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EXPERIMENTAL TEST OF BRICK CORNER

EXPERIMENTÁLNÍ ZKOUŠKA ZDĚNÉHO ROHU

Abstract

The paper describes experimental measurements of post tensioned prestressed masonry corner that is built in finished steel structure. The steel structure is designed so that many different tests with different input parameters could be done. Prestress is installed through prestressing bars using hydraulic cylinders. Prestressing bars were installed into the mortar joints during construction. Displacements are measured by potentiometer sensors and the results are evaluated using graphs.

Keywords

Masonry structure, prestressing, deformation, experiment.

Abstrakt

Příspěvek popisuje experimentální měření dodatečně předpjaté zděné konstrukce, která je vyzděná ve zhotovené ocelové konstrukci. Ocelová konstrukce je vyrobena tak, aby bylo možno provádět řadu různých zkoušek s různými vstupními parametry. Předpětí je instalováno pomocí hydraulických válců do předpínacích tyčí. Ty byly vloženy do spár během zdění konstrukce. Výsledné deformace zdiva jsou měřeny potenciometrickými čidly a výsledky jsou vyhodnoceny pomocí grafů.

Klíčová slova

Zdivo, předpínání, deformace, experiment.

1 INTRODUCTION

Due to underground mining of bituminous coal, tunnel and collector construction in urban developments, subsidence depressions with typical effects on buildings arise. In such affected areas, it is often needed to save the affected buildings by means of additional masonry structure prestressing and prestressing of foundations. This static securing is of great importance mainly for historic

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buildings as protection of cultural heritage is one of basic duties of developed states. This is also carried out by means of prestressing (pre-tensioning) strands or bars which are conducted along inner or outer wall faces and foundations. Then, in the place of their anchoring, an extreme triaxial state of stress arises, which can lead to crushing and destruction of such redeveloped buildings.

Although this redeveloping procedure using sufficiently introduced prestess is well-verified for reinforced concrete structures, this technique is not sufficiently tested for often non-homogenous and interrupted masonry structures.

For this reason, it is necessary to carry out experimental tests which are to allow better understanding of prestressed masonry structure behaviour. The tests are carried out using a laboratory testing device intended for tests of the triaxial state of stress. The assumed results are one of the first reached results of measuring works carried out with this laboratory device, which was made for the Faculty of Civil Engineering at VŠB – Technical University of Ostrava.

2 REINFORCEMENT IN THE MASONRY STRUCTURE

Horizontal reinforcement of a brick structure is carried out with undermined constructions in order to find out effects of horizontal deformation of terrain as well as for finding out effects of terrain curvature.

This method is intended for increasing in stability of disturbed structures and their service life enhancement. The basic principle of prestressing reinforcement is clamping of the disturbed construction, i.e. introduction of pressure forces into masonry structures so that arising of new cracks is prevented. Pressure forces can also be introduced in order to clamp existing cracks. As a matter of fact, masonry structure stability and load capacity in the structure.

One of the basic ways of masonry structure prestressing consists in usage of injection mortar and resins which close formed cracks up and which provide a bond between masonry material and inserted steel reinforcement. The reinforcement is inserted into a milled groove in a bed joint. The prestressing bars help to transfer load, mainly traction forces, and eliminate arising of further cracks. This method is called as post tensioned masonry [1], [2].

3 EXPERIMENTAL TEST

The device for prestressed masonry testing allows performance of various tests for various input parameters, e.g. usage of various materials (masonry units and mortar) and number of prestressing strands, intensities of prestressing forces, size and shape of anchoring plates, intensity of vertical loading and a number of layers of masonry units or joint thickness values, masonry bond, way of founding (free, sliding joint, etc.). Measuring of the masonry structure was carried out as an example for testing operation of the experimental device, with which the proposed procedure and testing methodology were verified [3].

The first stage of the experimental measuring works consists in lining a brick corner with an L-shaped ground plan. The lining is carried out into the prepared laboratory device which is intended for tests of the triaxial state of stress of the prestressed brick corner (see Fig. 1) with the ground plan of 900 × 900 mm. The total height of the laboratory device is 1,550 mm, the lining height is 870 mm (11 brick rows, joint included). The used brick material is a solid burnt brick with production dimensions of 290 × 140 × 65 mm on cement mortar M10. Strength values of bricks and mortar were gained from laboratory measuring of samples taken during construction lining. Masonry thickness is 450 mm. The temperature, at which the laboratory device works, ranges from 20 to 25 °C.

In this structure, two prestressed bars are inserted in the directions normal to each other, approximately at heights of 370 and 445 mm, which are anchored in wall plates sized 300 × 300 × 10 mm. In this measuring, prestressing force was installed only into one of the bars, to be specific, after vertical loading.

10.2478/v10160-011-0021-z

At the second stage, the structure of the brick corner is loaded with a vertical loading using a loading plate on the upper surface. This loading simulates vertical loading in the structure, e.g. from the ceiling, roof or other floors. A value corresponding to vertical loading of a detached house was chosen for vertical loading for the purpose of the laboratory measuring, causing stress in the footing bottom of 119.2 kPa. The surface of the wall plate intended for distribution of vertical loading is 0.6075 m^2.

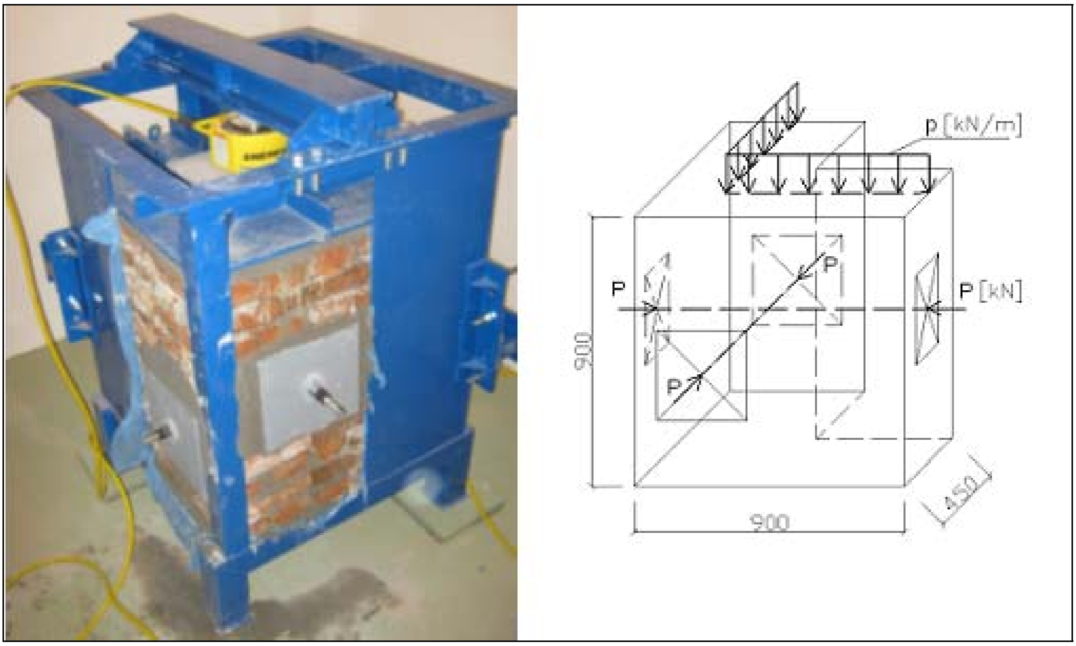


Fig. 1: Laboratory device for measuring of brick corner deformations (left), block scheme (right)

At the further stage, wall plates are fixed onto prestressing bars, and the required prestress is derived only for one bar using hydraulic loading. The prestressing force values depend on the total strength of masonry which is determined from the laboratory tests of bricks and mortar of the tested structure [4]. For indication, the values of prestressing forces are determined as 5, 7, 10 and 12% of the typical masonry compression strength normal to the bed joint. The test was performed according to [5].

According to the calculation ČSN EN 1996-1-1 [6] the characteristic value of masonry strength for common mortar is determined by the following formula:

$$f_k = K \cdot f_b^{0,7} \cdot f_m^{0,3} (\mathrm{N/mm^2}), \tag{1}$$

in which K = 0.35 which corresponds to the 4th class [7]. The resultant compression strength of masonry units gained from the laboratory tests carried out according to [8] is f_b =20.88 MPa, and the value of walling mortar compression strength is determined according to [9] je f_m =9.8 MPa. Having put the figures down into the above-mentioned formula, the characteristic strength of the masonry is f_k = 5.82 MPa. The distribution surface for the prestressing device is 0.09 m^2. The table shows values of prestressing strengths and their conversion to an oil-pressure unit in the hydraulic system [bar].

10.2478/v10160-011-0021-z

Tab. 1: Conversion of prestressing forces

	Stress in ZS [kPa]	Force P [kN]	Conversion [bar]
5%	291.0 kPa	26.19 kN	56.20 bar
7%	407.4 kPa	36.66 kN	78.66 bar
10%	582.0 kPa	52.38 kN	112.40 bar
12%	698.4 kPa	62.85 kN	134.87 bar

The experimental measuring is carried out using 10 potentiometric sensors fixed to the steel structures using steel angles. The placement of potentiometers is done using shifting holders which can be fixed in the required positions using tightening screws. Movement of the potentiometers is allowed in both the vertical and horizontal directions. The potentiometers are placed in four rows, each with 2 pieces. Handling with the sensors is easy and well accessible. The measured data are transferred into a measuring station; then the data are stored into a computer in the form of spreadsheets. The interval of the measured values for each shift is 60 sec.

4 GAINED RESULTS

The tests of the brick corner were carried out with subsequent loading of structure using a prestressing bar. The initial prestressing force was 5% of the total characteristic masonry compression strength normal to bed joints. This value was subsequently increased to the values mentioned in the Table 1, while the maximal value of prestressing force was installed on 12% of the total characteristic masonry strength, which corresponds to a force value of 62.85 kN. After measuring of final deformations from prestressing strength, the structure was unloaded.

For clarity of individual results, the potentiometric sensors were marked with the values of M20 thru M28 for measuring of shifts from deformation caused by the prestressing bar (according to Fig.2) and the potentiometric sensors marked M0 and M1 were fixed normal to the prestressing bar for taking any possible deformation in the other direction.

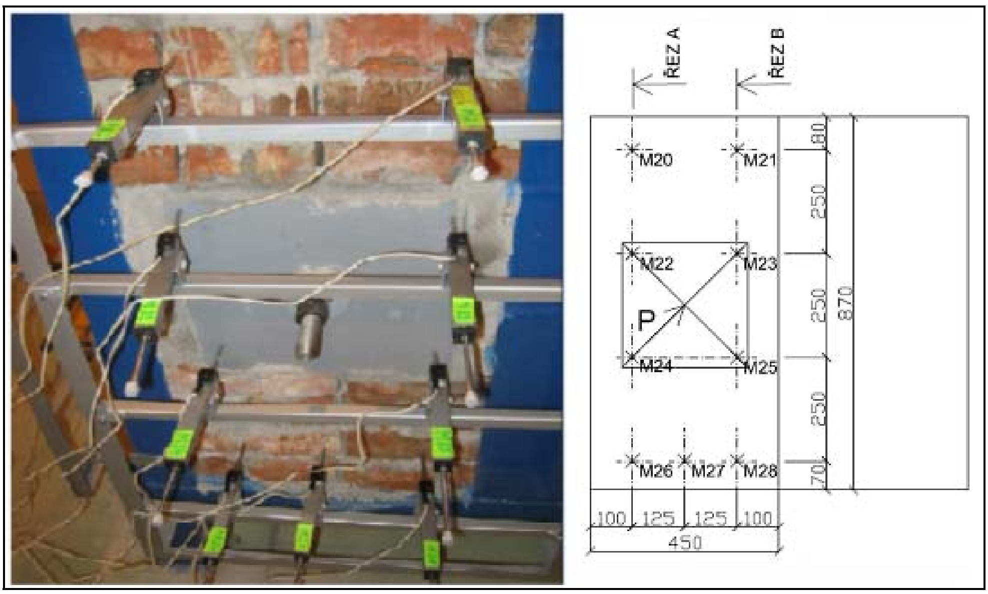
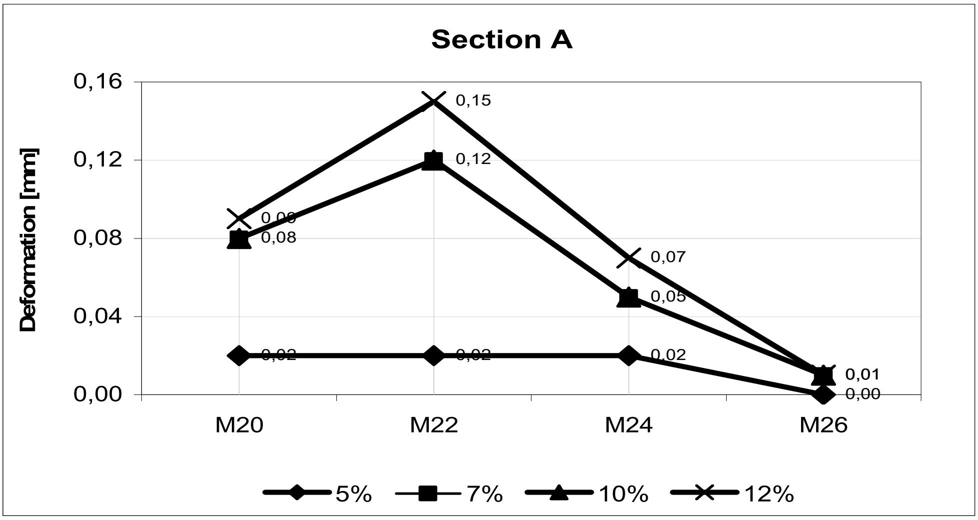
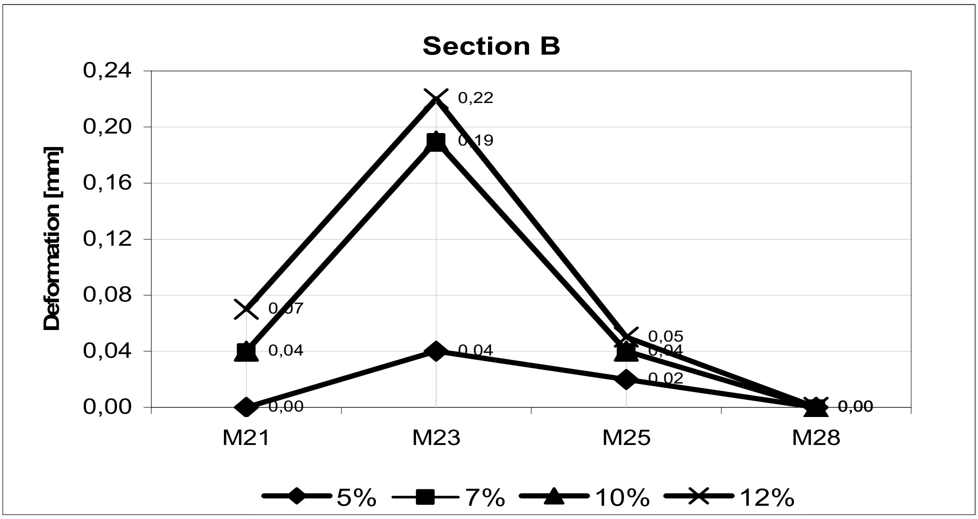


Fig. 2: Placement of potentiometic sensors M20 thru M28, the wall plate and prestressing force *P* [kN]

10.2478/v10160-011-0021-z



Graph 1: Deformation in A vertical section passing through the points M20, M22, M24 and M26



Graph 2: Deformation in B vertical section passing through the points M21, M23, M25 and M28

The most significant deformation courses occurred in the points M21 thru M25. These deformations correspond to estimations of maximal stresses and deformation in the anchoring points of the prestressing bar. For clarity of the results, the Graph 1 shows deformation courses through the A section, which pass through M20, 22, 24 and 26, and the Graph 2 shows deformation courses through the B section, which pass through M21, 23, 25 and 28, see Fig. 2.

10.2478/v10160-011-0021-z

5 CONCLUSION

The brick structure lined into the prepared steel structure was prestressed using prestressing force only in one direction, where the prestressing forces were inserted into the construction gradually.

Another direction of measuring will be focused on prestressing of the brick structure with greater prestressing force, then the prestress in two directions using greater prestressing forces and also various values of vertical loading.

Then modelling in the software programme based on the finite element method will be carried out and comparison with measuring results will be performed. Based on this comparison, it will be possible to improve the created models and to approximate the exact and simple procedures for masonry modelling.

The experimental measuring of the brick structure serves also as a background for tests of sliding joints, which resumes the project of the Ministry of Industry and Business of the Czech Republic, No. FR-TI2/846 Rheological Sliding Joint with Temperature-Controlled Viscoelastic Properties, in which verification of their temperature-depending rheological properties at common outdoor temperatures, in contact with brick constructions exposed to prestress is assumed.

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REFERENCES

[1] BAŽANT, Z.; KLUSÁČEK, L. Structural Analysis at Redevelopment of Buildings. VUT Brno, 2004.

[2] BRADÁČ, J. Effects of Undermining and Protection of Structures, vol. I and II. Dům techniky Ostrava. Ostrava, 1999. ISBN 80-02-01276-3

[3] MYNARZOVÁ, L. Static Analysis of Masonry Structures *Dissertation thesis 2009.* VŠB-TU of Ostrava 2009. ISBN 978-80-248-2064-4

[4] SCHUBERT, P.; HOFFMANN, G. Druckfestigkeit von Mauerwerk parallel zu den Lagerfugen. Mauerwerk-Kalender 1994, Ernst Sohn & Berlin 2004.

[5] ČSN 73 2030 Loading Tests of Building Structures. Common Regulations. Český normalizační institut, 1993

[6] EN 1996-1-1 Eurocode 6: Design of Masonry Structures. Part 1-1: General Rules for Reinforced and Unreinforced Masonry Structures, Český normalizační institut, 2007

[7] ISO 13822 Bases for Design of Structures – Assessment of Existing Structures. Český normalizační institut, 2005

[8] EN 1052-1 Methods of Test for Masonry, Part I, Determination of Compressive Strength, Český normalizační institute, 2000

[9] EN 1015-11 Methods of Test for Mortar for Masonry, Part 11: Determination of Flexural and Compressive Strength of Hardened Mortar, Český normalizační institut, 2000

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