Footings & Foundations

Every building needs a foundation to connect it to the earth, to anchor it and to provide a stable platform over decades or centuries. The choice of foundation style and materials will obviously be very important to the successful life of the building. What kind of "boots" should we give our building?

Earthbags don't really need a conventional foundation; you can fill the first course or two with gravel to keep water from wicking upward. And you can dig the first course into the ground a few inches to make sure that it has a good "toe-hold".

If your soil drains poorly (i.e. if it seems likely that this rubble trench will fill with water during heavy rains) then a French drain arrangement, where a perforated pipe embedded at the bottom of the foundation can collect the water and run it off to some "daylight" location away from the building, might be a good idea.

In areas where there is a danger of frost upheaval, then it might be a good idea to dig a deeper rubble trench, and fill this with enough rubble or drain rock so that the first course of bags will be embedded several inches below grade level. A French Drain is also a good idea under these circumstances.

Concrete Slab

Rubble trench foundations are mainly needed where the soil doesn't drain well, or frost upheaval is a problem. If you were to build on solid rock, or on a concrete slab, further foundations are probably unnecessary. The first course or two should be filled with gravel to prevent water wicking up into the wall.

When building an earthbag wall onto a concrete slab, you can sink rebar pins into the concrete and lay the earthbags on top to keep them in place. Rubble filled earthbags can also be used to build a stem wall for a straw bale (or other) wall.

Rubble Trench Foundation

1. Level the Site

First you want to select a building site that is well-drained, where water will not tend to collect. Then you can mark the perimeter to be leveled. Using a shovel and a level, clear the area of debris and get the area more or less level.

2. Dig the Perimeter Trench

In areas where heavier soils might not drain well, it is important to create a rubble trench. This helps keep moisture from wicking up into the bag wall, as well as keeping the wall from "heaving" if the ground freezes. Mark the interior perimeter of the wall and also the exterior perimeter (this depends on how wide your bags are.) Also mark where the entrance will be located, allowing enough space for a door and frame.

The trench should be approx. 25 – 35cm deep.

3. Fill the Trench with Cobbles

Gather, or have delivered, the rubble to fill the trench with. This can be small stones, gravel, or "urbanite" (broken up concrete debris). It is best to place a layer of large (10cm) rocks at the bottom of the trench and then layers of progressively smaller gravel. This aids drainage, and tamping these layers acts to wedge progressively smaller stones between larger stones, thus stabilizing and distributing the load in a horizontal as well as vertical plane. It is best to avoid rough or jagged gravel for the top layer(s) to avoid tearing the bags in the first course.

The trench may be lined with a wire mesh, especially if the local soil is a loose sand or similar that would easily cave in and fill the voids of the rubble. The wire mesh is not necessary with most soils.

How high to fill the trench depends on whether you want to recess the first row (or rows) of bags into the trench. In situations where flooding or earthquakes might occur, it may be advantageous to recess the bags into the ground, so that even if the soil surrounding the building is undermined, the building itself would likely not be affected. In other situations it is fine to lay the first row of bags at ground level.

Basements

Earthbags are suitable for basements and other underground applications such as cisterns and root cellars. Round or curved designs are inherently stronger than long, straight walls, which require reinforcing columns or buttresses.

- General guidelines for earthbag basements:
- 60cm wide poly bags (measured when empty)
- lime stabilized soil tamped solid
- 10%-20% type-S lime hydrate to dry soil by volume
- mix lime and soil thoroughly before adding water
- two strands 4-point barbed wire
- rubble trench foundation with French drain
- taper walls slightly outward
- use 6 mil polyethylene as a moisture barrier
- Build on high ground, and grade the site away from the building.

Dry climates are obviously more suitable than wet climates. Use caution -- working below grade is dangerous. Temporary shoring may be required. Avoid clay soils, as they can be highly problematic. The final design should be based on soil tests and calculations by a licensed engineer.

Regarding the tapering of the walls, concerns have been raised. Basement walls are also foundations, so they have to be able to bear a tremendous weight. Well compacted earthbags are capable of doing this, but if they are not vertical, then some portion of the force of the vertical load will be borne by the surrounding soil. This could be problematic because the backfill is rarely compacted, but instead is just tossed into place, so it cannot be expected to be as firm at the bag wall itself.

The slope (tapering) of the walls should be small enough to offset these concerns. The relevant force vectors are straight down (representing the weight of the house) and horizontal forces from the surrounding earth. The slope of the walls should be small enough to enable the downward forces to be accounted for, but great enough to account for the horizontal forces.

Bags and Filling

What Kind of Bag to Use?

Standard (22.5 Kg) woven polypropylene rice bags (or similar) are recommended. If you are going to fill the bags with loose material, it is pretty much imperative to use the poly bags, because they are stronger and will not deteriorate once they are plastered. If you intend to fill the bags with an adobe or stabilized material, then burlap or other natural materials for the bags may work, because once the wall has set up, the strength of the bag is not so important.

Polypropylene bags come in gusseted and non-gusseted styles. Both are appropriate for earthbag building; the gusseted ones are slightly better because the base of the bag doesn't produce pointed protrusions that need to be hammered back into the wall to make it smoother before applying a plaster.

The 22.5 Kg size of bag is about right for most applications; the wall will be about 38 cm thick when plastered. If you have larger bags, they might be used at the base, and if you have smaller bags, they might work near the top of a dome. It is also possible to use poly tubing that can be purchased in great rolls, but the individual bags have a few advantages:

1) the bags are cheaper
2) one person can do the work
3) each bag is quite light...about 16 kg when filled with scoria, and
4) with the seam at the base of the bag, it tends to stay where it is put, whereas the tubing has a tendency to roll, especially when filled with loose material.

Fill Material

The bags can be filled with whatever material you decide to use for this. Volcanic rock (scoria) is a good option if it is available locally, because it is lightweight and highly insulating.

You might be able to use the local soil from your site, especially if you live in an area where the climate is fairly moderate, or if you don't intend to inhabit the structure. At least one successful earthbag building has been made using bags filled with a mix of white beachsand and crushed coral.

Note, however, that soil (or sand) alone doesn't provide insulation. Soil is generally a very good thermal mass material and very poor at insulating, except that, because earthbag walls are usually quite thick they do provide some insulation from the outside temperature. The problem is that once the bagged material gets warm or cold it likes to stay that way for a long time, which can mean uncomfortable temperatures inside. In climates with extremes of temperature (either hot or cold) it is best to fill the bags with an insulating material. Possible insulating materials include scoria, rice hulls or perlite.

The mix should not contain more than 30% heavy clay soil to 70% sandier soil. If you use higher percentages of heavy clay, the real danger is that it might expand if it gets wet, or contract if it gets dry, so the challenge would be to keep it from taking on water. You wouldn't want to fill the bags with damp clay, since it would shrink as it dries, or it could provide moisture problems if it is left damp.

With earthbags, the exact proportion of clay to sand is not nearly as important as it would be with adobe or rammed earth construction. Anywhere from 5 to 35% clay should work fine; ideal might be 15 to 25%. You can figure out the relative % of your natural soil by doing a jar test. Fill a clear glass jar about 1/3 full of the soil, then add water to nearly the top and shake the whole mixture vigorously. Then let it stand for a day to settle out. Eventually the solids will settle to the bottom and the water will be fairly clear on top, with perhaps any organic material floating on that. On the very bottom will be the heavier aggregate, then above that the courser sand and then finer sand, and finally on the very top will usually be a clearly marked line of clay. Then you can compare the amount of each layer to determine the composition of your soil. You want the soil just moist enough so that it will compact and stay in a ball if you squeeze some in your hand.

Soil stabilization is rarely needed in earthbag construction. Under some circumstances it might be advised in parts of lintels or arches to make them more rigid, or if the fill material is too loose, such as with very fine sand, that doesn't want to compact into a solid.

Filling the Bags

Use large buckets to measure the fill material. Use the same number of buckets for each bag. This technique ensures a.) each bag is filled to capacity to save bags, and b.) each bag is the same size, which helps keep walls level. Bag stands are not needed.

During the filling process, the bag is held open with a large steel funnel (part of a chicken feeder) or similar. Leave about 20-25 cm of space at the top of the bag to allow this to be folded over when the bag is placed on the wall to seal the contents in. Double bagging (one bag placed inside another) can be used on the first course to help protect the bags from rupture on any sharp rocks.

Sew or Stitch the Bags Closed

Fold the bag end over; use 15 gauge wire about 23 cm long with one end cut at a sharp angle; make one stitch on one side and bend the end over; make a stitch in the center and pull the corner over; make a stitch in the other corner and pull the corner over; poke the remaining wire into the earthbag. This technique facilitates handling, prevents spills and enables bags to be filled to capacity.

Laying the Bags

Using the trench as guide, place the first row of bags down over the rubble in a neat row. It is important to carefully place each bag so that the folded-over flap at the top lays snugly against the bottom of the previously laid bag, so that each bag gets completely sealed.

The first several courses will be placed pretty much vertically, above each other. The bags should overlap in a brick-like pattern (running bond) as the wall goes up. This makes for stronger bonding of the wall. Also, note that before each bag is placed, a piece of polypropylene twine (about 1.5m long) can be put below it to eventually tie around two courses above the bag.

Lower courses: place gravel-filled bags (double bagged) working from the corners and openings to the center. It helps to tilt the first two bags against each other. Align bags to stringline; tamp the bags solid and level after the course is complete, working from the centre of the bags outward. Always put tops of bags (the ends you've sewn closed) butted against other bags (never facing outward on corners or ends). Maintain a running bond as in masonry.

Repeat the process using earth-filled bags, but with a few minor changes: turn bags inside out to avoid protruding corners; use lightly moistened soil; tamp the contents slightly after each bucket load is added; pre-tamp each bag after it is aligned in position. This last step lengthens each bag to ensure good overlap.

Make custom-sized bags to fill odd-sized spaces: measure the opening; fill the bag to the approximate level; cut off excess bag material; fold each side of the end toward the center and tuck under the bag; place the bag in the wall.

Tamping

Tamp earthbags solid and level after each course is complete. Tamp the high points first. Then evenly tamp the entire wall several times as you continually move the tamper. This last step avoids creating low spots.

A variety of methods and tools can be used for doing this, from simply stomping on the bags to using homemade tampers. A heavy tamper means that even though it takes work to lift it, you don't have to put as much muscle into the down-stroke. If the base of the tamper is about as wide as the bag is, one tamp will cover the entire width of the bag.

There's no need to tamp the bags excessively, just tamp until they're solid. One minute per bag should be plenty, maybe go two minutes if you're slow and tired. There's a change in tone when they become solidly compacted.

Barbed Wire

Add barbed wire: use two strands of 4-point barbed wire in-between each course of bags. The wire should be spaced about 10 cm in from each side of the bags. It can be temporarily weighted into place with bricks or stones until covered with the next course of bags.

The barbed wire has two functions: 1) it helps lock the bags together and 2) it helps resist any tendency for the wall to expand outward with the weight from above. This wire should be placed between every course as the wall goes up.



Use a sheetmetal slider to place additional courses so bags do not snag on the barbed wire: fill the bags on the slider; sew the end closed; tilt the bag into position and push it against the previous bag; after the bag is aligned, hold the end of the bag (it helps to lift it slightly) and jerk the slider out. Continue with gravel-filled bags until you are safely above grade to avoid risk of moisture damage.

Doors & Windows

There are various ways to introduce windows for lighting and doors into earthbag domes.

Basically any circular or arched shape can usually be accommodated, including a triangle with one of the corners pointing upward. Arches, circles, and pyramid shaped triangular openings are inherently more stable than rectangles, and more likely to last over time. However, if you can calculate that whatever lintel you use can support the weight of whatever is above it, this will work for rectangular openings.

As long as the windows and doors are well-constructed and integrated into the structure, there is no limit as to how many you have.



Door Frame Anchor

This is one method of anchoring the door frame to the bag wall, by placing a piece of threaded rod between the bags, with chunk of wood fastened with a washer and nut at one end of it. Then the door frame can be attached to the other end and tightened against the column. Other approaches to this are to simply drive a longer piece of threaded rod all the way through the column and fastening it in a similar way, or to put a piece of plywood with lots of nails poking through it and a heftier chunk of wood attached so that this offers something to anchor the frame to later.

Lintels and Shelves

Shelves can be placed in the same way as window and door lintels, between courses of earthbags, but projecting into the interior of the building.

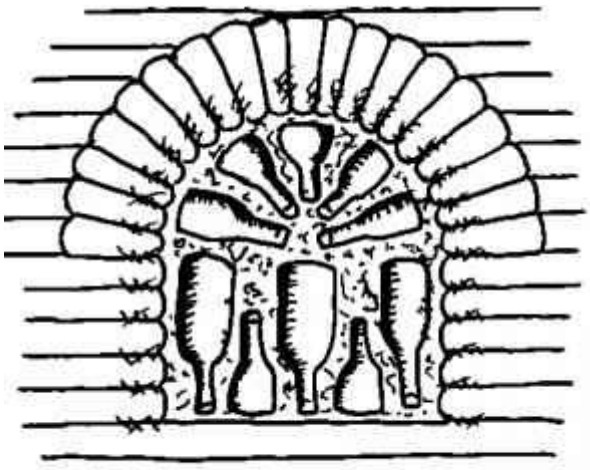
Similarly, alcoves can be created by placing containers or spacers and building the wall around them.

It is important to ensure that the spacer, container, or lintel used will be able to support the weight of the wall above it.

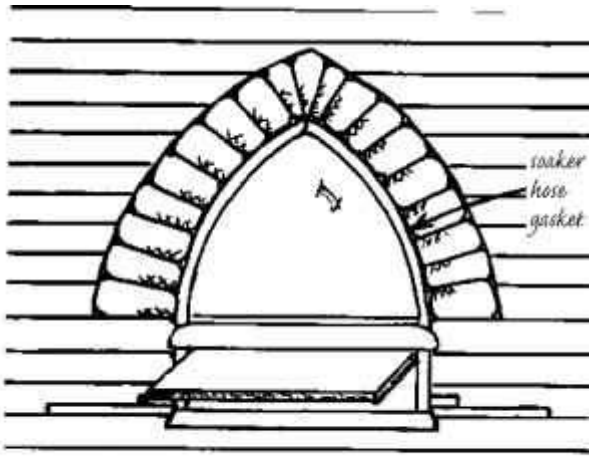
Arch Forms

Arch forms are used to support the earthbags during the construction of arched openings. Once the walls are completed, the arch forms can be removed. The arches are self supporting once the ‘keystone’ is in place.

Arched openings can later be filled in to provide surrounds to regular rectangular doors and windows. Bottle walls, window or stained glass sections, or simple masonry or adobe (straw-clay) fill can be used.



8.11: *Glass bottles, mortared in with adobe, provide insulation while giving ambient light.*



8.10a and b: *Two examples of arched, fixed glass with wooden doors or awning set below for ventilation.*

Roof

Ropes or heavy duty twine can be used in the wall to tie courses together, three courses at a time to ensure overlap. Similar ropes can be used to tie down roof joists when the roof is put in place. Note that a nail through the ropes holds tighter than tying.

Rendering

Earthbag structures can be rendered with basically any render mix, including earthen renders, papercrete, hempcrete, lime render, cement stucco, etc. A cement stucco or cement stabilised lime or earthen render is better for domes and other structures with minimal or no protection from rain, and for structures in humid climates.