PLASTIC ANCHORS IN HOLLOW BRICK MASONRY

KUNSTSTOFFDÜBEL IN HOHLMAUERWERK

FIXATION EN MACONNERIE DE BRIQUES CLOISONNES

Silvia Weber, Rolf Eligehausen, Bernhardt Lehr, Thomas Sippel

SUMMARY

The load-displacement behaviour of plastic anchors fixed in different bricks was investigated varying their type, the length of embedment, the position in the brick and the methods for drilling the holes.

ZUSAMMENFASSUNG

Das Tragverhalten von Kunststoffdübeln in unterschiedlichen Mauersteinen wurde in zentrischen Ausziehversuchen ermittelt. Variiert wurde der Dübeltyp, die Verankerungstiefe, die Setzposition im Stein sowie die Bohrlocherstellung.

RESUME

Des fixation présentant différentes longueurs d'ancrage, positions au sein de la brique et méthodes de percage ont été soumises à des esais de traction afin de déterminer l'influence de ces facteurs sur le comportement et la résistance des fixation dans différentes briques cloisonées.

KEYWORDS: Plastic anchors, Hollow bricks, Load behaviour, Load capacity
Ultimate loads, Embedment length, Positioning, Drilling methods

1. INTRODUCTION

Plastic anchors have Technical Approvals for application in masonry based on pull-out tests performed years ago in different types of hollow bricks.

In case of plastic anchors the tension load is transferred by friction between the expanded plastic sleeve and the walls of the bricks. The new requirements on the thermal insulation capacity of external walls leaded to the development of new products which show an increased ratio of the holes area of the brick to its total area. Additionally, the thickness of the external and internal walls of the bricks have been decreased, while the compressive strength is relatively high. A rather poor load-bearing behaviour of plastic anchors in masonry made out of these brittle hollow bricks is to be expected.

Therefore, an extensive experimental program was set up. Centric pull-out tests with five different plastic anchors which have a Technical approval of the Deutsches Institut für Bautechnik (DIBt) for application in hollow bricks were performed. Analogue to the behaviour of the plastic anchors in concrete, it is assumed that, installing the plastic anchors deeper than the minimum embedment length given in the Technical Approval can improve their behaviour. However, for hollow bricks the expanded part of the sleeve might than be situated disadvantageously in a hole. Depending on the configuration of the holes, the position of the anchors in the brick might influence the load-displacement behaviour.According to the Technical Approval percussion drilling is not allowed in hollow clay bricks. However, the physical effort for drilling in bricks with high compressive strength being rather large, percussion drilling is commonly used in practice. With percussion drilling the external and internal walls of the bricks are seriously damaged, leading to a reduction of the pull-out strength of the anchors.

The aim of the performed tests is to investigate the influence of parameters on the load-displacement behaviour and the pull-out strength of plastic anchors in different types of hollow bricks.

2. EXPERIMENTS

2.1 Materials

The technical characteristics of the five different types of plastic anchors tested in hollow bricks are shown in Table 1. The used bricks are made out of clay (Fig.1), limestone (Fig.2) and lightweight aggregate concrete (LWAC) (Fig.3 to 6). They have different sizes, configuration of holes and compressive strengths. The determined densities and compressive strengths are given in Table 2.

2.2 Testing programme

The plastic anchors were fixed in non cleaned holes drilled vertically. Centric pull-out tests with a servo-hydraulic testing machine where performed like shown in Fig.7. The selected position of the plastic anchors in the bricks can be seen from Fig. 1 to 6. The nominal length of embedment $h_{ef,nom}$ was increased or decreased. For the bricks type Hbl the following drilling methods were applied: rotary drilling and percussion drilling using three different machines I to III, having increased energies of percussion. The testing programme is shown in Tab. 3.

3. TEST RESULTS

In Figures 8 to 11 the monitored load-displacement curves (L-D-Curves) for plastic anchor Type 1 in clay bricks for different embedment length and for the selected positions „A“ and „B“ are shown. The holes were drilled using rotary drilling. Figures 12 to 14 show the results for bricks made of limestone, the anchors being in position „C“. In the Figures 15 to 17 the results for anchors Type 5 in bricks made of lightweight aggregate concrete are given. From the Figures 18 to 21 can be seen the load-displacement curves for plastic anchor Type 3, when drilling is performed using different methods and machines.

4. DISCUSSION

4.1 Hollow clay bricks

The influence of the design of the plastic anchors on the ultimate load can be seen from Figure 22, showing the measured ultimate loads of the different types of plastic anchors in hollow clay bricks at $h_{ef,nom}$. Type 5 shows the highest values while for Types 2 and 4 the scatter of the pull-out loads is rather high and the minimum values are in the range of the admissible load. In Figures 23 and 24 the influence of the embedment length on the ultimate load can be seen. In general the ultimate load is significantly reduced if the embedment depth is decreased or increased compared to the nominal value. From Figure 25 the influence of the position „A“ and „B“ of the anchors on the ultimate load can be seen.

4.2 Hollow bricks of limestone

According to Figur 26 the anchors Type 1 and Type 5 achieved the highest ultimate loads. The ultimate loads for Type 3 were in the range of the allowable load. Figure 27 shows that, increasing the embedment depth with respect to the nominal value resulted in lower ultimate loads in case of the tested anchors Types 1, 2 and 5. Fixing them deeper clearly showed that the expanded part of the sleeve is completely situated in a hole.

4.3 Hollow bricks of lightweight aggregate concrete

According to Figures 28 and 29 the influence of the embedment length on the ultimate load is rather small in case of blocs made out of lightweight aggregate concrete. However, when increasing the embedment length the expanded part of the sleeve can be situated in a hole, resulting in an unacceptable load-displacement behaviour (see Figure 17). On the contrary, reducing the embedment depth might positively influence the load-displacement behaviour (Figure 16) because the part of the sleeve with higher expansion force is situated in the wall of the brick. When using different drilling methods and machines (Figure 30 and 31) the highest ultimate load was measured for rotary drilling, though for this bricks percussion drilling is explicitly allowed. The higher the energy of percussion becomes, the stronger is the deterioration in the base material and the lower the measured ultimate load.

5. CONCLUSIONS

The result of the performed tests show that the load-displacement behaviour and the ultimate load of plastic anchors fixed in hollow bricks is significantly influenced by the type of brick, the type of the plastic anchor, the embedment depth and the way of drilling the holes. The measured ultimate load of some type of plastic anchor in certain hollow bricks was in the range of the allowable load. Furthermore, opposite to the current assumption an increase of the embedment depth often results in a significant reduction of the load-bearing behaviour of the anchor. Percussion drilling leads to large reduction of the ultimate load. Hence, the rules for the installation and the design of plastic anchors given in the Technical Approval of the DIBt should be reconsidered. It is proposed to determine experimentally the influence of percussion drilling when establishing the admissible load.

Tab.1: *Plastic anchors*

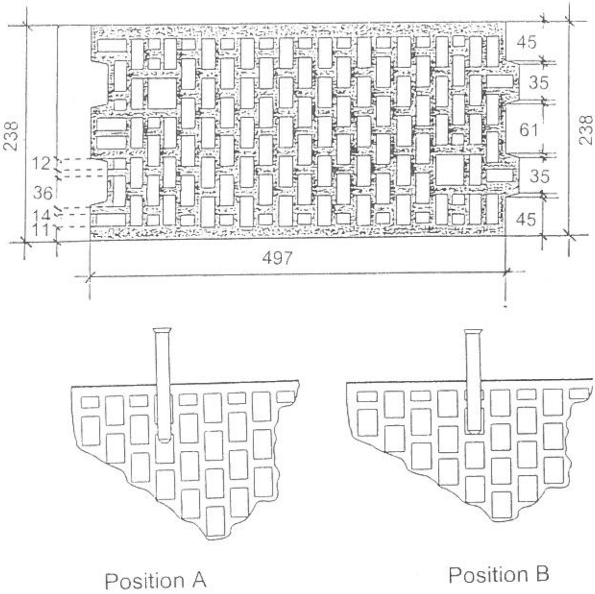
Technical Data	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5
Nominal diameter [mm]	10	10	10	10	10
Diameter of holes [mm]	10	10	10	10	10
Nominal embedment length [mm]	70	70	90	90	70
Depth of hole [mm]	≥80	≥80	≥100	≥100	≥80
Admissible Load [kN] acc. to Technical Approval of DIBt					
Clay bricks ≥HLz12	0,30	0,30	0,30	0,30	0,30
Limestone ≥ KSL 6	0,40	0,40	0,40	0,40	0,40
LWAC Blocs ≥Hbl 2	0,25	0,25	0,25	0,25	0,25

Tab. 2: *Hollow Bricks*

Brick	Size	Holes	Density [kg/dm³]	Compressive Strength [N/mm²]
Clay brick HLz	16 DF	Figure 1	0,77 0,84	13,9 9,5 and 16,6
Limestone KSL	10 DF	Figure 2	1,21	18,6
LWAC blocs Hbl	3K 16 DF	Figure 3, 4	0,9	4,6
	1K 12 DF	Figure 5, 6	0,9	3,3 and 5,7

Tab. 3: *Testing Programme*

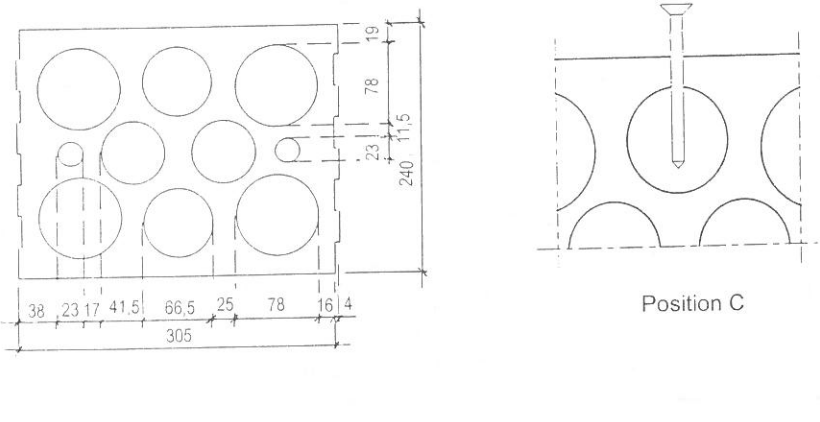
ANCHOR TYPE		1	2	3	4	5
BRICK TYPE	EMBEDMENT LENGTH	POSITION				
HLZ (see Fig. 1)	$h_{ef, nom}$	A, B	A, B	A, B	A, B	A, B
	$h_{ef, nom}$ -20mm	A	A	A		A
	$h_{ef, nom}$ +20mm	A	A			A
KSL (see Fig. 2)	$h_{ef, nom}$	C	C	C	C	C
	$h_{ef, nom}$ -20mm	C	C			C
	$h_{ef, nom}$ +20mm	C	C			C
3K Hbl 16DF (see Fig. 3)	$h_{ef, nom}$	E			E	E
	$h_{ef, nom}$ -20mm	E			E	E
	$h_{ef, nom}$ +20mm	E				E
1K Hbl 12 DF (see Fig. 5)	$h_{ef, nom}$	D	D	D		
	$h_{ef, nom}$ -20		D	D		
	$h_{ef, nom}$ +20	D	D			
1K Hbl 12 DF (see Fig. 6)	Rotary Drilling					D
	Percussion Drilling Machine I					D
3K Hbl 16 DF (see Fig. 4)	Rotary, Percussion Drilling Machine I; II,		E	E		
	Percussion Drilling Machine III		E	E		



Position A

Position B

Fig. 1: *Clay Brick. HLz 12-0,9-16 DF, Position A and B*



Position C

Fig. 2: *Brick of limestone KSL R 12-1,2-10DF, Position C*

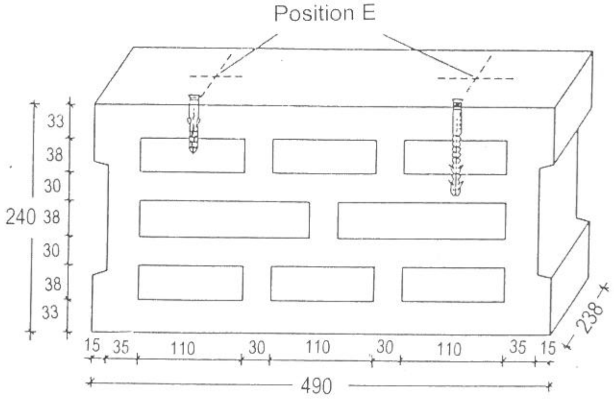


Fig. 3: *Brick of lightweight aggregate concrete. 3 K Hbl 2-0,9-16 DF, Position E*

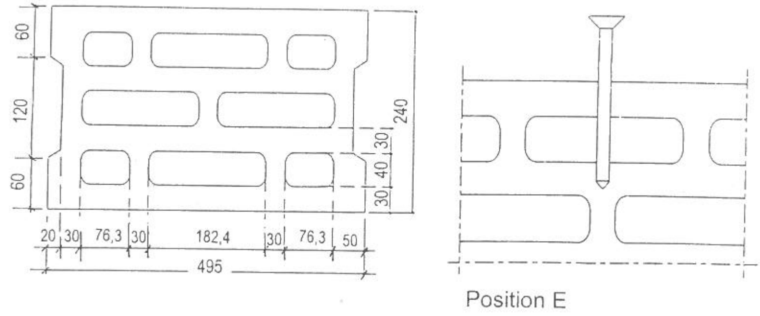


Fig. 4: *Brick of lightweight aggregate concrete. 3 K Hbl 2-0,9-16DF, Position E*

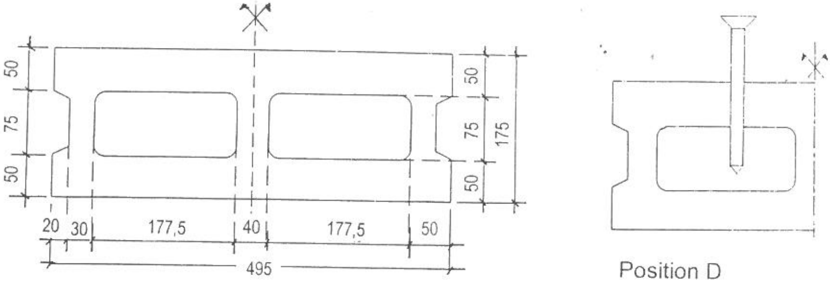


Fig. 5: *Brick of lightweight aggregate concrete. 1 K Hbl 2-0,9-12 DF, Position D*

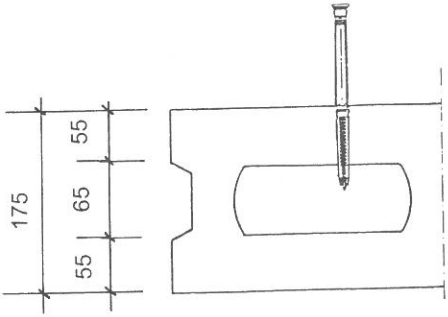


Fig. 6: *Brick of lightweight aggregate concrete. 1 K Hbl 2-0,9-12 DF, Position D*

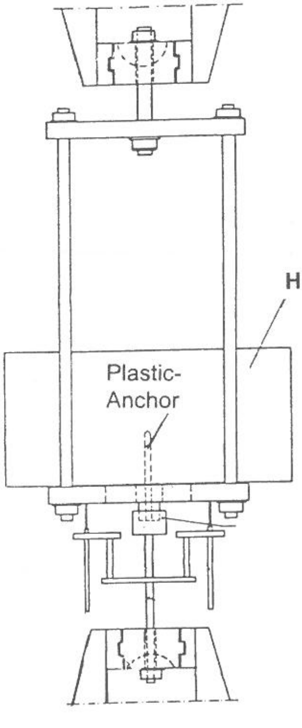


Fig. 7: *Testing installation.*

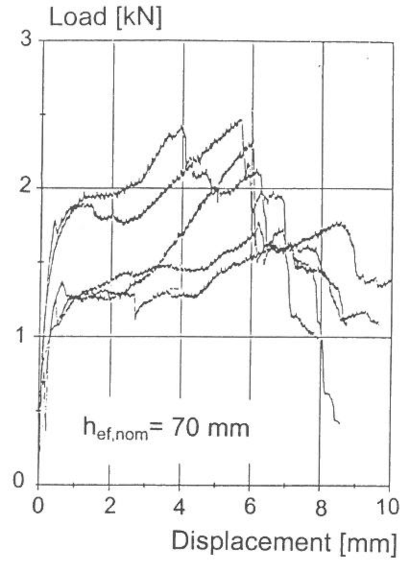


Fig.8: *L-D-Curves, PA Type 1, HLz,* h_{ef} *=70mm, Pos.A*

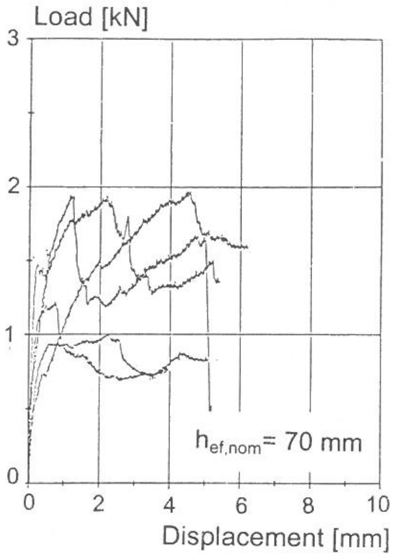


Fig.9: *L-D-Curves, PA Type 1, HLz,* h_{ef} *=70mm, Pos.B*

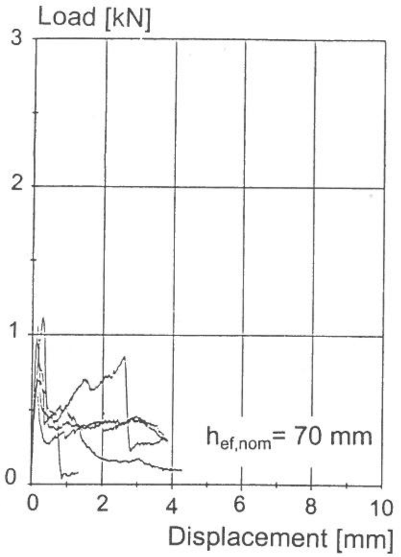


Fig.10: *L-D-Curves, PA Type 1, HLz,* h_{ef} *=50mm, Pos.A*

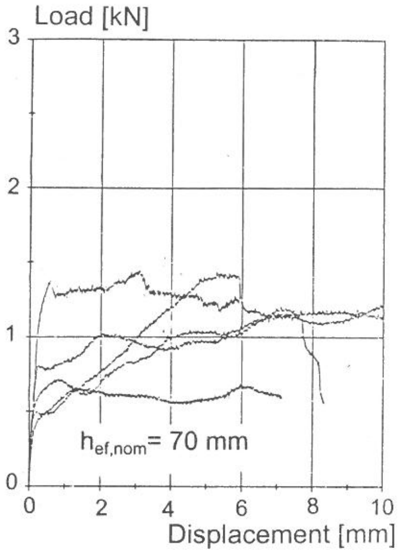


Fig.11: *L-D-Curves, PA Type 1. HLz,* h_{ef} *=90mm, Pos.A*

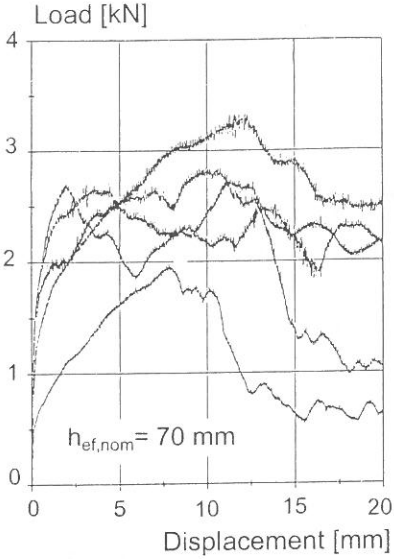


Fig.12: *L-D-Curves, PA Type 1, KSL, h_{ef} =70mm, Pos.C*

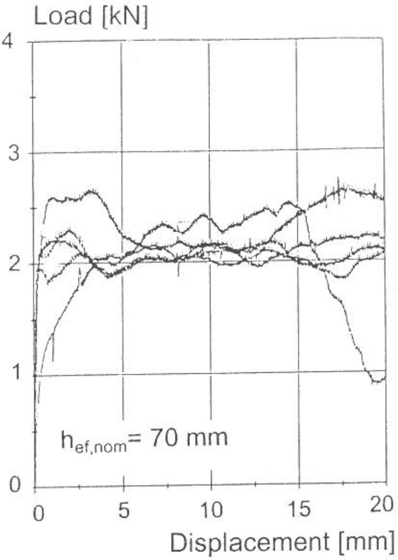


Fig.13: *L-D-Curves, PA Type 1, KSL, h_{ef} =50mm, Pos.C*

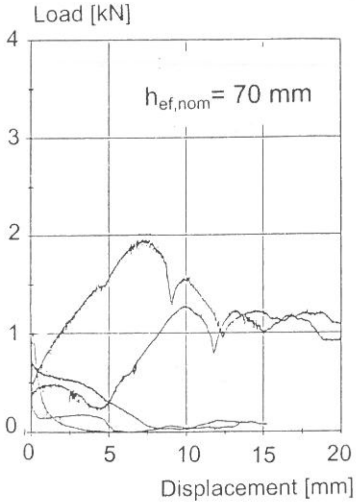


Fig.14: *L-D-Curves, PA Type 1, KSL, h_{ef} =90mm, Pos.C*

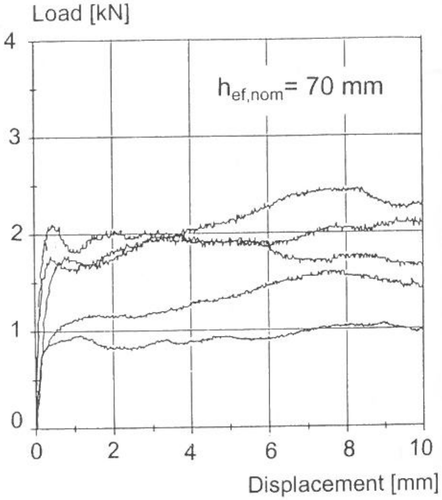


Fig.15: *L-D-Curves, PA Type 5, Hbl, h_{ef} =70mm, Pos.E*

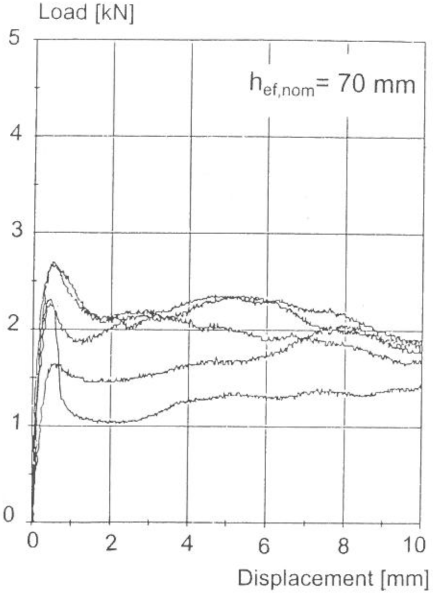


Fig.16: *L-D-Curves, PA Type 5, Hbl,* h_{ef} *=50mm, Pos.E*

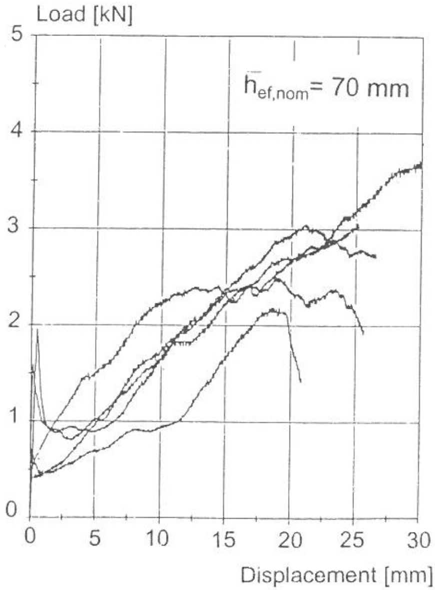


Fig.17: *L-D-Curves, PA Type 5, Hbl,* h_{ef} *=90mm, Pos.E*

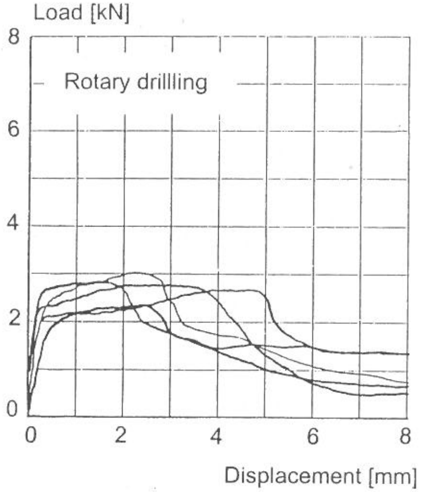


Fig.18: *L-D-Curves, PA Type 3, Hbl,* h_{ef} *=50mm, Pos.E*

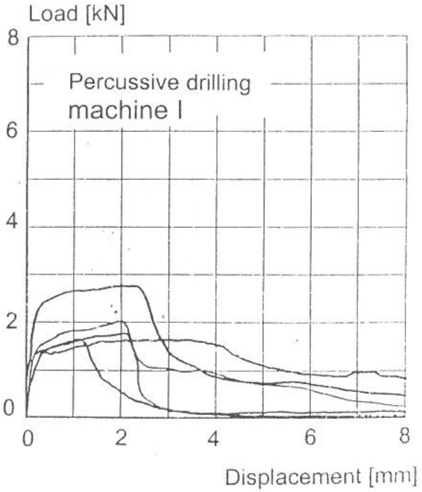


Fig.19: *L-D-Curves, PA Type 3, Hbl,* h_{ef} *=50mm, Pos.E*

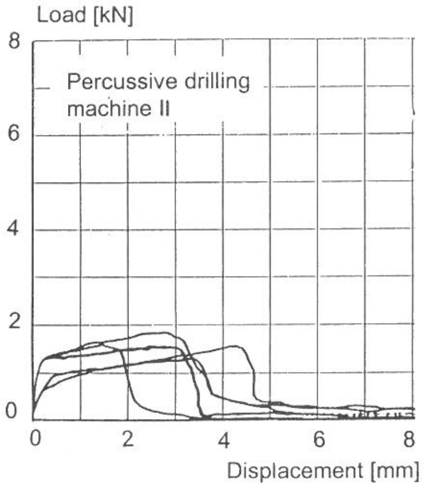


Fig. 20: *L-D-Curves, PA Type 3, Hbl,* h_{ef} *=50mm, Pos.E*

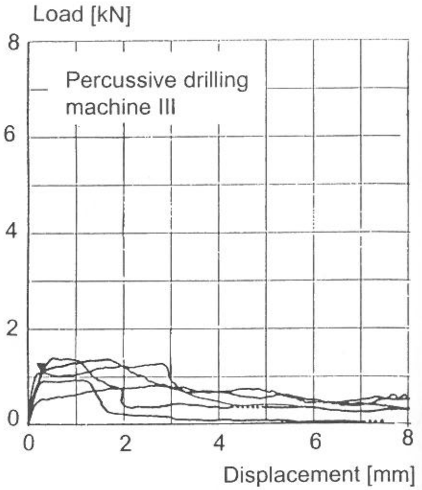


Fig.21: *L-D-Curves, PA Type 3, Hbl,* h_{ef} *=50mm, Pos.E*

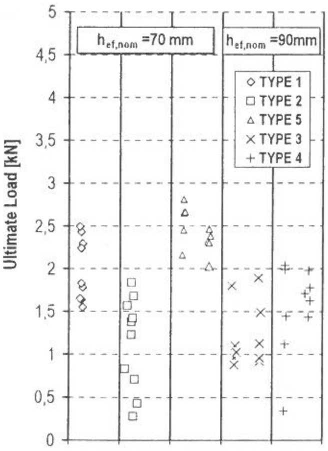


Fig. 22: *Ultimate Load, HLz* $h_{ef} = h_{ef,nom}$,

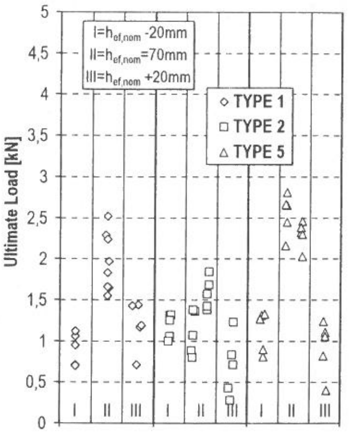


Fig.23: *Ultimate Load, HLz* h_{ef} *=varying, Pos.A*

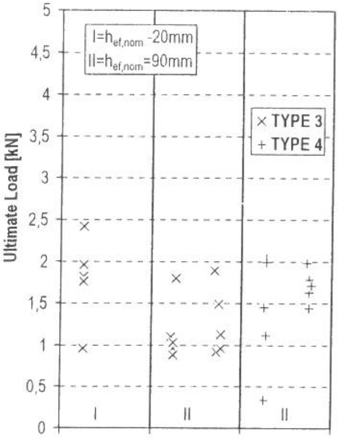


Fig. 24: *Ultimate Load, HLz*
h_{ef} *=varying, Pos.A*

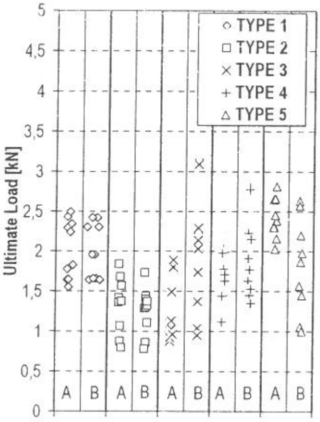


Fig.25: *Ultimate Load, HLz*
$h_{ef} = h_{ef,nom}$*, Pos.A and B*

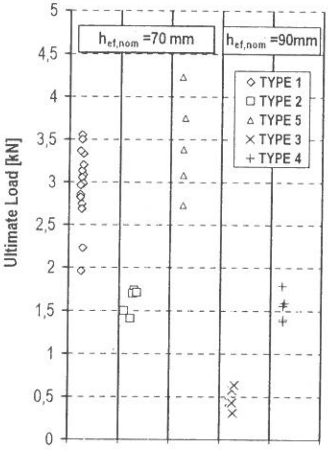


Fig. 26: *Ultimate Load, KSL*
$h_{ef} = h_{ef,nom}$,

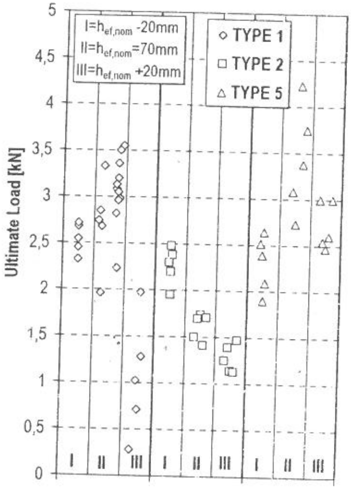


Fig.27: *Ultimate Load, KSL*
h_{ef} *=varying*

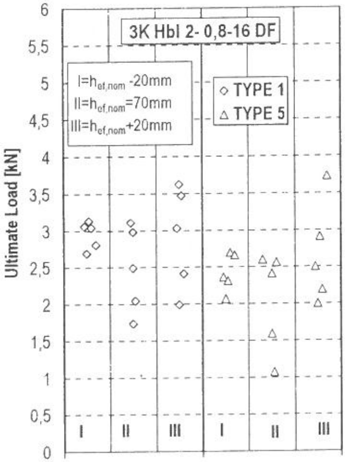


Fig. 28: *Ultimate Load, Hbl,3K 16DF*
h_{ef} = varying, Rotary Drilling

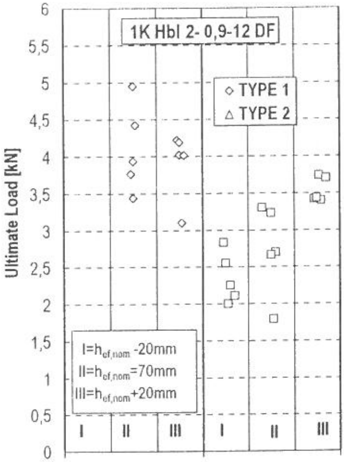


Fig.29: *Ultimate Load, Hbl, 1K 12DF*
h_{ef} = varying, Rotary Drilling

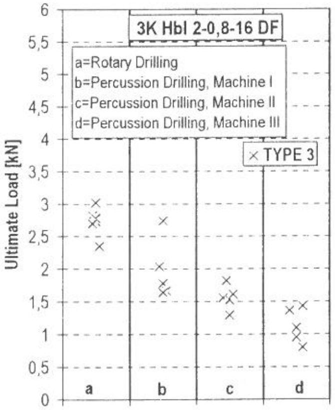


Fig. 30: *Ultimate Load, Hbl,3K 16DF*
h_{ef} =hef,nom, Drilling=varying

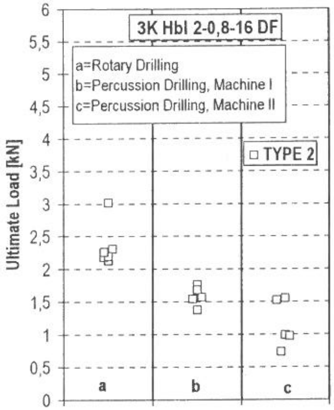


Fig.31: *Ultimate Load, Hbl, 3K 16DF*
h_{ef} =hef,nom, Drilling=varying