Chapter 8
The Stabilized Rammed Earth Building Technique and its Use in Australia

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8.1 Introduction

Building with earth today addresses key questions for contemporary architecture, given its involvement in changing the environment, pollution and the consumption of natural resources in general caused by the construction industry. According to John et al. (2001, p. 92), "the building industry and its products consume approximately 40% of energy and natural resources, and generate 40% of pollution produced by human activity as a whole, reaching up to 75% in the USA."

This article describes and discloses information about the stabilized rammed earth (SRE) technique practised in Australia, more precisely, experiences experienced and developed in Melbourne, Victoria. After discussing the difference between the contemporary Australian practice and the traditional rammed earth practised for centuries in Brazil, for example, the article comments on some particularities and characteristics of the design and execution of this technique.

The vast production of earth buildings currently in Australia has its origins in the second half of the nineteenth century, but it was 100 years later when rammed earth became an extremely popular technique in many regions of Australia, this recent architectural production has been thriving perhaps because of the lack of use history of earth buildings, which differs from other countries where it is related to historical heritage and precarious or low-income buildings.

Although there are other techniques with earth in this country, such as adobe, compressed earth blocks and mixed techniques, it is a fact that rammed earth predominates in contemporary Australian architecture, resulting in one of the countries

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that has invested most in regulation, university research and in the current implementation of numerous projects (Fernandes 2013, p. 20).

A little of this Australian experience is shared in this paper, which intends to describe and comment a little on the use of rammed earth with stabilized earth.

8.2 About the Production of Rammed Earth Made in Australia

In order to start the discussion about the production of rammed earth, it is necessary to look for a production chain that is structured in three factors emphasized here: in the obtaining of the material, in the manufacture of the formwork and in the expertise of the technicians and constructors. These last two points are related in an inextricable way, since it was from the practice of builders and technicians that the construction system was developed, resulting in the change of the manufacture and design of the forms, a central component for the production of SRE walls. Many Australian architects and engineers now know how to design and calculate for the use of rammed earth, which encourages and expands production, and consequently enables more builders to know how to work, and more products and equipment related to SRE production can be improved to optimize the production of this technique, which can be highlighted as an important contribution of the Australian practice.

On obtaining the construction material, earth, it is important to point out that is not restricted only to that present at the building site. In Australia, suppliers of soil and building aggregates, usually companies that provide paving material for roads and highways, generally located on the urban outskirts, are also responsible for providing material for the production of SRE. These companies provide different types of aggregates, typically types of gravel, rock sediments, sandy loam and clay with various granulometries, grind and reutilize concrete and burnt clay bricks. Diversity and availability of soil and aggregates are essential for the production and propagation of SRE buildings.

After observing the obtaining of the material and briefly pondering its execution, it concentrates on the specificities of the forms used for the execution of the walls, since these are different from those destined to the construction in reinforced concrete. Generally, the forms in question are produced by the constructors themselves entirely in wood or with a metallic structure, as will be seen in detail in the following item, in addition to Figs. 8.1 and 8.2 that illustrate the main instruments and tools necessary for the realization of the work.

Fig. 8.1 Equipment used in the building process of the stabilized rammed earth (*Photo* Oliver Petrovic 2014)

Fig. 8.2 Manufacturing of the steel framework and its use in the construction process (*Photos* Rodrigo Rocha 2015)

8.2.1 Differences Between the Traditional Latin American Method and the Contemporary Australian

The Australian method of SRE has significant differences if compared to the traditional rammed earth technique. Two main points stand out: the stabilization of the earth and the manufacture of the forms, also the mechanized compaction that confers effectiveness and adequacy to the contemporary production.

The traditional procedure for executing SRE buildings is through the use of timber frames locked by fixed or mobile external columns and filled with a mixture of soil with natural stabilizers, the clay already present in the used soil or lime.

Fig. 8.3 Example of the building process of a 12-m-tall reinforced SRE tower (*Photos* Oliver Petrovic 2014)

On the other hand, the Australian practice, besides using cement as the main stabilizer, it is a steel formwork and locked horizontally, avoiding the need for external columns. This allows the builders to build from outside the wall, on platforms over brackets cantilevered on the frames themselves. This change brings important changes to the construction system of rammed earth, as it gives agility to the construction process, enabling a continuous and efficient work. Another change, in aesthetic and economic terms, is the fact that with these forms the walls can be up to 20 cm thick, slenderer than those made by the traditional technique, usually with a minimum of 40 cm.

There is also a change in the design and structural performance of the wall. In the traditional technique, the rammed earth is maintained by its own weight, because the resistance of the wall is in the great inertia of its mass; thus, it resists only the compressive stresses, and thus is self-supporting. In contemporary practice, however, the SRE can function in a different way, similar to a reinforced concrete structure, which is resistant to tensile stress due to the stabilization with cement and with reinforcement in steel bars, as shown in Fig. 8.3 of the execution of a tower of 12 m of height.

(a) Manufacturing and use of the formwork

The formwork predominantly used in Australia was created in Perth, in Western Australia. After many years utilizing a formwork with a timber structure, plywood plates and specific tools and equipment (such as locking columns, screws, spacers, scaffolding and others), builders realized they could increase efficiency by using a formwork with a steel structure and plywood plates.

These plates have standard dimensions between 30 and 60 cm in height and 240, 180, 120 or 90 cm in length and weighing between 10 and 30 kilograms. The forms are structured by pre-fabricated, welded steel parts—a standard created due to the

Fig. 8.4 Different SRE types on the forefront of the Olnee Constructions office (*Photo* Rodrigo Rocha 2015)

need to customize the formwork, as shown in Fig. 8.4. A plywood plate is screwed onto the steel frame, and holes of 1.5 cm in diameter are drilled at every 15 cm on the upper and lower sides of its longest extension. These holes make it easier to assemble the formwork but will be visible on the finished surface of the wall when the formwork is removed. A layer of glass fibre resin is applied to the surface of the plywood to protect it from contact with the soil, ensuring its waterproofing and longevity, and also making it easier to the disassemble the formwork. It also safeguards the quality of the surface on the finished wall.

(b) Ideal mixture and mixing, soil types, and usage of cement and water

The stabilization of the rammed earth with cement allows it to be used in external environments and eliminates the need for plastering or coating.

According to Ciancio and Beckett (2015), the amount of cement in the mix is of 5–15% is required to ensure endurance to structural stress, longevity, stabilization and ability to withstand loads in compression. According to Dobson (2015), the moisture content is related to the type of mixing and compaction, aiming at the maximum dry density to guarantee a compressive strength of 2.5–5 MPa (25–50 kgf/cm^2), enough for using the SRE as sealing masonry, according to Middleton (1992).

The types of soil used in SRE in Australia vary according to the needs of the design and the use of the walls. According to Middleton (1992), usually one or two types of soil are used with not more than 2% of organic matter, free of leaves or branches with 5–20% of clay (including mud and silt), a minimum of 30% of sand, stones no larger than 40 mm and humidity between 4 and 12%. In some cases, crushed concrete or brick are also used as aggregates, materials found in conventional building waste.

Figure 8.5 shows, on the left, SRE wall that supports all loads of the roof structure with thermal insulation embedded in the wall to increase the thermal resistance of the wall and, on the right, the wall assembled over a window span of 1.2 m.

Fig. 8.5 Example of a curved reinforced wall with insulation, 2.5 m^2 K/W of thermal resistance, and a reinforced SRE beam with foam as an expansion joint (*Photos* Oliver Petrovic and Rodrigo Rocha 2014)

Additives are included in the mix to increase the longevity of the wall. It is suggested to use 1% of *plasticure*, a product developed by Techdry[1] for soil–cement monolithic walls. When added to the rammed earth mix during the manufacturing process, this water-repellent admixture will ensure water, salt and mould repellency, and strengthen the structure. It is also used in low concrete *slumps* (low consistency concrete), and its role is to ensure long-term resistance against weathering and deterioration. After the formwork is removed from the finished walls, their external faces receive a layer of a colourless solvent-based silicone binder, a penetrating sealer, which reaches deep into the capillaries of earth surfaces, providing the substrate with dust and waterproof sealer effect. As the strong water repellency reduces the absorption of water substantially, the occurrence of efflorescence and other waterborne staining effects are as good as eliminated, also prevents surface abrasion, that is responsible for most of the degradation in rammed earth structures. The manufacturer guarantees that the surface appearance and breathability are not significantly affected.

A mini loader is used to best prepare the mixture, as it ensures the materials are thoroughly mixed. Mixers are not recommended since the low-humidity mixture tends to stick to its walls and do not mix properly. The mini loader is also capable of placing the mixture into the formwork up to 3 m high, the limit its bucket can reach.

(c) Design details

Knowing how to design for SRE and its possibilities are essential for a plan that respects the technique's needs and potential. It resembles reinforced concrete, since they are both self-bearing and have a structural feature strong enough to support compression loads. According to Ciancio and Beckett (2015), SRE ranges from 1 MPa (10 kgf/cm^2) to 47 MPa (470 kgf/cm^2) of compressive strength, considering

[1] www.techdry.com.au.

Fig. 8.6 Detail of built-in electrical installation, example of built-in steel column and contrast with corten steel (*Photo* Rodrigo Rocha 2015)

the size of the steel structure incorporated inside the walls, granulometry of the aggregates, ramming pressure and quantity of cement and water in its composition.

A steel frame with the desired shape is required when executing fireplaces and ovens in SRE. The frame is incorporated into the building's wall and solid walls are built on its side, underneath and on top of it. The air vent must be centralized and end higher than the final surface of the wall.

The finishing of the top of exterior walls that are exposed to weather must receive a mix of water and *plasticure*, or like is it in other countries, adding a higher concentration of cement in the mix of its top layer.

When the architectural project is finalized, it is possible to plan the electric and hydraulic installations inside the walls. Future changes to them are not viable, as can be seen in Fig. 8.6. Connections to beams and structural columns allow the SRE to interact with other materials, like steel and timber, and other building techniques such as reinforced concrete, as shown in Fig. 8.7.

(d) Construction details

The execution is relatively simple and the building system is comprised of four people in the building site: two professionals with experience in carpentry, masonry and reinforced concrete, and two other workers that can be inexperienced. It is necessary to emphasize the importance of the design stage, which defines the position of the forms and distance between expansion joints, besides resolving architectural details, structural, electrical and hydraulic connections. The SRE execution can be roughly divided into two stages. In the first one, the formwork is assembled and the material mixture is placed in layers between 15 and 20 cm deep and rammed until the desired height for the wall is reached. Each compressed layer leaves a defined line on the wall's face, as visible on Picture 1. The second stage happens on the following day and consists of removing the formwork, triggering the wall's curing process. There is no need for any rendering or waterproofing.

Fig. 8.7 Example of connections to timber floor and steel roof beams (*Photos* Oliver Petrovic 2014)

Fig. 8.8 SRE building process over T-shaped steel beam and built-in steel column (*Photos* Rodrigo Rocha and Oliver Petrovic 2014)

At the start of the construction of a wall, the foundation block receives a strong and thick layer of cement and water, waterproofing it and working as a transition between the surfaces, strengthening the wall's stability. To execute SRE beams, T-shaped steel profiles are used and connected to the steel columns inside the walls. It is recommended to coat the steel column with expandable materials, such as expanded EPS foam, to absorb the movement between the metal structure and the wall. To execute a wall above the steel profile, a formwork is built on top of timber joists temporarily screwed to the wall, and temporary timber columns made *in loco* are used to support the beam until the formwork is disassembled.

The use of T-shaped steel profiles allows for a span of up to 10 m (Figs. 8.8 and 8.9). For spans of up to 4 m, it is recommended the use of only two 12 mm steel

Fig. 8.9 SRE building process over T-shaped steel beams (*Photos* Rodrigo Rocha 2015)

Fig. 8.10 Examples of use of formwork and aluminium platforms resting on cantilevered brackets in the SRE walls building process (*Photo* Rodrigo Rocha 2015)

rebar each 20 cm horizontally, connecting the side walls and supporting the beam's traction movement.

The curing process of a wall will depend on the quantity of cement and clay in the mix as well as weather conditions. Studies reveal that unstabilized rammed earth can take up to two years to complete its curing and retraction process, but this process is reduced to up to 30 days when cement is used. Depending on the amount of water in the mix, and if the external temperatures are high and air humidity is low, it is recommended to water the walls on the days following the framework removal to ensure they will not retract too quickly, causing fissures and cracks due to expansion and chemical reactions between components in the mixture.

To cover cracks and imperfections on the walls, it is recommended to wait until the curing process is finished. When doing it, it is imperative to use the same proportions in the new mixture to avoid changes in colour and texture in the corrected surface. In some cases, colourless water repellent is applied to the external walls after the cure process is over.

In relation to the formwork, it is recommended to standardize the height of the walls to multiples of 30 cm, and to avoid ending the walls halfway through the

Fig. 8.11 Examples of stains on wall caused by bad execution and/or design (*Photo* Rodrigo Rocha 2015)

forms, ensuring the top of the walls are levelled. A choice must be made between a superimposed or interlocked formwork layout depending on the desired appearance, as shown in Fig. 8.10.

8.2.2 Construction Pathologies

Stains are recurrent on SRE walls due to their curing period, which depends on the amount of clay and cement in the mix, as previously mentioned. Because of its water repellence, the use of *plasticure* allows a uniform and stain-free finish. Nevertheless, it is important to make sure no materials resting on top of the walls come in contact with water, as they can release minerals, impurities and chemicals that might interfere in the colour of the wall's surface. Tannin from timber and rust from metals are examples of these substances, and the consequences of their contact with SRE walls can be seen in Fig. 8.11. The tops of external walls must be protected from impurities, as rainwater can spread them along its sides, also causing stains.

8.3 Final Considerations

This article addresses a possibility of building with SRE nowadays. It is important to emphasize that the use of cement as a stabilizer makes it difficult to dispose of the wall in part since in a structured production chain, such as the Australian one, the discarded wall can be crushed and reused as an aggregate for other purposes or even for other SRE. The basic characteristics of SRE construction technique were summarized, gathering information and data that can help in the research about the techniques that use the earth as a construction material.

The earth, despite being proportionally the most used material in the world in construction, in the usual markets of Brazil is still classified as an alternative and primitive material. Most architects, engineers and builders are reluctant to use earth building techniques in projects because they do not know the present applications and possibilities of using this material found in abundance. Presenting how it is possible to build with earth today was, therefore, the main incentive of the article.

This article depicting Australian examples, which have a productive chain developed under construction with SRE, is written under the architect's eye that has experience in the use of SRE in Brazil and Australia, thus understanding the needs of the local market and the potentialities of the construction system in question, providing design and construction information for SRE, as they are being developed and employed in contemporary architectural production in Australia.

In order to promote the use of this technique, theoretical and practical knowledge must be promoted, as well as providing technical information about the use and applicability of this construction technique, which combines traditional knowledge with the current development of technology.

It is essential to build to understand the process of building a SRE wall, as well as designing to optimize the construction details and to improve the development of the technique. It is hoped, with this study, to encourage the research and application of this constructive technique in the academic and professional environment, expanding the use of raw or stabilized earth as a way to mitigate the environmental impact caused by the construction industry.

8.4 Citations

The building industry and its products consume approximately 40% of energy and natural resources, and generate 40% of pollution produced by human activity as a whole, reaching up to 75% in the USA (John et al. 2001, p. 92).

Although there are other techniques with earth in this country, such as adobe, compressed earth blocks and mixed techniques, it is a fact that rammed earth predominates in contemporary Australian architecture, resulting in one of the countries that has invested most in regulation, university research and in the current implementation of numerous projects (Fernandes 2013, p. 20).

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