

Structural Integrity Modelling of an Early Bronze Age Corridor House in Helike of Achaea, NW Peloponnese, Greece

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Abstract: Structural integrity modelling and simulation studies were performed on the Helike Corridor House (HCH), a monumental building excavated at the Early Helladic (EH) site of Ancient Helike on the NW Peloponnese, Greece. The aims of the research were to explore building materials and plan alterations of an earlier phase into an EH II-III period Corridor House. Static load analysis followed by buckling (failure) analysis was simulated using ANSYS. Results demonstrate that buckling would develop in the narrow corridor area, being the critical spot in the structure due to its configuration of long tall sidewalls. It is shown that when stairs are introduced, the structure becomes less susceptible to buckling. We conclude that the doubling of the outer walls was a high structural and functional technical innovation which required specialized knowledge on planning and construction highlighting the critical role architecture played in response to upcoming social transformations.

Keywords: Helike, Corridor House, Early Helladic Architecture, Structural Integrity, Finite Element Analysis

Introduction

The Helike Corridor House (HCH) excavated foundation walls (Katsonopoulou, 2011) reveal an outstanding and monumental house prototype of the late Early Helladic (EH) II-early III (mid- to second half of the 3rd millennium BC), fitting with the mostly debated architectural template of the Greek mainland in this period. This paper investigates analytical modelling and simulation studies on the HCH to test the way innovative features were incorporated to guarantee its structural integrity, and assess the significance of such architectural innovations to proto-urban setting.

More specifically, reviewing older research in the southern Greek mainland, the corridor feature has been associated with various material transformations and innovations in the EH period (Peperaki 2004; Maran and Kostoula 2014). Although it emerged individually as a widespread but distinct architectural trait in several sites (Hägg and Konsola 1986; Harrison 1995; Wiersma 2013), it was adopted with a patterned arrangement along the side walls of certain houses for the configuration of this innovative and complex kind of building, called the 'Corridor House', at some stage of the EH II (Shaw 1987; 1990; 2007). One aspect of the complex debate about establishing these external corridors has derived from the implication that they hosted stairways leading to an added second storey. More than that, the recovery of precious equipment and distinct

accessories from these houses, along with their presence as unique examples inside the settlements, has promoted arguments for their possible centralized administrative role and the rapid advance of the EH society towards hierarchical pre-state modes (Maran 1998; Pullen 2008).

On account of these regional and cultural connotations, further definition of the detailed material data of the known corridor houses has been long-attempted by an array of scholarly analysis of their design, purpose, construction techniques and material equipment (Themelis 1984; Pullen 1986; Aravantinos 1986; Shaw 1987; 1990; Wiencke 1989; 2000; Kalogerakou 1999; Maran and Kostoula 2014), always with an eye to verify the broader social advances of the period. Within this integrative framework, the present material and structural analysis of the particular HCH is expected to provide research on Helike with challenging implications that will go beyond the house's individual features and will contribute to understanding the social and economic significance of the settlement itself and also the rise of this long-debated building type in the wider mainland context.

The HCH was revealed during excavation work carried out by the Helike Project (Katsonopoulou 2011), an interdisciplinary and cross-cultural landscape archaeology and geomorphology project conducted in the major Helike area in Achaea, NW Peloponnese (Katsonopoulou 1998; 2005; Soter and



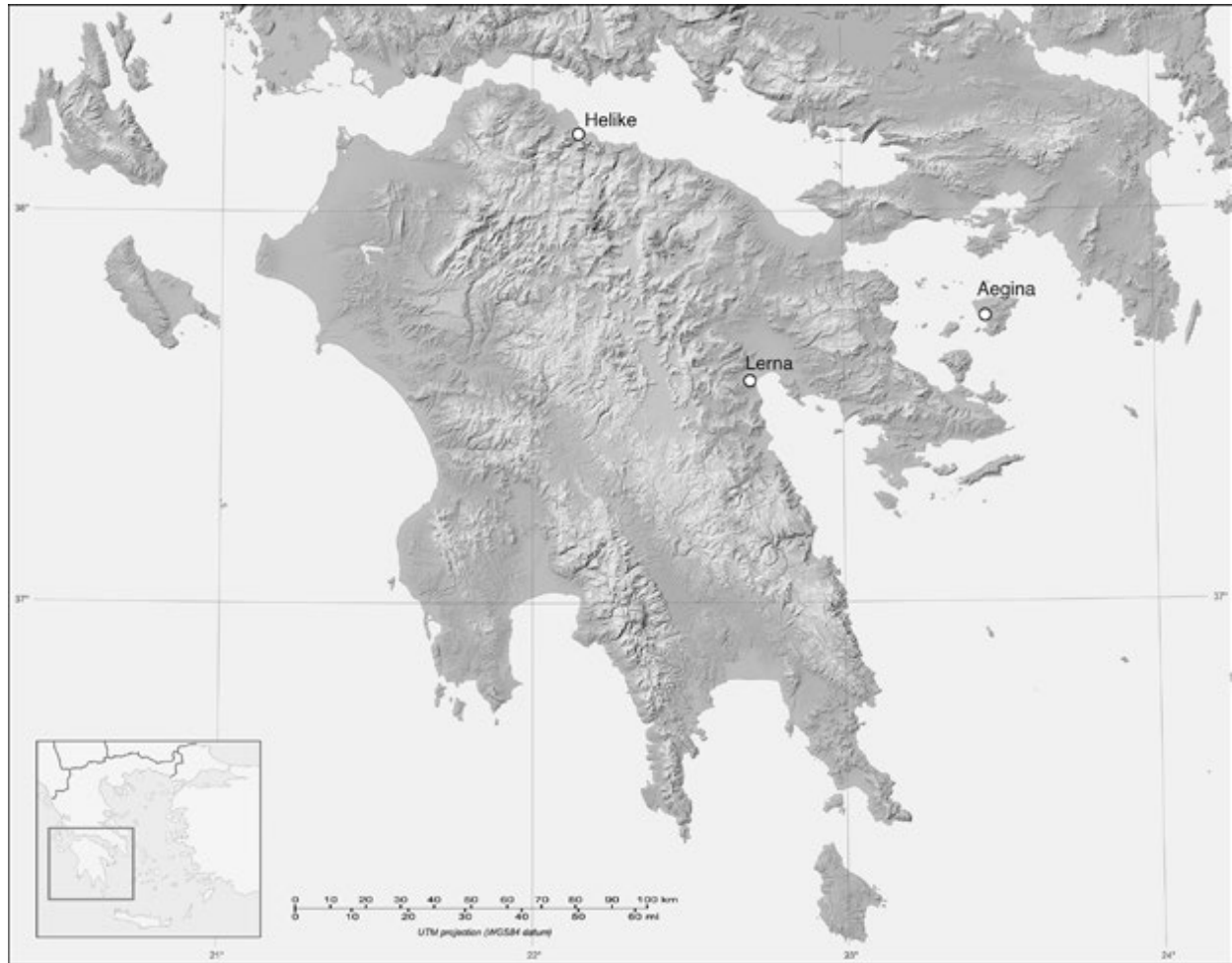


FIG. 1. THE GEOGRAPHIC LOCATION OF THE CORRIDOR HOUSES AT HELIKE, LERNA AND AEGINA.

Katsonopoulou 2011) from 1988 onwards. Although the particular structure was excavated along its western section only, as the rest of it extends into non-excavated neighbouring fields, its 'corridor' plan is testified by the arrangement of narrow corridors along the preserved external sides of an axially placed rectangular structure composed of a series of adjoining rooms.

In this paper we propose a tentative reconstruction of the HCH based on comparable reconstructed corridor house plans as assumed by Shaw (1987). In particular the closer association of the HCH should be established with the EH II 'House of the Tiles' at Lerna in the Argolid (Caskey 1959; Wiencke 2000), and the 'Weisses Haus' (although this one is more complex) at Kolonna in Aegina (Walter and Felten 1981), whose plans were critically assessed by Shaw (1987). The geographic locations of the mentioned sites are indicated in figure 1. In a brief account of the HCH, the reconstruction of the missing east long sidewall in terms of length and openings are mirrored on the excavated west walls as shown in the conjectural plan. The entrance, outside openings and blind rooms are hypothesized on the basis of the above equivalent houses. More noticeable parallels between the HCH and the latter include the interior rooms varying in width – the side chambers being wider than the intermediate area – and the non-axial arrangement of the

interior doorways. Certainly one has to consider that other versions may be plausible for the reconstruction of the HCH in terms of minor features.

The account of rich interior items in the HCH and the evidence to the fact that it was modified from an earlier simpler long rectangular building are highly significant to the research questions posed in this paper. A large number of cooking and drinking vessels were revealed in the central rooms together with a remarkable assemblage of big storage jars placed in a row along the long wall and bordering pebbled floor areas (Katsarou 2011). Hearths and a rich collection of tableware from the centre of the chamber were also revealed. The changing plan indicates the addition of the corridor areas to the long and narrow sides in order to accommodate the storage facilities on the ground floor. Furthermore it implies the addition of a stairway to the upper floor, sheltered entrance, balcony appendages, and other side rooms to acquire increased space and monumentality.

We should also note that the EH settlement of Helike has revealed a number of free-standing long rectangular houses built across an area of about 30 hectares (Katsonopoulou 2011). The buildings are arranged in poleodomic insulae and are aligned with long straight crossing cobbled roads, even featuring the

presence of at least one open plaza (Katsonopoulou 2011), all of which seem to have been built according to an earlier plan of the settlement. The clear-cut town planning of Helike is strongly indicative of a collective communal project and thus of an administrative regime to organize its accomplishment before putting it into practice. The precious possessions of several houses in gold and silver and intimate exotic clay imports as implied by the unique *depas* cup (Katsonopoulou 2011), strengthen the view that EH Helike constituted a rich trading community on the southwestern coast of the Corinthian Gulf. Within this context, the attribution of an administrative or socially differentiated role to the HCH, as assumed for corridor houses from other sites (Peperaki 2004; Maran and Kostoula 2014) are strongly justified. The above considerations provide an interpretative context for the HCH 3D reconstruction, materials characterization and structural analysis simulations described in the next sections.

1 Research Aims and Methodology

Reconstruction modelling, sometimes called ‘solid modelling’, ‘three-dimensional modelling’ or ‘Virtual Reality modelling’, has been used in archaeology since the late 1980s (Lock 2003: 152) and is now commonplace. The resultant ‘constructs, simulations and hyperreal worlds’ (Goodrick and Gillings 2000) have largely moved on from attempting to offer objective and accurate representations of the past as was claimed for many early models, to being a more exploratory method of thinking about what the past may have entailed. It is within this context of ‘what if modelling’ that we present this work based on an aspect of reconstruction that is relatively new to archaeology, that of testing the structural integrity of buildings.

Structural analyses through computer models are widely used in architecture and engineering to study the behaviour of real world structures (Lawrence 2012). These studies can replace real experimentation and measurements as the simulations are based on precise physical models allowing the specification of materials, geometries, and their ability to withstand a large variety of loads. Structural analysis requires thus, the specification of materials, their physical and mechanical properties, geometry, and the loads acting on the structures. This kind of analysis has been used before in connection to cultural heritage. For instance, finite element analysis has been employed to assess seismic vulnerability as a way to predict ruptures in the case of earthquakes (Shakya *et al.* 2012; Dowling 2004), as a guide to the restoration of monastic buildings (Miles 2014), to study the durability of materials (Varum *et al.* 2011; Ruano *et al.* 2012), and to test historical masonry structures for the restoration of the Bam Citadel destroyed by an earthquake in 2002 (Hejazi and Saradj 2014).

This research is based on ANSYS (Lawrence 2012; Sharpe 2008), which is a sophisticated modelling and simulation platform for testing and validating the physical behaviour of structures based on Finite Element Analysis and mechanical properties of materials. ANSYS provides a number of tools and utilities integrated and deployed from a single workbench. The HCH is the first Early Helladic corridor house to be analysed by this methodological tool.

The aims of the research are to formulate and validate hypotheses based on finite element modelling to test the structural integrity of the HCH. Results and conclusions

would be directly relevant to similar buildings where evidence is scanty (e.g. mostly foundation walls). Related research questions include:

- What is the structural value of the added corridors to the monumentality of the building, i.e. in terms of load bearing, can a clear indication be provided of whether or not a second floor might have existed?
- On what structural properties was the choice of construction materials based?
- Why and how was the plan of the earlier house modified resulting in long narrow corridors and their relationships to facilities on the ground and upper floor?
- How does the HCH compare with the ‘House of the Tiles’ at Lerna and the ‘Weisses Haus’ at Kolonna, Aegina, in terms of isometric relationships and building materials?

The modelling and simulations reported in this paper involves static structural analysis followed by linear buckling analysis, which aims to determine at which level the load (i.e. the weight of the roof and other structural components) renders the structure unstable. Developing such a simulation and analysis in ANSYS involves the following steps:

- Select the analysis to perform (e.g. linear buckling).
- Specify materials engineering data, i.e. their mechanical properties, which include the material’s density, compressive and tensile yield strengths, Young’s modulus of elasticity and Poisson ratio. Other properties such as the bulk and shear modulus are derived from Young’s modulus and Poisson ratio.
- Define the geometry of the structure as a solid 3D model.
- Specify the physical model and assign materials to various parts of the structure.
- Set up the initial forces and loads acting on the structure.
- Select a solution to perform (e.g. stress). The APDL (ANSYS Parametric Design Language) is used to solve the physical model and perform the simulations.
- Display the results in graphic and text report formats.

These steps are described in Sections 3 and 4.

2 Geometry and Materials Characterisation

2.1 Geometry Modelling

The ANSYS Design Modeler is a geometric modelling package with predefined geometric shapes and operations such as extrude, revolve and sweep together with advanced operators such as logic Boolean and blending. However, a number of operations are not intuitive and require various steps to complete and for this reason the 3D models of the house structure were drawn using SketchUp (2015), which provides a finer level of control and is more user-friendly. The models are then exported from SketchUp to a standard 3D file format and



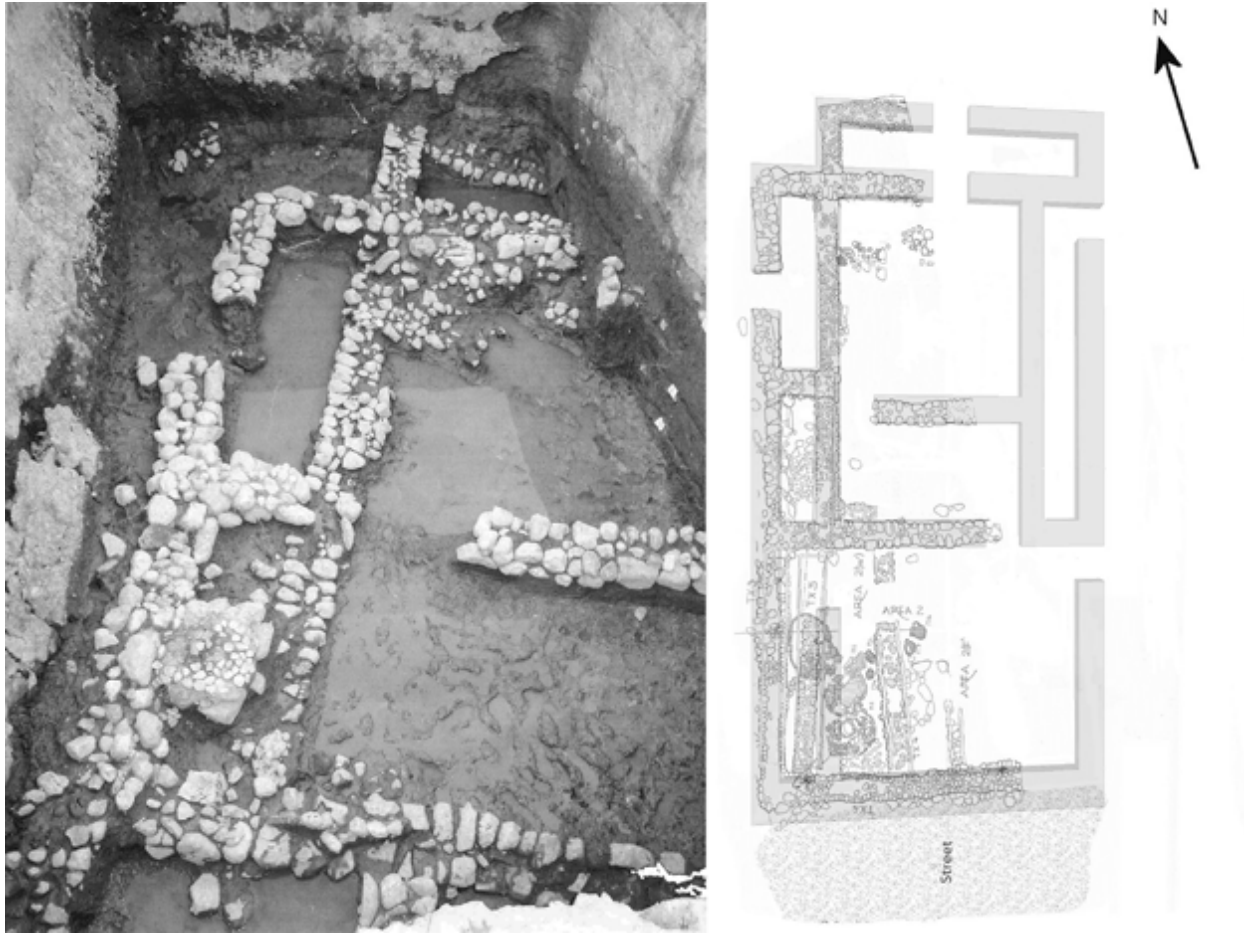


FIG. 2. LEFT: VIEW OF THE NORTH WESTERN PART OF THE HCH DURING FIELDWORK IN 2003; RIGHT: FULL DRAWING OF THE GROUND PLAN.

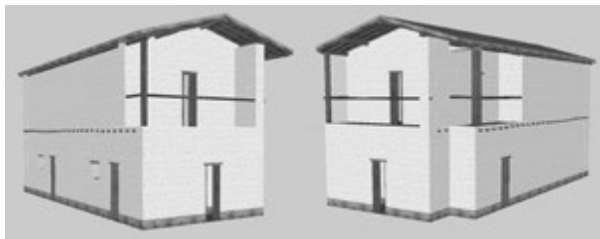


FIG. 3. THE 3D MODEL OF THE HCH, BASED ON THE HOUSE PLAN OF FIGURE 2.

imported directly into ANSYS Design Modeler providing a full integration into ANSYS Mechanical APDL.

The house plan geometry is derived from accurate measurements of the excavated foundation walls at the EH Helike site. Figure 2 shows part of the excavated foundation walls during the 2003 season and a corresponding drawing of the HCH with added conjectural plan that was used to guide the 3D reconstruction. Figure 3 illustrates two views of the 3D reconstructed house performed in SketchUp.

2.2 Materials Characterisation

The stone foundation walls of the HCH have been buried for the past 4,000 years at a depth of about 3 to 3.50m below present surface. Other structural materials such as complete bricks, wooden structures and roof tiles have not survived. Excavation shows that the house walls were built of adobe (sun dried mud brick), few samples of which have been recovered. Other assumed building materials are wood (*Pinus halepensis* and *Olea spp*) and reed (*Arundo donax*) with mechanical properties characterized as follows.

The Young's Modulus of elasticity is a measure of stiffness of an elastic material when stretched or compressed. The Poisson Ratio is the decrease in lateral measurement to the increase in length in a sample of material that is elastically stretched. The higher the Poisson ratio, the more elastic the material is. The tensile strength is the maximum amount of tensile stress a material can take before failure; it is defined as the ratio of *stress* (force per unit area) along an axis to *strain* (ratio of deformation over initial length). The compressive strength is the capacity of a structure to withstand loads in the elastic region.

The mechanical properties of materials are normally obtained through standardized destructive and non-destructive tests (Hibbeler 2013). In order to determine the compressive and

	Density Kg.m ⁻³	Young's Modulus MPa	Poisson Ratio	Compressive Strength MPa	Tensile Strength MPa
Adobe Brick	1,737	54.7	0.17	1.2	0.04
<i>Pinus halepensis</i>	600	10,770	0.17	61	81.6
<i>Olea spp</i>	990	17,770	0.25	62	31
Reed <i>Arundo donax</i>	234	9,000	0.25	665	321.7

TAB. 1. MECHANICAL PROPERTIES OF BUILDING MATERIALS.

tensile strengths of mud bricks together with their modulus of elasticity and Poisson ratio, it would be necessary to run destructive tests on a number of samples. Since only eroded samples of brick are available from the site, and these certainly cannot be subject to destructive tests, image-based analysis was performed yielding estimated composition of 30% gravel, 53% sand, silt and clay and 17% straw.¹ This led to density estimates and comparison with known properties of ancient mud bricks and other building materials elsewhere for the required mechanical properties (King 1996; Keefe 2005; Houben and Guillaud 1989). The adobe brick mean density was estimated at 1,737kg.m⁻³. The Young's modulus of elasticity was assumed 54.7Mpa (Adorni *et al.* 2013). The Poisson ratio was 0.17, the compressive strength 1.2MPa and the tensile strength 0.04MPa (Hejazi and Saradj 2014; Academia 2015). Table 1 shows the assumed mechanical properties of adobe brick together with other materials discussed below.

The upstairs floor structure of the HCH was assumed according to interpretations in the literature (Wiencke 2000) to be composed of three layers: a wooden supporting structure, a layer of reed and a layer of mud or rammed earth. The wooden component of the floor discussed in terms of the doorways at the 'House of the Tiles' (Maran and Kostoula 2014) would likely to have been constructed from transversal and longitudinal beams of the local species *Pinus halepensis* with mean diameter of 110mm and 180mm respectively. *Pinus* is also assumed for the construction of stair structure between ground floor and first floor. Evidence for *Pinus halepensis* can be found on the northwestern coast of Peloponnese during the Holocene (Lazarova *et al.* 2012). Radiocarbon analysis of sediment cores indicate that pine communities dominated the landscape during the Neolithic period but, possibly as a result of human intervention, were strongly reduced during the Early Bronze Age (Lazarova *et al.* 2012). The mechanical properties of *Pinus halepensis* quoted in Table 1 were determined by mechanical testing (Correal-Modol 2012; Zanne *et al.* 2009) and by similarity to related species (Ozkaya 2013).

Pollen diagrams also show evidence for cultivation of *Olea spp* in the northern Peloponnese in the Holocene (Lazarova *et al.* 2012). The use of *Olea spp* in the form of reinforcing beams above doors and window frames inside the upper floor wooden component is observed at the Cycladic Bronze Age settlement of Akrotiri, Thera, Greece (Palyvou 2005). In the HCH we may equally consider the possible use of reinforcing longitudinal beams from *Olea spp* beneath the *Pinus halepensis* floor structure, and also in the construction of the steps in the

stair structure. The assumed mechanical properties (The Wood Database) are quoted in Table 1.

Reeds are a building material widely used since ancient times mainly to support and hold mud or clay on floor and roof structures and fences. They are well adapted to saline environments (Koutsios and Kontopoulos 2011) and exist in abundance in the area of Helike to this day. It is assumed that the local species *Arundo donax* (Cartwright and Taylor 2011) is the mostly likely to have been used in the floor substructure. Its mechanical properties (Barreca 2012; Spatz *et al.* 1997) are quoted in Table 1.

The roof structure of the HCH is also conjectured as being of similar construction and materials as the upstairs floor: a wooden structure made out of supporting *Olea spp* beams overlaid by *Pinus halepensis* beams followed by a layer of reed *Arundo donax*. A layer of rammed earth would cover the reeds. The roof would have an added topmost layer of tiles. The mechanical properties of the roof structure were not tested as such; instead their equivalent weight acting on the supporting wall structure was used in the simulations reported in the next section. The total weight of the roof structure was calculated from the density of each material multiplied by their volume. The volume was directly obtained from the solid models generated in SketchUp.

3 Structural Integrity Simulation Settings and Results

Figure 4 shows the top level ANSYS schematic program to perform static structural analysis followed by linear buckling. In order to build a simulation model, one must work the way down from the top by first specifying engineering data. These are the mechanical properties for each material as defined in Section 3, which are added to the standard ANSYS database of material properties. The solution to static structural analysis is then used as input to linear buckling analysis as shown in figure 4.

Following *Engineering Data*, the *Geometry* of the structure is specified. All 3D geometries developed in SketchUp were exported as solid models in IGS, which is a data format designed to exchange 3D information. These were then directly imported into ANSYS. The 3D models were divided into groups as follows: 1) Foundations, 2) Walls, 3) Floor: wooden structure, 4) Floor: reed structure, 5) Floor: mud layer, and 6) Stair structure.

Figure 5 top shows the SketchUp model with two walls removed so that the interior floor and stairs could be visualized. Figure 5 bottom shows the imported geometric structures into

¹ Iliopoulos, I., *Image Analysis, Samples H61 and H21* [email]. Message to: Katsarou, S. 29 October 2014.



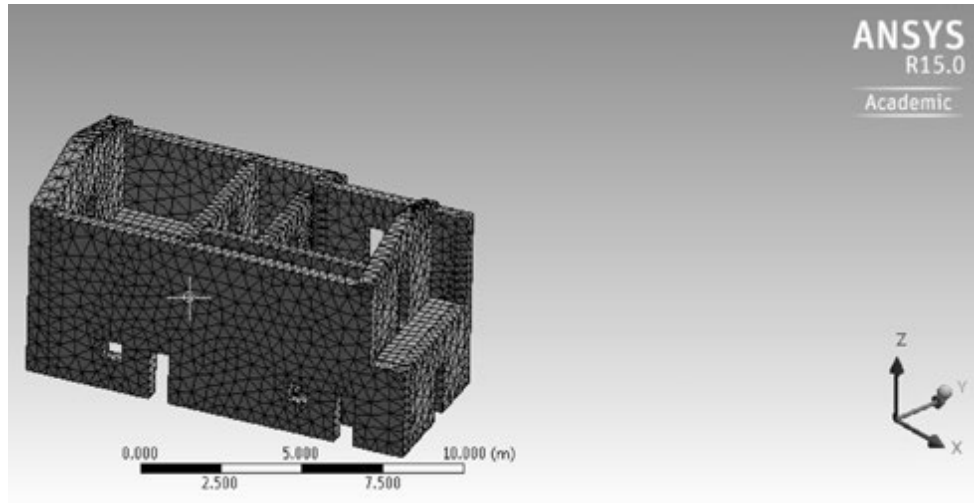


FIG. 6. TETRAHEDRAL MESHING OPERATION ON THE 3D STRUCTURE.

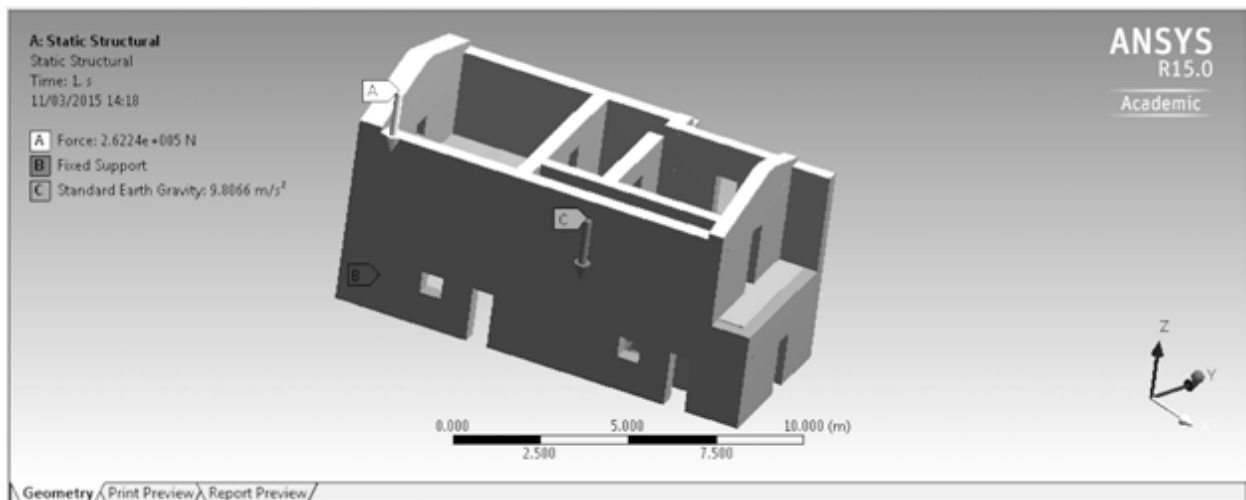


FIG. 7. LOAD SETUP SHOWING DOWNWARD FORCES ACTING ON THE SURFACES IN WHITE (A).

ANSYS. It is necessary to specify the bonding of various structures before the physically based simulation, that is, whether the various walls are allowed relative motion or not. In the simulations of the HCH we specified that all structures are bonded together and no relative independent motion is allowed.

Having imported the geometry, the mechanical *Model* is specified starting from meshing the 3D structure and assigning materials to their respective geometries. ANSYS has a range of meshing tools and mesh refinements to ensure simulations will accurately validate the physical model. We used tetrahedral meshing as depicted in figure 6. ANSYS has a 'physics preference setting' to ensure the most appropriate mesh is generated for each simulation. The size of each element of the mesh can be controlled by the user: the smaller the (finite) element, the more precise the answer, but the price to pay is that of higher computational costs.

In the *Setup* step the parameters of the analysis, namely all loads, forces and support acting on the structure are specified.

Only a single compression force is required given as the total weight of the roof plus the live load. The weight of the roof is carefully calculated from the geometry of its various components using their respective densities. A live load is added equivalent to 1ton (~9,800N) to represent people and furniture, yielding a total downward force of 262,244N acting on the surfaces indicated in red in figure 7. Inertial forces were also included using the standard gravity acceleration, so the weight of the wall acting on every element is also taken into consideration. When considering compression forces due to weight integration effects, note that the bricks at the bottom of the wall near to the ground are placed under considerably higher compression than the ones touching the roof.

Finally, a fixed support is added to ensure that wall structures are fixed to the foundations and are constrained in all directions, that is, the bottom surfaces of the walls are not allowed to slide or move along the x , y or z axes. ANSYS then solves the analysis (the *Solution* step) using the Finite Element Method by applying the specified loads and constraints propagated to each

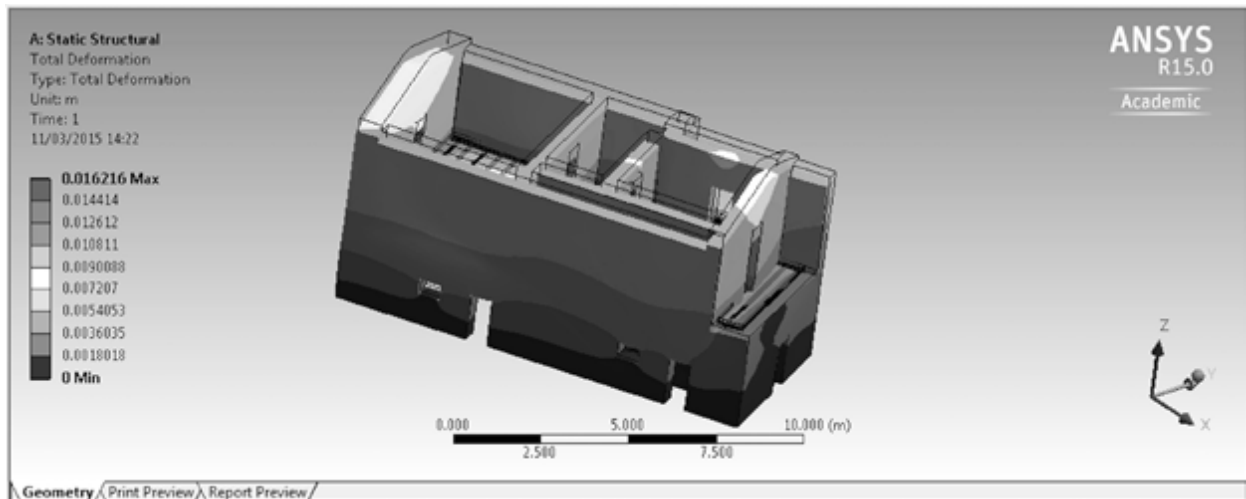


FIG. 8. TOTAL DEFORMATION IN STATIC STRUCTURAL ANALYSIS (EXAGGERATED FOR VISUALIZATION).

element of the mesh and then integrating the results, which can be reviewed using a range of graphical tools and tabular formats. The results for total deformation from static structural analysis are depicted in figure 8. The maximum deformation for the applied load is 16mm. This would be difficult to show on a 6m tall wall, so the deformation relative to the original outline in figure 8 is exaggerated for the purposes of visualization.

Buckling analysis is used to determine the buckling loads, or the loads in which the structure becomes unstable (Hibbeler 2013). It is justified and widely used to test slender structures such as walls and columns. The technique seeks to determine the load level at which the structure becomes unstable, and this is achieved by gradually increasing the load. The classic Euler formulation for a column is defined as: where F is the allowable load, n is the number of end conditions, E is the modulus of elasticity, L is the length of the column, and I is the moment of inertia. At the onset of instability (buckling) the structure will have a very large change in displacement with no change in applied load. To estimate this condition, the linear buckling analysis predicts the theoretical buckling strength by solving for the load multiplier as a function of the applied load: where K and S are constant and the response based on the loading $\{ \}$ is a linear function of $\{ \}$. The critical load specified through the load multiplier must be treated only as a prediction as the load multiplier is not a safety factor. In order to find the actual critical load, a non-linear analysis would be required. The research reported in this paper focuses on linear buckling only and thus, uses the load multiplier as a prediction of structure stability.

Simulations were performed on the HCH 3D model by including or removing various elements of its structure resulting in three relevant what-if scenarios as follows.

1. The house structure as defined by external and internal walls only.
2. The house structure with the addition of the upper floor components including the wooden structure, and the layers of reed and mud.
3. The house structure with the addition of the NNE long side stairway.

Figure 9 depicts the results of linear buckling analysis for the three cases considered. It can be seen that the weakest area of the house is the external wall of the corridor containing the staircase. The respective buckling load multipliers are 28, 30 and 39 where normally the higher the multiplier the more rigid and stable the structure. The simulations clearly demonstrate the relative importance of the stairs as a structural element as is evident in the highlighted areas of the model and by the change in load multiplier: by adding the upstairs floor, the multiplier goes from 28 to 30 but when stairs are added it goes from 30 to 39. Although these are rough predictions, it is clear that the structure would not collapse under the applied loads in normal circumstances – i.e., in the absence of large external disturbances such as an earthquake.

The interpretation of the results leads to the following assertions:

- The design inferred from the foundation walls is capable of supporting a second floor.
- The wall most susceptible to buckling is the outside wall to the stairs, along the NNE side of the house.
- The addition of the upper floor structure provides the HCH with the advantageous side effect of making the external NNE wall more rigid, and thus reducing the magnitude of buckling.
- The addition of the stairway makes the external NNE wall even more rigid and totally removes the probability of buckling on the ground floor.
- The designers have solved structural buckling issues by adding internal transverse walls at 90 degrees to the double NNE wall and to the west façade corridors, which made the structure more rigid and less susceptible to buckling. Instead of providing access to the second floor, these

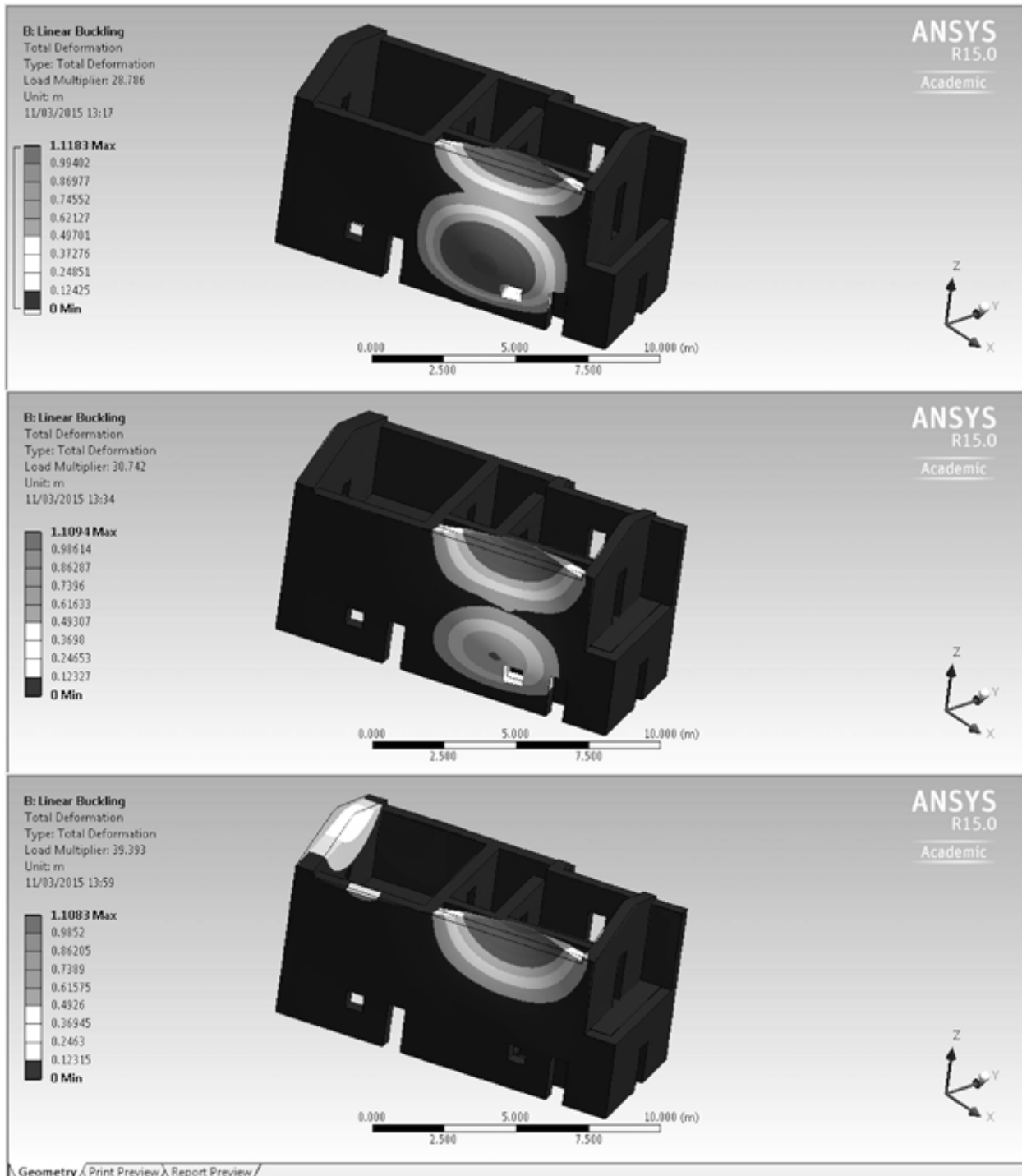


FIG. 9. TOP: BUCKLING OF THE HCH STRUCTURE DEFINED BY THE WALLS ONLY; MIDDLE: BUCKLING WITH ADDITION OF THE UPSTAIRS FLOOR; BOTTOM: BUCKLING WITH THE ADDITION OF UPSTAIRS FLOOR AND STAIRS.

corridors may have accommodated supplementary rooms in the periphery of the ground floor and a more complex entrance, and had possibly supported one or more upper floor balconies.

- The wall on the south façade was built thicker than any other wall (700mm against 470mm and 400mm of other walls), which also has the effect of reducing its susceptibility to buckling. Had it been built with the same thickness as the

other walls, our simulations show that it would be as prone to buckling as the NNE external wall.

4 Discussion and Conclusions

The present project has created a 3D model of the HCH from the measurements and plan inferred from its excavated foundation walls. The house plan was compared with the plans of corridor houses at Lerna and Aegina to enable interpretation



of missing components. The model was exported as a 3D solid and loaded into ANSYS for structural analysis. All construction materials were carefully defined concerning their dimensions and respective mechanical properties, namely density, Young's modulus of elasticity, the Poisson ratio, compressive and tensile strengths. These parameters were used to perform finite element-based structural simulations to study the behaviour of the structure and to verify whether or not it would be able to support a second floor.

The models have proved that the modification of an earlier EH II rectilinear ground floor house into a corridor type of building by transforming its sides into the form of double walls or corridors to accommodate the stairway access to the upper floor and auxiliary peripheral rooms, would have met perfectly the structural prerequisites for the HCH to achieve increased space and a monumental height. The suitability of the assumed building materials has been validated by successful structural integrity tests for their loads under normal circumstances. A static structural model followed by linear buckling analysis revealed the areas of the building more susceptible to buckling. It however verified that linear buckling would not develop under the imposed static loads, and the structure would be able to support a second floor thanks to the added 'corridors' and more subtle architectural choices.

Our research points to the specialization of Helike builders on planning and creating architecture. It is interesting to note the number of similarities between the HCH and the 'Weisses Haus' at Aegina, and the 'House of the Tiles' at Lerna. The scale is intriguing: the 'Weisses Haus' is about 1.5 times larger than the HCH while the 'House of the Tiles' is twice as large. This scale applies to length, width, and wall thickness. The HCH measures 6.25x12.50m with wall thickness ranging from approximately 0.45-0.55m, 'Weisses Haus' 9x18.5m with wall thickness of 0.60m while the 'House of the Tiles' measures 12x25m with wall thickness of 1m. The analogy looks too coincidental and may suggest that the sites shared architectural plans as suggested by Shaw (2007) in terms of size and internal arrangements. This may also strengthen the argument for similar engineering practices and construction materials, as half the size would call for half as thick wall as observed in the three houses. The observation may also account for the scenario according to which the plan and building techniques were optimized and then re-used across the region.

The HCH project suggests rapid architectural changes and technological advances through modifications of an earlier design into a monumental corridor house. The employment of standardized architecture such as the corridor type structure at Helike and the broader EH region is the result of social changes such as the need for accommodating a rising number of residents, an administrative centre, an assembly hall, a kin group or communal storage place. Such a social context would lead to the development of larger households and other buildings for public use.

The EH settlement of Helike was destroyed by an earthquake accompanied by fire resulting in its immediate abandonment, leaving the contents of its buildings intact and sealed under mixed terrestrial, marine and lagoonal deposits. Further research will address the structural weaknesses of the adobe brick walls of the free standing, two storeys HCH to the effects of an earthquake (Varum *et al.* 2014) as well as palaeo-seismological

data to determine the magnitude of the earthquake that would have been sufficient to destroy the house. These are working hypotheses to be tested in the next stage of our research.

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