Planning Buildings in Warm Humid Regions: Hints for NGOs

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Chapter 1: Introduction to Site Evaluation

All land is not equal. You are already looking for inexpensive, breezy land that is close to utilities and transportation.

Steep or soggy land can increase building costs dramatically. Land with high water levels during part of the year may make wastewater difficult to handle. Large proportions of the wrong kinds of clay in a soil or areas that have been filled may require expensive foundations. Some land has layers of slippery soil that cause landslides or slow soil creep and destroy structures. And other land may settle if groundwater levels are lowered by wells, or under the weight of buildings.

Get as much local advice as you can. This booklet has been developed for those who have difficulty finding local advisors in subtropical and tropical regions. It was developed to help local program directors who are trying to decide about purchasing property for new buildings.

Some of this information could be collected by a local volunteer. Science or social studies teachers or volunteers with a construction or technical background can help.

REGIONAL INFORMATION

Use internet maps to check for earthquake risk levels, the presence of limestone geology, and some other limiting factors for development. Get local opinions on these hazard levels for your project site. Information may be available from local builders, city building departments, and regional universities or research centers.

Important topics you must be aware of:

What problems with water and power supply are common?

What kind of rocks and bedrock are in the area?

Are there any caves or mines in the area?

Have there been any landslides, mudslides, or areas of collapsing soil in the region?

What kind of damage happens to buildings, roads, or bridges in the area?
WARNING SIGNS:
Ask first about a site with any of these characteristics before you spend too much time on it:

- Large wet areas.
- Very sandy soil in earthquake-prone regions.
- Very sticky clay soil.
- Dry, cracked soil areas, gullies, bare gravel or soil.
- A general hummocky appearance.
- Surface water that disappears underground.
- Leaning trees or posts on slopes.

BOUNDARY INFORMATION
If you are purchasing land from a future neighbor, they can show you the limits of the property. There should be some obvious locators like fences, walls, ditches, or rows of trees. If not, you could ask them to stack some rocks or place some stakes near the corners. Someone will need to visit the site several times to evaluate it, and you need to be sure everyone involved is looking at the same piece of property. If you decide to buy it you will need a legal survey that has measurements and compass directions.

When you are seriously considering a piece of land you will want to confirm its size. If you have a survey and the corners are marked it is a good idea to have someone double check the marked distances, and measure one diagonal line between the two closest corners. If you don't yet have a survey, it is important to be able to tell us about how much land is involved.

SITE PHOTOGRAPHS
Digital photographs of the land will help you to get advice about it.

Right: Building site in Cameroon

If you are seriously considering using a piece of property and may be working with designers or planners who haven’t visited the site yet, a careful series of photographs must be taken. These photographs must each overlap the area of the previous photo to show how they connect. Two separate series from each boundary line, one looking in and one looking out is very helpful. These should be put into labeled files (i.e. ‘northwest boundary, looking outward’, etc.). Additional photos should show any existing structures, landforms (cliffs, ditches), special plants, surface water, as well as the kind of buildings in the neighborhood.

If plants block the view of the site, use a ladder or climb a tree to get better views. Even if you already own the property, please see what kind of photos you can get before you remove too many bushes or trees.
ABOUT SLOPE
Land that is too flat may be soggy in damp climates. Land that is too steep will require expensive retaining walls or higher building foundation walls. Surveyors can show the exact 3-D shape of the land with detailed topographic maps. These are not necessary to compare land before purchasing it, but you do need some idea of how steep the land is.

The amount of slope is called the grade or gradient. This is the difference in elevation divided by the distance between measurements. Land that slopes 10 cm up or down in 1m of distance is called a 10% slope. This is steep enough that it will increase building costs and may make it hard to fit buildings on. Land that slopes 1 cm in 1m of distance has a 1% slope, and may be hard to drain. The shape of the property and the kinds of buildings and materials used in the area will also influence whether steep or flat land should be used.

SIMPLE SLOPE MEASUREMENTS
Land with a uniform slope (when you look up or down or across the slope, the surface of the land is mostly straight lines, without dips or curves):

If you have a survey and the corners are marked: It is a good idea to double check the marked distances, and measure one diagonal line between them. Then measure the difference in elevation of 2 or 3 different locations. It is best if these can be the corners. For a first site evaluation, 2 or 3 typical spots are good, as long as you note the exact distances between them. A contractor can mark these with stakes or stones. With a helper and a hose and some water he can measure these 'spot ele.

Land with curves or bumps may be harder to evaluate. How much it slopes from one side to another is still important to know.

If it has a steeper part and a less steep part: The slope of the steeper part is important to know if it is a major part of the site. You could have a second set of readings taken in the less steep part if time allows.

If the land curves: Surveyors usually locate and take spot elevations at a couple of high points on each ridge and a couple of low spots in each hollow. For a preliminary evaluation some good photos with some rough estimates of height or depth may be enough. ('Higher than my head when I stand here'...) Flat land with little slope:

Can you see where water flows, especially onto or off of the property? Look for leaves or debris missing where water flows, or lined up at the edge of a very slight channel.

Bumpy agricultural fields do not need to have the furrows measured. Just mention them.
HOW SOILS AFFECT BUILDINGS
All types of building construction depend on good foundations. Most also require some sort of wastewater treatment in the soil. This section describes some of the different kinds of soil that can raise construction costs or complicate building.

For earthen buildings soils must be correct for the type of construction. Soil tests are very important. Please see the ebook *Soils for Earthbag: Part 1 Soil Testing* available online at [http://www.scribd.com/doc/29252833/Soils-for-Earthbag-Part-1-Soil-Testing](http://www.scribd.com/doc/29252833/Soils-for-Earthbag-Part-1-Soil-Testing). These tests will give you a good understanding of the kind of soil on the site that you can discuss with engineers or designers who will help with your plans. If you are planning to build with earthbag, the companion volume will also be helpful as you evaluate sites, *Soils for Earthbag: Part 2 How to Build with Different Soils* available at [http://www.scribd.com/doc/38054243/Soils-for-Earthbag-Part-2-How-to-Build](http://www.scribd.com/doc/38054243/Soils-for-Earthbag-Part-2-How-to-Build).

SOILS FOR CONSTRUCTION
Soils high on hillsides tend to be shallower and coarser than those below. Very stony soils, and areas with boulders or rock ledge may be hard to dig or re-grade. If fill is available on a very stony site, it may be simplest to add fill for minor re-grading.

Exposed rock areas may complicate foundations. Most rocks have high bearing strength, but footings may need to be fastened to exposed rock ledge. In quake hazard areas hillside and ridge locations can amplify earthquakes and receive more intense quake damage.

Sandy soils may drain so quickly that they allow soakaways or septic systems pollute groundwater. Sandy soils also dry out too quickly for sports fields or public lawns, although clay and humus can be added to correct this problem. Sandy or silty soils of uniform particle size may also 'liquefy' during an earthquake.

Some poorly compacted materials do not provide a good base for buildings. This includes flood, landslide, and volcanic deposits as well as human debris. Some low-lying soils that contain large proportions of plant material begin to compact when drained. Some low-lying soils of tidal areas can become highly acidic when drained, damaging structures and destroying plant life.

The stickiness of heavy clay soils make them harder to dig and re-grade. Construction in clay areas may be delayed by rainy periods, and plants may have difficulty growing. Soils that have a grayish color, or mottled spots of more or less intense color may be too frequently wet to process wastewater. Some clays shrink and swell with moisture changes and cause serious building damage. (In the tropics many clay soils do this).

GENERAL PROBLEM SOILS:

Low Bearing Strength Soils and Fill
Buildings on narrow footings will settle unevenly on low strength soils. Standard shallow footings in tropical regions are often made of rock and rubble only slightly wider than the building walls. Either lighter building materials must be used, or wider footings with more reinforcement. This will increase building costs.
Any type of soil or rock that has been moved will settle, overall and more drastically above occasional voids. Volcanic ash, and material deposited recently by floods or mudslides is often poorly compacted. Areas that have buried trash or agricultural wastes will settle as the materials decompose. Areas of fill must either be regraded and methodically compacted in shallow layers, or have footings that rest on undisturbed soil layers.

**Landslides and Soil Creep**

Land and mud slides happen on hillsides, but also damage sites below. They are often caused by adding or removing soil or structures on the toe of a slope, or by the wetting of a weak layer. Sites prone to landslides include areas underlain by shale and other soft sedimentary rocks, and steep areas of clay soil. Regions with many seeps, springs, and small bogs are often subject to landslides or soil creep because a deep layer of impermeable clay prevents water drainage, and this increased soil water reduces friction between the soil layers above the clay.¹

Tree roots provide considerable stability to steep slopes, and also reduce soil moisture levels. Trees and vegetation should be untouched and grading kept to a minimum on slopes in areas known for landslides. Slopes where fire or drought has removed vegetation may also become subject to landslide. Disturbing the base, or toe, of a slope can destabilize large amounts of soil and rock above. Sometimes small amounts of erosion at the base of a slope can begin much larger landslides.

Signs of landslide activity include hummocky, dissected topography, abrupt changes in slope, trees or posts that lean, and debris in valleys and stream channels. Large scale aerial photographs may show the crescent shaped scarps and changes in vegetation created by past landslides. Stabilization measures may include replanting, redirecting runoff and/or providing drainage.² Many slides are too large for restraining structures of concrete. Bio-stabilization measures have become standard practice using vegetation, natural materials like logs and brush, and geo-textiles.


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² Charles W. Harris, ed. *Natural Hazards: Landslides and Snow Avalanches* in Harris and Dine, eds. (1998) Time-Saver Standards for Landscape Architecture
PROBLEM SOILS OF DRY REGIONS:

Expansive Soils
Soils high in plastic clays, and those located over some types of shale rock cause serious construction damage when their moisture levels change. Shales are layered rocks that weather and contain clay. They are commonly found in plains and on the sides of valleys, and often occupy preferred building locations in hilly or mountainous regions. Expansive damage to buildings from expansive clay is common around the world.

Pure montmorillonite may swell up to 15 times its dry volume. Natural expansive clay soils seldom increase more than 50% of their volume, but any increase of 3% is damaging, and 10% causes severe damage to foundations, retaining walls, and other confining structures. Buildings constructed during dry periods may become cupped as the soils around the building swell and force walls to tip inward during the next wet season. Construction during wet seasons may later experience down-warping as the exterior walls slant down and out after the surrounding soil becomes more dry than the soil beneath the building. Point leaks from water pipes can cause one-sided swelling.

Existing structures in the vicinity of a new building site should be inspected for signs of damage which could indicate expansive soils, like crack lines running diagonally upward from the tops of windows and doors. Cracks in buildings and bridges, and 'rollercoaster' roads and heaved or broken utility pipes are also indicators.

Several of these soil warning signs would indicate a serious problem with expansive soils:

- The soft, puffy, popcorn appearance of clay soil when dry.
- Soil that is very sticky when wet.
- The presence of substantial open cracks in dry clay soil.
- Lack of vegetation due to heavy, clay soils.
- Soil that is very highly plastic and weak when wet, but rock hard when dry.

The problems of expansive soils are greater the higher the proportions are of expansive materials, the thicker the layers of expansive material, and the more fluctuation experienced in moisture levels. Soils that are 12% or more clay, and that have a high plasticity will be expansive. Areas that have obvious dry and wet seasons receive more damage than areas where moisture levels stay constant. Sometimes even shade cast by buildings or soil drying from plants causes heaving because of differing moisture levels.

Construction can be done safely on expansive soils, but it will be more expensive. Buildings without basements are easier to modify for expansive soils than structures with sub-grade sections. Retaining walls

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3 Charles W. Harris, ed. Natural Hazards: Expansive Soils in Harris and Dine, eds. (1998)

are especially susceptible to damage. Retaining walls can be built if the expansive soil is covered with a waterproof layer, has extra drainage above, and the wall is completely backfilled with a different non-expansive soil. Stabilization plantings may be a more economical choice than retaining walls, although they require more ground area. Buildings on expansive clays may need expensive spread footings, or grade beams on drilled pier footings. Floor slabs are often disconnected from footings to allow vertical motion and are placed over void forms that allow the soil beneath to swell without raising the floor.

Another approach seeks to keep moisture levels consistent. Solid pavement one meter wide that pitches down from the building it surrounds may reduce fluctuation of soil moisture levels under the exterior walls. Consistent irrigation has also been used. But with these strategies underground utilities may require flexible connections to allow the pipes further from the house to be raised and lowered with the seasonal soil changes.

Plants should be kept 1.7 m from a building wall, and trees at least 5 m away. Very careful treatment of surface runoff is also necessary to prevent water soaking into different areas during severe storms.5

Subsidence: Hydro-compacting Soils

These difficult soils are located in arid or semi-arid plains at the base of hills or mountains, where material deposited by short but intense flash floods dried quickly without settling. These collapsible soils occur in fan-shaped layers where narrow valleys widen out. They are very porous and may be 40–60% empty voids. Often they form thick deposits located below more ordinary soil. When buildings are placed above collapsible soils, or the soil moisture level is increased, significant settlement can occur. Any very low density soils are cause for concern, or these signs in undeveloped plains below steeper regions:

- Small depressions in areas of fan deposits not associated with grading.
- Sinks where rainwater is gathered or retained (in areas without soluble soil or bedrock like limestone).

In developed parts of plains below steeper regions these signs should be investigated:

- Ponding and poor surface drainage.
- Curving cracks in soil or asphalt, misaligned or separated joints in concrete slabs and curbs.
- Tilted structures or evidence that cracks in structures or roads have been repaired.

Building footings cannot rest on these kinds of layers, and septic systems must be located far from buildings. Piles or posts must extend below the un-compacted soils to an undisturbed layer that has a good bearing strength.

One construction strategy is to pond or inject water or place an excessive load of fill to induce collapsing before construction begins. If the collapsible layer is not too deep, another option is to excavate and repack the material.6

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**Radon Gas**
This naturally occurring radioactive gas associated with uranium and radium occurs in glacial till and granitic rocks, and can be transmitted in groundwater. It can build up to levels that may cause lung cancer in tightly sealed houses that have basements or where showering with contaminated groundwater introduces the gas. Although sealed buildings and basements are uncommon in hot regions, buildings in rocky areas that include sub-grade construction could be tested for radon content, especially in temperate areas or if the building will be closed sometimes for air conditioning.

**Chemical Residues: Salt, Anhydrous Salts, and Gypsum**
Some bedrock in dry regions contains chemicals which are soluble. If groundwater is highly mineralized, or there is any record of caves in the region, sinkholes may be a possibility (see under Subsidence: Sinkholes in the Problem Soils of Humid Regions section below). Soils of bedrock areas that contain gypsum, table salt, or anhydrous salts may also contain these chemicals, which can prevent or limit plant growth and damage structures.

Some agricultural regions are also developing areas of salty soil. This has been caused by modern agricultural practices that may not be common in developing areas, including using plant-killers to remove weed plants. This allows more water to penetrate past the root zones, concentrating natural salts in field runoff. In some areas where field runoff collects or subsurface drainage emerges, salt concentrations have become high enough that white residue can be seen, and standard crops cannot grow. These salty soils can cause damage to structures as well as limit agricultural use. Saline seepage can only be limited by reducing water flowing into the soil above or using salt-tolerant plantings that capture soil moisture and reduce seepage.7

Soil heaving and property damage has also been linked to the presence of special salts in the soils of mildly saline lakebeds in arid inland regions. When the temperature drops past a certain level, soils that contain anhydrous salts increase suddenly in size. They seem to require water to enable the chemical process that causes expansion, and damage can be prevented by avoiding irrigation, treating wastewater and storm runoff at some distance from structures, and monitoring for utility leaks.8

If as much as 10% gypsum is naturally present in a soil, it can dissolve and cause the soil to collapse. Gypsum can resemble white sand, but reduces the available soil fertility for plants, and deprives them of soil moisture as well. It is also caustic to structures. Abundant gypsum can cause a barren 'badlands' appearance.9

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Vegetation is important to provide shade, reduce wind and wind-blown dust, and to moderate humidity and soil moisture in warm regions. If site soils do not already support a wide variety of plants, simple growing tests can be tried with the soil, using one or two quick-sprouting types of seed like radishes in soil samples, to evaluate how difficult it may be grow plants there after development.

PROBLEM SOILS OF HUMID REGIONS:

Subsidence: Organic Soils
These problem soils are usually saturated peat or muck soils found in low-lying areas. Because they contain high proportions of organic plant materials, when drained these begin to decay. They will compact rapidly during the first few years after draining. Subsidence often continues at between 1 and 3 cm per year. These soils are the reason for so much of New Orlean’s vulnerability to flooding.

Subsidence rates can be reduced (but not stopped) by allowing the soil to be saturated for longer portions of the year. Buildings require expensive piles or posts that extend below the organic material to a layer that has a good bearing strength. Connections to utility lines must also be flexible.

Subsidence: Sinkholes
Evidence of hummocky topography, or water flowing underground are cause for concern in areas with subsurface mines, lava tubes, or caves, such as karst regions. Karst is a type of landform found on limestone or dolostone bedrock, which includes few or sinking streams, caves, bedrock sculpted by solution, and dolines or round depressions. Humid tropical regions also include tower karst, where isolated steep walled hills are surrounded by a low-lying plain, and cockpit karst, where conical hills surround star shaped depressions. Regions that were covered by glaciers may have soils deposited above these characteristic shapes, but still have these groundwater systems below grade. See the world maps of carbonate rocks in the Appendix.

Regions with highly mineralized groundwater may also be areas of concern because similar sinkhole processes occur in areas with halite, anhydrous and gypsum bedrock, which are more common in drier regions.

It is hard to predict where a sinkhole may appear, because they are often the result of very gradual subsurface processes that continue for long periods without visible effects. Subsidence has been caused also by the withdrawal of oil or gas in the past, but current extraction techniques reduce this risk by replacing materials

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11 Worthington Groundwater at www.worthingtongroundwater.com/karst.htm Accessed 12-4-2008
12 or online at www.sges.auckland.ac.nz/sges_research/karst.shtm
with water. There is some evidence that heavy clay soils above caves, lava tubes, or bedrock with solution channels may be somewhat more risky places to build than lighter soils.

In some parts of the world areas with shallow soil deposits above soluble bedrock tend to gradually produce shallow and broad 'solution sinkholes'. Areas with deeper sandy soil tend to develop few and small 'cover-subsidence sinkholes', which also develop gradually. In Florida, US, areas with less permeable clay soils do not produce many sinkholes, but 'the ones that occur are deep and wide. These types of sinkholes are referred to as “cover-collapse sinkholes” because cohesive layers of sediment collapse into underground cavities when they form. The abrupt formation of sinkholes may follow extreme rain producing events...

Karst areas are generally difficult to develop well. Wastewater treatment might need to be more carefully planned because bedrock solution channels are common. Karst regions often have generous supplies of groundwater, but they are vulnerable to contamination. In selecting land for development, sites with thinner or lighter soils may be more stable. But thinner soils will definitely provide less wastewater cleansing. Wastewater systems may require deeper soils than needed in areas where solution channels are uncommon.

Karst areas have been targeted worldwide for environmental preservation because their less acidic soils often support rare plants and animals. In addition these soils tend to form slowly and only support a narrow variety of plants. They are easily damaged under the drought and flooding cycles often caused by their subsurface drainage. Badly eroded karst farming areas may not recover even 20 years after damaging factors cease.

Expansive Soils
Expansive clays are also found in humid regions. They will require sturdier foundations and retaining walls, as well as great care with grading for drainage. These soils are not as destructive in areas that have rain all year long as they are in regions with a dry season. See under Problem Soils of Dry Regions for a full discussion.

Chemical Residues: Acid Sulfate
Sediments and dredged material from the tidal edges of seacoasts are often high in iron sulfides, a material responsible for much surface water pollution from mining. Because machines enable larger land shaping operations than in the past, these soils are sometimes deposited on coastal sites. Land reclaimed from the sea may contain significant amounts. Because of the dark color of sulfidic sediments, they are sometimes confused with topsoil and mistakenly spread as a soil amendment on neighboring land.

After this chemical is exposed to oxygen, it changes from neutral to highly acidic within a few months. It is highly toxic to plants and animals, and causes erosion by killing plants that stabilized streams affected by its leachage. Aluminum and iron may be released into the environment, and sulfuric acid is produced in strong

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17 Charles W. Harris, ed. *Natural Hazards: Expansive Soils* in Harris and Dine, eds. (1998)
enough concentrations to damage metals and concrete in structures. ‘Improper drainage of acid sulfate soils can, in effect, create an acid wasteland that is very difficult to reclaim. The soils commonly occur in nearly level, low-lying areas that are attractive sites for drainage and construction.’ It is much simpler to avoid disturbing this type of soil than it is to repair the damage it causes.

**PROBLEM SOILS OF EARTHQUAKE HAZARD AREAS:**

**Quake Liquefaction Risk**

Earthquakes can cause sand or silt to liquefy if they are saturated with water. Vibration causes the voids in the material to collapse, or the material to behave as a fluid and lose its bearing capabilities. ‘Deposits most susceptible to liquefaction are... sands and silts of similar grain-size (well-sorted) in beds at least several feet thick...’ These kind of soils are common along riverbeds, beaches, dunes, and areas where wind-blown silt (loess) and sand are located.

The greatest dangers from liquefaction occur in marshes, wetlands or along shorelines where these soils are more than 60cm thick. Some areas may only have high water levels during part of the year, but earthquakes during this time can cause massive damage. Urban areas with dense construction near water bodies, and areas of reclaimed land are particularly liable to liquefaction.

Other results of quake vibration can include lateral spreads and flow failures. Lateral spreading is most common in soils deposited in flood plains, and can cause movement of 3-5 m on nearly flat areas. Flow failures can be catastrophic, because large blocks of intact materials are moved on top of a layer of liquefied materials. They may be up to 1.5 square kilometers, and can move many meters at great speed. They usually involve layers of saturated sands or silts on slopes greater than 6 or 7 percent.

Some types of more expensive construction can be safe in quake hazard regions without saturated soils. These include lighter buildings with more flexible connections or squatter buildings with heavier reinforcement. But because saturated soils can undergo sudden loss of bearing strength and/or lateral movement, it is harder to design safe structures for these areas. One strategy is to attempt to improve the strength, density, and/or drainage characteristics of the soil. If the susceptible soil is deep, (some extend as deep as 30 meters) modifying the upper 2 or 3 m of soil may not be adequate.

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Chapter 3: Shaping Buildings for the Humid Tropics

INTRODUCTION
Buildings for hot-humid climates should be comfortable in heat and dampness. The humidity is usually above 60% and often nearly 100% in many regions. Simple, low-cost buildings can be cool, dry, and mold-free.

In hot, humid areas trying to shut out unpleasant weather does not work well. Electricity for fans or air conditioning is unreliable and condensation from humidity causes more problems than the heat. Opening to the breezes is much more effective.

Peoples of hot, humid regions think of buildings as roofs and screens. Few rooms are completely ‘inside’. A sense of security and enclosure may come more from people or a compound or courtyard wall than the building walls themselves. True comfort comes from breezes which we cannot control, and the shade of a multitude of plants. Construction in hot, humid areas should cooperate with nature, use available materials, breezes and plants.

PLANNING FOR COMFORT
Buildings in hot-humid climates need to be well ventilated, unlike those in hot-dry climates. In dry regions heavy buildings moderate the temperature. But in areas where there also is a rainy season, heavy buildings are frequently damaged by mold growth caused by condensation.22

Left: Rooms with flow-through ventilation are best.

Hot-humid inland areas of the world have high humidity and temperatures that rise and fall slightly every day. Breezes in high humidity allow people to feel cooler because of evaporation from their skin. This is why ceiling fans make people feel cooler. Breezes also replace indoor air with fresh, keeping humidity levels from building up as people exhale both moisture and heat.

Let people control their own environment, and they will feel comfortable in a wider range of conditions. Provide access to a window or vent for each person, and make shutters or blinds adjustable. Acclimatized people in hot regions tolerate hotter and more humid conditions, but cannot tolerate weather that is as cool. People from other areas living short-term in the tropics suffer more from heat and humidity than the locals.

Buildings that rely on natural qualities for comfort need to be thoughtfully planned\textsuperscript{23}

**VENTILATION:**

\begin{itemize}
  \item \textbf{Catch the breeze:} Locate on a hill or raise above the ground, at a 20-40 degree angle to the prevailing breezes.
  \item \textbf{Don't block the breeze:} Space buildings out, and add breezeways in them. Build a minimum of 18 m downwind from a 3 m height building or wall to allow breezes in\textsuperscript{24}.
  \item \textbf{Make rooms breezy:} Each room needs 2 exterior walls, with many windows or vents, including low openings. Verandahs with outside stairs obstruct breezes much less than interior halls.
  \item \textbf{Make outdoor areas breezy:} Place them on the breezy side of the building, but protected from storm winds.
  \item \textbf{Porches can allow openings to windows in the center of the building.}
\end{itemize}

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\textsuperscript{23} Many of these are explained in Koch-Nielsen (2002) \textit{Stay Cool}, and in Brown and Dekay (2001) \textit{Sun, Wind and Light}.

\textsuperscript{24} Koch-Nielsen (2002) page 120
SHADING:

→ Keep sunlight off of building walls: Try to face the long sides (with most of the windows) towards the south and north so the roof overhang can shade walls and windows throughout the middle of the day.

→ Shade in the afternoon: Keep west and east sides short or provide screens, vines, or shrubs to shade.

→ Use white or light colors that stay cooler on sunny walls, roof, and pavement.

Best orientations for buildings to avoid afternoon overheating.

Above: Adjustable window screens keep sun out in Orlando and in Ouagadougou.
INSULATION:

➔ Keep attic heat out with a vented roof or a ceiling insulated with materials that don't soak up humidity.

➔ Use light-weight or well-insulated materials so the building won't feel hot.

➔ High ceilings let hot air rise above the people so the room feels cooler to its occupants.

PLANTINGS:

➔ Let tall, open trees shade roofs and shrubs and vines shade the ground or buildings to reduce the local temperature. Plants cool by evaporating moisture as well as by shading, like natural air conditioners.

➔ Don't make sun traps of heavy walls around sunny paved areas. Plant between walls and paved areas.

➔ Funnel breezes with building walls or plants: Buildings close together can aim and speed up the breeze.

Right: Plants and walls can funnel breezes.

Best orientations for buildings in the southern hemisphere.

Primary goal: always avoid afternoon sun during the hottest season on building walls or windows.
Chapter 4: Building Across Cultures

COMMUNICATION

Many people who help with building ideas in the tropics are from other parts of the world. This complicates understanding more than we realize. People can have very different ideas and values.

People routinely underestimate the importance of comments made by those who are not from their home culture. This may sometimes be from feelings of cultural superiority, but even the most humble may not understand simple connotations of statements by someone from a different cultural background.

Some people express opinions in such a mild way that more analytically-oriented people don't recognize these thoughts as important. In many cultures a 'no' answer is only polite if expressed indirectly, as 'perhaps'. A mild negative or a delaying tactic may actually in practice be a very definite 'no'.

Many of the peoples of the world are not analytical, don't plan ahead a lot, and focus more on who people are than what they do. Americans, other Anglos and some Europeans can seem to be materialistic and driven. Some cultures prefer simple or insubstantial building materials as a social statement of humility. Nationals may feel embarrassed for foreign designers, and avoid discussing this to avoid shaming them.

Having a neutral national friend who is willing to discuss issues and interchanges may also throw a completely different light on even official meetings that foreign helpers thought went well. Comments that may be negative or stressful could be better introduced by a third party and responses brought back by this mediator. In many places people prefer to use mediators to discuss sensitive issues with more respect.

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

If nationals will be using a building, it would be best for them to supervise their own surveys about building needs or possible new shapes. They should develop a first, and separate, plan for the buildings if possible. If buildings are to be shared, their needs and perceptions may not be well voiced once foreign helpers have begun commenting. The more that buildings can reflect local concepts, and be shaped by local people, the more useful, better loved and better maintained they will be. And those who participated in planning and making them will be empowered to build more in the future.

One way to build 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 may build relationships. Anna Heringer, the architect of the Handmade School in Bangladesh (shown on page 37), started the building project

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by working with local craftsmen. One craftsman said: “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.” 27 Designers should desire to learn from national craftsmen and the building clients.

Right: This Cameroonian building is both modern and traditional.

FORM FOLLOWS FUNCTION
This famous slogan has been a driving force in design in the industrialized world for more than a century. It has been so popular because it expresses a basic assumption of many western cultures. As building designers we seek to understand what functions will take place, and develop separate shaped areas appropriate for them.

In vernacular buildings form does follow function- but the important functions may be not activities, but social exchanges or markers of status. ‘Historically, spaces in vernacular house types rarely assumed function names. Actions and functions in the building were linked not to specific rooms... as much as to specific attributes... fireplace, type of window, doors...’ 28 Rooms or interior open spaces in buildings in many regions today are still rarely designated for a single function. In Indian houses kitchen activities spill over into the courtyard in the late morning, and in the afternoon other household chores. Cooking moves in the winter to an upper terrace, that serves as a sleeping platform in summer. 29 Our orientation to rooms that are dedicated to a single function may be at odds with the frame of reference of those we are trying to build for.

Another important cultural divide is whether cultures define self-worth by achievement (function) or by status or social role. These very different orientations may motivate different room designs. 30 In the efficient western office the worker often faces away from the door. Greeting and interchanges between people are more important in Asian offices where no-one sits with their back towards an entrance.

Much of how we think about buildings comes from culturally shaped presuppositions. Site planners and designers working across cultural lines should try to understand the reasons behind even simple conventions.


29 Schoenauer, Norbert, (2000) 6,000 Years of Housing, page 182-3

CULTURAL BUILDING FORMS

Traditional Western-derived building design often emphasizes visual effect over climatic adaptation or social function. Classical symmetrical axial layouts, and Romantic or Modern asymmetrical arrangements all aim for a pleasing visual composition. In many places traditional buildings and city layouts are fine-tuned to the culture and the climate in sophisticated ways quite different from those in the so-called developed countries.

Traditional buildings in many parts of the world are quite different from the west’s urban rowhouses or detached suburban homes. A courtyard or elevated dwelling compound often houses extended families in climatic comfort and privacy. Separate buildings on the sides of the site are connected by a privacy wall. The longer dimension of the site and the directions of larger buildings take advantage of desired winds or shade or sunlight. Ensuring comfort by climate-responsive locations is often a highly developed skill in vernacular buildings.

Twisted, dense street networks also can provide important functions. In some places they provide protection from dusty winds. In others, an emphasis on developing a harmony with the existing land forms gives variety to cities with a geometric organization inspired by a strong ruler. Symmetrical designs sometimes occur, but building and street layouts first respond to social realities before visual ornament. A city’s streets may seem random, but often form a very sophisticated sequence of public, semipublic, and semiprivate spaces, interspersed with small squares that function as local neighborhood territory.

In the hot and dry climate of the African savannah regions traditional compact closed villages of multi-story buildings provided both protection from marauders and climate. Shade is provided by tall buildings in the narrow lanes and squares and [a] barrier offered to sand and dust-carrying winds by the winding layout of the narrow routes. Views are important, but involve framed glimpses that beckon into spaces beyond.

In hot and humid regions buildings were more often spaced out. In the mountains of West Cameroon compounds seemed informal, but the approach route always led through a belt of crops directly to a more public entrance courtyard, ‘guarded’ by the house of the head of the family. Passageways led between the corners of the dwelling houses to private courtyards screened on three sides by lightweight woven fencing.

In Thailand, raised houses formed an extended-family compound. Instead of walls or fencing, elevation creates the important separation from public space. Separate houses were located around a central communal pavilion without walls. Spaces between the houses allowed access and ventilation without direct axial views into the central family space.

Arabic-influenced cities surrounded their most important public buildings with a dense network of lanes containing shops and workshops. The mosque would be located at the intersection of two major traffic routes, but with only the mosques’ minarets or dome showing from a distance. Cities were ‘composed of squares and rectangles that can be added to indefinitely; symmetry and finality in town-planning were avoided.

31 Lauber page 62

32 Lauber page 43

33 Lauber page 59
as a challenge to that perfection which only Allah could attain'.

Checkerboard city blocks are antithetical to the traditional cluster concept of closed precinct neighborhoods based on social affinities, not economic level.

Entrances to compounds also reveal much about the people who live or work there. Classical western design loves axial views into the center of the building and site from an impressive central gate. Most courtyard homes around the world turn blank walls or screened openings to the street. In some dense cities, separate shops form a street wall between simple gates into private family spaces beyond.

The primary entrance to most Asian building compounds is from a side or corner, which faces in an auspicious (and usually climatically superior) direction. The entry door faces a blank wall, which is called a ‘spirit wall’.

In many urban Chinese courtyard houses one enters the gate, and turns into an entrance porch or hall. Only if one is greeted and welcomed inside will the axial view down the center of the garden be revealed. The process of entering involves many layers of meaning which emphasize both privacy and formal greeting, whether an individual believes it shields the family from evil spirits or not.

An Indian house entrance may have a privacy wall blocking a direct view in, but opens into a spacious room that serves as a transitional area and a sitting room. From the far end of this room, views may open up to a courtyard, and porches, balconies, and rooms beyond. Some of the major spaces face across this axis of entry, de-emphasizing the actions of entry and leaving.

African courtyard houses of Arabic influence also have privacy walls at the entrance. Regular internal spaces surround one or more courtyards with central water features. There may be two main axes of the house, one for public and one for private regions, but they usually are not that of the entry.

Among sub-Saharan Africa’s tribal villages, walled compounds are common. These often appear to have randomly placed separate buildings. Obvious symmetry is not important, but because much daily life occurs in the open air, buildings define comfortable and appropriate spaces for outdoor work that reflect both physical needs and social position. The entrance to these African compounds appears somewhat random, often through a small entry space. Although the outside doorway or gate may directly face the opening into the private family area, it is never located opposite another family’s entrance, extending privacy to neighbors.

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34 Jellicoe, Geoffrey and Susan (1975) The Landscape of Man page 33
35 Schoenauer, page 150
36 Knapp, Ronald G., Chinese Houses, Tuttle, Singapore, 2005, page
37 Schoenauer, page 182-3
38 Schoenauer, page 150
In Latin America a short covered passage connects the street entrance to the private courtyard. Privacy may be provided by wooden shutters in the double entry doors. The kitchen door is often located on axis across the courtyard to allow easy surveillance, but it does not align with the most important rooms of the house.  

CHANGING CULTURES  
Old buildings were cheap and didn’t last long. But they often reflected a deep-seated non-crisis orientation of a culture: ‘When it breaks we fix it’. These ‘primitive’ buildings responded to the weather, the economy, and the people in many sophisticated ways. The relationships and work patterns of the people lasted longer than their buildings. The process of making buildings often taught young people how to behave and to understand their world. It was a basic personal skill, so houses seemed like a part of their own bodies.

Today people move, get different jobs, but expect houses to last. Few know how to build, many can’t afford the kind of houses they want. People spend more time inside, have more belongings, and need to lock up. Massive social and economic changes have occurred while first political and then cultural colonization have left people without much understanding of their historic culture. If no viable local building styles seem to exist, it is still important to mention that they may be there, or emerging, and should be looked for.

In many city areas people of the tropics still spend a lot of time outside and want porches or pavilions that shade and shelter them from rain. In the countryside people still prefer to cook over wood fires, outside where it is cooler. They can afford their fuel and it works well for traditional recipes. Any designer with Western training may unconsciously overemphasize interior spaces.

Separate buildings instead of rooms are the standard in some areas, sometimes for climatic as well as social reasons. Separate wash buildings as well as toilets keep moisture and heat out of the main building. Squat toilets may be preferred in separate latrines, using more appropriate amounts of water than the flush toilet. Sometimes it takes work and creativity to discover valid cultural reasons for present day forms.

The bottom line is that all buildings also have meanings. In some areas little steep roofs are only used on buildings of powerful men. Among some people piers on courtyard walls symbolize protection because they
look like the ancient shrines called 'pillars of the dead' and the pinnacled mosques. To some, round buildings feel more like home, and remind them of their village background. Others prefer rectangular houses because they are the better ‘rich people’s’ houses.

The only way to find out the meaning of buildings is to ask locals. Show photos of traditional building details or styles. Ask what these mean, and how these buildings make them feel. Ask about entrances and privacy, opinions of ornament and materials.

The social structures of people in tropical areas will be either expressed in their buildings or hampered by them. It is easy to overlook the functions of space that are important in a different culture. Even if one desires to make a different statement from the one which the customary building makes, to inject a countercultural reflection of our Lord’s values, only the people of that culture will be able to decide what that statement should be.

**HIDDEN COSTS**

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. 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.

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?

Buildings should still be built as simply as possible 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 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.”

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

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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 working together like this on buildings would be a good thing.

Buildings in tropical areas can be built well and beautifully and without great cost. Some new ideas can be combined with ancient traditions of responding to weather. New buildings can shelter people in ways that they need without abandoning all the beauty of their traditional building shapes. Asking about the past can enrich the future.

We want to build structures that will honor our Lord, and somehow in each local dialect, say:

‘You are welcome. Enter. Feel at home. Become all that the Creator desires you to be.’

Above: Traditional decoration in Cameroon.
Chapter 5: Choosing Building Materials

LIGHTWEIGHT MATERIALS

Next to cost and permanence, one of the most important goals for humid climates is to build of lightweight materials that don’t store much heat.\(^\text{43}\)

Traditional building materials like wood, grass, palm, and bamboo are cheaper as well as cooler than masonry. But because they rot easily or are eaten by insects, they are seldom used. They could be used more often above the ground level.

Even located on upper levels, wood or bamboo posts covered by wood boards or sheetrock may rot too quickly because they never can really dry out. A less vulnerable construction technique for wood or bamboo uses a single layer of wall with exposed structure.

Some traditional and some new masonry materials are lighter and cooler than stone or concrete. Compressed earth block, open bond brick, and adobe hold less heat and suffer from less condensation damage than concrete block. And a new combination of older materials called light earth may combine the permanence of masonry with the light, cool thermal performance of traditional buildings.

BAMBOO

Bamboo is cheap since it grows quickly, being ready for building after 3-6 years. Bamboo roof rafters can also span much further than wood. If bamboo is dried well and then given a simple smoke treatment it can last a very long time as long as it is not rained on.

Bamboo works best inside, or under a wide roof overhang. It can easily be bolted if the inside is packed with a little concrete and let dry before the bolt is tightened all the way.

\(^\text{43}\) Koch-Nielsen, p. 112
WOOD
Even if wood is not chosen for structure or walls it can be used for breathable wooden louvers, shutters, or railings. Ask older people in the villages which local woods are more durable. Wood can also be smoked to discourage termites and mold.

Right: Breezy wood louvers for walls in a Yaounde, Cameroon church.

Below: Wood louvers define a breezeway.

Wood may be available in unusual forms. Waste shipping pallets have been used to produce shutters and low-cost roof truss structures. Small diameter wooden poles may also be freely available or less expensive because they do not require milling. They are stronger than milled wood per cross-section area, and can be more resistant to rotting and termites.

Other lightweight materials include reeds and grass, and wood as basket work. They can be used for upper stories or to screen large openings in exterior walls.

Right: Wood basket-weave shutters.

ROOFS AND INSULATION
Traditional reed thatched roofs are cool, quiet, and last up to 40 years. Some people have begun making thatch in modular units assembled on the ground, which are more easily installed. This might be best for only moderately humid areas, since moldy thatch can cause health problems.

Many people prefer galvanized metal roofs because they won’t burn and keep rain out more completely for longer. Metal roofs are relatively inexpensive although they can be very noisy in a heavy rain and hot in sunny conditions. White, if available, is much cooler.

Natural materials can be used inside buildings to provide sound or heat insulation. Sea grass, rice hulls, and coconut fibers don’t absorb much humidity. Sea grass is a type of seaweed that is harvested from beaches where it washes up and can be made into batts or pellets. It’s natural high salt content is a fire retardant. Rice hulls, left over from growing rice to eat, also don’t burn very easily, and have an R-value of around 3 per

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Sea grass or rice hulls can be used in breathable bags. Coconut fibers are sometimes made into thick mats, but need to be treated with a simple fire retardant like borate.

Right: Rice hulls in bags to insulate, with woven mats hung below bags for ceiling.

Any of these may work well under a metal roof if rodents or insects are not too much of a problem. Vetiver grasses, that grow in many regions, are fragrant and somewhat insect and rodent repellant. It may be helpful to you to find out if any local people use dried vetiver for thatch or for insulating matting below the ceiling.

Wire or plastic mesh can be fastened between collar ties or under roof trusses to hold insulation in bags. Woven grass mats or fabric fastened below them would make an inexpensive, attractive ceiling. But the simplest way to keep rooms cool and quiet may be to bind reeds with wire or cord into thick flexible batts to use as an insulating ceiling that can be replaced periodically.

COMPARING MASONRY FOR COMFORT

People want houses that last, don't burn, and keeps insects, rodents, and thieves out. Stone and brick walls have been used for beautiful buildings worldwide. Many people build with concrete now, because these buildings seem modern, last a long time, and are cheaper and easier to build than brick or stone. They keep mosquitoes out better than wood buildings. For some people “Their dream house is of concrete, like the houses they see belonging to the rich. Even if they know they will sacrifice comfort and coolness during the day, or that they will never be able to afford that dream house, they do not care. They will wait for the day when they can have a 'real house'...”

The majority of permanent buildings throughout history have been built of earth. It doesn't burn, keeps pests and thieves out, is inexpensive and widely available. This flexible and beautiful material is being revived and becoming more generally accepted partly because of its excellent thermal performance.

A new office in Segou, Mali of earth.

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There are many ways to use earth. Buildings can be made of raw unbaked earth alone in massive cob walls or in individual mud blocks (also called adobe). Plain earth or earth with a little lime or cement or bitumen can be used in rammed earth walls or compressed earth blocks (CEBs). Or earth can be poured into sandbags and stacked for earthbag walls, in what has been called the cheapest building method on earth.

Earth buildings last well when maintained. Outside walls of raw earth that get rained on should be re-plastered every few years unless they have special coatings. Siloxane is a new water-repellant that allows unstabilized earth walls to 'breathe' and dry out. It is absorbed into earth or lime plaster, so that it does not wear off quickly.

Raw earth buildings need to be protected from rain and flooding to work well in humid climates. A good roof and a dry base of stone or cement stucco on gravel bags, or concrete are very important. Unstabilized earth construction must be raised 50 cm or more above the ground in rainy areas. A good vapor barrier must be placed between all unstabilized earth and concrete surfaces.

Many people don't realize that raw earth buildings are healthier than concrete in high humidity. They never absorb enough water to let mold grow on them like concrete does. The most dampness they absorb from the air (5-7% by weight) is not enough to let insects or mold grow (which need between 14 and 20%). Very humid air is near its dew-point. Every time that damp air warms up just a little more than a building, moisture in it condenses on the slightly cooler surface. Heavy concrete walls in very humid areas become frequently damp from condensation, causing algae or mold growth.

Many countries are beginning to include earth buildings in their building codes. Unfortunately, some codes apply unnecessary rules and make buildings more expensive without being safer. If your area does not have a code, you are free to build strong but cheaply. The earth buildings common in wet countries, like the UK and Germany, have lasted hundreds of years without following building codes.

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47 Minke, 2006, pp. 14-15

48 New Zealand and the Ivory Coast, among others, as well as states like New Mexico in the southwestern US.
Earth buildings can be finished with traditional windows and doors. Although they may feel much more comfortable, modern earth buildings may not look any different from structures built of brick or concrete or stone.

Hassan Fathy tested equally sized buildings in Cairo in 1964. On a March day the temperature varied between 12 and 28 C. A building of 50 cm thick mud block with a vaulted mud block roof only stayed a comfortable 21 to 23 C inside. A similar building of 10 cm thick precast concrete walls and roof became 9 C hotter inside than out. Overall it was within the human comfort temperature range for only 5 hours out of 24. Because the mud block held more heat, it warmed up slowly in the morning, and cooled off slowly at night. It also insulated much better than the concrete, and may have reflected more sunlight (depending on surface finish).

Materials work well in hot, humid weather if they don’t hold much heat and are well insulated. Fathy’s type of heavy masonry building receives too much condensation for humid inland regions of the tropics. CEBs have become widely popular because their lighter construction holds less heat than fired bricks and concrete CMUs, while also insulating the building better from outside temperature changes. This results in a cooler daytime temperature as well as less condensation during the early morning hours.

One alternative can make earth walls hold about as little heat as CEBs, but be much better insulated. This is when light gravels (naturally occurring volcanic scoria) are mixed with earth. This material, called light earth, combined with the low cost of earthbag construction techniques, may be the best material for humid tropics.

How common building materials compare at holding heat, insulating, and cost:

<table>
<thead>
<tr>
<th>Material/ thickness</th>
<th>Hold less heat (btu/in/°F)</th>
<th>Reflects Sunlight</th>
<th>Insulates better (R val.)</th>
<th>Costs Less</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid poured concrete- 15cm</td>
<td>2.7 times better (15)</td>
<td>Smooth: 35%</td>
<td>Insulates the worst (0.5)</td>
<td>Greatly &gt; materials + skilled labor</td>
</tr>
<tr>
<td>Fired bricks- rat trap 20 cm</td>
<td>4 times better (10)</td>
<td>Regular dark: 20%</td>
<td>2.8 times better (1.4)</td>
<td>&gt; materials + mason</td>
</tr>
<tr>
<td>Hollow conc. block- 20cm</td>
<td>5 times better (8)</td>
<td>Rough stucco: 20%</td>
<td>2.2 times better (1.1)</td>
<td>Standard with mason</td>
</tr>
<tr>
<td>CEB- 20cm</td>
<td>2.4 times better (17)</td>
<td>Light: 40%</td>
<td>4.4 times better (2.2)</td>
<td>&lt;materials + mason</td>
</tr>
<tr>
<td>Mud block or cob- 40cm</td>
<td>1.2 times better (33)</td>
<td>Light plaster: 40%+</td>
<td>8.8 times better (4.4)</td>
<td>33% materials? + mason</td>
</tr>
<tr>
<td>Earth in earthbag- 48 cm</td>
<td>Holds most heat- (40)</td>
<td>Light plaster: 40%+</td>
<td>10 times better (5.3)</td>
<td>Cheapest: site mat’ls + unskilled labor</td>
</tr>
<tr>
<td>Light earth in earthbag – 48cm</td>
<td>2.1 or more times better (19)</td>
<td>Light plaster: 40%+</td>
<td>12 + times better (6+)</td>
<td>Cheap: mostly site mat’ls + unskilled labor</td>
</tr>
</tbody>
</table>


50 This table has been assembled from data in Stay Cool, Building with Earth, and the Passive Solar Energy Book
Only bare CEBs will perform basically according to this table. These figures are for the basic materials, not including reinforcement or plasters. Clay plasters needed on the exterior of mud block and both sides of earthbag do not hold much heat. Cement stucco usually applied to hollow concrete block (CMU) holds a little more. Since CMU walls are sometimes installed partially filled with cement and rebar, or more often as infill with solid concrete bond beams and posts, they may hold much more heat than these figures indicate.

An actual test of small comparison buildings should be made in the humid tropics, similar to Fathy’s test. Interior air temperatures could be compared to wall surface temperatures. Some indication of the amount of condensation received would be extremely helpful. The performance of different surface finishes should also be made for condensation in interiors and reflectance of sunlight on exterior walls.

The costs of earth building materials are very low. A single story school built in the Philippines using earthbag with a reinforced cement vaulted roof cost 40% of the standard building costs for CMUs. A 100 square meter school built in 2010 in Haiti cost less than $20,000 despite Haiti’s inflated building materials and a site with poor soil for building.

Stabilized earth materials’ costs are controlled mostly by the cost of the stabilizer. Although earth construction of cement stabilized mud block or CEB use only 20% as much Portland cement as poured concrete and CMUs, they still use about 5% cement by volume. For buildings with porches or significant roof overhangs, exterior walls of pure unstabilized earth are both practical and inexpensive.

**EARTHBAG**

Earthbags are a simpler way to build with earth, using the strength of woven fabric bags while the earth dries. Because it is tamped, it has some of the properties of rammed earth without the need for heavy forms. Earthbag is finished with a plaster layer of earth materials and/ or cement or lime.

Right: Earthbags are stacked and tamped.

Earthbag building works well with a greater range of soils than most other earth techniques, between 5% and 30% clay. Earthbags can also be built of sand, gravel, or soil without clay, if they use some bamboo, wood, or steel reinforcement, or have a plaster of cement stucco, techniques which are better in dry regions. It can be reinforced enough to perform well even in high seismic risk regions.

Brick, concrete block, poured concrete, and earth blocks are much more expensive than earthbag. They also require more accurate mixes of materials and better trained labor than earthbag. Because earthbag is placed

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51 Built by Abakada at Barangay, Phillipines from [www.earthbagbuilding.com/projects/school.htm](http://www.earthbagbuilding.com/projects/school.htm)

in large units (standard bags are 48x60x15), construction proceeds quickly. Three untrained people take about an hour to lay one square meter of wall.  

**BRICK**

Common fired bricks are the most well-known earth material. They can make versatile thin walls. Solid brick works best where walls are shaded by plants or other buildings, because they do not insulate well. Rat trap bond stands bricks on edge around a hollow center. It uses 25% more brick than a solid single layer wall, but because it creates a hollow wall, in parts of India it is known to keep building temperatures inside \(58^\circ\text{C}\) lower than outside.  

Far left: A jali pattern in brick.  
Left: A rat-trap bond brick technique.  
Brick can be formed into beautiful openwork "jali", as Sri Laurie Baker created in India. Jali lets in subdued light, allows ventilation and glimpses out, but keeps the inside private and secure. Small scale jali keep driving rain out, but may cost only 10% as much as a window.

Low-fired bricks absorb more water than common fired brick. They are cheap, often fired with waste rice hulls. They can be used for inside walls, or outside with special finish coats.

**COMPRESSED EARTH BLOCK**

Compressed earth blocks (CEBs) use earth with about 5-10% clay. They are usually 2.5 times thicker than fired bricks, but they insulate better and moderate humidity better than fired bricks. These smaller blocks require more time for construction than the larger concrete CMUs.

Right: A school in Burkina Faso.

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53 More information on building with earthbags for humid regions is available at [www.earthbagbuilding.com/pdf/earthbagbuilding2.pdf](http://www.earthbagbuilding.com/pdf/earthbagbuilding2.pdf)


Because CEBs are less expensive than fired brick, and can be produced by individuals with simple equipment, these blocks are improving living conditions in many countries. In humid regions they must be either stabilized or protected by a substantial roof overhang.

Right: A CEB press.

CEBs produced with bitumen or cement cost more than raw blocks. The quality of individual production should be pre-tested before use in exposed areas, because poorly stabilized CEBs can be damaged by absorbing too much moisture. Stabilized CEBs can be coated with cement plaster.

MUD BLOCK
Unbaked mud block (or adobe) is usually built by masons, but is twice as thick as CEB walls. It is inexpensive because it does not require fuel or sophisticated equipment.

Right: Bas relief and openwork in earth construction

Because of mud block's historic usage, basic rules of strength for unreinforced construction are well accepted for regions not subject to earthquake hazard. In regions with medium or high risk of earthquakes, some sort of reinforcement may be necessary. Mud block can be used there as infill between concrete posts. Historic structures of mud block have been built up to 8 stories. It is strongest if built of short wall segments that include piers or corners. Windows should be spaced at least 1m from corners, and 1m apart unless a pier is located between windows. Corbelled window openings can be built without lintels.

Right: Large windows with lintels can be used in earth buildings.
Far right: Piers between windows for wall strength.56

Mud block requires water resistant mud plaster on exterior walls that must be renewed every few years. Like all raw earth construction, mud block should not be covered with concrete stucco. The concrete retains too much moisture and will decay the mud block. This material is a good choice for interior walls and furnishings, especially in buildings where reduced humidity is needed to preserve materials, like museums, libraries, and

56 These are from Stout, Patti, 2008, Simple Earth Buildings for the Humid Tropics, available at www.earthbagbuilding.com/pdf/
computer centers. Mud block walls are easier to clean and still retain much of their humidity-modifying properties if finished with a lime-plaster or tiled surface, or coated with a natural oil finish.

**RAMMED EARTH / COB**

Solid earth can be rammed or built as cob. These are both difficult to build in wet climates because they dry slowly. Rammed earth walls need large forms to hold the earth in, are waterproof, and strong enough to build in multiple stories. Cob walls are traditional in many parts of Africa. They are built of hand sized loaves of mud, without forms. Since they must be thick to be strong they may receive more condensation than CEBs.

**COMPARING EARTH CONSTRUCTION PROCESSES**

Construction materials may be chosen because of the availability of related materials, supplies, tools, or skills. This chart may help to evaluate the different strengths and requirements of different construction processes using earth.57

<table>
<thead>
<tr>
<th></th>
<th>Earthbag</th>
<th>Adobe</th>
<th>Rammed Earth</th>
<th>Cob</th>
<th>CEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special curing process? (→ delays)</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Special soil mix?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Relatively fast?</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Expensive forms?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Expensive tools and equipment?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Water required?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Usually (minimal)</td>
</tr>
<tr>
<td>Work in the rain?</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Excessive handling of materials?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Owner builder friendly?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Easy to make curved walls?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Drones?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>High R-value?</td>
<td>Yes**</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Foundation required?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Earthquake/flood resistance?</td>
<td>Excellent</td>
<td>Poor</td>
<td>Fair</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Plaster required?</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Green = Favorable  Red = Not Favorable

* Assumes a suitable soil is used (=most soil types)
** Assumes bags are filled with scoria, pumice, etc. (=porous volcanic rock)

**CMU INFILL**

The most common solution for those with enough money in warm, humid areas is to use weak, hollow concrete masonry infill between poured concrete posts and beams. These buildings don't heat up as much as solid masonry, and if painted with waterproof paints the inside walls can be scrubbed. In the US and Europe

57 Chart by Owen Geiger of [www.earthbagbuilding.com](http://www.earthbagbuilding.com)
hollow CMUs are made strong enough for structural use, or poured solid with concrete. The lighter, weaker blocks available in hot regions, sometimes called sand cement blocks, are better at insulating.

Right: Pouring a concrete bond beam on a block wall.

Usually the blocks are built first by skilled masons, leaving gaps for columns. After the block work is done, forms are added and steel reinforced concrete columns and bond beams are poured. This can be very strong in areas subject to earthquakes.

Increasing prices of steel and concrete, and unreliable concrete supplies complicate this type of building. In Africa, South America and Asia cement may be too valuable a commodity for common use. In the US a laborer works about half an hour to earn a bag of cement. In other countries it may take a laborer 3 days or more to earn the same bag. It is common practice for workers to use less concrete in the mix, and save bags out to use at home or resell. Concrete may not be right for places where public officials expect gifts, workers often 'borrow' supplies, and people are accustomed to more forgiving rule-of-thumb type work than high precision measurement.

Maintenance costs of repainting and scrubbing interior walls need to be considered before building with concrete. Additional intangible costs will also include discomfort from hot buildings, belongings ruined by mold growth, and health damage from living with mold. Overall concrete buildings may not be the best choice for hot and humid climates.

Left: This reinforced earthbag school at Leogane, Haiti feels cool and comfortable during the hot days.
Chapter 1:  Introduction to Site Evaluation


Websites:
US Department of Agriculture Natural Resource Conservation Service: [http:soils.usa.gov](http:soils.usa.gov)

Colorado Geological Survey: [http://geosurvey.state.co.us](http://geosurvey.state.co.us) especially tabidid=35

Florida Department of Environmental Protection [www.dep.state.fl.us/geology/geologic topics/](http://www.dep.state.fl.us/geology/geologic topics/)

Chapter 2:  Shaping Buildings for Climate


Websites:
www.yourhome.gov/au/technical/fs44.html


www.lauriebaker.net/work/work/booklets-and-writing-by-laurie-baker.html

www.akdn.org/images/slideshows/home_3.jpg and

Information about the Grando School in Burkina Faso.

**Chapter 3: Building Across Cultures**


**Chapter 4: Choosing Materials**

Baker, Laurie. *Rural House Plans*. These and other booklets are available free at his website at [www.lauriebaker.net/work/work/booklets-and-writing-by-laurie-baker.html](http://www.lauriebaker.net/work/work/booklets-and-writing-by-laurie-baker.html)


Websites:

Builders Without Borders at www.builderswithoutborders.org/PUBLICATIONS/PUB6.htm

Earthbag Structures includes testing and examples of work around the world at www.EarthbagStructures.com.

EarthbagBuilding focuses on houses for the developed world, but has a lot of project information, blogs, and references.

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Thatch palace page 24

METI page 24

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