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Accelerated Ageing Tests of Clay Roofing Tiles under Salt Mist Atmosphere

Cláudio Cruz [1]
Maria do Rosário Veiga [2]
Victor M. Ferreira [3]

ABSTRACT

Clay roof tiles are largely used in traditional construction in Portugal and other countries. Due to the exposition to a salt mist atmosphere, some cases of accelerated decay have been affecting the ceramic roofing tiles durability in coastal zones.

This paper presents two types of accelerated weathering tests of clay roofing tiles in a climatic chamber. In both of these tests the specimens are subjected to an atmosphere of salt mist produced by a NaCl solution spray.

The first is a simple cyclic test with each cycle consisting of a salt mist period and a drying period. The second is a composite test consisting of several phases. Each phase consists of several simple cycles followed by a large drying period. In each phase the specimens are subjected to cleaning and wetting operations.

The results obtained were discussed and compared. Accelerated ageing tests can cause different levels of alteration and degradation of the same types seen in natural exposed ceramic tiles. The composite test induced more degradation on the specimens than the simple cyclic test. Hydrophobic surface tiles may resist longer to salty mist but they can suffer higher damage than non-hydrophobic tiles. Some parameters as the raw materials and the firing temperature can influence the behaviour of the tiles under salt mist. Characteristics as the water absorption under vacuum and the porous structure may give some information about the relative durability of different types of tiles.

KEYWORDS

Clay roofing tiles, Accelerated weathering tests, Salt mist atmosphere, Durability.

[1] National Laboratory of Civil Engineering (LNEC), Buildings Department, Lisboa, PORTUGAL, ccruz@lnec.pt
[2] National Laboratory of Civil Engineering (LNEC), Buildings Department, Lisboa, PORTUGAL, rveiga@lnec.pt
[3] University of Aveiro (UA/CICECO), Civil Engineering Department, Aveiro, PORTUGAL, victorf@ua.pt

1 INTRODUCTION

Clay roof tiles are largely used in traditional construction in Portugal. In coastal zones some cases of accelerated decay have been affecting the roofing tiles durability, apparently due to the exposition to a salt mist atmosphere.

The crystallization of soluble salts is considered one of the main causes for the degradation of porous construction materials [Rodrigues and Gonçalves 2006]. In spite of NaCl crystallization can cause severe damages in service situations, it has been difficult to obtain the same level of degradation in artificially accelerated laboratory weathering tests, as noted by several authors [Gonçalves 2007, Lubelli 2006, Goodie & Viles 1997], which present some reasons that can explain that discrepancy.

To evaluate the performance of the clay roofing tiles subjected to a sea environment, an experimental study was carried out [Cruz 2010] based on artificial accelerated weathering tests. The study includes the development of accelerated weathering tests and aims at reproducing the pathology mechanisms observed in real conditions.

The study of the accelerated weathering tests of several kinds of tiles also aims at identifying the parameters having a higher contribution to the decay of roofing tiles.

2 MATERIALS AND METHODS

2.1 Test Specimens

The specimens were prepared through transversal cuts of the tiles. Specimens cut from the mid transversal area of the roofing tiles were preferentially used, having the width of the tile and circa 9 cm length (Fig. 1). The cut faces of the specimens were sealed with epoxy resin. Roofing tiles of two manufacturers (F1 and F2) were used. From manufacturer F1 three types of tiles of the same model 1 were used: F1 NH - model 1, non-hydrophobic red tiles; F1 B - model 1, non-hydrophobic white tiles and F1 H - model 1, hydrophobic red tiles. From manufacturer F2 five types of tiles of three models were used: F2 NH - model 1, non-hydrophobic red tiles; F2 B - model 1, non-hydrophobic white tiles; F2 H - model 1, hydrophobic red tiles; F2 T2 NH - model 2, non-hydrophobic red tiles and F2 T3 NH - model 3, non-hydrophobic red tiles. The tiles were fired at a maximum temperature between 950 ºC and 1050 ºC, with thermal cycles of 15 hours to 48 hours. They have thicknesses of 10 mm to 14 mm.

Figure 1. Specimens before and during tests

2.2 Artificial Accelerated Weathering Tests

Two types of tests were designed based on the European Norm EN 14147:2003 and adapted to what was thought to be realistic conditions for this product [Cruz et al, 2007]. These tests were carried out in a climatic chamber where the specimens are subjected to sets of cycles of wetting under salt mist atmosphere and subsequent drying. Salt mist is produced by spraying a salt solution into the chamber with a concentration of 110g of sodium chloride per litre of de-ionised water.

The first type of test is a simple cyclic test – simple weathering test – consisting of several 24 hours cycles (8 hours of salt mist + 16 hours of drying) with the temperature in the chamber maintained at 35ºC. For each type of tiles, one or two specimens were subjected to 10 cycles, another one or two to 20 cycles and three or four to 30 cycles [Cruz et al., 2008]. Since the degradation development stopped in the last salt mist/drying cycles, other operations rather than continue with more cycles should have been done to obtain higher degradation levels.

So, a second type of test – composite weathering test – was developed, taking into account the results of the previous simple test and designed to simulate different weathering actions, in several phases. Only specimens from the non-hydrophobic tiles (F1 NH, F1 B, F2 NH, F2 B, F2 T2 NH and F2 T3 NH) were subjected to the second type of test.

In the composite weathering test the cycles have the same 24 hours (8 hours of salt mist + 16 hours of drying) of the simple cyclic test. The temperature in the chamber was raised from 35ºC to 50ºC to obtain a higher level of drying in each cycle. The composite test consists of four phases of several 24 hours cycles followed by a large drying period, intended to promote the increase of degradation in the subsequent cycles. In some phases the specimens were subjected to cleaning with a dry brush to simulate the wind effect on the roofs. In one phase the specimens were subjected to a water spray followed by cleaning with a wet brush to simulate the rain and wind effect on the roofs.

So, the composite test was constituted by four phases with the following constitution and sequence of operations:

Phase 1:
- 13 cycles of 24 hours in the climatic chamber at 50ºC (8 hours of salt mist + 16 hours of drying)
- 10 days of drying in the climatic chamber at 50ºC

Phase 2:
- 10 cycles of 24 hours in the climatic chamber at 50ºC (8 hours of salt mist + 16 hours of drying)
- Dry cleaning with a brush
- 11 days of drying in the climatic chamber at 50ºC

Phase 3:
- 11 cycles of 24 hours in the climatic chamber at 50ºC (8 hours of salt mist + 16 hours of drying)
- Dry cleaning with a brush
- Wetting with water and cleaning with a wet brush
- 20 days of drying in the climatic chamber at 50ºC

Phase 4:
- 15 cycles of 24 hours in the climatic chamber at 50ºC (8 hours of salt mist + 16 hours of drying)
- 44 days of drying in the chamber at 50ºC
- Dry cleaning with a brush
- 30 days of drying in the climatic chamber at 50ºC

3 RESULTS

3.1 Visual Assessment

Visual inspection results (Table 1, Table 2, Table 3 and Fig. 2) demonstrate different types and levels of degradation caused on the specimens by the weathering tests. Alterations and degradations are of the same types seen in natural exposed ceramic tiles.

In the cyclic test hydrophobic specimens didn't show immediate defects but some of them suffered huge degradation following the access of the salty solution to the material under the protected surface. Hydrophobic tiles from manufacturer 2 seem to be more resistant to weathering than those from manufacturer 1.

In the cyclic test non-hydrophobic tiles, both red and white, showed low to medium degradation levels characterized mainly by pitting, some disaggregation and peeling, with a slightly higher level in the white ones.

In the composite test all of the specimens tested (only the non-hydrophobic ones) suffered higher degradations levels than in the cyclic test. Regarding F2 B specimens, they showed lower level of pitting, granular disaggregation and peeling than in the cyclic test, but they had other types of degradation that are localized and are potentially more severe.

Table 1. Alteration and degradation examples of manufacturer 1 specimens.

Specimens	*Cyclic test*	*Composite test*
F1 NH		
F1 B		
F1 H		Not tested
F1 H		Not tested

Table 2. Alteration and degradation examples of manufacturer 2 specimens.

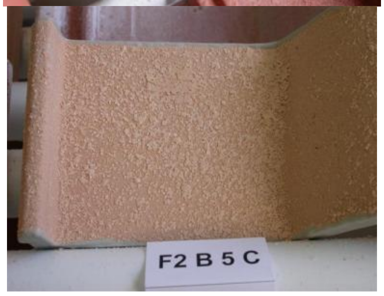
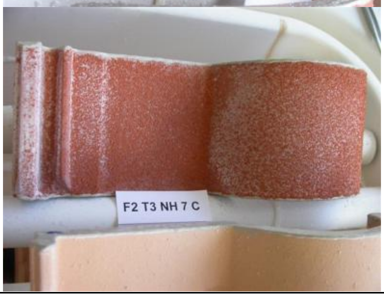
Specimens	*Cyclic test*	*Composite test*
F2 NH		
F2 B		
F2 H	None	Not tested
F2 T2 NH		
F2 T3 NH		

Figure 2 shows some examples of a higher degradation level (Delamination) and of localized degradations (Fissure/Fracture/Spalling) caused by the composite test.

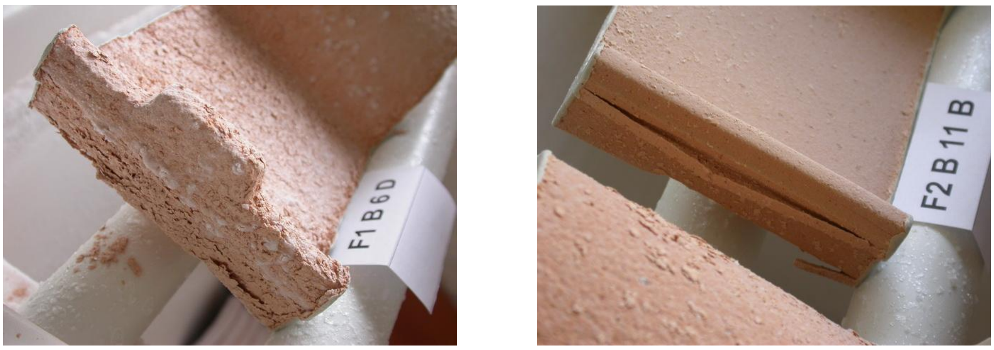


Figure 2. Delamination and Fissure/Fracture/Spalling caused by the composite test

Table 3. Alteration and degradation forms caused by the weathering tests.

Specimens	*Cyclic test*	*Composite test*
F1 NH	Pitting Granular disaggregation	Pitting Granular disaggregation Peeling Fissure / Fracture / Spalling
F1 B	Pitting Granular disaggregation Peeling	Pitting Granular disaggregation Peeling Fissure / Fracture / Spalling Delamination or Flaking
F1 H	None Fissure Bowing Plaquettes	Not tested
F2 NH	Pitting Granular disaggregation	Pitting Granular disaggregation Peeling Fissure / Fracture / Spalling
F2 B	Pitting Granular disaggregation Peeling	Pitting Granular disaggregation Peeling Fissure / Fracture / Spalling
F2 H	None	Not tested
F2 T2 NH	Pitting Granular disaggregation Peeling	Pitting Granular disaggregation Peeling Bowing Plaquettes Fissure / Fracture / Spalling
F2 T3 NH	Pitting Granular disaggregation Peeling	Pitting Granular disaggregation Peeling

4 RESULTS AND DISCUSSION

Visual inspection results demonstrate different types and levels of degradation caused by the two types of weathering tests on the specimens. As seen in the simple cyclic test, hydrophobic specimens don't show immediate defects but they can suffer huge degradation if the solution can pass through the protected surface. Hydrophobic tiles from manufacturer 2 seem to be more resistant to weathering than those from manufacturer 1.

In the simple cyclic test non-hydrophobic tiles, both red and white, show low to medium degradation levels, with a slightly increased level in the white ones. With the changes and new operations introduced in the composite test it was possible to achieve higher levels of degradations.

With the increase of the chamber temperature from 35ºC to 50ºC a higher level of drying was obtained in each cycle. As a consequence a higher level of degradations in the majority of the specimens was visible in the cycles of the first phase. The 50ºC temperature is consistent with summer conditions, where temperatures on coloured exposed surfaces may easily reach those values, or even higher.

The degradation development stopped in the last salt mist/drying cycles of the several phases of the composite test, just as it had happened in the last cycles of the cyclic test. The introduction of a large continuous drying period between the cycles of phases 1 and 2 allowed the reduction of the level of humidity of the specimens. In consequence, in salt mist/drying cycles of the phase 2, an increase of degradation was observed again. The long drying period is also a realistic action, correspondent to warm dry periods in summer.

With the cleaning with a dry brush, to simulate the wind effect, and the water spraying of the specimens and the cleaning with a wet brush, to simulate the rain and wind effect, the surfaces of the specimens were washed out and a degraded and cleaned surface was subjected to new cycles of salt mist/drying. The particles resulting from the degradation in these cycles had smaller dimensions than the materials resulting from the degradation on the previous phases. So, it was possible to observe different behaviour between the superficial and the internal materials of the specimens under the salt mist/drying cycles.

With the continuation of the composite test new forms of degradations were obtained, such as localised degradations beginning with fissures that evolve to fractures and spalling. These defects, despite being localized, can be of higher consequences, as they can reach the thickness of he tiles and have an effect on the water tightness of the tiles and of the roof.

Regarding F1 B specimens, the continuation of the composite test caused delamination or flaking. This is a progressive loss of material in the form of thin blades that can reach, as the localised degradations, all the thickness of the tile.

The composite test shows the influence of weathering changes, in particular high temperatures and of driven rain, on the durability of ceramic tiles. It simulates a sequence of weather actions commonly occurring in coastal zones of Portugal, where salt mist, high temperatures, wind and rain happen in natural cycles.

5 CONCLUSIONS

Artificially accelerated weathering tests composed of cycles of wetting with a salty mist and subsequent drying can be used to cause different levels of artificial weathering alteration and degradation to different ceramic roofing tiles. These defects are of the same types seen in natural exposed ceramic tiles.

In the composite test the degradations obtained were of the same types of the obtained in the simple cyclic tests, in many cases reaching a level of higher degradation, and also other defects of more critical types. For that it will have contributed the increase of the temperature of operation of the climatic chamber and the increase of the number of cycles salt mist/drying.

The introduction of long drying periods between the cycles in the composite and the dry and wet cleaning of the surfaces contributed to the continuation of degradation development. These operations try to reproduce the effects of natural events as wind, rain and long periods of dry weather.

The study [Cruz, C. 2010] allowed the identification of some characteristics and properties that can influence in the durability of the ceramic tiles subjected to marine atmosphere.

Hydrophobic tiles may resist longer to salty mist but they can suffer high damage if there is some penetration of salty solution.

White tiles showed higher levels of degradation than the non-hydrophobic red ones, so the raw materials (higher CaO contents in the white tiles) can influence in the durability. White tiles have higher absorption of water under vacuum and higher porosity than the red ones of the same manufacturer, although not always show higher absorption of water by immersion.

An accelerated ageing test of clay roofing tiles under salt mist atmosphere was thus obtained and validated, permitting to evaluate the durability of ceramic tiles on a comparative basis. The influence of some climatic conditions was assessed, making it possible to identify particularly risky conditions. This test will also make possible the realization of parametric studies to evaluate the influence of several parameters of composition and manufacture in the durability of roofing tiles under salt mist atmosphere.

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