The Romanesque-style rural Churchs of Portugal: An initial stride towards the complete digitalization by Heritage-BIM. The case study of S. João de Calvos (Guimarães, 13th Cent. AD).

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1. Introduction

This project presents a pilot case study focused on H-BIM digitalization of the rural Romanesque-style church of S. João de Calvos (Guimarães, XIII Cent. AD, Fig. 1)

The intention is to produce a detailed 3D digital model capable of integrating *geometric* and *non-geometric* dataset of information including:

1) historical, archaeological and archaeometric data for educational, awareness-raising tourism fruition purposes,

2) current state of the building in terms of pathologies, materials decay, data about previous restoration and ordinary/extraordinary maintenance.

Figure 1: Church of São João de Calvos and its geographic position

Take a look to the model here!

Figure 2: Picture of the North-West elevation of the Church

2. Methodologies

The digital survey of the Romanesque Chapel of S. João de Calvos integrated 3D recording methodologies based on photogrammetry, enabling the high-resolution capture of the chapel's architectural and decorative details (Fig. 2). The combination of aerial images obtained using UAS (Unmanned Aerial Systems) and terrestrial data ensured an accurate representation of the building's dimensions and characteristics, while advanced digital processing techniques generated three-dimensional models faithful to the structure's current state. This work involved the use of a DJI Mavic 2 drone equipped with a high-precision camera (1" CMOS sensor with 20 million pixels) for both the aerial survey of the exterior and the image capture of the chapel's interior.

To complement the collected data, a terrestrial survey was conducted using a Nikon Z6II equipped with a Nikon Z 24-70mm f4 lens, ensuring the high-resolution capture of architectural and decorative details.

The combined use of these techniques resulted in a detailed and accurate 3D model that faithfully represents the chapel and its current state of conservation. Moreover, the integration of the obtained data within a Building Information Model (HBIM) framework enhances the survey's utility, providing a strategic resource for future conservation, restoration, and monitoring initiatives. In addition, diagnostic techniques like ultrasonic surveys, moisture and decay mapping allows the identification of the current decay degree of building materials.

3. History of the church and construction phases

The church of S. João de Calvos has been classified as a Property of Public Interest since 1955. It originally served an old parish, already mentioned in 1220 in the Inquiries of King Afonso II, and designated as Sancto Johanne de Calvos, from the land of Vermuy, which disappeared during the Middle Ages (Câmara Municipal de Guimarães, sd).

It is an example of late rural Romanesque, 12th/13th century, modest, massive and artistically humble. Small in size, it has a longitudinal floor plan made up of two juxtaposed rectangular bodies, the nave and the chancel. It retains some elements of the original construction, but the nave and apse are from different periods. Various construction phases are visible, resulting from alterations that took place over time, particularly in the modern era. Negatives of structures that have since disappeared can be seen at various points, particularly those associated with the main and side doors. In ruins in the 20th century, with the interior completely uncovered, it was restored by the DGEMN in the 1970s (Património Cultural I.P, sd).

In order to identify the construction phases of the church, the team is carrying out a study based on the archaeology of architecture, the stratigraphic analysis of elevations, which first identifies and then arranges the traces that the constructive and destructive actions have left in the building, the Stratigraphic Units (SU). Once these have been identified, they are drawn on the elevations of the chapel (Fig. 3), arranged and the physical relationships (what joins, adjoins or cuts what?) and temporal relationships (what is prior, contemporary or subsequent to what?) are documented. In the final phase, they will be arranged in a construction sequence.

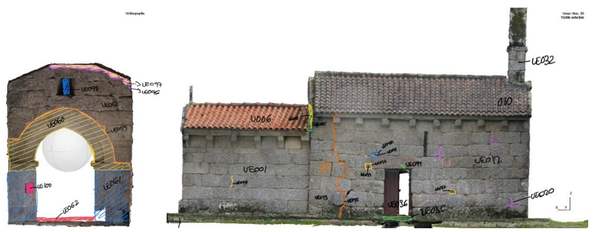

Figure 3: Working process of stratigraphic analysis: differentiation of SU

4. The analysis of building materials

4.1 Digital mapping

Ultrasonic Pulse Velocity (UPV) and Quality of Building Materials (QBM) are important methods used to evaluate and ensure the integrity of construction materials (Fig. 4)

•**UPV (Ultrasonic Pulse Velocity)**: This non-destructive technique used to assess the material's quality, density, and homogeneity.

•**QBM (Quality of Building Materials)**: This refers to the overall assessment and evaluation of construction materials to ensure they meet required standards for strength, durability, and performance.

Raster Plane-Picture of North elevation by photogrammetry

Geo-lithological identification of ashlars

Ultrasonic pulse survey (UPV) and QBM (Quality of Building Materials)

Figure 4: Examples of digital mapping

4.2 Physical and petrographic features

The church is made of alkali feldspar granite and aplite from local outcrops. The stones are characterised by mediocre mechanical strength, low porosity and imbibition coefficients. Granitic *facies* presents greater susceptibility to alteration than aplite.

Among the ashlars, the original bedding mortar, probably of aerial lime, has been completely degraded by scaling processes and was replaced in the 1970s by Portland cement

4.3 Micro-photogrammetric survey

Photogrammetry was carried out at specific points of the monument subject to degradation conditions or areas where fractures are present. Normally, surfaces with a size of 100 cm^2 are reproduced (Fig. 5). Digital Elevation Models (DEM) are associated with each surface. The objective is to perform photogrammetric surveys at biennial intervals and detect micro-morphological variations and volumetric loss of samples, quantifying the progression of stone degradation.

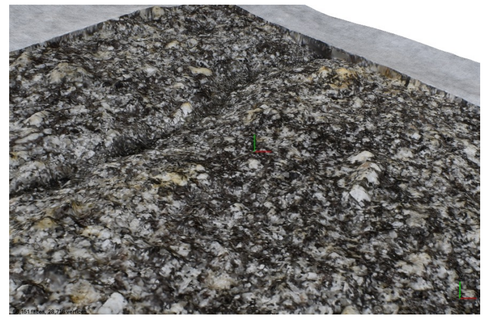

Figure 5: Examples of photogrammetric surveys

To fully realise the premise of wanting to create a functioning archive to document the state of the monument, there was a theoretical need to have a level of detail capable of describing the state of all surfaces, not only macroscopic pathologies and alterations, but also incoming and developing transformation from the original condition.

5. Conclusions

The next steps in this project will consist of creating a 3D digital model composed of layers, each of which will offer BIM data and integrated maps of material characteristics.

A geophysical survey of the ground adjacent to the church, in which the presence of historical burials is assumed, is also planned.

For the stratigraphic analysis of the elevations, the EU will be drawn on the elevations, the information on the elevations will be digitised and organised in a stratigraphic diagram. This will allow us to have a relative sequence that, thanks to the historical documentation and stylistic elements available, we will be able to date absolutely.

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