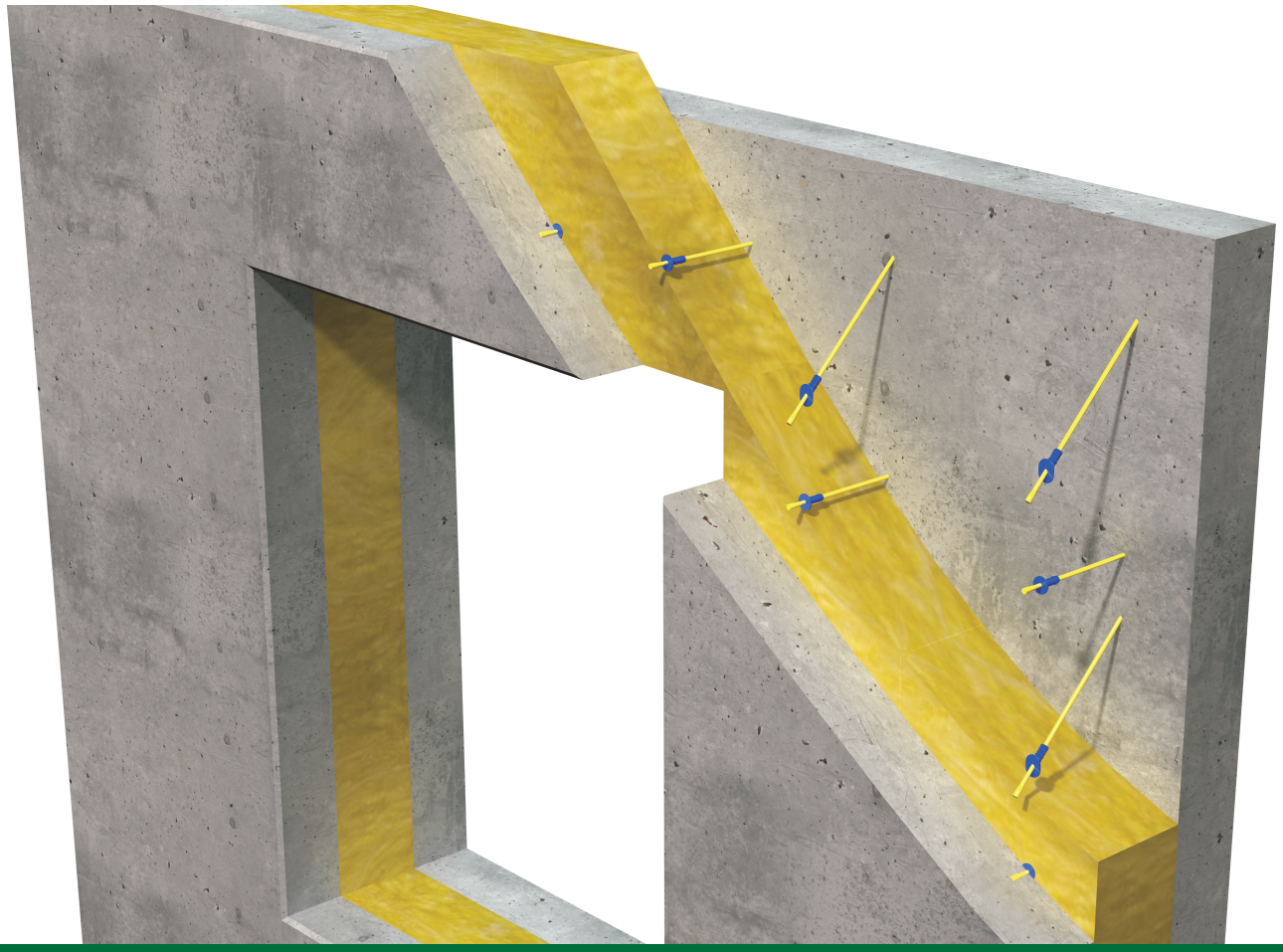
BT innovation



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The BT tie anchor system of fibrous glass-reinforced plastic (FRP)

Planning and installation recommendations

Disclaimer

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Germany

Contents

1. Advantages of the FRP connection system

- No thermal bridges
- Substantial energy savings, low heating costs
- Improved heat storage behaviour of building components
- Leaner construction due to lower thickness of concrete cover
- Higher efficiency in building component production
- Elimination of stainless steel utilisation
- Saving of production and installation costs
- Corrosion-proof, alkaline-resistant
- No impairment by electrical fields or magnetic fields
- Price stability due to independence from steel price fluctuations

2. General information, test values

Calculations, tests and inspections were based on the below material- and type-specific characteristic values of FRP tie anchors:

Nominal measurement and admissible tolerance deviations

- Bar diameter (d1) – 7.5 ±0.3 mm (Fig. 1-3);
- Diameter of anchoring distension – (d2) – 10.5 ±0.4 mm;
- Length of anchoring distension (L2) – 21.8 ±0.3 mm;
- Length of conical anchoring distension part (L3) -≤25 mm;
- Bar length (L1) ±0.3 mm.

Physical-technical values

- Density: 2000 – 2050 g/cm^{3};
- Water absorption: ≤0.05 %;
- Linear expansion coefficient:
  - Longitudinal direction – 5.0*10^{-6} K^{-1};
  - Transverse direction – 10.0*10^{-6} K^{-1};

- Thermal conductivity (Material value): 0.48 W / m*K

Physical-mechanical values

- Tensile strength: ≥1500 MPa;
- Resistance to compression: ≥1500 MPa;
- Cross-breaking strength: ≥1585 MPa;
- Tensile breaking stress: 39250 N;
- Shearing strength: ≥165 MPa;
- Young's modulus: ≥50000 MPa;
- Chemical resistivity: the stability of test samples was at least 76% of the original value after storage for 168 hours in NaOH, at a temperature 80°C.

A service life of ≥100 years can be deducted under consideration of the forecast change of condition and stability development in permanent application in a construction project.

Evaluation of test results evidenced that BT FRP tie anchors can be applied as tie anchors for three-layered walls of reinforced concrete, concrete and masonry walls.

3. Description of the FRP connection system

System description

The FRP connection system serves as bonding system between the two concrete shells of double walls with internal insulation. FRP tie anchors consist of a fibrous glass-reinforced plastic bar and a plastic ring – spacer and water barrier (Figure 1, 2). Both ends of FRP tie anchors are conically formed (not mechanically formed to shape!) by a special method as protection against tear-out of concrete. The plastic ring is fixed to the FRP body and serves as spacer for the anchor, support of insulating material and water barrier.

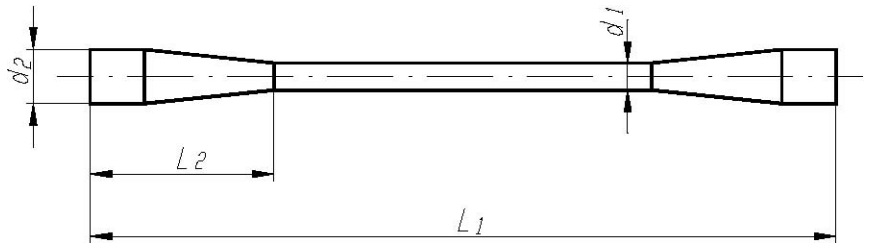

Figure 1 – FRP tie anchor.

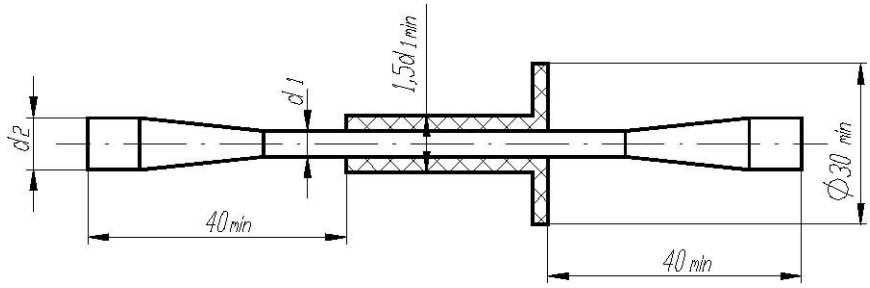

Figure 2 – FRP tie anchor with a straight plastic ring 90° to centre axis.

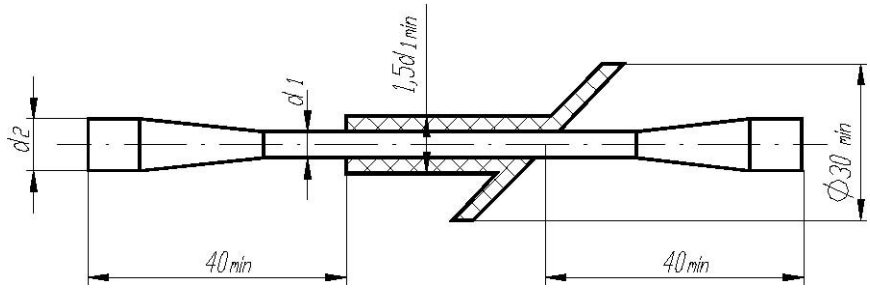

Figure 3 – FRP tie anchor with a diagonal plastic ring 45° to centre axis.

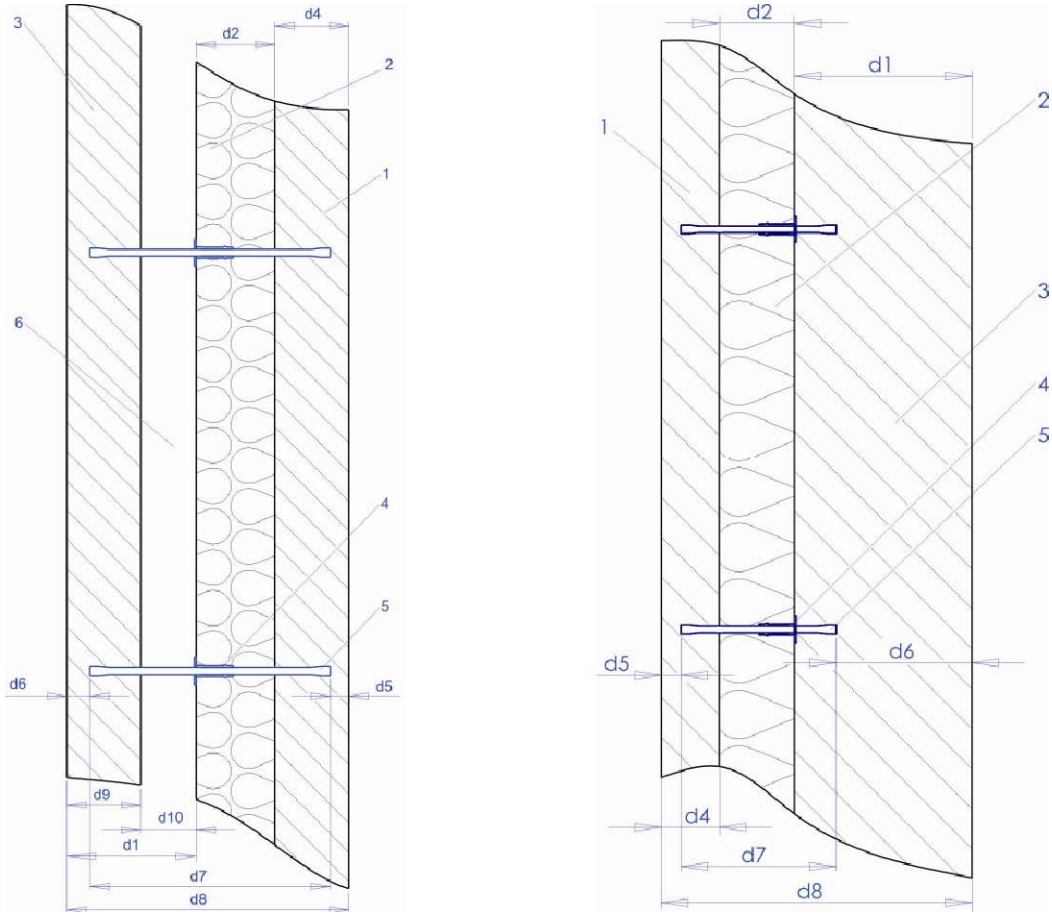

Figure 4
a) Thermal wall, b) Sandwich wall with FRP tie anchor system
(1 - Facing shell–; 2 – Insulating material layer; 3 – Bearing shell; 4 –Plastic ring – Spacer and water barrier; 5 – FRP tie anchor, 6 - Core concrete layer).

FRP tie anchors have been designed to absorb tensile loads when wall shells are connected to each other and absorb transverse loads from vertical displacement of wall shells (1, 3), loads during technological manufacturing and assembly processes as well as wind loads (Figure 4).

3.1 Calculation characteristics of an anchoring node.

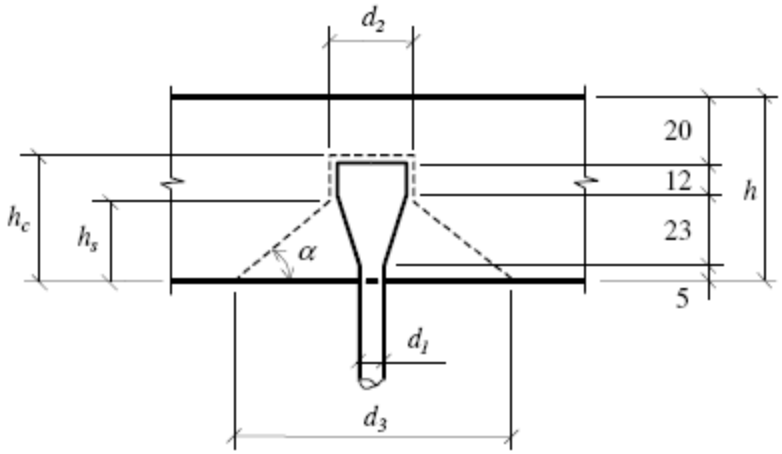

Figure 5 – Schematic diagram of an anchoring point under tear-out load.

Table 3.1 – Required anchoring lengths of FRP bars as a function of concrete grade and extraction force

Concrete type	Concrete class	Embedding depth of anchor h_c, mm	Extraction force, kN
Dense concrete	C 12/15	40	6.0
		60	8.9
		80	13.35
	C 20/25	40	7.00
		60	10.90
		80	15.95
	C 25/30	40	8.10
		60	12.70
		80	18.15
	C 30/37	40	9,10
		60	14.40
		80	20.45
	C 35/45	40	10.10
		60	16,05
		80	22.40
	C 40/50	40	10.95
		60	17.60
		80	24.35

The extraction force values for FRP anchors Ø7.5 mm shown in Table 3.1 were calculated with a safety factor. The real average value for an anchor embedded in concrete C25-30 is 14.1 kN at an embedding depth of 40 mm.

3.2 Calculation of FRP tie anchor lengths

The overall length of FRP tie anchors depends on the thickness of insulating material, thickness of core concrete layer(in double walls) and the embedding depth of the anchor in facing and bearing shell concrete. The concrete cover should not be less than 20 mm (Figure 4: d5 ≥20 mm, d6 ≥20 mm). The standard embedding depth in concrete of the conical shaped ends of the FRP anchor should be at least 40 mm.

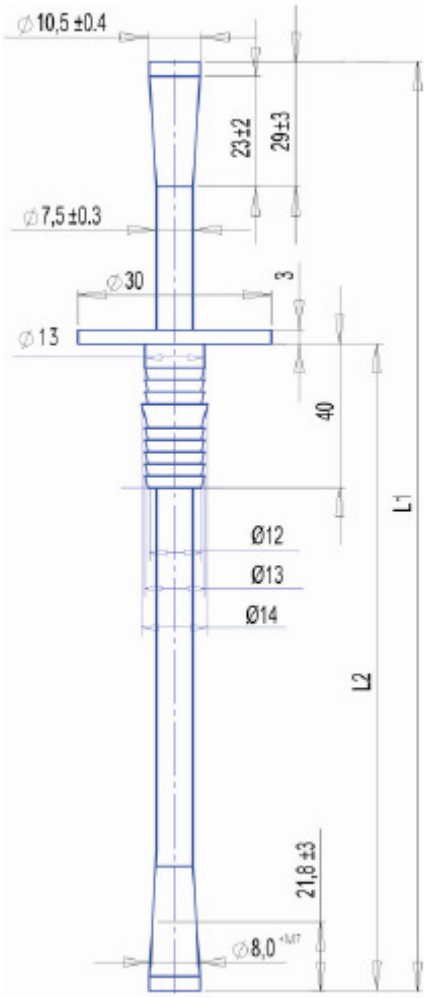

Figure 6 – FRP tie anchor.

The anchor length can be calculated with the below formula:

- **for sandwich walls (Figure 4b, 6)**

$$L1 = (d4 - 20) \times 2 + d2 \ [mm]$$

L1 – Length of FRP anchor;
d5 ≥20 mm -Concrete cover of facing shell – Fire-protection requirement;
d4 –d5 ≥40 mm -Embedding depth of FRP anchor;
d6 ≥20 mm -Concrete cover of bearing shell – Fire-protection requirement;
d2 – Insulation layer thickness.

- **for double walls (Figure 4a, 6)**

$$L1 = (d4 - 20) \times 2 + d2 + d10 \text{ [mm]}$$

If d4 > d9, replace d4 in formula by d9;
L1 – Length of FRP anchor;
d5 ≥20 mm -Concrete cover of facing shell – Fire-protection requirement;
d4 –d5 ≥40 mm -Embedding depth of FRP anchor;
d6 ≥20 mm -Concrete cover of bearing shell – Fire-protection requirement;
d9 –d6 ≥40 mm -Embedding depth of FRP anchor;
d10 – Thickness of core concrete layer;
d2 – Insulation layer thickness.

Table 3.2 - Application engineering examples

Facing shell thickness, mm	Insulation layer thickness, mm	Core concrete layer, mm	Bearing layer thickness, mm	Wall thickness, mm	Concrete cover, mm		Length of FRP tie anchor, mm
Double wall w/ internal insulation (Figure 3a):							
d4	d2	d10	d9	d8	d5	d6	L1
70	80	90	60	300	30	20	250
70	80	130	60	340	30	20	290
80	70	100	100	350	20	40	290
100	85	100	65	350	55	20	275
70	80	150	60	360	30	20	310
100	100	100	100	400	20	20	360
Sandwich wall (Figure 3b):							
d4	d2	-	d1	d8	d5	d6	L1
65	85	-	200	350	20	155	175
80	160	-	200	440	20	100	280

3.3 Arrangement of FRP tie anchors

FRP tie anchors are arranged in a uniform grid of 400 mm to maximally 450 mm. The minimum distance between FRP tie anchors must not be less than double the anchor embedding depth (Figure 4), e.g. embedding depth 60 mm - distance 120 mm, embedding depth 80 mm - distance 160 mm. Maximum edge distances must not exceed 200 mm (Figure 7).

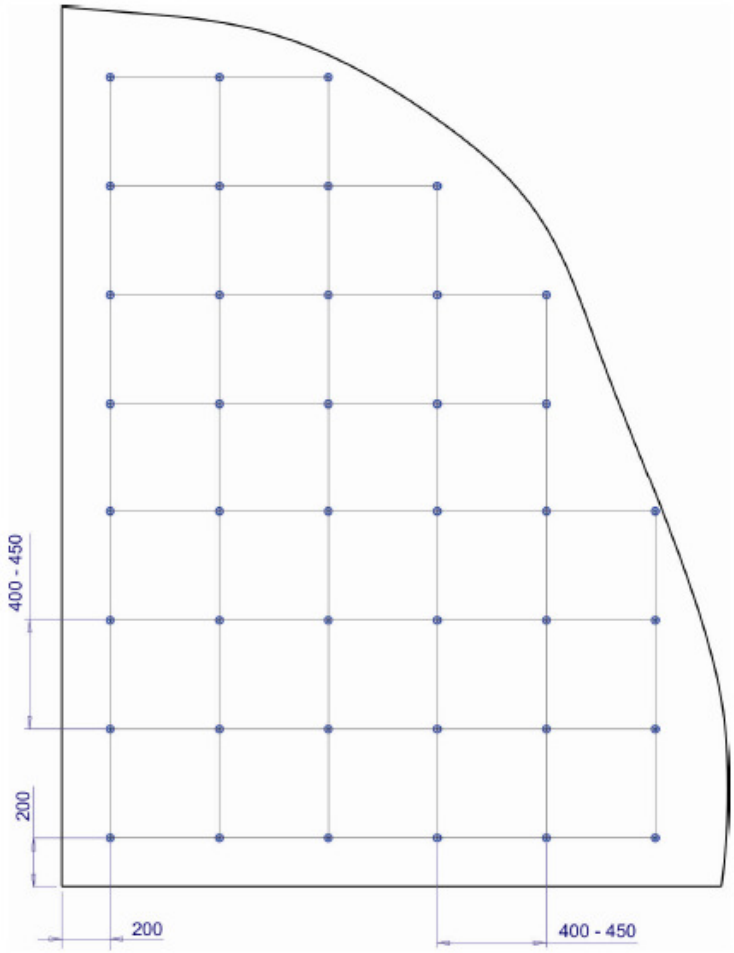

Figure 7 – Arrangement scheme and edge distances of FRP tie anchors in a double wall with internal insulation or a sandwich wall.

3.4 Walls with suspended facing shell

A combination of diagonal bars and straight bars shall be used in walls with suspended facing shells. Diagonal bars are provided to absorb vertical loads and as technologically required bracing during wall element manufacturing processes. Diagonal bars are placed at an inclination angle (typically 45°). Such connections absorb the load G that corresponds to the vector sum of the dead weight of the exterior shell G1 and the dead weight of the insulation layer G2. (see Figure 8).

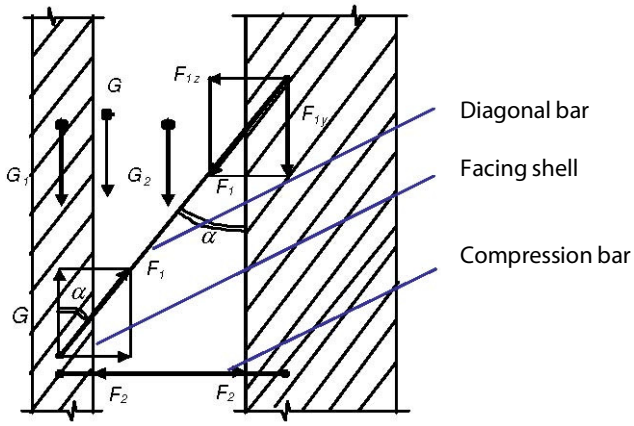

Figure 8 – Calculation scheme for a three-layered wall with FRP tie anchors

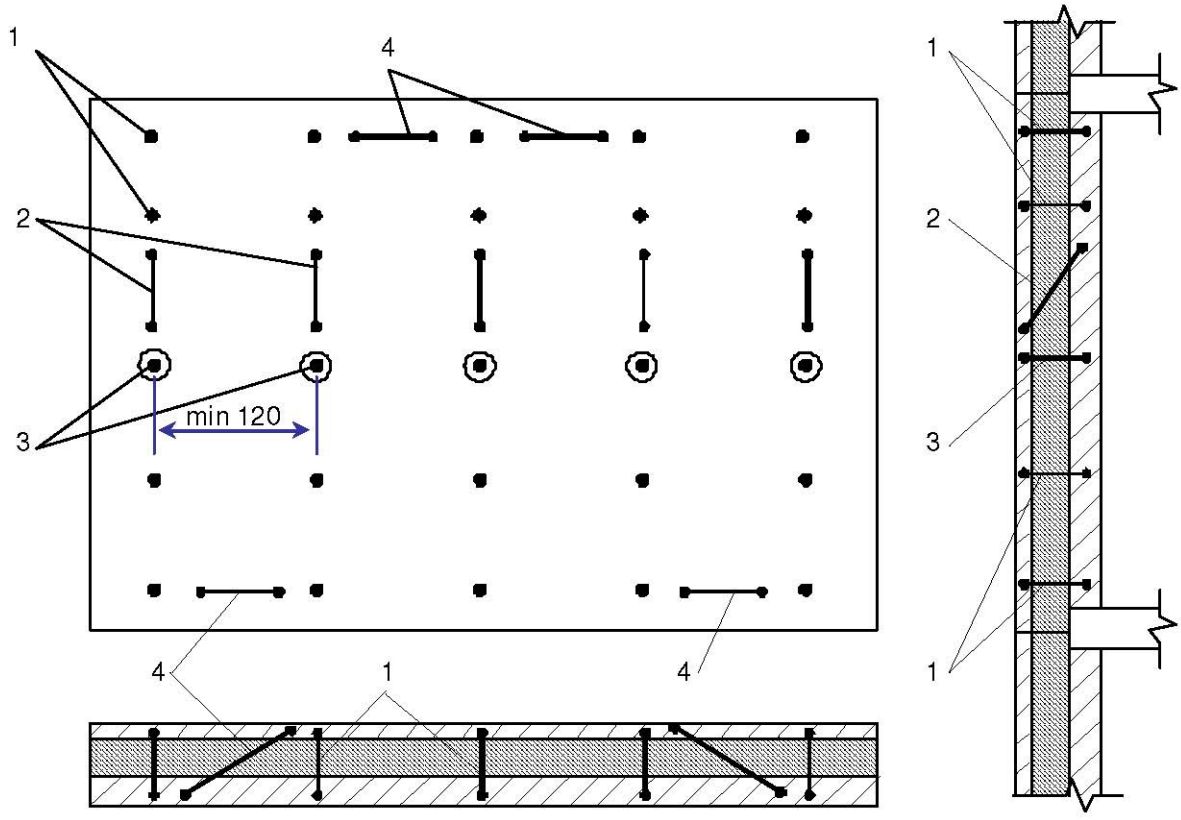

Figure 9 – Arrangement scheme for FRP tie anchors in a three-layered wall (1 – Straight bar (absorption of tensile and transverse loads); 2 – Diagonal bar – absorption of vertical stresses; 3 – Compression bar (absorption of transverse loads) 4 – Diagonal bar (bracing elements).

Diagonal bars (4) (bracing elements) should be placed at the same inclination angle as these diagonal bars (2), see Figure 9.

Horizontal diagonal bars (4) ensure the required wall stiffness during manufacturing processes and absorb technologically conditioned loads.

For general application cases the number of combinations 'Diagonal bar-compression bar' (2) (3) (Figure 9) equals the number of square metres of the facing shell surface; e.g. for a facing shell with a total surface of 18 sqm, 18 combinations 'Diagonal bar-compression bar' shall be used.

'Diagonal bar-compression bar' combinations are placed in a horizontal row in the upper third of an element. The minimum grid distance between the combinations is 120 mm. In addition, 4 horizontal diagonal bars are placed per wall element as bracing elements (4) (Figure 9).

Please, contact us if you require consultancy for wall elements with complicated geometries or recommendations and advice for optimal application of the system!

3.5 Marking of FRP tie anchors

Item No.	1	2	3	4	5	6 (L1, mm)	7	8	9 (L2, mm)
Marking	**GFV**	**_**	**x**	**_**	**7,5.**	**XXX.**	**X.**	**X.**	**XXX**

1 GFV – FRP tie anchor ;
2 _ Underline;
3 Type of anchor: g – Straight anchor, d – Diagonal anchor;
4 _ Underline;
5 Diameter d1 = 7,5 mm of FRP anchor (Figure 1-3);
6 Length of Anchor L1, mm (Figure 1, 6);
7 Number of conical flaring shapes;
8 Number of PE spacers (plastic rings);
9 Distance L2, mm (Figure 6);

Marking examples are shown in Figures 10 -11.

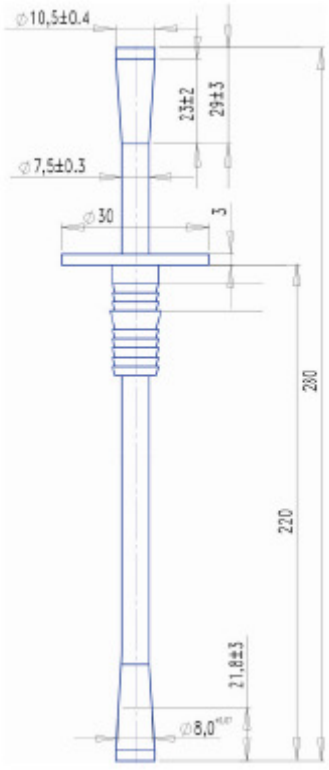

Figure 10 – Straight FRP tie anchor GFV_g_7.5.280.2.1.220

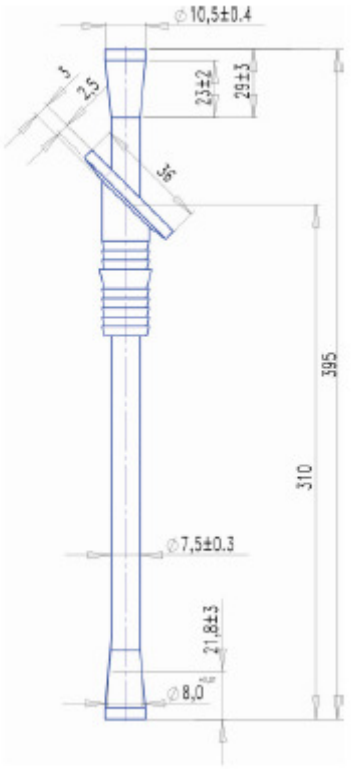

Figure 11 – Diagonal FRP tie anchor GFV_d_7.5.395.2.1.310

4. Technological installation procedure of tie anchors

Ensure during placing of FRP anchors that the requirements specified in design documents to embedding depths of anchors and required concrete cover. Organise the workflow in such a manner that the entire time period for installation of insulating material and insertion of FRP tie anchors after installation of reinforcement and concreting of facing shell is not longer than 15 - 20 minutes.

Despite the slightly higher material consumption in comparison to conventional systems (5 – 8 FRP anchors /sqm versus ~4 stainless steel nails /sqm), FRP tie anchor systems can be swifter installed. No pre-assembly work due to cumbersome fastening of anchors to reinforcement mats! No recesses in insulating materials!

The best bonding of FRP anchors in concrete is achieved by compacting fresh concrete after insertion of FRP anchors and curing of the concrete at a temperature of ≤60 – 65 °C. PE caps can be used for to facilitate insertion of FRP tie anchors (Figure 12). PE caps are specifically matched to the diameters of the conical ends of FRP anchors. The conical tips allow for easier insertion of PE caps into concrete and ensure the required concrete cover of 20 mm.

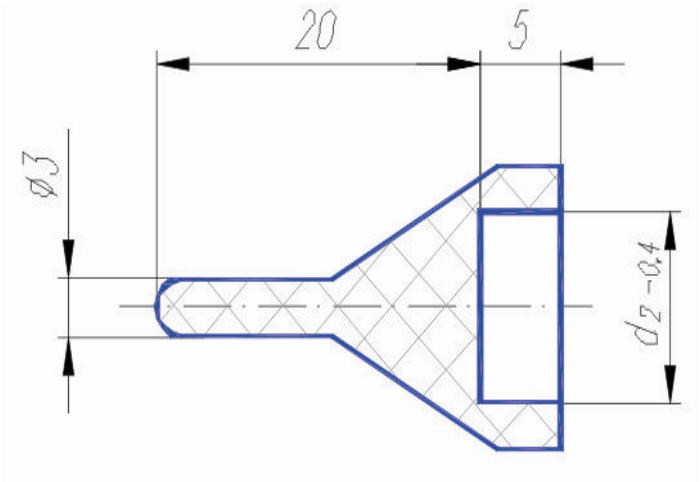

Figure 12 – PE cap (d2 – Figure 1; 2; 3).

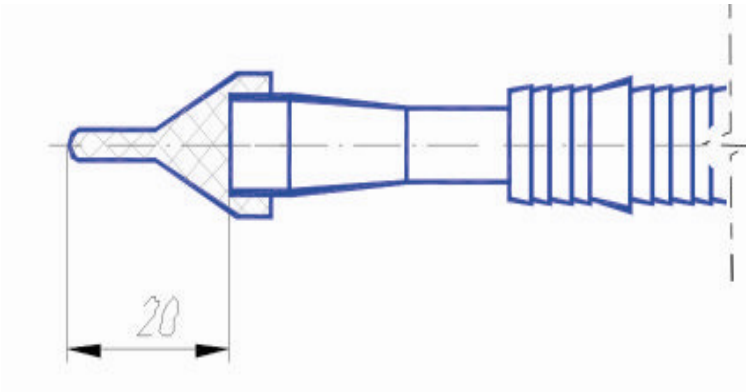

Figure 13 – FRP tie anchor with PE cap.

The technological installation procedure comprises the following steps:

1. Concreting of facing shell

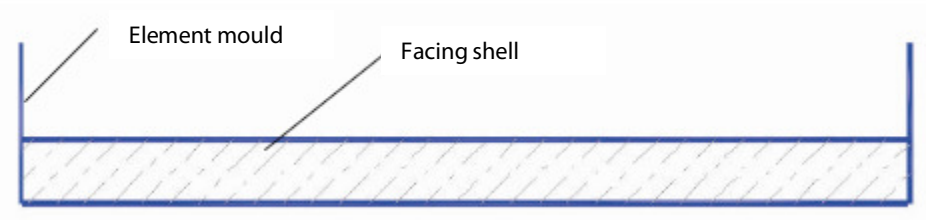

Figure 14 – Concreting of facing shell.

2. Laying out of insulating material on the concrete layer, marking of holes for tie anchor according to project-specific anchor arrangement scheme (pre-drill inserting holes for diagonal anchors).

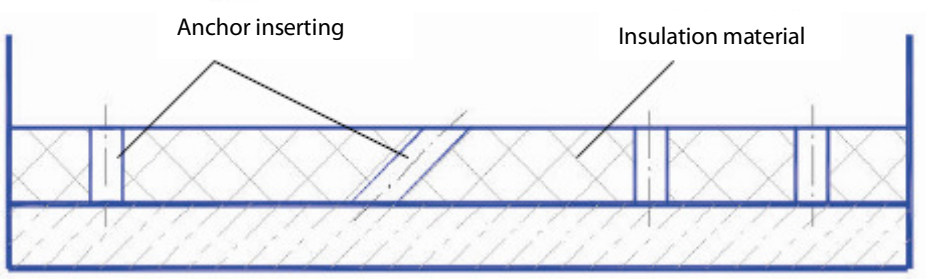

Figure 15 – Laying out of insulating material and drilling of inserting holes.

3. Insert FRP tie anchors into the fresh concrete of the facing shell through the insulation layer. The specified embedding depth can be kept either by pre-mounted PE caps that allow for pushing FRP tie anchors through to the PE cap end against the mould bottom,

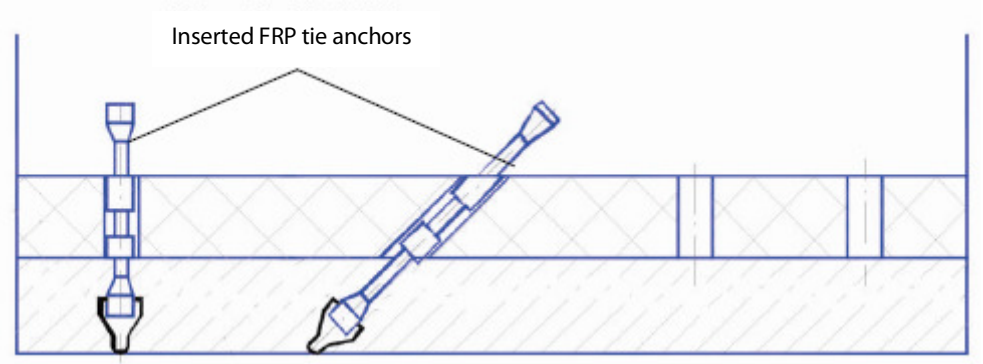

Figure 16 – Insertion of FRP anchors with PE caps.

or by using plastic rings that are retained on top of insulating material and simultaneously serve as spacers.

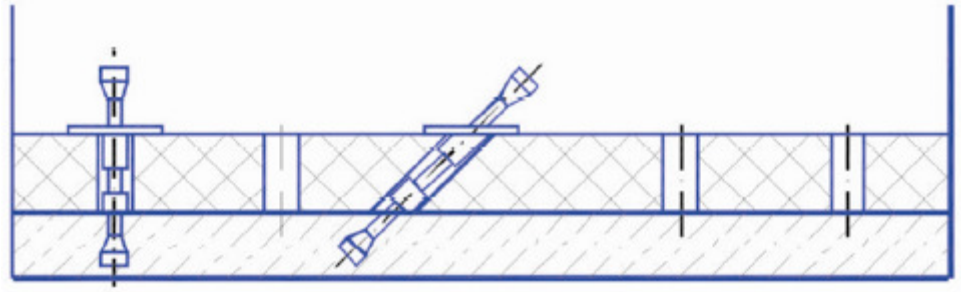

Figure 17 – Insertion of FRP anchors with plastic rings.

4. Following insertion of FRP anchors and placing of the upper reinforcement layer, install and compact the concrete of the bearing shell. Concrete compaction may be stationary on a vibrating table or by means of a poker vibrator. Compaction of concrete around built-in units (windows, doors, corbels) should be done locally with a poker vibrator. Following compaction, the manufactured elements (depending on technological equipment) can be left to harder on a table at hall temperature or in a downstream drier and the bearing shell surfaces can be finished after the respective hardening time.

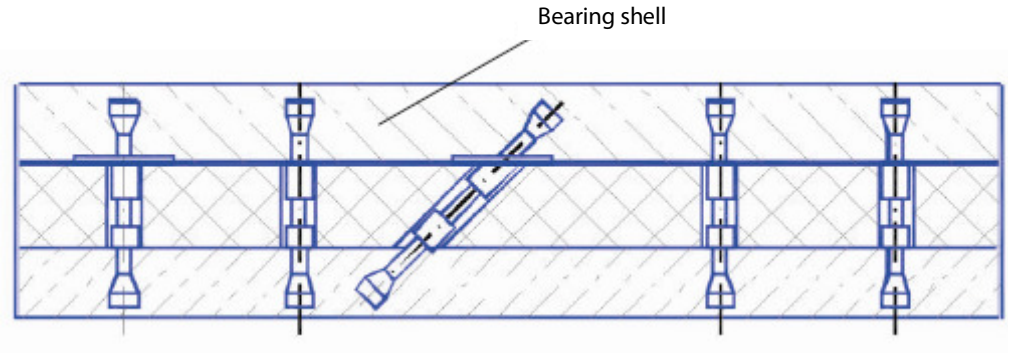

Figure 18 – Laying out of reinforcement mat and concreting of bearing shell of a sandwich wall.

Manufacturing of a sandwich wall can be done either as a 'positive' or a 'negative' mould. The second variant is preferably employed because a formwork-smooth surface of the facing shell is obtained. It is recommended to use a tilting table to lift the finished element from a horizontal into a vertical position.

5. Manufacturing of the initial shell for THERMO-PIN walls follows making of a facing shell for a sandwich wall system. Place the lower reinforcement layers, install concrete for the initial shell, trowel and compact the concrete. Following compaction, install insulation material and insert the FRP PINs according to the specified fastening system. Secure the insulation material by inserting adequate plastic anchors through the insulation layer into the initial shell concrete. Subsequently, leave the initial shell to harden and bond this shell to the freshly poured secondary shell (that is made like the initial shell except for the insulation layer) by using an appropriate turning system. Charge the wall again into the hardening section after which the manufacturing process of a THERMO-PIN wall is completed (Figure 19).

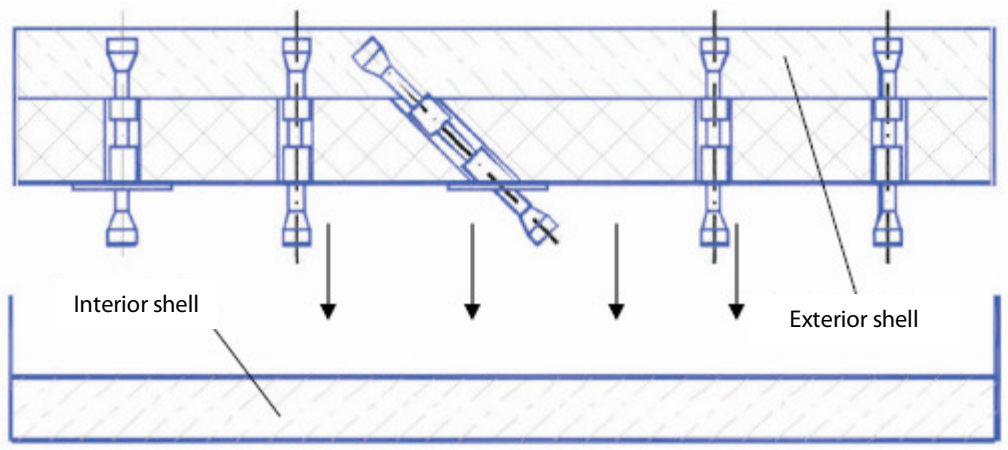

Figure 19 – Manufacturing of a THERMO-PIN wall.

Safety notes, environmental protection

Ecological information
FRP tie anchors do not emit any harmful substances. The material is environmentally-friendly and does not contain any harmful components for man or wildlife. There are no harmful impacts on the environment when the product is appropriately used according to the instructions for use.

Disposal notes
Disposal of residues and packaging material according to valid local regulations.

Transport notes
There are no restrictions for transporting of the FRP tie anchor system by road, sea or air.

Applicable regulations
The FRP tie anchor system is not subject to labelling requirements according to the Ordinance on Hazardous Substances. As for the rest, the safety and accident prevention regulations customary in the sector are applicable, e.g. mandatory wearing of safety footwear and adequate working clothes.

Physical and chemical properties
Flashing point: 380 – 410 °C;
Vapour pressure: not applicable, the product does not contain volatile components;
Density: 2000-2050 g/cbm;
Explosion hazard: none;
Solubility: not soluble in water or oil-containing solving agents;
Boiling: not applicable;
pH: not applicable.

Stability and reactivity
Conditions that should be avoided are not known. Material incompatibilities are not known. Combustion produces carbon dioxide and hydrocarbons as combustion products.

Fire-fighting measures
Extinguishing agents: Water, fire extinguishing foam, sand
Special notes: Wear a breathing apparatus and personal protective equipment. Special hazards are not known.

Appendix A – Application examples

Figure 20 – Laying out of insulating material and marking of inserting holes

Figure 21 – Insertion of FRP anchors

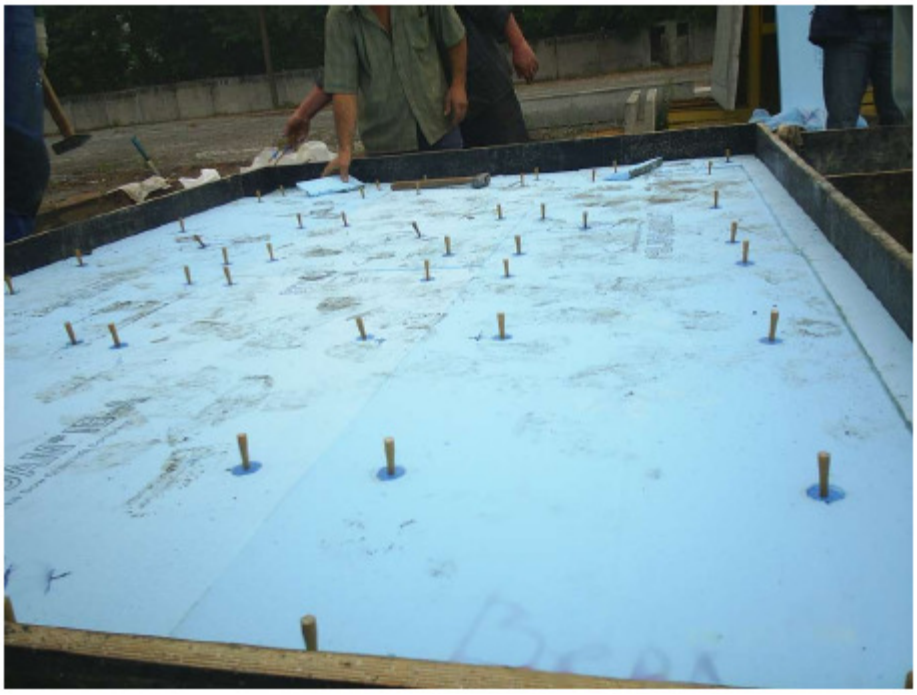

Figure 22 – Inserted FRP tie anchors

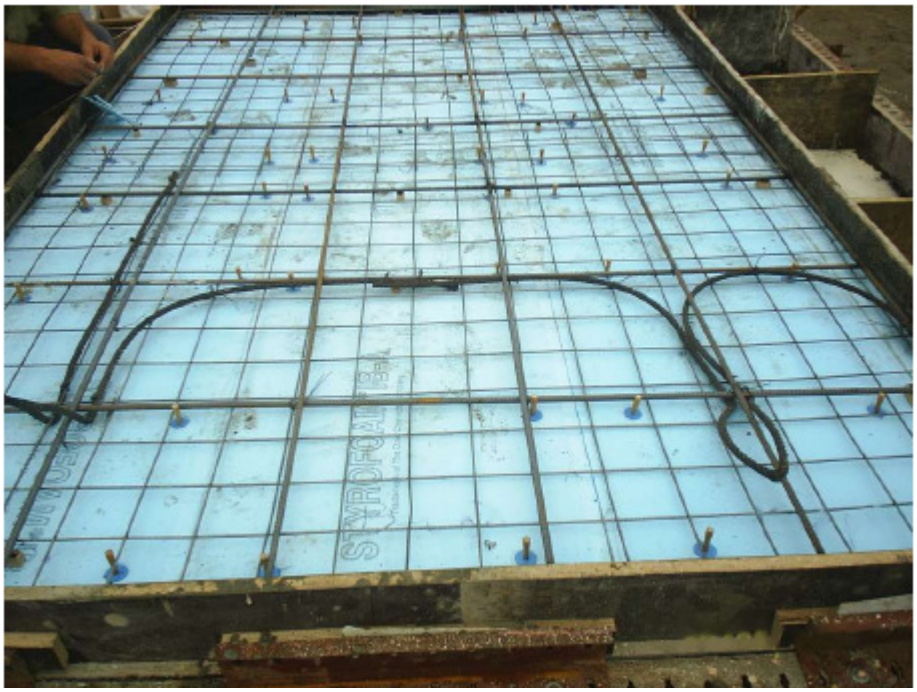

Figure 23 – Laying out of reinforcement mat

Figure 24 – Concreting of bearing shell

Figure 25 – Lifting of finished elements from the mould

Figure 26 – Touch-up work

Appendix A: FRP tie anchor 7.5 mm, application for the precast concrete production

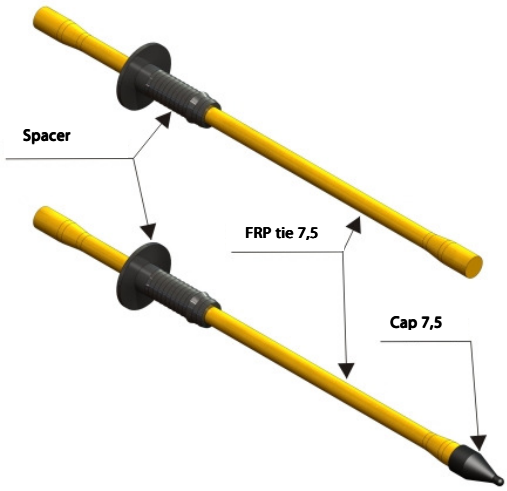

Figure A1: FRP tie anchor 7.5 mm.

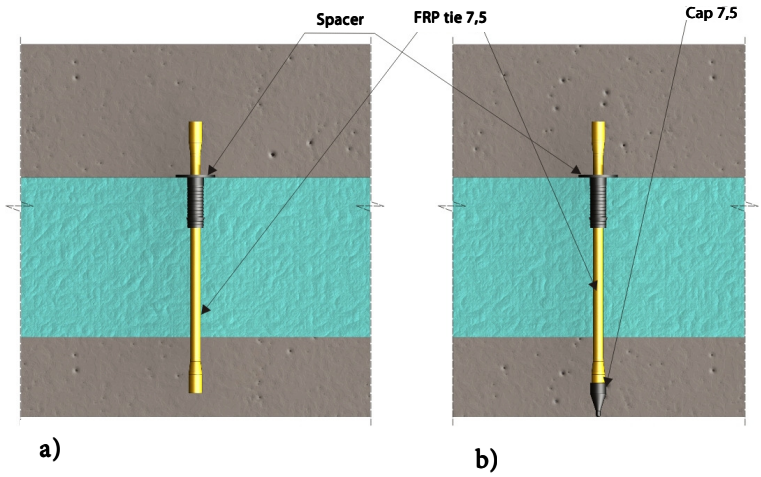

Figure A2: cross section, prefabricated concrete sandwich wall: a) - without cap 7,5; b) - with cap 7,5.

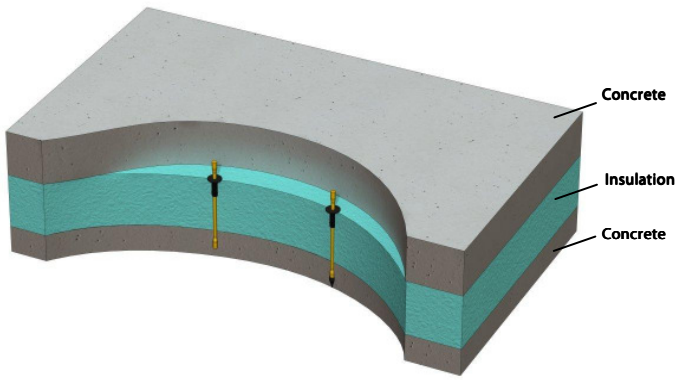

Figure A3: 3D – view - prefabricated concrete sandwich wall.

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Appendix B: FRP tie anchor 7.5 mm, application for the monolithic construction

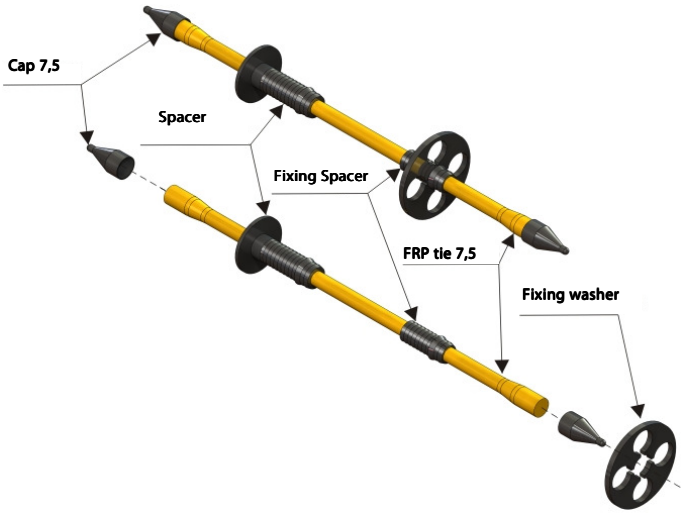

Figure B1: FRP tie anchor 7.5 mm.

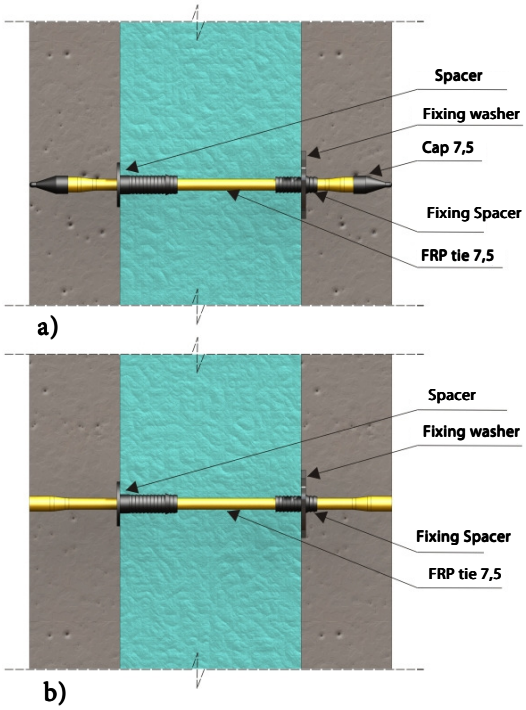

Figure B2: cross section, monolithic concrete sandwich wall: a) - with cap 7,5; b) - without cap 7,5.

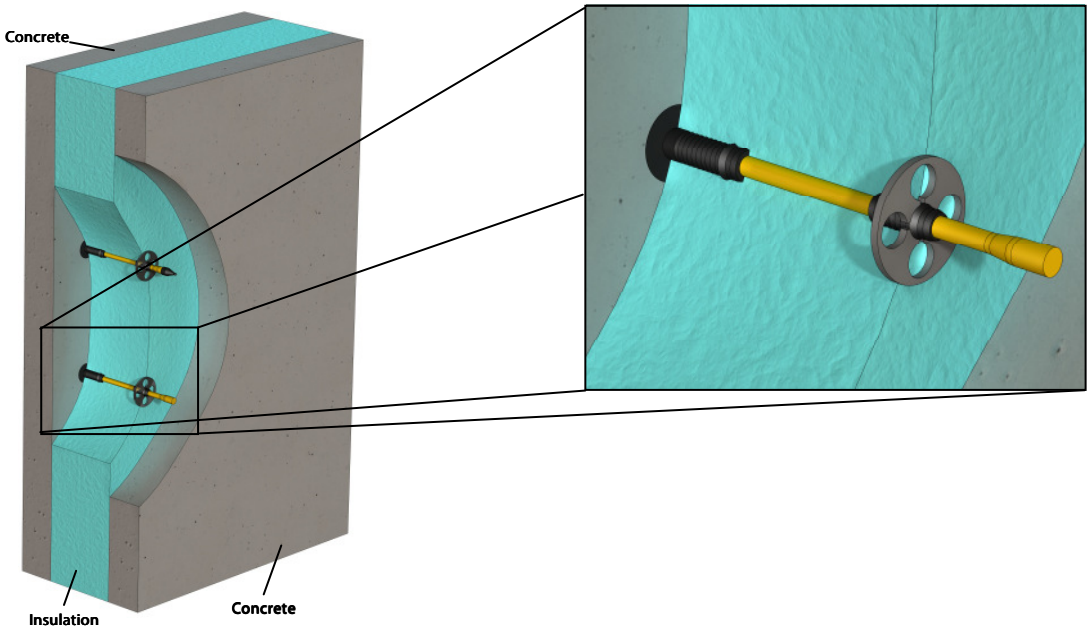

Figure B3: 3D – view - monolithic concrete sandwich wall.

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Appendix C: Marking of FRP tie anchors

Pos.	1	2	3	4	5	6	7	8	9	10
Marking	**GFV**	**_**	**X**	**_**	**7,5**	**XXX**	**X**	**X**	**XXX**	**XXX**

1. GFV – FRP tie anchor;
2. _ Underline;
3. Type of anchor: g – Straight anchor, d – Diagonal anchor;
4. _ Underline;
5. Diameter 7,5 mm of FRP anchor;
6. Length of Anchor, mm;
7. Number of conical flaring shapes;
8. Number of PE spacers (plastic rings);
9. Distance to spacer, mm.
10. Distance to fixing-spacer, mm.

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