Clay Brick Construction - Pre-eminent in the Sustainability Stakes

Despite the emergence of new high-tech alternative lightweight building technologies clay brick in house construction is confirmed as intrinsically 'perfect' for defining a sustainable and more energy efficient future.

The ante towards building greater sustainability into the built environments with materials that have lower impacts on the natural environment is growing exponentially. Clay brick, that has long been regarded as a superior building material for house construction has not evaded scrutiny this notwithstanding that the materials performance attributes [sound insulation, fire resistance to name a few], define the benchmark values in various building standards and codes of practice for alternate walling systems to aspire.

Historically, factors such as durability as a structural and aesthetic walling element, longevity, colour fastness and maintenance free qualities as a face brick have been used to reference the superior sustainability attributes of clay brick. These of course are fundamental building blocks for pursuing a sustainable future and for which clay brick has no peers in terms of its offering.

Sustainability however, particularly in the environmental context, has progressed to also include how building materials and building systems compare in respect of supporting healthier indoor living environments and in lowering operational energy consumption of houses.

Corobrik and the clay brick industry chose a long time back not to take the recognised thermal property of thermal mass in clay bricks, widely recognised for moderating indoor temperatures and the benign qualities of fired clay that assure no negative impact on indoor air quality, for granted. Extensive research provides interesting answers consistently reaffirming clay bricks pre-eminent status.

In the case of human health it is recognised that harmful chemical substances in the indoor air, dust and mould spores, high levels of carbon di-oxide, can lead to long term health problems. Research in Germany [9] of materials and their impacts on indoor air quality has concluded that clay brick is one of the few man-made building materials whose mineral properties meet 'all necessary requirements for healthy living'.

In the first instance the inorganic or inert qualities of fired clay release insignificant or minuscule volatile organic compounds (VOC's) or toxic fumes under normal or fire conditions to have any negative impact on air quality.

In the second instance, fired clay is a dry material that has a natural propensity to absorb and release humidity from the atmosphere to help keep humidity at a required 40-60 per cent level for healthy living and in the third instance it is not a food source for mould widely associated with 'sick building syndrome'.

It is not by chance therefore, that what became known as the "Healthy brick building", in Thalheim, Germany, built by KHB-Creativ Wohnbau GmbH in 2008, was the first single-family home certified by the Sentinel-Haus® Institut [10].

As for providing indoor thermal comfort and the lowering of operational energy usage for heating and cooling, the thermal mass inherent in clay brick construction brings the 'X' factor to the thermal efficiency equation. This is comprehensively portrayed in the paper: "The concept for a potential metric to characterise the dynamic thermal performance of walls" by the Priority Research Centre for Energy, The University of Newcastle, Australia as published in the Energy and Building Journal August 2012 [1].

This study, which built on the 8 years of empirical research [3] into the thermal performance of walling envelopes, identified that while the R-value is an important thermal property of a building material, the emphasis on R-value as the principal parameter influencing the thermal performance of walling systems was flawed. Notably it was found when measuring the actual performance of building modules [Table 5 below from 3], that the Insulated Lightweight (Ins-LW) module (R1.69) with 14% higher R-value walls used 117% more energy to maintain a comfortable living environment within 18 and 24°C range than the Insulated Brick (Ins-CB) (R1.48) module.

Table 5: Comparison of Energy Usage – Controlled Interior

Wall Type	R-Value (m^2K/W)	Heating Energy (MJ/m^2)	Cooling Energy (MJ/m^2)	Total Energy (MJ/m^2)	Normalised to Ins. CB
Ins-CB	1.48	28.3	0.3	28.6	1.0
CB	0.62	56.3	0.1	56.2	2.0
Ins-BV	1.72	32.5	10.4	42.9	1.5
Ins-LW	1.69	48.4	13.7	62.1	2.2

The study [3] demonstrated that the greater time in the comfort zone and resultant less heating and cooling energy consumed by both the Clay Brick cavity (CB) and Insulated Clay Brick (Ins-CB) modules relative to both Insulated Lightweight (Ins-LW) and Insulated Brick Veneer (Ins-BV) modules (R1.72) was due to the internal thermal mass "smoothing" the internal temperature fluctuations.

Building on this research, the study towards a dynamic thermal performance metric [1] found that the key to effective design is the use of a parameter which correctly encapsulates the influence of thermal mass and insulation properties under a dynamic temperature environment. The thermal performance metric is named the 'dynamic temperature response' or T-value. The lower the T-value of the wall the greater will be its energy efficiency.

When applying the T-value concept to comparisons of houses with the same R-value external walls they found:

1. Brick veneer houses use less energy than lightweight houses. Brick veneer walls have lower T-values than lightweight walls.
2. Cavity brick houses use less energy than brick veneer houses. Cavity brick has a lower T-value than brick veneer.
3. Cavity brick houses with brick internal partition walls use the least energy of all and have the lowest T-value.

Further endorsement of the added value thermal mass [thermal capacity] provides to walling envelopes for moderating the indoor temperature within the required comfort range is found and explained in the research pertaining to the wall CR Product [8]. In this research a higher CR Product [combination of thermal capacity 'C' and resistance 'R' of a wall] consistently equated to smaller amplitude ratios [lower fluctuation of temperature indoors in response to external temperature movement - as found in the T-value/Dynamic Thermal Response study [1]]. Nett benefit of reduced indoor temperature fluctuations is more time within the required comfort range.

In climates like South Africa, characterised by long hot summers and large diurnal swings – particularly in the interior of the country and at elevated locations, and which are pronounced in-between seasons i.e. in spring and autumn, the importance of this performance attribute becomes accentuated in the energy efficiency equation. Buildings in South Africa require not only insulation but also sufficient quantities of thermal capacity for energy efficiency. The CR Product research found that placing insulation between brick skins rendered the 'active' thermal capacity of the internal leaf seven times more effective than the outside leaf, providing the wall with the necessary propensity to self-regulate and better maintain the internal environment within the required comfort range [8].

Insulated lightweight walling envelopes on the other hand, as associated with alternate lightweight building systems such as LSFB, have no such propensity to self-regulate and are found to 'overheat' indoors during hot summer days, the insulation trapping the heat inside creating 'hotbox' conditions and necessitating a greater use of cooling energy [3,5&6].

As a way of explanation, the thermal mass and the thermal capacity it provides helps bricks perform like thermal batteries, slowly absorbing, storing heat during the day over a 6 to 8 hour period, and then releasing that heat when it is needed most [3]. This time lag for the sun's heat to pass from the outside to the inside, referenced as 'thermal lag', is what helps moderate internal temperature conditions for longer during the hottest periods of summer days. In winter the internal high mass brick walls that have slowly absorbed radiant and ambient heat during the day, release that stored heat to the cold evening air helping keep internal thermal conditions comfortable for longer.

The correlation in the findings of the extensive research out of both Australia and South Africa [1, 3, 4, 5, 6, 7 & 8] is consistent in confirming that conventional clay brick construction - double skin with appropriate levels of insulation between the brick skins for the climatic zone - affords superior thermal comfort with lower heating and cooling energy usage than comparable lightweight walling envelopes with the same or higher steady state R-values [resistance].

In the South African context, the modelling studies of both 130 m² [6] and 132 m² [7] house types using DesignBuilder EnergyPlus and Visual DOE software respectively, found the SANS 204 compliant clay brick house afforded greater thermal comfort and lower heating and cooling energy consumption compared to SANS 517 and SANS 204 DTS lightweight walled alternates.

The table of energy usage comparison values below for a Verdant house plan, as compiled from the Energetics full LCA [modelled using ASHRAE accredited DesignBuilder software recognised for being conservative in its treatment of thermal mass], endorses the comparative thermal efficiency of conventional double skin clay brick cavity wall construction and the same with insulation. Increasing the R-value of brick walls enhances the thermal efficiency in those climates that have colder winter periods. In the hotter and milder climates such as Brisbane, insulation applied in the cavity of a brick wall offers marginal energy savings and maybe considered an unnecessary cost. This is consistent with the finding of WSP Green by Designs research in respect of 130 m² and 40 m² house types in South Africa's six major climatic zones [5&6].

THERMAL MODELLING OF A VERDANT HOUSE PLAN

TOTAL AVERAGE ANNUAL (HVAC) HEATING AND COOLING ENERGY [kWh]

Based on 4 Orientations per Location

Values compiled from Energetics Full Life Cycle Assessment

Location/ Climatic Zone	Un-insulated Double Brick	Insulated Double Brick (R1.3)	Insulated Timber Frame	Insulated Timber more/(less) HVAC Energy than Double Brick	Insulated Timber more/(less) HVAC Energy than Double Brick Insulated R1.3
Newcastle	1086.50	1016.75	1328.75	22.27%	30.66%
Melbourne	1092.50	942.75	1183.50	8.33%	25.54%
Brisbane	1146.50	1123.50	1381.50	20.50%	22.96%
Total Average	3325.50	3083.00	3893.50	**17.08%**	**26.29%**

Note:
- ***Modelling used Design Builder-Energy Plus Software***
- ***These results are house design floor plan specific.***
- ***A different house design, floor plan with different windows and door placement will lead to different results.***

Studies specific to South Africa [6 & 7] go further in confirming that clay brick construction does this more cost effectively [with best payback for the insulation applied] than alternate building technologies such as Light Steel Frame Building, SANS 517 and SANS 204 compliant, over a 50 year lifecycle.

In the case of the 10 Show House development [2] in Perth for developers to demonstrate the environmental compliance of their houses, the double skin clay brick house of Jade Projects was the one and only house awarded an 8 Star Energy Rating per the Building Energy Rating System [BERS] of Australia. The other nine Show Houses, of which seven comprised steel frame with different highly insulated lightweight walling composites, some also being designed on passive solar design principles, achieved energy ratings of 5 or 6 Stars, the difference in rating essentially defining the added value of well-placed thermal mass and insulation in the building envelope.

The different energy ratings as recorded highlight how combining common sense Solar Passive Design principles [orientation, shading, insulation and ventilation for the climatology of the location] with the use of correctly placed thermal mass in the building envelope, the latter enhancing the propensity to take best advantage of the suns energy, provides for optimal thermal efficiencies cost effectively. The application of SANS 204 Deemed to Satisfy Standards for masonry construction [currently voluntary] is a step in the right direction towards greater energy efficiency of residential buildings throughout South Africa.

Moving to total energy consumed and the total greenhouse gasses GHG emitted for different construction types over a hypothetical 50 year lifecycle, the full Life Cycle Assessment (LCA) [4] by Energetics in Australia puts the superior thermal efficiency of clay brick construction in context. The LCA found that in the case of the Verdant floor plan, the lowest total GHG impacts [embodied and operational] over a 50 year lifecycle are achieved when the external walls are constructed of insulated brick and in the case of the Sirocco floor plan, when the brick walls had an R-value of 3.0. The LCA notes the timber frame weatherboard house as having the lowest embodied energy and that carbon sequestration, that was still being studied and debated, was not taken into account (as per Kyoto accounting rules) in the LCA.

This finding is mirrored in South African desktop research of a 40 m^2 house [5] where the clay brick house afforded a lower total energy outcome over a 40 year lifecycle than the SANS 204 compliant LSF alternate.

The lifecycle assessment research brings to the fore the inappropriateness of comparing the embodied energy values of individual components of walling systems as a measure of comparative 'greenness', and that only a full lifecycle analysis of combinations of materials used as walling systems fulfilling the same function can provide for meaningful comparison.

While the full Life Cycle Assessment established the heating and cooling energy benefits and the low lifecycle impacts clay brick construction provides, it also highlighted that a comprehensive approach to sustainability requires that we continue to build houses able to endure, with little maintenance and definitely no materials replacement, way beyond a 100 year lifecycle. Clay brick is the one man made walling material that has proven to be more than up to the task with the thermal efficiency benefits enduring way beyond the limited lifecycle of less durable alternate building lightweight walling.

Combine the thermal and health benefits of clay brick construction with the basket of other sustainability attributes such the low maintenance qualities of face brick that mitigate future carbon debt associated with a lifetime of maintenance, the longevity that mitigates future carbon debt associated with refurbishment and replacement of less durable materials and that clay bricks are reusable as masonry or pavers and/or recyclable as aggregate for concrete manufacture, road building and ground cover, and clay brick finds itself in a unique space for defining a sustainable future with low environmental impacts.

Reference sources:

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