A STRUCTURAL SURVEY OF FORT AMSTERDAM, ABANDZE, CENTRAL REGION, GHANA

CONDUCTED DURING THE 2019 FIELD SCHOOL IN ENGINEERING AND ARCHAEOLOGY OF HERITAGE BUILDINGS OF WEST AFRICA, ORGANIZED BY THE UNIVERSITY OF ROCHESTER & UNIVERSITY OF GHANA

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SUMMARY

This report documents the present structural conditions of Fort Amsterdam, Abandze, Central Region, Ghana, as assessed through visual inspections and archaeological stratigraphic exploration conducted by the faculty and students of 2019 Field School in Engineering and Archaeology of Heritage Buildings of West Africa, jointly organized by the University of Rochester and University of Ghana. The existing masonry structures of Fort Amsterdam present an extensive—possibly critical—state of damage characterized by fractures, wall misalignments, and soil erosion. Due to the lack of monitoring devices placed to follow the progress of fractures, the rate of decay cannot be properly judged except by noticing that in a number of cases modern repair—in the form of either the filling of a fracture or the entire reconstruction of a wall—show signs of new fracturing or impending collapse. The present state of structural decay of the monument clearly indicates the urgent necessity of a conservation process before any type of reconstruction can be considered. The conservation process should include: (a) placement of a structural monitoring system, (b) geotechnical analysis, (c) seismic risk evaluation, and (d) technical expertise in the consolidation of this type of historical masonry structures.

1. Introduction

In the course of the meeting between the faculty of the University of Rochester and University of Ghana 2019 Field School in Engineering and Archaeology of Heritage Buildings of West Africa, which took place at the Ghana Museums and Monuments Board (GMMB) in Accra on May 30, 2019, the GMMB Executive Director Mr. Kingsley Ofosu Ntiamoah asked Professors Renato Perucchio and Christopher DeCorse to provide a report on the present structural conditions of Fort Amsterdam, Abandze, Central Region. Fort Amsterdam is one of the European fortified trading posts in the Ghana UNESCO World Heritage site “Forts and Castles, Volta, Greater Accra, Central and Western Regions.” The GMMB request was motivated by a proposed reconstruction project which would affect the entirety of Fort Amsterdam. The work reported here was conducted by the Field School faculty and students at Fort Amsterdam during the period May 31 – June 22, 2019 under the supervision of Prof. Perucchio (structural engineering) and Prof. DeCorse (archaeology).

2. Objectives

During the structural engineering assessment we conducted a visual inspection of each wall and vault in building complexes B1-B4 (Fig.1), since those were the areas showing major to critical decay conditions and, in the case of B1-B3, would be the object of the proposed reconstruction. For each wall, the fractures affecting the masonry core were photographed and manually traced on the appropriated wall section extracted from the architectural survey provided by GMMB (Figures 2-29). The layout and depth of relevant structural foundations was determined at locations F1-F8 (Figures 30-32) either through visual inspection (location F1 and F2) or through archaeological stratigraphic excavation conducted at locations F3-F8. Finally, possible collapse mechanisms associated with the fracture distribution, wall misalignments, and support conditions at the foundation level were identified for each structural element.
3. Findings

3.1 Fractures Survey

3.1.1 Building Complex B1

Building complex B1 occupies the south portion of the fort, extending from the southwest corner to almost the southeast corner of the inner curtain wall (Fig. 2). The west and south wall are part of the inner curtain wall itself, while the north wall faces the inner courtyard. Two transverse walls (T1 and T2 in Fig. 2) divide the building into a three-story unit to the west and a two-story unit to the east. The only floor standing above the ground is the first floor of the west unit, which is carried by a barrel brick vault.

The south wall – and in particular the portion between T1 and T2 - presents an extensive series of vertical fractures extending from the top of the wall to the springing of the vault, as clearly visible on the inside of the wall at the vault indentation (Fig. 3-7). Two fractures, however, continue to the level of the foundation. A dense network of cracks affects the upper west corner. Like the south wall, the north wall is affected by several vertical fissures, which on the east side reach the foundation level breaking the wall into separate blocks while on the west side appear to stop at the springing of the vault (Fig. 8-11). Transversal wall T1 is nearly completely separated from the south and north wall by vertical fractures running in proximity of the corners (Fig. 12-14). Transversal wall T2 is separated from the south wall by a vertical crack located at the corner and ending at the springing of the vault (Fig. 15-17). Finally, the west wall does not show any significant fractures (Fig. 18).

3.1.2 Building Complex B2

This complex – originally a two-story unit – occupies the northeast corner of the fort (Fig. 19). The north and east wall are part of the inner curtain wall. The north wall stands to the second story level and is thicker up to the first floor in order to support the floor joists. Only fragments of the south and west wall survive. Two fractures, with limited extension and not reaching the roof level are present in the north wall (Fig. 20).

3.1.3 Building Complex B3

Symmetrically positioned with respect to B2, this is a two-story unit which occupies the northwest corner of the fort (Fig. 19). The north and west wall are part of the inner curtain wall. The south and west walls stand intact to the roof level, while the north and east walls contain only fragments of the second story. The south and west walls show clear signs of a collapsed brick vault that covered the first story (the vault indentation on the south wall and the trace of the generating arch on the west wall, Fig. 21). The north wall is largely reconstructed and thus carries no signs of the vault indentation. The south wall appears to be the result of two separate construction phases, corresponding to two approximately equal vertical sections (Fig. 22, 23). The west half is perpendicular and in-plane, while the east half leans outward and is noticeably out of plane (Fig. 24).

3.1.4 Building Complex B4

Complex B4 covers the north façade of the fort, including the northeast circular bastion, the north curtain wall, and the northwest bastion. While the curtain wall is essentially
undamaged, the northwest bastion shows a network of vertical fractures, extending from the battlements to the ground and, in some cases, reaching the foundations (Fig. 25-28). The cylindrical surface of the northeast bastion also shows a horizontal fracture running close to the base, and a diagonal fracture which extends to the curtain wall (Fig. 29). The southern part of this bastion has been extensively reconstructed. In the northwest bastion – the largest massive structure of the fort – vertical or nearly vertical fractures are present in the north and east faces, and on the south flank. They appear to be connected by a network of fissures present on the top of the bastion (Fig. 27, 28).

3.2 Foundations Survey

The foundations were examined at eight different locations – F1-8 in Fig. 30 – either through the archaeological stratigraphic excavation conducted by Prof. Christopher DeCorse at F2-F8 or by direct visual inspection at F1-F2. In all instances it was found that the masonry structure rests directly on lateritic soil, albeit at different depth from the present soil surface. In no cases, the masonry foundations comes in contact with solid bedrock.

3.2.1 Foundation F1

At the east section of the staircase added on the courtyard side of building complex B1 the foundation is exposed through soil erosion, which has lowered the soil from its presumed level at construction time by approximately 15 cm (Fig. 31). In this case, there is no structural foundation, since the masonry was directly laid out on the leveled soil surface.

3.2.2 Foundation F2

Due to the rapidly sloping ground on which the northwest bastion is built, soil erosion has extensively exposed the foundations at the apex and along the entire west face of the structure (Fig. 32). Based on the findings at F6 (see below) and on the current position of the original foundation block clearly visible at the apex, this erosion can be estimated to range between 1.5 m to 2.0 m at the apex itself. A remedial masonry structure is visible below the original foundation around the apex and along the entire west face of the bastion, possibly inserted in successive layers to counteract the progressive erosion.

3.2.3 Foundations F3 and F4

At location F3 the archaeological trench has exposed the base of the collapsed external (south) wall of the south curtain and has revealed the presence of a parallel masonry wall built on the south side of the curtain, presumably to reinforce it, but also entirely collapsed (Fig. 31). The south curtain wall rests directly on the lateritic soil, immediately below top soil level, while the adjacent wall penetrates slightly deeper (approximately by 30 cm) and is also resting on lateritic soil. In either case there is no actual structural masonry foundation. Similar considerations apply for location F4 (Fig. 31). Here the trench has exposed the base of a circular masonry structure, possibly the base of the collapsed southwest circular bastion. In this case too, the stonework rests directly on lateritic soil with no indication of structural foundation.

3.2.4 Foundations F5, F7, and F8
The archaeological exploration inside building complexes B1, B2, and B3 has revealed the presence of actual masonry foundations, albeit with different depth and structural composition. Across the collapsed south wall of B2, location F5 shows about 70 cm deep foundation made of rough stone pieces similar to those used in the vertical walls, connected with lime mortar – Fig. 32. On the south wall of complex B3 (location F7, Fig. 32) the foundation is lime-mortared but varies from west to east in depth (from 50 cm to 60 cm) and stone size (from smaller to more regular size), indicating the presence of two construction stages (which is consistent with the structure of the wall above). Finally, on the north wall of B1 (location F8, Fig. 31), the foundation is made up of well laid-out stones to a depth of 70 cm, but in this case, the stonework is mud-mortared (whereas the wall above has lime mortar.) In all these cases, the foundations rest on lateritic soil.

3.2.5 Foundations F6

The archaeological trench and the west edge of the north curtain wall (at the corner with the northwest bastion – Fig. 32) has revealed a well-built foundation of lime-mortared stones more than 160 cm deep resting on lateritic soil.

4. Conclusions and Recommendations

The existing masonry structures of Fort Amsterdam present an extensive state of damage characterized by fractures, wall misalignments, and soil erosion. Throughout the monument, extensive modern repair and reconstructions conducted in the second half of the 1900’s as well as traces of collapsed structures (including the complete disappearance of the outer south curtain wall and southwest bastion) give evidence of ongoing structural decay, possibly approaching a critical state. Due to the lack of monitoring devices placed to follow the progress of fractures, the rate of decay cannot be properly judged except by noticing that in a number of cases modern repair – in the form of either the filling of a fracture of the entire reconstruction of a wall – shows signs of new fracturing or impending collapse.

4.1 Building Complex B1

The extensive fracture pattern present in the south wall, north wall, and transversal wall T1 – Figures 3-14 – together with the findings at foundation level for complex B1 and for the adjacent south curtain wall – Figures 32 and 32 – suggest the presence of instability mechanisms likely due to foundations problems. In particular:

1. The south wall has lost the continuity in its own plane and the connection with the transversal walls T1 and T2. In conjunction with a possible erosion or displacements at foundation level this would set in motion an outward rotation mechanism, leading to structural collapse likely similar to the one that brought down the outer south curtain wall. The reconstruction of the vault could further contribute to the risk of rotation by producing a lateral thrust at the springing of the vault (i.e., at the very location where the indentation on the original vault has already weakened the wall.)

2. In the north wall, the east section of the wall (highlighted in Figures 8 and 10) is nearly completely separated from the rest of the structure. Brocken down in discrete blocks, this wall section appears to be developing an in-plane collapse mechanism that also extends
to a portion of transversal wall T1. It is important to notice that the affected sections of
the north and T1 walls correspond almost exactly to the sections shown missing in the
illustration of the interior of Fort Amsterdam published by A. W. Lawrence\textsuperscript{1} and possibly
reconstructed in the early 1950s by Lawrence himself. Considering the total lack of
structural foundations noticeable at the east base of the staircase attached to the
affected wall section (location F1 in Fig. 31), the pervasive instability condition could be
due to problems with the foundations at the northeast corner of B1. In addition,
difference in the bonding agent between the modern reconstruction and the old section
might have contributed to creating the fractures.

3. Due to its separation from the south and north walls, wall T1 is at risk of developing an
outward rotational mechanism. As indicated above, a sizeable portion of this wall is the
result of a modern reconstruction (possibly by Lawrence.)

4.2 Building Complex B2

The existing fractures in the north wall (Fig. 20) and the foundations brought to light on
the south wall (location F5 in Fig. 32) do not yield information on the possible cause of the nearly
total collapse of the south and west wall.

4.3 Building Complex B3

The noticeable misalignment of the east section of the south wall both in plane and in
elevation (Fig. 24) and the collapse of the north wall (Fig. 21) could have independently caused
the vault collapse. In the existing conditions, the reconstruction of the vault could cause the
rotation of the south wall by introducing a horizontal thrust in the section of the wall not
supported by adjacent structures (Figures 22 and 23). In addition, the possibility of a repeated
collapse of the inner north curtain wall cannot be excluded, since, in analogy with all the other
sections of the curtain, this is likely to contain a core of loose material, whose pressure on the
inner and outer containing walls increases due to water infiltration.

4.4 Building Complex B4

The pattern of vertical fractures in the northwest bastion is clearly related to the
progressive erosion of the foundations (Figures 25-28). Like the curtain walls, the bastion consists
of a mass of loose material contained by inclined masonry face walls. Under the effect of
increasingly weakening support along the west side, a state of horizontal tensile stresses
developed in the upper part of the north and south face walls causing the onset of vertical
fractures that have propagated to the foundations level. The west portion of the bastion is thus
gradually separating, inducing the outward rotation of the west face wall. In addition, as noted
above for complex B3, water infiltration through the extensive fracture network on the top of
the bastion (Fig. 27) can be assumed to increase the pressure exerted by the loose material thus
amplifying the effect of the foundation erosion on the west side and also generating instability
on the north and south sides. The pressure of the water-saturated loose material also explains
the pattern of fractures present in the northeast circular bastion (Figures 25 and 29).

\textsuperscript{1} A. W. Lawrence, Trade Castles and Forts of West Africa, 1964.
4.5 Recommendations

The present – possibly critical – state of structural decay of the monument clearly indicates the urgent necessity of a conservation process before any type of reconstruction can be considered. This should include the following:

1. The placement of a monitoring system to follow the progress of the structural decay and thus allow for immediate intervention in the case of imminent collapse.
2. A geotechnical analysis to determine the stability of the lateritic soil and the geological stratification of the ground on which the fort is built.
3. A seismic risk evaluation. The intrinsic fragility to ground accelerations of historical masonry structures is in this case compounded by the state of extensive structural damage in the walls.
4. Technical expertise in the consolidation of this type of historical masonry structures in order to avoid introducing new and possibly catastrophic damage by adopting inappropriate construction procedures.
building complex investigated in the present survey

FIG. 1 – PLAN OF FORT AMSTERDAM
FIG. 2 – WALLS OF BUILDING COMPLEX B1
FIG. 3 – BUILDING COMPLEX B1 – SOUTH WALL – view from the north
FIG. 4 – BUILDING COMPLEX B1 – SOUTH WALL – view from the north
FIG. 5 – BUILDING COMPLEX B1 – SOUTH WALL – view from the south
FIG. 6 – BUILDING COMPLEX B1 – SOUTH WALL – view from the south
FIG. 7 – BUILDING COMPLEX B1 – SOUTH WALL – view from the south
FIG. 8 – BUILDING COMPLEX B1 – NORTH WALL – view from the north
FIG. 9 – BUILDING COMPLEX B1 – NORTH WALL – view from the north
FIG. 10 – BUILDING COMPLEX B1 – NORTH WALL – view from the south
FIG. 11 – BUILDING COMPLEX B1 – NORTH WALL – view from the SOUTH
FIG. 12 – BUILDING COMPLEX B1 – TRANSVERSAL WALL T1 – view from the west

- **Active fracture**
- **Active fracture on east side of wall**
- **Fracture traversing T1 wall**
FIG. 13 – BUILDING COMPLEX B1 – TRANSVERSAL WALL T1 – view from the west
FIG. 14 – BUILDING COMPLEX B1 – TRANSVERSAL WALL T1 – view from the east
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FIG. 15 – BUILDING COMPLEX B1 – TRANSVERSAL WALL T2 – view from the east

- active fracture
- repaired fracture
- fracture traversing T2 wall
- non-traversing fracture
FIG. 16 – BUILDING COMPLEX B1 – TRANSVERSAL WALL T2 – view from the west
FIG. 17 – BUILDING COMPLEX B1 – TRANSVERSAL WALL T2 – view from the west
FIG. 18 – BUILDING COMPLEX B1 – WEST WALL – view from the east

- active fracture
- walled opening
- non-traversing fracture
FIG. 19 – WALLS OF BUILDING COMPLEXES B2 AND B3
FIG. 20 – BUILDING COMPLEX B2 – NORTH WALL – view from the south
FIG. 21 – BUILDING COMPLEX B3 – photographic survey - interior
FIG. 22 – BUILDING COMPLEX B3 – SOUTH WALL – view from the north
FIG. 24 – BUILDING COMPLEX B3 – SOUTH WALL – aerial view from the north-east
FIG. 25 – BUILDING COMPLEX B4 – view from the north

- active fracture
- repaired fracture
- eroded soil level
FIG. 26 – BUILDING COMPLEX B4 –view from the north
FIG. 27 – BUILDING COMPLEX B4 – BASTION – view from the north & above
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FIG. 28 – BUILDING COMPLEX B4 – BASTION – view from the west & the south
FIG. 27 – BUILDING COMPLEX B4 – view from the north
foundation investigated in the present survey

FIG. 30 – TOP VIEW
FIG. 31 – FOUNDATIONS