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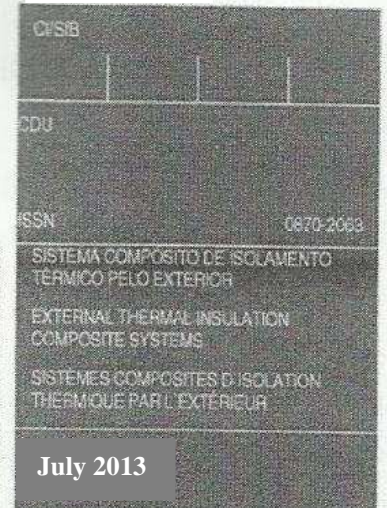
DH 928

APPROVAL DOCUMENT

Approval of new materials and construction processes

CANDIGRÉS – Cerâmica de Grés da
Candieira, Lda.
Candieira (Avelãs de cima)
3790-403 Avelãs de Cima
Aveiro
Tel. +351231 522 469
Fax +351231 515 081
E-mail: candigres@candigres.com
http:// www.candigres.com

CANDIWALL EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM



The situation of validity of the AD can be verified at the website of LNEC (www.lnec.pt)

APPROVAL DECISION

This Approval Document, drawn up in accordance with the 17th Article of the General Regulation of Urban Buildings, amended by Decree-Law No. 50/2008, of 19th March, defines the characteristics and lays down the conditions of application and use of CANDIWALL system as an external thermal insulation composite system, owned by the company CANDIGRÉS – Cerâmica de Grés da Candieira, Lda.

The approval is granted on the condition that the company CANDIGRÉS – Cerâmica de Grés da Candieira, Lda. ensures consistent quality of production, in particularly through internal production control, summarized in section 3.

The use of this system is still constrained by applicable regulatory provisions.

This Approval Document is valid until the 31st of July 2016 and may be renewed upon timely request made to LNEC.

LNEC reserves the right to suspend or cancel this Approval Document if any situations that justify it occur, in particularly before any fact which puts in doubt the constancy of the system quality or its constituents.

Lisboa and Laboratório Nacional de Engenharia Civil (National Laboratory for Civil Engineering), in July 2013.

THE BOARD

(illegible signature)

Maria de Lurdes Antunes

Member of the Board

1 – DESCRIPTION OF THE EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM

1.1 – General description

The CANDIWALL system is an external thermal insulation composite system (designated by the acronym ETICS from the Anglo-Saxon terminology – External Thermal Insulation Composite Systems), with ceramic tiles finishing. It is owned by the company CANDIGRÉS – Cerâmica de Grés da Candieira, Lda., with its headquarters and manufacturing facilities in Avelãs de Cima, and it is intended to thermally insulate the opaque areas of the facades. It is applied to exterior facings of masonry or concrete walls, giving the walls regularisation, waterproofing, thermal insulation and final finishing. It can also be applied to wooden props. This system, as ETICS systems in general, has the ability to: correct thermal bridges, reducing the problem of condensation on the inside; improve thermal performance in winter and also in summer, because it allows the entire wall thickness to contribute to thermal inertia; and protect the structure and the masonry from thermal shocks, thus contributing to the increasing of the durability of these elements. Additionally, it presents some practical advantages, since it does not reduce the indoor area and, in the case of rehabilitation, it produces minimum discomfort for users.

1.2 – CONSTITUTION AND MAIN CHARACTERISTICS

The CANDIWALL system comprises a thermal insulation layer of extruded expanded polystyrene (CANDIWALL BOARD), which is directly fastened to the prop by a bonding product (CANDIWALL ADHESIVE); this same bonding product is also used for the execution of the base layer. Finishing consists of ceramic tiles (CANDIWALL KLINKER), reclosed with joint grout (CANDIWALL GROUT) and it has protective and decorative functions. The system also includes auxiliary components, such as additional fastening bolts (CANDIWALL FASTENERS) and starter profile (CANDIWALL STARTER TRACK).

The same system in wooden continuous props is applied with fastening through specific bolts for this type of prop (CANDIWALL SCREW FASTENERS), without bonding product.

The constitution of the system is shown in the diagrams of figures II.1 to II.5 in Appendix II and in table 1. In tables 2 to 4 are presented the main characteristics of each system component.

Table 1 – Constitution of the CANDIWALL system

System components		Commercial designation	Description	Consumption (kg/m ²)	Thickness (mm)
Thermal insulation		CANDIWALL BOARD	Extruded expanded polystyrene plates with dimensions of 1250 mm x 550 mm x 50 mm and nominal mass density of 33 kg/m ² , with CE marking. The insulator has “tears” along the length of the plates, to which the tiles engage (width slightly higher).	—	40 to 120
Fastening system by bonding process	Bonding product of the insulating plates	CANDIWALL ADHESIVE	Monocomponent cement adhesive	3,5 to 4	—
	Bolts for additional mechanical fastening	CANDIWALL FASTENERS	Plastic bolts object of ETA 08/0172 and with CE marking.	—	—
Mechanically fastening system (wooden prop)	Fastening bolts	CANDIWALL SCREW FASTENERS	Propylene bolts	—	—
Base layer/bonding product of tiles		CANDIWALL ADHESIVE	Monocomponent cement adhesive	2,5 to 3,0	—
Finishing	Ceramic tiles	CANDIWALL KLINKER	Ceramic tiles with dimensions of 210 mm x 65 mm and 210 mm x 50 mm, water repellent.	—	14
			Ceramic tiles for corners (‘L’ shape) with dimensions of 210 mm x 65 mm + 90 mm x 65 mm and 210 mm x 50 mm + 90 mm x 50 mm, water repellent.		
	Joint grout	CANDIWALL GROUT	Colored pre-dosed grout, in powder, of mixed ligands, made up of cement, siliceous fillers and specific additives.	2,5 to 3,5 (tile with w = 65 mm) 4 to 5 (tile with w = 50 mm)	10

Table 2 – Characteristics of the base component of the CANDIWALL system –
CANDIWALL BOARD thermal insulation

System components	Tests	Values	
CANDIWALL BOARD	Reaction to fire class (Euro class) (EN 13501-1:2007+A1:200)	E *	
	Water absorption in a short period by partial immersion (W _p) (NP EN 1609:1998) (kg/m ²)	0,07	
	Permeability to water steam - diffusion resistance factor of water steam (μ) (EN 12086:2001)	82,6	
	Perpendicular tensile strength to faces – Tensile stress in rupture (NP EN 1607:1998) (kPa)	>500	
	Cut stress (σ) (NP EN 12090:1997) (kPa)	340	
	Cut module (NP EN 12090:1997) (kPa)	5,1 x 10 ³	
	Thermal conductivity (W/m.K)	0,035 (e = 40 to 60 mm) * 0,036 (e = 70 to 80 mm) * 0,038 (e = 100 to 120 mm) *	
	Apparent mass density (kg/m ³) (EN 1602:1997)	30	
	Endurances	Thickness (mm) Class according to the EN 13164:2008)	T1 *
	Compression resistance (kPa) (EN 13164:2008)	DS(10\Y)300 *	
	Class of dimensional stability under normal laboratory conditions (EN 13164:2008)	DS(TH) Class *	

* Values and classes of CE marking

Table 3 - Characteristics of the base components of the CANDIWALL system – bonding product for the insulation plates, base layer, finishing and bolts for system fastening

System components		Commercial designation	Tests		Values
Bonding product for the plates and bonding product for the tiles*		CANDIWALL ADHESIVE	Apparent mass density (kg/m ³)		1393
			Ash content at 450°C and at 900°C (%)		450°C: 96,4 900°C: 95,1
			pH		11,3
Finishing	Ceramic tiles**	CANDIWALL KLINKER (210 mm x 50 mm) Classification according to EN 14411: Group A II b	Determining dimensions and surface quality (ISO 10545-2:1997)	Measuring length and width (mm x mm)	Average of the 10 measured samples: 206,5 x 63,0
				Thickness	Average of the 10 measured samples: 14,6
				Side straightness (%)	Maximum deviation obtained: -0,36 to 0,20
				Orthogonality	Maximum deviation obtained: -1,64 to 1,60
				Surface flatness:	
			a) Central curvature (%)	Maximum curvature in relation to the calculated samples diagonal based on manufacturing dimensions: -0,53 to 0,18 %	
			b) Lateral curvature (%)	Maximum lateral curvature in relation to manufacturing dimension: -0,64 to 0,28 %	
			c) Warping (%)	Maximum warping in relation to the calculated diagonal based on manufacturing dimensions: -0,50 to 0,21 %	
			Water absorption (%) (ISO 10545-3:1997)		Average value: 6,7
			Chemical resistance (ISO 10545-13:1997)		Acids and bases: UHA
			Flexion resistance (ISO 10545-4:1997) (N)		2020 N
			Rupture module (ISO 10545-4:1997)		16,6
			Stain resistance (ISO 10545-14:1997) Class of stain resistance		Green chrome: 5 Iodine solution: 5 Olive oil: 5
			Expansion by humidity (ISO 10545-10:1997) (mm/m)		0
			Ice resistance (ISO 10545-12:1997)		No defects after ice-thaw cycles
Dilatometric analysis (ISO 10545-8:1995) (°C ⁻¹)		6,6 x 10 ⁻⁶			
Joint grout*	CANDIWALL GROUT	Apparent mass density (kg/m ³)		1348	
		Ash content at 450°C and at 900°C (%)		450°C: 97,9 900°C: 95,3	

			pH	11,7
Bolts for fastening the CANDIWALL system in solid or hollow props***	CANDIWALL FASTENERS	Type of bolt	CANDIWALL FASTENERS (see dimensional characteristics in table 2 and in Appendix 3 of ETA 08/0172)	
		Constituent material of bolts	Bolt (bolt body): polypropylene Nail: reinforced polyamide with glass fibers	
		Pullout resistance	0,30 – 0,75 kN (see ETA 08/0172)	
		Displacement to the scaling maximum force when applied in concrete prop (mm)	0,1	
		Displacement to the scaling maximum force when applied in masonry prop (mm)	0,3	
		Space between bolts (mm)	≥ 100	
		Distance from the corner (mm)	≥ 100	
		Prop thickness (mm)	≥ 100	
Bolts for fastening the CANDIWALL system in wooden continuous props*	CANDIWALL SCREW FASTENERS	Trial to determine rupture stress (kN)	0,9	

* Tests performed in LNEC

** Tests performed in Centro Tecnológico da Cerâmica e do Vidro (CTCV) (Technological Center of Ceramics and Glass) and provided by the system owner.

*** Tests contained in ETA 08/0172.

Table 4 - Characteristics of the auxiliary components of the CANDIWALL system

System components	Commercial designation	Type / Basic composition	Tests	Declared values
Protection and finishing profiles	CANDIWALL STARTER TRACK	Aluminum starter profile	Width (mm)	40 to 120
			Thickness (mm)	0,8
			Length (m)	2,5
			Type of material	EN AW-5754 (H22)

2 – APPLICATION FIELD

The system is intended for thermal insulation of the opaque involving in buildings facades, contributing to its energy performance and thermal and hygrothermal comfort.

The system should be applied on masonry props (for example ceramic bricks, chain aggregated concrete blocks, or autoclaved cellular concrete blocks) or concrete (fresh concrete casting *in situ* or prefabricated), or also in wooden continuous props. The system can be applied both in new construction and in rehabilitation construction; in the latter case the bonding grout of the insulation plates must be adapted to the characteristics of the prop (consult information about CANDIGRÉS); however, it does not apply to very thick and porous old props, because it alters water evaporation conditions in these walls, so

it not suitable for old resistant walls.

The system can also be applied in horizontal and inclined surfaces, since they are not directly exposed to rain.

Products for the system finishing should be preferably used in light colors. These colors make it easy to obtain a uniform color in facings and minimize the absorption of solar radiation by the coating and, therefore, the corresponding dimensional variations of thermal origin. The application of finishing in dark colors must be limited to facings reasonably protected from the action of weather agents, in particular solar radiation.

3 – MANUFACTURING AND QUALITY CONTROL

The manufacturing facilities of CANDRIGRÉS are located in Avelãs de Cima (Aveiro).

For the manufacture of the CANDIWALL system constituent CANDIDRÉS that produces ceramic finishing (CANDIWALL KLINKER) has manufacturing conditions and a system of quality control that focuses on raw materials and on the finished product, which LNEC analyzed and considered satisfactory. Appendix I provides a list of tests and verifications, as well as their periodicity, performed by the company in what the quality control at the factory is concerned.

For products purchased from other companies, including insulation plates, base layer, finishing, mechanical fastenings among others, the manufacturing quality control is done in their production units, where the corresponding registers are kept filed; CANDIGRÉS performs a visual inspection of each lot received and analyzes, registers and files the quality control sheets that accompany each one, as well as the CE marking compliance documents, in the case of insulator and plastic bolts.

The storage of finished products, after being introduced in commercialization packages, occurs in the covered facilities of the factory by a period of time that cannot exceed the validity periods established for each one, marked on the corresponding packages.

4 – COMMERCIAL PRESENTATION

4.1 – PACKAGING AND LABELING

The constituents of the CANDIWALL system are commercialized in the following ways:

- extruded expanded polystyrene plates (CANDIWALL BOARD) - plates with dimensions of 1250 mm x 550 mm; each package features product and manufacture lot identification and CE marking;
- bonding product and for the base layer/bonding product for tiles (CANDIWALL ADHESIVE) – paper bags containing 25 kg of product in powder;
- finishing: ceramic tiles (CANDIWALL KLINKER) – packages of 48 tiles and joint reclosing grout (CANDIWALL GROUT) – paper bags of 20 kg.

Each package features the following information: commercial designation, product reference, manufacture lot and date, color, indications for use and cautions, name and contact of the system owner company.

4.2 – Color range

CANDIWALL KLINKER finishing is available in a range of colors contained in the corresponding catalogs.

5 – SITE APPLICATION

5.1 – Applicators

CANDIGRÉS recommends that the application of the system is to be performed by applicators with specialized training for this purpose. Applicators list can be directly requested to the sales office of CANDIGRÉS, or with their representatives.

5.2 – General recommendations

5.2.1. Prop preparation

Like most of other coatings, the application of the CANDIWALL system should not be initiated before the prop has suffered the most significant part of its initial drying retraction, whereby in between the wall execution and the coating application should occur, at least, one month.

Props should present a flat surface, free of irregularities and imperfections in flatness higher than 10 mm when controlled with a ruler of 2 m in length. If this condition cannot be guaranteed, the surface should be regularized through the application of a grout composition with adequate composition and resistance to the system prop, which must be at least one month old when the thermal insulation plates are applied.

Props must have average absorption and be consistent and free of dust or oils agents and must be dry at the time of application of the system. Degraded concrete props must first be repaired, including the reinforcement treatment, if necessary. Cracked areas are also to be repaired, whenever they present opening cracks greater than 2 mm.

In rehabilitation work, props should be verified from the point of view of its consistency, degradation, cracking and water content, and the areas that do not offer adequate security must be removed and the damaged areas must be repaired. The existence of persistent high levels of water in non-rainy periods dissuades the application of such systems, and first it should be verified and corrected the source of humidity.

5.2.2. Assembly of thermal insulation plates

Insulation plates must be applied from bottom to top, from the starter profile, ensuring its horizontal position, supporting each row of plates on the previous one.

Plates are bonded to the masonry or concrete prop with CANDIWALL ADHESIVE bonding grout and subsequently fastened with CANDIWALL FASTENERS bolts (additional fastening).

In the case of wooden props plates must be fastened through CANDIWALL SCREW FASTENERS bolts.

The bonding grout is obtained by mixing the content of each product package (25 kg) with 6 to 6.5 l of (clean) water. Mixing should be done with a low speed mixer until you get a creamy paste with no granules.

Grout must be applied to the back of the thermal insulation plate, using a method that will depend on the prop flatness:

- on masonry with some irregularity, apply the grout on the insulation plate through a perimeter string with at least 12 bonding points evenly distributed;
- on a regularized surface, as grout or concrete, apply the grout on the entire surface of the inside face of the plate with a serrated trowel (tooth of 8 mm x 8 mm).

Plates must be assembled in a horizontal position in successive rows, from bottom to top, counter rowed in relation to the previous row. Similarly, on the corners, the tops of the plate rows must be alternated to ease the system locking.

Plates must be placed in its final position, pressing against the prop in order to crush the bonding grout and adjusting its contours and surface flatness with the adjacent plates, in order to prevent joint clearances and misalignment on the surface of the wall panels.

Verticality and flatness adjustment of each plate in relation to the adjacent plates must be continuously verified, using a metal ruler with 2 m and an air bubble level. Any open joints between plates must not be filled with coating grout, but with strips of the same material from the plates, before applying the coating. On the corners of the bays surrounding areas, plates must be assembled in order to "embrace" the corner, avoiding that joints in between them correspond to the alignment of the bay contours. This precaution will help reducing the tendency of crack formation from bay corners.

Placement of insulation plates must be careful and accurate, in particular in what regards the perfection of flatness in relation to adjacent plates, to avoid overall imperfections in the facade flatness, not acceptable by the designer or developer.

5.2.3. Mechanical fastening of thermal insulation plates

It is always used mechanical fastenings of insulation plates to the prop, in the case of masonry or concrete props fastenings are complementary of bonding, while in wooden props they are the only fastening method.

Fastening reinforcement for masonry and concrete props is accomplished by installing specific bolts (CANDIWALL FASTENERS), in number not less than 9 bolts per m² and at least in a 1 m zone along the corners of the building. In the case of fastening to wooden props are applied CANDIWALL SCREW FASTENERS bolts, also in number not less than 9 bolts per m².

Bolts must have adequate length to the thickness of the thermal insulation plate to be fastened. Bolts circular heads must be pressed in order to crush the CANDIWALL BOARD plate surface, so they are not salient in the plate. The resulting small cavities must be subsequently filled with coating grout, in a previous operation to applying the base layer/bonding product of tiles.

5.2.4. Treatment of singular points

Expansion joints must be respected, disrupting the system, and finished with the PARABOND CONSTRUCTION MS product, on joint background cord with polyethylene foam, with section of appropriate diameter.

In the CANDIWALL system it is not used any type of reinforcement on wall corners and on bays contours.

5.2.5. Tiles application

CANDIWALL ADHESIVE is applied in a single layer on CANDIWALL BOARD plates to bond CANDIWALL KLINKER tiles. This layer of bonding product also works as a base layer, due to its waterproofing and regularization ability and it is applied at constant thickness. Over thickness should not be applied to correct serious imperfections on the flatness of insulation plates, since the use of high thickness may cause the appearance of other anomalies (cracking, undulation, etc.). The application of the base layer on the CANDIWALL BOARD plates should be performed only after the hardening of the bonding grout so as to guarantee plates stability (1 to 3 days). CANDIWALL ADHESIVE must be applied by covering, using a stainless metal trowel.

The joints between the CANDIWALL KLINKER tiles are reclosed with CANDIWALL GROUT mortar (after 1 to 3 days).

5.3 – Weather conditions

The base layer/bonding product application of CANDIWALL KLINKER ceramic tiles of the CANDIWALL system should not be performed when the weather conditions significantly affect its fastening or drying process or its adherence characteristics to the prop, what may occur, particularly, in the following cases:

- when air temperature is higher than 30 °C or lower than 5 °C;
- when props are frozen;
- when it is raining or it is predictable to rain earlier than 48 h after concluding the application;
- when there are strong, hot and dry winds.

5.4 – Consumption

The product consumption for bonding the insulation pates is of 3,5 to 4 kg/m², according to the superficial characteristics of the prop.

To attain the base layer/bonding product of ceramic tiles, consumption is between 2,5 and 3,0 kg/m².

The consumption of joint reclosing grout is between:

- 2,5 and 3,5 kg/m² (tiles with w = 65 mm);
- 4 and 5 kg/m² (tiles with w = 50 mm).

5.5 – Validity period

Products to carry out the base layer/bonding product of ceramic tiles and plates bonding, as well as the joint reclosing grout should not be used after a period exceeding 12 months from the manufacturing date.

5.6 – Storage on site

Storage on site of the CANDIWALL system constituents should be carried out by keeping them on their original packages and in a dry, covered and moderately ventilated place.

Insulation plates should be stored on a horizontal, firm and clean base, without any contact with the ground.

Products in powder or paste forms should not be used when the package time exceeds the validity period (see 5.5), counted from the manufacturing date, which is stated on the package.

5.7 – Safety and hygiene precautions

CANDIWALL system application does not involve risks of flammability nor special risks of toxicity, since in the sites where application is occurring there is reasonable air exchange. When applying it must be avoided the possibility of contact between paste products and applicators eyes, and therefore it is advisable for them to use appropriate individual protective equipment, including goggles, and after the application is completed, they should wash their face and hands with water and soap.

In case of any contact of the product with the eyes it is recommended to immediately wash with water and soap; if there are any irritation symptoms immediately consult a doctor.

6 – SYSTEM MAINTENANCE AND REPAIR

6.1 – Cleaning and general maintenance operations

Usual cleaning of the coated facings surface with CANDIWALL can be carried out with water.

In case there are some whitish stains cleaning can be carried out with a mineral acid, with the following characteristics:

- density: 1,120-1,125 g/ml;
- consumption for dilutions: 1:6 = 60 m²; 1:3 = 30 m²; 1:1 = 5 m²
- solubility in water: total;
- pH: <1,0;
- acidity (ml. NaOH 1N.): 5,6 – 6,0.

Regular inspections should be made to the applied system, particularly in the joints, to ensure the non-occurrence of leaks.

6.2 – Localized repair

When inspections clearly show the need for repairs, these must be carried out immediately, by applicators with specialized training for this purpose, as recommended by the company (see 5.1).

Damaged areas must be repaired using appropriate components of the system and through the following steps: i) cut with a grinder a coating zone up to the insulator (corresponding to at least one tile), by the joints, in a regular way and with higher dimensions to the damaged area in about 100 mm in the

entire contour; ii) cut with a wheel an area of the insulator in a regular way, surpassing the degraded area in about 75 mm in the entire contour; clean the prop from bonding product and any dirt; iii) carefully bond in the clean area a portion of insulator identical to the one extracted, with appropriate dimensions to perfectly fit the produced cut; iv) apply base layer on the replaced surface, being careful not to stain finishing; v) level irregularities; vi) after drying for at least three days, apply finishing, identical to the original one.

If degradations are not accidental, their causes must be eliminated before repair.

7 – COMMERCIALIZATION CONDITIONS AND TECHNICAL ASSISTANCE

7.1 – Commercialization conditions

CANDIGRÉS sells its products through direct sales to retailers.

7.2 – Technical assistance

CANDIGRÉS is able to provide technical assistance on site, whenever it is requested. Technical assistance includes advising clients, application monitoring, complaints analysis and customers training.

8 – EXPERIMENTAL ANALYSIS

8.1 – Test conditions

Experimental analysis was carried out in the Testing Laboratory of Wall Coatings in LNEC (LNEC/LERevPa), in accordance to the LNEC document “Rules to Grant an Approval Document (AD) to External Thermal Insulation Composite Systems (ETICS) with ceramic tiles finishing” available in LNEC website, in http://www.lnec.pt/qpe/dh/regras_conc_DH, which meets acceptance criteria based on what is specified in ETAG 004 – “Guideline for European Technical Approval of External Thermal Insulation Composite Systems with Rendering”, from March 2000 (available in EOTA website, in: <http://www.eota.eu>), adapted and validated for finishing systems of ceramic tiles. It was also taken into account what is specified in CUAP 04.04/26 – “Common Understanding of Assessment Procedure of ETICS with rendering for the use on timber frame buildings”, from October 2007.

The study included behavioral tests conducted on the system and characterization tests of multiple components.

8.2 – Tests and assessment

8.2.1. Reaction to fire

Reaction to fire classification assigned in accordance with the european norm EN 13501-1:2007+A1:2009 – *Fire classification of construction products and building elements. Part 1: Classification using test data from reaction to fire tests* was B-s1,d0, meaning: B – reaction to fire performance, s – additional classification in relation to smoke production; d – additional classification to falling drops or flaming

particles. This classification is valid for CANDIWALL system with the characteristics presented in table 1 and with insulator up to 120 mm of thickness. This classification is considered to be satisfactory by national regulations in use for external coating of building walls up to 28 m of height, but it does not dispense adopting complementary measures that may in the meantime be defined in order to limit the spread of fire from the outside.

8.2.2. Test of resistance to wind suction

The results of the wind suction dynamic test are shown in Table 5.

After the test there were not found the following anomalies:

- rupture of insulating panels;
- delamination in the insulator or between the insulator and the coating;
- detachment of coating;
- lifting of panel;
- lifting of fastenings;
- detachment of insulating panels in relation to the prop.

There were not detected serious anomalies until the end of the cycles with the maximum load of 6000 N.

Therefore the admissible suction is $R_d > (6,0 \times 0,97) / 1,5 = 3,88$ kPa.

Table 5 – Wind suction test

Number of cycles	Suction in kPa	Observations (during the test)
4	1,00	--
1	1,50	--
1	2,00	--
1	2,50	--
1	3,00	--
1	3,50	--
1	4,00	--
1	4,50	--
1	5,00	micro crack joint grout
1	5,50	--
1	6,00	--
1	6,50	crack in the tile
1	7,00	--

8.2.3. Water absorption by capillarity

In the test of water absorption by capillary absorption values after 1 hour by the system constituted by the base layer/bonding product of tiles applied on the thermal insulation with two CANDIWALL KLINKER finishings were below 1 kg/m². thus, the system performance in relation to water absorption is considered to be satisfactory.

The results of the capillarity test are shown in Table 6.

Table 6 – Results of the water absorption by capillarity test

Samples constitution	Water absorption (kg/m²) – After 1 hour	Water absorption (kg/m²) – After 24 hours
CANDIWALL BOARD + base layer/bonding product + CANDIWALL KLINKER ceramic tiles coating (210 mm x 50 mm x 14 mm)	0,03	0,26
CANDIWALL BOARD + base layer/bonding product + CANDIWALL KLINKER ceramic tiles coating (210 mm x 65 mm x 14 mm)	0,05	0,31

8.2.4. Hygrothermal behavior

The test was performed on the system applied in a brick masonry wall ("maquette" of the system carried out in brick masonry with useful approximate dimensions of 3 m x 2 m).

After cycles of heat-rain and heat-cold the system showed no signs of degradation, particularly of the following types: tiles arching or blistering, tiles or joint grout cracking, adhesion loss of the tiles, detachment of the tiles or of the system to the prop; so the system behaviour to hygrothermal cycles is considered to be satisfactory.

8.2.5. Ice-thaw resistance

The result for the system with two finishing types (tiles of 210 mm x 50 mm and of 210 mm x 65 mm), in the water absorption by capillarity test after 24 hours, shown in table 6, is below 0,5 kg/m², allowing the system to be classified as resistant to ice-thaw with no need for additional tests.

8.2.6. Shock and perforation resistance

Table 7 shows the categories in which the system variants are inserted when exposed to shock (3 J and 10 J) and perforation resistance tests.

Table 7 – Classification* according to the shock (3 J and 10 J) and perforation results

Analyzed system variants	Category*
CANDIWALL BOARD + base layer/bonding product + CANDIWALL KLINKER ceramic tiles coating (210 mm x 50 mm x 14 mm)	Category I
CANDIWALL BOARD + base layer/bonding product + CANDIWALL KLINKER ceramic tiles coating (210 mm x 65 mm x 14 mm)	Category I

* Category I - Applicable in areas accessible to the public and exposed to strong shocks, but not subjected to misuse.

The two variants of the CANDIWALL system with CANDIWALL KLINKER finishing (dimensions of 210 mm x 60 mm x 14 mm and 210 mm x 50 mm x 14 mm) do not show deterioration after the 3 J and 10 J shock ball neither perforation with 4 mm puncture. The analyzed variants are classified with category I, and they can be applied in facades accessible to the public and exposed to shocks, but not subjected to misuse.

8.2.7. Permeability to water steam

Permeability to water steam is assessed by the air layer thickness of equivalent diffusion; values are shown in table 8.

Table 8 - Results of the permeability to water steam test

Analyzed system samples	Air layer thickness of equivalent diffusion (m)
CANDIWALL KLINKER ceramic tiles coating (210 mm x 50 mm x 14 mm)	0,06
CANDIWALL KLINKER ceramic tiles coating (210 mm x 65 mm x 14 mm)	0,23

The results of air thickness of equivalent diffusion of the coating system (not including the insulator) are within the required range (≤ 2 m).

8.2.8. Dangerous substances

According to the document given to LNEC by CANDIGRÉS all components of the system meet the legal limits for the content of products with some degree of toxicity or hazard.

8.2.9. Safe use

8.2.9.1. Adherence stress

a) Adherence stress of base layer to thermal insulation

The test was performed on the CANDIWALL system applied in a brick masonry wall after being submitted to hygrothermal cycles.

Table 9 shows the test results.

Table 9 – Results of the adherence of base layer to thermal insulation test

System	Adherence of the ETICS system to the prop (after hygrothermal cycles)	
	Result (N/mm ² and rupture pattern*)	Requirement (N/mm ²)
XPS + base layer/bonding product + CANDIWALL KLINKER ceramic tiles coating (210 mm x 50 mm x 14 mm)**	0,17 / PR: A	≥ 0,15 and tile mass ≤ 32 kg/m ³
XPS + base layer/bonding product + CANDIWALL KLINKER ceramic tiles coating (210 mm x 65 mm x 14 mm)***	0,16 / PR: A	

* Rupture pattern: RP:A – adhesive fracture (in the coating – thermal insulation).

** Mass density of 29 kg/m².

*** Mass density of 27 kg/m².

The results for the finishing system meet the required conditions.

b) Adherence stress of bonding product to ceramic tile coating

Table 10 shows the test results performed on samples of the system in dry state and after 48 hours of water immersion, with 2 hours and with 7 days of drying.

Table 10 – Results of the bonding product adherence to ceramic tile coating test

Constitution of the system samples	Conditions					
	Initial state (dry)		48 h of water immersion + 2 h of drying in a conditioned environment at 23 °C / 50 % HR		48 h of water immersion + 7 days of drying in a conditioned environment at 23 °C / 50 % HR	
	Result (N/mm ² and rupture mode*)	Requirement (N/mm ²)	Result (N/mm ² and rupture pattern*)	Requirement (N/mm ²)	Result (N/mm ² and rupture pattern*)	Requirement (N/mm ²)
XPS + bonding product + ceramic tile coating	0,21 /PR:A	≥ 0,15 or PR:C	0,14 / PR:A	≥ 0,12 or PR:C	0,23 / PR:A	≥ 0,15 or PR:C

* Rupture pattern: RP:A – adhesive rupture (in terms of coating – thermal insulation) and RP:C – cohesive rupture (within the insulator).

Results meet the minimum required values.

c) Adherence stress of bonding product to the prop (concrete plate)

The test was performed on samples of the system (concrete plates and bonding product) in dry state and after 48 hours of water immersion, with 2 hours of drying and with 7 days of drying. Table 11 shows the test results.

Table 11 – Results of the bonding product adherence to the prop (concrete plate) test

Constitution of the system samples	Conditions					
	Initial state (dry)		48 h of water immersion + 2 h of drying in a conditioned environment at 23 °C / 50 % HR		48 h of water immersion + 7 days of drying in a conditioned environment at 23 °C / 50 % HR	
	Result (N/mm ² and rupture mode*)	Requirement (N/mm ²)	Result (N/mm ² and rupture pattern*)	Requirement (N/mm ²)	Result (N/mm ² and rupture pattern*)	Requirement (N/mm ²)
bonding product + concrete plate	1,48 /RP:B	≥ 0,75	0,60 / RP:A/B	≥ 0,50	2,31 / RP:B	≥ 0,75

* Rupture pattern: RP:A – adhesive rupture (in terms of bonding product-prop), RP:B – cohesive rupture (within the bonding product) and RP:C – cohesive rupture (within the prop).

Results are within the range defined for ETICS with ceramic tiles finishing, and so it is considered to be satisfactory.

8.2.10. Thermal resistance

Heat transfer coefficient of the wall covered by the ETICS system (U) is determined in the following way in accordance to the norm EN ISO 6946:2007:

$$U = 1 / (R_{isol} + R_{rev} + R_{se} + R_{si} + R_{suporte})$$

where:

R_{isol} : Thermal resistance of thermal insulation (see insulation CE marking) in $m^2.K/W$.

R_{rev} : Coating thermal resistance (tabulated value referred in ETAG 004): 0,02 $m^2.K/W$.

R_{se} : External superficial thermal resistance – direction of the horizontal heat flow (walls): 0,04 $m^2.K/W$.

R_{si} : Internal superficial thermal resistance – direction of the horizontal heat flow (walls): 0,13 $m^2.K/W$.

$R_{suporte}$: Prop thermal resistance in $m^2.K/W$.

Thermal resistance in the CANDIWALL system may vary between:

less thickness of the insulator →

$$R_{isol} (40 \text{ mm}) = e / \lambda = 0,04 / 0,035 = 1,14 \text{ m}^2.K/W \text{ (minimum value)}$$

$$R_{\min \text{ sistema}} = R_{isol} (40 \text{ mm}) + R_{rev} = 1,14 + 0,02 = 1,16 \text{ m}^2.K/W$$

more thickness of the insulator →

$$R_{isol} (120 \text{ mm}) = e / \lambda = 0,12 / 0,038 = 3,16 \text{ m}^2.K/W \text{ (maximum value)}$$

$$R_{\max \text{ sistema}} = R_{isol} (120 \text{ mm}) + R_{rev} = 3,16 + 0,02 = 3,18 \text{ m}^2.K/W$$

8.2.11. Durability and proper use

The test results of shock (3 J and 10 J) and perforation resistance (see 8.2.6), adherence resistance (see 8.2.9.1 a)), hygrothermal cycles (see 8.2.4) and ice-thaw resistance (see 8.2.5) meet the defined conditions for ETICS with ceramic tiles finishing; so, the CANDIWALL system is considered to have a satisfactory behavior of durability and proper use.

8.3 – Components characteristics

8.3.1. Thermal insulation

The characteristics of CANDIWALL BOARD plates are presented in table 2.

Thus, CANDIWALL BOARD plates to be used should have the following information about the CE marking (according to the norm NP EN 13164:2008): T1-CS(10\Y)300-DS(TH), Euroclass E reaction to fire and thermal conductivities of 0,035 W/m.K (e = 40 to 60 mm), 0,036 W/m.K (e = 70 to 80 mm) and 0,038 W/m.K (e = 100 to 120 mm) (see table 12).

8.3.2. Bolts for thermal insulation plates

The bolts for mechanical fastening of the insulator to masonry or concrete props, complementary to plates bonding (CANDIWALL FASTENERS), are object of ETA (European Technical Approval) 08/0172 which is a favorable technical assessment of the ability to use this product; the bolts used in the mechanical fastening of the system (CANDIWALL SCREW FASTENERS) were exposed to the lifting resistance test according to ETAG 004.

The characteristics of the two types of bolts are shown in table 3.

8.3.3. Base layer/bonding product

CANDIWALL ADHESIVE product was exposed to characterization tests; the results are shown in table 3.

8.3.4. Ceramic tiles

The characteristics of the ceramic tiles are shown in table 3.

8.3.5. Fungi

Fungi resistance was assessed in joint reclosing grout samples, according to the American norm ASTM D 5590-94 “Standard test method for determining the resistance of paint films and related coatings to fungal defacement by accelerated four-week agar plate assay”; the obtained results in CANDIWALL GROUT showed some resistance to the development of fungi – with a slight growth in the first week (grade 1). Thus, it is considered that the system, with the referred finishing, presents a satisfactory behavior in terms of fungi development resistance.

9 – PERFORMANCE ASSESSMENT

In view of the results obtained in the tests, it is considered that the CANDIWALL system has a satisfactory behavior under normal conditions of use. In particular, it was confirmed that it meets the acceptance criteria defined by LNEC, gathered in the document “Rules to Grant an Approval Document (DH) to External Thermal Insulation Composite Systems (ETICS) with ceramic tiles finishing” available in LNEC website, in http://www.lnec.pt/qpe/dh/regras_conc_DH.

From the tests, analysis and observations made the following favorable aspects of these coatings are highlighted, within its field of application (see 2):

- the system has no noticeable degradation after hygrothermal cycles, indicating a good resistance to thermal shocks and to wetting / drying alternations and a good waterproofing ability;
- the system shows good resistance to mechanical shocks and perforation with classification in category 1, thus being considered to be suitable for use in facades accessible to the public and exposed to shocks, but not subjected to misuse (see table 7);

- the system shows good thermal resistance for insulation thicknesses, thus significantly contributing to thermal insulation and energy conservation of the building;
- due to its characteristics, the system eliminates thermal bridges in the external facing of walls, protecting the structure and the rough walls of thermal shocks and climate variations and granting thermal insulation, water tightness and aesthetics considered to be satisfactory;
- the system when applied with CANDIWALL KLINKER finishing and CANDIWALL GROUT joint mortar presents some resistance to fungal growth, being considered satisfactory its behavior in this aspect.

10 – VISITS TO SITES IN USE

Visits were made to sites in use that allowed us to verify the behavior of the CANDIWALL system. It was possible to testify the use ability of the system in its field of application. Indeed, the observed system applications presented a satisfactory and adequate aspect for the intended uses.

11 – ACCEPTANCE TESTS

Acceptance tests in site may be justified, if in doubt, to verify the identity of one or some of the system components in relation to the ones that were the subject of the Approval Document. Inspections have the responsibility of making that decision, if they consider it necessary.

In such a case, it must be carried out tests to check that, for the characteristics listed in Table 12, the product or products in question show values within the tolerance intervals specified in that table.

12 – REFERENCES

The company commercializes the CANDIWALL system for about 1 year and manufactures one of the constituents of this system: CANDIWALL KLINKER tiles.

Table 12 – Characteristics to be observed

System components		Characteristics		Values
Thermal insulation		CE marking		XPS (EN 13164:2008) T1-CS(10\Y)200-DS(TH) Reaction to fire (Euro class) – E Thermal conductivity (W/m.K): 0,035 (e = 40 to 60 mm), 0,036 (e = 70 to 80 mm) and 0,038 (e = 100 to 120 mm)
Bonding product of the plates and base layer/bonding product of the tiles		Apparent mass density (g/m ³)		1393 ± 10
		pH (paste product)		11,3 ± 0,5
		Ash content at 450 °C (%)		96,4 ± 0,5
		Ash content at 900 °C (%)		95,1 ± 0,5
Finishing	Ceramic tiles	Apparent mass density (kg/m ³)	210 mm x 65 mm x 14 mm	29 (≤ 32)
			210 mm x 50 mm x 14 mm	27 (≤ 32)
			210 mm x 65 mm x 14 mm + 90 mm x 65 mm x 14 mm (“L” shape)	29 (≤ 32)
			210 mm x 50 mm x 14 mm + 90 mm x 50 mm x 14 mm (“L” shape)	29 (≤ 32)
	Length and width (mm xmm)		(206,5 x 63,0): ± 2,0 % (admissible deviation in relation to manufacturing measure)	
	Thickness (mm)		6,7 ± 0,5	
	Water absorption (%)		1348 ± 10	
	Joint grout	Apparent mass density (kg/m ³)		1348 ± 10
		Ash content at 450 °C and at 900 °C (%)		450 °C: 97,9 ± 0,5 900 °C: 95,3 ± 0,5
		pH		11,7 ± 0,5
Bolts for solid or hollow props		CE marking		ETA 08/0172
Bolts for wooden props		Test to determine rupture stress (kN)		0,9 ± 0,1
Starter profiles		Mass by length unit (g/m)		375,13 (for e _{isolante} =120 mm)