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The estimation of compressive stress level in brick masonry using the flat-jack method

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Abstract

The paper presents the methodology of in-situ testing based on the flat-jack device. The flat-jack method belongs to the minor-destructive tests (MDT). Beside NDT, MDT are recommended for historical buildings. In the paper the results of authors' laboratory studies on brick walls were presented. Tests were carried out using various types of flat-jacks in terms of their shapes and materials from which they were made. Additionally, during flat-jack tests various methods of displacement measuring including optical measurements based on a digital image correlation method (DIC) were performed. The studies allowed the authors to provide recommendations on the selection of the flat-jack type for determining compressive stress in brick masonry.

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Keywords: flat-jack method, brick masonry, compressive stress level, existing buildings

1. Introduction

In the process of evaluating the technical condition of existing masonry structures, it is important in many cases to estimate the level of compressive stress in the walls and pillars. In engineering practice, there are commonly used

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methods to determine compressive stress in walls on the basis of a combination of loads on a structure. Such calculations usually have a large margin of error, which results from limited opportunities to take inventory of the current state of existing buildings and their structures. The flat-jack method creates many opportunities in the assessment of the stress state in masonry walls. This method involves the evaluation of the level of compressive stress, directly on the basis of in-situ tests. Tests are performed using thin pressure pads (flat-jacks), which are installed in slots made in the masonry bed joints. The flat-jack method can be classified as a minor destructive test (MDT). Numerous cases of application of the flat-jack method were described in studies concerning masonry structures [1-8]. Despite the many practical applications, research is being conducted, aimed at the adjustment of test procedures to different types of masonry structures. Flat-jacks made of different materials and with different shapes, as well as new systems for displacement measurement [9] are tested.

2. Description of the method

The flat-jack method was initially primarily used in geotechnical engineering to measure the stresses in rock mass, where its popularity continues [10]. The first application of this method in masonry structures took place in the 1980s [11]. In 1991, US standard ASTM C1196-91 [12] was established, concerning the application of the flat-jack method to determine the level of stress in walls. The result of this research are subsequent versions of American standards, including the latest one, of 2014 [13]. Recommendations in this regard have also been developed in Europe in the form of RILEM documents [14]. Rules concerning the use of the flat-jack method to assess the level of stress in the masonry walls are shown in Fig. 1a.

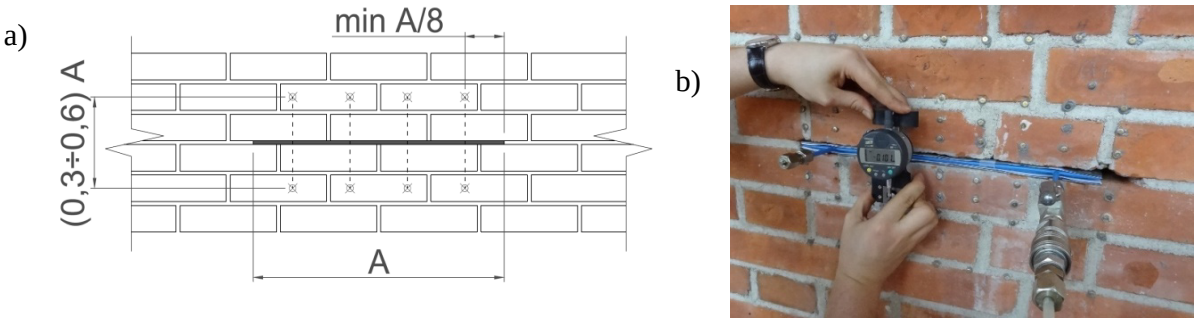

Fig. 1. Applying the flat-jack method to determine the level of compressive stress in masonry;
a) localization of base points acc. to ASTM C1196 [13]; b) own authors' research.

The first step establishes measurement bases, and measures the distance between them. Next, the bed joint is removed, which leads to local relief in the masonry wall - the effect is a reduction of the distance between base points. Then, a precise measurement of the slot depth is carried out. In the third step, a flat-jack is introduced into the slot. The pressure in the flat-jack is increased until the distance between the measurement bases is the same as before the test. The pressure in the flat-jack, necessary to achieve the original distance between base points is greater than what would result from the equalisation of stress levels. This effect is due to the rigidity of the flat-jack, and the difference between the area of the slot and the area of the flat-jack introduced to the structure. For this reason, appropriate conversion factors are applied. Finally, the compressive stress in the masonry (σ_c) is determined by the following relation:

$$\sigma_c = K_m K_a p \tag{1}$$

where: K_m is the conversion factor depending on the stiffness and shape of the flat-jack, K_a is the ratio of the flat-jack area to the area of the slot in the masonry, p is the pressure value, i.e. pressure that causes measurement bases to return to their original length.