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OPERATIVE TOOLS FOR BIM IN ARCHAEOLOGY: LIBRARIES OF ARCHAEOLOGICAL PARAMETRIC IFC OBJECTS

The creation of 3D models for Cultural Heritage has now become a common practice for the study and enhancement of works and contexts. Today, the progress of technologies applied to the survey and management of 3D data allows us to obtain high-resolution virtual replicas, in a short time and at a low cost. Within our contribution, we present the application of a BIM methodology to the management of archaeological contexts. BIM represents today one of the innovative technologies that allows to manage not only 3D models of existing objects, but also and above all, to connect a large amount of information of different nature to those models. All this data put together allows us to develop research, analysis and new surveys, because they are part of a real, complete data platform.

BIM was born as a method of designing infrastructures. Today, largely widespread in professional realities, it has become a common practice for engineers and architects. With BIM design, which takes place through a specific software, it is possible to create a 3D model of the building to be built, by using for each part of it, the so-called parametric objects. Parametric objects are three-dimensional models of structural, architectural and engineered system elements that are part of the existing or the planned building. They are defined as parametric because they have a large amount of information inside. This information concerns their geometrical shape, their morphology and the material and technique with which they were built; all the data inserted inside the parametric objects can be queried and form the basis for subsequent scientific analysis. Through a BIM, it is possible to create a real management system for the construction of an asset, a public work or a building, because it provides a platform for monitoring all their phases of life and a tool to control their management and maintenance activities (Fig. 1).

Over the last few years, especially in Italy, BIM applications have shifted to Cultural Heritage and have been adapted to historic buildings. This created the basis to develop analytic "Scan to BIM" processes, stressing on the need to obtain high-resolution and geometrically reliable surveys for historic buildings. HBIM, Heritage or Historic BIM, represents a consolidated reality within the scientific debate that focused, above all, on the detailed modelling of particularly complex elements part of the historical architecture, trying to create BIM models as close as possible to the existing reality (Murphy *et al.* 2013, 89-102).

In the last ten years, BIM made its way through the international archaeological debate, raising curiosity, questions and new challenges. The greatest potentiality of the use of BIM methodology in the archaeological field lies

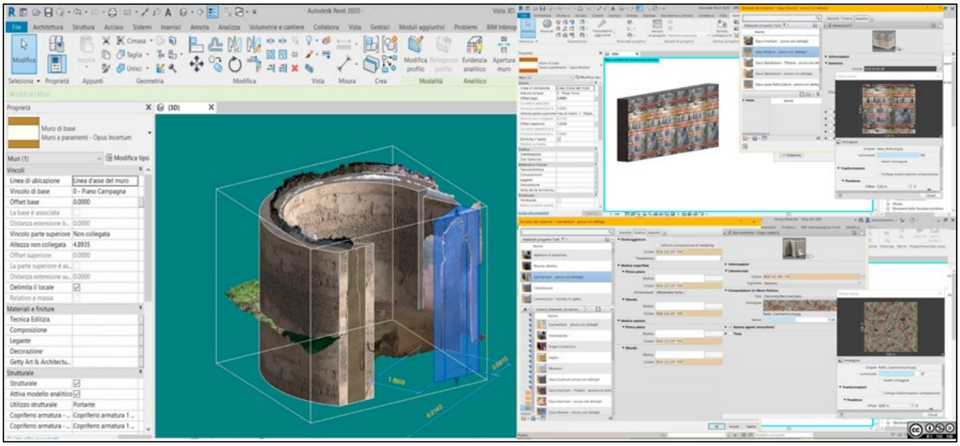

Fig. 1 – Parametric modelling of an architectural element complete with texture. On the right, an image of the Properties Sheet with the specification of construction information.

in the chance to obtain a three-dimensional reality-based model of the asset. Furthermore, the asset itself gets enriched with a large amount of information, becoming a real database. The data storage system within a BIM model provides a unified database for the design of maintenance and enhancement activities and to plan subsequent analysis. Moreover, it allows the creation of virtual reconstructions on the basis of the real geometric data of the archaeological evidence. Several teams have used BIM to generate three-dimensional models of archaeological sites. Examples are provided by the reconstructions of the Temple of Uni in Marzabotto and of the Solar Temple of Niuserra in Egypt. In the first case, the rules of Vitruvius’ *De Architectura* have been used as a reference to recreate in BIM the temple’s elevation (Garagnani *et al.* 2016, 251-270; Gaucci-Garagnani 2020, 181-188); in the second, measurements of the building material scattered in the site were used to propose the reconstruction (Bosco *et al.* 2018, 377-388).

For BIM or HBIM the major difficulty is recreating the variety of evidence present within an archaeological site. A BIM model indeed is based on the interaction of individual parametric objects: they create the model itself and allow the representation of the reality of the archaeological context. The project we present here proposes the creation of parametric BIM objects that can better represent the archaeological reality in all its complexity (Carpentiero 2018, 1-21; 2020, 69-86).

For object modelling, Autodesk Revit software has been chosen. Revit is organised in order to have a hierarchical subdivision of the parametric objects. This routine is closer, than it might seem, to the archaeological classifying process, because the ancient evidence is subdivided likewise by archeologists: in typology and building techniques. This subdivision is organised by Discipline and analytical Categories. For Discipline, we can identify three main topics: architecture, structure and systems. As to the analytical Categories, we have three: Family, Type and Instance. Each parametric object is identified by the categories it belongs to; for each Family of objects, numerous variations of Type are created, based on the variations of the object parameters. For example, in the Revit classification process, a Wall object would belong to the "Walls Family". Then, regarding the Type, there could be many different types of this family, based on different parameters like the geometrical shape changes and the construction technique.

In order to implement on a scientific basis, the BIM methodology and make easier and faster the modelling of archaeological structures, in a software created for modern architecture, a model of semantic library has been created. This model is very useful because the BIM archaeological objects it contains can be reproduced, and possibly modified, for other projects. The site of Pompeii has been chosen to be the reference context for the creation of this library. Considering its extraordinary state of conservation and the wide variety of architectural types it offers, Pompeii constitutes an essential point of reference for research concerning Roman architecture of the Republican and early-Imperial age. Later, in a second phase of research, the variety of types identified at Pompeii will be developed further and completed by using data coming from another site destroyed by the Vesuvian eruption in 79 CE, Herculaneum, where different destructive dynamics permitted the preservation of evidence that is no more recordable in Pompeii.

The Vesuvian context is therefore a valid field of experimentation to evaluate how to transform a BIM information system into a tool that can effectively support archaeological research, especially in the phases of data organisation and interpretation. These reasons led to the development of a research project whose aim is to adapt potentialities of BIM to the archaeological context, through the analysis of evidence discovered in Vesuvian sites. This goal will be achieved in two ways: on one hand, by perfecting the modelling phases through a case-study chosen in the domestic architecture of Pompeii (houses I 16, 5, 6 and 7[1]); on the other hand, by creating a semantic library model, exportable and including a range of parametric objects so wide and varied that it can correspond to the entire set of elements that would be part of a Roman building's BIM model. Here, the creation of the semantic library will be discussed.

At the origin of the creation of the semantic library model, there is a repertoire of architectonic and structural elements, as well as of hydraulic and thermal systems elements, of which a Pompeian house could be made of. This repertoire

[1] These houses are studied in the scope of a research program dedicated to the *atrium testudinatum* house of Pompeii "Modes d'habiter à Pompéi à l'époque républicaine", supported by Centre Jean Bérard, University Paris Nanterre and University of Naples L'Orientale: D'Auria, Ballet 2020.

Discipline	Family	Function	Morphology	Building technique	Materials
Structural	Wall	Outer wall – Front wall	With parallel sides	*Opus quadratum*	Sarno limestone
		Outer wall – side wall	With non-parallel sides	*Opus africanum*	Lava
		Dividing wall	Buttressed	Irregular *opus incertum*	Nocera grey tuff
		Retaining wall	With niches	*Opus incertum*	Napolitan yellow tuff
		Cellar wall	With half-columns	*Opus incertum* with rows of bricks	Foam lava
		Enclosure wall	Mixed lines	*Opus testaceum*	*Pappamonte*
		Partition wall		*Opus reticulatum*	Baked bricks
				Opus quasi reticulatum	Cut tiles
				Opus mixtum	Mud bricks
				Panelled *opus mixtum*	Clay
				Opus vittatum	Wood
				Opus vittatum mixtum	
				Opus craticium	
				Opus formaceum	
				Opus latericium	

Tab. 1 – Creation of the archaeological BIM object: Wall element's declension, based on the analytical Categories of Revit software.

has been developed by both a bibliographic[2] and a field survey, the aim being to gather all the possible variants of the elements. To identify these variants, the entire set of their features has been taken into account, as the variation of one of them can be regarded as a discriminating factor for the type identification. Therefore, for each parametric family of objects, the architectonic function, the morphology and the composition of each element have been analysed. For example, in the case of the "wall family", that makes part of structural objects, the different functions of the element inside the building have, at first, been identified (Tab. 1). A wall, indeed, can be an outer wall, a dividing wall, a retaining wall or a cellar wall and have therefore a load-bearing function; or it can be a partition or an enclosure wall and have no load-bearing function. Then, its shape in plan has been considered and finally, its composition, identifying materials and building techniques employed for its construction. These latter have been indicated using the traditional nomenclature of pompeianist studies. However, to get an easier identification of building techniques and of library's types, it has been considered worthwhile to guarantee an unambiguous identification of data, by linking them to standard systems like Art and Architecture Thesaurus (https://www.getty.edu/research/tools/vocabularies/aat/) or Thésaurus PACTOLS (https://pactols.frantiq.fr/).

[2] Useful are the analysis and categorization of ancient buildings' architectural elements, based on the different steps of the construction process, provided by Ginouvès, Martin 1985; Giuliani 1990; Ginouvès 1992. More recently, researches of ACoR program resorted to this sort of approach, see Camporeale *et al.* forthcoming.

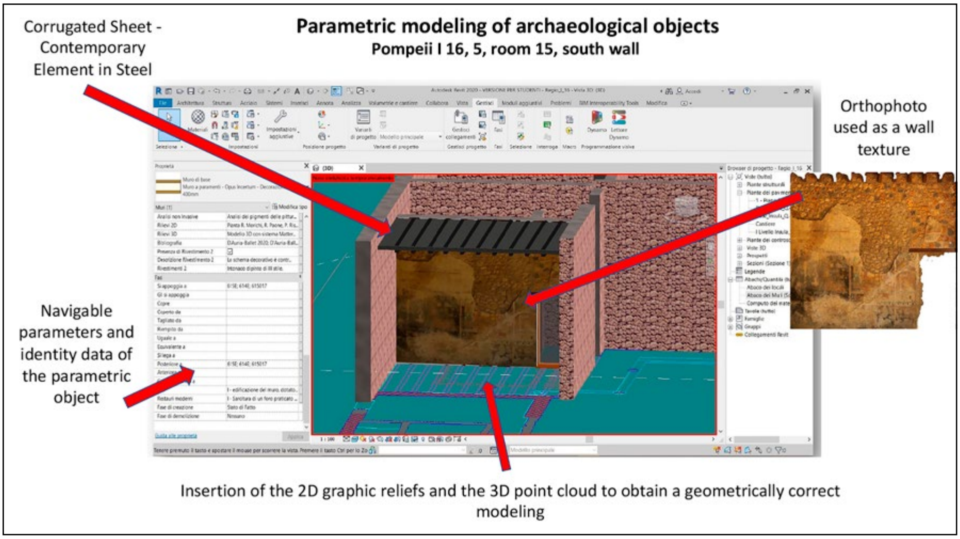

Fig. 2 – Insertion of information elements related to parametric modelling.

Based on the Pompeian archaeological evidence, in addition to the library of archaeological parametric objects, we created a library of building techniques specific to the Pompeian context, to be applied to individual objects (Fig. 2). Each element modelled in BIM is accompanied by its own construction technique, which is made browsable in the model by reading the internal stratigraphy of the elements. Each building technique is organised in Material tabs that group together the description of the technique, the pattern used for the texturing of the elements and the graphic appearance (line and fill style) that the material assumes within the *.dwg tables that can be extracted from the model. In order to obtain an excellent graphic rendering of the parametric objects modelled in BIM, orthophotos, obtained from photogrammetric surveys, were used as a texture for the external facings of the walls.

Correlation of data to the semantic library's objects is possible thanks to abacus. These are tabular structures that, in the scope of this project, have been enriched by a series of specific items, transforming them into a useful tool for archaeological analysis. This operation allows the adaptation of BIM to the archaeologist's needs and its transformation in an information system suitable to the management of data coming from archaeological investigations. In the case of a wall, for example, it is possible to fill the abacus with records concerning different topics (Fig. 3). In our work the following elements have been taken into account: the position of the wall inside the building, its function, the stratigraphic relationships with other elements, its constituent

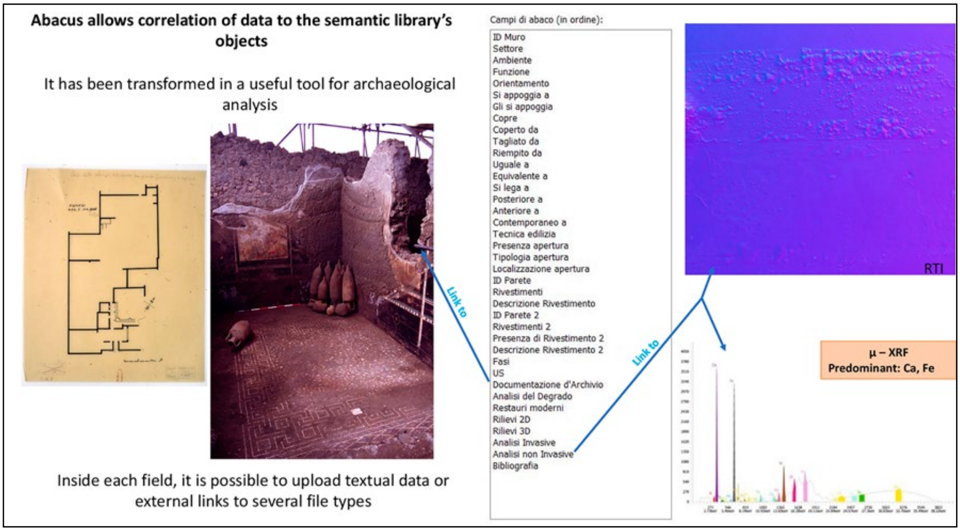

Fig. 3 – *Abacus* with entries dedicated to the specific archaeological evidence. All the items entered in the model can be queried and allow the definition of future analyses on the building (courtesy of Ministero della Cultura - Parco Archeologico di Pompei; copy or reprint is prohibited).

features – like the building technique employed – or its morphological features – like its shape or the presence of openings –, and the presence of a coating and its features. It is also possible to include data about the element's building history, its discovery (such as archive data or bibliography), the investigations it had undergone (as instance, invasive and non-invasive analysis) or about the graphic (2D and 3D surveys) and photographic documents, and the deterioration monitoring (building survey, modern restorations).

Inside each field, it is possible to input textual data or external links to several file types, including the ones for images and 3D reconstructions. Data filed in the abacus are then summarised inside a "property sheet". This property sheet supports any parametric object and is automatically displayed each time that the object is selected. In this way, the user may have an immediate overview of all data linked to the object, allowing therefore an easier management and query within the system.

Despite the fact that in the present case a proprietary software has been used, the archaeological parametric objects can be exported, without alterations or variations, in the IFC interchange format (Fig. 4). The IFC interchange format allows the BIM object to keep all the geometric and graphic characteristics and all the specific information, such as all the values in the property sheet, identified as the real attributes of the parametric object. The exported *.ifc files can be imported within all the software working in the BIM environment and

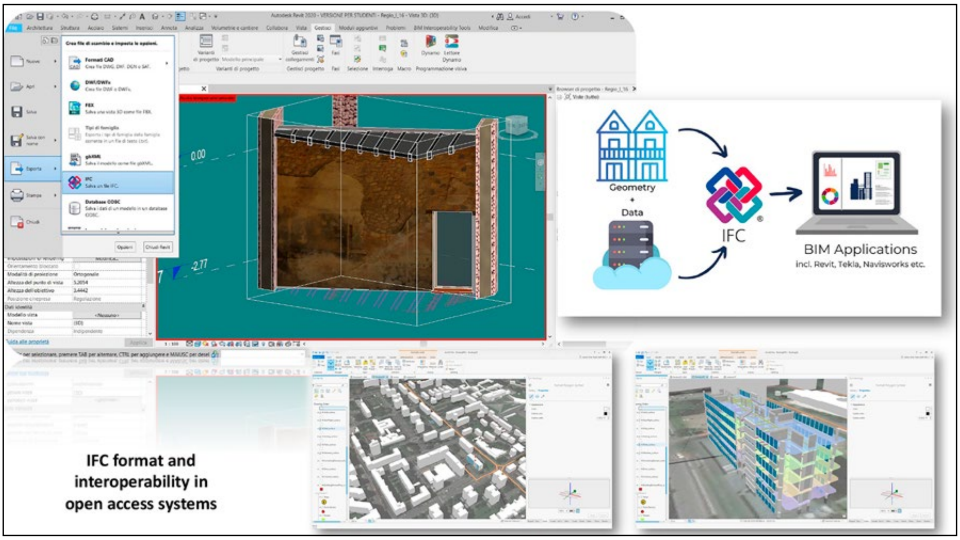

Fig. 4 – Export of archaeological BIM objects in the IFC interchange format.

are available on all modern Operating Systems. The export of archaeological objects in IFC format allows to bring BIM modelling closer to the FOSS world.

The proposed work, even though in its initial phase, aims to provide operational tools, of wide access and ready-to-use, for the creation of BIM models of archaeological contexts. The BIM objects have been modelled and defined on a scientific basis and are able to represent a wide range of evidence within the domestic architecture of Pompeii. A library of parametric archaeological objects modelled using the Autodesk Revit BIM environment software was created and exported in IFC format. The archaeological BIM objects have been enriched with graphic and constructive information that allow them to be used in all the BIM modelling of archaeological Roman domestic building structures. The IFC format enables to overcome the limitations of using non-FOSS software and create interoperable tools to use BIM as a management model for archaeological contexts.

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ABSTRACT

Building Information Modeling is the most consolidated work method for engineering design of buildings and infrastructural works. It allows you to create a comprehensive database starting from a 3D model of a building. Its use in archaeology allows to test and transform a working method born for engineering design, in an operational support for archaeologists during and after the field phase. Our contribution focuses on the application of BIM to archaeological evidence. It presents the initial stages of a research project, whose aim is the definition of operational solutions for the creation of BIM models. To implement, on a scientific basis, the BIM methodology and make the modelling of archaeological structures easier, a model of semantic library, based on Pompeian archaeological evidence, has been created. The BIM archeological objects it contains can be reproduced and possibly modified for other projects. They represent a support to share on a large scale the representation in BIM. All Archaeological Library's objects can be exported in the IFC format. This format can be opened and edited by all BIM software and worked on all OS; the export of archaeological objects in IFC format leads BIM closer to the FOSS world.