THE NEED TO IMPLEMENT CONSTRUCTION DEFORMATION SPATIAL MONITORING SYSTEMS IN ROMANIA

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Abstract: *Today, due to the "revolution" in the terrestrial measurements technology in recent years (GNSS technology, robotic total stations, 3D terrestrial laser scanners, a tilt sensor, etc.) monitoring the in situ behaviour of constructions, in real time, by using deformation space monitoring systems has become a certainty. This paper presents two such deformation monitoring systems and the arguments that support their implementation in Romania.*

Keywords**:** *deformation monitoring, in situ behavior of constructions, spatial monitoring systems, GNSS technology.*

1. Introduction

It is known that in Romania the monitoring work of *in situ* performance of buildings is regulated by *Law no. 10/1995 on construction quality*, as amended by Law no. 123/2007, which specifies that "monitoring the behavior of constructions in operation is made throughout the duration of their existence" as well as other laws, standards and regulations.

All the legislation in force stipulates that if for the buildings operated under normal conditions, without special risks, such as the civil, industrial, agricultural, art works etc., the monitoring period is three to four years shorter, until fading away of deformations and displacements is found, and the construction stabilizes, while in time monitoring the behaviour of massive structures (dams, locks, viaducts, etc.) operated under special environment conditions are carried out throughout the period of their operation.

When special events occur, e.g. a big or very big earthquake, resumption of emergency measurements of in time behaviour monitoring, at least of massive constructions is required, in order to avoid the danger of a disaster, by taking urgent measures, such as remedying any defects or warning and rapid evacuation of the population.

Making a new measurement cycle through the classical known geodetic methods (which provide high precision measurements and indicate the absolute sizes of deformations) involves a series of stages that can not be avoided (moving specialists to the objective to be monitored, actual performance of measurements and processing them etc.), which automatically implies a certain period of time required to prepare technical documentation and reach some relevant conclusions, which, in the above mentioned case, the occurrence of an earthquake of significant magnitude, could be much too late, a fact which could be avoided, however, by the use of automatic systems of spatial monitoring of land and buildings deformations.

To prevent the damage of buildings and to restore in case of necessity their aptitude for operation, a careful and constant monitoring, in real time is necessary, which is possible only by implementing some Spatial Monitoring Systems of Deformations.

2. Spatial Monitoring Systems of Deformations

In the world, as a result of a spectacular development in recent years of measurement devices and technologies, various objectives that require monitoring in situ behaviour have been equipped and monitored with modern equipment and technology, to mention e.g. just two of these objectives monitored since the early 2000s: *Hoover Dam in the U.S.* (monitored by GPS technology Trimble 4800, GTS 312 total station, laser scanners 3D Riegl LMS - Z 210, U.S. production) and the *London Millennium Bridge* (monitored by the technology of company Leica, i.e. GPS or SR 510, total stations TCA 2003, motion sensors and laser scanners Cyrax 2500) etc.

Next, two of the spatial monitoring systems currently available on the market are presented.

2.1. The Leica GeoMoS system of land and buildings displacements and deformations spatial monitoring

Leica Geosystems company has created a software specialized in automatic monitoring of deformations, called Leica GeoMoS [4], the suggested system being a very flexible and customizable one, able to combine geodetic instruments (total stations, GNSS antennas / receivers, 3D terrestrial laser scanners) with tilt sensors, geotechnical and meteorological sensors (temperature and pressure) able be used to monitoring deformation of dams, tunnels, bridges, tall buildings, as well as monitoring landslides etc.

Leica GeoMoS software includes an *online application* **-** *Monitor*, responsible for the control of sensors, data collection, from sensors included, and calculating the data received, operating as a management system of the occurred events (i.e. collecting information, working them out and sending them in real time), but also an *offline application – Analyzer*, responsible for visualization, analysis and data postprocessing. Besides the two main applications, the Leica GeoMoS software also includes an *adjustment application* **-** *Adjustment*, which gives the user both simulation possibilities in the monitoring network and the possibility to make decisions based on statistical optimization and data validation.

Leica GeoMoS stores all measurements and results in a SQL type database. Data can be accessed both locally and remotely, using GeoMoS Leica Analyzer and GeoMoS Leica Adjustment.

Leica GeoMoS provides communications solutions via M-Com Leica series or standard accessories. Leica M-Com series offers easy, reliable installation and communication possibilities to make the connection between sensors and multiple external devices. In addition, Leica GeoMoS also includes a TCP port / IP communication interface to support Ethernet technology and mobile networks. Leica M-Com Leica includes ComBox10/20 and Leica MonBox30. Leica Combox provides sensors to connect from the field to the Internet. In order to maintain the monitoring system in operation also during possible disconnections from the Internet, Leica MonBox allows Leica software to run on an integrated, embedded computer.

The main features of Leica GeoMoS software are great flexibility in choosing the monitoring equipment and method, storing information in a SQL type database, the parallel use of multiple sensors, a wide range of communication technologies for the control of sensors and data acquisition, creating a total station capable of measuring accurately at a distance (up to 8 km, with Leica TCA 1201M), editing and reprocessing data from the sensors, information import / export in different file types (ASCII DXF, WMF, standard Excel formats), automatic backup and archive, export XML files for the GeoMoS service users.

Leica GeoMoS suggests three types of spatial monitoring systems [4] i.e. the simple system, the advanced system and the intelligent system (Figure 1, 2 and 3):

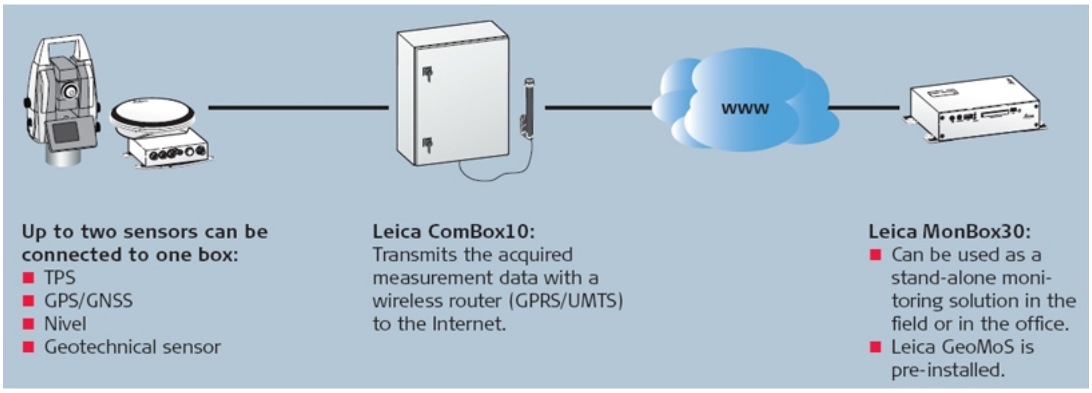

Fig. 1. The simple spatial deformation monitoring

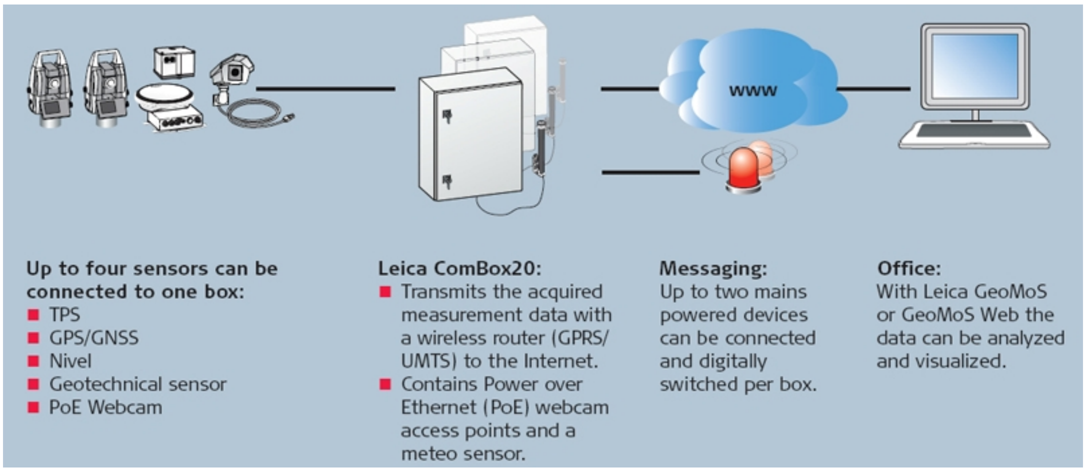

Fig. 2. The advanced spatial deformation monitoring

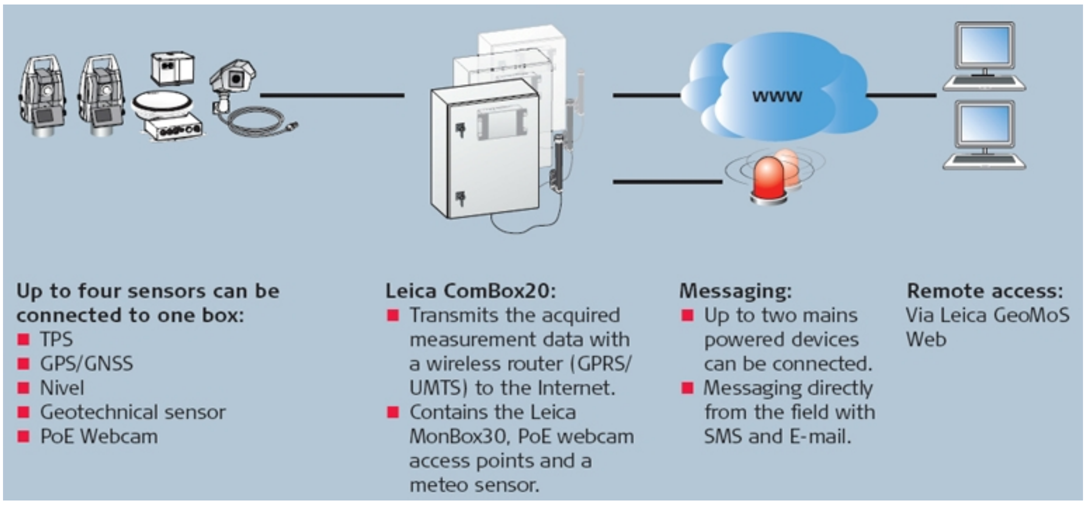

Fig. 3. The intelligent spatial deformation monitoring

A Leica Geosystems monitoring system (Figure 4) [4] can include various monitoring equipment used in data / measurements collecting, of which the user can choose the optimal device and method for deformation monitoring: Leica TM50, Leica TS50 Leica TM30, Leica TS30, System 2000 etc.

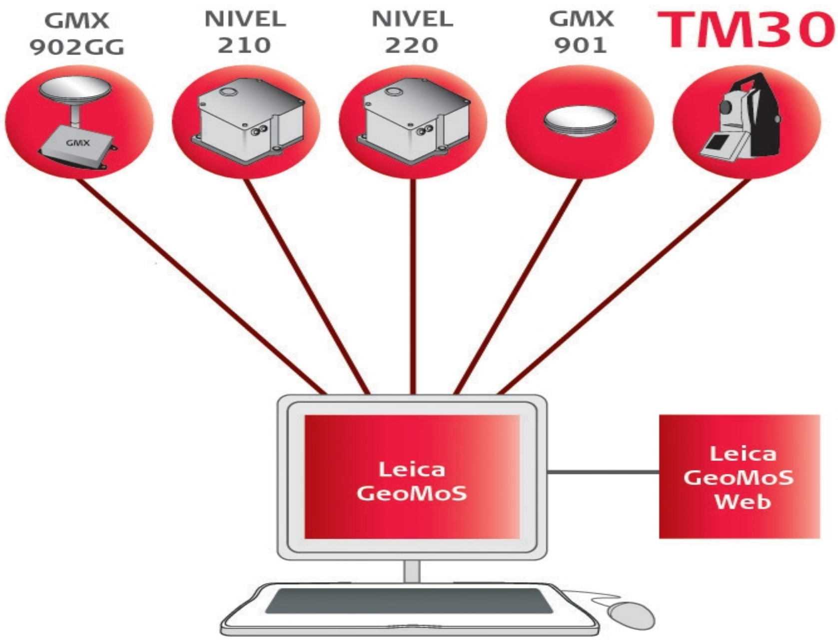

Fig. 4. Schematic diagram of a Leica GeoMoS system for spatial monitoring

2.2. The GOCA system of spatial monitoring of land and buildings displacements and deformations

The GOCA system of spatial monitoring (**G**NSS/LPS/LS **O**nline **C**ontrol and **A**larm System) [3], which is based on GPS/GNSS measurements and is automatically connected to alarm systems, has been developed based on a research and development project conducted at the Survey and Geomatics Department and at the Institute of Applied Research (IAF) by the University of Applied Sciences Karlsruhe, under the guidance of Prof. Reiner Jäger. The suggested system uses GNSS measurements / observations (obtained from existing global satellite navigation systems), LPS (local positioning systems, such as total station and surveying instruments) and LS (local sensors, such clinometers) for online monitoring of studied area movements (Figure 5) [3].

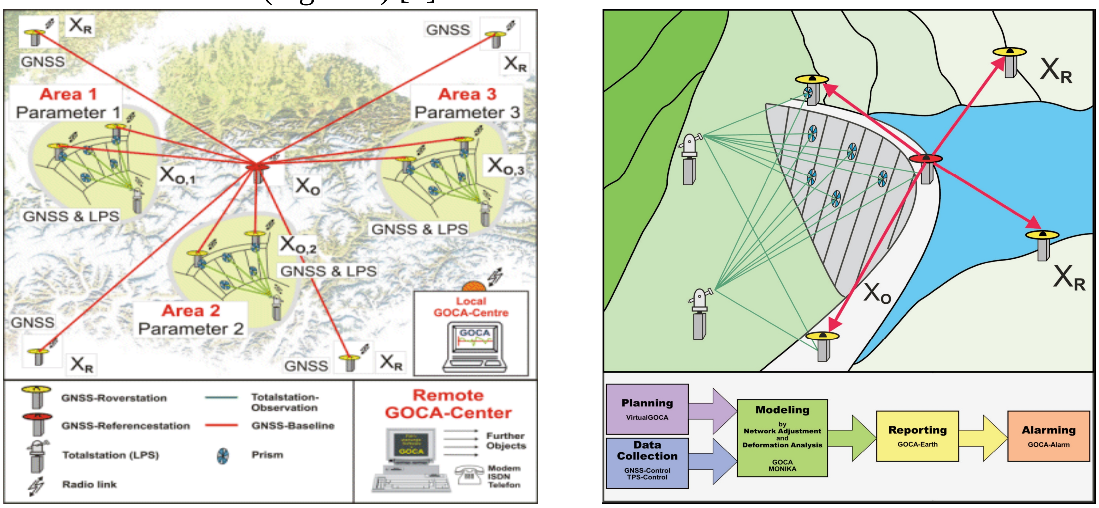

Fig. 5. Equipping objectives with sensors for online deformations monitoring online

Besides construction monitoring, GOCA system can be successfully used for applications in natural disaster prevention (landslides monitoring, volcano monitoring, earthquake prediction), the system being basically designed for online monitoring and alert when circumstances require.

GOCA Monitoring System suggests: on-line modeling from a classical monitoring network, collection and visualization of time series data, either directly from the GOCA-Center, or from a remote station, filtering and time series analysis and alarm automatically, when the monitored objective situation requires.

GOCA monitoring system consists of the following components: hardware for GNSS/LPS/LS sensors and communication hardware, hardwarecontrolsoftware and GOCA-Deformationanalysis-Software.

GOCA software is designed for the classical type of monitoring geodetic network, where the objects geometry is described the in a system of coordinates which is not influenced by the deformation process of the studied area, this coordinate system being represented by the stable reference points located in the area, as well as by the object - points, that are located in areas with the possible deformations of the monitored objective. To ensure a stability of the reference system for each observation epoch / cycle, the GOCA system concept includes detecting reference network points that become unstable, which is possible by using the Deformationanalysis application (Figure 6) [3].

As components of a GOCA matrix, GNSS sensors may be used just the same as total stations. If GOCA-Software-Deformationanalysis is responsible for processing and analysis of data from the sensors, the GKA application is responsible for communication between the GOCA-Deformationanalysis-Software and the components sensor. GOCA monitoring system works basically as an alarm manager system, being able to also make predictions on possible displacements and / or deformations of monitored objective (Figure 7) [3].

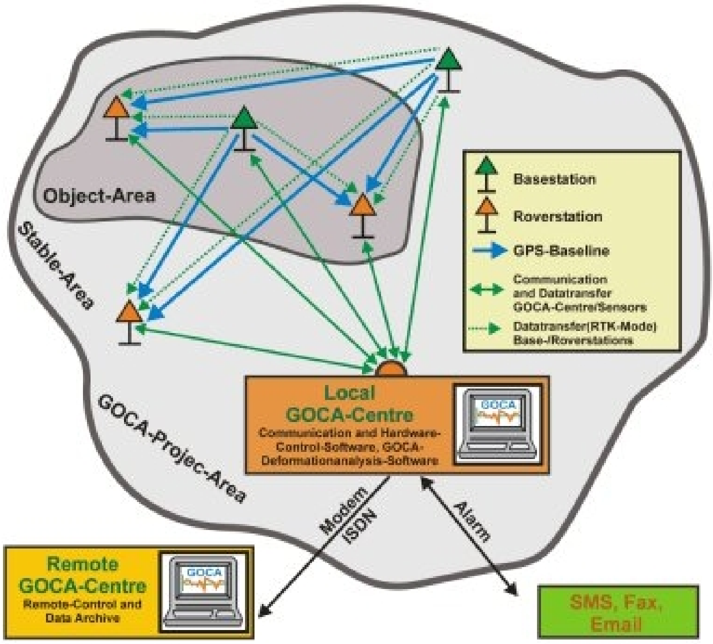

Fig. 6. Schematic diagram of a GOCA system for spatial monitoring

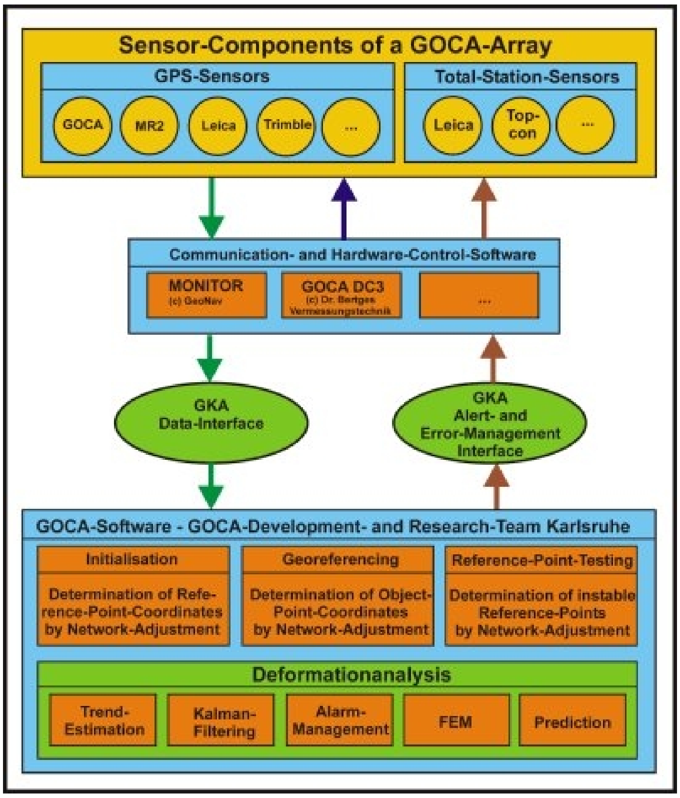

Fig. 7. The GOCA system of deformations spatial monitoring

The GOCA monitoring system software automatically generates a series of graphs, that show the evolution of the horizontal and vertical displacements of mobile points (mobile sensors) installed on the monitored objective (Figure 8) [3].

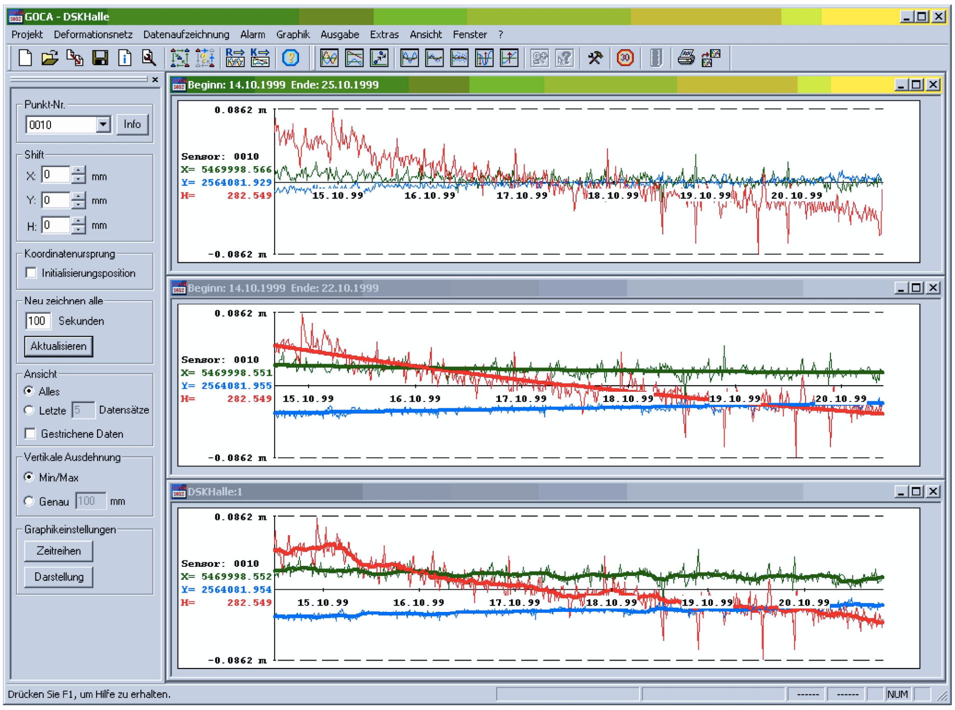

Fig. 8. Graphs with the displacements of sensors mounted on the monitored objective

3. Conclusions

Due to the continuous development of measurement and data processing technology, monitoring the *in situ* behaviour of constructions, in real-time, using spatial monitoring systems, became a certainty.

The existence of such spatial monitoring systems, also called deformations monitoring manager systems, allows taking urgent action in extreme cases, such as remedying of some defects or warning and rapid evacuation of the population in case of a high intensity or very big earthquake, avoiding thus the danger of some disasters.

Given the fact that the usefulness of such spatial monitoring systems of deformations can not be questioned and given the obligation of *in situ* behaviour monitoring throughout the operation duration of massive constructions, according to the legislation in force, those responsible for monitoring the behavior in time of objectives covered by specific legislation, should most seriously put to the problem of implementing in Romania, too, such spatial monitoring systems of land and buildings deformations. Even if the initial investment would need a consistent financial effort, in the long run, the costs linked to deformation monitoring can be reduced significantly.

The purpose of *in situ* behaviour monitoring of constructions being to obtain the necessary information in order to ensure normal operation ability for constructions and to evaluate the conditions for the prevention of incidents, accidents and damages, i.e. reduce material damages, avoid human life loss and environment degradation, a careful and ongoing monitoring, in real time of these is required, i.e. a systematic monitoring of the technical condition and performance evolution, accompanied by interventions to maintain or rehabilitate the ability for operation, which is only possible through the implementation of Spatial Monitoring Systems of Deformations.

4. References

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