Rammed Earth (pisé)

Rammed earth walls are constructed by ramming a mixture of selected aggregates, including gravel, sand, silt and a small amount of clay, into place between flat panels called formwork.

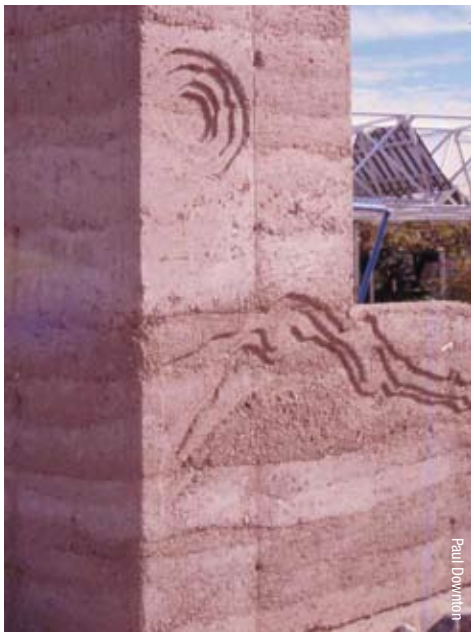
Traditional technology involved repeatedly ramming the end of a wooden pole into the earth mixture to compress it. Modern technology replaces the pole with a mechanical ram. Stabilised rammed earth is a variant of traditional rammed earth that adds a small amount of cement (typically between 5 and 10 per cent) to add strength and durability. Stabilised rammed earth walls need little added protection but are usually coated with a permeable sealer to increase the life of the material – this varies with circumstance and there are thousands of unstabilised rammed earth buildings around the world that have given good service over many centuries. Most of the energy used in the construction of rammed earth is in quarrying the raw material and transporting it to the site. Use of on-site materials can lessen energy consumed in construction. Rammed earth provides some insulation and excellent thermal mass.

The term pisé is of Latin origin from *pisé de terre*. First used in Lyons, France in 1562, the term applied to the principle of constructing walls at least 50cm thick by ramming earth between two parallel frames that are then removed, revealing a completed section of hard earth wall. While 50cm thick walls can still be constructed if desired, with or without cement, most modern rammed earth walls in Australia are built using cement at 30cm thick for external walls and 30cm or 20cm for internal walls.

PERFORMANCE SUMMARY

Appearance

The colour of rammed earth walls is determined by the earth and aggregate used. The ramming process proceeds layer by layer and this can introduce horizontal stratification to the appearance of the walls. The stratification due to ramming can enhance the overall appearance and can be controlled as a feature or eliminated. Aggregates can be exposed and special effects can be created by the addition of different coloured material in some layers and elements such as feature stones, alcoves or relief mouldings can be incorporated into rammed earth walls, at a price. Brushed finishes help reduce formwork marks that can create a concrete-like appearance, but this is only necessary with fine grain size ingredients.



Sample wall at the Environmental Research Laboratories in Tucson, Arizona.

Unusual finishes can be achieved by including shapes in the formwork that can be released after the wall has been rammed. Other possibilities include embedding rocks and other objects in walls for aesthetic effect.

Layers of ramming are visible as are the chamfered corners that are required to allow the walls to be easily released from the formwork.

It is possible to form vertical curves, made by carefully ramming along a drawn guideline on the interior of the formwork. Horizontal curves are also possible but require specialised, and therefore expensive, formwork.

Structural capability

Rammed earth is very strong in compression and can be used for multi-storey load-bearing construction. Research in New Zealand indicates that monolithic earth walls perform better under earthquake conditions than walls made of separate bricks or blocks. There is a five storey hotel in Queensland built of stabilised rammed earth. Rammed earth can be engineered to achieve reasonably high strengths and be reinforced in a similar manner to concrete, although horizontal reinforcement is not recommended and excessive vertical reinforcement can cause cracking problems.
[See: 5.5 Construction Systems]

Interesting structural features, including leaning walls, have been constructed in rammed earth. Any difficulties associated with placing and ramming around reinforcement can be eased by careful management of the construction process and need not add significantly to cost.

Perth rammed earth home.

Thermal mass

Thermal mass absorbs or 'slows down' the passage of heat through a material and then releases that heat when the surrounding ambient temperature goes down. Rammed earth behaves as a heavyweight masonry with a high thermal mass. [See: 4.9 Thermal Mass]

Insulation

Insulation is about stopping heat passing through a material rather than slowly absorbing or releasing it. As a corollary to its high thermal mass, rammed earth has only reasonable thermal insulating qualities. Insulation can be added to rammed earth walls with linings but is not intrinsic to the material and, on its own, it is unlikely to meet building code requirements for wall insulation. However, under certain design criteria (ie. simple rectangle with north facing glass) and in moderate (not temperate) climates it is still possible to meet the NatHERS overall five star performance standard. [See: 4.7 Insulation]

Insulation can also be added within the thickness of a rammed earth wall but this adds to its cost and changes the structural properties of the wall. However it gives the benefit of both excellent thermal mass and good thermal insulation in the one wall whilst retaining the desirable look, texture, feel, acoustics and low maintenance properties of the facing of rammed earth on each side.

Sound insulation

One of the best ways to insulate against sound is have monolithic mass – rammed earth provides this very well. It has excellent sound reverberation characteristics and does not generate the harsh echoes characteristic of many conventional wall materials. [See: 2.7 Noise Control]

Fire and vermin resistance

There are no flammable components in a rammed earth wall and its fire resistance is thus very good. In tests by the CSIRO a 150mm thick Cinva-rammed earth block wall (similar to rammed earth) achieved a near four hour fire resistance rating. There is no cavity to harbour vermin and nothing in the material to attract or support them so, its resistance to vermin attack is very high.

Durability and moisture resistance

The basic technology has been around for thousands of years and there are many rammed earth buildings still standing that are centuries old. Rammed earth possesses a generally high durability but all types of rammed earth walls are porous by nature and need protection from driving rain and long term exposure to moisture. It is essential to maintain water protection to the tops and bottoms of walls. Continued exposure to moisture may degrade the internal structure of the earth by reversing the cement stabilisation and allowing the clays to expand, however, in general, rammed earth has moderate to good moisture resistance and most modern Australian rammed earth walls do not require additional waterproofing. New water repellent additives that waterproof the walls right through may make rammed earth suitable for very exposed conditions, including retaining walls, but may inhibit the breathability of the material.

Rammed earth lends itself to use with timber and natural materials.

Breathability and toxicity

Provided it is not sealed with material that is impervious, rammed earth maintains its breathability. Finished walls are inert, but care should be taken in choice of waterproofing or anti-dust finishes to avoid adding toxicity to the surfaces.

Environmental impacts

Rammed earth has potentially low manufacturing impacts, depending on cement content and degree of local material sourcing. Most rammed earth in Australia uses quarried aggregates, rather than the 'earth' that it is popularly thought to be made from. On-site materials can often be used but materials should be tested for their suitability.

The embodied energy of rammed earth is low to moderate. Composed of selected aggregates bound with cementitious material, rammed earth can be thought of as a kind of 'weak concrete'. It may help to understand cement and earth products as being at different points on an energy continuum with earth at the low, and high strength concrete at the high end. Its cement and aggregate content can be varied to suit engineering and strength requirements.

Although it is a low greenhouse emission product in principle, transport and cement manufacture can add significantly to the overall emissions associated with typical modern rammed earth construction. The most basic kind of traditional rammed earth has very low greenhouse gas emissions but the more highly engineered and processed variant of rammed earth has the potential for significant emissions.

Buildability, availability and cost

Rammed earth is an *in-situ* construction method. Although its buildability is good, formwork for rammed earth demands good site and logistics planning to ensure that other trades are not adversely effected in the building program. Services should be well planned in advance to minimise difficulties. After walls have been rammed in place, conduits for pipes and wires can be provided much as in other masonry construction, but may impact on surface finishes. [See: 5.1 Material Use Introduction]

Basic materials for rammed earth making are readily available across Australia, but cement and formwork may have to be transported long distances, increasing environmental and economic costs. Testing of local aggregates and potential mixes is advisable if not using a proprietary system.

Proprietary approaches to rammed earth help guarantee consistency and predictable performance but come at a cost. The cost of professional rammed earth building is comparable to other more conventional good quality masonry construction, but it can be more than twice as expensive than a rendered 200mm wide AAC block wall.

[See: 5.12 Autoclaved Aerated Concrete (AAC)]

Rammed earth is particularly well established in Western Australia and most states have experienced builders who understand its potential and limitations. Rammed earth construction is relatively high cost. It typically requires high levels of control over material sourcing and batching and expensive formwork. A key element in controlling costs is to design walls as simple panels and to avoid unnecessary complexity. Traditional rammed earth using human power for ramming and simple wooden formwork can be low cost (and low energy) but this is rarely a realistic option.

There are good networks in Australia including a broad based national organisation, the Earth Building Association of Australia (EBAA), which is a not for profit organisation 'formed to promote the use of Unfired Earth as a building medium throughout Australia.'

TYPICAL DOMESTIC CONSTRUCTION

Construction process

Stabilised rammed earth is made by compacting a gravel, sand, silt, clay mixture and cement between formwork in a series of layers approximately 100mm thick.
The traditional rammed earth was just that, and was often dug from the same site as the building it was destined for, but the materials for modern stabilised rammed earth come primarily from quarries.

The modern process of making stabilised rammed earth is both labour intensive and highly mechanical, requiring the use of powered rams.


Paul Downton

Typical details

All structural design should be prepared by a competent person and may require preparation or checking by a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance. All masonry construction has to comply with the Building Code and Australian Standards. For example all masonry walls are required to have movement/ expansion joints at specified intervals.

Footings

Conventional concrete slab or strip footings are generally used, subject to soil conditions.

Frames and bond beams

Complex, more elaborately engineered structures may require reinforcement or frames that work in concert with the load bearing capacity of rammed earth. Simple and commonly built rammed earth buildings do not.

Load Bearing Walls

Rammed earth has fair compressive strength and it is common to make rammed earth a load bearing construction.

Formwork

Plywood or steel sheets are both used in making formwork, which is superficially similar to the formwork used for in-situ concrete, but with its own specific requirements.

Propping and temporary stays are required in the construction process and these may impact on other site work operations if the primary structure is more than just rammed earth. Walls are built in sections and the rise of each level of formwork is often visible in the final finish. Walls are built up in layers of approximately 100mm. As the wall rises it is possible to take out the lower portions of formwork provided the wall has set strong enough.

Joints and connections

Walls are built in panels of approximately 3.5m in length. When a wall consists of more than one panel a recess is built into the end of the first wall. The second wall then moulds into this to lock the walls together for lateral stability.

Fixings

Most conventional masonry fixings work with rammed earth walls and they usually need to be set in at about twice the depth normally used for concrete.

Openings

Openings can be made without lintels with spans of up to 1 metre in stabilised walls (subject to strength and engineering requirements). Specialised formwork can be made to make features like pointed arch or circular windows and the formwork can often be re-used.

Finishes

The off-form finish of stabilised rammed earth generally requires no additional finish. A clear water repellent coating may be needed in some instances and unstabilised rammed earth should be protected by eaves, overhangs or render, as they are more prone to erosion. Walls can be wire brushed shortly after being released from the formwork to eliminate the visual impact of the joins between the formwork and achieve an appearance closer to monolithic sandstone. Selection of the ingredients for rammed earth also affects this.

ADDITIONAL READING

BDEP *Environment Design Guide* www.environmentdesignguide.net.au

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