Zukunft Bau

Summary Report

Title

Recalculation of reinforced concrete structures with low strength

Initial Situation

The preservation of existing structures, even in the event of conversion, is of economic interest. It also serves to conserve resources.
If concrete compressive strengths < C12/15 are encountered, there is great uncertainty in practice how such structures should be dimensioned in accordance with the rules. This tends to lead to an underestimation of the load-bearing capacity and consequently to deconstruction or reinforcement measures. This could be avoided in many cases if clear rules for the treatment of such structures were in place.

Objective of the research project

The stability of existing structures must be verified in the event of conversion or change of use in accordance with current regulations. If the characteristic concrete compressive strength of reinforced concrete structures is determined on the basis of drill cores or if it is determined by conversion from existing documents, older structures very often show strengths below the strength class C12/15.

However, the scope of the Eurocode 2 central design standard, including its National Annex, is limited to concretes C12/15 - C100/115. However, this doesn’t mean that concretes with lower strength can’t be dimensioned. The lower limit in Eurocode 2 was partly chosen under aspects of durability (aspects of durability can be dealt with by an expert in individual cases if required).

For this reason, all relevant design and construction rules were analysed in the project with regard to their validity for low-strength concrete and commented for practical use.

In the first step, the possibilities were first examined on the basis of which a strength of less than 12 N/mm^2 can be found in existing structures. On the one hand, the structure may have been built according to plan from concrete that has a characteristic concrete compressive strength of less than 12 N/mm^2. On the other hand, the structure may have been planned with a strength class greater than C12/15, but due to a high coefficient of variation of the concrete compressive strength (resulting from construction errors, poor concrete quality, etc.), the characteristic concrete compressive strength is less than 12 N/mm^2.

In addition, DIN 1045:1925 to DIN 1045:2001 were examined for restrictions regarding the applicability of low-strength concretes in order to find out in which periods reinforced concrete structures made of low-strength concretes (< 12 N/mm^2) were permissible.

Subsequently, the relevant design and construction rules of Eurocode 2 Part 1 were analysed with regard to their validity for low-strength concretes.

Among other things, the examination of the applicability of the parabola rectangle diagram was of importance, since the parabola rectangle diagram forms is the basis for many Eurocode 2 verification formats.

Relevant design rules are, among other things, the designs for bending and shear force in the ultimate limit state, which were investigated for their applicability to low-strength concretes. The different surface properties of the reinforcement (smooth or ribbed) and their influence on the load-bearing capacity of the structural members also had to be taken into account.

Decisive for the interaction of concrete and reinforcement within reinforced concrete components are the anchorage lengths, which are necessary to ensure force transmission between the reinforcement and the concrete. The basis for determining the anchorage length is the bond strength, which is determined as a function of the concrete strength and the surface of the reinforcement. The bond strength and the resulting anchorage length are of great importance for the recalculation of existing structures, which is why the bond between low-strength concretes and ribbed reinforcement was tested in pull-out tests.

For the recalculation of existing structures made of low-strength concrete according to Eurocode 2, the requirements placed on load-bearing structures made of unreinforced or slightly reinforced concrete must also be considered. For example, in DIN 1045:1972 unreinforced components could still be manufactured in the strength classes Bn 50 (f_{ck} = 4 N/mm^2) and Bn 100 (f_{ck} = 8 N/mm^2), while a minimum strength class of Bn 150 (f_{ck} = 12 N/mm^2) was required for steel structure components.

Conclusion

The characteristic concrete compressive strength is of decisive importance for the recalculation of existing structures and can be determined by conversion from quantities given in existing documents or on the basis of drill core extraction.

Concretes with lower characteristic concrete compressive strengths are regularly encountered in existing structures, either because earlier measurement standards provided for these strengths or because a large coefficient of variation in the evaluation of drill core samples leads to very low 5% fractile.

In order to avoid that structures are only dismantled in practice because they cannot be dimensioned according to the current rules and regulations, the individual verification formats were evaluated with regard to their applicability to low-strength concretes. Extensive literature and our own experimental investigations were used for this purpose.

As a result, a commented version of Eurocode 2 was presented, from which some restrictions in the application of Eurocode 2 to low-strength concretes emerge. The background to this is explained in detail in the final report.

If, during sampling, coefficients of variation of the concrete compressive strength $v_x \geq 0.30$ (e.g. tamped concrete) are determined and the mean value is clearly above 12 N/mm², it may also be useful to leave the Eurocode design concept based on 5% fractile values of the concrete compressive strength. The first tests were carried out for this purpose.

Benchmark Data

Lemma: Low strength reinforced concrete structures

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Total costs: EUR 251.055,84

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Figures:

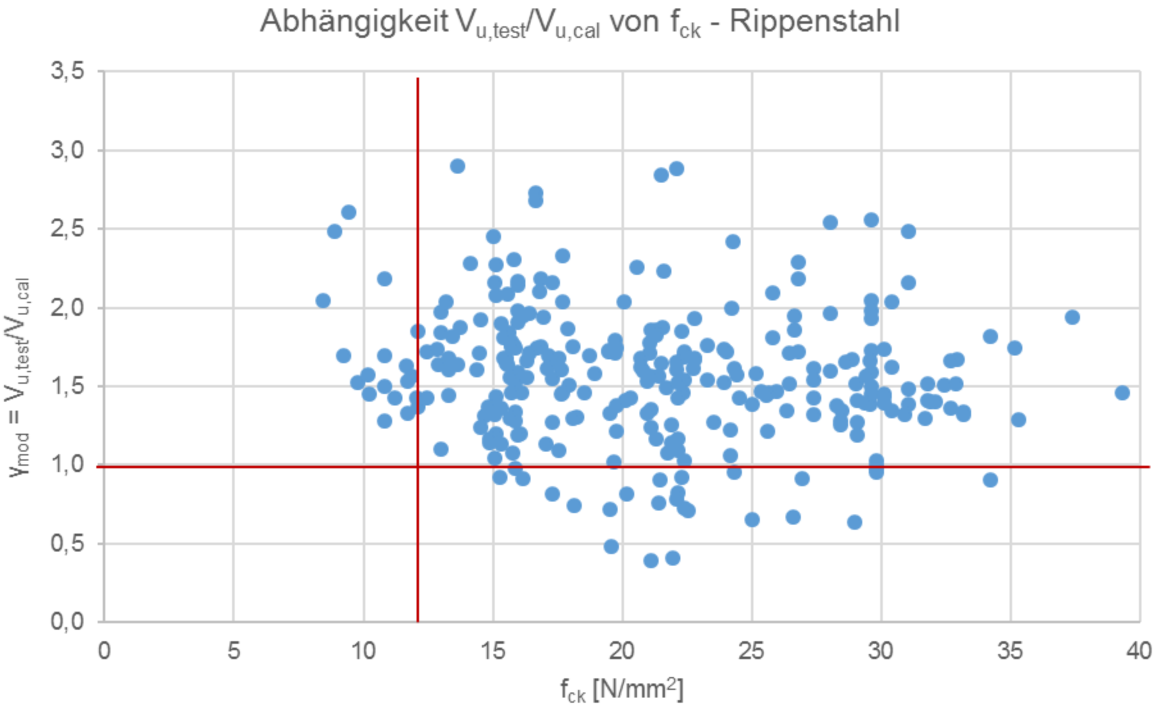

Figure 1: Figure 1.jpg

Model safety factor - Shear force carrying capacity without shear force reinforcement - Ribbed steel according to [DAfStb-Heft 597 – 2012]

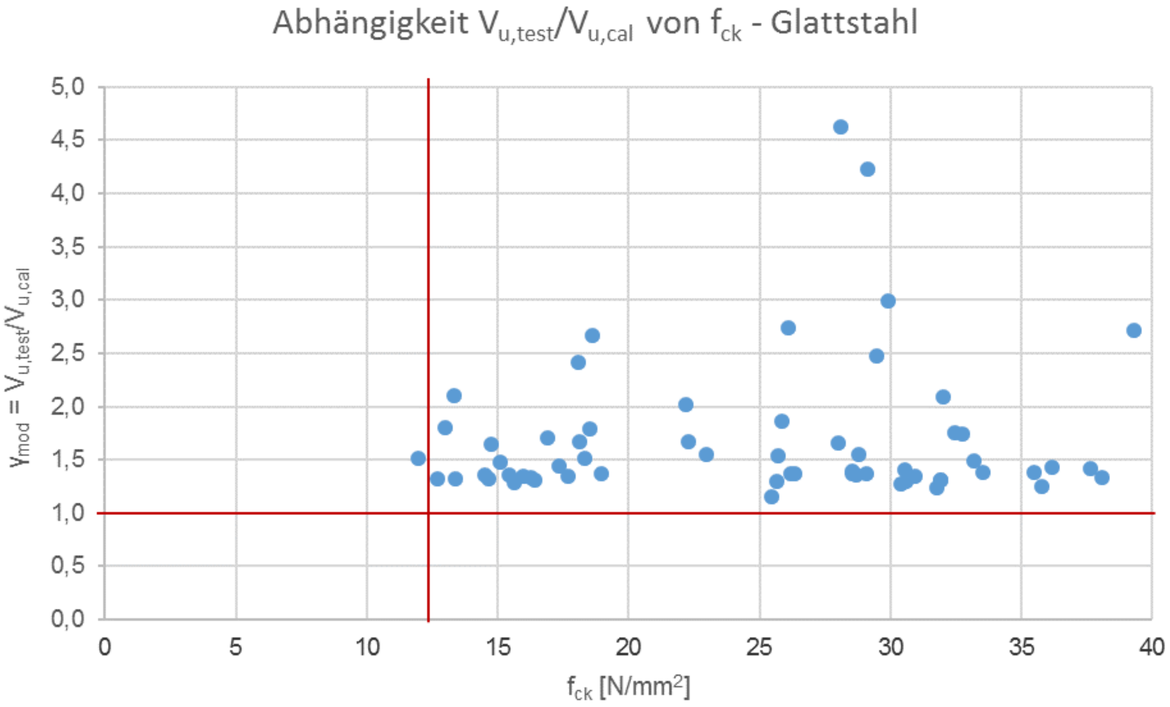

Figure 2: Figure 2.jpg

Model safety factor - Shear force carrying capacity without shear force reinforcement - Smooth steel according to [DAfStb-Heft 597 – 2012]

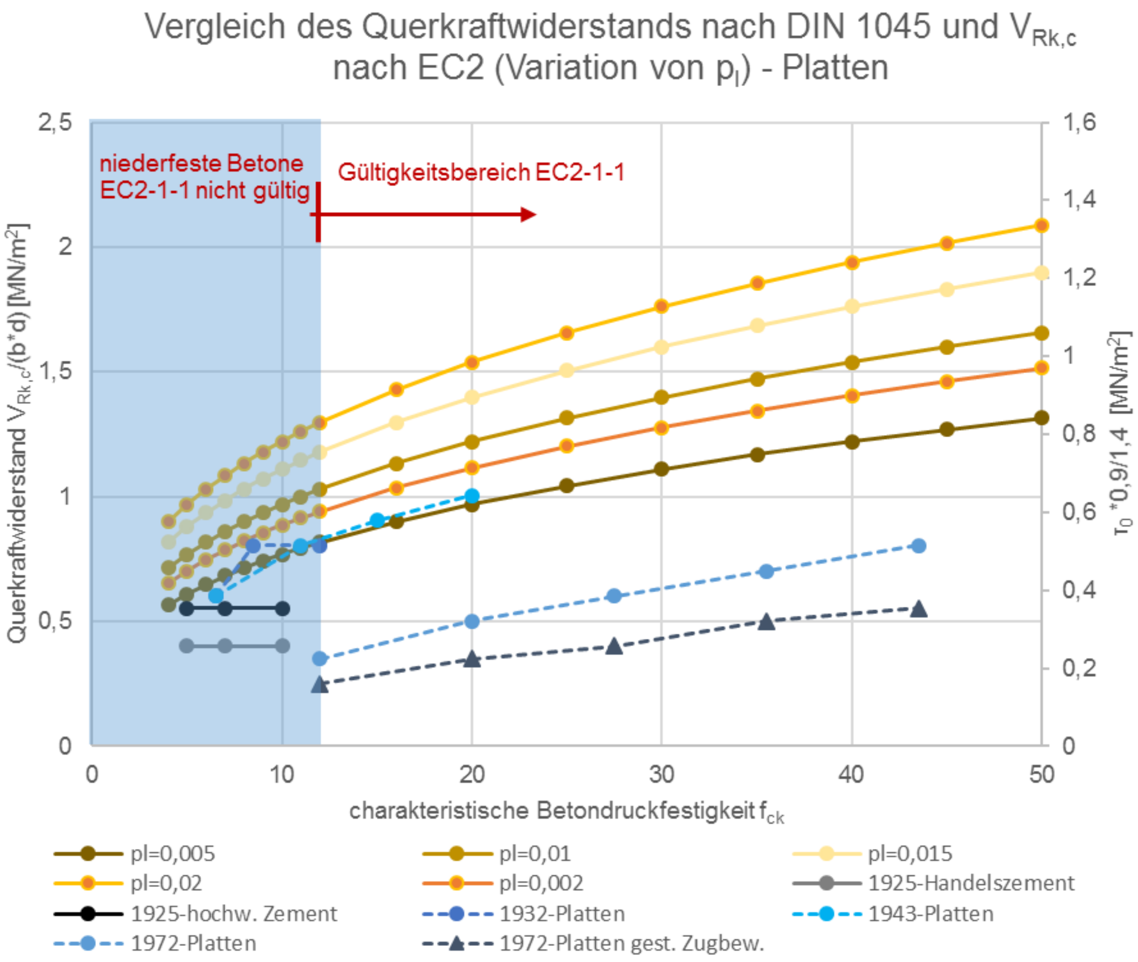

Bild 3: Bild 3.jpg

Comparison of shear force resistance of DIN 1045 and $V_{Rk,c}$ according to Eurocode 2 - Slabs

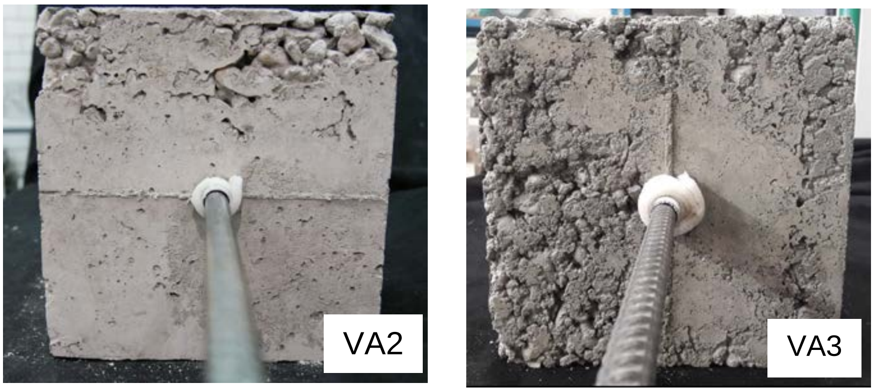

Figure 4: Figure 4.jpg

Pull-out test specimens of compression types VA2 and VA3

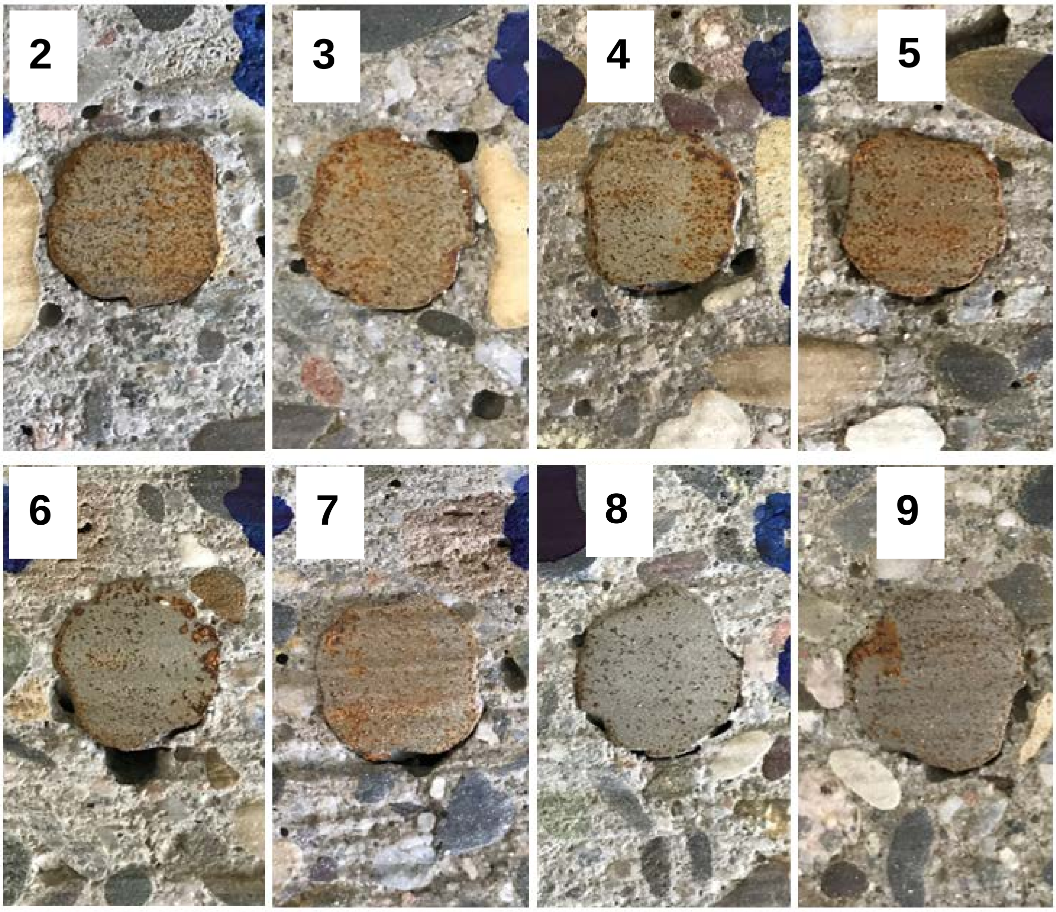

Figure 5: Figure 5.jpg

Sample cut surfaces of a test specimen - Compaction type VA2

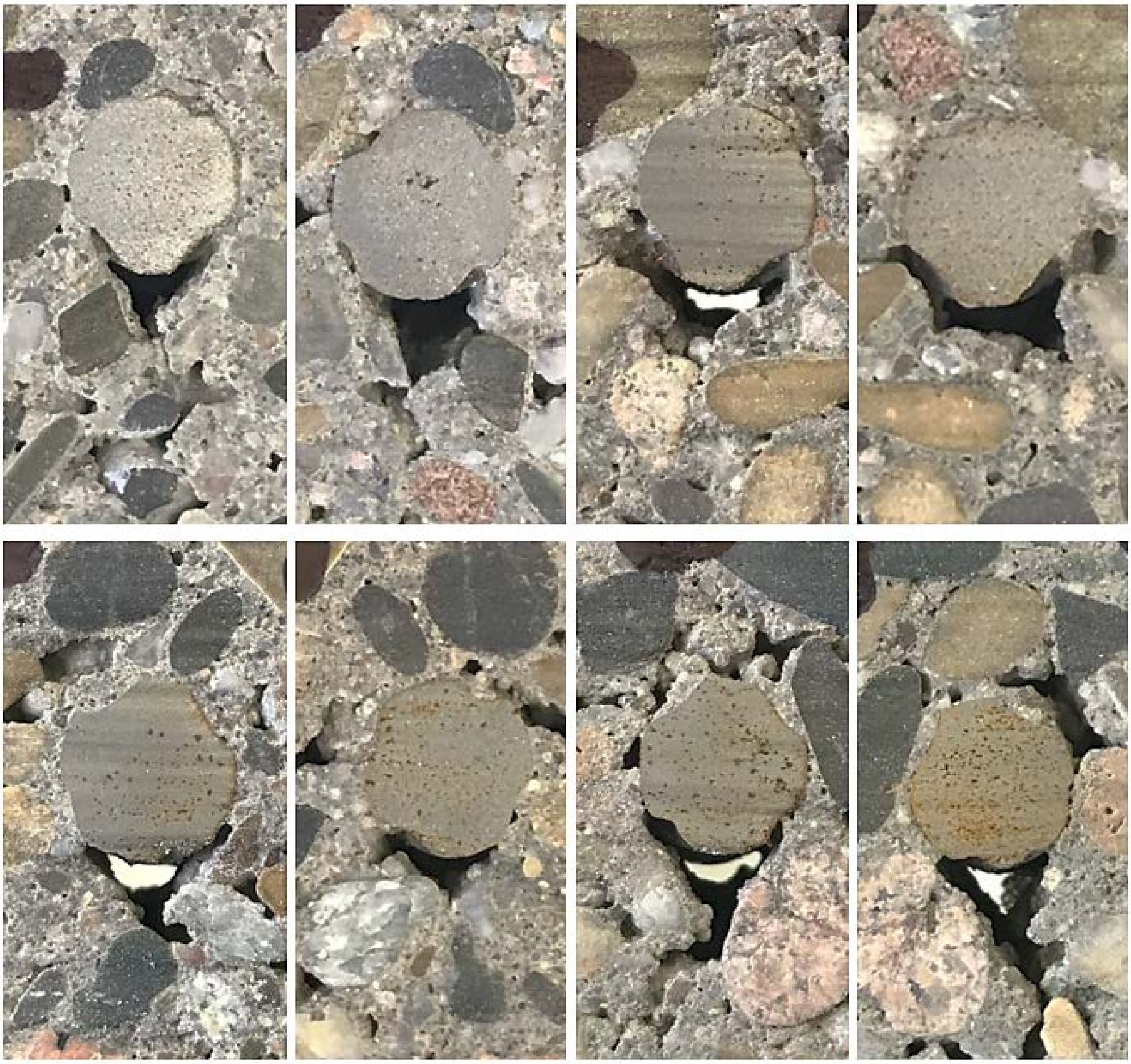

Figure 6: Figure 6.jpg

Sample cut surfaces of a test specimen - Compaction type VA3