Studying a masonry sail vault by Antonio da Sangallo the Elder in the *Fortezza Vecchia* in Livorno

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ABSTRACT

This work is part of ongoing research activities that are being conducted by the multidisciplinary Research Group on Historic Masonry Construction of the University of Pisa within the framework of the PRA 2017 research project "Architetture toscane rinascimentali: casi studio fra indagine storica, rilievo e analisi strutturale", funded by the University of Pisa. The research addresses interdisciplinary studies of historical constructions of interest from a historical and architectural point of view, which are considered representative of the Tuscan military and civil architecture of the fifteenth and sixteenth centuries. A first group of buildings consists of the "modern" military garrisons built in Pisa and Livorno on behalf of the Florentine government by Giuliano da Sangallo, Antonio da Sangallo the Elder and Antonio da Sangallo the Younger. In particular, the study is focused on the "Sangallo Fortress" in Pisa and the "Old Fortress" of Livorno, two works strongly marked by the presence of water which represents a real constructive challenge.

More in detail, the present paper illustrates some first results of an analytical study concerning equilibrium of the subterranean brick masonry sail vault in the “Canaviglia” seaward bastion of the “Fortezza Vecchia” in Livorno. The 16th century Fortress, of great historical and architectural interest, was designed by Antonio da Sangallo the Elder who fortified a pre-existing medieval castle placed in a strategic position from a military point of view [1]. The analysis aims at evaluating the vault mechanical response and resisting capabilities by starting from the detailed knowledge of its geometry and constituent materials and by paying particular attention to historical and architectural aspects as well.

The information collected by a laser scanner survey is used as input data for a numerical procedure aimed to approximate the vault intrados with a smooth surface, allowing a simple analytical description. Experimental investigations have been carried out to assess the main geometrical and mechanical parameters. Endoscopic tests and core-drilling have been performed in order to obtain information on the actual thickness of the vault and supporting walls along with the degree of connection between them. Flat jack tests have been used to evaluate the masonry main mechanical parameters.

Structural analysis has been performed within the framework of the safe theorem of limit analysis by searching for statically admissible stress fields within the vault according to Heyman’s hypotheses [2]. The weights of the vault and the overlying soil filling have both been considered. From the structural point of view, the vault is modelled as a shell. According to the hypotheses made on the material, it can be shown that if it is possible to find an internal stress distribution in equilibrium with the external loads and compatible with the resistance of the material, the structure can be considered stable. In particular, the analysis aims at investigating how the boundary conditions assumed between the masonry sail vault and vertical walls affect the statically admissible solution and the corresponding safety factor. A preliminary estimation of the vault safety level under vertical loads is provided in terms of both geometric and mechanical safety factors.

REFERENCES

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