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LONG-TERM MONITORING OF BUILDINGS CONSTRUCTED DURING THE INTERWAR PERIOD

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Abstract: Long-term structural health monitoring (SHM) is a fundamental component in the management of historical buildings, with numerous cases confirming its effectiveness in various urban and structural contexts. The research combines theoretical analysis and field measurements to evaluate the behavior of structures affected by adjacent demolition works. Key emphasis is placed on monitoring displacements and deformations using both classical geodetic methods and modern instrumentation. The study highlights the importance of configuring a coherent monitoring network based on fixed and mobile benchmarks, applying precision geometric leveling, and interpreting results in relation to temporal intervals and structural thresholds. Results from four measurement campaigns, including crack monitoring and total station observations, reveal moderate settlement and minimal horizontal displacements. These findings support the conclusion that SHM, when implemented with rigor and accuracy, is vital for ensuring the safety, durability, and sustainability of heritage buildings.Relevant national and international regulations, form the basis of the technical framework governing structural monitoring practices. By correlating empirical data with theoretical design assumptions and environmental factors, SHM contributes to predictive maintenance strategies, mitigation of urban risks, and the long-term preservation of architectural heritage.

Keywords: structural monitoring, deformation, heritage, crack monitoring, benchmarks

1. INTRODUCTION

In recent decades, the need to protect the built heritage has generated increased interest in implementing rigorous methods for the structural assessment of historic buildings. Among these, long-term structural monitoring stands out as one of the most important preventive activities, playing a key role in diagnosing the technical condition of structures and in supporting decisions related to strengthening, rehabilitation, or conservation interventions. In particular, buildings constructed during the interwar period exhibit significant vulnerabilities due to the absence of deep foundations, the materials used at the time, and the additional stresses caused by nearby construction work[1].

The monitoring of the structural behavior of buildings over time is a fundamental activity within infrastructure management, governed by specific technical standards and national and international regulations. It is carried out throughout the entire life cycle of a structure—from construction to decommissioning—and involves the application of rigorous methods for observing, measuring, and analyzing structural performance in relation to the surrounding environment and technological demands.

The importance of monitoring the structural behavior of buildings over time extends beyond the technical sphere, integrating into the broader framework of sustainable development and efficient urban infrastructure management. This activity plays a crucial role in ensuring the intelligent use of economic, social, and environmental resources, becoming a strategic tool in urban policy and the maintenance of the existing building stock[2].

Against the backdrop of rapid urbanization and the advanced aging of structures built in various historical periods, monitoring systems provide concrete, objective, and continuous data on their structural condition. This enables timely interventions through reinforcement or repair measures before deterioration reaches a critical threshold, thereby avoiding both the high costs of reactive measures and the risks associated with structural failure or forced evacuation[3].

Moreover, monitoring has a significant impact on public safety, especially in the case of essential buildings, where any structural dysfunction can have serious consequences for the proper functioning of the community. The same importance applies in densely populated areas, where the degradation of a single structure can generate cascading effects on adjacent buildings or network infrastructure[4].

The early identification of abnormal behavior or deviations from the original performance parameters significantly reduces the need for invasive interventions, such as demolitions or relocations. This preventive approach supports the preservation of valuable architectural heritage and minimizes the environmental footprint of construction activities, thus promoting sustainability, environmental protection, and circular economy principles in the built environment[5].

The primary purpose of structural monitoring is to ensure the preservation of essential requirements such as safety, stability, durability, and functionality of a building. It provides a framework for validating

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design assumptions and proposed engineering solutions, as well as for the rational planning of subsequent interventions. Furthermore, the data collected through monitoring becomes a valuable resource in the design of future structures with similar characteristics.

Monitoring thus offers an objective view of the actual performance of a structure, enabling technical decisions to be made based on predefined control thresholds: normal values (indicating operation within expected parameters), warning values (signaling the need for intensified observation), and alarm values (requiring urgent remedial actions)[6].

1.1. CLASSIFICATION OF MONITORING AND CONDITIONS OF APPLICABILITY

Depending on the nature, complexity, and functional importance of a structure, the monitoring of structural behavior over time is divided into two main categories, each with specific objectives, methods, and levels of detail: routine monitoring and special monitoring[7].

Routine monitoring represents a fundamental component of construction management and is generally applicable to all types of structures, regardless of their function or location. It involves the periodic performance of systematic visual inspections and basic control measurements aimed at identifying potential damage, cracks, settlements, or deviations from the initial geometry of structural elements. Typically, these actions are carried out using conventional methods by specialized technical personnel and serve to indicate early on the need for maintenance or repair interventions[8].

Special monitoring, on the other hand, is intended for structures that are highly exposed to natural risks (such as earthquakes, landslides, or floods) or anthropogenic risks (such as underground excavations, heavy traffic, or dynamic shocks), as well as for buildings with strategic functions or high cultural and historical value. In such cases, monitoring involves the implementation of advanced technological systems, including high-precision equipment such as smart sensors (IoT), extensometers, inclinometers, accelerometers, displacement sensors, 3D laser scanners, or imaging-based systems (photogrammetry or LiDAR). These systems ensure automated, real-time recording of the structure’s behavior, allowing for the continuous analysis of the evolution of monitored parameters[9].

Through its instrumental nature and high frequency of data acquisition, special monitoring provides a large volume of highly accurate information that is essential in critical decision-making processes. It also allows for the integration of results into predictive models and numerical simulations, contributing to the anticipation of the structure's future behavior and supporting decisions regarding strengthening, rehabilitation, or restricted use[10].

Thus, the choice of monitoring type depends on the structural characteristics of the building, its importance in the socio-economic context, and the specific risks of the site, with the goal of ensuring safe and sustainable use of the structure in all cases.

1.2. DISPLACEMENTS AND DEFORMATIONS RELEVANT TO STRUCTURAL BEHAVIOR

Among the phenomena closely monitored during structural health assessment, displacements and deformations hold a central role, as they are direct indicators of how a structure behaves under internal and external loads[11].

Figure 1. Displacement/Deformation

Vertical displacements represent downward movements of structural elements and typically result from the gradual consolidation of the foundation soil or changes in the hydrogeological regime (e.g., lowering of the groundwater table, water infiltration, or underground accumulation). When settlements are uniform, the entire structure subsides evenly, without generating significant internal stresses. However, differential settlements—variations in vertical displacement across closely spaced points—can lead to local imbalances, causing cracking, uncontrolled rotations of structural elements, distortions, and, in severe cases, the loss of the structure’s overall stability[12].

Horizontal displacements generally occur due to seismic actions, lateral earth pressures (from surrounding soil, fill materials, or water), or vibrations induced by heavy traffic, industrial operations, or other anthropogenic sources. Such displacements can compromise the stiffness of the structural system, leading to shear failures or instability of enclosure elements.

Tilting, a specific form of displacement, involves a deviation from the vertical axis of an element or the entire structure. It often results from uneven bearing capacity of the foundation soil, caused by phenomena such as landslides, geotechnical weaknesses, or localized erosion. Tilting has a significant impact on the redistribution of internal stresses, altering the load paths and increasing the risk of localized stress concentrations[13].

Accurate and continuous monitoring of displacements and deformations enables early detection of structural dysfunctions and provides critical data for strengthening interventions, repairs, or operational restrictions. This information is essential not only for ensuring the safety of the structure but also for preventing irreversible damage and extending the building’s service life.

Deformations reflect changes in the shape or dimensions of structural elements, occurring under the action of internal or external forces. These deformations can be elastic (reversible) or plastic (permanent), and they commonly appear in slender or elongated elements such as beams, columns, or slabs. In-plane deformations, such as bending or buckling, are critical indicators for assessing the serviceability state of a structure[14].

Cracking, material shrinkage, and differential expansion between materials with varying behaviors can generate hidden stresses, which are difficult to detect in the early stages. Such phenomena require precise and continuous instrumental monitoring to prevent major structural failures[12].

By systematically correlating real-world measurement data with the theoretical values established in the design phase and the actual operating conditions, the long-term structural behavior monitoring of buildings assumes a strategic role within the integrated management of structural performance.

This correlation enables a dynamic and contextualized assessment of structural behavior, providing essential information for validating design assumptions, identifying deviations from expected performance, and adjusting maintenance or reinforcement strategies[1].

In the medium and long term, the use of this information has significant implications for user safety, by ensuring that the structure's functional parameters (displacements, deformations, cracks, vibrations, etc.) remain within acceptable limits. Moreover, monitoring contributes to the continuous functionality of the structure, a critical factor for key infrastructure such as hospitals, bridges, power plants, or public buildings, where any disruption may result in substantial losses[6].

Another major advantage lies in the efficient allocation of resources: based on real-time data, necessary interventions can be prioritized, avoiding unnecessary works or the implementation of generalized and costly solutions. Consequently, this significantly reduces the risks and costs associated with emergency repairs, irreversible damage, or loss of functionality. Additionally, monitoring facilitates the transition from a reactive maintenance model to a predictive one, focused on prevention and optimization[10].

1.3. FRAMEWORK OF NORMATIVE ACTS AND TECHNICAL REGULATIONS IN FORCE

The monitoring of buildings throughout their operational life is governed by a well-defined set of legislative and normative instruments that establish the technical requirements, institutional responsibilities, and specific procedures applicable over the entire lifespan of a structure. The primary objective of this framework is to ensure long-term safety and durability by enabling early detection of potential degradations and the implementation of appropriate corrective actions[15].

In today's context—marked by rapid urbanization, environmental pressures, and increasing sustainability demands—regulations governing structural health monitoring (SHM) have acquired strategic importance. These provisions define clear standards for assessing structural performance and require the integration of tailored monitoring systems based on the type and significance of each structure.

Figure 2. Regulatory framework

Law no. 10/1995, as republished and updated, represents the cornerstone of Romania's construction quality assurance system. It establishes the obligations of designers, contractors, and owners throughout the building's lifecycle and incorporates SHM as an essential component of the broader quality management process[16].

A central element of this legal framework is the mandatory preparation and maintenance of the "technical construction logbook", which records all relevant data concerning execution, monitoring, maintenance, and any structural interventions. This documentation serves as an operational decision-making tool for ensuring structural safety and performance over time.

Normative P130-1999 defines the technical requirements for monitoring structures during their service life and operational phase, translating into practice the principles of Law no. 10/1995. Applicable to all building categories, it is particularly relevant for critical structures or those located in high-risk seismic or geotechnical zones[17].

The regulation distinguishes between two types of monitoring: routine monitoring, based on systematic visual inspections, and special monitoring, which involves advanced instrumental methods such as high-precision geometric leveling, GNSS surveys, total station measurements, and the use of displacement sensors or extensometers.

A dedicated monitoring project must be developed for each structure, specifying the measurement methods, observation points, applied technologies, and recording frequency. Results must be interpreted relative to design thresholds; exceedances trigger expert assessments and, where necessary, corrective structural actions.

Code P100-1/2013, aligned with Eurocode 8 (EN 1998), is the national regulatory reference for seismic design in Romania. It includes provisions for the integration of structural monitoring in seismic scenarios, particularly for critical buildings[18].

In such cases, accelerometric monitoring systems are mandatory, enabling real-time data acquisition on seismic response indicators such as base and top-floor accelerations, vibration periods, and signal attenuation.

The code also requires the appointment of a responsible person to analyze the monitoring data, generate behavior reports, and issue recommendations regarding the continued use of the structure following a seismic event. This type of monitoring supports the validation of design assumptions, the improvement of structural models, and the enhancement of resilience to exceptional actions[19].

In today's increasingly interconnected technical landscape, the harmonization of national regulations with international standards plays a pivotal role in ensuring regulatory compatibility, engineering interoperability, and the advancement of a modern, performance-driven professional culture. The adoption of European and international benchmarks—such as Eurocodes and ISO standards (including ISO 4866 on structural vibration measurement, ISO 12494 on ice action on structures, and ISO 13822 for assessing existing structures)—offers comprehensive methodological guidance for evaluating structural performance based on actual monitoring data rather than solely theoretical assumptions.

A significant trend in this harmonization process is the growing emphasis on intelligent Structural Health Monitoring (SHM) systems. These systems are designed not only for data acquisition, but also for automated real-time analysis, anomaly detection, and structural diagnostics. Although the implementation of SHM technologies in Romania is still in a developmental phase, the existing technical regulations—particularly Normative P130-1999 and Code P100-1/2013—already provide a structurally compatible framework that supports such advancements[18].

Achieving full alignment with international standards, however, involves more than legislative adaptation. It necessitates the strengthening of institutional capacities, the development of nationwide monitoring infrastructures, and the establishment of interoperable data repositories. These measures are crucial for enabling informed, technically substantiated decisions regarding building maintenance, risk mitigation, and structural rehabilitation.

1.4. METHODS AND EQUIPMENT APPLIED

The process of long-term structural health monitoring involves the integration of a complex set of methods, equipment, and technologies, regulated and tailored to the specific requirements of each individual project. The corresponding technical documentation mandates the use of solutions capable of accurately identifying positional changes and structural behavior. Monitoring plays a critical role in detecting settlements, displacements, or deformations of structural elements and is indispensable for evaluating long-term stability and operational safety[8].

Depending on the nature of the structure, monitoring methods are classified into two main categories: classical topographic methods and modern instrumental or digital methods. The former include well-established procedures such as geometric and trigonometric leveling, widely used in tracking structural behavior—particularly in the area of foundations. Geometric leveling, especially in its mid-level configuration, allows for precise determination of elevation differences using optical or digital equipment and graduated staffs. The use of invar rods in combination with digital levels ensures high precision and is recommended for monitoring sensitive structures. Trigonometric and hydrostatic leveling complement the suite of classical methods, offering viable solutions for challenging terrain or continuous monitoring of vertical displacements[20].

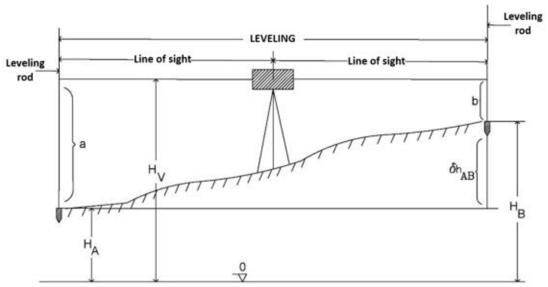

Figure 3. Midpoint Geometric Leveling Principle

In parallel, modern monitoring methods rely on the integration of smart sensors, GNSS technology, robotic total stations, and laser scanning systems. These enable automated data acquisition, real-time analysis, and the prompt transmission of alerts in the event of critical deviations. The use of machine learning algorithms and predictive modeling (digital twins) contributes to forecasting structural behavior and optimizing interventions[21]. However, challenges related to cost, standardization, and system compatibility remain an active concern among professionals.

A central element in the effectiveness of any monitoring system is the support network, composed of fixed and mobile reference points. Fixed benchmarks, located outside the influence zone of the construction site, provide the absolute reference frame for all subsequent measurements. These must be stable, accessible, and well protected. Mobile benchmarks, attached directly to structural elements, allow for direct recording of behavioral changes over time and are essential for detecting settlements, differential displacements, or cracking[11].


Figure 4. Types of Control Points

The success of a monitoring system depends on the rigorous design of the observation network, the precision of the equipment, and the consistent interpretation of the data collected. By integrating these methods and technologies, structural health monitoring becomes a strategic tool for quality management and safety in construction, enabling informed interventions and the prevention of major structural risks[22].

2. PRACTICAL IMPLEMENTATION OF MONITORING TECHNIQUES ON A HISTORICAL SITE

Historical buildings in Romania represent a fundamental component of the national cultural heritage, reflecting the diversity of architectural influences and the socio-economic evolution of different regions over time. These structures, dating from various periods, from the medieval era and Phanariot rule to the modern and interwar periods, stand out through their artistic, urbanistic, and memorial value[23].

Found both in major urban centers and rural areas, Romania's historical buildings include castles, manors, churches, inns, palaces, as well as bourgeois residences and industrial complexes of historical significance. Many of them are built in a variety of styles such as Gothic, Renaissance, Baroque, Neoclassical, Eclectic, or Art Nouveau, mirroring the multicultural and historical context of the Romanian territory.

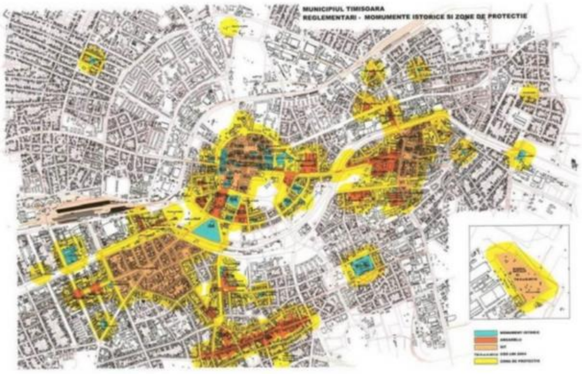

Figure 5. Cartographic Representation of the Historic Core of Timișoara

The central area of Timișoara stands out through its exceptionally valuable built heritage, composed predominantly of historical buildings dating from the 18th century to the early 20th century. Constructed mainly in Baroque, Secession, and Neoclassical styles, these edifices form an architectural ensemble of national and European heritage significance. Clustered around the city's main squares—Union Square, Liberty Square, and Victory Square—they represent not only the cultural identity of Timișoara but also serve as enduring witnesses to its urban and economic development over time[24].

Many of these structures were built in earlier historical periods, having been constructed using materials and techniques specific to their respective historical periods, often without solid foundations as defined by modern engineering standards. Unlike contemporary constructions, which rely on reinforced concrete foundations designed to distribute loads uniformly and ensure seismic resilience, historical buildings were frequently built on shallow or rudimentary footings, such as stone slabs or brick bases, placed directly on natural soil layers. As a result, they are inherently more vulnerable to settlement, ground movement, and structural imbalance[25].

In the current urban context, characterized by frequent interventions such as infrastructure works, partial demolitions, extensions, or functional conversions, these historical structures become particularly exposed to both anthropogenic and natural influences. Therefore, the long-term monitoring of their behavior is critical for preserving their structural and architectural integrity.

The demolition of a building in the central area of Timișoara, regardless of its technical condition, can cause local imbalances in the foundation soil, alter stress distributions, and trigger load redistributions in neighboring structures. Historical buildings adjacent to such interventions are especially sensitive to vibrations, differential settlements, and progressive cracking, which requires close monitoring using appropriate topographic and geotechnical techniques tailored to their structural characteristics[26].

2.1. DESCRIPTION OF THE SITE

The present study focuses on the long-term monitoring of buildings adjacent to a demolished structure located in the historic center of Timișoara, in the immediate vicinity of Union Square, a landmark of Romania's urban architectural heritage. The area under investigation is characterized by a dense urban fabric, predominantly composed of historical buildings erected during the 18th and 19th centuries.

These structures were built using traditional materials and techniques of the time, such as solid brick masonry, timber elements, and lime mortar, construction solutions that, although remarkably durable over time, no longer fully comply with current requirements for structural safety and performance under static or dynamic loads.

Figure 6. Pre-demolition state of the building

The demolition of the central building led to disturbances in the local equilibrium conditions of the foundation soil, resulting in a redistribution of stress within the adjacent built mass. In this context, neighboring structures may be subject to displacement and settlement phenomena, occurring both vertically, due to gravitational effects combined with a potential reduction in soil bearing capacity, and horizontally, through structural relaxation or the loss of lateral support.

The project aims to implement a periodic topographic monitoring system for buildings adjacent to the demolished area, with the objective of detecting and quantifying potential structural displacements. Observations are conducted both in the horizontal (planimetric) and vertical (altimetric) planes, performing repeated measurements using high-precision geodetic methods. This study presents and analyzes the results obtained from four successive measurement campaigns.

2.2. TOPOGRAPHIC MONITORING STRATEGY IN URBAN DEMOLITION CONTEXTS

This stage involved the establishment of fixed reference points, also known as benchmarks, positioned on stable ground outside the influence zone of the monitored structure, as well as the installation of monitoring marks affixed to the building under investigation (or to its load-bearing structural elements), in accordance with the project approved by the beneficiary.

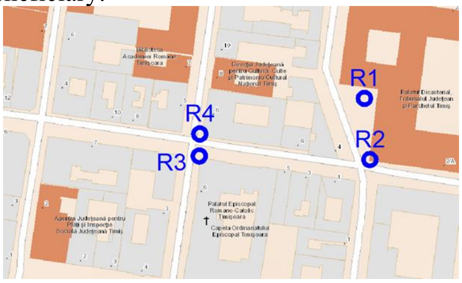

Figure 7. Fixed Benchmark Network

As part of this stage, the monitoring marks were also installed:

a) Monitoring marks identified in the project as M1...n, representing markers for long-term structural observation. These can be used in both horizontal and vertical planes and are equipped with a head suitable for positioning the leveling staff. They were used for conducting geometric leveling measurements.

Figure 8. Survey marker fixed to the monitored object

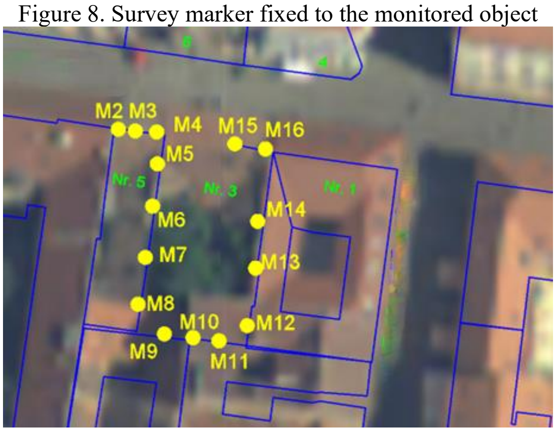

Figure 9. Installed Position of Monitoring Points

b) Topographic targets, identified in the project as T1...n, which will be used for total station measurements and will capture any potential horizontal position changes.

A total of 11 self-adhesive topographic targets were installed.

Figure 10. Placement of Topographic Targets

c) Crack monitoring benchmarks on the building, identified in the project as C1...n, are intended for tracking additional deformations by recording any displacements, indicated using a graduated scale.

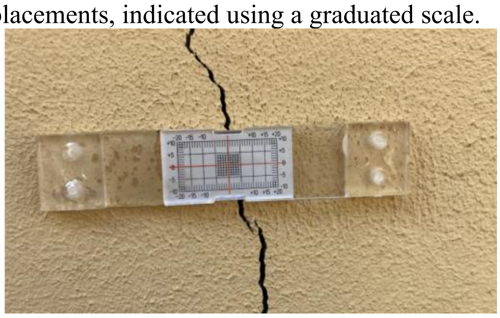

Figure 11. Crack monitoring benchmarks

A total of 3 crack monitoring benchmarks were installed in the areas of the most significant identified cracks, with detection performed both in the vertical and horizontal planes.

The first reading was carried out for the purpose of installing and stabilizing the monitoring benchmarks, representing the initial reference stage for the entire process of tracking the structural behavior of the building. Subsequently, three additional measurement cycles were performed, serving a verification purpose, under conditions where no construction work was carried out on site that could structurally affect the monitored buildings. These preliminary stages ensure the validation of the monitoring methodology and allow for future data comparisons in the context of potential interventions or structural changes.

Table 1 – The readings performed

No. of readings	**Date**	**Phase of the work**
Reading 0	21.03.2022	Installation and stabilization of benchmarks
Reading 1	19.04.2022	After 1 month
Reading 2	16.08.2022	After 5 month
Reading 3	01.02.2023	After 10 month

2.3. MEASUREMENT RESULTS

Following the completion of the four measurement cycles, the changes observed in all installed elements were analyzed in order to detect any potential shifts in position.

Table 2 – The readings performed

Benchmark designation	*Relative settlement Trench 0 – Trench 1 [mm]*	*Relative settlement Trench 0 – Trench 2 [mm]*	*Relative settlement Trench 0 – Trench 3 [mm]*
M2	0.0	0.1	1.8
M3	0.0	0.3	1.5
M4	0.3	1.5	3.1
M5	0.2	1.5	3.1
M6	0.1	1.2	1.3
M7	0.0	0.2	1.1
M8	0.1	0.3	0.8
M9	0.0	0.1	1.1
M10	0.0	0.4	0.8
M11	0.0	0.3	1.4
M12	0.0	0.2	0.7
M13	0.0	0.2	1.0
M14	0.0	0.1	0.7
M15	0.0	0.4	0.4
M16	0.0	0.7	0.8

As shown by the analysis of the graph, during the four measurement cycles a continuous settlement of the building was recorded, ultimately resulting in a total average settlement of 3.1 millimeters. In the interpretation of the results, Reading 0 serves as the reference value, against which all subsequent readings are compared. Thus, each following reading reflects the relative settlement accumulated in relation to the initial state.

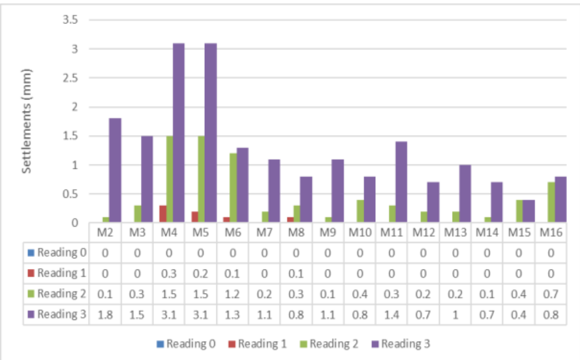

Figure 12. Crack monitoring benchmarks

Following the analysis of the measurements performed with the total station on the topographic targets, it was found that their positions did not change significantly during the studied interval, except for the distances between targets T5 and T6, and T5 and T9, which increased by up to 1.9 mm.

Regarding the crack monitoring benchmarks, by analyzing the photographs taken of the three crack monitoring points, the following differences were observed:

- ❖ Benchmark C1:
- → Total horizontal displacement – 1.8 mm
- → Total vertical displacement – 0.2 mm

Figure 13. Photograph at the installation and final reading of benchmark C1

- ❖ Benchmark C2:
- → Total horizontal displacement – 0.4 mm
- → Total vertical displacement – 0.1 mm

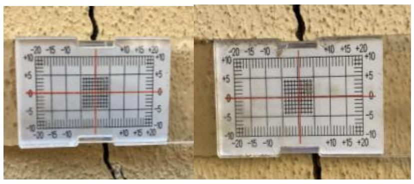

Figure 14. Photograph at the installation and final reading of benchmark C2

- ❖ Benchmark C3:
- → Total horizontal displacement – 1.6 mm
- → Total vertical displacement – 0.6 mm

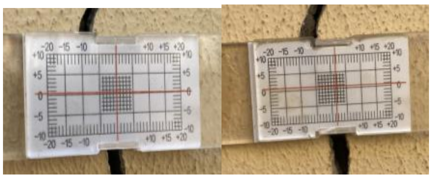

Figure 15. Photograph at the installation and final reading of benchmark C3

The initial photographs of the three crack monitoring benchmarks were taken on March 24, 2022, while the final photographs were taken on February 15, 2023, resulting in an observation period of 328 days for the analysis of their displacements.

It can be observed that most of the monitoring benchmarks, which were measured using precise geometric leveling, remained generally stable during the studied interval. However, settlements of up to 3.1 mm were recorded for the benchmarks located on the building situated closest to the street, particularly for those positioned in the immediate vicinity of the roadway where the building is actually located.

Although the presented diagram provides a clear view of the magnitude of displacements recorded during each measurement stage, one might initially conclude that the most significant displacements occurred during Reading 2 and Reading 3. Such an observation could suggest potential issues related to the structural stability of the monitored building.

However, for an accurate and well-founded interpretation of the recorded values, it is essential to consider the time intervals between readings, which play a crucial role in assessing structural behavior. The time span between Reading 1 and Reading 2 was 119 days, while between Reading 2 and Reading 3 it was 169 days. These time differences at least partially justify the greater variations observed, indicating that the evolution of displacements should be analyzed in relation to the duration between monitoring phases, not solely based on absolute values.

The solution adopted consisted of strengthening the foundation soil through concrete injections, as well as stiffening the wall located on the southeast side of the analyzed building by applying a welded mesh.

3. CONCLUSIONS

Monitoring the structural behavior of buildings over time is a key component of technical management, essential for preventing structural damage and ensuring long-term functionality and safety. This study addressed both theoretical and practical aspects of this process, focusing on historical structures in central Timișoara affected by major interventions, such as the demolition of a neighboring building.

The analysis highlights that a reliable monitoring system relies on a coherent network of topographic benchmarks, including fixed points placed outside the structure's influence zone and mobile benchmarks mounted directly on the targeted structural elements. In particular, the use of permanent markers proved crucial for maintaining measurement stability and repeatability over time, significantly enhancing the accuracy of the collected data.

The project emphasizes the need for a rigorous and structured approach to structural behavior monitoring over time, focusing on the proper configuration of benchmark networks, the appropriate selection of measurement methods, and the well-founded interpretation of results. The collected data not only validate the design assumptions but also provide valuable input for future interventions and support informed technical decision-making.

In conclusion, construction monitoring should not be viewed as a mere formal requirement, but as a fundamental tool for the responsible management of the built environment, especially in historical and vulnerable areas. By applying appropriate observation methods, using stable geodetic benchmarks, and rigorously analyzing the collected data, safe, predictable, and sustainable building operation can be ensured. This approach directly contributes to the preservation of built heritage and supports coherent and balanced urban development.

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REFERENCES

[1] Carrara, F. et al., Deep learning for structural health monitoring: An application to heritage structures, 2022

[2] Sestras, P. et al., A novel method for landslide deformation monitoring by fusing UAV photogrammetry and LiDAR data based on each sensor's mapping advantage in regards to terrain feature, Engineering Geology, Page. 107890, ISSN: 0013-7952, 2025

[3] Kong, X., Monitoring Time-Varying Changes of Historic Structures Through Photogrammetry-Driven Digital Twinning, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Page. 181–186, ISSN: 2194-9034, 2024

[4] Zhongjun, Ni, A Digitalization Framework for Smart Maintenance of Historic Buildings, 2023

[5] Azzara, R.M. et al., Ambient vibrations of age-old masonry towers: results of long-term dynamic monitoring in the historic centre of Lucca, 2019

[6] Herban, S. I., Vilceanu, C. B., Alionescu, A., Grecea, C., Studying the Movement of Buildings and Developing Models to Determine Real Settlements, Journal of Environmental Protection and Ecology, ISSN: 1311-5065, 2014

[7] Vîlceanu Clara-Beatrice, Herban Ioan-Sorin, Grecea Carmen, The contribution of geodetic engineering to special constructions monitoring, Universitatea Tehnică „Gheorghe Asachi" din Iaşi, 2012

[8] Brebu Floarea Maria, Vîlceanu Clara-Beatrice, Gridan Maria-Roberta, Geodetic studies on hydrotehnical structures movements and deformations monitoring, Scientific Bulletin of Politehnica University Timisoara, 2013

[9] Alionescu, A., Herban, S., Vîlceanu, C.– B., 3D modelling of cultural heritage objective in Timisoara using precise LiDAR, AIP Conference Proceedings, Page. 370002, ISSN: 0094-243X, 2019

[10] Chang, H.-F., Lin, T.-K., Real-time Structural Health Monitoring System Using Internet of Things and Cloud Computing, 2019

[11] Choi, J., Ma, Z., Kim, K., Sohn, H., Continuous Structural Displacement Monitoring Using Accelerometer, Vision, and Infrared (IR) Cameras, Sensors, Page. 5241, ISSN: 1424-8220, 2023

[12] Herban, I.S., Musat, C., Measuring and determining the dynamic deformation of constructions using modern technologies and techniques, Journal of Environmental Protection and Ecology 13, ISSN: 1200-1207, 2012

[13] Nuzzo, F.D., Brunelli, D., Polonelli, T., Benini, L., Structural Health Monitoring system with Narrowband IoT and MEMS sensors, IEEE Sensors Journal, Page. 16371–16380, ISSN: 1530-437X, 1558-1748, 2379-9153, 2021

[14] Kong, X., Monitoring Time-Varying Changes of Historic Structures Through Photogrammetry-Driven Digital Twinning, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Page. 181–186, ISSN: 2194-9034, 2024

[15] Gheorghe Lucian, Theoretical considerations referring to Law no. 10/1995 regarding the quality in constructions, Ovidius University of Constanta, Faculty of Mechanical Engineering, Industrial and Maritime, 2014

[16] Parliament of Romania, Law no. 10 of 18/01/1995,

[17] Vlad Lupăşteanu, Chingalata Costel, Construction condition assessment - why and how?, Bulletin of the Transilvania University of Braşov, 2018

[18] Viorel Popa, Update of the P100-1 Concrete Provisions, Mathematical Modelling in Civil Engineering, 2014

[19] Florin Pavel, Radu Vacareanu, Kyriazis Pitilakis, Preliminary Evaluation of the Impact of Eurocode 8 Draft Revision on the Seismic Zonation of Romania, Applied Sciences, 2022

[20] Teşilă, R., Rusu, G., Vîlceanu, Beatrice, Alionescu, A., Targeting displacements' monitoring of constructions through mathematical methods, AIP Conference Proceedings 1738, 350010, 2016

[21] Torzoni, M., Tezzele, M., Mariani, S., Manzoni, A., Willcox, K.E., A digital twin framework for civil engineering structures, Computer Methods in Applied Mechanics and Engineering, Page. 116584, ISSN: 00457825, 2024

[22] Grădinaru, A.P., Badea, A.-C., Dragomir, P.I., Badea, G., Integrating Cadastral Data with Seismic Risk Data in an Online Building Database for the Historical Centre of Bucharest City, Land, Page. 1594, ISSN: 2073-445X, 2023

[23] Romanian architecture, Wikipedia, 2025

[24] Timișoara, Wikipedia, 2025

[25] Azzara, R.M. et al., Structural Health Monitoring for Architectural Heritage: Case Studies in Central Italy, European Workshop on Structural Health Monitoring, Cham, Page. 3–12, ISBN: 978-3-031-07253-6, 2023

[26] Dmochowski, G., Szolomicki, J., Technical and Structural Problems Related to the Interaction between a Deep Excavation and Adjacent Existing Buildings, Applied Sciences, 2021