EOTA®

EUROPEAN ASSESSMENT DOCUMENT

EAD 340392-00-0104

November 2018

CRM (COMPOSITE REINFORCED MORTAR) SYSTEMS FOR STRENGTHENING CONCRETE AND MASONRY STRUCTURES

The reference title and language for this EAD is English. The applicable rules of copyright refer to the document elaborated in and published by EOTA.

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

The CRM (Composite Reinforced Mortar) system is composed of different components, namely:

- FRP (Fibre Reinforced Polymer) mesh (preformed);

- FRP mesh corner elements (preformed);

- FRP connectors (preformed / semi-impregnated);

- Chemical anchors;

- Inorganic matrix.

The chemical anchors are not covered by this EAD.

The FRP components of the system (mesh, mesh corner elements and connectors) are made of carbon and/or glass continuous fibres.

FRP meshes, as well as FRP mesh corner elements, are composed of fibre strands fully impregnated with a thermosetting resin. The mesh shall be formed by impregnating and weaving the fibre strands and, subsequently, polymerizing the resin to obtain the final product. Typically, the mesh is squared.

The FRP mesh is applied on the structural elements or concrete/masonry walls and then embedded in an inorganic matrix (mortar, concrete) (Figure 1.1 and Figure 1.2).

Transversal connectors consist in preformed or semi-impregnated unidirectional FRP bars, connected to each other through chemical anchors or inorganic matrix. Transversal connectors can pass-through the wall, or alternatively, one end can be completely embedded (Figure 1.1 and Figure 1.2).

This EAD is also applicable to the FRP components as single products, provided that they are placed individually on the market for an intended use as a part of CRM systems for strengthening concrete and masonry structures within the scope of the EAD. The same concept is not applicable to the inorganic matrix itself, which becomes object of the EAD only when part of the kit as a whole (see Table 2.1).

a)

(b)
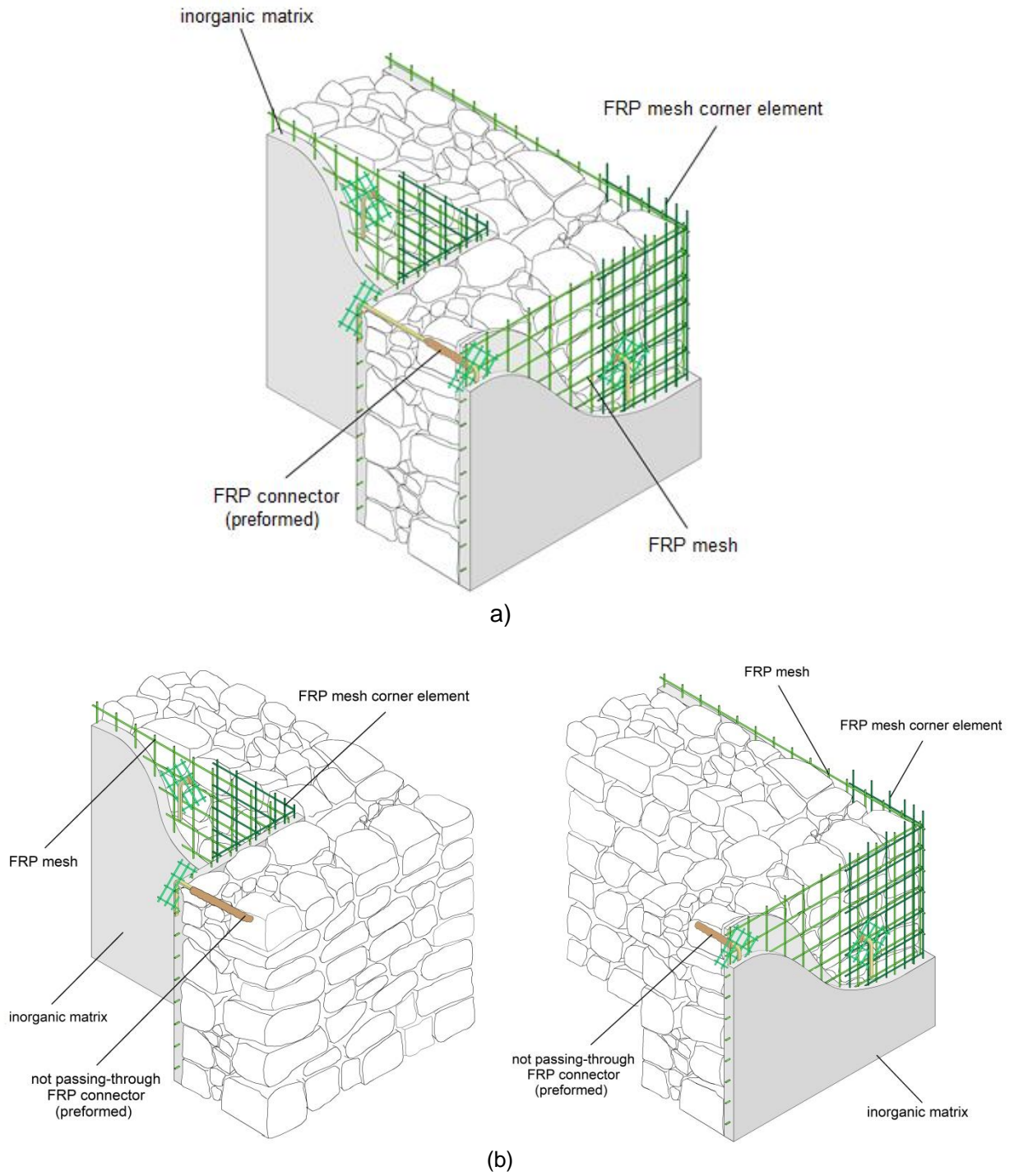
Figure 1.1 CRM system with FRP preformed connectors: (a) two overlapping connectors in the same passing-through hole; (b) not passing-through (embedded) connector.

a)

(b)
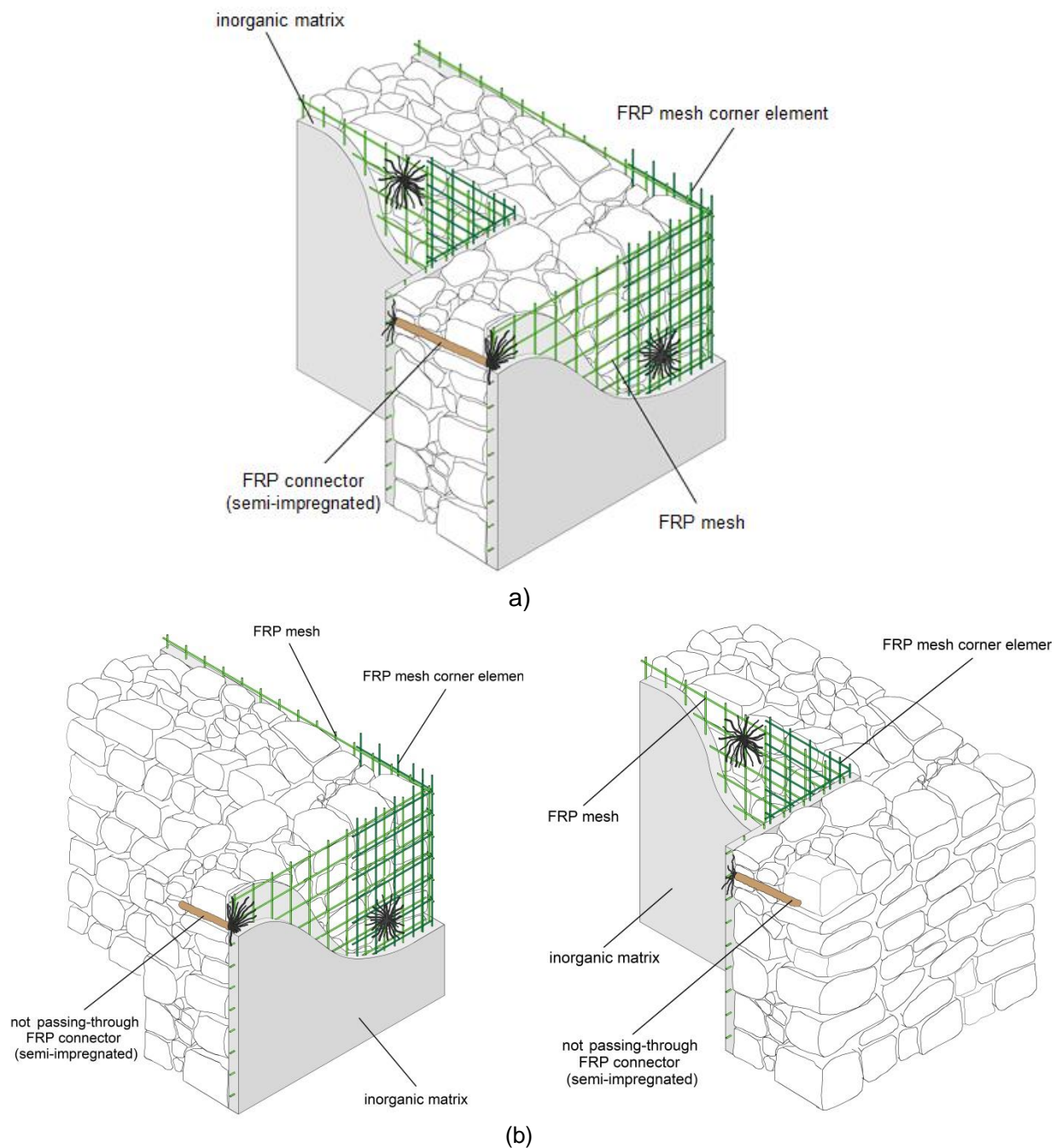
Figure 1.2 CRM system with FRP semi-impregnated connector:
(a) passing-through connector; (b) not passing-through (embedded) connector.

The product is not covered by a harmonised European standard (hEN).

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2   Information on the intended use(s) of the construction product

1.2.1   Intended use(s)

The FRP components of the CRM system are intended to be used in composition with an inorganic matrix and chemical anchors in highly specialized applications to strengthen existing and new masonry and concrete structures, especially for elements where two dimensions are predominant with respect to the other (walls, vaults, etc.). In particular, to increase the load bearing capacity, to enhance the strength, stiffness and ductility of structural elements.

The FRP components are used, in composition with inorganic matrix and chemical anchors, for reinforcement of structural elements subject to static, quasi-static, seismic/dynamic loading, also in environments subject to critical exposure conditions.

1.2.2   Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the "CRM system" for the intended use of 50 years when installed in the works (provided that the "CRM system" is subject to appropriate installation). These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[1].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3   Specific terms used in this EAD (if necessary in addition to the definitions in CPR, Art 2)

1.3.1   Monolithic mesh

The resistant mechanism of CRM System is based on the use of a monolithic mesh embedded in an inorganic matrix coating.

A FRP mesh can be considered monolithic when the shear resistance of the mesh junction in both directions of the mesh, determined as indicated in Annex C, is equal or higher than 0.05 times the tensile resistance of the mesh in the considered direction (warp and weft).

1.3.2   Warp wire

The compound of fibres (roving) running lengthwise in the Production Line.

1.3.3   Weft wire

The compound of fibres (roving) running crosswise in the Production Line.

---

[1]   The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

Note: All undated references to standards or to EADs in this Chapter are to be understood as references to the dated versions listed in Clause 4.

2.1 Essential characteristics of the product

Table 2.1 shows how the performance of the "CRM (Composite Reinforced Mortar) systems for strengthening concrete and masonry structures" is assessed in relation to the essential characteristics.

Table 2.1 Essential characteristics of the product and methods and criteria for assessing their performance in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability		
1	Tensile strength of the FRP mesh (longitudinal and orthogonal direction)	2.2.2.1	Level $\sigma_{u,m}$ [MPa]
2	Ultimate strain of the FRP mesh		Level $\varepsilon_{u,m}$ [%]
3	Young's Modulus of the FRP mesh		Level E_m [GPa]
4	Shear resistance of the mesh junction (in the two orthogonal directions)	2.2.2.2	Level F_{junc} [kN]
5	Freezing and thawing resistance of the FRP mesh	2.2.2.3	Level and description Retained tensile strength $\sigma_{u,FT,ret}$ [%] Retained elastic modulus $E_{FT,ret}$ [%]
6	Water resistance of the FRP mesh	2.2.2.4	Level and description Retained tensile strength $\sigma_{u,w,ret}$ [%] Retained elastic modulus $E_{w,ret}$ [%]
7	Saltwater resistance of the FRP mesh	2.2.2.5	Level and description Retained tensile strength $\sigma_{u,sw,ret}$ [%] Retained elastic modulus $E_{sw,ret}$ [%]
8	Alkali resistance of the FRP mesh	2.2.2.6	Level and description Retained tensile strength $\sigma_{u,alk,ret}$ [%] Retained elastic modulus $E_{alk,ret}$ [%]
9	Glass Transition Temperature of the FRP mesh	2.2.2.7	Level T_g [°C]
10	Tensile resistance of the FRP mesh corner elements	2.2.3.1	Level $F_{u,mc}$ [kN]
11	Tensile strength of the FRP connector	2.2.4.1	Level $\sigma_{u,con}$ [MPa]
12	Ultimate strain of the FRP connector		Level $\varepsilon_{u,con}$ [%]
13	Young's Modulus of the FRP connector		Level E_{con} [GPa]

14	Pull-out from reference substrates	2.2.4.2	Level and description Anchorage length, L_{anc} [mm] Pull-out load, F_{anc} [kN]
15	Lap-tensile strength of the FRP connector	2.2.4.3	Level and description Overlap length, l_{lap} [mm] Failure load of lap joint, F_c [kN] Lap tensile strength, σ_{lap} [MPa]
16	Freezing and thawing resistance of the FRP connector	2.2.4.4	Level and description Retained tensile strength $\sigma_{u,FT,ret}$ [%] Retained elastic modulus $E_{FT,ret}$ [%]
17	Water resistance of the FRP connector	2.2.4.5	Level and description Retained tensile strength $\sigma_{u,w,ret}$ [%] Retained elastic modulus $E_{w,ret}$ [%]
18	Saltwater resistance of the FRP connector	2.2.4.6	Level and description Retained tensile strength $\sigma_{u,sw,ret}$ [%] Retained elastic modulus $E_{sw,ret}$ [%]
19	Alkali resistance of the FRP connector	2.2.4.7	Level and description Retained tensile strength $\sigma_{u,alk,ret}$ [%] Retained elastic modulus $E_{alk,ret}$ [%]
20	Glass Transition Temperature of the FRP connector	2.2.2.7	Level T_g [°C]
Basic Works Requirement 2: Safety in case of fire			
21	Reaction to fire	2.2.1.1	Class

Table 2.2 shows how the performance of the FRP mesh is assessed in relation to the essential characteristics.

Table 2.2 Essential characteristics of the product and methods and criteria for assessing their performance in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability		
1	Tensile strength (longitudinal and orthogonal direction)	2.2.2.1	Level $\sigma_{u,m}$ [MPa]
2	Ultimate strain		Level $\varepsilon_{u,m}$ [%]
3	Young's Modulus		Level E_m [GPa]
4	Shear resistance of the mesh junction (in the two orthogonal directions)	2.2.2.2	Level F_{junc} [kN]
5	Freezing and thawing resistance	2.2.2.3	Level and description Retained tensile strength $\sigma_{u,FT,ret}$ [%] Retained elastic modulus $E_{FT,ret}$ [%]
6	Water resistance	2.2.2.4	Level and description Retained tensile strength $\sigma_{u,w,ret}$ [%] Retained elastic modulus $E_{w,ret}$ [%]
7	Saltwater resistance	2.2.2.5	Level and description Retained tensile strength $\sigma_{u,sw,ret}$ [%] Retained elastic modulus $E_{sw,ret}$ [%]
8	Alkali resistance	2.2.2.6	Level and description Retained tensile strength $\sigma_{u,alk,ret}$ [%] Retained elastic modulus $E_{alk,ret}$ [%]
9	Glass Transition Temperature	2.2.2.7	Level T_g [°C]

Table 2.3 shows how the performance of the <u>FRP mesh corner elements</u> is assessed in relation to the essential characteristics.

Table 2.3 Essential characteristics of the product and methods and criteria for assessing their performance in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Tensile resistance	2.2.3.1	Level $F_{u,mc}$ [kN]
2	Freezing and thawing resistance	2.2.3.2	Level and description Retained tensile strength $\sigma_{u,FT,ret}$ [%] Retained elastic modulus $E_{FT,ret}$ [%]
3	Water resistance		Level and description Retained tensile strength $\sigma_{u,w,ret}$ [%] Retained elastic modulus $E_{w,ret}$ [%]
4	Saltwater resistance		Level and description Retained tensile strength $\sigma_{u,sw,ret}$ [%] Retained elastic modulus $E_{sw,ret}$ [%]
5	Alkali resistance		Level and description Retained tensile strength $\sigma_{u,alk,ret}$ [%] Retained elastic modulus $E_{alk,ret}$ [%]
6	Glass Transition Temperature		Level T_g [°C]

Table 2.4 shows how the performance of the <u>FRP connectors</u> is assessed in relation to the essential characteristics.

Table 2.4 Essential characteristics of the product and methods and criteria for assessing their performance in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability		
1	Tensile strength	2.2.4.1	Level $\sigma_{u,con}$ [MPa]
2	Ultimate strain		Level $\varepsilon_{u,con}$ [%]
3	Young's Modulus		Level E_{con} [GPa]
4	Pull-out from reference substrates	2.2.4.2	Level and description Anchorage length, L_{anc} [mm] Pull-out load, F_{anc} [kN]
5	Lap-tensile strength	2.2.4.3	Level and description Overlap length, l_{lap} [mm] Failure load of overllap joint, F_c [kN] Lap tensile strength, σ_{lap} [MPa]
6	Freezing and thawing resistance	2.2.4.4	Level and description Retained tensile strength $\sigma_{u,FT,ret}$ [%] Retained elastic modulus $E_{FT,ret}$ [%]
7	Water resistance	2.2.4.5	Level and description Retained tensile strength $\sigma_{u,w,ret}$ [%] Retained elastic modulus $E_{w,ret}$ [%]
8	Saltwater resistance	2.2.4.6	Level and description Retained tensile strength $\sigma_{u,sw,ret}$ [%] Retained elastic modulus $E_{sw,ret}$ [%]
9	Alkali resistance	2.2.4.7	Level and description Retained tensile strength $\sigma_{u,alk,ret}$ [%] Retained elastic modulus $E_{alk,ret}$ [%]
10	Glass Transition Temperature	2.2.2.7	Level T_g [°C]

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as "shall be stated in the ETA" or "it has to be given in the ETA" shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

2.2.1 CRM kit

2.2.1.1 Reaction to fire

The CRM kit shall be tested, using the test method(s) according to EN 13501-1 relevant for the corresponding reaction to fire class, in order to be classified according to the Commission Delegated Regulation (EU) 2016/364.

When the above provision requires testing in accordance with EN 13823, the provisions and conditions in the standard shall be followed. For tests according to EN 13823 (SBI), substrates according to EN 13238 shall be used.

When not provided by the manufacturer, an inorganic matrix of class A1, with an organic content less than 1%, shall be used for testing. Information about the matrix used shall be reported in the ETA.

For extended application, the minimum inorganic matrix thickness and the FRP mesh with the highest weight per unit area shall be used for testing.

The reaction to fire class obtained from the tests shall be reported in the ETA.

2.2.2 FRP Mesh

2.2.2.1 Tensile properties of the mesh

Purpose of the test

Tensile tests are performed to evaluate the tensile strength, the Young's Modulus and the ultimate strain of the FRP mesh.

Test method

A summary of the number of specimens to be tested is reported in Annex A, while the test method is described in Annex B.

Tests shall be performed in the lengthwise (warp) and crosswise (weft) direction of the mesh.

If the mesh is balanced (the weight per unit area is the same in the two main directions), tests can be conducted in just one direction.

Assessment

The average value (arithmetic mean) and characteristic value of the tensile strength $\sigma_{u,m}$ [MPa], modulus of elasticity E_m [GPa] and strain $\varepsilon_{u,m}$ [%] have to be determined and reported in the ETA for warp and weft.

The characteristic value will be determined by using the appropriate value of k_n for unknown V_X reported in EN 1990, Annex D, Table D1.

2.2.2.2 Shear resistance of the mesh junction (in the two orthogonal directions of mesh)

Purpose of the test

This test method allows determining the shear resistance of the mesh junction in order to define a monolithic mesh (see 1.3.1).

Test method

A summary of the number of specimens to be tested is reported in Annex A, while the test method is described in Annex C.

Assessment

The average value (arithmetic mean) and characteristic value of the shear resistance of the mesh junction F_{junc} [kN] have to be determined in the warp and weft direction and reported in the ETA.

The characteristic value will be determined by using the appropriate value of k_n for unknown V_x reported in EN 1990, Annex D, Table D1.

2.2.2.3 Freezing and Thawing resistance

Purpose of the test

This test is performed to evaluate the influence of freeze-thaw cycles on the behaviour of the FRP mesh.

Test method

Conditioning shall be conducted on warp and weft FRP mesh specimens (Section 2.2.2.1)

All samples are subjected to freeze-thaw cycles by means of the following procedure: samples are conditioned in a humidity chamber for a week, at a relative humidity >90% and at a temperature of 38±2°C; they are then subjected to 20 freeze-thaw cycles. Each cycle consists of at least 4 hours at -18±1 °C, followed by 12 hours in a humidity chamber (>90% relative humidity, 38±2°C). Conditioned specimens are then tested in direct tension according to 2.2.2.1.

A summary of the minimum number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5× magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,FT,ret}$ [%], $E_{FT,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.2.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.2.4 Water resistance

Purpose of the test

This test is performed to evaluate the influence of water on the behaviour of the FRP mesh.

Test method

Conditioning shall be conducted on warp and weft FRP mesh specimens (Section 2.2.2.1).

Conditioning is done according to the indications given in Section 2.2.7 of EAD 340210-00-0104 for 1,000 and/or 3,000 hours at a temperature of 38±2°C and relative humidity >90%. Conditioned specimens are then tested in direct tension according to 2.2.2.1.

A summary of the minimum number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5**x** magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,w,ret}$ [%], $E_{w,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.2.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.2.5   Saltwater resistance

Purpose of the test

This test is performed to evaluate the influence of saltwater on the efficiency of the FRP mesh.

Test method

Conditioning shall be conducted on warp and weft FRP mesh specimens (Section 2.2.2.1).

Conditioning is done by immerging specimens in saltwater according to the indications given in Section 2.2.8 of EAD 340210-00-0104 for 1,000 and/or 3,000 hours at a temperature of 23±2°C. Conditioned specimens are then tested in direct tension according to 2.2.2.1.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5**x** magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,sw,ret}$ [%], $E_{sw,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.2.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.2.6   Alkali resistance

Purpose of the test

This test is performed to evaluate the influence of alkali attack on the efficiency of the FRP mesh.

Test method

Conditioning shall be conducted on both warp and weft FRP mesh specimens (Section 2.2.2.1).

Conditioning is done by immerging specimens in a liquid with pH=12.5 for 1,000 and/or 3,000 hours at a temperature of 23°C±2°C. Conditioned specimens are then tested in direct tension according to 2.2.2.1.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5**x** magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,alk,ret}$ [%], $E_{alk,ret}$ [%]) retained by exposed specimens with respect to the values recorded for unconditioned specimens (Section 2.2.2.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.2.7   Glass Transition Temperature

Purpose of the test

This test is performed to evaluate the Glass Transition Temperature (T_g) of the composite material of the FRP elements.

Test method

Glass transition temperature (T_g) shall be evaluated on three specimens according to EN ISO 11357-2, by using the DSC (Differential Scanning Calorimetry) method. The test is performed on hardened composite material portions, obtained from the FRP components.

The specimens shall be conditioned for 3 days at atmospheric pressure under standard temperature and humidity conditions (23±2°C, 50±5% RH). The glass transition temperature shall only be measured during the first heating cycle and shall be obtained by applying the "equal-areas method" in accordance with EN ISO 11357-2, §10.1.4; the heating rate must be 10°C/min.

Assessment

The minimum value of T_g [°C] obtained from the three specimens shall be given in the ETA.

2.2.3   FRP mesh corner elements

2.2.3.1   Tensile properties of the mesh corner elements

Purpose of the test

Tensile tests are performed to evaluate the tensile resistance of the FRP mesh corner elements.

Test method

A summary of the number of specimens to be tested is reported in Annex A, while the test method is shown in Annex D.

Assessment

The average value (arithmetic mean) and characteristic value of the tensile resistance in the direction of the concurrent threads $F_{u,mc}$ [kN] have to be determined.

The characteristic value will be determined by using the appropriate value of k_n for unknown V_X reported in EN 1990, Annex D, Table D1.

2.2.3.2   Other properties

All the other properties of the mesh corner elements are determined on the corresponding mesh type, tested according to 2.2.2. The methods shown in the relevant sections of 2.2.2 shall be used.

2.2.4   FRP connectors

2.2.4.1   Tensile properties of the FRP connectors

Purpose of the test

Tensile tests are performed to evaluate the tensile strength, the Young's Modulus and the ultimate strain of the FRP connectors.

Test method

A summary of the number of specimens to be tested is reported in Annex A.

The test specimen shall have a length of l=500 mm.

Aluminium cylindrical tubes can be used in order to allow the gripping of the bar extremities. The two extremities of each bar shall be inserted into these tubes and thereafter an anchoring bi-component epoxy with an elevate performance shall be injected. Alternatively, grips of the loading test machine can press directly the FRP connectors. Specific devices shall be used for the centring of the bar into the aluminium cylinder.

The tests shall be performed in load control, and with a constantly increasing load velocity of 0.2-0.4 kN/s.

After defining the cross-sectional area with the callipers, the tensile load, the tensile strength, the Young's Modulus and the ultimate strain shall be evaluated as described in ISO 10406-1.

Assessment

The average value (arithmetic mean) and characteristic value of the tensile strength $\sigma_{u,con}$ [MPa], modulus of elasticity E_{con} [GPa] and strain $\varepsilon_{u,con}$ [%] have to be determined and reported in the ETA.

The characteristic value will be determined by using the appropriate value of k_n for unknown V_X reported in EN 1990, Annex D, Table D1.

2.2.4.2   Pull-out from reference substrates

Definition of reference substrates

- *Concrete*

   Concrete will be prepared with the sandblasted surface in accordance with EN 1766.

- *Masonry*

   Masonry shall be compliant with EN 771-1 (clay) and EN 771-6 (natural stones) and must be chosen with as homogeneous as possible mechanical and physical-chemical characteristics, to reduce the dispersion of the results.

   Clay bricks shall have a compressive strength comprised in the range 15-25 MPa. The average effective resistance must be evaluated through at least six compression tests on cubic/cylindrical samples of brick, of approximately 50 mm size/diameter, made of the brick thickness. For the preparation of masonry specimens, a mortar with class not exceeding M5 shall be used (EN 998-2).

   Natural stone bricks (tuff) shall have a compressive strength comprised in the range 4-12 MPa. The average effective resistance must be evaluated through at least six compression tests on cubic samples, of approximately 150 mm size. For the preparation of masonry specimens, a mortar with class not exceeding M5 shall be used (EN 998-2).

   Natural stones (limestone) irregular in shape, not squared, whose larger size is less than 150 mm, shall have a compressive strength comprised in the range 50-150 MPa. The compressive strength of the stones must be evaluated through at least six compression tests (EN 1926). For the preparation of masonry specimens, a mortar with class not higher than M2.5 (EN 998-2) shall be used.

Test method

A minimum of 5 specimens shall be prepared. The test shall follow the general procedure reported in Annex E and shall be performed under standard conditions of temperature and relative humidity (23±2°C, 50±5% RH).

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

A description of the type of failure or combination of failure types shall be given.

The used anchorage length L_{anc} [mm] and the average pull-out load P_{anc} [kN] shall be reported in the ETA, together with the compressive strength of the substrate f_b [MPa].

The principal essential characteristics of the anchor material according to the relevant harmonized technical specification shall be reported in the ETA.

2.2.4.3 Lap-tensile strength

Purpose of the test

When applying CRM composite systems for strengthening of structural masonry or concrete members, overlapping of connectors can be necessary for the reinforcement.

Test method

This test shall be performed on three specimens with a joint configuration that closely simulates the actual joint in field application. The general test procedures as described in Annex F shall be used. Tests shall be performed under standard conditions of temperature and relative humidity (23±2°C, 50±5% RH).The overlap length shall not be shorter than 100 mm.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

The used overlap length l_{lap} [mm] and the properties of the anchor material used in the test according to the relevant harmonized technical specification shall be reported in the ETA.

The average value (arithmetic mean) and characteristic value of the failure load of lap joint F_c [kN] and lap-tensile strength σ_{lap} [MPa] have to be determined and reported in the ETA.

The characteristic value will be determined by using the appropriate value of k_n for unknown V_X reported in EN 1990, Annex D, Table D1.

2.2.4.4 Freezing and thawing resistance

Purpose of the test

This test is performed to evaluate the influence of freeze-thaw cycles on the behaviour of the FRP connector.

Test method

Conditioning shall be conducted on FRP connectors according to the indications given in Section 2.2.2.3. Conditioned specimens are then tested in direct tension according to 2.2.4.1.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5✕ magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,FT,ret}$ [%], $E_{FT,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.4.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.4.5 Water resistance

Purpose of the test

This test is performed to evaluate the influence of water on the behaviour of the FRP connector.

Test method

Conditioning shall be conducted on FRP connectors according to the indications given in Section 2.2.2.4. Conditioned specimens are then tested in direct tension according to 2.2.4.1.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5× magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,w,ret}$ [%], $E_{w,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.4.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.4.6   Saltwater resistance

Purpose of the test

This test is performed to evaluate the influence of saltwater on the behaviour of the FRP connector.

Test method

Conditioning shall be conducted on FRP connectors according to the indications given in Section 2.2.2.5. Conditioned specimens are then tested in direct tension according to 2.2.4.1.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5× magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,sw,ret}$ [%], $E_{sw,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.4.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.4.7   Alkali resistance

Purpose of the test

This test is performed to evaluate the influence of alkali attack on the efficiency of the FRP connector.

Test method

Conditioning shall be conducted on FRP connectors according to the indications given in Section 2.2.2.6. Conditioned specimens are then tested in direct tension according to 2.2.4.1.

A summary of the number of specimens to be tested is reported in Annex A.

Assessment

Conditioned specimens are visually examined prior to testing using 5× magnification to describe surface changes, such as erosion, cracking, crazing, checking, and chalking. The observations shall be reported in the ETA.

The percentage of average mechanical properties ($\sigma_{u,alk,ret}$ [%], $E_{alk,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (Section 2.2.4.1) and the exposure conditions shall also be reported in the ETA. These percentages are calculated on the basis of average results for the set of tested specimens.

2.2.5   Expression of performance

The values for the individual essential characteristics shall be stated in the ETA on the basis of the test results as described in Table 2.5.

Table 2.5 Expression of performance

No	Essential characteristics	Unit	Value
FRP mesh			
1	Tensile strength (longitudinal and orthogonal direction)	MPa	Average, Characteristic (EN 1990, Annex D)
2	Ultimate strain	%	Average, Characteristic (EN 1990, Annex D)
3	Young's Modulus	GPa	Average, Characteristic (EN 1990, Annex D)
4	Shear resistance of the mesh junction (in the two orthogonal directions)	kN	Average, Characteristic (EN 1990, Annex D)
5	Freezing and thawing resistance	%	Average
6	Water resistance	%	Average
7	Saltwater resistance	%	Average
8	Alkali resistance	%	Average
9	Glass Transition Temperature	°C	Minimum
FRP mesh corner element			
10	Tensile resistance	kN	Average, Characteristic (EN 1990, Annex D)
11	Other properties	-	referred to the corresponding mesh type
FRP connector			
12	Tensile strength	MPa	Average, Characteristic (EN 1990, Annex D)
13	Ultimate strain	%	Average, Characteristic (EN 1990, Annex D)
14	Young's Modulus	GPa	Average, Characteristic (EN 1990, Annex D)
15	Pull-out from reference substrates	kN	Average
16	Lap tensile strength	MPa	Average, Characteristic (EN 1990, Annex D)
17	Freezing and thawing resistance	%	Average
18	Water resistance	%	Average
19	Saltwater resistance	%	Average
20	Alkali resistance	%	Average
21	Glass Transition Temperature	° C	Minimum

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the products covered by this EAD, the applicable European legal act is: **Decision 1999/469/EC**.

The system 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 systems are:

1   for A1, A2, B, C classes (Products/materials for which a clearly identifiable stage in the production process results in an improvement of the reaction to fire classification, e.g. an addition of fire retardants or a limiting of organic material).

3   for A1, A2, B, C classes (Products/Materials for which **there is not** a clearly identifiable stage in the production process resulting in an improvement of the reaction to fire classification) and D, E classes.

4   for A1 to E classes (Products/materials that do not require to be tested for reaction to fire, e.g. Products/materials of Classes A1 according to Commission Decision 96/603/EC) and F class.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.1. For kits: The manufacturer (regarding the components he buys from the market with DoP) shall to take into account the Declaration of Performance issued by the manufacturer of that component. No retesting is necessary.

Table 3.1: Control plan for the manufacturer; cornerstones.

No	Subject/type of control	Test or control method (*)	Criteria, if any	Minimum number of specimens	Minimum frequency of control
Factory production control (FPC)(**)					
1	Incoming materials/Resins	Check of delivery ticket or label on the package	Conformity with the order	---	Each delivery
		Supplier documents or supplier tests' check			
2	Incoming materials/Fibres	Check of delivery ticket or label on the package	Conformity with the order	---	Each delivery
		Supplier documents or supplier tests' check			
3	Incoming materials/Chemical anchors	Check of delivery ticket or label on the package	Conformity with the order	---	Each delivery
		Supplier documents or supplier tests' check			
4	FRP mesh /Dimensions	With Callipers	According to the Control Plan	1 sample per relevant criteria	Every 5 hours of production
5	FRP mesh /Weight per square meter	Adjusted balance	According to the Control Plan	1 sample per relevant criteria	Every production batch, not exceeding 20,000 m^2
6	FRP mesh /Tensile strength	2.2.2.1	According to the Control Plan	3 samples	
7	FRP mesh /Fibre content	According to the Control Plan	According to the Control Plan	3 samples	Every three months
8	FRP mesh corner element /Dimensions	With Callipers	According to the Control Plan	1 sample per relevant criteria	Every 5 hours of production

Table 3.1: Control plan for the manufacturer; cornerstones.

No	Subject/type of control	Test or control method (*)	Criteria, if any	Minimum number of specimens	Minimum frequency of control
9	FRP mesh corner element /Weight per meter	Adjusted balance	According to the Control Plan	1 sample per relevant criteria	Every production batch, not exceeding 20,000 m
10	FRP mesh corner element /Tensile strength	2.2.3.1	According to the Control Plan	3 samples	
11	FRP mesh corner element /Fibre content	According to the Control Plan	According to the Control Plan	3 samples	Every three months
12	FRP connector /Dimensions	With Callipers	According to the Control Plan	1 sample per relevant criteria	Every 5 hours of production
13	FRP connector /Weight per meter	Adjusted balance	According to the Control Plan	1 sample per relevant criteria	Every production batch, not exceeding 50,000 pcs
14	FRP connector /Tensile strength	2.2.4.1	According to the Control Plan	3 samples	
15	FRP connector /Fibre content	According to the Control Plan	According to the Control Plan	3 samples	Every three months
16	Inorganic matrix /Organic content	According to the Control Plan	According to the Control Plan	According to tests or control methods	According to the Control Plan (***)
17	Inorganic matrix /Bond strength	According to the Control Plan	According to the Control Plan	According to tests or control methods	Every batch (****)

(*)   In all cases, the TAB and the manufacturer may agree to alternative tests or control methods or, where none exist, these parties may agree on the method.

(**)   The control will refer to all or to the single components of the kit that are to be assessed and CE marked independently from the kit in accordance with the present EAD.

(***) The frequency is determined case by case depending on the type of production process, the variation in the volume produced and the production process control.

(****) Batch: every quantity of material made in a single operation, or in the case of continuous production for a defined quantity (in tons) which shall be demonstrated by the producer to have a uniform composition and shall not exceed one day's production

Note: If a component is covered by an existing HTS, the FPC is deemed to be satisfied by the application of FPC foreseen in the relevant HTS, provided that relevant characteristics as of the control plan, have been achieved. Otherwise, conformity of purchased components with the order shall be established by the kit manufacturer.

3.3   Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for the product are laid down in Table 3.2.

Table 3.2 Control plan for the notified body; cornerstones

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	The notified body shall ascertain that, in accordance with the control plan, the manufacturing plant of the product manufacturer, in particular personnel and equipment, and the factory production control are suitable to ensure a continuous and orderly manufacturing of the components of the CRM system. Particular attention should be paid to the phases of impregnation and weaving of the fibre strands through thermosetting resin and the polymerization process in the production of the FRP components.	As defined in the control plan	As defined in the control plan	As defined in the control plan	At the beginning of the contract between NB and Manufacturer
Continuous surveillance, assessment and evaluation of factory production control					
2	It shall be verified that the system of factory production control and the specified manufacturing process are maintained in accordance with the control plan in order to ensure the constancy of product performance. Particular attention should be paid to the phases of impregnation and weaving of the fibre strands through thermosetting resin and the polymerization process in the production of the FRP components.	As defined in the control plan	As defined in the control plan	As defined in the control plan	Once per year

The intervention of the notified body for reaction to fire under AVCP system 1 is only necessary for products/materials for which a clearly identifiable stage in the production process results in an improvement of the reaction to fire classification (e.g. an addition of fire retardants or a limiting of organic material).

In this case the cornerstones of the tasks to be undertaken by the notified body under AVCP system 1 are laid down in Table 3.3.

Table 3.3 Control plan for the notified body in cases of AVCP 1 for reaction to fire; cornerstones

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control carried out by the manufacturer regarding the constancy of performance related to reaction to fire. *(for system 1 only)*				
1	Where the intervention of the Notified Body is necessary only because the conditions for the applicability of system 1 are fulfilled for reaction to fire, the notified body will consider especially the clearly identifiable stage in the production process which results in an improvement of the reaction to fire classification (e.g. an addition of fire retardants or a limiting of organic material).	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	As defined in the control plan	As defined in the control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control carried out by the manufacturer regarding the constancy of performance related to reaction to fire. *(for system 1 only)*				
2	Where the intervention of the Notified Body is necessary only because the conditions for the applicability of system 1 in the Decisions regarding reaction to fire are fulfilled, the notified body will consider especially the clearly identifiable stage in the production process which results in an improvement of the reaction to fire classification (e.g. an addition of fire retardants or a limiting of organic material).	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.1.	As defined in the control plan	As defined in the control plan	Once per year

4   REFERENCE DOCUMENTS

EAD 340210-00-0104	SRP (Steel Reinforced Polymer) kit made of steel micro-wires, fiberglass mesh and epoxy adhesive
EN 771-1:2011+A1:2015	Specification for masonry units - Part 1: Clay masonry units
EN 771-6:2011+A1:2015	Specification for masonry units - Part 6: Natural stone masonry units
EN 998-2:2016	Specification for mortar for masonry – Part 2: Masonry mortar
EN 1766:2017	Products and systems for the protection and repair of concrete structures - Test methods - Reference concretes for testing
EN 1990:2002/A1:2005	Eurocode - Basis of structural design
EN 1926:2006	Natural stone test methods – Determination of uniaxial compressive strength
EN 13238:2010	Reaction to fire tests for building products - Conditioning procedures and general rules for selection of substrates
EN 13501-1:2007+A1:2009	Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests
EN 13823:2010+A1:2014	Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item
ISO 385:2005	Laboratory glassware -- Burettes
ISO 4788:2005	Laboratory glassware -- Graduated measuring cylinders
ISO 10406-1:2015	Fibre-reinforced polymer (FRP) reinforcement of concrete - Test methods - Part 1: FRP bars and grids
EN ISO 6892-1:2016	Metallic materials - Tensile testing – Part 1: Method of test at room temperature
EN ISO 11357-2:2014	Plastics -- Differential scanning calorimetry (DSC) -- Part 2: Determination of glass transition temperature and glass transition step height
EN ISO 15630-2:2010	Steel for the reinforcement and prestressing of concrete -- Test methods -- Part 2: Welded fabric

ANNEX A - SUMMARY OF TESTS

The tables reported below summarize the number of specimens for the assessment of each of the FRP components constituting the CRM kit.

Table A1 - Number of tests for the assessment of the FRP mesh

No	Essential characteristic	Number of tests
1	Tensile strength (longitudinal and orthogonal direction)	15 (weft) + 15 (warp) 15 for balanced meshes
2	Ultimate strain	
3	Young's Modulus	
4	Shear resistance of the mesh junction (in the two orthogonal directions)	10 (weft) + 10 (warp) 10 for balanced meshes
5	Freezing and thawing resistance	5 (weft) + 5 (warp) 5 for balanced meshes
6	Water resistance	5 (weft) + 5 (warp) 5 for balanced meshes
7	Saltwater resistance	5 (weft) + 5 (warp) 5 for balanced meshes
8	Alkali resistance	5 (weft) + 5 (warp) 5 for balanced meshes
9	Glass Transition Temperature	3

Table A2 - Number of tests for the assessment of the FRP mesh corner elements

No	Essential characteristic	Number of tests
10	Tensile resistance	10
11	Freezing and thawing resistance	To be tested on the corresponding mesh type
12	Water resistance	
13	Saltwater resistance	
14	Alkali resistance	
15	Glass Transition Temperature	

Table A3 - Number of tests for the assessment of the FRP connectors

No	Essential characteristic	Number of tests
16	Tensile strength	5
17	Elongation	
18	Young's Modulus	
19	Pull-out from reference substrates	5
20	Lap-tensile strength	3
21	Freezing and thawing resistance	5
22	Water resistance	5
23	Saltwater resistance	5
24	Alkali resistance	5
25	Glass Transition Temperature	3

ANNEX B - TEST METHOD FOR TENSILE STRENGTH OF MESH WIRES (WEFT AND WARP)

B1. General requirements and summary of test method

The tensile strength of the single FRP mesh wire must be evaluated according to the procedure stated in the following sections.

B2. Test specimens

The test sample consists of a single wire of length l = 500 mm, extracted from the FRP mesh by cutting the transverse threads wires for the entire length of the mesh so as not to disturb the junction. The samples are taken in the same quantity both in the weft and in the warp.

Small panels of plywood or cardboard (thickness = 8 mm, length = 80 mm, width = 60 mm) can be used for specimen gripping, in order to avoid the rupture of specimen in the grip zone.

For the sample of twisted wire of mesh (warp direction), it is necessary to create a specimen with geometrical characteristics as reported in Figure B1, cutting a square with an additional knitting in both directions of the mesh, in order to avoid harmful twisting phenomena, with a consequent reduction of the tensile resistance of the wire.
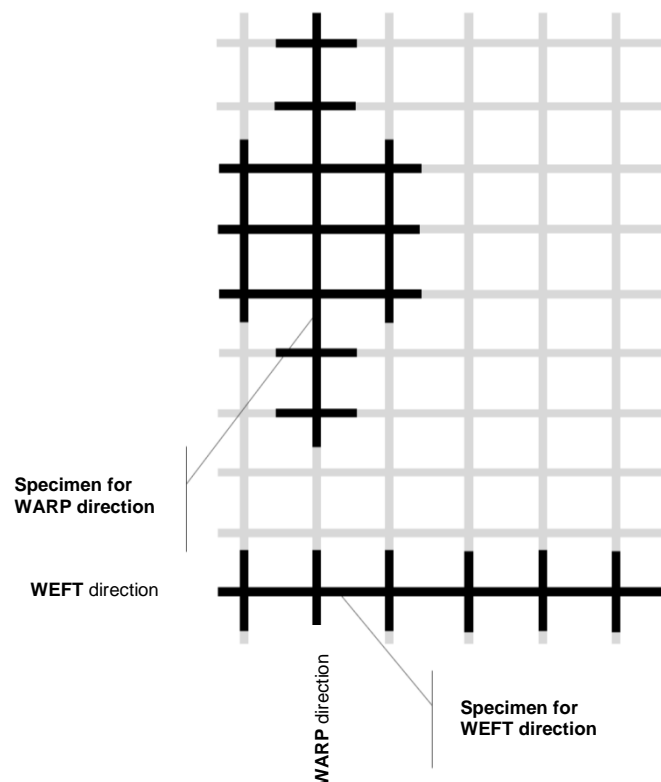

Figure B1 - Test specimen for weft and warp wires of mesh

The cutting process must be performed with techniques that avoid damaging the specimens and producing delamination inside the specimen. The specimens must be numbered, recognizable and it must be possible to trace the characteristics of the mesh from which they were obtained (traceability).

B3. Test equipment and materials

Strain gauges or displacement transducers

One instrument is needed with a measurement length of at least 50 mm with a maximum sensitivity of 1/1000 mm and it must be able to provide continuous indications of variation along the length of measurement.

Tensile (or universal) test machine

The testing machine shall have the appropriate load capacity to withstand the foreseen ultimate forces and must be equipped with an appropriately calibrated load cell and classifiable at least in class 1 with reference to EN ISO 6892-1 (resolution higher than 0.1 %).

Graduated cylinder (for nominal cross section determination)

Graduated cylinder Class A (ISO 4788) or graduated burette Class A (ISO 385) of a suitable capacity, having the minimum diameter compatible with the specimen dimensions.

B4. Testing of samples

The tests shall be performed in load control with a constantly increasing load velocity as indicated in ISO 10406-1 Section 6. Keep the loading rate as constant as possible so as not to subject the test pieces to shock.

B5. Processing of test results

For the determination of the geometrical properties of the sections, essential for the definition of the mechanical properties of the elements, the procedure described below shall be followed.

For both directions of the mesh (weft and warp) it is necessary to determine the nominal cross section, measuring the length and the volume of representative specimens, obtained from the same sample of mesh. Length and volume may be determined on a single segment of wire (not including joints) or a sum of several short segments.

Determine the length of specimens using a calliper. Determine the volume using the graduated cylinder (alternatively to the volume displacement method, it is possible to obtain more accurate results for the nominal cross section using the hydrostatic weighing method). Calculate the nominal cross section dividing the measured volume by the measured length.

After defining the cross-sectional area of both weft and warp wires, the tensile load, the tensile strength, the Young's Modulus and the ultimate strain must be evaluated as described in ISO 10406-1.

ANNEX C - TEST METHOD FOR SHEAR RESISTANCE OF THE MESH JUNCTION

C1. General requirements and summary of test method

The shear resistance of the mesh junction is evaluated according to the principles stated in EN ISO 15630-2. However, several adjustments of the method are required to adapt it to the case of FRP meshes, as described below.

C2. Sampling

The sample must provide one or more panels of mesh with a size sufficient to obtain the quantity of specimens indicated in Annex A.

The cutting process must be performed with techniques that avoid damaging the specimens and producing delamination inside the specimen. The specimens must be numbered, recognizable and it must be possible to trace the characteristics of the mesh from which they were obtained (traceability).

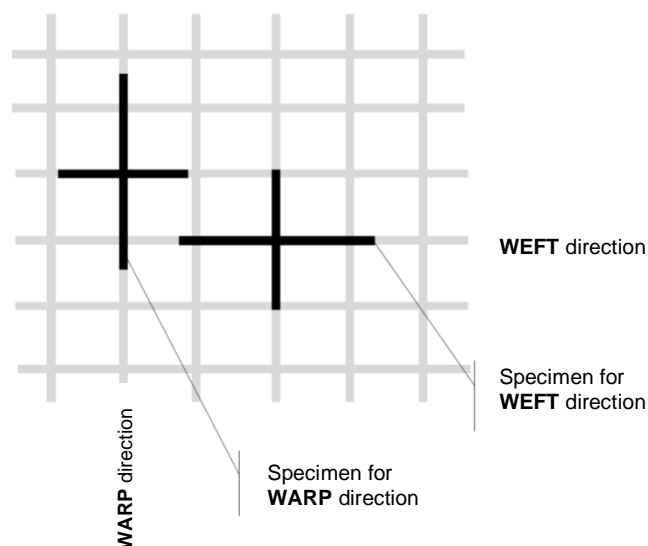During mesh sampling, it is necessary to identify the two main directions as WEFT and WARP.

Figure C1 - Test specimen for the determination of the shear resistance of the mesh junction

C3. Test specimen

Quantity

From the panels obtained in the sampling, 10 specimens are obtained for each of the identified directions (WEFT and WARP). The complete characterization of the joint resistance of the mesh therefore comprises the realization of the test on 20 specimens.

Dimensions

Each specimen consists of a longitudinal thread with length "L", on which the tensile force is applied, and a transversal thread with width "B" symmetrically distributed on the sides of the longitudinal thread (see Figure C2) on which a hook is applied to counteract the pulling effort.

The length "L" of the longitudinal thread shall ensure:

- an adequate "L1" length grip portion at the end of the specimen which will be clamped at the jaws of the testing machine;

- a minimum distance "L2" of at least one mesh opening (in the direction of the longitudinal thread) between the limit of the grip zone and the position of the transverse thread, and in any case sufficient for positioning the load hook on the transversal wire;

- a minimum distance "L3" of a mesh opening in the direction of the longitudinal thread) between the transverse thread and the free end of the longitudinal thread.

The width "B" of the transversal thread shall ensure:

- a free length of at least 30 mm on each side of the longitudinal thread;

- a free length "L4" of at least one mesh opening (corresponding to the direction of the transversal thread) on each side of the longitudinal thread.

When obtaining the specimens, other elements present (longitudinal or transversal wires) which can interfere with the application of the load devices must be eliminated by cutting. Particular attention must be paid to the elimination of any protuberances on the transversal wire which may alter the normal application of the load.

These operations must not alter the condition of integrity and resistance of the joint under test.
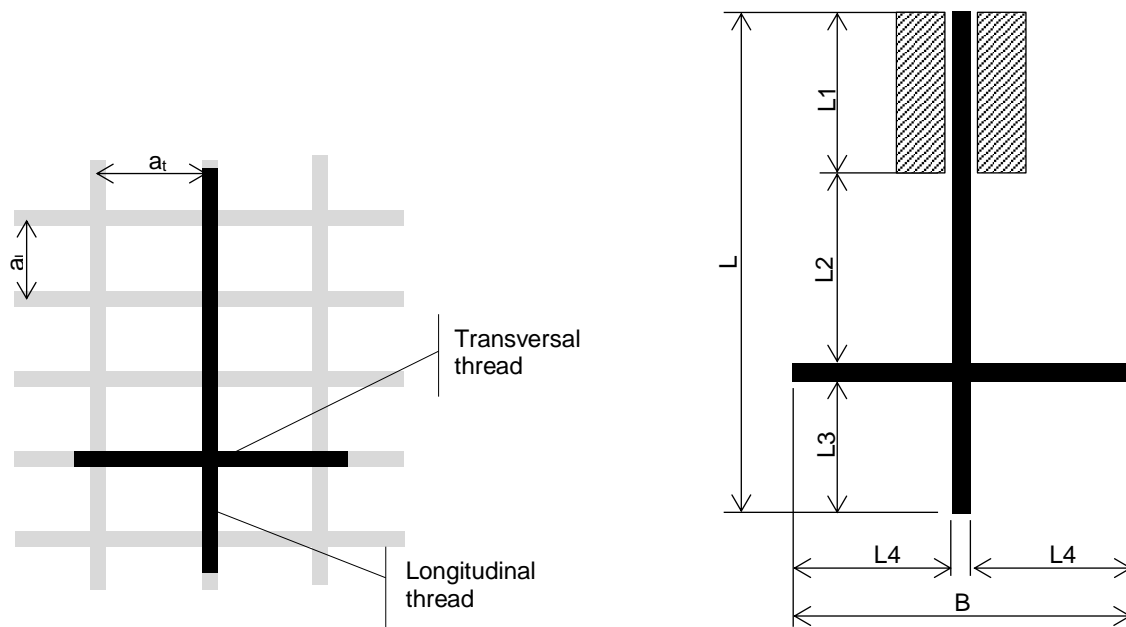
a$_l$	mesh opening on the longitudinal thread direction
a$_t$	mesh opening on the transversal thread direction
L	overall length of longitudinal thread
B	overall length of transversal thread (symmetric to the longitudinal thread)
L1	suitable to ensure a correct transmission of the tensile load
L2	$\geq$ a$_l$
L3	$\geq$ a$_l$
L4	$\geq$ a$_t$ and $\geq$30 mm

Figure C2 - Specimen dimensions

Storage

Store specimens carefully to protect against deformation, heating, exposure to ultraviolet light or other actions that may cause changes in the properties of the material.

C4. Test equipment and materials

Calliper

Calliper for the measuring of mesh opening, thread thickness and device positioning with an accuracy of ± 0.1 mm or better.

Meter

Meter or ruler divided into millimetres for the measurement of specimen dimensions with an accuracy of ± 2 mm or better.

Load measurement device

It shall allow the determination of the axially applied load on the longitudinal thread with an accuracy of ±1% of the measured value. The device shall allow constant monitoring of the applied load and the determination and the record of the maximum load reached.

The testing machine shall comply with the requirements for the tension-testing machines and classifiable at least in class 1 in accordance with EN ISO 6892-1 (resolution higher than 0.1 %).

Load application device

It shall allow the application of an axial load, acting:

- by means of a jaw which presses directly on the free end of the longitudinal thread and
- by means of a special hook which acts on the transverse thread (see Figure C3).

The assembly must ensure automatic alignment of the specimen and load hook so as not to introduce bending forces on the longitudinal thread (lack of alignment between the elements). Furthermore, any localized flexural stresses on the transversal thread must be minimized.

The load hook must act on the transversal wire by means of a cylindrical concave contact surface, with a radius of curvature between 1 and 3 times the nominal thickness of the transversal thread (measured in the direction orthogonal to the plane of the mesh).

The cylindrical support surface must have a slot (D in figure C3) which allows the positioning of the longitudinal wire, with a maximum clearance *l* of 1 mm between the edge of the cylindrical surface and the edge of the longitudinal thread. In case adjustable portions for the cylindrical surface are used (which allow defining the width of opening), the longitudinal thread must not be compressed between the elements.

If the shape of the joint has characteristics that do not allow the homogeneous contact between the concave surface of the hook and the transverse thread, the gap between the edge of the cylindrical surface and the edge of the longitudinal edge may be increased beyond the limit of 1 mm (keeping it in the minimum possible value) in order to guarantee full contact in the loading surface.

The width of each of the support areas of the load hook on the cross thread must be at least 30 mm.
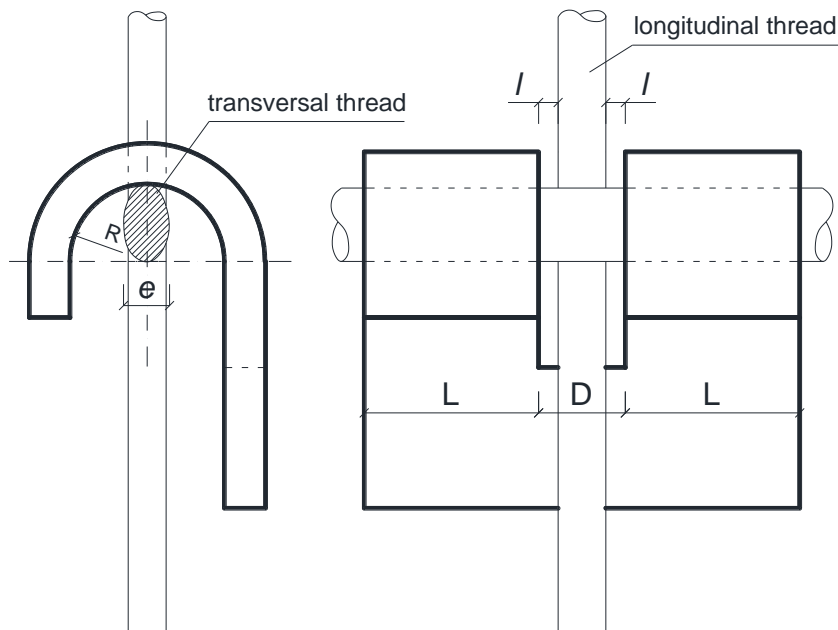
R   radius of curvature of the cylindrical concave surface

e   nominal thickness of the transversal thread (measured in the direction orthogonal to the plane of the mesh)

D   width of the slot which allows positioning of the longitudinal thread

l   gap between the edge of the cylindrical surface and the edge of the longitudinal thread (≤ 1 mm)

L   width of each of the load hook support areas (≥ 30 mm)

Figure C3 - Hook for load application on transversal thread

C5. Testing of specimens

Position the upper end of the longitudinal thread of the specimen in the gripping area and secure it to the load application device.

Position the load application hook on the transversal thread of the specimen, carefully centring the slit on the longitudinal thread and checking that any gap does not exceed the limit of 1 mm.

Fix the hook to the load application device ensuring the correct alignment of the assembly.

Apply the load gradually with a constant speed, with maximum variations of 25% with respect to the set value. Speed can be set:

- in terms of displacement of the two ends of the load device (example, in mm/s);
- in terms of time variation of the load (example, in N/s).

In any case, the set speed must allow the failure to be reached in a time between 1 min and 3 min.

Record the maximum load at the time of breakage of the joint and the breaking mode. In the case of a ductile behaviour (evident loss of stiffness with little or no increase in load with increase of displacement) the test is interrupted when visual inspection of the joint allows checking the break, without considering any further increases in the load.

C6. Processing of test results

For both directions of the mesh (weft and warp) the maximum load of the mesh junction shall be evaluated as described in ISO 10406-1.

ANNEX D - TEST METHOD FOR TENSILE RESISTANCE OF MESH CORNER ELEMENT

D1. General requirements and summary of test method

The tensile resistance of the mesh corner element must be evaluated according to the procedure stated below.

D2. Test specimen

The sample must provide one or more mesh corner elements with a size sufficient to obtain the quantity of specimens indicated in Annex A.

The test sample consists of a single bar constituting the pre-formed mesh corner wire in the standard length of the Manufacturer's commercial proposal; the bar must be extracted from the FRP corner element by cutting the longitudinal wires.

The cutting process must be performed with techniques that avoid damaging the specimens and producing delamination inside the specimen. The specimens must be numbered, recognizable and it must be possible to trace the characteristics of the corner elements from which they were obtained (traceability).

D3. Test equipment and materials

Tensile (or universal) test machine

The testing machine shall have the appropriate load capacity to withstand the foreseen ultimate forces and must be equipped with an appropriately calibrated load cell and classifiable at least in class 1 with reference to EN ISO 6892-1 (resolution higher than 0.1 %).

Steel gripping device

The gripping device may be of the type illustrated in Figure D1 and in any case able to uniformly distribute the vertical load transmitted by the testing machine on the mesh corner element.

D4. Testing of samples

The test on the sample constituting the preformed corner element must be carried out under load control, at a constant speed of 0.05 kN/s. The curved part of the corner element will be placed on a circular steel bar (pull end), of the same diameter as the curvature of the sample; the two lower ends of the sample will instead be fixed to the test machine by a system of the type shown in Figure D1.

D5. Processing of test results

The test must give a value of the tensile load T [kN] of the corner element. The value of tensile resistance $F_{u,mc}$ is calculated as the maximum load in each single wire, that is obtained from the decomposition of the total load T applied to the specimen in the two directions of the concurrent threads:
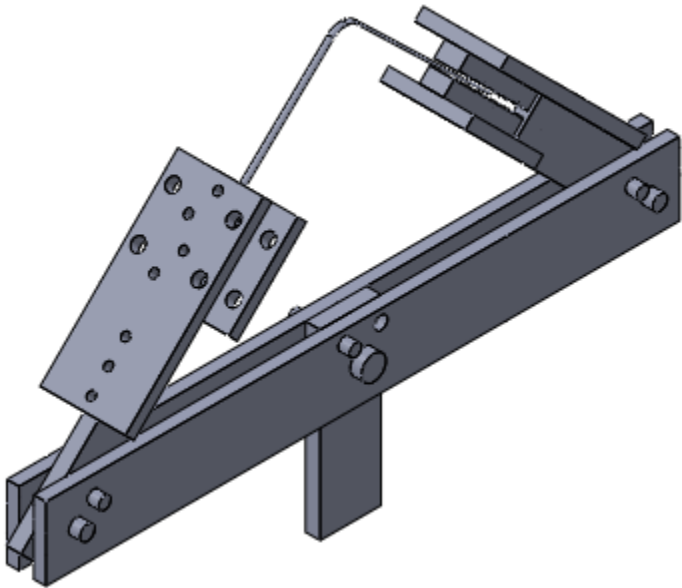
$$F_{u,mc} = 0.707\ T$$

D6. Accuracy of tests

The results obtained must be expressed by values with two digits after the decimal point.
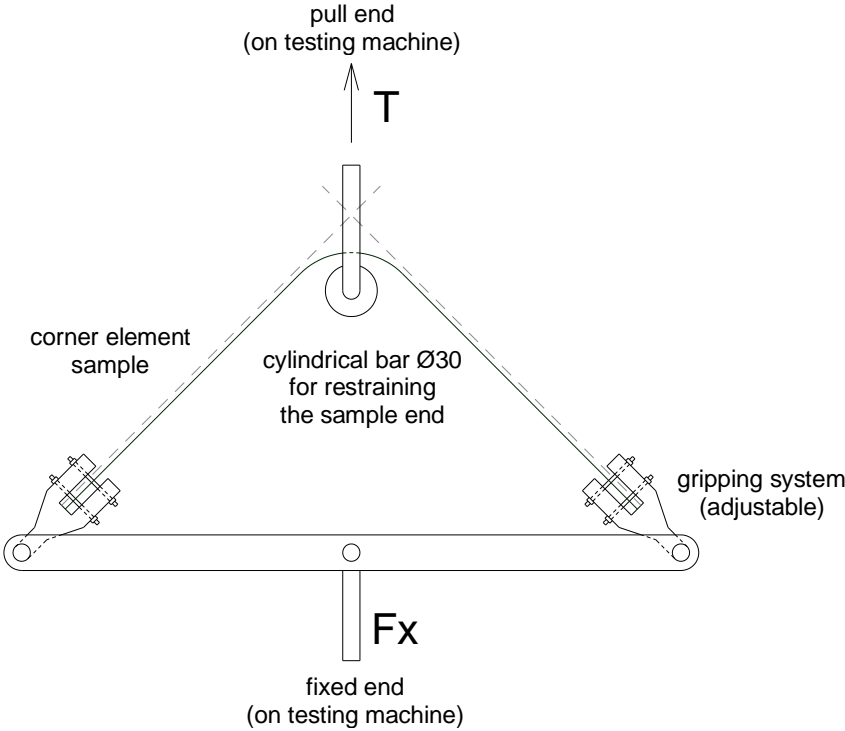
(a)

(b)

Figure D1 - Test setup for the determination of the tensile resistance of the corner element.
(a) Setup scheme; (b) three-dimensional sketch.

ANNEX E – TEST METHOD FOR PULL-OUT OF FRP CONNECTORS FROM REFERENCE SUBSTRATES

E1. General requirements

Test samples must be designed in such a way as to correctly represent the anchoring conditions inside the substrate on site and, at the same time, allow the test to be carried out easily.

Connectors shall be solidarized to a substrate to simulate a well-defined portion of the wall panel. The solidarization can be done by injection of cement grout or resin, indicated by the manufacturer.

E2. Test specimens

Concrete

The concrete test blocks shall be cast from concrete type MC (0,40) as specified in EN 1766. The minimum height and width are those necessary to allow an adequate positioning of the test device.

A hole with a variable diameter according to the system specifications shall be drilled by a rotary percussive or diamond drill, as specified by the manufacturer, in the centre of the cast face of the block.
Immediately after the drilling operation the hole shall be cleaned in accordance with manufacturer's instructions and the test block shall then be placed in its required orientation and the anchoring operation may be undertaken.

Masonry

Masonry bricks and mortar shall comply with the indications given in 2.2.4.2.

A one brick wall samples shall be built to be used for the pull-out tests, with an average thickness of the mortar joint between 10 mm and 15 mm. The minimum height of the samples must be at least 250 mm and in any case such that the anchoring length of the connector is equal to 2/3 of said thickness. The minimum height and width are those necessary to allow an adequate positioning of the test device. In particular, the confining effect exerted locally by a possible contrast structure placed near the connector to be extracted must be avoided. Therefore the minimum dimensions of the sample will be such as to allow the positioning of the contrast structure used for the test externally to the area potentially affected by a crisis by conical expulsion of the substrate, assumed equal $2L_{anc} + D_0$, being L_{anc} the anchorage length used and D_0 the diameter of the hole.

For anchoring lengths around 100 mm, a sample measuring 400mm x400mm may be sufficient. For greater operational convenience, it might be advisable to prepare larger masonry samples (for example 1.20 m x 1.20 m) on which carrying out more pull-out tests; in this case, it is necessary to guarantee the absence of interference between the different extraction points.

The masonry samples shall be conditioned in air for 28 days. After the maturation period, the hole for anchoring the connector, with a variable diameter according to the system specifications, will be executed with the use of a rotating tool. The hole will typically be made at the mortar joints.

FRP connector

Specimens are prepared starting from complete connectors in such a way to obtain a single rectilinear element. For "L-shaped" rigid connectors, the transversal wing shall be cut; for partially impregnated connectors, the total impregnation of the element over a suitable length may be necessary.

Any expedients and/or further details can be reported in the manufacturer's installation instructions.

The overall length of the connector must be such as to guarantee an anchoring length of at least 100 mm and a free portion, protruding from the substrate sample, which allows the assembly of the test equipment and the appropriate grip of the connector itself, as indicated in Figure E1.

Different anchorage length can be specifically indicated by the individual system. In this case, longer anchorage lengths may require a greater thickness for the substrate sample.

Application of the connector

Once the debris inside the hole of the specific substrate has been eliminated, by means of compressed air, the connector will be inserted inside the hole, with the anchoring methods indicated for the specific connection system in the manufacturer's product installation instruction.

The minimum time required between the application of the connector and the execution of the test must be the one indicated by the manufacturer for the specific connection system.

E3. Apparatus

For the execution of the pull-out test, a sufficiently rigid equipment will be used (e.g., hollow jacks) in order to perform tests in force control.

The free end of the connector will be suitably prepared to allow it to be attached to the testing machine. The applied load must be measured by a capacity load cell related to the maximum expected force.

The test system must allow the application of an axial load aligned with the connector, without introducing secondary lateral forces; this alignment must be ensured during the whole course of the test. The contrast device on the wall must guarantee an "unconfined" type test, that is to allow freely the unrestricted formation of the substrate failure cone.

The load measurement system must have a minimum accuracy of 2% of the maximum extraction load.

To detect the possible sliding of the bar with respect to the masonry element, appropriately arranged measuring instruments can be used. In this case a minimum accuracy of 0.02 mm is suggested.

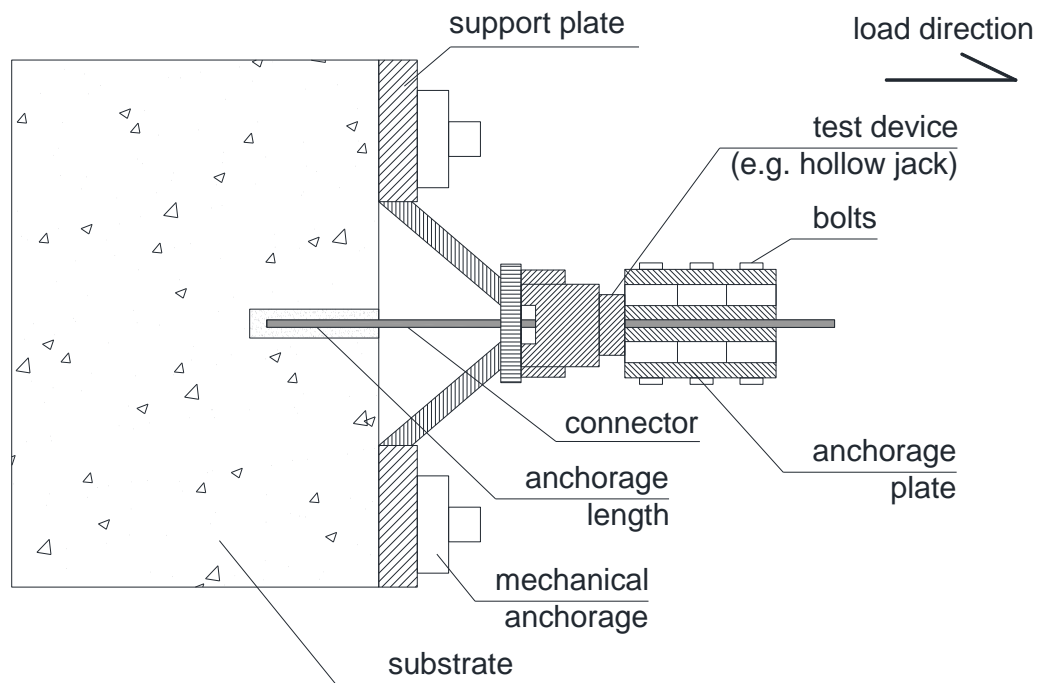A possible test sample scheme is shown in Figure E1.

Figure E1 - Test setup for pull-out testing.

E4. Test procedure

The test is performed in load control with a homogeneous speed, in order to reach the maximum load in a period of time between 1 and 3 minutes. The applied load and any displacement measurements can be recorded continuously, with a suggested frequency of 3 - 5 Hz. In any case, the maximum load reached, i.e. the "pull-out load", shall be recorded.

In the event that the load presents a recovery during extraction following significant displacements of the connector ("slipping" of the connector inside the hole), the test can be interrupted and the "pull-out load" will be considered as the maximum value of load reached before the apparent displacement of the connector.

It shall be ascertained that failure has actually occurred in the anchorage area of the connector and is not due to sagging or sliding between the test device and the connector. In this case the result will be discarded and the test shall be repeated.

It shall also be checked that, after the test, the masonry sample is not damaged outside the area directly involved in the extraction. In this case the result will be discarded and the test shall be repeated.

The failure mode shall be recorded, based on the following typical situations:

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.

ANNEX F – TEST METHOD FOR LAP-TENSILE STRENGTH

F1. General requirements and summary of test method

Samples shall be made in such a way as to correctly represent the overlapping joint conditions inside the substrate on site and, at the same time, allow the test to be carried out easily. The overlap length shall be not less than 100 mm.

F2. Test specimens

For the production of the test samples, an aluminium tube (or other material) with a thickness of approximately 1 mm and a length equal to that of overlapping connectors shall be used. The diameter of the tube must be equal to that of the hole normally made in the substrate, as indicated by the manufacturer for the specific connection system.

The first connector will be inserted into the tube, closing, subsequently, one end of the same tube with a special film. Then the anchor indicated by the manufacturer will be introduced into the tube and the second connector will be placed. Once the anchor has hardened, according to the times indicated by the manufacturer, the film will be removed and the test will be carried out.
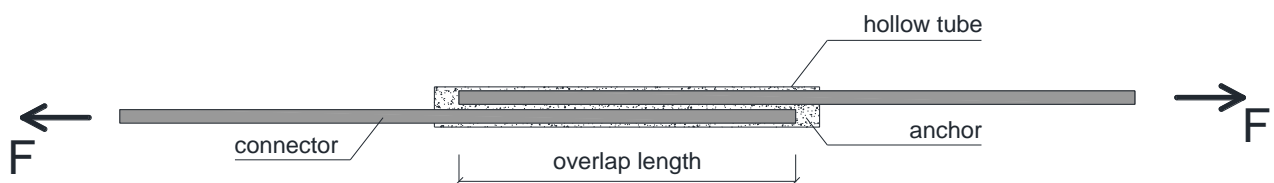
Figure F1 - Test setup for lap-tensile strength.

F3. Test procedure and results

The test procedure is the one already indicated for the tensile tests on the connectors (see Section 2.2.4.1). The test must be carried out in such a way as to ensure alignment of the applied tensile force with the axis of the connection. This alignment must be ensured throughout the course of the test.

The force corresponding to the junction failure and its failure mode shall be recorded, based on the following typical situations:

1. Failure of the anchor-connector interface
2. Failure within the anchor
3. Failure of the connector

It shall also be ascertained that failure does not occur in the gripping area of the connectors and that it is not due to sagging or sliding in the connection between the test device and the connector. In this case the result will be discarded and the test shall be repeated.