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OPTICAL MEASUREMENT OF THE ELASTICITY MODULUS USING DIGITAL IMAGE CORRELATION

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Summary: *This paper presents the utilization of Digital Image Correlation Methodology for measuring of elasticity modulus in compression demonstrated on lime-mortar specimen. Benefits of Digital Image Correlation measurement in comparison with standard methods will be presented.*

1. Introduction

Digital Image Correlation (DIC) is the non-contact (optical) technique that provides full-field and high resolution measurement of displacements and strains within an object subjected to loading. Outstanding advantages of DIC are the robustness, very low demands on specimen preparation and practically unlimited length scale range. It can be used in many cases where the standard methods using strain gages and/or extensometers are hardly realizable or do not provide enough data. The technique utilizes a sequence of consecutive images that represents the progress of the object deformation. In this sequence DIC observes a movement of individual templates of some texture employing the correlation technique. The template is a cutout of the texture that contains a small but distinguishable part of the texture. In the case of optical measurement the texture is generated by the surface of an object with significant structure (natural or artificial). The template is a cutout of the texture that contains a small but distinguishable part of the texture. In the case of optical measurements the texture is generated by the surface of an object with significant structure (natural or artificial). In our case the correlation algorithm is based on the direct definition of a correlation function (Peters, 1982), (Jandejsek, 2007). The region containing a shifted template in the after-image of the sequence is scanned by the template of the original image to get a matrix of correlation coefficients. A maximum value of this matrix gives the new position of the template and consequently the vector of displacement of the template. If it is desired to obtain the full-field displacements across the whole investigated plane, one has to define an entire regular grid of such templates. Subsequently, the strain or possibly stress fields can be evaluated. This procedure is done for the entire sequence so the time behavior of full-field displacements and strains is obtained.

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2. Experiment

An experimental investigation was made of the influence of specimen size on the measured data in the compression test (Drdácký, 2007). Six samples of lime mortar were tested (the ratio of the lime to sand fraction was set identically as 1:9). The samples were cubic in shape, with the same cross section base dimensions but with differences in height H, as imaged in Figure 1.

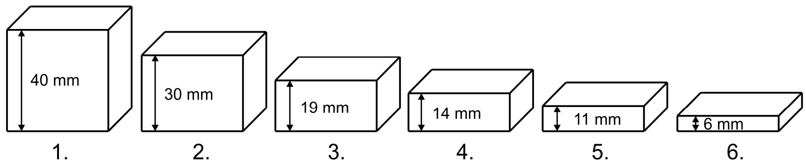

Fig. 1 Schema of investigated specimens.

The specimen mounted between two steel plates was loaded in compression by the Testatron electromechanical loading frame - see Figure 2 for the scheme of the setup. The loading was controlled by cross head displacement with velocity 0.45 mm/min until failure occurred. The resultant loading force was measured by the 100 kN load cell. An extensometer measuring the distance between the plates was used to record the standard loading curve. The front surface of the specimen was illuminated by circular diffuse light for the purposes of optical measurement. This light emphasizes the albedo and suppresses the topography, while the grain boundary remains visible. The Cannon EOS D10 high-resolution CMOS camera with an average frame rate of 1/3 fps was employed for image sequence recording. The frames were stored in jpeg Exif 2.2 file format, 3072 x 2048 image pixel resolution and RGB (24bits) color-map. The adjusting glass gauge was used for pixel calibration (DIC is dimensionless, like other optical methods).

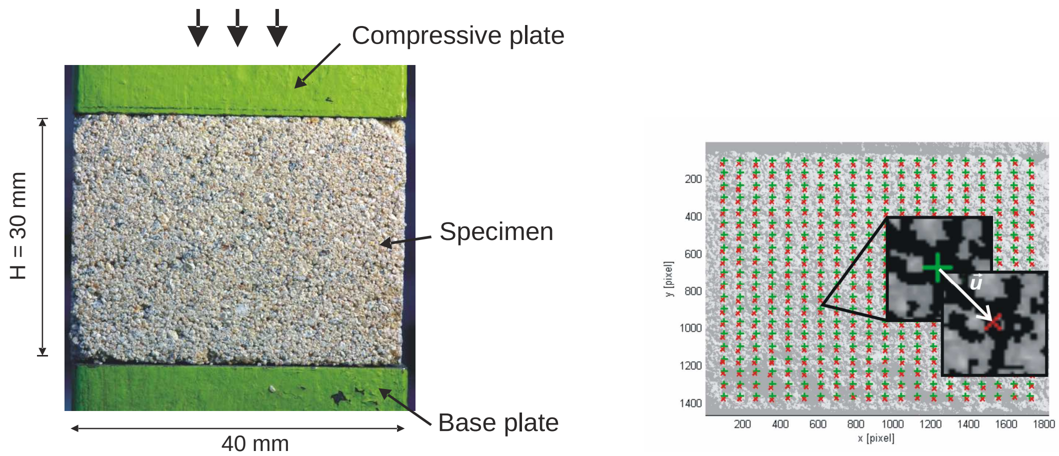

Fig. 2 Specimen n.2 in compression test, left, Digital image processing, right. (The initial grid of points (green +) and its new positions after deformation (red x).

3. Data Processing

Subsequently, the regular orthogonal grid of the control points was defined in the first image of the sequence (each point is the centre of the template), see Figure 2. The choice of grid density depends on the required results and the expected strain intensity. A finer grid should be applied for full-field measurement of the displacement gradient in the non-linear phase of specimen deformation. A coarse grid should be set to measure the linear behavior, as in the case of material elastic modulus evaluation (the sensitivity of the DIC method is typically 0.1 image pixel). It should be emphasized that regions in the vicinity of the contact surfaces with compressive plates must be avoided when the modulus of elasticity is being measured.

4. Results

The strain fields in the *x* and *y* directions: ε_x, ε_y can be calculated when the displacement fields in the x and y directions are known. The elasticity modulus was calculated from the ε_y field from the central part of the specimens face. The elasticity modulus measured by DIC was compared with the value obtained from the standard loading records (made by the extensometer and load cell). A comparison of the results is shown in table below.

Table 1

Specimen n.	**Specimen high H. [mm]**	**Modulus of elasticity [MPa]**	
		Standard method	**Digital Image Correlation**
1	40	56	600
2	30	89	1000
3	20	54	700
4	14	220	1600
5	10	280	1200

Only central part of the specimen is taken into account for DIC calculation avoiding regions encompassing the shear bands and contact areas; see Figure 3.

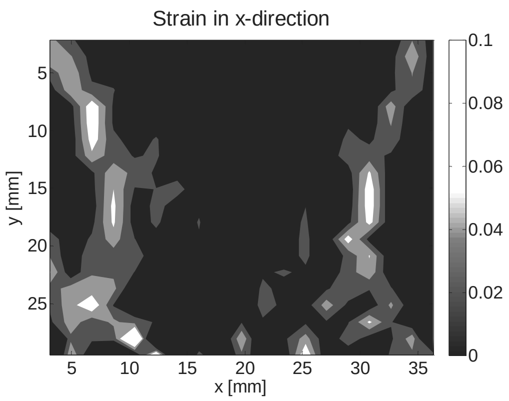

Fig. 3 ε_x field for specimen n. 2

On the contrary standard method measures the strain from grips displacement and therefore values of elasticity modulus are influenced by contact and damage areas. Consequently one order difference of elasticity modulus evaluation can be observed using these two approaches see Figure 6. A relative large deviation in values for series of specimens is regarded to heterogeneity of material.

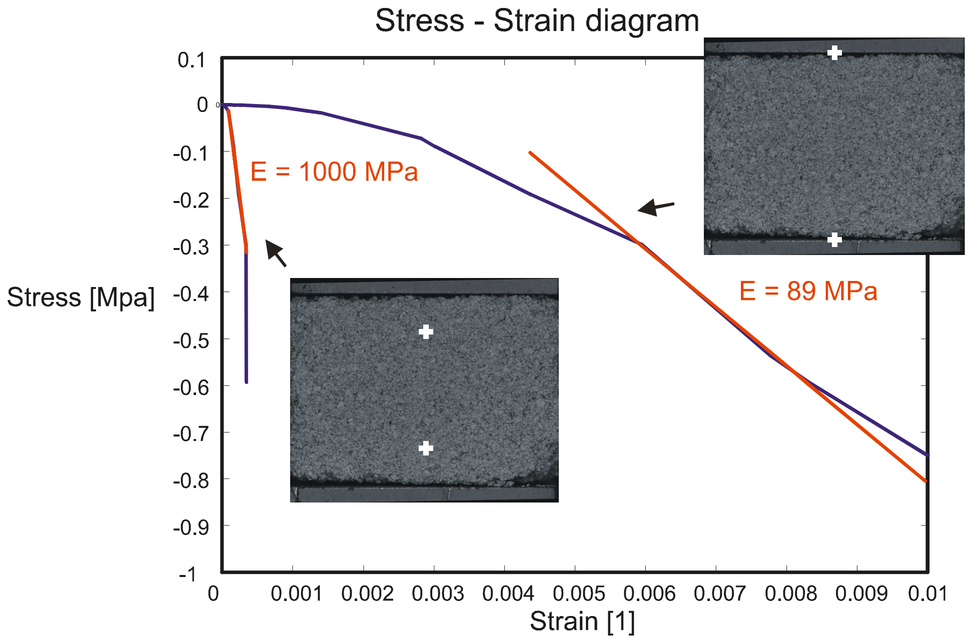

Fig. 6 The comparison of the measuring elasticity modulus in the different settings of control points. First, the points are on the edge of grips; second, the points are in the central part of specimens face.

4.1. Abnormalities measured

A major advantage of DIC is the ability to observe specimen behavior during the test. This makes it possible to show up some measurement abnormalities, which can lead to the exclusion of abnormal specimens from elastic modulus calculations. Moreover DIC reveals these crack and non-homogeneity detections earlier than they are visible by naked eye in photographs (Jandejsek, 2008).

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