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LABORATORY MEASUREMENT OF PRESTRESSED MASONRY

LABORATORNÍ MĚŘENÍ PŘEDPJATÉHO ZDIVA

Abstract

Pre-stressed masonry is one of the most common and also the most effective method of buildings repair. At Faculty of Civil Engineering laboratory equipment was designed for detailed analysis of post-tensioned masonry, specifically for measuring the deformation of masonry corner mainly around the anchoring plates that are used for transmission of pre-stressing forces into masonry. Measurements were performed for two values of pre-stressing force in both directions. In the paper there are also marginally mentioned numerical models for comparison with measured values.

Keywords

Masonry, pre-stressing, deformation, force, measurement.

Abstrakt

Předpínání zdiva je jednou z nejpoužívanějších a současně nejúčinějších metod sanace u staticky porušených objektů. Na stavební fakultě bylo vyrobeno laboratorní zařízení právě pro bližší zkoumání chování předpínaného zdiva. A to konkrétně pro měření deformací zděného rohu především v okolí kotevních desek, které slouží pro přenos předpínacích sil do zdiva. Měření bylo provedeno pro dvě hodnoty předpínacích sil. Předpětí bylo instalováno v obou směrech. Dále je zde okrajově pojednáno, jak se budou vytvářet numerické modely pro srovnání s provedenými měřeními.

Klíčová slova

Zdivo, předpětí, deformace, síla, měření.

1 INTRODUCTION

Masonry structures are commonly reinforced with reinforcement placed in the joins or clasped by using pre-stressed cables or bars to increase the resistance of the masonry, preventing cracking and also reducing of material consumption.

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Repair of the masonry structure with pre-stressing provides not only sufficient stability but also prevents formation of new cracks and extends the length of service life, [1].

While design of pre-stressed concrete structures is described in details in current codes, detailed design of pre-stressed masonry is not at disposal, especially with regard to actual masonry strength and the character and extent of masonry damage. The most difficult is the design of the pre-stressing force value. According to tests carried out in situ, 1/10 of vertical compression masonry strength is considered as a safe value. Settlement of the compressive strength is however dependant on available information about the masonry quality and also quality of walling, e.g. filling of joints with mortar, [2].

2 MEASUREMENT PROCEDURE

2.1 Description of equipment

Laboratory testing was performed on the equipment designed for measuring tri-axial stress-strain conditions in masonry corner. Masonry corner has plan dimension of 900 × 900 mm, height 870 mm. For testing mentioned in this paper clay brick with dimensions 290 × 140 × 65 were used, with strength f_b = 20.88 MPa and mortar M10 with strength f_m = 9.8 MPa. Strength of both materials were settled according to codes [3] a [4], on the basis of which the characteristic compressive strength of masonry was settled f_k = 7.6 MPa, [5]. During the masonry corner walling two pre-stressing bars, perpendicular to each other, were installed into bed joints. The bar in the direction A is in the height 370 mm and in the direction B 520 mm, Fig. 1. Specimen for laboratory testing is supposed in 1:1 ratio to the real structure.

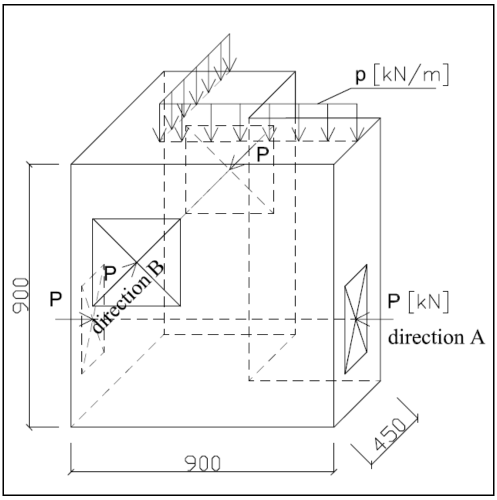

Fig. 1: Schematic model of masonry and location of pre-stressing bars in the direction of A and B

2.2 Load

The whole masonry corner was exposed to uniform vertical load 0.12 MPa. Vertical load was installed using hydraulic cylinder which was located between I-profile and steel plate with thickness 12 mm, strengthen with ribs, placed in mortar joint, for spreading the load uniformly if possible. The horizontal force 50 and 100 kN was installed through pre-stressing bars by means of hydraulic cylinders and anchoring plates. Three dimensions of anchor plates were used, specifically 300 × 300, 200 × 200 and 150 × 150 mm. The thickness of the anchoring plates is 10 mm. To ensure uniform transmission of pre-stressing forces, if possible, the anchor plates were placed into mortar joint. Pre-stressing was installed in both directions simultaneously.

The deformations were recorded by means of net of potentiometric sensors connected to the laboratory equipment, both in the direction A and B. The sensors were identified from M20 to M25 and their location was according to Fig. 2.

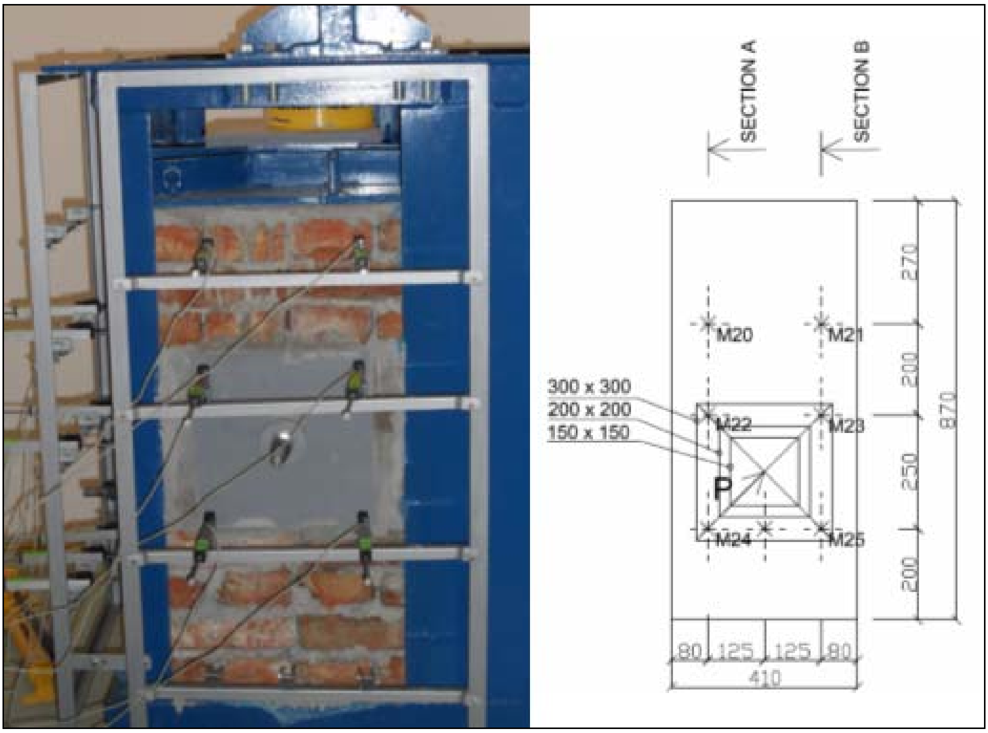

Fig. 2: Network of measured points of deformation in the direction A

In the Tab. 1 there are listed input values for the measurements. In the first two columns there are the dimensions of anchoring plates and their area. In the column 3 and 4 there are the stresses directly under the anchoring plate for pre-stressing force 50 kN and 100 kN.

Tab. 1: Input values for measurements, pre-stressing force of 50 and 100 kN

Anchor plate	Area [m^2]	Tension [MPa]	
		50 kN	100 kN
300 × 300	0.09	0.555	1.111
200 × 200	0.04	1.250	2.500
150 × 150	0.0225	2.222	4.444

2.3 Results

The network of deformation measuring points for the direction A is shown in Fig. 2, for the direction B the location of sensors was similar. In the graphs, Fig. 3 and Fig 4, there are deformations in the direction A for vertical load 0.12 MPa and pre-stressing force of 50 and 100 kN for anchoring plates with dimensions of 150 × 150, 200 × 200, 300 × 300. Horizontal line indicates the location of pre-stressing force. Resulting deformations on the Fig. 3 and Fig. 4 were made by averaging values in

M20 and M21 points, M22 and M23, M24 and M25. Y-coordinate corresponds to the potentiometric sensors location.

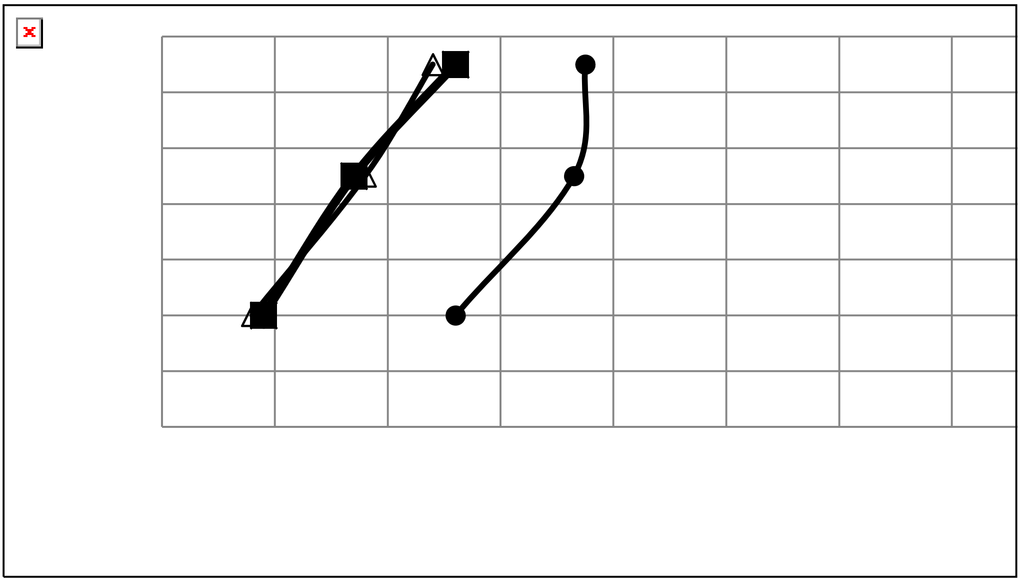

Fig. 3: Measured deformations in the direction A, pre-stressing force 50 kN

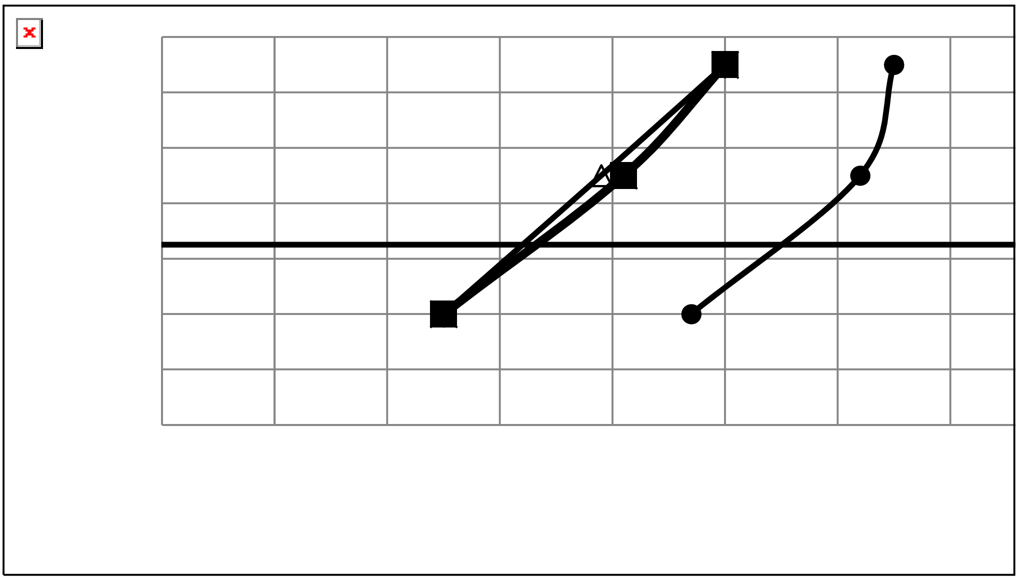

Fig. 4: Measured deformations in the direction A, pre-stressing force 100 kN

Fig. 3 and Fig. 4 shows that the total deformation for pre-stressing force 50 kN is about half of the deformation for pre-stressing force 100 kN for each anchoring plate.

In both graphs it is illustrated that the deformations for the anchoring plates 300 × 300 are smaller than the deformations with anchoring plates 200 × 200 due to higher stress under the smaller anchoring plates, see Tab. 1. Deformations of masonry for anchoring plates 150 × 150 are almost the same as for the anchoring plate 300 × 300. This could be due to the location of potentiometric sensors, which are not in direct contact with the anchoring plate 150 × 150 as well as the anchor plate

200 × 200, see Fig. 2. Stress in the point with potentiometric sensor is probably smaller than under the anchoring plate. Also the deformation could be influenced with deformation of anchoring plates exposed to concentrated load.

The results also show that the deformations are higher in the part above the anchoring plates. These waveforms of deformations could be caused by imperfect adherence of the anchoring plate to the masonry though the masonry was underplayed with mortar.

In the direction B there are similar result deformations.

3 MODELING OF MASONRY

Modelling of masonry structures is more difficult than modelling of steel or concrete structures, because the masonry is heterogeneous and anisotropic material, consisting of brick and mortar. Both these components have different physical and material properties. Therefore creating an appropriate model that expresses the real material and physical properties of the masonry is difficult. The same material characteristics cannot be guaranteed in the whole structure and therefore there are many variables which have to be taken into account in the modelling process, for example:

- Different material properties of basic components (brick/mortar).
- Age of structure.
- Interaction between components.
- Geometrical arrangement of bricks.
- Quality of manufacturing.
- Quality of materials.
- Different dimensions of basic components (dimension of brick/of mortar joint).
- Narrow dimension of mortar joint.
- Environmental influence.
- Eccentric load.
- Effective area of loading plate.

Modelling process and the structural analysis of masonry can be divided into two parts. In the first part the analysis in micromodel is used with detailed forming of brick and mortar including real placement of joints, in the second part less detailed macromodel is utilized, without modelling of individual bricks and mortar joints, with homogenized properties of masonry, [6], [7].

Micromodel and macromodel of different types of pre-stressed masonry in FEM software have been done in the past [8]. Actually authors are preparing the models of tested masonry corner, the aim is numerical model which corresponds with measured values.

4 CONCLUSION

The paper deals with laboratory measurements of post-tensioned masonry corner which was exposed to vertical loads and pre-stressing force of 50 and 100 kN. Laboratory testing should simulate the strengthening and repair of masonry buildings. The resulting deformation of the masonry can be influenced with imperfect adherence of the anchoring plate to the masonry or deformation of anchoring plates due to the concentrated load from pre-stressing.

Next measurement is in preparation. It is planned to use again clay bricks and general purpose mortar but with smaller compressive strength. It will be also possible to load with higher value of pre-stressing force, so that the specimen of masonry corner responds better to repaired masonry wall. Authors are going to compare the measured deformations with deformations calculated with numerical model using software on the basis of FEM, as is described in Sect. 3.

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