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МОНИТОРИНГ НА ИНФРАСТРУКТУРНИ СЪОРЪЖЕНИЯ – МОДЕРНИ МЕТОДИ И ПЕРСПЕКТИВИ

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MONITORING OF INFRASTRUCTURE FACILITIES – MODERN METHODS AND PERSPECTIVES

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Abstract:
Sustainable trends for the introduction of modern automated methods for monitoring large complexes of infrastructural facilities, based on modern technological achievements, the development of information technologies and artificial intelligence, are considered. Examples of automated monitoring systems implemented in leading industrial countries during the construction of underground facilities and bridges are shown.

Keywords:
Bridges, Tunnels, Infrastructure facilities, monitoring methods

1. INTRODUCTION

In last years, it is increasingly required to build infrastructure facilities and other major structures in the conditions of a highly urbanized environment with dense construction and intense underground and above-ground communications. Limited space and difficulties, and often the inability to limit the functions of infrastructure and the normal functioning of intensively built urbanized territories in cities and industrial areas, require the execution of transport tunnels, bridges, engineering facilities related to water farm, near each other or even with intersecting routes, as well as in the immediate vicinity or even under existing buildings and facilities. Solving complex problems during implementation requires monitoring of existing surrounding buildings and facilities for deformation, as well as the facility itself. The development of technology also creates opportunities for the installation of sensors in the elements and nodes of structures that allow lifelong monitoring of large -scale buildings and facilities.

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2. MONITORING OF FOCILITIES DURING THE CONSTRUCTION

The manuscript title is centered at the top of the page in 16 pt bold, all caps. Keep titles brief and descriptive. Spell out acronyms unless they are widely known. Avoid starting with articles or prepositions, e.g., “The study of … ,” or, “On the ….” . In most infrastructure projects, the idea of the monitoring is starting in planning and in the design of the structure, it is a key part of the project and begins during the construction of the facility, in most cases related to the construction stages. The deformations that occur during the construction of each stage are measured in order to define the necessary security and quality of construction works, check their limit values, etc.. During the construction of the bridge structures, a permanent monitoring of the realized deflections and displacements and strains in the structural elements is carried out. In the general case, in this type of structures, the known geodetic measuring devices, electronic tachometer, optical levels, etc. are used.

During the construction of subways and other underground transport communications, in some cases it is necessary to build subway stations, and in the process of their construction, tunnel boring machines must pass through them. This is the case with MS 8 (Metro Station 8) of the third metro line in the city of Sofia (Fig. 1). During the construction of the permanent support structure of the station, it was necessary to pass the tunnel boring machine through it. Due to the entry of the reinforced concrete slab of the vestibule into the track gauge of the tunnel boring machine, it was not possible to cast the concrete slab. Because of this it was necessary to build an additional steel structure on which the vertical supporting towers of the formwork of the upper slabs of the station would be supported. During the construction of the station, the tunnel boring machine with all the communications and installations serving it passes under the steel suporting structure, and the metro station is also an entrance to the tunnel sections, executed by NATM (New Austrian tunnelling method). In order to provide the necessary degree of safety and guarantee the quality of building, monitoring is systematically carried out in each sub-stage of construction. For this purpose standard geodetic equipment and corresponding methods are used.

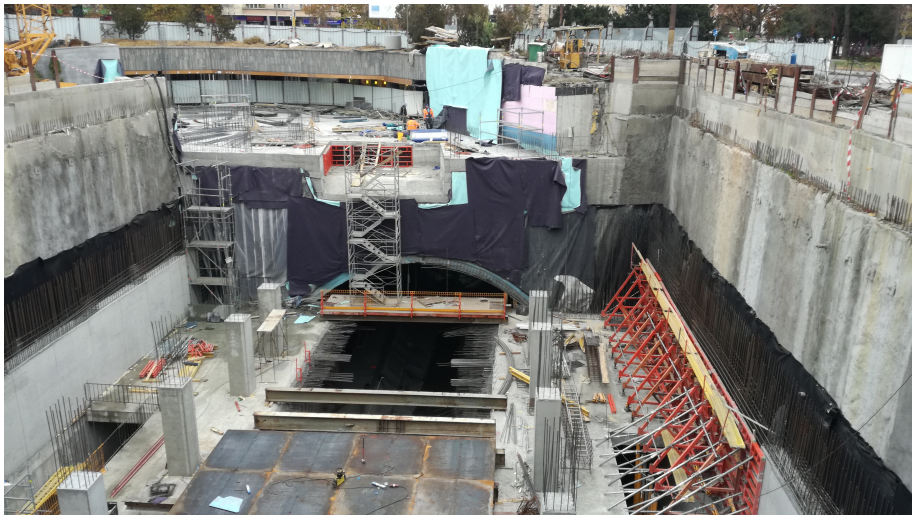

Figure 1. Display and use of automate Temporary support structure in the construction stage of MS 8 – III Metroline before the TBM passing up the station

During the execution of tunnels, a wider monitoring program is required, and in the project, in addition to the measurement of the deformations inside and outside the tunnel, the use of more measuring devices is required, such as the implementation of inclinometers in boreholes, devices for measuring the water level, etc. The monitoring of a facility and the defined

additional criteria are directly related to its specificity and location. Because of this is necessary to monitor the ground surface in the critical zone of the constructed facility including critical buildings, facilities and installations.

By tunnel constructions there are defined criteria for monitoring and recommendations for the use of the respective measuring technique, depending on the measured deformations and strains, and are mainly defined into two main groups [2] (Fig. 2).:

- Measurement of deformation on the surface of the earth and existing buildings and facilities;
- measurements of deformations in the tunnel and in tunnel ground [2].

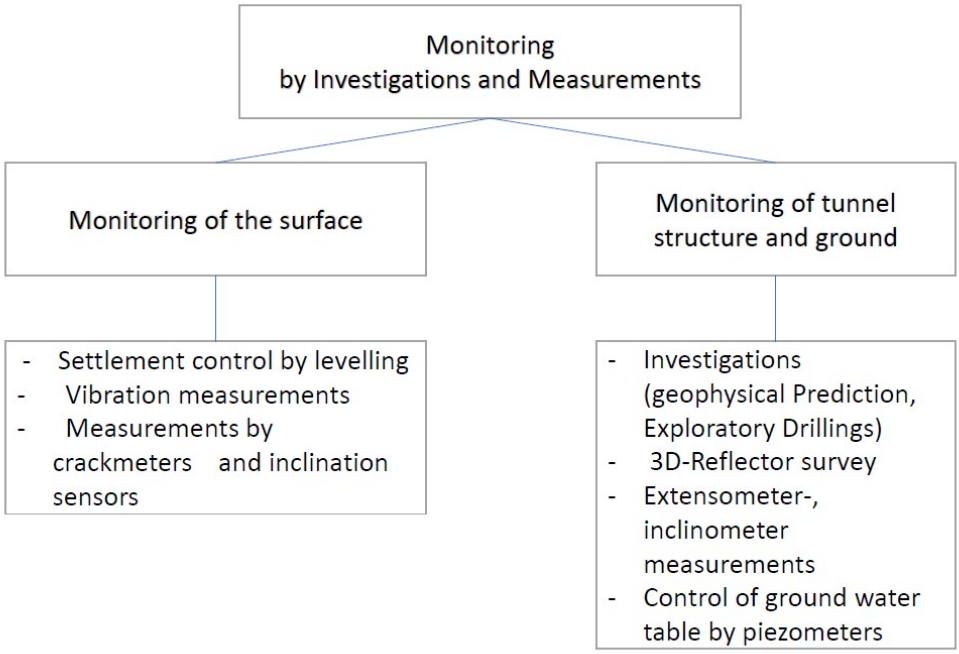

Figure 2. Main monitoring groups and their types according to [2]

3. MONITORING OF SURROUNDING BUILDINGS AND FACILITIES

During the construction of the bridge structures, a permanent monitoring of the realized deflections and displacements and strains in the structural elements is carried out. In the general case, in this type of structures, the known geodetic measuring devices, electronic tachometer, optical levels, etc. are used. During the construction of tunnels in urban areas, monitoring of the surrounding buildings and facilities are required, and the criteria defined for tunnel projects located in mountain ranges and in urbanized areas are significantly different [1]. In the construction of tunnels in mountain territories, the established criteria must ensure that no significant deformations will occur in the earth's ground , which would lead to destruction, collapses, landslides inside and outside the tunnel. In urban areas, additional monitoring of the surrounding facilities is required, therefore in [2] the types of monitoring are separated and stricter criteria are defined.

In the construction of urban tunnels, such as subways and metro tunnels, metro stations, the contracting authorities set criteria for the scope of the influence zone, in which given buildings and facilities fall, which are subject to monitoring [3]. Before the start of the

construction activities, an assessment is made of the condition of the relevant buildings and facilities falling within the active zone. Based on the assessment of the state of the buildings, a monitoring project is prepared, in which the number and type of sensors, the methods and methods of the measurements are determined, so as to ensure the maximum reliability and safety of the buildings and facilities falling into the critical area . In most cases, geodetic devices and methods are used to measure the deformations, detailed and described in [4].

Table 2. Classification of damages in buildings [3]

Risk category	**Degree of damage**	**Description of typical damage**	**Crack width [mm.]**	**Relative extension (%)**
0	insignificant	Cracks, like a hair		<0,05
1	Very light	Small cracks on the inner walls, Cracks in the exterior masonry	0,1 to 1	0,05 to 0,075
2	mild	Cracks easily removed. A few minor breaks on the interior of the building, Visible external cracks	1 to 5	0,075 to 0,15
3	Intermediate	Cracks may require additional treatment prior to grouting with appropriate means. Small repairs to the exterior masonry are possible. The doors and windows are nagging. Damages and interruptions are possible in the internal electrical and VIK installations. The insulation against atmospheric influences has been broken in some places	5 to 15 or more than 3	0,15 to 0,3
4	heavy	Major repairs that include restoration of sections of walls, especially shutters above doors and windows. Door and window frames are warped. The floors and walls are visibly tilted, the supports of the load-bearing beams are broken in places. The VIK installation has been interrupted	15 to 25, but also depends on the number of	>0,3
5	Very heavy	The damage is very serious and requires partial or major repair. Loss of supports in some beams, dangerous wall slopes, re-supporting required. Broken windows and window frames. Danger of building collapse due to loss of stability.	Usually more than 25, depending on the number of cracks	

4. LIFECYCLE MONITORING OF FACILITIES

In addition to monitoring during construction, with the development and continuous improvement of technology and the drive to optimize infrastructure maintenance costs, more and more lifetime monitoring systems are introduced and developed to be implemented in infrastructure projects. There are now effective software and hardware systems for monitoring almost all types of infrastructure facilities, such as bridges, tunnels, dams, etc. Different monitoring approaches depending on the type of facility are described in [5].

5. MODERN TRENDS

In the construction of some infrastructure projects, automated monitoring systems are applied. In some projects in Germany, when passing under bridges with tunnels, hydraulic pumps are placed in the area of the bearings, which compensates for the deformations in the upper structure of the bridge due to the passage with a tunnel in the area of the given facility fig. 3.

With the development of software and artificial intelligence, the application of digital twins has appeared and is rapidly entering the monitoring of infrastructure objects. Similar to the rest of the industry, for large bridges, tunnels, large sports facilities, tall buildings, etc. the implementation of digital twins is observed, and the technologies for their construction are already improving. In Germany, digital twins are implemented with pilot projects [6], through which the effect of their implementation is seen, as well as some specific problems that arise in a real environment [9].

Figure 3. Monitoring of a bridge with hydraulic bearings to compensate the deformations in the joints.

In addition to monitoring the facilities themselves, artificial intelligence is also used in the monitoring of facilities falling into the active zone during the construction of city tunnels and metro stations. This greatly eases the needed time to react when risky deformations are reached, by performing qualitative and rapid control over the observed structures [7].

An example of the use of a digital twin is a bridge in Hamburg, whose pilot project is described in [8]. In the specific project for the monitoring system, an artificial intelligence is also being developed, which is trained to recognize and analyze the current state of the structure. In order to ensure a maximum real assessment of the condition of the structure, control measurements and a review by competent engineers are carried out. The aim of the pilot project is to create a monitoring system for all facilities in the city, reducing the costs of inspecting the facilities, as well as improving and speeding up their maintenance.

6. CONCLUSION

With the development of technologies, more and more opportunities are opening up to perform the fastest possible monitoring and assessment of the condition of the facilities from the design, through monitoring the construction and surrounding buildings and facilities during the construction of a given facility to control during its life cycle. This creates an opportunity to design and build more complex structures, ensuring maximum reliability of the surrounding structures and optimizing the relevant construction times. On the other hand, the implementation of these systems is accompanied by corresponding risks and implementation problems that must be taken into account

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