

# AFFORDABLE EARTH HOUSING

SHARON DAVIS  
design

**5000 *for* 5000**

HOUSING COMPETITION  
A SHELTER AFRIQUE INITIATIVE



*Sharon Davis Design embraces the professional ideal of positively changing the way people live, both globally and locally, through multidisciplinary rigor and with compassion for the earth and humankind.*

At Sharon Davis Design process starts with material inquiry through which we push the social, environmental and economic objectives of the project. Through this process we strive to create material beauty that is unique to each place and brings dignity to every community. We have worked on multiple low cost projects in Africa and Nepal with a wide range of locally appropriate sustainable materials. Earth based construction has so far been the most affordable and practical solution for mass produced housing across a varying locations. The key to affordability, is efficient, effective design and construction with locally and readily available material, and engaging local labor. Jobs and future economic opportunity for the community are created in this way while also improving construction standards. Earth Based Construction is a good vehicle for these goals. Almost all soil types are suitable for earth based construction. Earth from the building site is used to create foundations, walls, floors, plaster and even roofing materials. Using the soil at the point of construction saves huge amounts on material cost. Earth based construction can also easily adapt to varying site conditions.



## Earth Based Construction Precedents - Sharon Davis Design

**1. Rwinkwavu Prototype House :** To respond to the community's needs for more housing in the rural town of Rwinkwavu, Rwanda, we were commissioned by Rwanda Village Enterprises (RVE) to design a 95-unit housing development on a 13 hectare site.

An initial prototype was built to test the affordability and constructability of various earth-based building techniques, the first proof-of-concept house was completed on budget at just **under \$100 per square meter (\$10 per square foot)**.

**2. Rwinkwavu Affordable Housing:** We worked with the community in an inclusive process, to empower the local people by asking them to set project priorities, engaging them to present their own ideas and strategies, and, ultimately, collaborating together to find solutions that truly met their needs. The result was a 4 bedroom single family house **(110 square meters) at a final construction cost of \$10,000 USD**.

### Key Design Features:

- Ferrocement Roof
- Compressed Earth Block Walls
- Earth Bag Walls
- Stabilized Rammed Earth Foundation
- Earth Plaster
- Earth Floor
- Natural light and Ventilation
- Compost Toilets
- Earthquake Safe





AFFORDABLE EARTH HOUSING Goals:



**Supply Chain Innovation** To use the existing site as a source of material for building construction; to avoid the cost in transporting building material from a long distance; to use earth in various forms such as blocks, compacted, rammed and as a mix with other stabilizing components; to encourage design strategies that can adapt to different site conditions.

**Local Capacity Building** To develop local design, and construction expertise as a permanent industry; to facilitate the dissemination of low-cost housing solutions, equipment, and technology to individuals interested in building; to provide home ownership training; to catalyze growth and provide a low cost housing model for future development projects in the sector and throughout Sub-Sahara Africa.



**Community Enhancement** To enhance the quality of life of the urban poor through exceptional design of housing communities; to engage the community from the earliest construction stages to strengthen perception of and commitment to occupancy within affordable housing projects; to provide for shared community spaces such as parks, markets, small businesses, etc.

**Environmental Sustainability** To use local and renewable construction materials; to create onsite renewable energy production, rainwater harvesting, composting toilets and other earth-friendly technologies; to serve as a model community for sustainability.



**Large Scaled Delivery Program** To plan a development scheme that allows multiple housing unit clusters which are very dense; to develop shared infrastructure and amenities to bring down the cost per unit; to create a comprehensive low-income housing solution that leverages the strength of mass production and can be easily replicable for future developments undertaken in Sub-Sahara Africa.

**Adaptive Model** To develop design solution that can adapt to various site conditions and climatic regions; to implement earth based construction technology which can be easily adapted to the composition of the soil condition available on every site.



Local unskilled labour to produce Compressed Earth Bloacks - Rwinkwavu Housing Project



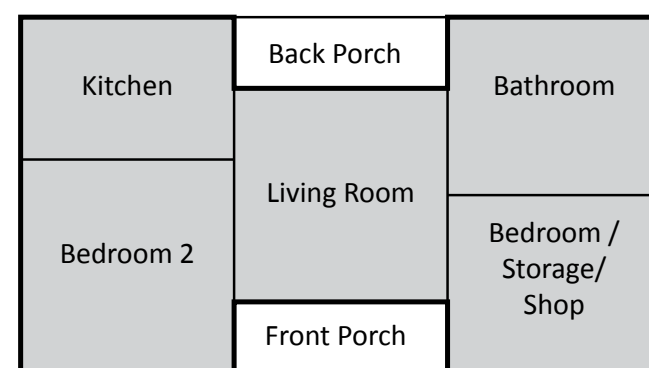
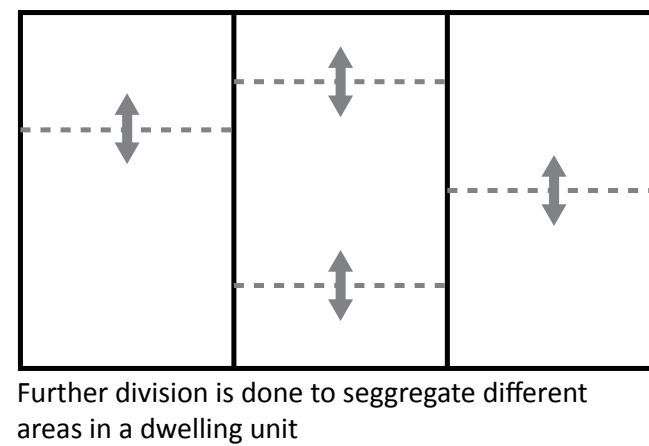
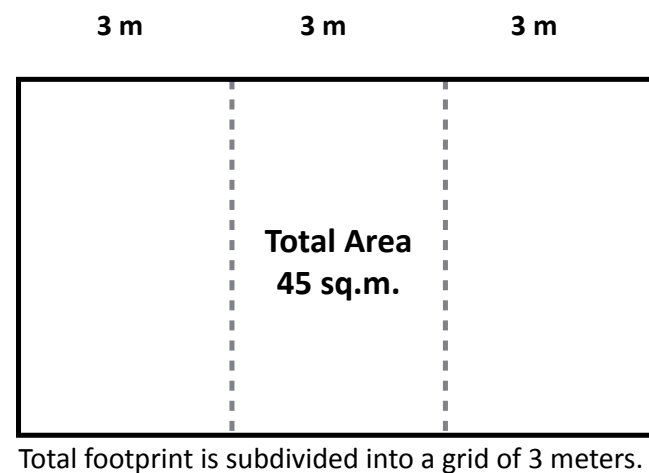
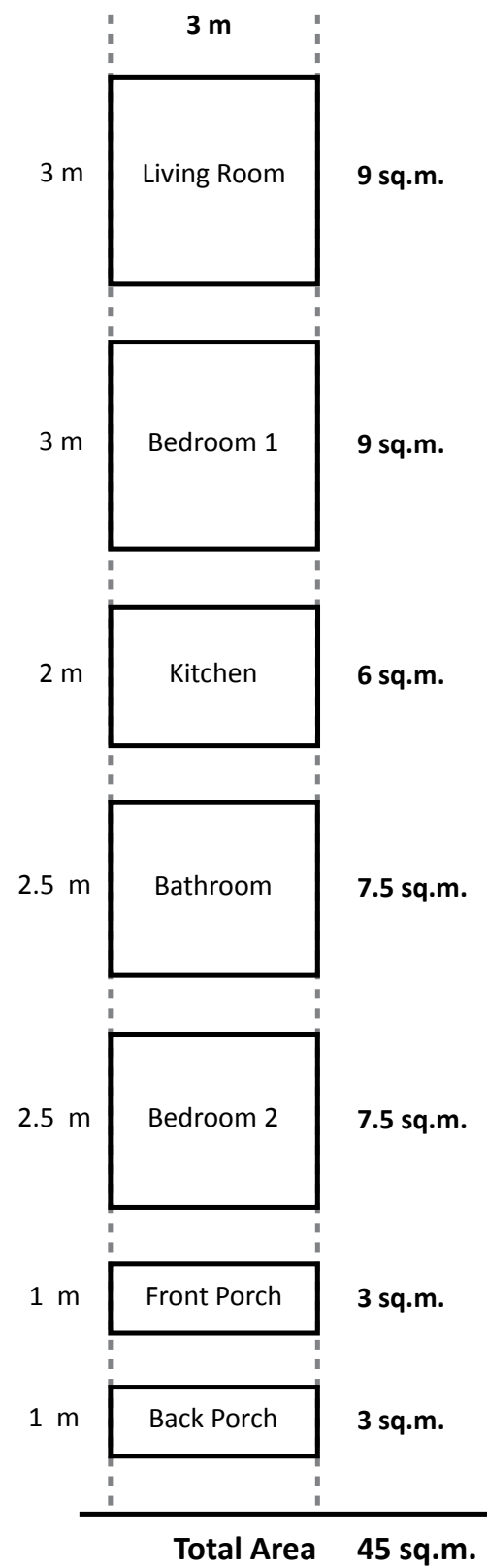
Natural Light and ventilation into the interior of the house - Rwinkwavu Prototype House



Compressed Earth Blocks produced on a large scale - Rwinkwavu Housing Project

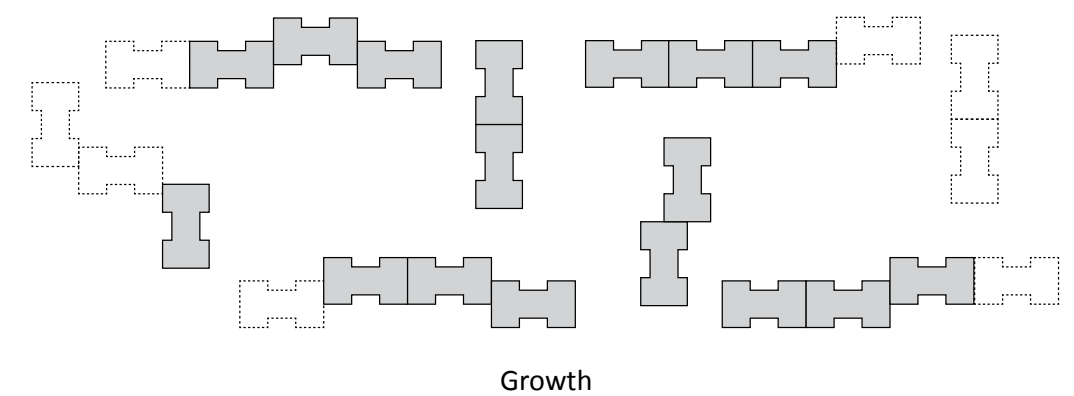
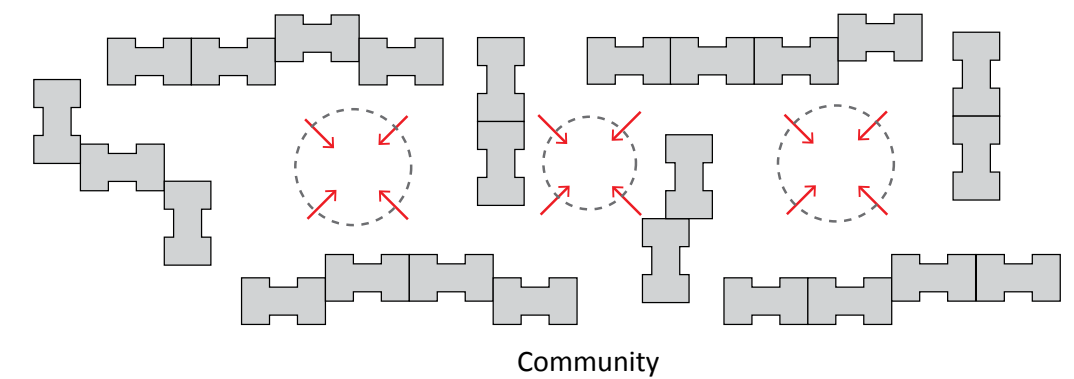
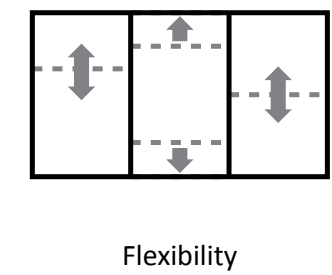
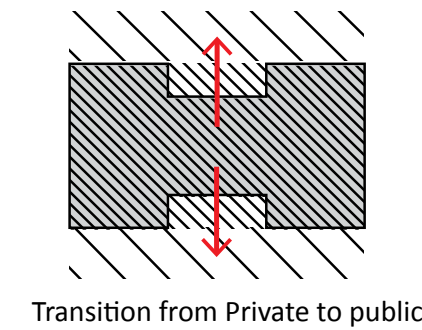
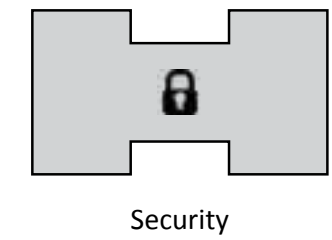
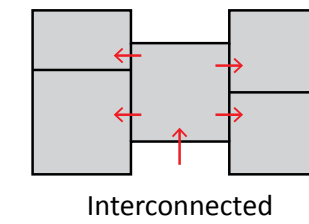
## Module Footprint

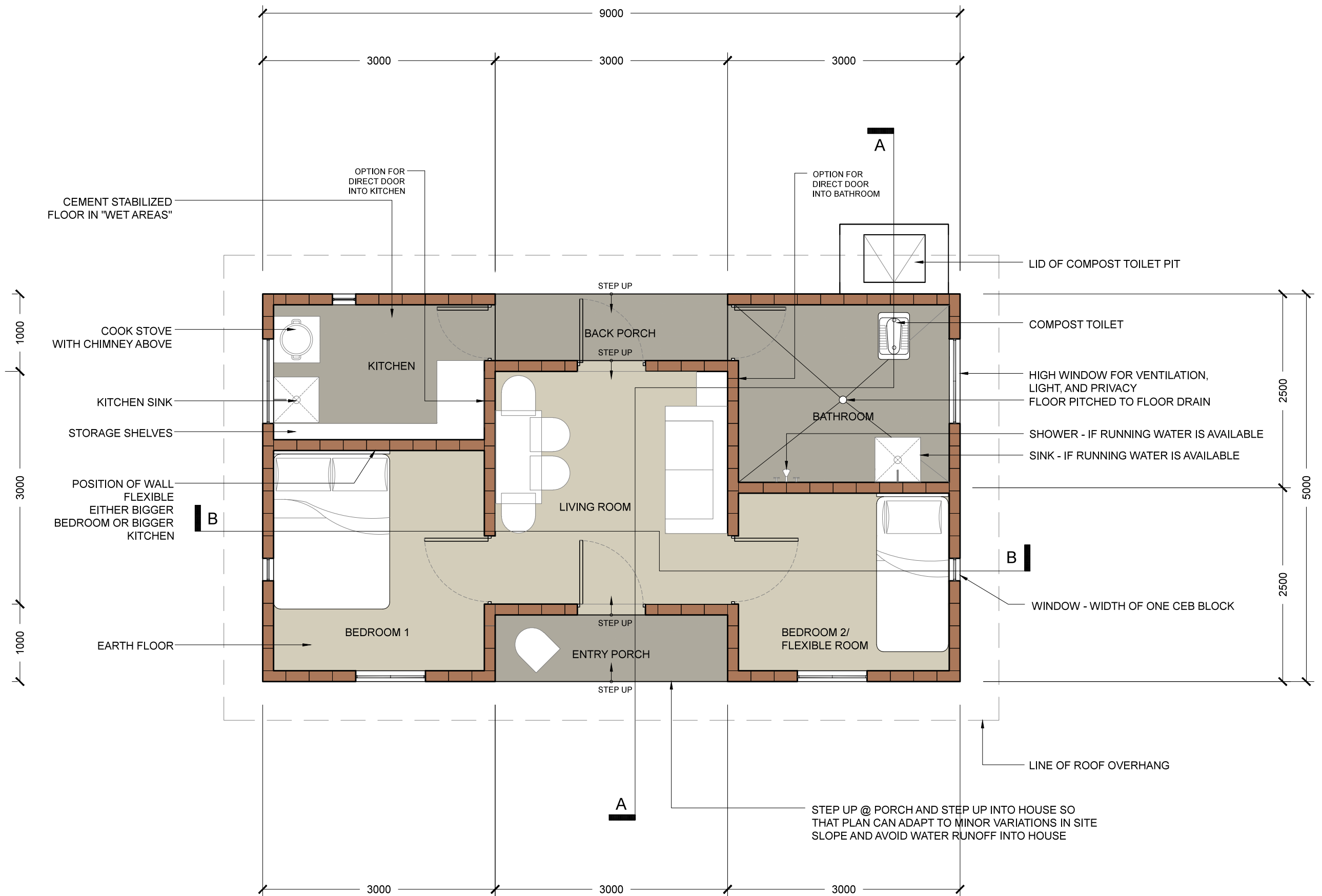
Simplicity is one of the keys to affordability. The plan consists of (3) simple 3mx5m blocks, that can host a variety of functions, provides ease of construction, and offers covered exterior spaces.



## Space Planning Concept

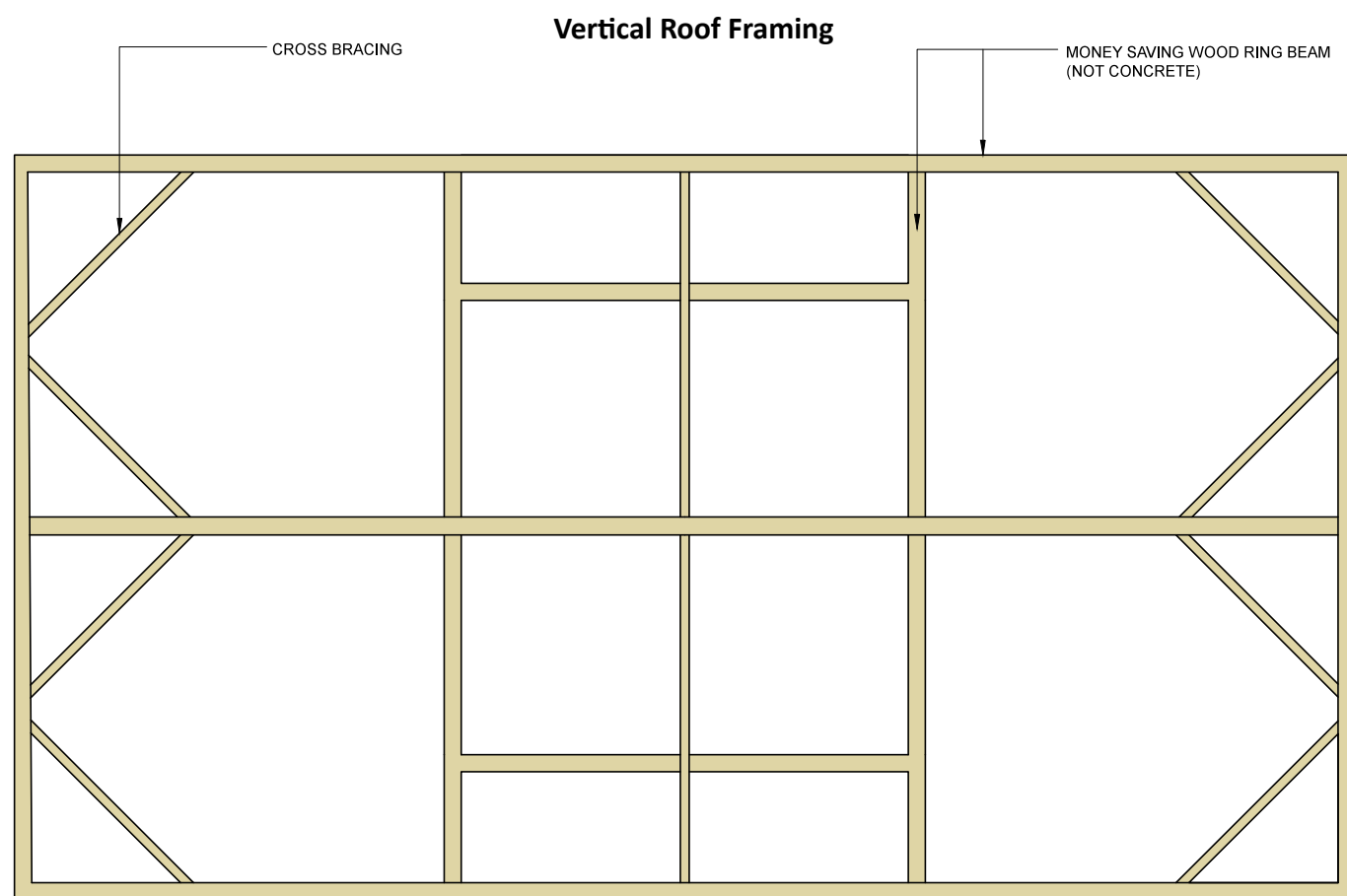
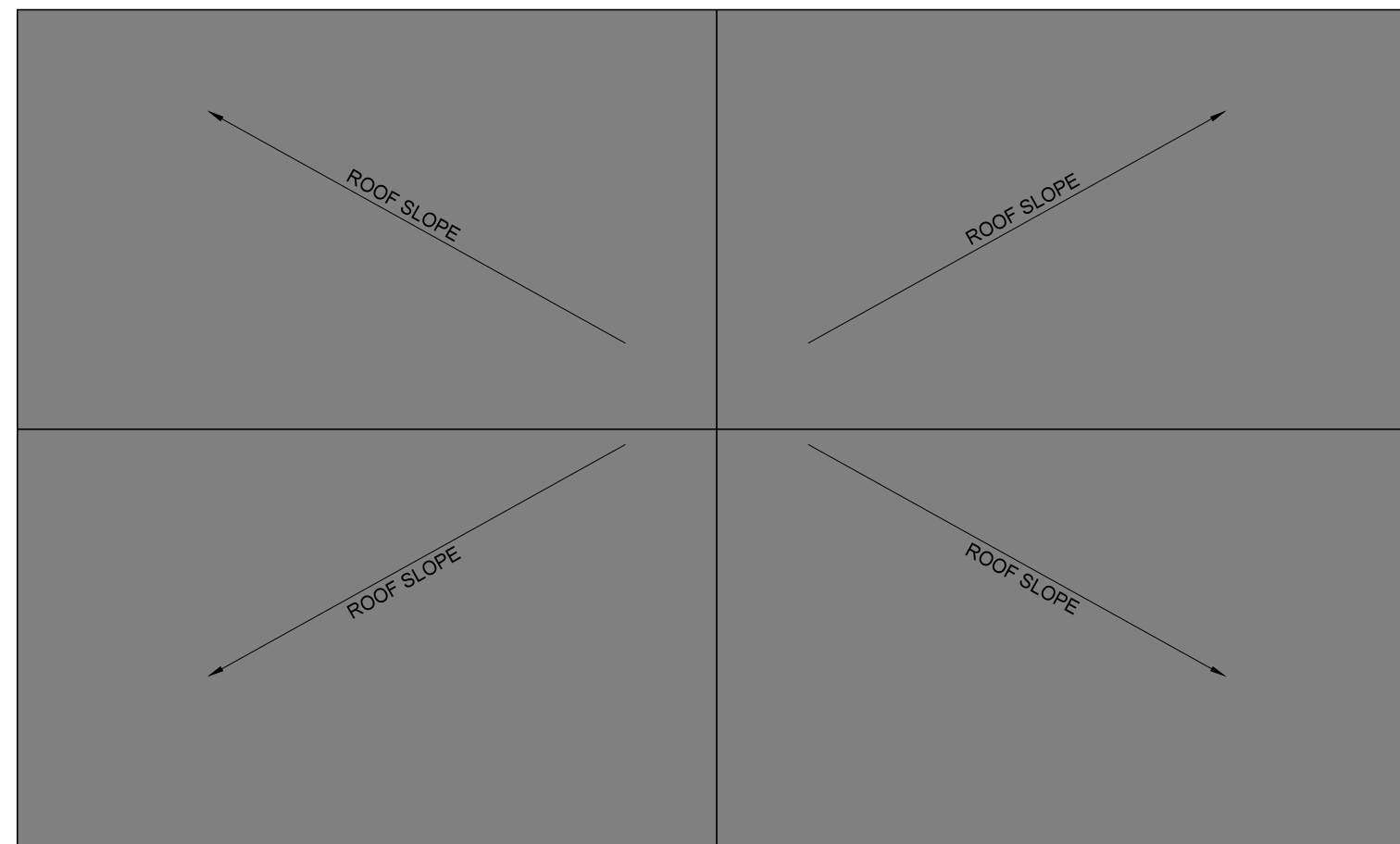
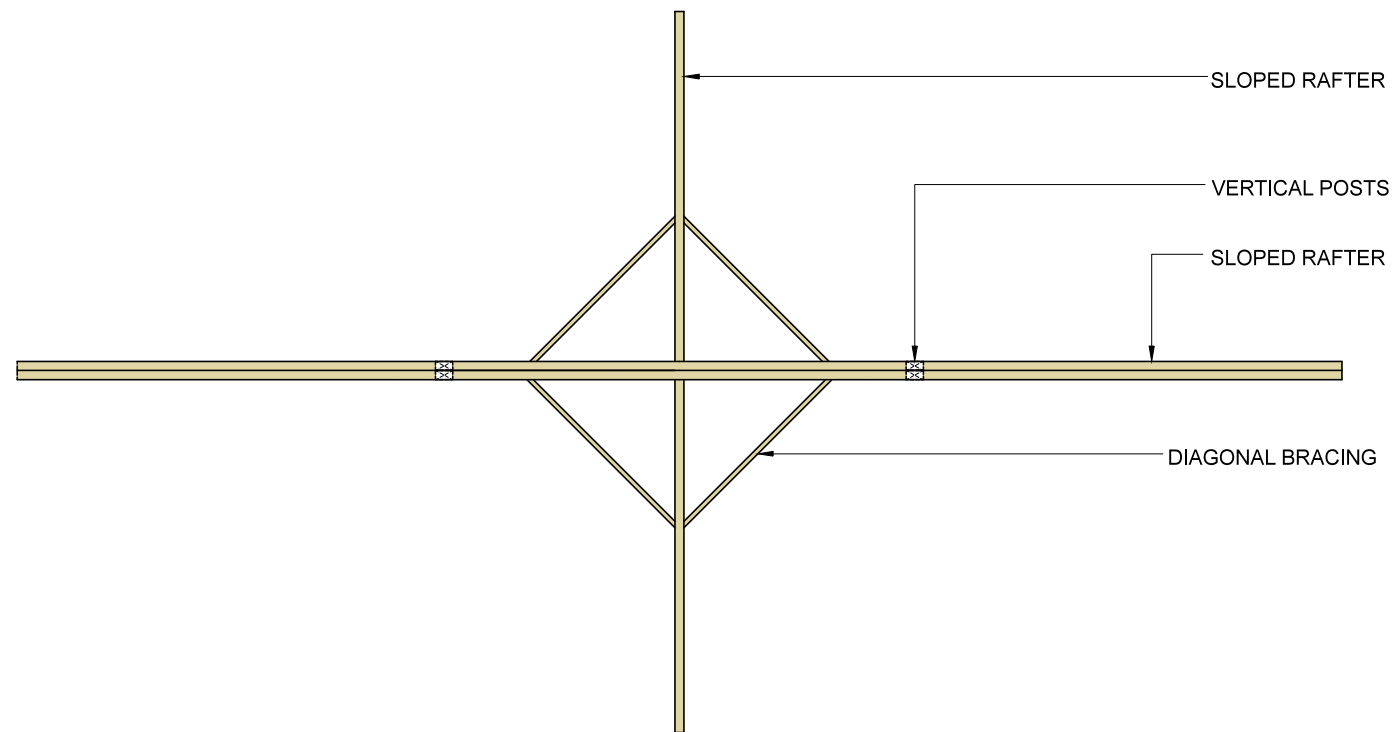
This simple floor plan eliminates internal circulation space to provide maximum usable space, and offers flexibility of interior partition locations.



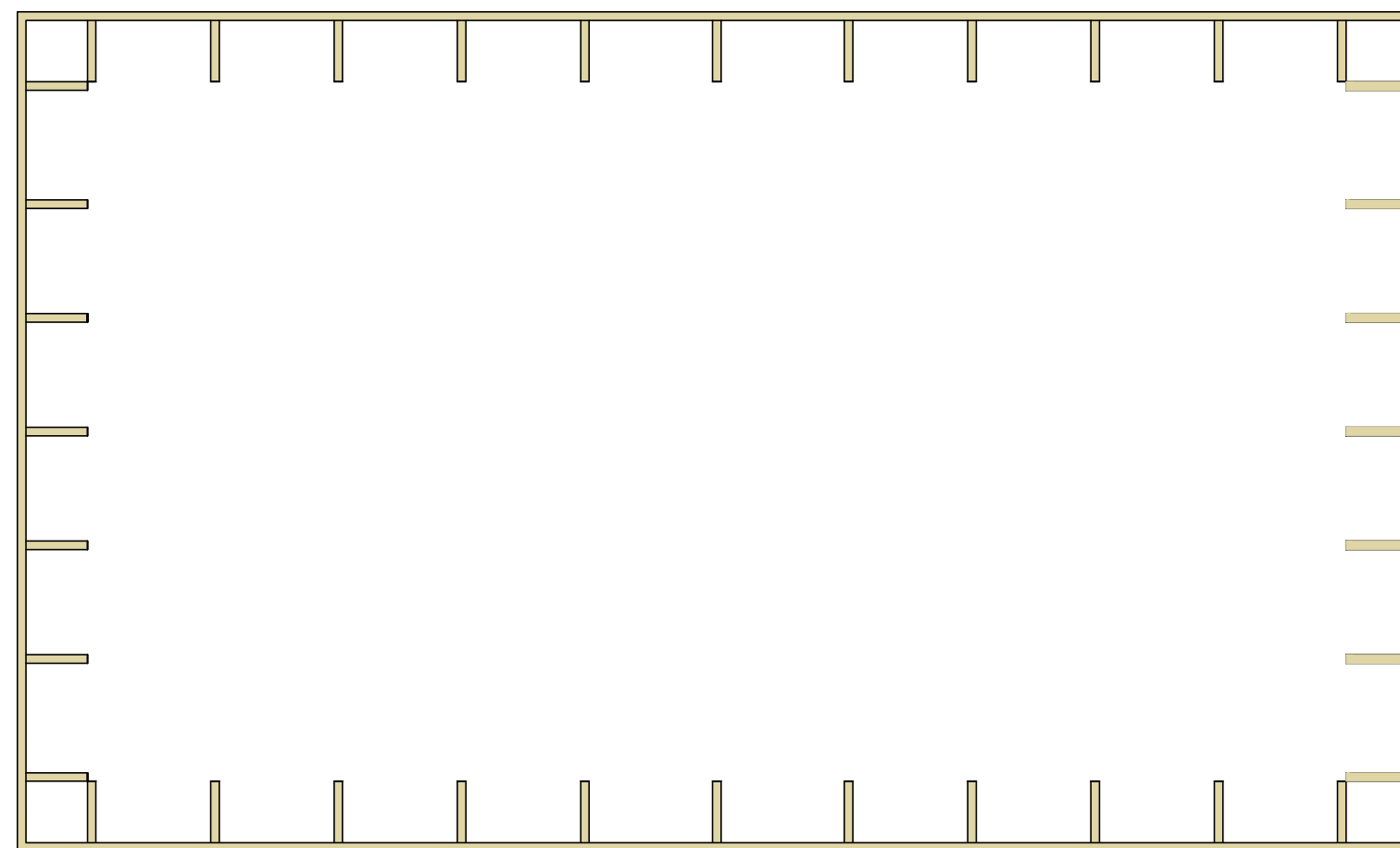


Floor Plan

scale 1:50



**Ferrocement Roof**

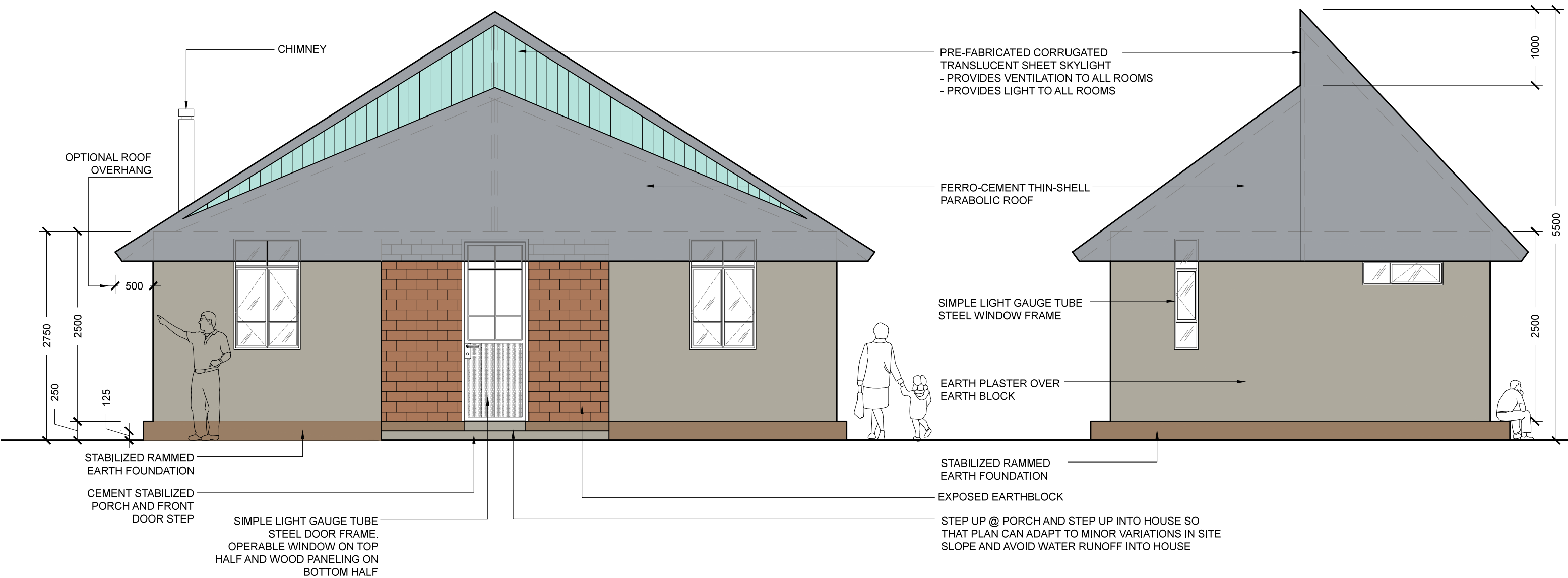


**Ring Beam and Horizontal Framing**

**Overhang Framing (optional)**

**Roof Framing Plan**

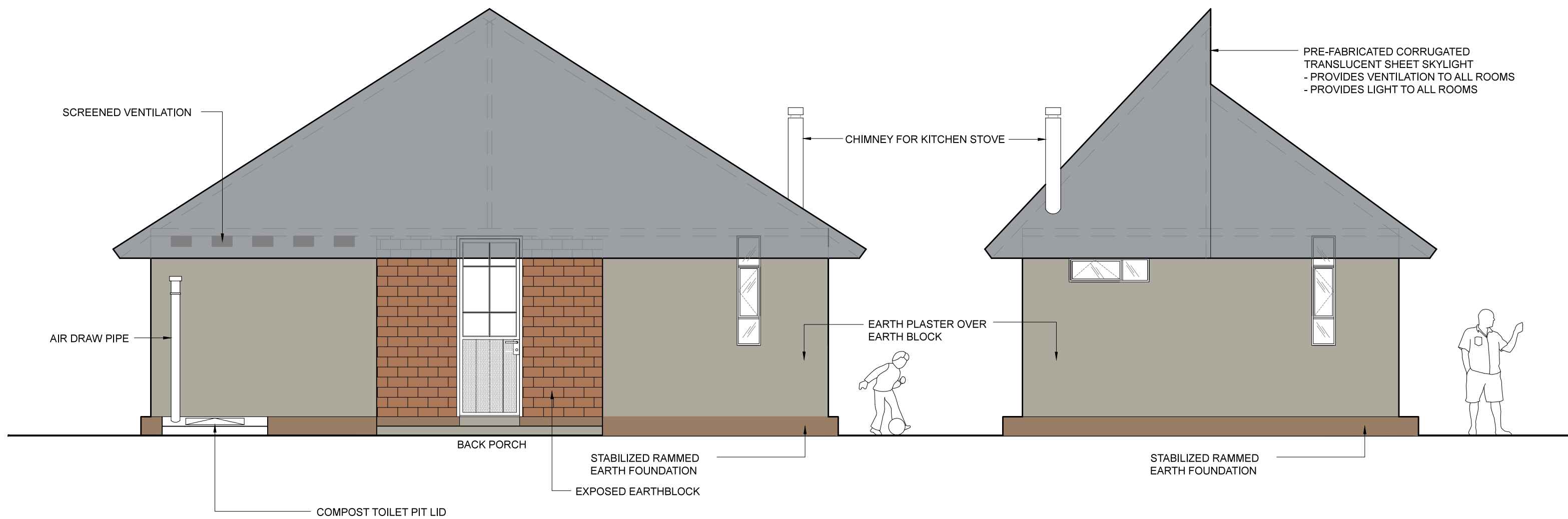
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Elevations: Front and Side

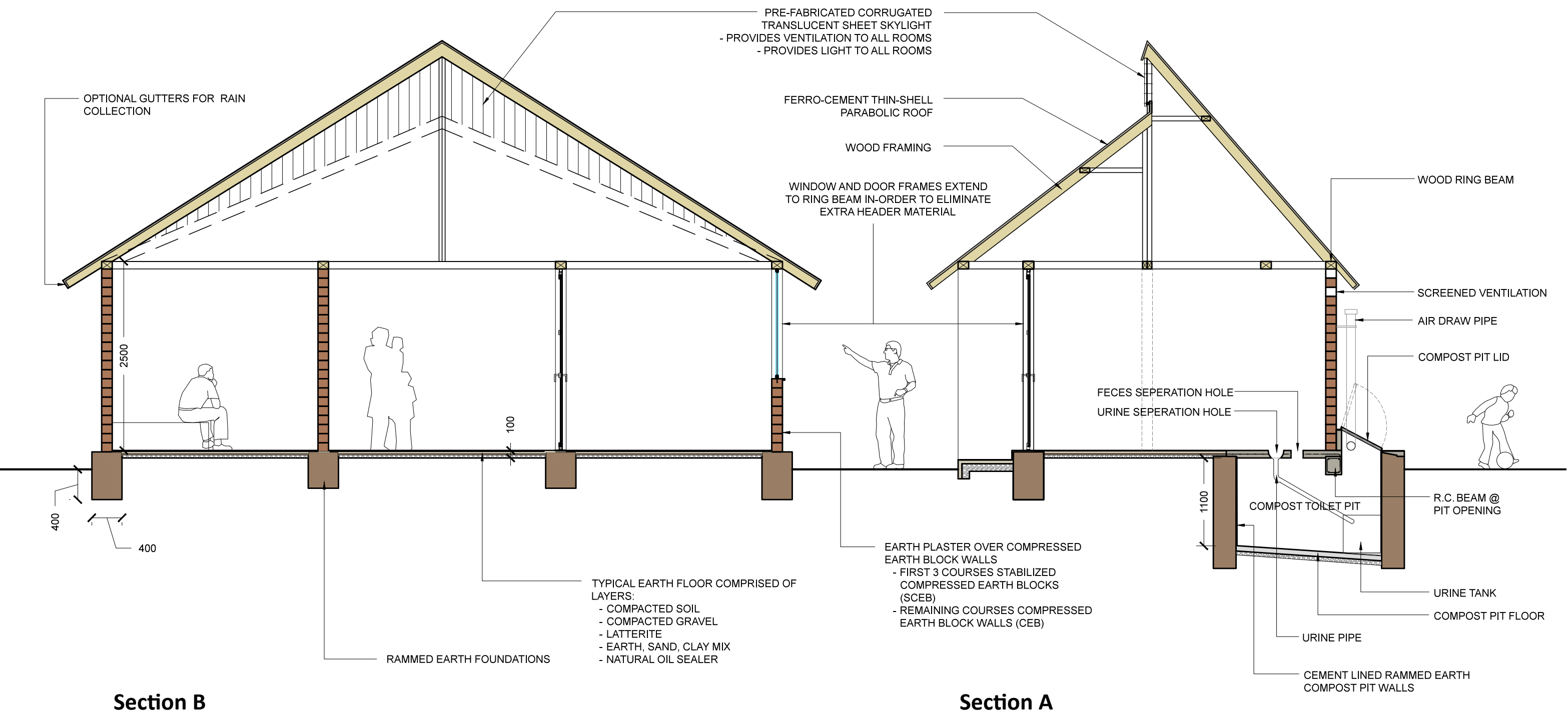
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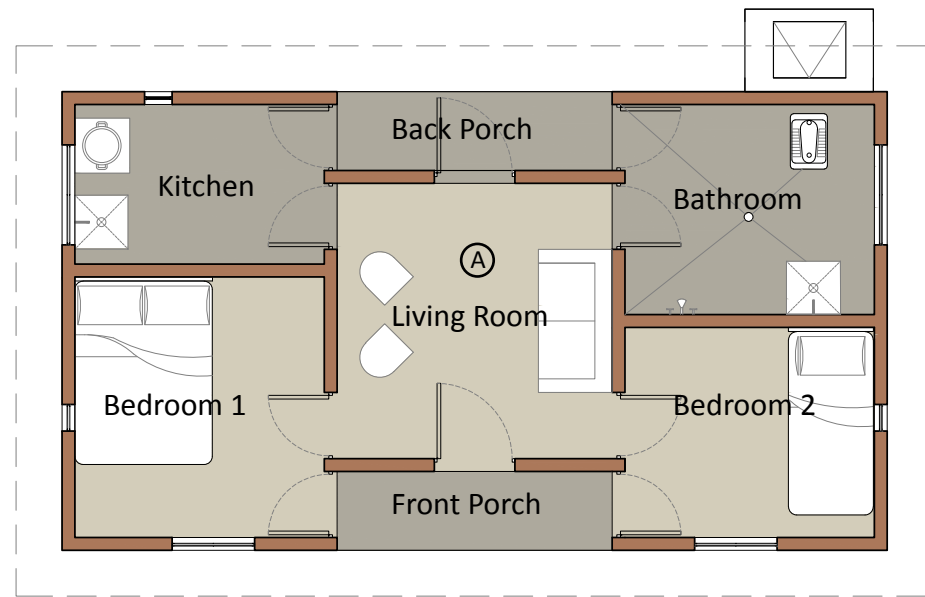




Elevation: Rear and Side

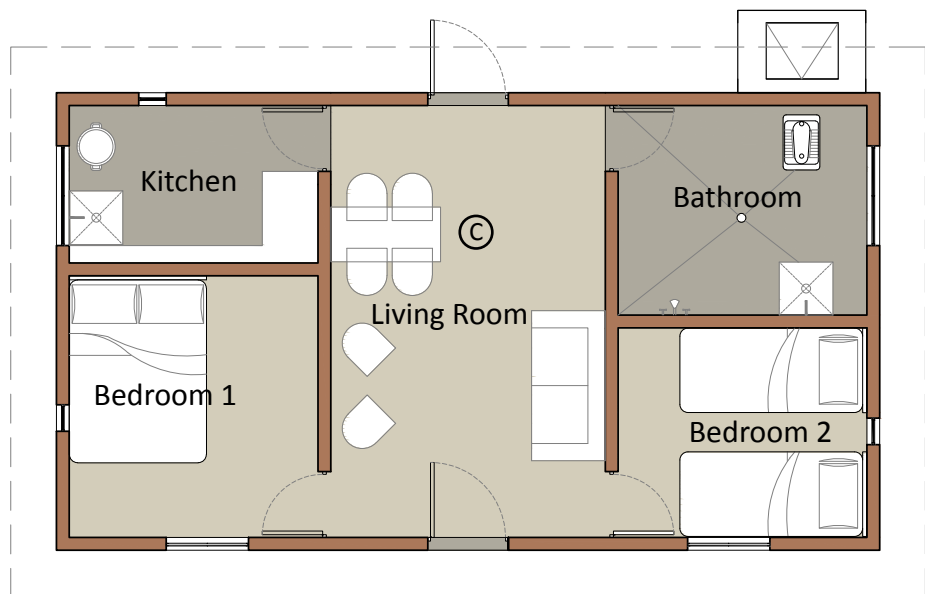
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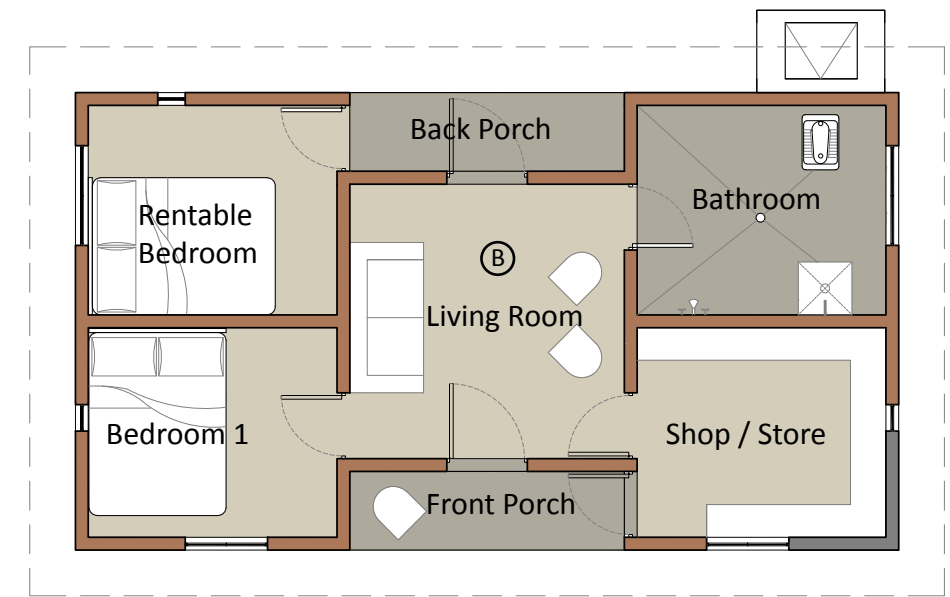
**Multiple Door Option:**

- Internal access to kitchen and bathrooms
- Direct exterior access to bedrooms



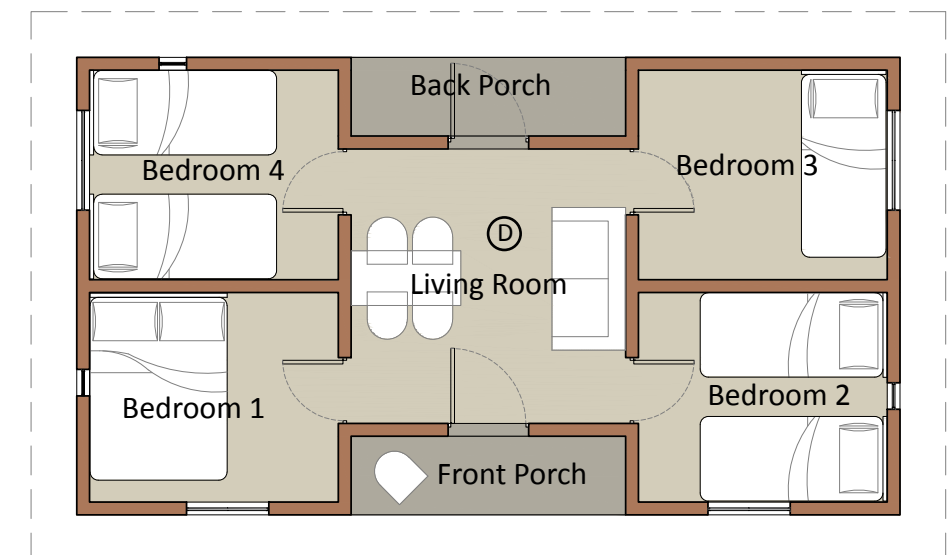
**Maximized Interior Footprint:**

- Front and/or back porch removed



**Income Generation:**

- Front room for store
- Back bedroom for rental
- Outdoor Kitchen



**All Bedroom Option:**

- 4 Bedroom house
- Assuming exterior (possibly shared) kitchen and bathroom

## Module Flexibility





Housing clusters will depend on site by site specifics, and the degree of urbanity in which they sit. The clusters can be made more or less dense, with or without shared amenities.

## Housing Clusters



## Walls : Compressed Earth Blocks (CEB & SCEB))

In our past experience with affordable housing and, for this design challenge, the key objective of affordability, is to produce locally with readily available material, to engage in local unskilled labor, and to ultimately in the process provide jobs and future economic opportunity for the community while improving construction standards.

Earth Based Construction is a good vehicle for these goals. Almost all soil

The first two courses can be made from Stabilized Compressed Earth Blocks (SCEB) by adding a small percentage of cement to the soil (aprox. 5%) to help stabilize and protect the base of the wall from moisture from grade or driving rain. The remaining courses can be made without cement, just 100% soil dug from site (CEBs).



(1) Digging the soil from a strategic area (such as future buried water cistern or soak pit)



(2) Sifted soil is poured into the earth block press. A stabilizer can be added to the mixture to produce a SCEB.



(3) Compressing the mixture manually by two people.



(4) Removing the block from the press



(5) Curing / Drying the blocks is done for a period of four weeks after manufacturing.



(6) Building with the blocks

### Earth Blocks with Rebar

To achieve earthquake safety standards, a standard earth block can be modified to allow for rebar. There are a large variety of earthblock making machines that produce blocks with holes for rebar, or interlocking blocks to reduce the need for mortar.



### Earth Plaster

An inexpensive earth-based plaster with lime and sawdust is applied to the earth block walls to give a smooth texture. This plaster resists water penetration, yet remains breathable, and makes the exterior more durable.

There are many different methods and combinations of earth plaster mixes, in order to adapt to local availability.





# Foundation : Rammed Earth



**Advantage:** Soil is dug for foundation trench is reused for foundation using unskilled labor. Small amount of cement is the only added material.

## Excavating and preparing stabilized earth mix :

- Top soil is removed carefully so that it can be reused for landscaping.
- The soil is excavated at the exact width of the foundation, so that the trench walls become the formwork for the foundation.
- The excavated soil is piled and sieved adjacent to the trench.
- This sieved soil is mixed with 3%-5% cement and a small amount of water just to moisten.
- The mix varies from site to site depending on the soil quality and the local requirement.
- Rebar is added near to the bottom of the foundation

## Pouring stabilized earth mix in trench :

- Once the mix is ready, it is poured into the trench 12cm at a time. The layer is levelled and the height of each course is checked with a simple gauge.
- This process is repeated after ramming down to about 6cm, until the desired height of the foundation is achieved

## Ramming :

- A handmade tamper is used to compact the earth mix poured in the earlier step. This is done manually till a clear sharp sound is heard and the tamper stops making marks on the soil.
- The rammed earth is checked in various places to ensure that the level remains consistent (about 6cm at a time)
- Once the entire course is complete, water is sprinkled on the previous course. This process is carried until one reaches the last course.

## Levelling the last course :

- When the last course is completed, the level of the top layer is checked with a level string line. If the top is too high in places it can be scraped down to achieve level.
- The foundation is cured for 3-4 weeks.

# Flooring : Earth Floor



## Digging, Leveling and Compacting :

Digging is usually done up to -80mm below the top of foundation. This helps to get a protective edge to all the layers of the floor and withstand the humidity. The soil is then leveled, rocks and large size debris are removed. Following that the soil is compacted using hand tampers.

## Gravel Layer :

- Gravel is the first layer on top of the compacted soil.
- Water is added while compacting the layer of gravel to allow firm contact with the soil below.
- 40mm layer of gravel ranging from 25-35 mm in diameter.
- 20mm thick layer of laterite: consisting of non-organic soil and small rocks, is poured over the gravel.
- Anti termite liquid is applied.



## Preparing third layer :

Laterite, gravel, fine sand, clay and water are mixed together to form a stiff uniform mixture to be poured on top of compacted laterite. Steel tubes are used to level the top and wooden float is used to smoothen the surface. This layer is 20mm below the top of foundation and 20mm on top to cover the foundation.

## Final finish layer :

The finish layer is a mix of fine sieved sand, clay and water. A steel float with few drops of clay-water mix is used to achieve a smooth surface. The surface is left to dry for sometime and see if any cracks come out. Cracks are sealed with the same sand mix. 5 coats of flax oil are applied once the surface is dry. This oiled surface takes a week to dry and thereafter the floor is ready.





# Roofing: Ferrocement Roof / Thin Shell Parabolic Roof

The roof for the affordable housing prototype we built was modeled on precedents we learned from in the area. This technology is low a low-cost building technique that uses readily available materials. Roof framing is from local timber, while the “formwork” for the ferrocement roof is made from old bed sheets and chicken wire.



Precedent we learned from: easy to assemble on the ground and lift into place offering assembly line possibility



detail from our prototype



interior of our prototype

## Strong = Economical use of Materials = Lightweight

The inherent **strength** of the parabolic shape gravity naturally gives to the fabric that receives the cement slurry allows this roof technology to be built with up to **50% less framing** than a typical corrugated metal roof and **70% less** than a clay tile roof. **Less framing = less cost.** The cement shell is only **1.5cm-3cm thick**, and therefore **does not use much material** and is extremely **lightweight**. The lightweight nature of the construction allows for the possibility of the roof (or sections of the roof) to be built on the ground in an **assembly-line** fashion therefore **bringing time and labor costs down**.

**Good Performance:** This roof technology performs well in a variety of ways.

**Durability and Repairability:** A latex additive (similar to what is found in common paints) is added to a small portion of the mixture giving the cement structure an added flexibility to resist cracking. And if cracks appear (they haven’t yet in our prototype that has been standing for 3 years) it is easy to mix more cement, water and sand, climb up on the roof and patch only where needed.

**Acoustic Performance:** Unlike the typical tin roof, the sound of rain is dampened by the solid nature of the roof material and therefore remains quiet when its inhabitants want to talk or sleep.

**Low Heat Gain:** The ferrocement roof will not transmit heat in the way a typical tin roof will.

**Light and Ventilation:** Our design features a skylight made from readily available long lasting corrugated fiberglass sheets that brings **light and ventilation into all the rooms** of the house. Because the skylight is at the apex of the roof, a natural “stack effect” is created sucking hot air up and out of the house, and **reducing the need for artificial lighting** therefore **reducing the running cost for the inhabitants**.



Our prototype: Roof framing made from local unmilled timber



Precedent: Roof framing made from milled wood or steel tubes



Our prototype: roof form made from old bedsheets and chicken wire

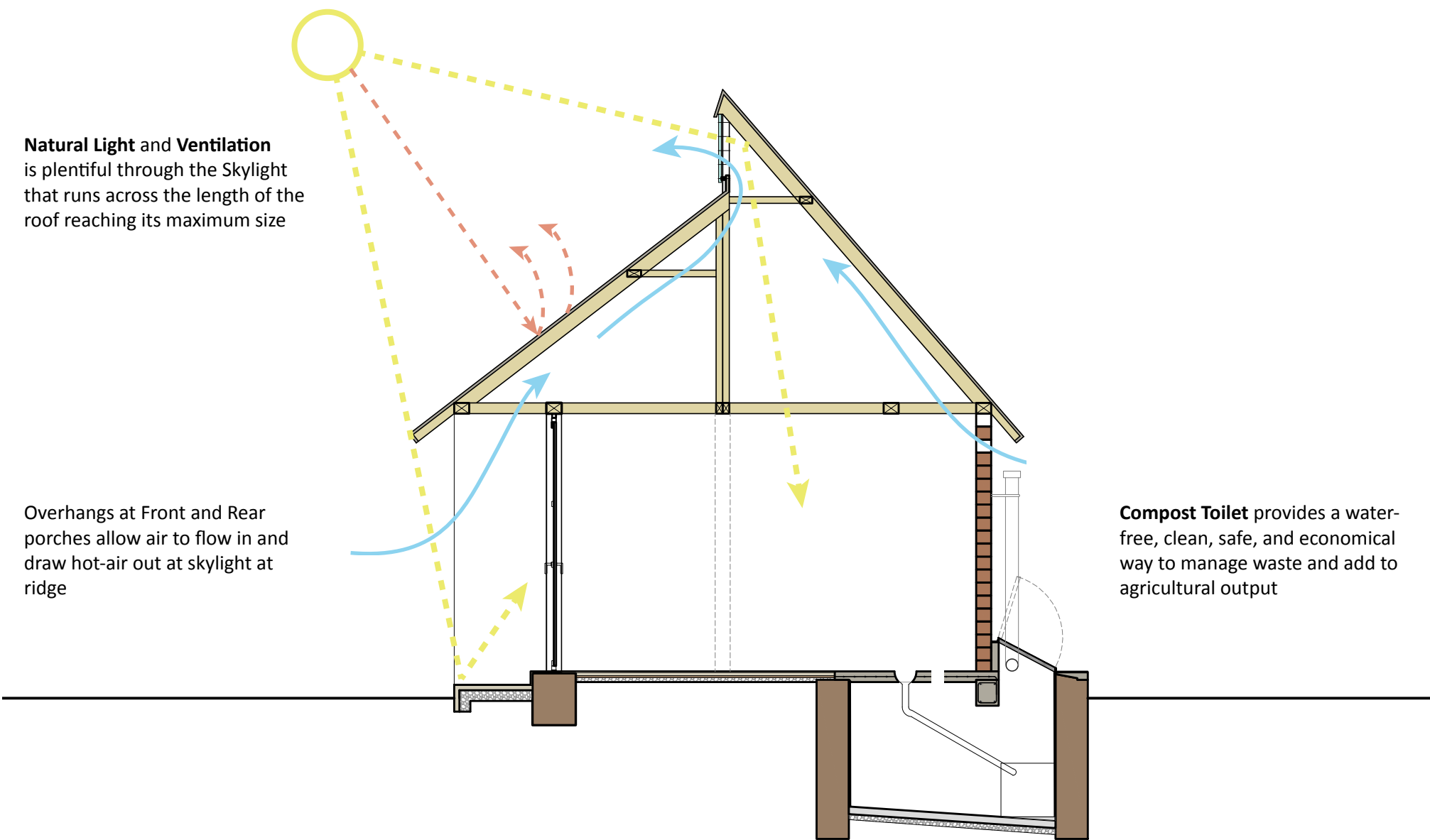


Precedent: roof form made from stretch mesh and chicken wire



Our prototype: roof covered with a slurry of cement, latex, sand mixture

Environmental Design



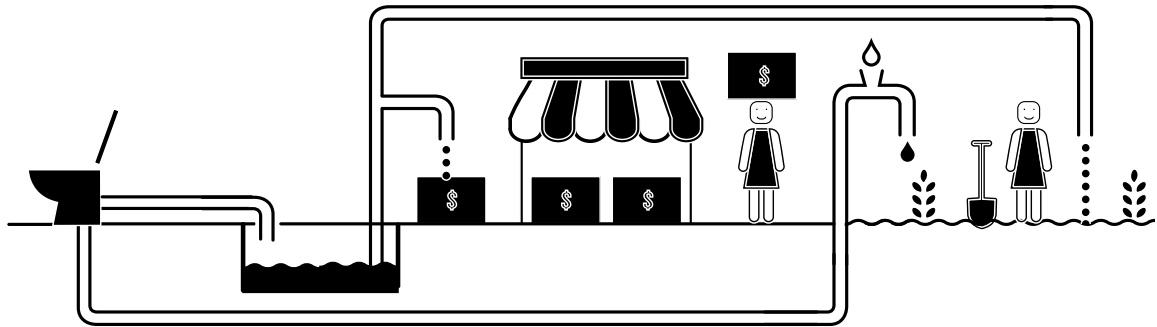
Compost toilets shown here at our affordable housing model



Ventilation at overhang of roof and in wall by subtracting blocks and adding insect mesh

**What is a Compost Toilet?**

A Compost Toilet is a toilet that requires no water, and turns valuable waste product into a valuable fertilizer.



Compost Toilet Diagram

**Why Compost Toilets?**

Because water is such a precious commodity, this type of toilet provides an much needed alternative to flushing good water down the toilet or a pit latrine.

Additionally, the composted waste from the toilets provides rich fertilizer for the agricultural training and production.

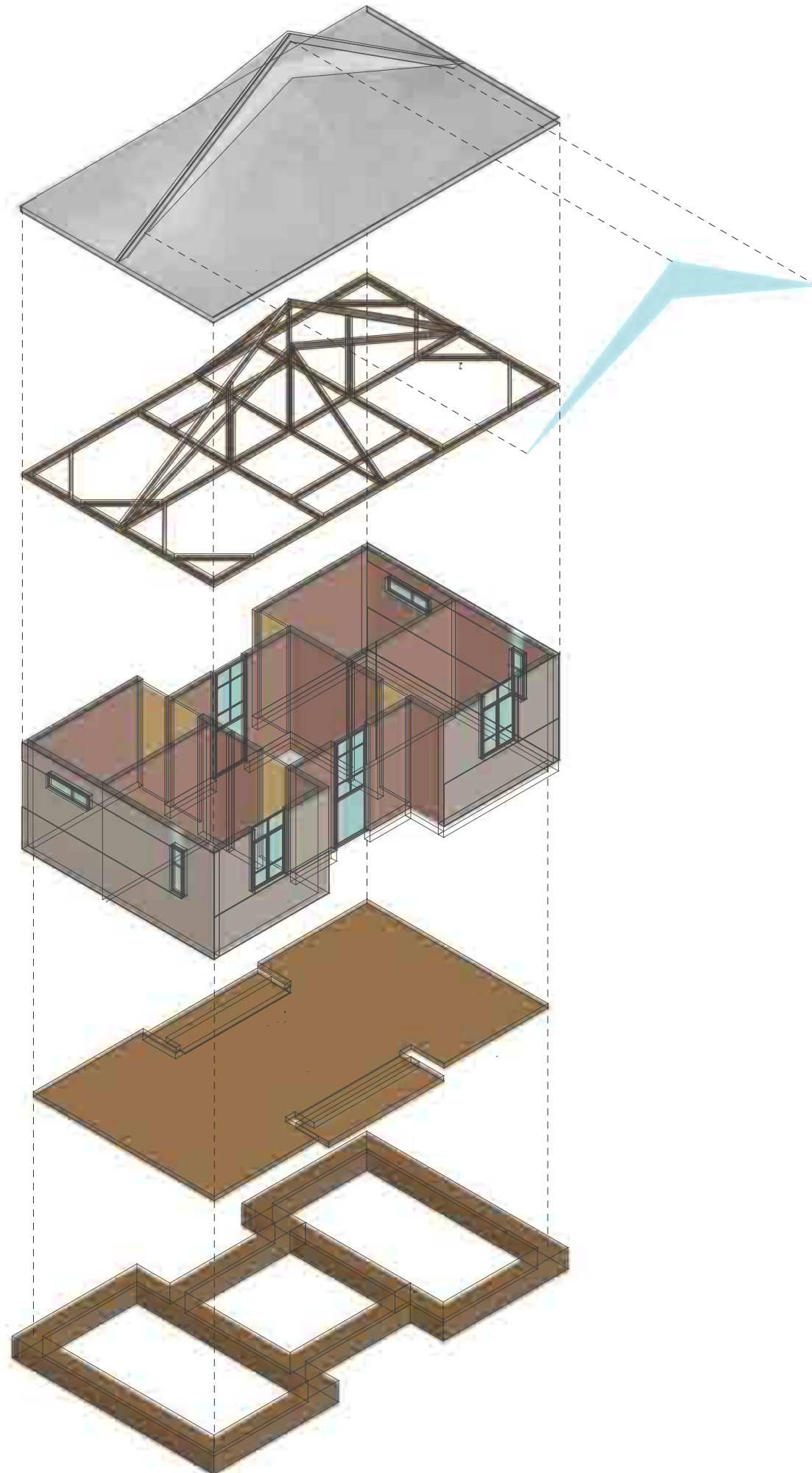
**How it works:**

Feces and Urine are separated. Feces go into the compost pit (the hole in the rear) and urine goes via a pipe into a urine tank (the hole in the front). It is very important to keep the two separate.

The urine, which is rich with nitrogen, phosphorus and potassium (the leading ingredients in industrial fertilizers), diluted with water and used to fertilize the plants. The feces is left to dry (with the aid of ash) and decompose in the compost pit for a couple years prior to being used as fertilizer.



## Bill of Materials



**Ferrocement Roof**  
 Fabric: 60+ m<sup>2</sup>  
 Chicken Wire: 60+ m<sup>2</sup>  
 Cement/Sand/ Latex Mixture: 1.2m<sup>3</sup>



**Translucent Corrugated Sheet Skylight**  
 Fiberglass corrugated sheet: 3.3m<sup>2</sup>



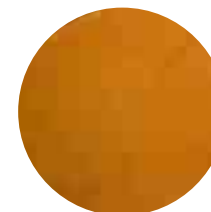
**Wood Framing:**  
 Milled Wood (ring beam and horizontal framing): 65 lm  
 Milled or Unmilled wood Vertical Framing: 22.7 lm  
 Overhang Wood: 46.4 lm



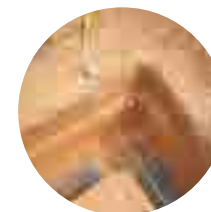
**Compressed Earth Block**  
 SCEBS (first 3 courses): 366 blocks  
 CEBS (remaining courses): 1,974 blocks



**Earth Plaster**  
 Exterior Walls: 47.9 m<sup>2</sup>



**Earth Floor**  
 Sealed Earth floor (interior dry spaces): 23.2 m<sup>2</sup>  
 Stabilized Earth Floor (optional for "wet" spaces): 15.7 m<sup>2</sup>



**Rammed Earth Foundation**  
 Soil (dug from the foundation trenches) + 5% cement: 11.18 m<sup>3</sup>





The primary objective is to create a community of high quality, sustainably constructed housing that is affordable to a variety of groups, including lower income households living in the urban areas. Sharon Davis Design is excited to contribute design solutions that offer new, affordable and sustainable housing models for Africans.