COMPARATIVE ANALYSIS OF THE THERMAL PERFORMANCE OF THREE TEST BUILDINGS

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ABSTRACT

This paper details the construction and preliminary thermal performance of three small test buildings constructed by UTS at Yarrawood in NSW. The project involves testing the thermal performance of the three buildings, one brick veneer, one mud brick and one of Hebel wall panels plus additional insulation. Some preliminary results obtained from one week's recording of temperatures inside and outside the building are presented and comments made on their actual performance relative to their expected performance.

KEYWORDS
Thermal performance, sustainable buildings, mud brick, Hebel, brick veneer, thermal monitoring

INTRODUCTION

There is no doubt that the burning of fossil fuels produces CO_2 emissions and that the majority of scientific evidence now considers that this leads to an increase in global warming. A significantly large part of this energy results from activities relating to the built environment and any reduction in this area would be significant.

> "It would appear that, for the industrialized countries, the best chance of rescue lies with the built environment because buildings in use or in the course of erection are the biggest source of carbon emissions generated by fossil fuels, accounting for over 50% of total emissions" (Smith, 2001)

In many counties therefore a concerted effort is being made to reduce both the embodied energy and the operating energy (heating and cooling) required in housing and energy rating systems such as the BASIX system in NSW are being developed and refined to quantify energy usage. Attention is being focussed on various types of housing construction in an effort to establish their energy usage and to see whether any particular system can provide significant energy savings.

Although the study of energy usage in buildings and their modelling by computer has been around for a long time (e.g. Robertson and Christian, 1985) there still remains some doubt as to the accuracy of present modelling programs. For example a one dimensional analysis does not take into account the complex conditions existing in the corners of buildings. The present modelling package in NSW is the Nathers program developed by CSIRO. There is widespread concern particularly in the earth building industry as to the ability of Nathers to effectively model thermal mass and there is no experimental evidence to refute this. The Accurate program is a development of Nathers and is claimed to offer better modelling of thermal mass but once again this has not been verified by experimental evidence.

The purpose of this study was to see whether the Accurate program effectively models both high thermal mass and high insulation in domestic buildings. The study focuses on the external walls of buildings[1]. To this end three small test buildings were constructed at the UTS campus at Yarrawood near Richmond in NSW. The walling systems chosen were brick veneer, insulated Hebel Panels and mud brick. The brick veneer wall system was chosen because it is used for the vast majority of new free standing housing in NSW and therefore provides a reference for comparison with alternative systems. The mud brick wall system was chosen because it is a growing revival of an ancient building method which is claimed to require significantly less heating and cooling energy due to its high "thermal mass". The third type of construction chosen was lightweight concrete (Hebel) panels backed by polystyrene panels for added insulation. This was seen as a high thermal resistance option as

[1] According to Wheeler (1977) approximately one third of energy loss occurs through walls and one third through the roofs in the case of uninsulated brick veneer dwellings.

opposed to the high thermal mass of mud brick and with brick veneer construction sitting somewhere in between.

DESCRIPTION OF BUILDINGS

The three test buildings are located on UTS property (Yarrawood), which is approximately half way between Richmond and Penrith on the western edge of the Sydney Basin. The site was once a conference centre but is now largely derelict. The area is classified as Climate Zone 6 by the Building Code of Australia.

Figure 1 – Substantially completed buildings

The three buildings are each 4.5 metres square in plan and face true north. They have an internal area of 16 square metres and an internal volume of 38.4 cubic metres. There is a single glazed door on the northern side with glass louvres above. The location of the buildings on the site was determined by the need to provide sufficient spacing to avoid shading by each other and by existing buildings as well as the need for access to services. Figure 1 shows the completed three buildings and Figure 2 locates them in plan on the site.

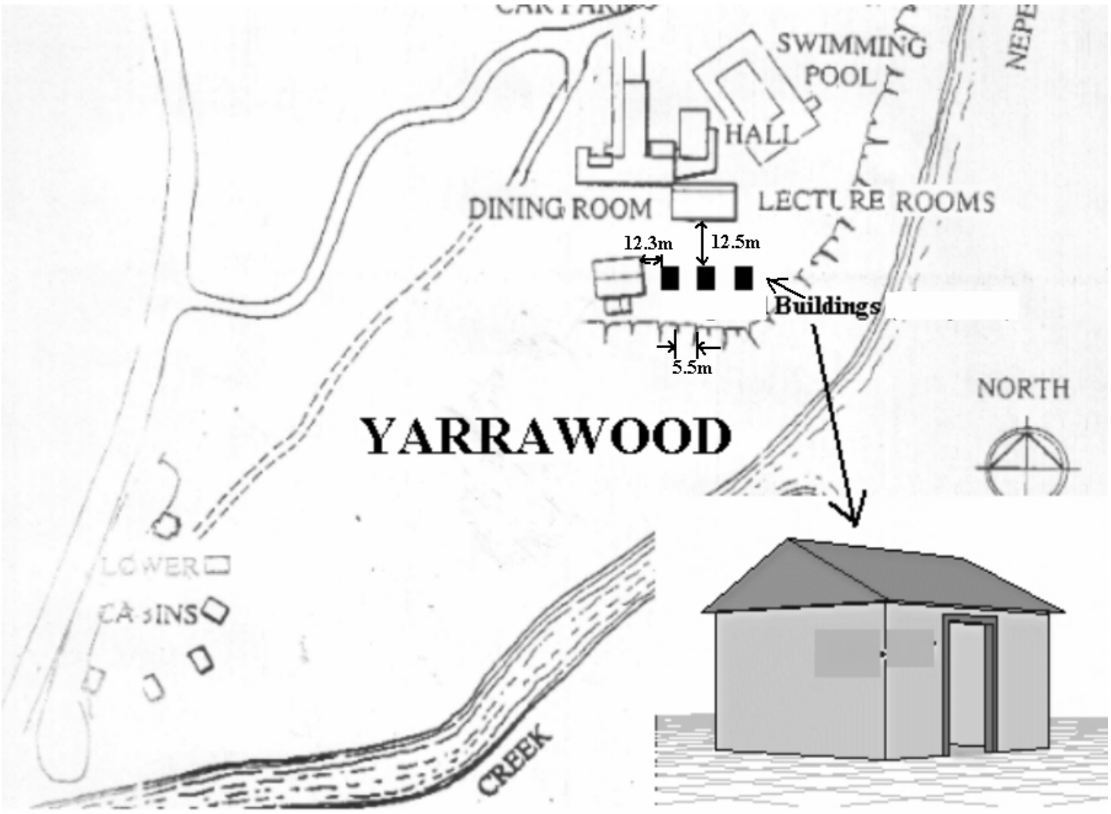

Figure 2 – Sketch plan showing location of buildings on site

Floor Construction

The floor is a conventional reinforced concrete slab on ground with a 100 mm thick slab and 300 mm by 300 mm edge thickenings. 150 mm by 86 edge set downs were used on the brick veneer and insulated Hebel buildings whilst there was no edge set down for the mud brick building. Some cutting was necessary to accommodate the slight fall from west to east on the site.

Roof Construction

The roof was conventionally framed with a 22 degree pitch with gable ends on the east and west sides. The eaves are 600 mm on the north side and 300 mm on the south side. The ceiling is 10 mm plasterboard and the roof sheeting is corrugated "Colorbond" – Colour Light Grey ("Windspray"). Air-Cell "Glareshield"[2] was placed

[2] www.aircell.com.au

directly under the roofing and R2 polyester insulation was placed between the ceiling joists and against the gable ends. The gables were sheeted with fibre cement boarding.

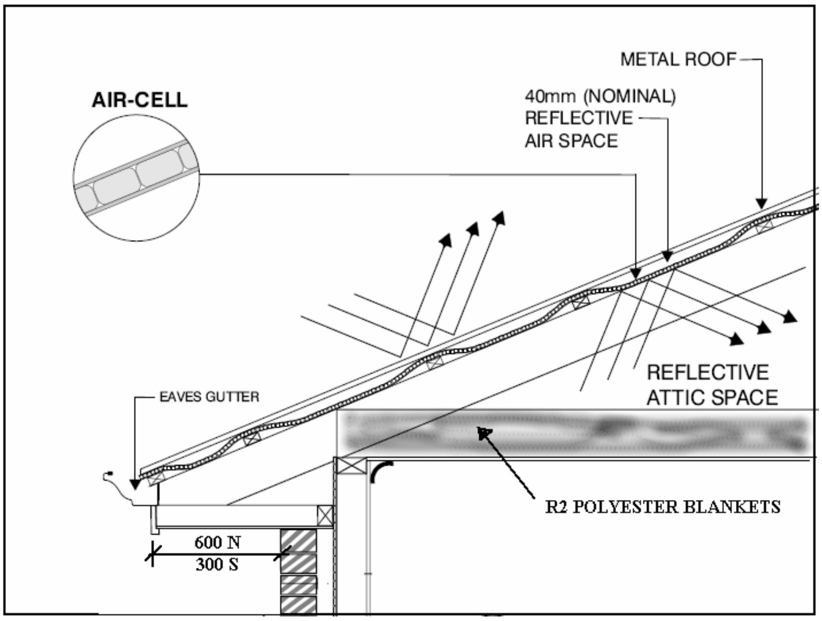

Figure 3 – Section through roof (Source: www.air-cell.com.au)

Door Details

The single light door on the north side is centrally located and consists of an 820 mm timber frame with 6.38 mm laminated glass. Above the door are two glass louvres with a glazed depth of 320 mm and width of 820 mm. These louvres were closed during this test series. The total glazed area of the door and louvres is around 1.33 m^2 with the overall opening including framing being around 2.11 m^2.

Brick Veneer Walls

The walls of the brick veneer building are of typical construction. The stud walls were externally sarked and R1.5 fibreglass batts were placed between the studs.

Insulated Hebel Walls

The insulated Hebel wall system consists of a normal stud wall with 50 thick SMTG Styrofoam™ (R1.79[3]) and 75 thick Hebel™ Power Panels™ (R0.51[4]) panels attached

[3] From www.aeromfg.com.au/html/residential_building.html

[4] From CSR Hebel Technical Manual – January 2006

to the stud wall using top hat steel sections. The Hebel and Styrofoam panels were

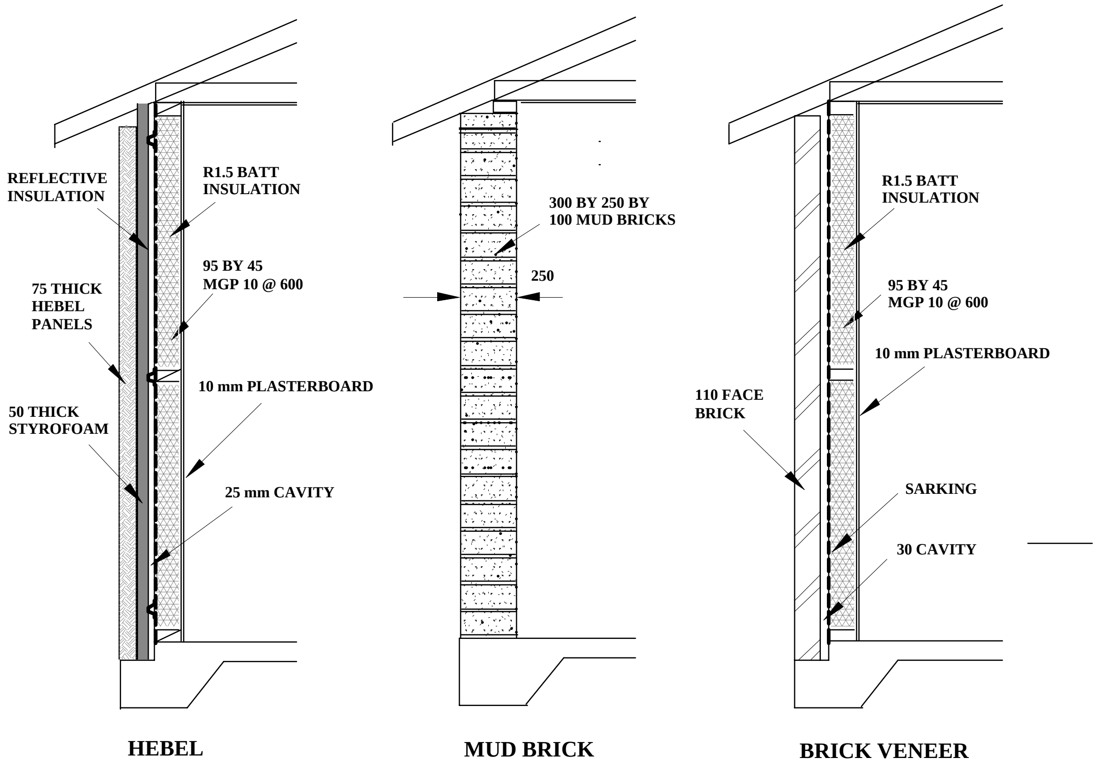

Figure 4 – Sections through the three walls

fixed to the top hat sections by screwing from the outside. Foil backed sarking was placed against the studs with the shiny side facing the 25 mm cavity between the studs and the Styrofoam.

Mud Brick Walls

The mud bricks were 350 mm long by 250 mm wide and 100 mm high. They were bitumen stabilised and were laid in a mortar consisting of a mixture of sand and a clayey soil. Joints were approximately 20 mm. Nine erosion specimens were placed in the south wall as part of a future experiment to measure the distribution of wind-driven rain erosion on the south face. A horizontal rain gauge has also been placed in the centre of this wall. The walls were laid by members of the Earth Building Association of Australia with assistance from architecture students from UTS who were undertaking an earth building elective.

THERMAL PROPERTIES OF BUILDING ENVELOPES

BCA Requirements

For Climate Zone 6 Clause 3.12.1.2 of Volume 2 of the Building Code of Australia (BCA,2006) requires roofs to have a minimum total R-value of 3.2 in an upwards direction. In this case the value quoted by Glareshield[5] is R1.4 upwards for a non-ventilated roof space and R2.2 downwards. If the R2 polyester blanket insulation is added to this the figure for upward heat flow is R3.4 and downwards R4.2.

Clause 3.12.1.4 requires walls to have a minimum total R-value of 1.7 in Climate Zone 6. Alternatively the walls are satisfactory if

a) they have a surface density of not less than 220 kg/m^2 and
b) they are constructed on a flooring system that is in direct contact with the ground, such as a concrete slab-on-ground or the like.

Brick Veneer Walls

The total R-value for the brick veneer wall system can be calculated as follows

Outside air film	0.04	(BCA, Table 2b wind 3m/sec)
110 brick skin	0.17	(BCA, Table 2a , 3.25 kg bricks)
Insulation	1.50	(R1.5 batts)
10 mm plasterboard	0.06	(BCA, Table 2a)
Inside air film	0.12	(BCA, Table 2b)
	1.89 m^2.K/W - this is greater than the BCA requirement of 1.7	

Insulated Hebel Walls

The total R-value for the insulated Hebel wall system can be calculated as follows

Outside air film	0.04	
75 thick Hebel panels	0.51	(CSR Hebel Tech Manual)
50 thick styrofoam	1.79	(www.aeromfg.com.au)

[5] www.aircell.com.au

Unventilated airspace	0.17	(BCA, Table 2b)
Extra for reflec. surface	0.48	(BCA, Table 2b)
Blanket insulation	1.50	
10 mm plasterboard	0.06	
Inside air fFilm	0.12	
	4.67 m^2.K/W	

Mud Brick Walls

250 thick mud brick walls have a surface density of around 400 kg/m^2 and in this case they therefore satisfy Clause 3.12.1.4 since they are built on a slab on ground. On its own a 250 thick earth wall has a total R-value of only 0.63 m^2.K/W according to NZS 4297:1998 “Engineering Design of Earth Buildings” but some researchers feel that this value is too high.

MEASURED THERMAL PERFORMANCE

After some initial manual monitoring single temperature data loggers (DS 19121G iButton® Thermochron®) were placed in the centre of each building on a table and externally in a shaded box mounted on the south side of the Lecture Rooms directly to the north (approx 1.5 metres above ground level). The measurements shown in Figure 5. were for the period 9.08 am on Friday 10th February to 10.30 am on Friday 17th February , 2006

CONCLUSIONS

During this initial survey period the outside temperature varied between 15 degrees and 33 degrees with an average of 23 degrees. Inside temperatures of the three buildings varied between 24 degrees and 30 degrees. The lowest average temperature was recorded for the insulated Hebel building (25.2º), the next for the brick veneer building (25.8º) and the highest was 26.6º for the mud brick building. The overall temperature difference between the three buildings on the hottest day was no more than 2 degrees for the maximum temperature inside the buildings, although on the hot days the average temperature in all buildings was unacceptable. This is not surprising since the buildings were completely shut up and no opportunity was therefore available to release excess heat at night.

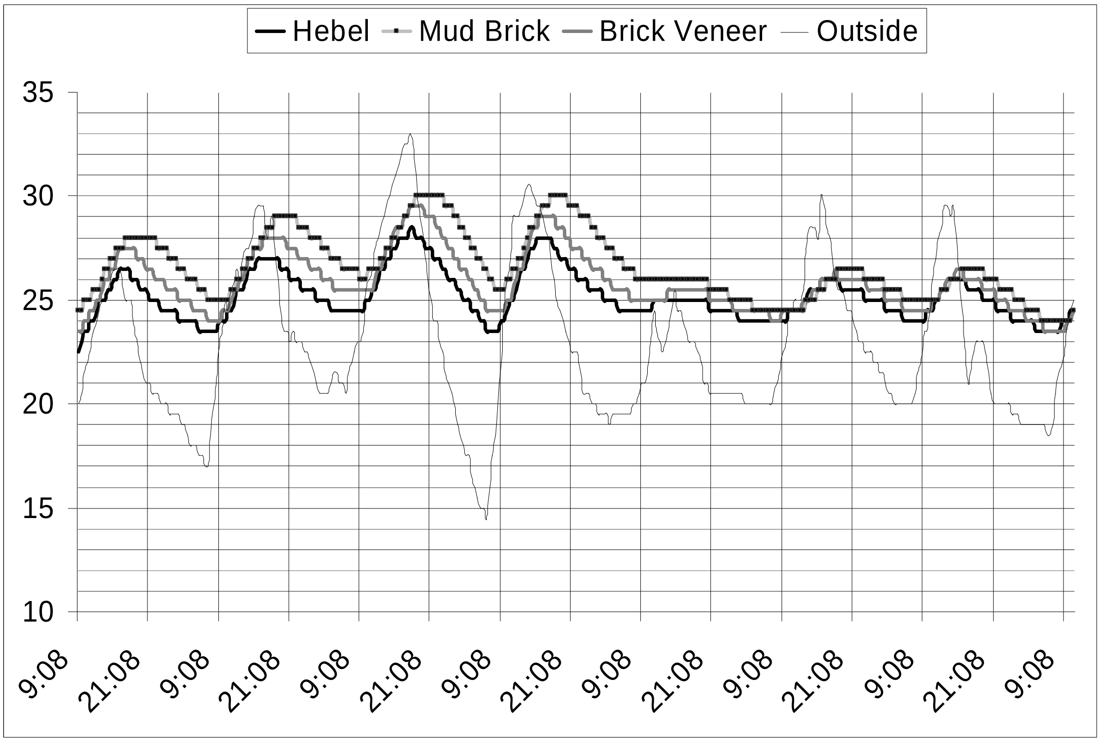

Figure 5 – Temperature data log for period 10th to 17th February

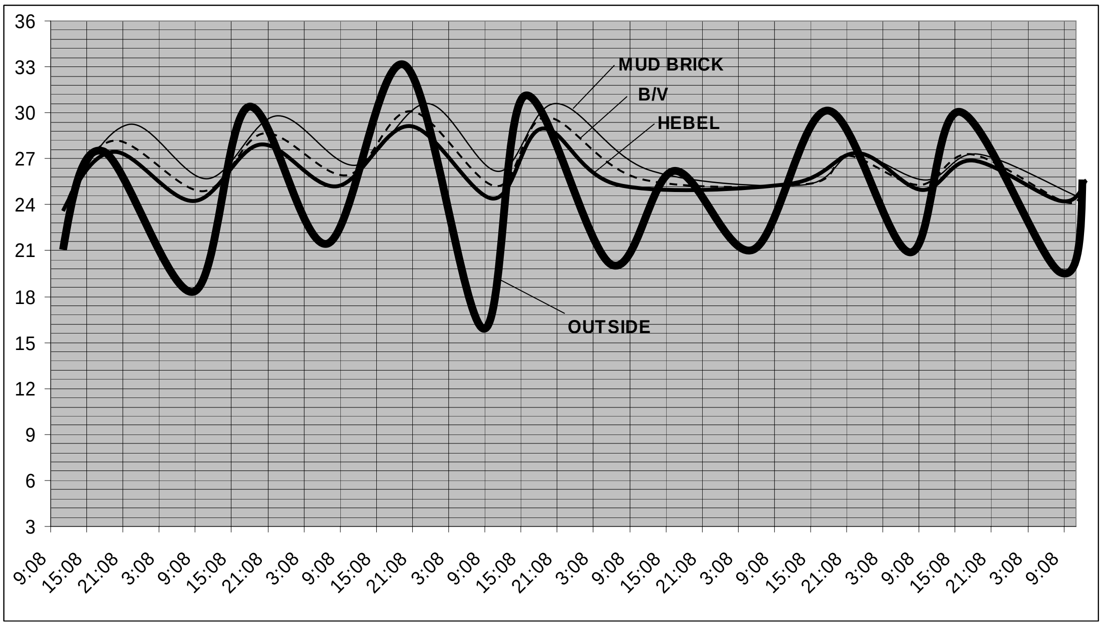

Figure 6 – Smoothed temperature curves

The effect of thermal mass can be quite clearly seen in Figure 6 where the thermal lag for the mud –brick building (high thermal mass) was around 4 hours. This was less than expected. Thermal lag for the insulated Hebel building (low thermal mass) was around 1 hour and for the brick veneer around 2 hours.

These results are only the beginning of a lengthy period of monitoring the test buildings and more data stations are to be installed. It is also envisaged that the effect of varying the configuration of the buildings (e.g. opening doors at night) will be investigated in the future and perhaps additional buildings (e.g. straw bale) will be constructed on the site.

ACKNOWLEDGEMENT AND DISCLAIMER

The author would like to acknowledge the generous monetary assistance provided by CSR Hebel, without whom this project would not have been possible. In particular I would like to acknowledge the tireless work of my colleague, Mr Gregory Moor, who organised and assisted in the construction and monitoring of the buildings, and Mr Shane West, who guided this project through the early stages of funding and approval and who devised the insulated Hebel walling system option.

I would also like to thank Austral bricks for providing and laying the bricks for the brick veneer building and to Peter Jirgens of “Make it Mud Bricks” for providing the mud bricks. Special thanks must also be given to members of the Earth Building Association of NSW (Ray Trappel, Peter Hickson and Gavin Scott) for their tireless work on the construction of the buildings and to students in the Earth Building Elective at UTS who assisted in laying the mud bricks.

It should be noted that the results presented here are for a particular configuration and method of operation of the test buildings only and should not at this stage be interpreted as conferring any particular preference for one or other form of construction. The intention to continue this testing throughout a full year at which time more detailed analysis of the results will be made and at that time changes to the buildings configuration and/or response to thermal conditions may be made to better reflect the normal operation of domestic buildings.

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