Terracotta

Remixing Australian Rammed Earth Architecture

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As Lecturer-in-Charge of the architecture course at Sydney Technical College, Hadley built “one of the finest schools of architecture in the Empire” and is credited with gaining Royal Institute of British Architects (RIBA) recognition of the course, which gave post-1923 graduates exemption from the RIBA examinations.

As an architect in private practice, Hadley drew from a wide range of revival styles in his designs for significant urban and suburban commissions, which included two town halls, several multi-storey city warehouses, numerous suburban churches and Sydney University’s original Wesley College and chapel.

Hadley’s “greatest contribution to NSW architecture remains his insistence on the importance of travel in Australian architectural training.” In 1928 and 1929, Hadley sponsored two £25 scholarships through the Board of Architects of NSW. The success of these must have provided the catalyst for his 1937 bequest.

The Byera Hadley Travelling Scholarships have been awarded since 1951 as a result of the Trust established by the Byera Hadley estate. The list of scholarship recipients over the years includes many architects who have contributed enormously to the profession and the broader community.

The Scholarships are awarded annually and administered by the NSW Architects Registration Board (the ‘NSW ARB’), in close collaboration with Perpetual as trustee.

The NSW ARB acknowledges that all text, images and diagrams contained in this publication are those of the author unless otherwise noted.

Clare Dieckmann was awarded the Byera Hadley Travelling Scholarship in 2021.

Cover image: Equestrian Centre Merricks. Photo by author

I'd like to begin this research by acknowledging the Traditional Owners of the land on which this project was undertaken. I would also like to pay my respects to Elders past and present.

Contemporary rammed earth buildings present an alternative material choice for Australian architects. Earth can be recycled endlessly, making unaltered mixtures of earth the most sustainable option.[1] The sustainable potential of earth is raising awareness towards where our broader construction industry chooses to extract materials from and our impact on the natural environment. Rammed earth buildings are often located within rural and regional settings set amongst beautiful landscapes of wine-growing vineyards in nutrient-rich soils. Australian rammed earth walls are coloured by the unique mineral composition of soil stamped beneath our feet.

The mild-temperate climates covering the Australian continent prompts Australian architects to design buildings from rammed earth made from red-brown coloured soils on subsoils rich in clay. The temperate-oceanic climates of southern Europe inspires European architects to utilise the thermal properties of earth, making earthen buildings with earth comprised of clay and loam. Rammed earth buildings in Australia and Europe are examples of architects responding to their local climate using natural resources readily found in the ground around them. This study of local soils and their history will reveal new ways of responding to our climate while protecting our natural resources.

Terracotta: Remixing Australian Rammed Earth Architecture

1. Introduction

In an aerial view up above Equestrian Centre Merricks, meandering pathways interlace between green rolling hills in an undulating landscape. The pathways travel between rows of trees and timber picket fences before curving around a lightly coloured rammed earth wall. The trail curves beside the wall until it reaches the edge of an Olympic-grade equestrian arena. Equestrian Centre Merricks is designed by Rob Watson from Watson Architecture + Design and Seth Stein Architects in the scenic Mornington peninsular landscape. A gradually curving rammed earth wall encompasses the centre and is made from the same colour of sand covering the horse jumping arena. The arena's edge is surrounded by a timber fence and gravel pathways leading horses to the stabling areas made from rammed earth. Stables, paddocks and rider's accommodation are built from oiled timber batons and a robust, thermal mass of rammed earth, keeping temperatures inside the stalls suitable for horses. Square windows cut into the wall are large enough for horses to poke their heads through and converse with other horses in the neighbouring fields. The journey down the spine of the Mornington Peninsula to the Equestrian Centre takes travellers through vast expanses of green fields, thick forests and beautiful landscapes. When venturing through the vibrant Australian landscape, flora, fauna, and nature come alive, expressing their personality.

Looking at an image through a window between two rammed earth walls at Mystery Bay House is a spectrum of pinks, reds, oranges, purples, and blues shining the colours of a sunrise. The tones of colour thrown across the morning sky seem to join with the surface of clay packed together to make the rammed earth wall. The earthy brown colour of the wall matches the colours of the sky. Mystery Bay House, designed by Jack, Rob and Sally Hawkins, is located on the south coast of NSW and, running along the spine of the house, is an earthy-coloured rammed earth wall that changes colour according to the time of the day. The spectrum of colour ranges from a deep earthy pink to a light paper tone during the course of the day. A richly textured surface complements the variations of colour, with plywood grains and formwork indentations left behind from the construction process present on the wall. When running a hand along the surface of the wall, the texture feels like loose soil to the touch, seeming like the soil aggregates might fall out if it were not for the clay sticking the wall together. The coloured spine of rammed earth nestles into the side of the hill by the bay and is complimented by the vast expanse of natural green landscape extending as far as the eye can see. Although the soil was not taken directly from the hill, the earth is a reminder of the natural landscape the house sits upon. The colour of the soil an indicator of where the earth was initially taken from, and the colours of mud hidden beneath a layer of green grass.

This Byera Hadley report is not meant as an instruction manual for how to build with rammed earth but is intended as a study of rammed earth under three methodologies. These methodologies are interviews,

Mystery Bay House: Yuin/
Eurobodalla. Photo by Rob Hawkins

site visits and historical case studies exemplified by the following: In an interview with Anna Nichols about her Sacred Mountain House, she describes an appreciation of rammed earth. She expresses how the house sits within the landscape of Mulbring, having a harmonious relationship with the adjacent mountain. She narrates how the natural landscape beautifully complements earth's natural grace and simplicity. During our interview, she highlighted how earth is a naturally waterproof material that can breathe, is porous and capable of withstanding environmental weather patterns. I asked all interview participants, including Anna, about what they thought the future of rammed earth would look like, with most of them optimistic, believing rammed earth would become more popular in the future; Before my site visit to PottersCroft in Tasmania, I couldn't have predicted what I would find. Upon arrival, I was pleasantly surprised to find a clay workshop with a kiln and a ceramics studio. To photograph the collection of buildings, I took to the sky with a drone to take shots from up above. Aerial photographs capturing more of the landscape and locating the ceramics studio's rammed earth walls within their rural context. Photographs captured while standing on the ground recorded more rammed earth details, including materials and surface texture. These techniques were replicated across all rammed earth site visits, providing a consistent aesthetic for this study; Research into the historical Villa Ficana in Italy examines how earthen houses constructed during the nineteenth century have aged over time. The village is one of the few remaining examples of a town made from the material. Terrace houses are constructed in rows next to one another, each house leaning on the other for support. Conservation efforts to save these terraces have brought people back into the village to live, and the Ecomuseum has helped teach the community to appreciate their earthen heritage. These three methods, including interviews, site visits and historical case study research, provide a medium through which Australian architects can learn new ways of innovating with rammed earth.

This study is arranged into four chapters titled non-stabilized rammed earth, prefabricated and modular rammed earth, rammed earth conservation and houses built with mud. Each chapter represents one major trend in rammed earth innovation and a packet of knowledge for Australian architects to utilize with their own practice. The first chapter focuses on non-stabilized rammed earth with a historical case study of the Centre For Alternative Technology in Wales, whose WISE building is made from rammed earth. The centre's advocacy for sustainable materials is followed by an interview with the builder of Edgars Creek House, who constructed a rammed earth façade and fireplace for the house. Similarly, Edgar's Creek was designed by Breathe architects, who advocate for sustainable building materials; The second chapter focuses on prefabricated and modular rammed earth. Research into the compressed earth blocks prefabricated for Sverre Fehn's Mauritzberg Prototype House exemplifies how earthen architecture was adapted for the Scandinavian climate. This research is followed by a study of Le Corbusier's Cité Permanente, where modular rammed earth units stack in a variety of formations across the landscape. An interview with Lehm Ton Erde provides an example of how contemporary architects prefabricate earthen walls with robotic technology. Lehm Ton Erde affectionately named their robot Roberta and have constructed their Werkhalle around the robot; The third chapter focuses on rammed earth conservation. Conservation of the Villa Ficana in Italy has brought the community together to live in rammed earth houses, fostered by a renewed appreciation for their earthen heritage. Similarly, Granada's Alhambra Gardens and Palace conservation effort is paired with an archaeological investigation. Conservationists make new discoveries about the palace while they work. An interview with John Jeffrey from Architectus reveals how the rammed earth walls of the Sydney Modern negotiated with the domain's garden landscape; The fourth chapter focuses on houses built with mud. An analysis of Hassan Fathy's book, *Architecture For The Poor*, shows mud building on an urban scale, with each home in New Gourna made from mud brick. Fathy relied on the skills of local builders to construct domes made from earth and mud bricks were prefabricated by the villagers. An interview with Cameron Anderson about the winery at Rosby exemplifies the strength of local knowledge, with local builders sourcing clay from locations only a few kilometres from the site. The fertile soil providing an optimal landscape for growing grapes. Most case studies are located within rural and regional areas, where buildings are made from local soils unique to their landscape.

Mystery Bay House: Yuin/Eurobodalla

Soil colour samples made from clay. Colours are based upon the averages of all rammed earth destinations visited.

Alphabetical List Of Destinations

This project encompases 5 states and territories within Australia. They are New South Wales, ACT, Victoria, Tasmania and South Australia.

The European portion of this study encompases 6 countries. They are Spain, Portugal, Belgium, Switzerland, Austria and the UK.

All case study photographs were taken by the author unless otherwise noted and all chapter images are referenced at the end of this report.

The composition of soil upon which each rammed earth building sits is noted underneath their photographs. Each soil type was referenced from the Harmonized World Soil Database map. The interactive map can be found here: https://hqfao.maps.arcgis.com/apps/dashboards/ab43f3f516364e77998f0c0abf655571

The average climate category for each destination is noted underneath their photographs. Data relating to Australian destinations was referenced from the Australian Building Codes Board's Climate Zone Map. The map can be found here: https://www.abcb.gov.au/resources/climate-zone-map.

Data relating to international climate zones was referenced from the Koppen-Geiger Climate Classificiation Map. This map can be found here: https://www.koppen-map.com/

All Australian rammed earth destinations are hyphenated with their traditional place names.

Equestrian Centre Merricks

Interview with Robert Watson from Watson Architecture + Design about the curved rammed earth wall at Equestrian Centre Merricks. The Equestrian Centre is located on the Mornington Peninsula.

CD:
How is flooding managed and how does water move across the landscape?

RW:
You can see the landscape is very wet here, and this is the nature of this peninsular area. We have no water retention problems here as there is a natural streamline that flows through, and a natural spring is located up this little gully that runs in summer too. The streamline runs through all these properties and drains out into the bay. Underneath the middle of our paddocks are three water tanks storing water. We won't have a shortage of water at the Equestrian Centre.

CD:
Are you experimenting with rammed earth mixtures?

RW:
The original location we typically source rammed earth from ran out of their mix, so we searched for another quarry. This quarry produced a much lighter-coloured aggregate. Throughout the testing process, we experimented with a recycled concrete addition to the mixture of earth. For the client, we made a batch of standard mix and a recycled concrete mix. When our contractor showed the client both combinations, they didn't tell us which was the concrete mix. When the client was asked which one they preferred, they chose the concrete mix. There's a recycling depot on the peninsula where the recycled concrete comes from. They crush the concrete there, recycling everything they can get their hands on apart from the steel reinforcing inside. We are building another project out of the recycled concrete mix.

CD:
How was the curved wall around the Equestrian Centre constructed?

RW:
We didn't use curved formwork for this wall because the curve is such a gentle sweep that we could facet each section. There are heavy bendable forms that can be curved into shape if we decided to bend each section. In another one of my projects, there are a couple of walls with a tight radius, and we are going to make custom curved forms for those. The bendable rubber forms are a good idea, but they do have their limits.

At the Equestrian Centre we stacked our formwork in 600mm risers. At a 600mm height, you can achieve an excellent compaction compared to 1200 or 900 shutters. We kept the strata at 600mm rises, and the thin layers didn't worry us at all. We were satisfied that a 600mm thickness would be robust enough.

The labour process is quite intense. The rammed earth contractors work quickly, and you try not to get in their way when they are on site. I have observed that the contractors are very good at getting the moisture content right, so the mixture compacts well. Once the mixture is compressed, they pull the form off immediately because it doesn't need a long setting time. There is cement in this mixture, which takes some time to set, however it is okay to pull those forms off as soon as they finish a row.

CD:
How does the soil compact quickly?

RW:
The setting process is a matter of moisture content and compaction, like a dry cake mix. The trick is getting the mix right. The rammed earth sits on concrete footings, and there are reinforcing bars inside the rammed earth for support. The reinforcing bars are challenging to ram around, but they strengthen the wall.

On another project, we are attempting more ambitious curves. We are placing reinforcing mesh inside these walls to give them more strength. These walls are insulated inside and have a 75mm Styrofoam layer between two earth layers. The Equestrian Centre's walls are pure rammed earth walls all the way through with no insulation inside. The insulative properties of pure rammed earth regulate the temperature enough for the horses. Horses don't like temperatures too warm.

CD:
How did you achieve the chamfers and openings in the rammed earth?

RW:
Rammed earth contractors are reluctant to leave the ends of rammed earth walls with a square edge. So, they place a piece of timber inside of the formwork mould. At the top of the run, another box sits there with a 50mm chamfer on it. The edges will break if the incorrect angles are applied to them. We are going to try and make these chamfers smaller through a process of trial and error.

All the rammed earth sections lock in together for stability. In this project, we built the wall in one direction so each portion could interlock and help with the curved wall's strength.

CD:
How is the wall supporting the weight of the roof on top?

RW:
The roof load has to get down to the ground. There are a series of posts inside of the rammed earth with plates on top to transfer this load from the roof to the ground. Rammed earth is good at bearing distributed loads however, not point loads. Where point loads occur underneath the roof, we take the load straight down to the footing. For a domestic house, rammed earth is fantastic at transferring loads to the ground as the forces are uniform.

CD:
How do the horses interact with the wall?

RW:
When the horses are inside the stalls, they like to poke their heads out of the windows and look at neighbouring horses in the other paddocks. The horses do enjoy having a connection with each other and talking. Within each double stall is one window cut from the rammed earth wall to look out from.

Closer to where the horses are located in the Equestrian Centre, we have chosen to use more timber. We thought the exposed rammed earth might be a bit too rough on them, but the horses have kicked the wood, and they haven't kicked the rammed earth.

CD:
How are the stalls ventilated and cooled?

RW:
The double stalls have a ventilated panel in the ceiling that allows the stalls to breathe. In addition, the window is positioned opposite the stall door to achieve cross-flow. We haven't sealed the top from the cold weather, and the roof ventilation works well during the warmer months. Even on 40-degree days, the stalls breathe out through the top because of the height and the roof angle, and the cross ventilation works very well. The stall temperature is comfortable for the horses.

CD:
How does the rammed earth weather?

RW:
The end of the wall exposed to the weather is a different colour due to the wet weather. When we have a lot of rain, the wall does get wet, however, the rammed earth will dry out and return to the light colour of earth again. The wall still has little imperfections on the surface from construction, which some people worry about, but I think these add to the walls' uniqueness.

Sacred Mountain House

Interview with Anna Nichols about Sacred Mountain House. Sacred Mountain House is designed by Peter Stutchbury Architecture and the house is located in Mulbring, New South Wales.

CD:
What are the characteristics of rammed earth you admire, and why was earth the right choice for your Sacred Mountain House?

AN:
Rammed earth is an ancient building material, employing an age-old construction method for today's use. Earth's grace and simplicity are beautifully contrasted with a unique thickness and character. Rammed earth has excellent passive solar qualities, including a monolithic mass that doesn't present as austere or cold yet is incredibly warm in spirit, having an almost matriarchal energy! Feminine grace, strength and stability are expressed with an organic look and feel. Absolute perfection is balanced with a pattern of imperfections.

CD:
Does rammed earth belong to Mulbring's landscape, and what made this place suitable for a rammed earth house?

AN:
Mulbring's landscape is ancient. Peter (Peter Stutchbury Architecture) spoke to me about the ancient escarpment above where the house is located. The mountain above and the house below bring harmonious balance to the landscape, and I am a great believer in the synergy of spirit, 'as above, so below.' Similarly, the house is made of earth, on top of a sacred mountain formed of ancient soil.

Millennia ago, Mulbring's lush green grass was once a bed for coral and fish on the bottom of a Triassic-age ocean. You can find many fossil specimens here, especially around the Mulbring Quarry. Our choice of materials reflected ancient layers of sand, sediment and fossilised life hidden beneath the earth. These unique layers are why I chose rammed earth. You could say the ground beneath our feet is also a type of rammed earth. Over thousands of years, life is layered and compressed, slowly forming the great mountains of our landscape. We found many fossils on-site during the excavations of our home's foundations. These fossils are very similar to our rammed earth samples!

CD:
The combination of rammed earth, plywood and glass is harmonious and beautiful. Can you describe how the natural strata of rammed earth walls match the wavy grains of plywood ceilings?

AN:
I was worried the ply would detract from the rammed earth, as I wanted the rammed earth elements to be the main focus and for the earth's layers and organic nature to shine. I personally feel the plywood detracts from this. However, many people who have visited the house love the combination and make encouraging comments. I guess the grains seem wild in an otherwise minimal pallet of materials. So, in some ways, the material pallet works.

CD:
The colour of rammed earth used for Sacred Mountain House is unique. Where was the soil extracted from, and what portions of material were mixed to create the final colour?

AN:
I was very particular about the colour. The colour you can see was exactly to my specification, and samples were made to test the colour and ensure the final pigment matched what I envisioned. The earth was sourced from Karuah, a town less than an hour north of here. Earth sourced from Karuah's landscape made our rammed earth walls have a distinct red-toned surface. I avoided the more orange earthen tones and the more mushroom taupe colour sometimes seen in rammed earth walls. The Karuah Quarry's location and colour produced the perfect result for us, so we settled on those colours. For the earthen wall's stability, fly ash and cement were added to the mix, and these additional materials gave the surface pigment a more muted tonal range.

CD:
How were your earthen walls waterproofed?

Rammed earth is naturally a waterproof material through the process of compression. The walls appear porous and do indeed 'breathe' by way of thermal capacity; however, earthen walls do not retain or absorb moisture. The mixing process only uses a slight drop of water or a light sprinkling of water with a green hose before mixing to minimise the amount of dust. The method of mixing rammed earth is nothing like mixing concrete or cement.

The walls are 400mm thick, so if they were to absorb or decompress due to weathering, effects would only be seen over hundreds of years. Long after the remainder of the building has disintegrated!

A water-based acrylic sealer was applied to the interior and exterior to minimise the walls' 'dusting', but this has little to do with waterproofing. The walls are identical inside and out, so there was no need to waterproof the exterior walls.

Unfortunately, building regulations stipulate a waterproofing product for wet areas. So, a clear waterproofing membrane was applied inside the bathroom areas. Thankfully, the product we chose is entirely transparent and has no shine or finish to compromise the natural look of earth. The membrane does, however, provide a level of protection from chemicals the modern homeowner may wish to use in their bathroom, like shampoos or chemical cleaners. Rammed earth contractors do not recommend these types of chemical products make contact with the wall, as there are several unknowns about how chemicals will react with the surface. Similar to natural products like marble or timber bench tops.

I had researched ways of naturally waterproofing the walls using the ancient method of lime scaling. The lime scaling process creates a soap scum on the walls, forming an impervious layer. I find it hilarious that we buy chemicals to remove soap scum or mould where mould was once a naturally occurring protective layer! Much the same as using modern paraben-based soaps on our skin and hair, only to reapply 'false' moisturisers and protectors.

CD:
Were there unexpected circumstances that occurred on-site, requiring innovative techniques to solve them?

From a cost perspective, we chose single-height Besser Block walls for the basement below. Having a larger budget, we would have made the entire double story from earth. However, two levels of rammed earth would have increased the walls' cost, size, and thickness. Ben and Rick (Rammed Earth Experts) advised Besser Blocks to remain within budget constraints.

CD:
Do you think rammed earth will be more widely used by people designing and building their homes in the future?

I wish it would be! Although there is a part of me, who wants to keep all the rammed earth houses for myself.

Mystery Bay House

Interview with Jack Hawkins about the rammed earth spine at Mystery Bay House. Mystery Bay House is located on the south coast of New South Wales.

CD:
What factors made you choose rammed earth for Mystery Bay House?

JH:
The clients (my folks) had always wanted to build with rammed earth. They were drawn to its unique warmth, texture and natural variation. We were also keen to increase the amount of thermal mass in the home, to offset the large areas of glass.

We started talking to our rammed earth contractor (Earth Structures) very early in the design process, and over the 2 years before we began construction, we refined the design and the mix.

During concept design, we built a series of prototype rammed earth bricks. Soil from the site was tested for plasticity index, lineal shrinkage & a sieve test for granular sizes. Unfortunately, this soil was deemed unsuitable because of the high silt (fine clay) content which causes cracking.

After much debate, numerous visits to quarries and rammed earth buildings around NSW, we decided to proceed with rammed earth, using a crushed red granite gravel from a quarry in the ACT. A wider range of soils are suitable when a small amount of cement is added to the mix, so we explored this too. It was disappointing not to use earth from the site, but we were able to use a locally sourced sand in the mix.

The final mix consists of crushed red granite, sand, cement, plasticure & water.

CD:
The colours of your rammed earth are distinct. How would you say they create a unique living experience?

JH:
The colour comes from the earth and sand in the mix. There's also a bunch of variables during mixing, filling and compaction, which contribute to the final colour.

During the day the natural light changes and with it the colours of the rammed earth. The red, oranges and pinks at sunset and sunrise have a beautiful effect on the wall. At night, in-ground LED wall washers up light the rammed earth internally, amplifying the texture and form markings.

CD:
When looking at each of those samples, did you consider the life cycle of the rammed earth?

JH:
We designed the home to last a long time, and so rammed earth's durability made it a solid choice. The small amount of cement in the mix, makes it a Cement Stabilised Rammed Earth (CSRE) wall. It's a variation on the traditional rammed earth used in ancient buildings. Whilst the cement content increased the embodied energy to the wall, it also improved the strength and durability.

CD:
What elements does the rammed earth wall support, and how strong is the wall?

JH:
The wall was originally designed to support steel-plate fins, glazing and a steel framed roof. The structural engineer designed large masonry anchors to fix the steel frame to the rammed earth. The wall was more than capable of supporting these loads.

However, as we planned the construction program, we realised that we needed to erect the entire steel frame before the rammed earth wall was built. So, we added steel columns, concealed within the thickness of the wall. The final rammed earth wall was built around the columns, making it non-load bearing.

CD:
What influenced your design decisions when choosing how much rammed earth encloses each room?

JH:
The rammed earth wall provides refuge from cold winds that cut across the exposed site, and thermal mass for passive heating and cooling. We wanted to see it both internally and externally.

The long plan is divided into four zones: the main sleeping quarters to the north, a living and cooking area, a service core, and a self-contained guest wing to the south. The rammed earth spine runs end to end. On the Eastern elevation, fine edges of steel provide a counterpoint to the monolithic rammed earth.

The house is only one room deep, so every room has a connection to the rammed earth wall. It features strongly in the open plan living, dining, and kitchen.

When the hallway doors are open, there are axial views along the length of the wall.

CD:
Can you describe how openings were designed within the wall?

JH:
Four oblique slices create an entry and framed views of the terraced garden.

At sunset and sunrise, these openings allow shafts of sunlight to pass through the building, like a giant sundial. The openings also provide some directional wind protection.

These sliced openings were a unique element of this rammed earth wall, and something our contractor had not done before. To create the tapered edge, we made a special steel form using a split round pipe.

CD:
How vital was the wall's thickness when designing angled chamfers?

JH:
The wall varies in thickness from 450mm to 900mm. The thinner sections of wall give space back to the hallway. The wall is thickened around outdoor areas and where splayed openings occur.

The openings are cut on a 35-degree angle, creating a 1500mm shear face of rammed earth.

CD:
Earth Structures were the contractors on this project. What methods did they use?

JH:
Earth Structures is a collective of skilled tradesmen from around Australia, with lots of knowledge and experience in rammed earth construction. A team of four built the wall at Mystery Bay.

The wall is 52 lineal meters, which was divided into 18 panels. The team built one full panel per day. Each panel was about 2 - 3m long x 2.5m high. All the mixing was done using a Bob Cat and the bucket gets loaded directly into the form. If it rained, they couldn't work as because the bob cat wheels would carry mud into the mix.

They used a modular prefabricated formwork, which could be assembled and taken apart quickly. The formwork is made from steel frames with a form ply lining. The ply can be replaced after a certain number of jobs.

Between each panel is V control joint which prevents cracking occurring on the panel face. The panel widths are based on the modular formwork widths. A custom- made form was reused for all the splayed openings.

Mystery Bay House: Yuin/Eurobodalla

CD:
Is the surface finish from when the mould was removed?

JH:
Yes, the finish is off-form, meaning it's what you see when the formwork was stripped, similar to most in-situ concrete walls. The formwork plugs were patched later with an earth mix. A small part of the tapered wall cracked when we removed the first formwork, but we managed to patch this up later. These small imperfections all add the character.

CD:
How was the wall waterproofed?

JH:
We designed eave overhangs, which protect the wall from some rain.

The cement content of the wall improves its water resistance.

Typically, you would design a concrete or tile capping for a rammed earth wall, however the clients didn't want this, so we've used a Solid Silane coating on the tops of the exposed walls at each end of the building. We may add a flashing later, but the coating has been effective so far.

CD:
What can you say about your location on Mystery Bay? Does rammed earth create a thermally balanced interior in your local climate?

JH:
Mystery Bay is on the NSW South Coast, which is a mild to cool temperate climate, but the winters do get quite cold.

Thermal mass stores and re-releases heat and cold; whereas insulation stops heat or cold flowing into or out of the building. Rammed earth has very good thermal mass, but limited insulation qualities.

The rammed earth wall at Mystery Bay acts like a battery, storing thermal energy during the day, then radiating this heat slowly during the night. This works really well.

We've tried to offset the limited insulation in the rammed earth and glazing, with high performance ceiling insulation and an in-floor hydronic heating system, which tops up heat in the concrete slab during the cooler nights. The clients are happy with the result, it's a comfortable house to live in year-round.

CD:
Given the sustainable benefits of rammed earth, what do you think is stopping rammed earth from being more widely adopted?

JH:
The availability of suitable local soil is a key factor. A lot of the embodied energy in rammed earth is in quarrying the raw material and transportation to site.

Rammed earth is also labor-intensive, which requires skilled and experienced tradesman. Finding the right people for the job can be difficult.

Unless designed and detailed properly, rammed earth is susceptible to water damage, in particular wind driven rain and long-term moisture.

Also, its thermal mass can be very effective in cool or cold climates, but is not recommended for tropical climates.

CD:
Could machines like robots be introduced to make rammed earth more widely used?

JH:
I'm not sure, to be honest. I think a lot of things will be automated in the future. Traditional rammed earth is labor-intensive, so if the demand is there, there's an opportunity to automate part of the process.

I also think rammed earth gets a lot of its charm and character from how it's made. There are variations that happen during mixing, filling and compaction, which make each wall different. If you were to automate this very ancient technique, and remove the human touch, something might get lost.

For one-off single dwellings, like the Mystery Bay House, I don't think on-site robotics will make economic sense for a long time.

Some businesses are experimenting with pre-cast rammed earth panels, which I think is an interesting concept.

CD:
Do you think people are open to innovations?

JH:
The effects of climate change and the impact of 8 + billion people on the planet is the biggest challenge facing the world in 2023. Buildings and construction contribute to around 40% of CO2 emissions. So yes, to address these problems will require innovation.

Rammed earth has high thermal mass and a carbon footprint 40 times smaller than concrete, so there's an opportunity for it to be part of the solution.

3. Non Stabilised Earth

This chapter focuses on non-stabilized rammed earth with a historical case study of the Centre For Alternative Technology in Wales, whose WISE building is made from rammed earth. The centre's advocacy for sustainable materials is followed by an interview with the builder of Edgars Creek House, who constructed a rammed earth façade and fireplace for the house.

Non-Stabilised Versus Stabilised Rammed Earth

Amongst a hum of rotating mixers, pneumatic rammers and buckets of soil being shovelled into a formwork mould, builder of the Centre For Alternative Technology (CAT), Rowland Keable, is discussing the benefits of non-stabilised rammed earth. Standing on the construction site, Keable describes why he chooses to build with the material, explaining, "from a sustainability point of view, you can knock it down, crush it all up, add some water to it and rebuild it again. Something you can't do with concrete." Excluding concrete from the mix explains Keable, means that rammed earth can be recycled time and time again, remoulded into new projects or back into the ground. Drawing from his experience in building rammed earth structures, he is keen to advocate for untreated mixtures of rammed earth and reassures us that the granular material is quite similar to pouring concrete, the only difference is that a chemical cement binder has been substituted with a binder of clay. Whether cement is in the mix or not, from his experience, the construction method is essentially the same. Removing cement from the ingredients list reduces the amount of global carbon dioxide emissions, with cement responsible for 10 per cent of these emissions. With his practice, Keable proactively removes cement from his construction process and contributes to the worldwide effort to fight climate change.[2]

The WISE building at the Center of Alternative Technology is an excellent example of rammed earth that does not include cement. Constructed by Rowland Keable, the building's curved earthen wall encircles a school and is the tallest of its kind in the United Kingdom. However, images of the construction process show that a large section of the wall collapsed during construction. Photos reveal the earth was not rammed from 100mm layers to 50mm layers as was instructed in the specification document. Therefore, a part of the wall needed to be rebuilt. On the other hand, due to the absence of cement in the mix, the material used in the broken wall could simply be broken up into smaller pieces, remixed, and reconstructed into a new wall, with strata at the correct height. This case study demonstrates the extraordinary recyclability of rammed earth, not only at the end of a building's life span but during the construction process, and at a cost benefit to the contractor. Rammed earth, which employs cement in the mix as a binder, is referred to as stabilized rammed earth, and while stabilized rammed earth is more waterproof and stronger than non-stabilized rammed earth, to the visitors observing the interior of the WISE building, the absence of cement is one of the Centre's inspiring attractions.[3]

The wall surrounding the WISE building at the Center for Alternative Technology in Wales does not use cement to bind the earthen mixture together. [4] During presentations at WISE, light streams down through

Figure 1: Sunlight Shining Onto The Rammed Earth Drum.

roof lights, highlighting the deep red colour of the wall, turning rammed earth into a presentation prop to demonstrate the advantages of non-stabilized rammed earth.[5] An additional layer of bright yellow ochre covers the entire Centre's exterior walls, placing attendees in a joyful mood. The cheerful yellow ochre contrasts perfectly with the lush green landscape surrounding the Centre. In addition to projecting a positive air onto the landscape, the mixture adds thermal mass and prevents cracking from occurring in stacked earthen blocks.[6] During practical workshops devised by the Centre, participants can learn how to build their own rammed earth walls. Visitors cover their entire bodies with mud when mixing rammed earth together and when squishing earth all over walls, plastering them with mud. According to CAT, the best way of learning about materials is to have clay stuck between hands and to get clothes soaked in mud. These practical workshop techniques are central to CAT's positive approach to fighting climate change.[7]

The WISE building at the Centre For Alternative Technology is a revision of large-scale ecological architecture, proposing a sustainable and aesthetically innovative building. A sectional axonometric drawing cutting through the centre of the circular drum reveals the components making up the design.[8] The round rammed earth wall is a modern interpretation of a presentation space, and the rammed earth walls provide optimal acoustic performance for projecting sound towards the audience. A circular roof light on top of the rammed earth walls throws ambient light across the room, with the raised lantern preventing direct sunlight from entering the space. One of the architects of WISE, Pat Borer, describes how "The design was intended to get away from people's image of green architecture as [having] grass all over it." [9] Borer's design sought to change the image of sustainable architecture as being covered with a blanket of green grass. Instead, the design with red rammed earth curved into a round drum presents a modern language. The Centre's design spoke a language entirely appropriate to contemporary architecture, avoiding a nostalgia for methods accepted in the past.[10] Earthen material that is typically considered traditional is upgraded by the ramming process, producing organic lines and a textural feel across the surface. The architects were keen to inform visitors of their earthen mixture by placing signs with information on the surface of the walls. The WISE centre is more than just a building but is a demonstration of CAT's mission at the forefront of contemporary sustainable advocacy.[11]

Visitors attending CAT considered the WISE building an inspiring place to learn about sustainability. Interviews with all types of people who visit and are connected to the Centre were conducted as part of an Oral History project led by Allan Shepherd. Shepherd's Oral History Project sought to document the history of CAT, protecting the Centre's story and sharing their journey with visitors. In an interview with Pat Borer, Shepherd records Borer reflecting, "I think [WISE] sets the right mood for lots of events and talks and so

Figure 2: Image of Yellow Ochre Exterior And Green Landscape

on. You are surrounded by all those lovely materials that are all in tune with what you're discussing. If you are having lectures about sustainability or talking about sustainability, it kind of reflects all of those values all around you."[12] In this quote, Borer discusses how being surrounded by walls made of sustainable materials legitimises the sustainable principles being shared with attendees. During presentations, glazing at the roof level throws sunlight upon the red surface of the wall, almost highlighting the material as a presentation prop. The curved walls, raked ceiling and floors ramping down towards the display, directing the viewer's eyes towards the rammed earth.[13] Alongside the value of presentations, Borer's quote highlights the journey CAT has taken from a venue devised as a collection of more rudimentary buildings in the landscape towards a dedicated space where people can gather and have a unified discussion about sustainable ideas.[14] The materials, spaces and planning combine to create an ecological experience projecting the philosophy of CAT for positive change.

Located at the Centre for Alternative Technology before the construction of WISE, the Autonomous Environmental Information Center (AtEIC) was previously built from rammed earth. AtEIC's purpose was to provide free information services to visitors curious about sustainable architecture via a 'drop-in' information desk and a shop.[15] In another interview with Pat Borer, he describes how AtEIC was CAT's first attempt at modern sustainable architecture, explaining, "I think it's got it, it's got a presence as you go into the shop. It's 'Whoa, this is good.' You could have made it much more utilitarian, it would have worked just as well, but it wouldn't have the certain something to sell the idea of green construction."[16] Like WISE, AtEIC actively spread information about sustainability, this time via a shop, free information desk and mail order room however, CAT's first attempt at designing sustainable architecture was slightly different.[17] Looking at images of the interior, daylight streams in from glazed roof lights, welcoming visitors into the space with a radiant quality of light and an airy sense of volume.[18] Supporting the glazed roof lights is the heavy rammed earth wall, this time constructed slightly differently from the wall in the new WISE building. Both buildings, however, interpret the Centre For Alternative Technologies aim of serving the public with free information services inside contemporary sustainable architecture.

A Colourful Place To Be

Another material choice that promoted CAT's sustainability initiative was lathering the entire exterior with a bright yellow ochre. Looking at images of the centre from far away, the bright yellow colour seems to contrast perfectly with the lush green landscape. In an article written for the Architects Journal, Hattie Harman notes how "light permeates this building, which merges organically with its surroundings," the brilliant yellow colour giving the impression that the sun is always shining.[19] The yellow layer of colour is made from a mixture of hemp lime, which is then covered with a layer of pigmented yellow

Figure 3: Rammed Earth Workshop

lime render on top. While projecting a joyful mood onto the landscape, the mixture adds thermal mass to the exterior walls.[20] In some instances, the lime render has further advantages, preventing cracks from occurring in stacked earthen blocks. An extra layer of lime is applied to internal partitions between collaboration spaces on the ground floor and within the WISE building, preventing shrinkage cracks from occurring in these walls.[21] The colourful pallet of rammed earth, ash timber flooring and yellow lime exterior create a low carbon composition of materials.[22] As visitors walk around the centre, 'real' sustainable materials are expressed joyfully, leaving guests in a positive mood about sustainability.[23]

CAT invited visitors to participate in practical hand-building workshops to learn new skills. Building a prototype themselves encouraged participants to "not just talk about doing things" but to conduct experiments with their own hands, discovering new techniques in a positive learning environment.[24] One member of a rammed earth workshop, Ben French, reflects that on "day one of the course and I am up to my elbows in mud… We get to know about squashing the mud to the right consistency, how to bind it with straw and push it through a recycled mesh held together with timber lathes, forming a rough plastered wall." French describes covering his clothes with mud when squashing dirt all over a wall. He felt the best way to learn about the material's characteristics was to get clay stuck between your hands.[25] An image of two other students removing plywood formwork from a rammed earth wall shows the result of their efforts. Getting their clothes soaked in mud was well worth constructing a physical wall that might be part of a building in the future. These practical techniques advocated for by CAT are different to reading about the harmful effects of climate change in books. Rather than reading about climate change's effects on paper, CAT set people to work on practical projects, "working for what they thought the solutions were," and this practical approach set them apart from other organizations.[26] Getting participant's hands muddy was an ethos central to CAT's foundation.[27]

The founders of CAT proactively transformed a disused slate quarry into a habitable home with their own hands. The gradual transformation of the dilapidated landscape through the physical efforts of volunteers is an important story at the heart of the Centre's legacy.[28] Images of excavated holes dug into the ground to locate intercessional water heating reveal how slate made up the majority of surface soil composition. When the landscape was first discovered, several thousand tonnes of slate in all shapes and sizes were found. These remaining slate fragments were offcuts, discarded after workers laboured for years digging the material from the ground. Accompanying the mounds of slate, cutting sheds, cottages, reservoirs, tunnels and railway tracks were found, these buildings forming part of the mining enterprise undertaken there.[29] Slate mined from this location was placed on railway tracks to be transformed into tables, roofs or fireplaces inside homes. However, when the founders of CAT arrived, the buildings were overgrown, and the landscape was covered in wildflowers, trees and shrubs, blanketing the past industrial activities from view.[30] How the earth-torn landscape that was once used as a source of extraction and mining was transformed by volunteers into a place where nature is protected and cared for is considered a phoenix story in the Centre's history. The Centre emerging from the ashes of industry into a source of environmental sustainability and imagination.[31]

Conclusion

Visitors can learn more about CAT's initiatives by venturing from the centre and into the historic landscape. Walkers are guided down bush trails by experienced tour guides, who they can ask questions about renewable energy, green building, renovations, woodland management, gardening, Zero Carbon Britain and sustainability in general.[32] CAT's most current initiative is their Zero Carbon Britain agenda, which lays out a plan for how Britain uses land and how renewal energy is produced. Zero Carbon Britain is led by Paul Allen and a team of employees who propose a significant shift in how Britain associates energy production with land use.[33] In 2007, the first of a series of reports was published. The first report, Zero Carbon Britain: An Alternative Energy Strategy, was followed by six more reports. The project brings together multiple stakeholders, including local councils, groups, and organizations, to address the challenging climate emergency. Webinars and seminars invite organizations to collaborate.[34] After meeting, participants are invited outside to walk along a trail through the landscape to see first-hand the impact of climate change. The Zero Carbon Britain trail places visitors within nature, giving them snippets of information about sustainability from a more informed perspective. The track provides a physical learning experience that connects people with the natural world instead of sitting in a webinar or reading a report.[35] The trail informs explorers about CAT's sustainable water systems, the rich diversity of plants and animals, and the slate industry's history.[36] The physical presence of these artifacts within the rugged, wet and climatically variable landscape highlights the immediate impact of climate change in real time.[37]

Breathe Architects are applying sustainability principles to their architectural practice in Australia. Their houses do not include air-conditioning, gas connections or mechanical heating and cooling. Along the same lines as the Zero Carbon Britain report, Breathe has published a Guide to Sustainable Materials, which strives to “make the most sustainable material choices possible”.[38] The guide records their experiences on past projects when choosing sustainable materials in the hope that other Australian architects might benefit from their knowledge. Damien Collins, the builder of Edgars Creek House, designed by Breathe Architects, generously shared his experience of building from rammed earth. Edgars Creek house is located at the end of a suburban street and faces a beautiful landscape of Iron Bark trees planted along a valley with running water flowing through. Collins explains how Breathe's lead architect, Madeline, was keen to apply her knowledge of earthen houses learned from her home country. From Arizona, she learned how thermal mass can be achieved, with the earth naturally heating and cooling indoor temperatures. Rammed earth warms interior spaces during the cooler months, with the interiors shaded by Iron Bark trees during the hotter months. Collins and Madeline experimented with various rammed earth mixes to ensure the colour and composition of the rammed earth walls mimicked the natural landscape and formed high thermal mass. Collins describes how most people in Australia have red brick or timber weatherboard houses. However, if homeowners want to build something unique, personalised, and sustainable, rammed earth is a good material choice.

Figure 4: View Over Courtyard Towards Study Rooms.
Figure 5: View Of Study Rooms.
Figure 6: View Of Roof Top.

Edgars Creek House: Merri-bek/Coburg

Edgars Creek House

Interview with Damien Collins from Never Stop Group about the rammed earth wall at Edgars Creek House. Edgars Creek House is located at the end of a street in suburban Melbourne. The house faces a valley of Iron Bark trees and is designed by Breathe.

CD:
How do your rammed earth walls reflect the landscape of Iron Bark Trees?

DC:
The location of our site is directly adjacent to the cliffs, so the architect intended to reflect the outlook towards the cliffs back onto the façade of the building. The other houses on the street look very similar to each other, however, this house is located at the end of the road and turns its back on the other homes to look towards the landscape. The house turns and faces the beautiful landscape of Iron Bark trees in the valley with running water flowing through.

CD:
How was the rammed earth mix determined?

DC:
We experimented with lots of different aggregates available to us. We were trying to find something that mimicked the colour and tones of the cliffs. There was a lot of trial and error to get the mix right.

CD:
Who was your rammed earth contractor?

DC:
The contractor we worked with was called Earth Structures. We collaborated with Dave, who was very helpful.

CD:
What percentages of material made up your mix?

DC:
The mix was made up of 6 per cent cement with a topping. The architects liked a more textural mix that was not too compact or too wet, and there was a fair bit of trial and error to achieve this. Earth Structures did a couple of sample panels for us. We collaborated with them a lot, and they listened to what we were trying to achieve.

CD:
Was the sloped land difficult to place rammed earth walls on?

DC:
The whole site is considered uncontrolled fill, so the building's three different pavilions were placed on three separate foundations of concrete, which sat on screw piles placed over the site. The rammed earth wall is at the front of the site and is relatively easy to access. Access to the fireplace was a bit harder as the fireplace is on the furthest pavilion. The rammed earth is built on the concrete slab, and once the concrete was poured, access wasn't too bad. However, forming the slab underneath the rammed earth was a challenge due to the site's slope.

CD:
The rammed earth walls have beautiful chamfers at a variety of angles. How were they made?

DC:
We manufactured some plywood shapes, and Earth Structures put them inside the formwork mould. The plywood shapes were placed within each bay of formwork. They rammed around the forms to get the angles, repeating the process as they went up.

CD:
How were your services located within the house?

DC:
In the instance of the bathroom ensuites, we surface-mounted the tapware. One of the walls in the shower is made from rammed earth, and the taps were placed on the other wall, which already had surface-mounted tapware.

A couple of conduits were cast within the rammed earth wall itself, and the wall has insulation in the middle, but otherwise, nothing else was cut into the wall, and the services were placed in other partitions. The rammed earth wall was built at the front of the site, and everything else was built around the back of it.

CD:
How did you waterproof the rammed earth in the bathroom?

DC:
We used the same sealing product externally on the internal bathrooms. The theory behind this was if the sealant could last against the elements on the exterior, then there would be no difference internally.

CD:
Other elements that are cast within the rammed earth wall are windows. How did you support the rammed earth around the windows?

DC:
The windows were very tricky and a challenge for our contractor. The rammed earth was built to a certain height, and structural steel was cast inside the wall. The steel is cantilevered on one side, and the rammed earth supports the other side of the steel. Once the steel is cast there, you can ram on top of it, and the window can be placed in the space under the steel lintel.

CD:
How is the rammed earth fireplace made?

DC:
The fireplace is a jet master dual-sided fireplace cast inside of the rammed earth. The flu inside lets air in from the outside to achieve a balanced atmosphere. This ensures the fire burns properly and the smoke rises from the flu. The fireplace was all set up and cast inside the rammed earth piece by piece. Each time another layer of rammed earth was added, we placed another part of the flu in the stack. We put a protective layer around the outside of the flu to protect the flu from the rammed earth and to avoid applying too much pressure.

CD:
What are the sustainable properties of your rammed earth walls?

DC:
Madeline, our architect from Breathe, is from California and is inspired by earthen houses in Arizona. She was keen to apply her knowledge of Arizona rammed earth houses and sustainable principles for these earthen walls. To achieve the wall’s thermal mass, we placed insulation in the centre of two layers of earth, meaning there is minimal thermal bridging from inside to outside. The insulation must stop at the end of the walls as the earth goes all the way around the outside, creating a bridge, but this doesn’t cause issues.

Breathe does not have mechanical heating and cooling in their homes. So, there is no air-conditioning or gas connections to the site. The house is ready for hydronic heating, but we didn’t install hydronic heating at the time, and we hoped the natural heating and cooling would be efficient enough. The people living there are going to collect wood from the reserve where the timber falls naturally and bring it back inside as fuel for the fire. The fire heats the main living, kitchen and dining area. There is always enough heating in the spaces. With all the trees in the reserve, there is enough shade in the hotter months.

CD:
How did you form up the earthen walls?

DC:
The formwork was made from steel shutters, where at every 600mm, another shutter would be bolted on top. Plywood boards would sit inside the shutters to create the shapes indented in the rammed surface. Each layer of rammed earth was 150mm and rammed down

into smaller layers.

CD:
Do you think the rammed earth process will evolve over time?

DC:
I think, like most things, rammed earth will evolve. Machinery might take over, and excavators with ramming attachments on the end might be introduced. Remote-controlled systems like these might take away much of that manual ramming task. The ramming process is a relentless undertaking similar to using a jackhammer all day. I think the process will evolve and turn into more machine-produced elements.

Like most artisan things, rammed earth is made by someone whose final product is down to the person and their tool. For example, if you are making bricks out of a factory, each brick is the same, therefore, maybe there is a way to retain some of that handmade quality of rammed earth with all of the walls deformities without having too much back-breaking labour as part of the process.

CD:
What are the factors stopping rammed earth from being more widely used?

DC:
I think there are a combination of factors. Rammed earth construction is hard work, and if the next generation of people coming through can find much more forgiving trades, they might take those options. Bricklayers are compensated highly because the work is demanding and arduous. The bricklaying process is challenging on your knees and hard on your back. Most of our bricklayers are European or British because bricklaying is still a trade that is common over there. Rammed earth doesn't have the same migration of workers, and so there aren't people arriving from overseas into Australia with rammed earth skills.

A lot of equipment is required to start a rammed earth business. You also need to have prerequisite experience and knowledge on how to ram, in addition to knowing how to run a business and the ability to purchase all the equipment to start your own company. A new rammed earth company is usually created when one grows large and then splits into two smaller companies.

CD:
What do you think will be a catalyst for this evolution?

DC:
I think there will be an OH&S directive that is going to drive change. Someone will take one of the rammed earth tools we have at the moment and find a way to adapt it. For example, someone might adapt a pneumatic rammer to an excavator and apply the technology to reach and ram at a certain height, making the process much easier. Maybe this is where the innovation will come from. Everyone will see how the innovations are working and be inspired.

CD:
What is the reason why the client chose rammed earth for their house?

DC:
I think people chose rammed earth because the material is unique. Most people have a red brick house or a timber weatherboard house. If you want to build a masterwork and something personalised, rammed earth is where uniqueness can come from. Most people in Australia wouldn't have seen a rammed earth wall. The identity of rammed earth is why the material is beautiful and why I like it. The material is different.

Edgars Creek House: Merri-bek/Coburg

Architect (Breathe) Builder (Never Stop Group) Rammed Earth Expert (Earth Structures) Wall Height (2 Storeys) Typology (House) Climate (Mild Temperate) Soil Name (Vertisol) Coarse Fragment (2%) Sand (14%) Silt (33%) Clay (53%) Texture Class (Clay light)

BC Materials: Bruxelles, Belgium

Bushey Cemetery: United Kingdom

Architect (Waugh Thistleton) Rammed Earth Expert (Earth Structures) Wall Height (2 Storeys) Typology (Cemetery) Climate (Temperate Oceanic) Soil Name (Greysol) Coarse Fragment (8%) Sand (24%) Silt (46%) Clay (30%) Texture Class (Clay Loam)

Yorkshire Sculpture Park, Weston Gallery: Wakefield, United Kingdom

Architect (Fieldon Fowles) Wall Height (1 Storey) Typology (Gallery) Climate (Temperate Oceanic) Soil Name (Greysol) Coarse Fragment (2%) Sand (35%) Silt (35%) Clay (30%) Texture Class (Clay Loam)

The Story Of Gardening At The Newt In Somerset: Castle Cary, United Kingdom

Architect (Stonewood Design) Rammed Earth Expert (Hydrock) Wall Height (2 Storeys) Typology (Museum) Climate (Temperate Oceanic) Soil Name (Cambisol) Coarse Fragment (13%) Sand (40%) Silt (40%) Clay (20%) Texture Class (Loam)

Secular Retreat: Chivelstone, United Kingdom

Architect (Atelier Peter Zumthor, Mole Architects, David Sheppard Architects) Wall Height (1 Storey) Typology (Retreat) Climate (Temperate Oceanic) Soil Name (Cambisol) Coarse Fragment (17%) Sand (44%) Silt (36%) Clay (20%) Texture Class (Loam)

Circular Brick House: Tienen, Belgium

Architect (AST 77 Architecten) Rammed Earth Expert (BC Materials) Wall Height (Over 2 Storeys) Typology (House) Climate (Temperate Oceanic) Soil Name (Luvison) Coarse Fragment (11%) Sand (41%) Silt (42%) Clay (17%) Texture Class (Loam)

Observation Tower Negenoord: Dilsen-Stokkem, Belgium

Architect (De Gouden Liniaal Architecten) Rammed Earth Expert (Craterre/Vessiere&Cie/BC Studies) Wall Height (Over 2 Storeys) Typology (Tower) Climate (Temperate Oceanic) Soil Name (Fluvisol) Coarse Fragment (2%) Sand (37%) Silt (42%) Clay (21%) Texture Class (Loam)

Writ In Water: Egham, United Kingdom

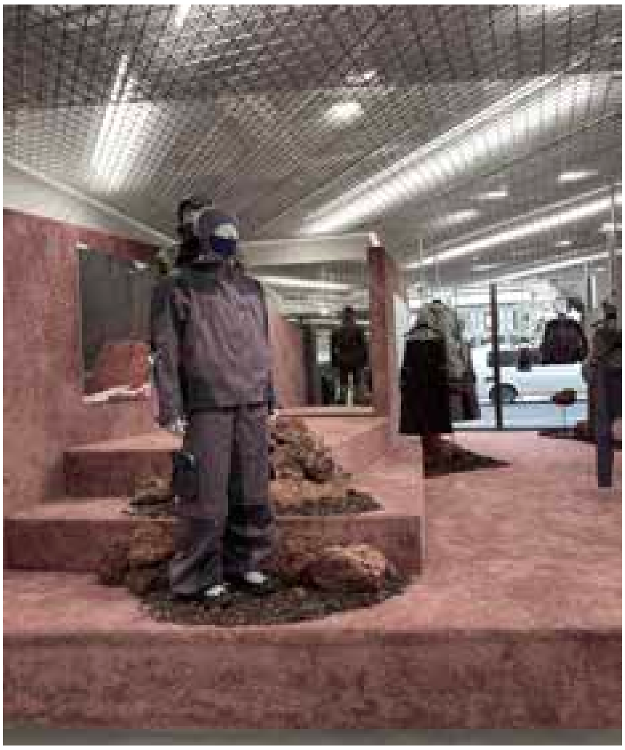
Architect (Studio Octopi) Wall Height (1 Storey) Typology (Artwork) Climate (Temperate Oceanic) Soil Name (Luvisol) Coarse Fragment (11%) Sand (41%) Silt (42%) Clay (17%) Texture Class (Loam)

For Our Country Memorial: Ngunnawal & Ngambri/Canberra

Architect (Daniel Boyd, Edition Office) Wall Height (1 Storey) Typology (Memorial) Climate (Cool Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

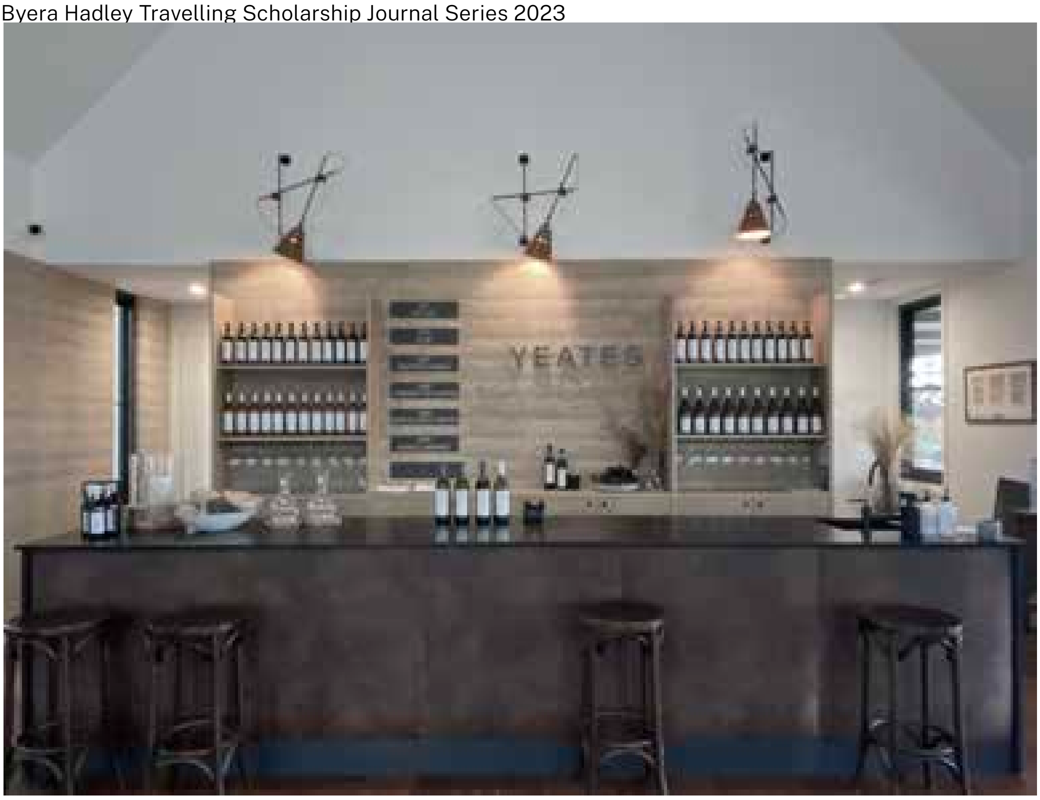
Kauwi Interpretive Centre: Ngangkiparinga/Lonsdale

Architect (Woodhead) Rammed Earth Expert (Adelaide Rammed Earth) Wall Height (1 Storey) Typology (Educational Centre) Climate (Warm Temperate) Soil Name (Luvisol) Coarse Fragment (18%) Sand (65%) Silt (18%) Clay (17%) Texture Class (Sandy Loam)



66degrees North: London

Architect (Gonzalez Haase AAS) Wall Height (Plinths) Typology (Retail) Climate (Temperate Oceanic) Soil Name (Technosol) Coarse Fragment (0%) Sand (0%) Silt (0%) Clay (0%) Texture Class (na)



Yeates Wines: Wiradjuri/ Eurunderee

Architect (Cameron Anderson Architects) Rammed Earth Expert (Justin Peggy) Wall Height (1 Storey) Typology (Cellar Door & Accommodation) Climate (Mild Temperate) Soil Name (Podzol) Coarse Fragment (18%) Sand (92%) Silt (6%) Clay (2%) Texture Class (Sandy Loam)

Yeates Wines: Wiradjuri/Eurunderee

4. Block and Modular Earth

This chapter focuses on prefabricated and modular rammed earth. Research into the compressed earth blocks prefabricated for Sverre Fehn's Mauritzberg Prototype House exemplifies how earthen architecture was adapted for the Scandinavian climate. This research is followed by a study of Le Corbusier's Cité Permanente, where modular rammed earth units stack in a variety of formations across the landscape. An interview with Lehm Ton Erde provides an example of how contemporary architects prefabricate earthen walls with robotic technology.

Prototype House

Prefabricated Clay Blocks

In the middle of a clearing between a forest of tall trees in Norrkoping, Sweden, bales of straw and heaps of mud are being packed into blocks by a hustle of workers. This image of Sverre Fehn's Prototype House shows rows and rows of earthen blocks visibly laid along wooden slats as the blocks dry in the sun. Eventually, each block will be stacked on top of one another to create Sverre Fehn's first foray into earthen construction.[39] The blocks in the photograph are left outside for a period of two weeks and are turned over every couple of days to let them bake evenly on both sides.[40] The process of creating the earthen blocks involved a mixture of mud and straw that was turned over in a concrete blender and packed into the moulds using a wooden mallet. The moulds were made from a combination of plywood and plastic with a clay slip sprayed on the surface to aid with removal. The plywood squares provided the size and shape of each block, while the mud was rammed dense at the edges and loose in the centre. After this moulding process, the plywood formwork was removed, leaving the clay to dry for two weeks.[41] This version of mud brick prefabrication is categorized as Norwegian mud brick or 'Norbrick' and is adapted from traditional mud brick-making processes to suit the Nordic climate.[42] Fehn adapted traditional mud brick-making methods to suit Scandinavian design.

Rather than employing one or two singular ecological improvements to Scandinavian design, Fehn reinterpreted Nordic architecture holistically.[43] Looking at the floor plan drawing, Fehn designed the skeleton of the Prototype House using a series of wooden struts with clay blocks stacked between regularly sized modules.[44] Each wooden strut was placed in a uniform array separated by a two-meter dimension, each two-meter module wide enough to stack three and a half mud blocks in one course.[45] All 640 blocks were stacked in courses within the timber frames and stuck together using a clay mortar. The increased percentage of straw to clay making up the mixture made each course much lighter than standard earthen blocks, meaning fewer bricks were needed for stacking into larger rows.[46] Once all the timber frames were filled with rows of clay bricks, the walls were covered by a mud plaster on the exterior and the interior, sealing the wall.[47] The smooth plastered finish is made from mud and covers the timber-framed

Figure 7: Earth Blocks Drying In The Sun.

and mud-block construction underneath, hiding the prefabrication process behind a solid wall. Fehn's first attempt at sustainable architecture was hidden from view, disguising his new earthen construction process with a familiar solid surface.[48]

Sverre Fehn's prototype house was meant to be part of a larger vacation and conference centre in Norrkoping, Sweden. The prototype planned to be duplicated 250 times over a large area comprising a golf course, tennis courts and equestrian facilities that were proposed for the luxurious venue.[49] Fehn drew the proposed houses in rows, forming lines between the Swedish forest and the golf course leisure facility. A sequence of homes conforming to the site's contours as the ground slopes down from the thicket of trees. The longitudinal floor plans characterizing each house are rotated to adhere to the terrain's fall and direct views across the natural landscape.[50] While Fehn's broader project lost momentum, a single prototype was built using compressed earth bricks.[51] Le Corbusier's design for La Cité Permanente d'Habitation was planned on a similar scale, proposing 188 units made from pisé in the hills of southern France.[52 53] Looking at the site plan of the proposal, the Cité Permanente was positioned high up on top of the slope, with the mountains reaching 1148 meters high at their tallest point.[54] Positioning the dwellings high up allowed inhabitants to look down upon the rest of the countryside, each window like a set of eyes peering across the landscape.[55] Section drawings through the steep slope underneath each unit show the terrain fluctuating between a 5-degree pitch at its lowest and an 18-degree rise at its highest. Le Corbusier modulated the ground level of each unit to step down the sheer incline.[56]

Drawings, models and small balsa wood maquettes formed part of Sverre Fehn's teams' competition proposal. Images of the balsa wood models show the balsa carefully curving over, representing a curved roof form.[57] Fehn's team understood the strengths of balsa wood by bending along the length of the materials timber grain. For the full-scale Prototype House, double-plywood curved arches were prefabricated and placed in a series along the length of the longitudinal plan.[58] To support the weight of the arches, the walls are topped with technically detailed triangular sill. The triangular sill supporting the material spanning between each roof arch. The material is made in layers from a combination of organic matter and earth. The assemblage weighing heavily down onto the walls. Each earthen layer comprises a heavy mix of laminated wood, cork, bark and earth.[59] Although heavy, the compacted layers of earth and cork are flexible enough to bend over the curved surface in thin laminated layers without breaking. To protect the organic earth and cork insulating the roof, longitudinal roof battens are placed on top, shielding the material from the weather. Like the original balsa wood models made for the initial competition proposal, the timber battens curve as a stepped series along their timber grains, gradually lapping over each other on the top of the

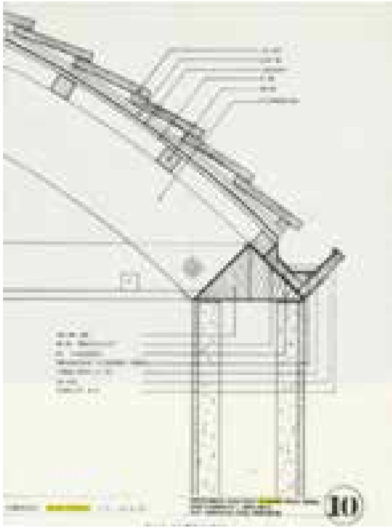


Figure 8: Provehus Mauritzberg 1:5 Detail.

Figure 9: Fra stuen, sett mot vest.

roof. Each timber batten overlaps the other to form a watertight seal. On either end of the roof, gutters are positioned on top of timber fascia to remove water from the roof and guide the water flow down to the ground.[60] Traditional curved earthen roofs were adapted by Fehn to the Scandinavian climate by laminating layers of prefabricated timber with thin sheets of earth wedged in the middle.[61]

Fehn took extra precautions to ensure the Prototype House could withstand the Scandinavian climate. A wall section detail drawing included in the set of construction drawings was used to build the prototype.[62] The illustration showing crucial layers of material that make up the wall assembly. First, a 25mm layer of straw-reinforced clay plaster provided a seal from the outside. Secondly, a layer of clay blocks was stacked in a bed of clay mortar between timber struts.[63] The clay blocks were aerated with straw to insulate the interior from the extreme cold, providing a barrier against the chill.[64] Continuing through the wall assembly, another layer of lime mortar seals the blocks on the inside, allowing a final layer of sand plaster and clay plaster to cover the interior surface. The entire assemblage created a 320mm thick wall, with 150mm timber studs embedded into either side of the wall. The 320mm assemblage is much wider than traditional timber construction commonly adopted in Scandinavia. Fehn originally intended for the walls to be made from brick, however, when it came to rationalising the built prototype, he felt it most suitable to make the walls from clay, significantly widening the thickness of the wall and introducing a completely new construction process.[65] Fehn's team adapted a typical timber frame wall detail to suit light earth construction. The final assemblage provides structure, insulative properties, thermal mass and a sealant primed to warm the interior from the chilly Nordic climate.

Coloured interior clay

Clay plasters covering the interior and exterior of the Prototype House were pigmented with yellow and a deep pink colour. Looking at an interior image of the house, a clay plaster is shown with a paper yellow glow, the colour illuminating the space.[66] The yellow plaster covering the interior wall matches the colour of the ceiling made from timber beams and lightly coloured carpet on the floor. Light streaming in from the window at the end of the house throws a gradient of colour across the interior surfaces, brightening the yellow tone of the walls, ceiling and floors. A fireplace in the centre of the room is covered with the same yellow plaster mix, adding a more organic aesthetic to the pallet of materials. All interior furnishings complement the colours of the walls and are made from lightly coloured timber with yellow upholstery. In contrast to the colour pallet of the interior is the colour pallet of the exterior. Looking at an exterior image of the house, clay plaster on the outside is shown with an earthy pink colour.[67] A pink tone chosen for the outside helps the building sit visually within the landscape by matching the colour of the soil on the ground. As the timber battens on the top of the

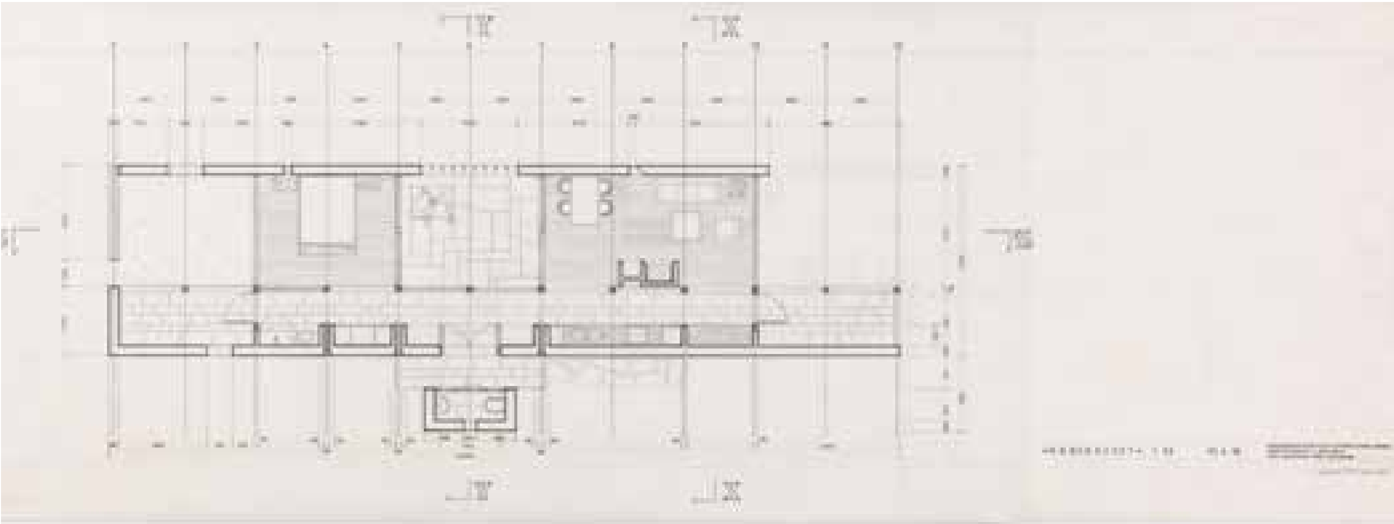


Figure 10: Mauritzberg Leisure House, Prototype 1:50 plan drawing.

roof begin to age, they gradually turn red, merging the colour of the roof with the hue of the exterior. Although volunteers applied all the coloured plaster on the exterior and interior, Fehn demonstrated the plastering technique, sharing his knowledge from a trip to Morocco, where plastering is everywhere. Fehn explains how the material is mixed with a combination of clay and straw and coloured with a dye.[68] The interior and exterior are covered with the dyed mix, wrapping the entire house in colour.

A series of openings are cut within the heavy earthen walls to provide cross breezes through the interior spaces of the house. Still referring to the exterior view of the Prototype House, windows give visual breaks between the coloured clay wall. Two vertical slit windows at either end of the house are embedded within the wall, and a large window cuts the clay through the middle providing light into an internal courtyard. Continuing through to the exterior view, a plan drawing of the house shows a series of openings in the opposite earthen wall and their relationship with the column grid.[69] Three similar vertical slit windows centred on the column grid are located on this wall. Another window, which is broader in dimension, lets additional light through to the outdoor garden. Finally, the entry door is cut in the middle of the wall to guide people towards the courtyard when they enter the house. The position of windows and doors allows air to flow across the spaces freely and directs people through to the light-filled areas in the home. Extending these functions, the openings provide thermal breaks from the thick insulating mass of earth. To provide more cooling air, partitions attached to the wall have large operable windows that direct air to and from each of the spaces, creating cooling cross breezes. Accompanying these attachments, kitchen benches, cupboards and sinks are located within niches along the wall, moulding the wall into a spine of activity.[70] Fehn carefully designed each connection and detail along the wall while considering the earth's structural stability.

In the Prototype Homes plan arrangement, all the living spaces face inward toward an internal courtyard, the interior view characteristic of a Nordic way of living.[71] Referring to the plan view of the house, a courtyard is drawn in the centre of the plan with rectangular-shaped tiles on the floor and glazing around the outside. The plan can be described as 'introverted' because all the house's spaces face inward toward this central glazed courtyard. The courtyard shines light into all the interior rooms while acting as a privacy barrier between the bedroom and the living areas.[72] Operable blinds on large glazed windows regulate the courtyard's light source and create a further privacy barrier between each room. The blinds can be adjusted to open the view into the yard or to close off views towards the courtyard completely. On one side of the courtyard is the bedroom. Despite the small dimensions of the bedroom, the bed fits comfortably within the space, and large glazed windows facing onto the courtyard make the room feel larger. The living, dining and kitchen area are on the other side of the courtyard. In the centre of this living space is a fireplace that acts as the central heating source. In addition to heating the living area, the fireplace becomes the social centre, with people gathering around the hearth on this side of the courtyard.[73] Bookending the living and bedroom spaces are two more external gardens providing more private outdoor space and light into the internal areas. Fehn's linear plan moves from more public to more private rooms along a linear gradient. They combine a sense of privacy and togetherness with a typically Scandinavian style.[74]

The longitudinal-shaped plan of the house connects views between the resort and the forest behind.[75] The site plan drawing completed as part of the original competition proposal shows two long rows of houses forming a line between the forest and the resort.[76] The sequence of homes follows the contours of the terrain and hugs closely to the edge of the woods. Linear earthen walls are drawn between each dwelling, accompanying the linear sequence of houses, their angle rotating as each house curves along the site. Each earthen wall acts as a dividing wall and a privacy screen between each house. The walls enclose the outdoor gardens and internal courtyards designed as private gathering spaces for the people living inside each home. As the line of houses weaves in and out of the forest, a unique arrangement of greenery is sectioned off for the outdoor garden. Providing views towards the gardens are a series of transparent windows arranged along the length of the plan. These windows also provide views into the broader forest from each room via a layer of sequenced windows.[77] Views towards the landscape connect the inhabitants of each house with their piece of nature and anchor them within the landscape. Fehn's proposed longitudinal design containing outdoor gardens, indoor courtyards and views towards the forest connects people with nature and provides them with a retreat from the busy metropolis of city life.[78]

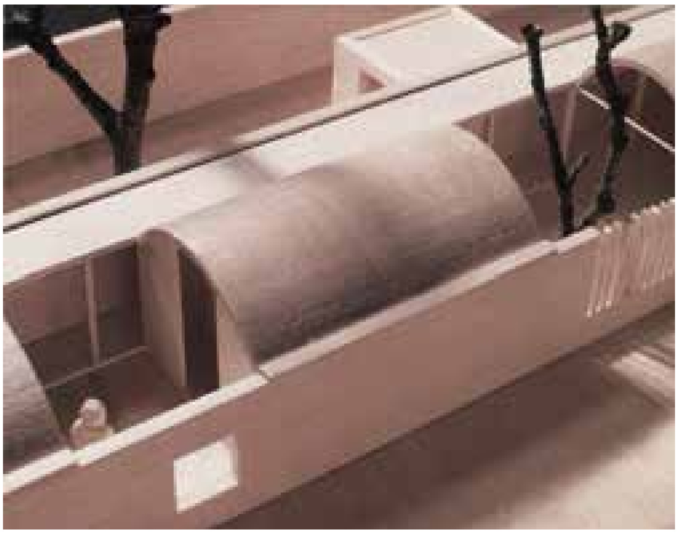


Figure 11: Site Plan for Fitidsboliger bygget i en gammel eikeskog.

Figure 12: Elevation view of the Prototype House.

Figure 13: Balsa Wood Model for Fitidsboliger bygget i en gammel eikeskog.

Cité Permanente

A Mixed Community

In the south elevation drawing of the Cité Permanente, silhouettes of people are shown interacting with each other, sharing conversations between balconies and gardens at street level.[79] Le Corbusier infused this southern elevation with life and personality to define his vision of living in a Cité Permanente made from earth. This elevation is part of a set of other unbuilt drawings by the French architect that outline a sequence of repeated modulated cells made from pisé. The pisé materiality chosen by Corbusier creates a fixed shape for each unit, generating possibilities for the standardized block to be stacked in an infinite variety of arrangements, able to be mixed, matched and stacked along the sloping landscape. Each housing unit could be freely assorted horizontally and vertically, stacking vertically two or three stories high.[80] Their changing heights diversify the ridge line at the very top of the elevation and provide difference along the entire length of the city. A minimalist unit or cell meant construction out of pisé was more feasible, with thick earthen walls between each row a more straightforward element to build.[81] The construction of Corbusier's Cité Permanente would have provided housing for hundreds of people, with each module a window into the unique personalities of each inhabitant. Their colourful furniture and personal items displayed behind each window. Le Corbusier envisioned the Cité Permanente as a place of neighbourly interaction and shared living.

Each unit in the Cité Permanente is designed as a unique block, and each of the cité's blocks is edged with curved earthen forms. Referring to the south elevation, the windows are framed collages of rectangular glass panels and mullions, signifying unique differences between each house.[82] A grid of horizontal floors and walls supports the glazed system of panels on the first and second levels, providing a visual break between the ground-level windows and the windows on the upper part of the elevation. To assist with delivering a further visual break, a railing is drawn along the entire length of the elevation, wrapping a neat skirt along the span of the façade. Defining visible edges on the upper part of the facade are arched roof forms, and visually edging the lower level of the façade are curved retaining walls. The curved roof forms on top define visual boundaries between each unit and bring forth a distinct feature on the roof line. Pairs of two parallel vaults give the impression each unit is broken in half, reducing their width by two and the earthen roof is planted with grass and vegetation.[83] Visually defining the lower elevation level are curved retaining walls, with these earthen walls mirroring the arched shapes on the top. These retaining walls swirl and curl around each other, weaving people in and out of their front gardens. The rammed earth maze forms a barrier between the inhabitant's private gardens and the street outside. Corbusier understood the unique malleability of the earth to bend and curve into rounded garden walls with ease.

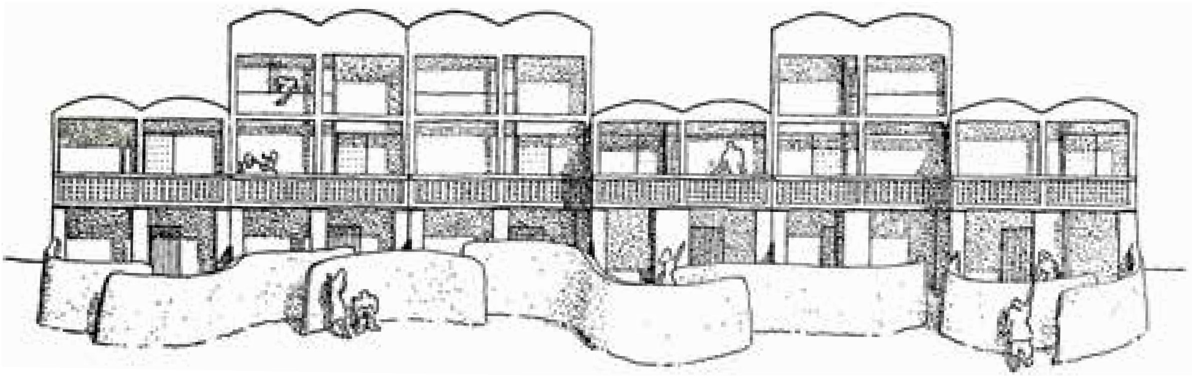


Figure 14: La facade sud

The earthen material pallet continued through to the interior. Looking at an interior perspective drawing of one of the units, visible granules of earth are drawn on surfaces to indicate where pisé would be used.[84] Walls would remain raw in these places, with plaster and tiles covering other pisé surfaces, including the curved ceilings and dividing party walls. In the drawing, Le Corbusier used pisé for three different wall types in a multitude of ways.[85] The first wall type was a pisé blade wall. Four blade walls are spaced across the plan in a grid arrangement. The smaller surface area of a blade wall allowed more free space within the floor plan. The second type of pisé wall was a half-bay wall. One of these walls divides the second-story room from the level below, providing an acoustic barrier to the communal areas. The third type of pisé wall was a shear wall. These walls support each unit on either side and provide an acoustic barrier between each dwelling. Corbusier added niches between these walls where shelving and storage cupboards could be located. This storage layer added a fourth dimension of depth and liveability between the pisé surfaces.[86] Raw pisé interiors evoke the hand-built construction process on the inside and were chosen by Le Corbusier as a material pallet friendlier to human living.[87]

Corbusier hoped his material choice would evoke a sense of harmonious living.[88] Looking at a drawing of the ground floor plan, curved earthen retaining walls weave in and out, travelling from the garden to the underside of the bottom floor, blurring the boundary between the indoors and the outdoors. Hugging the inside of the curved walls are bench seats that follow along the curve of the wall. Bench seats and chairs dotted throughout the garden bed provide places for people to sit and gather together outside. Lush greenery and plants grow on the wall's surface, covering the pisé with vegetation and forming the outdoor garden. Defined paths between the garden beds made from pebbles allow people to move through the garden and back into their units. Besides the ground floor drawing, a cross-section through the garden shows inhabitants gathering outside.[89] Silhouettes are shown sitting on benches and conversing with each other around a burning fire, with smoke shown rising between the circle of people. Corbusier hoped his garden design would bring people out of their units and into nature to sit around the fire and talk.[90] The pisé garden beds formed circles around the gathering places and prompted radiant spirits amongst the community.[91]

The prominence of vegetation and landscape in Le Corbusier's proposal is reminiscent of the twentieth-century idea of the garden suburb. Each unit is huddled together in a group and steps down the slope like a terraced garden trellis according to the fall of the land. Garden paths weave their way through back gardens, along terraces and across to the central public park on the urban plan, reinforcing the idea of garden suburb planning.[92] The street level circulation pattern is adapted to the alpine setting and the location's unique mountainous landscape, reaching 1148 meters high at the tallest point.[93] [94] Referring

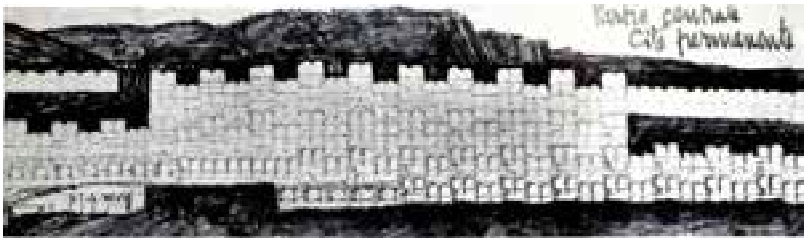


Figure 15: Aspect geometral de la cite
Figure 16: La coupe transversale

to the cross-section drawing through the site, a steep slope is shown underneath the units, and the houses are carefully placed on the hill as part of the proposal. Corbusier carefully navigated how the slope fluctuates from a 5-degree pitch at the lowest to an 18-degree rise at the steepest. [95] Negotiating further with the terrain, pisé retaining walls hold back masses of earth from sliding down the slope and provide a levelled surface for the ground floor gardens. As a further design move, the ground floor level is split in half, with the ground slab and gardens hugging the fall of the landscape. Le Corbusier designed the Cité Permanente to sit on the steep mountainous terrain of the French countryside.

While navigating the steep terrain, Le Corbusier designed the Cité Permanente for the Mediterranean climate. A Mediterranean climate is characterized by hot, dry summers and cold, wet winters. This climate is conducive to the growth of various shrubs, with soils producing citrus, olive, and grape crops.[96] The geometric aspect drawing of the Cité Permanente provides a zoomed-out view of the entire cité located on the Mediterranean slopes of southern France.[97] The effects of the cold polar winds are minimized by the south-facing slope, with the mountain blocking the polar winds from destroying crops and sending cold chills to the cité's inhabitants. The ridge of the mountain is about 20km away from the Mediterranean coastline, and Le Corbusier drew inspiration from the historic mountainous architecture when attaching the urban plan of the settlement to the hill.[98] Just like a Mediterranean settlement, the cité appeared fused to the surface of the mountain. The units are stacked horizontally along the steep contours of the mountainside and vertically up the face of the hill. The low, contour-hugging scheme covers the mountainside like a blanket. All of Le Corbusier's projects were characterized by this Mediterranean vernacular from this time onwards.[99]

A Multitude Of Eye Windows

Stacking the units up the mountain slope ensured an excellent outlook to the best of the countryside. Referring to the geometric aspect elevation drawing, each of the units was made from long, thin rectangles bundled into four rows,[100] and the houses were stacked on top of each other to give each of them a line of sight.[101] Only the bottom two rows with their line of sight obstructed. Corbusier's stacked design was created for inhabitants to observe and experience a view of the landscape through a thin rectangular unit plan or "cone of vision." Le Corbusier's sketches attempted to explore how the landscape was perceived and the effect of views out into nature upon the inhabitant's quality of life. The connection with the landscape created a harmonious relationship between the eye and the spirit.[102] The fully glazed windows on the south façade of the cité were meant to be looked through because they looked towards the most stunning landscape. The unit's windows are like an assortment of eyes peering towards the horizon.[103] The units huddled like pairs of eyes, with arched earthen roofs resembling eyebrows. This anthropomorphic

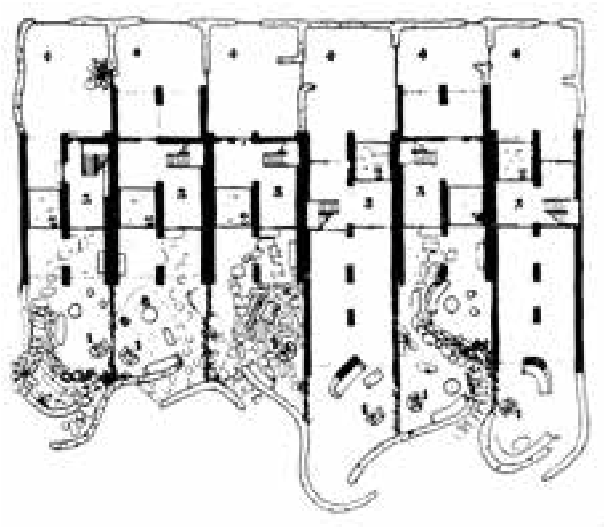


Figure 17: Rez-de-Chaussee

description of the cité's windows as eyes faced each unit towards the natural landscape.

The Cité Permanente's pisé was foreign to local French builders who were accustomed to precise European construction systems.[104] Quotes from historians at the time described the Cité Permanente as not possessive of Corbusier's signature flavour that would typically "anticipate and participate in the progress of twentieth-century emancipation," a familiar theme of progress and utopia spreading across Corbusier's work before this scheme. French builders were shocked when Corbusier proposed dwellings that would be made using hand tools, hammers and ladders and would be constructed by traditional labourers.[105] On the other hand, the scheme retained a sense of modulation and standardization with an overall feeling of order, though the choice of pisé meant the houses would be made from mud. Corbusier drew the homes with large, thick earthen walls, forming a heavy structure and enclosure that sat solidly on the ground. A mixture of modularity and natural materials with organic forms evoked by pisé were so foreign to local French builders that Corbusier's vision was ultimately compromised by the realities of industry.[106] Historians viewed local French people as disturbed that these houses might be encountered "within half a mile of the Champs Elysees," seeing the scheme as an affront to the norms of European thought.[107]

Conclusion

Drawn in 1949 and a contemporary scheme to the Cité Permanente drawn in 1948, was another scheme on the French coast called Roq et Rob. Like the Cité Permanente, Roq et Rob was made out of earth, yet this scheme was supported by metal elements. Le Corbusier called the metal "French Aluminium" when drawing the material alongside the pisé, "in that most exact and the modern of metals."[108] The two schemes can be compared by looking at interior images of the cité and Roq et Rob side by side. The cité's columns were made from thick pisé blades, whereas Roq et Rob's were made from thin metal posts. The metal posts made Roq et Rob's interior perspective seem light and open, with slender columns allowing more space for cupboards and joinery. While providing more room on the ground level, thin metal columns made the second-level floor slab smaller, giving the impression of an open void space above. Le Corbusier's metal elements were proposed as a modular grid system with a 226 x 226 x 226 equal square dimension. The dimensions of these cell units meant the cells could be designed for various applications with great freedom in schemes of two or three stories in height.[109] The mixture of modular 'cell-like' modules combined with the organic material of earth gave the progress and efficiency of machine-made cells a sense of humanity.[110]

On the border between Austria and Switzerland, rammed earth experts Lem Ton Erde use robotic

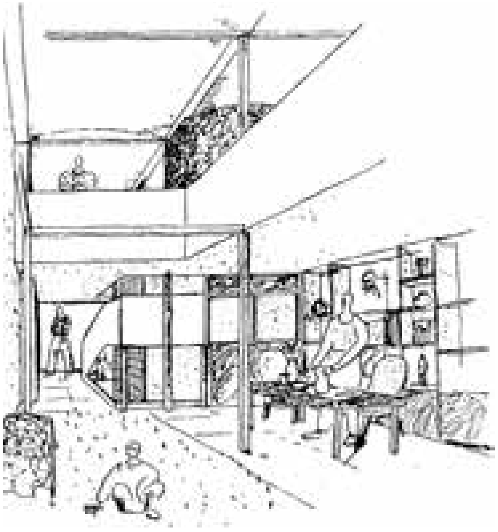


Figure 18: Perspectives interieures des maisons

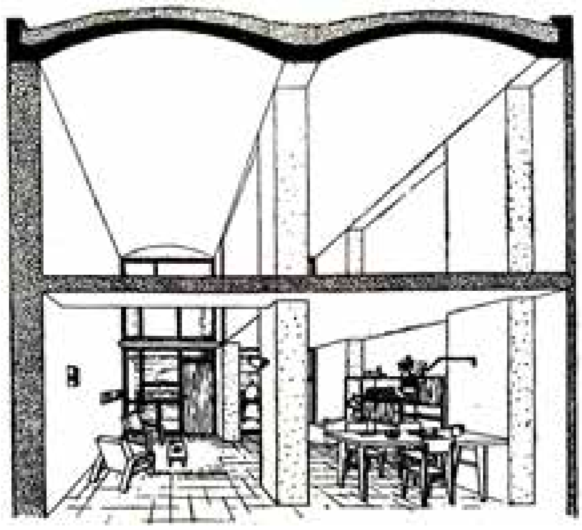


Figure 19: Coupe sur une maison familiale type a flanc de coteau

machinery to prefabricate rammed earth modules. Parts of engines from agricultural equipment are reconfigured by the team and adapted to become part of their rammed earth manufacturing process. A group member, Sami Akkach, agreed to an interview upon my visit to their factory in Austria and through our conversation, insights were shared into their prefabrication process. Sami explains how compost turners, customarily located on farms, are adapted to rotate dry mixtures of earth and engines borrowed from farming equipment are made into robots. Once the compost turner has combined the rammed earth mix, the earth is placed into a bucket, hoisted up by a crane and poured into Roberta, their prefabrication robot. Roberta feeds the earthen mixture through formwork and compacts the earth with a vibrating plate. After the plate has initially compacted the soil, robotic arms or pneumatic dampers finally ram the earth into position. Each layer of earth is rammed down from 16cm to 8cm high along a 40-meter wall length. Once the wall has been rammed all the way to the top, the formwork is removed, and the 40-meter length of wall is cut into smaller modules. When the rammed earth is completely dry, the modules are trucked off to site and arranged into position according to the architectural plans. Roberta is the third or fourth-generation version of the machine. Each time, the robot's parts are upgraded and modified to speed up the ramming process. Sami explains their approach is always in a state of experimentation, with Lehm Ton Erde constantly testing and improving their methods to open new opportunities for prefabricating with earth.

Lem Ton Derde: Roberta

Lem Ton Erde

Interview with Sami Akkach from Lem Ton Erde about their rammed earth prefabrication methods and mixing techniques. The Lem Ton Erde team, lead by Martin Rauch developed a prefabrication robot to make rammed earth less labour intensive and more efficient.

CD:
How do Lehm Ton Erde mix their rammed earth colours?

SA:
When we need material to make our rammed earth walls, we adjust the mix for various reasons. We can change the combination when rammed earth is applied to external or internal applications and when making different colours. We try not to adjust the colour too much because colour naturally comes from the clay within the ground. If we need to make a redder mix, more clay from the land must be added. In these instances, the clay is typically taken from another location, making the process less sustainable.

CD:
What is the process of making a dry mix of rammed earth?

SA:
We grab material from our storage area and sieve the aggregate with our machinery. We add a bit of extra gravel depending on the particle sizes present in the mix. In addition to pouring more gravel into the mix, we can add crushed brick or crushed concrete. We aim to mix a large amount of soil when planning the weight of a dry blend because when a smaller batch is made, there is more of a chance the colour will change. In the instance where the mix is too small and more soil needs to be added, clay is taken from different sources. The colours will look similar when the mixture is wet, but when the mix is dry, the wall will have slightly different pigmentation, which could ruin a project.

CD:
What equipment does your practice use to mix earth?

SA:
When the rammed earth specialists are ready to pour the earth into the formwork mould, we remove the mixture from the storage sheds and transfer the mix into a forced action mixer. The mixer allows us to turn over large particles. Most machines would break with earth being a dry mixture with 5-7 per cent moisture and large aggregate sizes. The forced action mixer is strong enough to make high-quality batches for us. When ramming earthen walls directly on a building site, we would mix the earth with a front loader, and specialists would pour the sand into the mould with shovels, buckets and rakes.

CD:
How is Lehm Ton Erde striving to make the mixing process more sustainable?

SA:
The mixing process has a minimal carbon impact, and our factory doesn't use fossil fuel energy sources to power our equipment. We have a hydroelectric plant to power our machines, and these alternative sources keep our process as low carbon as possible.

We have collected agricultural equipment and adapted the machines to make rammed earth. Speciality rammed earth products aren't available to buy, therefore we need to adjust our own devices. Sometimes, we use compost turners for dry mixing, adapted from farming systems. Once we have placed a bigger engine in machines like these, they are ready to be used in the rammed earth process.

CD:
How are percentages of material calculated when making a suitable mix?

SA:
Mixtures are made by feel and experience. Accurately measuring vast portions of earth is impractical, so an experienced hand makes all the difference. What specialists are looking for is an even distribution of aggregates. For external walls, we add larger particles to increase the walls' erosion resistance. A mix with more minor aggregates results in increased compressive strength, but larger pieces of rock can protect the exterior surface of the wall from erosion. A more textured wall with larger particles will stop water from flowing quickly along the surface.

An even distribution of aggregates ranging from small to large is needed, combined with 30% loam and about 20% clay. You never truly know how much clay is in the mix, and judging these amounts comes down to experience.

CD:
How do you test the mix?

SA:
The sign of a good mix can be tested if you take a handful of earth, squeezing the soil in your hand, and the particles bind on their own. When pressing the earth into a ball, you shouldn't be left with muddy residue on your hands. Then, allow the earth ball to drop to the ground. If the ball smashes into smaller pieces, this signals a good mixture.

Too little or too much moisture can impact the compressive strength and workability of the material. If the moisture content is too high, the material becomes too plastic, the mix will move around in the formwork when rammed, and the particles will not fall into position. Rammed earth walls will crack if the moisture is too wet. If the mix is too dry, the particles bounce into each other and don't fall into position.

We test our rammed earth mixtures every 50 cubic meters of material we make. We mix up batches and pour test cubes to send to our engineering partners. The engineers test the mix to make sure the compressive strength is correct.

CD:
How does clay help with binding a mixture together?

SA:
The clay inside the mixture binds everything together

with electrostatic forces. For this process to occur and the particles to bind together, the clay must be activated with water. While wetting the mixtures, we ensure all the different aggregates are covered with a clay coating. The way the material is mixed is essential because if too little clay is spreading around the mix, the particles won't stick together. Our forced action mixture is an excellent machine because the mixer presses all the particles into the bottom of the pan, and each piece of aggregate is coated.

When experimenting with different aggregate types like crushed brick, you must consider how the coating process will vary. If crushed brick is used, the mixture can be soaked in a slurry first, so when crushed brick is added to the mix, a clay coating will be maintained on the outside. There are tricks we use for each material.

CD:
Can you talk about your prefabrication robot, Roberta?

SA:
After we have mixed our clay and aggregate together, the next step is prefabricating our walls. We bring the mixture into the factory and place the mix into a bucket. The bucket is hoisted up with the assistance of a crane and put into Roberta, our prefabrication robot. We first developed Roberta with our building partners for the Herzog and de Meuron project in Basel. The Basel Ricola factory was the first project to use this prefabrication technique. The Roberta you see here is a third or fourth-generation version of the machine. We have upgraded the robot several times to speed up the process.

We were taking Roberta to various sites around Europe, but after a while, it was time to give the machine a permanent home. We built this factory around Roberta to house the robot.

CD:
How does Roberta work?

SA:
We put the robot on rails at the beginning of the line of formwork, and the formwork rails are adjusted depending on the required thickness of the wall. The sides of our formwork aren't tied together with pins because we have permanent formwork on both sides. The absence of pins means our rammed earth surface does not have permanent markings. In addition to these advantages, our formwork is much stronger than the formwork we would use to ram earthen walls on site.

The mix is compacted with a vibrating plate once the machine has fed our earthen mixture through the formwork. After the earth has been initially compacted, the pneumatic dampers ram the earth into position.

We ram a 40-meter-long wall at a time, with each layer ramming down from 16cm to 8cm. Once the robot has rammed one layer, the machine travels in the other direction to ram another layer. Once the wall has been rammed all the way to the top and the formwork is removed, we cut the wall with a saw. The rammed earth pieces are left to dry over a period of two to six weeks, depending on the thickness of the wall and the weather. Once the walls are dry, they are taken to the building site. We work closely with the architects and the construction teams to schedule when the walls will arrive so our factory has available space to stack the next batch of earthen walls.

CD:
How are the earthen pieces assembled on site?

SA:
When we receive a project from an architect, we collaborate with their team and share advice with them. During the process, we take their elevations and subdivide the drawings to optimise where each cut will be made. We identify the location of openings in the wall and finally place them in a rammed earth course.

We try to serialise the production process. One element is placed on site, and the next element is stacked next to the other. The components are arranged like brick courses to prevent deviation from a straight wall. When the clay is completely dry, the walls form a tongue and grove connection with each other.

CD:
What do you see happening to prefabrication in the future?

SA:
At the moment, this place is still a venue for experimentation. We are building many projects from rammed earth however, we still dedicate a lot of time testing and improving our methods. We are looking at expanding our factory to open up more opportunities.

ERDEN Werkhalle: Schlins, Osterreich

Architect (Martin Rauch & Lehm Ton Erde) Wall Height (Over 2 Storeys) Typology (Factory) Climate (Tundra) Soil Name (Fluvisol) Coarse Fragment (11%) Sand (47%) Silt (34%) Clay (19%) Texture Class (Loam)

School Pavilion Allenmoos: Zurich, Switzerland

Architect (Boltshauser Architekten) Wall Height (1 Storey) Typology (School) Climate (Warm-Summer Humid Continental) Soil Name (Histosol) Coarse Fragment (16%) Sand (27%) Silt (38%) Clay (35%) Texture Class (Clay Loam)

Eshtosa Encolsure Basel Zoo: Basel, Switzerland

Architect (Peter Stiener) Rammed Earth Expert (Lehm Ton Erde) Wall Height (1 Storey) Typology (Zoo) Climate (Warm-Summer humid continental) Soil Name (Histosol) Coarse Fragment (16%) Sand (27%) Silt (38%) Clay (35%) Texture Class (Clay Loam)

Equestrian Centre Merricks:
Bunurong/Mornington Peninsula

Architect (Seth Stein Architects and Watson Architecture + Design) Wall Height (1 Storey) Typology (Equestrian Centre) Climate (Mild Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

RACV Torquay: Wadawurrung/Surf Coast Shire

Architect (Wood/Marsh) Wall Height (Over 2 Storeys) Typology (Resort)
Climate (Mild Temperate) Soil Name (Planosol) Coarse Fragment (2%)
Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

Woodleigh School Homesteads: Bunurong/Langwarrin

Architect (Law Architects) Wall Height (1 Storey) Typology (School) Climate (Mild Temperate) Soil Name (Podzol) Coarse Fragment (18%) Sand (92%) Silt (6%) Clay (2%) Texture Class (Loamy Sand)

Kiln Tower for the Brickworks Museum: Cham, Switzerland

Architect (Boltshauser Architekten) Rammed Earth Consultant (LEHMAH AG) Wall Height (2 Storeys) Typology (Kiln) Climate (Tundra) Soil Name (Cambisol) Coarse Fragment (15%) Sand (40%) Silt (46%) Clay (14%) Texture Class (Loam)

Cinema Sil Plaz: Ilanz, Switzerland

Architect (Capaul & Blumenthal Architects) Rammed Earth Expert (Lehm Ton Erde, Aubry Sculptur, Baukunst, Team Cinema Sil Plaz) Wall Height (2 Storeys) Typology (CInema) Climate (Tundra) Soil Name (Retisol) Coarse Fragment (5%) Sand (37%) Silt (52%) Clay (11%) Texture Class (Silt Loam)

Visitor Centre at the Swiss Ornithological Institute: Sempach, Switzerland

Architect (mlzd) Rammed Earth Expert (Lehm Ton Erde) Wall Height (2 Storeys) Typology (Visitor Centre) Climate (Tundra) Soil Name (Cambisol) Coarse Fragment (9%) Sand (33%) Silt (47%) Clay (20%) Texture Class (Loam)

Rammed Earth Dome: Honggerberg, Zurich

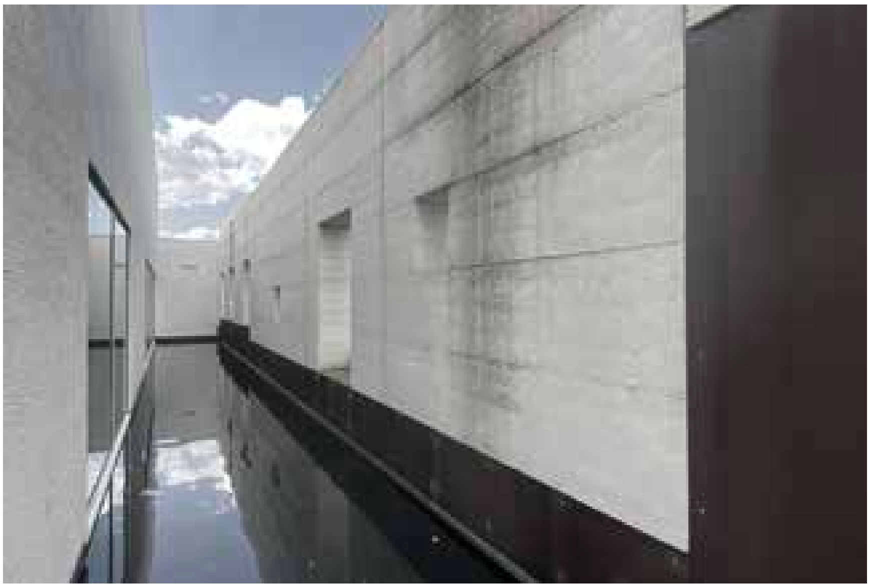
Architect (ETH Zurich Department of Architecture) Rammed Earth Expert (Martin Rauch, Lehm Ton Erde) Wall Height (1 Storey) Typology (Vault) Climate (Warm-summer humid continental) Soil Name (Cambisol) Coarse Fragment (15%) Sand (40%) Silt (46%) Clay (14%) Texture Class (Loam)

Monarto Safari Park: Pomberuk/ Murray Bridge

Architect (INTRO, studio gram) Rammed Earth Expert (Adelaide Rammed Earth) Wall Height (2 Storeys) Typology (Zoo) Climate (Mild Temperate) Soil Name (Calcisol) Coarse Fragment (12%) Sand (49%) Silt (33%) Clay (18%) Texture Class (Loam)

Our Lady of the Southern Cross Chapel: Wathwaurong/Manor Lakes

Architect (Branch Studio Architects) Wall Height (1 Storey) Typology (School) Climate (Mild Temperate) Soil Name (Luvisol) Coarse Fragment (16%) Sand (42%) Silt (35%) Clay (23%) Texture Class (Loam)



Bunurong Memorial Park: Bunurong/Dandenong South

Architect (BVN & Aspect Studios) Wall Height (2 Storeys) Typology (Cemetary) Climate (Mild Temperate) Soil Name (Podzol) Coarse Fragment (18%) Sand (92%) Silt (6%) Clay (2%) Texture Class (Loamy Sand)

Lenah Valley Bus Stop: Nipaluna/Hobart

Typology (Bus Stop) Climate (Cool Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

Tres Marias: Alentejo, Portugal

5. Conserving Earth

This chapter focuses on rammed earth conservation. Conservation of the Villa Ficana in Italy has brought the community together to live in rammed earth houses, fostered by a renewed appreciation for their earthen heritage. Similarly, Granada's Alhambra Gardens and Palace conservation effort is paired with an archaeological investigation. Conservationists make new discoveries about the palace while they work. An interview with John Jeffrey from Architectus reveals how the rammed earth walls of the Sydney Modern negotiated with the domain's garden landscape

Villa Ficana

Recovering An Original Earthen Mixture

Looking down upon a bird's eye view of the Villa Ficana, rays from the sun are hitting a pattern of tessellated roof tiles, with each roof tile bouncing back new colours of terracotta. On the side of the pitched roofs where the sun has direct access, the tiles appear as brightly coloured variations, and on the side of the roof with ambient light, the tiles appear with a subdued fluctuation of colour. Looking closely at each tile, some tiles appear in good condition, whereas others appear cracked and discoloured. In some village sections, entire portions of the roof have collapsed. Similarly, the terraces underneath the terracotta roofs vary; some appear in good condition, while others appear in dire disrepair.[111] Each roof form adheres to the shape of the terraces underneath, with some profiles wider and others smaller, matching the outlines below. The muted yellow plaster covering the exterior matches the terracotta tiles above. However, some plaster gradually strips away from the outside surface, revealing the earthen walls underneath. These earthen walls were constructed during the nineteenth century and are an excellent example of vernacular architecture in the region of Macarata.[112] [113] If the village is left to deteriorate further, its estimated life span could be as low as a few years.[114]

In the early 2000s, local authorities restored about half of the houses in the Ficana neighbourhood.[115] In 2004, a "Guideline for earthen buildings" was adopted by conservationists to recover and study the earthen building techniques.[116] Three techniques were discovered and named freemason, adobe and pisé. The freemason technique was conducted by superimposing layers of earth obtained from a mixture of soil, straw and water, which were pressed down and rammed. For the adobe technique, walls were built by superimposing bricks on top of each other in a staggered arrangement. To make the bricks, a mixture of earth, straw and water was pressed into moulds and allowed to dry. For the pisé technique, the walls were built by pressing the mixture with a wooden mallet into a formwork mould and left to dry.[117] Sometimes, the earthen mixture was moistened and stamped down with human feet. [118] A series of hand tools were utilized by builders, including shovels, spades, and blades to trim the walls with human hands. Conservationists are experimenting with all three techniques to replicate the hand-building methods and match the existing

Figure 20: Earth Houses Of The Villa Ficana Ecomuseum

earthen structures. Conservationists can restore the terracotta terraces to their original forms by rediscovering the original earthen techniques. [119]

Most of the earthen walls in Ficana are covered with plaster on the outside, hiding the material from view. Plaster was applied to the exterior of the walls because people were ashamed to expose their earthen walls. During the eighteenth and nineteenth centuries, people living in rammed-earth buildings lived in extreme poverty and overcrowded conditions. Therefore, the earth became associated with suffering, misfortune and shame, leading many people to abandon their earthen dwellings and live elsewhere.[120] The Villa Ficana Ecomuseum is leading the way by changing the cultural appreciation of earthen architecture through conservation.[121] Their conservation efforts are protecting the houses and welcoming people to return to the village to live there again. Currently, nearly all of the earthen houses are inhabited once more.[122] Similar conservation efforts aim to restore cultural appreciation for the cluster of buildings that make up the Alhambra in Spain. The Alhambra's original name is translated to 'the red fort,' referring to the surrounding landscape's layers of red clay soil.[123] Sitting on top of the red clay are a series of gardens and orchards that terrace down the slope of the hill.[124] These gardens played an essential role in feeding the inhabitants of the palace. The rammed earth retaining walls of the surrounding gardens and Alhambra are being meticulously restored to preserve the monument and restore cultural appreciation for the palaces. Through their conservation efforts, archaeologists hope to learn more about the history of the extensive gardens and the broader palaces of the Alhambra.[125]

Following the restoration of some of the earthen villas, the Ficana municipal authorities held a competition to start a museum initiative. In 2016, the competition winner formed the Ecomuseum Of Villa Ficana Raw Earth Houses. The Ecomuseum was granted nine earth houses free of charge, and each was turned into a museum. [126] Locating a museum inside examples of rammed earth buildings makes each space act like a cultural incubator for developing rammed earth knowledge.[127] The museum exhibits, digital websites and archives inform visitors of their historical identity and provide a venue to hold cultural workshops where rammed earth skills are shared.[128] Volunteers are trained at the museum about the neighbourhood's history and put into contact with rammed earth construction techniques, with the hope volunteers might build from rammed earth in the future. The Ecomuseum's website and digital archives also double as a data collection point for volunteers to refer to.[129] By collaborating with the International Association of Raw Earth Cities, the data collection centre can hold local knowledge and international methods of working with rammed earth in both paper and digital format, making the information easily accessible.[130] The centre acting as a reference point for anyone who wishes to build from rammed earth and as a demonstration point for rammed earth knowledge using books, documents and physical buildings.

The Ecomuseum's cultural activities foster social connections between local residents.[131] A series of workshops, meetings and guided tours bring people to the museum to learn about raw earth and promote more positive economic and social living models in the area. This conservation work helps associate positive experiences with the earthen houses, elevating feelings of inclusion and social connection in the collective memories of residents. The work of Ficana's Ecomuseum has sparked the interest of other major conservation agencies, including ICOMOS, AICAT, CNR, universities and local schools, fostering connections with younger residents.[132] The local elementary school in Macarata has formed a connection with the village by creating a project entitled A School Adopts A Monument and publishing the most informative document on the town called Dalla Terra, La Casa: Il Borgo Di Villa Ficana.[133] The project hopes for young people to re-discover their history and re-form connections with the heritage of Ficana. The school aspires to instil an appreciation for rammed earth in the next generation.

By far, conservationists' longest and most challenging work has been changing the view local people had about earth as a material.[134] Returning to the aerial view of the village, most of the earthen walls are covered by materials on the outside, so the earth cannot be seen. Occupants were ashamed to leave their earthen material exposed on the facade. In some cases, a layer of brickwork completely covers the outside. In other cases, the exterior is covered with plaster and lined with terracotta. [135] From the eighteenth and nineteenth centuries, the people of Ficana lived in extreme poverty, in overcrowded conditions and without toilets.[136] Thus, rammed earth became associated with suffering, misfortune and shame, leading many people to leave Ficana to live elsewhere.[137] Before conservation efforts began, there was an attitude of resistance and negativity towards restoring the building fabric woven with triggering memories of poverty. Yet, not everyone decided to move out and live elsewhere, there are a few hidden examples of people who, despite the challenges, chose to stay.[138] The presence of these people who stayed is evidence of their resilience and the longevity of earthen architecture. The stigma surrounding earth remains, yet restoration efforts are beginning to foster a renewed sense of appreciation and opportunity.[139]

Terraces Supporting Each Other

An image of a single row of earthen terraces shows each house leaning against the other, supporting the weight of the neighbouring house.[140] The houses in the picture are built directly on the ground and lean towards the curve of the land, relying on the buildings next door for support. Trees planted along the street bend and sway according to the terrain, and their branches lean additional weight onto the dwellings. Vegetable gardens, small grasses and plants grow in between the earthen walls, using their surfaces as a trellis to expand upon.[141] Each earthen house has a five-by-five meter square dimension, with each shape organically moving and shifting with the land to form

Figure 21: Il Borgo di Villa Ficana

rooms not quite square. The ground-level rooms, historically used for stables, shops or workshops, have floors directly attached to the slope.[142] These spaces are accessed by winding roads that snake through the narrow winding streets between the terrace rows.[143] The roads curve up and down the lines of terrace houses as they snake through the urban plan of the village. The earthen dwellings are topped with a sequence of roofs, with tiles that shimmer a colourful mix of earthen shades according to the rippling sunlight. Chimney stacks interrupt the terracotta tiles by poking up from the roof space and leaning gracefully in all directions.[144] Each earthen house leaning and swaying with the fall of the terrain.

As the families living inside each dwelling organically grew and changed, so did alterations and additions to the fabric of earthen houses.[145] In an interview with Nonna Fiora, a long-time resident, her experience of living in Ficana are revealed.

There were only two bedrooms: one for us (me, my husband and children), and the attic for the in-laws … Once it was nice because we went to one's house, then to another's house and we talked, we talked to each other, and we engaged in gossip. There was no television, there was nothing like that, and so then we chatted among ourselves. In the summer, we all worked together, embroidering under a tree, outside. There was harmony between us …. These houses are ancient, they are a heritage that must not be lost and we ʻold" people would like to deliver them to our grandchildren, to great-grandchildren to keep their memory.[146]

Nonna's childhood experience of living in an earthen house exemplifies an entire generation of people calling Ficana home. She speaks about how her grandchildren and children came together and played with each other on the streets between building rows. Nonna would like memories like these to be preserved as they were woven into the houses where she spent so much time. She says her earthen dwelling began with only two bedrooms and like many homes, families grew, causing physical changes in the building fabric to accommodate growing families.[147] Small extensions were made into bedrooms, and two terraces were merged to create one larger unit. Stables on the ground level were converted into workshops and street-level shops. Each generation left its mark on the built fabric over time, with signs of families growing and shrinking evident on the exterior of the streetscape. Families are lending and borrowing spaces to accommodate new people, with most alterations and additions occurring behind the front façade.[148] Behind a plastered or bricked-up street front was movement, adjustment and customization of earthen architecture, creating an infinite set of responses to the square terrace house.

With an increase in the activity of alterations and additions to earthen houses, there is an increased risk to the structural stability of load-bearing walls.[149] Returning to the aerial image, a clear difference can be seen between areas of rammed earth that remain untouched and portions of earth that have been altered. The original fabric is made from thick earthen walls, floors made out of terracotta tiles, wooden beams and staircases made from terracotta.[150] In some cases, foreign materials have been added by residents who do not have knowledge of rammed earth construction techniques and alter the stability of the walls. In other instances, terracotta tiles and timber have been removed from the earthen structures and added to other houses in other villages.[151] These alterations and additions have transformed the structures of earthen dwellings into a mixture of earth and contemporary materials. However, the most significant threat to the town is the complete demolition of earthen buildings to make way for concrete apartment blocks. Edging the same aerial view, apartments made from concrete and asphalt are beginning to surround Ficana. Therefore, conservation and restoration efforts are vital for the structural stability of each house and the survival of Ficana's earthen heritage. A wave of concrete and high rise threatens the village.[152]

Alhambra

The Alhambra Gardens

An arrangement of purple flowers, yellow flowers and green shrubs are displayed in a harmonious array of colours in this image of the Alhambra's gardens. The tufts of colour covering the slope to the palace are like patches sewn into a blanket. The rammed earth walls of the Alhambra palace appear only as tassels edging a living fabric of flowers. This image I captured on my travels to the palace gives a snapshot of the extensive gardens covering the slope and the critical role of agriculture and gardening in providing the palace's inhabitants with food.[153] Locating the gardens on such a steep slope warranted terracing the land and turning the ground into stable soil suitable for fertile growth. The pitch required thick retaining walls strong enough to hold back the mountain of earth. Therefore, rammed earth walls were chosen because the material was strong enough to hold back the garden beds. Large orchards, extensive gardens and pedestrian pathways weave through the series of terraces and retaining walls, hugging the slope's contours. The water pumped along the terraces from the nearby river moistens the gardens and ensures the soil is adequately irrigated for fertile growth.[154] Fertile soil, beautiful orchards and gardens create an urban paradise filled with abundant fruit and vegetables for the palace's inhabitants to enjoy.

In 2006, restoration was undertaken on one of the rammed earth walls retaining an orchard in the gardens. An image taken of the wall from the west shows greenery draped over the top and sides of the wall and where tree roots grow along the surface.[155] Underneath the draped vegetation, a grid of holes signals a series of attachments to the wall's surface, which have been removed over time. However, the overgrown vegetation and tree roots are splitting the earthen structure into pieces and are one of the primary sources of damage. Therefore, conservationists set out to undertake a restoration process. The first step in the restoration procedure was for conservationists to establish a safe distance between the wall and the garden by cutting back all vegetation. Once the roots had been removed from the wall, the earth was firmly anchored into the ground to stabilise the structure. The second step for conservationists was to clean the wall with a lime wash methodically. More potent chemicals were used where more damage was present.[156] Another image taken of the wall from the west after the restoration process shows all the vegetation removed, revealing the original rammed earth surface.[157] This image displays a system of ramps on the right-hand side of the wall, indicating a larger geometric layout of garden beds. Accompanying the discovery of the system of ramps, another wall was uncovered attached to the current one under conservation. These further archaeological discoveries are helping conservationists to piece together a larger picture of the Alhambra's gardens.[158]

Alhambra: Granada, Spain

In some circumstances, comprehensive damage has occurred to the rammed earth walls, shifting the response of professionals from conservation to intervention.[159] A photograph of the retaining wall's top shows a noticeable gap in the middle of the two walls.[160] To the left of the eroded gap, capping that would protect the wall from erosion has crumbled away, with the majority of the capping remaining in place to the right of the line. Therefore, conservators set about intervening at the junction between the two retaining walls. Firstly, the dirt from the top of the surface was removed, and secondly, the large gap between the walls was filled. The walls were filled with a mixture of sand and chemicals poured into the void, including a sealant over the top. The aim for conservators using the mix was not to restore the walls to their original form but to pack the gaps to a certain extent. Continuity between each length of the wall was gained by filling the void with sand. This is an essential intervention that gives structural stability to the assemblage of walls. Finally, water moving across the surface would be redirected and drained off to prevent further erosion.[161] In an image after the conservation work was complete, a significant difference can be seen due to the restoration work that had taken place. In this image, the gap between the walls had been filled, and the capping had been replaced. The assemblage of walls was once again restored into a strong retaining element. More and more restoration efforts like these are occurring as the Alhambra continues to decay. The increase in freezing winter temperatures due to climate change is causing more markings and cracks to appear over time.[162]

Seismic activity and underground movement of the hill underneath the Alhambra is another cause for concern for conservationists. Under The Special Protection And Interior Reform Plan For The Alhambra And Alijares (1987), a special progress report was published that outlined a geotechnical assessment of the land underneath the Alhambra for the first time.[163] In the report, the material causes of seismic movement underneath the Alhambra were analysed and categorized into groups. The groups included material that was classified as natural and material that was classified as artificial. Natural cases of seismic activity were identified as clay and water deposits. Layers of impermeable red clay separate layers of sand and loose conglomerates. Between these layers, pockets of groundwater may get trapped, causing pooling and movement of the terrain.[164] Artificial cases of seismic activity were identified as the building's overall weight. The instability of the landscape underneath the hillside where the walls rest is evidence of their effect on the ground. The load-bearing weight of Alhambra's architectural structures is visible in fissures and deformations along the wall's surface. The report assessed the terrain's ability to support a permanent load as large as the Alhambra in the long term.[165] Experts acknowledge that the subterranean level underneath the Alhambra has been under constant movement and change since studies began. Efforts to stabilise the terrain of the surrounding mountain will remain ongoing.

Accompanying the threat of Geological instability, the Alhambra has endured threats from urban

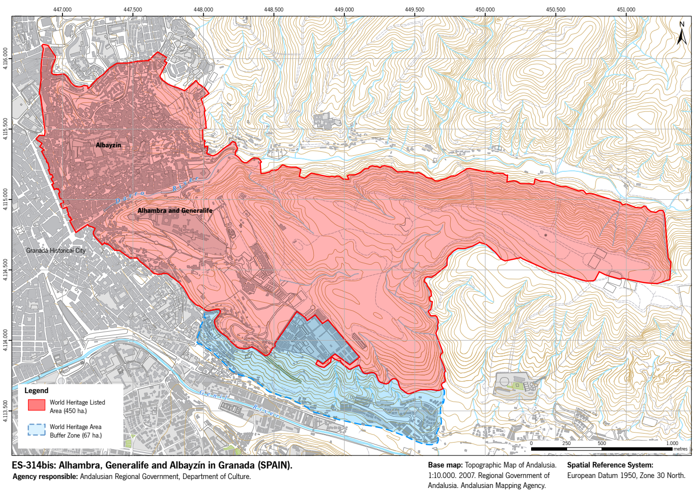


Figure 22: Alhambra, Generalife and Albayzin, Granada

interventions. Two protection boundaries are outlined in the Alhambra, Generalife and Albayzin, Granada Map.[166] The map shows the location of the Alhambra and a large area surrounding the monument, shown in red. The total area covered in red measures 450 hectares of land, including parts of a historical city and portions of the terrain. Next to the red covering, a blue buffer zone expands towards the south of the map. This blue area covers about 67 hectares and extends the protection of the area shown in red. This buffer zone was drawn up in hast to prevent a private development company from building luxury apartments in 1980.[167] The Special Protection And Interior Reform Plan and the Alhambra Map were drawn up alongside each other to streamline the conservation administration process and stop the apartments from being constructed. The blue buffer zone on the map covers the area under threat. The plan and the map show the Andalucian government's care for the monument and their determination to conserve the Alhambra. They argued the apartments would cause irreversible damage to the surrounding characteristic landscape in such close quarters to the monument. The documents took the site and expanded the site's protection zone into the surrounding urban setting and outlined the reasons for extended protection. In 1984, UNESCO declared the Alhambra one of the best-preserved Western Islamic Palaces and included the monument on their list of World Heritage Sites.[168] Inclusion on UNESCOs list protected the monument from damage in the future.

Crumbling Walls

Alhambra's fortress and palaces never became the primary residence of a royal family nor a major capital city for this region of Spain, leaving the complex abandoned for more than five centuries.[169] An English tourist, William Jacob, noted in 1810, "Without repair, to which the finances are inadequate'… it will in a few years be a pile of ruins; its voluptuous apartments, its stately columns, and its lofty walls, will be mingled together, and no memorial be left in Spain of a people who once governed the peninsula."[170] As Jacob had predicted, the passage of many years without dedicated protection led to the deterioration of the palace's architecture. The intricate floors were overgrown with weeds and moss. The Fountain Of Lions, arguably the most beautiful part of the palace, was surrounded by a pile of rubbish.[171] With such beautiful residences abandoned, squatters moved in. Gypsies, donkeys, vagrants and all sorts of settlers and their animals migrated to the complex, making their home inside the crumbling earthen walls.[172] Rooms once considered the most beautiful in the world were at risk of being lost to memory. Travellers who visited the monument were forced to use their imagination when looking at the crumbling walls and ceilings.[173] Without an urgent intervention by experts like UNESCO, whose goal was to protect and conserve the monument, Alhambra's priceless architecture would be lost forever.

Further to conservation activities, preventative planning measures have been implemented to stop visitors from conducting damaging behaviour.[174] For example, only a couple of years after the Alhambra was declared as Spain's National Monument, Charles Davillier and Gustave Dore were horrified when a foreign tourist casually removed a ceramic tile from the palace "as if he was doing the most natural thing in the world."[175] Davillier and Dore's concerns were echoed when tiles were looted, ceramic objects were removed, and widespread vandalism occurred. The Special Protection And Interior Reform Plan For The Alhambra And Alijares applied crowd management systems to prevent vandalism and damaging activity. The Plan balanced the need to protect the monument from tourists while remaining accessible to the public.[176] These balanced measures were defined as limiting the capacity of tourists visiting the complex each day and restricting access to more popular destinations between allocated times. Pedestrian routes were planned using adequate signage, limited population numbers accessing sensitive zones, and security cameras monitoring people for vandalism.[177] This data is collected, analysed and used to study the impact of people's movements. Consequences are weighed and compared against the benefits of generating revenue from paying tourists to fund conservation efforts.

Further inauthentic alterations were made to the structure to please the eye of visiting tourists, turning the Alhambra into more of a replica over time.[178]

Architect Owen Jones, who visited the Alhambra in the nineteenth century, sought to draw the Alhambra with strict scientific detail, publishing the drawings in Plans, Elevations, Sections, And Details Of The Alhambra in 1842.[179] On page 156 of this book is a colourful and accurate illustration of La Ventana Sala De Las Dos Hermanas (Window In The Alcove. Hall Of The Two Sisters) in print.[180] This wonderful nook is located at the upper end of the Hall Of The Two Sisters and looks onto the garden of Lindaraja. All the variations of colour and ornament present on the interior walls of the Alhambra are mixed in this alcove to the most beautiful effect.[181] Reds, blues, yellows and greens cover the intricate ceramic ornaments, creating a window of the utmost detail and elegance. This drawing is a testament to how Jones worked methodically, documenting the spaces uninfluenced by emotion and removing all influence on the work to simply look at what was there. Jones's work creates the most precise view and the basis for the historical record of Alhambra's structure.[182] Studies like these could be referred to when damage from fire, seismic activity and foreign materials occurred, leaving a mark on the surface.[183] These technical drawings set a date for materials and help create a chronology of the palace's transformation over time.[184]

Conclusion

Located within the sprawling greenery of the Royal Botanic Gardens in Sydney and adjacent to the green gathering spaces covering the domain is the Sydney Modern Gallery. The walls of the Sydney

Modern have been made from pink tones of rammed earth and symbolically retain the land of the hillside adjacent to the Royal Botanic Gardens. The pink earthen walls travel from the outside to the inside of the building, signalling the circulation spaces for visitors as they move from gallery to gallery. The walls offer boundaries between indoor gallery spaces and open outdoor gardens as they flow around the hill. In an interview with John Jeffrey from Architectus and the team who designed the gallery, I discovered the design connections between their rammed earth walls and the garden landscape. Jeffreys explains how rammed earth comes in various colours ranging from pale pigments to darker tones according to the make-up of the soil. When choosing the final colour, the team collaborated with John Oliver, the gallery's rammed earth expert, to identify a colour of rammed earth deemed acceptable. John Oliver used his years of experience with rammed earth to the build tall gallery walls flowing with colour. The new colour of the rammed earth walls provides a unique backdrop for artworks to be displayed and a departure from the typical white-walled gallery space.

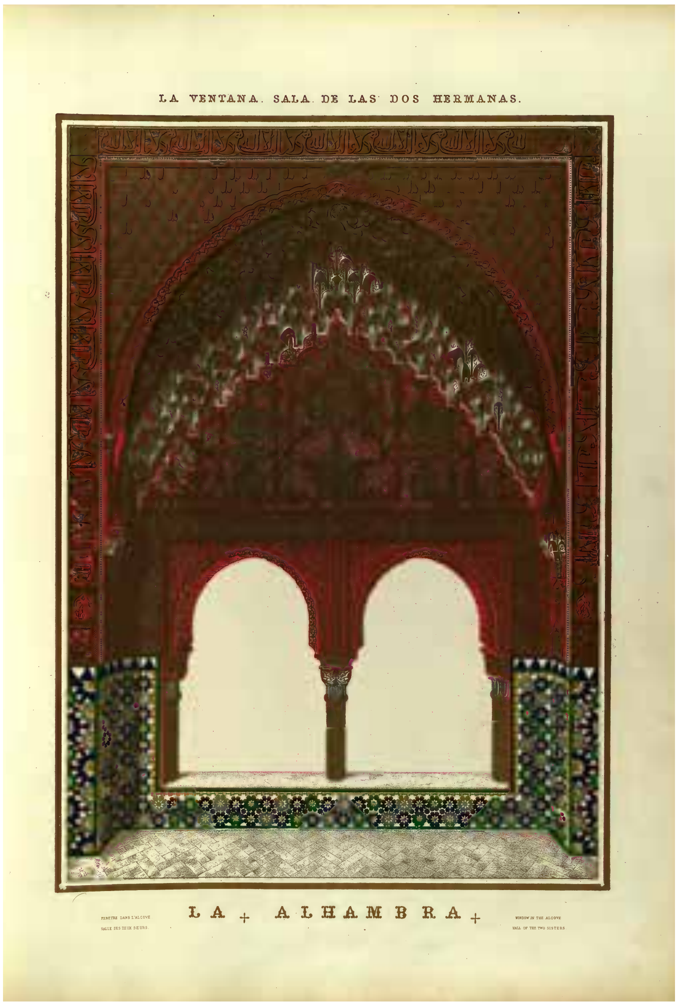


Figure 23: La Ventana Sala De Las Dos Hermanas

Granada, Spain

Sydney Modern

Interview with John Jeffrey from Architectus about the coloured rammed earth wall within the Sydney Modern. The Sydney Modern is designed by SANAA with a light pink wall indicating circulation spaces between galleries.

John Jeffrey's words are noted as JJ and John Olivers words are noted at JO.

CD:
How do your rammed earth walls negotiate with the existing landscape?

JJ:
Our earthen walls attempt to replicate a stratum of cuts in the side of the hill. The earthen walls travel from the outside to the inside of the building and back out again. This pattern repeats up the hill, highlighting the hill's terraced stratum as the landscape slopes upward.

CD:
Who was the gallery's rammed earth expert?

JJ:
Our project had a significant amount of rammed earth to build. Our rammed earth expert, John Oliver, relocated his workers from Queensland to Sydney to work on our gallery project. The difficulty of the site and working conditions during Covid were significant obstacles to contend with, however, Oliver anticipated these and successfully constructed the wall.

CD:
How was the colour chosen?

JJ:
Rammed earth comes in various colours, ranging from pale pigments to darker tones. SANAA collaborated with how John Oliver likes to work and identified a series of colours they would accept. We made a sample of those coloured strata off-site and began making some prototypes. We did look at the soil from the excavation, however, the quartz properties were not conducive to binding the rammed earth together, and the excavated soil was discounted. There are specific properties to look for in the material mix, including fine aggregates found in certain types of soils that bind earth harmoniously together. To find aggregates to produce a particular kind of colour, aggregates must be sourced from a specific place.

JO:
The material we used was 90% from the Sydney region. We could only get white and yellow sand locally and needed to add some red from further afield to give a bit more warmth.

CD:
How do the rammed earth walls create a unique gallery experience?

JJ:
Our rammed earth wall will display art, but not in the conventional sense of display, with specified lux levels, light levels and controlled light. Our wall is located in the front of house, public meandering areas, creating a different environment for hanging art. Works will be suspended from the spaces above, and there will be a series of fixed points along the wall at regular intervals. Due to the lateral light hitting the area and the room's double-storey height with full-height glazing, this space is not your conventional curatorial gallery.

CD:
Could rammed earth provide a different background for artists to experiment with?

JJ:
We often collaborated with SANAA about how we would curate the gallery spaces and the conventional 'white wall' art gallery rooms. I think the texture and colour of the rammed earth give SANAA a point of difference and an opportunity to produce something unique. I believe these great 'front of house' spaces are a backdrop for the best work. The colouring and the textural qualities of the earth open up many possibilities.

CD:
How do the walls organise gallery spaces?

JJ:
The rammed earth walls define the circulation spaces through the building. They travel from inside to outside, defining internal and external circulation routes. For example, one rammed earth wall defines the meandering area from gallery to gallery and finally the café. These aren't strictly gallery spaces.

CD:
How do the rammed earth walls meet other structural elements?

JJ:
A series of details were sketched for the building, showing the interface with the existing structure and the poured concrete. There are so many connections and positions needed to connect with both objects. SANAA likes to use curves in their designs, and our rammed earth walls curve around the hillside. These curves increase the complexity of construction, especially when organising the support footings and structures connecting to the wall. We have drawn connections to wet areas, identified areas where membranes are used and drawn the connection with balustrades above the wall. These details may have been complex, but we have done it, and the gallery has been built.

CD:
How were the rammed earth junctions detailed?

JJ:
We asked ourselves questions, including how we would demonstrate horizontal joints with cantilevers. How was the formwork going to work around the junctions? How were the movement joints going to work? And how would we deal with the top of the rammed earth wall where the top is exposed to the weather? In addition to these questions, we thought about how each rammed earth pour would join together.

Another critical question was how the rammed earth would interface with the façade and keep the water on the outside from coming in. We drew strip drains at the back of the wall and weep holes at the base of the wall to deal with these waterproofing conditions.

CD:
What type of formwork did you use?

JJ:
Because our rammed earth walls are curved, John Oliver used a series of horizontal purlins with a strong backing as formwork. We didn't want a finish similar to concrete but a more textured surface. Our backing boards were made from plywood to achieve texture, and you can see the grains from the surface of the plywood in the rammed earth face. You can see the 600mm plywood board horizontal lines and vertical joints between the form ply. These shapes in the surface of the rammed earth combine with the granular surface of a timber formwork. The grains in our timber formwork have different absorption rates, resulting in a textural quality and grainy effect, with the 150mm stratum the most prominent feature.

CD:
Can you describe John Oliver's ramming process?

JJ:
In the instances where John Oliver's team couldn't fit their machinery, the earth was rammed into place from the sides. In areas where no machines could be used, the earth was meticulously rammed by hand. For example, the earth was rammed by hand underneath steel beams. There is no apparent visual delineation between hand ramming and mechanical ramming. This showed great dedication from John Oliver's team to hand ram areas of the earth that couldn't be accessed by machinery.

Another unique aspect of these 'hard to reach' areas is where the soil is placed inside the plywood moulds by hand. Oliver's team would attempt to pump the mud in place to overcome the large distances the earth was travelling from. Pumping was something the team hadn't tried before and a process designed only for the gallery. The earthen construction process was a combination of placing the earth by hand and using a pump.

JO:
Due to the restricted, busy, and terraced construction site, we devised a pumping methodology for material delivery into the formwork. This dictated that we use a sandy material.

CD:
What do you think rammed earth construction will look like in the future?

JJ:
Rammed earth experts like John Oliver have developed their techniques for laying rammed earth over many years. There is expertise in getting the stratum at one hundred per cent or a more natural flowing texture. These unique aspects might be lost if the process becomes more mechanised.

Sydney Modern, Art Gallery of NSW: Gadigal/Sydney

Architect (SANAA & Architectus) Rammed Earth Expert (John Oliver - Rammed Earth Constructions) Wall Height (Over 2 Storeys) Typology (Art Gallery) Climate (Warm Temperate) Soil Name (Technosol) Coarse Fragment (0%) Sand (0%) Silt (0%) Clay (0%) Texture Class (na)

Alhambra: Granada, Spain

Architect (Various) Wall Height (Over 2 Storeys) Typology (Palace) Climate (Hot-Summer Mediterranean) Soil Name (Fluvisol) Coarse Fragment (2%) Sand (39%) Silt (40%) Clay (21%) Texture Class (Loam)

Cal Jordi & Anna Interior Renovation: Lleida, Catalonia/Spain

Architect (Hiha Studio) Wall Height (2 Storeys) Typology (House) Climate (Temperate Oceanic) Soil Name (Cambisol) Coarse Fragment (5%) Sand (31%) Silt (40%) Clay (29%) Texture Class (Clay Loam)

Gelida Refurbishment: Gelida, Catalunya/Spain

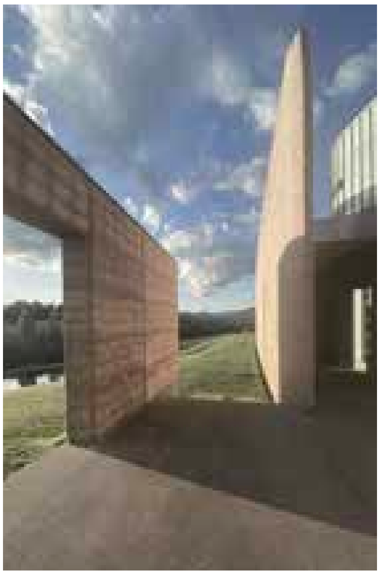
Architect (annapratsjoanvalls & Bruguers Gallego) Wall Height (2 Storeys) Typology (House) Climate (Hot-summer mediterranean) Soil Name (Cambisol) Coarse Fragment (5%) Sand (31%) Silt (40%) Clay (29%) Texture Class (Clay Loam)

PLANTA - Sorigue: Lleida, Catalonia/Spain

Architect (Sorigue & FETDETERRA) Wall Height (2 Storeys) Typology (Museum) Climate (Hot-summer mediterranean) Soil Name (Cambisol) Coarse Fragment (4%) Sand (43%) Silt (37%) Clay (20%) Texture Class (Loam)

Tarrawarra Museum of Art: Wurundjeri/Healesville

Architect (Powell & Glenn) Rammed Earth Expert (Earth Structures) Wall Height (Over 2 Storeys) Typology (Museum) Climate (Cool Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

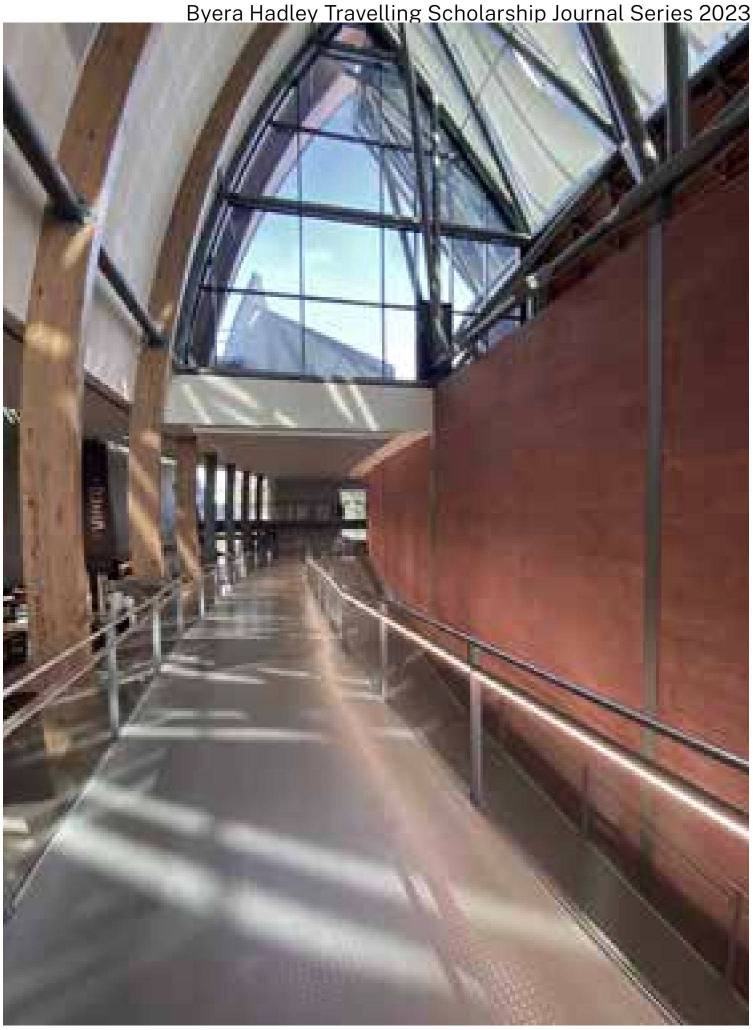


National Herbarium of NSW: Dharawal & Gundungurra/Mount Annan

Architect (Architectus) Wall Height (2 Storeys) Typology (Herbarium) Climate (Mild Temperate) Soil Name (Luvisol) Coarse Fragment (11%) Sand (37%) Silt (33%) Clay (30%) Texture Class (Clay Loam)

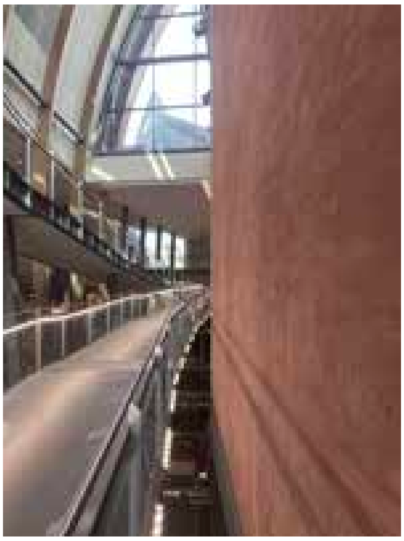
Port Phillip Estate Winery: Balnarring/Red Hill

Architect (Wood/Marsh) Wall Height (2 Storeys) Typology (Winery)
Climate (Mild Temperate) Soil Name (Planosol) Coarse Fragment (2%)
Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)



National Wine Centre: Tarntanya/Adelaide

Architect (Cox Architects) Wall Height (Over 2 Storeys) Typology (Winery) Climate (Warm Temperate) Soil Name (Technosol) Coarse Fragment (0%) Sand (0%) Silt (0%) Clay (0%) Texture Class (na)



MIBI Yoga Centre: Barcelona, Catalonia/ Spain

Architect (Elisabetta Carnevale Arquitectura De Terra) Wall Height (1 Storey) Typology (Yoga Studio) Climate (Humid subtropical) Soil Name (Technosol) Coarse Fragment (0%) Sand (0%) Silt (0%) Clay (0%) Texture Class (na)

PottersCroft: Panatana/Sorell

6. Mud Houses

This chapter focuses on houses built with mud. An analysis of Hassan Fathy's book, Architecture for the Poor, shows mud building on an urban scale, with each home in New Gourna made from mud brick. Fathy relied on the skills of local builders to construct domes made from earth and mud bricks were prefabricated by the villagers. An interview with Cameron Anderson about the winery at Rosby exemplifies the strength of local knowledge, with local builders sourcing clay from locations only a few kilometres from the site.

New Gourna Village

Old Style New Clothes

Under the expanse of the clear blue Egyptian sky, is an image of houses from New Gourna Village made from solid blocks of earth and clay.[185] [186] Intense rays of sunshine hit the exterior surface of the houses, bringing out a consistent earthen colour that covers all external surfaces with an earthy brown tone. Arched doorways, doomed roofs and lattice windows are moulded within the earth. Openings and domes are shaped with bare hands, creating organic curves and a hand-made aesthetic. The architect of New Gourna, Hassan Fathy, shaped these dwellings around the inhabitants as if each house was clothed in a fabric made from earth.[187] Fathy speaks the language of an established culture by adapting a new style from a centuries-old established tradition. Fathy hoped his "new designs that appear to have grown out of the landscape like the trees of the district have. They should look as much at home in the fields as the date-palm and the dom-palm. The inhabitants should live in them as naturally as they wore their clothes." [188] Fathy's new houses would harmonize with the natural environment and remain respectful to the established set of conditions. Fathy resolved to keep the same style of architecture and simply adapt a new 'outfit' by upgrading the same style from old to new and avoiding accusations of faked tradition.[189] The architect clothed the villagers in a fabric of handmade clay, carefully shaping a new architecture while maintaining the Gourni's heritage and giving them a new set of clothes.

Mud brick imposed a consistently wide dimension for the exterior and interior walls of New Gourna Village.[190] The Plan of Two Peasant Houses drawing shows a floor plan of two houses. Thick black lines representing the walls present the same dimensions enclosing each room, significantly restricting the floor area of each space. Fathy navigated the properties of the material in the most appropriate ways.[191] On the ground floor plan, a large square space labelled '1' has a round dome in the middle, indicating the guest room. This guest room has bench seats positioned on three sides of the room cast as niches within the mud walls. A carpet would be laid in this room for guests and hosts to meet and talk.[192] In the middle of the plan, a large outdoor space, labelled '3', indicates a spacious internal courtyard. The courtyard brings light and ventilation to the ground-level rooms while providing direct access to the first-floor rooms and rooftop

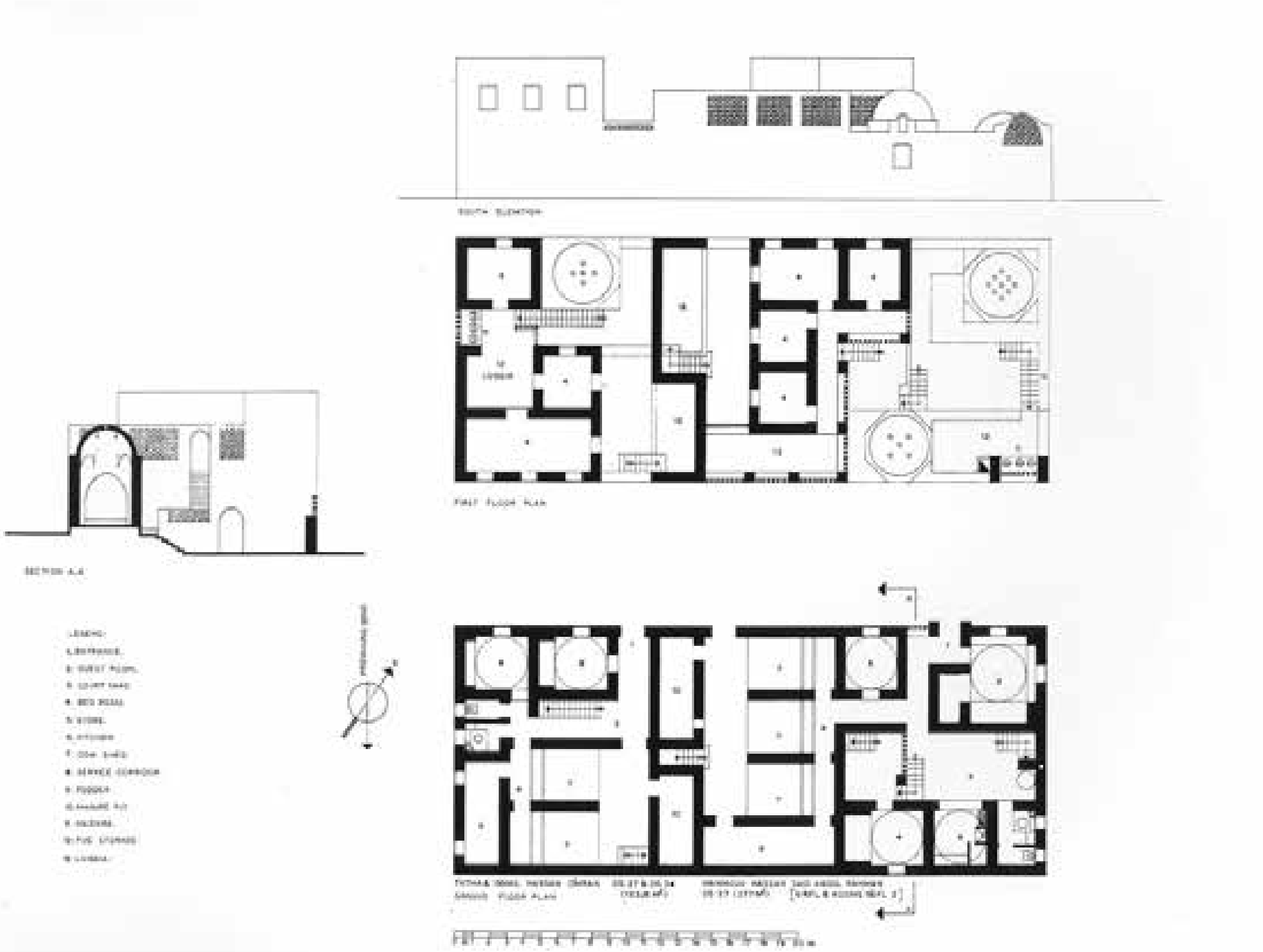


Figure 24: Plans of two peasant houses

Figure 25: Street in New Gourna

garden. On the second floor are four bedroom spaces. Locating the bedrooms on the second floor separated the sleeping spaces from the noisy gathering spaces beneath and positioned these areas in the cooler air.[193] Every house would include the same kind of spaces, yet they would be mixed into different arrangements according to the shape of the site and the thickness of the earthen walls in between.[194] Fathy designed the floor plans while considering the unique properties of raw earth.[195]

Looking at the rooms in the middle of the peasant houses, a series of spaces are shared between the two, including three cattle sheds and storage pits.[196] In New Gourna, family houses like these were organized into two types. The first type was described as the individual family home, and the second type was the badana or group of family houses like the two joined dwellings shown on the plan.[197] Fathy described these grouped houses as a "tightly related knot of people, consisting of some ten or twenty families…" counting the number of families within each group.[198] Fathy designed the mud-brick homes into clusters around small squares relating families living inside the houses to follow cultural groupings. Each badana was made up of a mix of families coming from different wealth backgrounds. Yet each group supported each other by following a communal way of life and helping each other with essential living needs. Each badana had a shared café, barber and grocer, and bread was baked in a communal oven and shared evenly amongst the group.[199] The communal squares would be a gathering space for all traditional feasts and collective activities vital to Egyptian culture. The badana defined Egyptian peasants' social and economic unit, and Fathy made deliberate design enhancements to support their way of life.[200]

The primary reference point for New Gourna is Hassan Fathy's book Architecture For The Poor: An Experiment In Rural Egypt.[201] The book has become a model for housing the world's less privileged, and with the world's population rising, the need for more healthy, safe and stable housing has soared.[202] Fathy begins the book by describing his research on mud-brick housing and Nubian brick building culture. The second chapter outlines how decisions were made on the architectural character of the villages homes and his role as lead architect. This chapter reflects on unique architectural details, including wind catchers and floor plan orientations for each house. The final two chapters reflect on the series of events that led to the stagnation of the project and a description of how the project ended. In addition to looking back on his work, Architecture For The Poor is seen by many in the community as a reference point in the literature of ecological architecture and a framework for sustainable development.[203] International conservation agencies, including the World Heritage Centre and World Monuments Fund, seek to preserve New Gourna, holding Fathy's work in great esteem.[204] On the other hand, some see these conservation efforts as deference to the villager's livelihoods. The villagers inhabit the spaces as living people and wish for their homes, not as artefacts to be embalmed or glorified by foreign actors. The villagers are altering and adding to their houses with concrete and unsympathetic makeshift structures, decreasing the authenticity of the mud dwellings and concerning conservators. The question of who 'owns' New Gourna is essential, and discussions around this will help strike a balance between the villagers and their valuable architectural heritage.[205]

Brick Making Process

For five years, between 1945 and 1949, Fathy supervised the development of Al Gourna Al-Jadida to rehouse the Gourni villagers from an archaeological zone beside the pharaoh's tombs to a new village.[206] Mud brick was the cheapest building material for constructing the new city and a material the peasants were accustomed to building with themselves. Fathy describes the optimism first displayed when the villagers heard of the project when "they learned that sand from the bed of the river would be needed for brick making, and this sand would have to be dug in a few weeks before the river rose, took all their donkeys and camels and themselves dug and carried all the sand we needed."[207] This example shows the villagers' enthusiasm for their new houses and the effort they were willing to apply when building their homes. To help keep up with the rush, machinery was acquired to process the sand that had already been collected. The brick-making press machine moulded the bricks with high speed. To speed the process up further, steam was discovered as the best way to apply water to the mud, with the hot precipitate enclosing the sandy particulates with a film of water. The steaming process removed the need to leave each brick to dry for days.[208] Once the muddy mixture was wet with water, the mixture was made into bricks. Innovations in the brick-making process were discovered due to the collaboration between Fathy and the peasants.[209]

Above all, Fathy wanted the villagers to be responsible for building their houses from the ground up. The villagers would dig the clay from the earth, make their lime, mix their mortar and make the bricks.[210] The best people to facilitate this task were the Aswani masons, who were experts at mud brick building and could teach even architects how to build. Fathy reflects, "It was not really so important that I had no supervisors to help me. The important thing was building, and that would be done by the Aswani masons. They would work without supervision and could, indeed, teach

Figure 26: Fathy's New Baris public buildings, 1967, with a museum in foreground and market vaults to rear. The Mashrabiya windows are made from earth.

Figure 27: Plan of New Gourna

a thing or two even to qualified architects."[211] Mud brick domes were an essential tradition to the Aswani masons, and the skill of building the domes was their trade. The Aswani would create the required domes and share their knowledge with the villagers, teaching them how to make the domes themselves.[212] Fathy reflects his relationship with the masons was the most reliable part of the project, For the villagers to take up mud building independently, Fathy needed to cultivate this culture where mud building would flourish.[213] Only then would the Villagers make the natural choice to move into their new houses.

Mud Domes

While Fathy laid out the plot boundaries and floor plans for each house, when it came time for construction, his drawings acted more like artworks than instructions to the villagers, with the Nubian builders relying on skills learned over generations.[214] With the domed roof a signature building technique for the Egyptians, Fathy chose to rely on their knowledge, incorporating local skills into his drawings. Fathy noted, "masons were master craftsmen to whom every detail of the work had become familiar over many years, for it was their technique. They knew by the heart of their proportions of the various rooms and, given the height of a dome or vault, could tell immediately where to begin the springing."[215] Fathy may have made detailed drawings of how he wished for the domes to be measured and constructed, however when the builders looked on they simply told him not to bother. Nubian builders were experts at mud brick building, having been responsible for the pyramids and the pharaoh's tombs. They had a deep understanding of how a mud brick dome should be formed. They knew the strength of a dome was derived from the shape of an eggshell and could span further distances than the same barrel-vaulted roof or flat roof.[216] In Fathy's eyes, local people were the most effective architects. This perspective of local construction knowledge is a pioneering idea in the realm of vernacular architecture.[217]

The scorching hot temperatures of the Egyptian desert meant cooling the houses was of utmost importance, However, cooling had to be achieved without the use of expensive mechanical air-conditioning that was unaffordable to the villagers. Therefore, principles of physical air movement through spaces were used to cool the rooms instead.[218]
This image of a Mashrabiya window is one way Fathy cooled the interior air. These windows were commonly found inside Egyptian mansions and were made from intricate wood latticework. In Al Gourna, the latticework was made from mud, resulting in a brilliant cooling effect. Built alongside the Mashrabiya windows, were mud domes whose concave height collected hot air, redirecting the heat from the interior by convection ventilation and the cooling internal spaces.[219] Fathy's choice of mud brick for hot desert temperatures ensured the warm, arid air of the Egyptian climate could be insulated and ventilated, keeping the villagers cool during the day and warm during the night. Fathy's innovative windows, convex

domes and mud bricks were simple, cost-effective methods that the villagers could easily copy without technical expertise. The New Gourna village model could withstand weather conditions anywhere in Egypt.[220]

Fathy focused much attention on the design of New Gourna's streetscapes because the street was considered an extension of the home.[221] Looking at the urban masterplan of the city, you can see the network of interlocking roads and the layout that facilitated communication and interaction between family members of neighbouring badanas.[222] These streets are made deliberately narrow, measuring only six meters wide. Their tight dimension and winding orientation discouraged unwelcome strangers from walking down private alleyways, protecting those living there. In addition to strategies of passive surveillance, the six-meter road width shaded the street frontages from the hot desert sun, making the local streets an additional outdoor room. A network of broader streets connected the narrow local streets to the main square through busy traffic routes. The trafficable roads were planned as more expansive, ten-meter spines, allowing for greater movement and increased pedestrian activity. Their width allowed for greater air movement, facilitating air ventilation between blocks of houses.[223] The values inherent in these streetscapes stemmed from the culturally entrenched relationships between Egyptian families, where the street acted as a meeting place between people, passive surveillance, and a passive cooling mechanism. Hassan Fathy believed the streetscape was to be made as beautiful as possible, surrounding activity on the street with a well-designed backdrop.[224]

Fathy aimed to address the villager's needs, providing them with a safe and healthy place to live. The architect could not have fully considered ecery aspect of entrenched Gourni culture that eventually led to the Gourni's refusal to move into their new homes. They argued the use of mud domes reminded them of graveyards and the dead.[225] Fathy had feared this reaction from the Gourni's, noting in his book, "When I found even the peasants hostile to the Gourna projects, I began to question the whole principle of the mud brick vault. I thought that perhaps, although it was sound economically, aesthetically, and from the standpoint of engineering, it might carry some suggestions of the tomb or some other discouraging associations to put the peasant off."[226] Critics claimed Fathy had made a mistake choosing mud domes as an aesthetic for the roofs, as traditionally, domes were used in funerary architecture rather than for houses in Egypt. Fathy disagreed with their statements, claiming a hidden agenda behind their reluctance to move away from their location.[227] Other critics detracted from the domes in different ways, claiming the architecture was a backward step against the progress of modernization in Egypt, and were concerned about their stability. Fathy may have been well-intentioned to the villagers, yet the prospect of uprooting seven thousand people, dismantling their blood and marriage ties and putting them together again within another

Figure 28: Pergola

setting was a big ask.[228] The Gournis were tied to the fabric of Old Gourna and stood fast in the landscape as they had done for many years.

Old Gourna was located beside the tombs of the Pharaohs and connected the village to their primary source of income, tomb-robbing.[229] The Gournis were experts at discovering royal graves, and many of them were employed by the Department of Antiquities on archaeological expeditions. However, by 1945, thefts from the tombs had reached unacceptable levels. The authorities set to change their economic reliance on grave robbing and selling artifacts. 900 Gourni families who relied on the tombs as their primary source of income were forced to change their way of life and move to a newly built village. With a keen understanding of the enormity of this task, Fathy was set on researching the needs of each family, hoping that he could find a way for the villagers to move voluntarily by fostering a sense of ownership over their new houses. [230] Fathy writes his designs “varied in size according to the area of the original houses they were replacing, into a variety of irregular plots, and by being ready to vary the plan of each to suit the people who would live in it, I made sure that I should think carefully about the design of each one, avoid the trap of adding variety without purpose, and produce a village in which the playing modulations would have a demonstrable reison d'etre.”[231] If 900 families were to uproot their lives and move, Fathy believed they deserved the chance to design their own homes. The best attempt was made at thoroughly researching the socio-ethnographic and economic characteristics of the people, tailoring the design to the community.[232]

Mud Palaces

Fathy hoped all people should have access to good living conditions, believing even the poorest of people could live in palaces, if they were made from mud.[233] He questioned overriding assumptions, saying, “why not? Certainly, the peasant's houses might be cramped, dark, dirty, and inconvenient, but this was no fault of the mud brick. There was nothing that could not be put right by good design and a broom.”[234] Believing in the transformational power of design to turn the most abundant of materials, mud brick, into a palace where the poorest could live in beauty and comfort was an ambitious vision. Fathy questioned the perceived differences between a peasant's house and a landowner's house, dismantling the association of wealth and good design. With attractive architectural design and remaining respectful to the local's needs, there was no reason why the houses shouldn't be aesthetically satisfying.[235] Fathy's uniquely Egyptian models and rejection of the prevailing modernist agenda showed his concerns were genuine.[236] This project aligned with his philosophy and professional aspirations to do good for the villagers.[237]

New Gourna's buildings which were eventually constructed, are currently being altered and adjusted by the villagers with foreign materials like concrete, decreasing their authenticity.[238] Looking at an image of one of Fathy's houses, you can see one of the

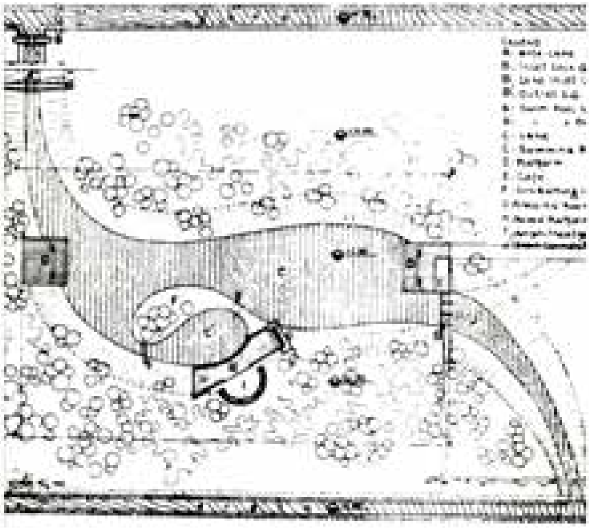


Figure 29: Plan of artificial lake

windows filled with concrete and a lean-to attached to the side of the building.[239] Most of the buildings have been altered with alterations to windows and doors, internal adjustments, covered courtyards, blocked wind catchers and domes which are gradually replaced with concrete roofs. Conservationists consider these changes as antithetical to Fathy's original design intention.[240] The most obvious differences can be seen over time. In 1997, the village possessed minor alterations including concrete balconies, with most of the houses retaining their original designs. In 2005, significant changes appeared, with entirely new homes constructed which possessed modern extensions. The alterations are conducted using found materials with the sole purpose of functionality, serving the needs of the villager's families who desire to improve their standard of living. These alterations seem unsympathetic to Fathy's original intention as a designer, yet their future needs could not have been foreseen in Fathy's original design.[241] The slight markings and alterations to dwellings, however, are in stark contrast to the threat of high-rise apartments made of concrete, which seek to demolish entire sections of the village. These new developments pose the most significant risk to New Gourna's inhabitants, making conservators the most concerned.[242]

Heritage organisations reached out to the Gourni people and sought to 'educate' them on their home's architectural significance. From the villager's perspective, on the other hand, conservation efforts were unwelcome and sought to impose foreign concepts of heritage without considering their livelihoods.[243] The Safeguarding Project of Hassan Fathy's New Gourna Village plan was announced in 2009 by UNESCO, ICOMOS and the World Monuments Fund and relied on Western conservation ideals. Their methods were based on planning legislation like land zoning, urban design guidelines and building regulations. These were widely used in Western planning systems and utterly foreign to the villager's needs in upper Egypt. For conservative organisations like these, it could be said that heritage could only be protected within an orderly and forensic framework where the houses were kept precisely as Fathy had initially intended.[244] Under the scheme, alterations and additions made from foreign materials like concrete were attached to the mud brick dwellings and had to be removed. With events like these, questions about who "owns" New Gourna have arisen. Were the villagers or the conservators the best people to protect Fathy's vision?[245]

The World Heritage Centre planned a conservation project on mud-brick houses despite the villagers' opinions. One of the project's key drivers is comparing the village's current state with the original architect's vision. Key aspects of Fathy's vision include the integrity of the townscape, urban and landscape values, and cultural centres, including the khan, marketplace and theatre. Accompanying instructions for larger buildings is a blanket instruction which covers the individual houses. All residential blocks were to be improved and restored, and the cultural buildings identified were to be reused after periods of neglect. Their structures would be restored using mud bricks to match the existing building. Some proposed actions go as far as completing the original village plan designed by Fathy, suggesting new earthen buildings be built and expanding the village.[246] Considering the concerns of preservationists, however, New Gourna has been occupied for around fifty years, and the town appears to be mainly as Fathy had initially designed.[247] The village is a living organism, not a lifeless artifact to be embalmed and glorified.[248]

During construction, so many of the Gourni opposed Fathy's project that they banned together and began vandalising the village. Their most damaging act was to break the dam holding the nearby lake and flooding the entire operation.[249] Fathy notes his reaction when discovering the villagers had flooded the new city, "When I reached my house, I found a note from Rustum, asking me to call as he had a telephone message from the chief inspector in Luxor saying that the whole village had been flooded and drowned. I felt dizzy, my head swam, and I dashed round to Rustum to hear more."[250] This confirmed the Gourni's lack of support for the project, which they had once been so enthusiastic about.[251] The mud bricks that had been prepared in a large batch beside the development were thoroughly washed away by the flow of water.[252] Despite these events instigated by the villagers and the changing attitude of the Department of Antiquities, who had employed Fathy, the architect looked back on the project and wrote down all he had learned.[253] He looked negatively upon the villagers, describing them as tomb robbers and claimed their sabotaging act was to protect their life of thievery.[254] Today, the declining condition of the surviving earthen walls is most probably caused by the rising subterranean water underneath the soil, echoing the original flooding of the village.[255] When Fathy abandoned the project in 1949, less than a quarter of the town had been constructed, and the project never reached completion.[256]

At the very beginning of the project when Fathy started studying the living conditions of Old Gourna Village, he observed the villagers didn't have access to clean drinking water, electricity or sewerage systems.[257] When designing New Gourna Village, he had hoped an artificial lake might solve these basic needs. In Architecture for the Poor, Fathy drew his vision for the lake.[258] The drawing depicts a beautiful oasis with curving lake edges, swimming pools, changing rooms, a café, an amphitheatre and tidal locks on either end. In addition to providing clean water and sanitation, the lake would solve another problem. A gaping hole would be left where the sand was removed from the earth during brick construction and Fathy intended for this hole to be transformed into an artificial lake. If birka's were not filled in again with earth from another hole, they would become sites infested with malaria, caused by mosquitos breeding on stagnant water. Pits like these were left after brick extraction processes all over Egypt and were given the name 'birka,' prompting an opportunity for Fathy. Fathy resolved that if New Gourna's birka had a canal directed through the centre, the water would be constantly flowing and be clean. In this scenario, the lake would provide sanitation to the villages and become a wellspring for fauna like ducks and geese.[259]

Conclusion

In regional Australia, Rosby Winery and Gallery drew upon local knowledge and materials to build their winery from rammed earth. My interview with Cameron Anderson, who designed the gallery, reveales how Rosby's history of pisé was one of the main reasons the winery was built from the material. He explains how Rosby has an existing series of earthen buildings on their land. Earthen buildings were constructed throughout regional Australia during the nineteenth and twentieth centuries. Rosby has a series of these buildings, including the original homestead, made from pisé which was extended in the eighties using mud brick. These buildings provided precedence and texture for the new winery design to draw from. Anderson notes, however, that he wasn't aware of the rammed earth building technique until their local builder, Justin Penny, suggested the material. Relying on the local knowledge of Penney, they sourced the rammed earth material from a local quarry about three kilometres from the winery's location. When Penny wasn't manufacturing the rammed earth walls, he was working away in his workshop over the hill, manufacturing the timber frames. The advantages of Penny's workshop located so close to the site meant the winery was built within a staggeringly short time, going from bare rammed earth walls to having a roof on top in just over a week. Anderson explains more localised construction, which has a community focus on local trades, makes sense in regional areas, and this is a reason why pisé buildings existed originally. Timber was sourced from local forests, and the earth was dug from the river nearby. For Anderson, this is the easiest way to build.

Rosby Wines, Cellar Door & Gallery: Wiradjuri/Eurunderee

Rosby Wines, Cellar Door & Gallery

Interview with Cameron Anderson from Cameron Anderson Architects about the rammed earth winery at Rosby. Rosby is located in a beautiful wine growing vineyard in regional NSW.

CD:
Where was your material sourced from to build Rosby's winery?

CA:
We sourced our material locally about three to four kilometres from the site. I wasn't aware of rammed earth until the builder I worked with specialised in the material, and he used a specific mix. The mix we used was compression tested and is structurally certified.

CD:
I am glad you sourced your material from your local area and collaborated with a rammed earth specialist.

CA:
I've been working with Justin Penney for about eleven years. He has built a few buildings with us.

CD:
How your rammed earth walls extend into the garden makes them seem part of the exhibition. How do the sculptural properties of rammed earth feature in your design?

CA:
One of the main reasons behind our choice of rammed earth is drawn from Rosby's history. Rosby has a series of earthen buildings on the land, and there are many pisé buildings in regional NSW. During the nineteenth and twentieth centuries, rudimentary earthen buildings were built all over regional Australia, and Rosby has a series of those buildings. The initial part of the homestead at Rosby was made from pisé and was extended in the eighties with mud brick. A couple more buildings are made from mud bricks on the property. These buildings were next to the cellar door and provided a precedent texture for the cellar door design. Regarding the sculptures in the garden, we wanted to extend the art program out from the gallery and cellar door into the garden.

CD:
What determined your choice of material pallet?

CA:
Our material pallet is all about respecting the suit of existing building materials, including rammed earth and exposed timber structures made from rudimentary bush timbers. Generally, the pallet is made from earth, wood, and galvanised iron. The area is bushfire prone, so the building had to be designed to a BAL 19 rating, which is one reason for our use of spotted gum timber. All the structural elements, windows, benches and cladding are spotted gum. The joinery inside the cellar door and the bathroom ceilings are made with form ply. We had form ply on site that served a previous life as a dance floor. The dance floor came out for every wedding and every party, so the form ply is a reference to our family story.

CD:
Do you think rammed earth walls create a unique backdrop for artworks inside the gallery? Rural

landscape artworks and welded steel sculptures feature in the exhibition.

CA:
I think rammed earth humanises the artwork a little bit. This idea is interesting because we debated the backdrop at length as part of the design process. The history of art research tells you art must be experienced with a neutral background. We looked at details where a white wall lining appeared in combination with the rammed earth. From these tests, we felt we could query the white box by humanising the art experience and making art less formal with a rammed earth backdrop. In addition to the informal material pallet, visitors can visit the gallery and cellar door in a natural rural setting. The rural location removing the feeling of a strict gallery space. Many of our artwork submissions sit well within the earthen gallery. In addition to these reasons, much natural light fills the room, making Rosby not your typical closed-door gallery.

CD:
I am interested to hear how you innovated new ways of working with rammed earth.

CA:
I think this is a critical time to work with rammed earth because we risk losing our engineering knowledge. The one thing you will find with rammed earth is that no industry bodies advocate for the material. The material has failed to gain support on issues like energy requirements, which is stopping the more widespread use of earth. Rammed earth architecture requires engineers to calculate loads correctly for each earthen project. Bill, our engineer, has opened our eyes to the possibilities of rammed earth, that's for sure.

CD:
Can you speak more about rammed earth's thermal capabilities?

CA:
Rosby is the most refined project in rammed earth we have done. Through the design process, we found that the energy requirement for rammed earth must be addressed. Because of earth's low insulation value, we found it much harder to prove earth is sustainable when digitally modelling the building. Other options include insulated rammed earth; however, people we have spoken to who have lived in a rammed earth building for thirty years know rammed earth is a good insulator.

CD:
Were the insulative properties of rammed earth an opportunity for wine storage?

CA:
We don't store much wine in Rosby's Cellar Door building however, we have a dedicated wine storage shed to store the bottles. We keep some wines, but the bottles might only be stored there for two or three weeks at a maximum, and we restock the building every weekend. This building is designed more

towards functionality between operating hours of ten and four rather than the long-term storage of wine. The doors are always open, the windows are always unfolded, and the night-purging air cools the interior down. We rarely actively heat the inside.

CD:
What formwork techniques were used to create the final surface finish?

CA:
The building was completed within a very tight timeframe, and we worked closely with our builders, Penney Constructions. First, we poured the concrete floor and allowed the floor to cure. All the main rammed earth walls were poured next, and the rammed earth lintels were formed as the last step. Overall, the construction of the rammed earth walls took just over a week, with one large wall pattern completed in a day. We were held up a little by the rain, but a good thing about the construction process was the builder, Justin, who manufactured the timber frames in his workshop over the hill while it was raining. When the rammed earth walls were up, out came the portal frames. They were installed in a day, and the ‘z’ purlins went up the next day. So we went from having bare walls to having the roof on after a week.

Justin made new formwork he developed himself. The formwork was more like a recycled plastic, producing a consistent surface. The formwork used for the landscaped rammed earth walls was made from plywood.

CD:
The openings are large with long lintels made with rammed earth. How were the lintel spans achieved?

CA:
Rosby is a small building, so we tried to maximise the openings and allow flowing connections between the gallery and the verandah during busy occasions. In addition, we maximised the bar area to allow greater access to the cellar door and serve more people. As a result, we built to the limits of spanning lintels at those datum heights. We don’t have much to play with regarding our BCA height clearance, so we needed to be careful about how we detailed the door frames to achieve the exit heights.

The lintel is 600mm, and we needed the building to open to the sculptures in the garden. Therefore, these were the measurements to achieve our openings. There is no steel beam under those openings, meaning the lintels are entirely made of rammed earth with some steel reinforcing inside the earth.

We questioned how we would attach timber boards to the rammed earth lintels during construction. There was quite a bit of complexity for such a small building to get details like this working. The openings were really about making the most out of a small building. At the end of the day, we can open the bi-folds up, and people stream into the gallery without the gallery feeling enclosed or busy. All the circulation happens out on the verandah.

CD:
What ramming machinery was used?

CA:
The mixing was done using a bobcat by specialists with years of experience measuring suitable sand and aggregate amounts. The bobcat bucket was lifted, and the builders shovelled the mix by hand. The sand was rammed using a small hand-held hydraulic rammer powered by generators.

CD:
Do you think there will be a way to mechanise the process in the future?

CA:
The issue with rammed earth is the process has to be quite precise because the mix needs to be rammed to the edges of the form. Otherwise, the earth might not be compressed enough and structural failures might occur. Possibly, mechanisation is an option, however, builders have extensive knowledge of their own processes.

CD:
What do you think the future of rammed earth looks like?

CA:
I think a discussion of decarbonisation comes into this question. I envision a time when you can take material from the site and work with local trades to transform the material into a building. In this situation, the mix hasn't had to be mined and converted into raw materials for fabrication and transported. I would love to do some sort of measure on the carbon footprint of our local building because I predict our results would be excellent. Our reliance on highly processed materials from overseas with high levels of embodied energy is problematic from an environmental, supply chain and disruption point of view. If we can get to the point where we are constructing without requiring high-energy prefabrication and transportation, we have reached a good milestone. More localised construction with a community focus on local trades makes sense regionally, which is why pisé buildings existed originally. Timbers came from local forests, and materials were sourced from the earth or river nearby. Building locally is the easiest way to construct.

Rosby Wines, Cellar Door & Gallery: Wiradjuri/Erunderee

Architect (Cameron Anderson Architects) Wall Height (1 Storey) Typology (Winery & Gallery) Climate (Mild Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

Musee De Plein Air Bokrijk: Genk, Belgium

Architect (BKRK Bakery, BC Architects) Wall Height (1 Storey) Typology (Bakery) Climate (Temperate Oceanic) Soil Name (Podzol) Coarse Fragment (14%) Sand (75%) Silt (20%) Clay (5%) Texture Class (Loamy sand)

Tres Marias: Alentejo, Portugal

Owner (Balthasar Trueb) Wall Height (1 Storey) Typology (Rural Hotel) Climate (Hot-summer Mediterrenean) Soil Name (Luvisol) Coarse Fragment (6%) Sand (39%) Silt (39%) Clay (22%) Texture Class (Loam)

Mystery Bay House: Yuin/Eurobodalla

Architect (Jack, Rob & Sally Hawkins) Rammed Earth Expert (Earth Structures) Wall Height (1 Storey) Typology (House) Climate (Mild Temperate) Soil Name (Phaeozem) Coarse Fragment (2%) Sand (33%) Silt (42%) Clay (25%) Texture Class (Loam)

Creek Chic House: Kaurna/Torrens Park

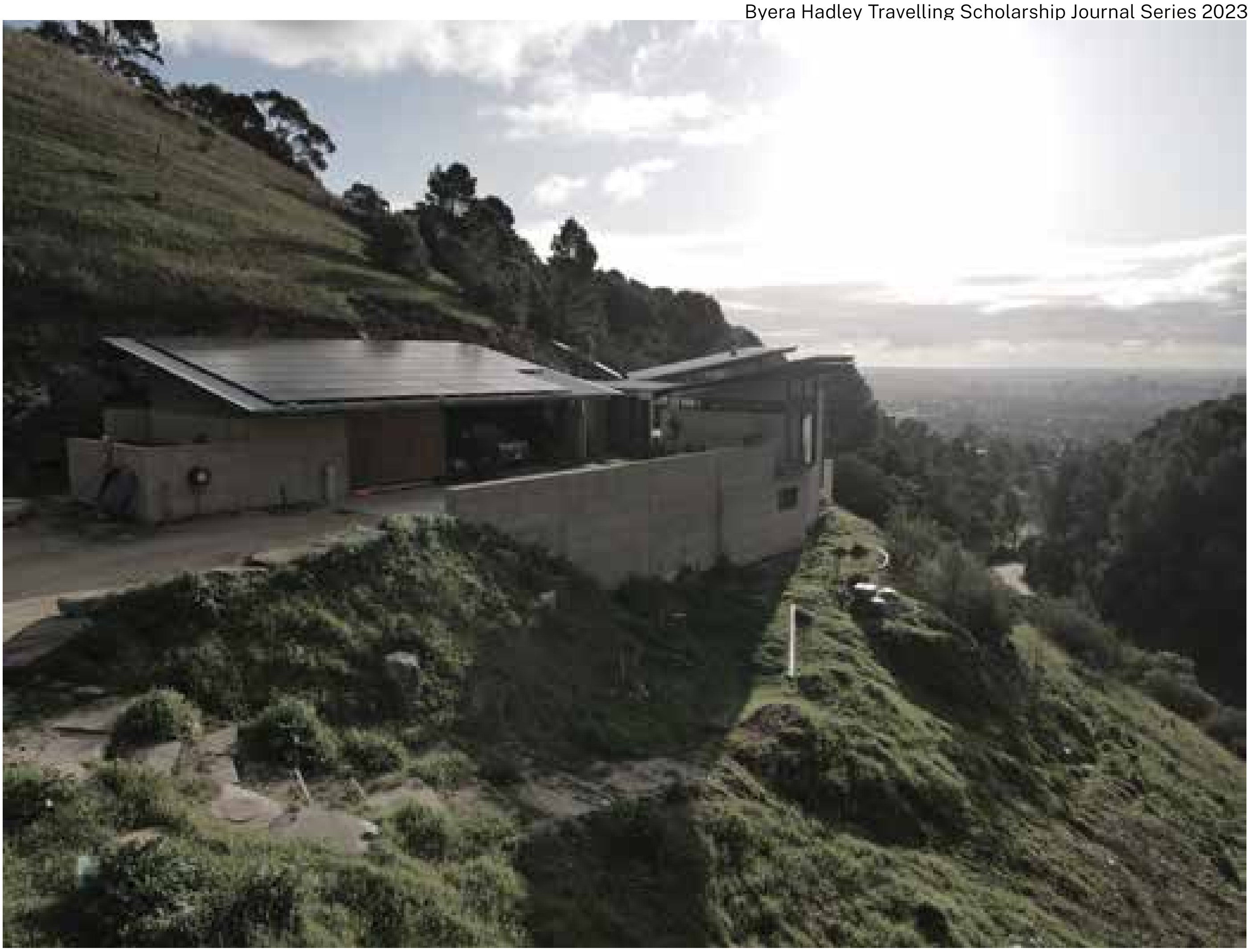
Architect (Troppo) Wall Height (1 Storey) Typology (House) Climate (Warm Temperate) Soil Name (Luvisol) Coarse Fragment (18%) Sand (65%) Silt (18%) Clay (17%) Texture Class (Sandy Loam)

PottersCroft: Panatana/Sorell

Builder (PottersCroft) Wall Height (1 Storey) Typology (House & Workshop) Climate (Cool Temperate) Soil Name (Vertisol) Coarse Fragment (2%) Sand (14%) Silt (33%) Clay (53%) Texture Class (Clay Light)

Sacred Mountain House: Awabakal/Mulbring

Architect (Peter Stutchbury Architecture) Rammed Earth Expert (Earth Structures) Wall Height (1 Storey) Typology (House) Climate (Warm Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)



Adelaide Rammed Earth House: Kaurna/Mount Osmond

Builder (Adelaide Rammed Earth) Wall Height (1 Storey) Typology (House)
Climate (Warm Temperate) Soil Name (Lixisol) Coarse Fragment (20%)
Sand (56%) Silt (22%) Clay (22%) Texture Class (Sandy Clay Loam)

Piccadilly House: Peramangk/
Adelaide Hills

Wall Height (1 Storey) Typology (House) Climate (Warm Temperate) Soil Name (Lixisol) Coarse Fragment (20%) Sand (56%) Silt (22%) Clay (22%) Texture Class (Sandy Clay Loam)

Bream Creek House: Panatana/
Sorell

Wall Height (1 Storey) Typology (House) Climate (Cool Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

Low Head House: Kanamaluka/Launceston

Wall Height (1 Storey) Typology (House) Climate (Cool Temperate) Soil Name (Planosol) Coarse Fragment (2%) Sand (49%) Silt (31%) Clay (20%) Texture Class (Loam)

Binalong Bay House: Larapuna/Bay Of Fires

Builder (FJM Homes) Wall Height (2 Storeys) Typology (House) Climate (Cool Temperate) Soil Name (Nitisol) Coarse Fragment (10%) Sand (26%) Silt (29%) Clay (45%) Texture Class (Clay Light)

Sacred Mountain House: Awabakal/Mulbring

7. Conclusion

BC Materials believes that for communities to acquire new knowledge, learning must be fostered through hands-on making and doing combined with time and patience.[260] I attended a Focus Workshop On Geo and Bio at BC Materials in Brussels to learn more about rammed earth. During the workshop, I listened to valuable information about sustainability while making a rammed earth wall from an experimental combination of materials. BC advocates for people to 'get close' to materials and methods by facilitating ways of experimentation. As a result of the workshop at their production hall, I felt more knowledgeable about where materials come from. In October 2018, BC Materials began as an Architectural company, which later expanded to transform excavated earth from construction sites into building materials. On a project-by-project basis, BC Materials acts as a material consultancy or production company alongside their work as architects.[261] They continuously monitor their products to make a homogenous mixture of earth from soils they find in the ground. Therefore, BC Materials is not your typical product organization because the company comprises of architects, workers and sympathisers, who all reflect on the impact of the Belgian construction sector. Their production hall is a fully demountable structure that can be transported to any construction site in the Brussels region to start mixing and testing materials.[262]

At Lehm Ton Erde's Werkhalle in Austria, testing is repeated until the ideal rammed earth mix is found.[263] During my visit to the ERDEN Werkhalle, I saw a variety of aggregates stored in piles and observed the testing procedures conducted upon them. I discovered thei workshops are built to explore and demonstrate earthen building materials, including ceramics, adobe, compressed earth blocks and rammed earth.[264] These materials are tested to verify moisture content, compressive strength and erosion resistance, and batches are tweaked with clay and fine aggregates to achieve different surface colours and finishes. Completed mixtures are then tested by certified testing companies to ensure compliance with current building standards.[265] Rough figures resulting from their tests are shared with anyone who visits the Werkhalle. These figures are based on past realized projects and are good rule-of-thumb values. These same numbers will vary depending on the materials, and extensive testing must be completed each time.[266] Most importantly, these numbers apply to non-stabilised rammed earth or earth without added cement. Adding cement to the soil mixture removes all sustainable advantages, increases CO2 emissions, reduces the material's ability to be recycled, and the walls no longer breathe. The ERDEN Werkhalle deals exclusively in 100 per cent earthen mixtures.[267]

Some architects are more reluctant to rely on a mixture purely made of earth. During my visit to the Yorkshire Sculpture Park, I observed a beautifully coloured, layered concrete wall surrounding The Western Gallery And Cafe. The architect, Fielden Fowles, explains how they visited rammed earth buildings, spoke with construction experts, and delved deeply into the precise mix of earth, sand and cement. The vulnerability of rammed earth to withstand exposure to Yorkshire's inclement weather meant their research took a turn to more durable materials. Fielden Fowles resolved that textured concrete would be better than even the most concrete stabilized rammed earth, and there were very few precedents in the UK showing how rammed earth weathered in their wet climate. Despite their reluctance to use rammed earth, the team sought local aggregate to create a more natural mix and endeavoured to reduce the amount of cement compared to standard concrete. Concrete would also retain the sloping ground behind the building, a task rammed earth could not perform.[268] The team chose the most sustainable option within their conditions wherever possible by sourcing materials locally and finding materials with rich patterns and textures. The sand and aggregate produced a tactile surface, drawing visitors in to observe the walls and feel the effect of lime plaster on the internal walls. The building breaks down physical barriers to experiencing artwork and connecting with the landscape.[269]

In the regions of New South Wales, earth is made from nutrient-rich soils used for growing grapes. Rosby's rammed earth Winery and Cellar Door sits within fifteen acres of green winegrowing hills.[270] The winery's grape vines were first planted in the 1850s within soils of red-brown loam.[271] Volcanic earth and sandy loam lie over a subsoil of clay, resulting in earth with high nutrient retention and good water movement, filtration and drainage. The winery's location 450m to 1100m above sea level is conducive to a climate of spring frosts and cold nights that delay bud bursts and the area's rainfall and humidity are typical of an inland grape-growing region.[272] The broader area of Mudgee is known for warm summer days and cool evenings, and the higher elevations result in slower ripening periods and wines of intense colour and flavour.[273] The atmospheric conditions provide a framework for the Shiraz and Sauvignon wines Mudgee was built on, and Rosby follows this heritage by offering low-impact viticulture and boutique wine production. In addition to these flavours, Rosby is experimenting with modern varieties, including Riesling, Sangiovese, Tempranillo, Vermentino and Pinot Grigio. New blocks of Riesling, Chardonnay and Sangiovese grapes have been planted in the vineyards to complement the wines already in the cellar.[274] Rosby's vineyard of grapes covers acres and acres of rolling green hills with rows of planted vines, slowly growing in the fertile soil of the coloured Australian landscape.

Acknowledgements

The most enjoyable part of this project was the journey taken to reach each destination. I couldn't have predicted the beautiful discoveries I made and the people I have met along the way. To everybody I have interacted with along this excellent journey, thank you for making this project a wonderful experience.

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And finally, thank you to my family for listening to my endless conversations about rammed earth. You jumped at the chance of becoming impromptu travel agents when discussing overseas destinations. Thank you for sticking by me on this journey.

About the author

Clare is a registered architect who strives to make our built environment a more liveable and beautiful place each day. Her work on private residences, sports and community centres, schools and museums of cultural significance has reinforced her desire to let people inhabiting spaces feel joy. She believes in the transformational power of design to change lives.

Her work as an emerging historian seeks to expand our understanding of Australian architecture, bringing this knowledge to the present to enrich architecture today. She has studied the hybrid transformations of Airports and the role automated robotics plays in our sustainability journey. She also writes about the importance of craft and model-making in architectural practice. Her work can be found in journals including Inflection, Architecture Bulletin and SAHANZ's annual conference proceedings.

This project was inspired by her experiments with clay initiated in the modelmaking studio. She was drawn to clay's flexibility, malleability and pliability, being able to shape the material into virtually any form with bare hands. Envisioning what building with clay might look like on a larger scale drew her to this study of rammed-earth architecture. In this way, a large-scale built form could take on the sustainable advantages of earth.

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