BUILDING NATURAL FIBER TUBE WALLS v.3.0

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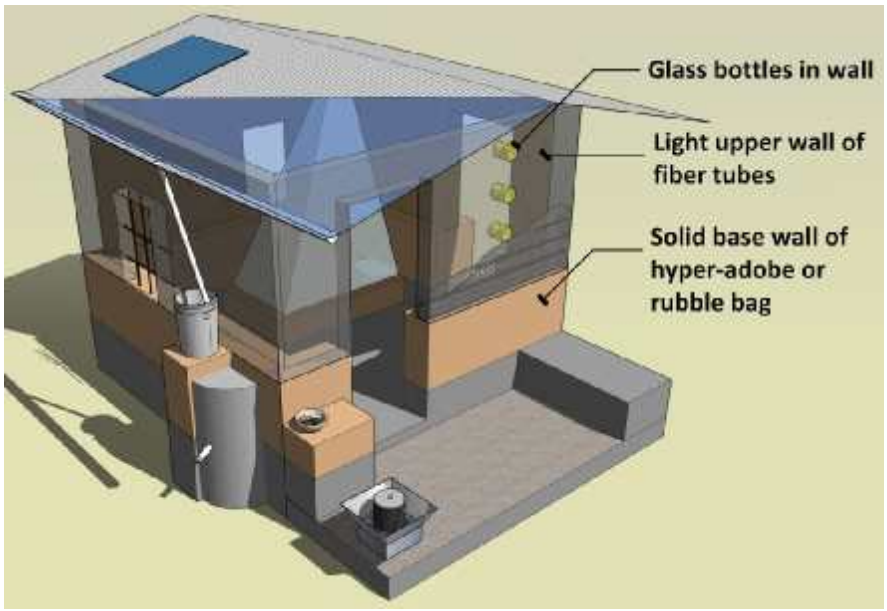
INTRODUCTION

"Low-cost… Self-built or self-improvable… Low-tech… Local materials… Greener than would otherwise be built… Replicable… where high-tech meets low-tech, low-cost-building efforts…"[i]



Mesh tube walls started when Jovoto posting this visionary statement by the Affordable Housing Institute defining a $300 house for the world's poor. Owen Geiger of the Natural Building Blog had discussed light natural walls and mesh tubes with Patti Stouter. He recommended that she enter a dual-material design that they had both been mulling over. Stouter's proposal (shown above) gained the popular vote in the June 2011 contest.

Mesh tube walls are a cross between two proven wall systems. Straw-bale is a flexible 45-60 cm (18-24") thick structural wall.[ii] Light clay (shown at right) is a highly insulating and mold-resistant 25 cm (10") thick wall infill material of straw or wood chips soaked in liquid clay.[iii]

Other techniques also contributed to the development of mesh tube construction. Hyper-adobe created by Brazilian engineer Pacheco made earthbag quicker and cheaper to build by using tubes of crocheted poly mesh instead of solid woven poly bags or tubes.[iv] Research by Thai engineers Thammanoon and Pichai demonstrated that bound tubes of vetiver grass with clay could create solid round-walled small buildings.

Plastic mesh tubing is manufactured for erosion control. These 'wattles' are filled with straw or wood chips and placed where they will intercept water eroding soil.[v]

Mesh tube's 18 cm (7") thick bearing walls benefit from the structural skin of mesh embedded in an earthen plaster. This new wall has some characteristics of insulation and some characteristics of thermal mass. Preliminary experiments indicated that natural fiber tube walls have a moderate compressive strength, strong enough for the single story structural walls of a small house supporting a light-weight roof in a region without snow.

If a place to build is available and some straw, clay, and lime, those most in need of housing can build. Patience is needed, but not great strength or complex training.

PROCESS

1 BASE 2 SEW 3 POUR 4 PLASTER

1 BASE WALL & ANCHOR LAYER

Mesh tube walls should be built on a water-resistant base wall that will add stiffness and resist mechanical damage. A masonry wall at least 18 cm (7") thick and 30-90 cm (12-36") high will do. In humid regions the base wall should extend up above the rain splash back level so that the wattle wall will not be frequently soaked.

The cheapest system (if gravel and cohesive soil are available) starts with gravel-filled or rubble-filled poly bags (gravel bags) and switches to cohesive soil in mesh tubes (also known as hyper-adobe). Poly bags for a 1 m (39") high base wall should be 38 cm (15") wide when empty. When filled and tamped they should make a wall 30 cm (12") thick.

The flexibility and tensile strength of these earthbag materials matches the mesh tube materials well. Information on earthbag building is available at www.BuildSimple.org. An introduction to hyper-adobe is also online at www.EarthbagBuilding.com. Base walls could also be built out of stabilized adobe or stabilized CEB (compressed earth block) courses supporting 'raw' earth adobe or CEB.

In seismic risk regions any masonry or earth base wall more than 60 cm (24") high should include horizontal reinforcement and be topped with some type of ring beam. If earthen base walls reach 1 m (39"), the 'stub' portions next to doors should also have added benches or piers to stiffen them, unless the door is less than 1.4 m (55") from a corner or intersecting wall.

Before the top layer of the base wall, lay strong poly cord or wire across the wall. Then lay the top layer. Lay long cord on top of the last layer of base material. This will be used to snug the fiber tubes and keep them firm and level.

For the anchor layer, fill a wattle tube with clay soil. Place it and tamp to level. Use the cord or wire ties to strap it firmly to the base wall. Tamp it lightly to level.

In seismic risk areas use rebar pins through the anchor layer to unite it to the earthbag layers below.

Scrape excess soil off the upper edges of the anchor layer to reveal the mesh. The first fiber tube layer will be sewn on to this anchor layer.

2 Fill & Sew

Fill

Wattle tubing must be stretched by hand. Pull it over a chute to make work on long sections easier. Cheap chutes made out of plastic or metal or modified plastic plant pots speed the process.

Stuff dry straw firmly into the tubes. Agricultural waste like rice straw or wheat straw works well, but any dry leaves can be used. Leaves from corn stalks are shown at right. Leaves of insect-repellant grass like vetiver will produce more termite-resistant walls. Dry sphagnum moss can also be used, or fibrous roots. Chopped stems could be used, but must be chopped very short.

Workers can hand fill tubes very firmly up to about 90 cm (30") maximum. For longer tubes use the head of a bedding fork or pitch fork. After a tube is filled 90 cm, insert the tines through the tube to hold the fibers tightly inside. Balance the tines on raised stones, and continue packing above.

As you walk the forks up the length of the tube it will allow consistent firm filling of tubes that span whole wall lengths. Tie off the ends when full.

Keep filled fiber tubes dry until you use them.

Assemble

A large needle used for finishing knitting is helpful.

Sew the first layer of fiber tubes with poly cord onto the anchor layer. Electrical pull line is one of the cheapest string to use.

Corners can stiffen walls if you alternate overlapping sides at corners.

Sew each additional layer carefully along both sides of the tubes and at all corner or pier overlaps. Check to make sure the wall is staying vertical.

Houses with rooms wider than 12' need walls that can hold up bigger roofs. Add some interior pole reinforcement or a bracing pier of earth or masonry.

Houses with many window openings will need small diameter poles or splints of bamboo sewn into the interior surface of the short sections of walls. These can extend to floor level to be tied to the base wall, and sewn into the anchor layer.

If rebar is cheaper than poles, use a 30 cm (12") wide base layer of earthbag and hammer vertical rebar into the wall at the edge of the tubes. Sew around the rebar to attach well to the mesh of the tubes. This will be strengthened in the plaster.

3 POUR & CHINK

POUR

Make sure your tube layers are horizontal. Run the cord from below the anchor layer up over the fiber tubes. Use a trucker's hitch to pull it tight and then tie it.

Also check that your walls are vertical. Brace them if needed before starting to wet them with clay.

Pour a liquid slip made of strong clay soaked in water onto each fiber tube layer or onto the outside of several layers.

Knead the liquid clay into the mesh tubes as you pour it on. But only poke or knead the surface for a few minutes.

The clay begins to harden within 15 or 20 minutes. If disturbed again, the surface will be softer and may not hold the plaster firmly.

If one clean layer is always left on top, it is easy to sew in more layers. If most of the walls are wetted up quickly, there is less chance of the straw being damaged by rain.

It is best to keep a strip of tarp on top of the walls if there is a chance of rain. A little dampness on the straw-clay will not damage it, since the clay has natural mold-resistant properties. Try not to let a heavy driving rain wash off all the clay and leave the straw soaked. Reapply the clay as soon as possible.

Also be sure not to wrap a waterproof tarp close around a wet fiber tube wall. The wall needs ventilation to dry in damp climates without any surface mold.

With a larger work team, each layer can be soaked from the top. Additional workers must follow quickly to sew a dry layer onto the fully soaked wattle more easily before the 'casted' clay sets up.

The liquid clay must pour like cream. It should cling to your hand and not run off. If you must mix it by hand, use a cooking whisk. A paint stirrer on a power tool softens all the lumps quickly.

The kind of clay used for pottery works very well. Sometimes

brick manufacturers have sifted powdered clay that is too fine for their bricks but works well for buildings.

If natural stony clay soils are available, cover them with water to soak. The next day, stir and dissolve all lumps. Let the mix sit for 15- 30 minutes. Then gently pour the liquid clay off the top of the bucket. Don't use the sand and silt or gravel left in the bottom of the bucket. It will look like a paste or porridge as you are pouring.

If modest sized sections of fiber tube are wetted up at one time, no bracing will be needed. Up to 1.2 m (4') long by 90 cm (30") high can be wetted without making the wall to sag. Alternate sections can be wetted on consecutive days.

CHINK

While the wattles are damp, work infill chink plaster rich with straw into the nooks on both sides to help stiffen the wall. This plaster should be rich in clay and sticky, since it will strengthen the wall.

Check for plumb and add temporary bracing as needed.

A fiber tube wall takes between 8 and 12 hours to stiffen up completely. As the straw and clay dries it can shrink about 8-12% in height. The finished height of each layer will be 11.5-13 cm (4.5-5 inches). If you pour the clay into 3- 4 courses at a time as you build, the shrinkage will take place gradually.

Do not staple each section of mesh tightly to a wood door or window frame until it has had clay poured on and dried completely. Finish the section above the lintel after the walls below appear dry on the outside. Or use wedges above a doorway, and remove them as the wall dries.

Embed vertical reinforcing in fiber mesh walls for more strength. Building a wood framework and inserting fiber mesh tubes will result in work to fill gaps left as the straw and clay shrinks.

4 PLASTER

The next layer of plaster can be a more sandy clay soil with some straw. Fill any depressions and level the wall.

When the plaster and wall feels firm and almost dry to the touch, do a finish layer of lime plaster on the exterior. Interior finishes should be delayed until the interior of the fiber tubes have dried completely. Interior wearing surfaces can be protected with lime wash coatings, or clay paint.

In humid climates the best traditional exterior finish is a thin layer of lime plaster. Lime swells and shrinks at the same rate as earth, so a thin layer will be stable. Any cracks that develop in lime plaster can be patched. The surface is maintained by painting every 4- 5 years with a thin limewash made of lime and water 1:10. This bonds with the existing surface and can fill cracks.

An illustrated how-to guide for lime plaster is free on the www.BuildSimple.org website (See the BSI resources page for a French version).

Lime has been the traditional material throughout the mediterannean and Europe. It creates a brilliant white surface that is mold-free and germ-resistant.

Manufacturing lime requires only a fraction of the energy needed to produce Portland cement. These materials also continue to harden by drawing carbon dioxide out of the atmosphere.

Below: A rich lime finish on a mesh tube wall.

Tests are needed to check whether any stabilized earth or lime, cement and sand plaster (1:1:6) can perform well on fiber tube walls. They may need a much thicker plaster coat to prevent cracking, because Portland cement does not shrink and swell in a compatible way with earthen walls. Hybrid coatings that coat earthen plaster with sealants like latex or siloxane[vi] may be more successful. They can seal the exterior but allow the earthen plaster to dry thoroughly between wettings.

Cement stucco should not be used over straw-clay or any type of fiber mesh because it attracts moisture and will not allow the organic fibers in the wall to dry.

One possible alternative for an exterior finish coat would be to paint a Magnesium oxide derived cement or plaster (such as Grancrete[vii]) in a slurry on the dried wall surfaces. Because this material bonds well with organic fibers, the surface of the nook plaster should be very straw-rich with just enough clay to hold it in place.

SUITABILITY

Mesh tube walls can be built by women, the elderly, or handicapped workers because it is much lighter work than building with earthbags or other masonry. Fiber tubes are a good type of earthen construction for areas with heavy (even expansive) clay soils. It is also an economical way to build with earth in areas of shallow, stony soils that have pockets of strong clay.

In tropical regions with intense termite problems, vetiver straw is recommended, and the roof and plaster must be well-maintained. Termites seek out damp, decaying materials, so a wall that is kept dry will not be attacked as intensely as a wall that is often damp. Vetiver's natural oils both repel termites and are mildly toxic to them[viii].

Wherever termites are a major problem in tropical regions, planting Vetiver grass plants at the base of the walls will help to deter termites and prevent soil erosion.

Fiber mesh tube walls are moderate weight with high shear strength relative to its weight. If a strong wood bond beam tops well-spaced window and door openings, the walls of a small building should be resistant to damage in earthquakes.

Light clay infill walls can reach R-values of 1.6- 2 per inch. Fiber tube is a denser material that combines milder insulation values with some thermal mass. AN 18 cm (7") thick wall has been tested at approximately R-3. If tubes are soaked with clay before placing the insulation value will probably be somewhat lower.

Fiber mesh tube walls can offer some thermal mass characteristics to increase comfort in climates where daily temperatures fluctuate above and below human comfort levels.

This technique is best used for exterior walls in hot, warm, or moderately cool climates. It can be used for non-structural interior walls in regions that experience snow, but for exterior walls more insulation must be added.

Mesh tube may be ideal for emergency shelters because it does not create a heavy structure that will be difficult to remove in the future. Characteristically refugee camps offer 'temporary' shelters that on average are used for more than 10 years. Bare sewn fiber tubes can be termporary insulation for a tent. But if residents have access to adequate amounts of earthen plaster and clay for slip, and adequate roofing material, they can make these temporary structures solid and keep them serviceable over the course of a decade.

Mesh tube walls may also be helpful as self-help additions to masonry buildings in many regions. Its light weight will not destabilize existing structures if earthquakes occur. If Magnesium oxide-based plaster like Grancrete is available, straw wattle could even be used to form corbelled hip roofs of small additions.

ECONOMICS

Housing that will be helpful for the poor or aid workers in the developing world must be inexpensive and use available materials. Cost is critical for those needing shelter.

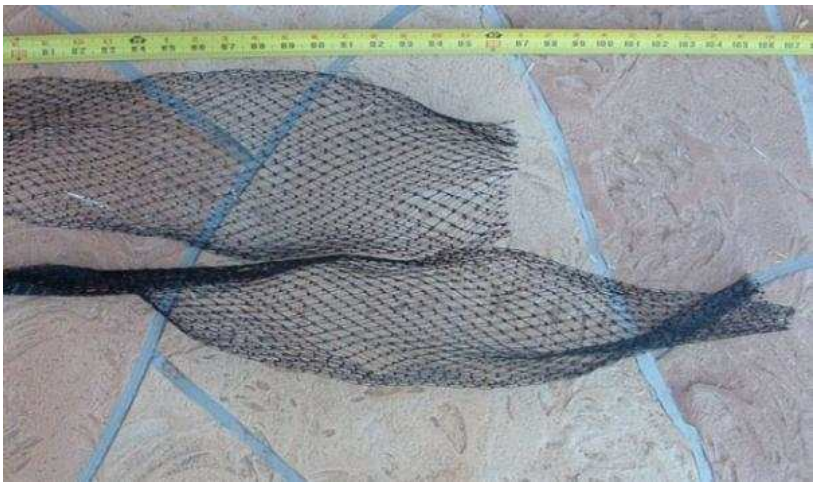
In some regions soil and straw may be available for little cost or by bartering. If appropriate soil is available onsite, laborers or a backhoe will be needed to dig it. The costs that follow reflect paying to purchase soil from a supply yard.

Erosion control wattles are common in the developed world, and this mesh used to make a mesh tube wall is relatively lightweight. Until mesh is sold for building purposes where needed, aid workers could bring mesh into the country in their luggage.

The first demonstration structure was built in Albuquerque, NM. This demonstration bench was an L-shape with earthbag piers to stabilize the 'stub' wall ends. A building of 4 walls would not require piers, so the materials and costs from the fiber tube portion of the project have been extrapolated to estimate costs and time for a small building.

ECONOMIES OF SCALE

All of the manufactured supplies for mesh tube construction can be purchased for greatly reduced prices in larger batches. The wattle net tube used is a nominal 8"/ 20 cm diameter (MN3-7WA8) purchased from MasterNet Ltd of Canada[ix]. Shipping a single roll (3000 feet/ 914 m) to New Mexico cost almost as much as purchasing the mesh. An NGO or business or cooperative group that ordered a pallet of 12 rolls may find the mesh nearer to 16.4 cents per m (5 per foot) instead of the 29 cents per m (9 per ft) reflected in this quote. If it proves to be strong enough, a



smaller 15 cm (6") diameter mesh would cost 16.4 cents per m (5 cents per foot) by the single roll and much less in larger orders.

Costs shown below are current US dollar values local to the southwest. Materials that may be free on-site are shown in parentheses.

SMALL HOUSE MATERIALS COST 10 M² (108 SF)

This estimate is for the walls of a 2.7 x 3.7 m (9' x 12') single story building planned for a non-hazardous location. Costs are listed separately for the 60 cm (2') high base wall of earthbag (with a 15 (6") cm deep foundation), and a 1.8 m (6') high upper wall of fiber mesh tube.

FIBER TUBE UPPER WALL:

$90	304 m (1000')	8"/ 25 cm diameter plastic wattle mesh
($105)	15 bales	Straw (2/3 to fill tubes and 1/3 for plaster)
($40)	0.2 m³ (7 cf)	Clay for slip used to wet walls
($20)	1/4 m³ (1/3 cy)	Clayey soil for chinking and smoothing walls
$48	22 kg (6 bags 50#)	Powdered hydrated lime for plaster
$4	22 kg (½ bag 50#)	" for 2 coats interior lime wash[x]
($20)	0.6 m³ (3/4 cy)	Sand for lime plaster
$10	3 small packages	Lightweight poly twine for sewing
$20	3 small packages	Poly cord for strapping
$14	180 m (600')	18 ga. galvanized wire to attach bond beam
($20)	four 7 cm x 3.7 m (3" x 12')	Wood pole or latilla for bond beam

($186)- $391 SUBTOTAL FIBER TUBE UPPER WALL

If more than 2 small windows are needed per wall, add costs for 2-5 cm (1-2") diameter poles or bamboo splints to stiffen the wall between windows.

HYPER-ADOBE BASE WALL:

$12	100'/ 30 m	8"/ 25 cm diameter plastic wattle mesh
$15	1 cy/ 0.8 m³	Gravel for wattle foundation
($24)	120	15" x 27" poly bags for earthbag base wall
$20	400 lf/ 120 m	Barbed wire for earthbag base wall[xi]
($40)	4 cy/ 3 m³	Cohesive soil for tube walls
$22	2- 90#/ 40 kg bags	Portland cement for stucco on base wall
$20	1/3 cy/ 1/4 m³	Sand for cement stucco

($86)- $150 SUBTOTAL HYPER-ADOBE BASE WALL

($272)- $541 TOTAL MATERIALS FOR WALLS

SMALL HOUSE LABOR TIME

These estimates assume earth and straw materials are easy to prepare and that scaffolding or ladders are available. Soils should be piled near the walls and a tarp available. Stony soils or sand needing screening will increase building and finishing times.

These estimates are for handy amateurs. Professional builders experienced with these materials should be able to build in less time. Strong workers will especially speed base wall construction. Careful workers can create smoother walls that will save time plastering.

Building Hyper-adobe base wall: 1/2 week for 2 people
Stuccoing exterior of base wall: 1.5- 2 days for 1 person
Building Mesh Tube upper wall: 2- 3 weeks for 2 people
Infill plaster interior and exterior: 2 weeks for 1 person
Lime plastering exterior upper wall: 1- 1.5 weeks for 1 person
2 WORKERS SHOULD TAKE 3- 4 WEEKS TO BUILD A HOUSE

SMALL SHELTER MATERIALS COST 7.4 M² (80 SF)

Unfortunately many emergency shelters become informal, long-term housing. The sheltered inhabitants are subject to heat or cold, thievery, and physical attacks through flimsy walls. A system for residents to build fiber tube walls could prevent a wide range of suffering as well as the resultant social ills that result from traumatized individuals.

This 2.4 x 3 m (8' x 10') shelter with walls of 2.1 m (7') average height, built out of thinner 15 cm (6") diameter tubes. The walls could be built without stucco on a 30 cm (12") high base wall and with only lime wash on the exterior. If a strong clay is used, the wood bond beam may not be needed. A tarp roof with bamboo or pole rafters could also cut costs.

($80)- $236 Fiber Tube Upper Wall
($69)- $110 Hyper-adobe Base Wall
($149)- $346 TOTAL SHELTER MATERIALS COST
2 WORKERS SHOULD TAKE 2.25- 3 WEEKS TO BUILD A SHELTER

More Information about Mesh Tube Walls

A 5 minute video called 'Hyper-Wattle' is available at Youtube to document the construction of the Albuquerque bench, the first mesh tube structure.

Recycled tube walls require some vertical bracing between corners. Plastic film, foam, and solid trash can be pressed firmly into wattles and covered with cement stucco. It may be a much quicker process to build as infill than existing techniques using plastic bottles stuffed with film. It may be successfully combined with Ubuntu compressed trash blocks as reinforcing piers. Plastic wattle walls may have significant insulation values if foam plastics are used.

Contact Patti at simple_earth@yahoo.com for more information or help with planning a mesh tube wall building.

About Build Simple Inc.

Since 2007 Patti Stouter has been designing aid buildings in different parts of the developing world. She combines training in landscape architecture, experience with a small family construction business, and a passion for empowering people. She offers training workshops and free online ebooks. Currently she specializes in earthbag, mesh tube wall, and Ubuntu-blox.

Left: An earthbag two-room school in Leogane, Haiti

Patti is a committed follower of Jesus or Isa and enjoys finding out about different cultures. All people groups in their variety reflect different facets of the character of the One who made them.

Because she is convinced that the Creator desires that all people have a loving family and home of their own, she assists self-help and aid groups as a volunteer. She has been privileged to meet and contribute to the work of dedicated people in Haiti, West Africa, and Central and South America. A personal desire is to be able to contribute to emergency relief.

"For I know the plans I have for you, declares the Lord, plans for wholeness and not for evil, to give you a future and a hope." Isaiah 29: 11

The work started as Simple Earth Structures has been expanded under the name of Build Simple Inc. Build Simple applied for federal 501(c)(3) tax-exempt status early in 2013.

[i] Smith, David A, *The $300 House, the Financial Challenge,* October 2010, online at the Harvard Business Review http://blogs.hbr.org/cs/2010/10/the_300_house_the_financial_challenge.html

[ii] Darcey, Donovan, *Seismic Performance of Innovative Straw Bale Wall Systems*, Pakistan Straw Bale and Appropriate Building, Truckee California 2009 available online at http://nees.unr.edu/projects/straw_bale_house/PAKSBAB_TestHandout_11_5_09.pdf

[iii] A good introduction to the light straw clay material is contained in the Design Coalition website at http://www.designcoalition.org/articles/Natural_LHJ/liteclay.htm. For more in-depth engineering information see Canada Mortgage and Housing Corporation, *Research Highlight: Initial Material Characterization of Light Straw Clay,* 2005, Ottawa Ontario online at http://www.cmhc-schl.gc.ca/odpub/pdf/63928.pdf?fr=1353817759673 and Forest Products Lab, *Engineering Report of Light Clay Specimens,* 2004 Madison Wisconsin online at http://www.designcoalition.org/articles/Lansing-LHJ/research/FPLreport.pdf.

[iv] Pacheco's process uses the tubing manufactured to create bags for vegetables. It is described in detail online at http://www.earthbagbuilding.com/articles/hyperadobe.htm and recent news at http://www.naturalbuildingblog.com/hyperadobe-update-from-brazil/

[v] For an example of erosion control use see information from Green Solutions online at http://www.greensolutions.us/logs.html

[vi] For more information about Siloxane see Prosoco, Inc, Siloxane PD Description and Use available online at http://www.prosoco.com/Products/d113db5a-0836-4c51-822e-b0006e080476

[vii] For more information about Grancrete see Jill Fehrenbacker, Grancrete: Quick-Dry Sprayable Concrete 4/25/05 online at http://inhabitat.com/grancrete/ or Material Safety Data Sheet for Grancrete B, 2006 available online at http://www.grancrete.net/products/msdsgrancretea.pdf

[viii] See abstract of Zhu B C et al, Evaluation of Vetiver Oil and Seven Insect-active Essential Oils against the Formosan subterranean Termite, 2001 Journal of Chemical Ecology available online at http://www.ncbi.nlm.nih.gov/pubmed/11521400

[ix] Contact Bill Murphy at MasterNet Ltd, Ontario Canada <bill.murphy@masternetltd.com>; website: http://www.masternetltd.com

[x] 1 litre mixed 1:2 lime powder to water should cover 3- 6 square meters for each coat of limewash, according to Mike Wye & Associates Ltd., http://www.mikewye.co.uk/mikeprices.htm#limewash

[xi] Or instead of bags and wire, $148 for the hyper-adobe which is quicker to build: 400' x 20"/120 m x 50 cm Raschel mesh for 12"/ 30 cm walls 12 cents per foot at Bag Supplies Canada Ltd., from Maurice Wilson <info@bagsupplies.ca>