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ESTIMATING DEFORMATIONS OF GIURGIU-RUSSE BRIDGE SUPERSTRUCTURE USING ANALYTICAL PHOTOGRAMMETRY

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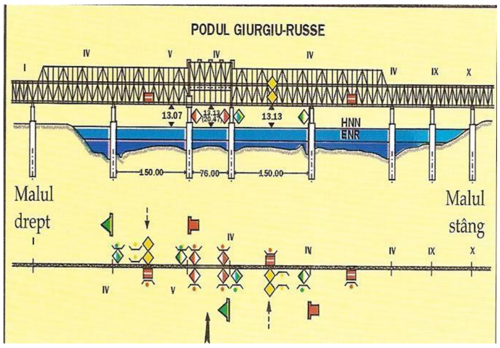
Abstract

The main objective of the project is estimating deformations of Giurgiu-Russe bridge superstructure using analytical photogrammetry. The results of the observations help us to establish what is the deformations state of the bridge, and what kind of subsides can appear over the years. There are two methods for measurement of the subsides through photogrammetry: main time base and main real space base. Measurements were realized using a terrestrial photogrammetric camera UMK 10/1318 and digital processing was achieved using the relationships of the parallax differences in every superstructure pursuit mark.

Key words*: bridge, Danube, deformations, photogrammetry.*

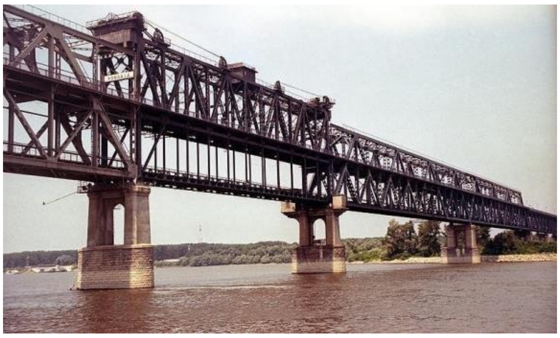
INTRODUCTION

The Friendship Bridge Giurgiu Russe is a steel bridge which connects Romanian south shore and Bulgarian north shore. The bridge was built with the aid of the Soviet Union (URSS). Also, the Soviets named “Friendship Bridge”, but after communist regimes fell (in the both countries), the bridge got the functional name “Danube Bridge”.



Picture 1. Giurgiu Russe bridge

The bridge is locate 1 km downstream of Giurgiu and 4 km downstream of Ruse and it cross The Danube at 489 kilometer from its shedding mouths. The construction began in 1952 and it was opened two years and a half later,in June 1954, designed by V. Andreev and N. Rudomazin. The bridge is 2.8 km long, and was the first bridge over the Danube (between Romania and Bulgaria),it has two decks: a railway and a two lane motorway. The central part is mobile and can be lifted for some types of boats.



Picture 2. Giurgiu Russe bridge

Photogrammetry can register objects and phenomena in a given time period and find a very good grounding in resolving the various problems in the field of scientific and engineering research. Exact reproduction of the objects photographed, new possibilities for automatic printing and using electronic computers offers certain advantages of photogrammetry for solving many technical cases from all sectors of the economy.
Currently, in the world there is a wide range of highly technical methods for measurement of three-dimensional deformations, starting with

classical and terrestrial photogrametry reaching interferometria chips.
In a three-dimensional image photogrammetry metric of an object can be obtained from two two-dimensional photos following the mathematical relationships of Photogrammetry.
There are two principle methods of measurement of deformations using photogrammetry, namely:
the principle of the time (presented by Ed Dauphin and k. Torlegard)
the principle and actual space base (presented by John Adler).

MATERIALS AND METHODS

In this paper we present the photogrammetric principle and the results obtained from the monitoring of traffic under deformations obtained from monitoring under the traffic bridge over Danube superstructure deformations from Giurgiu-Russe using real space base principle.
Photogrametry observations have been performed with Chamber 10/1318 UMK on ORWO WP18, WP20 boards. For coverage of every openings of stereoscopic bridge have been marked on the ground 10 shooting stations (mid-firm upstream and 5 downstream of the bridge) and have picked up 16 adapters (pair) streoscopice independent (8 for uploading static and 8 dynamic for uploading). In total for the studied area were made 40 normal shooting stations and were 64 ORWO boards.
On bridge’s metal deck on the railway and road between 12 and 16 cells at the intersection of the diagonals and pillars outsole with upper and lower of the beam were marked and the rivets encoded and scarce fuel were marked dotogrammetrics landmark. Shooting was executed simultaneously in the base heads for tracing deformations of the bridge under traffic and periodically to track the phenomenon of consolidation.Each stage of deformation is recorded progressively researched deck per couple stereoscopic independently.
The system used allows the operation of ON LINE and OFF LINE, program modules written in language Basic and Pascal (Turbo version) working under the MS-DOS operating system.

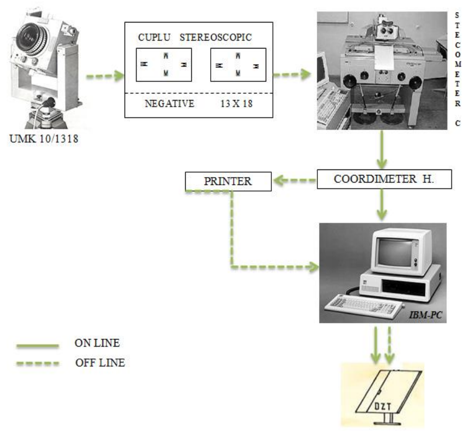


Figure 1. Operating system

RESULTS AND DISCUSSIONS

Determine the behavior of the bridge during numeric was done by measuring the numerical Stecometru C image coordinates (xD', xS’, pxS, z'S’, pzS) for static and load condition (xD', pxD, z'd, pzD) for loading dynamic status.
Variation deformations in Dxi, Dyi, Dzi may be expressed simply by measuring the horizontal and vertical paralaxelor on stereomodel successive requests. Because these can differ from Parallax couple to another just because of the change of the form of the deck’s bridge subjected to loads, they are called parallaxes and deformation.
The value of three-dimensional deformations were obtained with the following relationships (1):

$$DXi = b * \left(\frac{X'_D}{PX_D} - \frac{X'_S}{PX_S}\right)$$

$$DYi = b * f * \left(\frac{PX_S - PX_D}{PX_S * PX_D}\right)$$

$$DZi = b * \left(\frac{z'_D}{PX_D} - \frac{z'_S}{PX_S}\right);$$

Where:
Z’D=Z’D’+PZD;
Z’S=Z’S’+PZS;
Relationships (1) shall be valid only for the normal case of shooting because they are deducted from the relationships (2):

$$Xi = b * \left(\frac{X'}{PX}\right);$$

$Y_i = b * \left(\frac{f}{px}\right)$;

$Z_i = b * \left(\frac{z'}{px}\right)$

Similar can be found for cases diverted obtaining other formulas for Dxi, Dyi, Dzi but error's ellipsoids studied points are higher than in normal shooting cases.

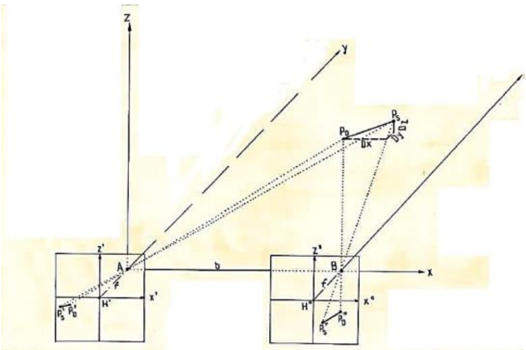


Figure 2. Coordinate systems

Accuracy of determining deformations of the deck's bridge through this method depends on the measurement errors of image coordinates from stecometru or from other stereocomparator precision guidance inner errors (main point position to the point of fotograma and middle focal length) obtained from the calibration of digital photogrammetric camera and precision measurement of the shooting.

Through the differentiation of (1) the precision of the method presented:

$$m_{DY} = \pm\sqrt{2} * \frac{Y^2}{b * f} * m_{PX}$$

Because the accuracy of the analysis and the Dyi Dxi average twice as great result:

$$m_{DX} = m_{DZ} = m_{DY}/2$$

The total average error occurred in a car chase between two successive phases:

$$M_D = \pm\sqrt{m_{DX}^2 + m_{DY}^2 + m_{DZ}^2}$$

Estimation of deformations the superstructure of bridges using analytical photogrammetry

In view of ensuring a very high accuracy in the determination that can occur at both the infrastructure and the superstructure of the bridge, was imposed as a necessity to use analytical photogrammetry and State of the art electronic computing.

Photogrammetric field observations were made with Zeiss Photheo 1318V19 and 10V1318 UMK camera, photographing the ORWO T01 and plates WP18.

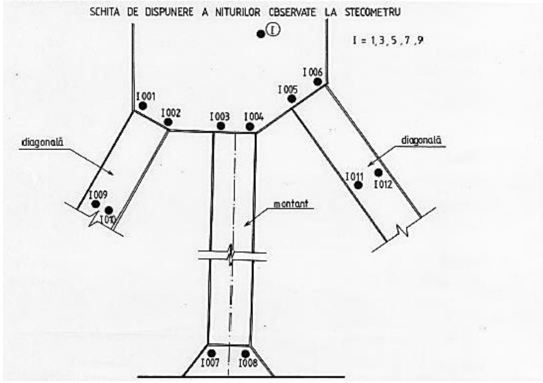


Figure 3

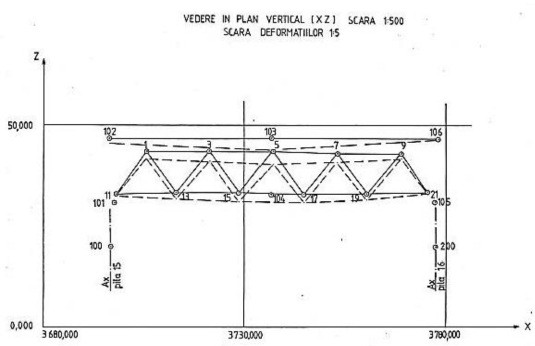


Figure 4

If we want to the superstructure's surveying of the bridge, the base and shooting distance must be choose while abiding by the rule of Gruber:

$$m_b = c\sqrt{m_k}$$

where:

„mb" represents the scale denominator photogrametric

„mk" represents the scale denominator that we want to get the plane

„c" is a constant and can take the following values:

C=150 for 1:mk ≥1:500

C=185 for 1:mk ≤1:100

In the relation 1/mb=f/Y follows the shooting distance Y=f·mb

The suport geodesic microtriangulation established of concrete depth pilasters outside the zone of influence; there were 10 shooting stations, 5 bridge upstream and 5 downstream from the bridge, which were determined in the local projection coordinates of the bridge, using precision apparatus, "WILD T3", electrooptic

tachometric "EOT 2000" and the level of compensation, the "Ni 007 ".
On the deck of the bridge between the metallic fuel cell no. 15 and 16 were at the intersection of the diagonals of the pillars with top flange of the beam and the bottom flange were marked with white paint rivets (bolts) that were subject to the comments fotogarmmetrics. Also have scored fotogrammetric's landmark on bridge infrastructure, respectively at the base and crest cells No. 15 and 16.
They considered two different ways for the implementation of the phenomen, the first is a less precise method that takes into account all the determinations of locating errors and the second procedure is strictly photogrammetric, the observations obtained with a high degree of confidence.
Determination of the reaction of the bridge in operation through the first process was done by measuring the numerical, Stecometer, C' and display on, Coorimeter, H' image coordinates in x', px’, z’, pz'. for rest and dynamic loading condition and the calculation of spatial coordinates spațialeXiF, YiF, ZiF socket of all characteristic points and landmark on the superstructure and infrastructure of Giurgiu-Russe bridge.
For photogrammetric coordinates were used the following relationships:

XiF=b$\frac{x_i'}{px_i}$;

YiF=b$\frac{f}{px_i}$;

ZiF=b$\frac{z_i'}{px_i}$;

where: Z’i=zi’+pzi
The transition from model coordinate system to the geodetic coordinates has been done with the help of roto-translation, using the relations:

XiG=A0+A1XiF+A2YiF+A3ZiF
YiG=B0+B1XiF+B2YiF+B3ZiF
ZiG=C0+C1XiF+C2YiF+C3ZiF

For more accurate assessment of the deformations which appear on the three axes of the coordinate-addressed a method which takes into account only the error of determining the focal distance ' f ' obtained from calibration Chamber, the error of determining the base "b" shooting and scoring errors at Stecometer.
The variation Δ Xi, ΔYi, ΔZi may be expressed by measuring parallaxes’s on rest stereomodel and successive requests stereomodelul. Deformations value has been obtained with the following relations:

ΔX=b$\left(\frac{x_s'}{px_s} - \frac{x_R'}{px_R}\right)$;

ΔY=b$f\left(\frac{px_R - px_S}{px_R \cdot px_s}\right)$;

ΔZ=b$\left(\frac{z_s'}{px_s} - \frac{z_R'}{px_R}\right)$

Where:
Zs’=z_s'’+pZs ;
ZR’=z_R'’+pZR ;
R=S;
S=D
Accuracy of determining the spatial coordinates depends on the measurement errors of x ', z'', and paralaxelor px, pz, inner guidance elements (main point position to the point of photogram and middle focal length) obtained from the calibration of digital photogrammetric camera and measuring of the shooting.
Because we want the influence of mesurement errors be minimal, the foundations have been measured on the ground with the accuracy of 1/100 000.
Since the measurements were made at stecometru C with a mean quadratic error of 0, 002 mm, accuracy of spatial coordinates for obtaining photogrammetric obtained by differentiation of relations 1 is as follows:

my=$\frac{Y^2}{bf} mp = \pm 4{,}4mm$;

mx=$\frac{Y}{f}$mx’=$\pm 0{,}7mm$;

mz=$\frac{Y}{f}$mz’=$\pm 1{,}0mm$

where:
mx’=0,002 mm
mz’=0,002$\sqrt{2}$ mm
mpx=0,002 mm
Total error obtained for calculating coordinates is:

Mm=$\pm\sqrt{m_x^2 + m_y^2 + m_z^2} = \pm 4{,}6\ mm$

Finally the geodetic coordinates will be affected also by locating error, which in the case of the present work is ±0,050 m. Not satisfied of the accuracy of methods we resorted to the second detailed photogrammetric method.

Through the differentiation of relations (3) we obtained formulas for calculating the reliability for the second method:

$$m\Delta y = \pm\sqrt{2\frac{y^2}{bf}mp} = \pm\sqrt{2}\frac{(70.000)^2}{11294*195,07}0,002mm = \pm 0,13mm$$

Since x and z movements accuracy is on average twice as high (Ben Adler) yields:

$m\Delta x = m\Delta z = 2m\Delta y = \pm 0,26mm$

The overall average error detrminare of deformațiilor is:

$$Md = \pm\sqrt{m_{\Delta x}^2 + m_{\Delta y}^2 + m_{\Delta z}^2} = \pm 0,4mm$$

Table 1

Bridge superstructure fully loaded dynamic

F=195.07mm | B=11.294m | CoupleB03-B02

Point number	Image coordinate				Model coordinate			Observations
	x'	z''	Px	Pz	X_F	Y_F	Z_F	
100	100.000	200.000	500.000	500.000	2.2588	4.4062	15.8116	„A" landmark at No.15 cell
101	103.001	229.610	499.557	500.028	2.3286	4.4101	16.4957	„G1" landmark at No.15 cell
102	98.728	275.632	499.610	499.981	2.2318	4.4097	17.5332	„G3" landmark
103	214.048	275.708	499.705	500.898	4.8378	4.4085	17.5523	„G2" landmark
104	212.241	234.957	499.256	500.914	4.8012	4.4128	16.6466	„G1" ;andmark
1	124.368	265.034	498.953	500.210	2.8151	4.4155	17.3216	
3	168.808	265.088	498.978	500.349	3.8208	4.4153	17.3296	
5	213.343	265.144	499.030	500.904	4.8284	4.4148	17.3371	
11	103.249	235.371	499.172	500.045	2.3361	4.4135	16.6391	
13	145.558	236.442	499.184	500.375	3.2932	4.4134	16.6704	
15	190.032	236.487	499.206	500.724	4.2993	4.4312	16.6786	

Table 2

Bridge superstructure fully loaded dynamic

F=195.07mm | B=11.294m | Couple A02-B02

Point number	Image coordinate				Model coordinate			Observations
	x'	z''	Px	Pz	X_F	Y_F	Z_F	
103	199.522	240.170	500.701	500.537	4.5846	4.4823	17.0198	„G3" landmark
104	200.000	200.000	500.000	500.000	4.6020	4.4885	16.1070	„G4" landmark
105	314.930	196.154	501.098	499.238	7.2306	4.4787	15.9659	„G5" landmark
106	319.020	243.211	501.748	498.767	7.3149	4.4729	17.0134	„G6"landmark
200	317.034	164.985	501.868	499.505	7.2678	4.4718	15.2330	„B" landmark at No.16 cell
1163	311.725	194.805	501.615	499.276	7.1511	4.4741	15.9194	Landmark on No.16 cell
5	201.296	229.771	500.037	500.374	4.6315	4.4882	16.7994	
7	246.285	230.294	500.821	499.224	5.6377	4.4812	16.7725	
9	291.274	230.496	500.826	499.231	6.6912	4.4812	16.7633	
15	177.832	201.358	499.299	500.187	4.0976	4.4948	16.1652	
17	222.536	200.869	500.518	499.858	5.1152	4.4939	16.1070	
19	267.234	201.980	500.944	499.525	6.1375	4.4801	16.1112	
21	309.616	202.551	500.626	499.228	7.1153	4.4829	16.1277	

Table 3

F=195.07mm | B=11.294m

Couple B08-B02 and A01-B01

Point number	Image coordinates (under load)				Image coordinates (rest)				Deformations		
	X's	P_{XS}	Z''s	P_{ZS}	X'R	P_{XR}	Z''R	P_{ZR}	ΔX (mm)	ΔY (mm)	ΔZ (mm)
100	100.000	500.000	200.000	500.000	100.000	500.000	200.000	500.000	0.0	0.0	0.0
101	103.175	499.723	229.605	500.011	103.001	499.557	229.610	500.028	0.0	-1.4	-5.9
102	99.232	500.075	275.633	500.008	98.728	499.610	275.632	499.991	0.0	-4.1	-15.6
103	214.555	500.168	275.658	500.134	214.048	499.705	275.708	500.898	0.0	-4.1	-34.6
104	212.454	499.464	234.922	500.147	212.241	499.256	234.957	500.914	0.0	-1.8	-25.0
1	124.807	499.372	264.998	500.050	124.369	498.953	265.034	500.210	0.0	-3.7	-18.9
3	169.250	499.399	265.040	500.104	168.808	498.973	265.088	500.349	0.0	-3.7	-25.7
5	213.780	499.449	265.100	500.145	213.343	499.030	265.144	500.304	0.0	-3.7	-32.7
11	103.478	499.381	235.371	500.011	103.249	499.172	235.371	500.045	0.0	-1.8	-7.7
13	145.797	499.418	236.417	500.071	145.558	499.184	236.442	500.375	0.0	-2.1	-15.2
15	190.261	499.443	236.442	500.127	190.032	499.206	236.487	500.724	0.0	-2.1	-22.4

Table 4

F=195.07mm | B=11.294m

Point number	Image coordinates (under load)				Image coordinates (rest)				Deformations		
	X'S	P_{XS}	Z''S	P_{ZS}	X'R	P_{XR}	Z''R	P_{ZR}	ΔX (mm)	ΔY (mm)	ΔZ (mm)
200	300.000	500.000	200.000	500.000	300.000	500.000	200.000	500.000	0.0	0.0	0.0
103	182.490	498.936	275.028	501.206	182.427	499.403	276.090	500.014	0.0	-4.2	-19.7
104	182.969	498.172	234.861	500.661	182.929	498.633	235.351	500.014	0.0	-4.2	-19.3
105	297.893	499.279	231.172	499.727	297.845	499.231	230.903	500.000	0.0	-0.4	-1.7
106	301.985	500.000	278.234	499.252	301.918	499.990	277.472	500.014	0.0	-0.1	-0.4
	(rest)				(under load)						
5	184.189	498.658	265.520	500.035	184.259	498.242	265.080	501.047	0.0	-3.7	-27.9
7	229.178	498.663	265.543	500.020	229.260	499.044	266.686	500.395	0.0	-3.4	-21.6
9	274.166	498.666	265.197	500.020	274.239	499.038	265.475	499.765	0.0	-3.3	-12.6
15	160.786	498.654	236.905	500.001	160.796	497.455	233.193	500.882	0.0	-10.8	-24.8
17	205.460	498.654	236.137	500.001	205.484	498.689	234.777	500.468	0.0	-0.3	-21.3
19	250.135	498.643	236.950	500.020	250.206	499.109	236.931	500.098	0.0	-4.2	-14.7
21	292.532	498.682	237.286	500.020	292.573	498.783	237.576	499.737	0.0	-0.9	-3.3

Table 5

Point number	Image coordinates (under load)				Image coordinates (rest)				Deformations		
	X'S	P_{XS}	Z''S	P_{ZS}	X'R	P_{XR}	Z''R	P_{ZR}	ΔX (mm)	ΔY (mm)	ΔZ (mm)
100	100.000	500.000	200.000	500.003	100.000	500.000	200.000	500.000	0.0	0.0	0.0
1001	119.211	499.418	261.744	500.003	119.172	499.574	261.803	499.574	0.0	-1.3	-13.7
1002	120.308	499.418	260.995	500.003	120.280	499.574	261.060	499.574	0.0	-1.3	-13.6
1003	122.797	499.402	260.959	500.017	122.280	499.574	261.030	499.572	0.0	-1.5	-14.3
1004	123.182	499.402	260.954	500.017	122.785	499.574	261.030	499.572	0.0	-1.5	-14.2
1005	125.555	499.427	261.208	500.017	123.165	499.560	261.271	499.572	0.0	-1.2	-13.2
1006	126.645	499.422	261.969	500.017	125.515	499.570	262.053	499.563	0.0	-1.3	-13.5
1007	122.812	499.422	234.780	500.017	126.626	499.529	234.857	499.563	0.0	-0.9	-12.1
1008	123.210	499.434	234.773	500.011	122.803	499.529	234.857	499.561	0.0	-0.8	-11.4
1009	111.641	499.414	249.760	500.011	123.195	499.545	249.602	499.582	0.0	-1.1	-13.1
1010	112.006	499.414	249.512	500.011	111.619	499.545	249.564	499.592	0.0	-1.1	-12.9
1011	134.041	499.414	249.495	500.011	111.986	499.232	249.589	499.953	0.0	-1.3	-13.3
1012	134.397	499.414	249.728	500.011	134.032	499.565	249.035	499.553	0.0	-1.3	-13.0
3001	164.011	499.460	262.053	500.000	134.395	499.599	262.234	499.533	0.0	-1.2	-21.3
3002	165.129	499.460	261.265	500.000	163.970	499.599	261.454	499.086	0.0	-1.2	-21.1
3003	167.467	499.460	261.237	500.037	165.083	499.599	261.440	499.086	0.0	-1.2	-21.8
3004	167.858	499.460	261.213	500.037	167.438	499.611	261.422	499.077	0.0	-1.3	-21.8
3005	169.580	499.460	262.183	500.037	169.558	499.611	262.394	499.077	0.0	-1.3	-22.1
3006	170.696	499.468	262.940	500.031	170.661	499.611	263.151	499.077	0.0	-1.3	-24.7
3007	167.524	499.458	234.792	500.037	167.512	499.535	235.002	499.078	0.0	-0.9	-19.4
3008	169.905	499.458	234.787	500.037	167.903	499.549	235.002	499.078	0.0	-0.8	-19.8

CONCLUSIONS

Photogrammetry is one of the most accurate methods for determining that a construction slump may suffer. In the example shown, the amount of bridge compaction is micrometric so the bridge superstructure has not undergone major changes.

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