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GEODETIC MONITORING OF BUILDINGS IN SERVICE STAGE AND IDENTIFICATION OF STRUCTURAL DEGRADATION CAUSES

BY

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Abstract. In this paper, we will present an analysis of the causes due to vertical displacements and settlings encountered in a series of buildings. Studying the behavior of an object, observing it’s evolution and detecting possible displacements is defined as monitoring in service stage. Buildings monitoring is important for ensuring stability and safety in service stage. The changes in the balance conditions can lead to partial or total destruction and can produce high material damages or life loss. Topo-geodetic measurements have been done for studying possible spatial displacement for a number of national patrimony buildings. Therefore, geodetic methods and techniques will be described together with the equipment used in monitoring. The aims of this paper is to identify the causes of structural displacements and degradations. Finally, after explaining and interpreting the changes of the structure, we will give solutions to extend the buildings life cycle.

Keywords: building monitoring; spatial displacements; structural degradation; geodetic observations.

1. Introduction

Monitoring buildings behaviour in time consists in a series of activities such as: measuring, processing and interpreting the effects, recording the results

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and proposing solutions for extending the lifecycle of the observed structures (Sătmăreanu, 2016). Detection of targets movements is used to prevent the damage of the buildings, regardless of the causes that produces this phenomena. The features of degradations and deformations can be of two types: external (involving natural factors: strong wind, heavy storms, earthquakes, ground waters) or internal (the use of unsuitable materials for building up the structure, inappropriate placing the building on land) (Dabija *et al*., 2016).

Tracking in time the behaviour of buildings is a extremely complex process, requiring special monitoring tools (Lepădatu *et al*., 2011). Depending on the importance of the studied objects, the accuracy with which deformations are determined must be as high as possible. Together with the development of society`s requirements in terms of technology, topographic equipment's have seen an upward evolution (Lepădatu *et al*., 2014). Starting from the use of classic levelling to measure displacements and degradations, ending up to operate with digital modern instruments : terrestrial laser scanner, unmanned aerial vehicle, satellite technique or wireless sensors for real-time monitoring (Lepădatu *et al*., 2016).

Traditional topographic methods for monitoring the behaviour of buildings in time have been replaced with contemporary techniques due to the cost efficiency, accuracy, acquisition and processing time for data (Boț *et al*., 2015). Other advantages of using the latest methods would be: small number of operators, real-time measurements, obtaining vertical and horizontal displacements without the need for visibility between points (Lepădatu *et al*., 2014).

In the case of terrestrial laser scanning, we can achieve high costs, a 3D model of the building through the point cloud, long range for measuring (Chazaly, 2006). The only disadvantage would be the lack of professional hardware and software for downloading and processing data (Morariu & Lepădatu, 2017). The satellite techniques and using airbone systems in the activity of monitoring in time involve a single detriment represented by vegetation near the examined object. On the other hand, these systems have a large coverage of the observed area (Meouche *et al*., 2016).

2. Material and Method

The monitoring of buildings by classic topographic methods is performed with the help of high precision geometric levelling for determining the deformations of the analyzed objects. Level is defined as the instrument that reads the movements of a building and it can be of two types: digital (Fig. 1 *a*) or automatic (Fig. 1 *b*) (Grecea *et al*., 2013). The working efficiency is high, allowing automatic recording of readings, the possibility of performing field check and intermediary calculations on the field with the mean of self-recording in the internal memory of the device.

Table 1
Features Concerning Digital-Automatic Level

Level	Accuracy for measuring level differences	Telescope magni-fication	Measu-rement time	Sighting distance	Internal memory	Weight
Digital	0.7–2 mm	24x	< 3s	2–100 m	1,000 surveys	2.5 kg
Automatic	1.8–2.5 mm	24x–32x	< 3s	1–100 m	>1,000 surveys	1.5 kg

a *b*

Fig. 1 – Leica-geosystems: *a* – digital level; *b* – automatic level.

Digital level allows measuring in a very short time with high accuracy, demanding a minimum of two operators depending on the complexity of the work. Information is stored and recorded in the internal memory of the gear. On the contrary, automatic level has improved with high precision. Height reading is done through the laser beam, involving just one worker. Therefore, the results are obtained by using automatic level are better in terms of accuracy, measuring time and costs.

The activity of surveillance and monitoring in timp takes place throughout the life of the building, beginning with the moment of execution. Relying on the importance of the objectives, the purpose, nature, endurance, the means and technical solutions applied, exploitation condition, grasping and organizing the data, tracking the behaviour in time divides into two categories:

a) current monitoring of the technical building`s condition (done by direct examination, visual control or by simple means);

b) special monitoring (based on instrument and device measurements).

Causes of deformation may be:

1. General;
2. Particular.

General causes are marked by geotechnical and hydrogeological conditions, physico mechanical properties of which the ground is formed.

Particular causes are defined by the limited geotechnical and hydrogeological data volume, but also by external factors: earthquakes, ground water level, climatic conditions and difficult ground foundation.

Deduction and detection in time of deformations has a particularly important role for building`s safety and stability, since misinterpretations can lead to material and human disasters.

3. Results and Discussions

,,Dunărea de Jos" University is a higher education institution, located in the center of Galați City, Romania. It was founded in 1948, comprising 10 buildings for each faculty and a student campus with 10 dorms.

This paper describes the techniques with which a number of buildings have been monitored over time due some causes, such as: foundation ground or particular factors. The aim of current tracking in time of building behaviour is to determine the status of buildings structure, identification of degradation and damage that occurred through exploitation or as a result of natural phenomena.

The topographic method applied in this study was high precision geometric levelling using Ni 007 classical level. The accuracy of the instrument referred in the technical book with which were read the ground marks and screw marks is ± 0.7 mm.

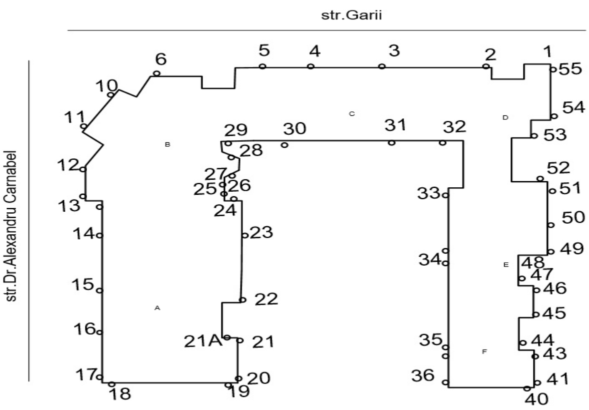
Survey measurements were done between three and twelve cycles for monitoring each building described in this present scientific work.

Objective number 1 – Faculty of Physical Education and Sport of ,,Dunărea de Jos" University, Galați (Fig. 2 *a*). The building is located at the intersection of Dr.Alexandru Carnabel street with Gării street (Fig. 2 *b*), built before 1940 with height form Semi-Basement +Ground Level+ two Floors, ground building surface of 2765 squares and a extended surface of 10468 squares.

Fig. 3 shows the values of cumulative and partial compactions for the first objective. These were determined on the basis of eight surveys. The first measurements date back to June, 3th, 1994 and the plotting of information was done with those made in May, 2008.

As noticed in Fig. 3, the process of vertical displacements is happening especially on building`s marks number 17, 21-23 and 25-31. The compaction of objective 1 for the marks mentioned are concerning because they pass normal limits and it is an active process of displacement. Being an old structure, it crossed all the earthquakes: 1940, 1977, 1986, 1990. This led to the amplification of the compaction phenomenon for the foundation ground. It is advisable to exercise careful control over these areas for early detection of possible infiltration from meteoric waters or water pipes.

a



b

Fig. 2 – Objective studied number 1: *a* – foto objective; *b* – outline location of the tracking marks.

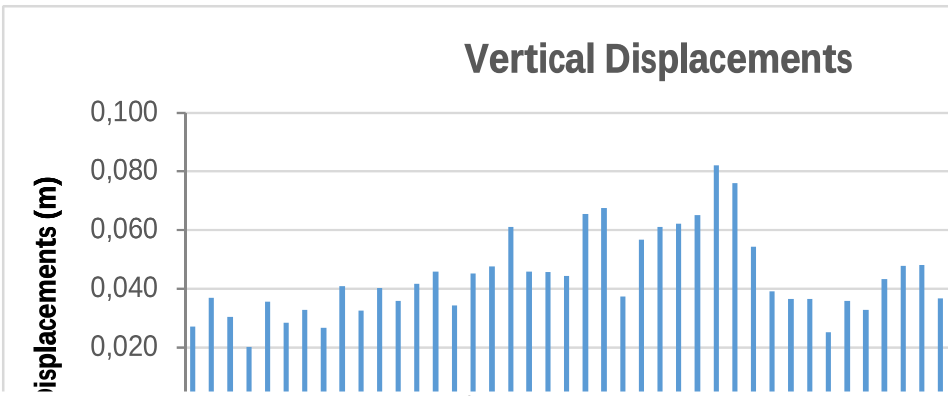
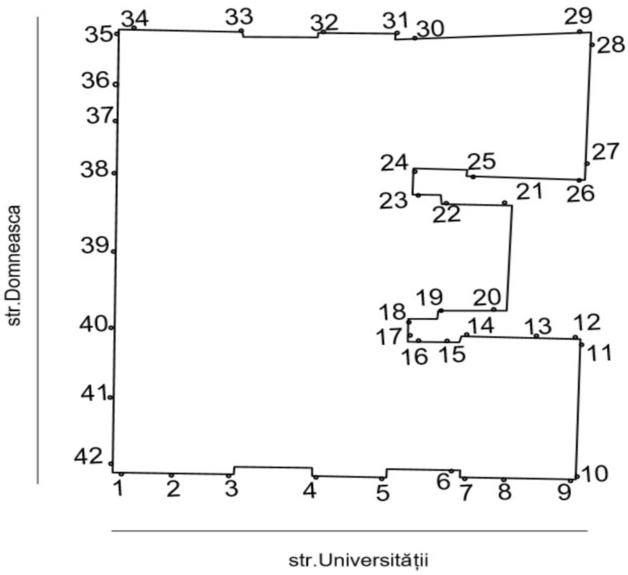


Fig. 3 – Settlings graphic for objective number 1.

Objective number 2 – Central building from „Dunărea de Jos ” University of Galați (Fig. 4 *a*). The main construction is located at the crossroads Domnească Street with Universității Street (Fig. 4 *b*), built before 1940's. It has Semi-Basement + Ground Floor+ First Floor Height with a ground surface of 3135 squares.

a



b

Fig. 4 – Objective studied number 2: *a* – foto objective; *b* – outline location of the tracking marks.

Issues regarding the cumulative and partial vertical deformations for objective number 2 started since 16 November 1988. Twelve survey observations have been made and the results are presented in Fig. 5.

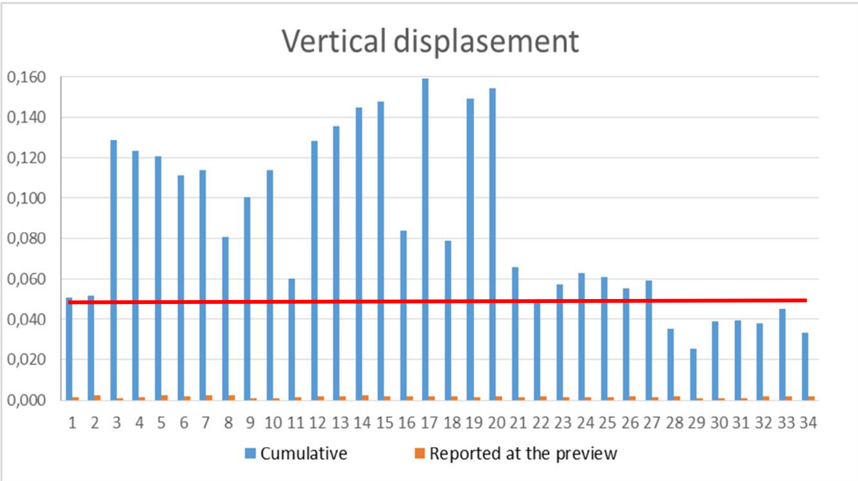


Fig. 5 – Vertical displacement for objective 2.

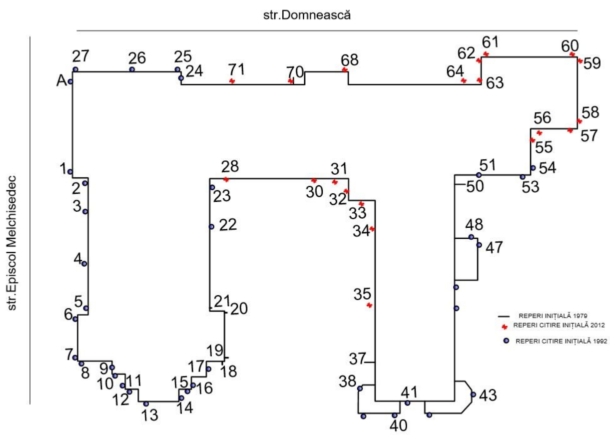
The graphic from Fig. 5 shows a process of displacement with preponderance on the side of the building with exceeding movements between marks 1-27. Displacements are normal for the age of the structure, but they need permanent surveillance. This is primarily caused by local water infiltrations. Of course we can add as factors: the age of the building and a series of earthquakes that affected the structural system, requiring significant rehabilitation at this time.

Objective number 3 – Faculty of Engineering from ,, Dunărea de Jos ” university of Galați (Fig. 6 *a*). The building is found at the cross of Domneasca Street with Episcopul Melchisedec Street, built up before 1940`s (Fig. 6 *b*).

Fig. 7 describes the process of vertical displacements that took place over the monitored marks over time from cumulative and partial point of view. The first observations occurred in the year 1979 and since then twelve surveys were developed.

The situation regarding objective 3, is worrying because the vertical movements are exceeding normal limits. From Fig. 7 we can say that some marks tend to move more, especially the ones on the right side of the building. This active phenomena of ground movement can be due to the degradation of meteorological water collection and removal systems, but we can not exclude degradations from repeated earthquakes. Large deep drilling is recommended to detect the areas under humidity conditions.

a



b

Fig. 6 – Objective studied number 3: *a* – foto objective;
b – Outline location of the tracking marks.

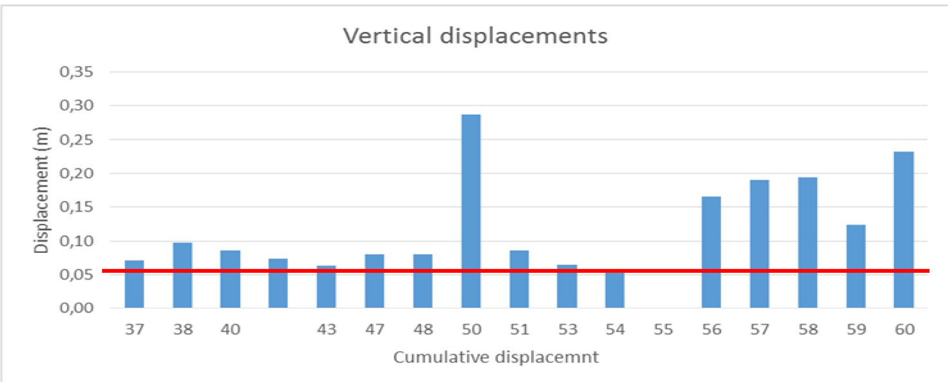
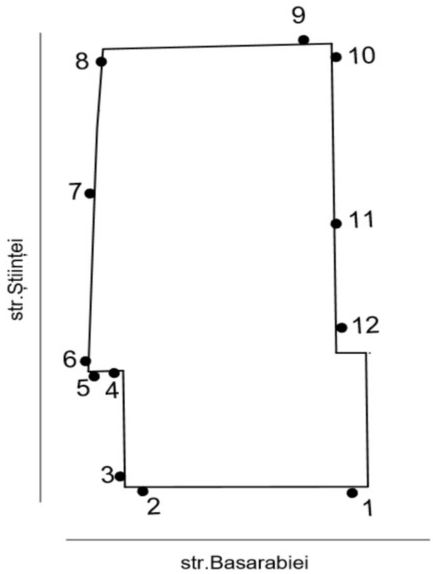


Fig. 7 – Vertical displacement for objective 3.

Objective number 4 – Faculty of Naval Architecture. ,, Dunărea de Jos ”University of Galați (Fig. 8 *a*). This instution is found at the crossroads between Basarabiei Street with Ştiinței Street (Fig. 8 *b*). It was built before year 1980 with Ground Floor + six Floors and has a ground surface of 871 squares and a built surface of 6097 squares.



a *b*

Fig. 8 – Objective studied number 4: *a* – foto objective; *b* – outline location of the tracking marks.

Vertical upward movements presented in Fig. 9, take place for all levelling marks, but they tend to stay in normal limits.

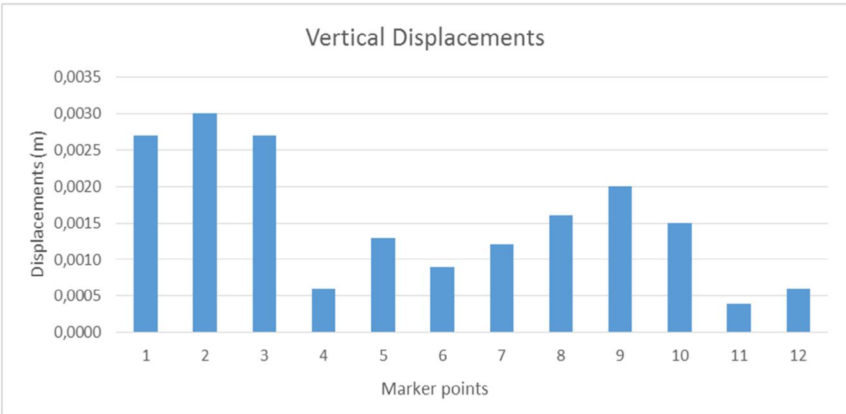
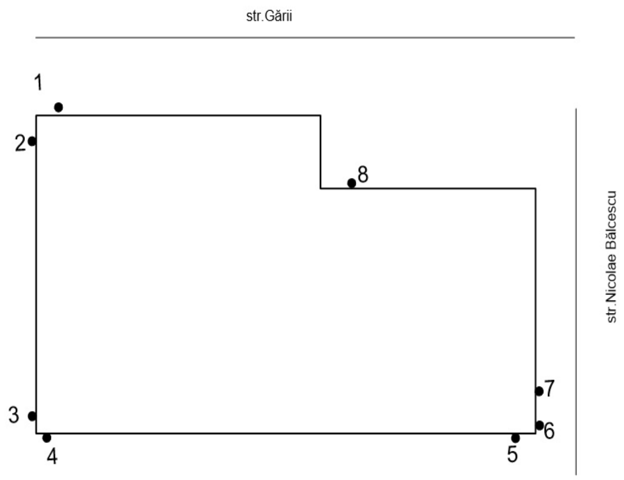


Fig. 9 – Vertical displacement for objective 4.

Objective number 5 – The building of the Faculty of Economics and Business Administration (Fig. 10 *a*) of ,, Dunărea de Jos” University in Galați is found at the intersection of Nicolae Bălcescu Street with Gara Street (Fig. 10 *b*). The building has a ground floor height + two floors, built before 1980.

a



b

Fig. 10 – Objective studied number 5: *a* – foto objective: Faculty of Economics and Business Administration; *b* – outline location of the tracking marks.

Fig. 11 shows cumulative and partial vertical displacements for the fifth objective, named Faculty of Economics and Business Administration. Values were determined based on three surveying measurements. The first survey took place in 1996.

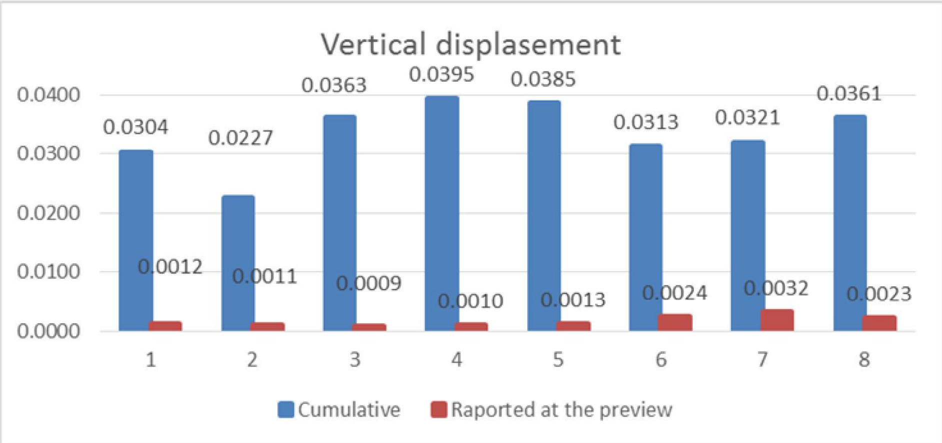


Fig. 11 – Vertical displacements for objective number 5.

It is noticeable that we have vertical deformations on all corners of the building, which are not uniform. The movements take place on the long sides of the building, but fall into acceptable compactions of 50 mm. The relatively large differences are found on side 1-4, towards sides 4-6. The causes of these vertical movements are due to the earthquakes that took place in 1986 and 1990, which caused degradations that overlapped with the phenomenon of compaction of the foundation ground.

4. Conclusions

Monitoring buildings is a very complex process and for obtaining the best results, we need to take into account the phenomena that occurs on the studied objects.

Classical topographic methods used in the tracking behaviour of structures in time should take into account the ground conditions and the equipment employed.

The present study case aimed to understand locally or as a total the evolution of vertical displacements over the monitored objects. The changes produced over the analyzed buildings were due to a series of factors. The most common are:

- the nature of the foundation ground;
- compactions of soil due to earthquakes;
- infiltration of meteoric waters;
- infiltration of water from the drain pipes damages or rainwater collection system;
- extreme climatic conditions, resulting in very large differences between maximum and minimum thermal;
- the age of buildings.

Vertical displacements were determined starting from a geodetic ground point network, placed outside the area of building`s influence. It turns out that in a visible way there were noticed significant degradations over the walls, girders, pillars, buoys and belts.

After the topographic surveys for monitoring the buildings, we know for certain that vertical movements are taking place, but with acceptable spread. Our proposal is to rehabilitate structural using performant materials for ensuring high stability of ground soil and to cease external factors that caused degradations. Also, is of high importance to use methods of rehabilitation that do not affect their architectonic style as buildings belonging to the national patrimony. The progress of topographic technology require using modern devices for monitoring in time the behaviour of buildings. Tools that can quickly and accurately determine collection and processing of fast data, with low costs can be: 3D laser terrestrial scanner, wireless sensors for real-time reading, satellite techniques.

We can state that the building area with topography branch make a collaboration in order to set up, execute and monitor structures in order to ensure safety and stability in exploitation.

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MONITORIZAREA GEODETICĂ A CLĂDIRILOR ÎN FUNCȚIE DE SERVICIU ŞI IDENTIFICAREA CAUZELOR DE DEGRADARE STRUCTURALĂ

(Rezumat)

Este prezentată o analiză a cauzelor cauzate de deplasările şi aşezările verticale întâlnite într-o serie de clădiri. Studierea comportamentului unui obiect, observarea evoluției lui şi detectarea posibilelor deplasări este definită ca monitorizare în stadiul de serviciu. Monitorizarea clădirilor este importantă pentru asigurarea stabilității şi siguranței în funcționare. Modificările condițiilor de echilibru pot duce la o distrugere parțială sau totală şi pot provoca daune materiale sau pierderi de viață. Au fost efectuate măsurători topo-geodezice pentru studierea posibilei deplasări spațiale pentru o serie de clădiri patrimoniale naționale. Prin urmare, vor fi descrise metode şi tehnici geodezice împreună cu echipamentul utilizat în monitorizare. Scopul acestei lucrări este de a identifica cauzele deplasărilor structurale şi degradărilor. În cele din urmă, după explicarea şi interpretarea modificărilor structurii, vom oferi soluții pentru extinderea ciclului de viață al clădirilor.