TETRAHEDRAL PROFILED CARBON ROVINGS FOR CONCRETE REINFORCEMENT

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ABSTRACT

Textile reinforcements have established themselves as a convincing alternative to conventional steel reinforcements in the building industry. Due to their high load-bearing capacities in addition to a smaller concrete cross section required, the bond between textile and concrete is extremely important. In contrast to ribbed steel bars ensuring a stable mechanical interlock with concrete (form fit), the bond force of carbon rovings has so far been transmitted primarily via the coating of the textile, i.e. by a cohesive adhesive bond with the concrete matrix (material fit). [1] However, this material fit does not enable the efficient use of the mechanical load capacity of the textile reinforcement. Solutions involving profiled rovings promise significant improvements in the bonding behaviour by creating an additional mechanical interlock with the concrete matrix. In order to achieve a form-fit effect between roving and concrete, a defined roving geometry based on ribbed steel bars has to be created. For this purpose, an innovative profiling process was developed and implemented; this included a reshaping-process with a uniform reorientation of all filaments, yet ensuring a linear orientation of each filament in the roving for minimizing yarn elongation under load. [2]

MATERIALS AND METHODS

Profiled carbon rovings were produced from 3200 tex carbon fiber heavy tows (CFHT) with 48 k filaments from Teijin Carbon (TENAX-E STS40 F13). As impregnation agent, an aqueous polymer dispersion on acrylate basis with 50 mass-% solid content called Lefasol BT91001-1 from the company Lefatex was selected. For the profiling of the carbon rovings, a newly developed profiling unit was used. This unit consists of two profile bars with alternately intersecting pins that interlock when the unit is closed. The cavity between the bars forms the carbon roving, whereas the profile is shown as a negative. During the reshaping process, the CFHT acquires a new and innovative geometry in the form of a tetrahedral shape (Figure 1) with a profile spacing of 20 mm and a defined deviation from the linear course on the roving surface [2]. The deviation is variable and was set to 3 angular degrees for the test specimens. The special feature of this geometry is the uniform reorientation of all filaments. Through the consolidation of the polymer matrix under IR radiation, the profiling is permanently stabilized.

Figure 1. Profiled carbon roving with a tetrahedral geometry; original and schematic illustration

The properties of the profiled roving were characterized in several tensile and bonding tests. For the analyzation of the bonding behaviour, this study focused on the pull-out test results. Pull-out specimens for testing purposes were created by embedding the profiled carbon rovings in fine concrete (Pagel TF 10 according to the construction certification abZ Z-31.10-182) through a lamination process. The pull-out strength was measured by a single-sided pull-out test with an extensometer between concrete socket and carbon roving using the tensile testing machine Zwick Z100. To determine the characteristic bond-slip relationship, specimens were tested at 20 °C exactly 28 days after the embedment. In order to compare these new tetrahedral-profiled rovings with standard rovings currently used for textile reinforcements, the identical testing was conducted for the straight fibre strands from the textile reinforcement SITgrid 040. This textile was extensively tested during the C³-Project and represents a reliable reference.

RESULTS AND DISCUSSSION

The characteristic bonding behaviour of the profiled carbon roving in concrete is shown in comparison with the straight fibre strand from the reference-textile in Figure 2. Due to the improved mechanical interlock of the profiled roving, its resulting bond strength is well above that of the straight fibre strand. Hence, the defined tetrahedral profiling shows two effects: firstly, the rovings offer enhanced bonding stiffness, recognizable by the steeper gradiant, and secondly, they provide increased pull-out resistance. Furthermore, the profiled rovings maintain their high tensile properties in addition to an improved bonding behaviour [2].

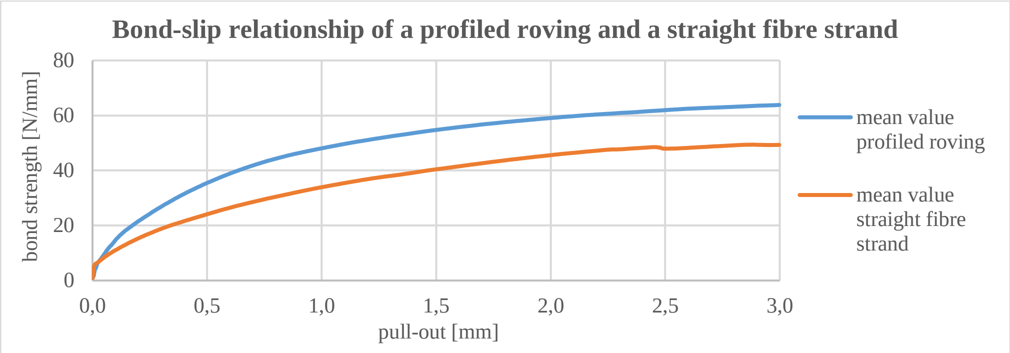

Figure 2. Bond-slip relationship of the profiled roving and a straight fibre strand with a concrete cover of 15 mm and an embedment length of 16 mm (fibre strand) and 20 mm (profiled roving) at 20 °C [2]

CONCLUSION

Results show that the newly developed profiled carbon rovings are able to transmit higher pull-out loads and demonstrate a significantly improved bond-slip behaviour compared to straight fibre strands, yet maintaining their high tensile properties. Therefore, the approach of a form-fit effect based on a uniform reshaping of all filaments proves to enhance the bonding properties between carbon rovings and concrete matrix. In conclusion, the newly developed profiled carbon rovings are expected to make an important contribution to the production of extremely resilient textile reinforced concrete structures with significantly better bonding behaviour. To enable the industrial application an automated laboratory unit has been developed at the Institute of Textile Machinery and High Performance Material Technology (ITM) in Dresden.

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REFERENCES

[1] Hahn, L., Rittner, S., Nuss, D., Ashir, M., Cherif, C. (2019). Development of Methods to Improve the Mechanical Performance of Coatet Grid-Like Non-Crimp Fabrics for Construction Applications. In: Fibres and Textiles in Eastern Europe, 27, 133(1), pp. 51-58

[2] Cherif, C. (2019). Neuartige Profil-Carbonrovings für die Betonbewehrung. In: Tagungsband, 11. Carbon- und Textilbetontage, Dresden, pp. 18-19.