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Case study

Contribution of engineering geology for the construction of a new museum gallery over an archaeological site at Lorvão Monastery, Portugal

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ABSTRACT

The rehabilitation of the Lorvão Monastery in Penacova, Portugal, included the construction of a new steel structure to house a museum gallery. The implementation of an archaeological excavation prior to construction revealed a mesh of ancient masonry walls, dating from the 16th to the 18th centuries, which needed to be preserved and made available for exhibition. To help understand the characteristics of this foundation ground, an engineering geology study was required, strongly conditioned by the presence of heritage, reduced space and difficult accessibility caused by the extensive temporary support used to ensure stability of the walls. The engineering geology study consisted of a detailed surface mapping, complemented by non-destructive in situ tests, the soil stiffness gauge (SSG) and the surface moisture-density gauge (SMDG) and by the use of the Bieniawski rock mass rating (RMR) geomechanical classification. Three geotechnical zones were defined. The non-invasive engineering geology study performed proved suitable to provide the geotechnical information necessary to redesign and construct the steel structure over a challenging archaeological site, preserving the heritage.

1. Research aims

The research aimed to improve the interaction between engineering geology, archaeology and civil engineering in the construction of an engineering structure over an archaeological site of significant heritage value. Using current site investigation techniques and tests was not feasible due to difficulties accessing the exploration equipment and to the high risk of destruction of the heritage. The alternative approach used was based on a detailed engineering geology mapping of the archaeology-excavated surfaces, complemented by non-destructive measurements with portable equipment (SSG and SMDG), and by the use of the Bieniawski RMR geomechanics classification. The engineering geology approach used, proved to be effective in obtaining the information needed for the appropriate design and construction of the foundations of the steel structure, assuring the preservation of the heritage.

2. Introduction

Seeking new utilizations for the Lorvão Monastery in Penacova, Portugal, the construction of a museum gallery was planned on the west and south courtyard of the cloister.

The archaeological excavations required by the project owner, Instituto de Gestão do Património Arquitéctonico e Arqueológico (IGESPAR), before construction, revealed buried ancient walls dating from the 16th to the 18th centuries; considered an invaluable heritage. The walls thus had to be preserved and made available for exhibition.

3. History highlights

The Lorvão Monastery (Fig. 1) is located 7 km southwest of Penacova and 19 km east of Coimbra in Portugal [1]. The monastery would most certainly have been founded in the 9th century after the Christian reconquest of Coimbra in AD 878 [2–4]. The building

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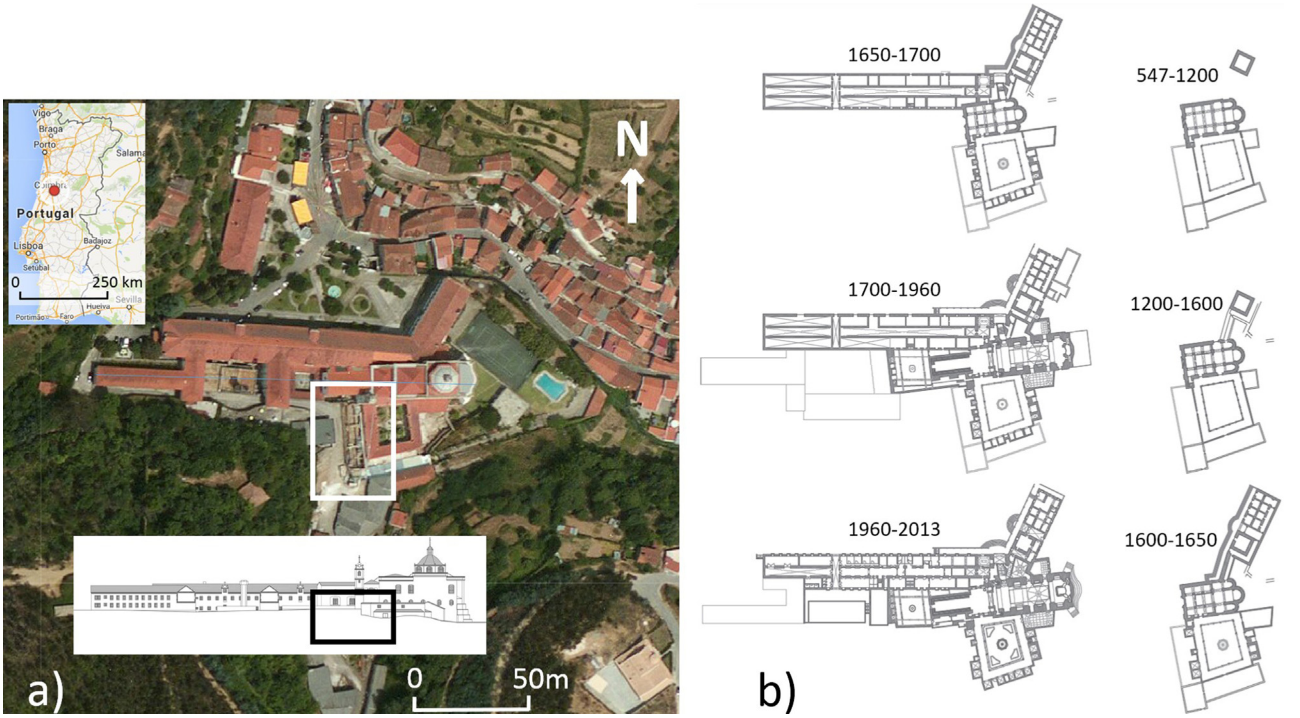

Fig. 1. a: location map [1] and south façade sketch [2] of the Lorvão Monastery, Penacova, Portugal, from a satellite view. The studied area is delimited by a rectangle; b: evolution of the ground plan of the Lorvão Monastery between AD 547 and AD 2013.
Modified from [2].

ceased to be a monastery in 1887. The classification of National Monument was attributed in 1910 [4].

The monastery has undergone several renovations over the centuries (Fig. 1b). At the end of the 16th century, a new renaissance cloister was built, surrounded by 13 chapels. The baroque balcony was added in the middle of the 17th century, followed by several other improvements to the building. The construction of a new building for the novices was undertaken at the beginning of the 18th century. The present church was rebuilt between 1748 and 1761 [3,4]. After important rebuilding in the 20th century, the monastery was predominantly used as a psychiatric hospital until 2007. The new museum gallery was intended to be both a purpose-built exhibition space for the vast collection of valuable artistic items related to monastery life and its occupants, and as a way to provide funds to reduce running and maintenance costs.

4. Work development

In 2006 a preliminary study, without any site investigation, was carried out in preparation of the construction of a contemporary steel structure, mostly stone cladded, in delicate contrast to the existing constructions, to be built over an area of the garden. The archaeological excavation undertaken at the beginning of construction revealed a mesh of masonry walls belonging to ancient construction phases of the monastery (Fig. 2a).

To redefine the structural foundations in this complex framework, an engineering geology study of the ground was requested. As the archaeological works necessitated deep excavations within the fragile ancient walls, intensive temporary support was used which left a significantly reduced available space. The use of geophysical exploration was not possible due to the depth of the excavation, and the reduced space between walls and the large number of metallic props and wood braces supporting the walls and to the buried chapels adjacent to the cloister. Use of mechanical exploration was also rejected due to the lack of space and the difficulty of positioning a drilling unit within the fragile ancient walls; such a procedure would have risked serious damage to the archaeological structures.

The engineering geology study developed was thus based on a detailed surface engineering geological mapping, complemented by non-destructive in situ tests, using light, small and easy to handle equipment (SSG and the SMDG) and by using the RMR geomechanical classification.

5. Characteristics of the SSG

The Soil Stiffness Gauge (SSG) causes very small vibrations on 25 different frequencies between 100 and 196 Hz, that are transmitted to the ground by the ring shaped foot (Fig. 2c), measuring the resulting deformation and the average value is displayed [5,6]. The deformation of the soil (δ) is proportional to the Young's modulus (E), the shear modulus (G), the Poisson's ratio (υ) and to the outside radius (R) of the ring foot. Dividing the force (P) by the deflection (δ), the stiffness (K) is obtained. The stiffness for a ring load in an elastic half-space is given by [7]: $K=(P/\delta)=(3.54GR)/(1-\upsilon)$. The stiffness modulus of the ground is computed using the relation $Eg=K(1-\upsilon^2)/1.77R$ [5]. The test procedure used was based on the ASTM Standard D6758 (2008) [8].

6. Characteristics of the SMDG

The surface moisture-density gauge (SMDG) has radioactive sources and radiation detectors enabling measurement of the in place density and moisture of the ground by direct transmission, backscatter, or backscatter/air-gap ratio methods [9]. The rod of the SMDG containing cesium-137 emits gamma radiation (photons), which is then measured by the detector at the base of the gauge. The photons collide with a large number of electrons, reducing the amount reaching the detector in proportion to the density of the material. The nuclear gauge also uses a 40 mCi source of