Heriot-Watt University

Heriot-Watt University
Research Gateway

Material evidence

Forster, Alan Mark; Medero, Gabriela M

Published in:
Building Surveying Journal

Publication date:
2014

Citation for published version (APA):
Forster, A. M., & Medero, G. M. (2014). Material evidence: Simulations have helped understanding of the performance of cob walls during flooding. Building Surveying Journal (pp. 31-33).

Material evidence

Simulations have helped understanding of the performance of cob walls during flooding, as **Alan Foster**, **Gabriella Medero** and **Tom Morton** explain

Being constructed using materials that are naturally deposited on flood plains, earth buildings are at significant risk of losing structural integrity if submerged under water for a extended periods. It is also clear that due to climate change the likelihood of flood events is increasing. However, meaningful data regarding the duration to which earh buildings retain their integrity or whether signs of deterioration manifest themselves before failure occurs was lacking.

Take the example of the Old School House at Cottown, Perthshire, built around 1760 of cob – one of the most frequently occurring types of earth construction. The building had been flooded five times in recent years, but while the submerged regions exhibited undercutting and loss of earth materials from the wall faces, there was no structural failure. In a bid to gather data, a study was carried out at Heriot-Watt University that simulated flood conditions on cob materials in a laboratory environment to better understand performance.

Cob materials

Cob construction relies on a suitable base made of rubble stone work built in lime mortar, on which are placed suitably prepared earth materials. Balancing the amount of clays and aggregates is essential for most types of earth building, and the clay component can vary from 10% to 40%. Additionally, straw is an essential component, increasing the tensile strength and reducing cracking. The cob material is generally lifted in place using a pitch fork, and built up in non-shuttered (unconfined) working lifts 500mm in height. Compaction is achieved by the operative's feet pressing the wall head then the use of a wooden plank dropped onto the surface, creating a level plane for the next lift. The sides are then 'pared', cut to a relatively perpendicular plane, before final consolidation using a 'mud hammer'.

The Old School House at Cottown has flooded five times without structural failure

Flood response experiments

The flood response testing investigated the deterioration of cob walls when subjected to submergence in water. Two principal types of sample were manufactured, with and without straw reinforcing. The materials selected followed those established by Clough Williams-Ellis and described in his book *Building in cob, rise, and stabilised earth*. 'Green' clay was procured from Errol brickworks, Perthshire, which is geotechnically characterised as 'grey veined brown very slightly organic very clayey'. A well-graded sharp sand was derived from Gowrie quarry, Perthshire. Organic straw was sourced locally. Extensive materials characterisation was undertaken, including Attenberg limits tests (liquid and plastic limit), specific gravity tests, water content and compaction tests. The samples were then placed in the flood testing apparatus and partially submerged in water. The samples were left submerged and assessed for displacement every minute using a data logging system.

Environmental scanning electron microscope (ESEM) analysis was used to evaluate the materials mineralogy, pore size distribution, hydrophilic (water attracting) and hydrophobic (water repelling) properties (wettability and suction), and also the bond of clay particles at the aggregate interface. In addition, an assessment of the straw reinforcing and its relationship with the clay minerals was undertaken. The samples were placed in the ESEM, with water vapour introduced into the chamber and subsequently condensed to investigate surface wettability.

The reinforced samples started to exhibit deterioration after five days, manifesting as an undercutting/erosion of the material below the water line. The rate of compaction of the sample (and therefore densification of the pore structure) had an influence on the rate of deterioration, with high compaction rates faring better. The sample at 500µm (see photo 2) has a relatively open textured appearance with an interconnected pore structure over a large order of magnitude. The pore size distribution ranges from several mm through to approximately 200µm.

The angular aggregate can clearly be seen with a range of particles sizes and distribution. Clay platelet agglomerations are adhered to the surface of the grains, ranging from several mm through to approximately 100µm. Straw reinforcing can be seen within the centre of the image and appears fibrous in nature. Clay is adhered across its surface.

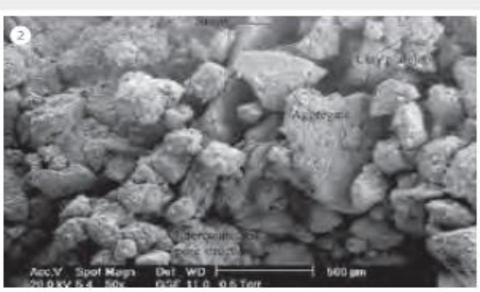
Photo 3 illustrates a thin layer of water that has coated the sample. The development of menisci between the clay/aggregate particles can be seen in several locations. The micro-pore structure is apparently full of water, while the macro-pores are still unsaturated. The clay particles and siliceous aggregates are hydrophilic in nature.

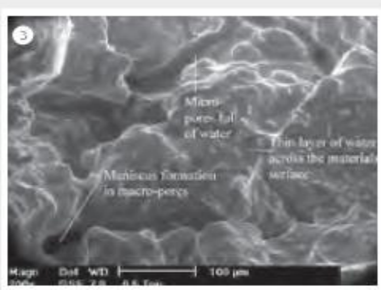
Discussion

From the flood response experiments on the cob samples (without reinforcing), it was clear that undercutting of the walls started almost immediately on submersion in water. This appears to correlate with the deteriorlogical mechanisms seen in the Old School House, Cottown.

The mechanisms of failure of the unreinforced, unconfined cob sample can therefore be understood. A relationship appeared to exist with an increase in compaction rates and a resistance to collapse when subjected to flooding. The unreinforced samples manufactured with 40 x compaction rate, collapsed after approximately two hours. This was opposed to the unreinforced samples manufactured with 80 x compaction rate that collapsed after 38 hours. It is clear that the walls' structural integrity during flooding is a function of the compaction rate, the materials composition, and whether the sample has been reinforced or not.

From early stage testing, it is clear that the use of straw reinforcing increases the ability of the cob walls to resist failure, and experiments were still ongoing several weeks after the collapse of the unreinforced samples. The general wettability characteristics of the cob samples appear to indicate that the clay and aggregate forming the body of the sample are hydrophilic in nature, and the straw hydrophobic. The hydrophilic nature of these surfaces enables the formation of menisci between the solid particles, and liquid creating suction forces that are believed to have an influence on the strength of inter-particle bond within the cob materials. Moisture transfer mechanisms will be complicated due to the combined hydrophilic and hydrophobic nature of the different components.





1 Cob wall construction comprises a rubble base topped with compacted and pared clay/straw mix

2 Cob sample at 40 x compaction

3 A thin surface layer of water has coated the sample with menisci

Conclusions

From preliminary laboratory work, the following may be concluded:

- cob walls that are suitably compacted, straw reinforced and are composed and manufactured of the correct materials appear to have the ability to resist total failure when subjected to initial flood conditions
- a correlation appears to exist between the rate of cob materials compaction and the duration to which the structural integrity of the walls was retained when the samples were submerged in water
- the use of straw reinforcing increased the duration to which the wall could be submerged before failure
- the materials for cob construction exhibited both hydrophobic and hydrophilic characteristics. This would have an influence on the materials' ability to saturate and dehydrate, and also have an impact on moisture transfer mechanisms
- unreinforced cob walls that were submerged in flood waters exhibited a undercutting pattern of deteriorology prior to failure.

It must be emphasised that this work is a preliminary investigation only, and additional data being currently produced will considerably increase the understanding of the cob materials.

Alan Forster is Programme Director for Building Conservation and **Gabriela Medero** a lecturer at School of the Built Environment Heriot-Watt University, Edinburgh; **Tom Morton** is principal Architect at Arc Architects

“

It is clear that the use of straw reinforcing increases the ability of cob walls to resist failure

More information
>

Williams-Ellis, C & Eastwick-Field, E (1999) *Building in cob, rise, and stabilised earth* Reprinted Edition, Donhead Publishing

To read the full version of the paper Traditional cob wall: response to flooding by Alan Forster, Gabriella Medero, Tom Morton and Jim Buckman (2008). see Structural Survey: Journal of Building Pathology & Refurbishment 26(4), 302-321 DOI: 10.1108/02630800810906557.
The authors would like to thank the National Trust for Scotland for access to the Old School House, Cottown and formative discussion

Further +info

Related competencies include
Conservation and restoration, Design and specification, Building pathology