On Roof Construction and Wall Strength: Non-Linear Structural Integrity Analysis of the Early Bronze Age Helike Corridor House

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Abstract

We have demonstrated [1] through Structural Integrity Analysis that the Adobe brick Early Helladic (EH II-III) Helike Corridor House design was sound and it was able to support a second floor. This paper furthers the research focusing on roof loads by performing non-linear and sensitivity analyses addressing two research questions: 1) Was the roof of a light tiled construction or was it heavy as described in [2] about four times heavier than a tiled roof; and 2) What would the behaviour of the structure be when subjected to adverse wet weather under light and heavy roof loads. Previous research has shown that Adobe bricks can absorb large quantities of water from 2 to 10kg/m^2 [3, 4]. Furthermore, if it absorbs 4kg/m^2 the overall strength of the wall is reduced by 50% [3]. Using mechanical properties of dry and wet Adobe bricks, we have performed non-linear analysis using ANSYS aimed at determining whether or not the structure would collapse under four conditions: LIGHT-DRY (light roof, dry Adobe), LIGHT-WET, HEAVY-DRY and HEAVY-WET. The results show that under a light roof the structure would stand. However, a heavy roof similar to early Minoan structures [2] would lead to total collapse of the house as the Yield Stress on the wall structure is greater than the maximum allowed for wet and for dry Adobe. This points to sophisticated construction techniques with tiled rooves and the possible use of stabilising materials such as lime, ash or organic to protect the tiles [5]. The theory that Helike builders were aware of such techniques could only be supported by planned forthcoming detailed soil analysis to identify possible stabilisers and this would raise further questions on wider interactions such as trade. This research offers new understandings of roof techniques and weight limitations for Adobe building Corridor Houses in a period where only scant evidence is available.

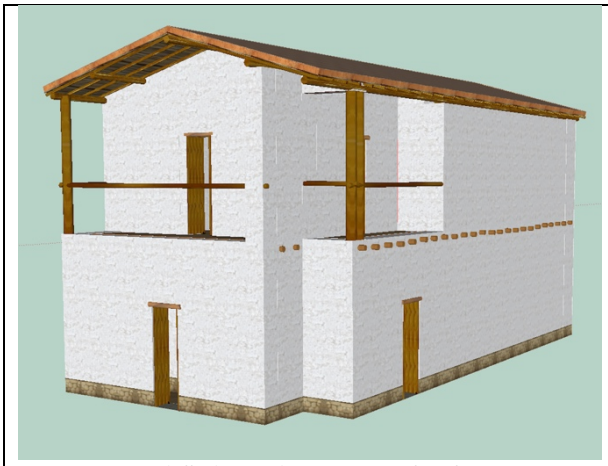
[1] M. Kormann, S. Katsarou, D. Katsonopoulou and G. Lock (2015). Structural Integrity Modelling of an Early Bronze Age Corridor House in Helike of Achaea, NW Peloponnese, Greece. *CAA 2015 Siena.*

[2] J. McEnroe (2010). *Constructing Identity in the Aegean Bronze Age*, University of Texas Press, 195pp.

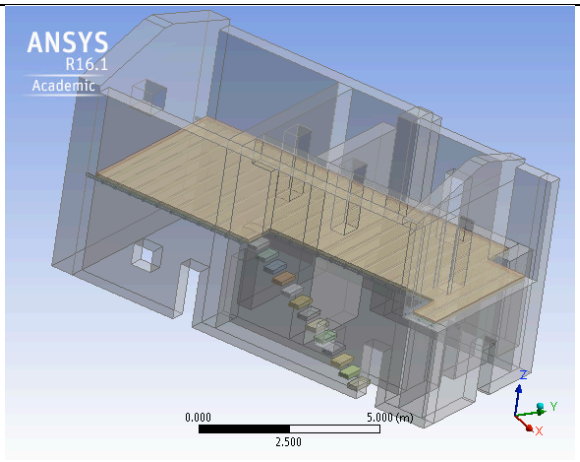
[3] H.G. Njau and E. Park (2015). Physical Properties of Unfired and Compressed Same Clay Brick Composites Reinforced with Natural Fiber from Tanzania, *Int J of Innovative Research in Advanced Eng*, Issue 4, Vol. 2 April 2015.

[4] L.A. Palmer and D.A. Parsons (1934). A Study of the Properties of Mortars and Bricks and their Relation to Bond. *US Dept of Commerce Bureau of Standards* Vol. 12, 609—644.

[5] R. Eires, A. Camoes and S. Jalali (2013). Earth Architecture: Ancient and New Methods for Durability Improvement. *Structures and Architecture: Concepts, Applications and Challenges – Cruz (ed)*, Taylor and Francis Group, London, 962—969.

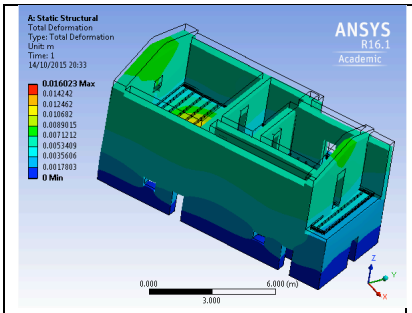


Modelled Corridor House in SketchUp

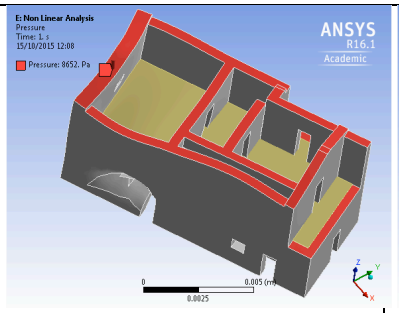


Imported model into ANSYS, roof removed

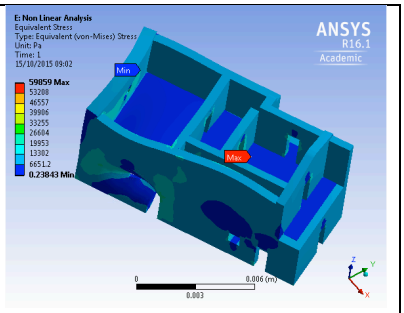
Figure 1: The Helike Corridor House model. The roof was replaced by its equivalent weight in the simulation studies



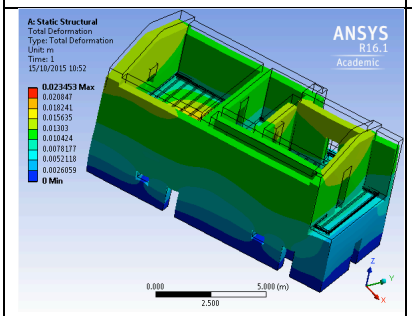
LIGHT-DRY linear deformation



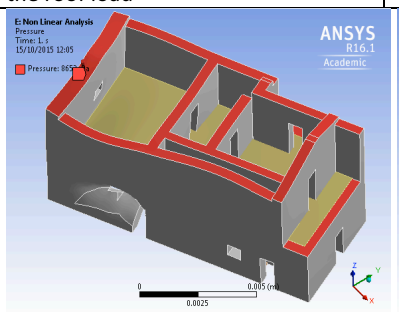
LIGHT-DRY how the structure would tend to deform non-linearly under the roof load



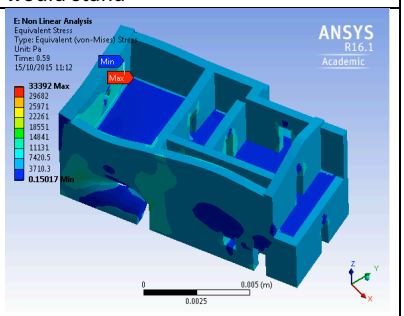
LIGHT-DRY stress: maximum allowed of 40,000Pa not reached, structure would stand



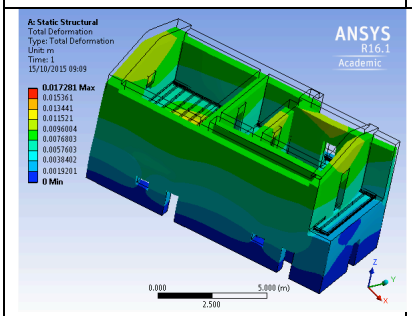
LIGHT-WET linear deformation



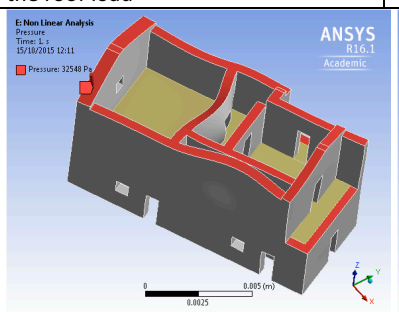
LIGHT-WET how the structure would tend to deform non-linearly under the roof load



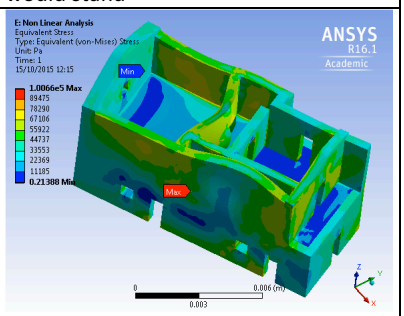
LIGHT-WET stress: maximum allowed of 20,000Pa not reached, structure would stand



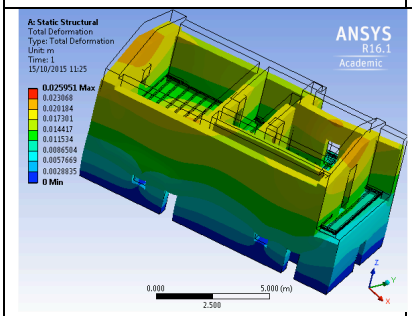
HEAVY-DRY linear deformation



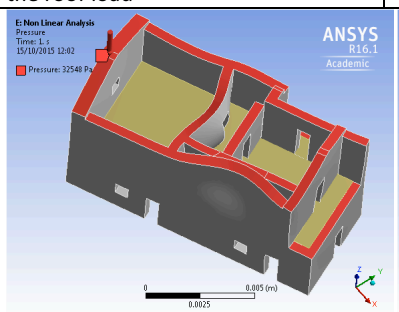
HEAVY-DRY how the structure would tend to deform non-linearly under the roof load



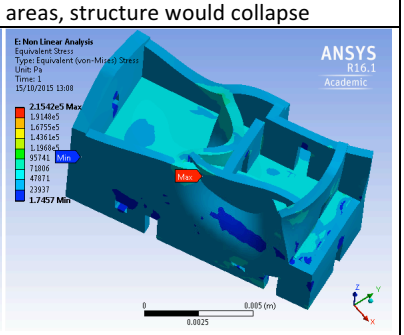
HEAVY-DRY stress: maximum allowed of 40,000Pa is reached in the yellow areas, structure would collapse



HEAVY-WET linear deformation



HEAVY-WET how the structure would tend to deform non-linearly under the roof load



HEAVY-WET stress: maximum of 20,000Pa is reached in all areas, structure would collapse

Figure 2: Non-linear failure analysis. The limit for stress is 40,000Pa for dry Adobe, and 20,000Pa for wet. If these values were exceeded on the wall structure, it would collapse.