MONITORING THE ROAD DISPLACEMENTS AND DEFORMATIONS

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***Abstract**: With the evolution of technology, human society has become able to produce major changes in habitat by creating large-scale engineering constructions: roads, highways, dams, bridges, viaducts, high-rise buildings. The action of land and building monitoring consists in determination of the observed objective behavior over time, action applied during the entire life cycle, starting from the moment of execution and ending with the end of life of the objective. Monitoring represents an activity of collecting, interpreting the information resulting from observation and measurements performed in order to determine changes in position over time so as to ensure stability and operational safety.*

***Keywords:** road monitoring, displacement and deformation, monitoring parameters, measurement epoch*

1. Introduction

Due to the modernization of our society, there is a need to develop new geodetic technologies that may be able to provide technical assistance to materialize the characteristic elements of buildings, control the various stages of execution and monitor the behavior in time of these objectives and the environment. In order to monitor an objective, it is necessary to identify the characteristic points that undergo changes of position, represented by displacements and deformations of the observed objective [1].

The displacement represents the change of the position of a point of the objective caused by different factors. Deformation is the change of the relative distance between the characteristic points of the objective [1], [4], [9].

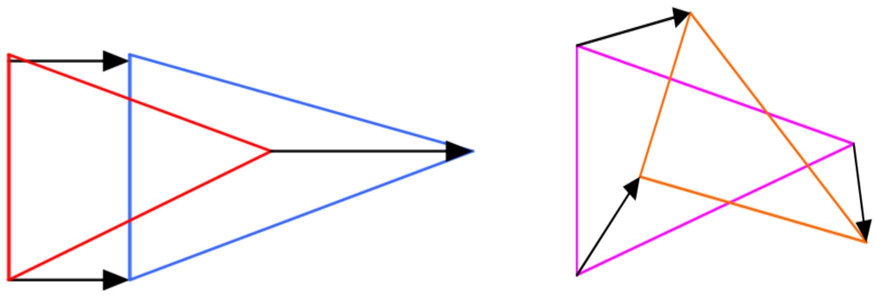

Fig. 1 Displacement and deformation

The category of displacements and deformations of an objective (Fig. 1) includes subsidence, structural elements arching, bulges, tilts, cracks, rifts, horizontal displacements [1].

The monitoring of the objective – land and/or building – consists in an activity that is performed with the help of precise measuring devices, at certain time intervals – measurement epochs –, intervals that are established according to the nature of the objective but also according to other parameters [3], [5].

As a case study in the present paperwork, the proposed objective to carry out the activity of monitoring the displacements and deformations is represented by a sector from the county road DJ 105N, located in Turnu Roșu, Sibiu county (Fig. 2).

County roads are of major importance in achieving public traffic, because they connect municipalities, cities and communal residences.

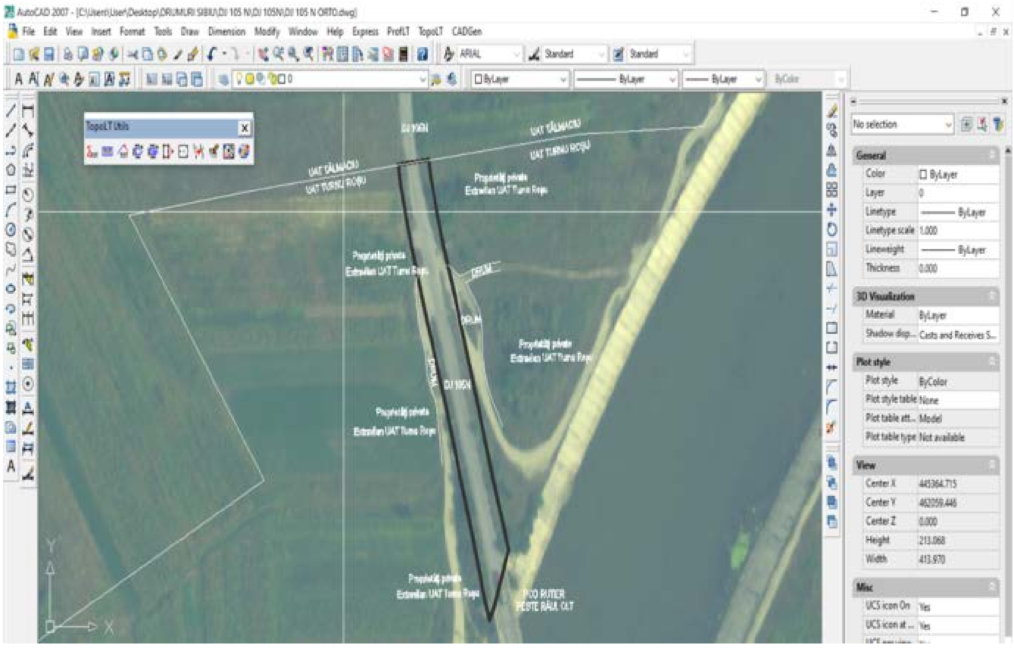

Fig. 2 Monitored DJ 105N sector

In this case, the fact that the road sector borders on the south with the Olt River, implicitly with the bridge that crosses this river, is perhaps one of the most important cause of road displacements and deformations, along with the heavy traffic. The climate changes affect the nature and level of both surface and groundwater, these having an important role in the dynamics of the phenomena of instability of the foundation ground.

Therefore, the purpose of carrying out these monitoring activities for the road sector consists in ensuring and sustaining the construction, supervising the foreseeable phenomena, verifying the impact of the traffic on the environment.

The technical condition of the road is established along its entire length, detailing the aspects for each road sector. It is covered with asphalt and the traffic is heavy.

2. Materials and Methods

In order to determine the possible displacements and deformations of the road, geodetic measurements were performed using precision equipment, Leica FlexLine TS10 3″ R500 total station. It was used for both first measurement epoch E1 and second measurement epoch E2.

As a measurement method, the polygonometric method was used, the geodetic measurements referring to a network of fixed reference points located outside the area of influence of the factors acting on the monitored objective and the terrain on which it is located. The polygonometric method is used to determine the horizontal displacements and deformations of curved objectives, large constructions or land. Using this method, a polygonometric traverse is carried out, including the reference points (S – observation stations, C – control points, O – orientation points), measuring angles and distances over object points (M), determining their spatial position for each measurement epoch [2], [6].

There is a six month time interval between two measurement epochs.

Before beginning the activity of monitoring the displacements and deformations of the road, the design and determination of the monitoring geodetic network was carried out (Fig. 3). It is composed of certain categories of points [1], [7], [8]:

- *Object points* M – placed on the objective to be monitored, precisely materialized and embedded in the resistance structure of the objective, moving along with it, and have the role of rendering the deformations or displacements of the construction
- *Observation stations* S – located outside the area of influence of the factors acting on the monitored objective and are used for the setting of the measuring devices for performing geodetic measurements towards the object points
- *Control points* C – used for determination of the eventual spatial position changes of the observation stations and they are located outside the area of influence of the monitored objective, in stable lands / buildings
- *Orientation points* O – located in stable areas, outside the area of influence of the monitored objective, far from traffic, so as to ensure the accuracy of determining the orientation of control points and observation stations.

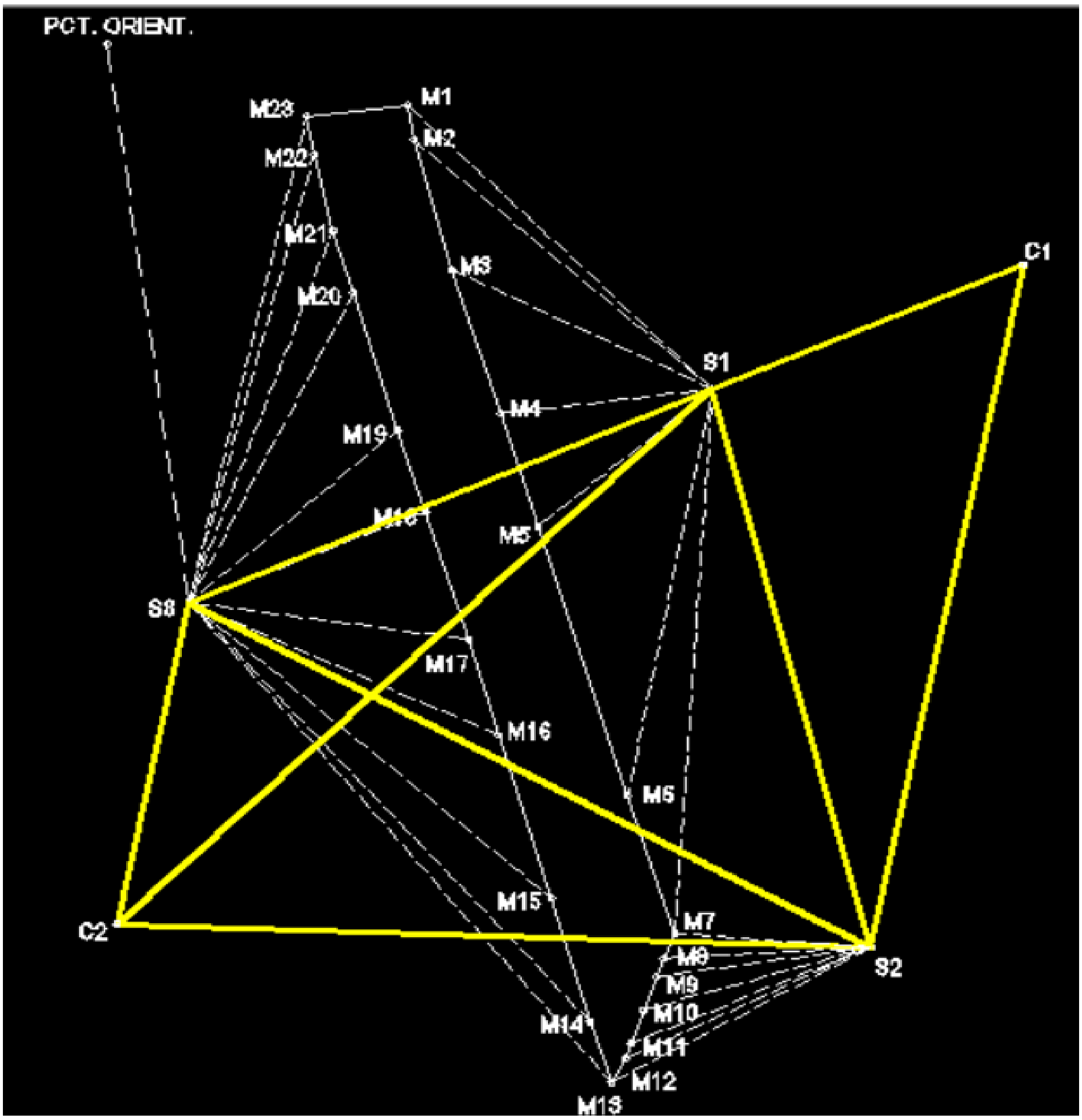

Fig. 3 Monitoring geodetic network

3. Results and Discussion

For the analytical processing stage, specialized computational and processing softwares were used to adjust geodetic measurements, and for the graphic processing the AutoCAD (2007) software was used, being the most popular computer-aided graphics and design software.

After processing the geodetic measurements, the coordinates of the object points for the first measurement epoch E1, respectively the second measurement epoch E2 were obtained (Tab. 1).

Tab. 1. Coordinates of the object points – measurement epoch E1 and E2

OBJ. PT.	coordinates			
	MEASUREMENT EPOCH E1		MEASUREMENT EPOCH E2	
	X	Y	X	Y
M1	462140.129	445363.876	462140.131	445363.872
M2	462133.807	445364.884	462133.807	445364.884
M3	462110.159	445370.870	462110.159	445370.871
M4	462083.921	445378.647	462083.923	445378.652
M5	462063.443	445384.567	462063.445	445384.574
M6	462014.326	445398.772	462014.326	445398.780
M7	461989.225	445406.288	461989.221	445406.297
M8	461984.719	445404.513	461984.724	445404.498
M9	461981.414	445403.405	461981.430	445403.377
M10	461975.333	445401.366	461975.350	445401.319
M11	461969.280	445399.338	461969.273	445399.355
M12	461966.436	445398.384	461966.443	445398.352
M13	461962.104	445396.231	461962.092	445396.245
M14	461973.168	445392.822	461973.171	445392.839
M15	461995.744	445386.681	461995.737	445386.657
M16	462025.313	445378.305	462025.306	445378.283
M17	462042.821	445373.555	462042.826	445373.567
M18	462066.071	445366.715	462066.065	445366.696
M19	462080.967	445362.251	462080.966	445362.247
M20	462105.973	445355.266	462105.972	445355.260
M21	462117.372	445351.972	462117.368	445351.958
M22	462131.160	445349.026	462131.160	445349.026
M23	462138.116	445347.775	462138.116	445347.775

Due to the fact that for the studied objective measurements were performed from a planimetric point of view, the monitoring parameters that were determined are represented by: the horizontal displacement of the current object point and the horizontal deformation of the current object point (Fig. 4).

Because of the requirements of high precision determinations of the road displacements and deformations, a vertical monitoring is carried out separatelly.

Data sets comparison between the two measurement epochs considered revealed that there are certain differences in the spatial position of the object points in the time interval between the two measurement epochs. There are object points that have not undergone significant position changes (the coordinate differences determined are due to measurement errors), but in the southern part of the objective, for most object points significant displacements and deformations were determined, with values of about 1cm (Fig. 5).

MARCI DE URMARIRE	COORDONATE EPOCA 1		COORDONATE EPOCA 2		DISTANTE ORIZONTALE (EPOCA 1)	DISTANTE ORIZONTALE (EPOCA 2)	DEPLASAREA ORIZONTALA (mm)	DEFORMATIA ORIZONTALA (mm)
	X	Y	X	Y				
M1	462140.129	445363.876	462140.131	445363.872	6,402	6,404	2	0.312
M2	462133.807	445364.884	462133.807	445364.884	24,394	24,394	0	0
M3	462110159	445370.87	462110.159	445370.871	27,366	27,366	0	0
M4	462083.921	445378.647	462083.923	445378.652	21,317	21,317	0	0
M5	462063.443	445384.567	462063.445	445384.574	51,13	51,129	1	0.2
M6	462014.326	445398.772	462014.329	445398.78	26,202	26,209	7	0.267
M7	461989.225	445406.288	461989.221	445406.297	4,843	4,843	0	0
M8	461984.719	445404.513	461984.724	445404.498	3,486	3,48	6	1.721
M9	461981.414	445403.405	461981.43	445403.377	6,414	6,419	5	0.78
M10	461975.333	445401.366	461975.35	445401.319	6,384	6,386	2	0.313
M11	461969.28	445399.338	461969.273	445399.355	3	3,002	2	0.666
M12	461966.436	445398.384	461966.443	445398.352	4,838	4,852	14	2.894
M13	461962.104	445396.231	461962.092	445396.245	11,577	11,591	14	1.209
M14	461973.168	445392.822	461973.171	445392.839	23,396	23,397	1	0.043
M15	461995.744	445386.681	461995.737	445386.657	30,732	30,732	0	0
M16	462025.313	445378.305	462025.306	445378.283	18,141	18,144	3	0.165
M17	462042.821	445373.555	462042.826	445373.567	24,235	24,233	0	0
M18	462066.071	445366.715	462066.065	445366.696	15,551	15,551	0	0
M19	462080.967	445362.251	462080.966	445362.247	25,963	25,964	1	0,39
M20	462105.973	445355.266	462105.972	445355.26	11,865	11,865	0	0
M21	462117.372	445351.972	462117.368	445351.958	14,099	14,1	1	0.071
M22	462131.16	445349.026	462131.16	445349.026	7,068	7,068	0	0
M23	462138.116	445347.775	462138.116	445347.775	16,226	16,223	3	0.185

Fig. 4 Determination of the object points displacements

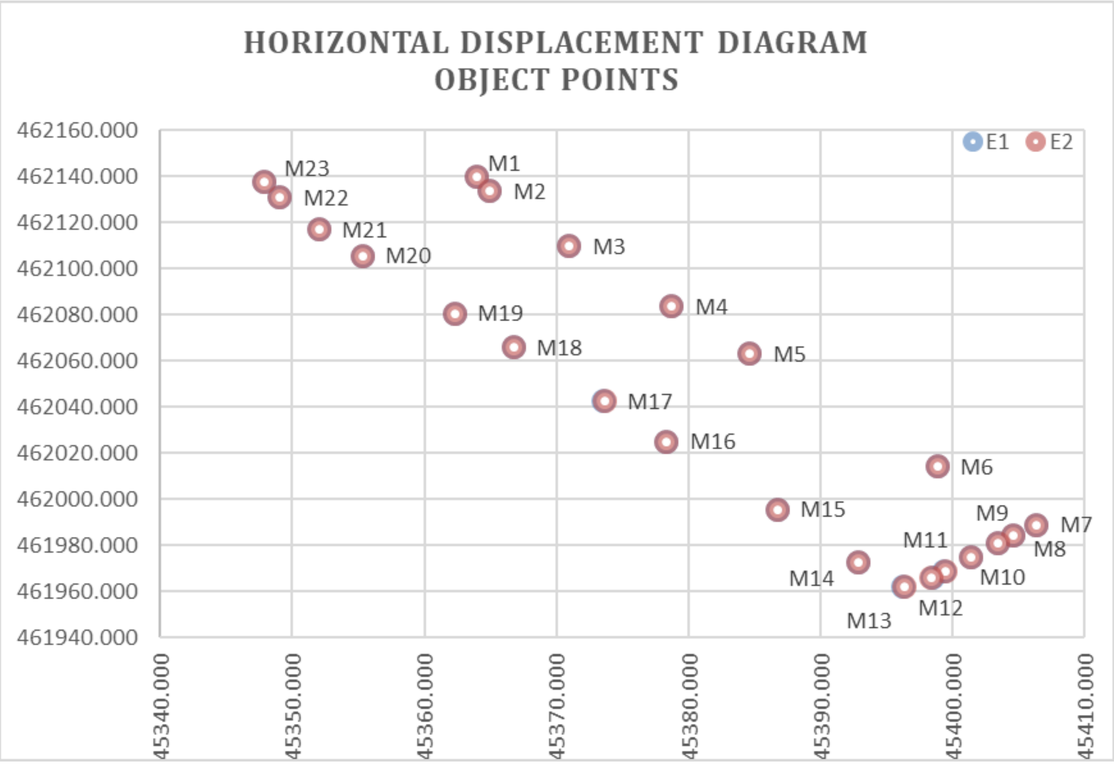

Fig. 5 Horizontal displacement diagram – object points

4. Conclusions

In conclusion, the activity of monitoring the behavior in time for various objectives in different fields of interest is very important. By carrying out the monitoring survey, comparing the initial situation with the situation resulting from the geodetic observations at the current measurement epoch, the technical condition of the objective is ascertained, the points that have undergone significant changes in spatial position are determined, as well as the causes of these changes and, at the same time, diminishing or even stopping displacements and deformations, in order to avoid any events with a negative impact on the objective, the environment and human life [6].

The substantial increase of the road network, the progressive substitution of the traditional construction-assembly procedures as well as the application of new procedures, brings the specialists in front of the need to know in more detail the changes of geometric shapes and the position in space and time of roads, execution projects, testing of elements and infrastructure, as well as during the execution and exploitation of roads [3], [5].

Within this project, the activity consisted in measuring, recording, processing and systematic interpretation of the values of the parameters that define the way the observed road sector maintains its requirements of strength, stability and durability.

The complexity of monitoring activity refers to the early identification of the changes of position and form of the whole road sector or of some of its elements, as well as to the notification of the appearance of some evolutionary phenomena that will be able to affect the road safety. This allows rapid action to be taken to prevent accidents, catastrophes and even loss of human lives [4].

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