

Ivan JANDEJSEK*, Daniel VAVŘÍK****MATERIAL CHARACTERIZATION USING DIGITAL IMAGE CORRELATION****URČOVÁNÍ MATERIÁLOVÝCH CHAREKTERISTIK POMOCÍ DIGITÁLNÍ OBRAZOVÉ KORELACE****Abstract**

This paper presents the application of Digital Image Correlation (DIC) methodology for evaluation of optical data acquired during loading test. DIC allows to measure specimen surface deformation fields. Benefits and new possibilities of DIC measurement in comparison with standard methods will be presented.

Abstrakt

Tento příspěvek je věnován aplikace metody digitální obrazové korelace ve vyhodnocení optických dat získaných během zátěžové zkoušky. Tato metoda se používá v experimentální mechanice k určování polí deformací vzorků vystaveným namáhání. Jsou vyzdvíženy výhody a nové možnosti DIC ve srovnání s klasickými metodami.

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 [1], [2]. 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 [3]. 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.

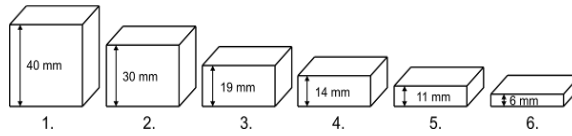


Fig. 1 Schema of investigated specimens.

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).

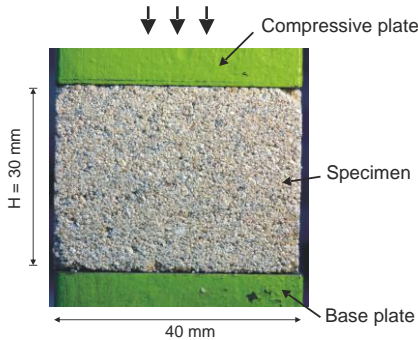


Fig. 2 Specimen n.2 in compression test, left, pixel calibration with glass gauge, right.

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 fig. 3. 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 behaviour, 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.

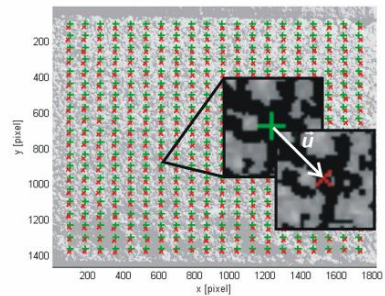


Fig. 3 The initial grid of control points (green +) and its new positions after deformation (red x).

Results

When the tracks of the grid points are known, the displacement field in the x and y directions can be calculated, see Figure 4 for an analysis of specimen No. 2. The influence of the contact surfaces is clearly visible. Friction between these surfaces and steel plates implies some constraint of the lateral deformation, as can be seen in the x displacement field. Contact with the plate is also manifested in the y displacement field.

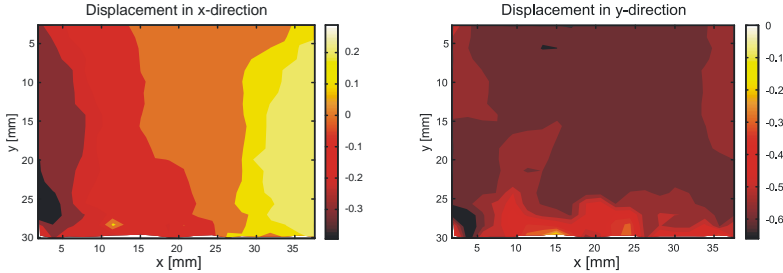


Fig. 4 x -displacement field, left, y -displacement field, right.

The strain fields in the x and y directions: ε_x , ε_y were calculated from the known displacement fields, see Figure 5. It is easy to observe the shear bands in the ε_x field, while the ε_y field is quite homogeneous.

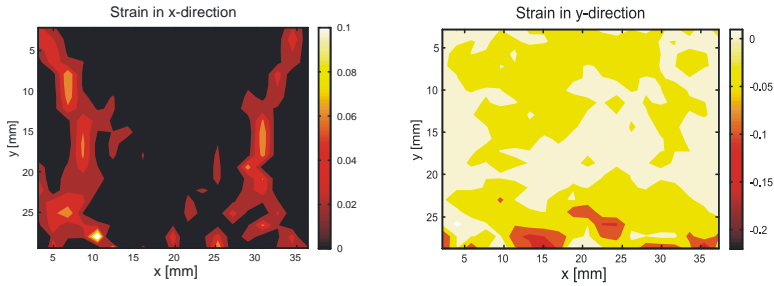


Fig. 5 ε_x field, left, ε_y field, right.

The elasticity modulus was calculated from the ε_y field from the central part of the specimens, avoiding regions encompassing the shear bands and constrained ε_y strain. The elasticity modulus measured by DTC 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.

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 contact and damage areas. Contrary standard method is influenced by these non-linearity softening specimen parts. Consequently one order difference of elasticity modulus evaluation can be observed using these two approaches. A relative large deviation in values for series of specimens is regarded to heterogeneity of material.

3 ABNORMALITIES MEASURED

A major advantage of DIC is the ability to observe specimen behaviour 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.

Some material or geometrical non-homogeneity was observed for specimen No. 1 (excluded), see Figure 6. The thinnest specimen, No. 6, had nonlinear behaviour almost from the beginning because of the relatively high fraction area with constrained ε_x . Moreover, a vertical crack was very soon indicated from the ε_x field, though this crack is not visible in the optical image, see Figure 7. This crack later became optically visible.

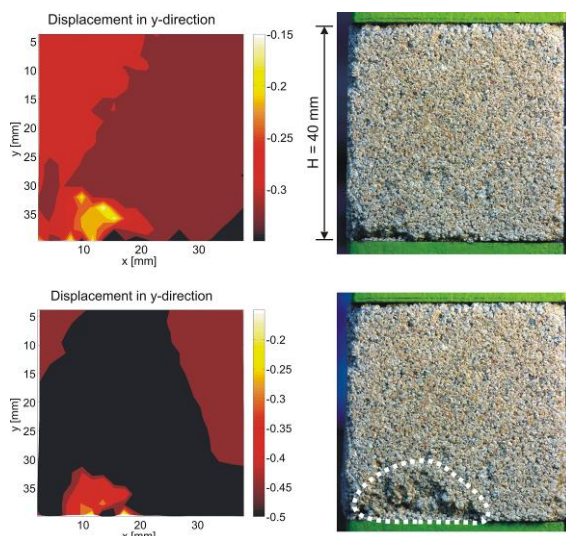


Fig. 6 Specimen n.1 and its y-displacements. Significant non-homogeneity was observed in left bottom corner.

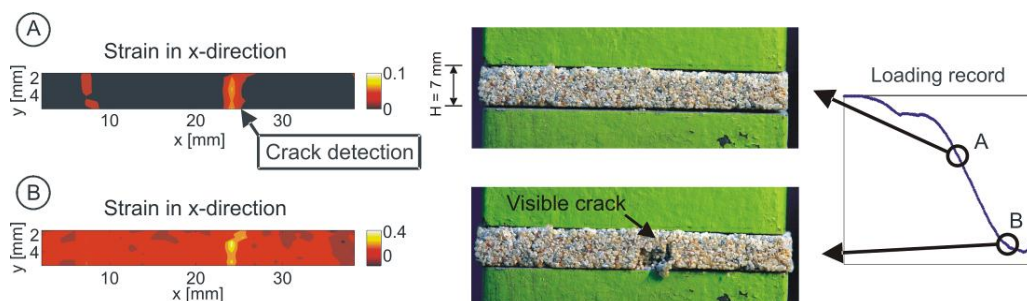


Fig. 7 State A. shows the crack detection in the strain field obtained by DIC at loading record A. Notice that the crack is not yet visible in the photograph. Letter B. shows the state at loading record B where the crack is already visible in the photograph.

REFERENCES

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