The concept of mutual displacements monitoring of gaps and fracturings of building constructions using fiber optic and CCD camera

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Abstract

The article presents the concept of mutual displacements monitoring of gaps and fracturings on building constructions components using fiber optic and CCD camera. Presented idea after tests and verification should contribute to make displacements monitoring easier.

Key words:
CCD CAMERA, LIGHT PIPE, GAP, FRACTURING, MONITORING, DISPLACMENTS

1 INTRODUCTION

The safety standard of modern construction are high, but despite providing specializing tests and analysis which should give proper data to make appropriate calculations by designers, it is very often that construction‘s elements during exploitation, are not able to carry a burden and burst. In some instances new buildings settle unevenly, under the pressure of the upper storeys, the ground can not bear their weight and buildings are getting settle down. Another example are expansion joint, planned by designers, which are supposed to take over negative environment influence on monolithic constructions elements (for example materials‘ thermal expansion).

Traditional monitoring of that kind of situations is based on stabilizing special positions for gap gauge, extensometers or clinometers. Those instruments allow to identity a changing position construction’s elements, which are in one dimension, in two or three dimensions by using mechanical gap gauge known from a literature. The concept of monitoring constructions, presented in this article, allows service staff for analyzing changes in three dimensions at the same time, quick archivisation and results presentation on the computer screen.

Additional advantage of presented solution is miniaturization allowing for not disturbing an architectural visual appearance – the assembly is stabilization two two-points light pipes signalers on monitored surfaces and, a CCD camera near researching object.

2 PRESENTED SOLUTION IDEA

Photos taken by using typical CCD camera are not metrical – we can not obtain straight results in metrical units, generally accepted for monitoring that kind of objects. Results are received in pixels – that comes from screen conversion, which is registered by CCD converter into readable on computer disc as a photo (in bitmap format without compression). An example of single light point register is presented on a figure 1.

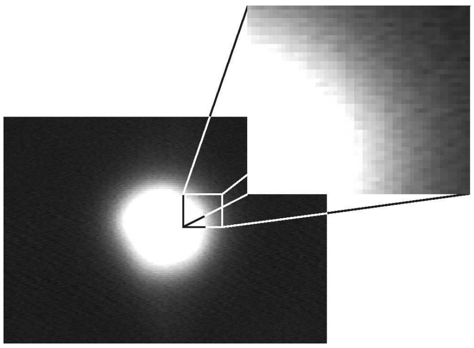

Fig. 1. Geometry of single light pipe point.

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To simplify identification of a single light pipe sign's geometrical centre we assume that registered object will be in 8-bit scale of grey (pixel represent one of 255 grey levels , value „0" is black, and 255 is white). Identification of a single point's geometrical centre is based on average value coordinates of the brightest pixels – value 255 (figure 2).

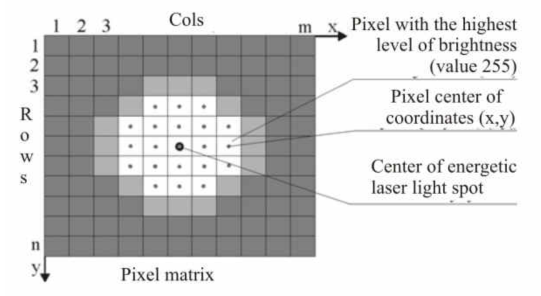

Fig. 2. Assign of coordinates of energetic center laser light spot.

Source: "Wykorzystanie metod geodezyjnych w ocenie stanu geometrycznego budowli."

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According to registered pictures, the middle of an observed point is marked by accepted for matrix local coordinate system x, y, computer program in conformity with the formula:

$$x_E = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

$$y_E = \frac{\sum_{i=1}^{n} y_i}{n} \quad (2)$$

where:

x_i, y_i – coordinates of pixel places on CCD matrix.

On figure 3 presented schematic scheme of two-pointed light pipe signaler.

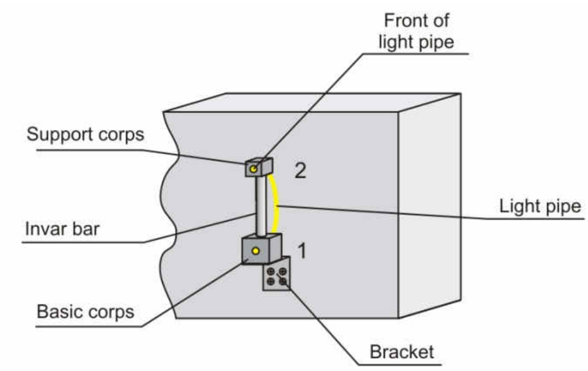


Fig. 3. Scheme of two-pointed light pipe signaler.

Attached to the object two-points light pipe signaler consists bracket, on which signalers are assembled. Support has also a basic corps which contains the origin of light pipe. With using (invar bar) support corps is raised with the end of light pipe inside. The head of light pipe is situated in one plane. In the middle of a corps is a target – head of light pipe. Light pipe applied in signaler contains core made from polymeric fiber, and the cover, in this case is an air. That solution allows to provide a beam of light to the light pipe's core, straight from the nearest environment. On the analyzing subject, near the crack, two two-pointed light pipe signalers must be mounted, we put also CCD camera not much further, in the center in relation to signalers.

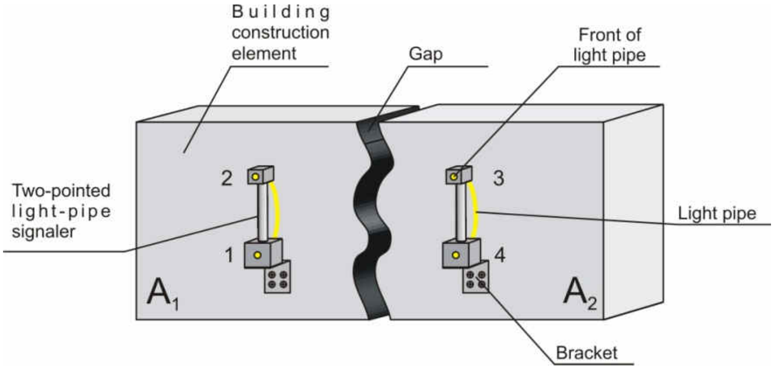


Fig. 4. Example of two two-pointed light pipe signalers marked on structure near gap.

On figure 5-8 presented possible to observation changes monitored position two elements of building constructions.

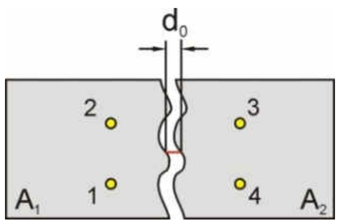


Fig.5. Parallel displacement

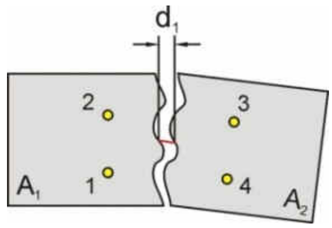


Fig. 6. Angular displacement

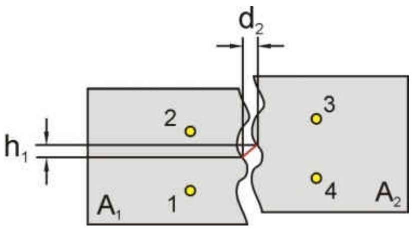


Fig. 7. Vertical moving

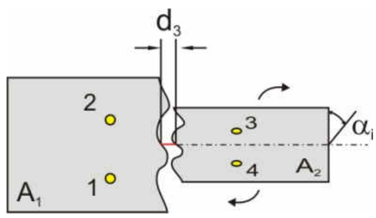


Fig. 8. Torsion

where on figures 5-8 changes position value of monitored building elements (A1, A2) marked: d_0, d_1, d_2, d_3, h_1, α_1; points 1-4 represented light pipe signalers.

In order to analyze taken pictures, we need to conduct a calibration procedure – rescaling coordinates from the CCD camera to metrical units [mm]. This procedure can be provided in a few ways, for example laboratory method, which is when we control moves of one light pipes signalers, assembled on a micrometrical table, with pitch settled d_m (ex. 0,1mm or 1,0mm) by using micrometrical table screws. After each move we register a picture. Then we count, by using accepted algorithm, an energetically middle of a point in xy coordinate system bitmap – in picture units – pixels [px]. From the set of coordinates following energetic middles, we mark a distance between them as a values d_i [px] and mark an average value:

$$d_{\acute{s}r} = \frac{\sum_{1}^{i} d_i}{n} \tag{3}$$

The calculation scale m from CCD matrix structure in a screen plane to actual structure, measured in millimeters amounts:

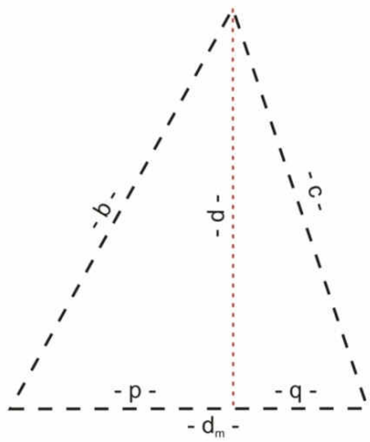
$$m = \frac{d_m}{d_{\acute{s}r}} \left[\frac{mm}{px} \right] \tag{4}$$

Another way of camera calibration is using it to setting a calculation scale of a special millimeter grid, we register a picture of a grid, which is settled in a measure receiver screen plane with CCD camera. Then in a picture coordinates structure xy we define number of picture's pixels which falls on an calibration grid.

In presented solution scale determining can be used also from the one single photo's observation in a following way: single light pipes signalizes are linked together by using a rod in couples (figure 3), and distance between them is settled and known. Modifying formula nr 4, in a place of movement d_m we put a known value of an actual distance difference between two signalers [mm], and $d_{śr}$ – it is the distance between a signalers (geometrical centers of light pipes points) received from picture computer's analysis.

Change of construction's elements location, as pictures 5-8 shows, can be specified by:

- ✓ change of light pipes' heads geometrical middles location recorded on digital pictures in relation to following measured periods. Obtained values of changes are in pixels, which have to be calculated to metrical values.
- ✓ in base of photo analysis, which have two two-points light pipe signalers. There are triangles built between light pipe's geometrical middles, and then by using triangle properties (picture nr 9), movings in pixels are counted (according to formulas 5,6,7,8) (Anigacz, 2007), which should be calculated to metrical values.



$$p = \frac{d_m}{2} + \frac{b^2 - c^2}{2d_m} \qquad (5)$$

$$q = \frac{d_m}{2} - \frac{b^2 - c^2}{2d_m} \qquad (6)$$

$$d = \sqrt{b^2 - p^2} \qquad (7)$$

Control equation:

$$d = \sqrt{c^2 - q^2} \qquad (8)$$

Fig. 9. Basic knowledge of triangle

- ✓ determining crack's movements from the analysis one two-point light pipe signalers shows, that situation of twisting construction's elements occurs.

3 SUMMARY

Presented system of monitoring gaps and cracks constructions elements which uses fiber optic and CCD camera, can facilitate service of control points located in civil engineer objects in hardly available or indistinctly places, after it is verification and introducing to practical use. An idea of presented combination is to streamline the process of checking constructions' safety, precisely a documentation of analyzing object, miniaturization and not disturbing architectural visual appearance.

Literature

1. Anigacz W. „A simulator of mutual displacements in hydrotechnical structures", Reports on Geodesy, No. 1(82), 2007, Warsaw University of Technology, page 13-16.
2. Bryś H., Przewłocki S., „Geodezyjne metody pomiarów przemieszczeń budowli", PWN, Warszawa, 1998.
3. Multi-author work under editing Kłoska K., Prószyński W., „Wykorzystanie metod geodezyjnych w ocenie stanu geometrycznego budowli.", Publishers Silesian University of Technology, Gliwice 2008.

Reviewer

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