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European Technical Assessment ETA 22/0135 of 13/07/2022

GENERAL PART

Trade name of the construction product	**SISTEMA ARMATEX TOTAL ETA**
Product family to which the construction product belongs	**PAC 34: BUILDING KITS, UNITS, AND PREFABRICATED ELEMENTS. Externally bonded system made of AR glass fibre mesh, connectors and mortar for strengthening of masonry and reinforced concrete elements**
Manufacturer	**BIEMME S.r.l via Tevere, 26 61030 Lucrezia di Cartoceto (PU) - Italy**
Manufacturing plant	**BIEMME S.r.l via Tevere, 26 61030 Lucrezia di Cartoceto (PU) - Italy**
This European Technical Assessment contains:	**19 pages, including 13 annexes which form an integral part of this assessment**
This European Technical Assessment is issued in accordance with Regulation (EU) n° 305/2011, on the basis of	**EAD 340451-00-0104 - Externally bonded system made of AR glass fibre mesh, connectors and mortar for strengthening of masonry and reinforced concrete elements**

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SPECIFIC PARTS

1. TECHNICAL DESCRIPTION OF THE PRODUCT

The **SISTEMA ARMATEX TOTAL ETA** is a structural reinforcement system consisting of:

- a bi-axial mesh (**GLASSTEX STRUKTURA 590 ETA**);
- a lime-based mortar (**BM IDRO FRCM – M15**);
- “open-end” connectors (**OPEN-HAND**);
- a lime-based injection mortar **(BM INIEZIONE**).

The bi-axial mesh (**GLASSTEX STRUKTURA 590 ETA**) is made of leno weaved alkali-resistant (AR) glass fibres, with a percentage of zirconium dioxide (ZrO_2) greater than 16%, with a special alkali-resistant and thermosetting protective treatment which makes it flexible, without shape memory and easily adaptable to the various surfaces on which the system is applied. The mesh is also characterized by a rough surface, obtained through fillers, whose purpose is to increase the adhesion performances.
Bi-axial meshes are bonded to the surface of structural elements through a lime-based mortar (**BM IDRO FRCM - M15**). The system is applied on internal and external surfaces of walls, by using thicknesses varying between 5 and 40 mm.
The transversal connector (**OPEN-HAND**) is made of AR glass fibres with a percentage of zirconium dioxide (ZrO_2) greater than 16%. Connectors are characterized by a preformed rigid ribbed central section, made by pultrusion, and "open" (not impregnated) ends (see Annex A3); the connector can have only one not-impregnated end (**OPEN-HAND 1**) or both not-impregnated ends (**OPEN-HAND 2**).
The connector is applied to the structural element by grouting with a lime-based injection mortar (**BM INIEZIONE**). Its function is to increase the shear resistance and the effectiveness of confinement of the supporting structural element.

The product description, with reference to its components, is given in Annex A.

2. SPECIFICATION OF THE INTENDED USE IN ACCORDANCE WITH EUROPEAN ASSESSMENT DOCUMENT N° 340451-00-0104 (hereinafter EAD)

The **SISTEMA ARMATEX TOTAL ETA** is intended to be used in highly specialized applications for strengthening masonry and reinforced concrete elements in either flexure, shear, pure axial and combined axial-bending stresses. It is used to improve the mechanical performances in terms of stiffness and strength under static, seismic and dynamic loads and to enhance the resistance and ductility of undersized or damaged structural elements.

Concerning product packaging, transport and storage it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport and storage, as he considers necessary in order to reach the declared performances.
The information about installation is provided with the technical documentation from the Manufacturer and it is assumed that the product will be installed according to it or (in absence of such instructions) according to the usual practice of the building professionals.

The specifications and conditions given by the manufacturer are summarized in Annex B.

The performances assessed in this European Technical Assessment, according to the applicable EAD, are based on an assumed intended working life of at least 25 years, provided that the conditions for packaging, transport, storage, installation as well as appropriate use, maintenance and repair are met. The indications given on the working life cannot be interpreted as a guarantee given by the manufacturer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

3. PERFORMANCE OF THE PRODUCT AND REFERENCES TO THE METHODS USED FOR ITS ASSESSMENT

The tests for performance assessment of SISTEMA ARMATEX TOTAL ETA were carried out in compliance with EAD 340451-00-0104 according to the test methods reported herein, as well for what concerns sampling, conditioning and testing provisions.
The numbering (#) in the following tables corresponds to the numbering of Table 2.1.1 of EAD 340451-00-0104.

3.1 MECHANICAL RESISTANCE AND STABILITY (BWR 1)

#	Essential characteristic	Performance
Mesh (GLASSTEX STRUKTURA 590 ETA) + Mortar (BM IDRO FRCM – M15)		
1	Tensile strength	Annex C1, Table C1
2	Ultimate strain	Annex C1, Table C1
3	Stress strain curve	Annex C1, Table C1
4	Lap tensile strength	Annex C1, Table C2
5	Bond strength on substrates: Pull-off test	Annex C2, Table C4 (ambient) Annex C2, Table C5 (conditioning)
6	Bond strength on substrates: Single-lap shear test	Annex C3, Table C6 (ambient) Annex C3, Table C7 (conditioning)
7	Freezing and thawing resistance	Annex C4, Table C8
8	Water resistance	Annex C5, Table C9
9	Alkali resistance	Annex C5, Table C10
10	Thermal resistance	Annex C1, Table C3
11	Tensile strength after low number of cycles (seismic behaviour)	No performance assessed
12	Tensile strength after high number of cycles (fatigue actions)	No performance assessed
Connector (OPEN-HAND) + Injection Mortar (BM INIEZIONE)		
13	Tensile properties of connector	Annex C6, Table C11
14	Pull-out from substrate	Annex C6, Table C12
15	Freezing and thawing resistance	Annex C7, Table C14
16	Water resistance	Annex C7, Table C15
17	Alkali resistance	Annex C7, Table C16
18	Thermal resistance	Annex C6, Table C13
19	Tensile strength after low number of cycles (seismic behaviour)	No performance assessed
20	Tensile strength after high number of cycles (fatigue actions)	No performance assessed
Other properties		
21	Conventional limit properties of composite system	Annex C8, Table C17 and Table C18
22	Glass Transition Temperature	T_g=72,8 °C

3.2 SAFETY IN CASE OF FIRE (BWR 2)

#	Essential characteristic	Performance
23	Reaction to fire	**B-s1, d0**

4. ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE (AVCP) SYSTEM APPLIED, WITH REFERENCE TO ITS LEGAL BASE

In accordance with the European Assessment Document EAD No. 340451-00-0104, the applicable European legal act is: **Decision 1999/469/EC**.

The system of assessment and verification of constancy of performance (AVCP) is: **2+**

In addition, with regard to reaction to fire for products covered by this EAD the applicable European legal act is: **Decision 1999/469/EC**, as amended by **Decision 2001/596/EC**.

The system of assessment and verification of constancy of performance (AVCP) is: **3**

5. TECHNICAL DETAILS NECESSARY FOR THE IMPLEMENTATION OF THE AVCP SYSTEM, AS PROVIDED FOR IN EAD 340451-00-0104

Technical details necessary for the implementation of the AVCP system are laid down in the Control Plan deposited at ITC-CNR.

Issued in San Giuliano Milanese, Italy on 13/07/2022
by ITC – CNR

Professor Antonio Occhiuzzi
Director of ITC-CNR

MORTAR PROPERTIES

Table A1: Properties of the mortars

Property	Units	BM IDRO FRCM – M15	BM INIEZIONE
Type of product	-	Lime-based (NHL 5) mortar *(CE marked natural lime according to EN 459-1)*	Lime-based (NHL 5) fluid mineral mortar
Use	-	Bonding of meshes	Anchoring/grouting of connectors
Application on	-	Masonry (clay, tuff, natural stone)	Masonry (clay, tuff, natural stone)
Appearance	-	Powder	Hazelnut coloured powder
Packaging	-	25 kg bags	20 kg bags
Thickness	mm	single layer 10 mm	Not applicable
Density of the mixture	kg/m^3	2000-2100 (fresh mortar, EN 1015-6) 1800-1900 (hardened mortar, EN 1015-10)	1200 (EN 459-2)
Compressive strength	MPa	>15 (EN 998-2)	3,5 (7 days) 9 (28 days)
Strength class	-	M15 (EN 998-2)	M10
Shear strength	MPa	0,15 (t.v.) (EN 998-2)	-
Adhesive strength	MPa	> 1 (EN 1015-12)	-
Resistance to water vapour diffusion	-	μ = 15/35 (t.v.) (EN 998-2) (*)	-
Reaction to fire	class	A1	A1
Reference Harmonized Standard	-	EN 998-2	-

(*) t.v. = tabulated value.

SISTEMA ARMATEX TOTAL ETA	**Annex A1** **of ETA N° 22/0135**
Product Description – Components – Mortar	

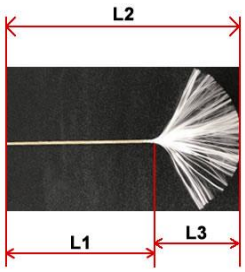
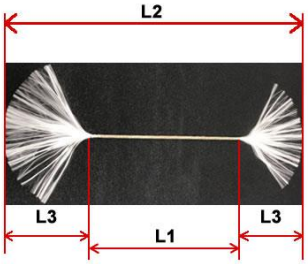
MESH PROPERTIES

Table A2: Properties of the mesh

Product		GLASSTEX STRUKTURA 590 ETA		
GEOMETRICAL AND PHYSICAL PROPERTIES				
Property	**Units**	**Value**		
Description	-	Biaxial mesh made of leno weaved alkali-resistant (AR) glass fibres, with a percentage of zirconium dioxide (ZrO_2) greater than 16%, with a special alkali-resistant protective treatment		
Appearance	-			
Colour	-	Red		
Mesh size (weft x warp)	mm	35 x 35		
Mesh opening (weft x warp)	mm	30 x 30		
Nominal area of single bar (only fibres), A_f	mm^2	2,84		
Nominal width of single bar	mm	7,75		
Bars for each side	n/m	29 (warp)		29 (weft)
Mass (inclusive of protective coating)	g/m^2	588		
Mass (without protective coating)	g/m^2	441		
Equivalent thickness	mm	0,082 (warp)		0,082 (weft)
Packaging	-	Rolls 1 x 50 m Rolls 2 x 50 m		
FIBRE PROPERTIES				
Fibre type	-	AR glass		
Fibre density	g/cm^3	2,68		
Modulus of elasticity	GPa	72		
		WARP		**WEFT**
Yarn linear density	tex	1200	640	2400
Yarn cross section	mm^2	0,45	0,24	0,896
Number of yarns	-	4	4	3
COATING PROPERTIES				
Coating type	-	styrene, butadiene, additives and microsilica		
Solid content	%	51		

CONNECTOR PROPERTIES

Table A3: Properties of the connector

Product		OPEN-HAND	
CONNECTOR GEOMETRICAL AND PHYSICAL PROPERTIES			
Property	**Units**	**Value**	
Description	-	AR glass connector with preformed pultruded rigid ribbed central section and "open" (not impregnated) ends	
Appearance	-	**OPEN-HAND 1**  	**OPEN-HAND 2** 
Colour	-	white	
Nominal diameter	mm	8	
Nominal cross-sectional area (composite material)	mm^2	50,2	
Nominal cross-sectional area (fibres)	mm^2	33,1	
Length of the preformed part (L1)	mm	200, 300, 400, 500, 600	
Length of the free end (L3)	mm	200	
Weight (raw material)	g/m	88,8	
Packaging	-	Boxes	
FIBRE PROPERTIES			
Fibre type	-	AR glass	
Fibre density	g/cm^3	2,68	
Yarn linear density	tex	2400	
Modulus of elasticity	GPa	72	
RESIN PROPERTIES			
Resin type	-	Epoxy resin	
Resin density (hardened, polymerized)	g/cm^3	1,07	
Resin glass transition temperature	°C	90	

SPECIFICATION OF INTENDED USE

- **INSTALLATION CONDITIONS**
  - T_{max}: +35 °C
  - T_{min}: +5 °C
  - Relative humidity: 50-95%
- **WORKING CONDITIONS**
  - T_{max}: +75 °C
  - T_{min}: -15 °C
  - Relative humidity: 50-95%
- **TYPE OF LABOR REQUIRED FOR INSTALLATION**

  The manpower necessary for the installation of the system must be adequately informed and trained from a technical point of view about the methods of installation, taking care to respect the progression of the operations as per the manufacturer's prescriptions. The recommendations are given in each technical data sheet concerning each individual product.
- **RECOMMENDATIONS FOR PACKAGING, TRANSPORT, STORAGE**

  Regarding packaging, transport, storage, it is the manufacturer's responsibility to take appropriate measures and advise its customers on this. The materials must be stored in cool, dry places in their original packaging, protected from direct sunlight and sources of moisture; these recommendations are reported in each technical data sheet concerning each individual product.
- **PRECAUTIONS AND LIMITATIONS OF USE**

  It is advisable to check the integrity of the package before using the products, if the mortars come into contact with water or if stored in humid environments they can degrade, therefore do not use the product if there are lumps. Once the mortar package has been opened, use all of the product.
  Check the expiry date of the premixed powder products (indicated on each individual package together with the production lot references).
  Check the temperature of the substrate (application range indicated in the technical data sheet of the mortar) and the presence of water stagnating on the surface.
  Check the compatibility of the environmental and climatic conditions of the construction site with respect to what is prescribed in the technical data sheets of the products that will be used for the installation of the system.
  In case of partial use of the mortar, mix it with water, scrupulously respecting the mixing proportions (by weight) indicated in the technical data sheet and in the bags.
  Work in the hours of the day compatible with the range of use of the mortar.
  Do not apply on surfaces exposed to direct sunlight, with imminent possibility of rain and/or on very windy days.
- **ORDINARY MAINTENANCE OPERATIONS**

  Visual investigations to check the maintenance-performance status of the system to be carried out at the discretion of the professional figure in charge.
  If the system also acts as a plaster coating for the structure, the ordinary maintenance operations of the protective coating (painting or coating) must be carried out over time. If, on the other hand, a protective plaster or an external thermal insulation coating system (ETICS) has been used on the system, the routine maintenance operations of the outermost protective states must be carried out over time.

SISTEMA ARMATEX TOTAL ETA	**Annex B1/1** **of ETA N° 22/0135**
Intended Use – Specifications	

- **MONITORING**

To monitor the state of conservation of the system over time, a visual monitoring of the state of conservation of the structures must be carried out at least once a year. Visual monitoring will serve to highlight the presence or absence of defects such as:
- crack patterns,
- colour variations,
- detachment of coatings,
- presence of saline efflorescence,
- presence of capillary rising.

In particular, as regards the crack patterns, the entire surface will have to be carefully analysed and subsequently graphic drawings will have to be drawn up where the various defects will be indicated. Based on the analyses found, the technician in charge will have to decide whether the state of conservation framework may already be exhaustive or whether further in-depth investigations will need to be carried out. At this stage it is advisable to pay close attention to the analysis of the crack pattern which can be local or widespread, to bring out possible instability phenomena in progress, possible phenomena of detachment of the system or not to represent any structural problem. In cases where the technician decides to deepen the level of knowledge of the state of conservation of the reinforcement system, non-destructive investigations such as local beating, infrared thermography, endoscopic investigations can be carried out.

- **EXTRAORDINARY MAINTENANCE**

As for the extraordinary maintenance of the system following exceptional events such as impacts, seismic actions, etc. or due to poor maintenance, first of all, an investigation on the defects must be carried out on the surface to analyse the possible state of damage (with extension and intensity). Subsequently, according to the type of damage found, the most suitable restoration work will have to be carried out, to guarantee the initial design performance for the reinforced structure.
Following exceptional events, the main problems encountered by the reinforcement system can be:
- possible (localized or diffuse) detachment of the matrix from the support;
- possible damage to the mesh;
- possible damage to the connectors.

Below are the main technical solutions to be adopted according to the type of problem encountered.

In the event of widespread detachment of the reinforcement system:
Remove it and rebuild the entire system, paying particular attention to ensuring the correct overlap between the existing mesh and the new mesh of the system to be repaired.

If there is a localized detachment of the reinforcement system:
Provide for the local removal and system restoration of the only area that was detected as damaged by the investigations, taking care, during the removal of the mortar, not to damage the mesh and the mortar in the surrounding areas. The work must be carried out paying particular attention to ensure the correct overlap between the existing mesh and the new mesh of the system to be repaired.

In the event of a break in the mesh inside the system:
Provide for the removal and restoration of the system only in the area that was damaged by the investigations, taking care during the removal of the mortar not to damage the mesh and the mortar in the surrounding areas. The work must be carried out paying particular attention to ensure the correct overlap between the existing mesh and the new mesh of the system to be repaired.

In case of connector breakage:
Remove the damaged part of the connector and apply a new connector nearby.

SISTEMA ARMATEX TOTAL ETA	**Annex B1/2** **of ETA N° 22/0135**
Intended Use – Specifications	

INSTALLATION INSTRUCTIONS

Preliminary operations
Before applying the system to the structure to be reinforced, it is necessary to know the design, the logistics of the construction site and it is also necessary to check the suitability of the support on which to apply the reinforcement system.

Verification of design documentation
In this phase, all the design documents and their correspondence with the construction site reality will have to be verified. Also analyse all possible logistical problems or limitations in the operation of the site.

Pre-installation work
Cutting the mesh
Unroll to the required length and first cut the mesh with suitable professional scissors. During the unwinding and handling operations of the mesh rolls, be careful not to bend or damage it.
Mixing of mortars
Weigh the amount of mixing water indicated in the technical data sheets of the mortars using a scale or a graduated container. Open the bags, pour the product into a bucket suitable to contain the quantity of a bag of mortar and the mixing water and mix the two components. Mix the product until a homogeneous and plastic mortar is obtained. The mixture can also be made with a concrete mixer, mixer screw or with suitable automatic mixing systems. In the case of using plastering machines fil them with the powder product, use suitable low-flow pumps and pipes increased in the section to facilitate pumping of the mixed product. If mixed with a cement mixer, avoid mixing times longer than 3 min. Avoid mixing partial quantities of product.
Equipment needed for the installation phase
For the application phase of the reinforcement system, it is necessary to have suitable containers on site to store the material after mixing it, trowels, stainless steel spatulas, running water, sponges, any plastering machine, templates, sheets (to protect the system from severe weather conditions). For the application of the connectors it is necessary to have a drill, a compressor and suitable instrumentation both manual and with pumping system suitable for fluid mortars**.**

Preparation of the substrate
- Make sure that the substrate is completely hardened, resistant and free of loose parts that detach;
- In the presence of deteriorated plaster, remove the surface until obtaining a support with sufficient resistance;
- Cleaning and saturation of the substrate by washing with low pressure water;
- Remove any efflorescence and salts by washing or through mechanical systems such as brushing, sandblasting or hydro-sandblasting;
- Check for the presence of cracks on the surfaces that will host the reinforcement (if present, carry out grouting-seams / or injections of consolidation in advance);
- On particularly irregular or poorly absorbent substrates, before applying the structural mortar, provide a layer of rough coating;
- Check for the presence of surface condensation or water stagnation on the surface;
- Check for the presence of sharp corners, otherwise proceed with their chamfering (minimum radius 20 mm);
- The substrate temperature must be between + 5 °C and + 35 °C.

SISTEMA ARMATEX TOTAL ETA	**Annex B2/1** **of ETA N° 22/0135**
Intended Use – Installation instructions	

System Installation

- Execution of holes (not less than 4 per square meter) of suitable diameter for inserting the connectors;
- Cleaning the holes;
- Anchoring application - grouting mortar;
- Insertion and fixing of the connector;
- Saturation of the substrate with water at low pressure (saturated substrate with dry surface);
- Possible application of structural rendering mortar;
- Application of the first layer of structural mortar by hand or by machine with thickness equal to 5 mm;
- Application of the AR glass fibre mesh on the still fresh mortar by passing the connectors inside the opening of the mesh;
- Ensure at least 15 cm of overlap of the mesh in case of overlapping;
- Opening of the dry part of the connector following a radial arrangement;
- Application of a second layer of structural mortar by hand or by machine with thickness equal to 5 mm.

Once the curing of the mortar has finished, it is possible to proceed directly with the surface finish by using smoothing compounds or water based primers. Use breathable and water-repellent products outdoors.

Connection elements

According to the characteristics of the design, the reinforcement system can be applied on one side or on both sides of the masonry structure and passing or non-passing connectors in glass fibre AR Glass Biemme OPEN-HAND 2 or Biemme OPEN-HAND 1 are used.

In the case of OPEN-HAND 1 non-passing connectors, after removing the plaster, perform the following cycle:

Realization of non-through holes inclined at about 45° (for at least 2/3 of the wall thickness) with a diameter of 14-16 mm in number not less than 4/m^2, cleaning them with compressed air or with aspirators, grouting them with injection mortar BM INIEZIONE, insertion of pre-impregnated AR Glass fiberglass connectors OPEN-HAND type 1. Subsequently, after applying the first layer of mortar, lay the mesh taking care to pass the connectors inside its openings, fan the dry part in a radial pattern and apply the second layer of mortar to finish.

If using OPEN-HAND 2 passing connectors, perform the following cycle:

Execution of through holes with a diameter of 14-16 mm in a number of not less than 4/m^2, cleaning them with compressed air or with aspirators, grouting them with BM INIEZIONE injection mortar, insertion of AR Glass pre-resinated glass fibre connectors OPEN-HAND 2. Subsequently, after having applied the first layer of mortar, lay the mesh taking care to pass the connectors inside its openings, fan the dry part in a radial pattern and apply the second layer of mortar to finish.

SISTEMA ARMATEX TOTAL ETA	**Annex B2/2** **of ETA N° 22/0135**
Intended Use – Installation instructions	

Table C1: Direct tensile strength (warp)

DIRECT TENSILE STRENGTH - AMBIENT (T=23±2°C , 50±5% RH)					
Description	**Symbol**	**Units**	**Failure mode**	**Average value**	**Characteristic value**
Tensile strength	σ_u	[MPa]	Diffuse cracking	367,7	191,0
Tensile strain	ε_u	[%]		1,05	0,47
Elastic modulus of stage A	E_1	[GPa]		288	55
Stiffness modulus in stage C	E_3	[GPa]		37	23

Table C2: Lap tensile strength (warp)

LAP TENSILE STRENGTH – AMBIENT (T=23±2°C , 50±5% RH)					
Description	**Symbol**	**Units**	**Failure mode**	**Average value**	**Characteristic value**
Tested overlap length	l_{lap}	[mm]	Diffuse cracking mainly in the overlap area	100	-
Lap tensile strength	σ_{lap}	[MPa]		222,39	135,60
Tensile strain	$\varepsilon_{u,lap}$	[%]		1,25	0,18
Elastic modulus of stage A	$E_{1,lap}$	[GPa]		144,6	34,5
Stiffness modulus in stage C	$E_{3,lap}$	[GPa]		24,6	14,6

Table C3: Thermal resistance (warp)

THERMAL RESISTANCE (T=75°C)				
Description	**Symbol**	**Units**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{u,therm}$	[MPa]	292,09	71,73
Tensile strain	$\varepsilon_{u,therm}$	[%]	1,02	0,49
Elastic modulus of stage A	$E_{1,therm}$	[GPa]	226,56	67,48
Stiffness modulus in stage C	$E_{3,therm}$	[GPa]	20,94	9,94
Retained properties				
Retained tensile strength	$\sigma_{u,therm,ret}$	[%]	79	-
Retained modulus in stage A	$E_{1,therm,ret}$	[%]	79	-
Retained modulus in stage C	$E_{3,therm,ret}$	[%]	56	-

SISTEMA ARMATEX TOTAL ETA	**Annex C1** **of ETA N° 22/0135**
Performances – Mesh + Mortar – Mechanical properties under direct tension, lap tensile strength and thermal resistance	

Table C4: Bond strength on substrate – Pull-off strength (ambient)

BOND STRENGTH (Pull-off) – AMBIENT (T=20°C , 50±5% RH)			
Properties of substrates			
Type	**CLAY**	**TUFF**	**NATURAL STONE**
Compressive strength, f_b [MPa]	25,0	4,1	57,0
Axial surface strength, $f_{h,sub}$ [MPa]	3,3 (average) 2,5 (characteristic)	0,4 (average) 0,1 (characteristic)	3,6 (average) 1,7 (characteristic)

Pull-off test					
Description	**Symbol**	**Units**	**Substrate**	**Failure mode(1)**	**Average value**
Pull-off strength	f_h	[MPa]	**clay**	C	0,96
			tuff	A	0,29
			natural stone	A/B	0,42

(1) A= Cohesive failure in substrate; A/B= adhesive failure between the substrate and the first layer of matrix; B= cohesive failure in the first layer of matrix; B/C= adhesive failure between the first and second layer of matrix; C= cohesive failure in the second layer of matrix; D= Bond failure at epoxy/overlay interface.

Table C5: Bond strength on substrate – Pull-off strength (conditioning)

BOND STRENGTH (PULL-OFF STRENGTH) – CONDITIONING (Properties of substrates in Table C4)											
Description	**Symbol**	**Units**	**Substrate**	**Ambient**	**Ageing**	**1000 h**			**3000 h**		
						Failure Mode (1)	**Average value**	**Retained $f_{h,ret}$ [%]**	**Failure Mode (1)**	**Average value**	**Retained $f_{h,ret}$ [%]**
Pull-off strength	f_h	[MPa]	**CLAY**	0,96	**Water**	B/C	1,82	189	B/C	1,71	178
				0,96	**Alkali**	B/C	1,66	173	B	1,49	155
			TUFF	0,29	**Water**	A	0,50	171	A	0,23	77
				0,29	**Alkali**	A	0,33	112	A	0,36	122
			NATURAL STONE	0,42	**Water**	A/B	0,59	141	A/B	0,59	141
				0,42	**Alkali**	B	0,61	146	A/B	0,45	109

(1) A= Cohesive failure in substrate; A/B= adhesive failure between the substrate and the first layer of matrix; B= cohesive failure in the first layer of matrix; B/C= adhesive failure between the first and second layer of matrix; C= cohesive failure in the second layer of matrix; D= Bond failure at epoxy/overlay interface.

SISTEMA ARMATEX TOTAL ETA

Performances – Mesh + Mortar – Pull-off strength
(ambient and conditioning)

Annex C2
of ETA N° 22/0135

Table C6: Bond strength on substrate – Single-lap shear strength (ambient) - warp

BOND STRENGTH (Single-lap shear strength) – AMBIENT (T=22°C , 50±5% RH)			
Properties of substrates			
Type	**CLAY**	**TUFF**	**NATURAL STONE**
Compressive strength, f_b [MPa]	25,0	4,1	57,0
Axial surface strength, $f_{h,sub}$ [MPa]	3,3 (average) 2,5 (characteristic)	0,4 (average) 0,1 (characteristic)	3,6 (average) 1,7 (characteristic)

Single-lap shear test

Description	Symbol	Units	Substrate	Failure mode(1)	Average value	Charact. value
Peak load	P_{max}	[N]	**CLAY**	MFI	4570,1	3062,1
			TUFF	MFI	5369,1	3636,9
			NATURAL STONE	NPA(2)	NPA(2)	NPA(2)
Bond capacity	P_{deb}	[N]	**CLAY**	MFI	4570,1	3062,1
			TUFF	MFI	5369,1	3636,9
			NATURAL STONE	NPA(2)	NPA(2)	NPA(2)
Conventional limit stress	$\sigma_{lim,conv}$	[MPa]	**CLAY**	MFI	536	359
			TUFF	MFI	630	427
			NATURAL STONE	NPA(2)	NPA(2)	NPA(2)

(1) MFI=Matrix-Fibre Interface.
(2) No Performance Assessed.

Table C7: Bond strength on substrate – Single-lap shear strength (conditioning) - warp

BOND STRENGTH (SINGLE-LAP SHEAR STRENGTH) – CONDITIONING (Properties of substrates in Table C6)

Description	Symbol	Units	Substrate	Ambient	Ageing	1000 h			3000 h		
						Failure Mode (1)	Average value	Retained [%]	Failure Mode (1)	Average value	Retained [%]
Peak load	P_{max}	[N]	**CLAY**	4570	**Water**	FR	3437	75	FR	2859	63
				4570	**Alkali**	FR	4207	92	FR	5026	110
			TUFF	5369	**Water**	FR	4353	81	FR	2750	51
				5369	**Alkali**	FR	3567	66	FR	3635	68
			NATURAL STONE	NPA(2)	**Water**	NPA(2)					
				NPA(2)	**Alkali**						
Bond capacity	P_{deb}	[N]	**CLAY**	4570	**Water**	FR	3030	66	FR	1009	22
				4570	**Alkali**	FR	2051	45	FR	2092	46
			TUFF	5369	**Water**	FR	2800	52	FR	2800	52
				5369	**Alkali**	FR	2118	39	FR	1149	21
			NATURAL STONE	NPA(2)	**Water**	NPA(2)					
				NPA(2)	**Alkali**						

(1) FR= Fibre Rupture; MFI=Matrix-Fibre Interface.
(2) No Performance Assessed.

SISTEMA ARMATEX TOTAL ETA

Performances – Mesh + Mortar – Single-lap shear strength (ambient and conditioning)

Annex C3
of ETA N° 22/0135

Table C8: Environmental durability test – Freezing and thawing - warp

FREEZING AND THAWING					
Assessment of surface changes					
No surface changes, such as erosion, cracking, crazing, checking, and chalking, were evidenced.					
Direct tension					
Description	**Symbol**	**Units**	**Failure mode**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{u,FT}$	[MPa]	Diffuse cracking	281,56	190,15
Tensile strain	$\varepsilon_{u,FT}$	[%]		1,01	0,45
Modulus in stage A (uncracked)	$E_{1,FT}$	[GPa]		112,50	77,46
Modulus in stage C (cracked)	$E_{3,FT}$	[GPa]		33,97	5,31
Retained properties					
Retained tensile strength	$\sigma_{u,FT,ret}$	[%]	Diffuse cracking	77	-
Retained modulus in stage A	$E_{1,FT,ret}$	[%]		39	-
Retained modulus in stage C	$E_{3,FT,ret}$	[%]		91	-

SISTEMA ARMATEX TOTAL ETA	**Annex C4** **of ETA N° 22/0135**
Performances – Mesh + Mortar – Freezing and thawing resistance	

Table C9: Environmental durability test – Water resistance - warp

WATER RESISTANCE							
Assessment of surface changes							
No surface changes, such as erosion, cracking, crazing, checking, and chalking, were evidenced.							
Direct tension							
Description	**Symbol**	**Units**	**Failure mode**	**1000 h**		**3000 h**	
				Average value	**Characteristic value**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{u,w}$	[MPa]	Diffuse cracking	518,85	395,81	382,41	184,40
Tensile strain	$\varepsilon_{u,w}$	[%]		1,45	0,74	2,09	0,30
Modulus in stage A (uncracked)	$E_{1,w}$	[GPa]		606,64	216,63	535,95	-(1)
Modulus in stage C (cracked)	$E_{3,w}$	[GPa]		34,63	22,65	5,97	1,62
Retained properties							
Retained tensile strength	$\sigma_{u,w,ret}$	[%]	Diffuse cracking	141	-	104	-
Retained modulus in stage A	$E_{1,w,ret}$	[%]		211	-	186	-
Retained modulus in stage C	$E_{3,w,ret}$	[%]		93	-	16	-

(1) Value not determinable due to the high dispersion of results.

Table C10: Environmental durability test – Alkali resistance - warp

ALKALI RESISTANCE							
Assessment of surface changes							
No surface changes, such as erosion, cracking, crazing, checking, and chalking, were evidenced.							
Direct tension							
Description	**Symbol**	**Units**	**Failure mode**	**1000 h**		**3000 h**	
				Average value	**Characteristic value**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{u,alk}$	[MPa]	Diffuse cracking	578,49	380,94	367,48	303,75
Tensile strain	$\varepsilon_{u,alk}$	[%]		2,49	0,47	1,53	0,15
Modulus in stage A (uncracked)	$E_{1,alk}$	[GPa]		642,57	83,43	733,42	198,58
Modulus in stage C (cracked)	$E_{3,alk}$	[GPa]		24,60	3,32	11,24	-(1)
Retained properties							
Retained tensile strength	$\sigma_{u,alk,ret}$	[%]	Diffuse cracking	157	-	100	-
Retained modulus in stage A	$E_{1,alk,ret}$	[%]		223	-	255	-
Retained modulus in stage C	$E_{3,alk,ret}$	[%]		66	-	30	-

(1) Value not determinable due to the high dispersion of results.

SISTEMA ARMATEX TOTAL ETA	**Annex C5 of ETA N° 22/0135**
Performances – Mesh + Mortar – Water and alkali resistance	

Table C11: Tensile properties of the connector + mortar – Direct tensile test

DIRECT TENSILE STRENGTH				
Description	**Symbol**	**Units**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{u,c}$	[MPa]	472,09	238,59
Ultimate strain	$\varepsilon_{u,c}$	[%]	1,82	0,88
Tensile modulus of elasticity	E_c	[GPa]	25,95	25,12

Table C12: Pull-out from substrates

PULL-OUT FROM REFERENCE SUBSTRATES					
Properties of substrates					
Type			**CLAY**	**TUFF**	**NATURAL STONE**
Compressive strength, f_b [MPa]			25,0	4,1	57,0
Pull-out test results					
Description	**Symbol**	**Units**	**Substrate**	**Failure mode (1)**	**Average value**
Anchorage length	L_{anc}	[mm]	**All**	**-**	100
Pull-out load	P_{anc}	[kN]	**CLAY**	**1**	7,81
			TUFF	**1**	4,02
			NATURAL STONE	**1**	1,27

(1) Legend (EAD, clause D4): 1. failure due to sliding of the connector; 2. failure at the anchoring-substrate interface; 3. failure of the substrate and/or substrate cone failure; 4. failure of the connector.

Table C13: Thermal resistance

THERMAL RESISTANCE (T=75°C)				
Description	**Symbol**	**Units**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{c,therm}$	[MPa]	719,18	593,95
Ultimate strain	$\varepsilon_{c,therm}$	[%]	2,83	2,06
Tensile modulus of elasticity	$E_{c,therm}$	[GPa]	25,51	21,18
Retained properties				
Retained tensile strength	$\sigma_{c,therm,ret}$	[%]	83	-
Retained tensile modulus of elasticity	$E_{c,therm,ret}$	[%]	91	-

SISTEMA ARMATEX TOTAL ETA

Performances – Connector + mortar – Tensile strength, pull-out from substrates and thermal resistance

Annex C6
of ETA N° 22/0135

Table C14: Environmental durability test – Freezing and thawing resistance

FREEZING AND THAWING RESISTANCE				
Assessment of surface changes				
No surface changes, such as erosion, cracking, crazing, checking, and chalking, were evidenced.				
Direct tension				
Description	**Symbol**	**Units**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{c,FT}$	[MPa]	393,54	187,80
Tensile strain	$\varepsilon_{c,FT}$	[%]	1,68	1,05
Modulus of elasticity	$E_{c,FT}$	[GPa]	23,73	18,95
Retained properties				
Retained tensile strength	$\sigma_{c,FT,ret}$	[%]	83	-
Retained modulus of elasticity	$E_{c,FT,ret}$	[%]	91	-

Table C15: Environmental durability test – Water resistance

WATER RESISTANCE						
Assessment of surface changes						
No surface changes, such as erosion, cracking, crazing, checking, and chalking, were evidenced.						
Direct tension						
Description	**Symbol**	**Units**	**1000 h**		**3000 h**	
			Average value	**Characteristic value**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{c,w}$	[MPa]	555,29	339,49	436,84	179,84
Tensile strain	$\varepsilon_{c,w}$	[%]	2,56	1,19	1,75	0,68
Modulus of elasticity	$E_{c,w}$	[GPa]	23,85	16,00	25,23	18,64
Retained properties						
Retained tensile strength	$\sigma_{c,w,ret}$	[%]	118	-	93	-
Retained modulus of elasticity	$E_{c,w,ret}$	[%]	92	-	97	-

Table C16: Environmental durability test – Alkali resistance

ALKALI RESISTANCE						
Assessment of surface changes						
No surface changes, such as erosion, cracking, crazing, checking, and chalking, were evidenced.						
Direct tension						
Description	**Symbol**	**Units**	**1000 h**		**3000 h**	
			Average value	**Characteristic value**	**Average value**	**Characteristic value**
Tensile strength	$\sigma_{c,alk}$	[MPa]	352,84	192,22	376,25	163,70
Tensile strain	$\varepsilon_{c,alk}$	[%]	1,42	0,79	1,68	0,43
Modulus of elasticity	$E_{c,alk}$	[GPa]	26,46	19,97	22,38	11,57
Retained properties						
Retained tensile strength	$\sigma_{c,alk,ret}$	[%]	75	-	80	-
Retained modulus of elasticity	$E_{c,alk,ret}$	[%]	102	-	86	-

SISTEMA ARMATEX TOTAL ETA

Performances – Connector + mortar – Freezing and thawing resistance, water and alkali resistance

Annex C7
of ETA N° 22/0135

Table C17: Mechanical properties of mesh

DIRECT TENSION				
Description	**Symbol**	**Units**	**Average**	**Characteristic value**
Ultimate stress	$\sigma_{u,f}$	[MPa]	682,8	293,6
Ultimate strain	$\varepsilon_{u,f}$	[%]	1,10	0,50
Elastic modulus	E_f	[GPa]	64,2	58,3

Table C18: Conventional limit strain

Description	**Symbol**	**Units**	**Substrate**	**Average value**	**Characteristic value**
Conventional limit strain	$\varepsilon_{lim,conv}$	[%]	**CLAY**	0,83	0,56
			TUFF	0,98	0,66
			NATURAL STONE	NPA (1)	

(1) No Performance Assessed

SISTEMA ARMATEX TOTAL ETA	**Annex C8** **of ETA N° 22/0135**
Performances – Tensile strength of mesh and conventional limit strain	