Zukunft Bau

SHORT REPORT

Title

Innovative members made of ultra-high-performance concrete (UHPC) with hollow circular cross-section and pre-tensioned non-metallic basalt fibre reinforcement polymer (BFRP) for extremely durable, material-saving concrete structures under extreme environmental conditions.

Cause / starting position

To increase the resistance of reinforced concrete components to environmental and chemical influences, an UHPC with high compressive strength and an extremely dense microstructure can be used. Durability can be further increased by replacing the steel reinforcement rebar with non-corrosive BFRP rebars. Furthermore, BFRP rebars have a higher tensile strength, which makes a pre-stressing possible.

Subject of the research project

Concrete components exposed to extreme and aggressive environmental conditions must be particularly durable and resistant. For such components, ultra-high-performance concrete (UHPC) can be used instead of standard normal strength concrete. UHPC has a high compressive strength as well as a high resistance against environmental and chemical influences due to its lower porosity and high density. In addition, the conventional steel reinforcement can be replaced by non-metallic fibre-reinforced polymer (FRP), which possesses a lower self-weight, a higher tensile strength and is more resistant against corrosion compared to conventional steel reinforcement.

In the present project, rebars of basalt fibre reinforced polymer (BFRP) were mainly used along with rebars of glass fibre reinforced polymer (GFRP) and conventional steel reinforcement bars (B500) used as benchmark. Overall, extensive experimental and theoretical investigations were carried out on various topics and questions with regard to the application of BFRP in concrete members made of UHPC.

Initially, several tensile and compression tests were carried out to determine the material properties and mechanical characteristics. The investigated fibre-reinforced polymer (BFRP and GFRP) rebars reached an average tensile strength twice as high as that of steel reinforcement bars and a modulus of elasticity that is about 25% of the modulus of elasticity of steel reinforcement. In addition, the durability of the BFRP was tested in various laboratory tests (alkali resistance, UV-resistance and frost-resistance) and subsequently evaluated with SEM images and EDX analyses. BFRP rebar merely could not comply with the minimum requirements for strength loss in the case of resistance to alkaline attack. Furthermore, fatigue tests with FRP were also carried out, which indicated a significant worse fatigue behaviour of FRP compared to that of steel reinforcement (B500).

A spun concrete mixture (UHPSC) from Europoles was adapted and optimized for the production of the test specimens as regular casted concrete with intended mechanical characteristics of a UHPC. With the adapted UHPC, various durability tests such as the determination of water penetration depth, frost resistance and freeze-thaw resistance were carried out. In all laboratory tests, the used UHPC showed very little damage and achieved the desired very high durability.

The bond behaviour of the BFRP and GFRP rebars was investigated using pullout tests. For all FRP rebars, the bond stress/slip relationships and maximum bond stresses were significantly lower than the values attained for steel reinforcement bars investigated as benchmark. Nevertheless, the bond strength values of the evaluated fibre-reinforced polymer rebars were higher than the design values according to Eurocode 2 and Model Code 2010.
The load-bearing behaviour of BFRP reinforced UHPC members was tested in various test configurations. In particular, the load bearing capacity and post-failure behaviour of columns made of spun concrete (UHPSC), investigations on the flexural strength of beams with rectangular cross section and plates as well as the evaluation of flexural and shear strength of members with hollow circular cross-section. In general, the experiments yielded satisfactory results and a sufficient correspondence with the comparative numerical evaluations.
Initial investigations were also carried out on the prestressing of BFRP, whereby an anchorage needed to be developed firstly. The BFRP rebars were then prestressed to 45% and 55% of their tensile strength. The prestress losses were in an expected range. In addition, fundamental aspects such as production, treatment, processing and execution were considered.
In summary, further evaluations are necessary e. g. with regard to the material composition (fibre-resin system) as well as the durability under chemical (alkaline) and physical (fatigue) deterioration of BFRP rebars.

Conclusion

The material combination studied (UHPC with BFRP rebars) is a very promising combination. However, a comprehensive treatment of the topic was not possible within the framework of the research project. On the one hand, the defined topic is too complex and on the other hand, the development of BFRP compositions is still in progress. However, valuable results on the most diverse questions could be obtained. At present, the application of UHPC members with BFRP rebars is possible in both building and civil engineering projects, where the primary focus is on durability and optimization with regard to maximum material utilization is of secondary importance.

Basic data

Short title: Innovative components reinforced with non-metallic basalt fibre reinforcement polymer (BFRP) made of ultra-high performance concrete (UHPC)

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