Zukunft Bau

SHORT REPORT

Modern car park construction with fibre-reinforced ultra high-performance concrete (UHPFRC)

Extended Version Titel:

Sustainable construction with prestressed elements made of ultra-high strength concrete (UHPC); application for car parks

Occasion/ Initial situation

Ultra-high-performance fibre-reinforced concrete holds great potential for precast concrete construction, both economically and ecologically. With the help of this innovative material, resource consumption and dead loads can be significantly reduced compared to conventional concrete construction methods, while at the same time durability is increased. Parking deck construction is therefore an ideal area of application for this promising material.

Subject of the research project

As part of the research project, the application of ultra-high-performance concrete for car parks was investigated. It turned out that car park construction is an ideal field of application for applying the advantages of ultra-high- performance fibre-reinforced concrete in construction practice. The material can be used very efficiently in car park construction due to its very good durability properties, the omission of conventional reinforcement in many areas, the saving of resources and dead weight due to the possibility of very slim construction, as well as due to the extremely high load-bearing capacities of the innovative material UHPFRC. After the creation of a catalogue of requirements for parking systems, which was produced in cooperation with the industrial partner Goldbeck, detailed variant studies were carried out to optimise the system topology. The results showed that a dissolved system of filigree, prestressed longitudinal beams and thin, ribbed slabs represents an optimum topology in terms of load-bearing capacity, economy, durability and efficiency. For the connection between longitudinal beams and panel elements, different variants are possible, which were investigated within the scope of the project.
The experimental and numerical investigations carried out showed that a thickness of only 35 mm for the panel elements spanning over 2.50 m is sufficient to meet the requirements of the ultimate limit state and serviceability limit state. Discrete trapezoidal ribs with a thickness of 85 mm and integrated discrete bar reinforcement significantly increase rigidity and load capacity. The discrete bar reinforcement also leads to a very ductile load-bearing behaviour. Due to the steel fibre reinforcement, the test showed a crack pattern with many fine cracks compared to normal concrete and thus a very good-natured behaviour with regard to durability. Despite the very thin elements and a concentrated load introduction, pure punching failure could not be observed in any of the tests carried out. The failure of the plate elements occurred rather in the form of a bending failure in the middle of the plate, analogous to the fracture line theory.
The investigations of the load-bearing behaviour of the prestressed UHPC longitudinal members showed that, despite the very slim beam and a web thickness of only 40 mm, very high load-bearing capacities result. The focus of the experimental investigations was set on the shear load-bearing behaviour of the prestressed UHPC beams. It became apparent that the ultimate shear load depends very much on the steel fibre content and that there is also a dependency between ultimate shear force and degree of prestressing. Due to the preload in

the beam and the crack-bridging effect of the steel fibres, shear and bending cracks could only be detected at a very high load level, which has a positive effect on long-term durability. For the connection of the longitudinal member with the panel elements and for the joining of the panel elements to each other, various possibilities were investigated and corresponding push-out tests were carried out for selected constellations. On the one hand, a dovetail-shaped slab joint was developed and analyzed, which makes it possible to connect the slab parts together without connecting reinforcement and thus more permanently or without coating. The compensation of constructional tolerances can be ensured by the arrangement of a narrow joint between the elements, which is subsequently poured again. The installation of the elements can be done very simply, analogous to the LEGO principle. The failure of this type of connection was caused throughout by shearing of the shear cams in the longitudinal member. The arrangement of stirrup reinforcement in the shear cams increases the ductility accordingly. In addition to the dovetail connections for the connection, cam connections with a dry, screwed joint and a wet joint were also examined.

Conclusion

The research project demonstrated the advantages of ultra-high-performance fibre-reinforced concrete, such as its excellent durability properties and the reduction of dead weight, for use in car park construction. The load-bearing system developed, consisting of prestressed longitudinal beams and filigree panel elements, has extremely small cross-section dimensions while maintaining the same load-bearing capacity. This and the developed joining principle without connecting reinforcement and coatings would result in considerable advantages during installation. Due to the excellent durability properties, any coatings (common in car park construction) can be dispensed with.

Basic Information

Short title: Modern car park construction with fibre-reinforced ultra high-performance concrete (UHPFRC)

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Total costs: 307.151,50 €

Proportion of federal subsidy: 199.651,50 €

Project duration: 2,5 Jahre

Figures:

Photo credits:

Figure 1: Bruchbild Plattenlement.png

Caption: Fracture pattern of a panel element with reinforced trapezoidal ribs after the test

Figure 2: Fügemethode mit schwalbenschwanzförmigen Schubnocken.png

Caption: Joining method with dovetail-shaped shear cams (test specimen before grouting the joint for tolerance compensation)

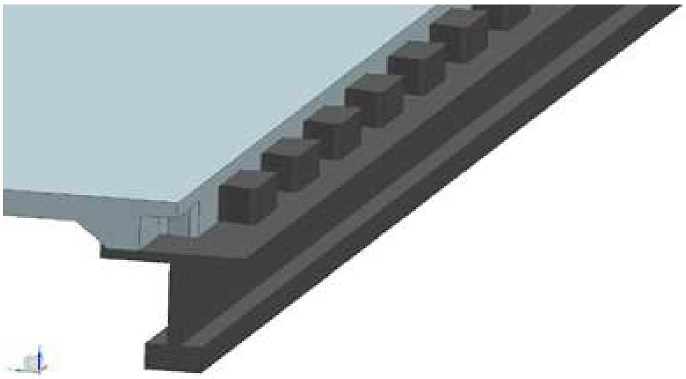

Figure 3: Fügemethode.png

Caption: Animated representation of the joining principle with dovetail-shaped shear cams on the longitudinal beam and the corresponding negative recesses in the panel elements

Figure 4: Längsträgerelement im Substrukturversuchsstand.jpg

Caption: Testing of a prestressed longitudinal member with a web thickness of 40 mm in the TUM substructure test rig

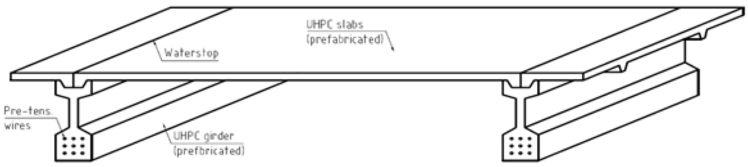

Figure 5: Parkdecksystem.png

Caption: Resolved parking deck system made of UHPFRC with prestressed longitudinal beams and filigree panel elements

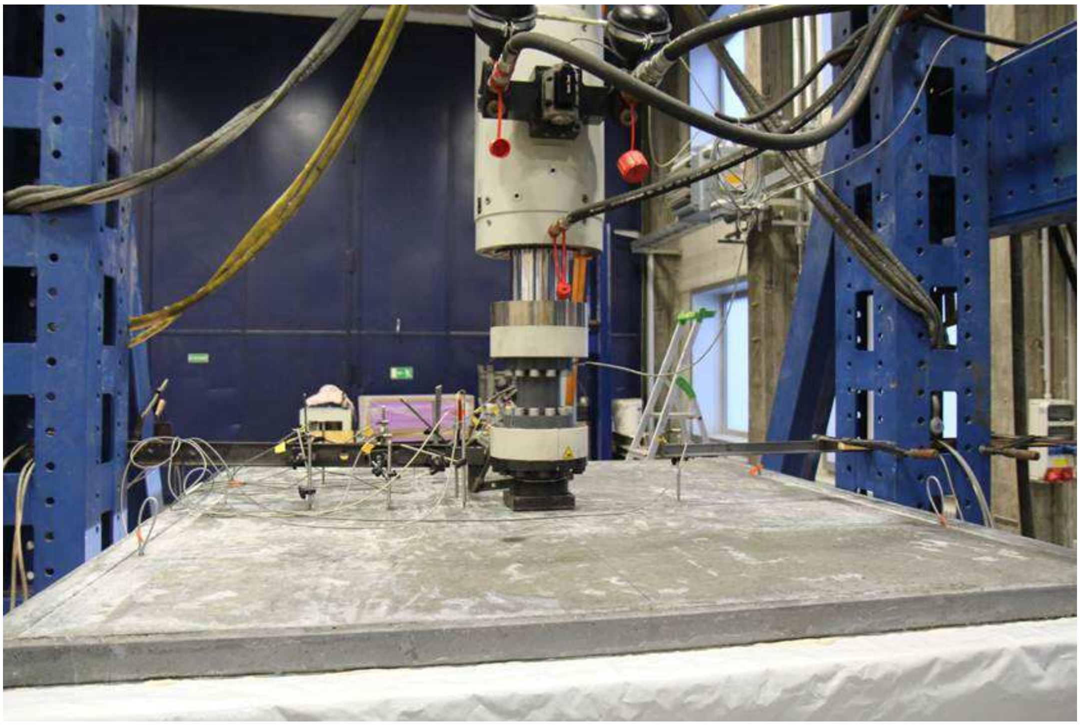

Figure 6: Prüfung Plattenelement.jpg

Caption: Experimental investigations on the punching shear and bending load-bearing behaviour of panel elements (thickness between the ribs only 30 mm) with and without trapezoidal ribs

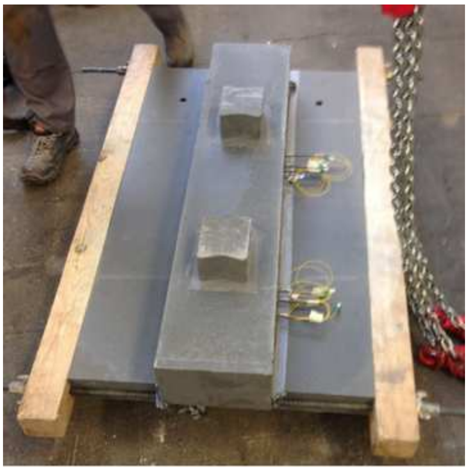

Figure 7: Schubnocken Längsträger.png

Caption: Test specimen for push-out tests: longitudinal beam element with dovetail-shaped shear cams