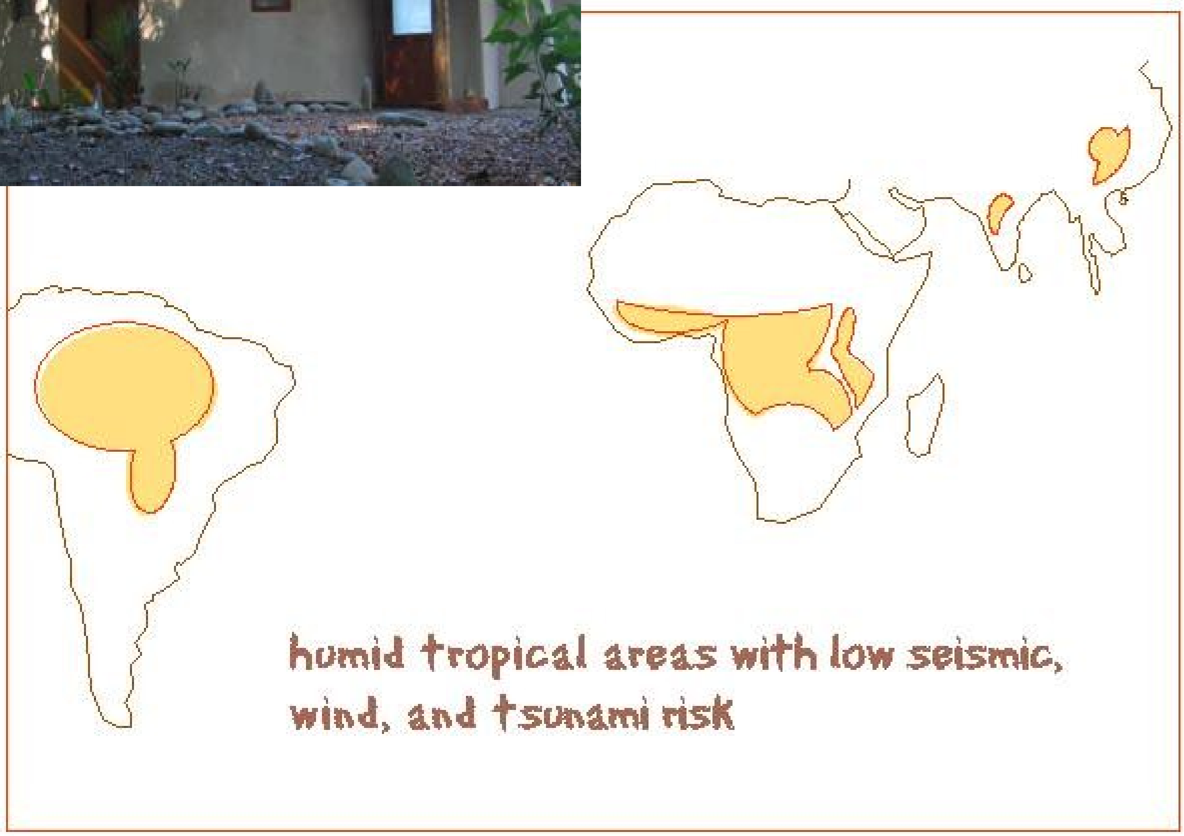
# *Earthbag Building in the Humid Tropics:*

## Simple Structures

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Online version available at www.earthbagbuilding.com.

Please share these free self-help guidelines and let us know how to improve them.

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In many parts of the world buildings must be extra strong for earthquakes or hurricanes and tsunamis. Other publications can help you plan for this.[1]

West Africa, northeastern South America and some parts of China and India do not have many earthquakes. If you live far enough inland where cyclones are not strong and tsunamis can't reach, these guidelines can help you try a new way of building simple structures with earth. Your buildings must resist termites and mold as well as be right for the climate, and for how people live.

Ideas for locating and shaping your building to be comfortable are in Shaping Buildings for the Humid Tropics, and examples of simple buildings are in Simple Earth Buildings for the Humid Tropics, both at www.earthbagbuilding.com.

## ABOUT EARTHBAG

Flexible form rammed earth, usually called earthbag, goes up quickly and is very easy to learn. Used bags from plaster, grains, or cement are available around the world. Unlike other earth techniques, a wide range of soil types can be used to build with bags. Because the empty bags are very light, they can be used for building in remote areas.

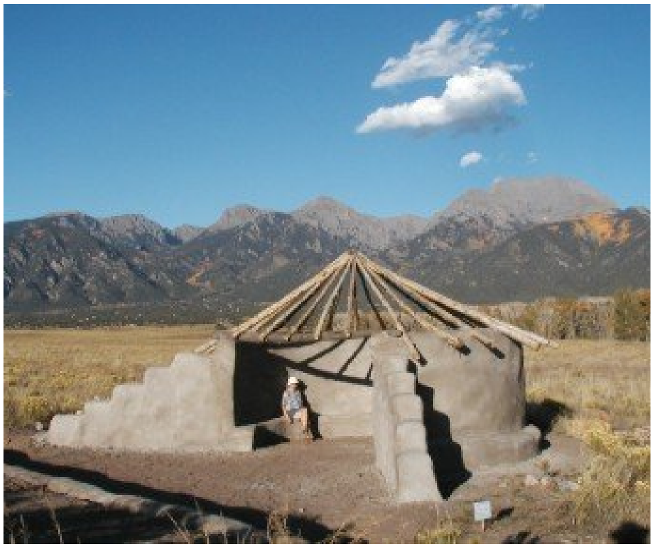
Left: Earthbag construction for a US National Park.

The UN has used this technique for refugee housing. Three ordinary people take about an hour to lay 12 square feet of wall. Preparing soil, filling, placing, and tamping bags do not require special strength or skills. Earthbags don't use any scarce resources.

Earthbags can be shaped into traditional walls that resemble standard masonry. Careful work can create beautiful structures with minimal costs. Walls are tamped with hand tools, and when dry become as strong as well-built cob walls or adobe walls. Standard earthbag walls combine the thermal properties of fired and stabilized masonry, with excellent performance in humidity, and good resistance to bullets. Highly insulated walls can be made with naturally occurring

Above: An earthbag home for an artist in South Africa.

1 Minke, Gernot (2001). *Construction Manual for Earthquake Resistant Houses Built of Earth.* Eschborn, Germany: GATE-BASIN at www.basin.info/publications/books/manualminke.pdf; Geiger, Owen (2008). *Post-Tsunami Affordable Housing Project.* Available at www.earthbagbuilding.com/articles.htm



Above: Graceful earthbag shelter in Colorado, US.

lightweight fills. Bags are covered with plaster to make a permanent wall.

Recent testing in an engineering laboratory at Queens University in Canada found that unplastered polypropylene earthbags of dry gravel or wetted and tamped sandy soil resisted almost ten times as much compressive force as conventional wood stud framing, per wall length. [2] The equipment was not strong enough to cause the earth-filled bag stack to fail, although they compressed somewhat under these extreme loads.

The properties that allow curving brick walls to be built of a single width of brick without reinforcing make flexible form rammed earth walls strong. Instead of curving walls, small interlocked piers spaced 4 m apart along a wall can give it side to side stability.[3] Openings can also be stiffened by adjacent piers, much like standard cob construction styles in many parts of Africa.

Below: Round room in a Thai earth block building.

Curving walls are common in traditional buildings. In many parts of Africa the roundhouse is a standard shape where concrete block has not replaced it with rectangular forms. Round building walls use less material and labor for the same interior space. And rounded rooms are always perceived as being larger than the same size rectangular room.[4] Perhaps it is more important to decide what shapes feel right to the people who will use them.

Further testing will refine earthbag uses for multi-story building or complex forms. But earthbag structures in many places are performing well- including South Africa, Uganda,

2 Daigle, Bryan C. (2008). *Earthbag Housing*. Ontario,Canada: Queen's University, p. 119
3 Hunter, Kaki and Kiffmeyer, Donald (2004). *Earthbag Building*. Gabriola Island, BC, Canada: New Society, p. 38
4 Smith, Michael. 'Cob' in Elizabeth, Lynne and Adams, Cassandra (2005). *Alternative Construction.* NY: Wiley, p. 123

India, Pakistan, Mongolia, Siberia, Thailand, Philippines, Brazil, Chile, Costa Rica, Mexico, Canada, and the US.

Below: Earthbag construction in the Philippines.

It is easy to prepare soil for earthbag walls by digging to loosen it, raking large stones out, and breaking up big clods. Topsoil, leaf mold, or many roots or sticks should not be used in the fill mixture. 10- 30% clay keeps the wall together once it has dried, but less clay may still be workable, depending on type. Fill material is tested by making bagfuls, tamping it, and drying for a week or two. If shrinkage or cracking occurs, the soil may need sand added. Testing the soil for how it performs is more important than finding out the proportion of clay.

Earthbags can be filled with a variety of earth materials. Most soils solidify when placed and tamped. For humid climates, fills that set solid will ensure continuing strength under simple clay finishes, even if cotton or jute bags are used that eventually decay.

Loose fill materials rely on bags for strength. Oil soaked sandbags used to make trenches during World War 1 are still standing almost 100 years later.[5] Plastic feed bags have not yet been tested in earth walls for longevity, but are known to need ultraviolet light to break them down because "polymers such as polypropylene and polyethylene resist biodegradation [by microbes] totally."[6]

Fabrics are now being used in many ways for their tensile strength. Bio-technical erosion controls are now used by engineers to repair hillsides, streambanks, and stabilize steep slopes newly cut into earth. These are often stronger and provide more permanent solutions than the rigid structures that were built in the past. This same technology works in buildings.

Earthbags can easily form arches without concrete over openings up to 1.2 m wide. The openings should be spaced at least 1 m from corners or other openings. Formwork can be removed after several courses have been placed above the arch.

One of the few limits on earthbag use is that it is difficult to add openings in an existing wall. A little extra forethought is helpful. An extra arch can be easily formed in a new wall where a door or window might be wanted in future. If filled with separate earthbags that are not woven into the running bond pattern, these can be easily removed for a new opening.

5 Kennedy, Joseph F. and Wojciechowska, Paulina. 'Earthbag' in Elizabeth (2005) p. 177

6 Woodings, Calvin (undated). 'New Developments in Biodegradable Nonwovens'. *New Fibers.* Retrieved 10-24-2008 from www.technica.net/NF/NF3/biodegradable.htm

Larger spans can also be created with cement stabilized earthbags. Cal-Earth's Hesperia test dome covered in cement plaster passed ICBO testing in California, a place with the strictest building codes in the world. The dome was not damaged by the heavy machinery placed on top to collapse it. Kelly Hart also recorded the strength of a dome covered with a paper and cement mixture that was very difficult to dismantle.[7]

In earthbag structures of wire-mesh reinforced cement plaster the tensile strength of the mesh, bags, and barbed wire and the compressive strength of earth work together well to produce buildings much stronger than required by building codes for earthquake hazard areas.

Left: A pointed arch in a Mexican earthbag building.

## Stabilizing Earth

How permanent is earth? Exterior walls of mud block or cob protected by overhangs and dry base courses with exterior-type clay finishes have lasted for hundreds of years. A majority of the buildings in many parts of Europe are actually made of raw earth, many of them 200- 500 years old. Many large historic structures of earth still stand, including pyramids in Mexico and China's Great Wall.

Depending on where you live, some objections to the use of raw earth may need to be answered. Finding other new buildings in the region made of earth would be helpful, but there are also many examples of attractive projects on the internet.[8] Older earth buildings that have not been mistreated can be visited.

Earth walls are not flammable, and insects or rodents cannot live in them if they are solid.[9] Tamped earthen walls are not easy for thieves to break through, and they are relatively cool and mold-free.[10] In addition, raw earth purifies the air by removing pollutants.

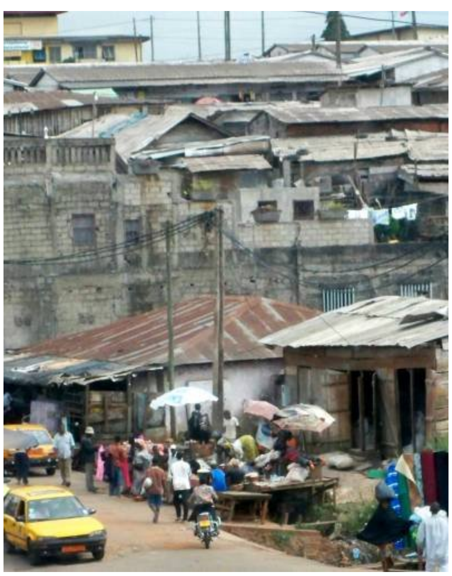
Simply because this generation thinks of concrete as safe and strong, it routinely adds cement or other expensive stabilizers to earth buildings that do not require it.[11] Ordinary

7 Both tests are available at www.earthbagbuilding.com/tests.htm
8 Examples are available at many earthbag sites, including www.earthbagbuilding.com/projects.htm
9 Minke, Gernot (2006). *Earth Building*. Basel, Germany: Birkhauser, p. 18
10 For a full discussion of R-values and performance: Stouter, Patti (2008). Shaping Buildings for the Humid Tropics. Available at www.earthbagbuilding.com/articles.htm
11 Houben, Hugo and Guillaud, Hubert (1994), transl. A. Gompers, J. Schilderman. *Earth Construction*. Intermediate Technology Publications, pp. 74

small houses can easily be built strong enough without cement or bitumen. Tests have shown that a careful balancing of the range of particle sizes in a soil may improve strength more than added cement. Some soils become weaker with the addition of certain proportions of portland cement. Some clay soils can be stabilized with lime alone, others with lime and a much smaller amount of cement.[12]

Right: Utah insisted on unnecessary concrete and wood posts for the first code- approved earthbag building in the state.

Rammed earth walls do not require chemical stabilizers. Because of their mechanical tamping they do not erode in rainfall. Earthbags are also called flexible form rammed earth because they share some properties of rammed earth. Soil masses become stronger with better mixing or kneading or under repeated tamping that causes vibration as happens in earthbag and rammed earth construction. CEBs have been considered stronger and more water-resistant because they are compressed. But the particles of CEBs are not able to align for strength in the press as well as they can under the vibration of repeated blows in damp earthbags or damp rammed earth construction.[13] CEBs have also been known to 'blossom' or expand when they absorb enough moisture.



Julius Nyerere of Tanzania calls cement 'European soil'. The widespread addiction to it is 'a kind of mental paralysis'. This material has surely increased the numbers of those without shelter by preventing earth building technology from being transmitted and improved. In Europe or America a worker can buy ten bags of cement with one day's wages. In rural Africa ten days' work is needed to buy a single bag. To raise the cash someone must leave the village to earn a wage...' [14] We have shown the world what we want, and they have forgotten how to build with what is nearby and beautiful.

Left: Concrete buildings in Yaounde, Cameroon.

12 Minke (2006), p. 45
13 Minke (2006), pp. 44- 45
14 Bourgeois, Jean-Louis. 'Speaking the Vernacular: Mud versus Money in Africa, Asia, and the US Southwest' in Kennedy, Joseph F., ed. (2004). *Building Without Borders.* Gabriola Island, BC, Canada: New Society, p. 39

Wise builders can begin to reverse this trend. Earthen materials have passed stringent tests during the past 30 years. They are better suited for construction than concrete in many ways. If we restore the reputation of earth and demonstrate how desirable it is, those who cannot pay for buildings will again be able to build for themselves.

Earthbag walls seldom need additives to give extra stability. If openings must be grouped very close together, stabilized earthbags can be used in that location. Lime alone, or lime and cement, or bitumen should be chosen after testing the soil. But for most buildings no stabilization is needed, and arches can be made of the standard soil mix.

Another material used to make earthbag walls more stable is barbed wire. Barbed wire, placed between courses of bags, adds tensile strength by preventing horizontal shearing between layers. Since polypropylene bags do not decay easily and barbed wire is galvanized for outdoor use, both materials should last. The steady naturally-limited humidity levels of protected solid earth walls have preserved wood as well as metal elements like ordinary nails over a hundred years.[15]

Left: Laying bags in Haiti.

Some builders may not want to use barbed wire in order to save labor and money. Others may be unsure about using new combinations of materials that have not already shown their permanence in the difficult environment of the humid tropics. Vertical earthbag walls do not need barbed wire as a structural element.[16] Simple earth is good enough; buildings of mud block and cob have stood for years without cement or wire. Their shape and dimensions rely on the compressive strength of earth. Ordinary sandbags stacked 3' high in long straight walls withstand the great horizontal pressures of floods without slipping between layers.[17] When barbed wire has not been available earthbag buildings have been built without it by dimpling layers to key them to each other.

Right: Wooden window jambs in earthbag walls.

15 Minke (2006), pp. 14- 15
16 Gernot Minke, email to the author, 10- 20-2008
17 Retrieved 10-24-2008 from Sand Bag Express Web site at sandbagexpress.com/filling

Barbed wire can be useful during the construction process until the wall is fully cured. It helps to reduce the chance that bags may shift. After the wall is cured and tied together with a bond beam the presence of the barbed wire is less important.

Earthbag domes are not recommended for simple buildings in humid regions. They would need porches added to shade walls and remove rainfall from the building's base as well as barbed wire for stability. The roof would need expensive waterproofing to prevent leaks that more easily cause structural problems in a roof than in a wall.

One way to introduce a new construction technique is to use it for a small structure, like a guard booth in a privacy wall or a materials storage area for the work site. If a small structure is finished attractively, and experienced first hand, it will be easier to see if earthbag is the right material for the larger buildings.

Left: Earthbag performance building for Next Aid in South Africa

## Exterior Earth Finishes

Exterior earth walls can be protected from erosion by rain with specialized clay coatings. Additives include various animal products, ash, and the milky saps of certain plants. Lime putty covered many of Europe's older earth buildings, but is an exacting process. If available to purchase locally it can work well. Oil mixtures are also often used successfully. Each soil reacts differently to additives. It may be wise to ask about old building techniques, and to find what additives are available for free or at low cost.

Right: Applying earth plaster.

Tile or natural stones inlaid on earth plaster can be used to protect exterior earthen walls in heavy rainfall areas. Only the lowest part of an exterior wall covered by a good roof overhang is frequently rained on, so lower wall portions can receive special tile or stone treatment while upper portions are simply plastered with water-repellent clay.

Cement stucco is not good for earth buildings. The concrete absorbs water, but dries out very slowly. Raw earth construction absorbs water more quickly, but also dries more quickly. A concrete covering prevents the earth from drying out, and wicks water to the earth structure, keeping it soggy[18]. Although concrete plaster is tempting, Spanish mission buildings in the US southwest have been damaged by cement coatings. "Moisture built up behind the walls and the adobe literally melted away leaving a shell of cement. The building looked fine from the outside, but actually dissolved away. It was a huge disaster that's still being dealt with."[19]

For interior finishes, earthen plasters are becoming desirable among those seeking chemical-free housing and natural beauty. Often linseed oil finishes are used for the lower 1-1.3 m of walls that will be wiped more frequently to clean them.

For areas with water use like kitchens and bathrooms, glazed tiles can be inlaid with earthen mortar on earth walls. Concrete grout can be used if necessary, because it results in only a small proportion of cement materials in contact with the wall surface.

Left: This kitchen is finished with colorful earthen plasters.

An intermediate step for those unsure about earthen finishes, may be to try light earth in earthbags stabilized by cement or bitumen. Light earth is a mixture of soil and a lighter weight aggregate like naturally occuring volcanic scoria or pumice. Up to equal amounts of soil and aggregate can be used. If this mixture is stabilized with cement, lime, or bitumen, it will be slightly more expensive, but can receive concrete stucco. It is less breathable and more sweaty than true light earth. But even stabilized light earth is much better insulated than concrete block, will receive less condensation, and is quick and cheap to build.

Right: A finished building in Haiti with detailing and a mural.

18 Hunter and Kiffmeyer (2004), p. 59

19 Owen Geiger, email to the author 10-23-2008

The cost and time to repaint every few years with mold resistant paint should be considered. Where low cost is important, time-tested earthen plaster is more than adequate.

## STEP BY STEP: Suggestions for Building with Earthbag in Humid Areas

General principles:

- Use as much lightweight gravel as you can afford for cooler, less sweaty buildings.
- Use as little wood or metal as possible, to avoid rot and termites.
- Use plan layouts that are stable, with curves or frequent piers or buttresses (see below).
- Make sure rainwater flows away from the bases of all walls. Place the building on a rise, or dig a swale around it. Slope earth down at least 2cm per meter for 4- 6m.
- Use a vapor barrier below the floor and between any concrete and earth.
- Provide a waterproof base course at least 60 cm high.
- Criss-cross bag courses at piers and corners.
- Provide wide roof overhangs (1.5 m is good).
- Test exterior finishes for performance.

Right: Although heavy equipment isn't necessary, this backhoe made filling the upper levels easier.

## SOIL TESTS:

Ball test: Wet soil just enough to hold together. Form into 4 cm balls. Drop them from 1.5 m height onto a hard surface. If they flatten only slightly the soil has too much clay and needs sand added. If the balls develop cracks, the soil is good for earthbag. If the balls break into 4 or 5 pieces they can be used for adobes or rammed earth or earthbag. If the balls shatter, the soil does not have enough clay.[20]

20 Hunter and Kiffmeyer (2004), p. 23

Bag test: Break up clods, remove larger stones, and mix just enough water that the mix starts to ooze through the fabric when the bag is tamped. Fill the bag until it holds its shape if dropped. (For light earth mix soil 1:1 or as planned with pumice or scoria). Fill several bags, tack closed with nails, or sew closed with wire or strong twine. Try some with additives mixed in. Tamp them, leave in the shade to dry for one to two weeks. When really dry, check for cracks and shrinkage. Check for strength. It should hold a nail without splitting.

Left: Buttresses on a house in Costa Rica.

## MATERIALS:

50# or 100# size polypropylene bags that don't have a slippery "non-skid coat", or flat-weave tubes.[21]

Soil and clayey soil for plastering, regular gravel and sand.

New polypropylene or nylon cord.

Diamond expanded metal lath for nailers.

Galvanized wire or nails.

3/4" maximum size light gravel.

Insulation under floor: pumice, scoria, or glass bottles.

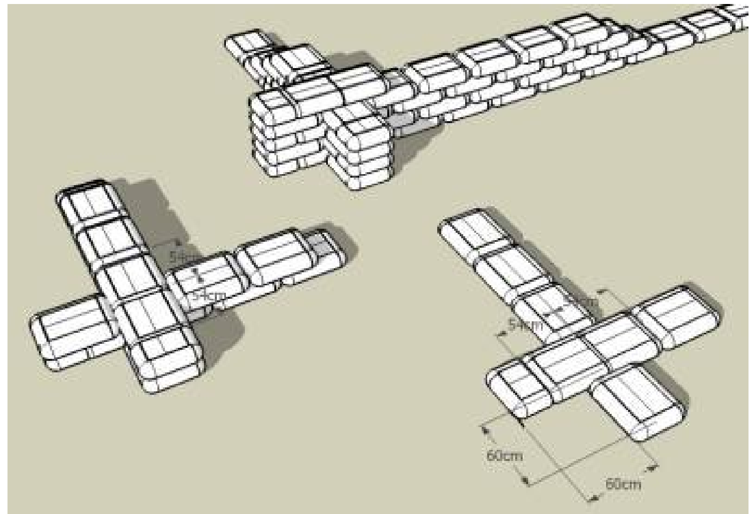
Good quality vapor barrier for under floor and lower portion of wall.

Small amount of concrete for exterior plaster of base courses.

21 Ibid., pp. 22- 23

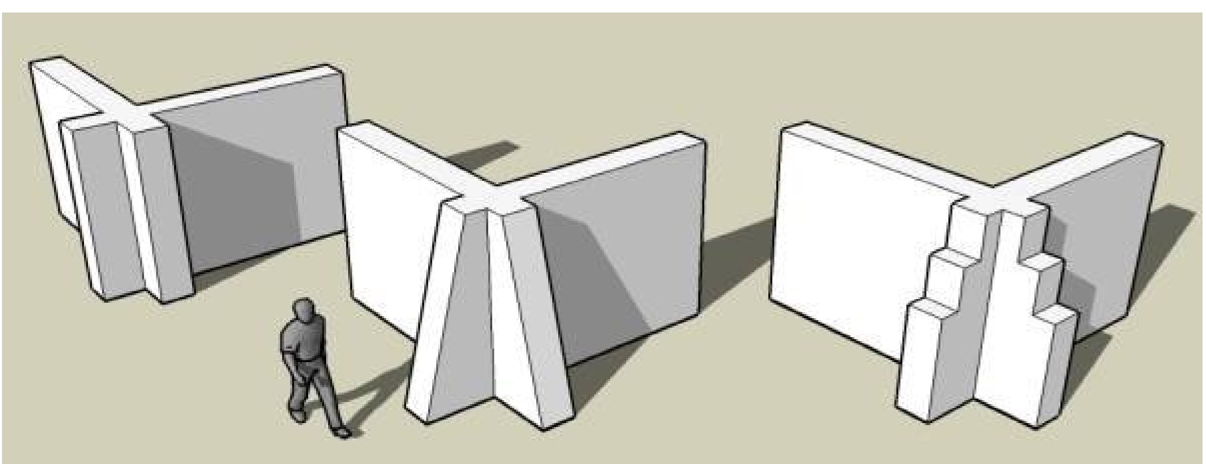
## LAYOUTS for non-hazardous areas:

Buildings should be built in ways that will fit with what you think is attractive and convenient. These guidelines are to give you a choice of how to make earthbag walls strong without using steel or wood reinforcing. These design details are based on conventional mud block construction techniques. They are not appropriate for areas that are subject to hurricanes or tsunamis, or that are within earthquake hazard zones.

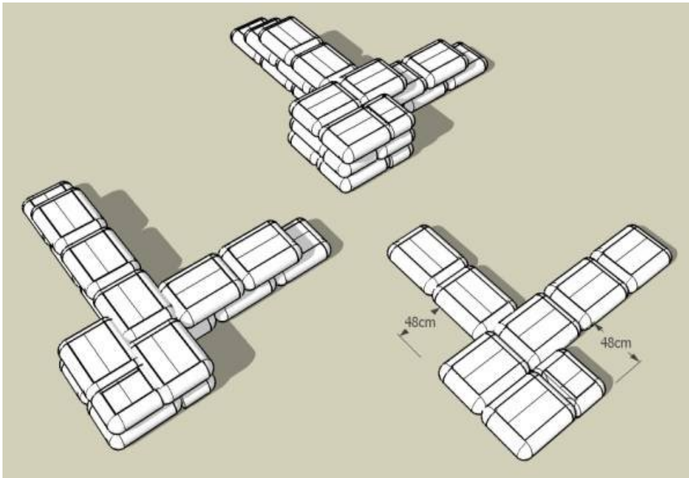



Right: Always start at the buttress end so the bags crisscross correctly.

- **Square outside corners:** Buildings that do not use any steel reinforcement should have a support buttress on one or both of the outside walls at square corners. If steel is available, a single rebar pounded down through the corner is enough without adding a buttress. Buttresses do make it easier to add to the building in the future. For a buttress, the bags must alternate every course to fasten it into the wall very well. They must also be tied together firmly every 3 layers with strong cord that will not rot. If the buttress is straight up and down, it should stick out from the wall at least 60 cm (or 2'). The buttress could start out a little wider, and step back as it goes up, or it could slope gently into the wall.



Above: Because buttresses need to be strongest near the ground they can slope or step inward as they go up.

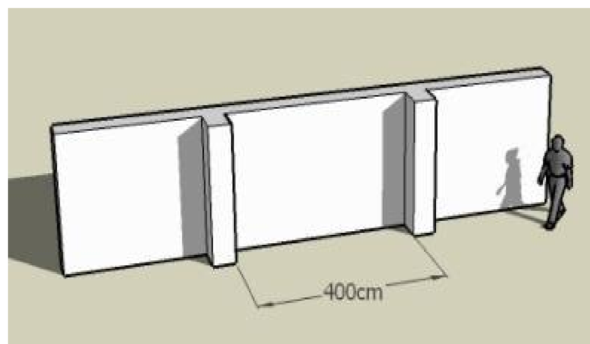



- ***Piers at outside corners:*** Instead of projecting buttresses, a single pier could be used. This does not project as far from the wall. Because the supports are made a part of a thickened wall, it only has to jut out as far as the width of the bag. Barbed wire or extra plastic straps should be used to hold this together.

Left: First 3 courses of a corner pier.

- ***Round outside corners:*** An appropriately sized round wall does not need piers or buttresses to support it. If the radius is between5.5 m (or 18') and 1 m (or 3') it will not need a pier or buttress.

- ***Straight walls:*** When any straight piece of outside wall is 4m (13') long or longer it needs a pier. If it has an intersecting wall inside that is built at the same time, this can work like a pier. It must be fastened firmly into the outside wall by alternating layers and strong cord.



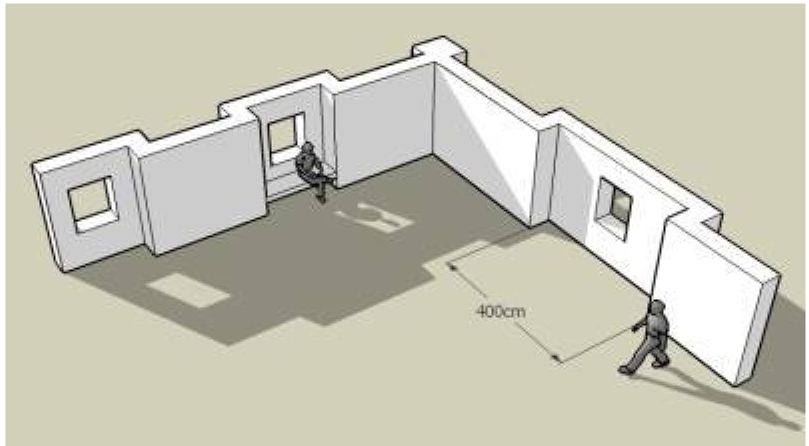

Right: Exterior straight walls need piers.

- ***Straight inside walls:*** Inside walls can have straight sections up to 6- 7.5m long (18- 24') or longer between sturdy intersections or piers, but may need some bracing inside until they dry.

- ***Circles:*** A full circle is a very strong shape, up to a 5m (16') radius. A circle larger than 10m across inside will need some piers. Some people build 3 or 4 circles for rooms at the outside corners, and let them hold up one large roof between them.

Right: Thai adobe buildings.

- ***Corrugated walls:*** Instead of curving or having piers, straight walls can jut out or in every 4m. This can provide storage areas or seating nooks inside. It may allow the house to have a simpler shape than one with piers and buttresses sticking out.



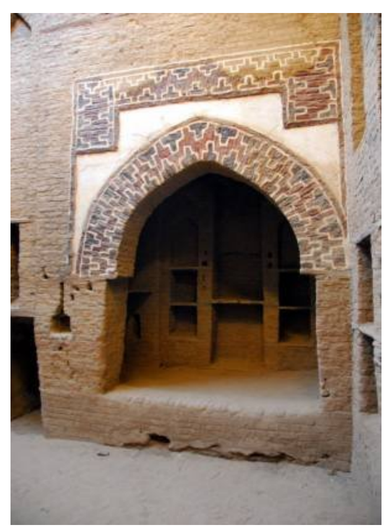

Right: Laurie Baker called this arrangement 'corrugated walls'.

- ***Wall height and thickness:*** Unreinforced earthbag walls should be less than ten times as high as they are thick. For thin 38cm walls, 3m (10') is maximum height. The upper third of a wall could be built of smaller bags than the base.

- If a building needs to sit on a retaining wall and the total wall must be higher than 3m, the lowest portion should be made thicker, and have more piers woven into the walls. This is only for small structures, and would need a reinforced concrete bond beam at the floor level and on top of the wall. The bond beam must be 15cm high and as wide as the wall.

- ***Window and door openings:*** Openings should be at least 1m from corners, or 50 cm from piers at corners. Locate windows in 38cm thick walls at least 2- 2.6 m from another opening. If they have a sturdy pier between them, two windows could each be located 50 cm from the pier.

- ***Window and door sizes:*** Arches can copy local styles- both pointed and round. Arches made of earthbags without cement are strong enough for windows or doors 1- 1.2 m wide. Two continuous rows of tubing instead of separate bags above the arch is recommended if it is available. Rows above the arch must be carefully tied together, and tied into the rows next to the opening on both sides.



Right: An Egyptian arch.

- ***Windows without arches:*** If a flat lintel is used it should extend 40 cm beyond the opening on each side. Use stone, or hollow precast concrete, or cast a reinforced lintel in place.
- ***Roof:*** This kind of earthbag house must have a roof that does not push out on the walls. Wood trusses, rafters from a supported ridge pole, or rafters tied together with a collar beam or cross ties put weight straight down on walls. They will need to sit on a stiff bond beam of wood or concrete that is fastened tightly to the earthbags.

Above: Forms for a concrete lintel above a window and a bond beam.

## GENERAL INSTRUCTIONS:

### FOOTINGS:

Pitch ground 1 in 50 for 3m minimum to direct all water away from base of wall.

Pave a sloping concrete or stone gutter from 40 cm inside the dripline to 40cm outside it, unless gutters will be attached to the roof.

In damp areas place perforated footing pipes (French drain) pitched 1/8" per foot minimum to meet grade, with screen where they surface.

Dig footings the width of all walls and piers to undisturbed subsoil. Slope footings to drain, and provide screened pipe to daylight on low side of building. Place stone and rubble that gets progressively smaller. Provide a level surface of gravel, and place a vapor barrier on top.

Right: Filling inside stone and mortar footings.

### PLACING BAGS:

Protect earthbags from sun exposure if they cannot be plastered soon, because 2 months full sun in hot areas will deteriorate them. Keep bags covered at all times unless directly working on that section of wall. Even one weeks' exposure to sun can cause problems. Do not use bags that have been left out in the sun.

Individual bags can be sealed by simply folding the top 20 cm of the bag over and laying it under the bag. This folded end is placed next to the previous bag. Some people sew, staple, or pin the top closed, so that bags can be prepped ahead and carried to their location without losing earth. This does not increase the strength of the wall.

Complete a whole course before tamping to keep the construction more level and ensure that bags are well locked together. Using the same quantity of fill in each bag will help keep the courses level- such as four buckets per bag.

If you use barbed wire, hold it in place with bricks or stones. A metal sheet may help you slide bags around to locate them accurately before the barbed wire grabs.

Left: Using a slider while overlapping bags at corners.

Stagger beginnings or joints of tube layers or bags to tie walls together vertically. This is called a running bond. Crisscross bags or tubes every course at piers and corners.

Tamp bags firmly and level. One kind of tamper is a concrete weight cast onto a sturdy pole. Another kind has a heavy metal plate fastened to a handle.

Next dimple bags with a sledge hammer or lay barbed wire. If barbed wire is not used, a good practice is to tie every three layers of bags together with cord at least 1m on center. Tie 3 layers together for each of 2 adjacent bags at each side of door openings or wall ends. At piers tie 3 layers together each side of the pier. These ties can also support plumbing or electrical lines 30 cm on center as necessary.

Place short lengths of screened pipe in between layers for access or ventilation holes. Provide a few extra! Often something else will need to go through the wall that no-one remembered.

Above: Tamping a building in Haiti.

Glass bottles can be used to let light into the building, laid crosswise under earthbags 2 or 3 every 50 cm. Closer together they should be surrounded with cement for added strength.

Bottles can also be placed lengthwise in the walls, with the sides of the bottle showing. The neck will be buried in the wall material. (In the interior photo on page 4 the green under the windows and in the rosette above are bottles.)

Left: Plastic pipe between tube layers for vents.

## BASE COURSE:

At least the first four layers of bags (extending 60 cm from proposed grade minimum) must be double bags filled with sand and gravel. The first bag layer at or above interior floor level should be pumice and sand or pumice-crete (1 yard pumice mixed with 2- 2.5 bags portland cement) to provide a thermal break from the soil temperature. If you are building in a very humid climate and can't afford to add pumice to all the walls, buy enough pumice or scoria for one course to insulate the walls from the ground below.

The lower courses can also be covered with cement plaster if that is available, or with dry stone stacked around it to keep the sun off and prevent damage. Fasten cord ties to the base course to attach plastic or wire mesh to attach concrete stucco. Place a vapor barrier between any cement stabilized earth and unstabilized earth.

Borax can be added to lower courses of soil filled bags as an added termite and mold deterrent.

Above: Vapor barrier over base courses.

## OPENINGS:

Work from the openings and wall corners towards the center of wall sections. Use sewed bag ends at openings and ends of piers or walls. Check walls and door openings for plumb.

Small windows or vent block 60 cm square or smaller can be added closer than larger windows.

Right: Forming an arch.

Shape arched window or door openings of

1.2 m max width over a temporary formwork of sandbags, wood, tires or barrels that can be removed later. If a wider opening is needed, a stone or cement lintel, or cement stabilized bags at the arch will be needed.

Use separate small bags to form the arch, banged into wedge shapes. Above an arch it is necessary to seal the bags by pinning or stapling the opening closed. Run 2 continuous tube layers above if available to strengthen arch. Do not remove formwork until 2 or 3 courses have been placed above the arch. After formwork is removed, plastic or wire mesh can be placed around the inside of the window opening if desired to help with finishing.

Pour flat lintels for windows in reinforced concrete. Extend 40 cm past the window opening on each side. Remove formwork when set.

Attach 4- 5 nailers on each side of door frames. These should be nailable plastic or expanded diamond type metal lathe 30 cm wide extending 50- 80 cm between courses. Nail or staple them into the earthbags below with U-shaped sections of sturdy wire. To fasten window frames use 2- 3 nailers each side.

Above: Fastening wire mesh as a base for concrete stucco.

For doors wider than 1.2 m use piers either side of the opening and let the concrete or wood bond beam span the opening. If a lintel this wide is needed, it must be formed of stone or reinforced concrete and extend 50 cm past the opening into the wall on either side. Instead of placing earthbags above the door, a light wood or bamboo vent or infill panel could be used if windows are not wanted.

## BOND BEAM:

Use strong plastic strapping or doubled cord 30 cm on center to fasten wood or concrete bond beam to the top 4 courses of bags.

Concrete bond beams for round buildings can be formed with metal or bendable light materials like thin plywood.

Wood bond beams must be made of insect and rot resistant wood and bolted together and/ or braced at all corners for stiffness.

Above: Rebar serve as braces for the bond beam form.

## ROOF:

Wood or bamboo rafters must be designed with collar ties, interior supports, or as trusses so that they will not exert outward force on the walls. Rafters must have a bird's-mouth and rest on the bond beam or attached sill.

Tie rafters to top 2 courses of bags if bond beam is a round pole, or use metal hurricane ties.

Above: Earthbag with thatch in South Africa.

## FLOOR:

Provide as much of an insulation layer under the floor as you can. This will reduce the amount of condensation in the building because the air will stay warmer. Use light pumice earth, scoria, or used bottles on top of the vapor barrier. Lay half liter glass bottles or smaller horizontal. In addition to this broken tile or brick or stone pieces can also be used as fill in the floor, on a 5 cm layer of sand to protect the vapor barrier.

Use stabilized earth or normal concrete floor. Sealed concrete or tile in earth mortar may be helpful at the building entry and in bathrooms to reduce maintenance in wet seasons. Tamped earth floors dry quicker than poured earth floors and can be permanently finished with additives.

## FINISHES:

Earth wall plaster should not touch concrete plaster. End earth plaster 15 cm or more above the ground on the exterior wall. Use special ingredients for exterior clay water repellent coatings.

Make a window sill of tile or stone that slopes down away from the window to protect the lower wall.

Paint concrete base course white or light to make insect tunnels obvious.

Right: A mud block building in Thailand.

## A Note About Working Across Cultures

Many people who help with building ideas are from other places, and don't realize how much this complicates understanding. Most communication includes obvious statements and less obvious inferences or connotations. People can have very different ideas and values. It is a sad fact that all people routinely underestimate the importance of comments made by those who are not from their home culture.[22] This may sometimes be from feelings of cultural superiority, but even the most humble and willing to learn may fail at understanding because they do not understand the connotations and subtle references made by someone with another cultural background.

One way to plan a building with people of other cultures is to first work with them to learn their techniques or to develop test structures. In discussions it is difficult to develop a level of caring and trust that leads to understanding. Actually getting dirty and watching and asking for help can lay the groundwork for later discussions. Anna Heringer, the architect of the Handmade School in Bangladesh that received the Aga Kahn Award, started the building project by working with local craftsmen to decide on building techniques. One craftsman reflected: "It was good to do tests and experiment together before starting the real construction, so we could understand it although we did not know the language. And everybody learnt a lot from each other. I learned how to build strong walls, how to use measurement tools, and the foreigners learned that the best mixing machines are water buffalos."[23] Unless designers want to learn from national craftsmen and the building clients, their understanding of the culture and needs will probably be sadly limited.

Having a neutral national friend who is willing to discuss the issues and interchanges may also throw a completely different light on even official meetings that foreign helpers thought went well. In addition, comments that may be negative or stressful could be better introduced by a third party and responses brought back by this mediator. Most of the world is more comfortable using mediators instead of face-to-face discussion about sensitive issues.

Above: The Ndebele have a very strong identity that is clearly shown by their houses.

Much of the world is not analytical, doesn't plan ahead a lot, and focuses more on who people are than what they do. Americans, other Anglos and some Europeans can appear too materialistic or driven. Nationals discussing construction with them may feel embarrassed for them and avoid discussing this to avoid shaming them. Others may express opinions in

22 Messick, Mackie. 'Intergroup Relations' *Annual Review of Psychology*, vol. 40, pp. 45- 82 quoted in Daigle
23 Suresh, Bangladeshi loam worker, quoted at www.anna-heringer.com/index.php?id=31, Retrieved 10-29-08.

such a mild way that the strangers don't recognize these thoughts as important. In many cultures a 'no' answer is only polite if expressed indirectly, as 'perhaps'.[24] A mild negative or delaying tactic may actually in practice be a very definite 'no'.

Because of these factors local people should do their own surveys about building needs or possible new shapes. They should plan the buildings if possible. Buildings may not end up what the helpers would have planned. But if they reflect local concepts, and are shaped by local people, they will be more useful, better loved and better maintained. And those who participated in planning and making them will be empowered to build more in the future.

Above: This Cameroonian building wants to be traditional.

Too many accidental lessons have been taught, like: 'fixing buildings is shameful'; 'nothing is worth building unless it is big;' or 'everyone needs to be alone'. It is hard to plan housing for both national and foreign staff. Foreigners too often are unable to share spaces or adapt to new ways. Nationals do deserve as good as the foreigners, but is what foreigners need good if they are (compared to the local culture) poorly socialized and overly individualistic?

Even if helpers know how to build 'better' than local people, it is best to use only a few method innovations or quality improvements in each project.[25] Using complicated skills says: 'you can't do this'. Using expensive techniques says: 'your ways are poor'. It also shows a lack of concern about the very delicate economic balance that most people manage. Throwing more money into a building may mean that a family can't buy enough food during the next difficult season, or any medicine for the next sick person. This would be a tragedy compared to the much lesser problem of poor shelter in a warm climate.

Left: Traditional decoration in Cameroon.

Buildings should be built simply so more can be built with limited money and local workers can copy the building styles. Laurie Baker applied a Quaker ethic to his construction

24 Lane, Patty (2002). *A Beginner's Guide to Crossing Cultures.* Downer's Grove, IL: Intervarsity Press, pp. 64-66, 90-92
25 Coffey, Matthew (undated). *Making It Stand.* Colorado Springs, CO: Engineering Ministries International

work in India. His desire to avoid the showy allowed him to recreate much that was timeless in the local buildings. This resulted in work of "uncompromising simplicity; delight in the naturalness of local materials and craftsmanship,... and a willingness to be boldly experimental in pursuit of cost reduction."[26]

Perhaps if the work is simple and uses common supplies, ordinary people may find ways to work together on their own projects. Among the Creek peoples of the US in the past a leader would pass out sticks that were proportionate in size to those needed for the proposed building. Several months later, when everyone had brought their share, the leader prepared them. Then all gathered to put them up and finish the building with materials on-site. Communities that could work together like this on buildings that they need would be a good thing.

## Acknowledgements

Thank you, Paul Dubois, for so many patient explanations about building in Africa, and practical help visiting the region. I also benefited from the willingness of CABTAL (Cameroonian Bible Translation Organization) and SIL staff and to discuss buildings.

Most of my information on adapting to tropical climates has been gathered from many excellent books that are the result of years of research. Yet since most of these books also cover many different climates, their wisdom may not be well known in the tropical world. Construction needs are great in the densely populated and under-developed regions of the humid tropics. Practical, accurate modern books need to focus on this region.

The information I share about earth and earthbag construction is also the result of years of research. Those who have promoted earth construction and developed earthbag systems generously share information. Dr. Owen Geiger of www.earthbagbuilding.com and www.grisb.org has been particularly helpful with many comments and proofreading. Kelly Hart's comments and involvement in both the Green Home Building and Earthbag Building websites have also been instrumental in this booklet. I hope others will continue to make appropriate technology more available to the tropical world.

Please contact me at handshapedland@yahoo.com with comments, photos of examples, and suggestions to improve these free resources.

26 Spense, Robin 'Laurie Baker- Guru of Low-Cost Housing' (2007). *The Architect's Website.* 13 April, 2007 Retrieved 10-23-2008 from BDOnline at www.bdonline.co.uk/story.asp?storyCode=3084818

## The Author

Trained as a landscape architect, experience with site planning, and passive solar building design in temperate areas has helped me understand the thermal needs of the tropics. Working on family building projects and being a stay-at-home mom may have also prepared me somewhat to understand those with limited means and labor-intensive traditions.

A year of working on buildings for western Africa, and a single trip to Cameroon make me a novice at working cross-culturally. I am a volunteer with a service NGO called Wycliffe Associates that supports international literacy and translation workers. WA provides support in many parts of the world to translators who seek to understand and help people of indigenous cultures. SIL and Wycliffe Bible Translators often become mentors of nationals who can express the full range of their home culture's thought and worldview as well as explore the Bible's teaching of a creator God who already knows and loves them and desires to be fully known by them.

Builders from other cultures who are Christians need to remember to follow the master who 'had nowhere to lay his head'. We appreciate the beauty of buildings, but Jesus cared more about the structure of his followers' relationships than about the temple in Jerusalem. Lets try to remember that visible structures are only aids to peoples' relationships among people. The good materials we should build with are those ideas and character traits that honor and reflect the glory of the one who quietly laid himself down to become a foundation.

## BIBLIOGRAPHY

### Building with Earth:

Two books of earthbag construction and one web brochure are very helpful:

Hunter, Kaki and Kiffmeyer, Donald (2004). *Earthbag Building.* Gabriola Island, BC, Canada: New Society.

This volume will probably end up stained and covered with earth as you keep checking out their details and advice while you build.

Phadke, Sourabh (2008). *Earthbags.* Available at www.mkf.in

*This 33 page booklet has nice illustrations and is a good introduction, available in English and Marathi. Check out the kaleidoscope project on the web site for a beautiful little structure and some step-by-step photos.*

Wojciechowska, Paulina (2001). *Building with Earth.* White Junction, VT: Chelsea Green.

A very helpful book about specifics of construction of earthbags.

Web sites that are very helpful include:

www.earthbagbuilding.com The best web site to explore how to's and who's done what with earthbags, By Kelly Hart. Lots of photos of examples and links.

www.grisb.org A lot of self-help resources and technical information in the publications section from Owen Geiger.

www.okokok.org/earthbag.php Kaki Hunter and Donald Kiffmeyer's website. Lots of good stuff.

www.networkearth.org/naturalbuilding/earthbags.html If your internet connection is slow you may appreciate this written encyclopedia of information about natural building.

Reports of test results available on the internet are:

Daigle, Bryce Callaghan (2008). *Earthbag housing: Structural Behaviour and Applicability in Developing Countries.* Kingston, ON, Canada: Queen's University available at https://qspace.library.queensu.ca/bitstream1974/1421/1/daigle_bryce_c_200809_msceng.pdf This test is going to do a lot to allow newcomers to earthbag to understand how strong it is. A nice discussion of cross-cultural and economic issues in Sri Lanka.

'Shear Testing of Sandbag Construction and Building Materials' *Geosynthetics International,* 14 #2, 119-126 available at www.apegm.mb.ca/pdnet/papers/sbag.pdf

www.earthbagbuilding.com/testing.htm This site has links to several test results, including Khalili's superadobe testing for California building code approval, and the first set of engineering tests run at West Point.

Other books about earthen construction methods are:

Minke, Gernot (2006). *Building With Earth: Design and Technology of a Sustainable Architecture.* Basel, Germany: Birkhauser.

A wealth of technical information about rammed, compressed earth, and mud block as well as some inspiring photos of building examples. If you're wondering about something, this book may have some test results and comments about it.

## Traditional Building Styles:

These photo books may help you choose some traditional shapes for your new building:

Steen, Bill and Athena, Komats, Eiko (2003). *Built by Hand.* Gibbs Smith

Taschen, Angelika (2005). *African Style.* Cologne, Germany: Taschen

## Working Across Cultures

Coffey, Matthew J. (undated). *Making It Stand.* Colorado Springs, CO: Engineering Ministries International. available at www.emi.org/volunteer/resources

This power point series explains how to help other cultures with structural

improvements. Contains examples of types of plans.

Kennedy, Joseph F., ed. (2004). *Buildings Without Borders: Sustainable Construction for the Global Village.* Gabriola Island, BC, Canada: New Society.

Lots of discussion about how to bring useful technology to people who need it from real life examples, including mistakes to avoid.

Lane, Patty (2002). *A Beginner's Guide to Crossing Cultures: Making Friends in a Multicultural World.* Downer's Grove, IL: Intervarsity Press.

This book includes many helpful charts about the cultural variables of different countries, as well as examples of cross-cultural misunderstandings and keys to correcting them.

## Photos:

Owen Geiger and others from the Earthbag Building website, thanks for sharing your photos of earthbag construction.

Photos not listed are by Patti Stouter or Dan Moore, mostly from Cameroon.

Photos listed by name without a web address are from www.earthbagbuilding.com.

p.1 Residence, Turtle Beach, Costa Rica, also page 12; Dennilton, South Africa, NextAid- Kennedy, also pages 9 and 20

p. 3 National Park station, Bluff, Utah, US, also page 11; Cape Town, South Africa, residence- www.thepropertymag.co.za

p. 4 Shelter, Colorado, US ; Adobe buildings, Thailand

p. 5 School, Philippines

p. 6 Residence, Mexico- www.karacadir.com, also page 27

p. 7 Residence, Moab, Utah- Hunter & Kiffmeyer, also page 10

p. 8 Orphanage, Haiti- www.pwojeespwa.blogspot.com also pages 10, 16, 17

p. 9 Studio, US, also pages 16, 18 and 19

p. 15 Egyptian arch www.2canadiansonbikes.com/photogallery/2007egypt/20070352.jpg;

p. 21 Ndebele house, South Africa www.thefaceofafrika.com/2008/06/african-architecture-2.html