

## reinforcement

# Bendable and recyclable thermoplastic rebars for durable concrete structures

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**A novel and recyclable thermoplastic composite reinforcement has been developed to design and build highly durable structures, as well as to reduce the current high cost of corrosion and contribute to circular economy. In the TOP-Crete project, the short and long-term mechanical properties of this reinforcement are characterised as long as their performance as embedded reinforcement.**

**A** new class of thermoplastic composite reinforcement bars for concrete structures, designed to address current limitations in durability, sustainability and supply chain flexibility, has been successfully developed by Sireg Geotech S.r.l. and Arkema. These rebars, marketed under the name Glasspree® TP bars (Figure 1), are produced by Sireg Geotech through a continuous pultrusion process using E-CR glass fibre direct roving impregnated with Arkema's Elium® resin – a thermoplastic acrylic matrix.

In addition to the advantages of traditional thermoset-based GFRP rebars, the thermoplastic nature of Elium® enables thermoforming after production. The bars

can be bent or shaped post-manufacturing, offering customisation possibilities at processing centres near construction sites, thanks to a dedicated heat-bending process and equipment developed by Sireg Geotech. This allows reinforcements to be shaped into their final geometry without compromising mechanical performance.

This approach offers several practical advantages. Glasspree® TP bars can be transported in straight lengths, reducing bulk and optimising logistics. Shaping is performed as needed according to project-specific geometries, thereby minimising pre-formed stock requirements and reducing production waste. This flexibility is particularly beneficial for infrastructure works with complex or variable reinforcement designs, enabling efficient large-scale implementation of thermoplastic GFRP rebars as a viable alternative to traditional steel reinforcement.

## Mechanical strength and durability

From a performance perspective, Glasspree® TP bars demonstrate tensile strengths of up to 950 MPa and an elastic modulus of up to 50 GPa, with diameters ranging from 6 to 25 mm. The bars are

approximately 75% lighter than traditional steel reinforcement, significantly easing handling, lowering transport costs and reducing labour intensity and the risk of worker injury (Table 1).

Their intrinsic corrosion resistance eliminates the need for protective coatings or treatments, extending the lifespan of concrete structures, especially in aggressive environments such as coastal zones, marine settings or areas exposed to de-icing salts. Additionally, Glasspree® TP bars are thermally stable and retain mechanical properties over a wide temperature range, supporting service life expectations of up to 100 years.

The rebars are also non-conductive – both electrically and magnetically – making them ideal for use in environments sensitive to electromagnetic interference, such as tunnels with signal systems, bridges with monitoring equipment, or urban rail, tram and metro networks.

## Cost savings across the lifecycle

From a cost perspective, thermoplastic GFRP rebars can offer economic advantages over traditional steel in specific applications, such as aggressive environments. Although the initial material cost



Fig. 1: Glasspree® TP bars

Tab. 1: Comparison of conventional steel reinforcement with TP-FRP rebars, highlighting performance, durability and cost-efficiency over service life

Property	Steel rebars	TP-GFRP rebars
Tensile strength	~500–600 MPa	up to 907 MPa
Elastic modulus	~200 GPa	up to 48 GPa
Density	7.85 g/cm <sup>3</sup>	~2.10 g/cm <sup>3</sup> (~75% lighter)
Corrosion resistance	Requires coating/protection	Intrinsic resistance (no coating)
Service life	50 years	Up to 100 years
Conductivity	Conductive	Non-conductive
Initial material cost	Low	High
Lifecycle cost (LCC)	High (maintenance needed)	Low

of GFRP is higher, it eliminates the need for protective coatings and other corrosion mitigation measures. Its lightweight nature simplifies transport and installation, reducing labour costs, while its inherent corrosion resistance minimises long-term maintenance and operational expenses. Lifecycle cost analyses indicate that, particularly under aggressive conditions, the overall economic efficiency of TP GFRP rebars can surpass that of steel. A key distinguishing feature of Glasspree® TP bars is their recyclability. At end-of-life, they can be separated from the concrete matrix and fully recycled. A specific recycling process was developed through an experimental program at Canoe, with clear and easily implementable results:

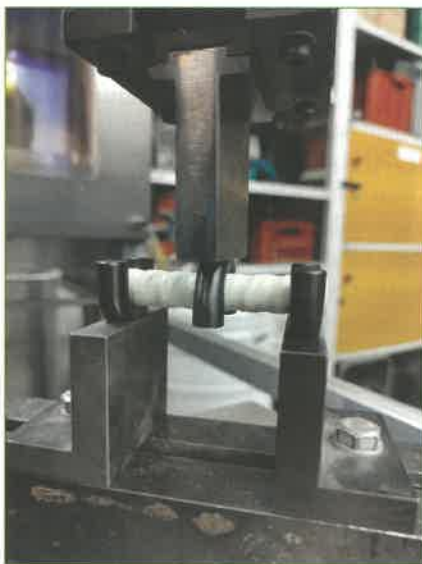


Fig. 2: Characterisation of mechanical properties of TP FRP: interlaminar shear test

mechanical recycling allows 100% reuse of end-of-life GFRP rebars, producing recycled thermoplastic granulate for use in standard industrial processes such as injection moulding. Additionally, production waste is systematically collected and recycled, contributing to a low-waste manufacturing cycle. This innovation is a game changer in the composites industry, as it allows GFRP rebars to be considered fully and easily recyclable products for the first time, removing them from waste streams and returning them to a circular economy.

### Characterisation of the mechanical properties

The characterisation of different mechanical properties was performed to allow an extensive use of newly developed rebars in different application fields (thus subjected to different loading and/or environmental conditions). It included short-term bar properties like for example tensile properties, shear strength, interlaminar shear strength and bond strength (Figure 2). Tensile properties are mainly governed by the load-bearing glass fibres. Therefore, it can be expected that the mechanical properties will be significantly affected if the loading direction is not parallel to the fibres' direction, or if the bars are not straight. For that reason, tensile strength of the bent rebars will also be a subject of ongoing experimental investigation. Harsh environment and extreme loading conditions can significantly affect the rebars and therefore the behaviour of the

TP-GFRP reinforced concrete structures. To investigate the performance and durability of the rebars under extreme conditions, different tests have been planned or performed, including tensile tests of the bars exposed to long term loading, fatigue loading, alkaline environment or extreme temperatures up to 700°C.

Based on a limited experimental investigation, the retention tensile strength of TP FRP rebars decreases linearly with increasing temperature at the rebar surface, reaching approximately 30% of the nominal value at around 300°C.

Regardless the fact that the extensive and robust experimental investigation is still ongoing, based on the available results, it can be stated that the overall behaviour of thermoplastic rebars is similar to commonly used FRP rebars with thermoset matrix.

### Experimental program on TP-GFRP reinforced concrete beams

An experimental program to characterise the flexural and shear capacity of full-scale concrete beams longitudinally reinforced with bendable thermoplastic GFRP bars with and without TP-GFRP transverse reinforcement is under development. Results have been predicted using some of the current standards, as ACI440.11-22 or Model Code 2020 and the Multi-Action Shear Model developed by UPC.

Eight beams (200 x 250 x 3,200 mm) with two different longitudinal reinforcement ratios (2φ12 and 3φ12), thermosetting or thermoplastic reinforcement and a straight or bent anchorage, were tested under a 4-point bending configuration. As observed in the load vs displacement curve (Figure 3), there is no significant difference on the performance of the beams with thermoplastic and thermosetting reinforcement. During the test, flexural cracks opened and propagated to the compression zone with the applied increasing load. In the third load cycle, and at a load level close to the theoretical flexural failure load, an inclined shear crack suddenly appeared and caused failure in almost all beams after the rupture of the stirrups in the bent area.

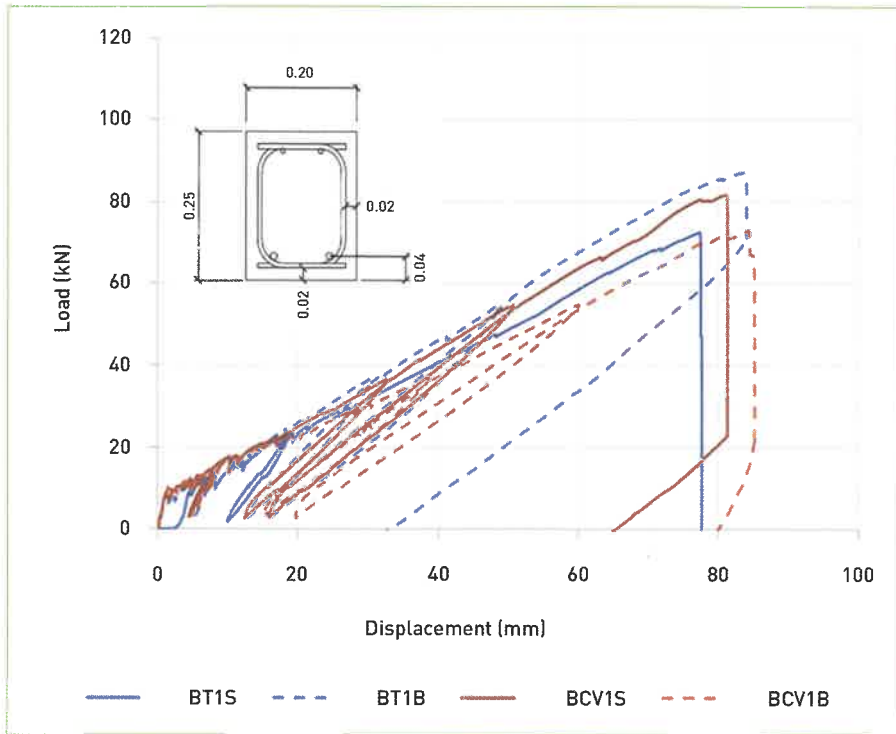


Fig. 3: Load vs displacement

Regarding the shear tests, which are currently under development, 12 beams are tested twice up to failure. The parameters under study are the longitudinal and transverse reinforcement ratio, type of resin (thermosetting vs thermoplastic) and concrete strength.

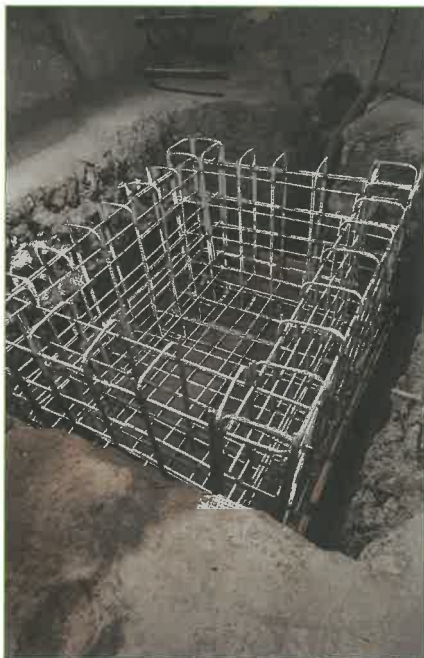


Fig. 4: Water sump

### First prototype in Czechia

TP-GFRP was employed as internal reinforcement for the newly constructed water sump, designed to capture aggressive groundwater that may infiltrate the collector through leaks in the existing concrete structure (Figure 4). Due to its non-corrosive properties, TP-GFRP was utilised in place of traditional steel reinforcement, thereby ensuring the long-term durability of this highly exposed structural element.

This work is a crucial component of the larger project titled “Reconstruction of Collector III, Pisárky Area, Brno”, which is currently being undertaken by Ohla ŽS, a.s. Regardless of the demonstrator’s size and the volume of installed reinforcement, this project is being funded by the Brno Water and Sewage Management Facility (Brněnské vodárny a kanalizace, a.s.), and the newly constructed sump will integrate into the Brno’s main public water management system.

### Outlook and industrial roadmap

Looking ahead, the next steps will focus on completing the experimental program to obtain a comprehensive understanding of the behaviour of thermoplastic GFRP

rebars. In particular, future tests will cover tensile and fatigue tests under sustained and cyclic loading, durability assessments in alkaline environments and at elevated temperatures (up to 700 °C), performance evaluation of bent bars to quantify the impact of thermoforming on tensile properties and shear, flexural and long-term tests on full-scale beams, considering different reinforcement ratios, resin types and concrete strengths.

The outcomes of these studies will provide the 360° knowledge required to benchmark thermoplastic rebars against conventional FRP and steel reinforcement.

On the industrial side, the roadmap foresees the transition from prototype production to scaled pultrusion lines for straight bars and bending operations, with a focus on increasing production speed, optimising processes and establishing effective methods for recycling waste. In parallel, pilot projects will be essential to demonstrate product performance in real structures, strengthen market confidence and pave the way for broader adoption and standardisation of thermoplastic GFRP rebars.

Finally, by consolidating experimental data on mechanical performance, durability and recyclability into practical design guidelines, this research can directly support future standardisation efforts, facilitating code acceptance and integration of thermoplastic GFRP reinforcement into structural engineering practice.

Overall, this development underscores the potential of thermoplastic composites to deliver high-performance, sustainable and adaptable reinforcement solutions for modern concrete infrastructure, particularly in applications demanding extended service life, design flexibility and reduced environmental impact. □

More information:

[www.top-crete.eu](http://www.top-crete.eu)

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