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LOAD TESTS ON MASONRY ELEMENTS WITH CHASES

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ABSTRACT

A research project on the structural behaviour of unreinforced masonry elements with chases subjected to compression is underway at the Institute of Structural Engineering. The main goal of the research project is to investigate the influence of cutting out chases for electrical wiring in masonry walls on masonry compressive strength.

Load tests on the first two series of masonry elements with chases have been completed. Each series consisted of seven clay block masonry elements with dimensions of 1200x1200 mm. The thickness of the elements was 150 mm and 175 mm. A standard cement mortar was used to produce 10 mm thick bed and head joints. Twenty-eight days after preparation 50 mm deep and 35 mm wide chases were cut in six elements of each series while the seventh one was left intact and served as a control specimen. Three different types of chases (horizontal, vertical and inclined), two each per series, were cut only on one side of the masonry elements. After placing the installation ducts, the chases were filled with gypsum or cement mortar. The compressive load was applied in a deformation-controlled manner up to the failure of the specimen. A considerable reduction in the masonry compressive strength was observed.

This paper presents the results of the load tests and discusses the structural behaviour of masonry elements with chases. A number of conclusions as well as recommendations for future research are given.

KEYWORDS: chases, clay blocks, load test, masonry compressive strength, unreinforced masonry.

INTRODUCTION

Accommodating electrical wiring and similar installations in masonry construction often necessitates the cutting of chases in masonry. These chases can considerably reduce the masonry compressive strength, which is the key parameter for the design of structural masonry. In general, the chases are cut vertically or horizontally, but as can be seen in many practical examples the chases in the walls can be cut quite arbitrarily, see Figure 1.

Figure 1: Arbitrarily Cut Chases in Masonry Walls

Previous research work in this area included tests on typical masonry elements with vertical and horizontal chases. Fischer [1] tested clay block masonry walls with three different thicknesses (102.5, 178 and 215 mm) and several combinations of mainly vertical 38 mm wide and 25 mm deep chases. A reduction in the masonry compressive strength up to 28.5%, compared to the strength for walls without chases, was observed. Kirtschig and Metje [2] investigated the influence of chases and recesses on masonry compressive strength. They performed numerous tests on clay block masonry with vertical and horizontal chases. In general, the reduction in masonry strength tends to be proportional to the reduction in cross-sectional area.

In addition, provisions for chases in masonry can be found in structural codes. Some of the codes, e.g. the Swiss Masonry Code SIA 266 [3] and Building Code Requirements and Specifications for Masonry Structures ACI 530-08/ASCE 5-08/TMS 402-08 [4], only give general recommendations, whereas others, such as the European Masonry Code ENV 1996-1-1 [5], provide tables with values of depth and width of chases that are allowed without additional calculations. Analogous provisions can be found in the Canadian Structural Masonry Code [6].

A research project is underway at the Institute of Structural Engineering to investigate the structural behaviour of typical Swiss unreinforced clay block masonry elements with chases subjected to compression. The main goal of the research project is to investigate the influence of chases on masonry compressive strength.

TEST PROGRAMME AND MASONRY MATERIALS

Load tests on the first two series of masonry elements with chases have been completed. Each series consisted of seven unreinforced clay block masonry elements. The test specimen dimensions were 1200 (length b_w) x 1200 (height h_w) mm. The thickness of the elements, t_w, was 150 mm (Series A) and 175 mm (Series B). The test specimens were produced and the chases were cut by the same professional mason. Dry, factory-made standard cement mortar was mixed with water at the construction site to build the wall elements in running bond. Both the bed and the head joints were 10 mm thick and fully filled. Twenty-eight days after preparation 45 to 50 mm deep (t_s) and 35 mm wide (b_s) chases were cut in six elements of each series while the seventh one was left intact and served as a control specimen, see Figure 2. For Series A specimens the chase depth equalled to 1/3 of t_w and for those of Series B 2/7 of t_w.

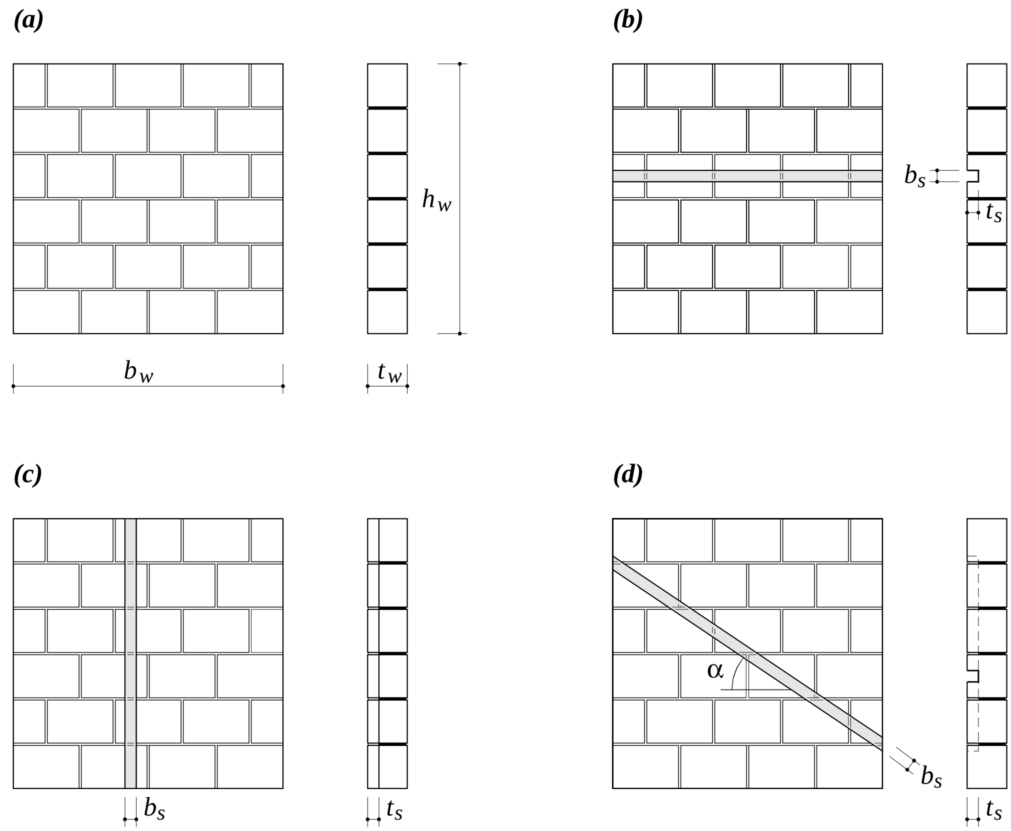


Figure 2: Test Specimens: a) Without Chases; b) Horizontal Chase; c) Vertical Chase; d) Inclined Chase

Three different types of chases (horizontal, vertical and inclined), two each per series, were cut only on one side of the masonry elements. The slope of inclined chases was $\tan\alpha = 3/4$. An overview of test programme is given in Table 1.

Table 1: Sample Designation for Test Programme

Wall thickness (mm)	Without chases	Horizontal chase		Vertical chase		Inclined chase	
		Gypsum infill	Mortar infill	Gypsum infill	Mortar infill	Gypsum infill	Mortar infill
150	A	AH1	AH2	AV1	AV2	AS1	AS2
175	B	BH1	BH2	BV1	BV2	BS1	BS2

Table 2 gives information on the properties of the two different types of (hollow) clay block units that were used. f_b denotes the unit's compressive strength and f_{bq} its splitting strength. The average compressive strengths of the cement mortar used for the joints and for chase infill were

17.1 and 17.2 MPa, respectively. The average compressive strength of gypsum used as infill for the chases was only 5.9 MPa.

Table 2: Properties of Clay Block Units

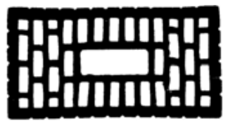
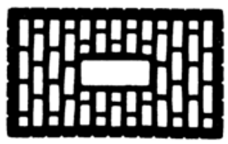
Unit	Shape	Dimensions (mm)	Void area (%)	f_b (MPa)	f_{bq} (MPa)
B 15/19		290x190x150	45	32.1	7.4
B 17.5/19		290x190x175	46	24.6	7.7

Figure 3 shows typically the preparation phases for a specimen with a horizontal chase. First, a masonry saw was used to cut the chase. Afterwards, the inner-rib leftovers of the hollow clay brick were removed by means of a chisel. Finally, the installation duct was placed and the chase was filled with gypsum or the same cement mortar that was used for joints. After a further two weeks the specimens were transported to the test site.

Figure 3: Preparation of the Specimen with Horizontal Chase

TEST SET-UP

Figure 4 depicts the test set-up. The axial load was applied by means of three hydraulic jacks (2) placed between the support frame (1) and the upper spreader beam (3). The test specimen (4) was placed between two spreader beams (3) and two sets of steel plates (6) that provided good contact with the specimen. In this way an unrestrained lateral deformation of the specimen was ensured. To achieve the exact position of the steel plates, two thin plaster layers (7) were applied to both the upper and the lower edges of the specimen. Additionally, a set of neoprene plates (5) were placed between the steel plates and lower spreader beam, which lay directly on the laboratory's strong floor (8). These neoprene plates ensured a uniform load distribution over the specimen. Both spreader beams had a thin Teflon layer on the faces towards the test specimen. After setting-up the specimens were subjected to an axial load, which was increased in a deformation-controlled manner up to failure of the test specimen.

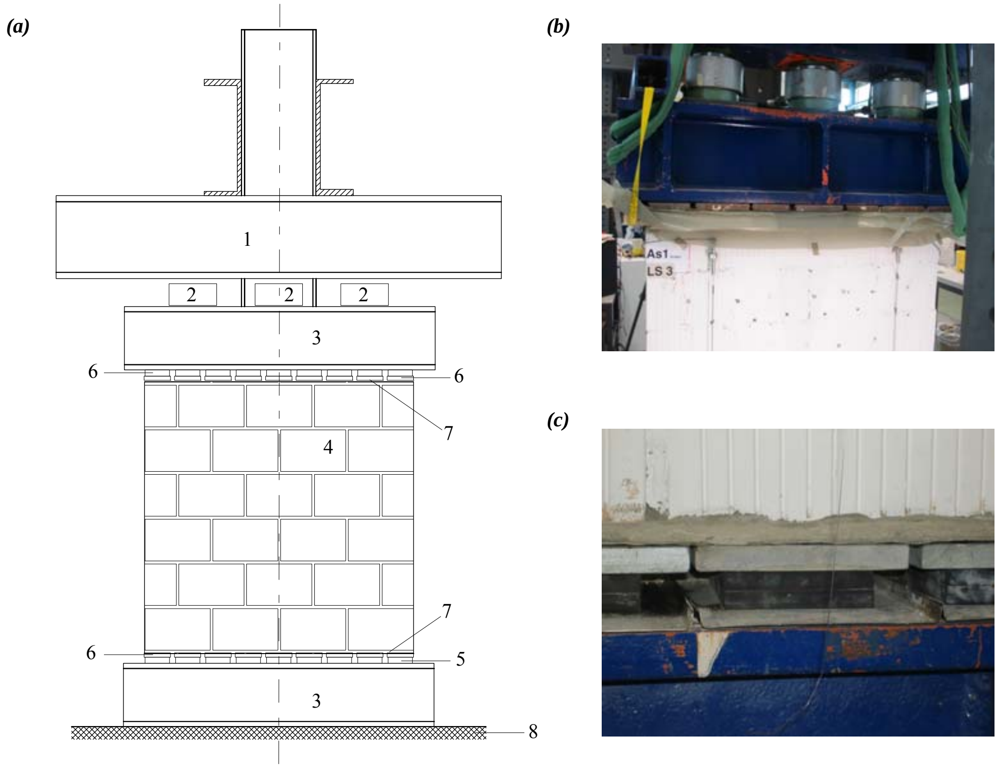


Figure 4: Test Set-up: a) Overview; b) Load Cells; c) Lower Support Detail

Apart from applied load, measurements included node displacements of the measurement nets on both specimen surfaces and deflection at the middle of the specimen. The measurement net consisted of triangles whose nodes were aluminium bolts glued in the middle of the clay brick unit's face and had two base lengths, $s_h = 300$ mm and $s_d = 250$ mm, cf. Figure 5. This figure also shows the net's relative position to the chases. Additionally, vertical shortening of the specimen was measured by means of four LVDTs with a base length of 900 mm; two on each surface (cf. Figure 5). All measuring devices were connected to a personal computer, which processed the data in real time. In order to follow crack development and to measure crack widths, the specimens were painted white prior to testing.

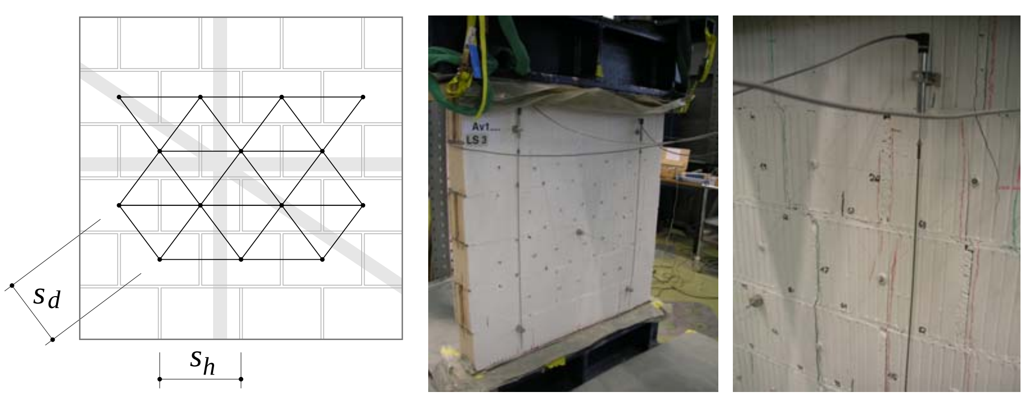


Figure 5: Measurement Net and LVDTs

TEST RESULTS

Table 3 shows the values of the masonry compressive strength f_x (perpendicular to the bed joints) obtained from both test series. F_{max} denotes the maximum recorded compressive force, A_w is the gross cross-sectional area and Δ is the percentile change of the compressive strength (a negative value signifying a reduction) compared to the control specimen (A or B).

Table 3: Test Results

Specimen	F_{max} (kN)	A_w (m^2)	f_x (MPa)	Δ (%)	Specimen	F_{max} (kN)	A_w (m^2)	f_x (MPa)	Δ (%)
A	849.1	0.18	4.72	-	B	670.3	0.21	3.19	-
AH1	666.1	0.18	3.70	-21.6	BH1	650.2	0.21	3.10	-3.0
AH2	637.2	0.18	3.54	-25.0	BH2	763.2	0.21	3.63	13.9
AS1	666.6	0.18	3.70	-21.5	BS1	543.7	0.21	2.59	-18.9
AS2	551.4	0.18	3.06	-35.1	BS2	471.6	0.21	2.25	-29.6
AV1	616.6	0.18	3.43	-27.4	BV1	745.8	0.21	3.55	11.3
AV2	689.6	0.18	3.83	-18.8	BV2	553.2	0.21	2.63	-17.5

Figure 6 presents the force-deformation characteristics of specimens AH1 and BS2. The deformation value shown in the diagram is an average of all four LVDT measurements (vertical shortening of specimen). As can be seen, these two specimens behaved more or less linear-elastically almost up to failure. The same was true for all other specimens. The first cracks appeared at a load level of about 50-60% of the failure load.

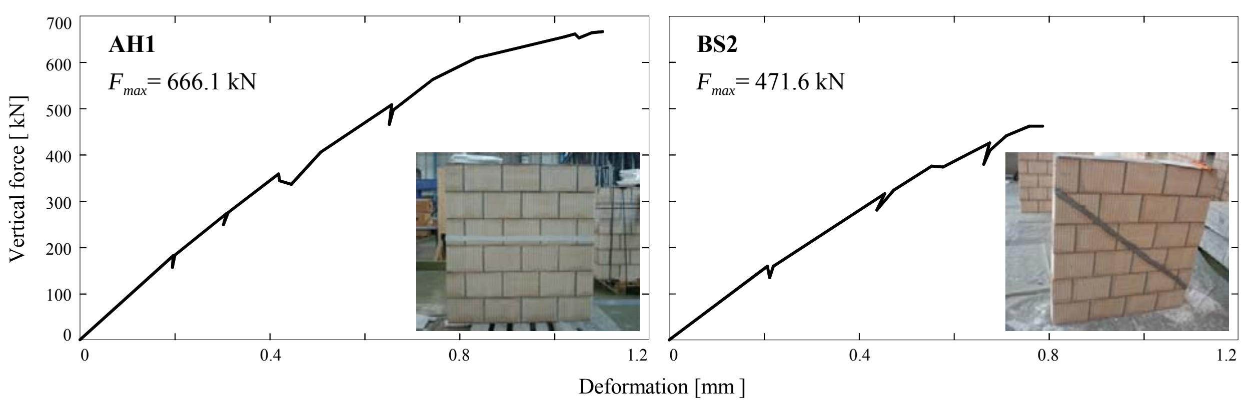


Figure 6: Force-Deformation Relationships for Specimens AH1 and BS2

Strains and curvatures were calculated from the displacements of the measurement net. Firstly, the changes in distance between the net nodes were measured and, in order to correct measurement errors, the analogy between the principles of the minimum of the sum of squared errors and the minimum of elastic strain energy was used [7]. For this purpose, using standard FEM software the measurement net was modelled as a (statically indeterminate) plane truss and the truss member's length changes were applied as loading. In this way node displacements could be obtained. Figure 7 shows displacement fields for both the front and back surfaces of specimen BS2 for three load stages LS2, LS3 and LS4 with corresponding loads of 160 kN, 320 kN and 430 kN, respectively. The drawing on the right shows back surface (with chase). In addition, Figure 7 presents a large crack opening (3 mm), which can also be detected in the deformation field.

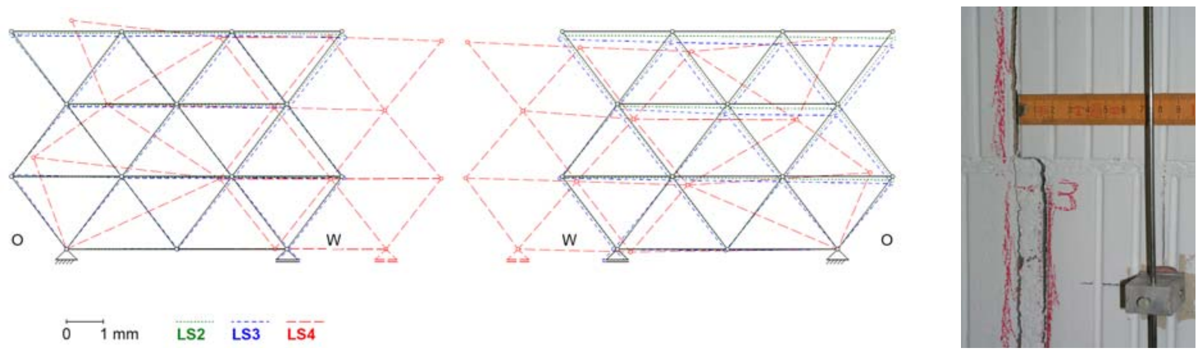


Figure 7: Deformation Field and Crack Detail (Specimen BS2)

Secondly, assuming linearity of the displacements over the area of the triangle, the constant average strains in each triangle were calculated from the nodal displacements [7]. Finally, from the calculated strains on both specimens' surfaces, the corresponding curvatures were calculated. Figure 8 shows the calculated strains and curvatures for the test specimen AH1 for four load stages LS2, LS3, LS4 and LS5 with the corresponding loads of 180 kN, 270 kN, 350 kN and 500 kN, respectively. Note that *x* and *y* are directions perpendicular and parallel to the bed joints, respectively. As can be seen, the strains were larger on the surface with a chase (back), i.e. the presence of the chase induced (small) curvatures, cf. also the Mohr's circle of curvatures in Figure 8 (c).

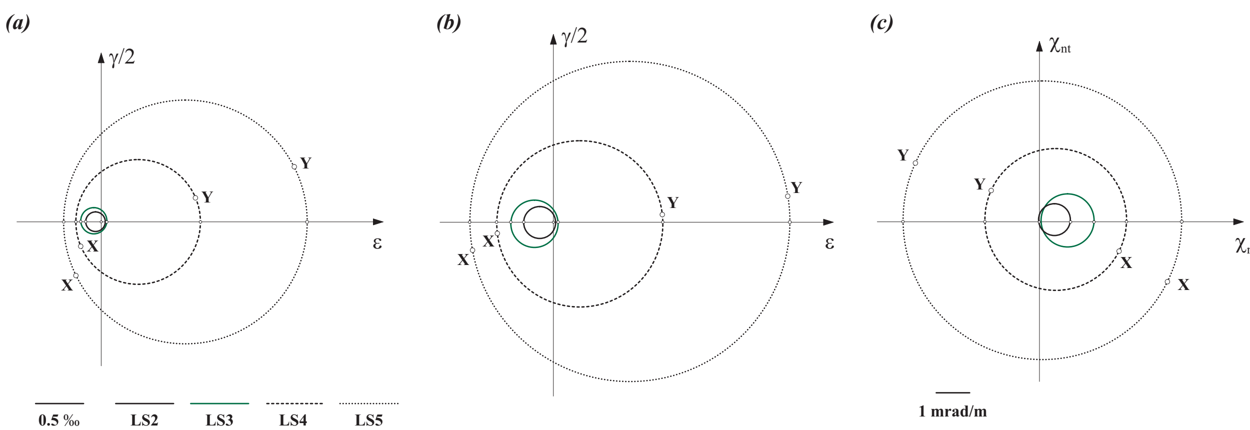


Figure 8: Mohr's Circles (Specimen AH1): a) Strains (Front Surface); b) Strains (Back Surface); c) Curvatures

The failure patterns observed during the tests are characteristic for masonry failing in compression. Subjected to vertical pressure, the specimens failed by exceeding the splitting tensile strength in the directions orthogonal to the applied pressure. For the specimens in series A failure planes developed perpendicular to the plane of the wall, thus dividing the specimen into several piers, see, e.g., the failure pattern for the specimens AV1 and AV2 shown in Figure 9. Series B specimens showed somewhat different patterns. Here, the failure plane developed parallel to the plane of the wall, thus dividing the specimen in two parts, see, e.g., the failure pattern for specimen BH2 shown in Figure 9. Failures of both series were brittle and the failure load for control specimens A and B (especially for specimen B) was lower than expected considering the mechanical characteristics of the components, the unit and mortar and according to code provisions [3, 5].

(a) ***(b)*** ***(c)*** ***(d)***

Figure 9: Failure Patterns: a) AV1; b) AV2; c) BH2; d) BH2 – Side View

DISCUSSION

From Table 3 it is obvious that cutting chases in unreinforced masonry elements reduces the masonry compressive strength f_x. For the series A specimens, in which the depth of chase was one-third of the element thickness t_w, the reduction ranged between 18.8% and 35.1%. Generally, the reduction of f_x was equivalent to the reduction of the cross-sectional area (30% considering average chase depth). For the elements of series B, where the chase depth was two-sevenths of t_w, a somewhat different behaviour was observed. For these specimens, with the exception of the elements with inclined chases, BS1 and BS2, a smaller reduction of f_x was observed and two specimens, BH2 and BV1, were even stronger than the control specimen, B. This has to be investigated further, but it seems that some damage to the control specimen during the transport from production site to the test site could be responsible for the unexpected low strength of the specimen B. A different failure pattern for thicker elements (see Figure 9) will also have to be considered. In order to perform a thorough analysis of the influence of the chases on the behaviour of masonry elements an analytical strut-and-tie model will be applied, cf. Mojsilović [8]. Such a model is able to give greater insight into the force flow in the masonry and will allow a better description of the behaviour.

The largest decrease in strength was observed for specimens with inclined chases. This fact should be taken into account when the chases are cut in load-bearing walls designed to transfer combined vertical and shear forces, i.e. an inclined resultant force. As a rule, the cutting of any kind of chases in such walls should not be permitted.

The difference in strength between elements with different infill, i.e. gypsum and cement mortar, is smaller that one could expect, especially for the results of series A. It seems that an infill, that is as strong as the masonry unit, e.g., an epoxy-based infill, should be applied in order to reduce the loss of the strength of elements with chases.

To clarify the above-mentioned issues and to gain additional insight into the problem further testing is needed. Tests with other element thicknesses (125 and 200 mm) will be performed as well as additional tests to assess the influence of chases that are cut on both element surfaces. Tests on elements with chases without infill and chases with stronger infill are also planned.

CONCLUSIONS

An investigation of the influence of chases in masonry elements subjected to compression is underway at ETH Zurich. Preliminary results of tests on the first two series of elements were analysed and allow a number of conclusions to be drawn:

- Chases can reduce the masonry compressive strength considerably.
- In general, a reduction of the masonry strength proportional to the reduction of the cross-section area seems to be a reasonable approach in analysing the influence of chases on masonry compressive strength.
- The type of the mortar material of chase infill had relatively small influence on the reduction of masonry compressive strength. It seems that an infill that is as stiff as the masonry unit has to be applied in order to reduce the loss in masonry strength.
- In order to complete the research project additional tests will be carried out and an analytical investigation based on a strut-and-tie model will be performed.

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