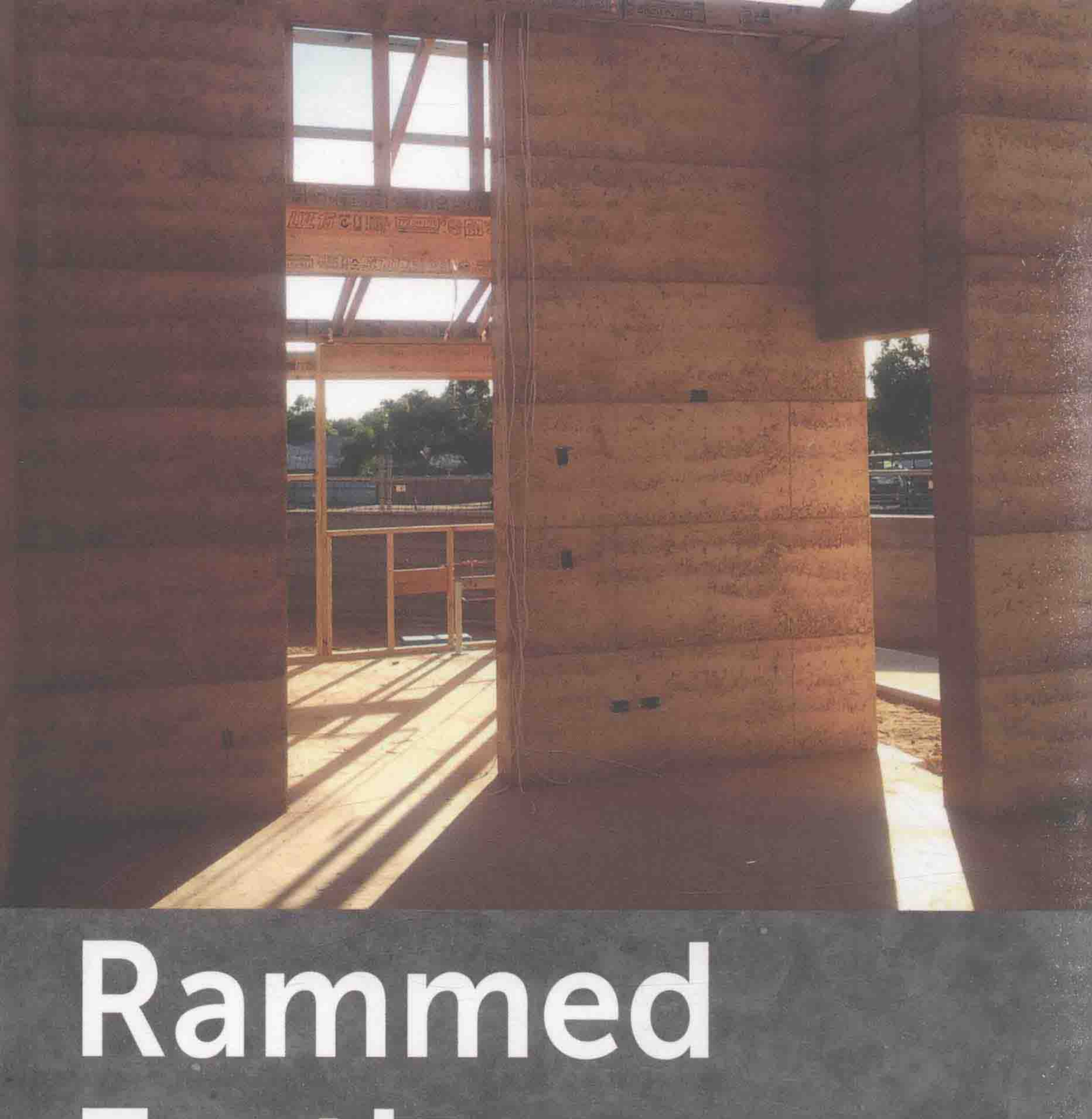

Rammed Earth Construction

Editors: Daniela Ciancio
& Christopher Beckett

Cutting-Edge Research on Traditional and Modern Rammed Earth

CRC Press
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A BALKEMA BOOK

PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON RAMMED EARTH CONSTRUCTION, PERTH AND MARGARET RIVER, WESTERN AUSTRALIA, 10–13 FEBRUARY 2015

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Cutting-Edge Research on Traditional and Modern Rammed Earth

Editors

D. Ciancio & C. Beckett

University of Western Australia, Australia

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Preface

The First International Conference on Rammed Earth Construction (ICREC 2015) is organized by the University of Western Australia (UWA). It is a four-day event that consists of a 2-day workshop held at the UWA Trinity College in Perth, and a 2-day conference held in Margaret River, Western Australia.

The ICREC 2015 workshop aims to promote the use of rammed earth in Australia and around the world. Experienced and well-respected rammed earth builders, engineers and architects have been selected as invited speakers to share their valuable knowledge on a variety of topics including: construction methods; standards and guidelines; laboratory procedures; heritage and conservation and thermal performances, analysis and design. The first two keynote papers contained in these proceedings from S. Dobson and D. Easton are part of the workshop event.

The ICREC 2015 technical conference is host in Margaret River, Western Australia, a region that has the largest concentration of rammed earth buildings and structures. The conference brings together academics and practitioners in order to communicate the latest developments in the design and analysis of rammed earth structures. These proceedings contain the keynote papers by Dr. Augarde and Dr. Hu, and the works presented in the technical conference in Margaret River. Each paper has been independently and anonymously reviewed by to 2 peers from within industry and academia who are experts in the relevant fields.

The editors would like to thank all the keynote speakers and authors for their effort and support for this conference. The editors are grateful to Ms. Dawn Feddersen for her assistance with secretarial duties for the ICREC 2015 event.

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A successful conference requires the involvement of a large number of people. The editors would like to thank the following individuals, companies and groups for their support in making this conference possible.

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Local Organising Committee (LOC):

Daniela Ciancio, *Conference Chair, University of Western Australia, Australia*
Chris Beckett, *Conference Vice-Chair, University of Western Australia, Australia*
Dawn Feddersen, *Conference Secretary, University of Western Australia, Australia*
Kenneth Kavanagh, *Formerly at University of Western Australia, Australia*
J. Antonio H. Carraro, *University of Western Australia, Australia*
William Smalley, *Scott Smalley Partnership, Australia*

Papers were reviewed by the LOC and by members of the International Advisory Board:

Charles Augarde, *Durham University, UK*
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Rammed earth in the modern world

S. Dobson
Director, Ramtec Pty. Ltd., Australia
Vice President, EBAA, Australia

ABSTRACT: Modern rammed earth has a long and successful history. Rammed earth is arguably the most popular form of building that exists on the planet but in some modern countries it is presently considered alternative or new and innovative. Modern engineering is being applied to structural design, thermal modelling, mix design, construction methodology and other aspects of an ancient building method that is now truly revived. Modern architecture has captured the essence of the past and the present to produce a bewildering array of buildings spread across the globe of amazing complexity and stunning beauty. The author has since 1976 built over 750 rammed earth structures in Australia and describes some old and some new buildings from around the world whilst outlining the many benefits of rammed earth, some sticking points that need resolution and some future predictions of where this expanding new industry can go.

1 INTRODUCTION

Leonard Cohen sang "First we take Manhattan, then we take Berlin".

Taking Manhattan:
The unfired earth building industry built the first Manhatten in the desert of Yemen at Shibam, over 1500 years ago with local earthen materials, all unstabilised and using the procedures of mud brick, cob and rammed earth (Figure 1). Over 500 buildings to 14 stories high. Some walls 1.2 m thick. All UNESCO World Heritage Buildings at Wadi Hadramaut, mostly still occupied, all walls fully loadbearing, held together with just clay and in an earthquake area (Earth Architecture 2014).

Taking Berlin:
14 years ago unstabilised rammed earth took Berlin with the Chapel of Reconciliation, the first modern rammed earth building in Germany for 50 years. Rammed earth contractor Martin Rauch, backed by a group of Engineers, Architects and others built the curved loadbearing unstabilised rammed earth walls and floor of the Berlin Chapel of Reconciliation. This was considered a major breakthrough in Germany, a country with thousands of old successful rammed earth buildings including House Rath in Weilburg, Germany, 7 stores high, loadbearing and built in 1828, which is still in use.

Rammed earth taking Manhattan, then Berlin, then the world:
Rammed earth exists historically in nearly every country in the world and is now actively being built new many countries worldwide. There are 7 billion people in the world and it is generally said that one third to one half live in earth buildings (earth buildings meaning: mud brick, rammed earth and cob plus about 20 other techniques), say 3 billion. South American researchers claim more rammed earth than mud brick worldwide which makes rammed earth the **most popular** building material on the planet. Interestingly it is still listed as an "alternative" building material in most modern countries.

Australia leads the modern world in quality and volume of modern rammed earth, all cement stabilised and almost all load bearing and often unprotected from the elements and over all Australian climatic zones, from the deserts to the snowfields and everything in between. Europe leads the world in modern unstabilised rammed earth, most loadbearing and much of it unprotected from the elements. Stabilisers

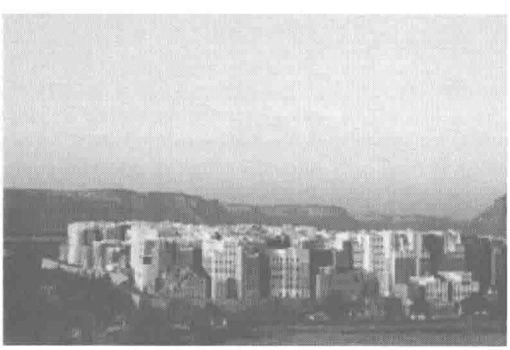

Figure 1. Manhatten of the desert: the world's first high rise.

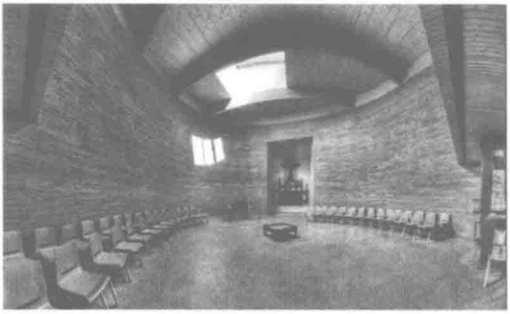

Figure 2. Taking Berlin: the rammed earth Chapel of Reconciliation.

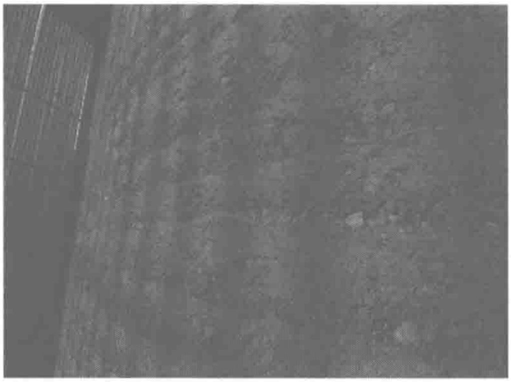

Figure 3. Berlin Chapel: unstabilised loadbearing rammed earth.

other than cement, such as lime, abound but will be given little mention in this discussion as most rammed earth in Europe and in third world countries uses clay as the binder (termed unstabilised) and in Australia cement is the predominant stabiliser by far.

An old Welsh saying for earth buildings was: "Give'er a good hat and stout boots and she'll last forever". This of course referred to unstabilised earth buildings needing a good roof with adequate overhangs and good foundations and details to keep the base of the walls dry, in order to achieve a long life which was generally measured in centuries, for mud brick and for rammed earth. This saying is now only partially true for rammed earth because with modern stabilisation methods (especially cement) and also with unstabilised methods, particularly from Europe, these rules can be relaxed significantly, sometimes totally.

Enormous advances have been made, in recent years so that now rammed earth can be built fully loadbearing in very tall buildings (4 stories load-bearing and more), in buildings of every size and shape, in extreme earthquake areas (including all of New Zealand, some middle eastern countries and North America including San Andreas Fault locations, Los Angeles, San Francisco, Vancouver and elsewhere along the west coast of North America, and including stabilised insulated reinforced rammed earth in most of these regions), in cyclonic wind areas (several Ramtec buildings survived undamaged in a real Category 5 Cyclone Beaufort Scale 12 Hurricane above 280 km/hr in the worst cyclone areas of Australia, fully exposed coastal), achieving very favourable thermal ratings, delivering excellent thermal comfort, totally waterproof, fireproof, very long lasting, extremely beautiful, low carbon, built at high speed of construction and at reasonable cost.

Modern rammed earth is becoming more globalised as Conferences spread the word and allow the forging of contacts and the exchange of information. The internet has played a large part in extending the reach of modern rammed earth from the many modern centres of excellence that include Europe, North America, Australia and elsewhere, to every corner of the globe. Historical methods of building in rammed earth are still valid and can still sometimes give walls that are beautiful, durable, load bearing, and which last for centuries. Such ancient techniques include taking suitable soil directly from the base of the building, dug out at the right time of year so that it is at optimum moisture content for maximum dry density compaction, and without any additive or mixing, hand ramming it using clay as the only binder, into traditional formwork and incorporating suitable wall protective measures (damp proof base course and top capping, controlled erosion breaks etc). Also examples abound of modern successful rammed earth buildings that are built to last, to almost every style of architecture.

In the past, earth was not widely promoted as it was freely available to all and thus not the provenance of serious business. Previously in many countries, earth was seen as a poor mans product and less desirable than the modern industrialised products that abounded after the great wars. No longer are these scenarios valid with increased enviro-awareness plus rammed earth is now a serious business and becoming more mainstream in a growing number of countries. Modern desirable rammed earth buildings are now making it an aspirational product. Promotion of rammed earth is underway and this will grow as sustainability, healthy home, aesthetics, low carbon and other issues become more important in building choices. Rammed earth is itself becoming a modern industrialised product, as wide ranging research moves it ahead. Carried forward by its many advantages. Rammed earth is now often considered as the product of choice from which to construct appropriate environmentally prestigious buildings.

2 RAMMED EARTH IN ANTIQUITY

The oldest buildings made of rammed earth are at Catahyouk near to Konya in Turkey, around 10,000 years old. They were lived in for about 1700 years. Now it is a famous archeological site with current ongoing excavations. Here, as was often the case with old buildings, the constructors were not respectful of the techniques used and evidence is clear of mud bricks of various sizes, with various mortar configurations, cob and rammed earth. I have seen clearly layered ancient ramming lines. All homes here are load bearing with earthen walls and roofs and floors. They are considered to be unstabilised (and clay is the binder) but Turkish rammed earth expert Prof Bilge Isek has been engaged recently to look to see if vegetable, or plant matter, as a stabiliser was used in the construction of the walls. Catalhyouk (Figure 4) is one of the first villages formed by mankind when nomads first settled and began to farm.

China has a history of rammed earth including parts of the Great Wall of China (built some 2500 years ago) and other Chinese rammed earth buildings to 4500 years old. More modern rammed earth circular Hakka structures and other major buildings in China are mere centuries old. Mexico at Teotihuacan has the 1900 year old Pyramid of the Sun about 70 m tall made of some 2 million tons of rammed earth, faced with stone. Watch towers built from rammed earth by Hannibal about 2000 years ago still exist.

The Romans used rammed earth extensively. Cities of rammed earth were built and the method was widely disseminated; for example, Spain has thousands of centuries old rammed earth buildings including the part rammed earth UNESCO listed Alhambra Palace in Spain, parts of which date to Roman times (Figure 5). Compare these

Figure 4. Catalhyouk: 10,000 year old rammed earth homes.

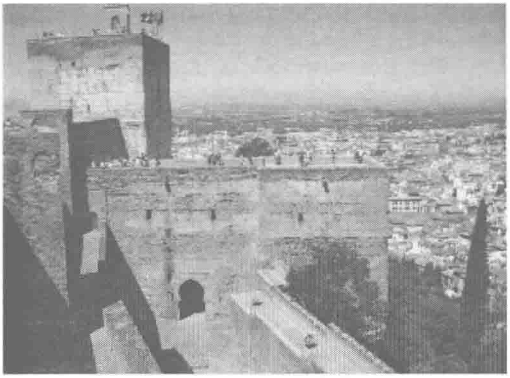

Figure 5. Rammed Earth Alhambra Palace in Spain.

Figure 6. Rauch House: 3 storey loadbearing unstabilised RE.

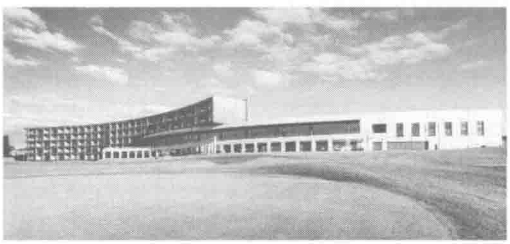

Figure 7. Royal Automobile Club, Victoria.

to modern RE structures like the Rauch House, a 3 storey loadbearing unstabilised rammed earth home in Austria using 85% of building fabric construction materials off site (Figure 6), and the Royal Automobile Club, Victoria, the biggest modern loadbearing RE building in Australia (Figure 7). The forms may have changed, but the feel is still the same.

3 MODERN RAMMED EARTH

3.1 *Thermal properties*

Rammed earth is generally the cheapest way to deliver high thermal mass walls. High thermal mass assists greatly in achieving comfort conditions. Both in winter and in summer. In winter they absorb the heat of the day, from well designed passive solar sun direction, and re-radiate it at night. Passive solar buildings can collect free sunshine to provide free heating forever so long as there is thermal mass to store it though the collecting time of the winter day prior to discharging it at night when needed. Lightweight materials cannot do this very well, regardless of R value.

In summer thermal mass walls, floors and also roofs even out the day to night temperature fluctuations. Particularly where there are significant variations between daytime and nighttime temperatures, thermal mass equalises and delays temperature transfer through the walls. By opening buildings at night stored heat can be released, a process known as "night purging", allowing heat to be absorbed again the following day. Lightweight highly insulative materials cannot do this well, regardless of their thermal resistance. Any wall mass outside any insulation layer is effectively quarantined from this desirable summer night activity. For example, in insulated brick veneer, which is currently the single most common form of building in Eastern Australia, the outer brick skin is thermally 'lost', and with it the ability to delay, reduce or even eliminate the costly daytime cooling loads, as rammed earth can. Cooling loads in the heat of the day can be reduced or eliminated in many climates (most climates within Australia) and delayed in all climates with common 300 mm monolithic rammed earth walls. With the hottest summer day air conditioning cooling caused electrical loads now established as the key determinant of all modern first world electrical infrastructure (both electrical generation and distribution), rammed earth has a major part to play. Global warming will exacerbate this problem worldwide, and rammed earth is a key part of the solution. In the USA this was realised and David Easton with a Californian electrical supply company built a thick walled monolithic rammed earth home to showcase the advantages.

Successful rammed earth homes have been built in every climate zone in Australia (yes, every: desert to snow) from Zones 1 to 7 of the Buiding Code of Australia (now called the National Construction Code or NCC) which correspond to northern tropic monsoon, high humidity, various desert categories, Mediterranean Climates and temperate warm to mild to cool moving south to alpine.

Unfortunately most computer thermal simulation programs used to approve buildings from a thermal perspective in Australia do not give adequate recognition to high thermal mass and therefore insulation is often required to be installed within the rammed earth walls particularly in the colder Zone 6 of the NCC. This Zone covers the coast of Victoria, plus almost from Sydney to Adelaide, and the S coast of WA. Fortunately insulated rammed earth is quite buildable and is now in widespread use across Australia. Unfortunately mud brick cannot have insulation inserted into the single skin construction without building 2 skins which doubles the cost and makes it uncompetitive. As a result, the USA (with similar min R value legislation), which led the world in modern adobe (mud brick) construction, has seen it's output plummet. The world's biggest adobe manufacturer, the Hans Sumpf Company of Fresno, California, has ceased production. In Australia the mud brick industry centred in Eltham, near Melbourne, in Climate Zone 6 of the NCC has been decimated by modern thermal laws. Most of the few thousand successful mud brick buildings built prior to thermal regulations in Australia would now be illegal to build. This is despite some of them being certified as true net zero carbon buildings, which is as good as you can get. E-Tool of Perth have done Life Cycle Analyses on some of these buildings to show this (eTool 2014). Many countries including the UK are planning legislation to have new buildings certified as net zero carbon, in the years ahead. Rammed earth (and mud brick), done correctly, can do this now.

Using thermal resistance values as the prime parameter leading to measures for thermal comfort is inaccurate, according to the research from The University of Newcastle (NSW) carried out for Think Brick (Page et al. 2011). The Earth Building Association of Australia agree, with significant such comment on their website. Recent Slovakian climate chamber tests of Australian style cement stabilised rammed earth walls with modelled daily outdoor temp fluctuations on the outside (of the test chamber) showed little temp change on the inside of the sample within the 24 hour period i.e. little temp change inside before reversals of temps began again on the outside (Stone and Bagoňa 2013). With insulation in the middle of the wall there was no internal temp change before reversals of temps began outside (Stone, C. pers comms). This backed up the advice of Rob Freeland of AMCER in Melbourne, who often stated that the energy rating systems for approvals in Australia were flawed because there was little temp variation further into the earth wall past the half way mark before the outside driving temp reversed as night followed day. The current research by the University of Western Australia, and the

Western Australian Department of Housing, into the 2 homes build alongside one another in Kalgoorlie in Western Australia may soon verify this again (Ciancio and Beckett 2013, Beckett et al. 2014). The 2 homes are identical and only differ in one having insulation in the centre of the 300 mm thick cement stabilised rammed earth walls and the other being monolithic (no insulation). Both houses are currently being monitored. Also a similar conventional lightweight house nearby in Kalgoorlie is also being monitored. Some day in the future the humidity/wet bulb side of further monitoring of these homes may take place. Humidity levels are so important for human comfort, that this is an important area of research. Rammed earth walls work so well in this area of balancing humidity (absorbing and releasing it) and most conventional building materials are very bad at this. Within all rammed earth there is a humidity flywheel and a separate thermal flywheel concept. Doing full computer thermal simulations of homes and taking in to account the full hygroscopic properties of all materials is currently near to impossible in Australia. Matthew Hall in UK is researching this (e.g. Hall and Allinson (2009)). Once this technique is mastered then further benefits of building in rammed earth may be able to be better quantified.

3.2 *Costs*

Perth prices today for one square meter of elevation wall area of a 300 mm thick finished monolithic rammed earth wall, of ideal constructability begin at A$275 (including 10% Goods and Services Tax which is $250 excluding tax). In Australia the density is typically around 2 tonnes per sq m with 1.8 t/m^3 being a low figure for a lighter cream coloured limestone mix and 2.3 t/m^3 being a high figure for a mix using a heavy base aggregate. Cement contents are typically 5 to 10% of the dry mix and strengths are generally contracted to exceed 2.5 MPa and usually exceed 5 MPa. The required strength for a single story heavy tile roofed building with 300 mm thick rammed earth walls without earthquakes or cyclonic winds is less than 1 MPa. Sirewall in Canada lead the world in exotic rammed earth of very high strength and colours and have achieved mixes up to 47 MPa and typically achieve above 20 MPa with below 10% cement. In the highly seismic areas where they operate they are making rammed earth a direct structural substitute for concrete (generic 20 MPa), but with many advantages. They do this, by very careful aggregate type and grain size selection, to facilitate approvals, to meet stringent earthquake codes whilst having insulation within the walls which is needed in their very cold climates, and to allow engineers to use conventional concrete calculations. Far south in California, David Easton faces less demands for both insulation and strength. In Europe where cement is frowned upon, due to cement manufacture releasing about 1 t of CO_2 per ton of cement and around 7 billion tons of cement being produced worldwide annually, they favour unstabilised rammed earth where all the binding is done with local clay and no additives. Strengths are generally contracted to exceed 2.4 MPa, they generally achieve 2.7 MPa, and 3 MPa is considered not consistently achievable and not needed anyhow.

3.3 *Health and hygroscopic properties*

Rammed earth is made as a "humid"mix, it is not liquid, it is not mud. It is a zero slump mix. It is placed and rammed, using kneading compaction. It is not poured and vibrated like concrete. The moisture content at ramming must be the optimum to achieve maximum dry density compaction for that rammer/ramming method. A common moisture content at placement is around 10% by soil mass. Once "dry", unstabilised rammed earth has an equilibrium moisture content of around 6–7% which preserves embedded wood as that moisture level is too low to permit decay/rot (Boltshauser and Rauch 2011). Quite separately rammed earth has a powerful ability to absorb and release moisture and to balance humidity. Minke (2006) states that solid fired clay bricks absorb and release so little water by comparison to unstabilised earth walls that they are inappropriate for balancing the humidity of rooms. But unfired earth is highly appropriate for this. Furthermore phase change materials are coming in as high tech wonders to the building industry and yet rammed earth can outperform many of these products, and often more cheaply as well. Suppliers of phase change products can easily calculate the quantity needed of their chemically advanced systems yet such determinations for the infinitely more sustainable earth wall products have no central promoter/calculator and are thus a more difficult task, in quantifying how much earth will do.

3.4 *Other properties*

The many desirable properties of well constructed rammed earth include:

- Long life;
- Adequate strength;
- Ability to build very high walls and buildings;
- Robustness/durability/abrasion and wear resistance;
- Good acoustic properties both in terms of reverberated sound and also as a barrier to stop the through transfer of sound;

- High thermal mass, and also the ability to introduce insulation within the wall (thereby achieving the attractive natural rammed earth face each side whilst allowing a wide range of R values to be selected);
- The ability to adjust the density by using different aggregates and thereby produce different structural and thermal properties;
- Desirable hygroscopic properties unmatched by most "modern" building products;
- The ability to breathe, meaning to absorb and release air thereby removing particulate matter and often producing a healthier air environment;
- Nil toxicity;
- The ability to produce a desirable humidity within a space that is optimal for human habitation ie rammed earth, by absorbing and releasing humidity as it does so well, balances the humidity and it is balanced to a level that is comfortable being not so low as to be dry and unpleasant (40%) and not so high as to also feel overly humid and unpleasant (70%) (Minke 2006). Additionally higher humidity levels in a building like 70 to 80% foster the growth of fungus spores and mould some of which are very unhealthy and some even deadly. With the powerful humidity equalisation benefits of rammed earth quantified, Minke (2006) reports desirable humidity levels of 45% to 60% in a 5 year test on an unstabilised all rammed earth wall home in 1985 in Germany and further reports that when the owner desired a 5% increase in humidity in his bedroom he achieved it by leaving the bathroom door open. In Canada a study by the British Columbia Institute of Technology showed interior relative humidity in a rammed earth walled home (with insulation in the centre of the wall) just above 50%, confirming Minkes work in Germany and demonstrating ideal comfort conditions for habitation and furthermore a humidity so low that mould growth was impossible. All in a Canadian area where mould in conventional timber homes was and is, a significant ongoing problem, with serious health issues;
- Desirable attenuation of various electromagnetic influences that can harm some humans (Minke 2006);
- Lessening of circadian rhythms being upset by electronic interference and increasing the desirable "earth grounded" human condition by sleeping within massive earth walled spaces (Nicole Bijlsma, speaking at EBAA 2014);
- No cavity is required with monolithic rammed earth and so there is no hidden place for hidden vermin, insects or mould;
- Air Changes and Health: using rammed earth homes in free running mode with often open ventilation, which is possible in all climate zones of Australia except perhaps Alpine, gives major health benefits and potentially major energy bill reduction. The thermal mass of rammed earth allows thermal comfort with reasonable air changes in Australia, produces a healthy home and avoids the unhealthy "sealed box" approach, so favoured by the NCC thermal rating programs;
- Environment: Most people respond favourably to a natural environment and rammed earth can provide this. Rammed earth mimics nature in appearance and in other ways. Biomimicry is alive and well with rammed earth and has been for thousands of years (BG 2014). Rammed earth has been acknowledged as providing a relaxing and calming effect on the occupants and thus has been widely used in churches, schools, hospitals, shops, jails and detention facilities (where inmates stay calmer) and the like;
- End of Building Life: totally recyclable with unstabilised returning to the earth from whence it came and with cement stabilised being crushable and re-useable. There is nil toxic residue;
- Fire: very high fire resistance and recognised as such since 1786 when the famous French architect Francois Cointeraux built a gold medal award winning house "an incombustible house that used unstabilised rammed earth as an inexpensive fireproof construction method that was advantageous against the highly flammable timber homes" (Rael 2009) of the time and he went on to publish extensively and to widely promote rammed earth. Modern rammed earth achieving 4 hour fire test ratings has been used in apartment separation as rated fire walls and in bushfire resistant housing which is of increasing importance in a warming global climate;
- Reinforcement: an easily reinforced material with conventional deformed bars as used in concrete but producing a very low propensity to rust of embedded steel, an ability to "protect" wood by maintaining an equilibrium moisture content so low that timber decay (certain to occur above 20% moisture content) is generally eliminated;
- Versatile: able to be used to build walls footings floors and roofs and lending itself to industrialisation as shown by recent developments around the world and which now are increasing;
- Speed: able to be built quickly, using materials often from nearby and sometimes with very little processing of the raw earth and sometimes with local labour using easily learned techniques, with very little water needed and potentially nil wastage of water or other ingredients;
- Beauty: a very beautiful product reaching deep into human consciousness as a visceral/intuitive beauty;
- and all at reasonable cost.

4 CODES, COMPLIANCE AND STANDARDS

On the question of standards there is a gap in Australian regulations. The NCC has a heading of Earth Building and the words "This page has been intentionally left blank". Previously this space had been occupied by CSIRO "Earth Wall Construction" Bulletin 5 Edition 4 however after nil complaints and nil problems with it from either providers or consumers, CSIRO requested that it be withdrawn from the NCC and it was. Without any consultation with the earth building industry, and to the direct and significant detriment of that industry.

Bulletin 5 now rates, with other publications as being a good book but having no legal standing, alongside EBAA "Building with earth bricks and rammed earth in Australia" (EBAA 2008) and SAI Global publication HBD195 "The Earth building Handbook" (Walker and Standards Australia 2002).

In New Zealand there is a suite of 3 Earth Building Standards operating (e.g. NZS (1998)). They are issued by BRANZ of Wellington New Zealand and covering rammed earth (stabilised and unstabilised) in a very prescriptive engineering way due to the unique problems in NZ of severe earthquakes, high rates of and levels of rainfall, high winds accompanying the rain and a liking for unstabilised earth buildings from many "deep green" consumers.

In USA there is "Standard Guide for Design of Earth Wall Building Systems" (ASTM 2010) which covers rammed earth. New Mexico, a southern USA state famous for adobe buildings, has an earth building standard.

In Germany there are new DIN Standards only in the German language, that relate to mud bricks and earth plaster but which do not cover rammed earth. A rammed earth standard is being worked on and Prof Horst Schroeder, who was very involved, told the writer not to expect a standard to cover rammed earth inside 3 years.

In France there is no rammed earth building standard. However Craterre-Ensag at their International Centre for Earth Construction at Grenoble are researching, teaching, promoting and training in general earth building at an extensive level. The PIRATE Project (an acronym for "Provide Instructions and Resources for Assessment and Training in Earthbuilding") is moving ahead on a large scale. The ongoing work of Craterre, together with other French teaching institutions has significant positive benefits for the field of earth building worldwide. On the French Island of Mayotte in the Indian Ocean due west of Perth, there is an earth building standard.

In Morocco there is an earth building standard, written only in French: "Reglement Parasismique Pour Les Constructions en Terre".

The Standards Association of Zimbabwe have a standard SAZ 724: Code of practice for rammed earth structures (SAZS 2001).

It is the writer's opinion that the best and easiest way to get a standard into play for earth building in Australia is to take EBAA (2008) to the NCC and to update it from an engineering viewpoint to NCC requirements so that it can be direct referenced into the NCC. This is an overdue issue for the earth building industry in Australia.

5 THE FUTURE: BARRIERS TO THE MORE WIDESPREAD USE OF RAMMED EARTH WORLDWIDE

The biggest obstacle to rammed earth in Europe, according to Boltshauser and Rauch (2011) is trust, the trust that is generated not by reading but by seeing touching, feeling and doing (building oneself). This requires more construction of modern RE buildings. There is no such problem in Australia. Rauch, a regular visitor to Africa feels that the solution to the problem there is to teach the advanced newer techniques and to show successful high end modern RE buildings so that it moves from a poor choice to an aspirational choice.

The biggest obstacle to wider use of RE in North America seems to be reluctance or the apprehension of some clients, engineers, architects and builders. To see more successful RE projects would increase their confidence. The mass proliferation of domestic RE homes in Australia, that aids RE awareness greatly, is unlikely there due to the base low cost and quality of the common conventional lightweight homes often seen there in "tract" housing. Even the Pneumatically Impacted Stabilised Earth (PISE) that David Easton developed in USA could not compete on pure price with the cheap "tract" housing of USA. In Australia the ACCC advises that some 80% plus of external home cladding is fired clay brick. In WA some 95% plus of homes are made of very high quality cavity fired clay brick, with which RE has been able to compete on price, quality, speed of construction and to sometimes exceed on thermal, sustainability, beauty and general "green" credentials. Particularly in Australian areas that are remote, or subject to cyclonic wind or are earthquake areas, the costs can favour rammed earth even more. Similarly on problem clay sites where brickwork must use the more costly articulated masonary construction, yet this comes standard with rammed earth, as no extra cost.

In the writer's view more RE would be built in Australia if more architects, designers, builders etc were totally familiar with it, more engineers had the confidence to readily certify it, more of the unknowns were researched away, thermal approvals were easier, the NCC was improved and big building interests took part in building RE walls so that larger projects could be undertaken with contractual confidence, rather than the small RE contractor (often contractually disadvantaged) being disadvantaged by the big builders (with contractual prowess and only one job to get through in RE) as has so often occurred. If a major outcome of this conference is that more Australian engineers gained the confidence to use (and certify) RE widely then that is a good outcome since the NCC relies on engineers to a significant extent and their confidence in RE will move the RE industry forward a lot.

6 CONCLUDING REMARKS

Thermal advances need to be sped up to provide better modelling, better laws, movement away from the outdated and inappropriate static R value test (a test carried out at fixed temperature) to more dynamic tests and inclusion of full hygrometric modelling which should so advantage RE and so disadvantage many "normal" building materials, whilst giving consumers better comfort conditions with less energy use. Full life cycle analysis should be implemented as it too should better showcase the benefits of rammed earth and also disadvantage many popular "normal" building materials, whilst overall significantly lessening CO_2 emissions.

In places where there is abundant labour and a need for buildings, such as remote communities, homeless areas, disadvantaged and poor people, refugee camps, within volunteer groups, indigenous groups etc, there is the opportunity to use rammed earth on a large scale over wide areas. We, the developed world, can provide the knowhow, equipment and training with labour and materials provided locally. This is a challenge to everyone present. With cement stabilised rammed earth having been used in many huge and successful dams, labelled Rollcrete in USA and elsewhere, there is a great opportunity to use the material in more civil works.

With stabilised rammed earth having been used in many successful building footing, floor, wall and roof situations and unstabilised rammed earth having been used in many successful building floors, walls and roofs, now is the time to use these techniques more widely. Developments in computer cut laminated veneer lumber and plywood and steel and separately in fabric forms will open the door to highly unusual architecture. Rammed earth can peak the "unusualness" since not only is the form/shape totally flexible but also the colours and textures, and over a very wide range. Detailed developments are likely in the field of 3D printing of houses. Mud (liquid earth) homes have already been printed and rammed earth will follow, in time. Using continuous mixing and delivery systems as developed by David Easton, Meror Krayenhoff and the author and continuous forming systems (to Ramtec hunches) and continuous ramming systems currently in use by Martin Rauch there is currently a big opportunity out there for a bold entrepreneur.

The future of RE will significantly be determined by people at this conference who hopefully at conference conclusion will have greater confidence to use more RE. For more than 30 years, many individuals have rammed away often alone, but now we have an emerging synergy. We are all moving onward and upward.

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