# Visual Renovation of Cultural Heritage Buildings Through Advanced Construction Materials - 2D-Printed Protective Cladding on Facade Scaffolds

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**Abstract.** Industry 4.0 has created models of thinking in education, which focus on developing skills through digital creative learning. This is increasingly being applied to the solution of multidisciplinary problems of great importance to societies. The preservation of Bulgaria's cultural heritage is a task that requires such approach. This paper proposes to combine technical experience with technological advancements and, as a result, to cater for elements of the life cycle of heritage buildings and cultural monuments that are at risk.

## Introduction and overview

Heritage sites are carriers of the historical and social development of societies. The modern principles of assisting countries in the preserving of tangible and intangible cultural heritage require the introduction of information and communication technologies in scientific education and culture.

In the last few years, the overlay of major factors such as climate change, military action, financial crises and others has created an environment of accelerated formation of heritage at risk, especially in countries such as Bulgaria, where there are accumulated negative effects far back in time. For them, system maintenance and restoration are a challenge, for which resources are lacking. Monuments of architecture are adversely affected by this. As a result of long-term gradual damage, they lose their means of expression as carriers of history, and often their condition deteriorates to the point of complete destruction. Counteracting these processes needs the entire educational resource of many scientific fields, whose specialists will participate in the procedures for renovation, restoration, and overall preservation of architectural monuments.

**More Important Problems and Risks of the Architectural Cultural Heritage of Bulgaria.** The investigation of the problem showed that in Bulgaria, the implementation of the legislation from 2009 [1] is part of an administrative process without significant practical resources. Thereof, the preservation of the immovable cultural architectural heritage of Bulgaria in the vast majority is subject only to theoretical formulation and in practice buildings with the status of cultural monuments for years are left to degrade [2].

However, the end result for Bulgaria is identical - numerous buildings are compromised in their architectural and / or structural parts to an extent that the budgets required for restoration are not within the capabilities of the owner's finances. Consequently, many of those properties have been destined to demolition, too.

In the ongoing abeyance for the competent authorities to create tools to preserve and restore deteriorating architectural monuments, they become an unacceptable visual composition of the urban exterior. This situation in the long run causes tangible and intangible losses in the cultural appearance of urbanised areas, especially those that rely on tourism, based on national architectural heritage (Fig. 1).
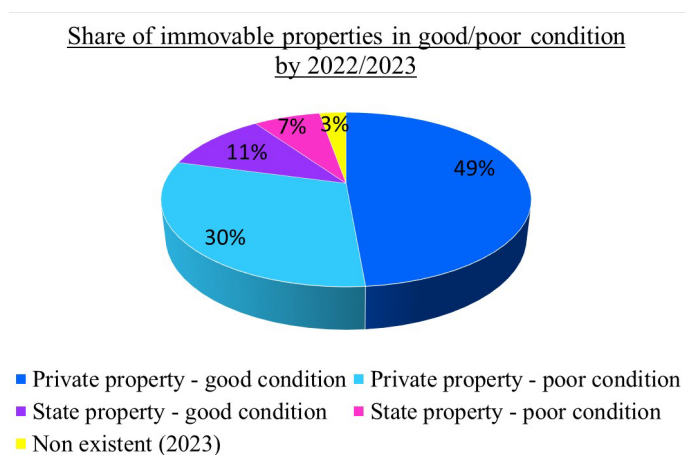
**Fig. 1.** Share of immovable properties in good/poor condition by 2022/2023 (left), House-Museum of Georgi Dimitrov, Tsar Simeon street, Sofia, Bulgaria (right)

**Temporary solutions – until the start of a restoration or until the final (self-)destruction.** Currently, the regulations for the management of such sites are limited to obliging owners to secure the facades if they are defined as potentially dangerous due to elements separating from them (various debris types, dust, etc.). Typically, this is carried out half-heartedly without the necessary care by means of applying safety nets to the specific building or monument. The result is poor appearance, low quality of protection and ongoing deterioration of the object behind the cladding (Fig. 2).



**Fig. 2.** The house of Ivan Geshov, Patriarch Evtimiy boulevard, Sofia, Bulgaria



**Fig. 3.** Printed safety net on the facade of the Faculty of Theology, Sveta Nedelya square, Sofia

In a small part of the affected sites, where the owner is a legal entity, compensatory mechanisms are applied to partially improve the fitting into the urban environment of architectural monuments in poor technical and visual condition. A problem with them is the missing conjunction between the

concept of maximum fitting into the urban environment and the aim to match the image to the original as much as possible (Fig. 3).

**Definition of the basic concept of a substitution mechanism through visual documentation and depiction of buildings with cultural heritage status.** In order to be properly managed and preserved for future generations, the management of architectural cultural heritage must be expanding its scope. All forms of inclusion of partial mechanisms for defining a building as a cultural value to society will contribute to the creation of a data system that from statistical would become public. If an administrative instrument is to be sought to support such reasoning, it is the Council of Europe Framework Convention on the Importance of Cultural Heritage for Society (Fairclough Convention) of 27 October 2005.

Based on it, the overall vision of cultural heritage as a resource for socially and economically sustainable development in Bulgaria can be set. This project is based on the practical application of several structural possibilities provided by the philosophy laid out in the document. The most important of them are:

Introduction of a model of cooperation "community with heritage", which offers the opportunity to the society to "see and desire" the restoration and subsequent preservation of the architectural heritage.

Introduction of a model of cooperation through the involvement of more interested to participate in parties. Their scope of works may vary from the processes of defining cultural heritage to those related to specific restoration and protection measures. The proposal could create a long-term option for cross-sectoral cooperation in heritage management processes.

Introduction of a model of cooperation by encouraging the preservation of the cultural properties through their public visual disclosure, in which the economic interest in their destruction becomes controversial for the institutions and the society. As a result, the idea of the need for consensus between owners and historical cost to create incentive and protection mechanisms.

**Visual renovation of deteriorating cultural heritage buildings through 2d images printed on protective cladding, on facade scaffolding systems– a project of UACEG.** The conservation of cultural heritage (in particular architectural heritage) makes it possible to preserve access to the past and the national identity, while respecting the principles of sustainable development of societies. Referring to the above-described models, it is possible to expand the theoretical and practical notion with the concept of" archiving" architectural monuments by temporary refreshment until the moment of their full restoration.

The main motive for the proposal comes from their significant visual contribution to the urban environment (negative or positive), especially in cities that are carriers of the historical potential of the respective eras. When this influence of the heritage buildings has a negative impact due to the degree of damage reached, it can be compensated by using the experience gained in construction. Specifically, to create replicas of facades on nets and/or sheets for facade scaffolds via digital printing. Analysis, commentary and specific examples in securing works in height during repair and restoration of buildings, including architectural monuments in urban environments is presented in [3] – (Fig. 4). From there one can judge the scope of the huge potential of digital solutions on printed facades.

The applicability of the nets and claddings, which are suitable for the temporary visual preservation of properties with this status in an urban environment of different historical periods and architectural complexity, were reduced to four groups within the study - (fig. 4). The results presented in fig. 2 and Fig. 4 were obtained by analyzing 159 cultural monument buildings in the city of Sofia (private and state owners), of which 106 are in good condition, 49 are in poor condition and 4 written off and demolished by 2023. In the framework of ongoing research, the different types of facade scaffolding claddings are investigated in terms of manufacturing technology, material type and possibilities for its processing to achieve diverse applications. The main goal is to ensure the structural bearing capacity of the possible design solutions. Intermediate results are presented in [4] and in fig. 5.
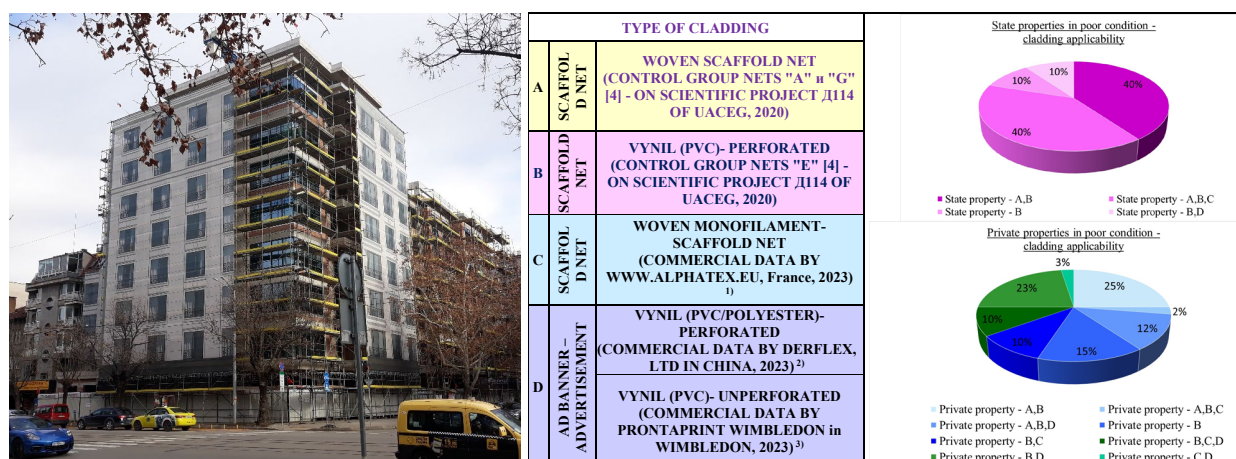
**Fig. 4.** Printed safety net on part of the facade scaffold during the repair of the facade of a building, Vitosha boulevard, Sofia [3] (left), Type of cladding (middle), State properties in poor condition - cladding applicability (top right), Private properties in poor condition - cladding applicability (bottom right)

The study of the possibilities for digital printing on different surfaces and materials showed constantly improving technological capabilities for the design and execution of images. Also, the manufacturers in this field of industry in Bulgaria have production resources whose product is graphics of a long-lasting full-color printing in volume and format, which makes it as close to the original as possible. low quality of protection and ongoing deterioration of the object behind the cladding (Fig. 2).

| PROJECT: "VISUAL RENOVATION OF DETERIORATING CULTURAL HERITAGE BUILDINGS THROUGH 2D IMAGES PRINTED ON PROTECTIVE CLADDINGS, ON FACADE SCAFFOLDING SYSTEMS" 2022/2023 | | | | | POSSIBILITY FOR FULL COLOR PRINTING | MINIMUM NUMBER OF PROFESSIONAL AND/OR SCIENTIFIC FIELDS REQUIRED FOR A PROJECT - CONTRIBUTION TO "EDUCATION 4" |
|---|---|---|---|---|---|---|
| TYPE | AREA MASS RANGE, [g/m²] | AVERAGED PORE % [%] | MEASURED PRESSURE RANGE, [Pa] | POSSIBILITY OF UV STABILISATION, [Kly] | POSSIBILITY FOR REFRACTORY TREATMENT | |
| A | 105-115 [4] | 50-45 [4] | 290-300 [4] | YES | N/A | NO / LIMITED | ARCHITECTURE, GEODESY GRAPHICS AND PRINTING; CIVIL ENGINEERING |
| B | 230-235 [4] | 20-22 [4] | 610-600 [4] | YES | YES | YES / ONE-SIDED UP TO 1200 dpi | BUILDING MATERIALS AND TECHNOLOGIES; GEODESY; ARCHITECTURE; GRAPHIC DESIGN AND ARTS; STRUCTURAL ENGINEERING; GRAPHICS AND PRINTING; |
| C | 130 [1] PENDING TESTS 2024 | 10 [1] PENDING TESTS 2024 | PENDING TESTS 2024 | YES, UP TO 120 [1] | YES | YES / ADDITIONAL TESTING REQUIRED | BUILDING MATERIALS AND TECHNOLOGIES; GEODESY; ARCHITECTURE; GRAPHIC DESIGN AND ARTS; STRUCTURAL ENGINEERING; GRAPHICS AND PRINTING; |
| D | 220-360 [2] PENDING TESTS 2024 | PENDING TESTS 2024 | PENDING TESTS 2024 | YES | YES | YES / ONE-SIDED UP TO 1200 dpi | BUILDING MATERIALS AND TECHNOLOGIES; GEODESY; ARCHITECTURE; GRAPHIC DESIGN AND ARTS; STRUCTURAL ENGINEERING; GRAPHICS AND PRINTING; |
| | 440 [3] | 0 [3] | PENDING TESTS 2024 | YES | YES | YES / ONE AND DOUBLE-SIDED UP TO 400 dpi | |

**Fig. 5.** Detailed properties of the 4 cladding types in terms of cultural heritage preservation

## Digital approaches to registration and preservation of immovable cultural heritage

At the time of the 4th Industrial Revolution, digital technologies became part of the procedures for verifying real estate. Since the end of the last decade, there have been a number of positive results in the introduction of systems for reconstruction and archiving of architectural heritage by laser scanning (LiDAR terrestrial laser scanners) with an emphasis on joining the applicable principles from BIM. Digital photogrammetry and laser scanning are traditional methods of collecting data in digital form (consisting of 2D images and 3D point clouds) to document heritage objects. This allows the rendering of realistic 2D and 3D results with high geometric accuracy and radiometric resolution [5, 6].

The identification of architectural objects achieved with the use of a 3D laser scanner and / or photogrammetric survey, is successfully used in graphic software oriented to civil engineering and architecture. Images as final products are practically identical copies of the original with high quality graphics and architectural authenticity. They can be graphically rendered in the groups of software to

create complex images, which when printed can repeat the photo visualization of facades, ornamentation and more.

Given the latter and the provisions outlined in [8] artificial intelligence can successfully be implemented to train the algorithms for processing the input data from the graphics softwares. Thus, one can obtain image classes in formats, through parametric representations for H-BIM related applications. The resulting parametric model can be used for the purpose of conservation and promotion of heritage, in packages of documentation systems. Confirmations that Scan-to-BIM reconstructions with the application of artificial intelligence (AI) to classify digital architectural heritage data such as the ones in [6] and [8] are becoming more common. This approach leads to solving a number of problems in mapping heritage buildings and monuments such as: time and labour consumption, creating libraries with graphic data, representing a comprehensively assembled architecture of the surveyed objects, increased graphics quality of the resulting images, etc.

After 2020 and the COVID-19 pandemic, the concept for the development of technical means of surveying and the accelerating and improving the processing of the received data to obtain the final product, have been further oriented towards the possibilities of operating image data aided by artificial intelligence [7, 8].

## Use of scaffold systems with printed claddings with copies of the facades of architectural monuments in poor condition and education 4.0

Education 4.0 is to a large extent accepted as a degree of paradigm because we do not have a model that is comprehensive enough to be applicable to all formats of the educational process sufficiently long. Within such a concept, the idea of creating training programs in design, with which various specialists can realize themselves professionally in the cultural heritage preservation field, is the bearer of the principles of the fourth industrial revolution (Industry 4.0) and Education 4.0. The proposed concept can be illustrated with several main directions:

Under the umbrella of such a system, the educational resource of secondary and higher education can be used. Appropriate directions for interaction are secondary and higher schools with programmes in arts and civil / structural engineering.

Thus, it will be responded to the rapidly changing labour market after 2020 in its need for digital literacy of staff in areas such as architecture and construction, art, cultural heritage. According to [9], it is expected that already in the next two decades over 90% of jobs in Europe will require a level of digital skills with varying degrees of competence.

The wide range of specialties (architecture, structural / civil engineering, arts) that interact to apply the idea into practice, allows the creation of prerequisites for interdisciplinarity in education, science, and practice within the secondary and the higher education, and between them as well. It is possible the learning process to develop in digital campuses, which will offer an interactive environment for connection between different schools, faculties and lecturers. A summary of the of the model applicability for this stage of the study is illustrated in Fig. 5. It shows that the necessary professional and scientific disciplines needed to carry out architectural heritage projects with the four types of nets and covers investigated, are four at minimum, even for the less applicable options as net type "A".

Graphic designs can be used as a form of improvement of the artistic and creative process in pupils and students, who are developing in the artistic fields. In addition, this niche is suitable for both men and women and at the same time provides equality in training and realisation on the labour market. Implementation of artificial intelligence in image generation procedures will improve workflows within the digitization structure itself for better results and time efficiency.

## Conclusions

If a project is created to illustrate the possibilities in time of applying digital images of facades on facade scaffold nets or sheets, then it can become part of the social inclusion of these buildings in the society's public life, and this inclusion to catalise a start to processes for managing the preservation of architectural heritage.

Given the significant number of architectural monuments throughout the whole territory of Bulgaria, which need restoration, the implementation of this decision can differentiate a niche of different specialties working for the maintenance and preservation of our immovable cultural heritage.

Visual renovation of cultural heritage at risk through advanced construction materials will refresh the appearance of the ancient parts of the urban areas and will show the public what their living areas can look like if mechanisms were found to support private interest in the preservation of architectural properties. In other words, fulfilling the described principle in the Fairclough Convention that cultural heritage should be considered as a capital or asset (resource), from which society and its citizens should derive greater economic benefits (Fairclough, 2009:35).

## Acknowledgments

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