Zukunft Bau

Short Report

Title

FIUHFA – Unreinforced ultra-high performance concrete façade panels
Realistic load-bearing behaviour of unreinforced, filigree ultra-high performance concrete façade panels
SWD-10.08.18.7-18.49

Reason/ Initial position

Innovative developments in the field of ultra-high performance concrete (UHPC) enable the construction of filigree and sustainable architectural concrete façades with a component thickness of only a few centimetres. However, complex reinforcement solutions are an obstacle to the widespread use of UHPC façades. For the design of unreinforced façade panels, there is a lack of further knowledge about the actions and the resistances in the design.

Subject of the research project

The large-format design of the façade panels made of ultra-high performance concrete requires multiple point-supported support, which creates a static indeterminacy. Indirect effects such as temperature changes, shrinkage of the facing shell made of ultra-high performance concrete or hygric effects, therefore, cause additional stresses on the façade panel and its anchoring, which must be taken into account in the design. Furthermore, multi-axial stress states, scale effects and the influence of increased temperatures on the strength of the ultra-high performance concrete must be taken into account in the design.

The research project funded by the ZukunftBau research initiative of the Federal Institute for Research on Building, Urban Affairs and Spatial Development made it possible to conduct in-depth investigations into the load-bearing and deformation behaviour of filigree, unreinforced large-format façade panels made of ultra-high performance concrete and to close the aforementioned knowledge gaps. With the support of companies from the field of building materials technology as well as from the field of joining technology, it was possible to form the basis of the project through fundamental experimental investigations of the tensile and flexural strength of ultra-high performance concrete.

Experimental material investigations on small-format specimens on the scale effect under centric tensile strength, uniaxial or biaxial flexural tensile strength enable the equation-based description of the relationships of the strengths. The generally valid description of the correlations allows the transfer to other concrete formulations. Furthermore, the influence of increased temperatures, the type of aggregate and the maximum grain diameter on the uniaxial flexural strength is determined experimentally.

The determination of design values of the centric tensile strength, the uniaxial and the biaxial flexural tensile strength of the ultra-high performance concrete is traced back to the characteristic value of the uniaxial flexural tensile strength. This is to be determined for the respective specific ultra-high performance concrete from the results of 3-point bending tests on mortar prisms with dimensions of 40 x 40 x 160 mm. Further influences from the type of loading, the scale effect, increased temperatures, different rock types and maximum grain diameters are represented by the previously derived relationships.

For a realistic description of indirect actions, experimental investigations were carried out on the surface temperature of rear-ventilated and non-rear-ventilated facing shells made of ultra-high performance concrete. Different colourings of the concrete, as well as different types of curing of the concrete surface, were considered. By deriving factors to take into account the influence of different concrete surfaces, the maximum surface temperature can be modified in the design. Furthermore, temperature expansion coefficients depending on the type of rock were determined experimentally and can thus be taken into account in the design. Subsequently, experimental investigations to determine the shrinkage strain as a function of different rock types were determined, evaluated and presented in an equation-based manner.

Within the scope of the project, large-scale component tests were carried out in the negative pressure test rig, the results of which are to serve as the basis for validating the design model as well as numerical FE models. Using validated FE models, sensitivity analyses were carried out on the influence of the substructure as well as on the stress distribution in the case of recessed corners. Furthermore, instructions on the internal forces of façade panels using FE methods were defined.

A consistent concept was developed for the design of unreinforced façade panels made of ultra-high performance concrete in the serviceability limit state and the ultimate limit state. This was finally validated using the results of negative pressure tests on large-format façade panels. The definition of design rules enables the transfer of the findings from the research project to building practice.

Conclusion

The experimental investigations on small-format specimens enable the derivation of fundamental findings on, among other things, the influence of the scale effect, the type of rock and increased temperatures on the tensile and flexural strength of ultra-high performance concretes. The realistic load-bearing behaviour of unreinforced filigree façade panels made of ultra-high performance concrete was investigated experimentally on large-format specimens. Based on this, a design concept could be derived and validated based on the test results. The definition of instructions for the determination of internal forces using FEM as well as design rules facilitates the transfer into practice.

Basic data

Short title: FIUHFA – Unreinforced ultra-high performance concrete façade panels

Project management:
Prof. Dr.-Ing. Matthias Pahn

Researcher:
Dr.-Ing. Milan Schultz-Cornelius
Stefan Carstens, M.Eng.

Total costs: 240.200,00 €
Share of federal subsidy: 131.460,00 €

Project duration: 24 Month

Figure:

Figure 1: Unreinforced ultra-high performance concrete façade panels

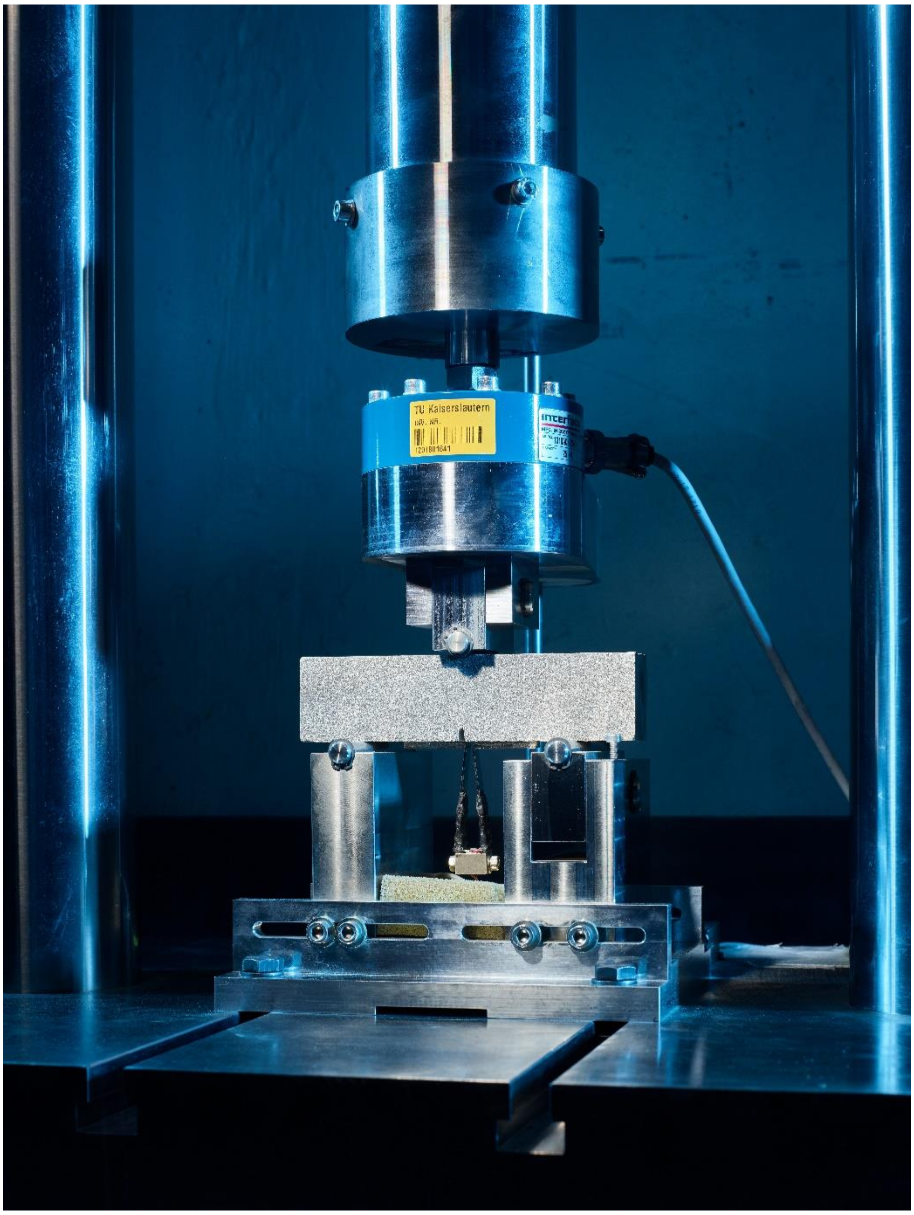

Figure 2: 3-point-bending test on prisms made of ultra-high performance concrete

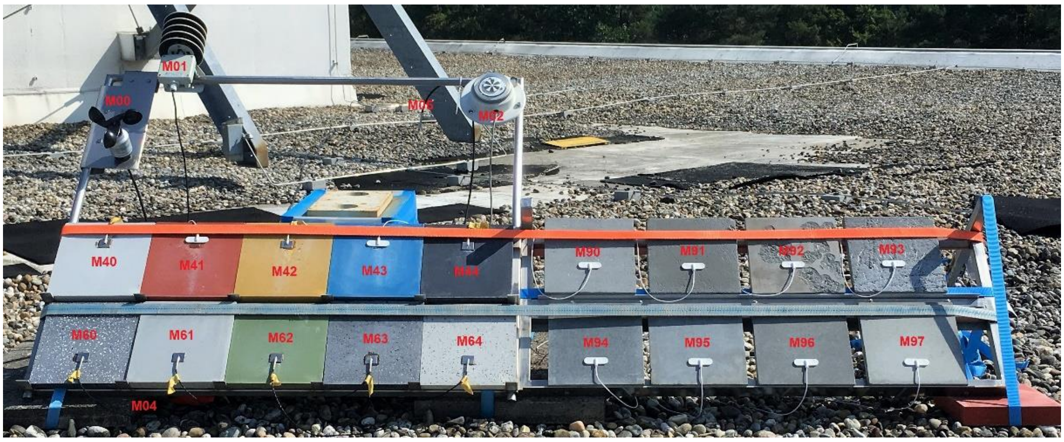

Figure 3: Test rig for determining the surface temperature of UHPC façade panels

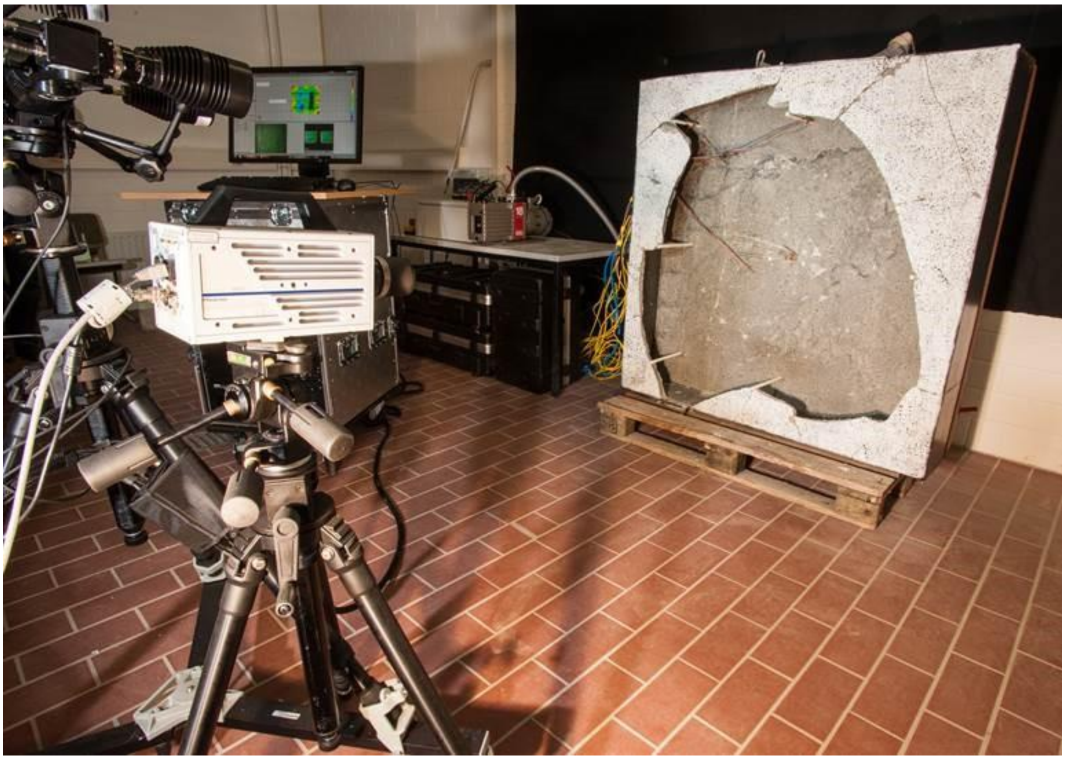

Figure 4: Test set-up for negative pressure tests on façade panels made of ultra-high performance concrete

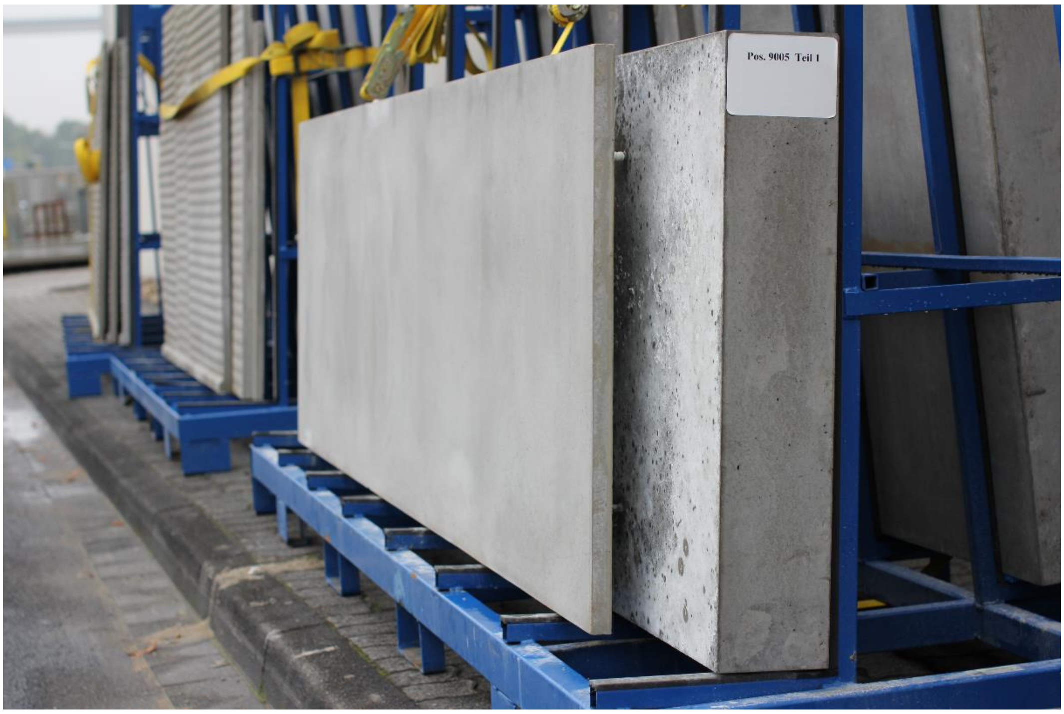

Figure 5: UHPC façade panels