TOPO-GEODETIC MODERN METHODS AND TECHNIQUES FOR BUILDING MONITORING PROCESS

Diana-Ioana MORARIU[1], Daniel LEPĂDATU[1]

e-mail: daniel.lepadatu@gmail.com

Abstract

Our proposal for this paper is to identify and introduce topographic methods and technologies to ensure the best monitoring of buildings of vital importance for society or those with significant structural damage due to compaction of soil. The main purpose of this study is to find and compare contemporary methods that have been developed in recent years and are used in applied topography, replacing traditional methods successfully. Recently, digital technology has evolved at the same time with society needs and development. The use of 3D laser scanner, combined GPS stations, laser or photogrammetric scanning, total or modern robotic stations and drones, appear to be the most suitable solutions nowadays. A comparative research using different scientific papers will be presented in a short table. Each method is described with its advantages and disadvantages.

Key words: buildings monitoring process, topography, terrestrial scanning, robotic total station, unmanned aerial vehicle.

INTRODUCTION

Topography is the technique of terrestrial measurements for representing shapes and details found on the ground, the results ending up in maps and plans. Details can be natural (land or hydrography) or artificial (roads, buildings, artworks). The goal is to determine the position and altitude of the points, regardless of the size of the area in which the objects under study are located (Brisan M.C., 2006).

The science which is fundamental for surveying and photogrammetry is Geodesy. Geodesy deals with determine the precise position of points in the field.

From historical point of view, topography dates back to ancient times. Since then, terrestrial measurements (Lepadatu D. et al, 2014) evolved fast, reaching different levels of professionalism in terms of methods, tools and systems of obtaining topographical points (Boș N.C. et al, 2015).

Surveying used in construction is present in all the stages of a project. Starting with initial steps of the job and ending up with time tracking at different periods to ensure operational safety.

Methods and techniques used to monitor a building are different. Taking into account the evolution of technology, the techniques will be chosen to optimize and obtain the fastest data. The objective of this paper is identify and discuss the methods and techniques of time tracking used in survey. We can discuss the use of lasergrammetry, robotic total station, GPS or a mixed combination of the instruments.

MATERIALS AND METHODS

Topography includes plenty of techniques and surveying methods. The study focuses on the modern instruments and methods used for monitoring buildings in time.

Valença (Valença J. et al, 2017) explains that optical and digital equipment has been widely available to engineers over the past two decades, which has led to the possibility of using them in structural building assessments. 3D laser technology collects structural data by providing qualitative and quantitative information. The only inconvenience is the high cost, the scanning range is between 100 m and 1400 m and the position of the instrument is important for determining the points.

On the other hand, Chazaly (Chazaly B., 2006) discusses the benefits of 3d laser scanner over traditional level: high speed measurement, the ability to perform in long range measurements in hard reaching areas and achieving density of points with precise map determinations. Chazaly presented in a table 1 the main advantages for using 3D laser scanner in different applications.

[1] “Gheorghe Asachi” Technical University of Iași, Faculty of Civil Engineering and Building Services

Table 1

The advantages of using the 3D laser scanner

Examples of applications	Density	Speed	Long range
Tunnel under traffic	X	X	
Highway and underpass	X	X	
Head of tunnel	X		X
Mapping of dams	X		X
Slope	X	X	X
Retail lifecycle	X		X

El Meouche (El Meouche R. et al, 2016) made a comparison between the classical method (Table 2) using the total station and the modern technique with UAV (Unmanned Aerial Vehicle). His study focused on an area in southern Paris, France named Etampes. The area is a medium urban density. He demonstrates differences between two techniques and what is representative of them. Another objective is to show which of the two devices can be used to obtain results that are used to draw a topographic plan.

Tabel 2

Comparison classic – modern technique

Characteristics	Classic Method / Total Station	Modern Method / UAV
Operating time	About 7 hours	About 4 hours
Accuracy	Centimetres/ under centimetres	Centimetres
Price	About 2000 €	About 1200 €
Data processing time	About 6 hours	About 6 hours

UAV has low precision due to the image resolution. A high level of precision can be achieved, only if a better resolution is used and an increased number of points is used during surveying.

On the other side, using the UAV has a disadvantage depending the area you study due to the vegetation because it makes hard to determine points. Thus, El Meouche states that simultaneous use of the total station with UAV may be the best technique in terrestrial measurement.

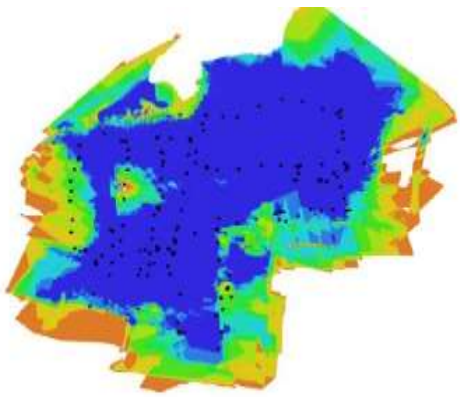

Figure 1. Overlapping image
(El Meouche R. et al, 2016)

Figure 2.Orthophoto
(El Meouche R. et al, 2016)

Goodwin (Goodwin N. et al, 2017) says that laser terrestrial scanning (TLS) is another application of LIDAR technology that captures millions of points from fixed positions. The 3D laser scanner operates on the principle of electromagnetic pulse by obtaining 3D dimensions of the point cloud. The author used this instrument for measuring the size of a gully located in Aratula, Queenisland, Australia.

The method used by Goodwin involved five permanent survey marks in the area studied for registering the ALS (Airborne Laser Scanning) and TLS datasets. The control points were measured using Global Navigation Satellite System (GNSS) with survey techniques the location projected into Geocentric Datum of Australia 1994. The positional errors were estimated to be less than ± 0.01 m in the horizontal and vertical directions. Also, thirty points were placed outside the gully for DEM (Digital Elevation Model) accuracy and the study was made with two ALS equipment and one TLS. He concludes that from geomorphic point of view, TLS has a greater sensitivity to detect changes in the gully than ALS. From operational perspective TLS cannot compete with geographical coverage or cost per area of ALS, but terrestrial scanning has higher precision. Finally, Goodwin says that ALS and TLS technology should be used together in topographic monitoring because traditional methods such as total station and differential or real time kinematic Global Positioning System (GPS) are time consuming and limited in spatial details.

Akgul (Akgul M. et al, 2017) monitored a forest road in Turkey to exactly determine the degradation due to meteorological conditions. Time tracking is an important factor for forest roads due to traffic safety. The road's grooves collect the water and subjects the pavement to pond and freeze causing deterioration. Other external factors contribute to the degradation of the road, such as: traffic, maintenance application, heavy vehicles, and pavement structure. The author thinks that using the 3D scanner has several advantages: fast data capture speed, does not require marking points on the ground, it records hundreds of points per second, high accuracy, long distance target. Also, geo-referencing is the most important factor for accuracy of surface model.

The objective of this study is to establish with high precision the values of deformations.

Data acquisition was taken with phase based scanner Z+F Imager 5010C and processing data was done with special software. Two fixed points and six portable targets were used between two scan stations. Fixed targets are used for georeferencing the point cloud.

Firstly, the points for control are established with instruments such as GPS and total station in the local coordinate system. The distance between two scan stations is 20 m and TLS instrument is set at 2 m height for giving the minimum point density at 10 m.

Finally, he concludes that the use of this technique is the most effective in monitoring roads because the results are closer to the reality than classic ways combining TLS technology with Geo-referencing.

Caijun (Caijun et al, 2016) claims that the mix of GNSS (Global Navigation Satellite System), InSAR (Interferometric Synthetic Aperture Radar) and Satellite Gravimeter technologies is used for the first time in the study of deformations produced by earthquakes. Modern Geodesy provides us with information on Earth science towards classic Geodesy and Seismology. Nowadays, soil deformation and geoid changes can be determined accurately with modern equipment.

Hyunsuk (Kim H. et al, 2017) chose to the shore near the Gyeongpo and Wonpyeong beach, Korea. Due to climate changes and human intervention, the coast is subject to deformations. The procedure of Hyunsuk consist in basic monitoring, video monitoring and these two means combined.

For the basic monitoring, shorelines attributes are studied „before" and „after" events. Data is collected by erosion history, aerial photography and satellite images, GPS surveys.

Video monitoring is based on the installation of video cameras using the recording of video feeds. Therefore, for obtaining 3-dimensional coordinates the airborne LIDAR mapping system is used to collect information. The aircraft is equipped with a laser scanner which fires a laser on the object on the ground and measures the time it takes the pulse to return. The main advantage of this instrument is that it can obtain continuous 3D geolocation information from the shoreline covering a large area.

On the other hand, Xyongyao (Xie X. and Lu X., 2017) affirms that classic approaches insufficient for tracking in time a tunnel. His study took place in Shangai West Tunnel on Changjiang Road, China. For this type of work, 3D terrestrial scanner was committed. After collecting the data in a short time, he created a 3D model of the tunnel with the help of software. Five scan stations were set up along the longitudinal profile of the tunnel. The distance between scan stations is determined by the incidence angle of TLS which is 65º. In the middle section of the tunnel the distance is 30 m, above ventilation area and under the road area is 8m.

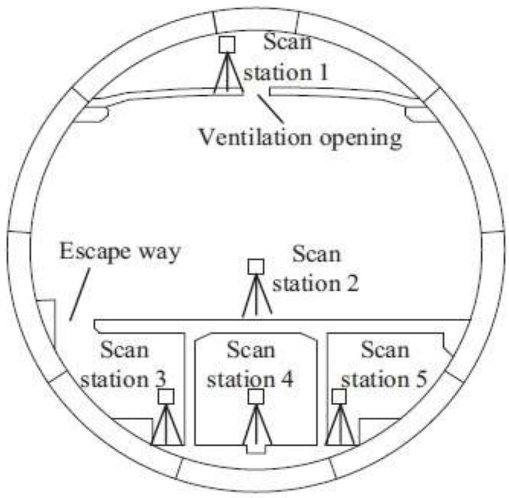

Figure 3. **Scan stations settlement in a tunnel**
(Xie X. and Lu X., 2017)

Janeras (Janeras M. et al, 2017) confronted four different practices to monitor the Monserrat massif in Catalonia, Spain. First time he uses total station to track any changes, second he uses sensors placed on the object to obtain in real time any movement, third the terrestrial scanner and the last one is the Ground - Based Synthetic Aperture Radar (GBSAR). In the end, he made a comparison between the four methods (Table 3).

Tabel 3

Summary of the characteristics according to the ability detect deformation

Instruments	Performances			Measurement Capability	
	Target	Accuracy	Maximum distance	Millimeter	Centimeter
Crackmeters	Point (sensor placement)	0.05 m	-	Adequate	Adequate
Total Station	Point (prism placement)	0.8 m	600 m	Limited	Adequate
GBSAR	Raster (pixel larger than 3 m^2)	3-5 mm	800 m	Poor	Limited
TLS	Raster (pixel around 0.01m^2)	5-10 mm	400 m	Poor	Adequate

Bryn (Bryn M. et al, 2017) analyzes in his paper the horizontal and vertical deformations produced by the subway on the constructions on its range. Control points for horizontal deformation will be determined with the total station and the vertical deformations with digital level. It is believed that the existence of subways produces additional deformations than those of soil and external factors. Horizontal geodetic grid control points are beaconed with reflective sheeting on the walls of the surrounding buildings. The method used for horizontal deformations is called „method of free station position”. This method assumes that the total station is located in the most suitable position. Location of the device is determined by resection and the control grid points and the deformation bench marks are measured by the polar method. The method developed by Bryn is called Analytic Hierarchy Process (AHP).

The main features of AHP are:

- precision;
- angle view;
- distance between points;
- number of points and visibility between them.

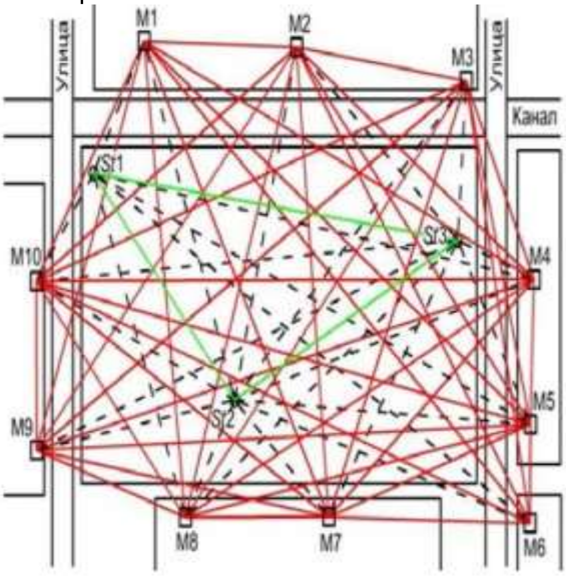

Figure 4.**Scheme of horizontal deformation**
(Bryn et al, 2017)

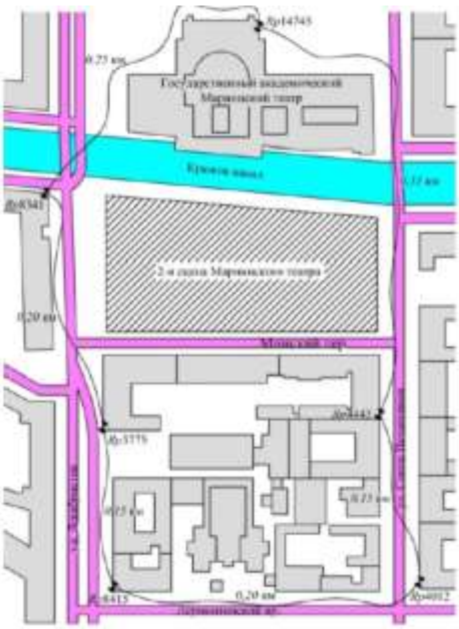

Figure 5. **Scheme of vertical deformation**
(Bryn et al, 2017)

RESULTS AND DISCUSSION

Monitoring buildings is essential for assuring operational safety, protecting the environment and human life. Studying the behavior of the constructions begins with its execution and takes place throughout the life of the building.

A comparative analysis is presented for time tracking different types of buildings: artwork, buildings, patrimony buildings, roads, dams using different methods and techniques for topo-geodetic survey. Starting from the classic method (total station, level) and ending with contemporary instruments (3D laser scanner, UAV, LIDAR technology), monitoring has evolved together with society needs. The table below presents different scientific papers, discussing the advantages and disadvantages which the technologies have.

Tabel 4

Advantages and disadvantages of the methods for monitoring constructions

Author / Scientific work	Method	Advantages/Disadvantages
Valença J./ Evaluation of lasergrammetry on monitoring a bridge	Combining laser scanning with image processing	- Automatic and accurate processing of data; - Higher speed, efficient quantity and quality of data.
Chazaly B./ The use of lasergrammetry for the art buildings	Definition of the main advantages of lasergrammetry	-Increased accuracy; -Allows stationing outside the studied area;
El Meouche R. / UAV photogrammetry implementation to enhance land surveying, comparisons and possibilities	Comparison between classic and modern technique using UAV and total station	- Modern method using UAV is more efficient for the cost, time and precision - Classic and modern way of measure take the same time for processing the data
Goodwin N./ Monitoring a gully using both airborne vehicle and 3D laser scanner	Compares airborne laser scanning with terrestrial laser scanning	- ALS has better coverage of an area than TLS -TLS offers higher information than ALS - ALS can be used for inaccessible places.
Akgul M./The use of TLS for roads	Monitoring forest road with terrestrial scanning	- Higher resolution ; - Acquiring fixed ground points with Global Positioning System increase the results to be closer to reality.
Caijun X./ Recent developments in seismological geodesy	Studying seismically deformation with GNSS and Satellite Gravemetry	- Higher precision; - Real time measuring;
Hyunsuk K./ Shoreline change analysis using Airbone LIDAR	Monitoring the coast using combined methods	- Efficient data provided by Airborne LIDAR System; - Economic plan for time tracking the shoreline; - Using this system the plan for preventing erosion can be established.
Janeras M./Multi-technique in monitoring	Combination of four methods	- Accuracy; - Obtaining results in real time; - Innovation in mixing classic and modern technology.
Xyongyao X./Obtaining 3D model of a tunnel	The use of terrestrial laser scanning	- Five stations were taken inside the tunnel for obtaining the 3D model ; - The point clouds allows us better study of the deformations; - Fast speed data.
Bryn M./ Geodetic monitoring of building surrounding an underground construction	Geodetic control of horizontal and vertical deformation with classic instruments	- Higher costs; - Time for monitoring is increased than modern techniques; - Combining total station and digital level for better results.

As a conclusion of the situations presented in this research, we can agree that the use of a single instrument is almost impossible in monitoring deformations for any type of building. It’s better to use at least two techniques for obtaining accurate results. Also, operating with modern instruments leads to successful surveying and achieving data in a short time with low costs. Nowadays, terrestrial laser scanning is used along with ground control points determined with GPS,

Topography is a science which studies the shape, dimension and movement of the ground. It is used in many fields: civil engineering, agriculture, land system planning, communication paths, hydrography, drawing of maps and plans.

Monitoring buildings by topo-geodetic methods is of high importance, assuring strength and stability during life cycle. This can be achieved by systematically time tracking the vertical and horizontal displacements of the studied object.

laser or photogrammetric scans and robotic total stations. This appears to be the most effective, accurate solution in modern survey. Mixing instruments is the best mean for obtaining results high in precision, the time for measuring and processing data is diminished, costs are widely reduced.

CONCLUSIONS

Supervising a construction is a systematic activity which involves collecting and utilizing information resulted from measuring, noticing the phenomena from the buildings structures in the process of interacting with the environment (climatic conditions, seismic movement, soil).

Monitoring using laser scanning technology can be a practical solution in areas where access to surveying points is impossible or measuring a large number of points. The only disadvantage is that if you do not have top hardware and software equipment, time for processing data may considerably increase.

An analogy between classical and modern ways of measuring deformations has revealed that even though the latest survey equipment offers fast measurements with less effort, it still depends on classic and simple instruments such as GPS, digital level or total station.

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