Building with earth
- the basics
More info on earth building:

www.cat.org.uk/ecobuild
www.adobebuilder.com
www.motherearthnews.com/green-homes
www.greenhomebuilding.com
www.nbnetwork.org
www.buildsimple.org
www.buildnaturally.com
What is adobe?

Adobe is a natural building material made from sand, clay, water and some kind of fibrous or organic material (sticks, straw, and/or manure), which the builders shape into bricks (using frames) and dry in the sun. Adobe buildings are similar to cob and mudbrick buildings. Adobe structures are extremely durable, and account for some of the oldest existing buildings in the World.

Why adobe?

In addition to being a durable, inexpensive material with a small resource cost, adobe can serve as a significant heat reservoir due to the thermal properties inherent in the massive walls typical in adobe construction. In climates typified by hot days and cool nights, the high thermal mass of adobe averages out the high and low temperatures of the day, moderating the living space temperature. The massive walls require a large and relatively long input of heat from the sun (radiation) and from the surrounding air (convection) before they warm through to the interior.

After the sun sets and the temperature drops, the warm wall will then continue to transfer heat to the interior for several hours due to the time lag effect. Thus, a well-planned adobe wall of the appropriate thickness is very effective at controlling inside temperature through the wide daily fluctuations typical of desert climates, a factor which has contributed to its longevity as a building material.
History

The word can be traced from the Middle Egyptian (c. 2000 BC) word dj-b-t “mud (i.e., sun-dried) brick.” As Middle Egyptian evolved into Late Egyptian, Demotic, and finally Coptic (c. 600 BC), dj-b-t became tobe “(mud) brick.” This was borrowed into Arabic as al-tub (al “the” + tub “brick”) “(mud) brick,” which was assimilated into Old Spanish as adobe (adobe), still with the meaning “mud brick.” English borrowed the word from Spanish in the early 18th century.

The earliest habitations of earth buildings have been found in the Indus River valley in India & in the Tigris and Euphrates valleys in modern day Iraq. Some examples date back to 7000BC. Arid lands with very little timber adapted earth and found vaulted and arched domes could distribute high loads to provide shelter. Adobe has been perceived as being a viable option to economic problems in the US up to as late as 1940 and has made a resurgence in the last decade as people look for economical and less environmentally damaging building technologies.

Although adobe’s origins are ancient it is testament to the fact that when used in the correct way and in the right setting it is a truly durable long lasting material.
Buildings made of sun-dried earth are common in West Asia, North Africa, West Africa, South America, South-Western North America, Spain (usually in the Mudéjar style), Eastern Europe and in the UK. In fact it is hard to find a place that has a moderate /good climate and does not have some examples of Adobe, rammed earth or cob buildings. As the map on the right shows only Russia, Canada and Greenland seem to be lacking in any earth buildings.
Soil testing

Here we learn a simple way to test soil for construction. We would advise that it is always best to consult an engineer or soil specialist before you undertake any large scale project.

Get together a sample of earth which you might like to use to make mud bricks. Collect earth from at least a few inches below the soil. The best soils for mud bricks would be ‘clays’, ‘clay loams’, ‘silty clay loams’, or ‘silty clays’. Sandy clay loam would require additional clay and or organic matter added (eg. Straw) to make an effective brick mixture.

Ball / sausage test

Here is a simple way you can go about determining what a particular type of soil is:

1. Place a small quantity of soil in the palm of your hand and add just enough water to make it plastic. If it doesn’t stain the fingers, doesn’t bind together and is gritty to feel, it is a sand.

2. If it doesn’t stain the fingers but can be rolled into a ball which barely adheres together, then it is a loamy sand.

3. If it forms a more solid ball which can be rolled into a cylinder, but breaks when the cylinder is bent, and if it still feels gritty; it is a sandy loam.

4. If when the cylinder is bent gently, it doesn’t break and if there is no feeling of grittiness, silkiness or stickiness; then it is a loam.

5. If it is similar to a loam but is sticky and can be polished, it is a clay loam.

6. If it shows the characteristics of a clay loam, but when squeezed, also has a gritty feeling, it is a sandy clay loam.

7. If it is like a loam, but is sticky and can be polished, it is a clay.

8. If instead of being gritty, it is silky but otherwise like a clay loam, it’s a silty clay loam.

9. If the characteristic of stickiness is stronger than anything else, then it is a clay.

Note: Organic soils are ones which have a large proportion of organic matter (25% or more). These are usually black or brown in colour and feel silky. It is possible to get organic types of all of the above soils.
Jar Test

To perform a “jar test” to determine your soil suitability. Fill a jar (or plastic bottle - make sure it’s see-through) halfway with the soil sample. Fill it the rest of the way with water. Shake vigorously for at least a minute, then let it sit overnight.

The next day, the soil will have settled into distinct bands. The bottom of the jar will have the larger-sized materials - sand and small pebbles - with smaller and smaller sized particles banding towards the top. The top band will be the clay or different silt. Ideally, the three bands will be about the same size. If your sample has more than a third sand (the bottom layer), you may not need to add any sand to your adobe.

The New Mexico State University (an expert on Adobe structures) recommends a mix of not more than 1/3 clay, not less than 1/2 sand, and never more than 1/3 silt. Can you draw a circle on the USDA chart opposite of the soil type range perfect for adobe?

Image source for the soil diagram: www.guaduabamboo.com
Calculate the volume of your wall:

Measure the length and height of the wall in meters.

Since the bricks are 20cm thick multiply length and height by 20 to get the volume of wall in cubic meters.

Imperial (for America)

Measure the length of the wall in feet.

Determine the height of the wall in feet.

Since bricks (and thus the wall) are made 8” (20 cm) thick, multiply the length by height by 0.83 (10 in = .83 ft).

Divide that by 27. This is the total volume in cubic yards of the wall.
Materials:

The most desirable soil texture for producing the mud of adobe is 15% clay, 10-30% silt and 55-75% fine sand. If you don’t have this ratio you may need to add more of one of the following:

**Base material**

Sand (about half - 50% of your total volume). Sand is usually sold by the ton, you can calculate tonnage by multiplying your volume by .83. The sand should be relatively fine sand - beach sand or slightly larger works fine.

**Binding material**

Clay (about a third of your total volume). Again, clay or fill dirt is usually sold by the ton. Multiply your volume by .9 if it is dry, .7 if it is wet.

**Elasticizer**

Rice husks (about 10 - 20% of your total volume). Sold by the ton you can calculate tonnage by multiplying your volume by .50.

Straw (about 10 - 20% of your total volume). Straw is sold in bales of various sizes. The most common “big” bales are 14”x18”x36” (35.5 cm x 45.7 cm x 91.4 cm, which is .15 cubic yards. So multiply your total volume by .015 to get the number of “big” bales you’ll need.

NOTE: The amount of sand you mix in is very dependent upon the clay you have available, your climate, and how strong you want the wall. It’s entirely relative - and there’s really no wrong way to do this.
Create a form for making the bricks

This is where you decide the thickness of your wall and the amount of bricks you want to make in one go. A small open frame (mould) can be made if you are making the bricks alone (for ease of use) or larger frames can be made if two people are going to be removing the bricks from the frame. In whatever case it is now that you decide the dimensions of your wall. In our recent workshop we aimed to create 40cm x 20cm bricks.

When making the frame try and use countersunk screws so you do not catch your fingers and hands manoeuvring the bricks out of the frame. Also make sure you use a carpenters or engineers square to get clean corners to your bricks.
Create the mix

Shovel together sand and clay in the pit. These should be mixed at roughly 5:2 ratio but again this may depend on the soil test and if any sand is needed at all? If you have the time create a few test bricks noting ratios then you can scale up these amounts when you come to building a bigger project.

NOTE: After a few trials you will get to know what consistency works and what doesn’t. Don’t be afraid to make mistakes there is not a wrong or right way to do this.

Add water

Enough to make the mixture “soupy.”

Mix together

The easiest way to do this is to take off your socks and shoes, roll up your trousers, and jump in with both feet. Dance in the pit until the mud becomes uniform. Mix it around until you don’t find any dry patches. There should be enough water in the mix so that it is easy to mix but is not runny enough to make you slip.

The mix

Have fun making the mix!
Add rice husk or straw

Rice husks are a by product of the food industry and are very useful in adobe brick manufacturing.

You are looking at adding about 20% to the volume in the pit, but add it gradually a bit at a time. You may need to use a shovel to turn the bottom of the pit over from time to time ensuring a good mix.

Keep mixing until it becomes stiff. You have got a good mix when you stamp, bring your foot back up and the mud holds the print before collapsing into itself.

Why adding straw/rice husks is important

Straw is useful in binding the brick together and allowing the brick to dry evenly, thereby preventing cracking due to uneven shrinkage rates through the brick.

You can of course make bricks without straw or rice husks but for the purposes of Building Trust workshops we include it.

Other things you can add:

Dung: Although it may make some people go “Eewww!” Dung can actually repel insects and reduce infestation.

Cement: This splits the adobe building world in two with some saying it makes no difference and makes the bricks ‘un-eco’ and others saying it creates stronger more water impervious bricks. In our previous projects we have left out cement and made sure the walls are safe from water... So far none have fallen over ...touch wood!
Quality control check

Transport some of the mixture onto a tarp and make sure it is all thoroughly mixed. You may want to add some more rice husks at this stage but try not to add any more water. This is also the last chance to get rid of any stray twigs, sticks or other objects that may impair the performance of the brick.

Lift the corners of the tarp to check mixture on the bottom and when you are happy you can start printing bricks.

Printing bricks

Use a shovel to fill frame/mould and make sure the mud mixture is firmly pushed into all the corners and pressed down firmly before removing the frame. Try and do this in one straight upward motion to stop any snubbing of brick edges. You may need a couple of people to nudge some troublesome bricks out. (You don’t need to be too precious as no one will see the bricks when plastered.)

You should leave the bricks in the mould for 10-15mins (however this time maybe slightly longer depending on the mix.)

The mix should hold form as a brick but slip out easily of the mould. If the mixture sticks to the frame, it’s probably too dry. Add more water to mix and try it again. If it is not holding form and the bricks are slumping when you lift the mould up, they are probably a bit too wet and you will need to add more fibre or mud.

Top tip: if using a metal frame it is best to lubricate the frame with oil before adding the mix. This makes the frame easier to lift away from the bricks when printing.
Curing

After an hour or so carefully tip each brick up, again try not to snub the edges too much and then leave them to dry somewhere with no rain and if possible not in direct sunlight (as this will induce rapid drying and cracking.) Leave the bricks to cure for at least a week. Resting them on concrete will result in faster drying than on plastic.

Testing

Once dry if you can drop a brick on its corner from about waist height and it does not break it passes the test!

...or you can try and do the Karate chop test... (Please don’t do this!)

Transporting

We would advise making the bricks on site but if you do have to move them from one place to another due to finding the right drying spot or any other reason they should be moved and stacked on a diagonal (like the image shown above.) Don’t be tempted to stack them flat or they will move around and break each other apart.

Next the building starts...
Load bearing

Adobe walls are load bearing, i.e. they carry their own weight into the foundation rather than by another structure, hence the adobe must have sufficient compressive strength. Adobe construction should be designed so as to avoid lateral structural loads that would cause bending loads. Curving walls is a good way to add more stability to adobe buildings due to the dissipation of any lateral forces working in any one direction.

Ground preparations

When building an adobe structure, the ground should be compressed because the weight of adobe bricks is significantly greater than a frame house, and subsequent foundation settling may cause cracking in the wall. The footing is dug and compressed once again. Footing depth depends on the region and its ground frost level. The footing and trench wall are commonly 24 and 14 inches, much larger than a frame house because of the weight of the walls. Loose gravel is added to the trench and then further compacted.

Foundations

If the local water table is unpredictable building a plinth of rocks or strong reinforced concrete to act as a foundation can be specified to ensure rising damp is not a problem. Otherwise the gravel trench with a bonding course of mortar should ensure any settlement if it is evenly distributed. The foundation needs to get down to the frost level (not a problem in our location.)

Of course a lot depends on the ground conditions when planning foundations. If building off bedrock just below the surface, very shallow foundations may be adequate but you would still need to think about water run off. With all significant building work (i.e. buildings not garden walls or features.) We would advise consulting a local engineer who will be able to give you site specific guidance.

An important rule of thumb is to make any foundation at least 150mm (six”) wider than the wall on each side of the base.

Building up the height of the foundation at least 100mm (4”) above ground level will protect against water and help with laying internal floors if needed. Some sources suggest creating this plinth from stabilized adobe bricks (that is to say bricks with 10% cement added to the mix) creates a good ground beam.
Building the wall

Adobe bricks are laid by course. Each course is laid the whole length of the wall, overlapping at the corners on a layer of adobe mortar. Adobe walls usually never rise above two stories because they are load bearing and have low structural strength.

Use a ‘Story pole’ (a piece of wood or metal driven into the ground to stake out the location of the wall) at each end of the proposed wall and use twine to keep the wall plumb and straight.

When laying bricks, smear some mortar on the underside in a slight mound running down the center of the brick. When you lay the next layer of bricks on top of this it will spread out evenly creating suction in the center and spreading to the sides of the bricks without mortar falling off the side when compressed with further courses. You then add a bit of mortar to the butt of the brick, you will be butting up against to lock them in sideways. (Again there is no right or wrong way to do this along as each brick has an even amount of mortar do what feels right for you.)

When laying the bricks use your thumb as a guide for spacing the bricks and leaving space for mortar.

Mortar

The same mixture used to make bricks, but without straw, is used for mortar and often for plaster on interior and exterior walls. Mortar can be layered on at approx 2cm-5cm (1” - 2”) thick.
Cutting bricks

Most of the bricks should have been cast at the right dimension but it is inevitable that some of the bricks will need to be cut to deal with ends and some junctions or openings. The most simple way of doing this is by scoring the top flat surface of the brick with a machete and then tapping it firmly. It should yield and fall in to two parts along your score line. Alternatively use a similar cutting tool to remove unwanted edges from the brick.

Once cut in two you can see how dry the bricks are. In the above example they remain quite damp internally. If building a load bearing structure you should consider leaving the bricks to cure for a bit longer. If building a perimeter wall or garden wall they should be fine.

A key thing is to make sure the bricks fit firmly together and overlap each other in each course. If you find that the bricks are starting to line up add a half brick and get back to nice generous overlaps.

Pointing

With fired bricks, a tool called a bucket handle is used to create smooth concave joints between each brick. As the name would suggest it is not a very technical tool and in adobe things are no different. A piece of plastic tubing is shown above but a spoon or bent metal will suffice (anything really that can be used to smooth the joints and prepare the wall for plastering.)
Apertures and Capping

When placing window and door openings, a lintel is placed on top of the opening to support the bricks above.

On top of the last courses of brick, bond beams made of reinforced concrete or heavy wood beams are laid. This provides a horizontal bearing plate for the roof beams and will redistribute lateral earthquake loads to shear walls that are more able to deal with the forces.

Plaster

Some ancient cultures used lime-based cement for the plaster to protect against rain damage. You can also use Tapioca to get a smooth even finish and it can be easier to access in some places than the lime based alternatives.

There are an assortment of tools available for plastering and they can range vastly in price. One of the great things about adobe is that the first few layers of plastering can be done entirely by hand, creating a sculptural quality to the whole process.
Plastering Cont.

Typically, plastering is done in three coats, a rough coat, a levelling coat and a finish coat.

Screen your materials with progressively finer screens as you go. The easiest way to do this is to break down larger clumps of clay and shovel against a screen.

The finish coat

Adding tapioca to the mix will act as a binding agent. Gluing the suspension together and making it easier to spread over the wall surfaces. See image of tapioca root above.

To make the finish coat follow instructions below:

Tapioca mix (binder)
- 1 part tapioca flour
- 1 part cold water
- 13 parts hot water

- Add tapioca flour to cold water in a bowl.
- Meanwhile bring a pot of boiling water to the boil & slowly add cold mixture. Water should go from transparent to translucent. Remove from heat and let it cool.

See tapioca plant above.
Plastering Cont.

Mix a dry mixture of finely screened sand and finely screened clay these should be at approx ratio 1:1. Set some of this aside for touch ups as if you combine it with the binder it will dry and cannot be used again. By setting some aside you can always add the binder for any touch ups.

Add the binder to the dry mix so it becomes workable and apply to the wall with a paint brush, hand or trowel which ever you think is best. You will get a different effect for each application method.
Lime Plastering - why use lime?

Lime is a good choice for creating a plaster. It creates a clean, durable and light surface which is resistant to both mold and the weather.

It is used when building with earthbricks or other natural materials as the lime creates a thin layer which attaches well to natural surfaces. Many historic buildings in Europe have been preserved for centuries using a lime plaster. Note however that every 4 or 5 years the plaster must receive a thin coat of lime-wash to maintain its strength.

Why lime is good to use with earthbricks?

- A lime plaster protects walls from rain, whilst at the same time allowing the walls to dry out. Whereas cement stuccos will retain and absorb water which can cause serious damage to earth walls in cool climates.

- There is limited/less cracking than with a cement stucco as the lime plaster shrinks and swells with heat in a similar way to earth.

- If damaged it is easy to repair with a new thin layer of plaster or limewash.

Materials

Lime plaster is not made with limestone. It is made from hydraulic builders lime (as shown in image above) or with quick lime, it is typically sold in sealed bags, labelled “type S” lime. Sometimes a proportion of lime is added to high quality cement, which is available at good masonry yards. For the exterior walls. If buy lime in countries where sealed bags are not available look for lumps of quick lime as air will not have got to all the lime. To test the lime submerge a lump in water for 6 seconds and remove. It should quickly start to break down (Wear gloves or use a spoon to do this as it will get VERY HOT.)
Making a lime putty:

- Always wear glasses, a long sleeved shirt and rubber gloves for mixing. (Pure lime can burn and irritate the skin so be careful!)

- Ensure to have a wet cloth and diluted vinegar nearby to remove spots

Tools needed:
- Wire whisk (as used in cooking)
- Trowel
- An electric drill (if possible with a paint mixing attachment)
- A bucket of water (ensure to keep tools wet until you can clean them.)

How to make lime putty:

You need: One 50 lb (23 kg) bag of hydraulic type S lime and 2 x 5 gallon buckets

- Fill the buckets 2/3 full of water. Open the sack of lime and separate the lime into two equal parts. (Don’t breathe in the powder!)
- Slowly add the lime into the two buckets. (Never pour water on top of this kind of powdered lime)
- Mix it together well
- Add a little more water if you need as needed to mix all the powder in smoothly.
- Scrape the sides of the bucket
- Continue to mix until there is no powder visible, and the putty is a very smooth and thick paste.
- Pour a little water on top of the putty and seal it with a lid

The putty will improve with time as long as it does not freeze!
How to make a lime plaster

Please remember that lime plaster can also burn/irritate your skin so ensure to use rubber gloves, and remove any patches of lime from your skin immediately.

One batch can easily be mixed in a wheelbarrow. Larger quantities can be made on a tarp placed in a hole.

What is in the mix?

**RATIO- 5:2:15**
Lime putty,
Short fibres,
Course sand

How to make it:

- First sift the sand to remove any small stones (If the sand contains salt or dirt be sure to wash it)
- Spread the sand and putty into thin layers and mix together well with a hoe or plastering tool
- Add a little water. (All the sand grains should now be covered in liquid putty.)

NB - The plaster should be more thick than runny. A little should barely hold onto a trowel when it is held vertical.
You can mix lime plaster ahead of time. Cover the mix and ensure to keep it humid under a tarp or in closed buckets.

Fibres give strength to plaster, but should be added at most 2 or 3 days before use. If the sand contains a little clay, prepare the plaster a few days ahead of time.
Adding fibre to the mix

There are several fibres which can be added to the mix to add strength to the plaster.

- Manure fresh and dry (best from horses or donkeys).
- Straw or animal hair chopped in 2 inch (5 cm) long pieces.
- Cattail heads look like a brown cigar. These grow in swamps.

Ensure to separate the fibres and mix them well into the plaster.

Additives:

Occasionally people add one quart (1 l) of boiled wheat paste to each 15 gallons of sand. However, your lime plaster should be sticky enough that you do not need to add any wheat paste. In South America the juice of cacti with flat leaves is added as this can help the lime plaster to be more resistant to the weather.

- Chop the leaves of Opuntia species (called prickly pear) and cover them with water for 2 weeks
- Add the juice to your plaster before the juice begins to ferment

In some regions, the hydrated lime available is not good quality and the plaster made will not harden within a day.

If this happens to your plaster you can use half Portland cement and half lime in this proportion- 1 part lime putty : 1 part powdered Portland cement : 6 parts sand. This mixed lime and Portland plaster will probably not work in thin layers on natural materials as well as pure lime plaster so it is preferred to find good hydrated lime to make the best plaster.
Preparing for Lime Plaster:

There are different ways to prepare for lime plastering depending on the wall surface you intend to place the plaster onto.

When adding to straw bales or Ubuntu blocks, you must soak the wall surface first with a thin clay slip. Ensuring to fill any holes or dips with an earthen plaster containing straw.

Add to smooth/scratch walls before they dry. If your mud blocks/CEBs do not have enough texture, you may have to attach some type of mesh before plastering.

When plastering on top of earthbags be sure to fill the spaces between the layers of earthbags with a sticky adobe plaster. If there is a high consistency of straw mixed in with the plaster it will crack less.

If plastering onto level walls of straw wattle or straw clay, you must use an earthen plaster containing a lot of straw.

Find out more about lime from: www.buildsimple.org

Slaking:

Slaking lime is literally the process of turning calcium oxide into calcium hydroxide in laymans terms it means storing lime under water this can be done a minimum of one week before using and as we have mentioned above the lime putty will get better the longer it is slaked.
Benefits of Lime Plasters

- Provides a breathable finish for wall systems
- Provides evenly distributed thermal mass, improving performance of your buildings insulation
- Naturally mold and mildew resistant
- Close to being carbon neutral (as opposed to cement-based stucco which is a high CO2 contributor)
- Can apply a pigment to create colourful plaster

Challenges with Lime Plasters

- Product cannot be bought off-the-shelf
- Not all hydrated lime is created equal; requires some knowledge to be sure you use the correct material
- Can be time consuming and physically demanding
- Not always easy to find skilled labour who are familiar with how to properly hydrate, mix, and apply lime plasters
- Must be handled carefully due to high alkalinity
Compressed Earth Bricks (CEBs)

Compressed Earth Blocks or Bricks (CEBs), are unfired bricks manufactured in a mechanical press that forms a compressed block out of an appropriate mix of fairly dry inorganic soil, non-expansive clay, aggregate, and possibly a small amount of cement.

The compression strength of a properly made CEB can meet or exceed that of a typical cement or adobe brick. Building standards have been defined for CEB.

Unstabilized compressed earth blocks should not be used lower than 10 cm off the finished floor grade. Stabilized compressed earth blocks, poured concrete, or waterproof masonry units and mortar may be used directly above floor grade.

If the blocks are stabilized with cement, fly ash, lime or rice husks, they can be used like bricks and assembled using standard masonry techniques or even in some cases dry stacked further, reducing total construction costs.

The soil mix

15-40 percent non-expansive clay, 25-40 percent silt powder, 40-70 percent sharp sand to small gravel

Modern compressing machines do not require aggregate to make a strong soil block for most applications.

In Cambodia, the Community Development Foundation mixes:

70-80 % of sand
20-30 % of local soil with 6-10 % of cement
Structure

In general CEBs should only be used for 1-2 story buildings. They may not be used for foundations or basement walls. All CEB walls should have a continuous footing (min. 25 cm thick). The footing width must be a minimum of thirty-three percent greater than the wall width. In case of a stem wall it should reach at least 20 cm above ground. Completed walls require either a reinforced bond beam or a 20 cm ring beam on top or between floors. Span of lateral supports should not exceed 7 m.

Finishes

Stabilized blocks create a brick wall that if properly stabilized can be left exposed with no outer plaster finish.

If the blocks are not stabilized they need a plaster finish, usually stucco wire/stucco cement and or lime plaster.

On the level

Always ensure to use a level especially when placing the first CEB and continue to check with each brick to ensure the bricks remain level and flat.
CEB Wall

Compressed earth brick walls are simple and easy to build. Bricks are placed on top of each other and watery mortar is poured inside.

The vertical steel rebars (D=10-12 mm, placed through every two bricks, should be caste into the ground-beam, thus their locations need to be defined very precisely when foundations are caste.

Principle drawing of a compressed earth brick wall.
Compressed Earth Brick Column

CEBs can be used to build columns, when they are forming a core for a concrete column caste inside.

Principle drawing of a compressed earth brick column.
Earth bags

This construction technique requires very basic construction materials: sturdy sacks that are filled with inorganic material usually available on site. Building is straightforward: bags are simply laid on layers.

Buildings with straight walls longer than 5 m in length need either intersecting walls or bracing buttresses or piers added.

Structure

The basic construction method usually begins by digging a trench down to undisturbed mineral subsoil. This trench can then be partially filled with cobble stones or gravel to create a rubble trench foundation.

In high seismic risk regions a reinforced concrete footing or grade beam is be recommended.

Above that, several rows of doubled woven bags (or tubes) are filled with gravel and placed into the trench and one or two courses above grade to form a water-resistant foundation.
Bag types

The most popular type of bag is made of solid-weave polypropylene, such as the type often used to transport rice or other grains. Polypropylene is chosen for its low cost and its resistance to water damage, rot, and insects.

Organic/natural materials such as hemp, burlap or other natural-fibre bags (like “gunny sacks”) can be used; however, since these may rot, they should only be used with fill containing a significant proportion of clay.

Bag fills

Generally inorganic material is used as filler, but some organic material (such as rice hulks) can be used if a strong matrix like wire mesh reinforces the plaster.

Filled with soil containing 5-50% clay, like reject fines, road base, or many subsoils, earthbags tamp into solid structural units but cannot withstand prolonged soaking. Subsoils with clay mold tightly and cure attached around the barbed wire barbs.

Layering up earthbags

Each earthbag should be carefully laid in to position, checking level continuously with each bag. You must ensure earthbag has been fully tampened down to ensure the bags remain tightly in positions.

Remember to always lay earthbag in the middle of two bags from previous level.
Reinforcement

To improve both friction between each row of bags and finished wall tensile strength, barbed wire is often placed between the courses. Twine is also sometimes wrapped around the bags to tie one course to the next, serving to hold the in-progress structure together and add strength.

Rebar can easily be hammered into walls to strengthen corners and opening edges and provide more resistance against overturning.

Further strength can be added with external pinning

Lay lengths of baling twine, nylon cord or poly cord between courses of earthbags as you build the wall. Leave approx. 30 cm of twine hanging on each side. Spacing of pins is roughly 50 cm. The pins are placed on opposite sides of the wall and tied tightly together. Rebar, saplings or bamboo pins can be used. Work in teams of two to install the pins. Tie one side, pull the twine tight and tie the other side. Use lots of force and the pins will be partially embedded in the wall.
Finishing

The structure is typically finished with plaster, stucco or adobe both to shed water and to prevent any degradation from solar radiation.

Start by levelling the biggest gaps in the structure with cement plaster.

Attach a chicken mesh on top with metal pins.

Add 1-3 layers of plaster depending on the required end result.

The finished result should be a smooth finish. Please remember to allow time for the plaster to dry.
Rammed earth

Rammed-earth buildings are found on every continent except Antarctica. Rammed-earth walls are simple to construct, non-combustible, thermally massive, strong, and durable.

Without machinery (powered tampers) they are labour-intensive to construct and they are susceptible to water damage if inadequately protected or maintained.

Building a rammed-earth wall involves compressing a damp mixture of earth that has suitable proportions of sand, gravel and clay (sometimes with an added stabilizer) into an externally supported frame or mould, creating either a solid wall of earth.

Historically, such additives as lime or animal blood were used to stabilize the material, whilst modern construction uses lime, cement or asphalt emulsions. Some modern builders also add coloured oxides or other items, such as bottles, tyres, or pieces of timber, to add variety to the structure.

Soil

The soils used are typically subsoils low in clay (between 5% and 15%), the topsoil being retained for agricultural use. Where soil excavated in preparing the building’s foundation can be used, the cost and energy consumption for transportation are minimal.

Compressed earth walls have a high thermal mass; like brick or concrete construction, they can absorb heat during the day and release it at night.
Structure

The compressive strength of rammed earth can be up to 4.3 MPa (620 psi). This is less than that of concrete, but more than strong enough for use in domestic buildings. Rammed earth using rebar, wood or bamboo reinforcement can prevent failure caused by earthquakes or heavy storms.

Construction

The construction of an entire wall begins with a temporary frame (form-work), usually made of wood or plywood, to act as a mould for the desired shape and dimensions of each wall section. The form must be sturdy and well braced, and the two opposing wall faces clamped together, to prevent bulging or deformation from the large compression forces involved.

Damp material is poured in to a depth of 10 to 25 cm (4 to 10 in) and then compacted to around 50% of its original height. The material is compressed iteratively, in batches, gradually building the wall up to the top of the frame.

Pictures:

Architects Rudanko + Kankkunen, rammed earth pavilion with integrated barley straw insulation, Ringa Mountain Farm, Tibet.