SOLAR TECTIC BUNGALOW

Lessons Learned Creating
The First Compressed Earth Brick Building
in Westchester County, New York

September 8, 2015

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The primary drivers of the project supporting it financially are:

- Ashok Chaudhari, whose goal to make a difference in housing for the world's poor started the project.
- Karin Chaudhari, who is the heart of the project.

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- Simal Shrestha, the Nepalese native who gave us insight into culture and building in his native land.
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- Alexandro
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- Johanna
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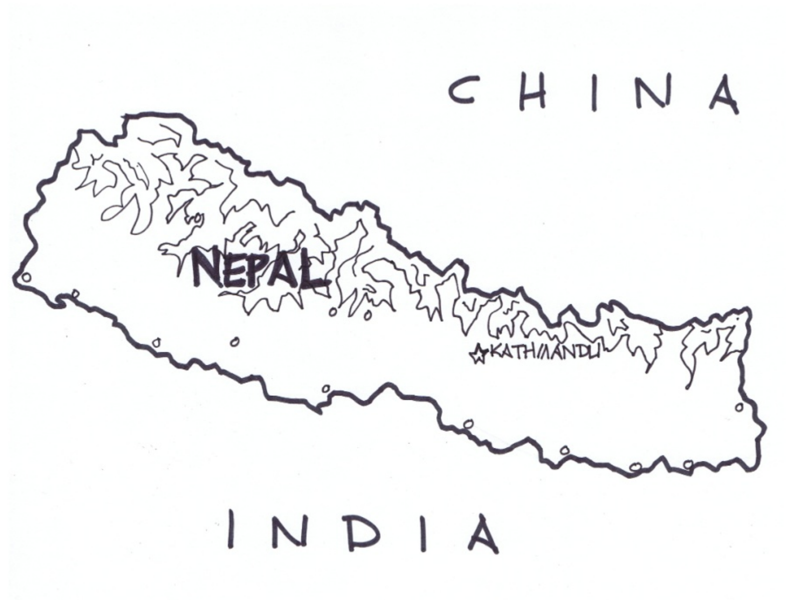
Cover Photos: The final shed image by Philip Jensen Carter; image of the proposed Solar-Tectic Bungalow by Molinelli Architects; back cover image by Philip Jensen-Carter

PURPOSE
Ideas are the most powerful tool that humankind has to improve its condition. Ideas handed down through generations and across communities get expanded, built upon and improved upon.

The purpose of this book is to spread ideas and share the lessons learned in building a compressed earth brick building that we hope would be an economically viable means to address housing conditions throughout the world. The ideas presented here are meant to be a first step, to inspire others, to help us build alliances and cooperation, so that we can go to the next step. At the end of the day, our success will be in how many homes are actually built.

BRIEF HISTORY
Ashok Chaudhari formed a company, Solar -Tectic Bungalow LLC (STB), to help bring solar technology to people who might not otherwise benefit from it. Ashok realized that such technology may require a building designed specifically with his goals in mind. Before the recent earthquake, his mother, Karin, was also concerned that too much reliance on concrete might pollute the beautiful rivers and streams of Nepal and wondered if there wasn't a better way to build eco-friendly. Ashok then set his sights on housing for the Nepalese rural poor in the lush foothills of the Himalayas. Ashok approached me about what kind of house might be economically viable and environmentally friendly there and what design improvements could be made. (He had seen my efforts to design viable housing for Haiti.)

Providentially, Ashok met Simal Shrestha, a Nepalese-born aspiring architect working in the solar industry in upstate NY. With Simal's input into local custom and client, we set about trying to design a house.



Many rural Nepalese homes are a combination of clay and stone with thatched roofs.

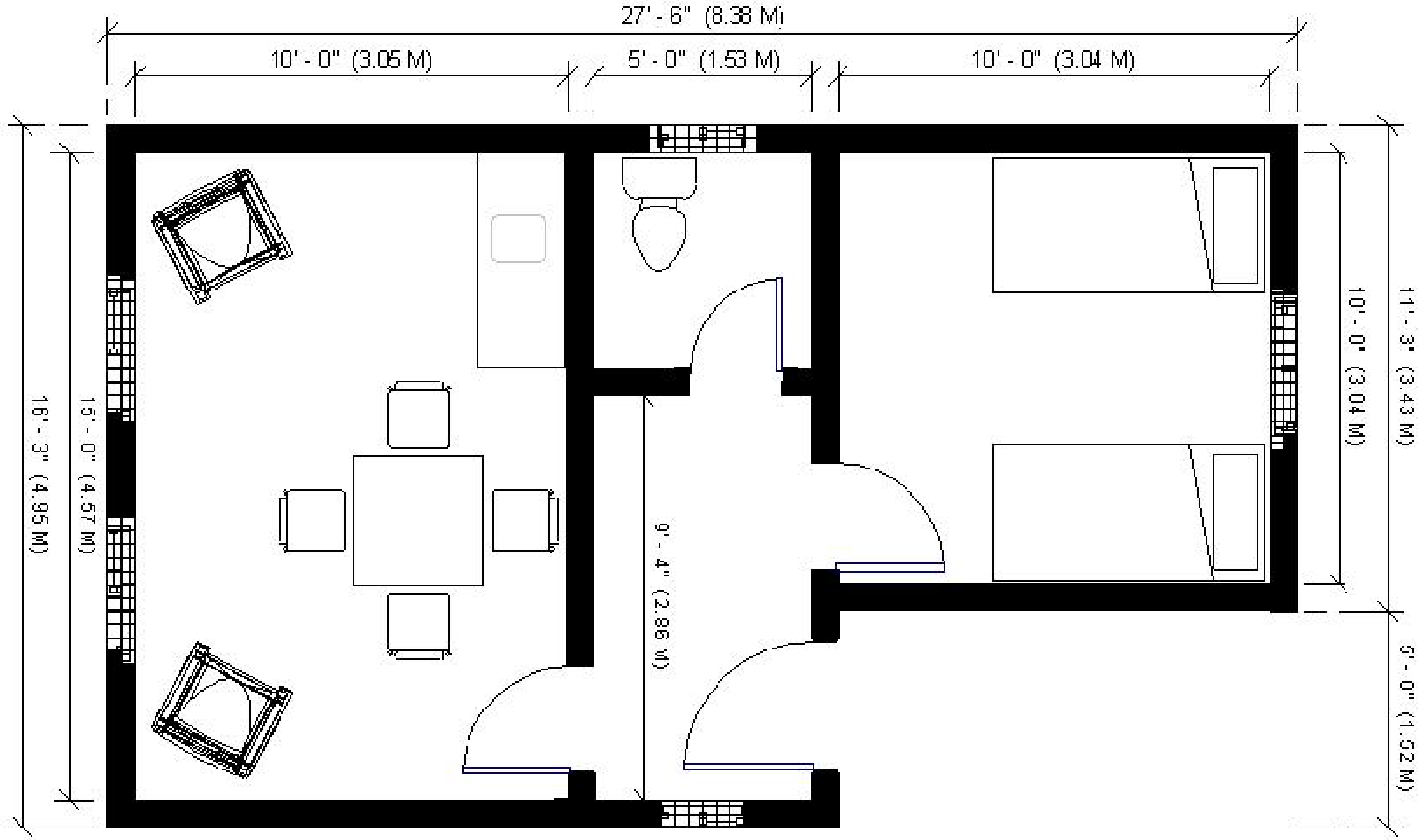
OVERARCHING CONCEPT

According to the IFAD (the International Fund for Agricultural Development, www.ruralpovertyportal.org), rural Nepal consists of subsistent farming families. Admittedly our solution would be aimed at the moderately or nearly poor (IFAD classifications) who have some land holdings but face poverty due to debt. If our design was affordable, we could perhaps improve their housing and relieve some debt.

Before we could design a viable house, we needed to know more about existing local materials and building techniques. For the Haiti Lakay house, I went down there for a week with the charity, Haiti Works (www.haiti-works.org), and was able to make significant advances seeing what traditional building techniques we could employ. Short of me making a trip to Nepal, we would have to do the same background research for that region some other way.

Simal provided that expertise. According to him, transportation of materials was the largest expense for any building project. The idea was to conceive a building made from local materials as much as possible. The local material being earth only. Simal too had thought that compressed earth brick might be a viable solution. The bulk of the material would be drawn from the site and the labor to produce the material would be local. A family could leverage their soil and labors into the house, saving them money.

Houses in this region are generally not heated. They do however want to seal themselves off from the weather - winds and rains. Cooking and sanitary facilities are traditionally outside the house. Our basic house does not move those services into the home, but allows for that option as is more common in Western homes.


27' - 6" (8.38 M)
10' - 0" (3.05 M)
5' - 0" (1.53 M)
10' - 0" (3.04 M)
16' - 3" (4.95 M)
15' - 0" (4.57 M)
9' - 4" (2.86 M)
10' - 0" (3.04 M)
11' - 3" (3.43 M)
5' - 0" (1.52 M)

THE SOLAR TECTIC BUNGALOW DESIGN

The images on these pages are based on the patented design (US D 723,713 S) held by STB LLC, Simal and me.

In this concept, the house will have double Compressed Earth Brick (CEB) walls without metal reinforcing. These are placed on a foundation 12" deep using concrete and stone. Every fourth course of the running bond is perpendicular to improve the bonding of the bricks. Resistance to lateral forces (earthquake, wind) is provided by the short span of walls, intersecting walls, the ferro-cement lintels over doors and windows, and the roof structure. (Ferro-cement uses steel mesh and concrete mixes to create structural elements.) The roof is a series of ferro-cement concrete shells formed on site which are composed of steel mesh embedded in concrete. The roof deck overhangs the wall in all directions through cantilever on the ends of the span but with ferro-cement outrigger supports on the other edges. The floor is made of the same brick as the walls. Calculations or tests on the extent of an earthquake that this building could sustain have not been done.

Doors and windows are shipped to the site and installed as with other accessories. There would be a single solar panel on the roof with a small battery storage allowing for 12 volt lights and cell phone charging. A bigger unit would be needed for a rice cooker.

The interior could contain a self composting toilet or other such sanitary provisions as might be readily available on the site. But the house would be an improved living condition even without these.

Nothing prevents the homeowner from expanding or adding personal decoration to the house such as traditional Nepalese wood carved elements. (We caution against colored stucco inside or out as this brick performs better if it can "breathe.")

SOLAR TECTIC BUNGALOW - HOW MUCH?

We ran rough numbers for the production of one house assuming that multiple houses might be built at the same time. Prices for materials based on Alibaba pricing ignoring minimum purchases. Some costs such as the screening frame, the Aurom 3000, etc. are amortized across multiple projects. Major soil digging is by backhoe. Transportation, mason's time, the backhoe and fuel are not calculated in the cost.

Gross Floor area	396 sf
Roof area	600 sf (13 shells 20'[6m] long)
Bricks Walls and Floors	8,100 (make 9000)
Man Hours	270 to make bricks (crew of 5)
	180 to assemble bricks (crew of 2)
	100 make roof and place (crew of 4)
	50 clearing, foundation, misc (crew of 2 with backhoe)
Total Man Hours	**600 man hours**

Cost (USD$)		
Bags of Cement	72	$220
Metal Mesh	3 rolls	$180
Doors	4	$400
Windows	5	$500
Misc		$200
Total Cost		**$1,500**

Options	
Basic Solar Kit	$800
Rice Cooker Grade Solar Kit	$2,000
Composting toilet, sink	$2,000

Total Construction Time about 8 weeks.

DEVELOPING THE DESIGN

The final design was influenced by the techniques that will be used to build it. Our goal was not to necessarily invent new techniques but to find the best ones. For that reason you will find we credit sources as we uncovered building methods that would aid us in our mission.

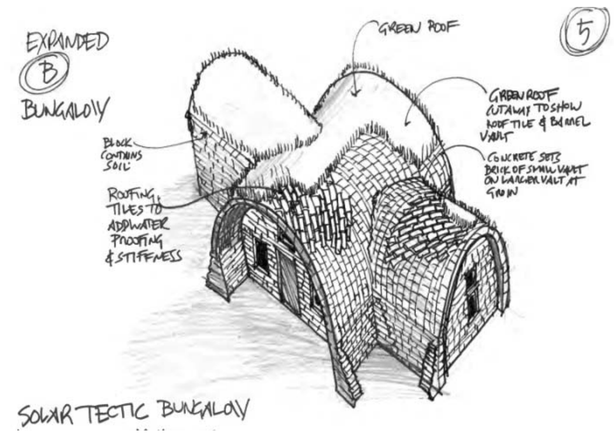
Walls were simple. You build bricks and you stack them. A concrete and stone footing would elevate the base off the ground and keep the walls from experiencing a frost heave. In this region, they would only need to be about 1 foot (.3 m) deep.

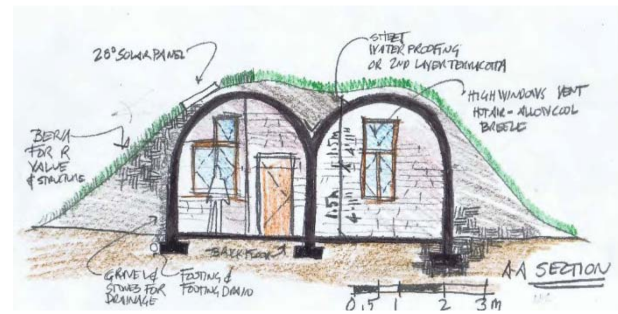
More challenging was the roof which we might also want to make strong enough to be a floor. The idea was that an economic roof that could support a floor would allow the homeowner to expand upward following the Nepalese custom. The technique of the roof would have the most substantial affect on the design and thus the aesthetics of the building.

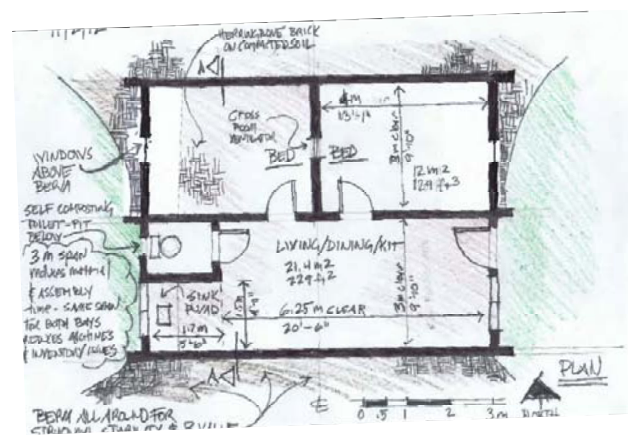
We looked at different roof/floor options. Traditional options including stick framed roofs and thatch were not as durable as we wanted. Wood rafters and decking would require a lot of lumber to be trucked to the site and was not leveraging local materials. We also looked at traditional concrete slabs but it would also require a lot of material to be shipped to the site including metal mesh and rebar and concrete form work. For our house, we investigated three other techniques. One of them would be a variation of the brick production that the Aurom 3000 brick machine would permit. Another would become a patentable invention. The three options we explored were:

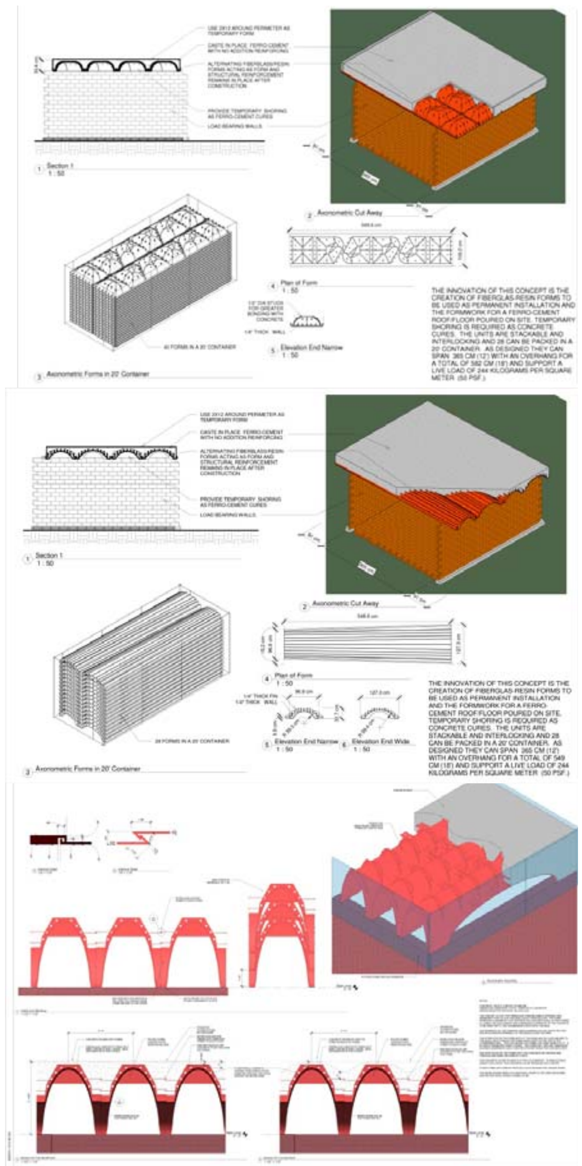
- a vaulted brick roof
- a fiberglass concrete form
- a on-site shell form covered over in concrete

CEB VAULT One technique I explored was to modify the mold of the brick machine with a steel insert to produce a wedge shaped brick so we could created arches and barrel vaults. The hope would be the resulting roof would be strong enough for about 30 psf live load (1,436 N/m^2) although it would not have any inherent water proof properties. This roof technique would result in a series of parallel or intersection vaults. To compensate for the outward thrust caused by arches, I envisioned banking soil on each side. This would also improve its resistance to earthquake and improve the houses ability to insulate the occupants from the outside weather. Water proofing the roof would require a tarp which is easily transportable. The roof would be covered with soil and seeded. This would not give us a flat roof for an optional second story without a lot more material needed to flatten the top of the barrel. At the end of the day it was believed that this design was too much like a Hobbit-hole and would be rejected for cultural and aesthetic reasons.









FIBERGLASS CONCRETE FORM

Another roofing technique I devised would create a concrete floor/roof without conventional mesh or rebar. STB and I received a patent (US 8,991,137) for this idea.

In this technique, fiberglass forms would be placed to span across the walls. The forms would be a permanent part of the roof providing both formwork (which would require temporary shoring) and reinforcement necessary to give the concrete sufficient tensile strength. It would do this through the tensile strength inherent in the reinforced fiberglass material and the form's geometry (trapezoidal, dome or shell.) The geometry of the form would distort the concrete in two planes to transport stresses through the material to the edges where the form would sit on the wall.

While we have received a patent, this idea needs more development and we have not yet produced a working proto-type due to the expense. (We have obtained bids to do this. If we can finance the prototypes, we would try it out on our shed.) If it proves successful we would incorporate it into the design. This building process may have a greater impact on building in general, not just for the STB design.

For the ST Bungalow, this would mean transporting the forms for each house, as they are used once and remain as part of the building. The forms would be light and can easily stacked to be transported in bulk.

There are three different versions of the fiberglass concrete form, from top left: the trapezoid, the dome and the last (and best) iteration, the shell.

ON-SITE SHELL

The design ultimately uses a thin shell ferro-cement panel which we found through Auroville, again, in a September 2004 document named "Manufacturing and Specifications of Prefabricated Ferro-cement Roof Channels."   (There are You-tube videos posted by an entity named "ebrohaugh" regarding this technique as used in Africa.) Page 4 of 7, is duplicated to the right.

In this technique, the earth is formed in a mold and roof panels are cast on top of the mold in the length and diameter desired. A layer of plastic is first put on the ground. A wire mesh is placed above it, with spacers to keep it from sitting directly on the plastic layer. Concrete is troweled onto the form so the mesh is embedded into it. A new layer of plastic is placed on top and the steps are repeated until there are enough roof panels for the project. This means the succeeding shells have an increasing radius. These cure in place until the individual shells are removed and set on the building.

In our design the change in radius helps us pitch the roof which is infilled with concrete. This could easily be flattened out if this had to be a floor.

For the shed project in Westchester, we still may try this technique. It would mean removing the current wood framed roof. Like the CEB process, we expect to learn quite a bit when we try this.

curing practices. Other material, like sand or bags, or plastic sheets can be used.

The current material is place over the roofchannel, both ends are blocked off by a cheap or easily available material like empty cement bags. This procedure ensures that there is sufficient moisture on the inside of the roofchannel during the whole curing period. The curing medium is kept moist all the time and never allowed to dry out. One should keep watering accordingly. Curing may also be done by any other appropriate method for curing cement elements.

A solar curing tunnell is used at AVBC is bigger elements.
A curing period of minimum 7 days to maximum 10 days is recommended.

IMPROPER CURING PRACTICE RESULTS DIRECTLY IN A BAD OR WASTEFUL ROOFCHANEL

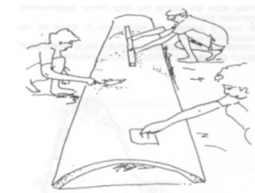
TRANSPORT

Transport to the site can be done by any convenient available carrier method. A flat platform bullock cart is used for short distances. A lorry for longer distances. The channels are stacked one above each other, up to a maximum of eight channels.
The roof channels are designed in such a way that they don't crack while being loaded on top of each other or during transport. Still it is advisable to drive carefully while transporting a load of ferrocement roofchannels, in order to avoid replacement charges.

INSTALLATION

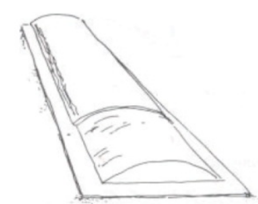
Care should be taken in handling the elements and sufficient people to lift the cannels in place need to be available. Normally two people per running meter are sufficient.
The lifting on top of the wall is usually done with the help of a small scaffolding.

The width dimension of the roofchannel defines the size of the roof/floor of the building. Allowance for a one or two centimeter gap between the channels during installation is in calculated.
The elements are placed next to each other and case is taken to adjust all the channels in one straight line.
After cleaning the sides with a wire brush, the valley in between is filled with a concrete mix having a ratio of 1:2:4.
The finishing is done with applying a cement plaster, and a cement milk mixture is painted on as a last coat.
A proper curing practice or method should be applied for the first 1 ½ week. Since the structure has to

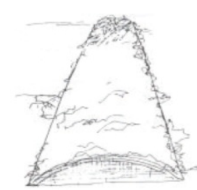


Surface finishing touches

Applying the econd layer of mortar



Finishing roof channel sides with serrations to facilitate joining channels



A curing method using coir dust & empty cement baggs

From top:
Simal closing the top of the Aurom 3000; Michael and daughter pulling down the level; bricks curing; Ashok testing a run of bricks; freshly compressed books curing.

COMPRESS EARTH BRICKS (CEB)

Compressed earth bricks or blocks are modular building units that use pressure on soil to create dense blocks. They are made with a machine that uses a lever to reduce the volume of the material in a mold. Ratios on mixes of soil, soil with Portland cement, shapes and compression ratios vary widely.

Researching compressed earth brick proved interesting but inadequate for us to create a design that was buildable and economical. There were many practical aspects to building this way that were unclear. For this reason, Ashok and I thought that building a prototype building (not necessarily a house) would yield all sorts of quantifiable information that would assist us in the design of an economic house.

Conventional fired brick in the United States usually has a compressive strength of 3,000 psi. (2,068 N/cm^2). We would not necessarily need that strength for a two story building. Since soil composition varied widely, we could not find any information on the ultimate strength of the compressed earth brick. One flaw in the experiment was that the CEB we would make would be using clay soil from the northeast United States. Aside an informal correlation between our climate and the more mild client in the foothills of the Himalayas, we need more definitive soils studies. As of this writing, we do not have that information.

We were also missing a realistic estimate into brick production. How large a group was necessary for optimal production? How many could they realistically make in an hour or in a day? How many of those bricks would fail? We needed more data on this to see if the amount of labor the family was to provide was realistic. (We envision a group of prospective home owners sharing labor in a CEB version of a barn raising.) By making the bricks ourselves, we would get a better understanding of these parameters.

THE AUROM 3000

In 2013, the Aurom 3000 cost $4,601 to purchase and $789 to ship its 1,367 pounds (620 kilograms) from India to Westchester County. It took about four months.

We were impressed with the Aurom 3000, but it took a while to understand it. Documentation on assembling it was sufficient but understanding how to use or adjust it took some time.

The machine comes complete with a mold for three bricks and soil hopper, scoops etc. . We got another mold for a hollow bricks which we ended up not using. The machine comes with spare parts and accessories such as grease, a grease gun, a pressure tester, wrenches, etc. You can be assured that your brick production will not be interrupted with down time while you wait for more parts.

Moving the machine is no easy feat even with the wheels and four men on each corner. We don't know how much it weights but I would not be surprised if it were about 1,000 pounds (454 kilograms.) We "danced" it onto to dollies or used the backhoe to transport it from the driveway to the brick yard. How to do this in the hills of Nepal would remain a logistic problem. We think that driving a backhoe to the villages with the machine tied in the bucket and towing a cart with bags of cement and other supplies is part of the overall solution.

Each morning we would lubricate the 7 points on the machine and another 4 on the hopper slide. We also started the day oiling the forms with corn oil or WD-40. It makes the first couple of molds clumpy but ultimately keeps things moving smoothly.

From top:
The shipment as it arrived ;
Transporting the Aurom 3000;
lubricating one of the 7 points on the machine (four more on the slide hopper)

From top: Closing the top of the machine; Pulling down the level (photo by Philip Jensen-Carter); the location of two bolts determine the depth of the compression; the two chains in the front must be tighter than the "V" chain (behind the hand) for the machine to pop the top at the right time.

The process is simple. Fill the soil mix in the mold while the lever is straight up (90 ° to the ground), smooth the top, and close/lock the lid. We found that having a screwdriver to clean the top of the mold was important for each iteration. The three solid brick mold has a convenient slide hopper which you can fill with the soil mix and slide over the mold. Slide it back and it removes the excess soil.

With the lid closed, pull the lever down to about 45°, the lid pops off and continue to push the lever down to 0° to extrude the bricks from the mold.

The most import thing to understand was the adjustments for the depth of the mold and tension on the chains attached to the lever:

- On the two legs of the machine opposite the lever are a series of hole in which two bolts sit. That determines the depth of compression and eventually the strength of the brick. We experimented to determine that for the three brick mold, the third hole from the bottom would give us 50% compression.
- On the lever side, two chains connect the lever to the top of the mold cover which pops once compression is complete. But those chains need to be tighter than the chain below them that are attached to the frame and the upper part of the lever. This chain has a turnbuckle. By adjusting the turnbuckle, (4 and 1/2 turns from completely tight) we controlled the pressure the machine will exert on the compressing soil mix before the top would pop up. If done properly, the top will release when the lever when the lever is 45° off the ground. As the lever continues to the ground, the newly formed bricks are push out of the mold.

THE SOIL MIX

There is a lot more science to the soil mix than we addressed. As an experiment in building we could not duplicate the soil they would have in Nepal, so we forged ahead with the available soil here in Westchester County.

One hundred years ago our site was pasture land for a dairy farm. Since the mid 1900s the region has new growth forest. According to the national soils database map (SSURGO) for NY119 region (httpp://websoilsurvey.sc.egov.usda.gov) , the soil in our location is classified as between LeB (Leicester Loam) and PnD (Paxton fine sandy loam.) Results from the tests that Cornel University did on some near surface samples gave us the result below - very little clay. And sample bricks made from that near surface soil yielded only 111 to 205 psi on the stress tests. This convinced us to dig deeper for more clay soil with which to make bricks. Our own experienced eyes showed us that the deeper we dug (below 24") the more clay component we reached - about 25 to 30%. (We mixed the soil in water and letting it settle into layers in a glass bottle. That was an archaic test but effective.)

Our goal was to use 95% clay soil and 5% Portland cement and get 50% compression. The compression would activate the cement and give the brick its compressive strength after curing 28 days.

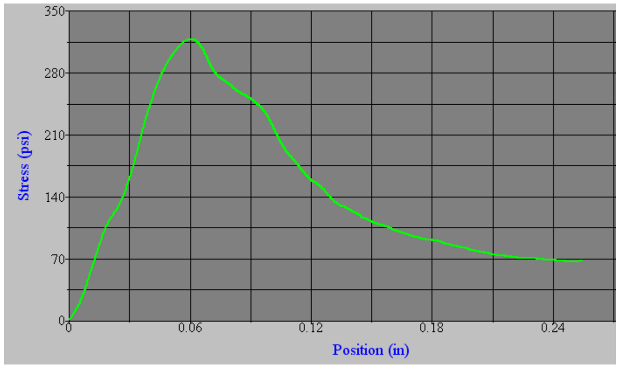
SOIL ANALYSIS KEY

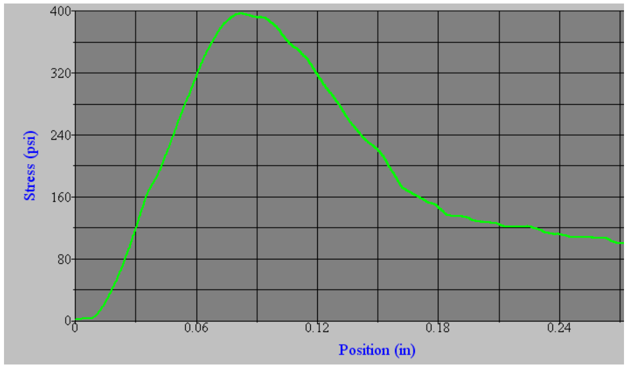
TS	Total Sand
Tsi	Total Silt
TC	Total clay
VCS	Very Coarse Sand
CS	Coarse Sand
MS	Medium Sand
FS	Fine Sand
VFS	very fine Sand
Csi	Coarse Silt
Msi	Medium Silt
Fsi	Fine Silt
CC	Coarse Clay
FC	Fine Clay

Result for surface soil 18" below grade- not used!!!

FRACTIONAL SAND					FRACTIONAL SILT					
VCS	CS	MS	FS	VFS	C Si	M Si	F Si	TS	T Si	TC
2.000	6.700	7.800	18.100	13.000	36.900	8.400	0.600	47.60	45.90	6.50

After curing, the brick on the left is dryer, stronger, more resistant to moisture conditions, and harder to scratch. The brick on the right will perform sufficiently to our needs and could dry out over time. Much darker and it will fail during handling.





RPI Stress tests for two CEBs we made on site.

MOISTURE CONTROL

Moisture content was hard to control. We do not have an exact formula as on any given day there might be more moisture inherent in the soil affecting how much we would add. This is the most critical skill that needs to be learned through experience on site.

There are tests you can do with your soil mix. Before forming a brick, make a clump and drop it 39" (1 m) to a hard surface. If it pulverizes, it is too dry. If it stays almost whole, it is too wet. If it breaks into smaller clumps, that might be right. After forming the brick, use compression test device that comes with the machine. If it penetrates without breaking the newly formed brick you have a good mix. If not, the brick might crack. We got about 15 bricks from each mix of the soil/cement (20 shovels full, 5 compresses) so we tried to test the first brick from each mix.

The quality of our output could vary with each mix but eventually we saw the darker brown bricks had too much moisture and were weaker or more likely to degrade when exposed to more moisture. The lighter brown bricks were dryer, stronger , easier to handle and more likely to resist moisture conditions.

The more moist the mix, the easier it is to compress the machine but the less stable and strong the brick. The dryer it is, the harder it is to compress but the stronger the brick. When it was too dry, two people could not compress all the way. We had to pry the top off. There was an incentive to create wetter bricks as it was easier for the person(s) pulling down the compression lever. Avoid this.

BRICK PERFORMANCE

After making the bricks, waiting for 28 days, we had two more bricks also tested by RPI. The results (on the left) were a brick with a compressive strength that ranged from of 319 to 397 psi. This performance was sufficient for our needs.

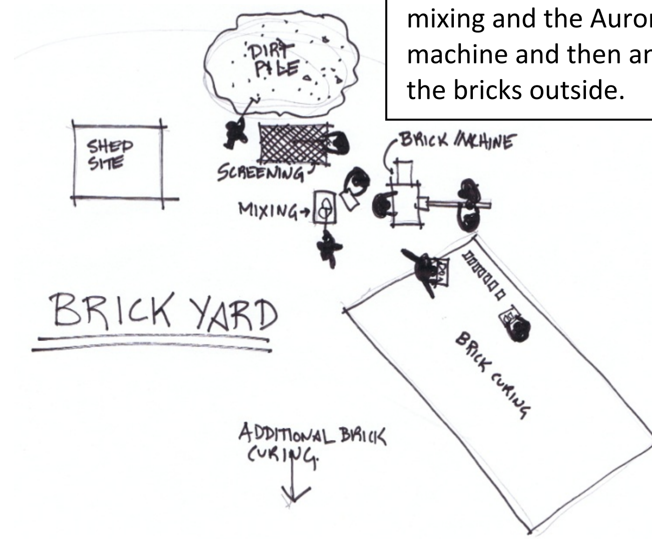
BRICK YARD AND PREPARATION

Using the backhoe we stripped the top soil (saved it) and flattened out the site for the shed and the brick yard. Once we excavated for the footings and flattened the site for the shed and the brick yard we got the approximate soil volume we needed. Digging down into the site also allowed us to getting a higher percentage clay soil.

Our goal was 5,400 bricks but as we got started in October the elements limited us to about 4,200 bricks produced. Each brick is 98.44 cubic inches or .057 cubic feet each. To have 95% soil and compress it 50%, we wanted to have a clay-soil pile as follows: 5,400 brick x .057 ft^3 x 95% x 2 = 585 ft^3 of soil. This translated to a dirt pile of about 10'x10'x6' or a bit larger to allow for some rocks and roots in the pile. We screened the soil through a wire mesh to remove any pebbles, rocks and roots bigger than 1/4" in diameter. (These pebbles could be used for mixing concrete for the foundation.) This screened soil was mixed at a 1:19 ratio Portland cement to soil (1 shovel of cement, 19 of soil) and mixed thoroughly. We yield about 15 bricks a batch.

On a 20'x50' sheet of plastic we comfortably placed 1,200 bricks to cure. After 10-14 days they could be easily handled. We should have stacked them on palettes after two weeks. The longer they sat on the plastic the more likely they would be caught in a puddle of water even though they were covered with another sheet of 20' x 50' plastic. Sitting in water they dissolved. The top sheet also trapped in moisture further stressing some of the wetter bricks. On the palette, we should have tented the pile rather than wrapped the brick tightly. This too trapped in water and stressed the wetter bricks so that we lost a lot more of them this way. The bricks made it through a very cold winter with many nights at 10°F (-12°C), but it was moisture that could destroy them.

We set up the brick yard next to the site of shed. Adjacent to the shed would be the dirt pile, the screening, mixing and the Aurom 3000 brick machine and then an area for curing the bricks outside.



Screening the dirt pile above; mixing the soil, Portland Cement and water below; Photos by Philip Jensen-Carter

THE BRICKS

We first tried to make hollow bricks but found that while removing them from the machine to a place for them to cure, 90% would crack. Even a spatula technique did not work. We decided to go with a conventional solid brick. This meant we could do three bricks per compression and use the soil hopper as well.

The solid brick would be 7.5" x 3.5" x 3.75" with the mold giving us the constant dimension of 7.5" long and 3.5" wide.

Some important metrics we discovered in this process:

- 100 bricks took 3 man hours
- A team of 4 could produce 130 bricks/hour (no screening)
- 1 bag of cement (94 lbs; 42.6 kg) yields about 250 bricks
- 1 batch, 20 shovels (4.4ft^3 or .12 m^3) yields about 15 bricks

From above: The hollow brick above was too hard to handle before it cured so we opted for the smaller solid bricks; Filling the hopper (photo by Philip Jensen Carter); removing the bricks

We found it took a minimum of 4 to 7 to make an effective team. To save time during the brick production days, we would have a lot of the dirt pile already screened. Mixing the soil and cement needed to be done just before the compression, so one or two people should work on that. One of the two could feed the hopper. One person would control the top of the machine, cleaning it, filling the mold and locking the lid. One or two people would work the lever (the person locking the top could assist one person pulling down the lever if necessary.) One or two people could ferry the formed bricks to the curing field. The more people, the easier it is on the workers and the longer the team could work.

The act of pulling down the lever to compress the brick was physically demanding. Few could last more than a few minutes, but some did it for the entire day. Strong back, shoulders and extra weight were helpful.

ASSEMBLING THE SHED

We stacked the best bricks on palettes adjacent to the shed site. We used conventional concrete and concrete block for the footing and foundations since we have a frost line of 42". (In Nepal it would be 12".) Once the mason set his batter boards and string the assembly could begin.

Instead of dry stacking or using mortar, we decided to create a slurry that was also 95% clay soil and 5% Portland cement. The clay soil was screen a second time using nylon insect screen to yield a very find powder the mason named "brown sugar." This was mixed with water as needed for a slurry that allowed the mason to level off the courses.

The solid brick would be 7.5" x 3.5" x 3.75" with the mold giving us the constant dimension of 7.5" long and 3.5" wide. The depth of 3.75" might vary slightly due to variations in the compression. For control we built the shed with the bricks on their side so the courses would be a very controlled dimension of 3.5". We would also build the wall as a solid double brick wall.

We decided not to use any steel reinforcing: rebars nor "ladder" wiring. Instead for every fourth course, we would do a header course to better bind the wall. Some bricks had to be cut to fit.

A skilled mason with a journeyman (selecting the best bricks and stacking them within arm's reach) were able to set 100 bricks a day. About 10% more were rejected during this process, mostly due to moisture damage because of the method we used to protect them.

Assembling was interrupted by the very cold winter and resumed in the spring without an visible damage done. To expedite completion, we roofed the shed with wood framing. Perhaps someday we will experiment with the ferro-cement roof system.

From above: The bricks stacked on palettes; "Brown sugar" used for the slurry instead of mortar; setting the bricks in place - note how they would dry once they were set and exposed to air; the shed project survived a winter.

THE FINAL SHED

The shed took 360 man hours and $1600 worth of materials to complete. The off the grid solar kit from Lotus Energy of Hudson NY cost another $730. Somebody wiser than us, could do a calculation to see if the human labor costs, time, food, injury risk, etc would be a net gain over the total costs of a conventional fired brick shed. But that is in North America. In remote areas the savings in energy and transportation would encourage this kind of building.

How long the shed will last in the American northeast remains to be seen but it survived a severe winter without the benefit of the roof overhangs. We expect to build another wall to test how the bricks will react if they are use as retaining walls (like for the Hobbit Hole) version with and without plastic.

We made 4,192 bricks. We used about 2,500 bricks with 200 leftover. Due to poor soil mix or storage, we lost about 1,500 bricks.

Counter-clockwise from above right: The shed with roof and door; from the back corner; inside looking at the glowing light and battery charged by the solar panel; inside the 12 volt LED light and front door; the solar panel on the roof. All images by Philip Jensen-Carter

CONCLUSION

We think our techniques are a viable way to building housing in Nepal. The goal has been to make this economically feasible so that the process will spread quickly to improve the human condition.

We can see a mason driving the backhoe, carrying the machine, and pulling a trailer with other building materials. They would travel to a village that has contracted for 3 or 4 houses. The families would donate the land, soil and most of the labor. They would work under the mason who would supervise the production of the bricks for a few weeks. As brick production ends, the first batch would be ready and the mason would lead them to assemble the first of the houses. The mason and the families would continue to work until all the houses are completed.

We learned a lot from this process. Our hope we can move this project forward to build housing in Nepal.

The use of CEB is expanding in Africa and Asia. We are sharing our information as we think this knowledge might be helpful to inspire people who might help us move forward with our Nepal project. It might also inspire others to continue the project on their own in Nepal or elsewhere.

If you want to learn more contact us at:

- www.stbungalow.com
- www.molinelliarchitects.com

On top left to right: Ashok Chaudhari, Ed Muller, Michael Molinelli, Dr. Martin Glassman; Below left to right: Johanna, Gustavo, Simal Shrestha, Michael Molinelli, Ashok Chaudhari, Philip Jensen-Carter, Ed Muller, Flavio. Images by Philip Jensen-Carter