CULTURAL HERITAGE

Series of History, Analysis, Conservation, Valorisation of the Cultural Heritage

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Series of History, Analysis, Conservation, Valorisation of the Cultural Heritage

The Series Cultural Heritage collects scientific contributions concerning the protection, the restoration, the enhancement and the management of Cultural Heritage both in general and in specific aspects. This purpose is pursued through both theoretical and operational contributions about the knowledge of cultural heritage, able to propose conservation and valorization actions, to suggest management strategies, and recommend adequate dissemination channels. The series collects essays on landscape and urban structures; on historic gardens and parks; on the archaeological heritage and on that which has been reduced to a state of ruin; on historical architecture and that belonging to the so-called "modern movement"; on the widespread heritage with traditional characteristics (rural, mountainous, vernacular).

On the cover:
Brescia Cathedral, picture by AIPnD ETS©

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14th International Conference on non-destructive investigations and microanalysis for the diagnostics and conservation of cultural and environmental heritage

Brescia (Italy) - 2023, November 28th/30th

edited by

Monica Volinia, Antonello Tamburrino

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Part four - Environmental Control and Protection

Knowledge coordination tool for the conservation of the church of Sant'Agata

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Abstract

The BIM (Building Information Modeling) approach to the construction sector is now well-established, both theoretically and practically, thanks to a legislation that encourages the use of such systems. In line with international trends, DM n. 560 of December 1, 2017 (as amended by DM n. 312 of August 2, 2022) envisions the mandatory use of BIM for public interventions, defining a road map based on the total amount of public works from 2022 on. This logic encompasses all interventions, including restructurings and restorations, which account for a significant portion of the Italian building sector.

This contribution proposes an experimental application on the church of Sant'Agata in Brescia, where an ongoing structural monitoring process has been activated, and a series of non-destructive investigations were conducted on the main roof structure. The numerous collected data denounce an evident malaise of the building and they are functional for the development of the restoration project.

The accessibility of the analysis' results and the need to coordinate many different professional figures, as frequently happens in case of restoration projects, has suggested the study of an HBIM model supporting the design activity, the knowledge management process and the planned future conservation practice. The procedure has implied a preliminary evaluation about the type of available information and then unconventional modeling solutions have been identified on the basis of the BIM available tools, creating a flexible and dynamic model, that offers the possibility of implementing and coordinating the data over time.

Keywords: HBIM, knowledge management, planned conservation, monitoring.

* Corresponding author.

The knowledge management activity related to an architectural valuable building constitutes the preliminary step when consciously approaching cultural heritage and its attainment implies to operate a reliable and functional organization of the whole acquired heterogeneous information, with the aim of creating a dynamic project environment. This purpose can be operatively pursued exploiting the tools offered by the BIM (Building Information Modeling) technology, whose primary application concerns the new constructions, experiencing the potential and the versatility of the method when implemented on historical buildings (HBIM). The case study concerning the church of Sant'Agata in Brescia has represented a fecund field for practicing a series of different information management solutions, in order to suggest a guideline to deal with an innovative and still poorly explored branch. The relevance of the building in the urban historical scenario, its compromised structural condition – denounced by a visibly important cracking framework mainly affecting the vaults and the under-roof walls – and the huge amount of available documentation have been thought to be appreciable features for the study's purposes. In particular, with reference to the treated information, the main source has been represented by the outcomes of the qualitative and instrumental investigations that had been performed on some portions of the structure by the engineering company (Foppoli Moretta e Associati S.r.l.) commissioned for the execution of current extraordinary maintenance interventions aimed to improve the building's seismic behavior.

Creation of the model and representation challenges

The most critical feature of the HBIM application lies in the need of dealing with existing buildings showing peculiar and complex geometries to be modeled, therefore one of the experimental values proper of the study lies in the research and in the definition of alternative techniques to the ones which are generally used for the representation of new structures having regular profiles. The non-standard approaches that should be pointed out rely on the same tools and functions provided by the modeling software and conceived for more commonly faced issues. These complexities sometimes risk to compromise the functionality of the method, leading to its marginal application in case of historical buildings. In this regard, the conducted work aims to provide an operative example based on solutions that seek their feasibility in the compromise between a sufficiently good level of representative accuracy and a limited processing time, in compliance with the general economy of the project. In this context, a significant parameter is represented by the definition of a level of detail which can vary within the same model according to the focus to be adopted. In the specific case, the attention has been set on the under-roof portion of the church, which is the area where the most of the investigations have been carried out, as well as the most significant region from the point of view of the structural impairment of the building. The modeling process has been developed by means of Revit software, supplied by Autodesk® company, a worldwide used support to the BIM applications. The modeling activity has been performed on the basis of the point cloud corresponding to the under-roof portion of the church, that was previously aquired by the commissioned geomatics company by means of 37 static scans executed with a laser scanner and aligned in a single rigid point cloud. The creation of the BIM model has relied on various techniques depending on the different structural elements to be represented; one of the most elaborated procedures has been carried out for the representation of the eight Palladian trusses composing the roof structure, which has

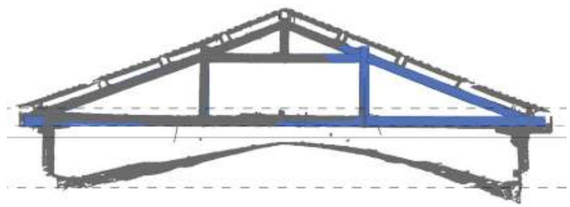

Fig. 1 Model adaptation to the point cloud.

involved the generation of new parametric families.

The model representing the generic truss has been created on the basis of dimensional parameters whose value could be modified in order to change the whole configuration of the structure allowing its adaptation to the actual geometry of the different trusses; the process has lead to the achievement of a good level of superposition between the model and the point cloud (fig. 1 Model adaptation to the point cloud). Besides, another significant representative solution has relied on the complementary use of Autocad software – supplied by the same aforementioned company – with the aim of creating a series of meshes corresponding to the internal surfaces of the considered structural element (such as the arches and the vaults), that have been subsequently loaded in Revit as local masses and conceived as references for the generation of the corresponding volumetric elements. Some modeling approximations and discretizations have also been assumed to limit the elaboration time and the size of the project file, allowing in this way the overall feasibility of the method (fig. 2 Final model and under-roof insight).

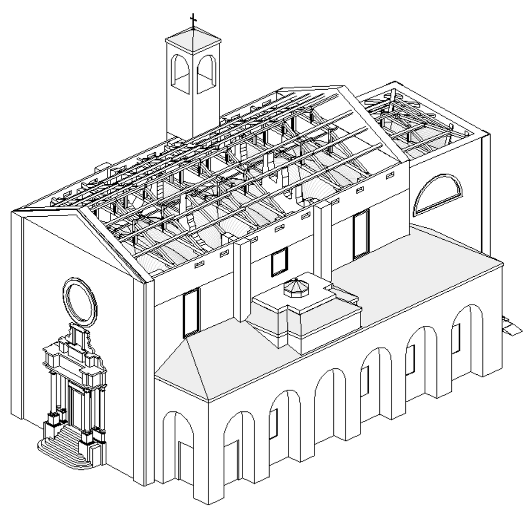

Fig. 2 Final model and under-roof insight.

Knowledge management possibilities

Considering the discussed case study, the knowledge management process, aimed to relate all the collected knowledge to the already built 3D model, has been implemented on several fronts; first of all, it has dealt with the historical documentation that has been retrieved both from the Superintendence archive and from the one of the parish, in order to recap the most significant constructive events involving the building and its components. Besides, another kind of treated information has been supplied by a series of surveys and investigations carried out by the commissioned company in the under-roof area, including the qualitative analysis about the state of conservation of the wooden trusses, resulting in the so-called 'degradation mapping'. Moreover, the BIM model has been supplied with the information related to the structural monitoring system based on linear displacement sensors that has been installed by the same company in order to register the width's variation of the most relevant cracks detected on the external surface of the vaults and on the under-roof walls. Finally, some non-destructive or low-destructive instrumental investigations have also been performed on the trusses to quantify some physical parameters: ultrasonic tests, humidity detections, penetrometric tests with resistograph and samplings aimed at defining the essence of the wood. For each of these categories of treated information, the management procedure has relied on three main working phases: a prior collection of the suitable documents, including photographic references, technical relations, and numerical data sheets, a following logic organization of these documents in folders on the on-line platform of Google Drive and a consistent association of the links with the corresponding elements in the model. The choice of uploading the documents on a shareable storage is coherent with the idea of data accessibility, also due to the implementation of a standard structure for each one of the databases related to a different branch of the whole knowledge, promoting in this way the reiterability of the method (fig. 3 Structure of the documents' folders). Concerning the historical documentation, it has been catalogued, organized and then integrated in the model by means of simple URL-type parameters associated to the modeled structural elements, reporting the directory of the corresponding folder of documents; instead, the treatment of the other types of collected information has implied more demanding and customized procedures. Indeed, both the degradation mapping and the cracking framework subjected to structural monitoring have been represented in the model by means of properly created adaptive

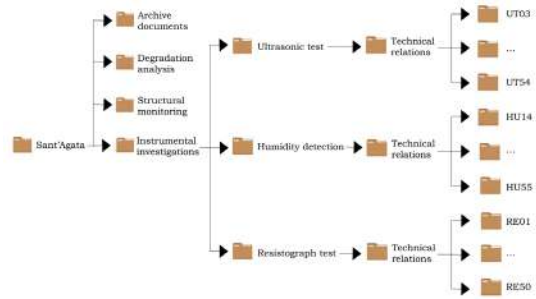

Fig. 3 Structure of the documents' folders.

families to be anchored on the surfaces affected by the superficial or structural damage; the modelled adaptive elements have also been provided by a series of text-type and URL-type parameters; the periodically recorded measurements of the monitored cracks' width and the corresponding temperature values have been plotted in linked diagrams.

Instrumental investigations and parametric families of placemarks

The analysis have included penetrometric tests (50), humidity detections (15), ultrasonic tests (15) and wooden samplings (4), that have been performed in some precisely selected points over the trusses corresponding to the most degraded portions or to the regions subjected to high structural solicitations, as the lower ties' ends and the lateral supports. From the HBIM point of view, the definition of a functional method allowing the correlation of these investigations and of their outcomes with the model has been a quite challenging point. One of the main purposes was to supply a graphical representation of the performed tests in the model, so that they could be easily identified just by looking at the 3D view. Furthermore, the intuitiveness of the chosen representative method was thought to be essential in order to promote an easy readability of the model, thus the different typologies of performed tests needed to be distinguished on the basis of simple criteria. At last, it was required to precisely localize the executed tests on the interested structural elements. A unique solution satisfying all these needs should be pointed out according with the functions available on Revit software; for this reason some possible approaches have been dismissed due to their unsuitability with respect to one or more of the outlined requirements. As an example, a possible solution could have been represented by the use of the labels: in this case new families of labels could have been created adopting different symbols to differentiate the tests' typologies. Moreover, the labels associated to the modeled elements could have been georeferenced on the single instances to precisely localize the investigation points. Nevertheless the illustrated approach exploiting the tags' functionality has a relevant disadvantage in the framework of the aforementioned needs: actually, the tags belong to the annotation category on Revit and, given their informative nature, they can be seen just in a specific 2D view of the model, as a plan, a section or a front view. This feature is a very limiting factor since the immediate visualization of the investigation points on the 3D view of the model was thought to be essential. Hence, another approach has been finally identified in the creation of new families of generic models representing, by means of conventional symbols, the different investigation types. In this case, the 3D created elements could be seen in the main project from any perspective in all the visualization modes, being full-fledged part of the model. The test based on the sampling of wooden cores from some of the trusses has represented an exception in the information treatment approach: for sake of simplicity, it has been introduced in the model by means of a new text-type parameter assigned to the trusses' family and dedicated to the definition of the wood species that have been detected through the macroscopic analysis of the collected samples: in all the analysed cases, the detected wood species is the *Picea abies* (also known as *Abies alba*), a type of conifer. Concerning the other tests, the choice of the 3D symbols that had to be developed in the family creation workspace has been based on the principle of full accessibility and intuitiveness (fig. 4 The placemarks in a zoom on the under-roof). It has also been necessary to define a method allowing to link the created placemarks to the corresponding interested portions on the trusses in order to precisely localize the investigated points. Therefore, it has been necessary to generate an additional family of adaptive generic models to create a physical link between each one of the introduced symbols and the related survey point. This connection has been represented by a very thin extrusion with circular section generated on a reference straight line having two adaptive points at its extremes. In order to correctly positioning the investigation points on the concerned beams, each truss has been isolated one by one to simplify the procedure: the exploitation of the adaptive points at the ends of the connecting lines allows to firmly and punctually fix the placemarks to the structural elements of the model. The introduced symbols are not mere icons, but they have been actually equipped with a

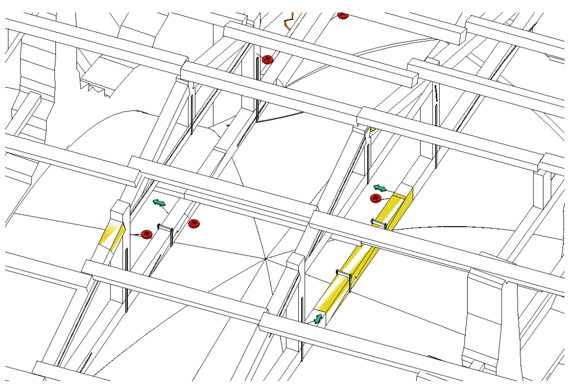

Fig. 4 The placemarks in a zoom on the under-roof.

series of parameters linking the information related to the specific test they represent. All the detection points have been listed in tables – one for each investigation type – that have been created as 'abacus' in a pretty unconventional way: it is possible to modify or update the parameters directly in the tables' cells and to extract the desired information for a long-term monitoring and conservation approach. Moreover, to improve the accessibility of the model, the placemarks have been provided with colours distinguishing the various investigation types; the colour assignment has relied on the creation of specific visualization filters based on rules (i.e. all the generic models whose parameter 'investigation type' is equal to 'humidity test' are painted in blue). The method is thought to be easily repeatable in case different kind of investigations are performed, just by conceiving a representative symbol to shape the new corresponding parametric family.

The illustrated management expedients, defined with non-standard modeling techniques, are though to allow the full readability of the model and to suggest a method to implement the information in a punctual and intuitive way, preserving the three-dimensional value of the data. The consistency of the documentation storage systems is intended to promote the data sharing and consequently the interoperability of the involved professional figures. At last, the limited required elaboration time suggests the feasibility of the method, which is expected to encourage the programmed conservation of cultural heritage.

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