Zukunft Bau

Summary Report

Title

Investigations concerning the correlation between compressive and tensile strength of old, low strength concretes as a basis for determining the bearing capacity of fastening materials such as for example anchors

Initial Situation

In the design of a new construction, the correlation between the concrete compressive and tensile strength is normatively regulated by DIN EN 1992-1-1. However, as there are many different time- and load-dependent impacts on existing structures, this correlation can't be used without any further investigations.
Among others, the concrete tensile strength affects the shear force resistance and the load-bearing capacity of anchors.

Objective of the research project

The present research project describes the experimental investigation of the correlation between the concrete compressive and tensile strength of old concretes. Due to many different time- or load-dependent influences such as subsequent hardening, the relationship described by DIN EN 1992-1-1, which is based on a testing age of 28 days, can't be assumed without any further observations for existing structures.

$$f_{\mathrm{ctm}} = 0{,}3 \cdot f_{\mathrm{ck}}^{2/3}$$

Among others, the concrete tensile strength affects the shear force resistance and the load-bearing capacity of anchors (Failure Mode: concrete cone failure). The currently used codes only apply to the use of anchors in normal weight concrete between strength classes C20/25 and C50/60, according to DIN EN 206-1. For concretes with a lower strength class, there is currently no basis of assessment available.

As a first step, several existing structures of various types of construction have been investigated by destructive test methods. The in-situ concrete strength was measured by testing drill cores. Depending on the available component/building size, approx. 60 drill cores were taken. For the determination of the axial tensile strength, the splitting tensile strength of the drill cores was tested and subsequently converted. Based on the results of the structural investigation of the in-situ concrete strength, it was possible to determine the correlation between the compressive and tensile strength. Apart from engineering structures and building structures there have also been bridges examined.

In addition to that, 24 datasets from the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau) have been analyzed.

The structural investigations as well as the age of the structure, type and size of the aggregate, casting direction and the depth of carbonation have been documented.

Based on the results of the structural investigations the properties of the old concretes could be described and the correlation between the characteristic in-situ concrete compressive strength and the mean value of the axial in-situ tensile strength has been determined.

In figure 2 the correlation between the characteristic in-situ concrete compressive strength and the mean value of the axial in-situ tensile strength is illustrated.

As a result of the structural investigations, the correlation between the in-situ concrete compressive and tensile strength can be described as follows:

$$0{,}23 \cdot f_{\mathrm{ck}}^{2/3} \leq f_{\mathrm{ctm}} \leq 0{,}50 \cdot f_{\mathrm{ck}}^{2/3}$$

As a second step, in this research project the bearing capacity of expansion anchors in old concretes with low compressive strength should be tested (Figure 3).

Unfortunately, most of the concretes that have been investigated have a mean value of the in-situ compressive strength that is greater than the mean value of the compressive strength of the strength class C20/25. Therefore, a larger number of tension tests for the determination of the bearing capacity of anchors in purpose-built test members had to be performed.

Therefore, a concrete with a low tensile strength was used for the test members.

The test members and the anchorage depth were dimensioned in such a way that the anchors would fail with concrete cone failure (Figure 4). The advisory group of the research project decided to use undercut anchors and head bolts instead of expansion anchors because of the local load application of undercut anchors and head bolts.

All the tension tests for the determination of the bearing capacity were performed on single anchors without edge and spacing effects. The chosen anchors were tested in cracked as well as in non-cracked concrete. The specially fabricated test members are pictured in figure 5 and figure 6.

In a final step the validity of the design concept for the failure mode “concrete cone failure” should be examined and if necessary revised based on the results of the investigations.

The test results prove that corresponding to the currently used methods for the use of anchors in normal weight concrete between strength classes C20/25 and C50/60 the bearing capacity for the failure mode “concrete cone failure” can be estimated for old concretes with a low strength class in the same way.

If there is a large deviation of the correlation between the concrete compressive and tensile strength from the relationship, described in DIN EN 1992-1-1, a calculation of the bearing capacity (concrete cone failure) of the anchor that is based on the in-situ concrete tensile strength provides more precise results.

Conclusion

As a result of the structural investigations, it can be stated that the correlation between the characteristic in-situ concrete compressive strength and the mean value of the axial in-situ concrete tension strength of old concretes can - on average - be described by the relationship included in DIN EN 1992-1-1. However, it has to be taken into account that in individual cases a large deviation might occur. The age of the concrete, depth of carbonation, casting direction, concrete density and scattering have been investigated as possible reasons of the deviation. Though, only the scattering factor proved to have a universal influence on the relation between concrete compressive and tensile strength.

With an increasing value of scattering the mean value of the axial in-situ concrete tensile strength, which is determined based on structural investigations, exceeds the value, which is calculated based on the characteristic in-situ concrete compressive strength according to the correlation included in DIN EN 1992-1-1. Further influence parameters couldn’t be determined.

The tension tests of undercut anchors and head bolts have shown that the bearing capacity for the failure mode “concrete cone failure” for concretes with a low strength class can also be estimated by the currently used methods for the use of anchors in normal weight concrete between strength classes C20/25 and C50/60.

For a large deviation of the correlation between the concrete compressive and tensile strength from the relationship, described in DIN EN 1992-1-1, a calculation of the bearing capacity (concrete cone failure) of the anchor that is based on the in-situ concrete tensile strength provides more precise results.

Benchmark Data

Lemma: Correlation between compressive and tensile strength of old concretes as a base to determine the bearing capacity

Researchers / Project managers: Jun.-Prof. Dr.-Ing. Catherina Thiele (TU Kaiserslautern), Dipl.-Ing. Michael Weber (TU Kaiserslautern)

Total costs: EUR 147.590,23

Amount of federal grant: EUR 81.654,30

Project duration: 27.02.2013 - 29.02.2016 (extension of project duration: 18 months)

Figures:

Figure 1: Bild 1.jpg

Structural investigations – core drilling

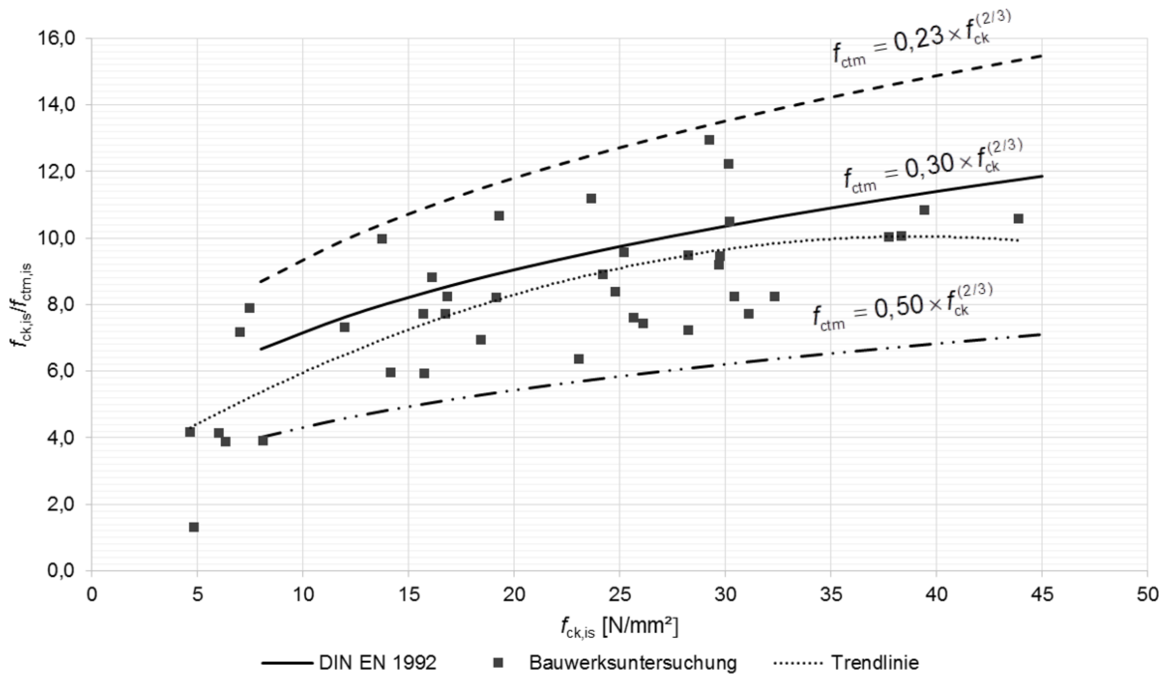

Figure 2: Bild 2.jpg

Correlation between the characteristic in-situ concrete compressive strength and the mean value of the axial in-situ tensile strength

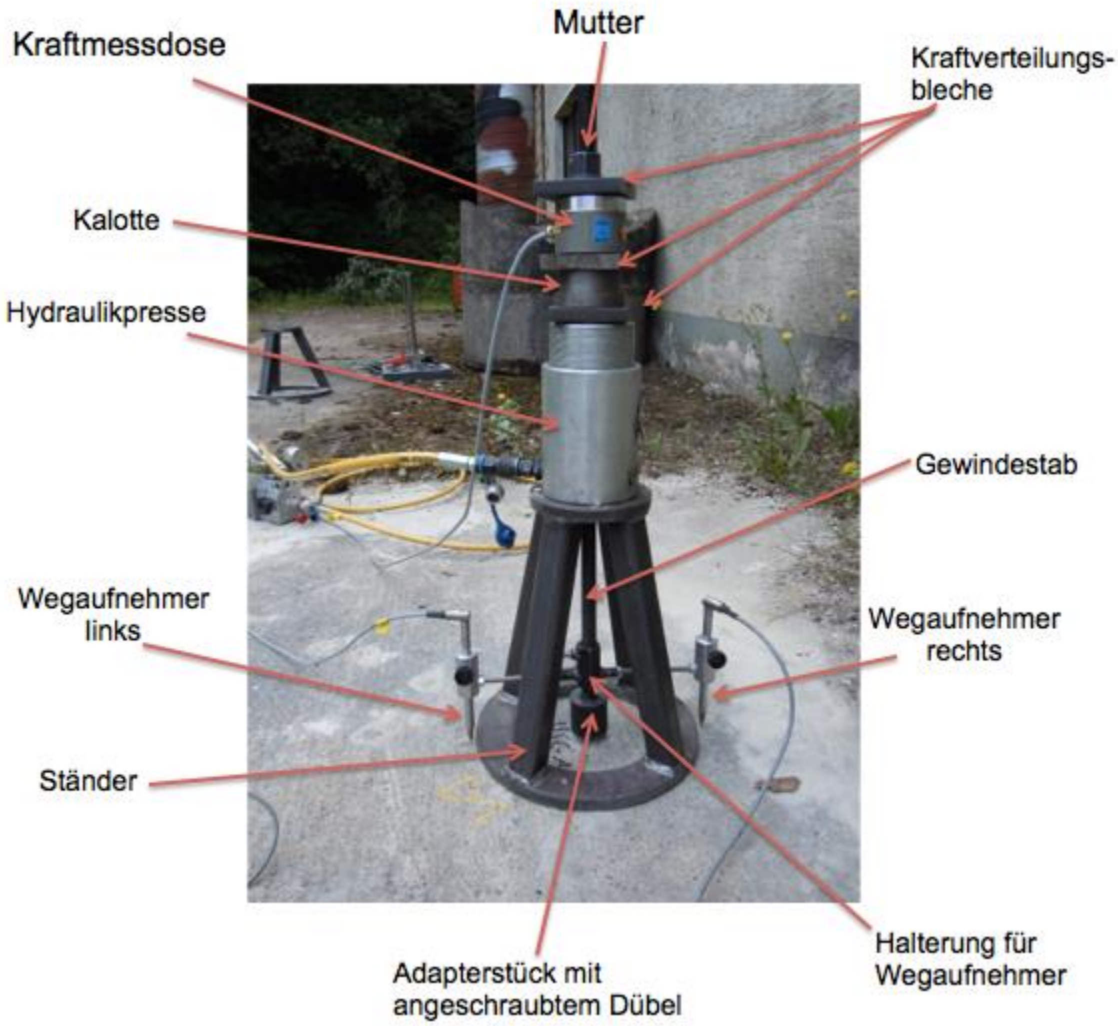

Figure 3: Bild 3.jpg

Tensile test of anchors at an existing structure – test set-up

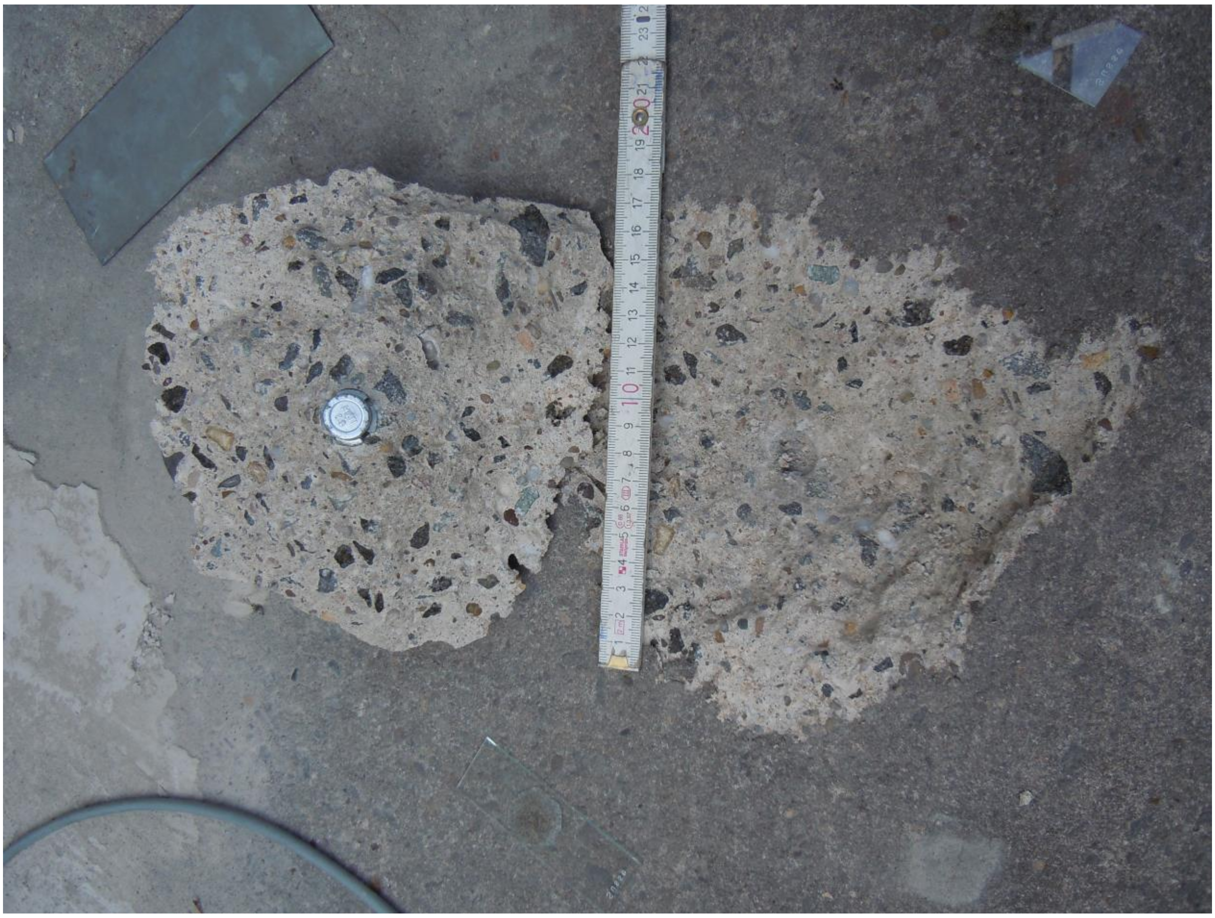

Figure 4: Bild 4.jpg

Tensile test of anchors at an existing structure – concrete cone failure (undercut anchor)

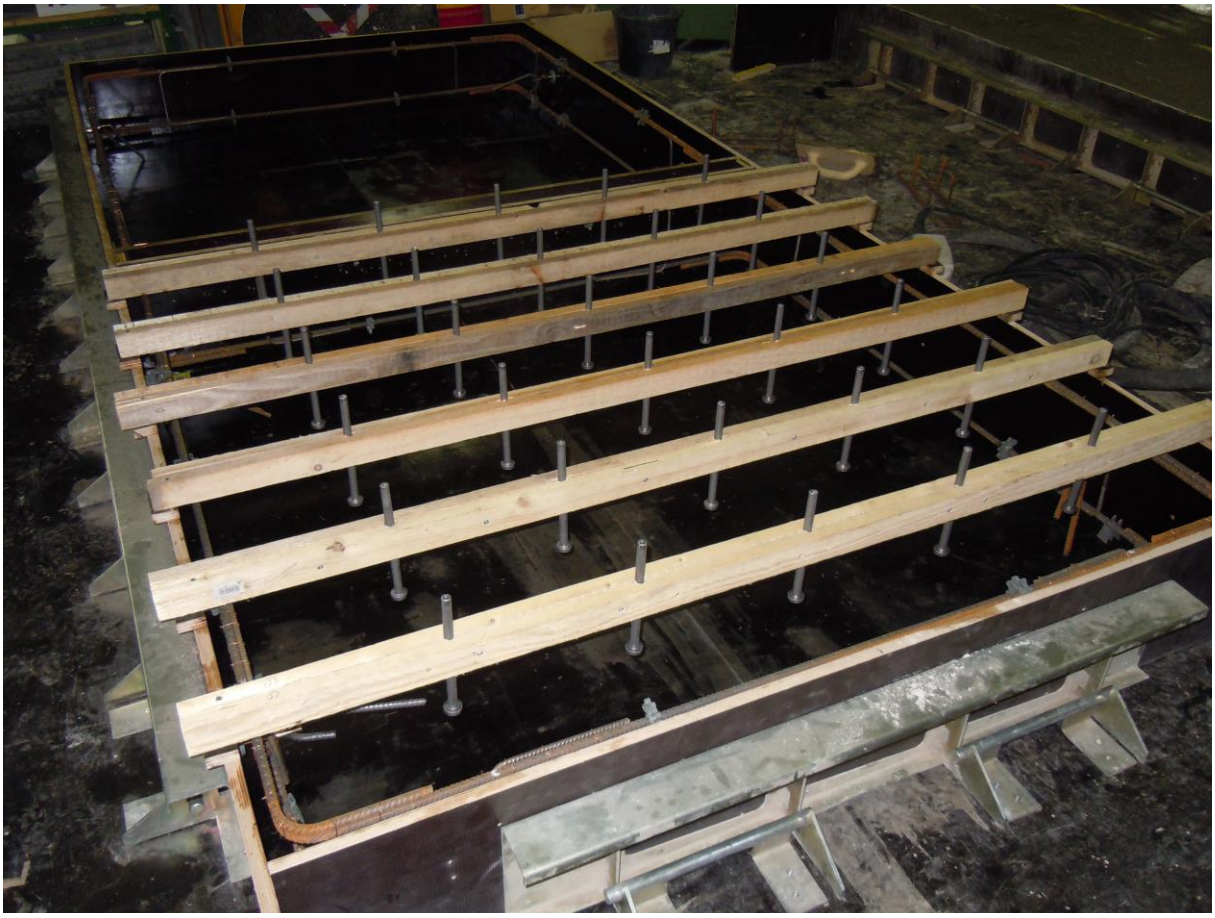

Figure 5: Bild 5.jpg

Test members – head bolt, non-cracked concrete

Figure 6: Bild 6.jpg
Test members – head bolt, cracked concrete

Picture credits: All pictures were taken by the institute of concrete structures and structural engineering, TU Kaiserslautern