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European Technical Assessment ETA 23/0854 of 10/11/2023

General Part

Technical Assessment Body issuing the ETA:	**TECNALIA RESEARCH & INNOVATION**
Trade name of the construction product	**RINFOR SYSTEM 5 – CRM**
Product family to which the construction product belongs	PAC 34: BUILDING KITS, UNITS, AND PREFABRICATED ELEMENTS.
Manufacturer	**AZICHEM S.r.l.** Via G. Gentile 16/A 46044 Goito (MN), Italy www.azichem.com
Manufacturing plants	Factory 1
This European Technical Assessment contains	27 pages including three Annexes which form an integral part of this assessment.
This European Technical Assessment is issued in accordance with regulation (EU) No 305/2011, on the basis of	EAD 340392-00-0104 CRM (Composite Reinforced Mortar) systems for strengthening concrete and masonry structures.

Translations of this European Technical Assessment in other languages shall fully correspond to the original issued document and should be identified as such.

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Specific parts

1. Technical description of the product

RINFOR SYSTEM 5 – CRM is a CRM (Composite Reinforced Mortar) system composed of different components, namely:

- GFRP (Fibre Reinforced Polymer) mesh (preformed)
- GFRP mesh corner elements (preformed)
- GFRP connectors (preformed).

This ETA refers to the GFRP meshes, GFRP corner elements and GFRP connectors used as single products, as a part of CRM systems for strengthening concrete and masonry structures.

This ETA refers to the following components, whose geometrical and physical properties are reported in Annex A:

- Three types of meshes:
  - ARMAGLASS STRUCTURA 33
  - ARMAGLASS STRUCTURA 66
  - ARMAGLASS STRUCTURA 99

- Three types of mesh corner elements:
  - ARMAGLASS CORNER 33
  - ARMAGLASS CORNER 66
  - ARMAGLASS CORNER 99

- Two types of “L shaped” preformed connectors:
  - ARMAGLASS CONNECTOR L 6
  - ARMAGLASS CONNECTOR L 8

- Two types of straight preformed connectors:
  - ARMAGLASS BAR CONNECTOR 6
  - ARMAGLASS BAR CONNECTOR 8

The GFRP meshes and the corner elements are constructed utilising bars made with a fiberglass core and coated with epoxy resin. The bars are fixed in the nodes with a stitching thread, with cells of square dimensions.

Meshes are named “ARMAGLASS STRUCTURA” followed by numbers which identify the mesh (for example 33 which identify a 33x33 mm mesh).

The corner elements are named “ARMAGLASS CORNER” followed by numbers that identify the mesh (for example 33 which identify a 33x33 mm mesh).

The connectors are preformed in an L shape or straight shape with related round dowel. The connectors are made with fiberglass impregnated with a thermosetting epoxy resin. The number following the name identifies the thickness of the wire.

2. Specification of the intended use in accordance with European Assessment Document EAD 340392-00-0104 (EAD hereinafter)

The GFRP meshes, the corner elements and the connectors (of the CRM system) have been designed to be used coupled with mortar, in highly specialized applications for the structural reinforcement of existing and new masonry and concrete elements. Due to the special features of the system, its effectiveness is substantial above all for elements in which two dimensions are preponderant with respect to the other (e.g., height and length with respect to thickness) such as walls, vaults, etc. The application of this composite system is needed to increase the load-bearing capacity, increase the resistance and ductility of these elements. The reinforcement of these structural elements is effective both in the static and dynamic fields. These interventions can also be performed in structures present in environments subject to aggressive climatic conditions.

Concerning product packaging, transport and storage it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport and storage, as he considers necessary in order to reach the declared performances.

The information about installation is provided with the technical documentation from the manufacturer and it is assumed that the product will be installed according to it or (in absence of such instructions) according to the usual practice of the building professionals.

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

The performances assessed in this European Technical Assessment, according to the applicable EAD, are based on an assumed intended working life of at least 50 years, provided that the conditions for the installation, packaging, transport, storage, installation as well as appropriate use, maintenance and repair are met. The indications given on the working life cannot be interpreted as a guarantee given by the manufacturer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

3. Performance of the product and references to the methods used for its assessment

The tests for performance assessment were carried out in compliance with EAD 340392-00-0104 according to the test methods reported herein, as well for what concerns sampling, conditioning and testing provisions.

The numbering (#) in the following tables corresponds to the numbering of Table 2.1, Table 2.2, Table 2.3 and Table 2.4 of EAD 340392-00-0104.

3.1 Mechanical resistance and stability (BWR 1)

3.1.1. GFRP mesh (Table 2.2 of EAD)

#	Essential characteristic	Performance
1	Tensile strength (longitudinal and orthogonal direction)	Annex C, Section C1, Table 5 and Table 6
2	Ultimate strain	
3	Young's Modulus	
4	Shear resistance of the mesh junction (in the two orthogonal directions)	Annex C, Section C1, Table 7
5	Freezing and thawing resistance	Annex C, Section C2, Table 8 and Table 9
6	Water resistance	Annex C, Section C2, Table 10 and Table 11
7	Saltwater resistance	Annex C, Section C2, Table 12 and Table 13
8	Alkali resistance	Annex C, Section C2, Table 14 and Table 15
9	Glass Transition Temperature	Annex C, Section C3, Table 16

3.1.2. GFRP mesh corner element (Table 2.3 of EAD)

#[(a)]	Essential characteristic	Performance
1	Tensile strength	Annex C, Section C4, Table 17
2	Freezing and thawing resistance	Annex C, Section C2, Table 8 and Table 9
3	Water resistance	Annex C, Section C2, Table 10 and Table 11
4	Saltwater resistance	Annex C, Section C2, Table 12 and Table 13
5	Alkali resistance	Annex C, Section C2, Table 14 and Table 15
6	Glass Transition Temperature	Annex C, Section C3, Table 16

[(a)] *#2, #3, #4, #5 and #6: tests covered with those carried out on the mesh.*

3.1.3. GFRP connector (Table 2.4 of EAD)

#	Essential characteristic	Performance
1	Tensile strength	Annex C, Section C5, Table 18
2	Ultimate strain	
3	Young's Modulus	
4	Pull-out from reference substrates	Annex C, Section C7, Table 21 and Table 22
5	Lap-tensile strength	Annex C, Section C5, Table 19
6	Freezing and thawing resistance	Annex C, Section C8, Table 23 and Table 24
7	Water resistance	Annex C, Section C8, Table 25 and Table 26
8	Saltwater resistance	Annex C, Section C8, Table 27 and Table 28
9	Alkali resistance	Annex C, Section C8, Table 29 and Table 30
10	Glass Transition Temperature	Annex C, Section C9, Table 31

3.2 Safety in case of fire (BWR2)

3.1.1. CRM kit (Table 2.1 of EAD)

#	Essential characteristic	Performance
21	Reaction to fire	No performance assessed

4. Assessment and verification of constancy of performance (AVCP) system applied, with reference to its legal base

In accordance with the European Assessment Document EAD 340392-00-0104, the applicable European legal act is: Decision 1999/469/EC.

The AVCP system to be applied is: 2+.

5. Technical details necessary for the implementation of the AVCP system, as provided for in EAD

Technical details necessary for the implementation of the Assessment and Verification of Constancy of Performance (AVCP) system are laid down in the control plan deposited at Tecnalia Research & Innovation.

The Control Plan is a confidential part of the ETA and is only handed over to the notified body involved in the assessment and verification of constancy of performance.

Issued in Azpeitia, on 10/11/2023

Miguel Mateos
Innovation and Conformity Assessment Point
Tecnalia Research & Innovation

ANNEX A: MATERIAL PROPERTIES

Table 1: GFRP MESH PROPERTIES

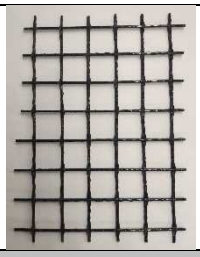
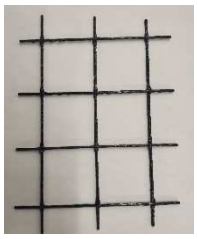
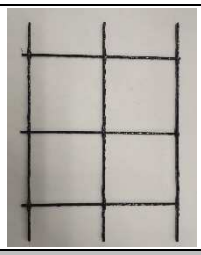
Mesh reference		**ARMAGLASS STRUCTURA 33**		**ARMAGLASS STRUCTURA 66**		**ARMAGLASS STRUCTURA 99**	
Appearance							
Geometrical and physical characteristics							
	Unit	Weft	Warp	Weft	Warp	Weft	Warp
Nominal bar sizes (diameter)	mm	3	3	3	3	3	3
Nominal bar cross sectional area	mm^2	7.07	7.07	7.07	7.07	7.07	7.07
Nominal area of fibres	mm^2	4.5	4.5	4.5	4.5	4.5	4.5
Mesh size	mm	33*33		66*66		99*99	
Bars/meter for each side	n	30	30	15	15	10	10
Weight per surface unit	g/m^2	830		450		310	
Fibre content by Weight (mean value, comprehensive of weft and wrap threads)	%	75 weft 75 warp		75 weft 75 warp		75 weft 75 warp	
Colour	-	Black		Black		Black	
Packaging	-	Roll height from 105 cm to 240 cm Roll length from 10 to 100 m Sheet width from 80 cm to 240 cm Sheet length from 200 to 600 cm					
Chemical and physical characteristics							
Fibre properties							
Fibre type	-	Textile glass fibre (continuous)					
Fibre density	g/cm^3	2.62		2.62		2.62	
Yarn linear density	tex	9600	9600	9600	9600	9600	9600
Resin properties							
Resin type	-	Thermosetting epoxy resin					
Resin density (hardened, polymerized)	g/cm^3	1.2		1.2		1.2	
Resin glass transition temperature	º C	104		104		104	

Table 2: GFRP MESH CORNER ELEMENT PROPERTIES

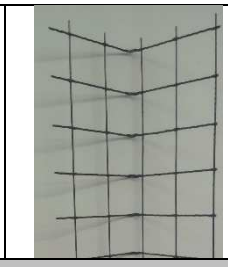
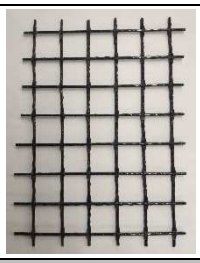
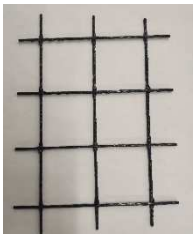
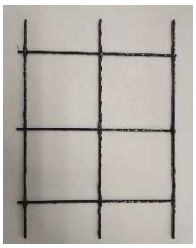
Corner reference		**ARMAGLASS CORNER 33**		**ARMAGLASS CORNER 66**		**ARMAGLASS CORNER 99**	
Appearance							
Geometrical and physical characteristics							
	Unit	Weft	Warp	Weft	Warp	Weft	Warp
Total height of the corner element	mm	1050		1050		1050	
Side length	mm	250		250		250	
Nominal bar sizes (diameter)	mm	3	3	3	3	3	3
Nominal bar cross sectional area	mm^2	7.07		7.07		7.07	
Nominal area of fibres	mm^2	4.5	4.5	4.5	4.5	4.5	4.5
Mesh size	mm	33*33		66*66		99*99	
Bars/meter for each side	n	30	30	15	15	10	10
Curvature radius	mm	10		10		10	
Weight	g/m	436		218		155	
Fibre content by Weight (*mean value, comprehensive of weft and wrap threads*)	%	75 weft 75 warp		75 weft 75 warp		75 weft 75 warp	
Colour	-	Black		Black		Black	
Packaging	-	40 pcs per box					
Chemical and physical characteristics							
Fibre properties							
Fibre type	-	Textile glass fibre (continuous)					
Fibre density	g/cm^3	2.62		2.62		2.62	
Yarn linear density	tex	9600	9600	9600	9600	9600	9600
Resin properties							
Resin type	-	Thermosetting epoxy resin					
Resin density (hardened, polymerized)	g/cm^3	1.2		1.2		1.2	
Resin glass transition temperature	º C	104		104		104	

Table 3: GFRP "L" CONNECTOR PROPERTIES

Connector reference		ARMAGLAS CONNECTOR L 6	ARMAGLAS CONNECTOR L 8
Appearance			
Geometrical and physical characteristics			
	Unit	Value	Value
Long side length	mm	150 - 1000	150 - 1000
Short side length	mm	100	100
Nominal diameter	mm	6	8
Nominal cross sectional area	mm^2	28.26	50.24
Weight	g/m	54	92
Fibre content by Weight (*mean value*)	%	75	75
Colour	-	Black	Black
Packaging	-	Box of 100 connectors	
Chemical and physical characteristics			
Fibre properties			
Fibre type	-	Textile glass fibre (continuous)	
Fibre density	g/cm^3	2.62	2.62
Yarn linear density	tex	45600	74400
Resin properties			
Resin type	-	Thermosetting epoxy resin	
Resin density (hardened, polymerized)	g/cm^3	1.2	1.2
Resin glass transition temperature	º C	103	103

Table 4: GFRP "STRAIGHT" CONNECTOR PROPERTIES

Connector reference		ARMAGLASS BAR CONNECTOR 6	ARMAGLASS BAR CONNECTOR 8
Appearance			
Geometrical and physical characteristics			
	Unit	Value	Value
Long side length	mm	150 - 3000	150 - 3000
Nominal diameter	mm	6	8
Nominal cross sectional area	mm^2	28.26	50.24
Weight	g/m	54	92
Fibre content by Weight (*mean value*)	%	75	75
Colour	-	Black	Black
Packaging	-	Box of 100 connectors	
Chemical and physical characteristics			
Fibre properties			
Fibre type	-	Textile glass fibre (continuous)	
Fibre density	g/cm^3	2.62	2.62
Yarn linear density	tex	45600	74400
Resin properties			
Resin type	-	Thermosetting epoxy resin	
Resin density (hardened, polymerized)	g/cm^3	1.2	1.2
Resin glass transition temperature	º C	103	103

ANNEX B: SPECIFICATION OF INTENDED USE

B.1. STORAGE CONDITIONS

All materials must be stored in their original packaging in dry environments, at temperatures between +5°C and +35°C, taking care not to damage them during handling. The materials must be protected from direct sunlight and the action of atmospheric agents.

B.2. INSTALLATION CONDITIONS

Temperature range of use: between +5°C and +35°C.

B.3. INSTALLATION INSTRUCTIONS

1. Remove the existing plaster and all the degraded parts, saturate the support with low pressure water, apply if necessary a scratch coat of mortar.

2. Position the GFRP mesh on the surface at half the expected thickness of the intervention using appropriate spacers if necessary. Overlap the mesh bands for at least 15 cm in all corner areas apply GFRP corner.

3. Drill the holes where the connectors will be inserted.

4. Clean the hole and inject with vinylester-based resin to anchor the connector.

5. Install the GRP straight connectors and GRP L-connectors as connecting elements of the reinforcement system.

5.1. “L” connectors: Before inserting the connector in the hole, place a GFRP distribution gusset which will be blocked against the mesh during the grouting phase of the same.

5.2. “Straight” connectors (with round dowel): The round dowel can be glued with epoxy resin before or after inserting the straight connector.

6. Wait for the resin used to grout the connectors to harden and apply one or more coats (depending on the required reinforcement thickness and the mortar used) of the mortar on the surface.

ANNEX C: MECHANICAL PROPERTIES

C1: GFRP MESH - MECHANICAL PROPERTIES

Table 5: Mechanical properties of GFRP mesh in warp direction

Product	Tensile Strength $\sigma_{u,m}$ (MPa)		Tensile Strain $\varepsilon_{u,m}$ (%)		Modulus of elasticity E_m (GPa)	
	Average	Characteristic value	Average	Characteristic value	Average	Characteristic value
33x33	859	728	2.14	1.85	40.61	37.69
66x66	881	712	2.29	1.74	42.07	40.32
99x99	833	730	2.25	1.95	40.03	38.03

Table 6: Mechanical properties of GFRP mesh in weft direction

Product	Tensile Strength $\sigma_{u,m}$ (MPa)		Tensile Strain $\varepsilon_{u,m}$ (%)		Modulus of elasticity E_m (GPa)	
	Average	Characteristic value	Average	Characteristic value	Average	Characteristic value
33x33	915	771	2.28	1.70	42.01	40.25
66x66	964	805	2.48	1.95	42.24	40.89
99x99	903	796	2.31	1.96	39.45	36.31

Table 7: Shear resistance of the mesh junction

	Shear resistance F_{junc} (kN)			
	Warp		Weft	
Product	Average	Characteristic value	Average	Characteristic value
33x33	0.669	0.383	0.618	0.381
66x66	0.663	0.362	0.707	0.464
99x99	0.731	0.511	0.617	0.381

C2: GFRP MESH - ENVIRONMENTAL DURABILITY TEST

Freeze-thaw exposure conditions:
All samples were conditioned in a humidity chamber for a week, at a relative humidity >90% and at a temperature of 38±2°C; they were then subjected to 20 freeze-thaw cycles. Each cycle consisted of at least 4 hours at -18±1 °C, followed by 12 hours in a humidity chamber (>90% relative humidity, 38±2°C).

Table 8: Resistance of GFRP mesh specimens after freeze-thaw exposure

Product	Direction	Tensile Strength $\sigma_{u,FT}$ (MPa)	Tensile Stress $\varepsilon_{u,FT}$ (%)	Modulus of elasticity E_{FT} (GPa)
		Average	Average	Average
66x66	WARP	833	2.09	41.35
	WEFT	948	2.44	41.30

No surface changes were evidenced.

Table 9: Freezing and thawing resistance – Retained tensile properties

Property	Product [1]	WARP	WEFT
		Retained	Retained
Tensile Strength	**66x66** 33x33 99x99	94.6%	98.3%
Modulus of elasticity	**66x66** 33x33 99x99	98.3%	97.8%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other meshes.

Water exposure conditions:
All samples were conditioned according to Section 2.2.2.4 of EAD 340210-00-0104 for 1000 and 3000 hours at a temperature of 38±2°C and relative humidity > 90%.

Table 10: Resistance of GFRP mesh specimens after water exposure

Product	Direction	Exposure time	Tensile Strength $\sigma_{u,w}$ (MPa)	Tensile Stress $\varepsilon_{u,w}$ (%)	Modulus of elasticity E_w (GPa)
			Average	Average	Average
66x66	WARP	1000h	839	2.15	41.45
		3000h	846	2.28	41.38
	WEFT	1000h	881	2.39	41.93
		3000h	890	2.55	39.80

No surface changes were evidenced.

Table 11: Water resistance – Retained tensile properties

Property	Product [1]	Exposure time	WARP	WEFT
			Retained	Retained
Tensile Strength	**66x66** 33x33 99x99	1000h	95.2%	91.4%
		3000h	96.1%	92.3%
Modulus of elasticity	**66x66** 33x33 99x99	1000h	98.5%	99.3%
		3000h	98.4%	94.2%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other meshes.

Saltwater exposure conditions:
All samples were conditioned by immerging specimens in saltwater (solution of 245 g NaCl and 40.94 g Na_2SO_4 for 10 l of distilled water) for 1000 and 3000 hours at a temperature of 23±2°C.

Table 12: Resistance of GFRP mesh specimens after saltwater exposure

Product	Direction	Exposure time	Tensile Strength $\sigma_{u,sw}$ (MPa)	Tensile Stress $\varepsilon_{u,sw}$ (%)	Modulus of elasticity E_{sw} (GPa)
			Average	Average	Average
66x66	WARP	1000h	901	2.27	41.09
		3000h	873	2.21	41.06
	WEFT	1000h	962	2.38	41.52
		3000h	934	2.34	42.21

No surface changes were evidenced.

Table 13: Saltwater resistance – Retained tensile properties

Property	Product [1]	Exposure time	WARP	WEFT
			Retained	Retained
Tensile Strength	**66x66** 33x33 99x99	1000h	102.3%	99.7%
		3000h	99.1%	96.9%
Modulus of elasticity	**66x66** 33x33 99x99	1000h	97.7%	98.3%
		3000h	97.6%	99.9%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other meshes.

Alkali exposure conditions:
All samples were conditioned by immerging specimens in an alkaline solution (pH=12.5) for 1000 and 3000 hours at a temperature of 23±2°C.

Table 14: Resistance of GFRP mesh specimens after alkali exposure

Product	Direction	Exposure time	Tensile Strength $\sigma_{u,alk}$ (MPa)	Tensile Stress $\varepsilon_{u,alk}$ (%)	Modulus of elasticity E_{alk} (GPa)
			Average	Average	Average
66x66	WARP	1000h	860	2.00	42.90
		3000h	859	2.28	41.11
	WEFT	1000h	923	2.40	41.89
		3000h	923	2.41	37.91

No surface changes were evidenced.

Table 15: Alkali resistance – Retained tensile properties

Property	Product (1)	Exposure time	WARP	WEFT
			Retained	Retained
Tensile Strength	**66x66** 33x33 99x99	1000h	97.6%	95.8%
		3000h	97.5%	95.8%
Modulus of elasticity	**66x66** 33x33 99x99	1000h	102.0%	99.2%
		3000h	97.7%	94.0%

(1) Products in bold letters are those directly tested. Retained percentages are also valid for all the other meshes.

C3: GFRP MESH - GLASS TRANSITION TEMPERATURE

Table 16: Glass transition temperature of GFRP mesh

Product [1]	Tg (minimum)
66x66 33x33 99x99	104ºC

[1] Products in bold letters are those directly tested

C4: GFRP MESH CORNER ELEMENT - MECHANICAL PROPERTIES

Table 17: Tensile resistance of GFRP mesh corner elements

Product [1]	Tensile resistance T (kN)		Tensile resistance in the direction of the current threads [2] $F_{u,mc}$ (kN)	
	Average	Characteristic value	Average	Characteristic value
66x66 33x33 99x99	3.63	3.02	2.56	2.13

[1] Products in bold letters are those directly tested
[2] $F_{u,mc} = 0.707\ T$

C5: GFRP CONNECTORS - MECHANICAL PROPERTIES

Table 18: Mechanical properties of the GFRP connectors

Product [1]	Tensile Strength $\sigma_{u,con}$ (MPa)		Tensile Strain $\varepsilon_{u,con}$ (%)		Modulus of elasticity E_{con} (GPa)	
	Average	Characteristic value	Average	Characteristic value	Average	Characteristic value
ARMAGLASS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	926	828	2.20	1.93	44.95	42.85
ARMAGLASS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	966	879	2.37	2.19	43.36	41.41

[1] Products in bold letters are those directly tested.

Table 19: Lap tensile test results for GFRP connectors

Product [1]	Load at failure Fc (kN)		Lap-tensile strength σ_{lap} (MPa)	
	Average	Characteristic value	Average	Characteristic value
ARMAGLASS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	25.53	22.76	903	805
ARMAGLASS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	41.00	33.61	816	669

[1] Products in bold letters are those directly tested.
[2] Properties of anchor used in the pull-out tests are shown in Table C12.

The used overlap length l_{lap} was 110 mm.

C6: GFRP CONNECTORS - MECHANICAL PROPERTIES OF ANCHORS

Table 20: Properties of the Epoxy resin used in lap-tensile

Generic type and use			Bonded anchor for anchorage of rebars									
ESSENTIAL CHARACTERISTICS			**PERFORMANCES**									
Installation parameters			**Φ8**	**Φ10**	**Φ12**	**Φ14**	**Φ16**	**Φ20**	**Φ24**	**Φ25**	**Φ28**	**Φ32**
Rebar diameter Φ [mm]		$d=d_{nom}$	8	10	12	14	16	20	24	25	28	32
Drill hole diameter [mm]		d_0	10/12	12/14	14/16	18	20	25	30	32	30	32
Effective anchorage depth [mm]		h_{ef} Min	60	60	70	75	80	90	96	100	112	128
		h_{ef} Max	160	200	240	280	320	400	480	500	560	640
Minimum thickness of concrete member [mm]		h_{min}	h_{ef} + 30 mm ≥ 100 mm; h_{ef} + 2d0									
Minimum allowable spacing [mm]		S_{min}	40	50	60	70	75	95	120	120	130	150
Minimum allowable edge distance [mm]		C_{min}	35	40	45	50	50	60	70	70	75	85
Rebars: Steel B450C, Concrete - C20/25, Rotopercussion drill, air drill, Dry and wet concrete			**Φ8**	**Φ10**	**Φ12**	**Φ14**	**Φ16**	**Φ20**	**Φ24**	**Φ25**	**Φ28**	**Φ32**
40°C/24°C[1][2] Ψsus0=0,80	non- cracked	$N_{Rec,stat}$ (kN)	14.3	20	27	28.9	32.7	51.9	68.8	71.3	92.6	103.9
	cracked	$N_{Rec,stat}$ (kN)	6.7	9.4	16.8	20.2	22.9	36.3	48.1	49.9	64.8	72.7
		$N_{Rec,eq,\ C1}$ (KN)	6.7	9.4	16.8	20.2	22.9	36.3	48.1	49.9	64.8	…
72°C/50°C[1][2] Ψsus0=0,68	non- cracked	$N_{Rec,stat}$ (kN)	11.5	16.2	23.7	28.9	32.7	51.9	68.8	71.3	92.6	103.9
	cracked	$N_{Rec,stat}$ (kN)	5.7	8.1	13.8	16.9	20.9	35.6	48.1	49.9	64.8	72.7
		$N_{Rec,eq,\ C1}$ (KN)	5.7	8.1	13.8	16.9	20.9	35.6	48.1	49.9	64.8	…
Cutting effort without lever arm[3][4]	non- cracked	$V_{Rec,stat}$ (kN)	6.7	10.5	14.8	20.3	23.4	38.4	52.2	54.4	71.8	82.1
	cracked	$V_{Rec,stat}$ (kN)	6.7	9.5	13.2	14.4	16.6	27.2	36.9	38.5	50.8	58.2
		$V_{Rec,eq,\ C1}$ (kN)	6.7	9.5	13.2	14.4	16.6	27.2	36.9	38.5	50.8	58.2

Table 21: Properties of the Vinylester resin used pull-out test

Generic type and use			Bonded anchor for anchorage of rebars							
ESSENTIAL CHARACTERISTICS			**PERFORMANCES**							
Installation parameters			**M8**	**M10**	**M12**	**M16**	**M20**	**M24**	**M27**	**M30**
Rebar diameter Φ [mm]		d	8	10	12	16	20	24	27	30
Drill hole diameter [mm]		d_0	10	12	14	18	24	28	30	35
Diameter of the hole [mm]		d_{fix}	9	12	14	18	22	26	30	35
Depth of the hole [mm]		h_1	h_{ef} + 5mm							
Minimum thickness of concrete substrate [mm]		h_{min}	MAX {hef + 30 mm ≥ 100 mm; h_{ef} + 2d_0}							
Tightening torque [Nm]		T_{Fix}	10	20	40	80	130	200	250	280
Fixable thickness [mm]		t_{fix}	0 to 1500							
Minimum allowable spacing [mm]		S_{min}	40	50	60	75	100	115	120	140
Minimum allowable edge distance [mm]		C_{min}	40	50	60	75	100	115	120	140
Partial factor of safety related to the installation of the anchorage	Category I1	γ_{inst} (-)	1.00							
	Category I2	γ_{inst} (-)	1.20							
Resistance to tensile loads Combined strength of pull-out and concrete cone			**M8**	**M10**	**M12**	**M16**	**M20**	**M24**	**M27**	**M30**
Concrete C20/25	-40°C/+40°C (T_{mlp} = 24°C)	$\tau_{Rk,ucr}$ [Nmm²]	16.0	12.0	12.0	12.0	9.5	9.5	8.0	8.0
Concrete C20/25	-40°C/+80°C (T_{mlp} = 50°C)	$\tau_{Rk,ucr}$ [Nmm²]	11.0	8.5	8.5	8.5	7.0	7.0	6.0	6.0
Concrete C20/25	-40°C/+120°C (T_{mlp} = 72°C)	$\tau_{Rk,ucr}$ [Nmm²]	6.0	4.5	4.5	4.5	4.0	4.0	3.0	3.0
Cracked concrete C20/25	-40°C/+40°C (T_{mlp} = 24°C)	$\tau_{Rk,cr}$ [Nmm²]	-	9.0	9.0	9.0	6.5	-	-	-
Cracked concrete C20/25	-40°C/+80°C (T_{mlp} = 50°C)	$\tau_{Rk,cr}$ [Nmm²]	-	6.5	6.5	6.5	4.5	-	-	-
Cracked concrete C20/25	-40°C/+120°C (T_{mlp} = 72°C)	$\tau_{Rk,cr}$ [Nmm²]	-	3.5	3.5	3.5	2.5	-	-	-
Increasing factor for cracked concrete classes C30/37		$\Psi_{c,uc/ucr}$ [-]	1.12							
Increasing factor for cracked concrete classes C40/50		$\Psi_{c,uc/ucr}$ [-]	1.23							
Increasing factor for cracked concrete classes C50/60		$\Psi_{c,uc/ucr}$ [-]	1.30							
Resistance to tensile loads Characteristic strength for the concrete cone			**M8**	**M10**	**M12**	**M16**	**M20**	**M24**	**M27**	**M30**
$K_{ucr,N}$			11.0							
$K_{cr,N}$			7.7							
$C_{cr,N}$			1.5 h_{ef}							
$S_{cr,N}$			3.0 h_{ef}							
Resistance to tensile loads Concrete cracking resistance			**M8**	**M10**	**M12**	**M16**	**M20**	**M24**	**M27**	**M30**
$C_{cr,sp}$ [mm]	If h = h_{min}		2.5 h_{ef}		2.0 h_{ef}		1.5 h_{ef}			
	If h_{min} < h < 2h_{min}		Interpolated value							
	If h ≥ 2h_{min}		$C_{cr,Np}$							
$S_{cr,sp}$ [mm]			2.0 $C_{cr,Np}$							

C7: GFRP CONNECTORS - PULL-OUT FROM REFERENCE SUBSTRATES

Table 22: Pull-out from reference substrates

Product [1]	Substrate[2]	Anchorage L_{anc} (mm)	Pull-out load P_{anc} (kN)	Failure mode
ARMAGLASS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	Concrete	120	16.61	1+3
	Clay		6.07	2
	Tuff		5.34	2
	Natural stone		10.53	2+3
ARMAGLASS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	Concrete	120	29.70	1+3
	Clay		14.90	2
	Tuff		10.90	2
	Natural stone		9.20	2

[1] Products in bold letters are those directly tested.
[2] Properties of anchor used in the pull-out tests are shown in Table C12.

Failure mode:
1. failure due to sliding of the connector
2. failure at the anchoring-substrate interface
3. failure of the substrate and/or substrate cone failure
4. failure of the connector

Table 23: Properties of substrates

Substrate	Compressive strength of material f_b (MPa)
Concrete	60.5
Clay	20.8
Tuff	4.1
Natural stone	120.0

C8: GFRP CONNECTORS - ENVIRONMENTAL DURABILITY

Freeze-thaw exposure conditions:
All samples were conditioned in a humidity chamber for a week, at a relative humidity >90% and at a temperature of 38±2°C; they were then subjected to 20 freeze-thaw cycles. Each cycle consisted of at least 4 hours at -18±1 °C, followed by 12 hours in a humidity chamber (>90% relative humidity, 38±2°C).

Table 24: Resistance of GFRP connector after freeze-thaw exposure

Product	Tensile Strength $\sigma_{u,FT}$ (MPa)	Tensile Stress $\varepsilon_{u,FT}$ (%)	Modulus of elasticity E_{FT} (GPa)
	Average	Average	Average
ARMAGLASS BAR CONNECTOR 6	892	2.44	45.08
ARMAGLASS BAR CONNECTOR 8	870	2.99	40.46

No surface changes were evidenced.

Table 25: Freeze-thaw resistance – Retained tensile properties

Product [1]	Property	Retained
ARMAGLASS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	**Tensile Strength**	96.3%
	Modulus of elasticity	100.3%
ARMAGLASS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	**Tensile Strength**	90.1%
	Modulus of elasticity	93.3%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other connectors.

Water exposure conditions:
All samples were conditioned according to Section 2.2.2.4 of EAD 340210-00-0104 for 1000 and 3000 hours at a temperature of 38±2°C and relative humidity > 90%.

Table 26: Resistance of GFRP connector after water exposure

Product	Exposure time	Tensile Strength $\sigma_{u,w}$ (MPa)	Tensile Stress $\varepsilon_{u,w}$ (%)	Modulus of elasticity E_w (GPa)
		Average	Average	Average
ARMAGLAS BAR CONNECTOR 6	1000h	885	3.12	44.74
	3000h	837	2.00	44.29
ARMAGLAS BAR CONNECTOR 8	1000h	928	2.40	43.04
	3000h	900	2.09	43.21

No surface changes were evidenced.

Table 27: Water resistance – Retained tensile properties

Product [1]	Property	Exposure time	Retained
ARMAGLAS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	**Tensile Strength**	1000h	95.5%
		3000h	90.3%
	Modulus of elasticity	1000h	99.5%
		3000h	98.5%
ARMAGLAS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	**Tensile Strength**	1000h	96.0%
		3000h	93.2%
	Modulus of elasticity	1000h	99.3%
		3000h	99.7%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other connectors.

Saltwater exposure conditions:
All samples were conditioned by immerging specimens in saltwater (solution of 245 g NaCl and 40.94 g Na_2SO_4 for 10 l of distilled water) for 1000 and 3000 hours at a temperature of 23±2°C.

Table 28: Resistance of GFRP connector after saltwater exposure

Product	Exposure time	Tensile Strength $\sigma_{u,sw}$ (MPa)	Tensile Stress $\varepsilon_{u,sw}$ (%)	Modulus of elasticity E_{sw} (GPa)
		Average	Average	Average
ARMAGLAS BAR CONNECTOR 6	1000h	880	2.52	45.04
	3000h	851	2.20	44.60
ARMAGLAS BAR CONNECTOR 8	1000h	967	2.48	42.82
	3000h	892	1.98	43.91

No surface changes were evidenced.

Table 29: Saltwater resistance – Retained tensile properties

Product [1]	Property	Exposure time	Retained
ARMAGLAS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	**Tensile Strength**	1000h	95.0%
		3000h	91.9%
	Modulus of elasticity	1000h	100.2%
		3000h	99.2%
ARMAGLAS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	**Tensile Strength**	1000h	100.1%
		3000h	92.4%
	Modulus of elasticity	1000h	98.8%
		3000h	101.3%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other connectors.

Alkali exposure conditions:
All samples were conditioned by immerging specimens in an alkaline solution (pH=12.5) for 1000 and 3000 hours at a temperature of 23±2°C.

Table 30: Resistance of GFRP connector after alkali exposure

Product	Exposure time	Tensile Strength $\sigma_{u,alk}$ (MPa)	Tensile Stress $\varepsilon_{u,alk}$ (%)	Modulus of elasticity E_{alk} (GPa)
		Average	Average	Average
ARMAGLAS BAR CONNECTOR 6	1000h	938	2.51	44.75
	3000h	899	1.99	43.67
ARMAGLAS BAR CONNECTOR 8	1000h	889	2.30	41.82
	3000h	873	1.90	42.08

No surface changes were evidenced.

Table 31: Alkali resistance – Retained tensile properties

Product [1]	Property	Exposure time	Retained
ARMAGLAS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	**Tensile Strength**	1000h	101.2%
		3000h	97.1%
	Modulus of elasticity	1000h	99.6%
		3000h	97.1%
ARMAGLAS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	**Tensile Strength**	1000h	92.1%
		3000h	90.4%
	Modulus of elasticity	1000h	96.5%
		3000h	97.1%

[1] Products in bold letters are those directly tested. Retained percentages are also valid for all the other connectors.

C9: GFRP CONNECTORS - GLASS TRANSITION TEMPERATURE

Table 32: Glass transition temperature of GFRP connectors

Product [1]	Tg (minimum)
ARMAGLAS BAR CONNECTOR 6 ARMAGLASS CONNECTOR L 6	103ºC
ARMAGLAS BAR CONNECTOR 8 ARMAGLASS CONNECTOR L 8	103ºC

[1] Products in bold letters are those directly tested.