Title page

Homes for Jubilee

A Manual for Building Disaster-Resistant Homes for Those Who Have Nothing.

February 25, 2015 draft

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Includes the entire text of 4th edition of **The EcoShell I** by David South of the Monolithic Dome Institute

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Dedication

This book is dedicated to all who have supported the **Homes for Jubilee** project and to all who would like to support a project similar to the **Homes for Jubilee** project.

This book was not developed in a vacuum. There were hundreds of people who made it possible. I can name only a few of them. There are my students in Haiti who have tried their best to teach me the Haitian culture and who have laughed at me when I have blundered. One of their favorite stories is when I was talking about the slope of a flat roof using metric measurements (one centimeter per 48 centimeters) and my hands were demonstrating English measurements (one inch per 48 inches).

Pastor Benoit, President of the Lutheran Church of Haiti, would not let me have a quiet and comfortable retirement. Every time I think I am getting close to solving one of his assignments, he challenges me with another impossible challenge. As my father said, "The impossible takes a little longer."

There are my granddaughters from the US and Haiti, the ladies from preteen to middle-aged, who have adopted me as their Grandpa and who have more confidence in my ability to solve Pastor Benoit's challenges than I do. How can I let them down?

Then there are the technical experts, such as:

Dr. Richard Klingner, retired engineering professor from the University of Texas at Austin, who mentors me and insists that I get things right,

Joe Warnes, one of the top disaster-resistant construction experts in the world who has on occasion has called me Don Quixote,

Van Smith who has done in Belize what I would like to do in Haiti,

David South, President of the Monolithic Dome Institute, who has encouraged me, guided me, and put up with my weird ideas, and most of all developed and improved the EcoShell concept of building,

Nolan Scheid, who built a castle using dome technology.

There is the team organized by Mission:Haiti which ensures my physical, mental, and spiritual well-being on my trips to Haiti and whose members have become close friends. The team is headed by Helen Roenfeldt, Executive Director of Mission:Haiti, and Lophane Laurent, the leader of the Haitian portion of the team. The team includes drivers, translators, security personnel, cooks, people on short-term missions, and even a lady who washes my filthy clothes after I have been out in the field. They all have become my friends.

There is my wife Judy, who puts up with my heading out on a regular basis to chase yet another windmill (if you have not read Don Quixote, you should), has reviewed every draft I write, and takes my spelling errors and grammatical errors in stride as she drips red ink over all of them.

Then there are those who have supported my work with their prayers, their encouragement, their ideas, and their money.

This book is dedicated to all of them.

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By Saint Justin Pierrelus

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The Preface

By Herb Nordmeyer

I never planned to go to Haiti.

After passing my 70th birthday, I had retired from corporate America and had my life well-planned. My time would be divided between:

- leading wilderness kayaking trips,
- adopting granddaughters who needed a grandpa,
- writing devotions for our church,

- writing and publishing technical books,
- writing and publishing books with some of my granddaughters,
- developing a specialty stucco business, and
- consulting.

Alice, whom I adopted as my kid sister, and many others, kept prodding me to go to Haiti for just one short-term mission. Meanwhile, Pastor Benoit, President of the Lutheran Church of Haiti, read one of my books and decided that I should move to Haiti for ten years since it would take that long to get all of the projects done which he thought I should adopt as my own. After repeatedly turning down his offer, I finally mentioned it to my wife. Her "NO!" was much louder than mine. The only one who was not on board with my going to Haiti for one short-term mission was me. Then I listed to a sermon in a church I was visiting titled, "When the time is right, God will call. Answer!" I finally agreed to go.

My good friend Ann gave me a new cane. One that would fold for easier traveling on the plane to Haiti.

In September, 2013, I made what I thought was my first and last trip to Haiti. Pastor Benoit showed me the need for earthquake-resistant and hurricane-resistant housing. He challenged me to find or develop technology to build earthquake- and hurricane-resistant housing for Haiti, especially the slum called Jubilee, which could be build for $1,000 US materials cost. In November, 2013, I was back in Haiti where I agreed to go four times per year, as long as my health and finances held up.

Here are a few of the people who have gone out of their way to make my work in Haiti technically feasible.

Joe Warnes, whom I met when I was a speaker at one of the World of Concrete events, is one of the leading disaster-resistant construction experts in the world. He informed me that I should build to F-5 tornado standards and then the structures would be resistant to both earthquakes and hurricanes. He also said I should call them disaster-resistant structures.

Dr. Richard Klingner, retired engineering professor at UT-Austin, and a long time colleague at ASTM (American Society of Testing and Materials), introduced me to the work that Blondet did following the Peruvian earthquake. He expects as much analysis and planning from me as he does his PhD students.

My friend, David South, President of the Monolithic Dome Institute, invited me to participate in a dome building workshop in October, 2013, and regularly provides guidance and encouragement.

My students teach me the Haitian culture and feel free to laugh at me when I propose something which will not fit their culture.

While this is a construction manual for building dome houses in Jubilee, it is also the story of that wild ride that started with my first trip to Haiti.

With all of this build-up, I am a failure. The cost of materials ended up being about $2,000 US. I invite you to go out and fail like I have failed.

(New page)

The Plan

By Herb Nordmeyer

The Challenge

The Impossible Challenge

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. Following an eye clinic which was held in Jubilee in 2012, residents asked why the eye clinic was brought to Jubilee. Discussions followed, and other teams visited Jubilee. Some of the residents decided they wanted a church, so a Lutheran Church was built on Rue Lamartrniere. The original structure consisted of a blue tarp roof and woven palm leaves for walls.

Based on the foundation and the vertical rebar, one can see that the church is planning on expanding. In April, 2014, a larger church building was dedicated. Since that time, the larger church serves not only as a church, but also as a community center. Among other things, it is used for sewing classes and medical clinics.

In 2013, Pastor Benoit challenged Herb Nordmeyer to find or develop a technology to build a disaster-resistant housing 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; in fact, Herb has failed. However, working with David South, President of the Monolithic Dome Institute, Van Smith, Dr. Rich Klingner and many others from the US, and from Haiti, he has identified and modified a technology which will result in a disaster-resistant structure and has a material cost in Haiti of $2,000 US.

The book is divided into 5 parts.

First is an introduction by the Mayor of Gonaives.

Second is this part which identifies conditions specific to building in Jubilee.

Third covers preparation before we can start building.

Fourth is the text of David South's EcoShell I book.

Fifth is a supplement to the EcoShell book with details concerning building a 6.1 m (20 ft.) dome in Jubilee.

Construction Techniques

We looked at a number of building techniques, but after the initial study, we concentrated on three of them. Two because they provided the most space for the least number of dollars of materials, and the third because it is the indigenous building technology of Haiti and with a few modifications it can be built disaster-resistant.

Dome - EcoShell

- Most space per cubic meter of concrete.
- Dome shape.
- Produces an earthquake- and hurricane-proof house with minimal materials.
- Minimal footings and foundation are required.
- Can be built with basalt reinforcement which is not attacked by chlorides, like steel rebar is. This results in a more permanent structure that is not destroyed by deteriorating rebar.
- Difficult to expand.
- Built with a balloon form, so once we decide on a size, we need to spend $3,000 to $4,000 US. If we want to change the size of the homes we are building, we need to purchase a second balloon form.
- Cost per unit, without finishing (doors, windows, painting, internal walls), will be about $2,000 US for a 6.1 m (20 ft.) dome. This would provide 29.5 sq meters (314 sq ft) of interior space.
- Can be built with ventilation blocks for windows, or can be built with window bucks so conventional windows can be installed.

- Installing a center hole in the dome with a short pipe extending above the dome (with a rain cap on it) will produce a thermal chimney. This will encourage hot air collecting near the ceiling to exit the dome and be replaced with cooler outside air. A roof turbine will accomplish the same thing.
- Vines can be planted to grow on the outside of the dome. This will reduce the thermal transmission through the dome which would cause the interior to heat.
- With the concrete surface of the dome, water will be shed, and little or no water will penetrate through the dome skin unless there are cracks in the concrete. To eliminate any leakage, a silicone-based water repellent (Silane and Siloxane-based water repellent) is recommended, or the dome can be coated with an elastomeric paint.

Figure 1 EcoShell I home under construction. (who owns this photo?)

Confined Masonry

- This is the indigenous building technique of Haiti.
- Can be built one story, and later a second and third story can be added.
- Looks like a normal house.
- With minor changes in the currently used building techniques, a hurricane- and earthquake-resistant structure can be built.
- With light-weight roofing block Herb has developed, can pour a flat roof that weighs about 40% less than a conventional flat roof.

- Cost, for a house with the same space, will be about $3,000 to $3,500 US depending on the foundation needs.
- Based on our soil survey, a substantial foundation will be needed in the proposed building site.

Figure 2 Confined Masonry Construction

Cylinder Home

A modification of the dome is a cylinder which is several stories high and one apartment or two apartments on each story. Construction is more complex than the EcoShell dome but has many of the structural advantages of the dome. Building multiple stories will require a more enhanced foundation.

For a three-story, 6.1 m (20 ft.) diameter cylinder, an outside stairway could be installed and one apartment would be on each level. With a three-story, 9.14 m (30 ft.) diameter cylinder, two apartments could be installed on each level.

The steering committee from Jubilee preferred the dome concept to the confined masonry concept, since it would result in more homes built with the same number of dollars. Prior to our survey of the soil (we would need a larger foundation), they also expressed interest in moving towards three-story cylinder homes as they gained experience in dome construction.

Compromises

- As mentioned above, Pastor Benoit challenged Herb to develop or find technology so we could build earthquake- and hurricane-proof houses at $1,000 US for material cost.
- In Haiti, the material cost for a 6.1 m EcoShell dome meeting those requirements with a concrete floor will be about $2,000 US.
- In Haiti, the material cost for a 4 m x 7 m confined masonry house meeting those requirements will be about $3,500 US.
- Other building techniques, such as Structural Concrete Insulated Panels, would cost about the same as for confined masonry.
- Several panel construction techniques were examined which would cost more.
- To meet the $1,000 US goal, we would need to use the EcoShell dome technique and reduce the size to 4.6 m (half the size) and remove the concrete floor.
- The leaders from Jubilee stated that the City of Gonaives will not approve a project which does not have a concrete floor.
- The building site has a high water table. We will need to place a vapor barrier on the ground and build the foundation and slab above grade. Building on the elevated foundation requires a concrete slab so we can pressurize the Airform for the EcoShell.
- Since there are chlorides in the water, steel rebar tends to degrade within a few years. As a result, we need to move from steel reinforcing to basalt reinforcing.
- Since the average family has 8 or 9 members, we need to stay with the 6.1 m dome. As a result, we need to increase our material budget per house from the $1,000 US goal to $2,000 US practical.

- This may impact fund-raising, but at the moment we do not know how it will.
- The above is specific to building in Jubilee. In other parts of Haiti and in other parts of the tropics, there may not be a high water table and there may not be a chloride problem. In those areas, the footings can be dug into the ground and steel rebar can be used in the footings and slab rather than basalt rebar. If steel rebar is used, the thickness of the slab needs to be increased from nominally 5 cm (2 inches) to nominally 10 cm (4 inches).

How Large Is Adequate?

The title of this section asks an impossible question. To get an estimate as to what is adequate, Herb 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 Herb 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 Herb 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 m² (50 ft.²) per person.

Herb 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 m² (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.

Options Available

Everything is a compromise. The cost of building a 6.1 m dome utilizing this technology is site-specific and is related to the cost of materials and to 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 Herb Nordmeyer to find or develop a technology to build a disaster-resistant structure for a material cost of $1000 US or less. After considerable research, Herb settled on the EcoShell dome. He selected the 6.1 m dome to base all of his calculations on. While he does not have costs for building in Haiti at this time, he has 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. To build it in central Texas, the cost of materials would be about $1,800 US. Building it in Haiti will be more, but at the moment I don't know how much more.

Build a 5.33 m (17.5 ft.) Dome

If we were to decrease the size of the dome from 6.1 m (20 ft.) to 5.33 m (17.5 ft.), 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 ft.) Dome

If we were to decrease the size of the dome down to 4.6 m (15 ft.), 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 ft.) Dome W/O 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 in Haiti.

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

Why Domes Are Inherently Earthquake- and Hurricane-Resistant

- Buildings come apart where leverage can be exerted; with a dome there are few portions of the structure where leverage can be exerted.
- The dome, with the foundation, becomes one unit and behaves as one unit.
- No permanently attached overhangs to be torn from the structure.
- Use adequate permanent reinforcement in the footer and the slab.
- Easy to ensure that all concrete is well consolidated.
- Use 8 bags of Portland per cubic meter (6 bags per cubic yard) of concrete for the footing and the slab.
- Use 10.6 bags of Portland per cubic meter (8 bags per cubic yard) of concrete (stucco) for the dome.
- Screen clay out of the sand and gravel.
- In areas where steel rebar deteriorates, replace with basalt rebar.
- The dome itself is reinforced with basalt rope, so the shell can be thin, but still be structurally strong.
- The basalt reinforcement does not need to be covered with 5 cm of concrete to protect it from corrosion, so the shell of a basalt-reinforced dome can be much thinner. Currently we are working with 2.5 cm in thickness when excellent quality control is practiced. We will not go that thin, because we want to incorporate a safety factor.
- The double curve (spherical shape) of the dome makes it strong even though the walls are thin.
- The dome is securely tied to the slab and footings.

The Community and the Conditions

Location

- Gonaives is located about 153 km (95 miles) north of Port-au-Prince on Route 1 (N 19.448125, W 72.686756). It is the largest city in Haiti outside of the Port-au-Prince metropolitan area. Gonaives has a population of about 300,000 (2011) and is the capital of the Artibonite Department. Travel time between Port-au-Prince and Gonaives is usually three to four hours.

Jubilee is a low-lying area about 1.6 kilometers (1 mile) SSW of downtown Gonaives. It started as a dumping ground for unwanted trash, including people. The people salvaged what food and building supplies they could from the garbage dumped in the area, and used the building supplies to build their homes. So, Jubilee has become a collecting point for those who have nothing.

Originally the streets were unimproved and there were no latrines, however, in recent years some streets in Jubilee have been paved, some of the open ditches along the streets, which serve as storm sewers and sanitary sewers, have been concrete lined, and some community latrines have been added. The open ditches also serve to drain water from under the community since the water table is high. Periodically, collected debris in the ditches is shoveled onto the street and often children play in the debris.

Most, if not all, of the residences in Jubilee do not have electricity. The Lutheran Church has been wired for electricity but on a recent Sunday, a generator was being used to provide power. The Jubilee school has electricity.

Running water is not available. There are periodic sources of water which people go to and haul water in buckets to their homes. At the moment, Herb does not know if the water is provided by local wells or via a city service.

There are no sewer connections in Jubilee, and we do not know of any plans to install sanitary sewers.

Population of Jubilee

So far, Herb has not found any record of a census of the population of Jubilee. Even the leaders of Jubilee do not know how many people live there. One report by the Lutheran Church of Canada estimated the population as being about 12,000 in 2011. To obtain an estimate, Herb has a map which identifies the boundaries of Jubilee. He will count houses based on an aerial photograph of the area.

Orlando, one of the leaders in Jubilee, stated that all of the houses in Jubilee are occupied. Since many families consist of 8 or 9 members, Herb will make a preliminary population estimate by multiplying the number of houses by 7.

The current aerial photo of the area on Google Maps is not up to date, since the current church in Jubilee (dedicated April, 2014) is not shown, and neither is the original blue tarp and woven palm leaf church built in late 2012.

Speculation indicates the population may be as high as 25,000.

Economic Activity in Jubilee

A sewing school has been started and meets in the church / community building. They have five pedal-powered sewing machines.

With micro loans a mattress rehabilitation company has been developed. On a recent visit to Jubilee, the entrepreneurs had several mattresses spread out on Rue Lamartrniere working on them, As we approached in a vehicle, they picked them up so we could pass and then laid them back down and went to work on them.

There is an abandoned market building. Rumor has it that it will be developed into a technical school, but before that can be effective, more primary education needs to be implemented.

A website (www.jubileekidsinc.org) refers to the community as Jubilee Blanc. The website and the school associated with it are sponsored by

Jubilee Kids, Inc.
139 Altama Connector
Box #313
Brunswick, GA 31525

Jubilee Kids, Inc., is a 503 (c) 3 corporation and sponsors a school, a nutritional program, and periodic medical clinics.

A brief internet search did not find references to Jubilee Blanc other than associated with the Jubilee Kids, Inc., and related sites.

There are other small businesses which Herb is not aware.

Many of the people in Jubilee are ready and willing to work, and they put together any opportunity they see.

Building Site

We will build the initial three homes on property within Jubilee which is owned by members of the Lutheran Church in Jubilee.

After these three homes have been built as model homes, we will proceed with the building of Jubilee Lutheran Village.

Jubilee Lutheran Village will be built on a site which is owned by the City of Gonaives and is currently used as a dump site for garbage. The Mayor of Gonaives has approved the concept and has stated that he will make land available for building the first homes. If we can do what we say we can do, he will make more land available.

The main entrance to Jubilee Lutheran Village will be from Rue Lamartrniere - that is the street the Lutheran church is on. Although it is currently uses as a dump site. There is no indication that it has been used as a landfill (holes dug and the garbage buried).

Initial walking indicated the site is about 23 hectares (60 acres) in size. The land to the right (west) of an extension of Rue Lamartrniere is lower and more subject to flooding than the area to the left (east) of an extension of Rue Lamartrniere.

Two soil samples have been taken. Information about those samples is located in the section titled **Soil Samples and Foundation Needs.**

We took about a dozen GPS readings, and they are listed in the section titled **GPS Readings.**

Utilities

To get to the dump behind Jubilee, garbage trucks drive through Jubilee. Periodically garbage is spilled from the trucks onto the streets of Jubilee.

At the moment, Herb does not know of any garbage collection in Jubilee.

Several buildings in Jubilee have electricity, but a vast majority of the homes do not.

There are water taps in several areas in Jubilee, but as far as Herb knows, there is no water service.

There is no sewage service in Jubilee. There are latrines which have been installed, so much of the sanitary waste is collected in the latrines. The ditches beside the roads, which are designed to serve as storm sewers, usually contain anaerobic water.

Water, electricity, and sewage collection may some day be available in Jubilee, so each house which is constructed will have pipes laid so such utilities may be installed at some future date without having to tear up the foundation.

To provide sanitary waste disposal, a latrine will hopefully be installed on each block. This document does not address the design of the latrines, who will be responsible for installing them, or who will be responsible for maintaining them.

Some streets in Jubilee are paved and have concrete drains alongside of them. Other streets are unimproved.

Streets will need to be installed to serve the new area of Jubilee, but this document does not address that area other than to suggest width and frequency.

If Rue Lamartrniere were extended, and the other streets parallel to Rue Lamartrniere and east of Rue Lamartrniere were extended onto the building site, then cross streets could be installed as needed. One of the areas which will need to be addressed is the low area as Rue Lamartrniere enters the building site. The photo was taken from the building site, looking back towards Jubilee three days after a heavy rain.

Up until the past three years, the use of solar did not make sense unless it was in a remote area where building transmission lines was not economically feasible. With new technology, the cost of solar installations has dropped substantially.

While it is not a product which is currently on the market, a new product is in development which within a year or two may provide an economical way to add electricity to each of the domes. Herb will monitor this development.

Soil Samples and Foundation Needs

On January 25, 2015, we took soil samples from two locations at the proposed building site. One location was about 20 m into the site from the end of Rue Lamartrniere. The second location was about 100 m further into the site, and in line with Rue Lamartrniere.

Due to the loss of a battery from the GPS unit, we were not able to measure the elevation or provide GPS locations.

Earlier, at the church, the elevation was measured at 12.2 m (40 ft.). At the City of Bryan, on the edge of Jubilee, the elevation was also measured at the same elevation.

Garbage was not located on the surface of either site, but was located within one m of both sites.

Site 1

- 0 cm to 25 cm - Sandy-loam or sandy-silt soil.

- 25 cm to 36 cm - Clay content increased so that by 30 cm Herb was able to roll cylinders of soil between his fingers. Soil was packed and very hard to dig with the tools available (hand garden trowel).

Site 2

- 0 cm to 30 cm - Sandy-loam or sandy-silt soil - consolidated, but easier to dig than Site 1.
- 30 cm to 45 cm - Clay content increased so that by 30 cm Herb was able to roll cylinders of soil between his fingers. The soil was moister than at Site 1.

- 45 cm to 60 cm - Clay content increased, and moisture content increased so Herb was able to squeeze the soil and it would extrude between his fingers.

Figure 3 Soil collected about 15 cm below surface

Discussion with residents in area

- It was a 5-minute walk to a body of water (mouth of Baie Grammont).
- Ground water was about 1.2 m from the surface.

Soil samples will be transported to Texas, and Herb will do analytical work on them. Based on observations, it appears that the following are true:

- The soil has very little bearing strength when wet.
- For building a confined masonry structure which is one story in height, to be earthquake- and hurricane-resistant, the footings will probably need to be 70 cm wide. For building a confined masonry structure which is 2 or 3 stories in height, the footings will probably need to be closer to 1 m in width to provide earthquake and hurricane resistance. The footing requirements will add substantially to the cost of building a confined masonry structure on this site.
- Similar enhanced footings would be required for building cylinder homes.
- The EcoShell dome is a lightweight structure, and the weight of the structure is shared between the footings and the slab. Based on 6.1 cu m (8 cu. yds.) of concrete needed for a 6.1 m (20 ft.) dome, the weight of the structure would be 14,230 kg (32,000 lbs). Approximately half of that would be the slab which would be bearing directly on the soil surface. 7,840 kg (17,250 pounds) would be the weight of the dome shell. If we calculated all of that weight to be applied to the 20 cm wide (8 inch) by 19.2 m (63 ft.) footing, we would be applying 0.20 kg per square cm (410 lbs per square foot). This is within the anticipated support capabilities for the soil we examined.

- The above calculations are slightly misleading since they apply the entire weight of the shell of the dome onto the footing. Since the slab is poured in conjunction with the footings and is tied to the footings with a permanent reinforcing material (basalt rebar), the weight will be spread to the outer portions of the slab. If we assume that the force will be applied to the outer 1 m (3.3 ft.) of the slab (a conservative estimate), the weight would calculate to be 0.09 kg per square cm (188 lbs per square foot). This is well within the bearing capacity of the soil.
- As a result, Herb has concluded that of the building technologies examined, the EcoShell is the only one which can be cheaply and safely built on the site.

Problems With 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 (328 ft.) lengths, and are nearly1.8 m (7 ft.) 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 Herb 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 Airform is inflated to an air pressure that equals 15.25 cm (6 inches) of water. With the 6.1 meter (20 ft.) 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 Airform 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 Airform could be torn. That would take the Airform 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 ft.) 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 Airform 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 Airform 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.

The Governance

Meeting with the Leaders of Jubilee

A meeting was held with the leaders of Jubilee to find out what they wanted out of the project and to review our progress.

During that meeting we covered the different types of houses that could be constructed, costs, advantages and disadvantages of the different types of structures. Each of the leaders was given an English copy of the EcoShell book, the Blondet Manual, and Quality Concrete for Haiti. At the time of the meeting we had not dug into the subsoil to determine the load-carrying capacity of the soil profile.

Construction techniques reviewed were Confined Masonry, EcoShell Domes, and Cylinder Homes. The group favored the EcoShell Dome concept, with the cylinder home concept coming in second. Since that meeting, an examination of the soil profile indicated that the Confined Masonry and the Cylinder Homes would be more expensive than we had estimated at that time due to the enhanced foundation required.

The leaders favored having a concrete floor in the houses, rather than using a compacted dirt floor. One of them indicated that the City of Gonaives would require us to place a concrete floor in homes we constructed.

The leaders favored a 6.1 m (20 ft.) dome over a smaller dome, even though it would cost more and result in fewer homes being built.

We discussed whether the homes for Jubilee Lutheran Village should be on discrete lots or built around a perimeter with a common garden area located in the center. No decisions were reached. This is a decision which should be made on a local level.

Mission:Haiti had discussed building additional latrines in Jubilee. As the project progresses, discussions will take place concerning siting of latrines in the Jubilee Lutheran Village building area.

The leaders wanted to know whether the people of Jubilee would be building the houses, or whether outsiders would be brought in to build the houses. Herb expressed that for the first dome, he would be the crew chief and he would like the leaders of Jubilee to serve as his crew. The goal would be to not only build the dome, but to train each leader to be a crew chief on future domes. Since that time Dan Hildebrand, who build a dome school in Les Cayes, Haiti, has agreed to join Herb for the first dome in Jubilee. He plans on bringing some of the equipment he has stored in Port-au-Prince.

After the leaders were trained to be crew chiefs, than Herb envisioned that people of Jubilee, especially those who would benefit from the homes, would become the crews to build the domes. The leaders liked this concept.

Herb was asked if they saw an opportunity to go outside of Jubilee and build a dome for a customer who would pay for the building, would there be any problem with that? Herb responded that as long as the materials which were paid for by the donors was purchased that he did not see a problem with that concept.

Lutheran Church of Haiti Building Committee

The Lutheran Church of Haiti has a building committee. This building committee will interact with the leaders of Jubilee, the City of Gonaives, etc. Those who are building the houses will be working directly with that LCH building committee. Moneys which have been donated to Mission:Haiti which are to be spent in Haiti will be forwarded to the LCH building committee for disbursal.

Building Slums

One of the problems with building communities is they are often built in isolation of economic and other realities. This has resulted in people trying to do good, but building slums. Some of those slums are very high-priced slums. In the building program, we need to constantly look for holistic approaches and how people can support all or part of their needs from within their community. Providing garden space for each family so the family can grow some of their own food is one of the ways. Providing micro loans to people within the community is another way.

Legal & Political Decisions

- A committee or committees should be formed to make decisions.
- Participants should include, but not necessarily be limited to the leaders of Jubilee. Pastor Benoit should be on the committee representing the Lutheran Church of Haiti.
- The Mayor of Gonaives, or his representative, should be involved for some of the decisions to be made.

Herb will be involved in technical and engineering decisions, but the committee will be involved in the political and community decisions since it is their project for which they must take ownership if it is to be successful.

Following are questions which go beyond the engineering and construction of the houses which the committee(s) needs to address.

- Who will own the homes?
- Who will pay for the land if a payment is required?
- How will funding of the construction be handled?
- How will rent be determined?
- Where will rent money go?
- Who will decide who gets which house?
- How much sweat labor will each family which gets a house be expected to contribute?

Factors Impacting Density of Housing

Space per person	UN recommendation - nominally 3.75 sq meters (40 sq ft)
People per family	8 to 9
Number of stories	based on soil conditions, we are limited to one story
Garden space	need to include a garden space, size to be determined by the committee
Trees	Trees help make these houses into homes; we need to include trees. Currently in Jubilee, there are very few trees.
Streets	Street width and accessibility

Who Would Build the Houses?

One of the first questions asked by the steering committee was who would build the houses. Would we bring in **outsiders** or would we teach the residents of Jubilee to build the houses?

Herb's response was that this was their project, and he was there to help them. His idea was to use the 6 of them as his team, and he would train each of them to be in charge of building future houses. He thought he could train each of them with the construction of one house. They liked that idea.

Each member of the steering committee was given a copy of the EcoShell I book (in English), and Herb explained he was working on a supplement which would give specific instructions for building the 6.1 m (20 ft.) dome. He also stated that he proposed having the manual translated into Creole and published so each member of the building crew (and building inspectors and others interested in the technology) could have a copy. Autographed copies of the manual could be given to each person or group which donated money to build a house in Jubilee.

The leaders could see the advantages of building a construction business based in Jubilee, using Jubilee residents, and bringing money from other portions of Gonaives into the Jubilee community.

Meeting with the Mayor

On the evening of Thursday, January 28, 2015, Herb, Pastor Benoit, and Rose Augustine (who adopted Herb as her grandpa) met with the Mayor of Gonaives in the Mayor's home. Herb explained the project and furnished the Mayor copies of books he is working on. The Mayor asked numerous questions and gave his blessing to the project. He made land available for us to build our initial houses; and after they are built, if we have done what we have said we are going to do, he will make more land available. After the meeting, he walked us out to Pastor Benoit's pickup. The pickup would not start, so the Mayor helped him get it started.

The Specifics for Building Jubilee Lutheran Village

Layout of Streets

- Assume 18 m (59 ft.) wide streets.
- Rue Lamartrniere is nominally north and south and is near the dividing line between the areas which can be used for building and the areas which are too low for building.
- Extend Rue Lamartrniere south across the building site.
- Extend an unnamed street which are east of Rue Lamartrniere approximately 140 m (460 ft.) and roughly parallel to Rue Lamartrniere south across the building site.

- Lay out a cross streets which are perpendicular to Rue Lamartrniere and approximately 140 m (460 ft.) south of the furthest south street in this section of Jubilee. The proposed street would be approximately 510 m (1,673 ft.) south of the Lutheran Church.
- Start a north-south street which starts 280 m (920 ft.) east of Rue Lamartrniere and extends from the proposed cross street and extends south
- Distance between the cross streets will be determined by the size of the lots and the number of lots the committee determines should be in each block. Currently it appears that a spacing of 60 m (197 ft.) would produce blocks which are 0.84 hectare (2.08 acre) including the streets and easements.
- The area exclusive of the streets and easements would be 122 m (401 ft.) by 42 m (138 ft.). This would be 0.51 hectare (1.26 acres).
- If such blocks were divided into 12 lots, each would be approximately 427 sq. m (4,550 sq. ft.). This would be about 60% of the size of a small US city residential lot.
- Stakes will be used for laying out the streets. The Lutheran Church of Haiti has heavy equipment which can scrape the garbage off the sites which will be used for building.
- A discussion needs to take place with the City of Gonaives as to whether they need to approve of the layout proposed and whether they want to be involved during any of the work related to installing roads and the drainage ditches which will be placed beside them.

Size of Structures

- UN states that 28 m^2 (300 sq ft) is adequate for a family of 8 in a tropical area.
- That would require a 6.1 m EcoShell or a confined masonry house which is 4 m (13.1 ft.) by 7 m (23 ft.).

Layout on Lot and Fences

- This is an area which needs to be addressed by the committee.
- Fences need to be incorporated into the overall plan.
- As one of Herb's students told him last year when Herb suggested that we could build more houses if we did not build as many fences, "If you do not build a fence, by the time your daughter is 13 years old, she will make you a grandfather."
- Many of the lots in Jubilee are smaller than 10 m by 15 m. If we used that size lot we could put 34 houses on one of the blocks delineated by north-south roads every 140 m (460 ft.) and east-west roads every 60 m (197 ft.).
- Do we want to divide each block into discrete lots, or do we want to place the houses around a common area?
- If discrete lots were used and they were 20 m (66 ft.) wide by 40 m (132 ft.) deep (about the size of a standard US lot), 8 houses could be built on each hectare.

- If the houses were laid out around the perimeter and the center areas would be a common area for gardens, then we could easily double the density of housing without impacting the livability.
- Prior to more development in this area, we need to determine the cultural needs and desires of the people and the amount of garden space/yard per family. We want to help them build houses which will improve their lives.
- Plans should include a latrine for each block. It would be more accessible to the residents and more protection would be provided to the young ladies if the common area concept was used and a single perimeter fence was built around each block.

Clearing the Land

Based on the geology of the site observed, with the top 25 cm being a sandy-loam or a sandy-silt, and the lower soil being clay, it is recommended that when the site is cleared, it be scraped to remove any garbage, but not be scraped any deeper than necessary to remove the garbage. This will provide the most stable ground to work on.

If the bottom of the 30 cm (12 inch) forms are set at ground level, and then fill (sandy-loam or sandy-silt) is brought in from the areas which will end up being ditches along the roads, there will be a minimal disturbance of the soil in the area, and the top of the slab will be about 30 cm (12 inches) above grade.

Drainage Plan and Elevation of the Slabs

It appears that the highest areas of the dump are to the east of an extension of Rue Lamartiniere (the street the Lutheran church is on). Currently it appears that some of the rain falling on the dump flows along the streets of Jubilee, but most of it flows to the west. Elevations need to be taken so a drainage plan can be developed so this building project will not negatively impact existing homes in Jubilee.

The western portion of the dump is currently not being used and on Thursday morning was covered with water. Building in that area would result in additional problems.

Figure 4 Mud flat on west side of dump site

Sources of Help

Dan Hildebrand built a 40-ft. EcoShell dome at Les Cayes, Haiti. It is 191 kilometers west of Port-au-Prince on the southern Haitian peninsular. This is the largest dome which Nolan Scheid knows of which was sprayed with a mortar sprayer.

Dan has some of the equipment which he used stored in Port-au-Prince and two of his trained crew currently live in Port-au-Prince. In talking with Dan on February 14, he indicated that he would be willing to come and help with the first dome, bring one of his trained crew members to help train the crew, and make his equipment available if we have a secure area to store it.

Pierre Labaze has a passion for building domes in Haiti. Recently he re-contacted David South concerning building domes in Haiti. David South introduced Pierre to Herb via email and they will be talking about how they can help each other.

Jeff Green is a pastor in Branson, Missouri, with a passion for low cost building and innovation.

Donations

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Materials List

The following list of materials is broken down into sections. When an item is required in several areas, it is listed in each of those areas. In several cases, alternatives are listed, such as No. 3 steel rebar and 6 mm basalt rebar. In areas of high chlorides, the basalt rebar should be used; in most other areas, the steel rebar is cheaper and just as durable.

This list envisions forming the shell of the house with bucks for doors and using concrete ventilation blocks formed into the wall for windows. The doors, and internal walls are not included in this list.

Capital Investment

- Airform - EcoShell I 20 ft.
- High-pressure blower
- Generator (Electricity is not readily available in Jubilee and in Gonaives, where it is readily available, it is not be reliable.)
- Clamps for Airform

- Scaffoldings -Fabricate from angle iron

Capital Investment - Optional

- Air Compressor - 5 hp to 8 hp gasoline engine (for spraying stucco)
- Concrete Mixer - rotating drum 0.25 cubic meter (9 cu. ft.) (Mixing concrete)
- Mortar Sprayer W/air lines, etc. (for spraying stucco onto the dome)
- Mortar Mixer - paddle type 0.25 cubic meter (9 cu. ft.)

Tools

Some tools may already be available.

- 5-gallon buckets
- Battery-powered Hammer Drill / bits
- Extension cord
- Hammer
- Hoe
- Hog ring pliers
- Level (120 cm)
- Mortar mixing trough (if mixer is not available)
- Saw, wood
- Saw, hack
- The Lutheran Church of Haiti has a table saw which will be useful in cutting the form board.
- Screwdrivers
- Screed to level concrete
- Shovel
- Tamper
- Tape measure
- Trowels
- Water barrel
- Wheelbarrow

Reinforcement for Footing

- 6 mm basalt rebar - 100 meter roll - for footing

- In areas without high chlorides, No. 3 rebar is more than adequate.

Reinforcement for Slab

- 6 mm basalt rebar - 100 meter roll - for footing
- In areas without high chlorides, No. 3 rebar is more than adequate.
- Basalt mesh for slab 25 mm sq,(50 sq m) has been suggested; however, it may be difficult to get it imbedded into the slab.

Concrete for Slab and Footing

- Aggregate - Gravel (2.5 cm max size) (cu m)
- Aggregate - Sand (w/o clay) (cu m)
- Portland Cement (bags)

Hardware & Supplies for Slab and Footing

- Hardware - Center pivot - assembled by Herb
- Hardware - galvanized steel coupling - 20 mm - center point
- Hardware - galvanized steel pipe - 60 cm x 20 mm - center point
- Hardware - PVC pipe - 12 mm x 3 m lengths - marking arm
- Hardware - PVC threaded nipple - 12 mm - marking arm
- Hardware - Decking screws - Window & door frames
- Hardware - 3 in. diameter drainpipe, 1 elbow, & 1 cap - drainpipe for commode
- Hardware - 1.5 in. diameter drain pip, 1 elbow, & 1 cap - drainpipe for sink
- Hardware - 1 in. diameter drainpipe, 1 elbow & 1 cap - stub out for electricity
- Hardware - 0.75 in. diameter pipe, 1 elbow, and 1 cap stub out for water
- Lumber - 3 sheets of 1/2 in. sheets (12 mm) plywoog - form boards
- Lumber - 65 pieces of 5 cm x 5 cm x 60 cm) Stakes for form boards
- Lumber - 6.5 m - Screed board
- Vapor barrier slab - (10 sq m) 3.05 x 30.5 x 4 mil clear

Reinforcement for Dome

- Basalt rope 3 ply, 1,000 ft.
- Epoxy or polyester resin - 500 ml

Stucco for Dome

- Aggregate - Sand (w/o clay) (cu m)
- Portland Cement (bags)
- Hydrated lime or mortar fat

Hardware & Supplies for Dome

- Hardware - hog rings - 0.5 in. galvanized
- Hardware - Tapcon screws 0.25 in. x 1.25 in.
- Hardware - Packet of 4 bits for Tap Con Screws

Monofoam Primer (gals) comes in 5 gal bucket (check with David South about an alternative which is cheaper)

- Hardware - SS Hook bolts for window & door bucks
- Jack stand - Support inside the dome to support a scaffold outside the dome.
- Lumber - Bracing (m)
- Lumber - Dimensioned (nominally 5 cm x 10 cm) (m)
- Screen - 25 mm - fabricate angle screen with lumber
- Screen - 6mm - fabricate angle screen with lumber
- Screen - 1 mm - fabricate angle screen with lumber
- Lumber - Plywood - 1/2 in. sheets (12 mm) Window & Door Frames
- Ventilation turbine - 30 cm (12 in.) with base

Material Availability

The Airform and Blower

The Airform needs to come from Monolithic. The Airform for the 6.1 m dome weighs approximately 170 pounds and fills a 3 ft. 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 in checked baggage. This means that prior to building any domes in Jubilee, we need to have a couple weeks for ordering and delivering the Airform 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, but if we have someone who is good at tinkering, we can probably save a few hundred dollars. The downside of this is we would need to build the pressure regulating system.

Under normal circumstances, a small backup generator is needed to ensure that the blower has power when the Airform is in use. Electrical power is erratic in Haiti, so the generator needs to be dependable enough to furnish constant air pressure to the Airform from the time the stucco is first applied until the second coat has cured for 24 hours (a total of 60 to 72 hours). If after the Airform has its first coat of stucco, it momentarily loses pressure and is then repressurized, it will cause the initial layer of stucco to shatter.

Basalt Rebar and Basalt Rope

The 6 mm basalt rebar ships in 100 m rolls which are 2 m in diameter and 5 cm thick (80 inches in diameter and 2 inches thick) (there is a report that one supplier sells it in smaller diameter rolls) and weighs 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 rolls are under tension, so care needs to be taken when cutting the ties.

The basalt rope ships in nominally 1,000 ft. 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.

Other Materials

When materials are available in Haiti, we will use them rather than shipping a similar product to Haiti.

Building the Jack Stand & Scaffold

For applying basalt rope and stucco to the top of the dome, it is necessary to have access to the top of the Airform. This could be done with a scaffold placed on the outside of the dome, but it would require a relatively large scaffold. An alternative is to place a support inside the dome, hereinafter referred to as a jack stand, which will provide the support for a relatively simple scaffold.

A jack stand is often used inside the larger domes to provide support for external scaffolding. It may be a misnomer for what we will be building inside the Airform, but we will use that term.

The jack stand will consist of two sections. The lower section will consist of three legs which will be pieces of 3.2 cm (1.25 in.) thin wall conduit or Chain link fence top railing. The bottom two inches of each leg will be flattened and bent to form a two inch foot. In use the legs will be splayed to provide a 1 m diameter footprint and will be attached to the slab with Tapcon anchors. Positioning is important since the axle passing through the top of the Airform must be in exact alignment with the top center of the Airform.

The upper section of the jack stand will provide an attachment for the three legs. An axle will pass through a grommet in the top of the Airform and provide for the attachment of the scaffold. The axle needs to contain a clamp to provide an airtight seal as it passes through the grommet.

The airtight seal may be made with the following combination of materials. Materials listed from the top:

- Nut

- Metal washer
- PVC disk
- Rubber washer
- Airform material
- Rubber washer
- PVC “washer disk”
- Metal disk attached to the axle.

The clamp needs to be adjustable so when it is attached, the natural curvature of the Airform is not modified. This can be accomplished by the use of a piece of all thread, where the all thread is permanently attached to the head of the tripod and the metal disk forming the bottom of the air tight seal is threaded so it can be moved up or down the all thread.

A second way the adjustment can be made is to have the metal disk permanently attached to the axle. The lower portion of the axle would be threaded. A nut would be mounted in the tripod head and the axle would be rotated to raise or lower it.

A polar scaffold will be constructed in Haiti. It will either be a curved ladder or a segmented ladder. One end will rest on the ground and have a width of at least 0.5 m (20 in.). The majority of the ladder will be 0.5 m (20 in.) in width, with the upper 0.5 m (20 in.) tapering. The upper end will attach to the axle which is on top of the jack stand. The attachment will be such that the foot of the ladder can be elevated above the ground and moved around the Airform.

The polar scaffold will be constructed so there is a space of 0.4 m ( )to 0.75 m ( ) between the polar scaffold and the air form, including at the top of the Airform. This distance will allow one person to be on the ladder with a MortarSprayer and effectively spray; but if a MortarSprayer is not available, it will be close enough to allow hand trowelling.

Question: How thick should the axle be so it is not bent when in use?

(new page)

The EcoShell I Version 4

By David South, Monolithic Dome Institute

(insert full text)

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The Details - Building a 6.1 m EcoShell in Jubilee

by Herb Nordmeyer

Reason for the Supplemental Material

In 2000, Monolithic Dome Institute published David South's book EcoShell I. In 2014 the fourth edition was published. This supplement in no way is meant to replace that book, but instead is aimed at supplementing that book for people who are interested in building earthquake-resistant and hurricane-resistant housing in difficult situations. From here on out, we will refer to this kind of construction as disaster-resistant housing.

The specific instructions are for building a 6.1 m (20 ft.) EcoShell in Jubilee, Gonaives, Haiti. This is an area where is a high water table, soil conditions are less than ideal, and high chlorides prevent the use of steel rebar in the footings and slab. While specific to Jubilee, this information is relevant to many areas in the third world.

In developing this supplement, I tried to identify every tool, every piece of equipment, and all materials that 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 onto my spreadsheet and which I will be discussing in this supplement.

One of the most important things that I had forgotten was how hard it is to drill one hole in concrete 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 has to ream-out the preformed holes. Suddenly a several-hour job became a job that could be done in less than 30 minutes to an hour. The only problem is ensuring that the angle plates are positioned correctly when they are being installed and lining up the Airform so additional holes do not have to be drilled through the Airform and shorten its life.

Nolan Scheid countered with the fact that there are several types of drill bits. If the larger diameter Tapcon screws are used, one can use the smallest (3/16 in.) SDS bits. In a battery-powered hammer drill, they penetrate easily into the concrete and this results in being able to accomplish the task in a minimal amount of time.

While this document 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 document 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.

In the slum of Jubilee, in the city of Gonaives, Haiti, the groundwater table is high and is brackish. In some areas it is just over a meter below the surface. 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 are using the metric system and following with the English equivalents. Mr. South uses the English system and in some cases follows it with a metric equivalent.

Much of this document addresses building the 6.1 m (20 ft.) 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. A down side of building with the EcoShell concept is if short cuts are taken in building that failures are likely.

Site Preparation

The item numbers refer to the 4th edition of EcoShell I, published in June, 2014.

Items 1, 2, and 3 (pages 3 and 4)

Clearing the area, leveling the area, and firming the area are covered.

The same type of preparation is needed for most structures that are built. These steps are very important. Depending on the type of soil you are building on, you may want to add base material.

Item 4 (page 4)

You can use a stake in the center of the site, but there is a better way.

Due to the high water table and the potential of flooding, the footings will not be dug into the ground. By designing to place the footings on the surface of the ground, and by using form boards which are 30 cm (12 inches) the slab will end up being 30 cm (12 inches) above grade.

Since the footings are placed on top of the ground, it is necessary to install the vapor barrier before the form boards are installed. This will help keep the concrete slab dry. Ideally the vapor barrier should be a single sheet of polyethylene plastic with a minimum thickness of four mils. Since ideal seldom exists on a construction site, if more than one piece of polyethylene plastic is utilized, it should be lapped a minimum of 30 cm (12 inches).

Roughly mark out where the building is to be located and lay a vapor barrier on the ground. When the vapor barrier is laid down, throw dirt on it to keep it from being picked up by the wind.

The center marker, a stake (alternate method of installing a center pipe is listed in the next paragraph) should be set so the top of it is the desired elevation of the slab above the compacted soil or base material.

Use a 45 cm (18 inch) length (or longer) of 20 mm (3/4 inch) steel pipe with a coupling on the upper end of the pipe instead of the stake. The soil in the Jubilee site will not resist the pressures placed on the steel pipe when the measuring arm is attached. To ensure the pipe will hold up through the pouring of the slab, mix enough concrete to embed the pipe so it will remain stable. The top of the coupling should be the finished height of the slab. Find something and plug the end of the coupling so the threads do not get messed up.

The Forms

Item 5 (page 5)

The base of the dome is circular, so your footing and slab should be circular. You can measure from the center post to where each supporting stake is located, but that takes time and requires two people. You can tie a string to the post and hope it does not get wrapped around the post as you move around the perimeter of the future dome.

An easier way is to install a **marking arm**.

Insert a pipe nipple into the coupling of the 20 mm (3/4 inch) pipe.

Do not tighten it down tight.

Add a 20 mm (3/4 inch) pipe T to the pipe nipple. Do not tighten it down tight.

Attach a 20 mm (3/4 inch) PVC pipe using a threaded adapter. The pipe should be approximately 30 cm (12 inches) longer than the radius (that's half the diameter) of the dome. It is okay to splice several pieces of pipe together.

It is possible to make a pencil or pen mark on the PVC pipe, but the mark might come off. Place each mark, and then grove the top of the pipe with a shallow saw cut. Then mark the saw cut with a pen or pencil. This will make the mark permanent. For a few of those marks, you will want to drill a 1 cm (3/8 inch) hole in the pipe. Here is a list of the points you need to mark. The primary mark is measured from the center of the center pipe. The other marks are measured from the primary mark.

- The edge of the Airform of the dome
  3.05 m (10ft. 0 in.) This is a critical measurement, and every other measurement is based on this measurement. This mark will be referred to below as the prime mark. Drill a hole.
- The edge of the slab
  The slab is 30 cm (12 inches) larger than the dome. Therefore, the mark for the edge of the slab is 15 cm (6 in.) outside from the prime mark. Drill a hole.
- The inside edge of the form stakes
  If the form boards are 13 mm plywood, then the mark would be 13 mm outside of the edge of slab mark.

- Tapcon screw line
  Each angle iron has 3 holes. The two outer holes are located approximately 1.6 cm (5/8 in.) inside from the prime mark. Drill a hole.
- Hooks or basalt rope loops
  The hooks are placed about 2.5 cm (1 in.) outside of the prime mark. Drill a hole.

Items 6, 7, and 8 (pages 5 & 6)

The stakes should be placed about 60 cm (2 ft.) apart, and should be driven vertically into the ground. They need to be firm enough so they will hold up after the form boards are attached and the concrete is poured. Stakes should be driven in until approximately 33 cm (13 in.) remains above grade.

Items 9, 10, and 11 (pages 7 & 8)

Remove the center pivot from the center coupling. Place a straight board on the coupling and the other end beside one of the perimeter stakes. Using a level to ensure the board is horizontal, mark the stake. Move to the next stake and mark it. Then cut off all of the stakes at the elevation of the center coupling.

Alternative - Using the board and the level as a reference, drive each stake into the ground until it is level with the top of the coupling on the center pipe.

Alternative - If you do not have a straight board and an accurate level, you can fabricate your own level with a piece of clear plastic tubing.

(We need to add a drawing of a home-made level.)

Items 12 and 13 (pages 8 & 9)

Reinstall the center pivot, and recheck everything.

Item 14 (page 9)

Normally the footing would be dug on the inside of the forming stakes. Since we are elevating the slab, footings do not need to be dug.

Whether there are plans for installing electrical, water, or sewer connections at some point in the next 20 or so years, it is much easier to install lines running underneath the footing at this point so the slab does not have to be torn up at that future date.

Item 21 refers to digging trenches and laying pipe for future water (3/4 in. diameter), sewer (3 in. diameter), and electrical (1 in. to 1.5 in.) connections. Since the footings are being placed on the surface of the ground, it is appropriate to install them at this time. Be sure to have a tight-fitting cap to go on each of these pipes. Locations should be determined where a sink and a commode might someday be located. The electrical pipe should be located where a future wall is to be located. The water pipe and the electrical pipe should come up a few inches above the slab and should be located a few inches from the shell of the dome (make sure that it does not interfere with the angle iron pieces which tie the Airform to the slab). The commode pipe should have a right angle bend in it and should end up flush with the top of the slab. Place a cap on the exit end of the sewer pipe and a cap on the inside of the water and the electrical pipes.

Items 15, 16, and 17 (pages 10 & 11)

The form boards can be just about anything which will bend. If plywood is used, it should be exterior grade (CDX) and nominally 10 to 13 mm (0.5 in.). To get it to bend, it needs to be soaked in water for a day or two. The form boards should be 30 cm (12 in.) wide. For a 6.1 m (20 ft.) dome, two sheets of plywood are needed. So the forms can be removed from around the slab after the concrete sets, they need to be treated to prevent the concrete from sticking to them. There are form-release chemicals which can be used, but in most third world countries, waste motor oil will work well.

The plywood forms will have to be replaced after constructing several domes. If a number of domes are to be built, there are plastic forms that are available which in the long run would be cheaper and easier to use than the plywood forms. Here is one source.

http://www.metalforms.com/C/17/PlasticConcreteForms

Items 18 and 19 (pages 11 & 12)

The form boards need to be attached to the perimeter stakes. While it is much easier to add screws through the form boards into the stakes, when it comes time to remove them, a problem develops. Utilize decking screws which are long enough to go through the stake and the form board. Where two form boards meet, add a splice.

Building in Jubilee, we will use basalt rebar, and the slab will be 5 cm (2 in.) thick. In other areas, it may be cheaper or easier to use steel rebar and a slab that is 10 cm (4 in.) thick.

Item 20 (page 12)

Take whatever time is necessary to end up with your form boards level and all of the loose dirt removed from the vapor barrier within 10 cm (8 in.) of the form boards. Fill, base material, or soil needs to be placed in the center of the slab area to raise the level to 5 cm (2 in.) from the finished slab level. To keep the fill material from scattering to the footing area, stack rock, broken concrete block, or other inert chunks of material about 20 cm (8 in.) from the form boards. The stack should be tapered inward until it is within 5 cm (2 in.) of the final slab level. For best results, add the fill material in 5 cm (2 in.) lifts and tamp until the fill material is approximately 5 cm (2 in.) from the final slab level.

Items 21 and 22 (page 13)

This was taken care of as part Item 14.

Determine where the door or doors will be located and mark where the door buck or bucks will be located.

Reinforcing the Slab and Footings

Item 23 (page 14)

It is now time to install two continuous 6 mm basalt rebar. The basalt rebar comes in coils which are about 2 m (80 in.) in diameter. It is under a lot of tension, so care must be taken in opening the coils. Cut off the required length of a ring, plus about a half meter for an overlap. Place them inside the forms and tie them so they end up being about 10 cm (4 in. apart. Block them up so they are about 10 cm (4 in.) above the vapor barrier.

In areas where the chloride corrosion problems are not a problem, it is appropriate to use number three rebar (10 mm) in the footing. The rebar should be spliced with a minimum of a 30 cm (12 inches) overlap.

An alternative to using the basalt rebar, would be to use two pieces of basalt rope, coat them with epoxy, and twist them together to replace each piece of 6 mm basalt rebar.

Items 24 and 25 (pages 14 and 15)

In areas where chlorides do not cause a problem, number three rebar may be used. When steel rebar is used, there should be 3.8 cm (1.5 inches) of concrete beneath the rebar, and also above the rebar. This requires a concrete slab that is at least 8.9 cm (3.5 inches) in thickness. The rebar should be placed approximately 38 cm (15 inches) apart. Each rebar should end approximately 2 inches from the form board. After the rebar are placed in one direction, rebar are placed at a 90° angle to the first set, and wire tied together to make a mat. The mat needs to be blocked up so that there is about 3.5 cm of space beneath the rebar mat.

In Jubilee, to mitigate damage caused by chlorides, the steel rebar should be replaced with basalt rebar. The same 38 cm (15 inches) pattern should be utilized, with the rebar laid in both directions and tied together to form a mat. Since the basalt rebar does not need as much protection as the steel rebar, it can be elevated so that it is in the center of a 5 cm (2 inch) slab.

If a decision is made to use basalt rope in place of the basalt rebar, a problem develops in trying to get it in the center of the slab. The easiest way is to pour approximately half of the concrete for the slab and then lay the basalt rope in the fresh concrete. Rather than 38 cm (15 inches) between the rebar, the basalt rope should be approximately half of that, or 19 cm (7.5 inches) between each piece of rope. The problem with using this technique is you have to pour half of the concrete and level it off before you pour the rest of it. This can lead to a cold joint which would impact the life of the slab.

Herb is having discussions with a gentleman who is developing a technique for applying basalt rope in the center of a slab in a circular pattern after all of the concrete has been poured, and screeded.

Leave the marking pipe attached to the center stake as it will be needed when the stainless steel hooks or basalt ties are added to the fresh concrete.

Pouring the Concrete

Items 26 through 32 (page 15 through 18)

The three most important things about mixing concrete are:

- one - Use as little water as possible,
- two - Screen the clay out of the sand and gravel, and
- three - Do not use less Portland cement than is specified.

Items 33 through 35 (pages 19 & 20)

Since about 2.5 m^3 (3.2 $yd.^3$) of concrete is needed for a 5 cm (2 in.) slab, unless you have a ready mix truck, it is not likely that you will be able to pour the entire footing and slab within a 15-minute period. As a result, select one portion of the slab and footing and start pouring in that area. Have someone with a rod working the concrete in the footing to ensure that the concrete in the footing is well consolidated.

As you bring it up to approximately the finished level, continue pouring, but have someone use a rod to help consolidate the concrete, then screed the concrete off as you go, and use a jitterbug to consolidate the concrete on the surface of the slab. If you need to add more concrete, jitterbug it.

Add a drawing of a jitterbug

Keep the working line of the concrete wet so you do not inadvertently form any cold joints. As more concrete is added to the concrete in place, rod the area so it will bond better.

Item 36 (page 20)

As the concrete is brought up close to the finish level, use a screed board to level it off. If there are low areas, more concrete can be added, but then it must be jitterbuged to densify it. After that, it can be re-screeded.

Items 37 and 38 (page 21)

Installing the stainless steel hooks is straightforward, but they are expensive. Since they form the juncture between the slab and the dome, if non-stainless steel hooks are used and if they deteriorate, the dome will not remain securely tied to the footing and the house will no longer be disaster-resistant. Use the hole in the marking arm that is 2.5 cm (1.0 inch) outside the anticipated location of the air form. Mark a continuous line in the slab, except for the doorways.

Alternative to the Steel Hooks

Basalt rope can be coated with epoxy and formed to replace the stainless steel hooks. This needs to be done ahead of time.

Add drawing

Using a notched stick, install the coated epoxy rope into the slab along the continuous line to a depth of 10 cm (4 in.). This should result in a "M" of coated basalt rope being exposed above the slab every 30 cm (12 in.) around the slab, except where the door (s) are located. On each side of each doorway, there should to two "M" loops.

Rod the concrete where the basalt rope has been inserted, to ensure that the concrete is well consolidated. Cut a groove between each of the basalt rope "M" to a depth of about 2.5 cm (1 in.) and about 2 cm (0.8 inches). This is to allow the dome to key into the slab.

Item - Finishing the Slab

To obtain the best finish, delay trowelling until after the bleed water from the concrete has surfaced and dissipated. After there is no sheen left on the fresh concrete, the concrete surface can be finish-troweled. If the surface is troweled before the bleed water is gone, the surface will have a tendency to dust over time. Also the surface may spall.

After the surface has been troweled, the edge of the Airform can be etched with a pointed stick run through the prime mark hole as the marking arm is rotated around the slab.

The surface of the slab should be protected from evaporation.

Item 39 (page 22)

Remove the form boards after the concrete sets. The form boards can be reused if they are carefully removed, cleaned, and stored for the next job.

Item 40 (page 22)

If a line was not etched into the concrete with a stick under "Item - Finishing the Slab," a pencil can be passed through the hole at the prime mark, and a pencil mark can be made around the slab where the Airform will be located.

Items 41 through 43 (pages 23 & 24)

Use Tapcon Anchors which are:

- 1/4 in. in diameter
- by 1.25 inches long,
- with a 5/16 in. hex head.

Pilot holes can be drilled with 3/16 inch diameter SDS bits used in a battery-powered hammer drill. These are the smallest size of SDS bits which are available.

When reusing the balloon form, as much as possible, use the same holes as were used the first time to prevent the destruction of the lower edge of the balloon form.

The Airform for a 6.1 m (20 ft.) dome weighs about 80 kg. (176 lbs.), so to make the work of attaching it more pleasant, a structure needs to be added to support some of that weight. Also, blowing air into the Airform will make the work more pleasant.

One alternative, which is not mentioned in The EcoShell book, is to add a jack stand which adjusts to the height of the roof. If it is designed with a "topknot" to pass through the top of the dome, it can also support a polar scaffold which will make coating the Airform with stucco, and adding the basalt rebar, easier.

If this option is considered, talk to the Monolithic people about modifying the balloon form.

Based on the recommended operating pressure, the following conditions will exist:

	metric	English
• Water pressure	15.25 cm	6.0 in.
• Pressure	15.25 g per sq. cm.	31.2 lbs. per sq. ft.
• Lift for a 6.1 m (20 ft.) dome	4,455 kg	9,800 lbs.
• Lift per Angle Clamp	71 kg	156 lbs.
• Lift per Tapcon anchor	23.6 kg	52 lbs.

With these loads, be sure to use the specified Tapcon anchors.

Item 44 (page 24)

Sealing is critical for being able to inflate the balloon form. The water, electrical, and sewer stub outs need to be capped so they will not leak.

Placement of Jack Stand

The jack stand needs to be placed so the axle is directly over the center pivot of the slab and is directly in line with the grommet in the top of the Airform. It also needs to be placed so the clamp on the jack stand is at the same height as the Airform when it is inflated and no jack stand is present. Any misalignment or improper height adjustment will be visible from the inside of the Airform. If stresses show to one side, the axle is misaligned. If stresses are distributed around the axle, the top of the jack stand is at the wrong height. Take the time to get it right.

Item 45 (page 25)

Installing turbine ventilator base

Place the base of the turbine ventilator over the axle at the top of the Airform. It should remain loose. When the area is stuccoed, stucco will be applied between the Airform and the base of the turbine ventilator.

Attaching the polar scaffold

Attach the polar scaffold to the axle at the top of the Airform. Check to see if any leakage occurs around the axle; and if so, tighten the clamp nut to stop the leakage.

Security & operation of the inflation equipment

If the inflator is placed on the ground, or very close to the ground, it may suck up some dirt and wear the internal parts. Place the inflator on a structure where it will not suck up dirt and will not be knocked over.

From the time the inflator and generator are placed on the building site until they are removed from the site, 24-hour security is needed at the building site.

From the time the first stucco is applied to the Airform until the second coat has cured for 24 hours, an operator needs to be present to ensure the generator does not run out of gasoline.

If possible, an auxiliary gasoline tank needs to be installed for the generator so one does not risk the pouring of gasoline on a hot manifold or a hot exhaust.

Items 46 and 47 (pages 25 & 26)

With the first EcoShell we build in Jubilee, we will install a door buck similar to the design shown in Item 46. The modification we will use is that we will use basalt rope threaded through the boards instead of stainless steel hooks.

While we are doing this, we will talk to various concrete artisans to see if any of them would be able to pre-cast a concrete door frame which could be leaned against the Airform and incorporated into the house. If they can, we will ask that they incorporate basalt rope into the pre-cast concrete door frames to tie them to the dome they are installed on.

Rather than use bucks to allow the placement of conventional windows, concrete ventilation blocks will be used. These will be placed against the Airform and supported by lumber. Rather than place them high on the wall as would normally be done in the US, the ventilation blocks will be placed about 1 m above the slab to increase the ventilation of the dome. They will be drilled, and loops of basalt rope will be dipped in epoxy and inserted into the holes. This will allow them to be tied to the basalt rope which will be wrapped around the dome.

Item 48 (page 26)

(Talk to David South about the alternate formula for spraying/rolling the primer onto the Airform)

Items 49 to 50 (page 27)

Spray starting at the bottom of the Airform. Better results will occur if the bottom one m is thicker than the rest of the first coat and when it is allowed to stiffen slightly before the rest of the dome is stuccoed.

With the first coat of stucco, when pressure in the Airform is lost and then re-pressurized, the stucco tends to explode. If pressure is lost, allow the stucco to cure for 24 hours and then when repressurizing, bring the pressure up to 2.5 cm (1 in.) less than had originally been used.

The first coat of stucco is very fragile. It will crack, but by maintaining an even air pressure and taking care with adding the basalt rope, the cracking can be kept to a minimum.

Items 51 to 52 (page 28)

This section is straightforward; however, to make the adding of the basalt rope easier, we are working on a system to tie a net to drape over the dome. This will result in a better layout of the basalt rope and will result in less time with a person on the polar scaffold to install the rope. This will reduce the risk of someone inadvertently bumping the shell and cracking it.

Building a Frame for Tying a Net

Build a frame with 6 sections of 1/2 inch PVC pipe, each nominally 3 m (10 ft.) long. Join them with PVC Ts. The resulting frame should be basically circular. Do not glue the joints. Face the leg of each of the Ts down. Attach a 1.5 m (5 ft.) long piece of PVC to each of the PVC Ts to act as support legs. This results in a nominally 6 m (20 ft.) circle with legs which support it.

Since none of the joints are glued, the frame will be wobbly. To stabilize it, take 1 m pieces of No. 3 rebar and drive them vertically into the ground 60 cm (24 in.) in a pattern where the legs of the frame can be slipped over the vertical rebar.

Go out and try it out before going to Haiti.

Item 53 (page 29)

Inspect, inspect, inspect. The error you catch at this point will save grief later on.

Item 54 (page 30)

There will be a tendency to step on, or put weight on, the dome as the basalt rope is being installed. DON'T! That will lead to cracking of the inner coat of stucco.

Item 55 (page 31)

Allow each coat of stucco to cure before adding the next coat of stucco. Each coat should be about 1.25 cm (1/2 in.) thick. With three coats of stucco, that will result in 3.75 cm (1.5 in.) of stucco.

With the base of the turbine ventilator, it should be set on the first coat of stucco. Basalt rope should go over the base, and then the second coat of stucco should secure the base into place.

Item 56 (page 31)

To remove the Airform, first, turn off the inflator and open the access hatch. The Airform will be lightly stuck to the first coat of stucco. Do not try to loosen it at this time. Remove all of the Tapcon anchors and all of the anchor clamps. Remove them from the dome and store them before starting to remove the Airform from the dome.

As much as possible, loosen the air tight clamp at the grommet of the Airform.

Remove the polar scaffold and store until it will be needed for the next EcoShell.

Remove the jack stand. It needs to be adjustable enough so the legs can be removed to facilitate the removal of the upper portion of the jack stand.

Starting at the doorway, pull the Airform from the stucco on the roof of the dome. With one person inside the Airform and one outside, remove the upper portion of the Airform.

With everyone out of the Airform, peel the Airform from the stucco and then carefully remove it from the dome. Clean, fold, and store the Airform in a dark area so UV rays will not destroy the material.

Finishing out the EcoShell

Adding a Door

Allow the stucco to cure for a week or more, then a door can be installed in the doorway.

Adding the Turbine Ventilator

The base of the turbine ventilator is firmly embedded in the stucco of the EcoShell. After the stucco has cured for a week, it is safe for a barefooted person to climb on the

EcoShell and install the top of the ventilator. As soon as it is installed, if there is any wind, the turbine will start turning and start pulling air from the

upper portion of the dome and exhausting it. Since hot air rises, this will remove the hot air and will allow outside air to replace it.

Painting the EcoShell

The EcoShell can be painted bright or pastel colors. Some people use Elastomeric paint, which gives the outside of the EcoShell a "rubber-like" coating.

Sealing the EcoShell

Silane and Siloxane-based water repellents are examples of excellent choices for deterring water from entering the stucco, while maintaining the breathability of the wall system.

Squash on the Roof

If one wants to plant squash, cucumber, or any other vine next to their EcoShell, the vines will climb over the EcoShell and provide shade. This will keep the inside of the EcoShell a little cooler.

Adding Walls

Walls produced with lumber and sheetrock can be added, but a better way is to hang burlap and stucco each side of it. The section of burlap which is attached to the dome should be folded three times and attached in place with Tapcon screws. The burlap is allowed to hang down and lap on the floor a couple of inches. Where two pieces of burlap come together, they should be overlapped about 5 cm (2 in.) and stitched. Add a few Tapcon screws which are not fully set so the stucco can key into them.

If the wall is to have a door or a window, it should be framed with wood and the burlap nailed to the wood.

If electrical lines or water lines need to be added, they can be lightly sewn to the burlap and then buried in stucco.

If trowelling the stucco on, one plasterer stands on one side of the burlap and steps on the part lying on the floor. He, and the plasterer on the other side of the burlap load their trowels and smear stucco onto the burlap with their trowels following the same paths. If a sprayer is used, the first coat is just a light dusting of stucco to stiffen the burlap; and the second coat, from the other side, adds a little more thickness. Keep this up (alternating sides) until the wall is about 3.8 cm (1.5 in.) thick.

Adding a Sleeping Loft or Storage Area

If you are planning on adding a sleeping loft/storage area at a future date, the first thing to do is to determine the height of the shelf (to keep things simple, we will refer to the area as a shelf). It should be high enough so the tallest person living in the home does not bang his head on the underside of it. Then determine whether there is enough room above that elevation for the intended use of the shelf. If it is to be a sleeping loft, there must be easy access every day.

Ideally, if a decision is made when the EcoShell is being built, it would be approprate to add two extra horizontal wraps of the basalt rope after the second coat of stucco is applied. Build the area where the shelf will go a half inch thicker than the rest of the shell. This will provide a solid anchor for the Tapcon anchors which will be used to attach the structure for the shelf.

If a wall is to be installed in the EcoShell, it would be appropriate to install it along with the shelf, to help support the shelf.

Add design section for the shelf.

Springboards for Thought

Airform

Can Tapcon anchors be reused? How many times?

How many extra SDS bits are needed for drilling holes for the Tapcon anchors?

If a jack stand inside the Airform is used to support a polar scaffold, should the Airform be constructed with a hole in the top so a pipe on the top of the jack stand can extend through, a gasket seal developed, and the polar scaffold attached to that pipe?

The better we seal the Airform, the easier it is to maintain even pressure.

Can we place a flap on the inside of the Airform to slow the loss of air in the event of a blower failure?

Is a pressure relief valve (dryer vent with a weight attached) useful to prevent inadvertent over-inflation of the balloon form?

Accessories to Airform

Is a sunshade over the dome to help curing, protect from rain while stuccoing, and make the work more pleasant in the heat a reasonable option? Will winds make a sunshade more of a problem than a help?

Termites are bad in Haiti; can we produce (or have produced) pre-cast doorframes instead of wooden frames which are stuccoed?

Consider using molds to attach to the Airform so a more decorative concrete entrance can be developed. There are many concrete artisans in Haiti.

Stuccoing, Reinforcing, and Curing Stucco

Curing the stucco/concrete - moisture-retaining cloths / Hudson sprayer

With the first coat of stucco, when pressure in the Airform is lost and then re-pressurized, the stucco tends to explode. Can the Airform be re-pressurized at a lower pressure without causing damage and then the second coat be applied?

After the first coat is applied and until the second coat is cured, the dome is fragile. Include photo of Nolie's dome.

When building Jubilee Lutheran Village, should first dome be used as an equipment security room?

Develop a "net" made from basalt rope to simplify the adding of the basalt reinforcement over the dome. Build a 6.1 m circle from 1/2 in. PVC, support with legs. Tie a net using basalt rope. Would overhand knots be better, or would hog rings be better, for maintaining the strength of the basalt rope? Taper net inward.

Will vertical strips of SpiderLath work as well as basalt rope for reinforcement? If so, how much of an overlap is needed with the SpiderLath? If SpiderLath will work, a strip of SpiderLath imbedded in the footing/slab may provide an adequate tie between the slab and the dome.

The suggestion has been made by several people that hemp rope would be a "natural" substitute for basalt rope. Hemp slowly decays with time and is not as strong, so it should not be used for a permanent structure.

Add -Ons

Vent turbine on top to pull warm air from dome would be better than a 1.5 m plus thermal chimney in the event of a hurricane.

Notes - not to be placed in the book

Herb needs to meet with David South, President of the Monolithic Dome Institute, to ensure he is covering all requirements on the building project (Thursday, Feb. 26)

Herb needs to tabulate the GPS data and elevations and plot them out on a map to lay out the prime areas on the site for building.

Herb needs to put together documents so interested parties can start raising funds. Our initial goal should be enough cash:

- to purchase necessary capital equipment (balloon form, etc.) and ship to Gonaives (about $7,000 US).
- to build 5 domes ($10,000 US).
- If we do not have enough to build 5 domes, we need enough to purchase and ship basalt rebar and basalt rope to Gonaives to build 5 domes. That would require about $2,500 US. Fund-raising for the domes could then continue after that shipment was made.

By March 1, 2015, Herb needs to finish the construction manual and furnish a copy to Lophane so it can be translated. The preliminary translation needs to be furnished to the Mayor of Gonaives so he can write an introduction. After it is translated, Herb needs to arrange for publishing. To have books published for transfer to Haiti by April 15, the translation needs to be complete by April 1.

By February 15, 2015, order the EcoShell Balloon Form (will be done Feb 26),

By March 15, 2015, deliver the Airform to John so he can arrange for Mission:Haiti to ship it. Check with John to see whether it goes to him or to Teeters in Riviera Beach.

Pour the slab for the first house the third week of April, 2015.

Erect the dome the 4th week of April, 2015.

Pour the slab for the second house the 4th week of April, 2015.

Last of April, have a meeting to discuss successes, failures, and plan for future building.