Conservation, Rehabilitation and Integration of Cultural Heritage

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Abstract. The report presents a study of world literature, charters, recommendations and regulatory standards in the area of restoration of architectural monuments. We have studied the knowledge gained from the time of Schliemann to the present. There is also an analysis of a number of publications from Bulgaria, as well as publications by the author in the same field. Emphasis is placed on geotechnical technologies to restore the foundations of architectural monuments. The practical experience of restoration activities in a number of countries is also extensively presented. This study provides guidance for a series of lectures systematically developed on the same topic.

Keywords: Restoration · Monuments · Charter · Micro-piles · Churches · Stone

1 Introduction

The preservation, restoration, and integration of cultural and historical heritage is nowadays a result of modern archeology development, which began in the mid-eighteenth century with the excavations of Pompeii and especially of the city of Troy - the remarkable Schliemann's discovery in 1871. The latter was followed soon by excavations of Mycenaean civilization in Peloponnese. However, even at Troy excavations, Schliemann was sharply criticized for the ruthless methods of working, which revealed the intended purpose, but at the same time destroyed many other artifacts of later eras such as the explosions when work was starting up. At that time archeology was already being studied at universities and a number of working rules were taken into consideration. Nearly 150 years after Schliemann, archeological approaches, as well as architecture, urban planning, and construction, have developed. A number of legal norms have been adopted in the civilized world, which regulate the activities for the preservation, restoration, and integration of cultural heritage in modern cities.

The celebrated fathers of the restoration and integration of the cultural and historical architectural heritage of the XIX century are Eugene Viollet-le-Duc in France and William Morris in England etc.

The modern city development is a continuation of traditions inherited from the past. Architectural monuments are precisely the starting points of urban planning, which determine the specific image and spirit of a city. They define the concept that has dominated

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urban development throughout all ages. Preservation and restoration of architectural monuments nowadays are subject to specific principles and requirements, which are not always regulated by law but have established global requirements for the protection of cultural heritage. In addition to the general principles, there are too many architectural and construction rules in the theory and practice of restoration related to the design, technology, materials, and organization of works. It is these problems that are subject to the current study and in particular - their condition today.

The topic is too broad and therefore within this study will be considered only the starting points and rules for the restoration of architectural monuments and modern technologies to strengthen their foundations, especially micro-piles technology.

2 A Brief Literary Overview and Current State of the Problem

2.1 The Actual State of the Problem in Europe and Worldwide

Guided by the topic of the study, nine contemporary papers have been selected to give an initial idea of the problem in Europe and worldwide. Based on the information from these reports, knowledge will be methodically expanded and refined until a sufficiently clear picture is obtained due to reasoned opinions and opportunities for putting the theory into practice. The first document we launch is the European Cultural Heritage Strategy for the 21st Century, adopted by the Council of Europe in 2017. This strategy is detailed in Bold and Pickard [1].

The Strategy [1] provides a comprehensive introduction to the history of European integration in the field of protection and restoration of cultural heritage and sets out the principles and working methods. These principles have been systematically presented in the development of projects of different scales.

The second document under consideration is also of fundamental importance, giving the European Union policy guidance on the protection of cultural heritage. This is the "Opinion of the European Committee of the Regions - Towards an integrated approach to cultural heritage for Europe" [2], compiled and published in 2015. The 48 points recorded in the document deplete the guidelines and recommendations for the development of this activity.

The third document we are paying attention to in this study is the final report [3] from the implementation of STORM, an interesting research project done by 20 participants from 7 European countries within the Union's Horizon 2020 research and innovation program, continued from 2016 to 2018. The study focuses on the effects of natural disasters, which are among the most serious threats to cultural sites.

Fourth in place is the Dutch engineer Van Balen [4]. This report focuses on current issues and new requirements for preservation and maintenance of new monuments, discussing in detail the risk assessment, monitoring and accountability activities of officials engaged in these activities. It is through these factors assessment that form the proper documentation of monuments and compliance with current information requirements.

Important methodological issues for students' education in the field of protection and restoration of cultural monuments are also presented in detail in the report of the Egyptian architect Embaby [5]. His paper aims to propose an educational methodology for dealing with heritage conservation projects: "adaptive reuse of historical buildings" in design studios of architecture and interior design programs, by promoting a design philosophy which supports the integrated approaches of revitalizing heritage values of the traditional communities and creates new activities based on conservation principles, sense of historic buildings and its cultural context, and continuous with local communities needs.

Another aspect of cultural heritage conservation and restoration approaches are the Proceedings [6]. Reports in the compendium reflect the Chinese approach to the issue - from philosophical through historical and up to narrowly professional technical point of view. There are comparisons of the Chinese approach with the European and others. There are reports from British and Japanese professionals that further enrich the range of opinions and concepts.

A multidisciplinary approach for choosing the best opportunity to preserve and restore cultural heritage in developing countries is given in a report by two Dutch scientists - engineers van Egmond and Erkelens [7]. The report provides useful schematics and examples of the necessary steps in the recovery process. Useful Case Studies are delivered.

Another non-European approach to the protection of cultural heritage is shared in the report by Egyptian scholars Elnokaly and Elseragy [8]. The experience of restoring historic buildings in cities and combining them with new constructions is presented. Examples from Cairo, Tunisia, and others are showing up.

In the end, there is Spiekermann's article [9]. The old cities of Aleppo in the Syrian Arab Republic, Shibam in Hadramaut/Yemen, and Sibiu (former Hermannstadt) in Romania are threatened by physical, social, and economic decay.

2.2 Authoritative Sources of Geotechnical Knowledge of Micro-Piles Technology

An early publication of the American Association of State Highway and Transportation Officials (AASHTO) from 1988 is the Manuel on Subsurface Investigations [11]. It outlines all the traditional laboratory and field methods for geotechnical exploration, valid to this day. It also shows the zoning of geotechnical characteristics in different states. A greater number of later American published techniques for the analysis of micro-piles and geotechnics, in general, have been developed on the basis of this practical guide.

The core of the modern micro-pile analysis is presented by Bruce et al. [12]. The steps of the computational procedure, the restrictive conditions of the computational model, the required volume of geotechnical study, a table with the average values of the main soil varieties are outlined there. Taking these data into consideration, the analytical formula and its variations for the carrying capacity of micro-piles are regulated.

Micropiles are regulated in Europe through general guidelines in Eurocode 7 and in standard EN 14199, but these documents are to be developed in the coming years.

Very useful is Ischebeck [13]. Ischebeck is the author of the modern type of rigid anchors and micro-piles and he shares several practical examples, with which he demonstrates a convincing combination of experimental results and theoretical analysis in order to successfully solve micro-pile problematic.

The variety of micro-pile applications is very well presented in Lizzi's review [14]. The author shows illustrations of foundations reinforcement of masonry with micro-piles, reinforcement of inclined towers like the one in Pisa, strengthening of landslides and deep excavations, tunnel vaults, and more. The presented report shows the empirical approach of sizing through the measured deformations of completed analogous structures.

2.3 More Interesting Bulgarian Contributions in This Area

A new chapter in our research opens the book of Ivanova [10]. At the beginning of the book, we've got a remarkable foreword on the architecture, history, and issues of the same building by two remarkable Turkish architects. She also pointed out that the most significant damages in architectural monuments come from the soil base. If their soil base turns out to be weak over time to withstand the load. the building or monument may tilt or crack.

In addition to the most recent publications on the subject of the study presented above, we have included a very valuable classical knowledge of the reinforcement and restoration of building structures of the past. They are written by some prominent Bulgarian scholars and can largely serve as textbooks in this discipline. These are the monographs by Ignatiev et al. [15] and Venkov's [16]. Thereafter the author gives useful information about the history of construction and restoration of "St. Stefan", the Bulgarian church in Istanbul, built entirely of steel.

Large-scale restoration works on historic monuments and infrastructure in the beautiful town of Balchik, located on a huge landslide at the steep coast of the Black Sea, are subjects of two papers [17] and [18]:

– The paper [17] presents in detail the geological features of Balchik and the evolution of deep landslides there. The role of hydrodynamic groundwater pressure and marine abrasion of the landslide has been emphasized. The implemented and designed reinforcement measures are shown with diagrams and details. The comprehensiveness and originality of the project measures for the permanent stabilization of the area are being emphasized.
– The paper [18] details the experience of the first large drainage gallery in Bulgaria to strengthen deep landslides. The adopted tunnel technology with TBM, which was first implemented for similar purposes, is also highlighted. The shared experience contributes to the further technological development of tunnel construction and reinforcement activities. The effect of the drainage gallery really proved decisive for stabilizing the huge landslide under the town of Balchik and for preserving the cultural monuments.

The huge practical and theoretical experience gained from the strengthening the 70 m deep landslide under the town of Balchik and the subsequent local fortification measures for the cultural monuments in the city are presented in detail and analyzed in Kolev's monograph [19]. There are a few papers by the same author dedicated to examples of the practice for the strengthening of church foundations in Bulgaria. Such paper is [20]. An interesting technical problem in the restoration of an old church has been studied and described historically in [21]. An original geotechnical approach for stabilizing the landslide under a church in Balchik by means of diaphragm walls and anchors is described in [22]. The proposed reinforcement technology is complex, but ensures the independence of the building from the development of landslides around it. One more paper [23] is dedicated to the analysis of geotechnical sustainability and strengthening the church of St. Stefan in Istanbul. The undertaken strengthening of the soil under the church is theoretically substantiated in the same report.

2.4 Brief Information About the Bulgarian Experience in Strengthening Architectural Monuments Through the Technology of Micro-Piles

The restoration of architectural monument buildings is the topic of the paper [24]. The successful restoration of the building is due to very well executed micro-piles under the foundations. The architectural qualities of the fortified monument are completely preserved; all the fortification elements and activities have remained discreet.

3 Purpose and Scope of the Study

The study focuses on two issues:

- The principles of the restoration of the architectural monuments, regulated in the charters;
- The technical capabilities of micro-piles for the restoration of architectural monuments such as churches, fortresses, towers, etc.

On the way to these goals, research will be limited to:

- General methodological and legal framework;
- Problems in the field of construction and geotechnics;

The study is intended to benefit both students and scientists, mostly engineers, architects, builders, investors, and municipal executives. It has a comparatively narrower professional profile, and so, from numerous problems, it excludes topics devoted to:

- Town planning and architectural details;
- Building materials for non-structural elements;
- Installations in buildings;
- Energy efficiency;
- Ecology.

Excluded topics are also important, but they require additional time, space, and effort to elaborate on the timelines set out in this study.

3.1 Principles of the Restoration of the Architectural Monuments, Regulated in the Charters

The main sections of the cited Strategy [1] are grouped as Technical Co-operation and Consultancy Program, consisting of:

- Monuments and sites;
- Historic towns;
- Territories.

Each section of the Strategy structure has a uniform structure of statements, which includes the following items:

- A brief summary of past achievements;
- Aims and approaches of the programs;
- Methodology;
- The taken actions;
- Summary of principal results.

On the other hand, the expected results can be also uniformly grouped: political, institutional, social, economic and territorial development, knowledge and education, site significance.

It is noteworthy that the accumulation of knowledge and educational goals are an integral part of cultural heritage preserving and restoring process, along with other indisputable effects of this activity. It is along this path that our research evolves to contribute to all other applicable science.

There are many European regulations within the subject; also there are national codes for the restoration works. There are many good practices of cultural heritage management and conservation.

A good example of international cooperation is mentioned respective the above cities: Aleppo, Shibam, and Sibiu. As Aleppo and Shibam are listed on UNESCO's World Heritage List, and Sibiu applied for this status in 2006, there is international interest and commitment to preserve these cities and to support them in finding ways for a viable future [9]. Public Authorities, NGOs, and inhabitants face challenges in preserving historical buildings and social and cultural structures that have been growing over hundreds, even thousands of years, in all their colorful variety. At the same time, they must create an adequate environment for living and working in these places. Physical preservation alone could turn the old cities into huge museums; hence, a comprehensive approach of preservation and development must focus on improving the living conditions of the inhabitants as well as sustaining the economic viability of the locations. At the same time, it must focus on making these historical sites better places to live while building on given physical and social structures turns out to be the most appropriate way of preserving urban heritage. The German Agency for Development Cooperation (GTZ) supports those cities, as well as others, in this effort. In addition to the information in the report, according to me, it is interesting to have a new discussion these days because Aleppo was virtually destroyed last year by the war in Syria.

3.2 Classical Technological Approaches for Restoration of Architectural Monuments

The classic technologies for restoration and strengthening of architectural monuments remain the most widely used worldwide. The strict requirement for protection of the original monument and the unstable original construction are the main prerequisites for this. Building materials that are as close as possible to the original ones should be used, the construction should not be overloaded, the general architectural image should be preserved, etc.

4 New Tasks Ahead of the Study

The new tasks this study poses are due to the contemporary problems that have arisen and are reduced to two aspects:

– Technogenic causes of deformation of old cultural monuments;
– Technical capabilities of micro-piles for the restoration of architectural monuments such as churches, fortresses, towers, etc.

4.1 Technogenic Causes of Deformation of Old Cultural Monuments

Impact of Vehicle Vibrations and Construction Mechanization on the Construction of Old Cultural Monuments. These are very common reasons for deformation nowadays when the number of cars in cities exceeded all expectations, and the construction of huge new buildings significantly changed the groundwater levels in the respective areas. The large difference in the foundation depth of new and existing buildings has in many cases caused unwanted deformations and loss of stability. The passage of heavy-duty trucks near old buildings has caused the cracking and demolition of masonry structures built over a hundred years ago.

There is a clear example of damage to a monument from new roads in Istanbul. St. Stephen's Church, as well as all the other large buildings in Istanbul's Fener district, were built on long timber piles because the soil was very weak. A newly built highway and dredging of the bay have destabilized the shore and cracks in the church building over the past 30 years. Recently, this church was completely restored and regained its architectural splendor. The work on the restoration and assessment of the artistic value of the monument are presented in detail in the book [10]. The cut ground base under the church was reinforced with a belt of injections up to a depth of 20 m using Jet Grouting technology. In this way, all deformations were stopped and the details of the building superstructure were restored. The technical decision for St. Stephan is presented in [23]. The problem is not decided by codes and standards, nor is there a specific methodology for it. So far, it finds a number of successful practical answers and realizations in our country and around the world. The hypothesis proposed in [23] is theoretically justified entirely with the methods of Soil Mechanics and in accordance with practical experiences. Several functional relationships between soil characteristics and structural elements have been sought, suggesting optimum cement solution parameters. The role of groundwater and their dynamics is also taken into account.

We have new research and design of vertical vibration protection of the Central Military Club building in Sofia - national architectural monument. The building is cracked due to the prolonged operation of vibrating rollers around it. The first results are already available, but a long series of additional analyzes are yet to be done and new dependencies, valuable for the practice and theory of barriers against vibration and earthquake effects on buildings, will be also identified.

Change of Groundwater Level in the Area Around the Building. There was an original technical solution, presented in [20] for cultural heritage protection in Veliko Tarnovo City in Bulgaria. The pressurized steel water pipe under the street had a breakdown. As a result of the water pressure, a stone retaining wall collapsed down to the original apse of a famous church - a national monument. The restoration works are combined with the creation of conditions for new archaeological excavations and the creation of a gallery for exhibiting the historic layers below the street. There was constructed a complex bridging underground structure in difficult technological conditions. The bridging structure simultaneously ensures street traffic, retains ground and landslide pressure from the slope and serves as a facade and gallery. The applied technology did not damage the archeological layers.

Another interesting case was in the Pazardzhik City, where a 180-year-old basilica was fortified. There were cracks appearing and evolving one hundred and forty years after the construction of the arches and walls of the Cathedral of the Holy Virgin in Pazardzhik that threaten it from collapse [21]. While getting familiar with the archival materials and the initial survey of the area, there were other features revealed in the geological profile of the foundation - swollen Pliocene clays and the improvement of the surrounding area are the reasons for the permanent decrease of the groundwater, which led to the rotting of the wooden piles under the temple. The construction of sewerage and lining of the nearby irrigation canal mainly caused the subsequent emergency condition of the building. The forced lowering of the groundwater level has led to the rotting of the timber piles under the building and the appearance of cracks in the walls. The examination of cracking shed additional light on the deformation mechanism of the building and pointed to additional measures to strengthen the foundation with stripes and in the transverse direction. The negative effect of the excessively long reinforcement process was noted. The risk of collapse was evaluated and recommendations were made to improve reinforcement. The performed analysis can be directly used in future planning and restoration works.

4.2 Technical Capabilities of Micro-Piles for the Restoration of Architectural Monuments Such as Churches, Fortresses, Towers, etc.

One of the most commonly used modern technologies for strengthening the base in such cases is that of micro-piles. The implementation of micro-piles under the foundations is an effective means of strengthening the structure and at the same time does not violate the architectural form. An opportunity is created for the permanent restoration of the monument.

Micro-piles' practice does not have a very long history, so it started at about 30–40 years ago. In its essence, this technology can be likened to a symbiosis between two construction means - one of the pile foundations and one of the injections. After all, current piles can best resemble rigid injection anchors, placed vertically or sum-up vertically on the ground beneath building foundations.

The technology of micro-piles and their application in the construction and renovation of buildings is developing faster than their theoretical analysis; the theory is catching up with practice. This is not an isolated case in Geotechnics and there are mainly two reasons for it:

– Soil is not a homogeneous and isotropic environment;
– The injection is a process that is difficult to control to achieve desired shapes and parameters of a healthy environment. That is why, at this stage, the analysis approaches are mostly empirical and need constant experiments. This is also evident from the brief overview of several key publications for the design and execution of micro-piles.

Micro-piles are still under development and need to be studied because they are very convenient for use in restoration work on buildings, bridges and other monuments. The answers to these new research tasks will be done through the own studies of current project participants and with references to the published world experience.

The limit states for micro-piles are further analyzed in [12]. Table criteria are given to evaluate the durability of this structure type. Recommendations of [12] lay in the Micro-pile Design and Construction document issued by the US National Highway Institute. This document is by far the most complete guide to the design and execution of micro-piles in all aspects. In addition to analysis and design features, there is guidance on materials, machinery, technology, valuation, contracting, etc.

A good example of the great potential of micropilots in strengthening architectural monuments is the case of the cracked building of the Military Club in Sofia ten years ago - a national cultural monument. The building of the Military Club [24] is one of the most beautiful architectural monuments within the Bulgarian capital of Sofia. The building is a brick structure with three floors and a basement. Foundations are made out of massive stone blocks on the clay. The building is located in the heel of a slight slope, near the highest point of the city. During the period from 2006 to 2008, a tunnel for the Sofia subway route was built under the street at depth of about 20 m. A deep shaft control between tunnel and ground, surrounded by diaphragm walls was constructed about 10 m aside, in front of the building. The ground is multi-layered, including sand aquifer above in silt and plastic clay. During the construction of diaphragm walls of the trench, a draining effect into the soil quickly formed a very steep seepage curve between the building and the shaft. The rapid decline and great amplitudes of the groundwater level resulted in an adverse settlement of the foundation under the front facade and arches on the facade of the building are cracking, fissures are dissolving, and a real danger for the stability of the structure occurred. After the investigations, injection with micro piles is performed along the contour of the building facade. The possibilities of technology helped to achieve a high-pressure injection into the soil under the building and to be slightly lifted foundation and to close the cracks in the arches and columns.

There are many examples in all Europe for the great potential of micro-piles for the restoration of building structures. A residential building in Sofia was built 50 years ago and It possesses four floors and two entrances. The building had dangerous large deformations caused by its inclination. Foundations are strips in the depth of 2.50 m each. The reason for the uneven subsidence is swelling silt thicker than 6 m below the building. The first cracks appeared more than ten years ago and reinforced concrete elements have gradually shown cracks 5 to 10 cm of separation. Prior to the restoration of the upper structure, the ground was stabilized and foundations were reinforced by a system of inclined, vertical micro-piles to mitigate swelling of clay and stop further deformation of the building. These were micro-piles injections, installed using the pressure of the grout. The plan for their deployment is done according to the measured subsidence and tilting of foundations. The injection was performed in two phases to achieve higher injection pressure. The lengths of the piles were 4 m each. Control measurements were performed one year after repairs and showed no new subsidence. The restoration of the roof structure is also completed.

The results of ongoing research on these issues are finding their place in the lectures and reports within the Project RE-BUILD.

5 Conclusion

The activities for the restoration of the cultural monuments have a history of more than 150 years. The accumulated knowledge and practical experience from them has led to strict regulations in a number of charters and codes in Europe and around the world. All documents emphasize the basic principles of approach to cultural heritage: protection of the monument in all circumstances; restoration of the monument subject to preservation of the original.

There are many events and factors that can damage architectural monuments. Nowadays, new causes have appeared, such as car vibrations, deep excavations for modern buildings and much more. At the same time, construction technologies are developing very rapidly, offering us new means for strengthening and restoring architectural monuments. Micro-pilots are just this type of new construction technology, which has a variety of possibilities and is subject to future improvement and wider application in practice.

The restoration traditions in different countries have explored, highlighted, and compared so we achieve knowledge crossing and a new level of understanding of the restoration works.

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