases of frost damage in situ are also presented.

KEY WORDS: frost resistance, frost damage, ceramic tiles, durability

INTRODUCTION

The durability of building materials depends on several different variables; one of which is the material's frost resistance. Two main factors influence this resistance: the climatic conditions to which the material is exposed and the reaction to frost action of the material.

There is no generally accepted theory which could describe how frost damage occurs, but there is general agreement that both a high moisture content (i.e. a high degree of saturation) and low temperatures are required.[1] The climatic conditions which characterize a typical frost-damaging winter could consist of several days of heavy rain followed by low temperatures.[1, 2, 3] According to the records of the Hydrometeorological Institute of Slovenia, Slovenia has very heterogeneous climate conditions: there is a continental climate in the north-east, a severe alpine climate in the Alps, and a sub-Mediterranean climate in the south-west. The mixing of all these effects results in large changes in weather conditions within small areas, over short periods of time. In such an environment the possibility of ceramic products being frost-damaged during the winter is high. Porous materials may be saturated with water, and when the temperature drops to 0°C the freezing process begins. When water freezes, it expands, and if insufficient space is available the rising pore pressure can cause serious damage to the material.

How ceramic building materials, such as ceramic tiles for outdoor areas, clay roofing tiles and facing bricks, react to frost action depends on several different variables, such as the effect of the material, its composition and properties and the effect of production methods[4]. The suitability of clay for manufacturing a frost-resistant product depends mostly on the type of clay minerals present, and on the mineral content and particle size distribution. During manufacturing processes the technological parameters of shaping, drying, firing, and cooling, may introduce certain faults or weaknesses, which can determine the final frost resistance of the product.[5] All these variables influence the nature of the ceramic body – the pore size and size distribution, the pore shape, and the strength of its structure[6], as well as the nature of the surface layers (especially in the case of glazed ceramic tiles).

In order to predict the frost resistance of a ceramic product which is constantly exposed to weathering, in our case ceramic tiles for external cladding, certain laboratory tests have to be performed. The available test methods may be divided into two groups: direct testing and indirect testing. Direct testing makes use of repeated freezing-thawing cycles in a climatic chamber, according to different standard methods which simulate naturally occurring weather conditions. Indirect testing is based on the fact that pore structure and pore size distribution have a major effect on the behaviour of materials when exposed to freezing and thawing. Such tests can be used to predict whether or not the material will suffer frost damage.

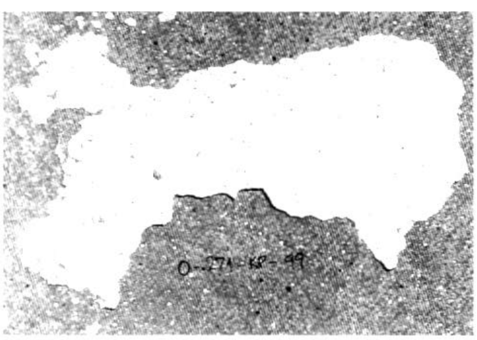
LABORATORY TESTS

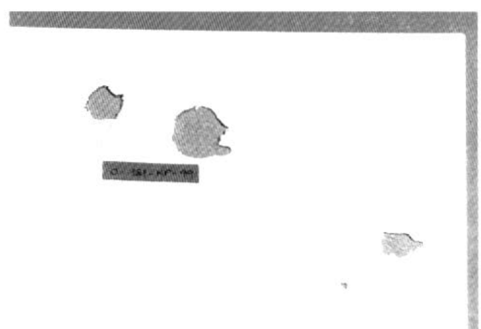
A series of dry-pressed and extruded ceramic tiles with a water absorption of less than 3% were exposed to freezing-thawing cycles according to the standard method EN ISO 10545-12. After impregnation with water, at an air pressure lowered by 60 kPa, the tiles were subjected to freezing-thawing cycles. In each cycle the temperature was lowered to below –5°C at a rate not exceeding 20 °C/h. The minimum temperature was maintained for 15 minutes. The tiles were then immersed in water at a temperature of +5°C for next 15 minutes. In each test 100 such cycles were performed.

RESULTS

All of the types of frost damage observed in the laboratory tests can be classified into four major groups: peeling, chipping, crazing and lamination.

The most commonly detected type of damage observed on the dry-pressed glazed ceramic tiles after the freezing-thawing test was peeling of the glaze. In Figures 1, 2 and 3 large-scale peeling of the glaze of some tiles from BIb group, having a water absorption between 2 and 3%, can be seen. In Figure 4 the beginning of peeling of the glaze of ceramic tiles from group BIa, having a water absorption of 0.1%, is shown. The reason for this damage was probably the lack of adherence between the glaze and the ceramic body. Water entered the free space under the glaze, froze and then expanded. There was an increase in the pressure on the glaze from below, which caused separation of the glaze from the ceramic body surface, i.e. peeling. It was observed that the glazed ceramic tiles with a water absorption of between 0.5 % and 3 % (Figures 1, 2 and 3) suffered more extensive peeling damage than the glazed ceramic tiles with a water absorption below 0.5 % (Figure 4). The reason for such behaviour may be the lower firing temperature for products with a higher water absorption. At such temperatures hardly any melting takes place, and only dry sintering occurs.[5] This process leads to a rather weak bond between the ceramic body and the glaze surface, which can after exposure to severe conditions result in frost damage. The reason for peeling of the glazed surface, especially of porcelain ceramic tiles, may also lie in the second firing of the glaze. The thin layer between the ceramic body and the glaze surface can therefore be considered as the "weak point" of glazed ceramic tiles regarding to frost resistance.





Figures 1, 2, 3: Peeling of the glaze of ceramic tiles group BIb after frost resistance test.

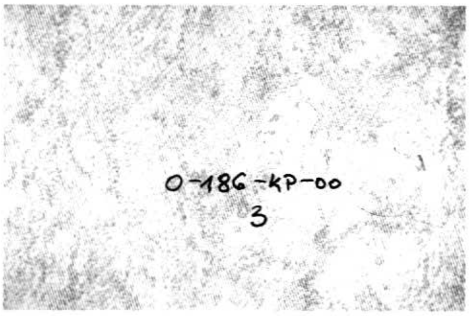
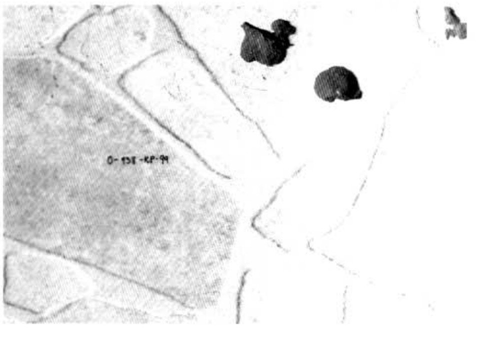


Figure 4: Peeling of the glaze of ceramic tiles group BIa after frost resistance test.

The second major group of detected frost damage was chipping, i.e. the breaking-off of cone-shaped pieces of tile consisting not only of the glaze but also of the ceramic body. This type of damage is presented in Figures 5 and 6. This type of damage is probably due to an increase in the volume of water that has penetrated into the ceramic body when the tiles were subjected to freezing. When water inside the pores freezes, the ceramic body is subjected to a considerable tensile forces, which can lead to damage.



Figures 5, 6: Chipping - frost damage to dry-pressed glazed ceramic tiles after frost resistance test.

The glazed ceramic tiles which were exposed to freezing-thawing tests also suffered crazing damage, which can be seen, in Figure 7. This type of damage is probably caused by the stresses which occur, under severe exposure conditions, due to the different coefficients of expansion/contraction of the glaze and the clay body. As a result a network of hairline cracks occur on all or part of the glazed surface of the tile. After further exposure of such damaged tiles to cycles of freezing and thawing, other types of damage, such as chipping, may also occur.

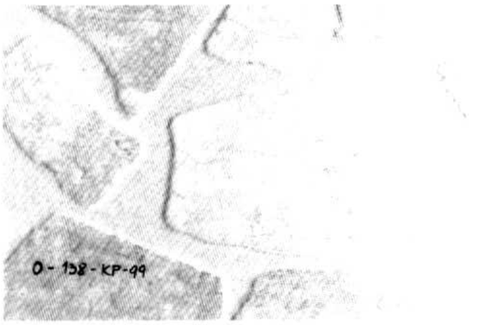
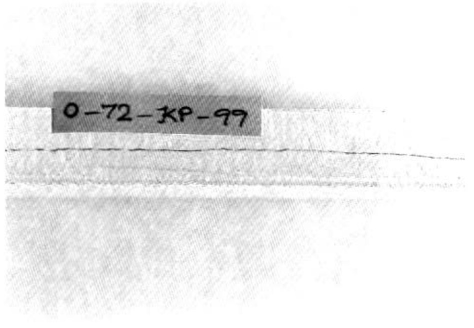
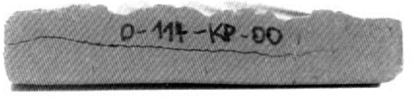


Figure 7: Crazing of glaze of dry-pressed glazed ceramic tiles after frost resistance test.

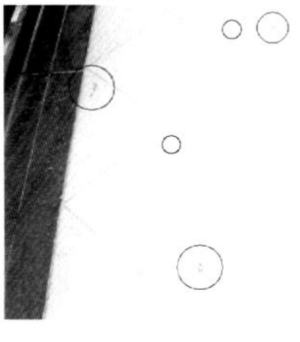
Figures 8 and 9 show damage in the form of lamination of the ceramic body of extruded unglazed tiles. In these cases the damage was probably due to the shaping process, because in general ceramic tiles of this type are frost resistant. The extrusion process may have resulted in a laminated structure. In this process the degree of de-airing and the time between the shaping and drying are very important factors.[5] The result, after freezing and thawing cycles, was a de-lamination of parallel layers.

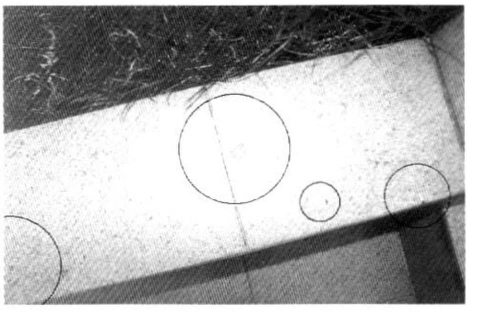




Figures 8, 9: Lamination of extruded unglazed ceramic tiles after frost resistance test.

As already stated, laboratory frost resistance tests are performed in order to detect non-frost resistant products. However, not all non-frost resistant ceramic tiles can be detected because the reliability of frost resistance tests is not absolute. Even though many ceramic tiles are subjected to laboratory tests, many cases of frost damage still occur in situ. In Figures 10 and 11 two examples are presented of cases of frost damage to dry-pressed glazed ceramic tiles, which had been declared by the manufacturer as suitable for outdoor areas, and had been installed as cladding for a balcony and for a path around a house.





Figures 10, 11: Frost damage to dry-pressed glazed ceramic tiles in situ.

CONCLUSIONS

Four types of frost damage were observed on the ceramic tiles which were subjected to frost resistance tests: peeling, chipping, crazing of the glaze, and lamination of the ceramic body. All these different types of damage are typical for the reaction of ceramic tiles to frost action, and they are related to many different variables such as the type of raw material, its preparation, and the technological parameters of shaping, drying and firing.

Also, during the manufacturing process certain faults may occur in the material, which result in its poorer resistance to frost.

Laboratory freeze-thaw tests can be used to detect non-frost resistant ceramic tiles, but unfortunately the reliability of such tests is not absolute. It is very difficult to evaluate the frost resistance of ceramic tiles according to only one test, especially regarding the length of their service life. This is because the whole system, not only the tiles but also the other materials used for installation of the tiles, must be frost resistant, and properly installed.

LITERATURE

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