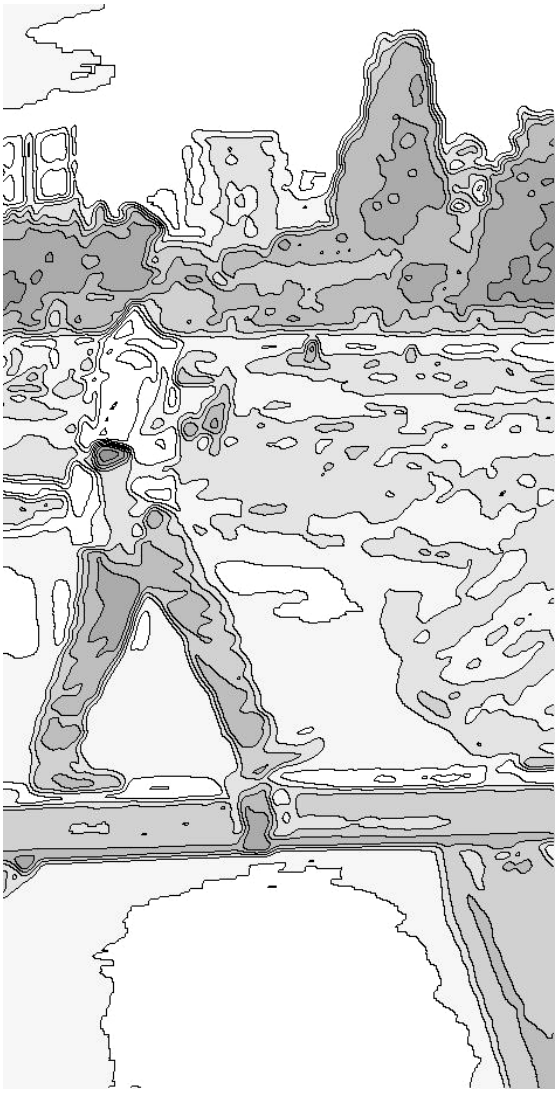
building to learn

Rammed earth building

student project pack



constructionarium

What is Rammed Earth

Rammed earth is a form of unbaked earthen construction. It is mainly used to build walls but also columns, floors and foundations.

Rammed earth has been used in a wide variety of structures for both load-bearing and non-load-bearing walls over many centuries. Rammed earth walls are found throughout the world with many examples throughout Asia, including sections of the Great Wall of China, in the Middle East, Africa, Latin America and Europe.
The traditional rammed earth technique is still used in many developing countries. In industrialised countries, the development of more effective construction methods makes the technique relevant as well. Australia and New-Zealand have seen an important increase in the number of rammed earth buildings being built lately. In some areas of Australia, rammed earth even represents a significant proportion of new buildings work.
In the UK, it is also undergoing a renewed interest. Rammed earth was probably introduced to Britain by the Romans and has been used in the UK for around 2000 years. However the most significant period of construction followed its reintroduction into the UK in the early 19th century. Throughout the 19th century a number of rammed earth and rammed chalk buildings were erected in Southern England.
In recent years an increasing number of rammed earth projects have been completed in the UK. The most famous applications to date include the Eden Project Visitors Centre and the Centre for Alternative Technology's at AtElC Building.

Eden Project Visitor Centre (1999)
Grimshaw Architects, In Situ Rammed Earth)

Stabilised rammed earth house, Western Australia

Rammed earth is formed by compacting moist soil inside a temporary formwork. Loose moist soil is placed in layers 100-150mm deep and then compacted. When earth is compacted its volume can reduce by up to 50%. Traditionally manual rammers have been used for compaction but nowadays pneumatically powered dynamic rammers are commonly used. Each time the top of the formwork is reached, it is re-erected higher and the process begins again.
As a result of this construction method rammed earth walls often exhibit a distinctive layered appearance that is quite attractive and is undoubtedly one of the appeals of rammed earth construction. As a result, walls are often left without plaster or render.

Rammed earth: Advantages and limitations

Advantages

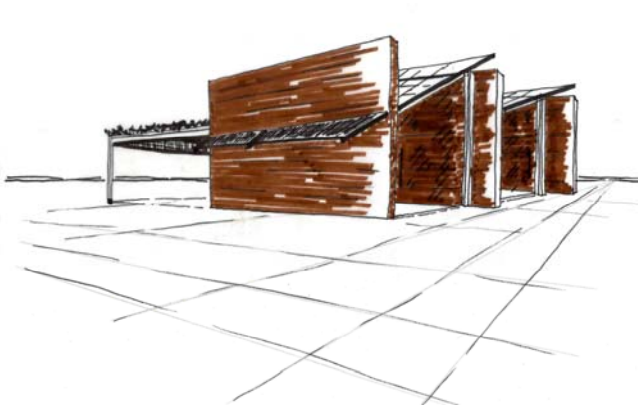
The stimulus for the latest development of rammed earth in the UK has primarily been the desire to reduce the environmental impact of building and explore more sustainable and natural building methods. Also, rammed earth can be a particularly beautiful finished material due to its construction method as explained above and as can be seen on the pictures above. This has also been a reason for an increasing use of the material.
Moreover, while it offers the qualities of other earth construction methods, among which regulating the internal relative humidity and providing an important thermal mass, rammed earth construction has higher strength and stiffness than other earth construction methods such as cob and adobe and enables therefore more flexibility in the design possibilities it offers.
Also many rammed earth building operations can be undertaken by a relatively inexperienced labour force.

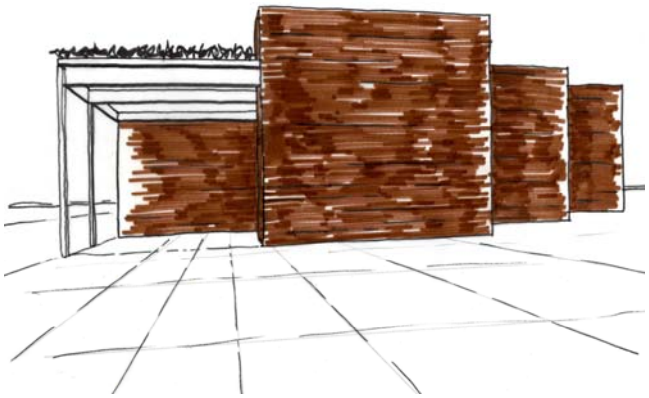
Limitations

The main limitation of rammed earth is its durability. Indeed rammed earth is susceptible to decay in presence of water. This requires special consideration in design and construction and throughout its service life. To overcome this problem external walls are generally built on upstands and often protected with large eaves extensions.
In cases where walls cannot be protected by using such building details, rammed earth can be stabilised. This is done by adding cement to the basic soil mix. Stabilisation enhances material durability and wet strength but at the expense of using cement, a major contributor to global CO2 emissions. This technique has been largely used in USA and Australia with now more than 1000 buildings having been built.
Another drawback of rammed earth construction is the important thickness of the walls that is required. To ensure lateral resistance of the walls and allow construction, the walls are typically 300-450mm thick although this can vary largely according to design requirements. This is due to the low strengths of the material.
Not all soils are suitable for rammed earth construction and must be carefully selected. Extensive laboratory testing being often needed, many established earth builder take material from quarry sources sometimes resulting in transportation of materials over considerable distances.

The Rammed Earth Building

The Rammed Earth Building is made up of two parts: a “rammed earth part” made of three walls, and a “timber part” open on its four sides at the extremity.





The building is orientated to maximise the amount of sunlight entering the structure through the roof.

The walls carry the loads from the timber roof above. To ensure the durability of the structure, the roof is designed to overhang most of the walls and protect them from the rain. The elements of exposed wall are protected by adding cement to the basic soil mix.

The walls are 350mm thick and respectively 5.6m, 4m, and 2.4m long. Their heights range from 2.3m to 3.5m. Totally 14.6m^3 of earth are used in the building.

Part of the roof is clad with a transparent polycarbonate. The remainder is a green roof designed to retain surface water runoff and enhance biodiversity. The structure of the green roof part is entirely made of timber elements. The green roof element has been designed such that it can be constructed offsite and lifted into place.

The roof experiences significant uplift force. To anchor the roof without increasing the tension in the rammed earth walls, a timber beam has been provided at each point where the rafters connect to the walls and is anchored in the walls by builders bands attached to a reinforcing bar in the wall. The building is braced bays using steel cables and timber posts.

The building is supported on mass concrete strip foundations under the walls and pad foundations under the timber posts.

The Rammed Earth Project has been designed to demonstrate the place of vernacular architecture in the 21stCentruary built environment.

Brief

Your brief is to construct the building presented over the Constructionarium week.
You will have to use different earth mixes (unstabilised for most of the structure and stabilised for the parts left exposed).
You will have to coordinate efficiently the construction of the walls and the erection of the timber roof in the rammed earth part.
You will also have to ensure the offsite fabrication of the green roof.

Site layout at the start of the week

Your site is level.
You will use off-site production methods to manufacture the green roof. You need to agree with the client's representative as to the location of your offsite assembly area.
You will also have to prepare the earth mixes to be used for the walls.

Plant and Equipment

You will have limited access to a tower crane for lifting the green roof.
You will be provided with pneumatic rammers for construction of walls.

What you will have to do

- Create a GANTT chart of key activities and time for completion; determine need for power tool training of operatives; meet daily with client's representative; submit method statements for approval by site manager; submit list of kit and equipment & plant requirements to store manager.
- Set out and cast foundations.
- The key positions of the timber posts must be set out on the concrete foundation.
- The columns inserted in the walls must be connected to the foundations.
- Each post must be braced with temporary struts for stability.
- Construction of the rammed earth walls ensuring their lateral stability.
- Offsite manufacturing of the green roof.
- Ramming of the walls involves working at height. Safe access must be considered at every stage of the construction to ensure a safe working environment.
- **Stability of the overall structure must be ensured at all times and risk assessment methods statement report produced before each major construction activity commences.**

Friday feature

You will complete the building by lifting the green roof in place**. Great care must be taken as the green roof is lifted in place**: The lifting method might lead to non negligible compression in the roof and as the roof is lifted with some of the beams supporting it missing, a frame will have to be provided or a set of temporary beams installed in the part of the roof being lifted.

References

Walker, Peter. Rammed Earth, Design and construction guidelines. Garston: BRE Bookshop, 2005

Graham McHenry, Jr., Paul. Adobe and rammed earth buildings, Design and construction. Tucson: The University of Arizona Press, 1984

Minke, Gernot. Earth Construction Handbook – The building material earth in modern architecture. Southampton: WIT press, 2000

P17 - RAMMED EARTH PROJECT - RISK ASSESSMENT

Ref	Activity element	Significant potential hazards	Population at risk	Design action to be taken to reduce risk	Residual action required/information for the Students
1	Working close to excavation (when working on foundations)	Contact with contaminants	Site personnel	Ensure adequate information about ground conditions is known	Contact member of CITB staff to ensure ground conditions are safe for working by students
2	Temporary stability during walls construction (before shutters removed)	Collapse of rammed earth wall with shutter during construction of the walls	Site personnel	Panel struts provided by contractor to be properly fixed	Students to develop method statement to ensure stability during construction. Students/Contractor to check propping of shuttering before beginning to ram earth after each lift. Temporary propping only to be adjusted / erected under supervision of contractor.
3	Temporary stability during roof construction (once shutters removed)	Collapse of rammed earth wall during installation of roof and bracing elements	Site personnel	Adequate propping to be used to ensure walls stability during construction	Students to develop method statement to ensure stability during construction. Students/Contractor to check propping of walls prior to installation of the roof and bracing elements. Temporary propping only to be adjusted / erected under supervision of contractor.
4	Permanent stability	Site personnel / End user	Site personnel	Adequate stability system provided, adequate connections designed	Students to ensure the cables used for bracing are adequately stressed by provided turnbuckles. Students to ensure all connections are correctly built and installed
5	Moving plant	Being run over/harmed through activity of plant by others	Site personnel		All plant to be operated only by trained personnel. Access route to be marked out on site and all site personnel and visitors on site to be briefed prior to entering the site
6	Lifting operations	Knocks to heads, falls of material, collisions	Site personnel		All lifting operations to be controlled on site by trained personnel
7	Crane overturning	Personel in and around crane likely to be injured	Site personnel		Students to place crane mat and develop safe method of working
8	Working at height	Falls, potential of falling tools/material causing injury of people below	Site personnel	Safety handrail provided on access platforms and on formwork for work on walls construction. Green roof designed to be lifted in place hence minimizing operations at height	Students to adopt safe working pratices. Appropriate Personal Protection Equipment (PPE) to be worn at all times. **No access** to the green roof once off-ground. Access platforms and safety handrails only to be adjusted / erected under direct supervision of contractor
9	Hand tools	Injury through misuse (especially when cutting timber), injury through uninterrupted use for too long (earth rammers).	Site personnel	Design involves extensive use of hand tools	Handtools to be used only by trained personnel (students shall besupervised at all time when using hazardous equipment)
10	Noise and vibrations	Risk of Vibration White Finger	Site personnel	No design action can be taken as building the walls necessarily involves the use of handheld powered percussive equipment	No invidual is to use an earth rammer for more than a total of 2.5hours in any one day
11	Exposure to irritants and hazardous materials	Concreting works (foundations)	Site personnel		Reduce skin contact with concrete by providing adequate PPE and ensure students are aware of the hazards. All materials and containers to be clearly labeled