Technický a skúšobný ústav stavebný, n. o.
Building Testing and Research Institute
Studená 3
821 04 Bratislava
Slovak Republic
Phone: +421 2 49228101
E-mail: sternova@tsus.sk
Website: www.tsus.sk

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# Evaluation Report to European Technical Assessment

# ETA 23/0523 – version 01 of 20/11/2024

| | |
|---|---|
| **Trade name of the construction product:** | Composite GFRP bar reinforcement TopBAR |
| **Product family to which the construction product belongs:** | Product area code: 26<br>PRODUCTS RELATED TO CONCRETE, MORTAR AND GROUT |
| **Manufacturer:** | Composite Group s. r. o.<br>Panenská 5<br>811 03 Bratislava – mestská časť Staré Mesto<br>Slovak Republic<br>https://composite-group.com/ |
| **Manufacturing plant:** | Composite Group s. r. o.<br>Priemyselná 8<br>924 01 Galanta<br>Slovak Republic |
| **This Evaluation Report contains:** | 17 pages |
| **This Evaluation Report replaces:** | — |

# 1. Introduction

This report describes the methods used to assess the composite GFRP bar reinforcement Composite TopBAR for its intended use.

This report describes the methods used to assess the fitness for the intended use of the composite GFRP bar reinforcement Composite TopBAR in accordance with the Essential Requirements, as specified in EAD 260023-00-0301 (Edition 01/2019,) Carbon, glass, basalt and aramid FRP (Fibre Reinforced Polymer) bars as reinforcement of structural elements, if not determined differently in the following.

# 2. Description of the product and Intended use

## 2.1 Description of the product

Composite GFRP bar reinforcement Composite TopBAR for concrete is a glass fiber reinforced polymer bar made of strands of glass fibers that are impregnated with a thermoset polymer resin. The bars are profiled on the outside with reinforcing rib (winding) to improve cohesion with concrete. As a standard Composite TopBAR reinforcement is produced in diameters of 6 mm, 8 mm, 12 mm, 16 mm.

## 2.2 Intended use

Composite GFRP bar reinforcement Composite TopBAR is used to reinforce load and non-load bearing elements of monolithic and precast concrete structures. It is used primarily in those parts of buildings that are exposed to an increased risk of corrosion, in structures with requirements for protection against electromagnetic influences, and in structures were cutting of the reinforced structure is considered.

Composite TopBAR is intended to be used as reinforcement of construction works and elements made of reinforced concrete (beams, columns, panels, slabs and other structural elements). Bars are use in parts of concrete structures in which is full bond between reinforcement bar and concrete at whole length of a bar.

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.

# 3. Evaluation of Available Data

## 3.1 Cross-sectional properties

Cross-sectional properties have been determined by the tests according to EAD 260023-00-0301, clause 2.2.1. Test results are documented in [8] and presented in Table 1 to Table 4.

**Table 1 – Effective diameter $d_{eff}$ and effective cross-sectional area $A_{eff}$ of rebars with diameter of 6 mm**

| Diameter (mm) | Test piece no. | Effective cross-sectional area $A_{eff}$ (mm²) | | Effective diameter $d_{eff}$ (mm) | |
|---|---|---|---|---|---|
| | | Single value | Average | Single value | Average |
| 6 | 1 | 29,9 | 30,2 | 6,2 | 6,2 |
| | 2 | 29,7 | | 6,2 | |
| | 3 | 30,0 | | 6,2 | |
| | 4 | 31,5 | | 6,3 | |
| | 5 | 29,7 | | 6,2 | |
| | 6 | 29,8 | 30,0 | 6,2 | 6,2 |
| | 7 | 30,7 | | 6,3 | |
| | 8 | 29,8 | | 6,2 | |
| | 9 | 29,7 | | 6,2 | |
| | 10 | 29,9 | | 6,2 | |
| | 11 | 29,6 | 29,7 | 6,1 | 6,2 |
| | 12 | 29,8 | | 6,2 | |
| | 13 | 29,7 | | 6,2 | |
| | 14 | 29,7 | | 6,2 | |
| | 15 | 29,6 | | 6,1 | |
| Maximum value | | 30,2 | | 6,2 | |
| Minimum value | | 29,7 | | 6,2 | |
| Average value | | **29,9** | | **6,2** | |

**Table 2 – Effective diameter $d_{eff}$ and effective cross-sectional area $A_{eff}$ of rebars with diameter of 8 mm**

| Diameter (mm) | Test piece no. | Effective cross-sectional area $A_{eff}$ (mm²) | | Effective diameter $d_{eff}$ (mm) | |
|---|---|---|---|---|---|
| | | Single value | Average | Single value | Average |
| 8 | 1 | 52,3 | 52,5 | 8,2 | 8,2 |
| | 2 | 52,5 | | 8,2 | |
| | 3 | 52,5 | | 8,2 | |
| | 4 | 52,6 | | 8,2 | |
| | 5 | 52,5 | | 8,2 | |
| | 6 | 53,0 | 53,4 | 8,2 | 8,3 |
| | 7 | 53,1 | | 8,2 | |
| | 8 | 53,1 | | 8,2 | |
| | 9 | 54,0 | | 8,3 | |
| | 10 | 53,9 | | 8,3 | |
| | 11 | 52,3 | 52,6 | 8,2 | 8,2 |
| | 12 | 52,5 | | 8,2 | |
| | 13 | 52,5 | | 8,2 | |
| | 14 | 52,6 | | 8,2 | |
| | 15 | 53,2 | | 8,2 | |
| Maximum value | | 53,4 | | 8,3 | |
| Minimum value | | 52,5 | | 8,2 | |
| Average value | | **52,8** | | **8,2** | |

**Table 3 – Effective diameter $d_{eff}$ and effective cross-sectional area $A_{eff}$ of rebars with diameter of 12 mm**

| Diameter (mm) | Test piece no. | Effective cross-sectional area $A_{eff}$ (mm²) | | Effective diameter $d_{eff}$ (mm) | |
|---|---|---|---|---|---|
| | | Single value | Average | Single value | Average |
| 12 | 1 | 118,7 | 115,3 | 12,3 | 12,1 |
| | 2 | 115,4 | | 12,1 | |
| | 3 | 113,8 | | 12,0 | |
| | 4 | 114,1 | | 12,1 | |
| | 5 | 114,3 | | 12,1 | |
| | 6 | 114,6 | 114,7 | 12,1 | 12,1 |
| | 7 | 115,4 | | 12,1 | |
| | 8 | 113,6 | | 12,0 | |
| | 9 | 115,0 | | 12,1 | |
| | 10 | 114,9 | | 12,1 | |
| | 11 | 117,9 | 116,1 | 12,1 | 12,2 |
| | 12 | 118,3 | | 12,1 | |
| | 13 | 113,7 | | 12,0 | |
| | 14 | 115,2 | | 12,1 | |
| | 15 | 115,4 | | 12,1 | |
| Maximum value | | 116,1 | | 12,2 | |
| Minimum value | | 114,7 | | 12,1 | |
| Average value | | **115,6** | | **12,1** | |

**Table 4 – Effective diameter $d_{eff}$ and effective cross-sectional area $A_{eff}$ of rebars with diameter of 16 mm**

| Diameter (mm) | Test piece no. | Effective cross-sectional area $A_{eff}$ (mm²) | | Effective diameter $d_{eff}$ (mm) | |
|---|---|---|---|---|---|
| | | Single value | Average | Single value | Average |
| 16 | 1 | 209,4 | 209,1 | 16,3 | 16,3 |
| | 2 | 208,0 | | 16,3 | |
| | 3 | 210,0 | | 16,4 | |
| | 4 | 208,9 | | 16,3 | |
| | 5 | 209,3 | | 16,3 | |
| | 6 | 207,8 | 208,9 | 16,3 | 16,3 |
| | 7 | 209,7 | | 16,3 | |
| | 8 | 208,5 | | 16,3 | |
| | 9 | 209,1 | | 16,3 | |
| | 10 | 209,3 | | 16,3 | |
| | 11 | 208,6 | 208,4 | 16,3 | 16,3 |
| | 12 | 208,3 | | 16,3 | |
| | 13 | 207,9 | | 16,3 | |
| | 14 | 208,1 | | 16,3 | |
| | 15 | 208,9 | | 16,3 | |
| Maximum value | | 209,1 | | 16,3 | |
| Minimum value | | 208,4 | | 16,3 | |
| Average value | | **208,8** | | **16,3** | |

### 3.2 Tensile strength

Tensile strength has been determined by tests according to EAD 260023-00-0301, clause 2.2.2. Test results are documented in [9] and presented in Table 5.

**Table 5 – Tensile strength**

| Test piece no./ Diameter (mm) | Tensile strength $f_{ft}$ (MPa) | | | |
|---|---|---|---|---|
| | Ø6 | Ø8 | Ø12 | Ø16 |
| 1 | 1184 | 1200 | 1115 | 952 |
| 2 | 1356 | 1154 | 1100 | 906 |
| 3 | 1305 | 1113 | 1067 | 866 |
| 4 | 1353 | 1180 | 1105 | 938 |
| 5 | 1320 | 1174 | 1125 | 939 |
| 6 | 1260 | 1123 | 1136 | 935 |
| 7 | 1177 | 1095 | 1187 | 953 |
| 8 | 1252 | 1211 | 1073 | 967 |
| 9 | 1186 | 1198 | 1141 | 930 |
| 10 | 1153 | 1111 | 1097 | 1010 |
| 11 | 1221 | 1184 | 1115 | 943 |
| 12 | 1181 | 1142 | 1128 | 1000 |
| 13 | 1189 | 1154 | 1143 | 904 |
| 14 | 1193 | 1209 | 1080 | 960 |
| 15 | 1297 | 1139 | 1147 | 931 |
| 16 | 1226 | 1216 | 1079 | 934 |
| 17 | 1248 | 1148 | 1121 | 965 |
| 18 | 1224 | 1218 | 1153 | 923 |
| 19 | 1197 | 1155 | 1100 | 973 |
| 20 | 1171 | 1152 | 1135 | 942 |
| 21 | 1229 | 1170 | 1120 | 892 |
| 22 | 1133 | 1194 | 1054 | 899 |
| 23 | 1148 | 1189 | 1138 | 945 |
| 24 | 1148 | 1138 | 1052 | 962 |
| 25 | 1121 | 1157 | 1130 | 939 |
| Average value $f_{t0}$ | 1218,9 | 1165,0 | 1113,6 | 940,3 |
| Standard deviation | 66,307 | 34,741 | 33,005 | 32,032 |
| Coefficient of variation | 5,4% | 3,0% | 3,0% | 3,4% |
| Minimum value | 1121 | 1095 | 1052 | 866 |
| Maximum value | 1356 | 1218 | 1187 | 1010 |
| Characteristic value $f_{t0k}$ | 1103,2 | 1104,3 | 1056,0 | 884,4 |
| Type of failure | rupture of vicinity in anchor area | | | |

### 3.3 Tensile modulus of elasticity

Tensile modulus of elasticity has been determined by tests according to EAD 260023-00-0301, clause 2.2.2. Test results are documented in [9] and presented in Table 6.

**Table 6 – Tensile modulus of elasticity**

| Test piece no./ Diameter (mm) | Tensile modulus of elasticity *E* (GPa) | | | |
|---|---|---|---|---|
| | Ø6 | Ø8 | Ø12 | Ø16 |
| 1 | 52,2 | 53,2 | 52,8 | 52,4 |
| 2 | 51,3 | 52,5 | 51,0 | 52,4 |
| 3 | 51,9 | 52,6 | 51,3 | 51,1 |
| 4 | 51,8 | 51,8 | 51,6 | 50,7 |
| 5 | 52,3 | 51,1 | 51,8 | 52,0 |
| 6 | 51,0 | 51,9 | 52,3 | 52,2 |
| 7 | 52,4 | 51,2 | 51,9 | 53,2 |
| 8 | 50,6 | 52,4 | 51,3 | 52,3 |
| 9 | 51,4 | 51,8 | 50,9 | 52,1 |
| 10 | 51,8 | 53,1 | 51,5 | 52,9 |
| 11 | 51,0 | 53,3 | 51,4 | 51,7 |
| 12 | 51,5 | 52,1 | 51,9 | 51,3 |
| 13 | 51,7 | 52,0 | 51,8 | 55,3 |
| 14 | 51,0 | 51,8 | 51,5 | 55,3 |
| 15 | 50,0 | 52,2 | 51,3 | 52,8 |
| 16 | 51,7 | 52,3 | 51,5 | 53,7 |
| 17 | 50,8 | 53,7 | 52,2 | 51,5 |
| 18 | 52,0 | 53,7 | 52,3 | 51,8 |
| 19 | 51,9 | 52,2 | 52,9 | 52,1 |
| 20 | 51,3 | 52,6 | 51,6 | 52,4 |
| 21 | 51,3 | 52,9 | 51,9 | 53,6 |
| 22 | 52,0 | 51,6 | 53,7 | 51,0 |
| 23 | 51,7 | 53,6 | 52,5 | 52,3 |
| 24 | 50,0 | 53,4 | 52,4 | 53,0 |
| 25 | 51,0 | 52,1 | 52,4 | 52,0 |
| Average value $E_f$ | 51,4 | 52,4 | 51,9 | 52,4 |
| Standard deviation | 0,633 | 0,760 | 0,642 | 1,143 |
| Coefficient of variation | 1,2% | 1,4% | 1,2% | 2,2% |
| Minimum value | 50,011 | 51,05 | 50,872 | 50,695 |
| Maximum value | 52,398 | 53,704 | 53,65 | 55,344 |

### 3.4 Tensile failure strain

Tensile failure strain has been determined by test according to EAD 260023-00-0301, clause 2.2.2. Test results are documented in [9] and presented in Table 7.

**Table 7 – Tensile failure strain**

| Test piece no./ Diameter (mm) | Tensile failure strain $\varepsilon_{ft}$ (mm/mm) | | | |
|---|---|---|---|---|
| | Ø6 | Ø8 | Ø12 | Ø16 |
| 1 | 0,022 | 0,023 | 0,021 | 0,020 |
| 2 | 0,023 | 0,022 | 0,022 | 0,020 |
| 3 | 0,022 | 0,023 | 0,020 | 0,020 |
| 4 | 0,021 | 0,023 | 0,020 | 0,020 |
| 5 | 0,021 | 0,023 | 0,021 | 0,020 |
| 6 | 0,022 | 0,022 | 0,020 | 0,020 |
| 7 | 0,023 | 0,022 | 0,021 | 0,020 |
| 8 | 0,021 | 0,023 | 0,020 | 0,021 |
| 9 | 0,021 | 0,022 | 0,021 | 0,020 |
| 10 | 0,022 | 0,021 | 0,021 | 0,023 |
| 11 | 0,023 | 0,023 | 0,021 | 0,021 |
| 12 | 0,020 | 0,023 | 0,023 | 0,023 |
| 13 | 0,021 | 0,021 | 0,023 | 0,021 |
| 14 | 0,022 | 0,022 | 0,021 | 0,020 |
| 15 | 0,024 | 0,022 | 0,021 | 0,023 |
| 16 | 0,022 | 0,022 | 0,022 | 0,020 |
| 17 | 0,022 | 0,021 | 0,021 | 0,021 |
| 18 | 0,023 | 0,022 | 0,022 | 0,020 |
| 19 | 0,023 | 0,021 | 0,023 | 0,020 |
| 20 | 0,022 | 0,022 | 0,021 | 0,021 |
| 21 | 0,022 | 0,022 | 0,021 | 0,022 |
| 22 | 0,022 | 0,023 | 0,020 | 0,020 |
| 23 | 0,022 | 0,023 | 0,020 | 0,021 |
| 24 | 0,022 | 0,023 | 0,020 | 0,020 |
| 25 | 0,022 | 0,023 | 0,021 | 0,021 |
| Average value $\varepsilon_{ft0}$ | 0,022 | 0,022 | 0,021 | 0,021 |
| Standard deviation | 0,0009 | 0,0007 | 0,0010 | 0,0010 |
| Coefficient of variation | 3,9% | 3,3% | 4,5% | 4,9% |
| Minimum value | 0,020 | 0,021 | 0,020 | 0,020 |
| Maximum value | 0,024 | 0,023 | 0,023 | 0,023 |
| **Characteristic value $\varepsilon_{ft0k}$** | **0,020** | **0,021** | **0,019** | **0,019** |

## 3.5 Compressive strength

Compressive strength has been determined by tests according to EAD 260023-00-0301, clause 2.2.3. Test results are documented in [10] and presented in Table 8.

**Table 8 – Compressive strength**

| Test piece no./ Diameter (mm) | Compressive strength $f_c$ (MPa) | | | |
|---|---|---|---|---|
| | Ø6 | Ø8 | Ø12 | Ø16 |
| 1 | 306 | 456 | 492 | 383 |
| 2 | 336 | 501 | 535 | 375 |
| 3 | 316 | 494 | 458 | 435 |
| 4 | 353 | 540 | 493 | 400 |
| 5 | 351 | 516 | 460 | 442 |
| 6 | 320 | 553 | 508 | 430 |
| 7 | 314 | 500 | 477 | 414 |
| 8 | 370 | 524 | 482 | 384 |
| 9 | 300 | 560 | 495 | 381 |
| 10 | 310 | 548 | 461 | 385 |
| 11 | 311 | 468 | 427 | 409 |
| 12 | 311 | 477 | 481 | 381 |
| 13 | 313 | 534 | 450 | 391 |
| 14 | 287 | 529 | 475 | 396 |
| 15 | 307 | 497 | 485 | 431 |
| Average value | 320,3 | 513,1 | 478,6 | 402,5 |
| Standard deviation | 22,395 | 31,724 | 25,823 | 22,756 |
| Coefficient of variation | 7,0% | 6,2% | 5,4% | 5,7% |
| Minimum value | 287 | 456 | 427 | 375 |
| Maximum value | 370 | 560 | 535 | 442 |
| **Characteristic value** | **279,1** | **454,8** | **431,1** | **360,6** |
| Type of failure | delamination | | | |

## 3.6 Compressive modulus

Compressive modulus has been determined by tests according to EAD 260023-00-0301, clause 2.2.3. Test results are documented in [10] and presented in Table 9.

**Table 9 – Compressive modulus**

| Test piece no./ Diameter (mm) | Compressive modulus $f_c$ (GPa) | | | |
|---|---|---|---|---|
| | Ø6 | Ø8 | Ø12 | Ø16 |
| 1 | 48,01 | 50,19 | 42,51 | 44,62 |
| 2 | 44,76 | 51,43 | 43,46 | 45,97 |
| 3 | 42,91 | 51,26 | 48,03 | 50,50 |
| 4 | 42,78 | 47,23 | 43,12 | 49,93 |
| 5 | 47,81 | 43,80 | 45,63 | 46,28 |
| 6 | 46,56 | 43,03 | 45,16 | 53,64 |
| 7 | 42,49 | 43,72 | 44,77 | 46,80 |
| 8 | 43,08 | 51,67 | 44,68 | 51,11 |
| 9 | 44,88 | 46,94 | 41,52 | 50,70 |
| 10 | 42,90 | 44,01 | 46,92 | 50,29 |
| 11 | 48,09 | 51,81 | 41,94 | 47,15 |
| 12 | 42,54 | 48,39 | 41,79 | 48,95 |
| 13 | 46,83 | 47,44 | 43,80 | 53,81 |
| 14 | 46,65 | 48,64 | 43,02 | 47,12 |
| 15 | 49,85 | 46,97 | 44,09 | 46,28 |
| Average value | 45,3 | 47,8 | 44,0 | 48,9 |
| Standard deviation | 2,487 | 3,101 | 1,878 | 2,822 |
| Coefficient of variation | 5,5% | 6,5% | 4,3% | 5,8% |
| Minimum value | 42,49 | 43,03 | 41,52 | 44,62 |
| Maximum value | 49,85 | 51,81 | 48,03 | 53,81 |
| **Characteristic value** | **40,8** | **42,1** | **40,6** | **43,7** |

### 3.7 Bond strength in concrete by pull-out testing

Bond strength in concrete has been determined by tests according to EAD 260023-00-0301, clause 2.2.4. Only centric test was performed, with reinforcement bars not submerged in alkaline solution. Test results are documented in [11] and presented in Table 10.

**Table 10 – Bond strength in concrete by pull-out testing**

| Bond strength in concrete by pull-out testing $\tau_b$ (MPa) | C20/25;20°C | | | C50/60;20°C |
|---|---|---|---|---|
| | ∅6 | ∅12 | ∅16 | ∅16 |
| 1 | 24,6 | 12,7 | 10,1 | 19,9 |
| 2 | 27,8 | 13,3 | 10,7 | 18,1 |
| 3 | 27,5 | 12,0 | 10,4 | 19,9 |
| 4 | 20,9 | 13,3 | 10,1 | 18,7 |
| 5 | 25,7 | 13,6 | 9,8 | 20,0 |
| Average value | 25,3 | 13,0 | 10,2 | 19,3 |
| Standard deviation | 2,788 | 0,638 | 0,342 | 0,867 |
| Coefficient of variation | 11,0% | 4,9% | 3,3% | 4,5% |
| Minimum value | 20,9 | 12 | 9,8 | 18,1 |
| Maximum value | 27,8 | 13,6 | 10,7 | 20 |
| **Characteristic value** | **18,8** | **11,5** | **9,4** | **17,3** |
| Type of failure | pull-out | | | |
| Average substrate compressive strength in MPa | 29,2 | 29,0 | 28,9 | 60,8 |

## 3.8 Transverse shear strength

Transverse shear strength has been determined by test according to EAD 260023-00-0301, clause 2.2.5. Test results are documented in [12] and presented in Table 11.

**Table 11 – Transverse shear strength**

| Transverse shear strength $\tau_s$ (MPa) | Ø6 | Ø8 | Ø12 | Ø16 |
|---|---|---|---|---|
| 1 | 216,4 | 177,2 | 169,2 | 151,1 |
| 2 | 206,2 | 164,6 | 174,7 | 146,0 |
| 3 | 211,9 | 185,8 | 184,5 | 158,4 |
| 4 | 218,7 | 176,6 | 176,4 | 159,1 |
| 5 | 242,5 | 189,8 | 159,2 | 149,5 |
| 6 | 228,3 | 172,8 | 163,4 | 159,6 |
| 7 | 215,9 | 173,6 | 167,1 | 146,3 |
| 8 | 199,5 | 189,4 | 166,9 | 157,5 |
| 9 | 229,8 | 182,6 | 181,4 | 157,3 |
| 10 | 215,6 | 186,7 | 172,9 | 163,9 |
| 11 | 252,5 | 217,8 | 170,0 | 144,7 |
| 12 | 241,3 | 198,3 | 169,0 | 158,1 |
| 13 | 198,5 | 172,6 | 170,3 | 153,7 |
| 14 | 235,0 | 186,6 | 175,2 | 160,2 |
| 15 | 213,9 | 204,6 | 183,2 | 151,6 |
| 16 | 222,4 | 193,1 | 181,1 | 155,3 |
| 17 | 223,9 | 197,3 | 176,8 | 165,3 |
| 18 | 220,2 | 180,7 | 184,9 | 155,7 |
| 19 | 247,0 | 177,6 | 178,8 | 169,5 |
| 20 | 209,5 | 185,5 | 166,4 | 159,0 |
| 21 | 250,0 | 202,9 | 178,7 | 165,8 |
| 22 | 240,6 | 181,0 | 174,1 | 162,0 |
| 23 | 224,8 | 203,0 | 188,3 | 157,9 |
| 24 | 205,2 | 187,6 | 185,1 | 160,2 |
| 25 | 224,4 | 180,9 | 173,4 | 159,4 |
| Average value | 223,8 | 186,7 | 174,8 | 157,1 |
| Standard deviation | 15,445 | 12,196 | 7,517 | 6,269 |
| Coefficient of variation | 6,9% | 6,5% | 4,3% | 4,0% |
| Minimum value | 198,5 | 164,6 | 159,2 | 144,7 |
| Maximum value | 252,5 | 217,8 | 188,3 | 169,5 |
| **Characteristic value** | **196,8** | **165,5** | **161,7** | **146,1** |
| Type of failure | shear at both surfaces | | | |

## 3.9 Interlaminar shear strength

Interlaminar shear strength has been determined by tests according to EAD 260023-00-0301, clause 2.2.6. Test results are documented in [13] and presented in Table 12. Span to diameter ratio was 3:1.

**Table 12 – Interlaminar shear strength**

| Interlaminar shear strength (MPa) | Ø6 | Ø8 | Ø12 | Ø16 |
|---|---|---|---|---|
| 1 | 43,51 | 44,44 | 47,32 | 46,78 |
| 2 | 47,71 | 46,97 | 44,19 | 46,30 |
| 3 | 46,16 | 49,37 | 47,38 | 48,95 |
| 4 | 47,26 | 45,33 | 47,55 | 49,21 |
| 5 | 47,71 | 42,55 | 46,51 | 48,41 |
| 6 | 48,15 | 45,08 | 50,04 | 44,83 |
| 7 | 43,07 | 46,59 | 49,52 | 48,44 |
| 8 | 45,06 | 47,10 | 47,49 | 46,78 |
| 9 | 43,95 | 49,12 | 48,07 | 48,83 |
| 10 | 43,51 | 45,46 | 48,36 | 47,01 |
| 11 | 44,84 | 44,82 | 45,58 | 48,41 |
| 12 | 45,28 | 47,35 | 44,65 | 49,34 |
| 13 | 45,72 | 44,07 | 49,12 | 48,44 |
| 14 | 44,61 | 46,47 | 49,17 | 46,85 |
| 15 | 46,16 | 44,70 | 47,32 | 47,84 |
| 16 | 45,06 | 44,95 | 49,23 | 47,68 |
| 17 | 47,71 | 46,21 | 46,74 | 47,90 |
| 18 | 44,61 | 46,84 | 47,20 | 45,82 |
| 19 | 46,16 | 46,59 | 46,22 | 46,08 |
| 20 | 47,04 | 45,96 | 49,81 | 47,23 |
| 21 | 43,95 | 43,06 | 50,74 | 49,24 |
| 22 | 47,93 | 48,23 | 48,25 | 47,87 |
| 23 | 46,16 | 43,81 | 48,36 | 45,98 |
| 24 | 45,94 | 45,46 | 51,67 | 45,34 |
| 25 | 47,71 | 49,12 | 45,81 | 48,09 |
| Average value | 45,8 | 46,0 | 47,9 | 47,5 |
| Standard deviation | 1,565 | 1,814 | 1,831 | 1,284 |
| Coefficient of variation | 3,4% | 3,9% | 3,8% | 2,7% |
| Minimum value | 43,07 | 42,55 | 44,19 | 44,83 |
| Maximum value | 48,15 | 49,37 | 51,67 | 49,34 |
| **Characteristic value** | **43,1** | **42,8** | **44,7** | **45,3** |
| Type of failure | Interlaminar (horizontal) shear | | | |

## 3.10 Tensile fatigue

No performance assessed

## 3.11 Creep failure

No performance assessed

## 3.12 Coefficient of longitudinal thermal expansion

Coefficient of longitudinal thermal expansion has been determined by tests according to EAD 260023-00-0301, clause 2.2.9. Test results are documented in [14] and presented in Table 13.

**Table 13 – Coefficient of longitudinal thermal expansion**

| Coefficient of longitudinal thermal expansion $\alpha_{sp,L}$ (°C$^{-1}$) | ∅6 | ∅12 | ∅16 |
|---|---|---|---|
| average value | 5,4 E-06 | 5,3 E-06 | 4,8 E-06 |

## 3.13 Coefficient of transverse thermal expansion

Coefficient of transverse thermal expansion has been determined by tests according to EAD 260023-00-0301, clause 2.2.10. Test results are documented in [14] and presented in Table 14.

**Table 14 – Coefficient of transverse thermal expansion**

| Coefficient of transverse thermal expansion $\alpha_{sp,T}$ (°C$^{-1}$) | ∅6 | ∅12 | ∅16 |
|---|---|---|---|
| average value | 1,59 E-05 | 1,57 E-05 | 1,77 E-05 |

## 3.14 Glass transition temperature

Glass transition temperature has been determined by tests according to EAD 260023-00-0301, clause 2.2.11. Test results are documented in [14] and presented in Table 15.

**Table 15 – Glass transition temperature**

| Glass transition temperature $T_g$ (°C) | ∅12 | | | |
|---|---|---|---|---|
| Glass transition temperature, first cycle | $T_{g,I}{}^{S}$ | 89,6 | $T_{g,I}{}^{C}$ | 93,9 |
| Glass transition temperature, second cycle | $T_{g,II}{}^{S}$ | 106,3 | $T_{g,II}{}^{C}$ | 109,7 |
| Cure ratio $T^{S}_{g,I}$ - $T^{C}_{g,I}$ | 4,3 | | | |

## 3.15 Long-term relaxation

Performance not assessed.

## 3.16 Maximum service temperature

Maximum service temperature has been determined experimentally by tests according to EAD 260023-00-0301, clause 2.2.13. Resulting value was evaluated as characteristic value from first/second derivation. Test results are documented in [15] and presented in Tables 16 to 18.

**Table 16 – Maximum service temperature** – diameter 6 mm

| Diameter (mm) | No. of the test specimen | Effective cross-sectional area $A_{eff}$ (mm²) | Load $P$ (N) | Extreme of the 1st derivative $T_c$ (°C) | Extreme of the 2nd derivative $T_{1a}$ (°C) | Maximum service temperature $T_{max}$ (°C) |
|---|---|---|---|---|---|---|
| **6** | 1 | 29,9 | 168 | 90,5 | 68,6 | 66,8 |
| | 2 | | | 90,7 | 73,2 | 72,2 |
| | 3 | | | 84,6 | 66,8 | 65,2 |
| | 4 | | | 86,9 | 71,8 | 70,2 |
| | 5 | | | 89,6 | 75,0 | 72,2 |
| | | | **Average** | 88,46 | 71,09 | 69,31 |
| | | | **Minimum** | 84,60 | 66,84 | 65,17 |
| | | | **Standard deviation** | 2,65 | 3,34 | 3,21 |
| | | | **Coefficient of variation** | 3,0% | 4,7% | 4,6% |

**Table 17 – Maximum service temperature** – diameter 12 mm

| Diameter (mm) | No. of the test specimen | Effective cross-sectional area $A_{eff}$ (mm²) | Load $P$ (N) | Extreme of the 1st derivative $T_c$ (°C) | Extreme of the 2nd derivative $T_{1a}$ (°C) | Maximum service temperature $T_{max}$ (°C) |
|---|---|---|---|---|---|---|
| **12** | 1 | 115,6 | 802 | 103,7 | 71,7 | 68,4 |
| | 2 | | | 107,6 | 72,6 | 70,8 |
| | 3 | | | 107,3 | 72,2 | 70,2 |
| | 4 | | | 107,8 | 72,0 | 68,5 |
| | 5 | | | 102,1 | 70,9 | 67,8 |
| | | | **Average** | 105,71 | 71,88 | 69,14 |
| | | | **Minimum** | 102,13 | 70,92 | 67,83 |
| | | | **Standard deviation** | 2,62 | 0,64 | 1,26 |
| | | | **Coefficient of variation** | 2,5% | 0,9% | 1,8% |

**Table 18 – Maximum service temperature** – diameter 16 mm

| Diameter (mm) | No. of the test specimen | Effective cross-sectional area $A_{eff}$ (mm²) | Load $P$ (N) | Extreme of the 1st derivative $T_c$ (°C) | Extreme of the 2nd derivative $T_{1a}$ (°C) | Maximum service temperature $T_{max}$ (°C) |
|---|---|---|---|---|---|---|
| **16** | 1 | 208,8 | 1410 | 105,8 | 72,1 | 68,6 |
| | 2 | | | 105,8 | 72,1 | 68,6 |
| | 3 | | | 106,0 | 72,0 | 69,1 |
| | 4 | | | 105,0 | 72,6 | 70,0 |
| | 5 | | | 107,0 | 71,9 | 69,5 |
| | | | **Average** | 105,91 | 72,15 | 69,17 |
| | | | **Minimum** | 104,98 | 71,94 | 68,58 |
| | | | **Standard deviation** | 0,74 | 0,24 | 0,63 |
| | | | **Coefficient of variation** | 0,7% | 0,3% | 0,9% |

### 3.17 Bond strength in concrete at maximum service temperature

Bond strength in concrete at maximum service temperature has been determined by test according to EAD 260023-00-0301 (method ISO 10 406-1, Clause 7). Maximum service temperature value was determined at 80°C. Test results are documented in [11] and presented in Table 19.

**Table 19 – Bond strength in concrete at maximum service temperature**

| Bond strength in concrete by pull-out testing $\tau$ (MPa) | C20/25;80°C | | |
|---|---|---|---|
| | **Ø6** | **Ø12** | **Ø16** |
| 1 | 16,4 | 11,1 | 7,7 |
| 2 | 17,5 | 11,9 | 8,9 |
| 3 | 17,8 | 10,9 | 8,9 |
| 4 | 16,3 | 12,3 | 8,8 |
| 5 | 18,1 | 10,9 | 8,0 |
| average value | 17,2 | 11,4 | 8,5 |
| standard deviation | 0,823 | 0,642 | 0,568 |
| variation coefficient | 4,8% | 5,6% | 6,7% |
| minimal value | 16,3 | 10,9 | 7,7 |
| maximal value | 18,1 | 12,3 | 8,9 |
| characteristic value | **15,3** | **9,9** | **7,1** |
| type of failure | pull-out | | |
| average substrate compressive strength in MPa | 29,2 | 29,0 | 28,9 |

### 3.18 Strength of FRP bent bars

No performance assessed

### 3.19 Reaction to fire

No performance assessed

### 3.20 Alkali resistance

Alkali resistance has been determined by tests according to EAD 260023-00-0301, clause 2.2.16. Solution consisted from demineralized water mixed with 8,0 g of KOH and 22,4 g of NaOH. Resulting pH was > 13. Only rate of percentage of mass loss and tensile retention rate was determined. Test results are documented in [16] and [17] and presented in Tables 20 and 21.

**Table 20 – Alkali resistance – rate of percentage mass loss**

| Rate of percentage mass loss (%) | Ø6 | Ø10 | Ø12 |
|---|---|---|---|
| 1 | 2,24% | 0,80% | 0,38% |
| 2 | 2,29% | 0,80% | 0,36% |
| 3 | 2,26% | 0,79% | 0,36% |
| 4 | 2,24% | 0,80% | 0,36% |
| 5 | 2,24% | 0,79% | 0,36% |
| average | 2,25% | 0,80% | 0,36% |
| standard deviation | 0,000219 | 0,000055 | 0,000089 |
| coefficient of variation | 0,97% | 0,69% | 2,46% |
| result of visual inspection | chalking of surface (loss of colour) | | |

**Table 21 – Alkali resistance – tensile retention rate**

| Tensile retention rate $R_{et,t}$ (%) | Ø6 | Ø12 | Ø16 |
|---|---|---|---|
| 1 | 88,0% | 69,2% | 69,7% |
| 2 | 84,7% | 52,5% | 66,4% |
| 3 | 89,6% | 57,8% | 75,2% |
| 4 | 86,7% | 64,6% | 69,0% |
| 5 | 89,2% | 69,5% | 67,1% |
| average | 88% | 63% | 69% |
| standard deviation | 0,0199 | 0,0741 | 0,0347 |
| coefficient of variation | 2,3% | 11,8% | 5,0% |
| minimum | 84,7% | 52,5% | 66,4% |
| maximum | 89,6% | 69,5% | 75,2% |

The tensile retention capacity $R_{et,t}$ (%) for specimens of 3000h at temperature of 60°C ±3°C: No performance assessed

The interlaminar $R_{et,i}$ (%) capacity retention after submersion in alkaline solution: No performance assessed

## 4. References


[1] EAD 260023-00-0301 „Carbon, glass, basalt and aramid fibre reinforced polymer bars as reinforcement of structural elements", edition January 2019

[2] EN 206:2013+A2:2021 Concrete – specification, performance, production and conformity.

[3] EN 705:1994 /AC:1995 Plastics piping systems – Glass-reinforced thermosetting plastics (GRP) pipes and fittings – Methods for regression analysis and their use

[4] EN 1990:2023 Eurocode 0 – Basis of structural design and geotechnical design

[5] EN 1992-1-1:2023 Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings, bridges and civil engineering structures

[6] ISO 10406-1:2015 Fiber-reinforced polymer (FRP) reinforcement of concrete – Test method. Part 1: FRP bars and grids

[7] ISO 11359-1:2023 Plastics – Thermomechanical analysis (TMA) – Part 1: General principles

[8] Test report no. 20-21-1567 (Cross-sectional characteristics). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 13.09.2021

[9] Test report no. 20-21-1568 (Tensile properties). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 19.01.2022

[10] Test report no. 20-22-0097 (Compressive strength). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 23.01.2022

[11] Test report no. 20-22-0094 (Bond strength by pull-out testing). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 19.01.2022

[12] Test report no. 20-21-1611 (Transverse shear strength). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 27.09.2021

[13] Test report no. 20-21-1612 (Interlaminar shear strength). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 13.01.2022

[14] Test report no. 462204576-01 (Coefficient of longitudinal thermal expansion). Issued by the Institute for Testing and Certification, as, test laboratory, Zlín, Czech Republic, 11.11.2021

[15] Test report no. 20-21-1643 (Maximal service temperature). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 10.12.2021

[16] Test report no. 20-22-0096 (Alkali resistance). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 19.01.2022

[17] Test report no. 20-24-1081 (Alkali resistance). Issued by Building, Testing and Research Institute, Testing laboratory, Laboratory branch Bratislava, 27.08.2024

[18] Rules of the Technological Process of GFRP – Control plan. Published by Composite Group, s. r. o., Bratislava, Slovak Republic, 09/2024

[19] Guidelines for the use, transport, storage and handling of composite reinforcement GFRP bar-reinforcement Composite TopBAR, Rev. 0. Published by Composite Group, s. r. o., Bratislava, Slovak Republic, 04/2022


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Prepared by: Ing. Patrik Ševčík