VERTICAL DEFORMATION DETERMINATION FOR BRIDGES BY LOADING WITH TEST CONVOYS

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***Abstract**: In the present paper monitoring methods of the viaduct performance assuring the access to the bridge over the "Danube-Black Sea" channel on the road DN 22C Cernavoda - Constanta, at km 1978 are presented. The monitorisation takes place in static and dynamic loading with auto vehicle conveyors, in order to establish the comportment of the structure (arrows, tensions, dynamic characteristics) under the action of the conveyors and in order to compare this comportment with that resulted from the design calculations; a certain accordance between them will prove, on the one side, that the made assumptions are accurate and, on the other side, that the structure realised in compliance with the project meets the quality terms.*

Keywords: load, displacement, subsidence, darts, arrows, precision levelling.

1. Generalities

Topo-geodetic methods are in many cases the only one methods allowing the absolute determination of the size and direction of the movement of a building or area of land with constructions as well as the determination of the movements and deformation made by other methods.

By analyzing structural elements characteristic points were established, subject to the observations and their movements in the controlled loads (by schemes of the bridge load presented in the paper) lead to establishment of the static superstructure behaviour.

Measurements of SC TOPOPREST SRL Piatra Neamt, set some specific deformations for bridges such as **subsidence, Negative arrows (Contrasăgețile) and arrows**.

- Subsidence - Are vertical movements down of the construction foundations and the land under them and are met at all new constructions.

- Negative arrows (Contrasăgețile) - represent the vertical movements of the foundation construction areas.

- Arrows - are specific elements of the building such as columns, beams or plates and are caused by vertical or horizontal applications.

The construction in consideration is a bridge, which was realized in the following solution: Lattice steel main beams with four openings (53.20 m 79.80 m 62.70 m 50.24 m), the lower foot trusses are placed two feet railways and the upper trusses are placed roadway National Road 22C.

For current connecting the national road 22C with the bridge it was necessary to build an access viaduct partly made in line, in part curve to the left (away Bucharest-Constanta) having 9 openings of about 18.00 m in length and curved viaduct right Constanta achieved with 7 spans 18.00 m length each.

The new superstructure was made of S355 steel main beams (OL52) profiles with a form of "double T" rolled 600mm height with feet constant in thickness, the cross section using 12 beams. The viaduct provides a roadway of 8.40 m and two sidewalks of 1.50 m each (including protective railing)

The characteristic points studied were those related to the support elements respectively with the openings of the cell (in order to determine the respective arrows - negative arrows).

2. Measurements approaching mthods

Static load assumptions started with the idea that in oder to establish the response of the superstructure in static regime (arrows and ~~voltages~~ tensions) the bridge should be loaded with standard truck convoys with four-axle, weighting 410 kN ± 5%

Measurements were performed on eight stages (charging scheme):

- Step 1 - load two trucks;
- Step 2 - load four trucks;
- Stage 3 - bridge discharged;
- Step 4 - load three trucks;
- Ste p 5 - load six trucks;
- Step 6 - bridge discharged;
- Phase 7 - charge six trucks in the shaft;
- Step 8 - bridge discharged;

In accordance with the design theme, specifically static load test of the bridge over the Danube-Black Sea Canal, to Cermavoda, Km 1 978, in order to determine the deformation characteristic points two methods for determining the deformation values have been established:

1. Method I - making geodetic levelling paths for each loading stage;
2. Method II - **strains observations in real time on fixed ruler placed in specific points**

2.1. METHOD I - making geodetic levelling paths for each load step

Establishing the compaction of the construction is generally made with the geometric precision levelling with mobile benchmarks embedded in the construction, moving in the same time with them, constrained by other fixed points outside the building that mak up the support network. Depending on the goal, the shape and size of the object examined, the geometric levelling network can be realized as closed polygons, or traverses approximately parallel to each other.

In order to determine the values of deformations (subsidence) in the characteristic points of the bridge using this method there were performed geodesic levelling paths two-way closed one starting point located outside the zone of deformation.

When making geodetic measurements was used Leica DNA03 level with invar groom, ensuring accuracy of 0.3 mm / km double levelling.

To ensure accuracy in the determination of strains, we proceeded with materialization with metal bolts of the tracked points, their positioning followed the tracking project.

In Stage 0 - Measurements were performed before loading the bridge (the bridge being open before loading is considered the basic stage).

A geodetic levelling round trip route has been made, departing from a levelling located in a stable area in terms of deformation, and the establishment accuracy of calculations on the entire route was of 0.19 mm and an accuracy of point determination of allowances of 0.04 mm.

Simultaneously seven fleximeters/tensionmeters for measuring the vertical elongations ((F1 ÷ F7) 1/10mm precision) in the x section = 0.375 x 0.375 x 17.80 = L1 = 6.68 m of the opening D1 have been placed, which measured the arrows of the main beams.

The results for the deformation measurements on the tracked points are shown in specific files, which are parts of the present paper (Figure 3, Figure 4 and Table 1).

The same methods were applied to all eight stages - related to the bridge data loading schemes, measurements are reported to those in "Stage 0".

2.2. METHOD II strains observations in real time on fixed ruler placed in specific points

To check and remove any errors that might occur during the measurements, another method has been used, which consists of :

• Placing the characteristic points of the vertical graduated scale (in this case the location of the vertical ruler was left half position L1);

• Total station locating at the point located outside the bridge (the undistorted area).

The total station location outside the perimeter under study in order to make direct reading scale rule has made possible to read in real-time the deformations (compressions) for all the above mentioned steps.

The observation of ~~reading~~ the deformations in real time was completed with the timing of events so that specialists can receive ~~provide~~ all data related to how the bridge deformation under load.

Fig. 1. Image with the reading process on the vertical axis

3. Measurement results

With combined methods for determining the deformation is possible to eliminate the errors arisen when establishing them.

Values thus obtained will be reported in the test included in the draft project for the bridge, respectively including the values for the deformations the projected limits.

For each analysed point a personalized card will be prepared, which contains the data obtained by measurements.

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CIF RO 8596112 Capital social 20.700 lei

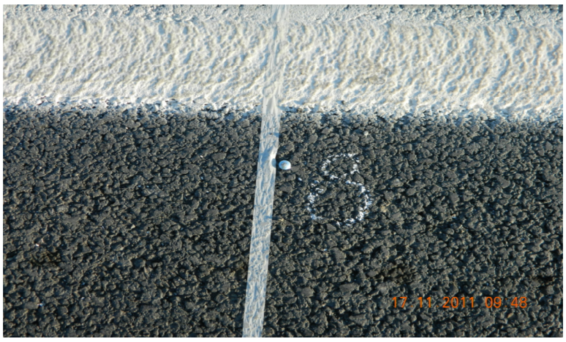
SR EN ISO 9001:2008
Certificat nr. 2472/2011
SR EN ISO 14001:2005
Certificat nr. 1263/2010
SR OHSAS 18001:2008
Certificat nr. 984/2010

Încărcare pod peste Canal Dunăre Marea Neagră, la Ceranavoda, 17-11-2011

Metoda I – Nivelment Geodezic
Deformații (tasare) în punctul 8 – ax pod – poziția ½ L1

Tracking point counting 8 is located on the axis of the first opening, heading ½ L1.

Fig. 2. The materialization of the tracking point no.8.



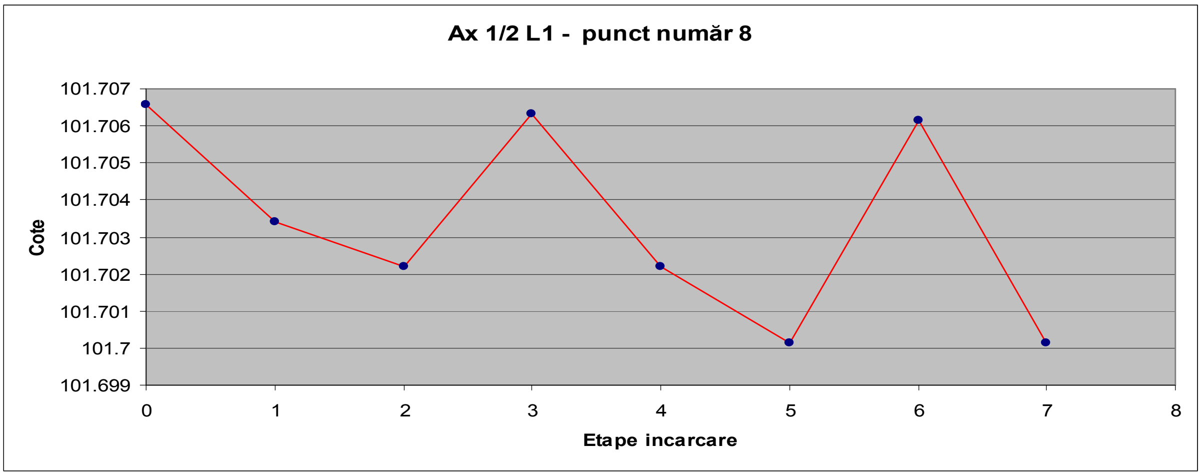


Fig.3. Diagram behavior at different stages of the bridge, point no. 8

Legend:
- Share point in time T0 = 101.7066 m (bridge open before loading).
- Loading phase (measuring steps):
- Stage 0 free bridge before loading measurements performed between the hours of 9:45 to 10:00,
- Step 1 - load two trucks, measurements made between the hours of 10:12 to 10:22;
- Step 2 - load four trucks, measurements made between the hours of 10:30 to 10:36,

- Stage 3 - bridge downloaded, measurements made between the hours of 10:46 to 11:02;
- Step 4 - load three trucks, measurements made between the hours of 11:02 to 11:15,
- Step 5 - Load with six trucks, measurements made between the hours of 11:18 to 11:37;
- Step 6 - Bridge downloaded, measurements made between the hours of 11:39 to 11:55;
- Stage 7 - six trucks in axle load, measurements made between the hours of 12:02 to 12:14.

All data will be centralized and made available to the expert, who will analyze and interpret the data obtained.

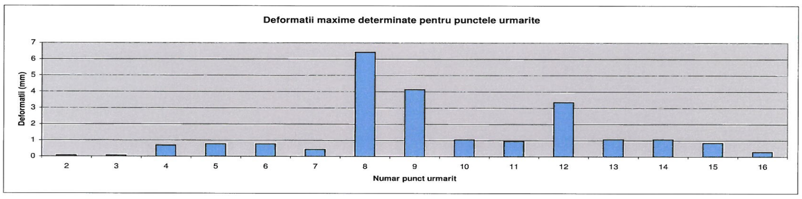
Fig. 4. Centralization of get results and maximum deformations diagram

Metoda I - Nivelment Geodezic

Neinchideri trasee nivelment (mm)	Etape		Numar punct de urmarire / Cota (m)															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.19	0	neincarcat	100	100.8188	100.7688	101.2593	101.3173	101.2377	101.6392	101.7066	101.6233	102.0160	102.0910	102.4505	102.7916	103.0739	102.0072	100.8542
0.05	1	2 camioane		-	100.7689	101.2600	101.3180	-	-	101.7034	-	102.0162	102.0916	102.4519	102.7922	103.0741	102.0077	100.8545
-0.31	2	4 camioane		-	-	-	-	101.2385	-	-	101.6201	-	-	102.4531	102.7927	-	102.0077	100.8545
-	3	neincarcat		-	-	-	101.3179	-	101.6390	101.7063	101.6231	102.0168	102.0917	102.4512	102.7923	103.0742	102.0079	100.8544
0.24	4	3 camioane		-	-	-	101.3179	-	-	101.7022	-	-	102.0918	102.4528	102.7921	103.0739	-	100.8544
0.12	5	6 camioane		-	-	-	-	101.2381	-	-	101.6199	-	-	102.4498	102.7920	103.0741	102.0072	100.8545
-	6	neincarcat		100.8188	100.7689	101.2594	101.3177	101.2383	101.6388	101.7062	101.6240	102.0171	102.0920	102.4512	102.7927	103.0747	102.0080	100.8544
-	7	6 camioane in ax		-	-	-	-	-	-	101.7002	-	-	102.0911	102.4501	102.7927	103.0749	-	100.8545

Date comparative

minim cota (m)	100.8188	100.7688	101.2593	101.3173	101.2377	101.6388	101.7002	101.6199	102.0160	102.0910	102.4498	102.7916	103.0739	102.0072	100.8542
maxim cota (m)	100.8188	100.7689	101.2600	101.3180	101.2385	101.6392	101.7066	101.6240	102.0171	102.0920	102.4531	102.7927	103.0749	102.0080	100.8545
diferenta (mm)	0.06	0.06	0.68	0.77	0.77	0.44	6.41	4.13	1.04	0.96	3.35	1.06	1.06	0.85	0.29



4. Conclusions

The data obtained by the two methods of tracking points, provide the experts mathematical concrete information in order to establish the conclusions regarding the operational stability of the bridge.

Readings performed by means of cross - bridge high precision geodetic levelling and under the bridge reading with fleximeters/tensionmeters ensure elimination of errors that can occur during measurement operations, or calculation, so that the values provided to the beneficiaries should be safe. On the other side the sets of measures and the specitic conclusions established by the experts in the field are thus based on determinations that were checked.

By using real-time deformation observations when performing measurements, designers or the construction team shall receive information on the deformations of the construction, data that can be immediately compared with those established in the project, enabling in this way the consideration also of other charging schemes, if the deformation limits given in the project are not respected.

In conclusion we can state that the simultaneous use of two methods:
- Ensures a secure database.
- Eliminate realising of a new set of measurements in the situation that after postprocessing (strain) data would appear outside of the design limits;

- Gives certainty to those that establish conclusions and determine appropriate measures.

Table 1 Static method reads fleximeteres

Fleximetre	***Fleximetre readings***				
	PD	***PÎ t = 0***	***PÎ t = 15'***	***PD t = 0***	***PD t = 10'***
F1	12,27	12,96	12,99	12,35	12,35
F2	14,10	14,86	14,88	14,18	14,18
F3	12,43	13,21	13,24	12,50	12,50
F4	9,62	10,34	10,35	9,67	9,67
F5	2,35	2,88	2,90	2,40	2,40
F6	16,25	16,59	16,61	16,29	16,29
F7	7,80	8,05	8,06	7,84	7,84
Fleximetre	***Arrows (mm)***				
	PD	***PÎ t = 0***	***PÎ t = 15'***	***PD t = 0***	***PD t = 10'***
F1		6,9	7,2	0,8	0,8
F2		7,6	7,8	0,8	0,8
F3		7,8	8,1	0,7	0,7
F4		7,2	7,3	0,5	0,5
F5		5,3	5,5	0,5	0,5
F6		3,4	3,6	0,4	0,4
F7		2,5	2,6	0,4	0,4

PD - bridge downloaded before test
Pi t = 0 - Bridge convoy loaded at time t = 0
Pi t = 15 '- bridge loaded with convoy at time t = 15'
PD t = 0 - Bridge convoy downloaded at time t = 0
PD t = 10 '- bridge convoy downloaded at time t = 10

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