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European Assessment Document for

Kits made of alkali-resistant glass fibre mesh, connectors and mortar for strengthening of masonry and reinforced concrete elements by external bonding

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 kit made of alkali-resistant (AR) glass fibre mesh, connectors and mortar for strengthening of masonry and reinforced concrete elements by external bonding (in the following referred to as “kit for strengthening of masonry and reinforced concrete") is a structural reinforcement system consisting of (see Figure 1.1.1):

- a bi-axial mesh (A), with variable mass per unit area;
- a lime- or cement-based mortar (B);
- “open-end” connectors (C) (*optional*);
- a lime-based injection mortar (D) (*optional*).

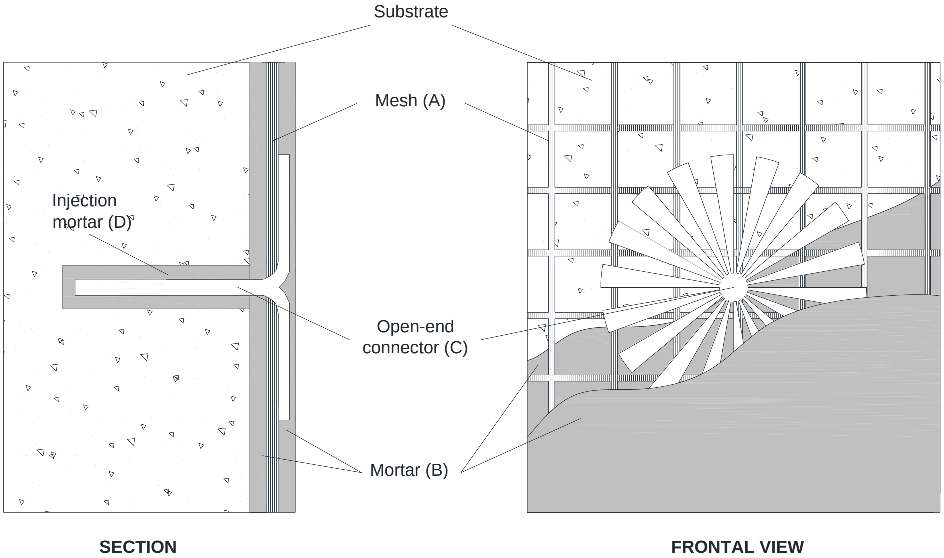

Figure 1.1.1: Components of the kit for strengthening of masonry and reinforced concrete elements

The bi-axial meshes (A) are made of leno weaved AR glass fibres, with a percentage of zirconium dioxide (ZrO_2) greater than 16%, with an alkali-resistant protective treatment. They are flexible, without shape memory and easily adaptable to the various surfaces on which the kit is applied. Meshes are also characterised 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- or cement-based mortar (B). The composite kit is applied on internal and external surfaces of walls with a thickness between 5 and 40 mm.

The “open-end” connector (C) is made of AR glass fibres with a percentage of zirconium dioxide (ZrO_2) greater than 16%. Connectors are characterised by a preformed rigid ribbed central section (made of Glass Fibre Reinforced Polymer, GFRP) and "open" (not impregnated) ends (see Figure 1.1.2); the connector is applied to the structural element by grouting with a lime-based injection mortar (D). Its function is to increase the shear resistance and the effectiveness of confinement of the supporting structural element. Connectors can pass-through the wall (both ends not impregnated), or alternatively, one end can be completely embedded (only one impregnated end).

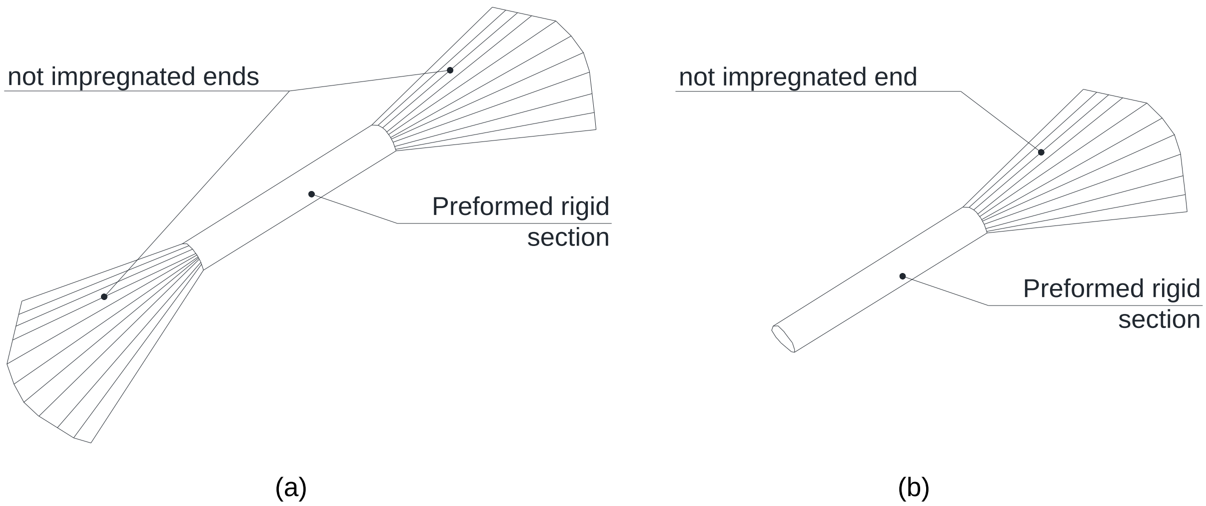

Figure 1.1.2: Example of "open-end" connector (variable length of the preformed rigid section): a) both ends not impregnated; b) one end not impregnated

When installing the connectors, the free (not-impregnated) ends are fanned out in a radial arrangement and fixed through the lime- or cement-based mortar (B) in order to join the connector with the reinforcement system (mesh plus mortar) (Figure 1.1.3). Alternatively, only one end can be completely embedded (not passing-through connector).

The kit for strengthening of masonry and reinforced concrete can also be applied in several layers (maximum 3 layers of mesh).

Application of the kit for strengthening of masonry and reinforced concrete is typically handmade.

Figure 1.1.3: Kit for strengthening of masonry and reinforced concrete: (a) application on clay masonry; (b) application on natural stone masonry

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, e.g., with regard to the intended end use conditions, 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 as long as the details of the assessment methods as laid down in this EAD are respected.

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

1.2.1 Intended use(s)

The kit for strengthening of masonry and reinforced concrete is intended to be used in highly specialised applications for strengthening masonry (clay, tuff and limestone according to EN 771-1[1] or EN 771-6) 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. Thus, uses with low performance requirements are not covered by this EAD.

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 kit for strengthening of masonry and reinforced concrete for the intended use of 25 years when installed in the works (provided that the kit for strengthening of masonry and reinforced concrete is subject to appropriate installation (see 1.1)). 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[2].

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

1.3.1 Acronyms

AR Alkali-Resistant

GFRP Glass Fibre Reinforced Polymer

LVDT Linear Variable Differential Transducer

MPII Manufacturer's Product Installation Instructions

RH Relative Humidity

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1 All undated references to standards in this EAD are to be understood as references to the dated versions listed in Clause 4.

2 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

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of the kit for strengthening of masonry and reinforced concrete is assessed in relation to the essential characteristics.

The assessment of the kit's mechanical resistance is carried out by means of the assessment of the mechanical resistance of the kit components or a combination thereof, which is decisive of the behaviour of the whole kit.

Table 2.1.1 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 properties		
	- of mesh (A) plus mortar (B)	2.2.1.1	Level σ_u [MPa], ε_u [%], E_1 [GPa], E_3 [GPa]
	- of connector (C) plus injection mortar (D) (*)	2.2.1.2	Level $\sigma_{u,c}$ [MPa], $\varepsilon_{u,c}$ [%], E_c [GPa]
2	Lap tensile strength of mesh (A) plus mortar (B)	2.2.2	Level l_{lap} [mm] σ_{lap} [MPa], $\varepsilon_{u,lap}$ [%], $E_{1,lap}$ [GPa], $E_{3,lap}$ [GPa]
3	Bond strength of mesh (A) plus mortar (B) on substrates		
	- Pull-off test	2.2.3.1	Level f_h [MPa], $f_{h,w,ret}$ [%], $f_{h,alk,ret}$ [%]
	- Single lap shear test	2.2.3.2	Level P_{max} [N], P_{deb} [N] $\sigma_{lim,conv}$ [MPa] $P_{max,w,ret}$ [%], $P_{deb,w,ret}$ [%] $P_{max,alk,ret}$ [%], $P_{deb,alk,ret}$ [%]
4	Pull-out from substrate(*)	2.2.4	Level L_{anc} [mm], P_{anc} [kN]
5	Tensile properties of dry mesh (A)	**Error! Reference source not found.**	Level and description $\sigma_{u,f}$ [MPa], $\varepsilon_{u,f}$ [%], E_f [GPa], $\varepsilon_{lim,conv}$ [%]
6	Freezing and thawing resistance		
	- of mesh (A) plus mortar (B)	2.2.6.1	Level and description $\sigma_{u,FT}$ [MPa], $\varepsilon_{u,FT}$ [%], $E_{1,FT}$ [GPa], $E_{3,FT}$ [GPa] $\sigma_{u,FT,ret}$ [%], $E_{1,FT,ret}$ [%], $E_{3,FT,ret}$ [%]
	- of connector (C) plus injection mortar (D) (*)	2.2.6.2	Level and description

No	Essential characteristic	Assessment method	Type of expression of product performance
			$\sigma_{c,FT}$ [MPa], $\varepsilon_{c,FT}$ [%], $E_{c,FT}$ [GPa] $\sigma_{c,FT,ret}$ [%], $E_{c,FT,ret}$ [%]
7	Water resistance		
	- of mesh (A) plus mortar (B)	2.2.7.1	Level and description $\sigma_{u,w}$ [MPa], $\varepsilon_{u,w}$ [%], $E_{1,w}$ [GPa], $E_{3,w}$ [GPa] $\sigma_{u,w,ret}$ [%], $E_{1,w,ret}$ [%], $E_{3,w,ret}$ [%]
	- of connector (C) plus injection mortar (D) (*)	2.2.7.2	Level and description $\sigma_{c,w}$ [MPa], $E_{c,w}$ [GPa], $\varepsilon_{c,w}$ [%] $\sigma_{c,w,ret}$ [%], $E_{c,w,ret}$ [%]
8	Alkali resistance		
	- of mesh (A) plus mortar (B)	2.2.8.1	Level and description $\sigma_{u,alk}$ [MPa], $\varepsilon_{u,alk}$ [%], $E_{1,alk}$ [GPa], $E_{3,alk}$ [GPa] $\sigma_{u,alk,ret}$ [%], $E_{1,alk,ret}$ [%], $E_{3,alk,ret}$ [%]
	- of connector (C) plus injection mortar (D) (*)	2.2.8.2	Level and description $\sigma_{c,alk}$ [MPa], $E_{c,alk}$ [GPa], $\varepsilon_{c,alk}$ [%] $\sigma_{c,alk,ret}$ [%], $E_{c,alk,ret}$ [%]
9	Thermal resistance		
	- of mesh (A) plus mortar (B)	2.2.9.1	Level and description $\sigma_{u,therm}$ [MPa], $\varepsilon_{u,therm}$ [%], $E_{1,therm}$, $E_{3,therm}$ [GPa] $\sigma_{u,therm,ret}$ [%], $E_{1,therm,ret}$ [%], $E_{3,therm,ret}$ [%]
	- of connector (C) plus injection mortar (D) (*)	2.2.9.2	Level and description $\sigma_{c,therm}$ [MPa], $E_{c,therm}$ [GPa], $\varepsilon_{c,therm}$ [%] $\sigma_{c,therm,ret}$ [%], $E_{c,therm,ret}$ [%]
10	Tensile strength after low number of cycles (seismic behaviour)		
	- of mesh (A) plus mortar (B)	2.2.10.1	Level n_{seism} [-], *or* $\sigma_{u,seism}$ [MPa], $\varepsilon_{u,seism}$ [%], $E_{1,seism}$, $E_{3,seism}$ [GPa]
	- of connector (C) plus injection mortar (D) (*)	2.2.10.2	Level $n_{c,seism}$ [-], *or* $\sigma_{c,seism}$ [MPa], $E_{c,seism}$ [GPa], $\varepsilon_{c,seism}$ [%]
11	Tensile strength after high number of cycles (fatigue actions)		
	- of mesh (A) plus mortar (B)	2.2.11.1	Level $n_{fatigue}$ [-], *or* $\sigma_{u,fatigue}$ [MPa], $\varepsilon_{u,fatigue}$ [%], $E_{1,fatigue}$, $E_{3,fatigue}$ [GPa]
	- of connector (C) plus injection mortar (D) (*)	2.2.11.2	Level $n_{c,fatigue}$ [-], *or* $\sigma_{c,fatigue}$ [MPa], $E_{c,fatigue}$ [GPa], $\varepsilon_{c,fatigue}$ [%]
12	Glass transition temperature of the connector (C) (*)	2.2.12	Level T_g [°C]
Basic Works Requirement 2: Safety in case of fire			
13	Reaction to fire	2.2.13	Class

No	Essential characteristic	Assessment method	Type of expression of product performance
Note: (*) Procedure not relevant if the components (C) and (D) are not part of the kit.			

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.

Where not explicitly expressed differently, the *mean value* is intended here as the arithmetic mean, i.e., the sum of the numerical values of a data collection divided by the number of data in the collection.

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

2.2.1 Tensile properties

2.2.1.1 Mesh (A) plus mortar (B)

Purpose of the assessment

Tensile tests are performed to evaluate the tensile strength, the stiffness moduli and the ultimate strain of the mesh embedded in mortar.

Assessment method

The mechanical properties of the specimens shall be determined according to the procedure summarized in Annex B.

Tests shall be conducted in both directions of the reinforcement mesh.

Tests shall be conducted on all the number of layers foreseen in the manufacturer’s product installation instructions (MPII).

A minimum number of twenty specimens for each number of layers to be subjected to uniaxial tensile test shall be prepared for each system configuration (i.e., weight per unit area), laid up according to the procedure indicated in Annex B and the manufacturer’s instructions.

Tests shall be performed at a temperature of 23±2°C and 40-70% RH.

Expression of results

The failure mode shall be reported in the ETA.

The mechanical properties (average and characteristic value) to be determined and reported in the ETA are (see Annex B and Figure B.5.1 for the meaning of symbols):

a) Tensile elastic modulus of stage A, E_1 [GPa];
b) Failure stress σ_u [MPa] and strain ε_u [%];
c) Tensile stiffness modulus of stage C, E_3 [GPa].

The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

2.2.1.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

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

Assessment method

The test specimen shall have a length of l=200 mm. Only the rigid part of connector made of GFRP shall be tested, which means that the non-impregnated ends shall be cut from the specimen.

Specimens shall be constituted by the connectors embedded in mortar. Special moulds made of Plexiglas (or Teflon or other easily disassembling material) with the final dimensions of the specimen shall be made. The mould can be made, for example, of two Teflon half cylinders, cut along the axis, with a variable diameter as a function of the product to be tested (about 7d, with d diameter of the connector).

The connector shall be positioned in the middle of the mould, paying attention to its alignment, and the mortar shall be injected in it. The tests shall be performed after the specified minimum curing time of the mortar has been reached, but in any case after not less than 28 days.

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 connectors. Specific devices shall be used for the centring of the bar into the aluminium cylinder.

The tests shall be performed in displacement control, and with a constantly increasing velocity of 6 mm/min.

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.

Expression of results

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

The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

2.2.2 Lap tensile strength of mesh (A) plus mortar (B)

Purpose of the assessment

When applying composite materials for strengthening of structural masonry or concrete members, splices and laps can be necessary for the reinforcement. To determine the relative tensile strength at the grid overlap area, lap tensile strength testing is required.

Assessment method

The general test procedures as described in Annex B shall be used on tension tests of composite panels. The specimens shall consist of only one layer of lapped material. The mesh in the panel shall be two pieces with an overlap length in the middle. The tested overlap length shall be the minimum overlap length according to the MPII; however, the overlap length shall not be shorter than the tab length defined in Annex B to avoid influence on the load transfer mechanism during the tensile test. Each piece of mesh shall have the same dimensions as described in the tensile strength testing (clause 2.2.1.1), such that the overlap length is positioned at mid-length of the test specimen.

Ten specimens shall be tested in standard laboratory conditions (23±2°C, 50±5% RH).

Expression of results

The used overlap length l_{lap} [mm] and the failure mode shall be reported in the ETA.

The average (arithmetic mean) and characteristic value of the lap tensile strength $\sigma_{lap}=F/A_{f,tot}$ [MPa] shall be determined, where $A_{f,tot}$ represents the mesh cross sectional area evaluated as the number of yarns *n* multiplied by the single yarn cross sectional area A_f (see Annex E, clause E3.1). Furthermore, the mechanical parameters σ_{lap} [MPa], $\varepsilon_{u,lap}$ [%], $E_{1,lap}$ [GPa], $E_{3,lap}$ [GPa], calculated as indicated in clause 2.2.1.1 points a), b) and c) and Annex B, shall also be reported in the ETA.

The characteristic value shall 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 Bond strength of mesh (A) plus mortar (B) on substrates

Definition of reference substrates

- *Concrete*

  Concrete type MC (0,40) shall 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). The following conditions shall be followed to prepare the testing specimens.

  In particular, clay bricks shall have a compressive strength in the range of 15-25 MPa. The average effective resistance shall be evaluated through at least six compression tests on cubic/cylindrical specimens of brick, of approximately 50 size/diameter (tolerances according to EN 771-1, table 1), made of the brick thickness. The general procedure of EN 772-1 shall be followed. For the preparation of masonry wall specimens for the single-lap shear tests (see 2.2.3.2), a mortar with class not exceeding M5 according to EN 998-2, table 1, shall be used.

  Natural stone bricks (tuff) shall have a compressive strength in the range of 4-12 MPa. The average effective resistance shall be evaluated through at least six compression tests on cubic specimens according to EN 772-1, of approximately 150 mm size (tolerances according to EN 771-6, table 1). For the preparation of masonry wall specimens for the single-lap shear tests (see 2.2.3.2), a mortar with class not exceeding M5 according to EN 998-2, table 1, shall be used.

  Natural stones (limestone) irregular in shape, not squared, whose larger size is less than 150 mm, shall have a compressive strength in the range of 50-150 MPa. The compressive strength of the stones shall be evaluated through at least six compression tests according to EN 1926. For the preparation of masonry wall specimens for the single-lap shear tests (see 2.2.3.2), a mortar with class not higher than M2,5 according to EN 998-2, table 1, shall be used.

2.2.3.1 Pull-off test

Purpose of the assessment

The test allows to determine the adhesive strength of the bonded composite system (mesh embedded in mortar) on different substrates. It determines the bond strength to the substrate or the tensile strength of either the overlay or substrate, whichever is weaker.

Assessment method

For tensile bond testing, twenty-five specimens shall be prepared for each substrate. One layer of composite material (mesh embedded in mortar) shall be applied onto the substrate according to the MPII. Twenty specimens shall then be exposed to water and alkali conditions for 1000 and 3000 hours according to the procedures of 2.2.7 and 2.2.8. Five specimens shall be kept in standard laboratory conditions (23±2°C, 50±5% RH) as control specimens. A summary of the minimum number of specimens to be tested is reported in Annex A.

The test shall follow the general procedures of EN 1542 with the following deviations to take into account the different substrates:

- Concrete: prisms with 300 mm x 300 mm x 100 mm sizes (according to EN 1542) and concrete type MC (0,40) (according to EN 1766);
- Masonry: test shall be conducted on solid blocks. Dollies shall be bonded on the larger surface of the brick or natural stone block leaving a distance from the edges at least equal to the size of the dollies (see examples in Figure 2.2.3.1.1 and Figure 2.2.3.1.2, sizes are to be considered as indicative as the test shall be performed on blocks commonly found on the market).

When a circular cut is not feasible, it shall be allowed to cut the substrate in a hexagonal geometry to circumscribe the disk used for testing. If the substrate is cut in a hexagonal geometry and failure occurs in the substrate, the area of hexagon shall be used for the bond area for determining the pull-off strength.

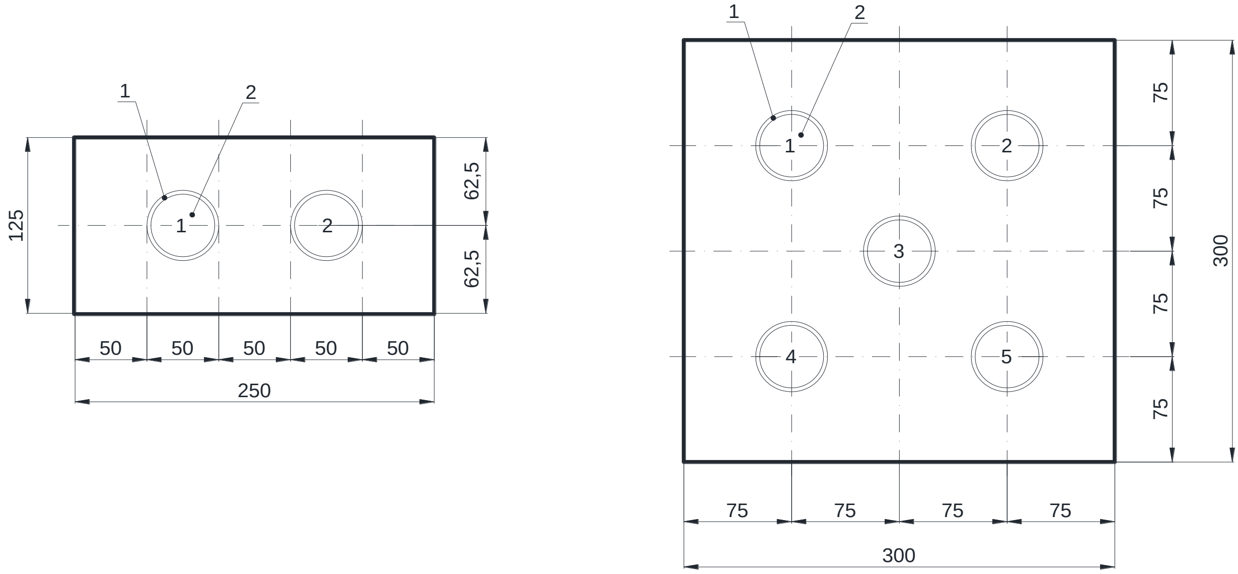


Figure 2.2.3.1.1: Plan of clay (left) and tuff (right) specimen showing dolly locations; 1: Annulus around test area, formed by coring; 2: 50 mm steel or aluminium dolly

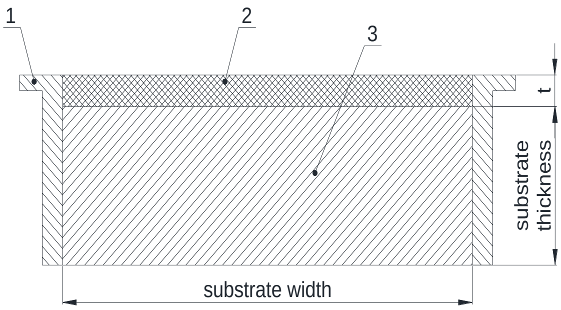


Figure 2.2.3.1.2: Cross section through specimen (1: mould; 2: layer of mesh (A) plus mortar (B) with maximum thickness *t*; 3: reference substrate)

Expression of results

The failure mode shall be recorded for each individual test result according to the indications of EN 1542.

The average (arithmetic mean) pull-off strength f_h [MPa] of control specimens shall be reported in the ETA, together with the compressive strength of the substrate f_b [MPa] and the axial surface strength of the substrate $f_{h,sub}$ [MPa] according to EN 1542.

The percentage of bond strength retained by exposed specimens with respect to control specimens (residual bond strength, $f_{h,w,ret}$ [%] and $f_{h,alk,ret}$ [%]) and the exposure conditions (duration) shall also be reported in the ETA.

2.2.3.2 Single-lap shear test

Purpose of the assessment

The test allows to determine the shear bond strength of the composite system (mesh embedded in mortar) adhesively applied to a flat concrete or masonry substrate.

Assessment method

A minimum of twenty-five specimens shall be prepared for each substrate. One layer of composite material (mesh embedded in mortar) shall be applied onto the substrate in accordance with the MPII. Twenty specimens shall then be exposed to water and alkali conditions for 1000 and 3000 hours according to the procedures of 2.2.7 and 2.2.8. Five specimens shall be kept in standard laboratory conditions (23±2°C, 50±5% RH) as control specimens. The test shall follow the general procedure reported in Annex C and shall be performed at 23±2°C and 40-70% RH.

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

Expression of results

The failure mode shall be reported in the ETA for each product.

For the control specimens, the average (arithmetic mean) and characteristic value of the maximum load P_{max} [N], the bond capacity P_{deb} [N] and the conventional limit stress $\sigma_{lim,conv}$ [MPa] shall be reported in the ETA, together with the compressive strength of the substrate f_b [MPa] and the axial surface strength of the substrate $f_{h,sub}$ [MPa] according to EN 1542. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of maximum load and bond capacity retained by exposed specimens with respect to control specimens ($P_{max,w,ret}$ [%], $P_{deb,w,ret}$ [%], $P_{max,alk,ret}$ [%] and $P_{deb,alk,ret}$ [%]) and the exposure conditions (duration) shall also be reported in the ETA.

2.2.4 Pull-out from substrates

Purpose of the assessment

The test is performed to determine the pull-out strength of connectors from the reference substrates described in clause 2.2.3.

Assessment method

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

Expression of results

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]. In addition, the position of the hole (mortar joints or other configurations) shall be reported in the ETA.

2.2.5 Tensile properties of dry mesh (A)

Purpose of the assessment

The tensile test on dry mesh specimens shall be carried out to define the stiffness and strength of the mesh in order to allow the determination of the conventional limit strain $\varepsilon_{lim,conv}$ of the kit for strengthening of masonry and concrete.

Assessment method

Tensile tests shall be performed on at least 5 specimens according to the procedure indicated in Annex E at standard laboratory conditions (23±2°C, 50±5% RH). Test specimens shall be cut from the mesh roll supplied by the manufacturer in both directions.

Expression of results

The stress strain curve shall be determined. The characteristic value of the ultimate stress $\sigma_{u,f}$ [MPa], the ultimate strain $\varepsilon_{u,f}$ [%], the average elastic modulus E_f [GPa], and the conventional limit strain $\varepsilon_{lim,conv}$ [%] (Annex E) shall be determined and reported in the ETA. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1. The failure mode shall also be reported in the ETA.

2.2.6 Freezing and thawing resistance

2.2.6.1 Mesh (A) plus mortar (B)

Purpose of the assessment

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

Assessment method

Freezing and thawing conditioning shall be conducted on tension composite panel specimens (clause 2.2.1.1, with the minimum number of layers). The specimens shall be conditioned for one week in a humidity chamber (>90% RH, 38±2°C). They shall then be subjected to twenty freeze-thaw cycles. Each cycle consists of a minimum of four hours at -18±2°C, followed by 12 hours in a humidity chamber (>90% RH, 38±2°C). After at least seven days, the conditioned specimens shall be tested in direct tension according to 2.2.1.1.

Expression of results

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

The average (arithmetic mean) and characteristic value of the tensile strength $\sigma_{u,FT}$ [MPa], stiffness moduli $E_{1,FT}$ and $E_{3,FT}$ [GPa], strain $\varepsilon_{u,FT}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.1. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1. The percentage of average mechanical properties ($\sigma_{u,FT,ret}$ [%], $E_{1,FT,ret}$ and $E_{3,FT}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (clause 2.2.1.1) and the exposure conditions shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.6.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

This test is performed to evaluate the influence of freeze-thaw cycles on the behaviour of the connector embedded in injection mortar.

Assessment method

Conditioning shall be conducted on connectors embedded in injection mortar (clause 2.2.1.2) according to the indications given in clause 2.2.6.1. After at least seven days, conditioned specimens shall be tested in direct tension according to 2.2.1.2.

Expression of results

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

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

The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{c,FT,ret}$ [%], $E_{c,FT,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (clause 2.2.1.2) shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.7 Water resistance

2.2.7.1 Mesh (A) plus mortar (B)

Purpose of the assessment

This test is performed to evaluate the influence of water on the behaviour of the mesh embedded in mortar.

Assessment method

Conditioning shall be conducted on tension composite panel specimens (clause 2.2.1.1, with the minimum number of layers) according to Annex F for 1000 and 3000 hours at a temperature of 38±2°C and a relative humidity >90%. After at least seven days, the conditioned specimens shall be tested in direct tension according to 2.2.1.1.

Expression of results

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

The average (arithmetic mean) and characteristic value of the tensile strength $\sigma_{u,w}$ [MPa], stiffness moduli $E_{1,w}$ and $E_{3,w}$ [GPa], strain $\varepsilon_{u,w}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.1. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{u,w,ret}$ [%], $E_{1,w,ret}$ and $E_{3,w,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (clause 2.2.1.1) and the exposure conditions shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.7.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

This test is performed to evaluate the influence of water on the behaviour of the connector embedded in injection mortar.

Assessment method

Conditioning shall be conducted on connectors embedded in injection mortar (clause 2.2.1.2) according to the indications given in clause 2.2.7.12.2.7. After at least seven days, conditioned specimens shall be tested in direct tension according to 2.2.1.2.

Expression of results

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

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

The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{c,w,ret}$ [%], $E_{c,w,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (clause 2.2.1.2) shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.8 Alkali resistance

2.2.8.1 Mesh (A) plus mortar (B)

Purpose of the assessment

This test is performed to evaluate the influence of alkali attack on the efficiency of the mesh embedded in mortar, by immerging specimens in a liquid with pH≥9,5

Assessment method

Alkali conditioning shall be conducted on tension composite panel specimens (clause 2.2.1.1, with minimum number of layers).

Conditioning shall be done by immerging specimens in an alkaline solution for 1000 and 3000 hours at a temperature of 23 °C±2 °C. The composition of alkaline solution consists of 118,5 g of $Ca(OH)_2$, 0,9 g of NaOH and 4,2 g of KOH in 1 litre of tap water. After at least seven days, conditioned specimens shall be tested in direct tension according to 2.2.1.1.

Expression of results

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

The average (arithmetic mean) and characteristic value of the tensile strength $\sigma_{u,alk}$ [MPa], stiffness moduli $E_{1,alk}$ and $E_{3,alk}$ [GPa], strain $\varepsilon_{u,alk}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.1. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{u,alk,ret}$ [%], $E_{1,alk,ret}$ and $E_{3,alk,ret}$ [%]) retained by exposed specimens with respect to the values recorded for unconditioned specimens (clause 2.2.1.1) and the exposure conditions shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.8.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

This test is performed to evaluate the influence of alkali attack on the efficiency of the connector embedded in injection mortar.

Assessment method

Conditioning shall be conducted on connectors embedded in injection mortar (clause 2.2.1.2) according to the indications given in clause 2.2.8.1. After at least seven days, conditioned specimens shall be tested in direct tension according to 2.2.1.2.

Expression of results

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

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

The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{c,alk,ret}$ [%], $E_{c,alk,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (clause 2.2.1.2) shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.9 Thermal resistance

2.2.9.1 Mesh (A) plus mortar (B)

Purpose of the assessment

This test is performed to evaluate the performance of the mesh embedded in mortar when subjected to thermal stresses.

Assessment method

Tensile tests according to 2.2.1.1 shall be conducted on tension composite panel specimens (clause 2.2.1.1, with the minimum number of layers) at the upper temperature of use indicated by the manufacturer, or at 80 °C when not provided by the manufacturer.

The upper temperature shall be reached with thermal gradients not higher than 30°C/h and each specimen shall be maintained at the extreme temperature for at least 6 h. A special heating jacket, connected to the tensile test apparatus, can be used to heat the specimen.

Expression of results

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

The average (arithmetic mean) and characteristic value of the tensile strength $\sigma_{u,therm}$ [MPa], stiffness moduli $E_{1,therm}$ and $E_{3,therm}$ [GPa] and strain $\varepsilon_{u,therm}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.1. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{u,therm,ret}$ [%], $E_{1,therm,ret}$ and $E_{3,therm,ret}$ [%]) retained by exposed specimens with respect to the values recorded for unconditioned specimens (clause 2.2.1.1) and the exposure conditions shall also be reported in the ETA.

2.2.9.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

This test is performed to evaluate the performance of the connectors embedded in injection mortar when subjected to thermal stresses.

Assessment method

Tensile tests according to 2.2.1.2 shall be conducted on connectors embedded in injection mortar at the conditions given in clause 2.2.9.1.

Expression of results

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

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

The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

The percentage of average mechanical properties ($\sigma_{c,therm,ret}$ [%], $E_{c,therm,ret}$ [%]) retained by exposed specimens with respect to the value recorded for unconditioned specimens (clause 2.2.1.2) shall also be reported in the ETA. These percentages shall be calculated on the basis of average results for the set of tested specimens.

2.2.10 Tensile strength after low number of cycles (seismic behaviour)

2.2.10.1 Mesh (A) plus mortar (B)

Purpose of the assessment

This test is performed to determine the behaviour of the mesh embedded in mortar under cyclic loading (seismic behaviour).

Assessment method

Five specimens shall be prepared according to the procedure of clause 2.2.1.1 with a minimum number of layers.

Fifteen cycles at 1 Hz shall be applied on the specimens. The cyclic loads consist of a lower stress level equal to 5% of the respective characteristic short time tensile strength according to clause 2.2.1.1 and an upper stress level equal to 90% of the respective characteristic short time tensile strength. If no failure occurs during the cycles, the specimens shall be tested in direct tension according to 2.2.1.1. The test shall be performed in standard laboratory conditions (23±2°C, 50±5% RH).

Expression of results

The number of cycles n_{seism} causing failure shall be reported in the ETA or, if no failure occurs during the cycles, the arithmetic mean and characteristic value of the tensile strength $\sigma_{u,seism}$ [MPa], stiffness moduli $E_{1,seism}$ and $E_{3,seism}$ [GPa] and strain $\varepsilon_{u,seism}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.1. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

2.2.10.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

This test is performed to determine the behaviour of the connectors embedded in injection mortar under cyclic loading (seismic behaviour).

Assessment method

The test shall be performed on connectors embedded in injection mortar and prepared according to the procedure of clause 2.2.1.2.

Fifteen cycles at 1 Hz shall be applied on the specimens. The cyclic loads consist of a lower stress level equal to 5% of the respective characteristic short time tensile strength (clause 2.2.1.2) and an upper stress level equal to 90% of the respective characteristic short time tensile strength. If no failure occurs during the cycles, the specimens shall be tested in direct tension according to 2.2.1.2. Test shall be performed in standard laboratory conditions (23±2°C, 50±5% RH).

Expression of results

The minimum number of cycles $n_{c,seism}$ causing failure shall be reported in the ETA or, if no failure occurs during the cycles, the arithmetic mean and characteristic value of the tensile strength $\sigma_{c,seism}$ [MPa], elastic modulus $E_{c,seism}$ [GPa] and strain $\varepsilon_{c,seism}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.2. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

2.2.11 Tensile strength after high number of cycles (fatigue actions)

2.2.11.1 Mesh (A) plus mortar (B)

Purpose of the assessment

This test is performed to determine the behaviour of the mesh embedded in mortar under fatigue loading.

Assessment method

Five specimens shall be prepared according to the procedure of clause 2.2.1.1, with a minimum number of layers. Dynamic tests with 2×10^6 cycles shall be carried out with a stress ratio R = 0,1 (where R represents the ratio between the minimum and maximum stress applied) and an upper stress correspondent to 60% of the characteristic conventional limit stress $\sigma_{lim,conv}$ derived in the single-lap shear test (clause 2.2.3.2) for the substrate with the highest value. The testing frequency shall be chosen to be between 1 and 3 Hz. Cyclic loads shall be applied on the specimens until fatigue failure or the limit number of cycles (2×10^6) is reached. Test specimens reaching the limit number of cycles without failure shall be tested in direct tension according to 2.2.1.1. Test shall be performed in standard laboratory conditions (23±2°C, 50±5% RH).

Expression of results

The number of cycles $n_{fatigue}$ causing failure shall be reported in the ETA or, if no failure occurs during the cycles, the arithmetic mean and characteristic value of the tensile strength $\sigma_{u,fatigue}$ [MPa], stiffness moduli $E_{1,fatigue}$ and $E_{3,fatigue}$ [GPa] and strain $\varepsilon_{u,fatigue}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.1. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

2.2.11.2 Connector (C) plus injection mortar (D)

Purpose of the assessment

This test is performed to determine the behaviour of the connectors embedded in injection mortar under fatigue loading.

Assessment method

The test shall be performed on connectors embedded in injection mortar and prepared according to the procedure of clause 2.2.1.2.

Dynamic tests with 2×10^6 cycles shall be carried out under a stress ratio R = 0,1 and an upper load of 60% of the respective average short-time tensile strength (clause 2.2.1.2). The testing frequency shall be chosen to be between 1 and 3 Hz. Cyclic loads shall be applied on the specimens until fatigue failure or the limit number of cycles is reached. Test specimens reaching the limit number of cycles without failure shall be tested in direct tension according to 2.2.1.2. Test shall be performed in standard laboratory conditions (23±2°C, 50±5% RH).

Expression of results

The minimum number of cycles $n_{c,fatigue}$ causing failure shall be reported in the ETA or, if no failure occurs during the cycles, the arithmetic mean and characteristic value of the tensile strength $\sigma_{c,fatigue}$ [MPa], elastic modulus $E_{c,fatigue}$ [GPa] and strain $\varepsilon_{c,fatigue}$ [%], and the relative failure mode shall be determined and reported in the ETA. The meaning of the mechanical properties is the same of that indicated in clause 2.2.1.2. The characteristic value shall be determined by using the appropriate value of k_n for unknown V_X according to EN 1990, Annex D, Table D1.

2.2.12 Glass transition temperature of the connector (C)

Purpose of the assessment

This test shall be performed to evaluate the glass transition temperature (T_g) of the preformed rigid ribbed central section made of GFRP of the open-end connectors.

Assessment method

The 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 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; the heating speed shall be 10°C/min. The value of the glass transition temperature shall be determined through the “Half-step-height” method (EN ISO 11357-2, clause 10.1.3).

Expression of results

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

2.2.13 Reaction to fire

Purpose of the assessment

This test shall be performed to evaluate the reaction to fire of the kit for strengthening of masonry and reinforced concrete.

Assessment method

The kit for strengthening of masonry and reinforced concrete shall be tested, using the test method(s) relevant for the corresponding reaction to fire class, according to EN 13501-1.

The kit for strengthening of masonry and reinforced concrete shall be classified according to the Commission Delegated Regulation (EU) No 2016/364 in connection with EN 13501-1.

1. *Preparation of specimens*

In addition to EN 13501-1, the following product properties of the kit for strengthening of masonry and reinforced concrete shall be considered when preparing the test specimens:

- Type of mesh (A) (composition, thickness, weight per unit area);
- Type of mortars (B) and (D) (composition, thickness, weight per unit area);
- Amount of organic content of mortars (B) and (D). The mortars with the highest amount of organic content (related to the mass in dried conditions as in end use application) or the highest Q_{PCS}-value (according to EN ISO 1716)[3] shall be used for preparing the specimens.

Further indications are given in the following sub-clauses.

2. *Indications for mounting and fixing*

a. *EN ISO 1182 (Non-combustibility test)*

Open-end connectors (C) shall not be considered for testing and classification regarding non-combustibility, because they can be considered discrete and not continuous components.

The reaction to fire behaviour of the lime- or cement-based mortar (B) and the lime-based injection mortar (D) not falling under EC decision 96/603/EC (as amended by decisions 2000/605/EC and 2003/424/EC) shall be tested by considering the product with the highest amount of organic content.

3 If the requested information on organic content or Q_{PCS}-value of mortars are not available, the Q_{PCS}-value shall be tested to determine the worst case.

The reaction to fire of the mesh (A) shall be tested according to the indications of EN ISO 1182.

b. *EN ISO 1716 (Heat of combustion, Q_{PCS} -value)*

The test shall be performed with all components except for cases which are classified as A1 without testing, according to decision 96/603/EC (as amended by decisions 2000/605/EC and 2003/424/EC). Open-end connectors (C) shall not be considered for testing and classification regarding heat of combustion (Q_{PCS}), because they can be considered discrete and not continuous components.

The combination of components and layers thicknesses leading to the highest gross heat of combustion of the kit shall be identified. An example of calculation for kit is shown in EN 16724, Annex A.

c. *EN ISO 11925-2 (Single-flame source test)*

For the relevant classes, single-flame source test shall be performed by considering the following indications for the preparation of the test specimen.

The specimen shall be prepared to the required length (250 ±2 mm) and width (90 ±2 mm) considering a layer of mesh (A) embedded in mortar (B), following the indications given in clause B.3.

The specimens shall be prepared with the lowest thickness of the layer of mortar (B). If the organic content is higher than 5%, the highest thickness shall be used additionally for preparing the test specimens.

The mesh (A) with the highest Q_{PCS}-value per unit area shall be used for preparing the test specimens.

d. *EN 13823 (SBI test)*

For the relevant classes, the SBI test shall be performed by considering the following indications for the preparation of the test specimen: a layer of composite material, made of a layer of mesh (A) embedded in mortar (B) according to the indications of the manufacturer, shall be installed on one of the substrates foreseen by EN 13238.

Open-end connectors (C) shall not be considered for testing and classification regarding the SBI test, because they can be considered discrete and not continuous components.

For mortars (B) having an organic content less than or equal to 5%, the lowest layer thicknesses shall be used for preparing all three test specimens. For mortars having an organic content higher than 5%, both the lowest and the highest thickness of the mortar shall be used to prepare the test specimens.

The mesh (A) with the highest Q_{PCS}-value per unit area shall be used for preparing the test specimens. At the long wing of the SBI specimens, a vertical joint of the mesh shall be considered at a distance of 200 mm away from the inner corner of the specimens by 100 mm overlapping of the layers of mesh (that means the joint begins at a distance of 150 mm and ends at a distance of 250 mm away from the inner corner).

3. *Extended application of test results*

The results of the tests considering the aforementioned parameters in fully are also valid for products:

- of the same defined product-type;
- mortars (B)
    - with equal or lower organic content;
    - with equal or greater thickness, if the organic content is equal or less than 5%;
    - with thickness between those tested in the test, provided that the worst result of the two thicknesses tested is used for the intermediate thicknesses, if the organic content is higher than 5%.
- mesh (A)

- of the same material with an equal or lower Q_{PCS}-value per unit area.

Expression of results

The reaction to fire class shall be stated in the ETA, together with the substrate for which the classification is applicable.

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 Commission Decision 1999/469/EC, as amended by Commission Decision 2001/596/EC.

The applicable AVCP system is 2+ for any use except for uses subject to regulations on reaction to fire.

For uses subject to regulations on reaction to fire the applicable AVCP systems regarding reaction to fire are 1, or 3, or 4 depending on the conditions defined in the said Decision.

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 3.2.1.

The manufacturer (regarding the components he buys from the market with DoP) shall take into account the Declaration of Performance issued by the manufacturer of that component. No retesting is necessary.

Table 3.2.1 Control plan for the manufacturer; cornerstones.

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) **[including testing of samples taken at the factory in accordance with a prescribed test plan]**					
1	Incoming materials	Check of delivery ticket or label on the package Supplier documents or supplier tests' check	Conformity with the order	---	Each delivery
2	AR-glass fibres/Zirconia content (ZrO_2)	X-ray fluorescence	According to the Control Plan	1 specimen	Each delivery
3	Mesh (A)/Dimensions	With Callipers	According to the Control Plan	1 specimen per relevant criteria	Every batch (*)
4	Mesh (A)/Weight per square meter	Adjusted balance	According to the Control Plan	1 specimen	Every batch (*)
5	Mesh (A)/Organic content	Clause 2.2.2 of EAD 040016-01-0404	According to the Control Plan	3 specimens	Every batch (*)
6	Mesh (A)/Cross-sectional area of single yarn in warp and weft	According to the Control Plan	According to the Control Plan	1 specimen per relevant criteria	Every batch (*)
7	Mesh (A)/Tensile strength	Clause **Error! Reference source not found.**	According to the Control Plan	3 specimens	1 per year or at least 2500 m^2
8	Connector (C)/Dimensions	With Callipers	According to the Control Plan	1 specimen per relevant criteria	Every batch (*)
9	Connector (C)/Weight per meter	Adjusted balance	According to the Control Plan	1 specimen	Every batch (*)
10	Connector (C)/Glass transition temperature of connector (C)	Clause 2.2.12	According to the Control Plan	1 specimen	1 per year

Table 3.2.1 Control plan for the manufacturer; cornerstones.

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
11	Mortars (B and C)/Organic content	According to the Control Plan	According to the Control Plan	1 specimen	At each change in production process or production process control parameters or every 5,000 m^3 or 8,000 t/machine
12	Mortars (B and C)/Bond strength	According to the Control Plan	According to the Control Plan	3 specimens	Every batch (*)
13	Mesh (A) plus Mortar (B)/Tensile strength	2.2.1.1	According to the Control Plan	3 specimens	1 per year
14	Connector (C) plus Injection Mortar (D)/Tensile strength	2.2.1.2	According to the Control Plan	3 specimens	1 per year
(*) Batch: every quantity of material made in a single operation, or in the case of continuous production for a defined quantity (in linear meter or square meters or tons) which shall be demonstrated by the manufacturer to have a uniform composition and shall not exceed one day's production					

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 composite system are laid down in Table 3.3.1.

Table 3.3.1 Control plan for the notified body; cornerstones

No	Subject/type of control	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 composite system.	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 process, after its modification or when starting a new production line.
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.	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 3.2.1	As defined in the control plan	As defined in the control plan	Once per year

The intervention of the notified body under AVCP system 1 is only necessary for reaction to fire 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 3.3.2.

Table 3.3.2 Control plan for the notified body; cornerstones

No	Subject/type of control	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					
1	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 agreed between the TAB and the manufacturer	As defined in the control plan agreed between the TAB and the manufacturer	When starting the production process, after its modification or when starting a new production 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					
2	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 3.2.1	As defined in the control plan agreed between the TAB and the manufacturer	As defined in the control plan agreed between the TAB and the manufacturer	Once per year

4 REFERENCE DOCUMENTS

EAD 040016-01-0404	Glass fibre mesh for reinforcement of cementitious or cement-based renderings
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 772-1:2011+A1:2015	Methods of test for masonry units – Part 1: Determination of compressive strength
EN 998-2:2016	Specification for mortar for masonry – Part 2: Masonry mortar
EN 1542:1999	Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength by pull-off
EN 1766:2017	Products and systems for the protection and repair of concrete structures - Test methods - Reference concretes for testing.
EN 1926:2006	Natural stone test methods – Determination of uniaxial compressive strength
EN 1990:2023	Eurocode - Basis of structural and geotechnical design
EN 13238:2010	Reaction to fire tests for building products - Conditioning procedures and general rules for selection of substrates
EN 13501-1:2018	Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests
EN 13823:2020+A1:2022	Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item
EN 16724:2015	Thermal insulation products for building applications - Instructions for mounting and fixing for determination of the reaction to fire testing of external thermal Insulation composite systems (ETICS)
EN ISO 1182:2020	Reaction to fire tests for products - Non-combustibility test (ISO 1182:2020)
EN ISO 1716:2018	Reaction to fire tests for products - Determination of the gross heat of combustion (calorific value) (ISO 1716:2018)
EN ISO 6892-1:2019	Metallic materials - Tensile testing - Part 1: Method of test at room temperature (ISO 6892-1:2019)
EN ISO 11357-2:2020	Plastics - Differential scanning calorimetry (DSC) - Part 2: Determination of glass transition temperature and step height (ISO 11357-2:2020)
EN ISO 11925-2:2020	Reaction to fire tests - Ignitability of products subjected to direct impingement of flame - Part 2: Single-flame source test (ISO 11925-2:2020)

ISO 7500-1:2018	Metallic materials - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system
ISO 10406-1:2015	Fibre-reinforced polymer (FRP) reinforcement of concrete - Test methods - Part 1: FRP bars and grids

ANNEX A SUMMARY OF TESTS

No	Essential characteristic		Clause in EAD	Minimum number of tests
1	Tensile properties			
	- of mesh (A) plus mortar (B)		2.2.1.1	20
	- of connector (C) plus injection mortar (D)		2.2.1.2	5
2	Lap tensile strength of mesh (A) plus mortar (B)		2.2.2	10
3	Bond strength of mesh (A) plus mortar (B) on substrates (1) (*Pull-off test*)	Ambient (control)	2.2.3.1	5
		Water	2.2.3.1 and 2.2.7.1	5 for each duration
		Alkali	2.2.3.1 and 2.2.8.1	5 for each duration
	Bond strength of mesh (A) plus mortar (B) on substrates (1) (*Single-lap shear test*)	Ambient (control)	2.2.3.2	5
		Water	2.2.3.2 and 2.2.7.1	5 for each duration
		Alkali	2.2.3.2 and 2.2.8.1	5 for each duration
4	Pull-out from reference substrates (1)		2.2.4	5
5	Tensile properties of dry mesh (A)		**Error! Reference source not found.**	10
6	Freezing and thawing			
	- of mesh (A) plus mortar (B)		2.2.6.1	5
	- of connector (C) plus injection mortar (D)		2.2.6.2	5
7	Water resistance			
	- of mesh (A) plus mortar (B)		2.2.7.1	5 for each duration
	- of connector (C) plus injection mortar (D)		2.2.7.2	5 for each duration
8	Alkali resistance			
	- of mesh (A) plus mortar (B)		2.2.8.1	5 for each duration
	- of connector (C) plus injection mortar (D)		2.2.8.2	5 for each duration
9	Thermal resistance			
	- of mesh (A) plus mortar (B)		2.2.9.1	5
	- of connector (C) plus injection mortar (D)		2.2.9.2	5
10	Tensile strength after low number of cycles (seismic behaviour)			
	- of mesh (A) plus mortar (B)		2.2.10.1	5
	- of connector (C) plus injection mortar (D)		2.2.10.2	5
11	Tensile strength after high number of cycles (fatigue actions)			

No	Essential characteristic	Clause in EAD	Minimum number of tests
	- of mesh (A) plus mortar (B)	2.2.11.1	5
	- of connector (C) plus injection mortar (D)	2.2.11.2	5
12	Glass transition temperature of the connector (C)	2.2.12	3
13	Reaction to fire	2.2.13	According to relevant standards in connection with Commission Delegated Regulation (EU) No 2016/364

Note:

(1) Minimum number of tests is referred to each substrate foreseen by the intended use of the product (concrete, clay, tuff and limestone masonry)

ANNEX B TENSILE TESTING OF COMPOSITE SPECIMENS

B.1 Summary of test method

A thin flat strip of material having a near-constant rectangular cross section shall be mounted in the grips of a mechanical testing machine and loaded with monotonically increasing displacement while recording load and displacement. The ultimate strength of the material shall be determined from a maximum load carried before failure. The specimen strain or elongation is monitored with displacement transducers to determine the nominal stress-strain response of the material, and from that the cracking stress and strain, ultimate tensile strain, tensile stiffness modulus before and after cracking of the cement-based matrix shall be derived.

B.2 Apparatus

The testing machine shall have the appropriate load capacity to withstand the foreseen ultimate forces and shall be equipped with an appropriately calibrated load cell and classified at least, with reference to EN ISO 6892-1, clause 9, in class 1 according to ISO 7500-1 (resolution higher than 0,1 %).

The testing machine shall be equipped with a gripping system which allows to lock the ends of the specimens by applying a sufficient lateral pressure to prevent the slippage of the specimen with respect to the grips and the sliding of the mesh inside the matrix. If necessary, appropriate arrangements shall be made to prevent slippage, for example by holding the mesh wires at the ends of the specimen by means of suitable metallic clips.

In any case, bending stresses in the specimen shall be avoided (e.g., by using rotationally self-aligning grips).

The accuracy of instruments used for measuring dimensions of the test specimens shall be suitable for reading within 1 percent of the specimen dimensions.

Note: Accuracy=± (the sum of the amount of the error plus the amount of the expanded measurement uncertainty). For values of both error and expanded measurement uncertainty see last calibration certificate of the instrument.

B.3 Test specimens

Specimens can be produced individually by using special moulds or can be cut from larger panels, by using the materials (meshes and mortars) supplied by the manufacturer.

The materials (meshes and mortars) supplied by the manufacturer shall be used to produce the specimens using a wet lay-up procedure.

If specimens are produced individually, special moulds made of Plexiglas (or Teflon or other easily disassembling material) with the final dimensions of the specimen shall be made.

If specimens are cut from larger panels, the rectangular panel moulds can be made by attaching a Plexiglas (or Teflon or other easily disassembling material) surface to a particle board and installing aluminium edges to control the panel thickness.

The composite large panels (or single specimens) shall be manufactured by using a manual impregnation technique in the mould by first applying a thin layer of the mortar, followed by a layer of the mesh, pre-cut to the panel (or single mould) size, which shall be pushed within the fresh mortar. The top layer of mortar shall then be applied as flat as possible with a finishing trowel. Individual specimens shall then be cut from the large panels by using, for example, a diamond-tipped wet saw with a rigid fixture to ensure consistent specimen widths.

Control of fibre mesh alignment is critical in the lay-up procedure. Effective cutting tools and methods need to be used, and precautions shall be taken to avoid notches, undercuts, uneven surfaces, or delamination. The specimen preparation method shall be recorded.

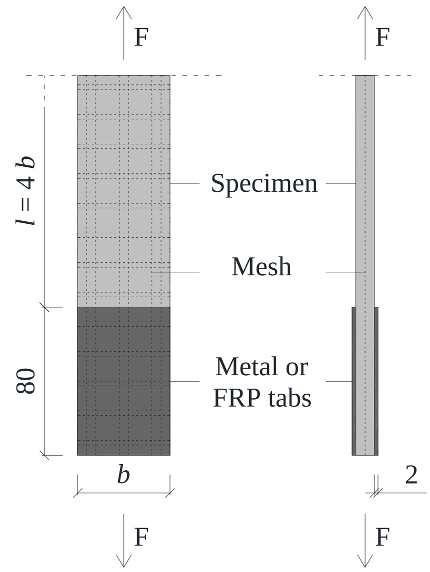


Figure B.3.1: Geometry of specimens and tabs (minimum dimensions). Dimensions in mm.

Test specimens shall be rectangular. Their width shall be a multiple of the mesh spacing and be such to include at least two grid openings (minimum 3 threads). The thickness of the specimens is a function of number of layers and thickness of matrix for each layer. In case the strands in multiple layers are staggered with respect to each other, the same number of threads shall be used in each layer along the width of the specimen. The width of the specimen shall not be greater than that of the traction machine grips, otherwise a uniform distribution of normal tensile stresses would not be ensured in the specimen.

The minimum length of the specimen, excluding the gripping length, shall be at least four times the width of the specimen. Longer lengths are preferable to minimize the influence of the gripping system.

Specimens shall be equipped with tabs in the gripping area to avoid failure of specimens in such zone (Figure B.3.1). The tabs can be metallic (aluminium or steel) or made of fibre reinforced polymers (FRP; e.g., GFRP). Tabs (two at each end, one at each face) shall have the same width as the specimen and shall be glued to it by using specific adhesives to avoid slip among the tab and the specimen. It is necessary to respect the time and environmental conditions for the complete curing of the adhesive before carrying out the test.

A minimum tab length of 80 mm shall be used. The thickness of the tabs shall be at least 2 mm in order to uniformly distribute the gripping force to the overall width of the specimens.

To avoid dispersion of results, care shall be taken to prepare the specimens, to grip them and to align the specimens in the test machine. Non-alignment of fibres causes a non-homogeneous distribution of stresses among the threads that constitute the mesh specimen. In addition, an inappropriate gripping system may cause failure of the test specimens at the ends or a partial break of threads and, consequently, a relevant dispersion of the results.

Curing of specimens

Specimens to be tested shall have a maturation period of at least 28 days from the date of preparation. Preservation of specimens shall be carried out in standard laboratory atmospheric conditions (23±2°C, atmospheric pressure, 50±5% RH).

B.4 Test procedure

After conditioning and before testing, specimen type, geometry and environmental conditioning test parameters shall be recorded. The width and thickness shall be measured at three locations along the specimen and averaged.

The specimen shall be placed in the grips of testing machine, taking care to align the axis of the gripped specimen with the testing machine axis. During the test preparation phase, an axial force not greater than 5% of the anticipated failure load can be applied to avoid potential bending effects in the specimen.

The load shall be applied under displacement control, with a constant rate not exceeding 0,2 mm/min in the non-cracked phase (A) and crack formation phase (B) (Figure B.5.1). The rate can be increased up to 0,5 mm/min at the end of the cracked stage.

A suitable instrument for strain measurement (extensometer) shall be attached to the specimen, with a minimum gauge length of 200 mm.

During the test, the load value, the displacement of the moving end and the deformation of the extensometer shall be recorded continuously or at frequent regular intervals (minimum frequency 3 Hz).

The stress value is defined as the ratio of the load and the mesh cross-sectional area $A_{f,tot}$=n A_f, where n is the number of yarns and A_f is the cross-sectional area of the single yarn.

The displacement transducer can be removed before anticipated failure to avoid damage to the sensor, but load readings shall continue until failure.

The maximum load and corresponding displacements at, or as near as possible to, the moment of rupture shall be recorded, along with the failure mode and location.

B.5 Calculation

Expected tensile stress – strain curve: The recorded data will likely result in a near trilinear response curve (Figure B.5.1) with an initial line for uncracked specimen (Stage A), a secondary line for cracked specimen (Stage C), and possibly a curved transition segment in between (Stage B – crack formation). The expected tensile stress, σ_f, versus tensile strain, ε_f, curve of a specimen is shown in Figure B.5.1. In particular, the ultimate values are:

σ_u = ultimate stress obtained in the test in correspondence with the peak force value [MPa];

ε_u = ultimate strain obtained in the test at the peak force value [%].

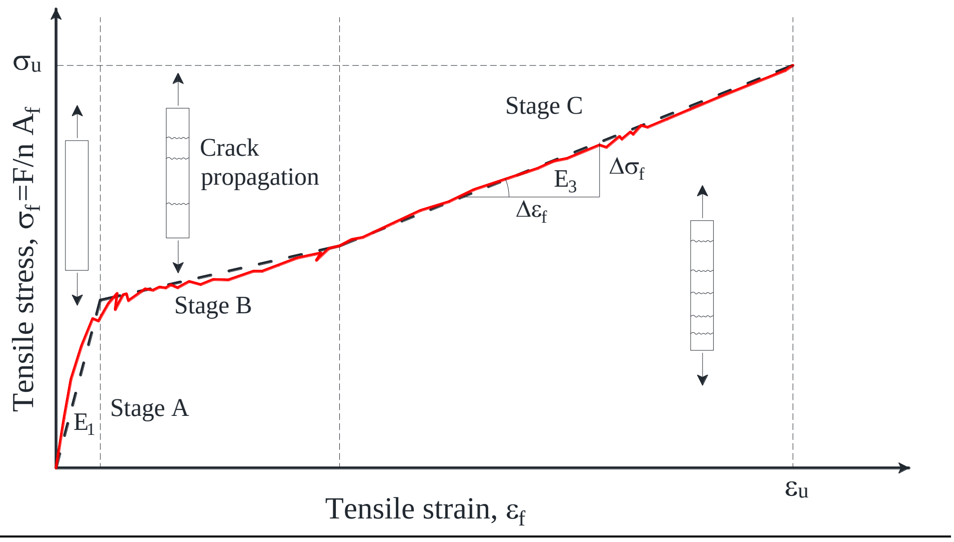


Figure B.5.1: Example of tensile stress-strain curve

Tensile stiffness modulus of un-cracked specimen (Stage A): On the linear segment of the initial line of the stress-strain curve corresponding to un-cracked behaviour of the specimen (stage A) two points connecting the results in a line that closely follows the trend and slope of the response curve at that region shall be selected. The tensile stiffness modulus of the un-cracked specimen E_1 shall be calculated using:

$$E_1 = \Delta\sigma_f / \Delta\varepsilon_f \qquad \text{(B.5.1)}$$

where:

$\Delta\sigma_f$ = difference in tensile stress between two selected points [MPa];

$\Delta\varepsilon_f$ = difference in tensile strain between two selected points [%].

Tensile stiffness modulus of cracked specimen (Stage C): On the linear segment of the stress-strain curve corresponding to cracked behaviour of the specimen two points connecting the results in a line that closely follows the trend and slope of the response curve at that region shall be selected. The tensile stiffness modulus of the cracked specimen E_3 shall be calculated using:

$$E_3 = \Delta\sigma_f / \Delta\varepsilon_f \qquad \text{(B.5.2)}$$

B.6 Parameters to be recorded

At least the following information shall be recorded to the maximum extent applicable:

- Date and location of the test;
- Identification of the material tested including material specification, type, and designation;
- Orientation of the fibre grid;
- Area of grid reinforcement by unit width and nominal cross-sectional area of all specimens;
- Method of preparation of test specimen including labelling system, geometry, sampling method, cutting, tab identification, geometry and adhesive used;
- Description of the test machine;
- Conditioning parameters and results;
- Temperature and humidity during testing;
- Number of specimens tested;
- Speed of testing;
- Type and placement of transducers on the test specimens;
- Stress-strain curve and tabulated results;
- Individual strengths, average, standard deviation, and coefficient of variation (in percent) for the population;
- Individual strains at peak and average, standard deviation, and coefficient of variation (in percent) for population;
- Stress and strain used for modulus calculation;
- Individual moduli of elasticity and average, standard deviation, and coefficient of variation (in percent) for population;
- Failure mode and location of failure for each specimen.

ANNEX C SINGLE-LAP SHEAR TEST

C.1 Summary of Test Method

This Annex describes the apparatus and procedure for evaluating the bond properties of composite systems adhesively applied to a flat concrete or masonry substrate. The direct single-lap shear test shall be conducted using a push-pull configuration, where the substrate prism with square or rectangular cross-section is restrained while the composite strip is pulled until failure.

C.2 Apparatus

Tests shall be conducted using a direct single-lap shear test set-up. The prism shall be restrained against movement by two steel plates placed against the square or rectangular end cross-sections of the prism. The bottom square plate shall be gripped to the testing machine. The top plate shall be a rectangular or C-shaped steel element connected to the bottom one through four steel bars bolted to the two plates. In case of masonry, the top plate shall be positioned at a minimum distance of 40 mm from the edge of the masonry block (Figure C.3.1), to avoid that compression induced by the top plate can influence the stress state in correspondence of the bonded composite system.

The displacement and the applied load shall be recorded continuously during the test.

Slip measurement — Linear variable differential transducers (LVDTs) shall be mounted on the substrate surface close to the top edge of the bonded region to measure the displacement of the strip with respect to the substrate (an example is shown in Figure C.3.1). The LVDTs (named LVDT a and b in Figure C.3.1) react off of a thin aluminium Ω-shaped plate bonded to the bare fibres immediately outside the bonded length.

Rotation measurement (optional) — Two optional LVDTs (named LVDT c and d in Figure C.3.1) may be used to monitor the horizontal displacement of the substrate in the direction perpendicular to the face of the composite strip. The LVDT c and d react off of the face of the substrate block parallel to the one to which the composite is applied. The measurement point shall be approximately at half of the length of the substrate.

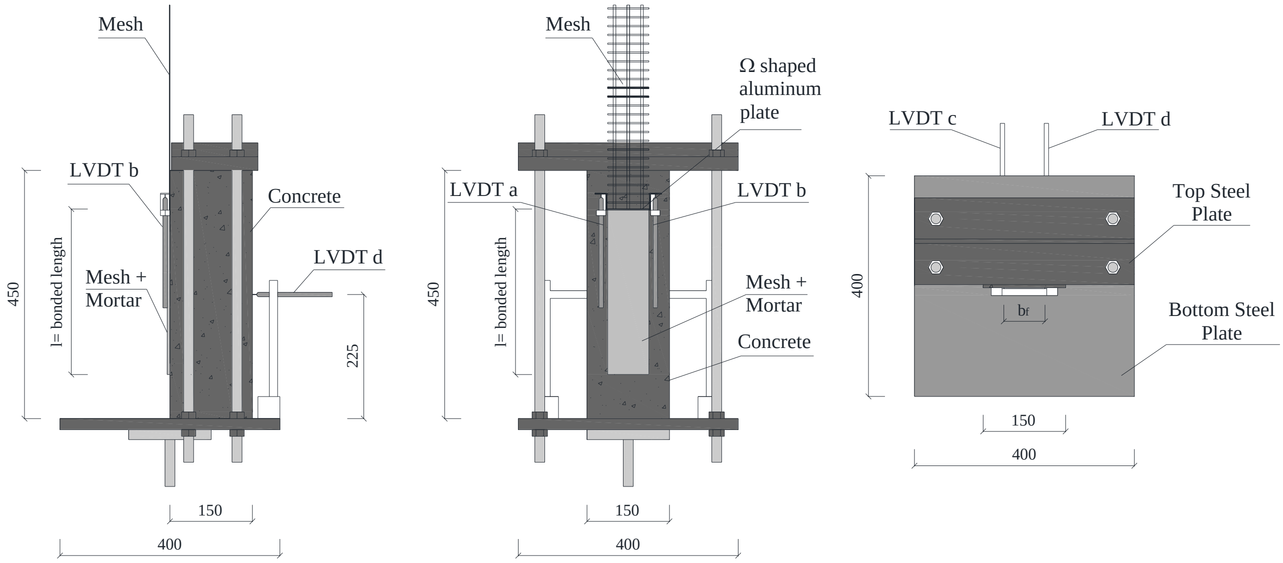
C.3 Test Specimens

Concrete

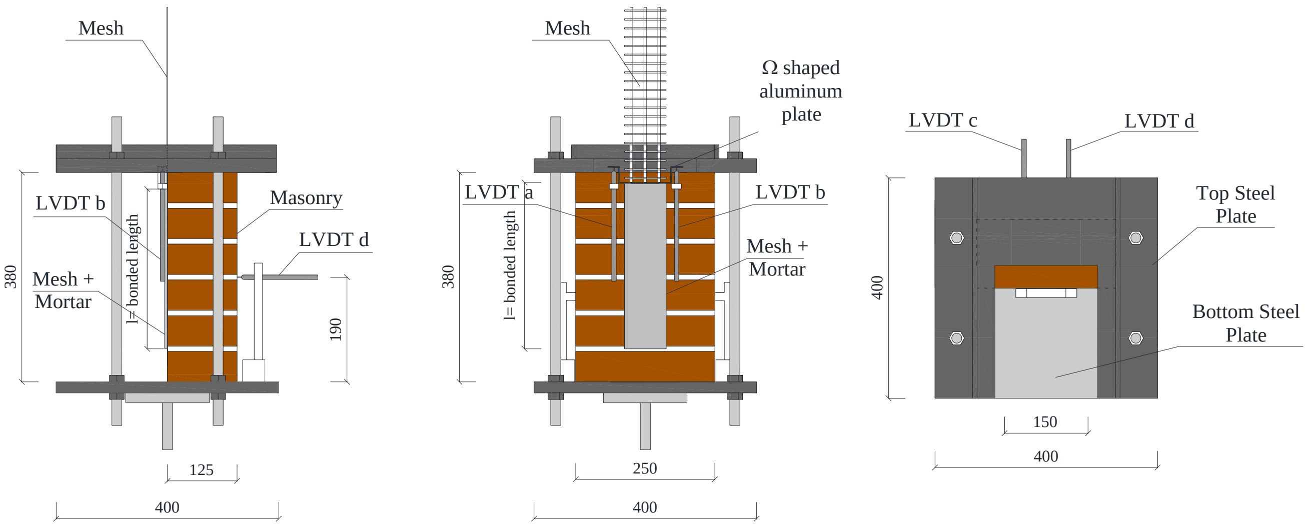
The concrete test specimen shall conform to all requirements of EN 1766, considering an MC (0,40) concrete type. The dimensions of the concrete prism shall be at minimum 150 mm width × 150 mm depth × 450 mm length. Also greater dimensions of the prism can be chosen. The sides of the specimen shall be at right angles with the top and bottom. All surfaces shall be smooth and free of scars, indentations, holes, or inscribed identification marks. The prisms shall be reinforced on one face (neither the casting one nor the end cross-sections shall be used) with bonded reinforcement. Because the formed faces of the concrete prism might have a different amount of aggregates near the surface, the position of the face used to apply the composite with respect to the casting one shall be clearly recorded.

Surface preparation of the specimen face that will receive the composite system shall be in accordance with the MPII. Details of the surface preparation shall be recorded with the test data.

The distance d_f between the beginning of the bonded area and the top edge (at loaded end of the composite strip) of the concrete prism shall be minimum 40 mm to avoid spalling of concrete (Figure C.3.2). Bond breaking is easily accomplished using, for example, masking tape that covers the concrete surface from the top edge to the beginning of the bonded area.



(a)



(b)

Figure C.3.1: **Schematic of Suitable Apparatus for Direct Single-Lap Shear Test. Example for: (a) concrete specimens and (b) masonry specimens (dimensions in mm)**

Masonry

Test shall be performed on masonry made of bricks according to EN 771-1 (clay) or EN 771-6 (natural stone) (see clause 2.2.3 for details). Masonry shall be composed of layers of bricks so that the total length is at least 380 mm. In case of natural stone, the number of stone layers shall be comprised between 3 and 6. The thickness of the mortar shall be 10±2 mm. The width of the face where the reinforcement is applied shall be of at least 125 mm.

Surface preparation of the specimen face that will receive the composite system shall be in accordance with the MPII. Details of the surface preparation shall be recorded with the test data.

The distance d_f between the beginning of the bonded area and the top edge (at loaded end of the composite strip) of the masonry element shall be 20±2 mm (Figure C.3.3). Bond breaking is easily accomplished using, for example, masking tape that covers the masonry surface from the top edge to the beginning of the bonded area.

Composite system (mesh plus mortar)

The system applied to one face of the specimen shall meet the following requirements as shown in Figure C.3.2 and Figure C.3.3:

- The composite system shall be applied in accordance with the MPII. The manufacturer's instructions should be followed as to the elapsed time between system application and testing.
- The width of the applied composite system b_f shall be a multiple of the mesh grid spacing and shall be such to include at least two grid openings (three threads). The composite system shall be centred on the strengthened face of the substrate.
- The bonded length of the applied composite system shall be equal to 300 ± 5 mm. The composite system shall be centred on the strengthened face of the substrate.
- Outside the bonded area, the mesh shall be left bare (without mortar) in the overhang length; two tabs may be bonded to the end of the bare mesh to improve gripping during testing.
- The mesh strip shall be longer than the bonded length *l*. The total length L_f of the composite strip shall be calculated in accordance to Equation (C.3.1):

$$L_f = l + d_f + 300 \text{ mm} \quad \text{(C.3.1)}$$

The overhang length can be reduced if the testing machine does not allow to fit long strips, but shall not be less than 150 mm.

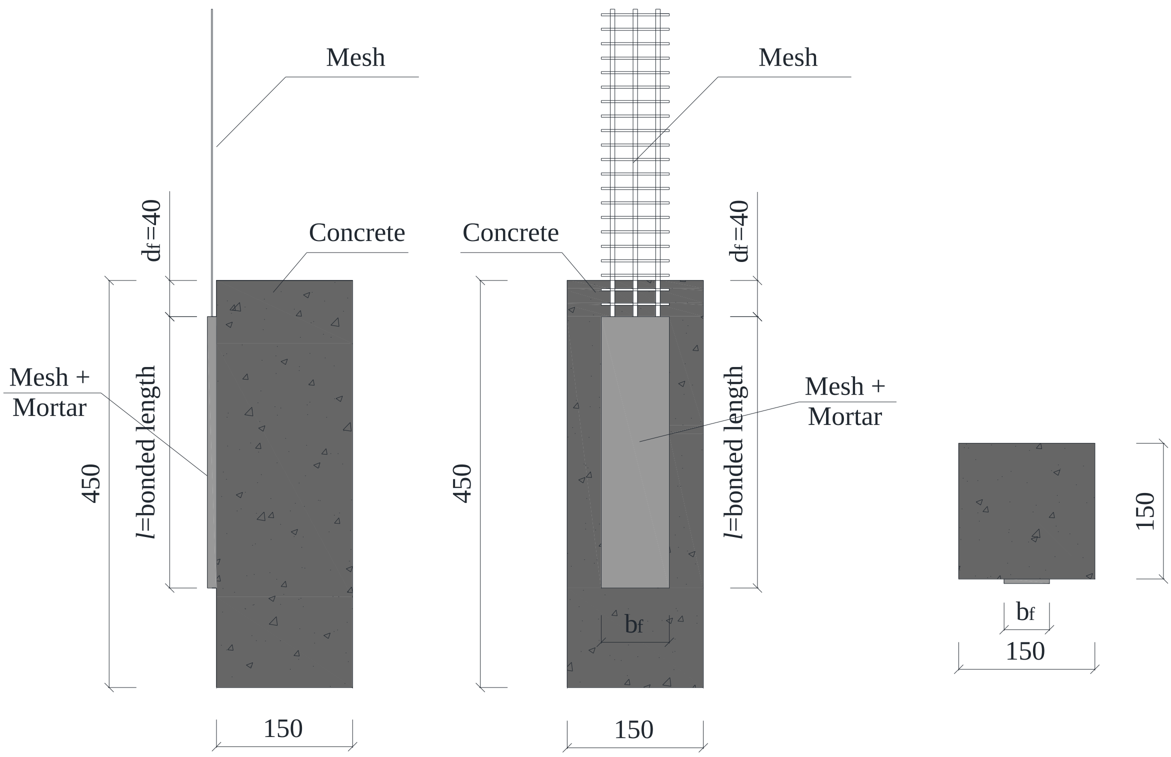


Figure C.3.2: Specimen dimensions (mm) and details of bonded composite system (concrete specimens)

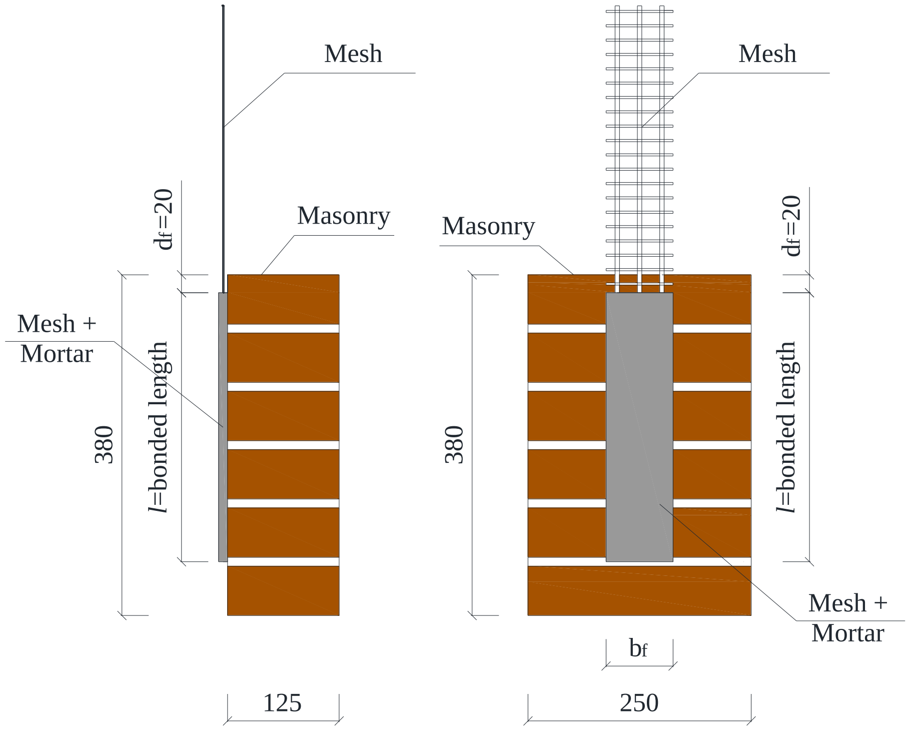


Figure C.3.3: **Specimen dimensions (mm) and details of bonded composite system (masonry specimens)**

C.4 Test Procedure

1. Centre the specimen in order to have the composite strip perfectly aligned with the clamping wedge.
2. Apply an initial pre-compression to the support by tightening the bolts of the four steel bars used to connect the top and bottom plates. The total pre-compression force applied to the four steel bars shall be measured using a torque wrench. The total pre-compression shall be not greater than one fourth of the maximum applied load expected. In addition, the total force applied to the four steel bars divided by the cross-sectional area of the prism shall provide a stress that is lower or equal to one tenth of the compressive strength of substrate.
3. Clamp the loaded end of the strip within the wedges of the testing machine. Slowly adjust the position of the head of the machine so that no force is applied to the strip prior to testing when the strip is firmly clamped.
4. Pull the strip in displacement control, increasing the displacement of the machine stroke continuously and without shock. The displacement shall be increased at a constant rate equal to 0,2 mm/min.
5. Perform the test in stroke until the composite strip completely detaches from the substrate.
6. The expected load response in terms of applied load versus global slip, *g* measured by LVDT a and b of Figure C.3.1, can be represented by the bi-linear response of Figure C.4.1. The maximum force P_{max} corresponds to the maximum applied force. The debonding load P_{deb} shall be determined as the value of load characterised by a substantial variation of the force-displacement curve, thus implying a significant modification of the overall stiffness of the system.
7. The conventional limit stress $\sigma_{lim,conv}$ shall be determined as the ratio between the maximum force P_{max} and the mesh cross-sectional area $A_{f,tot}$.

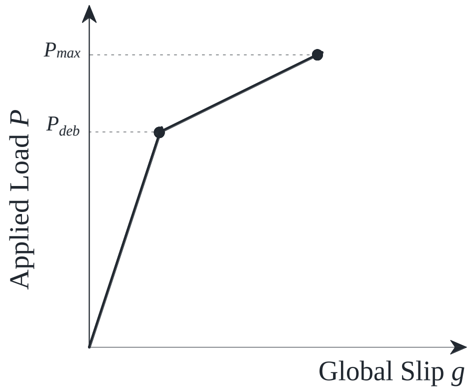


Figure C.4.1: Example of load-displacement curve

C.5 Parameters to be recorded and test results

Record at least the following information to the maximum extent applicable:

Test Parameters

- Date of test, test temperature and relative humidity.
- Length of composite system to the nearest 1 mm for each specimen.
- Width of composite system to the nearest 1 mm for each specimen.
- Distance between the beginning of the bonded area and edge of substrate to the nearest 1 mm for each specimen.

Test Results —Provide results for each test and average and statistics for specimen population.

- Maximum applied force P_{max} in N for each specimen.
- Maximum measured displacement in mm for each specimen.
- Global slip measurement corresponding to the maximum applied force — the average measurement obtained from LVDT a and b, named global slip, *g*, shall be calculated for each specimen.
- Out of plane displacement corresponding to the maximum applied force measurement — If LVDT c and d are used, the obtained values shall be recorded for each specimen.
- The load-global slip response shall be recorded.
- Failure mode for each specimen.
- Bond capacity P_{deb} and coefficient of variation
- Corrections made to data including test values omitted from calculated average and basis for omitting test values (such as failure mode). Note any other deviations from the procedure.

ANNEX D TEST METHOD FOR PULL-OUT OF CONNECTORS FROM REFERENCE SUBSTRATES

D.1 General requirements

Test specimens shall 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 shall be done by injection of lime-based injection mortar.

D.2 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 in the MPII, in the centre of the cast face of the block.
Immediately after the drilling operation the hole shall be cleaned in accordance with the MPII and the test block shall then be placed upright and the anchoring operation shall be undertaken.

Masonry

Masonry bricks and mortar shall comply with the indications given in clause 2.2.3.

A one-brick wall specimen (a masonry wall specimen with thickness equal to the length of the single masonry block) shall be built to be used for the pull-out tests, with an average thickness of the mortar layer between 10 mm and 15 mm. The minimum thickness of the specimen shall be at least 250 mm and in any case such that the anchoring length of the connector does not exceed 2/3 of the 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 shall be avoided. Therefore, the minimum dimensions of the specimen shall be such as to allow the positioning of the contrast structure used for the test externally to the area potentially affected by a failure by conical expulsion of the substrate, assumed equal to $2L_{anc} + D_0$, being L_{anc} the anchorage length used and D_0 the diameter of the hole. For anchoring lengths around 100 mm, a specimen measuring 400 mm x 400 mm may be sufficient. For greater operational convenience, it might be advisable to prepare larger masonry specimens (for example 1,20 m x 1,20 m) which are used to carry out more pull-out tests; in this case, it is necessary to guarantee the absence of interference between the different extraction points, on the base of what is indicated in the paragraph above.

The masonry specimens 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, shall be executed with the use of a rotating tool. The hole shall be made at the mortar joints (T-joints). In addition, the manufacturer may request other configurations. The tested configurations shall be reported in the ETA.

Open-end connector

Specimens shall be prepared starting from complete connectors in such a way that a single rectilinear element is obtained, i.e., the total impregnation of the element over a suitable length may be necessary.

The anchoring length of the connectors in the substrate shall be that indicated by the manufacturer for the specific connection system and for the specific substrate in the MPII. If not otherwise specified, a value of 100 mm shall be used. The overall length of the connector shall be such as to guarantee the specified anchoring length and a free portion, protruding from the substrate specimen, which allows the assembly of the test equipment and the appropriate grip of the connector itself, as indicated in Figure D.3.1.

Application of the connector

Once the debris inside the hole of the specific substrate has been eliminated, by means of compressed air, the connector shall be inserted inside the hole, with the anchoring methods indicated for the specific connection system in the MPII.

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

D.3 Apparatus

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

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

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

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

To detect the possible sliding of the connector 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.

> *Note: Accuracy=± (the sum of the amount of the error plus the amount of the expanded measurement uncertainty). For values of both error and expanded measurement uncertainty see last calibration certificate of the instrument.*

A possible test specimen scheme is shown in Figure D.3.1.

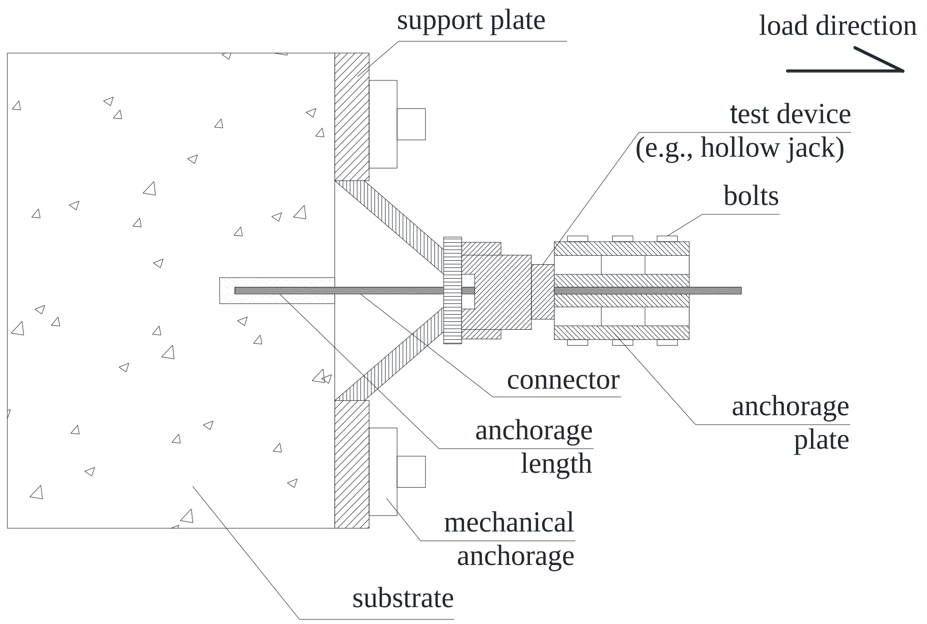


Figure D.3.1: Test setup for pull-out testing

D.4 Test procedure

The test shall be performed in load control with a constant 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 shall be recorded continuously, with a frequency of 3 - 5 Hz. 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 shall be interrupted and the pull-out load shall 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 and is not due to sagging or sliding between the test device and the connector. In this case the result shall be discarded and the test shall be repeated.

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

D.5 Parameters to be recorded

At least the following parameters shall be recorded:

a) the description of the substrate, with all relevant information;
b) the dates of preparation of the substrate, the installation of the connector and the execution of the pull-out test;
c) the installation mode and the position of the connector;
d) the anchorage length;
e) the pull-out load;
f) the load rate used or, alternatively, the time necessary to reach the pull-out load;
g) the description of the type of failure.

ANNEX E TENSILE TESTING OF DRY MESH

E.1 Summary of Test Method

The tensile test on dry mesh specimens is carried out to define the stiffness and strength of the mesh in order to determine the conventional limit properties of the composite system. A thin flat strip of dry mesh having a near-constant rectangular cross section shall be mounted in the grips of a mechanical testing machine and loaded with monotonically increasing load in tension while recording load and movement. The ultimate strength of the mesh shall be determined from a maximum load carried before failure. The specimen strain or elongation shall be monitored with strain gauges to determine the nominal stress-strain response of the material, from which the tensile modulus of elasticity can be also derived.

E.2 Apparatus

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

The testing machine shall be equipped with a gripping system which allows to lock the ends of the specimen by applying them a sufficient lateral pressure to prevent the slippage of the specimen. Bending stresses in the specimen shall be avoided (e.g., by using rotationally self-aligning grips). Strain/elongation measurements shall be made with an extensometer applied to the mesh.

E.3 Test specimens

The mesh used to make the specimens shall be identical to that used for the composite system. If the mesh is supplied with an organic coating, this shall also be present in the tested specimens. Conversely, if the reinforcement mesh is not provided of any coating, the mesh shall not be impregnated with any substance.

The test shall be carried out in displacement control on a mesh specimen comprising a number of threads (bundle of filaments) equal to that of the specimens used for tensile testing of composite system (Figure B.3.1).

The width of the specimen shall not be greater than that of the tensile machine grips. Otherwise, uniform distribution of stresses in the specimen would not be assured.

The minimum length of the specimen, excluding the portions required for grips, shall be at least 4 times the width of the specimen.

Specimens shall be equipped with tabs in the gripping area to ensure homogeneous distribution of stresses. The tabs can be metallic (aluminium or steel), made of fibre reinforced polymers (e.g., GFRP) or of thick cardboard.

Tabs (two at each end, one at each face) shall have the same width as the specimen and shall be glued to it by using an adequate adhesive. The tab length shall be calculated based on the maximum expected tensile load and on the strength of the adhesive between the tab and the specimen. A minimum tab length of 50 mm is recommended. The thickness of the tabs shall be adequate to distribute uniformly the gripping force to the overall width of the specimens. A minimum thickness of 2 mm is recommended.

To avoid dispersion of results, care shall be taken to prepare the specimens, to grip them and to align the specimen in the test machine. Non-alignment of fibres causes a non-homogeneous distribution of stresses among the threads that constitute the mesh specimen. In addition, an inappropriate gripping system may cause failure of the test pieces at the ends or a partial break of filaments and, consequently, a relevant dispersion of the results.

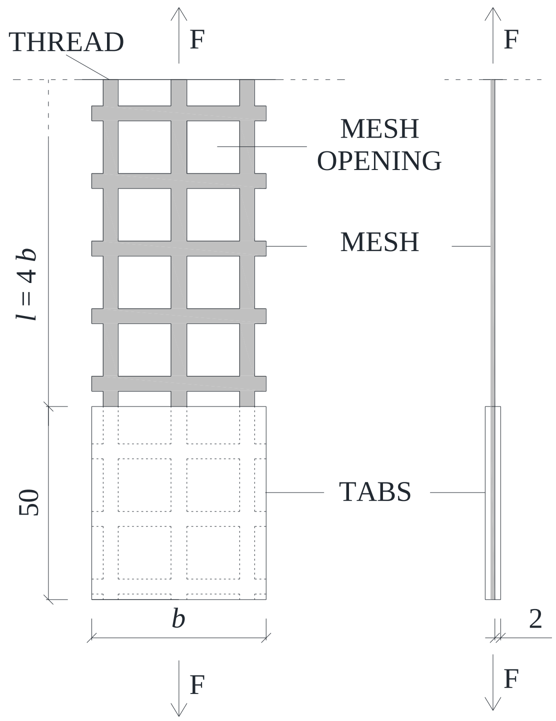


Figure E.3.1: Geometry of mesh specimens and tabs (minimum dimensions, in mm)

E.3.1 Determination of the mesh cross-sectional area

The mesh cross sectional area $A_{f,tot}$ (area of fibres, without coating) shall be determined by multiplying the area of the single yarn A_f by the number of yarns in the width of the specimen, n. The area of a single yarn (A_f), expressed in mm², is calculated as:

$$A_f = \frac{T_x}{\rho \cdot 1000} \qquad \text{(E.3.1.1)}$$

where

T_x is the yarn linear density [tex]

ρ is the fibre density [g/cm³]

E.4 Test procedure

The specimen shall be placed in the grips of the testing machine, paying particular attention to its alignment with the axis of the machine. During the test preparation phase, an axial force not greater than 5% of the anticipated failure load can be applied to the specimen in order to align the specimen.

The load shall be applied under displacement control, with a constant rate not exceeding 0,5 mm/min.

A suitable instrument for strain measurement (extensometer) shall be attached to the specimen, with a minimum gage length of 25 mm.

During the test, the load value, the displacement of the moving end and the deformation of the extensometer shall be recorded continuously.

The stress value is defined as the ratio of the load and the mesh cross-sectional area $A_{f,tot}$, calculated by multiplying the area of the single yarn A_f for the number of yarns n ($A_{f,tot}$=n A_f) in the width of the specimen (see eq. E.3.1.1).

For each test, the value of the ultimate stress $\sigma_{u,f} = P_u / n A_f$ (where n indicates the number of yarns) and the elastic modulus E_f shall be determined. The latter shall be determined by referring to the stresses and deformations measured in the range $P_u/10$ and $P_u/2$.

The reference values to be used to define the stress-strain curve are the arithmetic mean of the E_f values obtained from all the tests and the characteristic value of the ultimate stress $\sigma_{u,f}$.

The conventional limit strain $\varepsilon_{lim,conv}$ is defined as the abscissa of the point that, on the average stress-strain curve, has $\sigma_{lim,conv}$ (Annex C) as ordinate (Figure E.4.1).

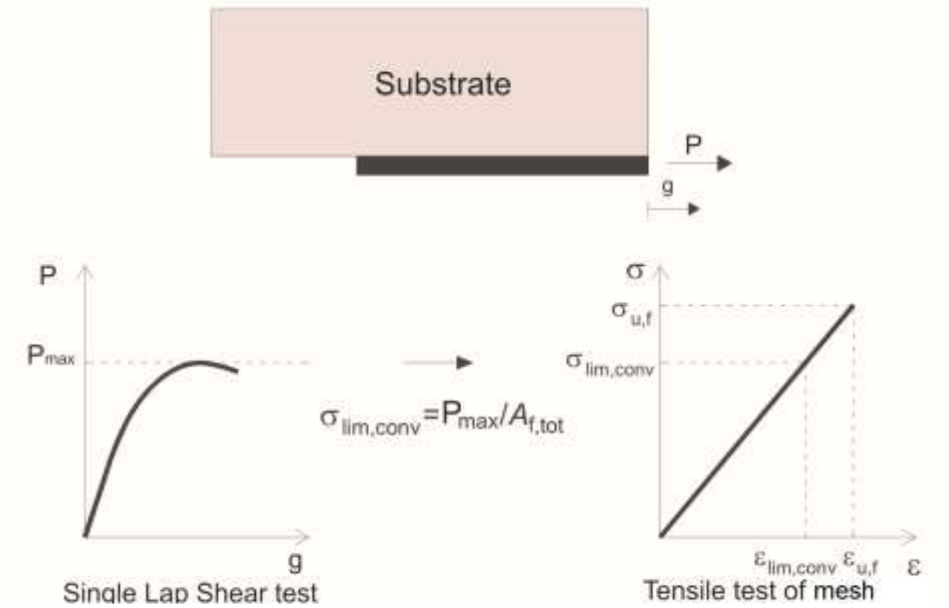


Figure E.4.1: Evaluation of the conventional limit strain $\varepsilon_{lim,conv}$

E.5 Parameters to be recorded

The following information shall be at least recorded:

- Date and location of the test,
- Identification of the materials tested including material specification, type and designation,
- Size of the specimen,
- Description of the specimen preparation,
- Orientation of specimens with respect to the two directions of the mesh,
- Conditioning parameters,
- Environmental conditions of the test (temperature and relative humidity),
- Number of specimens,
- Specimen alignment and gripping system used,
- Test speed,
- Type and location of transducers used to measure deformation,
- Results of the test,
- Stress-strain curve and tabulated results.

ANNEX F WATER CONDITIONING

F.1 Summary of Test Method

Specimens shall be placed in an enclosed chamber containing a heated, saturated mixture of air and water vapour. The temperature of the chamber shall be maintained at 38±2 °C. At relative humidity (RH) higher than 90%, a very small temperature difference between the specimen and the surrounding vapour causes the formation of condensation on the specimens. The exposure condition shall be varied by selecting the duration of the test (1000 and 3000 h). Any effects such as erosion, cracking, crazing, checking, and chalking shall be observed and recorded.

F.2 Apparatus

Test chamber - constructed of corrosion-resistant materials with supports for the test specimens.

Source of heated water vapour can be created by one of the following methods:

- *Heated Water Tank*, within the test chamber, a water supply, and a water level control.
- *Water vapour (steam) generator*, located outside the test chamber, a water supply, and a means of introducing the vapour to the test chamber.

Thermostatic control, for the water heater with the sensor located adjacent to the specimen holders, or a means of controlling volume of steam.

Thermometer, with sensor located adjacent to the specimen holders.

F.3 Test Specimens

Specimens shall be those foreseen in clauses 2.2.7.1 and 2.2.7.2.

F.4 Test Procedure

1. Generate the saturated water vapour.
2. Adjust the temperature of the saturated air and water vapour mixture so that the air temperature next to the test specimens is 38±2°C.
3. The temperature of the water vapour shall be the same or higher than the air temperature next to the specimens. This is a requirement in order for this procedure to work correctly. Indeed, water vapour temperatures that are greater than 38°C tend to make condensation more uniform over the test specimens.
4. Support flat specimens approximately 15° from the vertical with the front side facing up. Slotted non-metallic supports are suitable for flat specimens. Position 3-dimensional specimens on a support so that the primary surface is as close to end-use position as possible. Material used for supports shall be of sufficient stiffness so that they do not distort or sag during prolonged use. The minimum distance between adjacent specimens or between specimens and the walls of the chamber shall be at least 30 mm. Arrange specimens so that condensate from one specimen cannot drip on other specimens.
5. Droplets of condensation shall appear evenly on the specimen at all times if the chamber is operating properly. Short interruptions to inspect or remove specimens are permitted, but such interruptions should occur no more than once each day.
6. To control for variability within the apparatus, reposition the specimens on a regular basis so that all specimens spend equivalent amounts of time in the various areas of the apparatus (front, back, left, right, and centre).
7. Conclude the test after the specified period of time (1000 or 3000 h).
8. Wipe the test specimens dry. Record any changes in colour, blistering, etc. Evaluate specimens no less than 5 min and no more than 10 min after removal from test, as the effects from water exposure can change within a short time. Remove only as many specimens as can be rated within the specified time.
9. Rate the specimens again after they have been removed from the test for a recovery period long enough that moisture absorbed within the specimens dries out and the specimens reach moisture

equilibrium with room air. A recovery period from 12 to 24 h is generally sufficient. The post-recovery rating allows evaluation of the permanent effects of the exposure as distinct from the transient effects.

F.5 Parameters to be recorded

Record at least the following information:

- Specimen identification,
- Results of the assessment(s),
- Hours of test duration,
- Test temperature,
- Special conditions of test or any deviations in test procedure.