DETERMINATE DYNAMIC DEFORMATION OF CONSTRUCTIONS USING THE INTEGRATED SYSTEM – LEICA 1200

Ioan Sorin HERBAN, University "Politehnica" of Timişoara, sorin.herban@ct.upt.ro
Cosmin Constantin MUŞAT, University "Politehnica" of Timişoara, cosmin.musat@ct.upt.ro

Abstract: *-It is known that long term movements of structures and constructions can be monitored using topographical instruments. Measurements are taken over minutes, hours, weeks, mounts or years to a number of targets to measure settlement, displacement or long term permanent or specific deformations. At the "Politehnica" University of Timisoara in Department of Land Measurements and Cadastre one of research area is concentrated on the dynamic deformation of structures. Monitoring equipment includes precise and modern instruments like leveling, total stations GPS. A recent research about a structural bridge was measured and studied by the authors on the Power thermal Central (CET South) in Timisoara included the use of integrate system GPS / TPS Leica 1200 form by robotically total station and a RTK GPS system. The total station results are compared to the GPS data. Outlined in this paper are the results from total station measurement and GPS sessions of the structural bridge.*

Keywords*: displacement, integrate system GPS / TPS, movements, monitoring, dynamic deformations.*

1. Introduction

The development of measuring techniques has permitted and created the possibility to observe and emphasize the behavior of the studied buildings. There are loads of classification criteria's methods of research and observation of buildings and structures.

Taking about this into consideration, there have been developed criteria's made by types of deformations, types of equipments and place where the equipments are situated during the observations.

By the place where equipment are located during the observations process there are two possibilities to determine the movements and deformations:

- physical methods: with the equipment located inside the building; in this case the equipment move at the same time with the building so relative movements and deformations can be evaluated.
- geometric methods: in this case, the equipments are placed outside the building or of its influential area, the measurements will be linked to a network of fixed points situated outside of the deformation area of the factors that can affect the building and the foundation ground that it is situated on.

Through this process will be established absolute values of the horizontal or vertical movement. The topographic-geodetic methods belong to this category of determinations of movements and deformations.

Monitoring the dynamic behaviour of large structures has been always a topic of great relevance, due to the impact that these structures have on the landscape where they have been built.

Many instruments and surveying methods have been used in order to support the control of these structures. However, the main aim in most of the developed plans has been to ensure the possibility of measuring displacements in a singular number of points. The difficulty in the measurement of these displacements is to find a spatial measurement technique that respond to a numerous properties, such as, precision, reliability, low cost and easiness to use.

Some of these advantages can be seen in several methods, but it is really hard to find a method compromising all of them. In the next paragraphs some of the approaches developed in this context are reported (starting with the classical techniques and finishing with the new technologies).

2. Different styles and multicritteria approach to determining building deformations

Over the years specialists in measurements developed techniques and technologies to estimate correct, accurate and precise structures movements. These techniques are presented as follows:

- Classical topographic methods based on angles, distances and height variation measurements are very popular in the quantitative surveying field. The equipment used consists of accurate and appropriate theodolites or total stations. When the point that has to be determined is inaccessible, indirect methods are used, for example: single or multiple intersections.

Furthermore, contact sensors can complete these measurements, such as: an inclinometer, a pendulum, dial gauges or extensometers. However, this contact nature prevents them from use at the final stages of destructive load testing, and they can only acquire measurements in one dimension.

- The Global Positioning System (GPS) has been used in structural monitoring of large structures with considerable range of displacements, as well as combined with other sensors. In spite of this, GPS has two significant limitations, as well. Firstly, as signals are received from satellites, coordinates cannot be measured indoors or through above obstacles. The second limitation is that the current precision levels of GPS are limited to +/- 1cm horizontally, and +/- 2cm vertically.
- Digital close-range photogrammetry has been an alternative, and is highly accurate. It also offers a quick, remote, three-dimensional data acquisition with images that provide a permanent visual recording of the test, but the compulsory use of targets might be disadvantageous in some circumstances; especially when the access to the object is risky or when it is inaccessible to operators. Due to the lack of scale definition in the photogrammetric process, measurements must be taken by using additional instrumentation.
- Terrestrial Laser Scanning has become a new alternative to the monitoring of structures incorporating novelty approaches and computer methods. Although the approaches noted above present an accurate modelling strategy and have demonstrated their viability for structural monitoring, none of them has been tested yet over complex structures such as large and high structures. The reported analysis focuses on two main problems: the first one is the accuracy and the stability of georeferencing, which is fundamental to make comparisons between different multi-temporal scans; the second one is the computation of deformation based on the acquired point-clouds. Particularly, a comparison is performed using different surfaces types, such as: resample point cloud, mesh and polynomial surface.

Determination movements and irregularities of an object in the primary analysis requirements strains in relation to time and space. Current development of constructions, imposed the need to monitor changes and possible displacements. In this sense becomes critical to analysis behaviour of objects such as bridges, dams, towers, buildings with a high pitch, not only in terms of phenomenology, but also as a result of processing and the inclusion of cases in these models of analysis.

Representation of deformations as a function of time schematic it can be seen in fig. 1:

Phenomenon During	Phenomenon type	Characteristics	Evaluation methods
0.01 s	OSCILLATIONS	Oscillation from own machines	Continuous measurement
1 s		Oscillation from own construction	Continuous measurement and specific geodethic methods
10 s	SHORT TIME MOTIONS	Strains under the demands dynamic short	Geodethic methods, fotogrametric methods, satellite methods
24 h		Strains under the demands dynamic long	
10 yars			Geodethic methods, fotogrametric methods, satellite methods
100 years	LONG TIME MOTIONS	Tectonic movements Movements of the earth's crust	

Fig.1. Schematically representations of deformations and the methods used to determinate movements

3. Aprioristic knowledge of a certain deformation model

During the determination of a deformation, we will always find a cause that through a transmitting function will lead to the effect.

The transmitting function is expressed through mathematical relations, is part of the statistics category, we cannot be sure of what is going on just with a certain probability we can find a relationship. The effect is always the deformation, defined as a spatial modification.

The role of geodetic tracking networks is to observe and determinate whether or not movements or deformations to a certain building occurred. Usually there is initial information of the movements that interest us or of movements critical to an object.

The precision and integrity of the apriorical knowledge on the behaviour of the building are differentiated, but the base parameters for a deformation model that must be taken into consideration are:

- representative points;
- the delimitation of the information domain;
- the evolution in time of the movements;
- the direction of the studied movements;
- size of the movement.

After every measuring cycle a different type of information model appears, that must be verified or modified. Often the aprioristic knowledge and every modification of the model influence the configuration of the network as well as the observation program, thus taking birth an interactive effect between measurements and model. Schematically it's presented in figure 1 types of movements and types of measurements for different type of movements and oscillations.

4. Performance and some technical specifications of used equipment

The precision and technical specifications are different for total station and GPS system. So for total station we have:

- Angle and distance measurement (IR-Mode):

TCRA1205+’s precision angle-measurement system operates continuously providing instant horizontal and vertical circle readings that are automatically corrected for any “out of level” by a centrally located twin-axis compensator. The coaxial EDM uses a visible red laser, has various measuring modes, and measures to prisms and reflective tape. The range is excellent – 3 km to a single prism – and the accuracy superb –1mm + 1.5 ppm

- PinPoint – reflectorless EDM (RL-Mode)

PinPoint is the ideal tool for measuring to wall corners, inaccessible objects, facades, rock faces, roofs and walls inside buildings, in fact to anything at which it is difficult to set up a reflector. PinPoint’s tightly bundled laser marks the point exactly with a small red dot. Measurements are taken instantly and directly (no complex routines measurement). And with PinPoint you can also take very long distance measurements to prisms. Very small laser spot, marks the point exactly Accuracy 2mm + 2 ppm.

Fig. 2. Studied structure and used instruments

- Automatic Target Recognition (ATR / LOCK)

With ATR, you only need to point roughly and take measurement; TPS1200+ hen fine points to the center of the prism and measures, all fully automatically. In LOCK mode TPS1200+ remains locked onto the reflector and follow it as it moves. Measurements can be taken at any time.

For GPS mode some specifications for smart pole are presented as follows: SmartAntenna as stand-alone rover when not on SmartStation, the SmartAntenna can be used with the RX1250 as an ultra light, fully fledged SmartRover. Use it on a pole as an RTK rover or on a tripod for logging data and post processing, with all the capabilities and performance of GPS1200+. RTK communication devices. There is a wide choice of communication devices with SmartStation. Radio modems, GSM, GPRS and CDMA modules fit neatly into a small, waterproof, clip-on housing (Figure 2)

5. Dynamic models to determinate movements of structure

The vehicle that runs on the route is a “Vehicle for taking and staking coal” with a frequency of 1200 t/h, type T 3214, having an arm 35 m long and weighing 460 tons.

The foundation land is made from a succession of sandy grounds that have the density ID = 0,47 ... 0,56. These values of the density correspond to a state of mid density of foundation.

After the first topo-geodetic measurements in 2006, we have established the difference between rail A and B, presented in table 1 as maximal and minimal values Table 1.

Table 1 Minimal and maximal values

Measur. cycle	Line	Horizontal Deviance mm		Vertical Deviance mm		Escarpment Deviance mm
		Int.	Ext.	Min.	Max.	
I	A	-45	+30	-14	-169	-36
	B	-36	+28	-14	-196	+15
II	A	-54	+43	-14	-177	-40
	B	-41	+33	-14	-213	+19
III	A	-58	+46	-14	-182	-40
	B	-46	+37	-14	-215	+22

As it can see the difference in horizontal plan and in vertical plan is significant, so we did measurement with GPS in RTK model to establish deformation and compare with measurements with total stations. Also with GPS technology the number of target point are significantly larger and the results are closer wit reality from the ground.

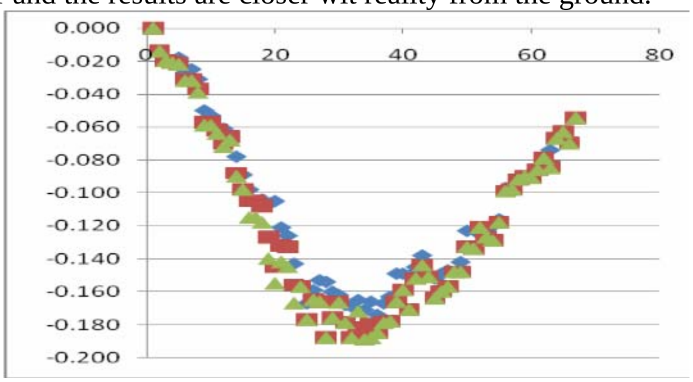

Fig. 3. Statistical representation of settlements of A track

In figure 3 it can see statistical representation of deformation in vertical plan. Also the dynamic movement of the structure is was measurement and represented in figure 4. The value of this deviation is very small being of order tents of mm.

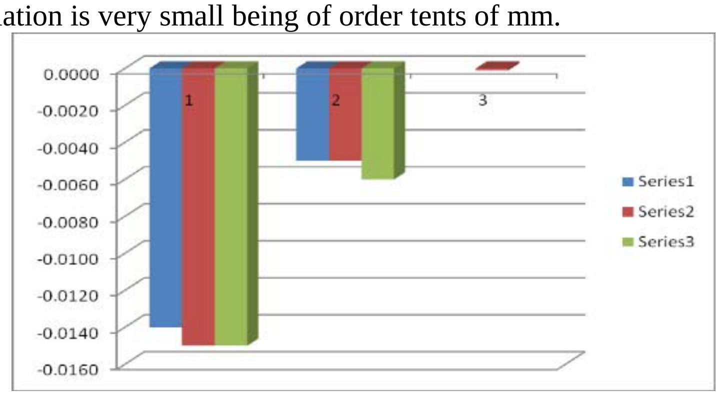

Fig. 4. Representation of instant settlements

The deviations in horizontal plan are more concluding in booth methods and it is presented in figure 5.

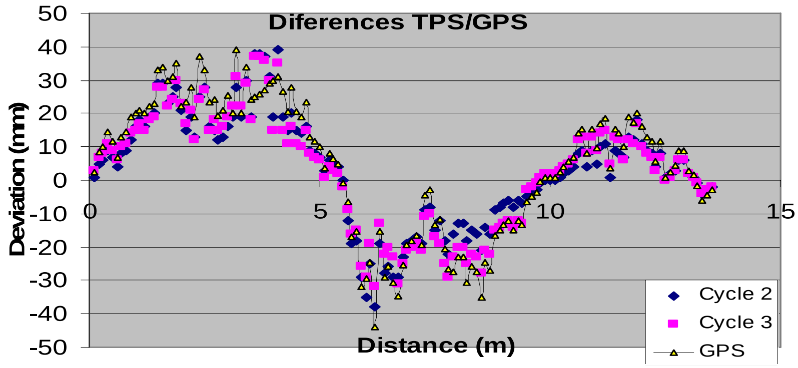

Fig. 5. The displacement measured by GPS and Total Station 150150

6. Conclusion

The topographical methods used to determining vertical and horizontal movements are the most accurate methods for evaluated real deformations and inducted security exploitation.

The tests executed have shown the necessity of a modern approach based on different quality reports according to the precision factors evaluated and characteristically elements of the error ellipsis for the monitoring network points.

From the results presented it can be seen that measuring the slow dynamic deformation is possible.

The total station resolved from the trial in the dynamic way with a moving machine were in appropriate domain compare with the results that were obtained from GPS for horiyontal plan.

7. References

1. *Roberts G. W., Meng X., and Dodson A H., Structural Dynamic and Deflection Monitoring using Integrated GPS and Tri-axial Accelerometers, Proc ION GPS 2000, 13th International Technical Meeting of the Satellite Division of the Institute of Navigation, Salt Lake City, USA, September 2000.*
2. *Dodson A. H., Meng, X. and Roberts, G. W., Adaptive Methods for Multipath Mitigation and Its Applications for Structural Deflection Monitoring. International Symposium on Kinematic Systems in Geodesy, Geomatics and Navigation (KIS 2001), Banff, Canada*
3. *Herban, S. -Procedee şi metode topografice de urmărire a tasării construcţiilor- Zilele academice Timişene -2001*
4. *Neuner J., Sisteme de pozitionare globala, Ed. MatrixRom, Bucuresti, 2000*
5. *Herban S., General considerations regarding the methods in determining deformation in construction, Scientific Buletin of the "Politehnica" University of Timisoara, tom 51(65), 2006, pp.71-74*
6. *Herban S., et.al., UPTimisoara, Complemente de Masuratori Terestre, Ed.Politehnica, Timisoara, 2006*
7. *Herban S., Developing Models in the study and the traking of movement of buildings, Journal of Geodesy and cadastre, nr.7/2007, pp.33-40*
8. *Manual, Leica Geosystems, Switzerland. [online]. Available at: http://www.leicageosystems.com/civil/application.htm [1st October 2008]*