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Performance of External Thermal Insulation Composite Systems (ETICS) with Finishing Ceramic Tiles

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ABSTRACT

External Thermal Insulation Composite Systems (ETICS) are innovative systems; their application improves the buildings' thermal insulation, reduces thermal bridges, protects the walls from temperature variations thus increasing the structure durability. They enable the application of a diversity of finishing materials.

Ceramic tiles finishing, which are very traditional in Portugal, can improve the impact resistance of those systems.

The assessment of ETICS performance and durability is carried out based on "ETAG 004 – Guideline for European Technical Approval of External Thermal Insulation Composite Systems with rendering", that establishes requirements and test methods.

However, systems with ceramic tiles finishing are not covered by ETAG 004. Therefore, it is necessary to adapt test methods and requirements for this type of systems.

This paper presents an assessing methodology for performance of External Thermal Insulation Composite Systems (ETICS) with ceramic tiles finishing and its application to a specific system. An experimental campaign is being carried out and tests of bond strength in ETICS after natural weathering were already performed and are presented. Those tests measure bond strength between base coat and insulation board and between tiles and base coat.

KEYWORDS

Assessment methodology, Thermal insulation systems, ETICS, Finishing ceramic tiles.

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1 INTRODUCTION

External Thermal Insulation Composite System (ETICS) are applied in opaque areas of facades and contribute significantly to energy efficiency. These solutions contribute for the increase of thermal insulation, the correction of thermal bridges and the reduction of interior condensations. ETICS also have the function of protecting the structure and the masonry from thermal impact, thus increasing the durability of these elements.

The ETICS are considered multi-component systems [Collina & Lignola 2010] applied on external walls, composed by insulating boards fixed to the substrates by a bonding material or by mechanical elements, a mesh embedded in the base coat and a finishing coat with decorative functions and of complementary water and impact protection.

The compatibility between the different components is essential for the good performance of the global system, contributing for its durability [VEIGA & PINA SANTOS 2009 e COLLINA & LIGNOLA 2010].

In these systems a diversity of finishings can be applied: paintings, synthetic coverings, mineral binder finishings such as silicates or cement. It is also possible to use discontinuous coverings, like ceramic tiles, stone slabs or of another nature, although these kinds of finishing are not covered by ETAG 004 [EOTA 2000]. The use of ceramic elements on external walls has a large tradition in Portugal. On the other hand, this kind of finishing presents good impact resistance and improves the behavior to fire, contributing for the satisfaction of the requirements of fire safety.

ETICS can be fixed to substrate by bonding or by mechanical elements or by both methods. Bonding is the most used type of fixation, and usually the product used as base coat can also be used as adhesive; bonded systems can also be used with some supplementary mechanical fixings (for example anchors), that according to MORAIS [2007] enable the fixation of thermal insulation boards until the set of the adhesive product. In the mechanical fixation systems, the connection of the insulation boards to the substrate can be constituted by direct anchors or by profiles (for example metallic non-oxidable material). The mechanical fixed systems can include or not complementary adhesive [EOTA 2000]. Choosing the fixing process to the support through vertical profiles allows the existence of a blade of air, allowing the elimination of the risk of condensation in the thermal insulation. However, they are more sensible to the wind pressure due to the suction effect.

ETICS can be applied on masonry of clay units, cement blocks or stone, or on concrete substrates (either cast in situ or prefabricated) [EOTA 2000]; however, they should not be applied on thick and porous old walls, especially if they have high water content, as it would retard the water evaporation, leading to the appearance or acceleration of degradation processes [VEIGA & MALANHO 2010].

ETICS are considered innovative systems and their performance evaluation should be based on ETAG 004 - *Guideline for European Technical Approval of External Thermal Insulation Composite Systems with rendering* [EOTA 2000], which establishes requirements and test methods for assessment of the Essential Requirements defined in the Construction Products Directive.

Products or systems not covered by this or another ETAG, will require the preparation, by the approval Institute, of a simplified specific guideline (CUAP - Common Understanding of Assessment Procedure) which must be submitted to the members of EOTA.

2 PERFORMANCE EVALUATION OF EXTERNAL THERMAL INSULATION COMPOSITE SYSTEMS (ETICS) WITH FINISHING CERAMIC TILES

2.1 Characteristics of ETICS

To validate the assessment methodology an ETICS was analyzed, constituted by thermal insulating boards bonded to the substrate, a mesh embedded in the base coat and finishing of ceramic tiles. For the tests, two kinds of ceramic tiles finishings will be used with equal tile dimensions and water absorption, only differing in the joint width: one with 80 mm standard joints (the most common in the market) and the other one with 1 to 2 mm joint width, simulating a critical situation, to assess the sensibility of the method. The ETICS was applied on two rigs of brick masonry, one rig located inside LNEC´s Wall Renders Test Station and subjected to the hygrothermal test 28 days after its application (Fig. 1) and another with smaller dimensions, in LNEC´s Natural Test Station, subjected to natural exterior environment (Fig. 2). In each rig two areas with different joint widths were set (Fig. 2 – 1 and 2). For comparison, it was also analyzed a similar system with 80 mm standard joints after two years of natural weathering by exposition to exterior environment (Fig. 3).

The comparison between the results obtained permits the evaluation of the effect of the accelerated ageing test and its comparison with natural weathering.

The behaviour of the system with the two ceramic tiles finishing variants will be compared with the same system with a classic finishing of synthetic painting, which has been already fully tested and considered fit for use.

Figure 1. ETICS subjected **to** hygrothermal cyclic testing (with 80 mm and with 1 to 2 mm joint widths).

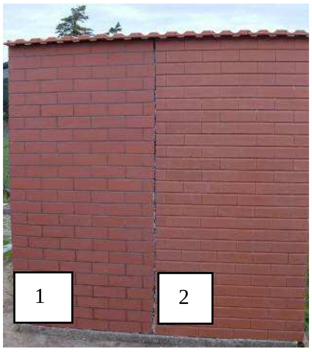

Figure 2. ETICS after 28 days of weathering (1- with 80 mm standard joints and 2 - with 1 to 2 mm joint width).

Figure 3. ETICS after 2 years of weathering (with 80 mm standard joints).

2.2 Methodology for assessment

The methodology for assessment of the fitness for use involves an experimental campaign according to the rules and test procedures specified in ETAG 004 [EOTA 2000] whenever applicable. In the situations not covered by ETAG 004 [EOTA 2000] specific test methods and requirements were developed or adapted based on existing specifications.

The experimental campaign was developed in order to answer to the most serious defects that can occur in ETICS with ceramic tiles finishing: detachment of tiles; condensation inside thermal insulation caused by the decrease of water vapour permeability; increase of the system mass per m^2 and influence on bond strength of the adhesive; cracking of the joints (causing infiltrations of water); differential dimensional variations of the tile finishing due to different coefficients of thermal expansion of materials and different thermal absorption coefficients of the various colours and also related with the thicknesses of the joints.

a) Detachment of tiles

Detachment of tiles of buildings' facades is one of the most serious problems, producing fall of tiles and thus reducing the safety level (Lucas & Abreu 2005), especially for tiles applied on high zones. To analyze the tendency of occurrence of this anomaly a bond strength test will be carried out between the basecoat plus finishing and the thermal insulation board, according to ETAG 004 [EOTA 2000]. The results will be analyzed taking into account the action of tiles' self weight.

b) Condensations

The ceramic tiles have a low water vapour permeability compared with current synthetic finishings, so the diffusion of water vapour will take place mainly through the joints between tiles. For the system with ceramic tiles and joints the test procedures for determining the water vapour permeability, according to NP EN 12086 [IPQ 1997] will be adapted, using a specimen simulating the system tile-joints-adhesive-insulation.

d) Cracking of joints

To analyze the problem of water infiltration by the joints, the Karsten tubes technique will be used. This technique is based on a methodology adopted by RILEM [RILEM 1980] and has been used in previous studies of LNEC [Magalhães 2002, Veiga et al. 2009]. It consists on placing Karsten tubes on the system, covering tiles joints, filling them with water and measure the amount of water lost to the substrate, by water permeability under low pressure, after certain periods of time (Fig. 6).

c) Increase of mass per m^2 of the system (due to the mass of tiles) and its influence on the adhesive bond strength

It will be checked if the mass of the tiles used contributes significantly to the increase of the total mass of the ETICS, by calculating the mass of the system before and after application of the tiles.
To simulate the mass increase and verify how it may affect the adhesive bond strength a weight will be placed on top of ETICS (insulation product + render) and its effect will be analysed on the deformations and on the bond strength between ETICS and substrate.

e) Thermal expansion

The coefficients of linear expansion of tiles and mortars will be determined according to EN ISO 10545-8 [IPQ 1996] and will be compared. Susceptibility of the system to the differential thermal dimensional variations will be checked.

Figure 5. Test of water vapour permeability.

Figure 6. Water permeability under low pressure test with Karsten tubes.

2.3 Experimental campaign

The bond strength tests were already accomplished, in order to analyze the problem of detachment of tiles with 80 mm joints applied on a ETICS. These tests were carried out after 28 days (Fig. 2 – 1) and after 2 years (Fig. 8) of natural weathering.

ETAG 004 [EOTA 2000] requires the test of bond strength between base coat and insulation board to accomplish safety in use requirements. As ceramic tiles finishing is not covered by ETAG 004, it was necessary to adapt this test to analyze the adhesion of the tile to the base coat.

For the bond strength between base-coat and insulation board the incisions were made until the insulation board (Fig. 7). In the case of the bond strength between tiles and base-coat the incisions were made until the tiles (Fig. 7). Results are presented in Tables 1 and 2.

Table 1. Bond strength test between base-coat and insulation board.

ETICS with analysed	*Bond strength*		*Standard deviation*	*Fracture pattern*
	Individuals values [N/mm^2]	*Average values* [N/mm^2]		
ETICS after 28 days of natural weathering	0.24	0.21	0.03	cohesion fracture in the insulation board
	0.20			
	0.20			
ETICS after 2 years of weathering	0.12	0.17	0.07	
	0.22			

Table 2. Bond strength test between tiles and base-coat.

ETICS analysed	*Bond strength*		*Standard deviation*	*Fracture pattern*
	Individuals values [N/mm^2]	*Average values* [N/mm^2]		
ETICS after 28 days of natural weathering	0.25	0.30	0.05	cohesion fracture in the base-coat
	0.32			
	0.34			
ETICS after 2 years of weathering	0.15	0.17	0.02	50% cohesion fracture in the insulation board and 50% cohesion fracture in the base-coat
	0.19			50% cohesion fracture in the insulation board and 50% cohesion fracture in the base-coat

For ETICS with paintings, synthetic coverings or mineral binder finishings such as silicates or cement, ETAG 004 (EOTA 2000) requires that, after hygrothermal cyclic testing, the minimum bond strength between base coat and insulation product should be at least equal to 0,08 N/mm^2 or failure occurs in the insulation product.

Values obtained in bond strength test between base-coat and insulation board are higher than 0,08 N/mm^2 and the failure occurred in the insulation board (Table 1 and Fig. 10 - 1), addressing the requirements. .

Values obtained in bond strength test between tiles and base-coat are also higher than 0,08 N/mm^2 (Table 2) addressing the requirements (Fig.10 - 2).

Results show that after two years of weathering the system suffers a small decrease in bond strength between base-coat and insulation board. A higher decrease seems to occur in the test between tiles and base-coat, however, the failure in the system weathered for two years was partly in the insulation board and may have been due to lack of precision of the incision, that may have exceeded the thickness of the tile and reached the insulation (Fig.11).

The complete set of tests described in 2.2 will be carried out in the next year, on the system after natural weathering and also on the system after accelerated ageing tests. Additionally, all the tests referred to ETAG 004 [EOTA 2000] which are applicable on ETICS with ceramic tiles finishing will also be performed, such as impact with hard body of 3 J; impact with hard body of 10 J; resistance to perforation (Perfotest).

The differences obtained for systems with normal and thin joints will give information about the influence of thickness of joints. The results will also be compared with those obtained for a similar system with a synthetic finishing.

Figure 7. Incisions on ETICS.

Figure 8. Bond strength test.

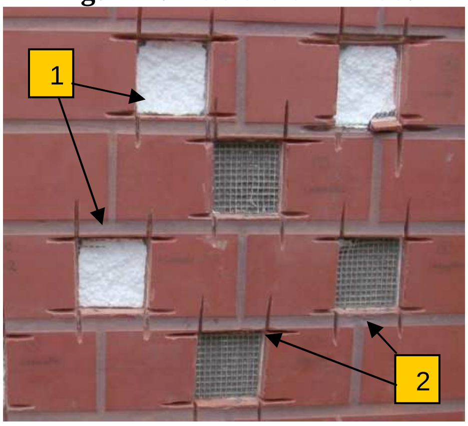

Figure 10. Results of bond strength test between base-coat and insulation board (1) and between tiles and base-coat (2).

Figure 11. Results of bond strength test between tiles and base-coat on ETICS after 2 years of weathering.

3 CONCLUSIONS

The application of ceramic tiles finishing on ETICS is expedted to provide an improvement of impact resistance and fire behaviour of systems.

However, ETICS can present several kinds of anomalies. Taking into account their degree of severity, some anomalies involve consequences which may endanger the users´ safety and other less serious anomalies, which nevertheless contribute to poor performance of the system. Thus, a methodology for evaluating performance to respond to the main problems which may occur in buildings with these kind of systems was developed to assess the fitness for use of ceramic tiles as ETICS finishing. As this type of finishing is not covered by ETAG 004, it was necessary to adapt test methods and requirements based on existing ones and develop specific test methods.

The methodology is being applied to a specific ETICS, with two different joint withes. Adhesion tests were already carried out on the system after 28 days weathering and after 2 years weathering to try to predict the behaviour of ETICS with tiles finishing over time and analyze the problem of detachment.

The bond strength values decreased with time, but after two years weathering they are still higher than the ETAG requirements.

The results of the system performance after accelerated and after natural weathering will be compared. A comparison between the specific system studied and a similar one with a synthetic painting finishing will be carried out as well.

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