The UTS Durability Test for Earth Wall Construction.

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Abstract

This paper looks at the development of earth buildings in Australia and examines the Bulletin 5 accelerated erosion test which was introduced in the 70's to deal with the question of durability. The paper then goes on to outline the limitations of this approach and gives details of a new durability spray test developed by the authors at the University of Technology, Sydney.

Keywords

Durability, earth walls, erosion, spray test

Introduction

To examine the issues effecting the durability of earth walls in Australia we must appreciate the historical and environmental context of earth building on this continent.

Historical Context

Australia has a short European based building history. The country was first settled by the English in 1788 and the early buildings were crude constructions and of temporary nature. There are no remaining earth buildings before the mid nineteenth century, however we have written reference to the use of earth wall construction during this early period of settlement. The first European settlers who arrived in Sydney Cove were not aware of Aboriginal construction methods but soon found the small acacia trees were suitable for wattling and plastering with clay. The trees became known as wattles and the building process wattle and daub. Governor Philip began a new settlement at Parramatta and before the end of 1790 there were thirty-two houses completed, built of wattles, plastered with clay and thatched. Termites, rain and increasing property development led to the destruction of all early earth wall buildings in Sydney. The earliest remaining earth buildings are from the mid nineteenth century and are all located in rural areas far from the city. It should be noted that these remaining buildings have well maintained surface coatings as well as wide roof overhangs (Figure 1)

Figure 1 Pise' house near Bathurst c1850.
(note the wide roof overhang and rendered walls)

Environmental Context

With the advent of the industrial revolution earth wall construction declined during the mid nineteenth to mid twentieth century, however shortages of building materials following the Second World War led to a renewed interest in earth wall construction. The preferred wall construction material in Australia is fired clay brick without an external coating and this same appearance is preferred in earth wall construction. Although Australia is a very dry continent the majority of the population live in dwellings in the coastal regions with annual rainfall averaging between 600mm and 1800mm per year (Figure 2). The traditional areas of earth building such as Egypt and North Africa have annual rainfalls averaging between 200mm and 500mm per year. The erosion of earth walls by wind driven rain coupled with the preference for uncoated surfaces has led to studies on the durability of earth walls in the Australian environment.

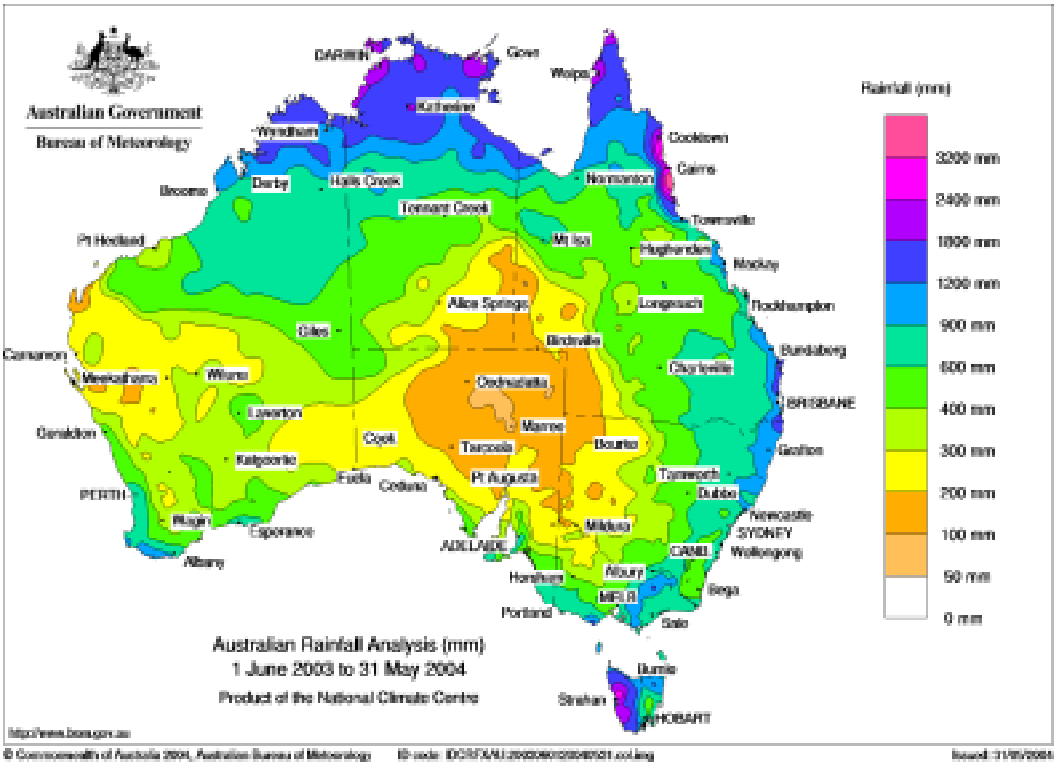

Figure 2 Australian Annual Rainfall

Majority of dwellings are in the 600 to 1800 areas.

Due to their limited durability in an unstabilised state earth buildings have in the past been seen to be inferior to more permanent materials such as stones and fired clay bricks.

“We note also that in the United Kingdom and France that earth walling is limited to the smaller domestic and farm buildings. In the old villages the parish church and the manor house, and any buildings having more considerable architectural pretensions, were invariably built of brick or stone. Thus we may take as a tacit admission that unstabilised earth walling did not possess sufficient permanence to justify the expenditure of a large amount of effort and elaboration in fittings and decorative work.” (Fitzmaurice, 1958, p5)

The perceived lack of durability of earth has been a significant barrier to its acceptance as a modern building material. Major earth buildings that have survived over long periods are mainly located in areas of minimal annual rainfall, are protected by large overhanging eaves, or are covered with protective coatings.

For effective prediction of the service life of earth buildings it is necessary to have an accelerated durability test which is a reliable predictor of in-service performance. Middleton (1952) constructed many rammed earth test walls at the Commonwealth Experimental Building Station in Sydney in 1949. What these experiments demonstrated, after 43 years of exposure, was the dramatic effect climatic conditions have on the durability of earth walls.

Bulletin 5 Spray Test

In response to an increased interest in earth construction in the 70's the Commonwealth Experimental Building Station in Australia developed an accelerated erosion test based on spraying water horizontally onto specimens using a specific nozzle (Schneider, 1981). This test is referred to as the “Bulletin 5” accelerated erosion test (Figures 3 & 4) as that is the name of the document in which it is contained.

This spray test is called up in the Building Code of Australia and a modified version was included in the New Zealand Code of Practice on earth wall buildings (NZS 4297,1998).

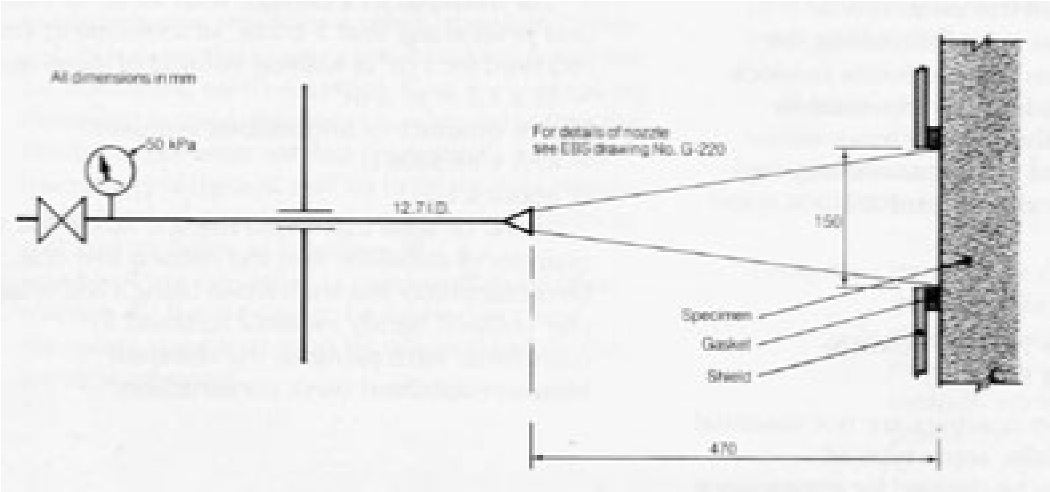

Figure 3 Bulletin 5 Accelerated Erosion Test

Figure 4 Bulletin 5 Accelerated Erosion Test

The test consists of spraying the face of a sample for a period of one hour or until the sample is penetrated. The test is interrupted at fifteen-minute intervals and the depth of erosion measured with a 10mm diameter flat-ended rod. The total depth after one hour is divided by sixty to give erosion in mm per minute. The maximum permissible erosion rate for all types of earth construction is one mm per minute.

Development of UTS Spray Test

Two general difficulties in using the Bulletin 5 test to predict earth wall performance became obvious to the authors. The first is that the test does not in any way simulate rainfall and as can be seen in Figure 5 actually bores holes in the specimens. Secondly in interpreting the results of the test no consideration is given to the climatic conditions in which a proposed building is to be located.

Figure 5 Earth Block showing erosion created by Bulletin 5 Test

The authors investigated many different nozzles to make the basic Bulletin 5 spray test setup more representative of the turbulent erosion pattern of rainfall.

In the end the Fulljet series of nozzles (manufactured by Spraying Systems Company in Illinois) were found to be ideal in that they produce a narrow spray which is made turbulent by the internal vanes (See Figure 6) and were relatively inexpensive. The 1550 nozzle was chosen for its ability to produce stream velocities of around 9 m/sec, this being similar to recorded values of wind velocity during rain in Sydney.

Figure 6 FullJet Full Cone Nozzle

Field tests were then conducted by the authors over a three year period to establish a relationship between erosion in the field and erosion in the laboratory using the new setup. These tests involved measuring the wind driven rainfall at the site (See Figure 7) and correlating the erosion of the field specimens relative to the erosion of the laboratory specimens adjusted for the relative volumes of water impacting the specimens (Heathcote,2003).

Figure 7 Wind Driven Rain Rose (Heathcote,2003)

A testing procedure was developed where the one specimen was tested in the laboratory and then in the field. The field-testing was done at a weather station where wind and rainfall data was available. From previous experience it was noted that wind driven rain predominantly came from the south and therefore the specimens were faced in a north/south orientation to receive maximum exposure. To simulate wall construction the edges were protected from the weather by a PVC tube (Figure 8).

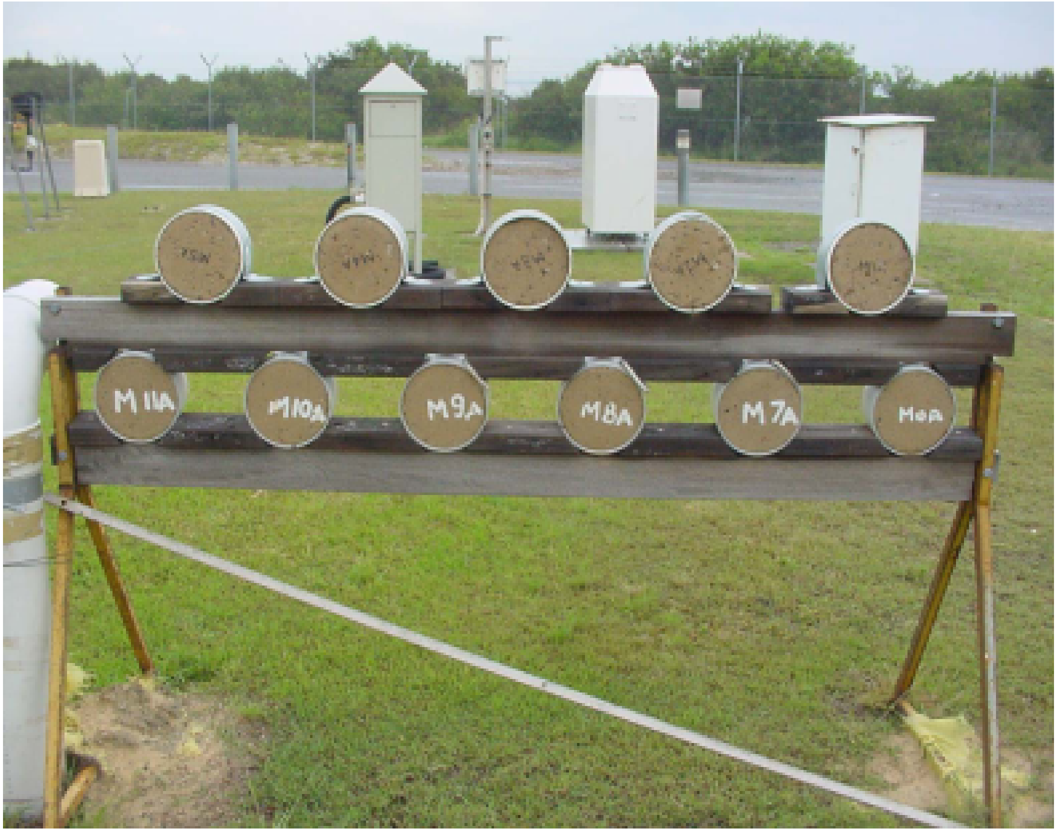

Figure 8 Specimens being Field Tested at Weather Station

The results of this investigation enabled the authors to produce a relationship between the annual rainfall at a particular site and the spraying time necessary for there to be a one to one relationship between the erosion depth in the field and the erosion depth of specimens in the laboratory, assuming an average wind speed during rain of around 7 m/sec, and a service life of 50 years.

Based on established relationships between erosion and water velocity correction factors were then established for situations where the average wind speed during rain was higher or lower than 7 m/sec. Details of this work are yet to be published but are based on the work of Heathcote (2003).

UTS Spray Test

Details of the setup of the UTS spray test are given in Figure 9. Figure 10 shows a specimen being tested at UTS.

Figure 9 UTS Spray Test Setup

In the test specimens are placed with their external face surface exposed to the spray, which impacts the specimens through a 100 mm diameter hole. A Fulljet 1550 nozzle is positioned 350 mm from the face and water is sprayed at a pressure of 70 kPa. The runoff water is filtered before being re-cycled.

The time of exposure for the specimens is calculated as follows

Time of Exposure (mins) = Annual Rainfall (mm) /10 × Wind Factor

Where Wind Factor = 0.5 where average wind during rain < 4 m/sec
= 1.0 where average wind during rain =7 m/sec (Default)
= 2.0 where average wind during rain < 4 m/sec

For example if the mean annual rainfall in Sydney is 1200 mm (Sydney) then the time of exposure is 120 minutes. For a rainfall of 600 mm in a low wind area the time would be 600/10 × 0.5 = 30 minutes.

Specimens are then sprayed for the calculated duration and the resulting erosion depth measured. This erosion depth is an indication of the mean erosion depth to be expected for in service conditions but is to be multiplied by a factor of safety of 2 to take into account the limitations of the experimental data. Furthermore, it is assumed that local areas of erosion 50% greater than that calculated will occur. Therefore

edicted Average Loss of Wall Thickness Over 50 Year Period

= 2 × Measured Erosion depth

Predicted Maximum Localised Loss of Wall Thickness

= 1.5 × Predicted Average Loss

For example if a building is to be located in Sydney and the maximum depth of erosion after 120 minutes is 5 mm then the predicted average wall thickness loss over 50 years would be 10 mm with localised areas of erosion reaching 15 mm.


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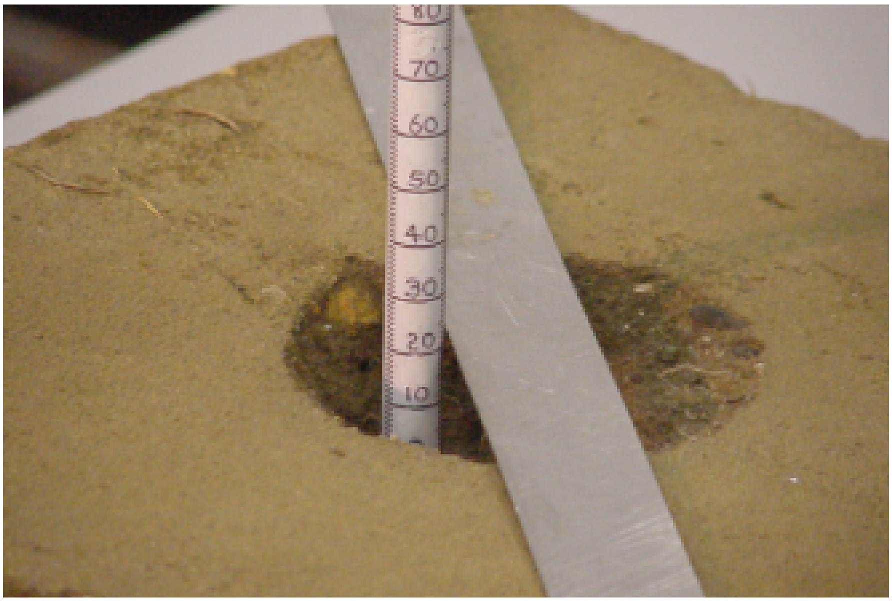
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Figure 10 UTS Accelerated Erosion Test

Allowable Wall Erosion

Erosion of walls rarely pose a structural problem, bearing in mind that earth walls are generally much thicker than normal masonry walls. For a 250 thick single storey wall even a loss of 50 mm will have little structural significance. Erosion therefore is more a problem of aesthetics, and a similarity can be drawn between acceptable levels of erosion and acceptable classes of surface finish in concrete work. Adopting 3 categories we might define

Class 1 Surface – Surface where the average surface erosion over a 50 year period is not expected to exceed 4 mm with local areas of erosion of 6 mm.

Class 2 Surface – Surface where the average surface erosion over a 50 year period is not expected to exceed 8 mm with local areas of erosion of 12 mm.

Class 3 Surface – Surface where the average surface erosion over a 50 year period is not expected to exceed 12 mm with local areas of erosion of 18 mm.

The required surface finish would then be specified by the Client and that would form the basis of the acceptance testing of materials in accordance with the UTS test outlined above.

Conclusions

Little work has been done to date in developing a laboratory test which is a reliable predictor of the in-service erosion of earth wall buildings. The UTS Erosion test given in this paper has been developed as a result of extensive field and laboratory testing and provides a logical basis for acceptance testing of earth building materials used in a particular climatic region.

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