

The Structural Function of the Dutch Buttressing of the East Curtain Wall of Elmina Castle, Elmina, Ghana.

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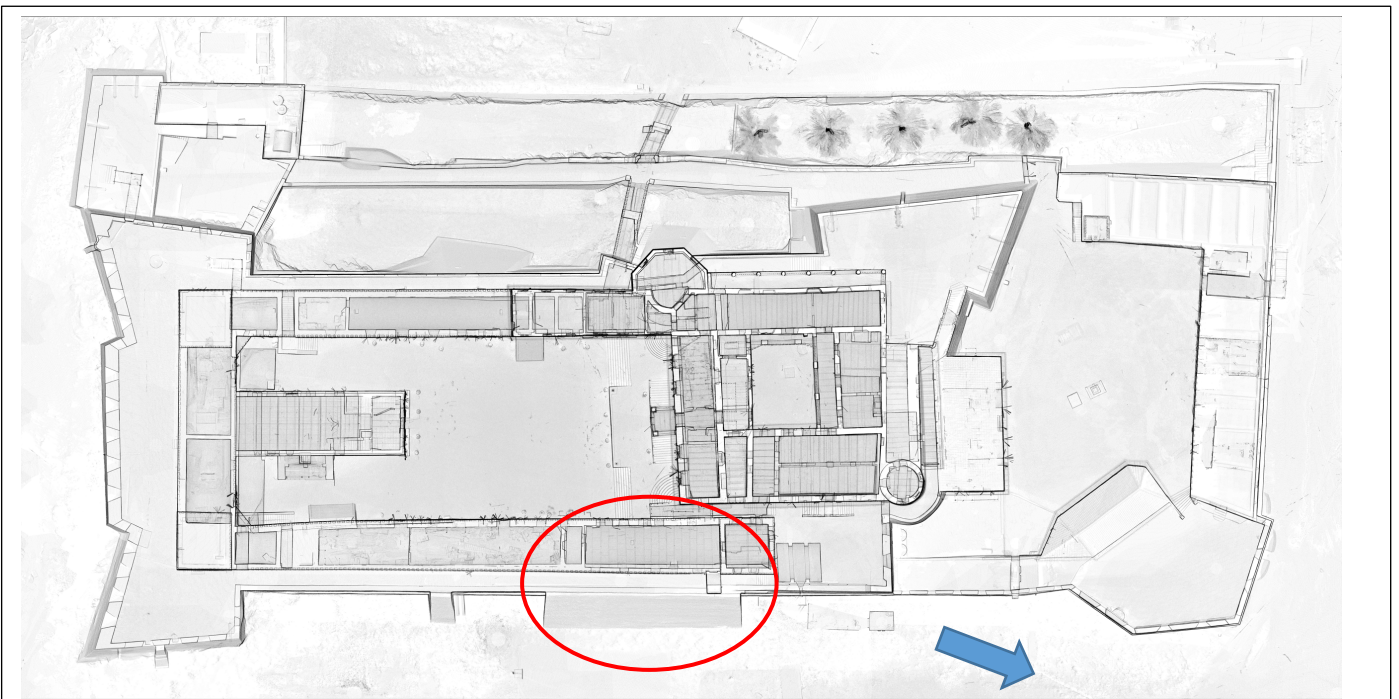
ABSTRACT

As the oldest and best preserved early European building in Sub-Saharan Africa, Elmina Castle the first of a series of trading bases along Africa's West Coast. Erected in 1482 by the Portuguese Crown to protect its control of the gold trade, after the 1637 Dutch conquest the castle became a major hub of the Atlantic Slave Trade involving Europe, Africa, and the Americas. Acquired by the British in 1872, the castle came under control of Ghana with the country independence in 1957 and is currently part of a UNESCO World Heritage Site in Ghana.

The Elmina Castle has been the object of a multidisciplinary (engineering and historical archeology) field school conducted at Elmina, Ghana, by the Archaeology, Technology, and Historical Structures program of the University of Rochester in summer 2017 and 2018. At the present time, the building consists of an inner keep of three-story buildings and a large courtyard surrounded by curtain walls, with bastions at the southeast, southwest, and northwest corners (see attached figure). The structure shows a combination of mud-mortared and lime-mortared sandstone masonry macro elements, incorporating original 1482 Portuguese elements (towers, walls) with successive Portuguese, Dutch, and British reconstructions and modifications. European built fired-clay bricks were first used sparingly by the Portuguese for windows and doors openings, and then in very large number for extensive vault construction by the Dutch.

The present paper focusses on the structural static and dynamic analysis of the east curtain wall which features two massive masonry buttresses which reach up to the parapet but were built only along selected portions of the wall. Historical documents clearly show that these buttresses are a Dutch addition, since they do not appear in the only drawing showing the castle still in Portuguese hands in 1637 while they are present in detailed - and particularly accurate - Dutch maps of the second half of the 1700's. Like the western curtain wall, the original eastern curtain wall appears to be built with foundation resting on levelled limestone bedrock, as reported by the Portuguese chronicles describing the 1482 construction process. The laser-scan and photogrammetric survey conducted during the field school and information extracted from the historical record allow us to construct a reasonably accurate building sequence beginning from late Portuguese occupation (before 1637) to the mid 1700's. The late Portuguese west wall was extended in elevation and considerably thickened with mud-mortared masonry covered by lime plaster, and a two-story building was added along its entire length, with the inner side of the curtain wall becoming part of the new building. The first (ground) story of the building is vaulted with a 4m-span barrel vault approximately 15 cm thick (the length of an average Dutch brick.) This thin vault - excellently executed with bricks interlocking in two directions - carries a considerable

dead load of loose material 1m deep at the crown and is in undamaged structural conditions. To explain the presence of the irregular buttressing architecture noted above, we make the following hypothesis. The section of the original Portuguese wall later covered by the buttress is likely not built on the bedrock but on compacted loose soil and debris used to fill an area where the bedrock does not reach the level of the courtyard (a procedure largely attested in other European forts along the coast of Ghana.) The wall carried by this weaker foundation could have been damaged by the 1615 earthquake in Elmina or by the Dutch assault on the castle, or both. The dead loads introduced with the extension and thickening of the wall and the construction of the vaulted building could possibly have caused concerns in the Dutch builders, who, noticing signs of rotational instability, reinforced the wall with a buttressing system limited only to the affected areas. We test the structural conditions on which the hypothesis is based through a sequence of 2- and 3D nonlinear FE static and dynamic models, by first testing how the presence of a pocket of loose soil affects the dynamic response of the Portuguese wall under lateral accelerations, then testing the static and dynamic effect of the Dutch modifications to the wall, and finally introducing the effect of the vaulted building. In modeling the curtain wall, we test separately the case of a solid masonry wall or, as it is more likely, of a wall with an internal mass of loose material bound by external and internal masonry curtain. 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 Explicit.



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