PRESTRESSED HOLLOW-CORE CONCRETE SLABS – PROBLEMS AND POSSIBILITIES IN FASTENING TECHNIQUES

SPANNBETON-HOHLDECKENPLATTEN – PROBLEME UND MÖGLICHKEITEN IN DER BEFESTIGUNGSTECHNIK

DALLES ALVEOLAIRES EN BÉTON PRÉCONTRAINT – PROBLÈMES ET POSSIBILITÉS DES TECHNIQUES D'ANCRAGE

Clemens Lutz

SUMMARY

In the present, prestressed hollow-cored concrete slabs are tendentiously used as ceiling systems. Therefore, fastening techniques with regard to these slabs gain in an increasing importance. In this article, advantages of these members and problems by application of anchors are described, and different structural responses between several types of anchors are experimentally determined. Accordingly, it seems to be essential to choose or to adapt suitable anchors for ceiling systems.

ZUSAMMENFASSUNG

Spannbeton-Hohlplatten finden als Deckensystem eine immer breitere Verwendung und einen immer größeren Anwendungsbereich. Somit gewinnt auch eine korrekte Befestigung in diesen Platten zunehmend an Bedeutung. In diesem Artikel wird auf die Vorteile der Platten, aber auch auf die Problematik, die bei der Montage von Dübeln entstehen, eingegangen. Ferner wird gezeigt, dass es große qualitative Unterschiede bezüglich der Tauglichkeit verschiedener Befestigungssysteme gibt, weshalb eine sorgfältige Auswahl bzw. Anpassung prinzipiell geeigneter Dübel stattfinden muss.

RESUME

Actuellement, les dalles alvéolaires en béton précontraint sont utilisées de plus en plus fréquemment. Par conséquent, les ancrages appropriés gagnent d'importance. Dans cet article, nous traitons les avantages de ces dalles et les problèmes reliés à l'utilisation de chevilles. De plus, nous montrons que les dif-

férents systèmes révèlent de grandes différences qualitatives, et qu'il est par conséquent essentiel de choisir et d'adapter des ancrages adéquats.

KEYWORDS: prestressed hollow-core concrete slab, ceiling, anchorageable thickness, anchor

1. ADVANTAGES AND PROBLEMS

Prestressed hollow-cored concrete slabs made of high-strength concrete are prefabricated concrete members with large hollow proportions. In practice, they are interconnected after assembly by joint grouting compound. In comparison with conventional concrete members, this type of concrete plates has a lot of economical advantages, especially in saving material, energy and in reducing weight of transportation. Outstanding features are quality control, schedule time and costs. Additionally, formworks which are used to produce in-situ concrete are saved in application of these slabs. In the present, this ceiling system is increasingly used in industrial buildings, office buildings and also in domestic architecture. Figure 1 shows cross sections of two types of prestressed hollow-cored concrete slabs (with different minimal anchorageable material thickness: 25 mm and 30 mm).

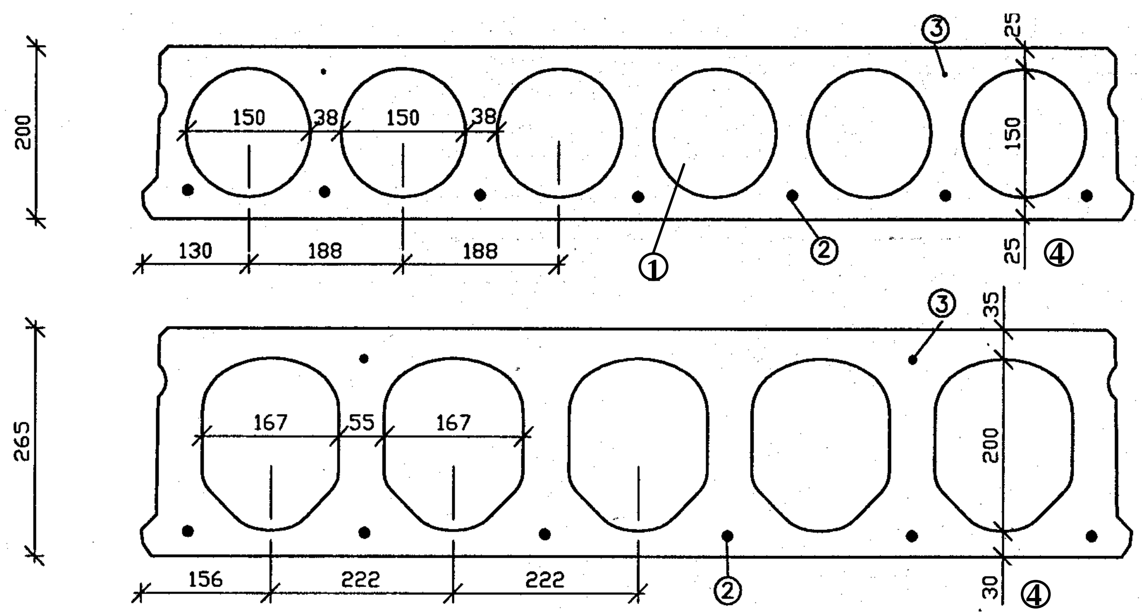


Figure 1: Cross sections of two types of prestressed hollow-cored concrete slabs (1: cavity, 2: prestressed wire, 3: steel, 4: minimal anchorageable material thickness d_{mat}, here: 25 mm and 30 mm)

In spite of above mentioned advantages, the application of anchors in prestressed hollow-cored concrete slabs is not satisfied, particularly in case of thin members. The worst case is that anchors are fastened in near of position A (see fig. 2). The distance between the opposite of casting side and the hollows is the smallest. This distance is defined as minimal anchorageable material thickness d_{mat} (in German: Spiegeldicke). For some types of slabs the value d_{mat} is very small. This small value of thickness is relevant for load carrying capacity of anchor systems. Tables 1 and 2 show experimentally measured thickness d_{mat} of slabs with a minimal anchorageable thickness of 30 mm and 25 mm respectively. All values in table 1 are above 30 mm. Some values in table 2 are only just 25 mm. For slabs with d_{mat} = 25 mm there is no sufficient reserve in comparison to slabs with d_{mat}= 30 mm! Furthermore, crashing of concrete closed to the hollows often occurs during drilling. Consequently, the minimal anchorageable material thickness and also the effective anchorage depth for anchors are reduced (see fig. 3) and load carrying capacities of ceiling systems are negatively influenced. Therefore, it is necessary to determine whether all types of fasteners are suitable to be used in prestressed hollow-cored concrete slabs. Additionally, it is prohibited to install an anchor in near of a strand of wire because of interests of safety (zone C in fig 2).

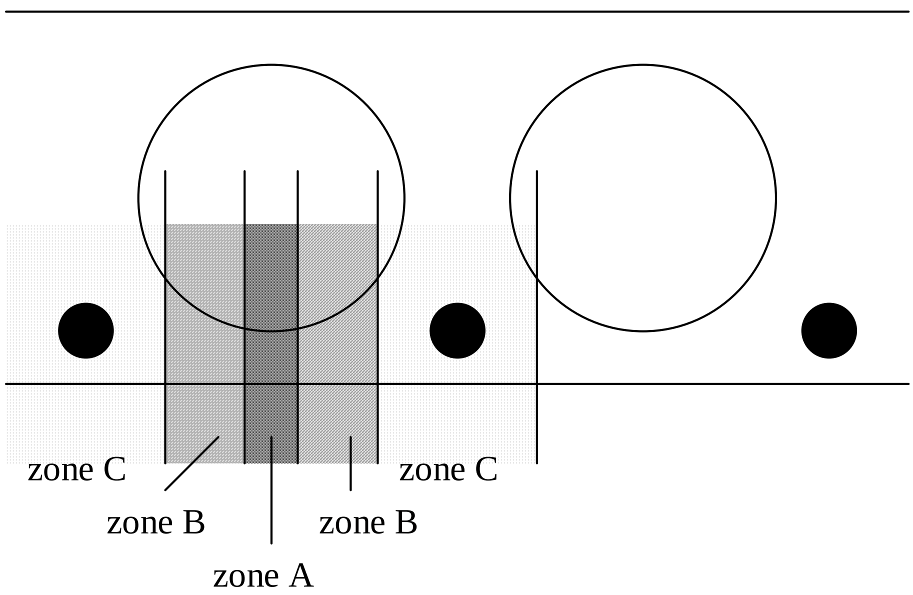


Figure 2: Sectors of a prestressed hollow-cored concrete slab.
Zone A: minimal anchorageable material thickness;
Zone B: anchorageable sector;
Zone C: prohibited sector for fastenings because of interests of security (prestressed concrete wire)

Table 1: measured values d_{mat} (slab with a minimal anchorageable thickness of 30 mm)

d_{mat} [mm] (measured minimal anchorageable material thickness)	39,6	42,3
	43,1	44,2
	42,3	45,0
	40,9	43,8
	37,8	39,2
Range [mm]	38 (>30) to 45	
Average [mm]	41,8	
Variation coeff. [%]	5,70	

Table 2: measured values d_{mat} (slab with a minimal anchorageable thickness of 25 mm)

d_{mat} [mm] (measured minimal anchorageable material thickness)	25,1	26,7
	26,7	28,5
	27,6	28,5
	26,8	27,5
	26,2	28,6
	25,0	26,1
Range [mm]	25 to 29	
Average [mm]	26,9	
Variation coeff. [%]	4,60	

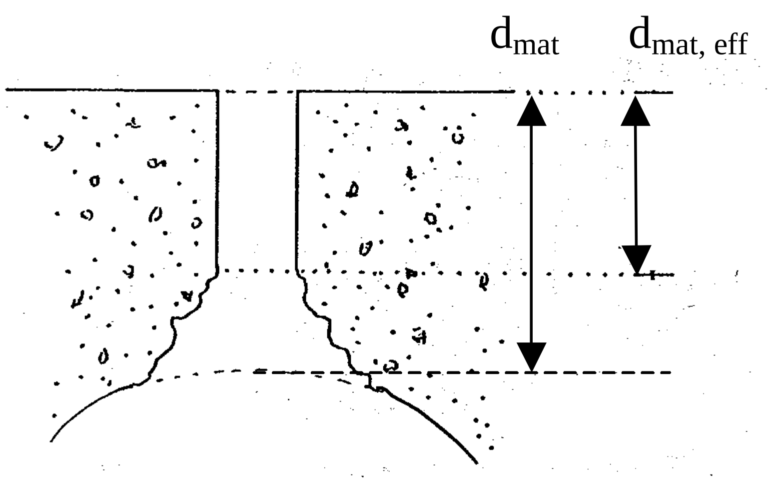
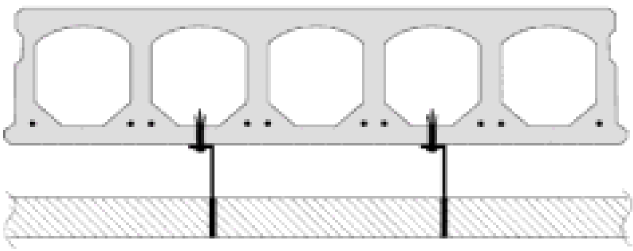


Figure 3: The minimal anchorageable material thickness d_{mat} after drilling is reduced (:=$d_{mat, eff} < d_{mat}$).

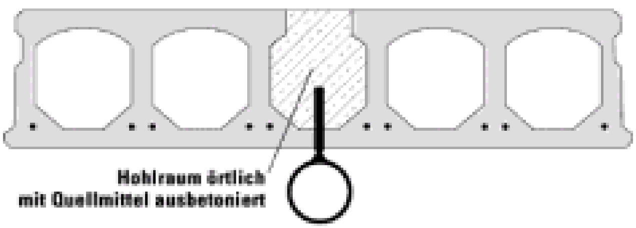
2. POSSIBILITIES AND TEST RESULTS

In general, there are three types of possibilities to fasten installation pipes, suspendic and acoustics ceilings, lighting appliances, safety precaution systems and beams (see fig. 4). In the following, fastenings with different types of *anchors* according to possibility (1) will be studied in detail. As results, these anchors applied in prestressed hollow-cored concrete slabs show their quite different suitability.

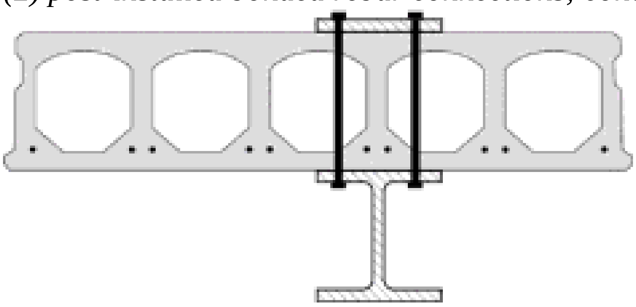
There are already several types of special fasteners on the market, which have approvals for using in hollow-cored concrete slabs. Objective of this work is to investigate suitability and quality of other types of anchors in these members. Therefore, pull-out tests were carried out in the uncracked concrete zone of these slabs with a minimal anchorageable material thickness d_{mat} of 25 mm and 30 mm. Herein, different types of anchors – concrete screws, injection anchors, suspendic ceiling fasteners, deformation-controlled expansion anchors and torque-controlled expansion anchors – were used. The sizes of anchors chosen for these experiments were between M6 and M10.



(1) only anchors



(2) post-installed bonded rebar connections; concrete suspension



(3) construction, fastening through the slab

Figure 4: Three types of possibilities to fasten installation pipes, suspendic and acoustics ceilings, lighting appliances, safety precaution and beams

For each test, one borehole was produced with the help of a hammer drill. Position of the borehole was chosen in such a way that the thickness of concrete corresponds to the minimal anchorageable thickness d_{mat}. Depth of the borehole is equal to this minimal thickness (position A, fig. 2). Typical crashing of concrete closed to the hollows was often observed after drilling. Consequently, the effective anchorage depth was reduced. After installation of the anchor system the fastener was subjected to concentric tension up to failure. For concrete screws, setting tests with concrete screws were also carried out additionally [1].

Figure 5 outlines an equipment for pull-out tests where one load cell, two LVDTs and a steel support frame are used. Figure 6 shows a pull-out cone of a concrete screw. Pull-out test results for different types of anchors are represented in following figures. Figure 7 shows measured load carrying capacities of different types of anchors used in concrete slabs with a minimal anchorageable material thickness of 30 mm. All test results are given in relation to the failure load of concrete screws, type 1 (which is chosen as reference anchor).

Figure 5: Pull-out tests in a prestressed hollow-cored concrete slab

Figure 6: Pull-out cone of a concrete screw

From figure 7, it can be seen that the highest load carrying capacity was obtained in torque-controlled expansion anchors (column 7). The average failure load was 93% higher in comparison to anchor, type 1 (reference anchor). Relative loading carrying capacities of other anchors are summarized in the following:

- concrete screws, type 2 (column 2)	+64%
- deformation-controlled expansion anchors (column 4)	+30%
- injection anchors (column 6)	+12%
- special fasteners for hollow-cored concrete slabs (column 5)	±0
- concrete screws, type 1 (column 1)	±0
- suspendic ceiling fasteners (column 3)	–26%

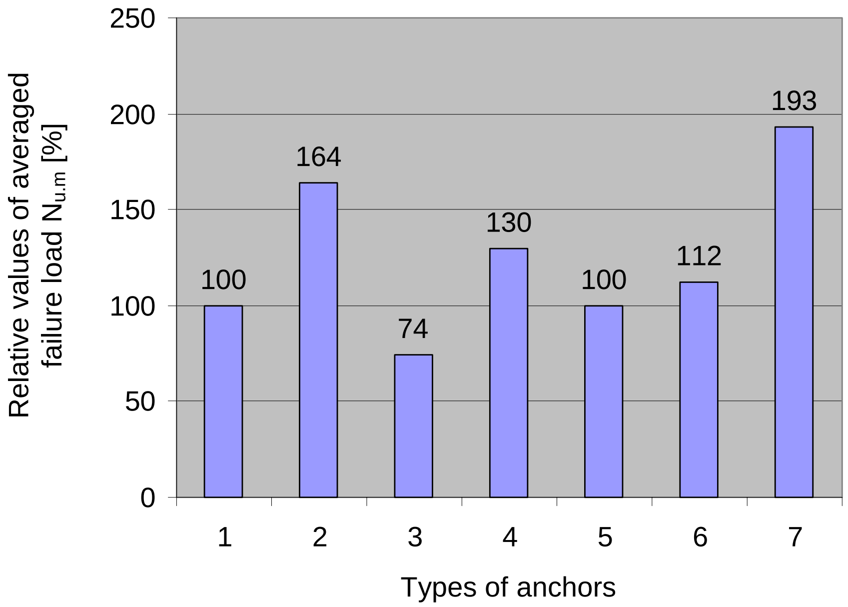


Figure 7: *Pull-out test results for different types of anchors (minimal anchorageable material thickness: 30 mm). All test results are given in relation to the failure load of a concrete screw, type 1 [1].*
1: concrete screws, type 1
2: concrete screws, type 2
3: suspendic ceiling fasteners
4: deformation-controlled expansion anchors
5: special fasteners for hollow-cored concrete slabs
6: injection anchors
7: torque-controlled expansion anchors

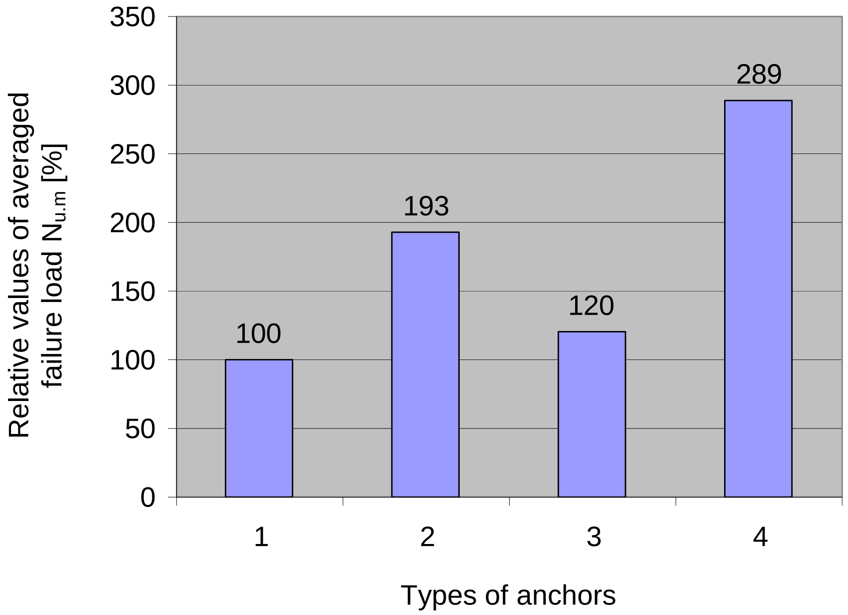
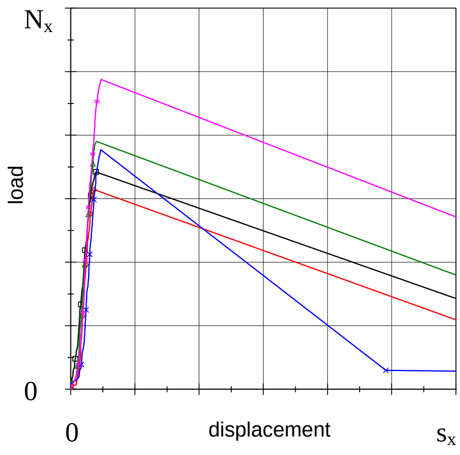


Figure 8: *Pull-out test results for different types of anchors (minimal anchorageable material thickness: 25 mm). All test results are given in relation to the failure load of a concrete screw, type 1.*
1: concrete screws, type 1
2: deformation-controlled expansion anchors
3: suspendic ceiling fasteners
4: special fasteners for hollow-cored concrete slabs

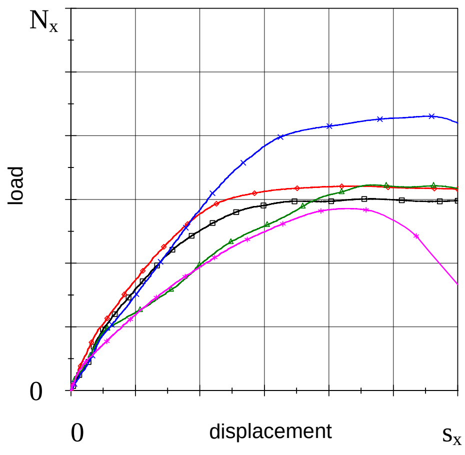
Figure 8 shows experimental results of different types of anchors used in a thin hollow-cored concrete slab with a minimal anchorageable material thickness of 25 mm. All mean values of load carrying capacities are represented in relation to the averaged failure load of anchor, type 1. Relative loading carrying capacities of other types of anchors are summarized as follows:

- special fasteners for hollow-cored concrete slabs (column 4) +189%
- deformation-controlled expansion anchors (column 2) +93%
- suspendic ceiling fasteners (column 3) +20%
- concrete screws, type 1 (column 1) ±0

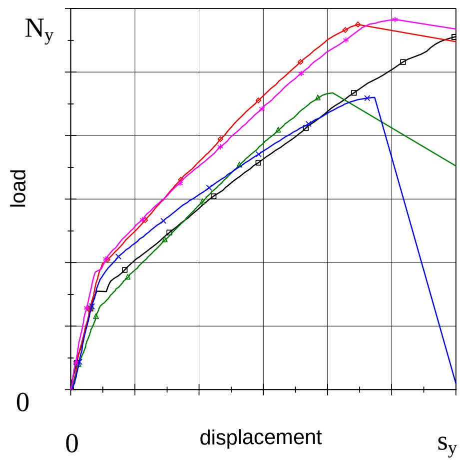
For most of structural designs the averaged load carrying capacity is not alone the value which characterizes the material properties. Displacements and statistic values are also important factors. In figure 9 load-displacement-diagrams on the left and right are compared (diagram a and b): Failure load and statistic values according to the load carrying capacities of these both types of anchors are almost the same (see also table 3 for statistic values), whereas the displacements and statistic values according to the displacements are quite different. Therefore, it may be questioned, which type of anchor is more suitable for hollow-cored concrete slabs. Anchors of type 1 behave more brittle, anchors of type 2 behave more ductile. In this case, displacement at the permissible load is essential. Type 1 seems to behave more positive than type 2. In figure 9 c.) and d.) anchors of type 3 reach higher load carrying capacities on average in comparison with type 4, but they have also higher displacements. It is harmful if displacements are to high and come outside of linear area (see fig. 10).



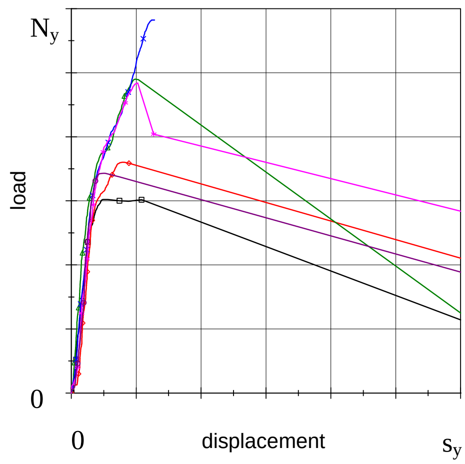
a.) type 1



b.) type 2



c.) type 3



d.) type 4

Figure 9: Load-displacement-curves for different types of anchors.
Diagrams a.) and b.): Difference in displacement with almost the same failure load.
Diagrams c.) and d.): Difference in failure load and displacement

Table 3: Statistic values of two types of anchors in a prestressed hollow-cored concrete slab with d_{mat}= 30 mm (see figure 9)

	a.) Type 1	b.) Type 2
Variation coefficient at failure load $N_{u,m}$ [%]	17	17
Displacement at 0,5 $N_{u,m}$ [%]	100	560
Variation coefficient for displacement at 0,5 $N_{u,m}$ [%]	11	25

Obviously, the load carrying capacity is not only the aspect characterizing anchors. In principle, three groups of anchors could be distinguished according to their load-displacement-behaviours (see fig. 11):

- Group 1: anchors with little displacements, i.e. the tested injection anchors.
- Group 2: anchors with larger displacements and high load carrying capacities, i. e. one of the tested torque-controlled expansion anchors.
- Group 3: anchors with larger displacements and reduced load carrying capacities.

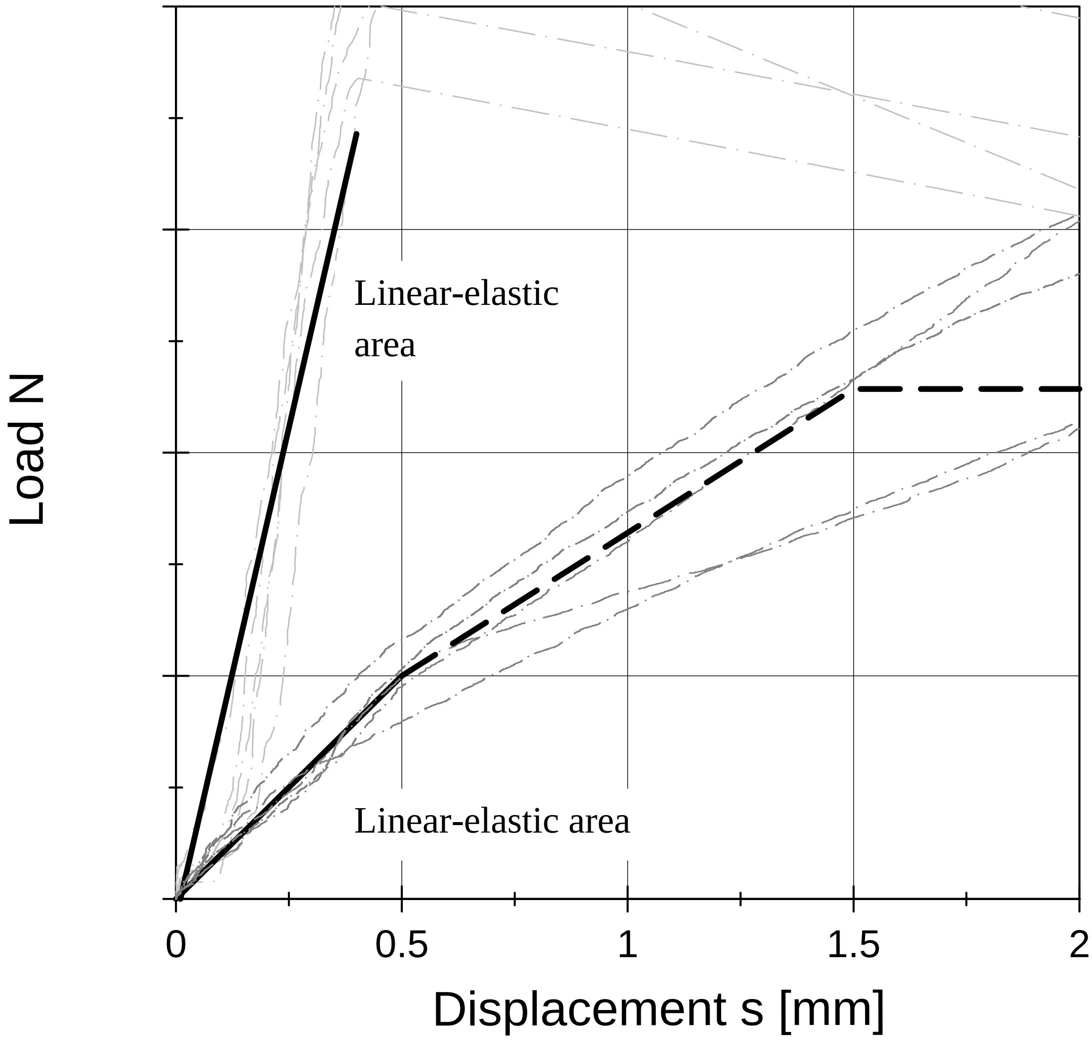


Figure 10: Experimental load-displacement-curves and simplified linear curves for two types of anchors in a prestressed hollow-cored concrete slab (here: with d_{mat}= 30 mm).

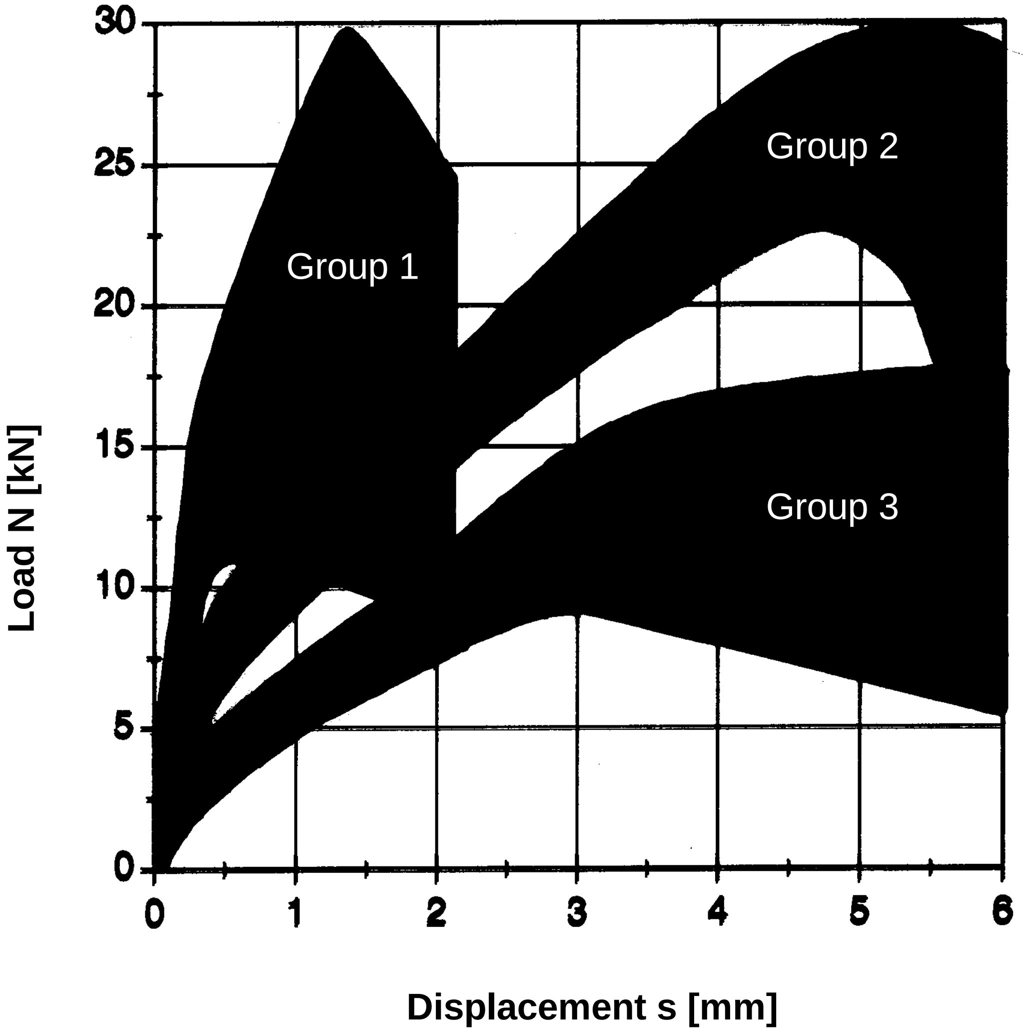


Figure 11: Load-displacement-curves of anchors in prestressed hollow-cored concrete slabs (here: with d_{mat}= 30 mm) can be distinguished in three groups. There are serious differences in carrying load capacities, but also in displacements

According to the above mentioned observations, it can be concluded that anchors of group 1 in connection with serious statistic values in according to load carrying capacities and displacements are most suitable to apply in prestressed hollow-cored concrete slabs. Though, further tests have to be done (sustained load, fatigue tests and so on).

REFERENCES

[1] LUTZ, C.: Anchors in prestressed hollow-cored concrete slabs. IWB Activities 3 (2001)

[2] LUTZ, C.: Nachträgliche Befestigungen in Spannbeton-Hohlplatten. IWB Mitteilungen, Jahresbericht 2000-2001