Rammed earth building: present trends and future possibilities

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Abstract

An introduction to the range of earth building techniques and designs in use in Western Australia.

Key words

Adobe, pressed earth, pisé, cob, earth building, Australia

Thank you John. Ladies and gentlemen, fellow earth builders, delegates: it's good to be here after 22 hours in the plane and 16,000 km, it is great to be present at Terra 2000. We will now speak about continuing the tradition into new earth building. New earth building is alive and well. It's alive and well over an enormous geographical area using numerous different techniques, all modern methods of construction. Earth building or unfired earth is being constructed at a growing rate worldwide. Today I wish to talk about the recent history of rammed earth in Australia, that's my background, and to show some slides of this. I want to talk in general about material properties of new earth buildings, I want to talk about government initiatives in Australia and in other countries and particularly the development of standards for new earth building worldwide. I want to cover areas of research that are needed into new earth buildings, as it is not always known that there's a long way to go in research of new earth buildings.

The most common form of new earth building worldwide in my order or my ranking of popularity is the adobe block, the most popular. This is exemplified by the beautiful buildings of the southern United States of America, New Mexico, the work of CRATerre in Africa and in many other countries. I would rate the second most popular form of new earth building as pressed earth brick which is done in nearly every country of the world. I would rate the third most popular method of new earth building in the world as rammed earth, which is my area of interest. And there are a lot of also-rans which are widely used in certain areas but not on an international scale; they would include cob, poured earth, wattle and daub and many other earth building techniques, all practised in localised areas. The definitions or explanations of some of these terms that are used are:

- Adobe block is a liquid earthen material poured as a slurry into a mould with an open top and open bottom on the ground, the mould is removed, the blocks are dried, turned to dry, then taken to the wall and laid in the wall by masons using conventional block-laying techniques.
- Pressed earth brick is a moist or humid mix, not a slurry, not a liquid, but pressed in a machine, person-powered or machine-powered, to apply hydraulic pressure to squeeze that block to increase its density. It is then also dried in the sun and later laid in the wall using masons and conventional block laying techniques.
- Rammed earth, or pisé, or pisé-de-terre is a technique where walls are made using low moisture content materials at optimum moisture content for maximum dry density compaction, where that earth is placed but not poured into formwork set up on site and then rammed using reciprocating rammers or kneading compaction in the formwork. The forms are removed giving a dense hard stone-like wall.
- Cob is widely existing here in southern England but is not widely used for new buildings in England and my brash advice would be that if you want to build new buildings like the beautiful old buildings that you have here, you need to decide: do you want the concrete monsters that will otherwise emerge as the future heritage of this and many other countries, or do you want these beautiful earthen buildings? I believe the way is to develop the standards first to let the bureaucrats do their job to open the door so that the contractors will follow. Many will say the contractors should lead in building new earth buildings, but it's a hard task in a country where it's difficult to get approval.

New earth has been used to build almost every imaginable style of building, including sheds, shops, studios,

homes large and small, commercial projects, wineries, schools, offices, taverns, hotels, churches, cathedrals, chalets, lodges, boundary walls, retaining walls, floors, roofs, barrel vaults and so forth. In fact I can't think of any modern building that couldn't be built with a modern earth building technique. Colours for new earth buildings range from pure white through all the earthy tones including yellows, browns, oranges, beige, pinks, reds, even through to grey and black. Colour variations within a project and even within a panel of earth wall can be produced, often with striking results, and often effects can be given that cannot be produced using any other building technique other than earth building. Textures available in new earth buildings range from absolute smoothness through to pebbly finishes, to coarse rocky finishes with everything in between and with several finishes often present in one wall panel. Again, this is a technique that cannot be mimicked by other than earth building techniques. New earth walls are widely used as both a structural and a load-bearing material. New earth buildings have successfully been built on flat and sloping sites, on sand and clay sites, on stable and reactive soil foundations in normal wind conditions and cyclonic wind conditions and in everything in between; in snow areas and desert areas; in earthquake zones that range from mild to the strongest in the world.

In Australia rammed earth buildings are growing in popularity in all areas. Rammed earth is commonly used in all style of buildings, from small buildings to luxury mansions. Western Australia leads the world in rammed earth technology and in the sheer volume of new rammed earth buildings constructed in the last twenty years. Perth, Western Australia, which is my home, also boasts the biggest fired clay brickworks on one site in the world which is listed in the Guinness Book of Records and with a population of around 1.52 million. Perth is a small city and also the most remote capital city in the world, and among its other extremes it is one of the windiest capital cities in the world.

To be successful, new earth buildings of all types must be seen by consumers as being superior to other methods of building and areas of importance include:

- structural soundness, this includes withstanding self weight and foundation forces and wind loads and earthquake loads
- the ability to keep out the elements. The walls need to be totally weather-proof under all weather conditions.
- shrinkage of soils. All earth buildings do have shrinkage and this needs to be measured, understood, controlled in an acceptable manner. It can be controlled and it commonly is.

The environmental benefits of earth building over non-earth building are a major plus for unfired earth. Nearly all unfired earth building techniques have substantially less energy requirements for production than conventional fired clay bricks. Bear in mind that where I come from the standard building is a double clay-fired brick wall, cavity construction. To use the world's fossil fuel supplies to produce fired clay bricks is a gross waste of embodied energy. While aluminium may be thought of as congealed electricity, so too can fired clay bricks be considered as congealed energy.

Unfired earth building as an environmentally green building material is difficult to surpass. I would like to talk about the living and environmental benefits of new earth buildings. The comfort benefits of living in an earth house need to be emphasised. Earth buildings have a much higher quality of space about them than the same space defined by conventional building materials. This widely recognised benefit is the well known feeling of wellness or good vibrations or nice feeling that so many occupants of earth buildings have described over the centuries. Earth walls have colour, texture and feel appeal that is rated highly desirable by nearly all occupants. The tactile attractiveness of most earth walls is very widely accepted. Other comfort benefits are that the Faraday cage, the so-called EMF effect, is said to not exist with earth walls. (Further and more decisive research is required in this area.) The area of building biology where earth buildings are said to have major advantages over conventional buildings needs further research and publication. Most forms of earth building can be recycled in all or part. Well designed and constructed earth buildings are low-maintenance. Low maintenance or simple affordable maintenance is very desirable and commonly achieved with well constructed new earth buildings.

The thermal properties of earth walls are highly desirable, having a very high thermal mass at reasonable cost. This is particularly so with new earth buildings in the Australian climate which in many areas is quite mild. The inhabitants of nearly all well designed new earth buildings continue to be pleased with the comfort afforded by such buildings, largely due to the high thermal mass evening out the day-time/night-time temperature fluctuations. This effect is commonly known as the thermal flywheel. Earth has a good balance between thermal transfer or resistive insulation, or U factor, and thermal storage or capacitive insulation known as thermal mass. A good balance of these properties is required for year-round comfort in a house. Earth has this balance, whereas many other conventional building materials do not. In Australia rammed earth is almost certainly the single most cost-effective form of thermal mass available in the entire building industry. Further work is required to make available computer programs to better predict the thermal performance of earthen buildings of various types in various climates. Account must be taken of the thermal mass benefits of thick earth wall buildings for capacitive insulation and any thermal analysis should not be totally reliant on resistive insulation alone as measured by R value or U factor. The debate in Australia at the moment about R factor versus capacitive insulation is raging and it is unresolved. We do not want to go down the path of

some countries who have legislated for energy-efficient buildings and have legislated out of existence modern earth building which is quite wrong.

Earth buildings with their ability to breathe can act as a moderator of humidity with a huge capacity to absorb and release humidity and they can lend themselves to in-built evaporative cooling applications. Earth walls can absorb moisture vapour and release it at a later time when its cooling effect can be of real benefit. This is a property requiring further research so that these benefits can be quantified and mathematically modelled so that the performance of the building can be accurately predicted before it is built.

I would like to talk now in general about the material properties of new earth buildings. I will start with acoustic benefits. These have been measured all over the world but my knowledge from Australia is as follows: an STC sound or transfer coefficient of 57 was measured for a 300 mm (1 ft) thick rammed earth wall, which is 57 decibels loss of sound level in transferring through the wall, which is an excellent product for domestic building. The reverberated sound from earth walls is not harsh on the human ear and produces a nice living environment. We have built sound recording studios because of those good sound reverberation characteristics.

Fire resistance: a 300 mm-thick (1 ft) rammed earth wall was tested in Australia and gave a rating of four hours, four hours and four hours for structural adequacy, integrity and insulation, which is an exceptionally high result for a low or reasonable cost material commonly used to build houses. Embodied energy is very low for nearly all forms of earth building and this needs to be further studied, further quantified and further publicised so that the low energy usage in producing new earth buildings is given proper credit. I have talked before about resistive and capacitive insulation, that is the energy used over the life of the building, which is quite different to embodied energy which is the energy used to build the building. They are both important issues.

To summarise the points made so far. Some of the factors taken into account in the decision-making process to select new earth for a chosen new building project include the following.

- desirable colour and texture
- desirable thermal properties
- human scale and desirable feeling of wellness or the earth connection within the building
- reasonable cost: cost is always important in new building no matter what it is made of
- low embodied energy during the construction of the building
- low energy use over the life of the building
- low maintenance over the life of the building's ability to be recycled

Using rammed earth for cyclone refuge is particularly relevant to tropical countries where tropic monsoonal climates generate tropical cyclones of high intensity. In Darwin hundreds of buildings between one and three storeys high previously built using locally-produced cement-stabilised pressed-earth blocks safely withstood Cyclone Tracey in 1975 which had wind speeds in excess of 200 km an hour (24 m/h). In 1999 Cyclone Vance on the Western Australian coast passed over one of our rammed earth buildings with wind speeds of 267 km an hour (165 m/h) with no damage. In early 2000 Cyclone Rosita in Western Australia with wind speeds 270 km an hour (167 m/h) moved over one of our houses that we'd only built about a month before with no damage whatsoever to our rammed earth building. A tourist resort built from timber nearby was hit by the same cyclone, and was totally destroyed. The owner described containers from ships, sea containers, being blown away by the wind and landing 2 or 3 km (1–2 miles) inland. So earth buildings can resist these types of forces. In the earthquake rating game earth buildings can resist the most severe earthquakes in the world if they're designed right. That design is critical but earth buildings can be designed to resist extreme earthquakes, cyclones and other extreme forces of nature.

A joint technical committee was formed, Committee BD83, to develop a standard for regulating all new earth buildings in Australia and New Zealand. Unfortunately the Joint Committee broke down and only New Zealand moved ahead and published a standard to regulate all earth building in New Zealand. It is now in force, it is legal and I am told it is working well. In Australia, with a history of earth building, there is still not a published standard but it is being worked on. The Standards Association of Australia are preparing to publish an advisory document. the Australian Earth Building Handbook, co-authored by Dr Peter Walker. The Earth Building Association of Australia is also producing an advisory document to promote new earth building and that is hopefully going to be available to members in a few months time.

Narrative to Stephen Dobson's illustrative slides

- (Fig 1) Rammed earth has been used in many public arenas. This church at Margaret River was one of the first and created a public awareness of rammed earth which has seen the Margaret River area become home to the highest percentage of new rammed earth constructions in Australia. 20% of all new homes are built using rammed earth. In addition, many of the local wineries and tourist resorts have been constructed out of rammed earth. When people saw this building a lot built new earth houses from the confidence it gave and they moved into new earth construction. If you want in your country to start new earth building then try to build public buildings so people can see them. This was very successful in Australia as a starting point so people would follow and build other earth buildings as a result of this.

Figure 1. Church at Margaret River, Western Australia (Stephen Dobson).

Figure 2. Interior of a rammed earth house, Australia(Stephen Dobson).

- (Figs 2 and 3) These are fairly typical of the rammed earth inside a house in Australia. Some of them are extremely beautiful, very well finished, very comfortable to live in. Happy customers are the best advertising for any business and new earth building is no different.
- (Fig 4) This is a fairly modern style of house that we've recently built. It is built of rammed limestone, a mixture of white clay, white limestone, white cement and water rammed in formwork in position on site. We've tried to make it a fashionable building material to make people see it as a desirable way to build their houses.
- (Fig 5) This house at Gill Street, in the Perth suburb of Mosman Park has Ramtec's load-bearing unreinforced rammed limestone walls 300 mm thick (1 ft) and two stories high. The walls were built in position using on-site techniques by Ramtec using a mix based on a local crushed limestone product. Rammed limestone was used to build this two-storey inner suburban home to create a streamlined, modern effect. Rammed limestone consists of crushed limestone and white cement and is used extensively in coastal and city projects. These are quite tall walls, all load-bearing.
- (Fig 6) Rammed earth rural retreat featuring solar design - northerly aspect provides light and warmth. The thermal mass of the walls (300mm [1 ft] thick)

Figure 3. Interior of a rammed earth house, Australia (Stephen Dobson). See Colour Plate 2.

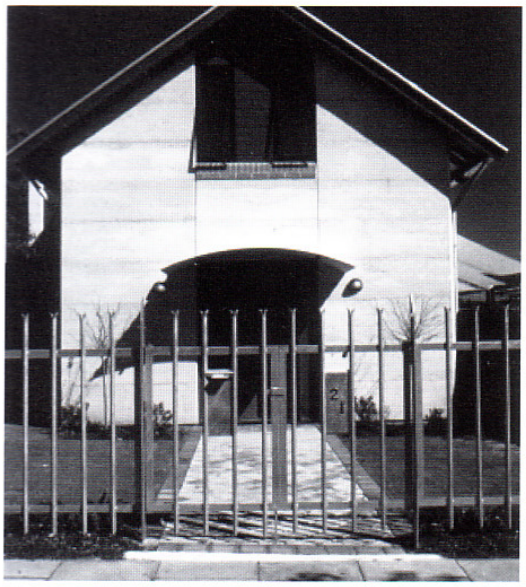

Figure 4. House made of rammed (white) limestone, Australia (Stephen Dobson). See Colour Plate 3.

Figure 5. House at Gill Street, Mosman Park, Western Australia, constructed of load-bearing unreinforced rammed limestone walls 300 mm thick and two storeys high (Stephen Dobson).

evens out daytime/night-time temperature fluctuations and provides a pleasant living environment.

- (Fig 7) Rammed earth in a tropical setting at Broome, Western Australia. Wide verandahs, interesting pillars and design for cross-flow ventilation to capture any breeze make this home ideal for living in the tropics.
- (Fig 8) This is a rammed earth visitor information building built by Ramtec at Kakadu National Park, a World Heritage wilderness area in the Northern Territory of Australia.

Where to from here? In conclusion, now is the time to go forth and multiply the number of new earth buildings. Or really to go and build large numbers of earthen buildings with complete confidence. The technology is not perfect, but it works very well. It is proven. The level of understanding is adequate to build almost any size or

Figure 6. Rammed earth rural retreat featuring solar design, Australia (Stephen Dobson).

Figure 7. Rammed earth in a tropical setting at Broome, Western Australia (Stephen Dobson). See Colour Plate 4.

Figure 8. Rammed earth visitor information building at Kakadu National Park, Northern Territory (Stephen Dobson). See Colour Plate 5.

shape of building in earth. There are major areas of future research needed, but these are adding to proven techniques. The current techniques do work and they work well. Some have worked well for hundreds of years. If anybody would like any further information, then I would be pleased to assist at any time. Thank you for the opportunity of talking here.