Concrete and Building in Haiti

Preparation for Building an EcoShell in Jubilee

As of January 5, 2015

By: Herb Nordmeyer

Introduction

Jubilee is one of the worst slums in Haiti and is a strong Voodoo area. Until three years ago it did not contain any Christian churches. Last year, Pastor Benoit challenged me to find or develop a technology to build a disaster-resistant structure for a material cost of $1000 US or less. The concept was to locate residents who owned the lot they were living on and help them build a disaster-resistant home. Further, the building technique needed to be something that with a trained leader, the people who would be living in the houses would be able to build. Herb's father used to say, "The impossible takes a little longer." This assignment is taking a little longer, and this report addresses our progress.

On January 19, 2015, I head back to Haiti. On this trip, we hope to determine the availability and prices of raw materials for building, make decisions on the size and complexity of the prototype house, inspect and select building sites, meet with the mayor of Gonaives, and a number of other things.

A preliminary spreadsheet has been developed to help us price out the building of disaster-resistant houses in Jubilee.

Numerous people have helped in this endeavor, including, but not limited to:

- David South, President of the Monolithic Dome Institute,
- Paul Miertschin, Architect in San Antonio, and a tireless worker to improve conditions in Haiti (He died on December 30, 2014, and will be missed.),
- Van Smith who is working to build homes in Belize,
- My students in Haiti who laugh when I suggest something which will not work in Haiti,
- Helen Roenfeldt, Executive Director of Mission: Haiti,
- John Rougeux, with Mission: Haiti, and who I think can do anything. (I saw him import two sinks into Haiti in his checked luggage.),

- Judy Nordmeyer, my wife, who tirelessly corrects my bad grammar and lack of spelling ability.

Selecting the Technology

Numerous technologies were examined, and we kept coming up with a materials cost which was several times higher than Pastor Benoit's goal. We finally settled on the EcoShell I technology. We could build the strongest structure with the least volume of concrete.

In 2000, Monolithic Dome Institute published David South's book EcoShell I. In October, 2013, at David's invitation, I attended a workshop on building Monolithic Domes where we built a new and improved EcoShell. In 2014 the fourth edition of David's book was published. I took David's book to Haiti in July, 2014, and shared it with Haitian contractors to see what we needed to do to adapt the construction technique to Haitian conditions

As part of the process, I tried to identify every tool, every piece of equipment, and all materials which are needed to produce a disaster-resistant house where there are no Home Depots within 1000 miles. To do this I developed a spreadsheet that listed materials and their costs. I then shared what I had accomplished with others, and listened as they laughed at my nitpicking. After they stopped laughing, many of them added very useful pieces of information, which I then added to the spreadsheet and which I will distribute with this report.

One of the most important things that I had forgotten was how hard it is to drill a hole in concrete, using a hammer drill, to insert a Tapcon fastener. What is even harder is to drill the holes for the 63 plates that need to be used to hold down a 6.1 m EcoShell. Each of those plates requires three holes to be drilled into the concrete. Van Smith explained the simple guide that could be utilized to stick wooden chopsticks into the concrete work where each Tapcon fastener needed to go. Rather than having to drill the holes, with the chopsticks one simply has to ream-out the preformed holes. Suddenly a several-hour job became a job that could be done in less than 30 minutes.

While this report is written specifically for building in Haiti, it is recognized that it could be utilized in other countries. Monolithic Dome Institute, is given permission to distribute this report to whomever they feel could benefit from it. They also are given permission to distribute the accompanying spreadsheet, and to modify it as needed to fit various conditions. Much of what is in this report and will be learned during the January, 2015, trip to Haiti will be incorporated into a supplement to the EcoShell I book. We plan on translating it to Haitian Creole.

In the slum of Jubilee, in the city of Gonaives, Haiti, the groundwater table is high and is brackish This impacts the use of steel rebar in footings and slabs. If we want the homes we build in Jubilee to survive for more than five years, we need to address that problem. In many other parts of the world, in fact in many parts of Haiti, the brackish water problem does not exist.

Wherever you are building, look at the problems and make modifications to these suggestions which will adequately address those problems.

Much of the world uses the metric system. As a result we have used the metric system in this report and have followed it with the English equivalents.

Much of this report addresses building the 6.1 m (20-foot) EcoShell which provides adequate space, although cramped, for a family of eight in a tropical area. If a family can afford a home with twice the space, more power to them, but there are many who can barely afford a home consisting of a tarp for a roof and some woven palm leaves for the walls.

There are other construction systems that can be used, but when one considers lifespan, and efficient use of materials, as well as ease of construction, it is difficult to beat the concept of an EcoShell.

How Large Is Adequate?

The title of this section asks an impossible question. To get an estimate as to what is adequate, I reviewed a Heritage Foundation report, **How Poor Are America's Poor**, dated August 27, 2007.

- The average house size for people designated by the US government as poor was 41.2 m² (439 ft.²) per person.
- In the 1890s in New York City tenements, each person had about 1.9 m² (20 ft.²) of space.
- In very-low-income countries (Pakistan, India, China, Nigeria) the average living space per person is 6.2 m² (65.5 ft.²). This is not an average for the poor, but an average for everyone in the country.

In other research I found:

- In Africa the average area per person is 8 square meters (85.2 ft.²),
- In Asia the average area per person it 9.5 m² (101.2 ft.²), and
- In industrialized countries it averages 34.5 m² (370 ft.²).

While I has not read UN sources directly, he has found several sources which refer to the UN recommendations for minimal space in tropical countries:

- David South reports that the UN has determined that the average family habitation in developing areas needs to be about 28 m² (302 ft.²) for a family of 8. That is 3.5 m² (37.75 ft.²) per person.

- Another source indicates that minimal space should be 4.7 m^2 (50 $ft.^2$) per person.

I has observed people in Haiti crowded into much smaller spaces than anything reported here. In one home, which was nominally 2.4 m x 3 m (8 ft. x 10 ft.), there were 12 people living in it. That is less then 0.7 m^2 (7 $ft.^2$) per person.

This report proposes that an earthquake-resistant and hurricane-resistant structure be built, and that add-ons, such as a kitchen under a tarp, be used to expand the living area. In the event of inclement weather or other problems, the entire family can move into the secure structure.

Further, this report proposes that water, sewage, and electrical systems are stubbed out so that when they become available, they can be installed.

If after the first structure is built, a similar structure could be attached to it, that would double the secure area of the home.

Problems Building In Jubilee

In the Mandarin language, the word for "problem" is the same as the word for "opportunity," so we do not have problems, we have opportunities.

Chlorides

In Jubilee there is a high water table, and the water is brackish. That means the water contains sodium chloride or salt. The chlorides attack steel rebar causing it to swell and then to lose tensile strength. If we use steel rebar in the foundation, after a few years it will no longer have any tensile strength, and it will have expanded enough so that it probably will have cracked the concrete. There are ways of treating steel rebar, such as painting with a corrosion-inhibiting paint, or coating with epoxy. The first method would give us an extra 10 years of life for the rebar, the second method would require importing the epoxy-coated rebar into Haiti. Other solutions involve the use of basalt rope, basalt mesh, basalt rebar, or split bamboo to replace the rebar.

Footing

Applying basalt rebar into the footing trench appears to be an excellent choice, since it is stronger than steel and it is not corroded by any of the chemicals it would come in contact with. Currently, basalt rebar would have to be purchased in the United States and shipped to Haiti. The rolls come in hundred meter lengths, and are nearly 7 feet in diameter. We would have to plan months ahead so that we would have basalt rebar available to use.

Applying basalt rope to the foundation trench would not be a very good alternative, because it would tend to sag and need to be held up every few inches. An alternative might be to take two pieces of basalt rope, coat them with epoxy, and twist them together to form basalt rebar. This would produce a relatively stiff product that should function very well as rebar. The basalt rope is not currently available in Haiti, but it is small enough, and light enough, that it could be transported in checked bags for building the first house or two. If very much were to be utilized, it would be appropriate to ship it.

Another alternative would be to use bamboo. While we have not seen any bamboo rebar in Haiti, bamboo was introduced into Haiti some years ago in an attempt to control soil erosion. Information that I has read indicates that about six times the diameter of bamboo is needed to provide reinforcement which is equivalent to that of steel. The recommendation for the footing is for two pieces of Number 3 steel rebar. This is a cross-section of 1.42 cm^2 (.22 $in.^2$). If bamboo were used, a cross section in the footings would be about 8.5 cm^2 (1.3 $in.^2$).

Recommendations for producing bamboo rebar involve drying it in place after the stem has been cut and placed on a rock, slab, etc., for a period of 6 months. The leaves and stems should be left attached to the stem of the bamboo. This helps drying the bamboo. After the bamboo has been dried, it should be impregnated with a borax solution.

When bamboo is exposed to changes in moisture concentration in the concrete, it can expand, and then shrink. This has the ability to crack concrete, and to break bonds between the concrete and the bamboo rebar. At least one reference suggests that bamboo rebar should only be used in footings and slabs. These are the only areas where we would consider using it.

Slab

25 mm x 25 mm (1 inch x 1 inch) basalt mesh could be used for the slab of the structure. This would allow the concrete floor to be thinner; however, placing the concrete could be difficult, because it would be necessary to pour the footing, pour the slab to one half the proposed thickness, install the basalt mesh, tie the basalt mesh to the reinforcing in the footing, and then pour the rest of the concrete to be used in the slab. The basalt mesh is small enough and light enough so, like the basalt rope, it could be carried in checked baggage on an airplane. If it were going to be utilized on a regular basis, it would be appropriate to ship it.

Basalt rebar could be utilized in the slab without any of the difficulties associated with the pouring of the concrete; however, as mentioned above, basalt rebar is not currently being imported into Haiti. If we were to use it, we would need to arrange for shipping it in.

Using the basalt rope and producing basalt rebar on site would not save any money and would take extra time, if we were going to build a number of homes. For one or two homes, it would work.

Bamboo rebar would work if we can find a group to produce it in Haiti.

Dome

Basalt rope can be used for reinforcement of the domes, and it does not require concrete cover to protect it like steel rebar does. This allows the shell of the dome to be thinner. A decision to use basalt rope in the dome is an excellent choice.

When using steel rebar for the dome, the concrete in the dome needs to be approximately 10 cm (4 inches) thick to adequately protect the rebar. This results in the use of approximately 6.12 m^3 (8 $yd.^3$) of concrete. By moving to basalt rope, it is easy to cut the amount of concrete in half. This savings actually would pay for the cost of the basalt rope that is used.

Recently, the chief engineer at the Monolithic Dome Institute determined that with basalt rope, the shell thickness could be reduced to 2.5 cm (1 inch) if the basalt rope is installed every 30 cm (12 inches) in each direction, and if a quality concrete stucco were used on it. Such a shell would gain much of its strength from the spherical shape. At 2.5 cm, it would not resist projectiles propelled by a tornado, but would resist hurricane-force winds. If a projectile did penetrate the shell, it would be easy to patch.

In Haiti, we do not look for reducing the thickness of of the concrete in the dome to less than 1 1/2 inches, and then only after we have had considerable experience in building these structures.

Aggregate

Very little of the aggregate in Haiti meets any standard gradation. Much of the sand contains up to 20% clay. To achieve the quality stucco or concrete skin that we need on a dome, we need quality fine aggregate. This can be produced with lots of hand labor by people operating screens, or it could be produced by installing a sand and gravel plant that has the ability to size and wash sand. If such a plant were put in, there would be a market for the sand and gravel that is produced.

An alternative would be a pedal-powered rotating drum where a man would shovel sand into one end, clays would fall through, appropriate graded sand would fall into a second container, and oversize would exit the end of the two. Such a system would have to be operated with very dry aggregate, or it would have to be operated with a water spray. If it were operated between the very wet and the very dry states, the clay would tend to clog up screens.

A Reality Check

Building a dome sounds like a simple and easy process, until we look at the force that is being exerted by the inflated air form. The air form is inflated to an air pressure that equals 15.25 cm (6 inches) of water. With the 6.1 meter (20 feet) dome, we're talking about 6,820 kg (15,000 pounds) of pressure. All of this is exerted along the edges of the dome.

The air form is held down to the concrete by 63 equally spaced angle clamps. Each angle clamp is held in place by three Tapcon fasteners. That is 189 Tapcon fasteners. That means there is a fastener every 10 cm (4 inches). Each Tapcon fastener needs to resist a force of 36 kg (80 pounds). If the concrete is not adequately cured, the concrete may not be adequate to allow the screws to have that holding power. If someone is in a hurry and leaves one screw out, that increases the pull on those screws adjacent to it, which could cause them to fail. If someone decides to save a little money and replace some or all of the Tapcon screws with another variety screw, a failure may occur.

If a failure occurs, there is a real possibility that the air form could be torn. That would take the air form out of service until such time as repairs could be made. That is assuming that it would be possible to repair the damaged air form.

If we install the footing, without a complete slab, that force would be pulling up on the footing and pushing down on our dirt or gravel floor. We probably would not pull the footing completely out of the ground, but we would pull it up in some areas to the extent so the air could leak out. This would result in a footing that is not level and, more importantly, is not able to maintain the air pressure we need within the dome.

If a determination was made to install footings and not install a slab, the footings could be anchored to the soil either by installing vertical footings down into the soil, or by the use of earth anchors. Either method should have an engineer review the data concerning the installation of the tie to the earth, and review the soil characteristics in the area where the houses are to be built.

If we have a slab, and it is not adequately reinforced, with the uplift around the circumference and the pressure in the middle of the slab, we could crack the slab just inside from the footing. Once such a crack started, there would be a tendency for it to continue around the slab. We do not need 6,820 kg (15,000 pounds) of concrete to hold the dome down, as long as the slab remains in one piece. This means that reinforcing the outer meter (3.5 feet) of the slab is important. It also means that the concrete needs to be of good quality.

To eliminate the problems just being discussed, is it possible to inflate the dome to a lower air pressure? Yes, it is, but when that is done, and stucco is either blown onto the air form, or troweled onto it, the air form gives. This can lead to cracking of the stucco. We will have some cracking in that first coat of stucco we apply to the air form. If we have cracks in the outer layer of stucco, the shell of the dome will not hold up as well when it is exposed to high winds and/or seismic movements. It will also have more of a tendency to leak.

If we lose air pressure in the dome at any time from when the first stucco is applied, until the last coat of structural stucco is applied and cured, cracks are likely to occur and the integrity of the dome will be compromised. This means that we need a constant electric source to run the blower. In Gonaives, periodic power failures are common. We need to have a standby generator available at the building site whenever we have an air form inflated. Additionally, we need to have an operator there who can connect and start the generator if an electrical failure occurs.

By upgrading the footing and tying it to the earth as mentioned above, we could eliminate the cost of the concrete for the slab and the cost of the reinforcing for the slab. The floor could be pea gravel or packed earth until such time as a concrete paver floor was installed or until a concrete slab was installed.

Options Available

Everything is a compromise. The cost of building a 6.1 m dome utilizing this technology is site-specific, and related to the cost of materials, and the availability of materials in that particular area. If we were building in Central Texas, the cost would be less than if we were building in Haiti.

If furnishing 28 m^2 of living space is the most important parameter in making a decision as to what we are to build, we probably need to increase our budget. If the budget is the most important parameter, then we need to either construct a smaller dome, or construct a dome that does not have a concrete slab. This is a decision that needs to be carefully weighed before it is made. Following are some of the options that are available.

Increase the Budget

When this project started, Pastor Benoit challenged me to find or develop a technology to build a disaster-resistant structure for a material cost of $1000 US or less. After considerable research, I settled on the EcoShell dome. I selected the

6.1 m dome to base all of my calculations on. While I do not have costs for building in Haiti at this time, I have developed a cost of about $1800 US to build one in Central Texas containing a concrete floor. That cost does not include windows, doors, internal walls, and bringing in electrical and plumbing, other than providing stub-outs for them. Since the costs in Haiti are likely to be higher than in central Texas, we will either need to

- increase the proposed budget,
- build a smaller dome,
- remove the concrete floor from the dome, or
- build a smaller dome without a concrete floor.

If we are going to build a 6.1 meter dome and place a concrete floor in it, we're going to go over budget.

Build a 5.33 m (17.5 feet) Dome

If we were to decrease the size of the dome from 6.1 m (20 feet) to 5.33 m (17.5 feet), we would reduce the amount of concrete and reinforcing materials that were needed to 80% of what the larger dome would require. An off-the-cuff estimate of materials for building such a structure in central Texas would be about $1,450.

Build a 4.6 m (15 foot) Dome

If we were to decrease the size of the dome down to 4.6 m (15 foot), it would reduce the amount of concrete and reinforcing materials that are needed to about 56% of what the larger dome would require. An off-the-cuff estimate of materials for building such a structure in central Texas would be about $1,045.

Build a 4.6 m (15 foot) Dome Without a Concrete Slab

If we removed the slab and increased the footing by making it 10 inches wide and 12 inches deep, and used a series of earth anchors to hold the footing in place, we could reduce the cost to less than $800 if built in central Texas. Under those conditions, we would be close to the $1,000 US goal.

As soon as we have the costs of materials in Haiti, we will develop better cost estimates for the project.

Materials To Ship To Haiti

We want to use as much material which is produced in Haiti, or which is already being imported to Haiti as possible. There are somethings which we will need to ship to Haiti.

The Air Form and Blower

The air form needs to come from Monolithic. The air form for the 6.1 m dome weighs approximately 170 pounds and fills a 3 foot cube. As a result, it cannot be brought into Haiti as part of checked baggage. The air forms for the smaller domes weigh less, but in all probability they still could not be brought into Haiti is checked baggage. This means that prior to building any domes in Jubilee, we need to have a couple weeks for ordering and delivering the air form to the ship, transportation time in the ship, and time to get through customs. This means that making decisions concerning what size dome we want to build is a decision that needs to be made as soon as possible.

Monolithic sells a blower and sells a list of parts if someone wants to build their own blower. If we have someone who is good at tinkering, we can probably save a few hundred dollars.

A small backup generator is needed to ensure that the blower has power when the air form is in use. This may be available in Haiti.

Basalt Rebar and Basalt Rope

The 6 mm basalt rebar ships in 100 m rolls which are 203 cm in diameter and 5 cm thick (80 inches in diameter and 2 inches thick) and weigh about 6.1 kg (13.5 pounds). Two rolls are needed per 6.1 meter house if basalt rebar is used for the slab.

The basalt rope ships in 1,000 foot rolls which weight 7.7 kg (17 pounds). Two rolls are needed per dome, if this rope is not used to reinforce the footing or the slab.

Conclusion

This report is furnished to keep all parties informed and to assist Pastor Benoit and others in making decisions as to where we want to go with this project. A spreadsheet is being developed which win finished will list all of the components which go into each of the options which are listed. The draft spreadsheet is attached. When decisions are made concerning where we want to go, and prices of the raw materials have been determined, a detailed guide will be produced.