Structural Analysis Under Static and Dynamic Conditions of the West Curtain Wall of Elmina Castle, Elmina, Ghana

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ABSTRACT

Elmina Castle is the oldest permanent European structure in Sub-Saharan Africa, the first of a series of trading bases along Africa's West Coast. Built in 1482 as São Jorge da Mina by the Portuguese Crown, the castle served as an imposing commercial outpost for over four centuries of international trade. After the 1637 Dutch conquest, the castle became a major hub of the Atlantic Slave Trade involving Europe, Africa, and the Americas. The castle is currently a UNESCO World Heritage Site and a national Ghanaian museum.

The building is the best-preserved example of early European masonry construction in Sub-Saharan Africa. Construction and rebuilding cycles under the Portuguese and the Dutch introduced materials and technologies new to West Africa and reflected changes in European defensive architecture. The Elmina Castle has been the object of a multidisciplinary field school conducted at Elmina, Ghana, by the Archaeology, Technology, and Historical Structures program of the University of Rochester in summer 2017 and 2018.

In this preliminary study we focus on evaluating the changes in structural stability and lateral capacity of the western curtain wall resulting from the structural changes introduced during its five-hundred years of occupation, see attached Fig. 1. The castle is built on a rock mass projecting into the sea, and the western wall protects the only side accessible by land. The wall is constructed with rough stones held by a combination of mud and lime mortars and extends from an octagonal tower next to the castle gate to the south-west bastion. A flaring at the base of the wall near the gate suggests that a second tower might have existed at this location in early Portuguese times and then collapsed during late Portuguese occupation - possibly due to the 1615 earthquake historically documented at Elmina. The height and the thickness of the curtain wall were increased during the Dutch occupation and a two-story brick vaulted building was erected alongside the entire wall. At a later stage, two additional stories were added next to the octagonal tower.

Four models are tested numerically via non-linear 3D FE analysis. We first consider the early Portuguese wall with and without the presence of the hypothetical tower next to the gate. We then introduce the Dutch-period thickening of the curtain wall and the addition of a vaulted two-story

building. Finally, we include the two-story addition on the north section of the wall. The architectural models and the masonry characterization are derived from the manual and digital surveys and systematic visual inspections conducted over the entire castle. The masonry physical characterization is based on published material and the non-linear mechanical behavior is modeled through the concrete damaged plasticity formulation available in Abaqus/CAE. The collapse conditions induced by gravitational loads and pushover analyses are evaluated using both static and dynamic (FE explicit) models.

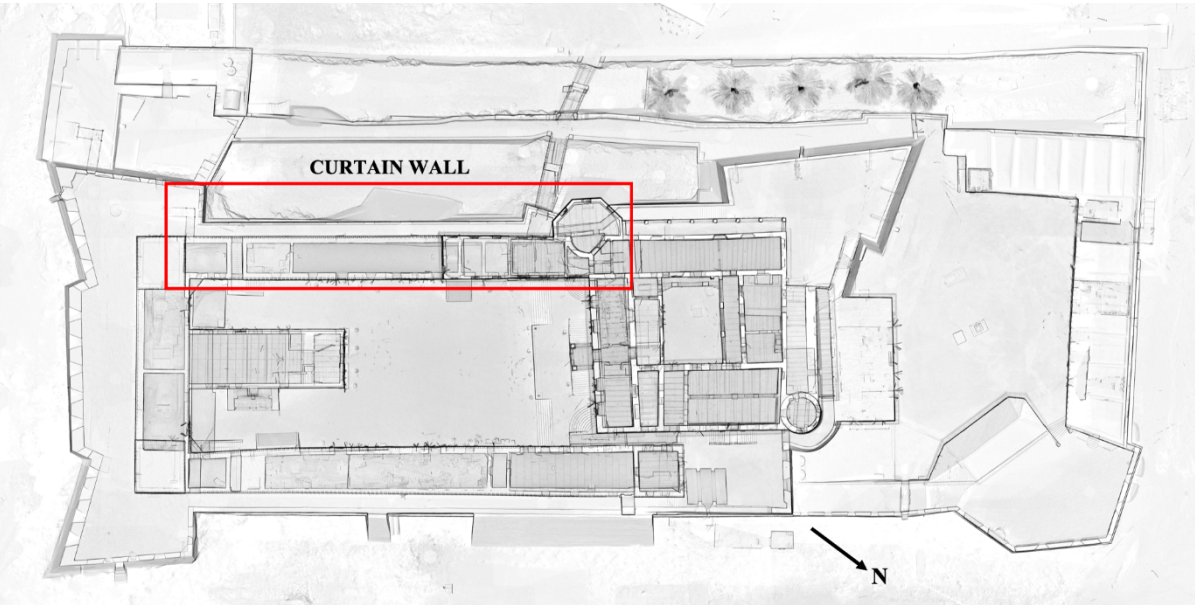

Figure 1. Elmina Castle floor plan, based on 2017-2018 FARO Scans taken by Michael Jarvis. U. Rochester/ U. Ghana, Legon, Field School.