AUSTRALIAN MASONRY IN THE 21st CENTURY – STRATEGIES FOR SUSTAINABILITY

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ABSTRACT
There is an increasing emphasis on sustainability in all of its forms worldwide. This is particularly the case in the building industry driven by a rapidly changing regulatory environment aimed at encouraging sustainability practices. In Australia, the recent introduction of a carbon pricing scheme has also resulted in an increased focus on energy intensive materials and practices due to the higher costs of fossil fuel based power generation and other carbon intensive manufacturing processes. It has also resulted in an increased interest on energy efficiency in all of its forms, and in particular, the design, construction and operation of buildings. A national building energy standard incorporating an assessment and rating framework is also being prepared. This environment has created a number of threats and opportunities for the masonry industry – masonry is an energy intensive material and its market share is under threat for this and other reasons, but in a life cycle context it has significant advantages in relation to longevity, consistent performance, and the potential for use in buildings with lower operational energy. As a result, the masonry industry has been pro-active in developing a range of research and communication strategies to meet this challenge and take advantage of potential opportunities. An overview is given of the current Australian scene together with the strategies being adopted by the masonry industry to ensure that masonry remains a widely used construction material.

KEYWORDS: sustainability, masonry, energy performance

INTRODUCTION
There is an increasing emphasis on sustainability in all of its forms worldwide. This presents both threats and opportunities for the masonry industry which are being addressed to widely varying degrees in different countries [1]. This is particularly the case in the Australian building industry, driven by a rapidly changing regulatory environment to encourage sustainability practices. The recent introduction of a carbon pricing scheme has also increased the focus on energy intensive materials and practices due to the greater costs of fossil fuel based power generation and other carbon intensive manufacturing processes. It has also resulted in an increased interest on energy efficiency in all of its forms, and in particular, the design, construction and operation of buildings. A national building energy standard incorporating an assessment and rating framework is also being prepared. This environment has created a number of threats and opportunities for the masonry industry – masonry is an energy intensive material and its market share is under threat, but in a life cycle context it has significant advantages in

relation to longevity, consistent performance, and the potential for use in buildings with lower operational energy. As a result, the masonry industry has been pro-active in developing a range of research and communication strategies to meet this challenge and take advantage of potential opportunities. As described below, significant progress has been made and work is continuing in an increasingly competitive building industry environment.

AUSTRALIAN MASONRY

Masonry, along with timber, steel and concrete is one of the four primary construction materials used in buildings in Australia. It is used in a wide range of both loadbearing and non-loadbearing applications in a number of forms (predominantly fired clay and concrete, and to a lesser extent, autoclaved aerated concrete, natural stone and calcium silicate). As such, it may serve as the primary structural element in structures such as 3-4 story "walk up" apartment buildings or low rise commercial structures, or as a veneer or infill in housing or high rise framed construction. A more detailed overview of the Australian masonry scene has been presented recently [2].

In many respects the Australian masonry industry is still very traditional and conservative, and in the past has been complacent in responding to the development of alternative systems. A good example of this was the emergence of precast and tilt-up concrete construction systems in the 1980's which made major inroads into the use of masonry in light commercial construction without any coordinated response by the masonry industry – as can be seen from Table 1, precast (17%) and tilt-up construction (5%) now make up 22% of the external walling market. However, in relation to sustainability issues this has not been the case. Over the past 10 years or so, the masonry industry has been pro-active in meeting the increasing market threats, challenges and opportunities created by the greater focus on sustainability (particularly related to the perceptions associated with materials with inherent high embodied energy such as fired clay, concrete and cement). From an industry perspective, it is important to note that sustainability is a broad term encompassing not only traditional sustainability issues but also economic sustainability in an increasingly competitive walling market.

Table 1: Total Australian External Walling Materials

Material		*Total Multi-Res*	*Houses*	*TOTAL RESIDENTIAL*	*Non-Residential*	*TOTAL WALLING MARKET*	*Market Share*
Brick veneer	'000m²	810.3	11,757.0	12,567.3	856.7	**13,424.0**	**37%**
Full Brick	'000m²	541.4	2,905.8	3,447.2	1,094.9	**4,542.1**	**12%**
Total Brick	*'000m²*	*1,351.7*	*14,662.8*	*16,014.5*	*1,951.6*	***17,966.1***	***49%***
Fibre Cement	'000m²	399.1	1,643.1	2,042.2	611.1	**2,653.3**	**7%**
Concrete masonry	'000m²	728.6	288.3	1,016.9	1,864.9	**2,881.8**	**8%**
Precast	'000m²	1,261.4	0.0	1,261.4	5,150.7	**6,412.1**	**17%**
Tilt up	'000m²	44.4	0.0	44.4	1,699.1	**1,743.5**	**5%**
Colorbond	'000m²	6.4	0.0	6.4	2,824.7	**2,831.1**	**8%**

Composite Panels	'000m²	0.0	0.0	0.0	1,053.2	**1,053.2**	**3%**
Glass	'000m²	17.4	0.0	17.4	473.9	**491.3**	**1%**
Other	'000m²	36.3	485.3	521.6	144.1	**665.7**	**2%**
Total	**'000m²**	**3,845.3**	**17,079.5**	**20,924.8**	**15,773.3**	**36,698.1**	**100%**

As can be seen from Table 1, the largest masonry market is in residential construction, where brick veneer, and to some extent cavity brick, is the commonest form of walling, with partially reinforced single skin concrete masonry being used in tropical (cyclonic) areas. Masonry in its various forms is widely used because of its aesthetic qualities, its strength and longevity and its physical characteristics related to thermal efficiency, sound transmission and fire resistance. In recent years, various forms of lightweight construction have become popular as a masonry alternative (due in part to perceived site problems with masonry related to workmanship and high labour costs). Lightweight construction typically consists of external rendered fibre cement sheeting with a layer of insulation on a timber frame lined with plaster board. Often these systems incorporate air conditioning to provide internal thermal comfort with no attempt to optimise the thermal performance of the building using solar-passive design principles where the inherent thermal mass of masonry walling can be used to advantage.

With the increasing emphasis on CO_2 emissions, masonry is also potentially disadvantaged because of the higher levels of energy required in the manufacture of masonry units and the cement used in the mortar. However, if the full life cycle of a building is considered, a different picture emerges. Recent life cycle assessment studies for typical Australian homes [3] have shown that regardless of construction type, the operational energy for the house over its design life far outweighs the embodied energy of the materials, with emissions from embodied energy representing only 11% of the total emissions over a 50 year life cycle. Operational performance is therefore a key factor in the design of a sustainable housing system.

CURRENT REGULATORY ENVIRONMENT

The Building Code of Australia (BCA) [4] was first introduced in 1988 and is the overarching regulatory document for buildings in Australia. This is a performance based code, but in many instances also has “deemed-to-satisfy” requirements for ease of use. Energy related regulations were first incorporated in 2003 and have been progressively refined and become more stringent since that date.

A key component of defining the energy performance of a building is its energy star rating, with the current regulations for new residential construction consisting of a 10 star rating system obtained by thermal modelling of the performance using appropriate software (this does present some problems as the ratings which can be achieved are to some extent software dependant, reflecting the inherent problems associated with the modelling of a complex physical process with different software packages based on varying basic assumptions). For each climate zone, unique starbands have been set taking into account the extremes of the local weather conditions, with the maximum energy consumption per unit area (MJ/m^2) for each half starband level being specified. Houses with higher star levels are considered to be more thermally comfortable than those of lower star levels. Houses rated at 10 stars are considered thermally comfortable without the need for artificial heating and cooling.

As an alternative to theoretical modelling, the "deemed-to-satisfy" provisions of the BCA can be used to satisfy the rating requirements. These are more simplistic (but convenient) provisions which may not fully reflect the important influence of thermal mass which is inherent in heavy walling. The original deemed-to-satisfy requirements for thermal performance placed the emphasis on the thermal resistance (R value) of walling systems with no consideration of the influence of thermal mass which can be used to advantage in a dynamic temperature environment. As a result of subsequent research and input from the masonry industry, this has been rectified to some extent. The usage of these two alternative approaches varies across the country as reflected in Table 2. There is clearly a need for the industry to be strategically focussed on both possible rating approaches.

Table 2: Percentage of Home Builders Using Deemed-to-satisfy or Star Rating Systems

	QLD	NSW	VIC	SA	WA	TAS	ACT
Deemed-to satisfy	27	38	17	33	32	58	0
Star Rating	73	62	83	67	68	42	100

FUTURE REGULATORY ENVIRONMENT

The regulatory environment in relation to sustainability is an evolving process. A key aspect of this relates to the building industry, as buildings are central to both Australia's economy and its greenhouse gas emissions. In 2010/11 the value of approved building work was approximately $A75billion, with $A47 billion of this spent on residential building work. The building sector accounts for approximately 19% of Australia's energy consumption and 23% of its carbon emissions [5].

In 2009, the Council of Australian Government agreed to the "National Strategy on Energy Efficiency", which is designed to substantially improve the levels of energy efficiency across the Australian economy. One of the measures requires the development of a consistent, outcomes-based framework for national building energy standard-setting, assessment and rating to drive significant improvements in energy efficiency [5]. This will rationalise a range of current inconsistent measures which are predominantly state based, and produce a building rating methodology which will allow buildings across Australia to be compared fairly. All building types will be rated using a ten star scale and include quantitative information about the performance of the building. A single rating tool will be specified for demonstrating compliance. It is also intended to include embodied energy and life cycle aspects in the revised provisions. These details are still under development, but from a masonry perspective it is imperative that the focus be on the full LCA rather than just embodied energy.

Once implemented in 2015, the Framework will play a key role in creating effective design procedures. In this context, it can be seen that the future of masonry in Australia as a building material will crucially depend on meeting the challenges presented by the Framework accompanied by an effective communication strategy to the industry and the community at large (supported by appropriate research). As described below, a range of initiatives are already in place or in progress to meet this challenge.

BACKGROUND RESEARCH AND DEVELOPMENT

Over the last 10 years the Australian masonry industry has been pro-active in the area of sustainability through the involvement of individual brick and paving manufacturers and particularly through its industry associations (Think Brick Australia and the Concrete Masonry Association of Australia). This has included a major collaborative research project between Think Brick Australia and the University of Newcastle involving full scale experimental studies and parallel analytical modelling of the thermal performance of Australian housing systems. Other Think Brick projects have included: the development of a climate design tool for a range of Australian locations to facilitate sustainable design; dissemination of information on solar-passive design; detailed life cycle assessments of typical housing systems; the refinement of manufacturing techniques to minimise carbon emissions and maximise recycling opportunities; extending the range of innovative and attractive walling products; and embodied energy studies for various building materials.

DESIGN FOR CLIMATE

Think Brick Australia has developed a user friendly web based tool *("The Climate Design Wizard")* to allow designers to optimise the energy performance of a building using solar-passive design principles [6]. Based on all available previous weather records, for 27 locations in Australia (including the largest cities and locations with high levels of population growth), the designer can obtain either a list of the best sustainable design strategies for that location, or an in-depth project report presenting design strategies and detailed information for each of the following in a user friendly format (see, for example, Figure 1):

- climate overview with data records and best orientation
- air temperatures
- heating and cooling degree hours to maintain internal thermal comfort
- sun and shade data (solar irradiation and sky condition)
- humidity
- wind
- rainfall (including rain water re-use strategies)

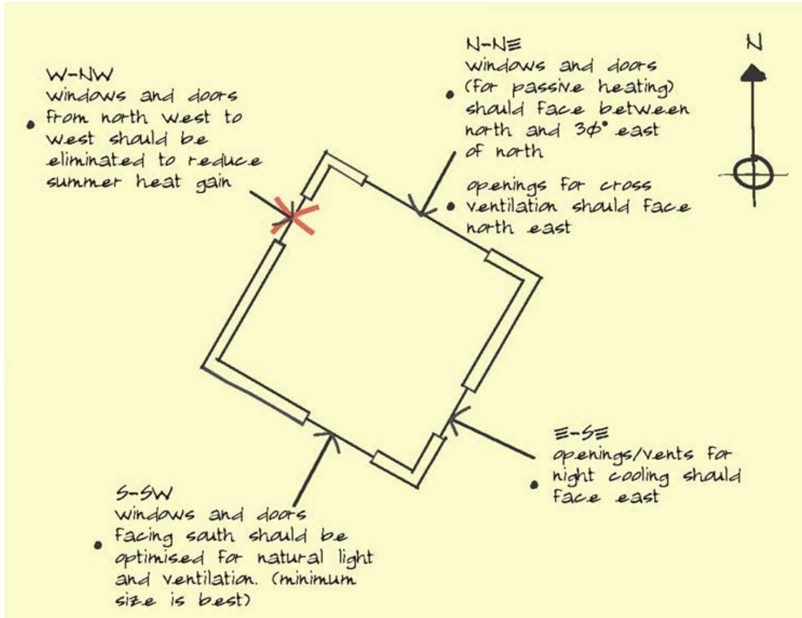


Figure 1: Typical Output From Climate Design Wizard [6]

LIFE CYCLE INVENTORY OF BUILDING PRODUCTS

Recently a life cycle inventory of Australian building products has been produced by the Building Products Innovation Council (BPIC). BPIC is Australia's peak body representing the building products sector and is focussed on presenting a unified and coordinated approach to regulatory changes affecting the building industry. In partnership with the Federal Government, BPIC has recently completed a 3 year project to produce a life cycle inventory data base of building materials to assist in the preparation of LCA's to allow a more accurate and consistent assessment of the impact of various building materials on the environment [7]. An introduction and guide to the preparation of life cycle assessments of building products has also been produced. This work was sponsored by a wide range of product manufacturers, including the brick industry through Think Brick Australia.

LIFE CYCLE ASSESSMENT OF AUSTRALIAN HOUSING

In 2008 Think Brick Australia commissioned a total life cycle assessment (LCA) of residential housing to quantify the environmental impact of clay bricks [8]. The study examined different floor plans, climatic zones, building orientation and materials of construction. The full LCA involved the collection of data on clay extraction, manufacturing processes, transport requirements, construction elements and end-of-life disposal. It also included the modelling of all aspects of the operational energy of the house, including the energy required to maintain the internal thermal comfort of the houses, thus allowing the comparison of the total emissions over the lifetime of each house. The walling systems covered the range of typical housing systems: cavity brick; insulated cavity brick; insulated brick veneer; reverse brick veneer; and insulated timber (weatherboard). For each walling type two different house designs were considered, as well as the orientation and location of the house (three different climate zones). Each LCA study was performed on the complete house, not just the external walling system.

The main findings of the assessment were:

- total operational energy (heating, lighting, hot water and appliances) is the dominant contributor to the performance of the house over its life (up to 90%). The outcome was similar for all wall construction materials. The external walling materials of a house therefore have very little impact on the overall greenhouse gas emissions over its full design life.
- the design of the house itself has a greater impact on the lifetime performance than does the selection of the materials for the exterior wall construction. The building design effects were found to be more critical than building orientation.
- brick performance was comparable to other materials over a 50 year life of the building; for longer life spans, brick became the best performing material.

The critical role of operational energy identified in the report reinforces the importance of solar-passive design and the effective use of the thermal mass of heavy walling in increasing energy efficiency.

SUSTAINABLE UNIT MANUFACTURING PROCESSES

In recent years, major improvements have been made in sustainable manufacturing processes, both in terms of energy use and water consumption during manufacture. All manufacturers have reduced greenhouse gas emissions since 2000 (as high as 30% in the case of one major manufacturer). Initiatives have included:

- improved firing processes with replacement or conversion to modern gas fired kilns.
- use of non-virgin raw materials with the recycling of brick products and the addition of industrial and urban waste materials having calorific values which lower the fuel used for firing (fly ash, bottom ash and furnace slag, organic wastes and coal slurry and coal shales in some instances).
- water harvesting and re-use, with some plants becoming water self sufficient.

PRODUCT RE-ENGINEERING

There have been a range of initiatives in product re-engineering to remain competitive in the marketplace and at the same time address sustainability issues:

- traditionally, masonry units with coring of <30% are considered as "solid" and are treated as such in the Masonry Structures Code AS3700. With advances in manufacturing technology, units with coring up to 40% have now been developed. These require less raw material and fuel for firing, are lighter to transport, and lighter to handle during construction.
- both the clay and concrete masonry industry have developed a wider range of units capable of producing low maintenance walling of appropriate colour and texture and unit size requiring no additional finishing coat. This has resulted in a range of architecturally attractive innovative external walling systems with a choice of matt, semi-gloss or gloss finishes of various colours and natural finishes.
- a good recent example of product re-engineering to maintain market share, is the development of the "Q Block" [9]. This is a non-loadbearing clay block system with 40% coring for internal walls. It consists of 90mm fired clay units with tongue and groove ends to provide horizontal alignment, laid in 1mm thin bed adhesive mortar with no mortar in the vertical perpends (see Figure 2). Compared to a conventional product, this lighter Q Block requires less firing energy, has lower transport and handling costs,

and due to the ease of laying with the thin bed mortar has reduced site problems in relation to quality control and workmanship.

- Prefabricated walling systems have been trialled by several manufacturers, but with mixed success. Their development has been hindered by the fractured nature of the building industry and its associated trades and the widely scattered population centres requiring high transport costs.

Figure 2: Q Block System [9]

UNIVERSITY OF NEWCASTLE RESEARCH

This project was instigated by Think Brick Australia in 2001 to assist in providing an effective response to the market and regulatory challenges of a wider sustainability agenda. The key goals of the project were to provide a sound understanding of the thermal performance of walling systems using both theoretical and experimental techniques and to provide a credible basis for a subsequent communication strategy to the industry and the community. The research is on-going and has involved the investigation of the thermal performance of a range of domestic walling systems. A detailed report on the first eight years of the study has been produced recently [10].

Over the project period, various walling systems have been tested (cavity brick, insulated cavity brick, brick veneer with and without insulation, lightweight construction and insulated reverse brick veneer). All wall elements as well as walling systems were first tested in a Guarded Hot Box apparatus (constructed in accordance to the ASTM Standard, (ASTM C 1363–97)) to obtain their thermal resistance (R-value). Each walling system was then incorporated into a representative full scale housing module to observe its performance in a complete building under real weather conditions. A parallel theoretical investigation was also performed, including the development of thermal modelling software (NUMBERS) which was verified using the test results [10]. The housing modules were constructed on the University of Newcastle Callaghan Campus in suburban Newcastle which has a typical moderate Australian climate. Each module was studied with the interior space being either in a 'free-floating' state (directly influenced by real weather conditions), or with the interior artificially heated or cooled to a preset temperature range of 18-24 degrees Celsius with the heating/cooling energy measured. The typical modules are shown in Figure 3. After the initial observation of the windowless modules, a major opening was inserted in the northern walls to more realistically represent solar-passive effects in a north facing room (see Figure 3(a). The window/floor area ratio was typical for that of an Australian house, thus allowing the study of the heat flow mechanisms of the walling systems (rather than a complete house).

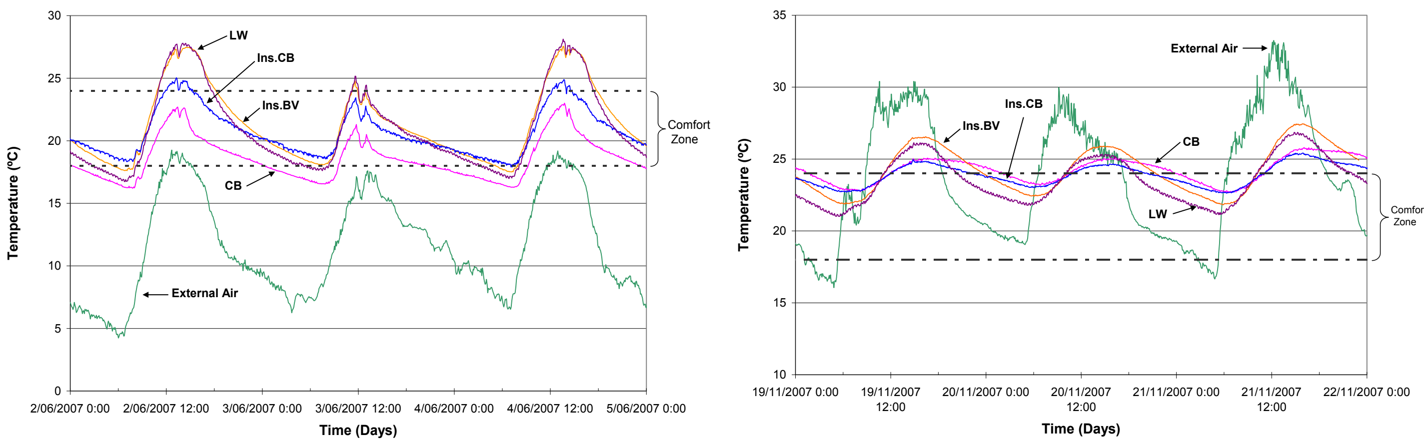
The modules had a square floor plan of 6 m x 6 m and were spaced 7 m apart to avoid shading and minimise wind obstruction. With the exception of the walls and roof, the buildings were of identical construction following standard Australian practice, being built on a concrete slab-on-ground and aligned in a manner so that the north wall of each building was aligned to astronomical north. The roof was supported by an independent steel frame which allowed the removal and replacement of walls as required. Instrumentation recorded the external weather conditions and the incident solar radiation on each wall (vertical plane) and on the roof (horizontal plane). For each module, temperature and heat flux profiles through the walls, slab and ceiling were recorded in conjunction with the internal air temperature and relative humidity. In total, 105 data channels were scanned and logged every 5 minutes for each of the modules for the duration of the testing program. Full details of the instrumentation and tests are described in Reference [10].

(a) Brick Veneer and Cavity Brick Modules **(b) Lightweight Module**

Figure 3: Housing Test Modules

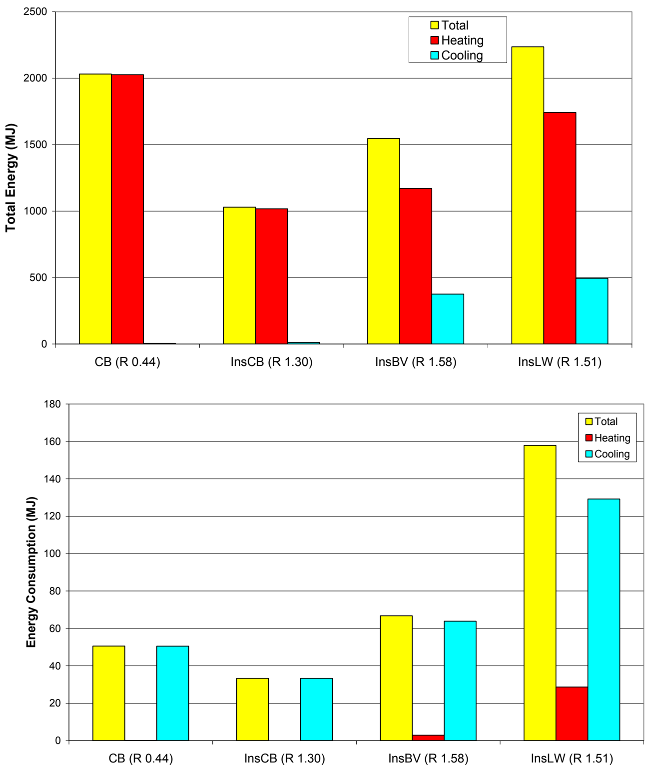
For the first time in the Australian context, the testing program has provided hard experimental data on the in-situ thermal performance of the various walling systems used in domestic construction. Importantly, the results have confirmed the beneficial effects of thermal mass (combined with appropriate insulation) in enhancing interior thermal comfort and in controlled conditions, significantly reducing energy consumption. As an illustration, some typical results for floating and controlled interior conditions are shown in Figures 4 and 5. Figure 4 shows external and internal air temperature profiles for modules with an opening in the northern wall for typical warm and cool conditions for cavity brick (CB), insulated cavity brick (Ins.CB), insulated brick veneer (Ins.BV), and lightweight construction (LW) with the interior of each building free to float. It can be seen that the heavy walling systems have a superior performance with regards to the periods within the comfort zone (taken as 18-24 degrees Celsius). For cases when the interior was controlled to maintain the internal temperature in the range of 18-24 degrees Celsius, the superior performance of the modules with heavy walling is again apparent (see Figure 5). Note that there is no direct correlation between R-value and module performance in either the free floating or controlled cases. This was found to be the case for all seasonal conditions. The lower heating/cooling demands for the Ins.BV module compared to the LW illustrates the contribution of the thermal mass of the external brick skin, even though it is located on the external side of the insulation barrier [10].

As indicated above, one key research finding from the first stage of the investigation was the confirmation that the thermal resistance (R-value) does not directly correlate with the thermal performance of real buildings, which under diurnal temperature cycles are subjected to a dynamic temperature environment. Thermal resistance is a static parameter which does not capture in a dynamic temperature environment the contribution of thermal mass which, due to thermal lag, plays a significant role in influencing the internal conditions. From a detailed analysis of the data obtained from the housing modules, a more realistic wall performance parameter reflecting its performance under a dynamic, rather than static temperature environment is under development. This parameter (called the Dynamic Temperature Response or T-value) incorporates the combined effects of both insulation and thermal mass and has significant potential as a future key design parameter for both walls and complete buildings [11].



(a) Winter conditions (June 2007) ***(b) Summer conditions (November, 2007)***

Figure 4: External and Internal Temperatures of Housing Test Modules Under Internal Floating Conditions (with North facing window)



Cool conditions – 6 week period July/August, 2008 ***Warm conditions- 4 week period - October, 2007***

Figure 5: Energy Consumption for Test Modules Under Cool and Hot Conditions

COMMUNICATION AND MARKETING STRATEGIES

Underpinned by the various research and development initiatives (including those described above), an important component of the industry response to the sustainability challenge has been a coordinated communication and marketing strategy to better inform the various stakeholders of the key aspects of energy efficient design (regulators, architects, engineers, builders, project home developers and the public in general). These initiatives have included:

- the development of effective industry websites and literature with user friendly information on the various aspects of sustainable design [12,13].
- the presentation of the research results at national and international conferences.
- the publication of key research findings in peer reviewed journals.
- involvement in the design and construction of a number of display homes incorporating thermal mass and effective solar-passive design principles to demonstrate the achievement of high star ratings without the need for artificial heating or cooling.
- presentations by researchers and industry representatives to key industry stakeholders throughout Australia.
- communication with, and lobbying of, appropriate government and semi-government bodies to ensure they are fully informed of the key outcomes of recent research.
- appropriate publicity and lobbying to ensure that LCA studies are used so that the whole picture is considered (particularly the consideration of operational energy).

CURRENT AND FUTURE CHALLENGES

Despite the progress which has been made, there are still considerable challenges to be overcome for masonry to retain its place as a key construction material in an environment dominated by sustainability issues and other market pressures. These include:

Skilled Labour Shortages and Site Workmanship Problems - **i**n recent years, the number of skilled masons and technical college bricklaying graduates have both decreased and often been replaced by less skilled labour, often trained on the job. This has the potential to adversely affect the quality of the masonry construction (particularly for housing) and also to create a desire on the part of some builders and specifiers to eliminate masonry from the job (since it is perceived as an additional "wet trade" with associated problems). To address this problem, the masonry industry has established the Australian Brick and Blocklaying Training Foundation (ABBTF), funded by a levy on brick and block production. The ABBTF has in place a range of initiatives to address the skills shortage and improve the general standards of masonry construction [14]. These include accelerated bricklayer training programs, apprenticeship recruitment and support, Step Out programs in schools to gain hands on experience in bricklaying, participation in careers expos and general recruiting initiatives. These programs have had considerable success and in the medium term should help to solve the skills shortage problem.

Alternative Walling Systems - in recent years various walling systems have emerged (particularly for housing), partly as a result of the problems described above. Apart from potential advantages in relation to site labour costs (through prefabrication, panelisation etc), some systems claim better sustainability credentials due to their lower embodied energy and high thermal resistance. As described earlier, contrary to the common perception, this does not mean that masonry systems are inferior, but the challenge remains in correcting those perceptions. Masonry construction methods have essentially remained unchanged for centuries, with masonry units being individually placed in a wall using site mixed mortar. This process is obviously labour intensive with potential workmanship and quality control problems. Clearly there is the potential to treat the masonry wall as a system which can be delivered to the site and installed in one operation. Various systems have been proposed in the past (with limited success), but there is certainly the potential to develop an energy efficient, prefabricated masonry product with strong sustainability credentials to compete with other emerging walling systems.

SUMMARY AND CONCLUSIONS

Masonry is a material with many inherent advantages (longevity, durability, low maintenance, fire resistance, high thermal mass etc), and for this reason has a major share of the Australian walling market, particularly for housing. However, with the increasing emphasis on all aspects of sustainability (particularly those associated with embodied and operational energy), there is a need for the masonry industry to continue to be pro-active in this area to ensure it maintains its market share. Current and future initiatives have been described, both in relation to background research and in the communication and marketing strategies which have been adopted.

ACKNOWLEDGEMENTS

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