Zukunft Bau

STRUCTURE OF THE SHORT REPORT

Title

Anchoring tendons with innovative composite anchor plates using high strength concrete and fiber reinforced polymers

Motive

The load transfer of tendons to the structure has been ensured until now by the use of massive steel plates. With the development of composite anchor plates ("Hybridanker"); consisting of an ultra high performance concrete (UHPC) core and a steel or fiber reinforced polymer tension ring confining the UHPC core; a new, lighter, resource-friendly and economical alternative shall be accomplished.

Purpose of the research project

Composite anchor plates shall provide an innovative solution for load transfer and load distribution of high strength tendons into the structure, in contrast to the traditionally used heavy steel plates. The big tendon forces shall be absorbed and transferred to the structure by an UHPC core, which optimally houses the anchoring element (nut, washer plate, anchor head), and a steel or fiber reinforced polymer tension ring confining the UHPC core (see Figure 1). By the use of UHPC and the reduction of the required steel, a considerable weight reduction, among other things, shall be achieved.

In order to develop composite anchor plates for future application as an anchorage element, a pre-dimensioning and form finding of the composite anchor plates was carried out. Thus, static loading according to the Guideline for European Technical Approval of Post-tensioning kits (ETAG 013, [1]), as well as the expected characteristic material properties were considered. A strut model for load distribution within the composite anchor plate and a geotechnical model for stiff bodies on a soft ground for the load transfer below the anchor plate were used to determine the composite anchor plate dimensions (see Figure 2).

The actual mechanical resistance of the calculated composite anchor plate dimensions was analysed during an extensive experimental testing programme. This programme covered compressive tests and load transfer tests on composite anchor plates with variation of the following parameters: UHPC compressive strength, type of confinement, type of anchorage, bearing condition and composite anchor plate dimensions. These tests allowed the determination of the short-term mechanical behaviour. The influence of long-time loading was studied by means of fatigue tests and long-duration static tests. In addition to composite anchor plates with an outer steel or fiber reinforced polymer tension ring, a further variation of composite anchor plate with a steel spiral embedded in the concrete as confinement was also tested. Compressive tests (see Figure 3) showed, among other things, that punching shear failure of the UHPC within the composite anchor plates occurred along the connecting line between the bearing line of the anchorage element and the opening in the structure (see Figure 7). Load transfer tests according to ETAG 013 (see Figure 4) evidenced that the ultimate loads depend on the stiffness of the concrete body and confirmed the geotechnical model used for pre-dimensioning. In fatigue tests according to ETAG 013 (see Figure 5) no failure occurred after two million load cycles, neither for 80 MPa nor for 100 MPa stress amplitude. The permanent strength of composite anchor plates was determined as at least 90% of the short-term ultimate load by means of the long-duration static tests performed (see Figure 6).

Additionally to the experimental determination of the mechanical behaviour, verification of results for certain selected compressive tests was carried out by means of a Finite Element Model Analysis with the software ANSYS 14.5.

The expected resistance of the composite anchor plates against chemical and physical effects, for instance, against salts, acids, leaching, temperature, humidity or freeze, was assessed by means of an extensive literature research regarding the durability properties of the used materials, namely, UHPC, steel and fiber reinforced polymers. Additional reasonable protection measurements were also considered.

Based on the experimental and theoretical analyses a design concept is subsequently presented. By means of this design concept, the required minimum dimensions for the outer diameter, height and ring thickness for the composite anchor plates can be determined in dependance on the design loads.

Finally, the experiences during the casting of composite anchor plates are summarised and the resulting suggestions for series manufacturing are presented. Eventually, an evaluation of economic efficiency for the production of composite anchor plates is carried out and the results are compared with the costs for production of steel plates for the same design load.

Summary

The performed analyses and tests show that composite anchor plates can economically and reasonably replace steel plates for the anchorage of tendons. They can also fulfill both short-term and permanent load requirements, whereas they provide adequate resistance against most of the chemical and physical actions too.

The developed design model enables the determination of the minimum required dimensions of the composite anchor plates in dependance on the design loads.

Composite anchor plates with spiral reinforcement embedded in concrete particularly provide a high potential due to the good corrosion protection and should be further analysed.

Key data

Short title: Composite anchor plates (Hybridverankerungen)

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Total costs: 199.300,00 €

Federal grant: 129.300,00 €

Time period: until 31.03.2014

FIGURES:

Figure 1: Prinzip Hybridanker de-eng.jpg
Legend: Functioning principle of composite anchor plates (left: anchorage of a bar with domed nut; right: anchorage of strands on wedge plate)

Figure 2: Vordimensionierung eng.jpg
Legend: Boundary conditions for determination of composite anchor plates geometry

Figure 3: Druckversuch eng.jpg
Legend: Exemplary and schematical representation of test setup for compressive tests

Figure 4: Lastübertragungsversuch eng.jpg
Legend: Exemplary and schematical representation of test setup for load transfer tests

Figure 5: Ermüdungsversuch eng.tif
Legend: Exemplary and schematical representation of test setup for fatigue tests

Figure 6: Dauerstandversuch eng.tif
Legend: Exemplary and schematical representation of test setup for long-duration static tests

Figure 7: Hybridanker nach Druckversuch.tif
Legend: Exemplary composite anchor plate after compressive test (left: upper side of composite anchor plate; right: lower side of composite anchor plate)