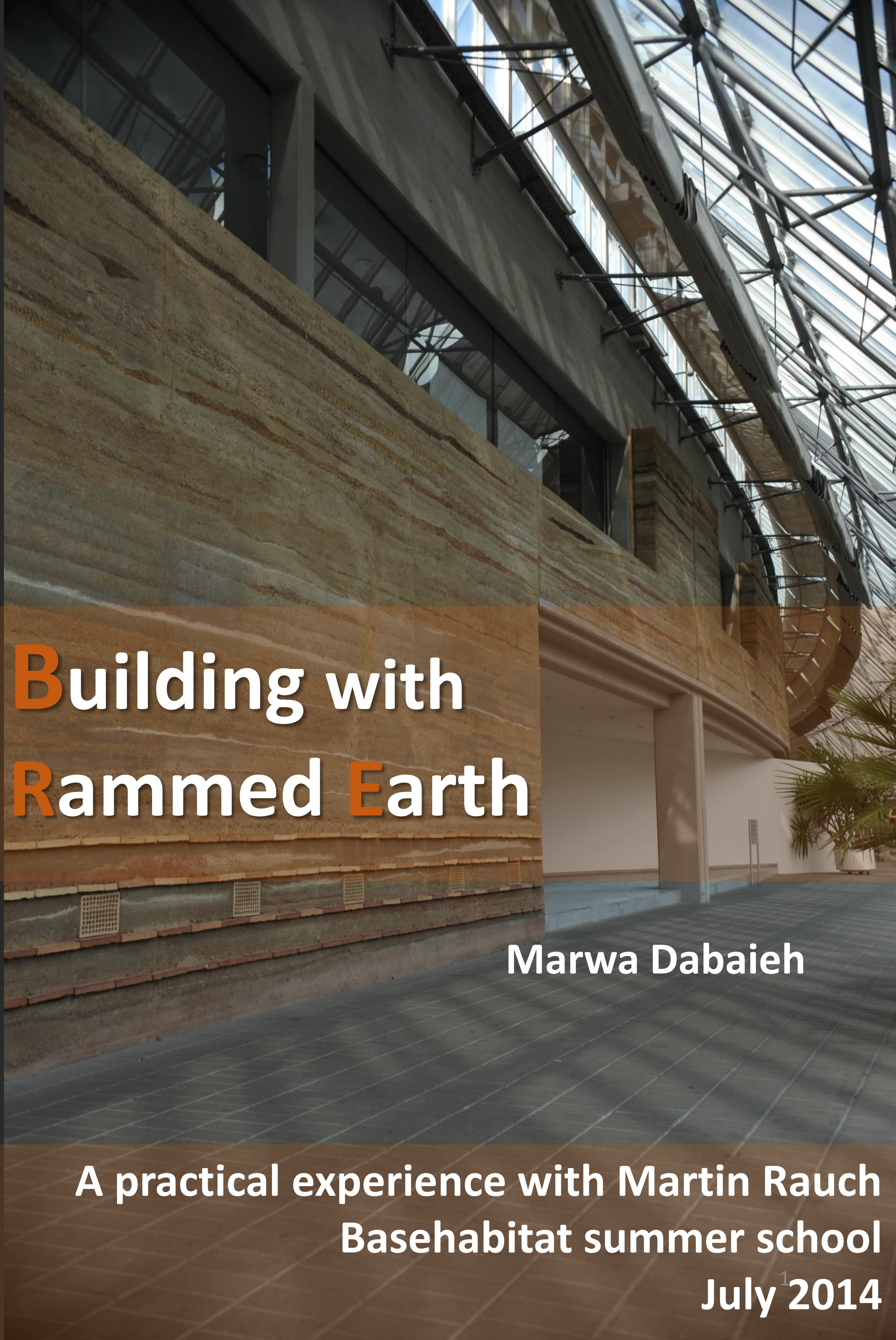
Building with Rammed Earth -A practical experience with Martin Rauch

Dabaieh, Marwa

2014



Building with Rammed Earth

Marwa Dabaieh

A practical experience with Martin Rauch
Basehabitat summer school
July 2014

Author: Marwa Dabaieh

Cover design and layout: Marwa Dabaieh

Photos by the authors unless otherwise stated

Back cover photo: Philipp Steiner

ISBN 978-91-628-9221-0

About

This booklet is a documentation for one week hands on workshop experience with Martin Rauch and his team. More information was added to this booklet for a complete overview on rammed earth construction from historical background to contemporary practice.

Table of content

Building with rammed earth

What is rammed earth?

Rammed Earth (pise) is a natural building method that is thousands of years old, and has been used in all of earth's continents. Rammed Earth buildings have many favorable qualities. They are low-tech construction process and economical to build. They need low maintenance and they are suitable for the cold and hot climate.

History and background

Rammed earth is an ancient construction technique that utilizes only the earth to create thick, durable walls, which can be load bearing, low-cost, heat-storing and recyclable. It was developed independently in many parts of the world, and is also commonly known by its French name “Pise”.

The technique of rammed earth is simply based on compacting soil between vertical formwork boards, which are then removed leaving a mass soil wall. Usually this technique is used in regions whose soil composition is unsuitable to make sun dried clay bricks (Keable, 1994; Easton, 1996).

Excavations in China have uncovered rammed earth constructions dating from the 7th century B.C. as parts of The Great Wall of China, begun more than 5,000 years ago were built of stone and rammed earth (Easton, 1996). Rammed earth technique was used in the arid regions of North Africa and the Middle East, where earth was the only logical building material, where the massive high walls with their small openings protect them from the heat and dust of the desert.

Rammed earth had been seen as a quick, easy construction technique to build fortifications; a cheap way to build dwellings; and has been recently recognized as a sustainable construction technique which uses only what is available at the site. Since the 1970s the use of rammed earth has been prompted in Europe and the United States as a sustainable construction material. Rammed earth is based on naturally damp and crumbly earth which is compressed into form and left to dry and harden. It is the heaviest form of earthen building. Rammed earth structures can therefore be loadbearing. The earth is filled into a form and compressed in layers similar to conventional in-situ concrete. Alternatively large rammed earth blocks can be pre-cast in molds and then assembled on site much like brickwork on a larger scale.

Advantages of Rammed Earth

- Ramming requires little water, which can be an important consideration in dry climates with sacristy of fresh water.

- They require few other resources like aggregates or additives to improve their properties.

- Earth can be recycled, is easy and agreeable to work.

- Has good insulating properties if built with high thermal mass especially for hot climate.

- Known fact earth gives off no harmful emissions.

- Good for noise reduction and insulation.

- Earth doesn’t burn, so rammed earth walls are fire proof.

- Load bearing, which reduces the need for structural supports, therefore reducing building costs. Standard 400mm thick rammed earth walls can be used as load bearing in constructions up to four stories high.

- Termites and other pests are of little concern to rammed earth walls.

Disadvantages of Rammed Earth

-It is labour-intensive to build, which makes them relatively expensive.

- Some degree of carpentry skills are needed to build the formwork.

- The ramming itself is relatively time-consuming and hard physical work.

Building methods and techniques

Soil identification and preliminary soil site tests

In his workshop we used soil brought from outside and it already identified with components and whether it needs other additives to enhance its characteristics. Generally a series of field tests should be conducted using a sample from the site taken from a depth of 0.5 meter, to ensure that the surface organic materials are not included. Two simple site tests can be done explained below.

The drop test

A handful of un-sieved soil was taken, moisten and made into a ball, which was held in hand and left to dry for a few minutes before dropping it. If the ball is broken into a few lumps that is an indication of a good mix.

The jar test "Particle size test"

In order to know the proportions of different particle sizes of the soil, the jar test could be used. That is to get a preliminary assessment of the ratio of coarse to fine particles in the soil. Two thirds of a bottle was filled by soil taken from the site, and water was added to fill the bottle. The bottle is shaken till all the soil particles are suspended then it is left to settle for a few hours. As the water cleared, you can see the formation of different soil layers separated by clearly visible lines. The sand layer normally settle at the bottom as its particles are heavier, then layers of silt and clay stays on top.

Soil mixing

As it is the normal scenario with earth buildings the secrete recipe is not known yet. The mix depends on the type of the soil available on site. So the experience plays an important role in reaching a proper mix and following the famous saying -Grandma know how to make pizza-. However the agreed upon proportion onsite was:

2.5 gravel, 2 course sand and 2.5 clay

Mixing is the most essential operation to ensure homogeneity of the soil used. After the thorough dry mix process (using drum mixture) water was added gradually. The mixture had to be turned over while water is sprinkled to ensure that all the particles will be moistened. The amount of water added to the soil is very important, because if the mixture contains little water the soil will not be properly squeezed, and with too much water the soil becomes too wet and water will resist compaction. Generally speaking water forms 10%-15% of the mixture, and the mixture should look quite dry after adding it. The drop test gave an indication of the amount of water needed to achieve plasticity, but the site conditions also had an effect, as water evaporates while mixing specially in hot weather.

To attain optimum results it is advised undertaking soil screening, crushing and mixing as a one continuous process. It is important primarily to ensure an even dispersal of moisture content within the soil mix. Rotating-drum can be used to achieve uniform mix on site. Rotating-drum type mortar mixers work adequately when the soil is high in sand and gravel content but in general this is a slow procedure.

In summary soils suitable for rammed earth construction are broad. The soil mix should include sands with sufficient clay and silt, clayey silts, clayey gravels and gravel-sand-clay mixtures. Though soil suitability guidance is helpful it is also very general and therefore vague. Soil suitability test is as a must (shrinkage, strength, erosion resistance) of individual soil samples.

Foundations

Foundation design for rammed earth buildings is very similar to that for low rise buildings. Concrete strip footing are the most common types of footings. The size of footings depends on the type of the supported structure and the soil bearing capacity underneath the foundation. It is important that foundation is of sufficient depth to avoid frost underneath and footings should be well protected from water infiltration. The ground immediately adjacent to the base of a rammed earth wall should be well drained. Also extended eaves and raised footings protect walls from rainfall. Generally the installation of surface and underwater drains and damp-proof courses are considered essentials. We used bitumen sheets for water insulation.

Foundation after ramming

Pouring the concrete mix

Foundation formwork assembly

Formwork

Formwork in rammed earth construction is used as a temporary support during soil compaction. Formwork can range from simple to complicated systems and you can use plywood or steel ones. Like concrete formwork it is required to have sufficient strength, stiffness and stability to resist pressures it is subjected to during assembly, pouring the soil mix, and dismantling. However, unlike concrete, rammed earth formwork can be removed after compaction, enabling much faster re-use efficient organization of formwork is essential to efficient rammed earth construction. Martin Rauch, has commented that typically 50% of his site time is spent erecting, aligning, checking, stripping, cleaning, moving and storing formwork (Boltshauser & Rauch, 2011).

When making a choice of formwork the following general criteria should be kept in mind:

-Strength and stiffness of the formwork to be able to withstand the outward pressure of earth mix and to maintain the form without excessive distortion during ramming.

-Durability, adaptability for appropriate maintenance as forms must be able to meet the expected number of uses under normal site.

-Formwork must not be too heavy or bulky in order to avoid making assembly and disassembly difficult and time-consuming.

-Formwork should contain smooth horizontal and vertical holes for bolts and ties to allow easy and consistent horizontal and vertical alignment.

Any formwork system should contain

- Shutters from both sides of the form.
- Ties and bolts.
- Props or stays- the (fixed or movable) vertical posts used to brace the form.
- Wedges for adjustment of the formwork.

To dismantle the formwork the metal bolts should be removed slowly and the formwork should slid upwards slightly before being removed from the wall. The process had to be done slowly and gently so that earth does not stick to the formwork and damage the surface. The wall is advised to be covered by plastic sheets to protect it from direct sunshine and rain.

Ramming

The mixed moist soil was poured in the formwork creating a uniform level of almost 15 cm, which after ramming was compressed to 10 cm. As soon as the first layer was rammed properly another was poured to be rammed, and so on. Both electric and hand metal rammers were used to ram the soil. The metal were composed of a steel rod with a flat steel plate, the weight of the rammers and the size of the plates differs to suit the purpose for example to ram the corners.

A layer was considered to be properly rammed as soon as an echoing sound was heard from the rammers, an indication of the compactness of that layer. The width of the formwork enabled users to stand inside it and ram, an advantage that ensured that all the corners and the edges were rammed properly.

Plastering, rendering and re-touch

One of the advantages of using smooth formwork is to achieve a smooth fair-faced surfaces. Rammed earth walls do not need plastering, it is advisable to sponge the surface with a moist towel immediately after dismantling the formwork. In case there were any small holes in the walls, they can be filled by hand from the same soil mixture.

In the workshop we experimented a number of materials to render the walls, such as clay and lime. Also casein protein was used which is a natural materials that are dissolved in water and is easily applied to the walls using brushes or sponges.

Disassembling the formwork carefully and gently

The tools used for the re-touch

Re-touching process

Rainfall erosion lines

Erosion breaks can be made in different ways. The main purpose is to protect the rammed earth walls form heavy and continuous rains. The mix is 4 gravel sand and 1/2 eco cement bag and you can add one spoon of colour power. Erosion line can be every second or third layer.

Shrinkage

Rammed earth as all earth building materials containing clay, swell on contact with water and shrink on drying. Only with tests you can predict the percentage of shrinkage. The range of acceptable shrinkage percentage differs from one building code to another and the range is from 0.05% till 3 %. Regardless of any code requirements, the shrinkage characteristics of a soil should be examined and incorporated into the design to satisfy the serviceability requirement of the structure.

Color lines

Every third or fourth layer you can add a color line for decoration. One spoon of color power is added to the mix. Add the colored layer in the edge of the wall then pour the normal mixture on top and ram.

Openings

Arched and flat openings can be made by using block-out forms or using structural lintels inserted inside the wall formwork are an effective means of providing openings over modest spans up to 1.5 m. Lintels can be formed from wood, concrete, steel (T or angle section) and stone. Lintels require adequate bedding length to avoid bearing problems and preferred spans not to exceed 3 M.

Roof support

For loadbearing rammed earth structure, lightweight timber are most widely used for typical floor ceilings and for roofs. Also load-bearing self-supported earth vaults and domes can be used. In the absence of a wall plate the roof may be tied down directly to the wall with ties (usually metallic), embedded within the wall. In this workshop we used metal sheets as a shed to protect the upper surface of the wall.

Quality Control

The most common problem influencing quality of construction on site is keeping the earth dry prior to, during and following construction. Material selection is important to the finished quality of rammed earth. Quality of in-situ rammed earth can be measured by strength (cylinder or cube compressive strength), dry density, surface hardness and finish.

Fire Safety

Rammed earth can be classified as non-combustible material. A 30 cm wall is capable of providing fire resistance of at least 90 minutes.

Codes of practice

Some countries have specific codes or standard for rammed earth construction like in Germany. Some good literature as a references can be used for rammed earth construction like Middleton (1992), Houben & Guillaud (1994), Keable (1994) King (1996) and Röhlen& Ziegert (2011).

Cement stabilization

Cement can be been used but not to exceed 5% of the soil mix. Reasons for using cement are varied, but mainly for improving durability and strength combined with reducing risk but it is not recommended.

Costs and feasibility

According to Martin Rauch, in Europe, 1m² of rammed earth cost 100 euro, that is due to the fact the labor wages are very high. Rammed earth is more economical in developing countries in that scene.

Maintenance & Repairs

Maintenance of a rammed earth building is not more burdensome than the maintenance of any other traditionally-built earth dwellings. However, a rule of thumb, absence of regular maintenance can be more damaging in earthen structures than in other building types. It is important that a suitable maintenance schedule for rammed earth structures is set and sustained. Water is a major agent of decay in rammed earth buildings. Maintenance should seek to protect rammed earth from water borne deterioration. A good boot (foundation) and a good hat (roof) guarantee long less maintenance or repairs.

Productivity

Productivity of rammed earth construction depends on several factors like site circumstances, weather conditions, workers proficiency and formwork system. Generally, Organization of formwork is one of the most time-consuming in rammed earth construction. Productivity rates quoted for rammed earth vary between 5hrs/m3 to over 25hrs/m3 (CRATerre, 1982).

Thermal properties of rammed earth walls

Rammed earth have largely been recognized with the poor thermal insulating properties. The thermal performance of rammed earth is measured in a many ways. The most common used ones are:

Thermal Storage

This is a measure of the specific heat capacity expressed in volume terms and has units of J/m3 C. Houben & Guillaud (1994) claims that for rammed earth the thermal storage is around 1830 J/m3C.

Thermal Resistance (R-value)

The R-value is a measure of resistance to heat flow through a given thickness of a wall and is measured in m2 K/W. A 30 cm thick rammed earth wall has an R value between 0.35-0.70 m2 K/W (Berge, 2009). Generally, the more thermal resistance the material has the better insulating properties. Thick walls are required to provide sufficient high thermal mass. Improved insulation techniques are needed to increase the thermal performance of wall cross sections. A rammed earth wall density can rang from 1700 to 2200kg/m3 (Berge, 2009).

Conclusion

The recent widespread use of rammed earth across the world is an evidence to its success as a building material. Design and detailing of these buildings has evolved and developed in recognition of the material's low strength, relatively high drying shrinkage, poor water resistance and low thermal resistance.

References

- Berge, Bjørn (2009). *The Ecology of Building Materials.* Architectural Press
- Boltshauser, Roger & Rauch, Martin (2011). *Haus Rauch: ein Modell moderner Lehmarchitektur = The Rauch house : a model of advanced clay architecture*. Basel: Birkhäuser
- CRATerre, 1982. Recommendations pour la conception des bâtiments du Village Terre. Plan Construction/AGRA.
- Easton, D. 1996. *The rammed earth house*. White River Junction, Vt.: Chelsea Green Pub. Co.
- Easton, David (2007). *The rammed earth house*. rev. ed. White River Junction, Vt.: Chelsea Green Pub. Co
- Houben, Hugo & Guillaud, Hubert (1994). *Earth construction: comprehensive guide*. Londonb Intermediate Technology:
- Kapfinger, Otto & Rauch, Martin (2001). *Martin Rauch: rammed earth = Lehm und Architektur*. Basel: Birkhäuser
- Keable, Julian (2011). *Rammed Earth Structures ; a code of Practice*. Warwickshire: Practical Action Pub
- Röhlen, Ulrich & Ziegert, Christof. (2011). *Earth building practice: planning, design, building*. 1. ed. Berlin: Beuth

Basehabitat summer school
July 2014