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Verification of Permissible Anchorage Strength of Reinforcing Steel Bars in Masonry Walls according to DIN 1053-3 and DIN EN 1996-1-1

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ABSTRACT

Permissible values of anchorage stresses for the verification of the anchorage of steel bars in reinforced masonry are specified in the German standard, DIN 1053-3, or in the European standard, Eurocode 6. The anchorage strength values for vertical reinforcement confined within masonry units infilled with mortar or concrete were determined according to the German standard for reinforced concrete, DIN 1045. This was based on tests on specimens made of clay masonry units. Recent studies on specimens with calcium silicate shaped masonry units provided significantly lower values of anchorage strength, sometimes even lower than those with reinforcement embedded in the bed joint. It is assumed that the lower values in case of reinforced masonry compared to reinforced concrete, are mainly caused by the influence of water absorption of the masonry unit on the bond between reinforcing steel and mortar. The lower anchorage strength values can also been attributed to the high water-cement values of the used mortars in order to improve their flow properties. Another reason is the reduced compacting capability of the mortar infill. The assignment of design values of anchorage stresses in confined mortar or concrete infill, analog to DIN 1045, without differentiation of cross-sectional geometries and masonry unit types, is therefore not assured and constitutes a significant security risk. For the specification of the anchorage strengths of concrete, in the Eurocode 6, the influence of water uptake of the masonry unit on the bond between reinforcing steel bars and concrete also was not taken into account. In addition, considering the corresponding application standards for masonry mortar (mortar assignment groups), DIN V 18580, the anchorage strengths of mortars according to Eurocode 6 are considerably higher than the values given in DIN 1053-3. Looking forward to the upcoming introduction of the Eurocode 6, there is an urgent need to resolve these uncertainties.

The aim of this research project was thus, to examine the permissible anchorage stresses for the anchoring of reinforcing steel bars in masonry, taking into account various factors, and to propose, if necessary, new characteristic values. In the first step, the test results obtained from the literature were compiled and analysed. In a second step, the bond properties between reinforcing steel bars and mortar were determined in pull-out tests for both horizontally oriented reinforcement in the bed joints and vertically oriented reinforcement within masonry units infilled with mortar. As a reference, also investigations without contact to masonry unit material were carried out. The general purpose mortars M 5, M 10 and M 20 used for the tests were chosen so, that the compressive strength corresponded to the minimal standard compression strength of the respective mortar group according to DIN V 18580. As reference concrete a C25/30 was used. According to the literature, the lowest recordable anchorage stresses were arised with calcium silicate masonry units. For this reason, they were mainly used for the tests as masonry units. The reinforcing steel bar diameter was varied between 6 and 14 mm.

In general, the experimental results showed that by increasing the compressive strength of mortar, a significantly lower increase of anchorage stresses is recorded, than initially assumed by determining the permissible values of the anchorage stresses in DIN 1053-3. According to the literature results, lower bond strengths can also be achieved with the use of additives in the mortar. The tests on specimens with bed joint reinforcement confirmed that the type of masonry unit has a significant influence on the bond between reinforcing steel and mortar. The calculated anchorage stresses of the specimens of calcium silicate masonry units are thus always smaller than those of the other masonry units, and - especially in vertically oriented reinforcement in shaped masonry units infilled with mortar – smaller than the values specified in the various standards. Due to the strong influence of the cross-sectional geometry of the cavities of the shaped masory units and the way of filling them with mortar – after each layer of masonry unit or after storey height – as well as the attainable degree of compaction of mortar infill, the calculated bond stresses for vertically oriented reinforcement in small cavities (edge length ≤ 65 mm) were lower than in great cavities (edge length ≤ 135 mm).

From the measured local bond-stress-slip relationships, the mean anchorage stresses were calculated by solving the differential equation governing the bond behaviour numerically. After this, regression calculations for the relationship between the mean anchorage stress and the mortar compressive strength in reinforced masonry have been conducted for each reinforcement arrangement, similar to reinforced concrete. Table 1 shows the resulting characteristic anchorage strengths.

Tabelle 1: Proposal of characteristic anchorage strength of reinforcement in mortar

Arrangement of reinforcing steel bars	Bond quality	Mortar		
		M 5	M 10	M 20
-	-	N/mm²		
1	2	3	4	5
Horizontally, in the bed joint or not confined within masonry units	regular	0.30	0.50	0.80
	good	0.50[1)]	0.75[1)]	1.20[1)]
Verticallly, in confined mortar infill or not confined within masonry units	regular	0.30	0.50	0.80
	good	0.35	0.60	0.90

1) this value can be increased about 30 % for clay masonry units

The different hygric properties of the masonry units influence the mortar compressive strength. On that account, it would be in the future useful to specificate the characteristic anchorage strengths as a function of the effective mortar compressive strength in masonry instead of referring it to the corresponding mortar group. In view of a better utilization of material, it would also be useful to provide characteristic anchorage strengths for the different types of masonry units. To this end, there is still need for further research.