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A CONCEPT OF MONITORING DILATATION GAPS OF ENGINEERING BUILDINGS WITH USE OF AN OPTIC WIRE CCD CAMERA

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1. INTRODUCTION

Monolith buildings as well as those built from prefabricated elements are cracking because of construction mistakes, incorrect geo-technical identification and uneven settling can undergo cracking which loosen the construction and with a final effect can contribute to a building disaster. Examples of this can be visible cracking of building objects (figure 1 and 2) and the cracked section of a concrete monolith building (figure 3).

Figure 1. A detached house built in the area of intensive mining exploitation. Source: www.google.pl

Figure 2. Muliti-family house – a cracked supporting wall, in the area of intensive mining exploitation. Source: www.google.pl

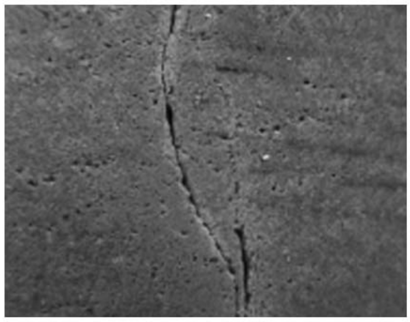

Figure 3. A cracked wall of a monolith concrete construction. Source: www.google.pl

So far, in practice for monitoring of cracks and slots in a building, mechanical and more and more often electronic crack-meters are used, where for measuring we use physical occurrences and where linear deflections depend among others from changeability of a capacity, inductivity, resistance and so on [Bryś H., Przewłocki S., 1998, Wolski B. 2007]. Development of optic electronic and especially that in optic wire and picture technology (CCD cameras) and their common availability in technical use, allowed the authors to elaborate a system of measurements for monitoring dilatation gaps of construction elements of engineering buildings with digital technology 2D by use of optic wire technology and a high resolution camera CCD.

The proposed technology of monitoring can replace the presently used classical methods, which are used with engineering objects (in dam galleries, industrial buildings, etc.) where slits meters and clinometers are used.

2. CONCEPTION CONDITIONS OF THE MEASURING SYSTEM

Pictures performed by a typical CCD camera are not metrical - we do not achieve direct results in metrical units which are generally accepted while monitoring such occurrences. Results are achieved in pixels – it results from convection of a picture recorded by a CCD transformer onto a computer disc in a form of a picture without compression in the form of a bitmap. An example of recording of a singular dot by a camera is presented in figure 4.

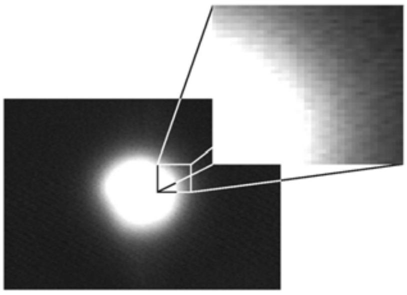

Figure 4. Geometry of a picture of recorded singular dot.

Aiming at making identification of a geometric middle of a singular dot possible it is accepted that the picture is recorded in 8-bit gray scale, where a pixel represents one of 255 grey levels (value 0 is colour black and value 255 is colour white).
The process of identification of the geometric middle of a dot is run by averaging coordinates of the lighter pixels – of a value of 225 (figure 5).

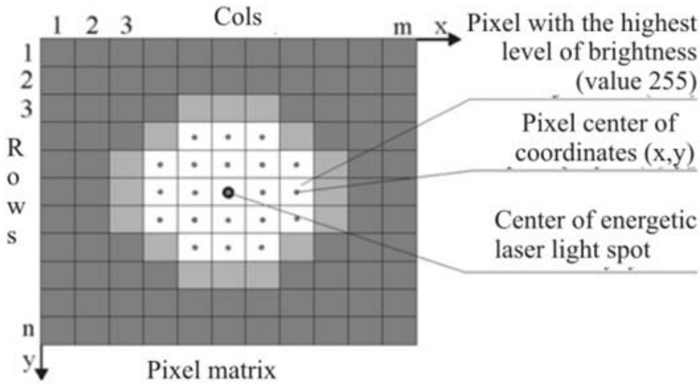

Figure 5. Assign of coordinates of energetic center laser light spot.
Source: "Wykorzystanie metod geodezyjnych w ocenie stanu geometrycznego budowli." Multi-author work under editing K. Kłoska, W. Prószyńskiego, Publishers Silesian University of Technology, Gliwice 2008.

The presented component of the system is connected to the object double points optic wire signalization which consists of a cantilever where the signalization is located. The base body is located on the cantilever where the beginning of an optic wire is placed. By means of an invar rod, the aiding body is elevated, with the end of an optic wire placed in the middle. Fronts of optic wires are located in one plane. The middles of bodies are an aiming point which constitutes the front of optic wire. An optic wire used in

signalization has a core made of a polimer fibre and the coat is pure air. Such a solution allows insertion of a beam of light into the core of an optic wire directly from the closest neighbourhood.
On research object we mount double points optic wire signalization (figure 6, 7) and not far distance in centre between signalizations CCD camera.

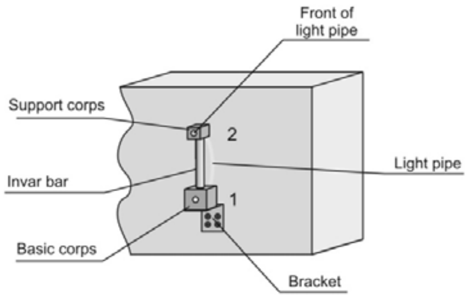

Figure 6. Scheme of two-pointed light pipe signale.

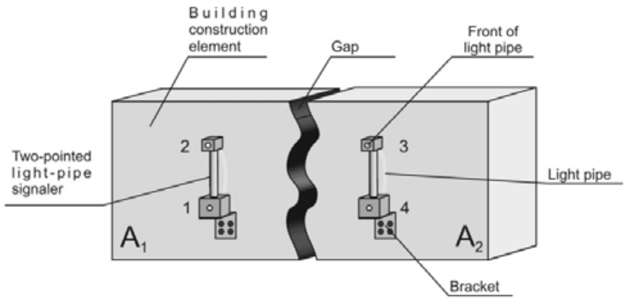

Figure 7. Example of two two-pointed light pipe signalers marked on structure near gap.

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.

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:

$$d_{śr} = \frac{\sum_{1}^{i} d_i}{n} \quad (3)$$

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

$$m = \frac{d_m}{d_{śr}} \left[\frac{mm}{px} \right] \quad (4)$$

But 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 6), 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.

3. EXPERIMENTAL RESEARCHES

In practice, the following cases of inter displacements of pairs of signalizations can occur (figure 8, 9, 10, 11, 12, 13). The version presented in picture 8 was accepted for initial experimental researches, where simulations were performed in laboratory conditions.

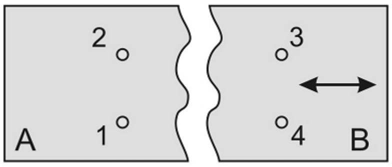

Figure 8 - a possible version of monitored horizontal deflections.

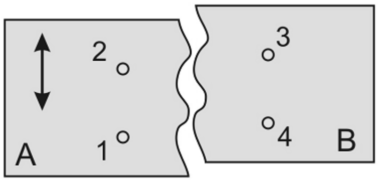

Figure 9 - a possible version of monitored horizontal deflections.

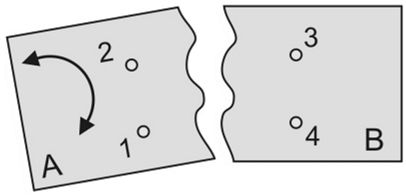

Figure 10 - a possible version of monitored vertical deflections.

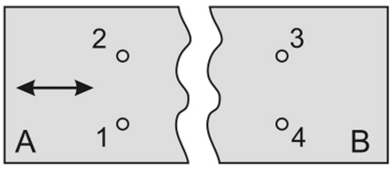

Figure 11 - a possible version of monitored vertical deflections.

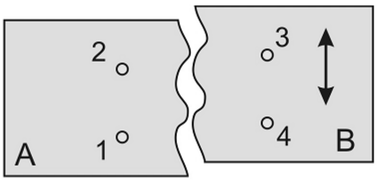

Figure 12 - a possible version of monitored deflections and rotations.

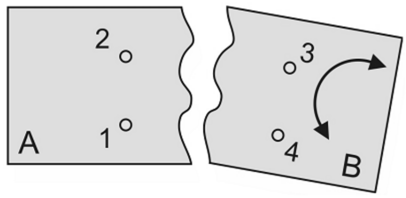

Figure 13 - a possible version of monitored deflections and rotations.

Figure 14. A camera from Canon EOS 40D.

A Canon camera presented in figure 14 was used for experiments and a component of two optic wire signalizations located at a micrometric table and adjoined tribrach. (figure 15 and 16).
A CCD camera characterizes with the following technical data: effective resolution 10,1 million pixels, type of CCD sensor: CMOS APS-C, type of colour filter RGB, maximal resolution of recorded picture 3888 x 2592, a proportion of pictures taken [w:h] 4:3, lens / focal length 35-420 mm, lens/lens aperture f/2,8 – 4,5 ISO 200.
The micrometric table however has a deflection range of 0,000 – 12,50 mm with a step of 0,01 mm.

As test distances, sections of a length of 1500mm and 4500 mm were accepted at the beginning of which a head level was located together with micrometric table and optic

wire signalization component and on the other end the above mentioned CCD camera with a tripod.

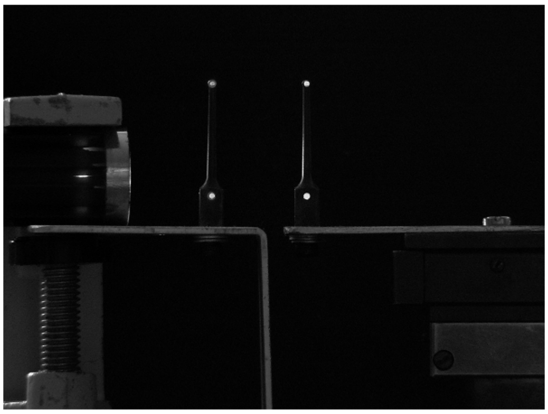

Figure 15. Registered picture from a CCD camera.

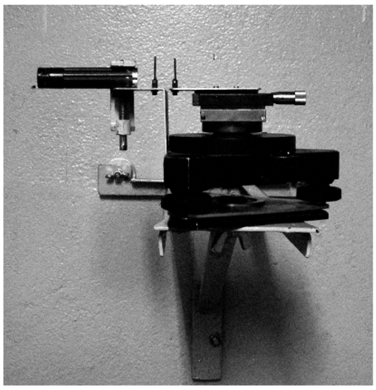

Figure 16. Placement of optic wire signalizations on a micrometric table during the experiment.

The experiment went as follows: after side lighting of a core of optic wire, signalizations and receiving visibly lit optic wire faces, one of the pairs of signalizations was held stable during the whole period of the experiment and the other pair was moved by 0,1 mm in a range of 1mm. Each movement was registered by a CCD camera and then sent to a mobile computer. The results of experiments were presented in tables 1 and 2.

Table 1. Points 1 and 4 of optic wire signalizations' locations registered by CCD camera at a test distance of 1500 mm and their appointed differences

Distance 1500mm						
step [mm]	Left down optic wire signalization "LD"		Right down optic wire signalization "RD"		Distance d_i [px]	Measure difference $\Delta d = d_i - d_0$ [px]
	X [px]	Y [px]	X [px]	Y [px]		
0,0	1340	1975	2169	1964	829,07	0,00
0,1	1315	1971	2149	1973	834,00	4,93
0,2	1295	1987	2134	1976	839,07	10,00
0,3	1280	1951	2124	1941	844,06	14,99
0,4	1271	2047	2118	2036	847,07	18,00
0,5	1280	2001	2132	1990	852,07	23,00
0,6	1340	1989	2197	1977	857,08	28,01
0,7	1258	2040	2120	2028	862,08	33,01
0,8	1274	1954	2139	1943	865,07	36,00
0,9	1263	2010	2132	1998	869,08	40,01
1,0	1274	2007	2148	1995	874,08	45,01
3,0	1450	1900	2412	1889	962,06	132,99

d_0 – step 1 (829,07px)

$$d_i = \sqrt{(X_{LD} - X_{RD})^2 + (Y_{LD} - Y_{LD})^2}$$

Table 2. Points 2 and 3 of optic wire signalizations' locations registered by CCD camera at a test distance of 1500 mm and their appointed differences

Distance 1500mm						
step [mm]	Left up optic wire signalization "LU"		Right up optic wire signalization "RU"		Distance d_i [px]	Measure difference $\Delta d = d_i - d_0$ [px]
	X [px]	Y [px]	X [px]	Y [px]		
0,0	1337	1013	2151	1003	814,06	0,00
0,1	1311	1017	2130	1007	819,06	5,00
0,2	1293	1025	2116	1014	823,07	9,01
0,3	1277	989	2104	979	827,06	13,00
0,4	1268	1084	2099	1074	831,06	17,00
0,5	1278	1038	2113	1027	835,07	21,01
0,6	1337	1026	2178	1014	841,09	27,02
0,7	1256	1077	2103	1066	847,07	33,01
0,8	1271	992	2121	980	850,08	36,02
0,9	1259	1047	2114	1036	855,07	41,01
1,0	1271	1045	2129	1033	858,08	44,02
3,0	1449	937	2394	923	945,10	131,04

d_0 – step 1 (814,06px)

$$d_i = \sqrt{(X_{LU} - X_{RU})^2 + (Y_{LU} - Y_{RU})^2}$$

Table 3. Points 1 and 4 of optic wire signalizations' locations registered by CCD camera at a test distance of 4500 mm and their appointed differences

Distance 4500mm						
step [mm]	Left down optic wire signalizator "LD"		Right down optic wire signalizator "RD"		Distance d_i [px]	Measure difference $\Delta d = d_i - d_0$ [px]
	X [px]	Y [px]	X [px]	Y [px]		
0,0	1745	1546	1969	1547	224,00	0,00
0,1	1743	1561	1968	1564	225,02	1,02
0,2	1742	1562	1968	1565	226,02	2,02
0,3	1742	1565	1969	1567	227,01	3,01
0,4	1742	1566	1970	1568	228,01	4,01
0,5	1741	1571	1971	1573	230,01	6,01
0,6	1742	1568	1973	1570	231,01	7,01
0,7	1743	1566	1975	1568	232,01	8,01
0,8	1745	1568	1978	1571	233,02	9,02
0,9	1735	1540	1969	1542	234,01	10,01
1,0	1743	1569	1978	1571	235,01	11,01
3,0	1748	1557	2007	1558	259,00	35,00

d_0 – step 1 (224,00px)

$$d_i = \sqrt{(X_{LD} - X_{RD})^2 + (Y_{LD} - Y_{RD})^2}$$

Table 4. Points 2 and 3 of optic wire signalizations' locations registered by CCD camera at a test distance of 4500 mm and their appointed differences

Distance 4500mm						
step [mm]	Left up optic wire signalizator "LU"		Right up optic wire signalizator "RU"		Distance d_i [px]	Measure difference $\Delta d = d_i - d_0$ [px]
	X [px]	Y [px]	X [px]	Y [px]		
0,0	1743	1281	1962	1282	219,00	0,00
0,1	1741	1298	1961	1298	220,00	1,00
0,2	1741	1299	1962	1300	221,00	2,00
0,3	1741	1301	1963	1302	222,00	3,00
0,4	1740	1302	1964	1303	224,00	5,00
0,5	1740	1306	1965	1308	225,01	6,01
0,6	1740	1305	1967	1305	227,00	8,00
0,7	1741	1302	1969	1303	228,00	9,00
0,8	1743	1304	1972	1306	229,01	10,01
0,9	1733	1276	1963	1277	230,00	11,00
1,0	1741	1305	1972	1306	231,00	12,00
3,0	1747	1293	2001	1293	254,00	35,00

d_0 – step 1 (219,00px)

$$d_i = \sqrt{(X_{LU} - X_{RU})^2 + (Y_{LU} - Y_{RU})^2}$$

Basing on table 1 and 2, the simulated value of 1 mm responds to a displacements between points P1 and P4 of a value of 45 pixels and between P2 and P3 of a value of 44 pixels. It is possible to accept that the value of displacements of 1 pixel on CCD responds to the value of 0,03 mm of a linear displacements between a pair of signalizations at distance 1500mm.
However, basing on table 3 and 4, the simulated value of 1mm responds to displacements between points P1 and P4 of a value 11 pixels and between points P2 and P3 of a value of 12 pixels. So it is possible to accept that the value of displacements 1pixel is equal to 0,1mm at distance 4500mm.
Received values of singular pixels during the experiment conclude from using about 1/2 parts of the CCD surface and taking pictures with optical focusing about x12.

4. CONCLUSIONS

The presented idea and results in the initial stage of terrain researches of the system of changes in opening of cracks and gaps of elements of building constructions with use of optic wire and CCD camera.
For the series of simulation observations of cracks, a high precision of defining the increase of linear displacements between pairs of signalizations with an average error of 0.05 mm were achieved.
Further experimental researches will aim at definition of the range of using the method for real objects from various distances together with evaluation of precision of measurements.

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