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IN SITU ASSESSMENT OF STRESS STRAIN CURVE FOR MASONRY BY FLAT JACK TEST

BY

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Abstract. In actual approach for masonry buildings regarding the structural analysis or assessment of the building behaviour during its lifetime, information about the existing stresses and effort in the structure and information about the material characteristics are strictly essential. The use of this tests in historic masonry buildings is facilitated by the fact that it can be done in any area of the building (wall, pillar and arch), allowing a comprehensive picture of the stress state and mechanical properties of masonry with a high degree of accuracy and speed of execution. This paper studies the testing methods with thin flat jacks from the specific literature point of view and an actual test is performed on an existing masonry building with two flat jacks in order to determine the characteristic curve for masonry.

Keywords: flat jack method; masonry structures; stress-strain curve.

1. Introduction

Generally, the various research techniques for masonry buildings are classified according to the damage degree produced on the expertise structure. Thus, in accordance with this criterion, investigation techniques are divided into:

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a) *non-destructive tests*: radar method, ultrasound method, thermography, recoil method and dynamic characteristics measurement;

b) *semi-destructive tests*: flat jack testing method, tests on samples;

c) *destructive tests*: tests on elements in order to determine the mechanical characteristics of the masonry.

According to P100-3/2008 - Appendix D, the use of flat-jack testing method for masonry buildings survey is facilitated by the fact that it can be applied in any area of the building element (wall, pillar and arch). This leads to detailed information about the building efforts state with the advantage of speed of execution and interpretation of the actual test results. The test should be repeated, if during the intervention work areas with different masonry characteristics are noticed in the uncovered element.

This *in situ* testing method is described in the standards: ASTM Standard C 1196-91 the method with one flat jack and ASTM Standard C 1197-91 the method with two jacks. Flat jacks testing method is a minor-destructive test that can be performed in situ to determine the following characteristics of the existing masonry: the stress state in a wall of the analysed building; axial compression strength of masonry; masonry deformability characteristics which define the constitutive law σ–ε and the modulus of elasticity (Soveja & Gosav 2014).

2. *In Situ* Flat-Jack Testing Method

The test equipment (Fig. 1) consists of two or more thin flat jacks, a hydraulic pump with pressure reading monometer and linear devices for measuring deformations.

Fig. 1 – Testing equipment (Archiproducts company).

The flat jacks are thin steel rooms which can be manufactured in different shapes. They are used in accordance with the uncovered mortar joints in order to ensure a satisfactory coincidence for contact surface (the dissolution of joints is performed by mechanical rotary which uses rectangular flat jacks or by circular saw with semicircular flat jacks).

2.1. Single Flat-Jack Method

The assessment of the stress state is based on the stress relaxation caused by a cut perpendicular to the wall surface. The stress release is determined by a partial closing of the cutting, *i.e.* the distance between the edges of the slot after the cutting space is lower than before (Fig. 2). A thin flat-jack is placed inside the slot and the pressure is gradually increased to restore the distance measured before the cut. The displacement caused by the cut and those subsequently induced by the flat-jack are measured by a removable extensometer before, after cutting the slot and during the tests (Fig. 3). *P* corresponds to the pressure of the hydraulic system driving the displacement equal to those read before the slot was executed (Binda & Tiraboschi, 2014).

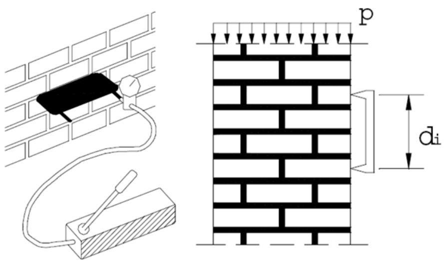


Fig. 2 – Loading principle for one thin flat jack test (stage 1) (Grecchi, 2012).

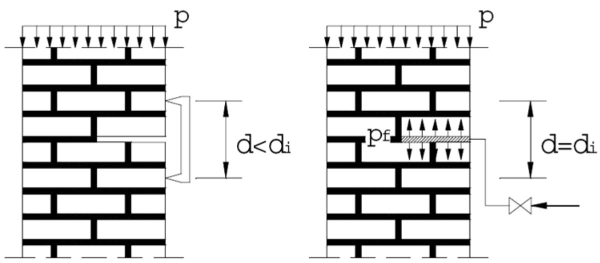


Fig. 3 – Loading principle for one flat jack test (stage 2) (Grecchi, 2012).

The test consists in converting the pressure from the thin flat jack, measured by manometers in compression efforts (Simoes *et al.*, 2012):

$$\sigma_m = pK_m \frac{A_p}{A_t},$$

where: σ_m is the compression stress in the masonry; ρ – flat jack pressure; K_m – calibration factor; A_p – area of the flat jack in contact with the masonry; A_t – cutting area.

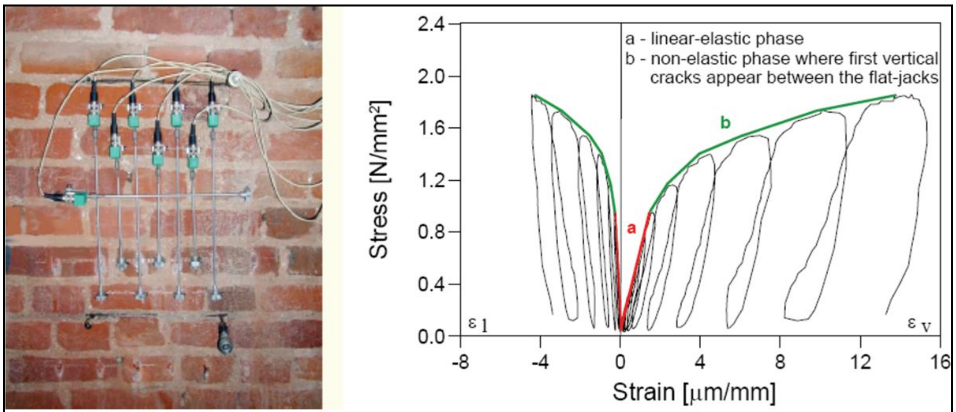
Due to pressure losses during the loading of the thin flat jack, laboratory calibration is recommended by another hydraulic jack, resulting Km coefficient equal to the ratio of the pressures read at the jack:

$$K_m = \frac{p_{ph}}{p_{pp}},$$

Following these calibrations, similar studies estimate K_m calibration coefficient value at 0.7 (Parivallal *et alI.*, 2011).

2.2. Double Flat-Jack Method

In situ masonry testing with two thin flat jack is achieved by cutting two parallel joints and isolating o part of the tested wall. Masonry behaviour regarding axial compression is simulated by gradually increasing the pressure from the flat jack introduced in the uncovered joints and measuring vertical and if necessary horizontal displacement during the test (Fig. 4).



a) b)

Fig. 4 – Two thin flat jack test (Binda *et al.*, 2007).

The tangent elasticity modulus is obtained based on current technical regulations, ASTM C 1197-91 Standard, using the following relation:

$$E_t = \frac{\delta f_m}{\delta \varepsilon_m},$$

where: δf_m is the increment of stress; $\delta\varepsilon_m$ – correspondent increment of strain.

The secant Young's modulus is given by the following equation:

$$E_t = \frac{\sigma_m}{\varepsilon_m},$$

where: σ_m represents the compression increase in the masonry to the appropriate value for the point in which the secant elasticity modulus is researched; ε_m – increase of the vertical specific deformation to the appropriate value for the point in which the secant elasticity modulus is researched.

The Poisson's coefficient for masonry is obtained using the following equation (Simoes *et al.*, 2012):

$$\nu = \frac{\varepsilon_h}{\varepsilon_v},$$

where: ε_h is the horizontal strain; ε_v – vertical strain.

3. In Situ Double Flat-Jack Test on a Existing Masonry Structure

The purpose of the experiment is to assess in situ the followings: the characteristic compression curve for masonry and the shear strength for mortar joints subjected to compression loading.

The experimental device (Fig. 5) is made of semiovale hydraulic jack having the following dimensions 35 × 25 × 0.3, a manual hydraulic pump and a recording system for the measurements. The uncovering of the joints from the analyzed masonry was performed at a distance of five rows with a drill without percussion in order to avoid introducing supplementary damaging vibrations, which could significantly influence the masonry.

In order to measure the deformation of the tested masonry sample, three linear displacement transducers had been installed vertically and one horizontally (with measurement accuracy up to 0.01 mm).

The pressure from the flat jacks was monitored by a pressure transducer attached on the hand pump. The measuring range of the transducer is 0.1-100 bar with an error of 0.01%. The displacement and pressure transducers were connected to a data acquisition system allowing data registration and the control over the loading speed of the jacks with oil.

Experimental assessment of the characteristic curve for masonry subjected to axial compression loading started with an initial load of 3 bars in order to remove possible errors in measurements due to the press settlement in the mortar joints. The test itself started with zero pressure, which was increased constantly up to a pressure of 18.8 bar, at which the masonry failure was recorded.

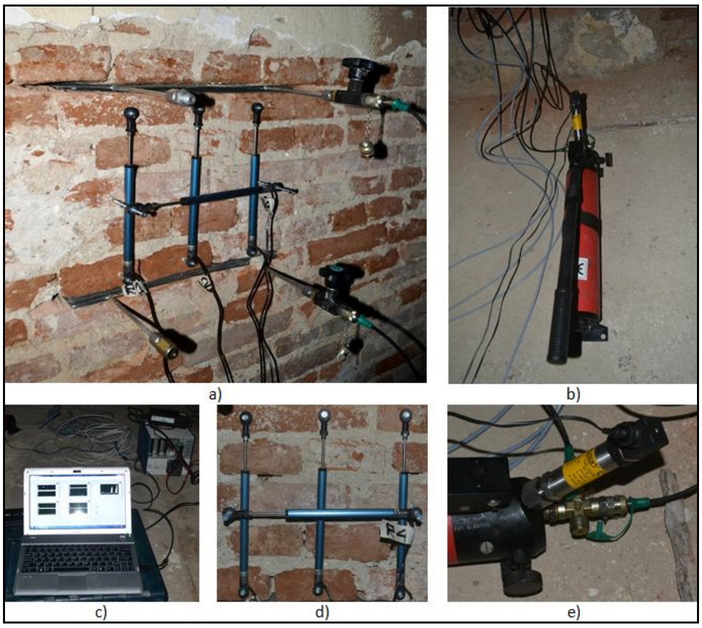


Fig. 5 – Used equipment and preparation of the experiment with flat jacks.

The assemblage of the linear transducers for measuring the displacements was carried out between the two flat jacks, at a distance of 10 cm from their edges. The first vertical crack appeared at a pressure of 6.85 bar, close to transducer three (Fig. 6).

Fig. 6 – Crack development in masonry during two flat jacks test.

After correcting with adequate calibration coefficients the results of the flat jack, the compressive strength of masonry resulted to be 0.91 N/mm^2. The elasticity modulus for masonry was computed for the elastic behaviour plateau (until a pressure of 0.31 N/mm^2 was reached) obtaining the value of 1,094 N/mm^2 (Fig. 7).

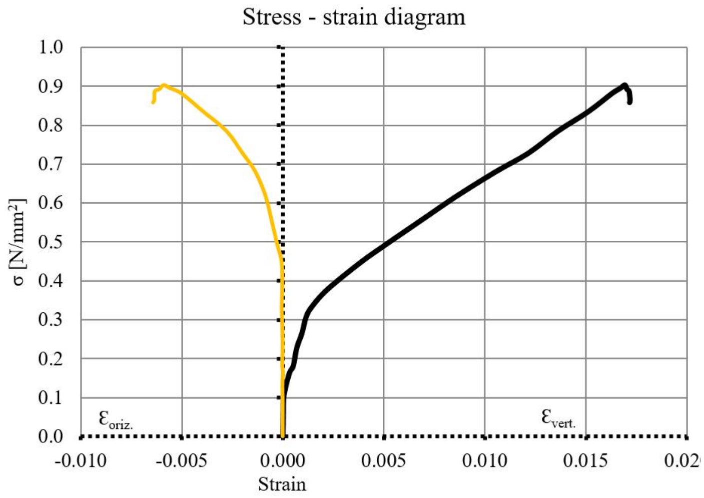


Fig. 7 – Masonry stress strain curve.

4. Conclusions

Flat jacks testing method is a minor-destructive test that can be performed in situ to determine the following characteristics of the existing masonry: the state of stress in a wall of the analysed building, axial compression strength of masonry, masonry deformability properties which define the constitutive law *σ-ε* and modulus of elasticity. The use of this tests in historic masonry buildings is facilitated by the fact that it can be done in any area of the building (wall, pillar, arc), allowing a comprehensive picture of the stress state and mechanical characterization of masonry with a high degree of accuracy and speed of execution. If masonry with apparently different characteristics is found during the intervention works in uncovered areas the test could be repeated immediately (Soveja & Gosav, 2014).

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DETERMINAREA *IN SITU* A CURBEI CARACTERISTICE DE COMPORTARE A ZIDARIE UTILIZÂND METODA PRESELOR PLATE

(Rezumat)

În tehnica curentă privind analiza structurală sau urmărirea comportării în exploatare a structurilor existente din zidărie sunt strict necesare informații privitoare la stările de tensiune şi eforturi existente în structură şi informații legate de caracteristicile materialelor. Utilizarea acestei metode de încercare în expertizarea structurilor vechi din zidărie este facilitată de faptul că se poate efectua în orice zonă a elementului de construcție permițând obținerea unei imagini cuprinzătoare a stării de eforturi pentru ansamblul clădirii. De asemenea, prezintă avantajul rapidității de execuție a încercării propriu-zise şi al interpretării rezultatelor. În acest articol se studiază metodele de încercare cu prese plate existente în literatura de specialitate şi realizarea efectivă a încercării cu două prese plate la o structura existentă din zidărie, pentru determinarea curbei caracteristice a zidăriei.