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AUSTRALIAN MASONRY AT THE CROSSROADS

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ABSTRACT

Masonry in its various forms is widely used because of its aesthetic qualities, its strength and its physical characteristics related to thermal efficiency, sound transmission and fire resistance. However, in recent years, it has lost market share to alternative materials and systems in a number of areas. Despite having leading edge technology for unit manufacture, the Australian masonry industry is very traditional and conservative, and to some extent complacent.

To remain competitive, the masonry industry must be able to adapt to change and be receptive to innovation. This applies not only to advances in materials technology and the development of new products and building systems, but also to changes in the regulatory framework to meet the demands of increased emphasis on thermal and acoustic performance, seismic resistance and sustainability. This is in a climate of decreasing support for, and activity in, pure and applied masonry research by universities and government research organisations such as CSIRO.

These issues are discussed in the Australian context and in particular, the need for the industry to be pro-active and address these challenges. Many of the issues raised will also relate to the Canadian scene.

KEYWORDS: industry, challenges

INTRODUCTION

Masonry in various forms has been used as a construction material for thousands of years. In the modern context, there is also a long tradition of masonry construction in Australia dating back to the first European settlement with the arrival of the First Fleet from England in 1788. Masonry, along with steel, concrete and timber is still one of the four primary construction materials used in buildings in Australia today [1]. It is used in a number of forms (fired clay, concrete, calcium silicate, natural stone and autoclaved aerated concrete) and in a wide variety of loadbearing and non-loadbearing applications. In some cases it serves as the primary structural element in structures such as 3-4 storey “walk-up” apartment buildings or low rise commercial structures (taller unreinforced masonry (URM) buildings are no longer permitted because of seismic design restrictions). In many other cases, masonry is used as veneer or infill in housing or high rise framed construction.

Masonry in its various forms is still widely used because of its aesthetic qualities, strength and physical characteristics related to thermal efficiency, sound transmission and fire resistance. As Hogan [2] states, "the appeal of masonry also lies in less tangible properties, such as its handcrafted persona, its link with history, and its old-world charm. As it has for centuries, masonry continues to symbolize craftsmanship, permanence, and quality".

Despite these attractive features, for masonry to remain competitive, the industry must be able to adapt to change and be receptive to innovation. This applies not only to advances in materials technology and the development of new products and building systems, but also the changes in the regulatory framework to satisfy the increasing emphasis on thermal and acoustic performance, seismic resistance and more general aspects related to sustainability of building products and systems.

In many respects, the Australian masonry industry is still very traditional and conservative and to some extent complacent in responding to the development of alternative systems (a good example of this was the emergence of tilt-up concrete construction in the 1980s which made major inroads into the use of masonry in light commercial construction without any coordinated response by the masonry industry). However, there is certainly the potential to develop new and innovative products and systems and to build upon the state-of-the-art technology that is used in the manufacture of masonry bricks and blocks. It is rather incongruous that masonry units manufactured using these sophisticated technologies are then delivered to the site and still assembled unit by unit (often by semi-skilled labour) using techniques which have remained essentially unchanged for generations.

This paper gives an overview of the past and present Australian masonry scene and discusses the current challenges confronting the masonry industry. To some extent, masonry is at "the crossroads," but provided the industry is prepared to meet the challenges ahead, there is immense potential for this versatile material in the future. These issues have already been presented in an Australian context [1], but many of the issues raised are universal and will also relate to the Canadian scene.

MASONRY AS A MATERIAL

Masonry in its various forms is one of the oldest building materials, dating back many thousands of years. From the beginning of recorded history the use of sun-dried earth bricks, crudely fired clay bricks as well as shaped stone blocks has been recorded. From ancient times to the present day, the basic nature of masonry has remained unchanged, with convenient sized masonry units being bonded together by some form of mortar to produce a composite walling material. Major technological advances such as effective kiln firing and the use of mortars containing lime and/or sand with pozzolanic properties resulted in larger and more durable structures. The industrial revolution also saw the development of Portland cement and the mechanization of much of the brickmaking (and later block making) process.

The use of masonry in Australia dates back to the first white settlement in 1788. The supplies accompanying the First Fleet included brick moulds, along with 5000 bricks brought over in the *Scarborough*. One skilled brickmaker, James Bloodsworth, appeared on the convict list, and he was later to become a brickmaker and Superintendent of Works [3]. The first hand-made bricks were made in March 1788 by convicts at a spot about a mile from the settlement at the head of

Long Cove (now Darling Harbour) [4]. This activity continued at an expanding rate both in Sydney and other subsequent penal settlements such as Newcastle and Port Macquarie. With the increasing availability of skilled labour, the volume and quality of bricks increased rapidly and the first private brickyard was opened by John Palmer in Woolloomooloo in 1802.

Over the ensuing 100 years or so, with the progressive introduction of mechanization the quality and volume of bricks increased dramatically with a large number of privately owned brickyards being established in both the city and country areas (for example, in Sydney alone, in 1890 there were more than 113 brickyards in operation [3]). These economies of scale produced a cheaper product which resulted in masonry (both brick and natural stone) being a preferred building material for a wide range of applications.

In the twentieth century, the advent of Portland cement resulted in the emergence of additional masonry materials in the form of concrete bricks and blocks, calcium silicate bricks, and most recently, autoclaved aerated concrete units. This, combined with further advances in clay brick making technology (firing and manufacturing methods, mechanisation, emission controls etc), has resulted in a wide range set of economical masonry products being available to the consumer. One major recent change in the clay masonry industry has been the conversion of manufacturers from dry pressed to extrusion brick forming (for example, in N.S.W., dry pressed product now only accounts for less than 2% of annual production).

These changes have been accompanied by progressive rationalization of the industry, with a large number of small producers being replaced by a small number of large companies often producing the full range of clay and concrete products. This services a country which has one of the highest per capita consumption of masonry in the world, approximately three times that of the USA [5]. For example, in 2002/2003, Australian masonry production consisted of 1.64 billion clay brick units for structural purposes, 243 million clay pavers, together with 2.86 million tonnes of concrete bricks, blocks and pavers.

FUTURE TRENDS FOR MASONRY IN AUSTRALIA

In the short term, it is likely that current practices will continue. However, there is increasing pressure on the industry to remain competitive both in relation to the basic masonry materials, and the resulting walling systems. The traditional methods of on-site bricklaying will come under increasing threat because traditional construction methods require an additional wet trade on the job site. The cost and potential shortage of skilled labour and the move towards a system approach to buildings through prefabrication, panelisation etc. are also major factors. It is clear that to compete effectively the masonry industry needs to be innovative in its approach. This would be expedited if building product manufacturers marketed the final product (i.e. the masonry wall element as a structural system) rather than the individual components (bricks and mortar ingredients) which are then assembled on site by a third party.

Other societal factors will also have an influence on future trends. The increasing emphasis on the sustainability aspects of buildings and building products will see the increased use of waste and recycled products in the manufacture of masonry materials. Requirements related to thermal performance and energy efficiency are also likely to result in changes to the geometry and coring pattern of masonry units to reduce their mass and increase their thermal resistance.

It is also likely that traditional mortars will progressively be replaced by thin-bed adhesives which will produce higher levels of bond strength and therefore enhanced structural performance. This has been made possible by much better controls on dimensional accuracy of units during manufacture together with advances in adhesive technology (this approach also eliminates many of the current site problems in relation to workmanship). Walling systems reflecting these trends are already emerging both in Australia and overseas. Two recent Australian examples are the "Smart Masonry" system, a core filled and reinforced dry stack concrete block system [6] and the "Slick Brick" system, which uses diamond ground fired clay bricks with an interlocking key that eliminates the vertical mortar joint in conjunction with thin-bed jointing technology [7].

In this context there is also likely to be the increased use of a system approach to buildings, with panelisation and off-site construction techniques to avoid workmanship and other site problems. Light prestressing or reinforcing can be used to enhance masonry flexural strength as well as provide robustness for ease of transportation. These techniques are not new, but economic and commercial imperatives are likely to lead to greater support for this type of approach to design.

An additional factor which will have an influence is the increased emphasis on the seismic performance of building being imposed by current building regulations. In most areas of Australia it is still feasible to use unreinforced masonry, but there is an increased emphasis on the achievement of quality masonry and the establishment of well defined load paths to ensure adequate seismic resistance. This in turn imposes an accompanying requirement for the effective performance of ties and connections as well as the achievement of reasonable levels of bond strength. Since conventional masonry has a high mass and low tensile strength, this increased emphasis on seismic performance may give an added impetus to the development of lighter products with enhanced tensile strength [8].

DESIGN AND CONSTRUCTION

Masonry is a material which is inherently strong in compression and weak in tension (as a result of the relatively low tensile strength of the material, and particularly the low bond strength between the masonry unit and the mortar joint). As a consequence, throughout history masonry structures have been designed to avoid tensile stresses through the use of arches and domes to span openings. Masonry bearing walls were designed by specifying minimum thicknesses which were governed not by the predicted level of compressive stress, but to avoid tensile stresses being induced in the cross-section by the applied lateral loads (that is, ensuring that the resultant of the vertical and horizontal loads on the cross-section passed through the middle third of the thickness). This resulted in thick, massive walls and buildings which became uneconomical with increasing labour costs. There are many surviving examples of this approach to the designs of loadbearing buildings, many of which have heritage value and are now being upgraded and recycled.

So called "structural masonry" evolved in the 1950s and utilized cellular bearing wall construction and shear wall action to transmit lateral loads. With this approach, the walls transmit lateral loads through in-plane rather than out-of-plane action with the floor slabs acting as horizontal diaphragms tying the walls together. More effective use is therefore made of the high compressive and shear strength of the masonry, as well as the small but finite tensile bond strength between the units and the mortar. Thin walls and an extremely efficient structural

system thus results. Accompanying this change in design approach has been an increased understanding of the behaviour of masonry structures as a result of the significant world wide expansion in research activity that has occurred over the last 40 years or so.

In the Australia context, this approach to loadbearing design was pioneered in Perth in the 1960s with the construction of a series of high rise apartment blocks, demonstrating the viability of this form of construction [9, 10]. On a smaller scale, the 3-4 storey "walk-up" apartment buildings common in most parts of Australia are based on similar principles. The height limitations on unreinforced masonry loadbearing structures imposed by the earthquake loading code now limit this form of construction to four stories.

CODES AND REGULATIONS

Prior to the 1960s, no Australian design codes for masonry existed, with British and North American standards being used. Separate codes for blockwork and brickwork were then produced, with the blockwork code being heavily influenced by North American practice and the brickwork code by European (and particularly British) practices. As a result of this ad hoc development of design codes, there were major inconsistencies in the provisions and procedures for the design of clay and concrete masonry. Many of these were arbitrary and historically based, with no technical justification [11].

During the period from 1983–88, these standards were reviewed and rationalized to reflect the current state of knowledge, culminating in 1988 in the first unified Australia masonry code (AS3700) [12]. As part of this process in 1984, an innovative wall tie standard that pioneered the concept of the experimental determination of in-situ strength and stiffness of ties was also introduced [13]. This code revision process also included the progressive conversion from a working strength approach to one based on limit states and ultimate strength design. One feature of all of these codes was the move away from highly prescriptive rules to a performance based approach in all rules and regulations. With appropriate revision and updates these codes form the basis of the current Australian masonry standards.

The 1989 Newcastle earthquake resulted in an added emphasis on seismic performance in Australian Structural design codes. This event, although only moderate in magnitude, produced a disproportionate degree of damage (in excess of A$1.5 billion), with much of this being to unreinforced masonry [14]. Current code regulations in all the Australian material codes reflect this greater emphasis.

One factor which will impact on future code preparation is the diminishing number of independent researchers and contributors willing (and able) to serve on code committees. This has resulted from changes in strategic direction and priorities by government supported research organizations such as CSIRO and also universities, with little or no recognition being given to the benefits of employees participating in code preparation. Code committees are increasingly being dominated by industry representatives pursuing their own priorities and agenda, with the resulting potential loss of objectivity of the committee. This is an issue which needs to be addressed by Standards Australia and other similar organisations. It would appear that there may be similar issues in Canada as industry is providing most of the funding for Standards development and the associated design handbooks and software (although committee membership may still be reasonably balanced in this context).

WORKMANSHIP AND SITE SUPERVISION

The construction of masonry buildings has a long and proud tradition, with many outstanding examples surviving the centuries in many countries around the world. Traditionally, the mason was a highly regarded craftsperson with a high level of skill and dedication. Unfortunately, in recent years in Australia, with some exceptions, this tradition has not been upheld with the quality of workmanship and site control decreasing significantly.

This trend was graphically illustrated in the aftermath of the 1989 Newcastle earthquake which produced a disproportionate amount of damage for the size of the tremor, with a large proportion of the damage being to unreinforced masonry. The poor general performance of masonry was the result of a combination of factors ranging from poor design and detailing on the part of the structural engineer and the architect, to lack of supervision and particularly to poor workmanship [15]. It is reasonable to assume that similar practices occur in other parts of Australia, so that the consequences of a similar seismic event in a large population centre such as Sydney are frightening to contemplate.

Despite the large amount of damage and widespread publicity at the time, the reality is that little has changed since 1989. The relevant codes have been revised and updated, and there is a general acceptance that earthquakes are one of the loading conditions which should be considered in design. However, in general, design, construction and supervision practices have not changed significantly. Masonry in most cases is still being considered as "non-structural" material, with minimal supervision from the architect and engineer. There is clearly an on-going need for education and awareness at all levels of the building industry, from the tradesman through to the professional. This is a major challenge for the masonry industry which must be addressed.

One positive response from the industry is that significant resources for training and technical support are now available, with both major industry associations (the Clay Brick and Paver Institute (CBPI) and the Concrete Masonry Association of Australia (CMAA)) producing a range of design manuals and education material. In particular, the CBPI has produced a series of teaching packages for engineering and architecture students that have been distributed to all universities in Australia [16]. It is hoped that in the longer term this will raise the level of knowledge of masonry in the relevant professions.

RESEARCH

Up until the mid-twentieth century, masonry design was based predominantly on "rule-of-thumb" empirical methods. Masonry structures relied on gravity for stability, walls were extremely thick and stress levels were low. The advent of the shear wall concept and structural brickwork in the 1950s resulted in thinner walls and much higher stress levels. The design of these elements therefore required a more rigorous engineering approach, with a detailed knowledge of mechanical properties and member behaviour being necessary. A consequence of this was a progressive increase in research activity, particularly in relation to fundamental behaviour and material properties (although still well behind similar studies for steel and concrete).

In the latter half of the twentieth century, the growth in research activity has continued to accelerate. A good indicator of this is the number and size of international masonry conferences

which are now held on a four yearly cycle (the Canadian Masonry Symposium, the North American Masonry Conference, the U.K. International Masonry Conference and the International Brick/Block Masonry Conference (IBMAC)). There is also a regular Australasian Masonry Conference, with the next of this conference series to be combined with the 14th IBMAC in Sydney in 2008.

Added impetus to learned society activities of the masonry industry has been given by the formation of the British Masonry Society and the Masonry Society in the United States, with accompanying journals and technical literature.

This research activity over the past 50 years or so has resulted in a much improved understanding of the fundamental behaviour of masonry in its various forms and under various loading conditions, and in particular the behaviour of reinforced and unreinforced masonry under seismic loading. As for other structural materials, this has been accompanied by the development of sophisticated computer based numerical techniques capable of modeling quite complex masonry structures and structural elements.

Masonry research in Australia over this period, although limited in scale due to the relatively small number of groups and individuals involved, has been innovative and of high quality and has certainly had an impact internationally. This research has taken place within universities and research institutions such as CSIRO with significant advances being made in both applied and fundamental areas. Some notable examples which have been internationally recognized include the development of the bond wrench test (now used around the world and recognized in Canada as a measure of compliance at the worksite), fundamental studies on the in-plane and out-of-plane behaviour of masonry, size and shape effects in masonry compression tests, compression and lateral load design and fundamental bond studies.

Despite this tradition of research excellence, the number of active masonry researchers and research groups has diminished dramatically in recent years. With the exception of the Masonry Research Group at the University of Newcastle, there is now only limited masonry research activity across the sector with a relatively small number of academic staff being involved (CSIRO has also withdrawn entirely from this area of activity).

A similar trend appears to be occurring in Canada, with areas of research activity and expertise being confined to a limited number of universities. Retirements and the attraction of other research activity seem to have had a significant effect. Similar trends also appear to be occurring in other countries in Europe which have traditionally had a strong research base.

In this area, masonry in Australia (and to some extent internationally) is at the crossroads. A strong and healthy research base is necessary to ensure that industry remains competitive. As mentioned earlier, it also means that the pool of academics and other researchers willing and able to participate in code development has shrunk dramatically. It is likely that similar comments apply to a number of other countries (including Canada).

Some of the areas relevant to Australia that need further in-depth research to allow realistic and economical design procedures to be developed include: the behaviour and design of unreinforced

and partially reinforced masonry under seismic loading; fundamental reliability studies to allow the derivation of safety factors to produce comparable levels of safety for masonry as for steel and concrete structures; realistic and simple rational design procedures for wall ties; sustainable design in the masonry industry; thermal performance of masonry structures; effective and economical panelisation systems; and shear design of partially reinforced masonry. This list is not meant to be exhaustive – more to give an indication of the wide range of topics across engineering and building science which still require investigation. *The question is, how will this research be carried out in a sector with a rapidly shrinking pool of experienced researchers?*

THE CHALLENGES

Masonry in all its forms remains a widely used and popular building material. However, as has been discussed, it is at the crossroads and to remain competitive the masonry industry must be *proactive* rather than *reactive* in meeting the challenges ahead.

These challenges include:

- The changing regulatory climate which is placing increasing emphasis on building performance (particularly in relation to energy performance and efficiency).
- The development of more efficient construction techniques for masonry which will eliminate site labour problems and guarantee a quality product.
- The emergence of alternative materials and building systems, particularly panelised construction which by default eliminates many site problems.
- The increasing emphasis on the sustainability aspects of building construction, including the use of recycled and waste materials.
- Education at all levels in the various aspects of masonry design and construction, from the "brickies labourer" through to the professional engineer and architect.
- Ensuring that there is an active masonry research base to provide input into solutions for many of the above challenges. (This will also provide a pool of potential participants on the relevant code committees who can provide independent input and advice).
- The development of techniques and systems which overcome the inherent low tensile strength of masonry.

Provided the masonry industry is innovative and receptive to change, masonry does have the potential to remain a competitive and economical product. Some of the challenges can be met at an industry-wide level, as they are generic to all types of masonry (collaboration and cooperation between the CMAA and CBPI can expedite this process, as has been the case recently in relation to seismic behaviour). Other aspects, which are more product focused, will need to be solved at a more local level by the relevant industry group. In both cases, input from University based researchers will be invaluable.

It may also be necessary to change some of the basic thinking and long traditions associated with masonry construction. With all of the advantages of modern technology, it does appear rather incongruous that masonry units, manufactured using the latest techniques in modern plants, are delivered to site and then assembled brick-by-brick using techniques and systems which have remained essentially unchanged for centuries. The question that must be asked is… *Is this still appropriate for the 21st century?*

It is clear that masonry in Australia is at the crossroads and that there are many challenges ahead for the masonry industry to remain competitive. The correct strategies and approach must be developed to ensure that masonry remains an effective and popular walling material into the future.

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