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SOLID BURNT BRICKS' TENSILE STRENGTH

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Abstract. This paper deals with experimental testing of solid burnt bricks and mortar in pure (axial) tension. The obtained working diagrams will be further use for a detailed numerical analysis of whole brick masonry column under concentric compressive load. Failure mechanism of compressed brick masonry column is characterized by the appearance and development of vertical tensile cracks in masonry units (bricks) passing in the direction of principal stresses and is accompanied by progressive growth of horizontal deformations. These cracks are caused by contraction and interaction between two materials with different mechanical characteristics (brick and mortar). The aim of this paper is more precisely describe the response of quasi-brittle materials to uniaxial loading in tension (for now only the results from three point bending test are available). For these reasons, bricks and mortar tensile behavior is experimentally tested and the obtained results are discussed.

Keywords: tensile strength, pure tension, brick, mortar.

1. Overview

The aim of this paper is determine solid burnt bricks' and mortar tensile strength in "pure" tension. Obtained working diagrams will be further used for detailed numerical analysis of whole masonry brick column. Under concentric compressive load of masonry column, bricks are gradually damaged by lateral tension accompanied by appearance and development of cracks. These cracks are caused by contraction and interaction between two materials with different mechanical characteristics As a result of this mutual interaction, mortar that has a lower Young's modulus and has tendency to greater lateral strain, is transversely "pressed" and masonry units, on the contrary are transversely "stretched" [1, 2].

Figure 1. Experimental setup.

2. Experimental setup for bricks

Six P20 solid burnt bricks with dimensions of 290×140×65 mm (the declared compressive strength is 20 MPa) were experimentally tested in pure tension test. All specimens were measured and the specific dimension were used for each specimen. Steel plates were glued on brick's face in longitudinal directions by means two components epoxy glue Akepox 2040 according to technological procedure in laboratory conditions. Akepox 2040 reaches the maximal strength in seven days, after that the specimen were tested. Brick with steel plates were placed into testing equipment LabTest 4.100SP1 by means two snap hooks (Fig. 1). This equipment adds load in form of deformation in regular steps.

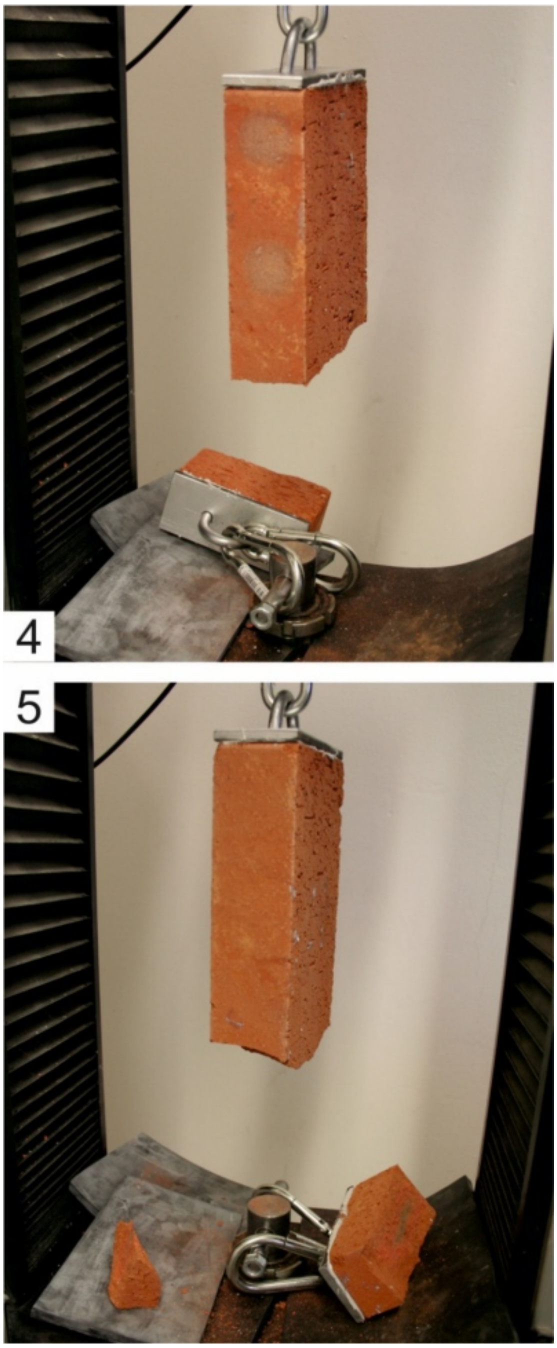

Figure 2. Failure of specimens no. 4 and 5.

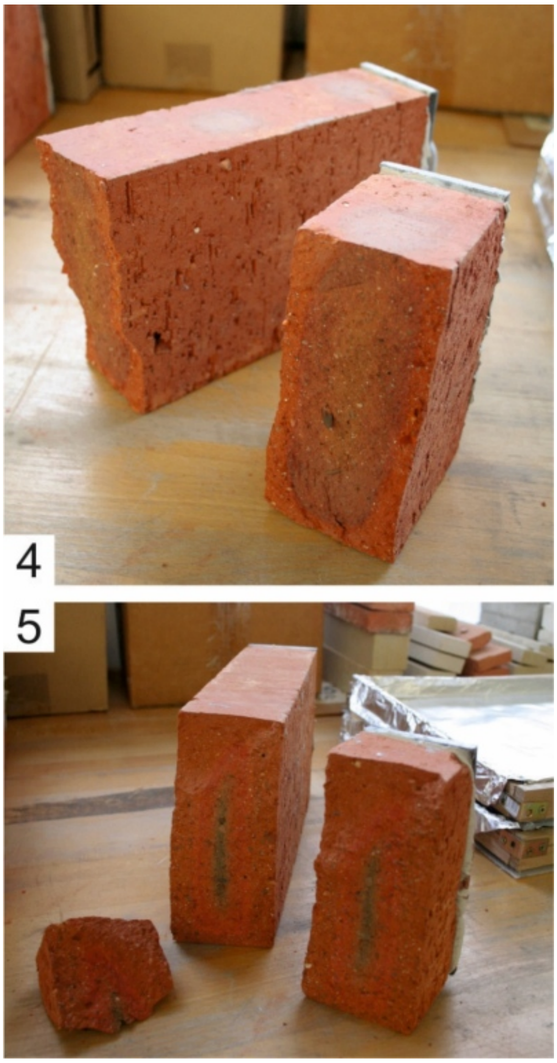

Figure 3. Cross-sections of specimens no. 4 and 5.

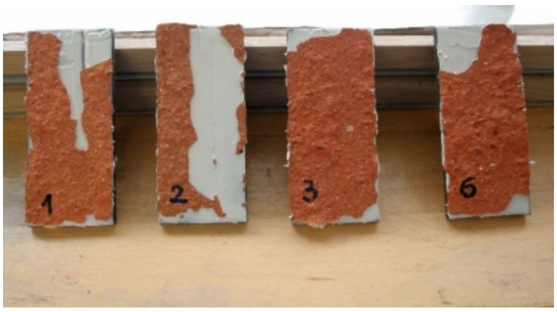

Figure 4. Failure of specimens no. 1, 2, 3 and 6.

3. Discussion of the obtained results

Failure occurred at the interface between steel plate and brick with the exception of two samples. These two samples had initial damage from manufacturing. During experimental testing was observable a slowly opening of the crack following by brittle failure. Failure mode of both specimen (no. 4 and 5) is showed in Fig. 2.

After failure, different level of burning is evident on the cross-section of specimens. Grey core in specimen 5 indicates incomplete burning process. Specimen 5 showed lower tensile strength, however it is necessary take into account the size of initial crack from manufacturing.

Other specimen showed failure between brick and one of steel plates. Reason of this type of failure is given by low interface adhesion. Usage of insufficient amount of epoxy resin is probably the explanation. Another stone specimens were also tested in pure tension test and the expected failure was reached – all specimens failed in stone (interface strength was higher than specimen tensile strength). Fig. 4 shows failure of specimens 1, 2, 3 and 6.

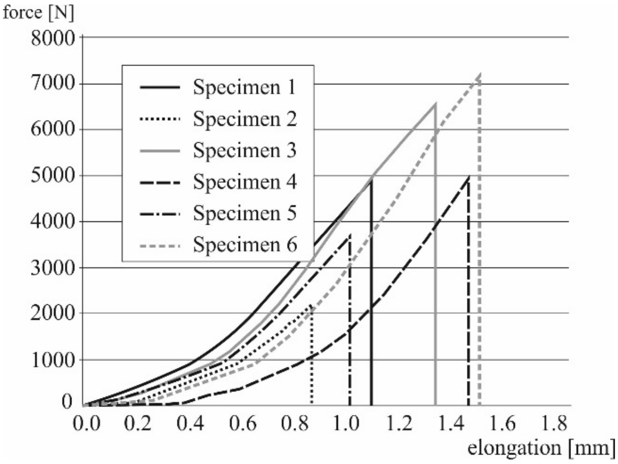

Figure 5. Working diagram force-elongation of bricks.

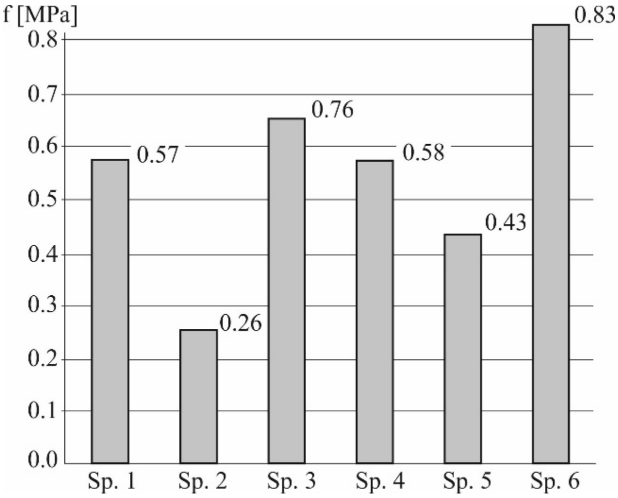

Figure 6. Tensile strength of bricks.

Figure 5 shows working diagrams of each specimen. The highest value of force was reached for specimen 6. Specimen 6 (together with specimen 3) was quite enough glued (see Fig. 4) and the failure occurred predominantly in very first layer of masonry unit [3]. This layer has improved properties thanks to glue penetration into porous system. For this reason, there is no failure direct at the interface, but a small layer of brick was thrown away.

Specimen 1 and 2 show poor gluing of steel plate, especially specimen 2 has the lowest value of reached force. Specimens 4 and 5 had an initial manufacturing crack and have failed in brick. The maximal value of reached force is different, it could be caused by distinct depth of initial crack. It was not possible to measure the size of initial cracks, because there were only hair cracks observed. The possible solution is using specimen with notches whose accurate size would enable a conversion force to area.

The initial slip of the specimens is not displayed in working diagrams (Fig. 5). The diagrams show brittle rupture in all cases.

Average tensile strength was determined to 0.64 MPa with standard deviation 0.15 MPa. Specimen no. 2 was not taken into account.

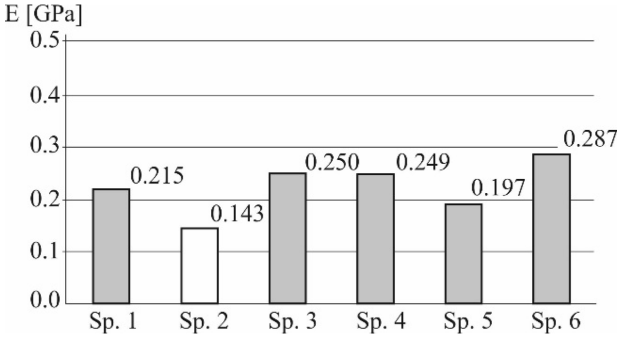

Figure 7. Young's modulus of bricks.

Figure 8. Failure of mortar specimens.

Young modulus was obtained as secant modulus between two loads: 90 % N_{um}, 40 % N_{um}, where N_{um} is maximal load. Average modulus of elasticity was determined to 0.24 GPa with standard deviation of 0.03 GPa. Specimen no. 2 was not taken into account.

4. Experimental setup for mortar

For mortar pure tension test, three mortar specimens with dimensions 40×40×160 mm were made. Specimens were tested after 28 days to ensure mortar's hardness. Steel plates were glued on mortar specimens after 21 day from construction (meaning the maximal strength of epoxy resin in 7 days was respected).

Mortar with steel plates were placed into testing equipment LabTest 4.100SP1 by means two snap hooks as well as bricks.

FIGURE 9. Failure of specimen M2.

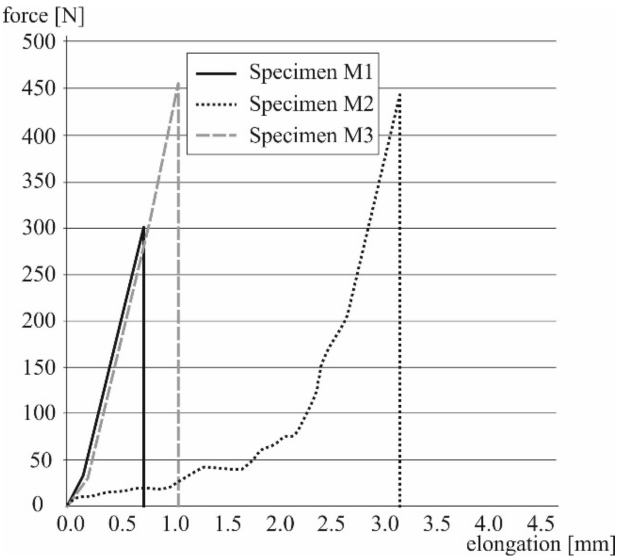

FIGURE 10. Working diagram force-elongation of mortar.

5. Discussion of the obtained results from mortar testing

Two mortar specimens show failure close to THE glued steel plates. After failure of specimen no. M1 small place of incomplete gluing is evident. Specimen no. M2 failed approx. in a half of its length. Calculated values of tensile strength and Young modulus are reported in bar charts (Fig. 11 and 12).

The initial slip of the specimens is not displayed in working diagrams (Fig. 10). The diagrams show brittle rupture in all cases. Average tensile strength was determined to 0.25 MPa with standard deviation 0.04 MPa.

Young modulus was obtained as secant modulus between two loads: 90% N_{um}, 40% N_{um}, where N_{um} is maximal load. Average modulus of elasticity was determined to 0.047 GPa with standard deviation of 0.005 GPa.

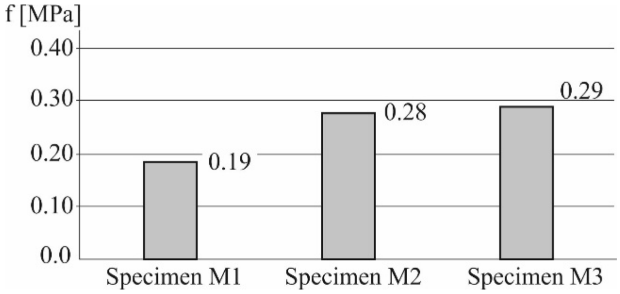

FIGURE 11. Tensile strength of mortar.

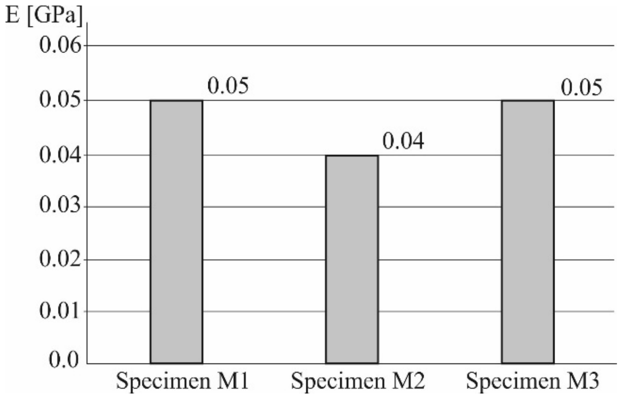

FIGURE 12. Young's modulus of mortar.

6. Summary

Reached values of Young's modulus and tensile strength of bricks are lower than the expected. The expected tensile of bricks strength was approx. around 1.5 MPa and the reached value with the exception of specimen 6 is not even half of that. Simultaneously stone specimens were tested, whose failure matches to expected, and therefore the amount of used epoxy resin was determined as the reason of lower obtained values. Also the low tensile strength of the specimens with the manufacturing crack (no. 4 and 5) for which were not possible to determine the effective area resisting to the force and thus it was not possible to recalculate the obtained tensile strength for the effective area. After this recalculation, the value of tensile strength of specimens 4 and 5 is expected higher than the determined ones. The experimental testing of bricks will be repeated and the results mutually compared and discussed.

Tensile strength of mortar met the expectation; however due to small amount of specimens the testing will further continue and reached values will be evaluated.

Acknowledgements

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