THE USE OF LASER SCANNER FOR MONITORING STATIC TESTED CONSTRUCTION

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Abstract: *The paper presents the practical aspects of monitoring static tested construction highlight the possibility of using laser scanning technology. Viability confirmation for using laser scanning technology is done by making simultaneous geometric leveling measurements to determine the arrow made by construction elements subjected to static testing. Finally conclusions are drawn regarding the viability of using laser scanning technology.*

Keywords: *Monitoring, Geometric leveling, Laser Scanner*

1. Introduction

Monitoring static tested construction is made by determining the arrow of the structural elements of construction, such as beams, columns, plates subjected to vertical or horizontal bending that causes them.

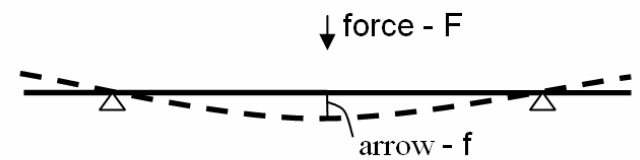


Fig.1. The arrow

2. Additions

Monitored construction, in the present case, is a road bridge which has continuous beam type suprastructure, made by console casting, consisting of three openings: one central of 155 m and two marginal of 77.5 m. The total length is 310 m and width at the top of the deck is 14.75 m.

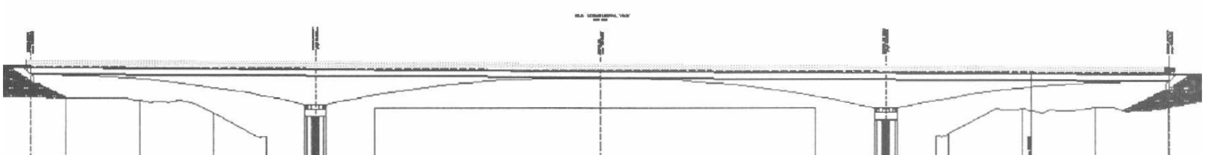


Fig.2. Construction studied

The construction testing can be done by static or dynamic trials. For the static testing are used various devices and methods for determining the arrows. From the topo-geodetic point of view, in order to determine vertical movements, most often used method is geometric leveling, and the measurements are made with high precision instruments. In the case of monitored construction have been made two sets of measurements in September 2011. A set of measurements was performed using middle geometric leveling method or equal lenghts using a electronic level such as Topcon DL 101-C, with accuracy of 0.4 mm / double km leveling and possible readings of the order 0.01 mm on the the invar staff bar code with a length of 3 m. These measurements will be used as a reference, with them comparing the second set of measurements made with terrestrial laser scanner Leica Scan Station 2, which has accuracy of determining the spatial position of points of 6 mm at 50 m and 2 mm precision of modeled surfaces.

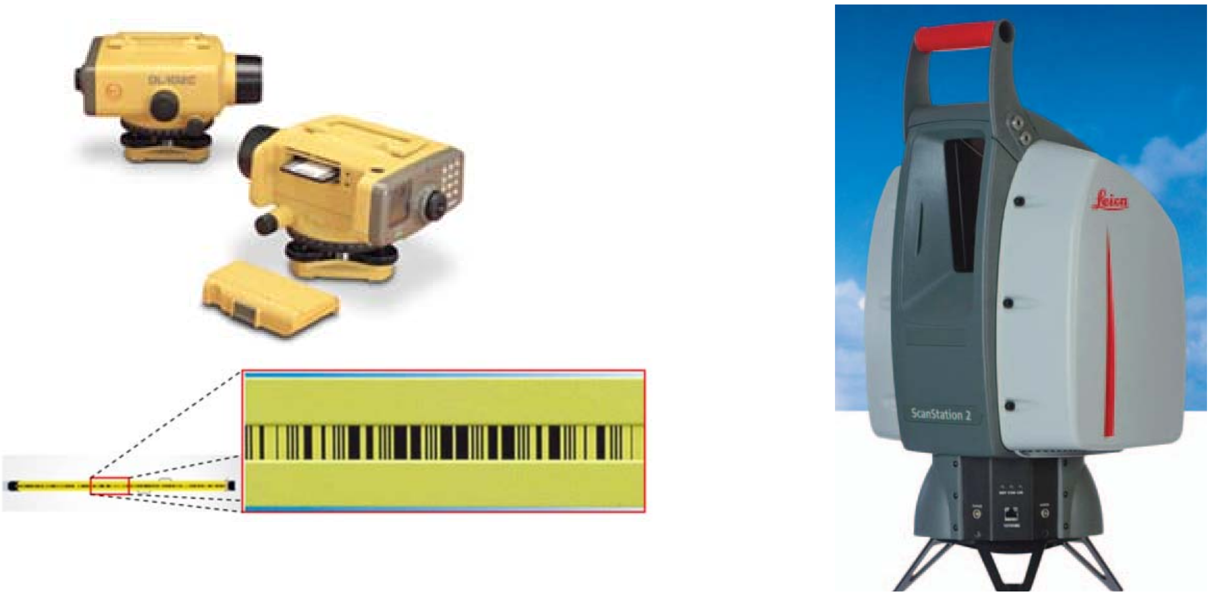
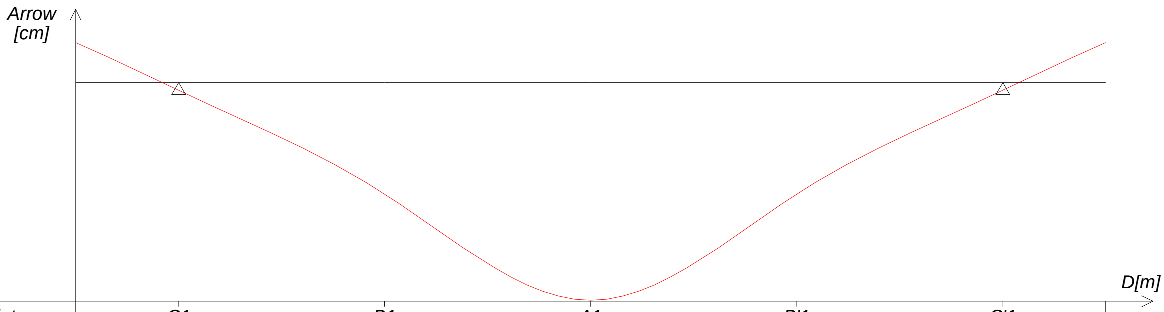


Fig.3. The equipment used for measurements

For the static testing of the bridge were used three load hypotheses with 12 trucks of 34 tons located in a convoy consisting of two parallel rows, one in the central opening and the other two on the marginal openings. In the three hypotheses measurements were performed using the middle leveling method.

In order to test the laser scanning technology in the case of loading the central opening of the bridge measurements were performed also with terrestrial laser scanner, and we scanned only the central opening.

In the case of loading the central opening of the bridge the theoretical values calculated for the arrow are presented in the following figure, the values are only for the central opening.



Points	C1	B1	A1	B'1	C'1
Theoretical arrow	-0,3	-4,2	-8,2	-4,2	-0,3

Fig.4. Theoretical value of the arrow

In order to have reference values, measurements were performed before loading the construction in the three hypotheses, this was considered stage t^0, the next step of measurements are performed during the loadig of the central opening hypothesis.

Fig.5. Taking measurements

At each stage, in the case of leveling measurements, readings were made on a number of 43 points, including four of them located at the two ends of the bridge were used as reference points and the remaining 39 located on the bridge structure (according to the project) have been object points that were used to calculate the arrows. The time during which measurements were made was between 60 and 75 minutes for each stage. Therefore following the measurements at each stage were calculated level differences between points and the distances corresponding to the leveling line.

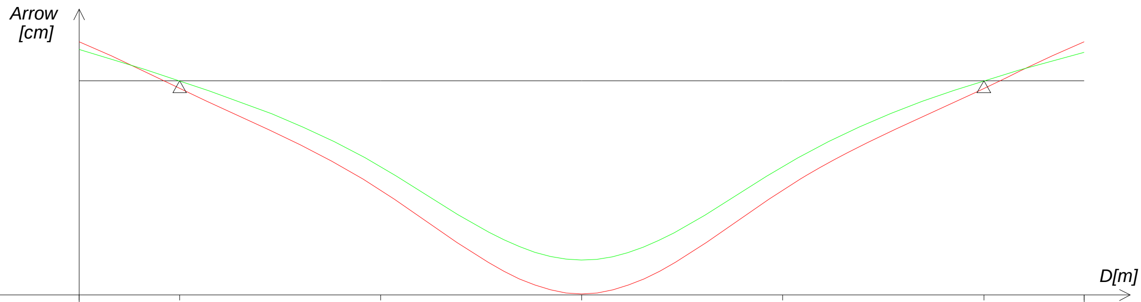
Level differences and distances between points obtained in each stage were processed using geodetic data processing program - SiPreG. This program uses the method of least squares to compensate measurements and obtain final results, as a reference we used a system of local altitudes. The standard deviation of the network composed of the 43 points is 0.1 mm in stage t^0 and 0.3 mm in stage t^1, the accuracy of determination for point heights fits in 1 mm minimum value required in the project and the performance of measuring devices must cover an area at least 50% higher than the expected maximum deformation.

Having available compensated heights of the points at each stage arrows were calculated and compared with theoretical data in the project. For comparison, we kept further the corresponding values for the central opening, for which measurements have been made also using terestrial laser scanner.

Table 1. Arrows calculated in stage "1" compared to stage "0"; Loading on the central opening; Leveling measurements

Point	Calculated arrow (cm)	Theoretical arrow (cm)	Differences (cm)
C'1	0,0	-0,3	0,3
B'1	-3,3	-4,2	0,9
A1	-6,9	-8,2	1,3
B1	-3,3	-4,2	0,9
C1	0,0	-0,3	0,3

Graphical representation of leveling measurement results can be found in Figure 6.



Points	C1	B1	A1	B'1	C'1
Calculated arrow	0,0	-3,3	-6,9	-3,3	0,0
Theoretical arrow	-0,3	-4,2	-8,2	-4,2	-0,3
Differences	0,3	0,9	1,3	0,9	0,3

Fig.6. The results of leveling measurements

In the case of measurements using terrestrial laser scanner it was chosen the method of stationing on the known coordinate points to make the determinations in two stages, the laser scanner allowing to be used in this way, and with two-axis compensator incorporated each measurement (determined point) have received corresponding correction. Therefore measurements from the two stages have the same reference, no longer need multiple points to make point cloud registration, bringing them to the same coordinate system.

In each stage was performed one scanning station to measure the central opening. Station from which measurements were made it was located about 100 m from the bridge, measurements at each stage lasting about 20 minutes. If we wanted to measure the whole construction the measurements could have taken around 80 minutes. If the laser scanner could be placed under the bridge (which is impossible because of the existence of water), time could be reduced to about 60 minutes.

For each scanning stage we obtained about 500,000 points in the central opening, the results can be seen in the figure below.

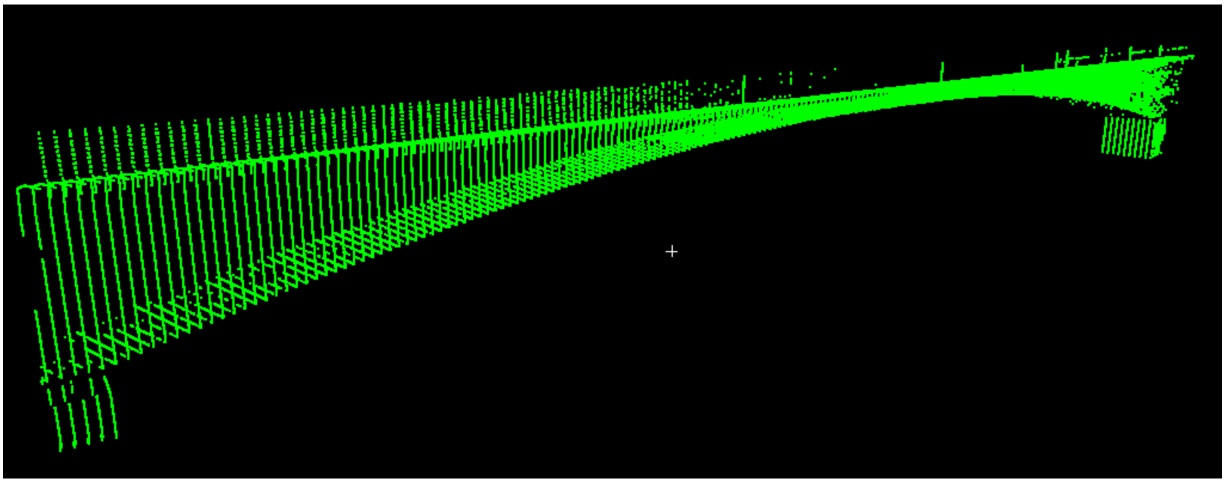


Fig.7. Point cloud resulting from scanning

The primary analysis of measured data is done by overlapping the point clouds from the two stages of measurement (Figure 8: with green point cloud resulting in stage t^0 and with red the point cloud resulting in stage t^1).

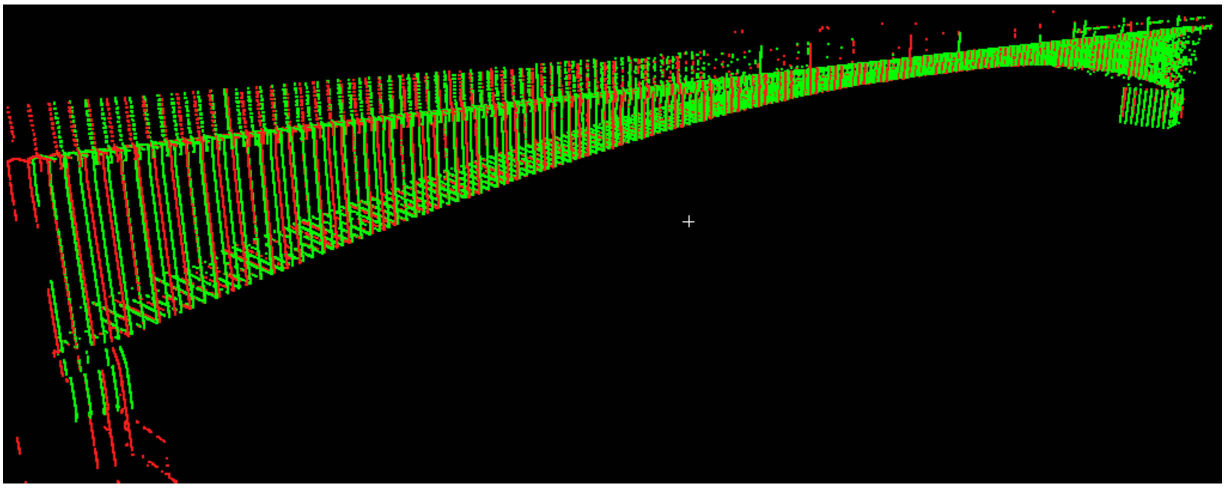


Fig.8. Overlapping point clouds

At a first visual analysis we can see the differences between the points determined in the two stages. In Figure 9 the horizontal displacement of scanned points is due to initial orientation of the scanner and because the scan grid chosen that was different in the two stages, to see if this influences the final result. Vertical displacement is due to the loading of bridge.

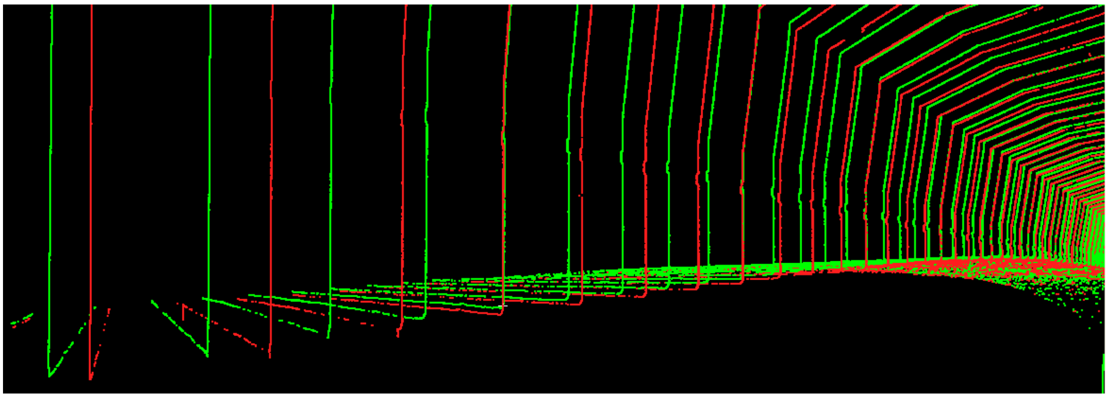


Fig.9. Overlapping point clouds - detail

The easiest way to determine the arrow is to create sections with the same origin, through the two point clouds using the Cyclone software. Creating individual sections can be achieved by selecting two points in the desired section or automatically by creating a alignment and imposing a sectioning interval, this method was further used.

The first operation to obtain sections is to create the alignment from which the sections are made. For alignment we chosen the transverse axis passing through the middle of the bridge and the sections were perpendicular to it. The menu "Tools" / "Alignment & Sections" provides the routine "Create sections" in which the section parameters are introduced: the point of beginning and end of sections, the space between sections, the dimensions of left, right, up, down and thick sections(Figure 10).

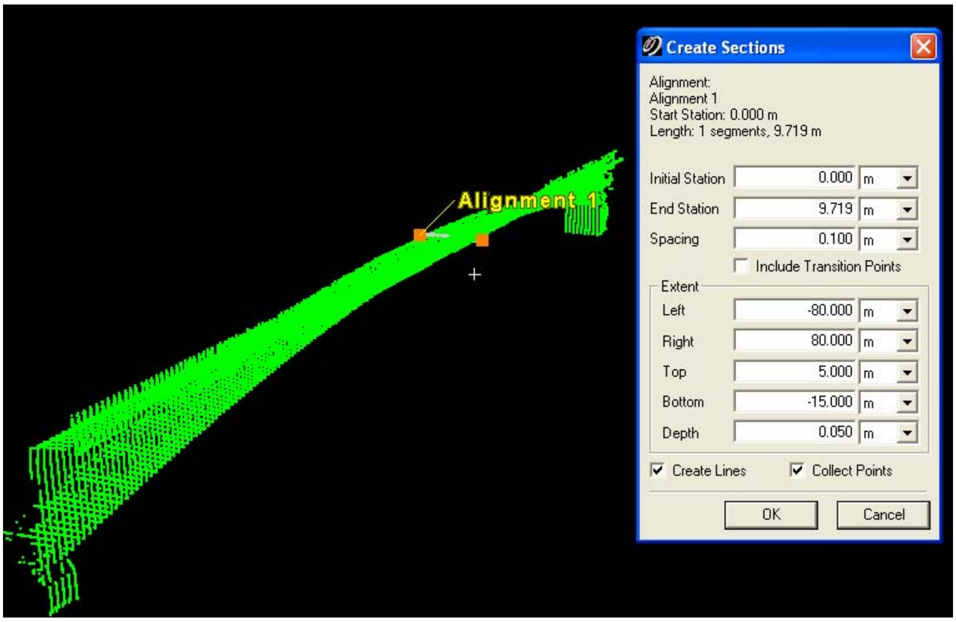


Fig.10. Creating sections

In the routine "Sections manager", created sections can be viewed, adjusted on the directions left, right, top, bottom and thickness, as needed (Figure 11).

Sections can be obtained in the point cloud system (georeferenced system) or a local coordinate system of each section.

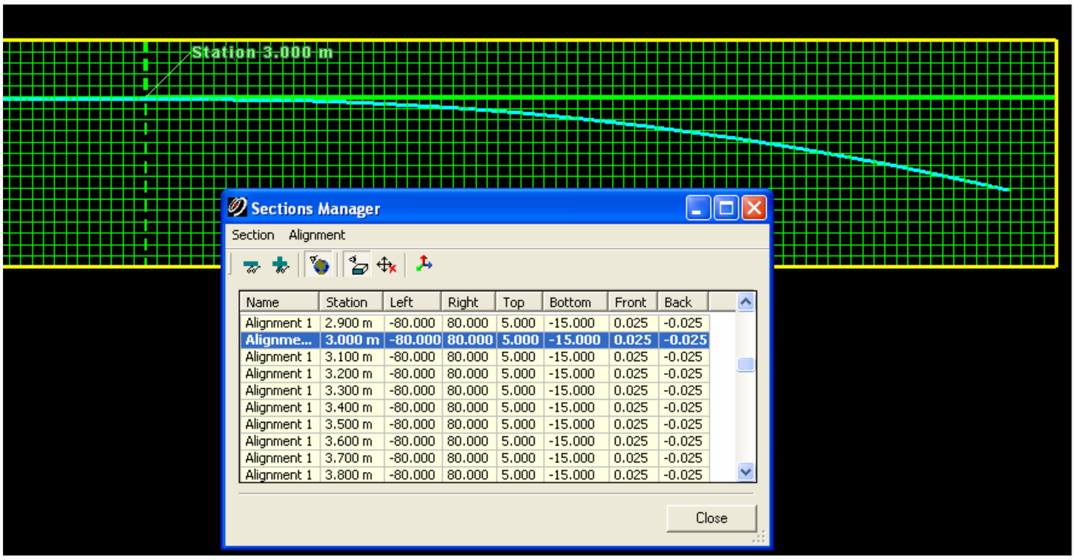


Fig.11. Visualization of sections

With sections generated for the two stages, common areas will be selected to determine the arrow. Determination can be made in Cyclone software, measuring the value of the arrow in the same points where it was determined from the measurements of geometric leveling, or at other intervals along the length of the entire section. The results can be obtained using other CAD programs, because the generated sections can be exported in other various formats.

Figure 12 shows measured values of the arrow, and in Table 2 the comparison with theoretical values.

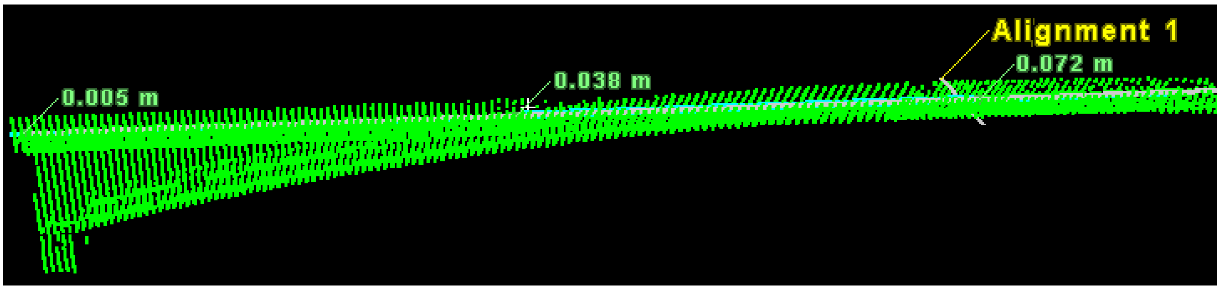


Fig.12. Measuring the arrow

Table 2. Arrows calculated in stage "1" compared to stage "0"; Loading on the central opening; Terestrial laser scanner measurements

Point	**Calculated arrow (cm)**	**Theoretical arrow (cm)**	**Differences (cm)**
C'1	0,5	-0,3	0,8
B'1	-3,8	-4,2	0,4
A1	-7,2	-8,2	1,0
B1	-3,8	-4,2	0,4
C1	0,5	-0,3	0,8

In Table 3 are calculated the differences between the results obtained from the two measurements. As shown in table the differences between measurements fall within the tolerance of the laser scanner measurement, which confirms the viability of using this technology.

Table 3. Differences between the results obtained from the two measurements

Point	Calculated arrow M1 (cm)	Calculated arrow M2 (cm)	Differences (cm)
C'1	0,0	0,5	-0,5
B'1	-3,3	-3,8	0,5
A1	-6,9	-7,2	0,3
B1	-3,3	-3,8	0,5
C1	0,0	0,5	-0,5

3. Conclusions

With the development of laser scanning technology for surveying side, this can be used as easy to get the results that some time ago were impossible.

Monitoring of land and buildings can be made taking advantage of the short time to measure thousands to millions of points on the object monitored and the possibility of measuring these points without the need for them to be marked.

In the case of monitoring static tested buildings, for measuring vertical displacements and deformations, the high precision geometric leveling method remains among the most accurate and the laser scanning technology is not reaching similar accuracy for measuring large buildings.

The advantage of laser scanning technology, in this case is about the possibility of measuring a building where access is impossible to perform the measurements using conventional methods.

4. References

1. ONOSE, D., Construction Behavior Tracking - Course Notes, Faculty of Geodesy, TUCEB;
2. ONOSE, D., 3D Monitoring of Land and Building - Course Notes, Faculty of Geodesy, TUCEB;
3. COŞARCĂ, C., Terrestrial Laser Scanning - Course Notes, Faculty of Geodesy, TUCEB;
4. LEICA GEOSYSTEMS - HDS Traing Course, Leica Geosystems Office in Milton Keynes, United Kingdom;
5. SAVU, A., Improvements of the surveying and geodetic work in the field of communications paths - PhD Thesis, Faculty of Geodesy, TUCEB.