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Abridged report

Manufactured prestressed masonry walls with high earthquake resistance (AZ: Z 6-5.4-02.18)

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1 Intention of the research project

Latest developments of the standards with reference to the design of buildings in German earthquake territories postulate higher horizontal substitute encumbrances. The purpose of this research project is the examination of improved shear and deformability behaviour as a result of prestressed masonry.

The intention of the research project is the analysis of the improving effect of prestressed masonry with coupled ceiling in relation to the shear and deformability behaviour.

2 Management of the research project

2.1 Clamping device

In cooperation with the company SUSPA/DSI, Langenfeld/Germany, a clamping device with connectable strands (St 1570/1770, Ø 0,6”, $P_{O,max}$ = 189 kN) for the prestressing of masonry was developed. Figure 1 shows the fixed anchor with a strand installed. For the clamping anchor (figure 2), a screw anchor was selected to prevent slippage.

Figure 1: Fixed anchor with a strand installed

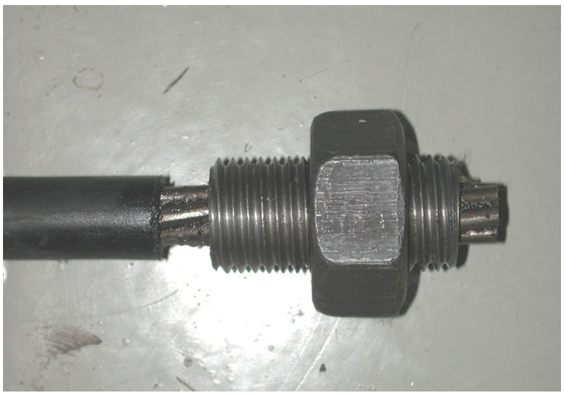


Figure 2: Clamping anchor

2.2 Wall attempts

There were four walls that are usually used for the stiffening of buildings with three floors, with dimensions and extra loads tested. In the experiment, only the bottom floor was considered. For simulation of the dead load of the floors above, a bed joint stress of σ = 0,50 N/mm^2 in the bottom bed joint was applied.

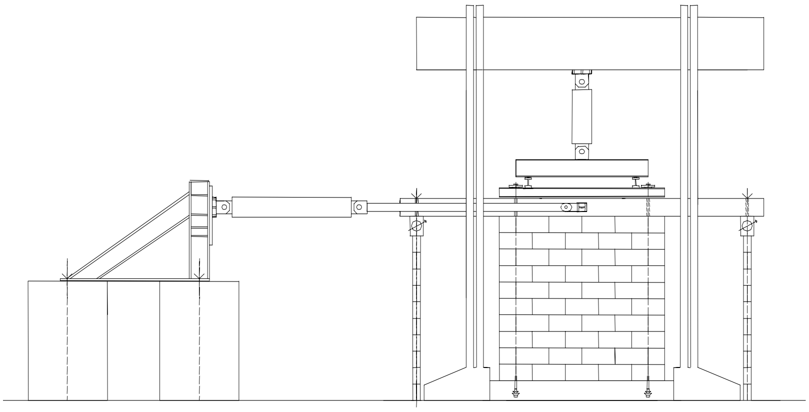


Figure 3: Complete experiment setup, wall W1

All walls were prestressed with two strands and provided with a beam on the top. The beam simulated the rotation disability of the ceiling over the shear wall and was supported on both or only on one end on a wall band. This bearing is equivalent to that of exterior or partition walls. Figure 3 shows the wall W1 in the complete experiment setup. In addition to the length of the walls, the distance between the strands was varied.

Table 1: Dimensions of the walls, prestressed loads and absorbed horizontal force

	Wall 1	Wall 2	Wall 3	Wall 4
Wall level	2,50 m			
Wall thickness	0,175 m			
Wall length	2,50 m	2,50 m	1,25 m	1,25 m
Distance of the strands	2,00 m	1,25 m	0,75 m	0,75 m
Bearing of the beam	double sided	double sided	Double sided	One sided
Prestressing (2 · P_0)	360 kN	356 kN	352 kN	274 kN
First crack force [kN]	217	223	110	101
	- 227	- 220	- 114	- 100
Horizontal displacement at the first crack force [mm]	3	6	7	11
Failure of the wall or achievement of the break off criterion [kN]	109	89	60	34
	- 105	- 94	- 60	- 16
Maximum horizontal displacement before breakdown [mm]	17	23	23	20

The walls were loaded with a horizontal static circular head displacement. The speed was displacement-controlled with 0,008 Hz in three cycles per deformation step applied. Figure 9 shows the cycles against the time for the first four deformation steps.

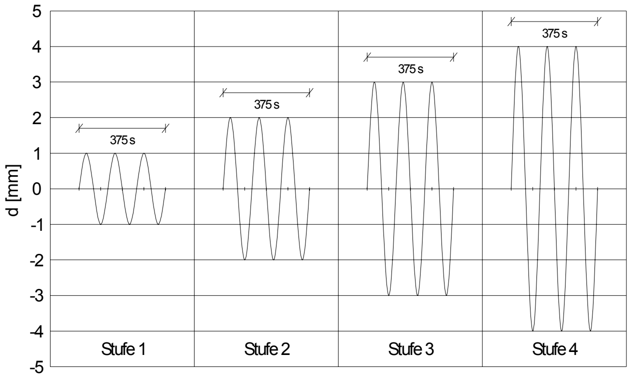


Figure 9: Representation of the first four deformation steps

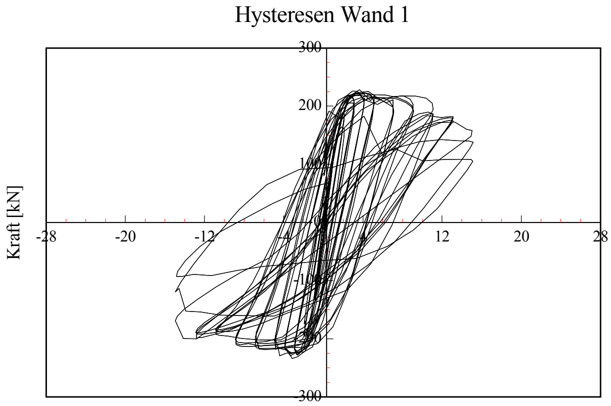
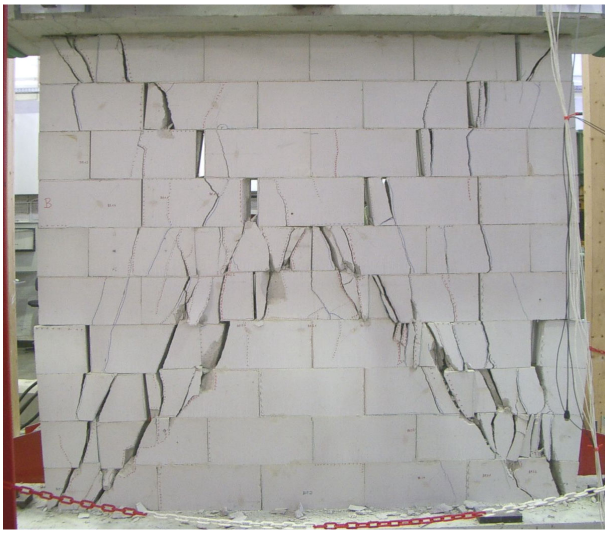


Figure 10: Hysteresis with horizontal head deformation [mm], W1



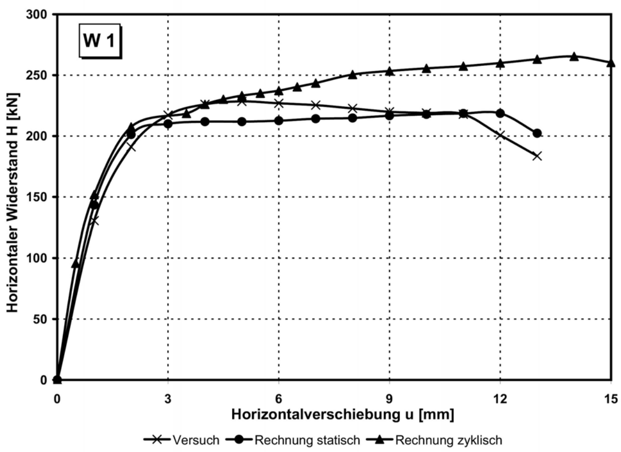
The horizontal displacement per deformation step was applied in 1 mm steps until there was a distinctive crack image, and then in 2 mm steps. Table 1 indicates the corresponding results.

As example for wall W1, figure 10 shows the absorbed movement horizontal force hysteresis and figure 11 the crack image.

Figure 11: Crack image of wall W 1

2.3 Engineering model for earthquake-stressed masonry

The determination by calculation of the capacity curves is performed by the application of the FEM programme ATENA. In the beginning, the static-cyclic deformation load (figure 9) of the test was replaced in the calculation analysis by a static head deformation. Later, the force was extended to a static-cyclic load with one deformation cycle each.



The extreme values of each single hysteresis are combined to one capacity curve, which reproduces the shear stiffness of the walls. For example figure 12 shows wall W1 in the experiment, with static and cyclic load.

Figure 12: Comparison between calculated and experimental capacity curves

The experimentally determined capacity curves have been bilinearly idealised [4] and after that, the suspension ductility was determined (figure 13).

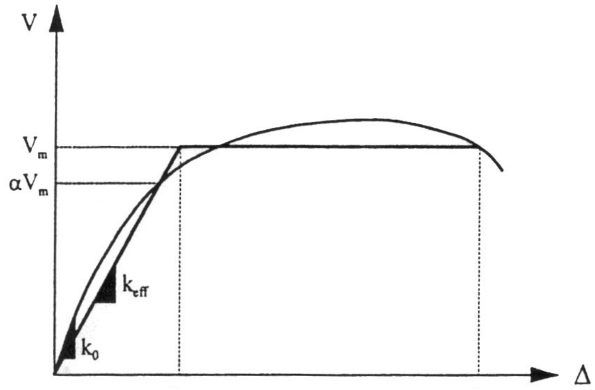


Figure 13: Linearised capacity curve [4]

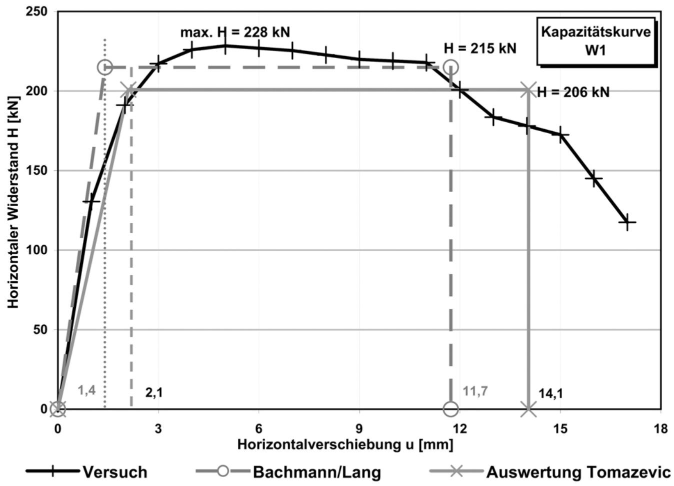


Figure 14: Comparison of the capacity curves of W1

The engineering model is based on the capacity considerations of Bachmann/Lang [5], which were published in 2002 for buildings made of masonry under earthquake load. These considerations have been applied in the current investigations to prestressed masonry. Figure 14 shows the comparison between the experimental capacity curve, the idealisation according to Tomaževič [4] and calculated capacity according to Bachmann/Lang for wall W1. A good accordance between the different curves can be seen.

3 Summary

At four different prestressed masonry walls (height h= 2,50 m, thickness d= 0,175 m, length l= 2,50 m and 1,25 m), static-cyclic shear attempts have been made. With the aid of the FEM-programme ATENA, the shear capacity of each wall could be re-calculated. The comparison between the calculated and experimentally determined capacity curves shows a high accordance.

4 Literature

[1] Budelmann, H.; Gunkler, E.; Husemann, U.; Becke, A.: *Rationell hergestellte Wände aus vorgespanntem großformatigem Mauerwerk mit hohem Erdbebenwiderstand* (AZ: Z 6-5.4-02.18) Zwischenbericht des IBMB der TU Braunschweig und der FH Lippe und Höxter. Juni 2003.

[2] Budelmann, H.; Gunkler, E.; Husemann, U.; Becke, A.: *Rationell hergestellte Wände aus vorgespanntem großformatigem Mauerwerk mit hohem Erdbebenwiderstand* (AZ: Z 6-5.4-02.18). In: Mauerwerk-Kalender 2004. Ernst & Sohn, Berlin 2003, S. 635 - 641

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[4] Tomaževič, M.: *Earthquake-Resistant Design of Masonry Buildings*. Slovenien National Building and Civil Engineering Institut, Imperial College Press, 1999

[5] Bachmann, H.; Lang, K.: Zur *Erdbebensicherung von Mauerwerksbauten*. Institut für Baustatik und Konstruktion, ETH Zürich; IBK Bericht Nr. 274, Mai 2002.