Concrete and Building in Haiti
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Introduction

On September 28, 2013, I received an invitation from David B. South, President of the Monolithic Dome Institute, to participate in one of his dome-building workshops. Recent research had resulted in a technique to build with basalt fiber rather than using rebar, so the chloride problem found in Haiti is not as big an obstacle. Since the next workshop was the week of October 7th, I cleared my schedule and headed to Italy, Texas. My objective was to learn as much as I could about the EcoShell system of building.

On October 15, 2013, I met with two executives from Imison Construction, a South African company, and learned about their construction system. The meeting did not concern Haiti, but when they found out about my involvement in Haiti, we discussed the possibility of using their panels in Haiti. One of them would like to accompany me on one of my trips to Haiti to gain firsthand experience.

Information is provided concerning Metrock SCIP, Advanced Structural Panels, and alternate mixing systems for concrete.

The word concrete is used for a mixture of aggregate, Portland cement, water, and possibly other materials. The aggregate may be small and the concrete can be used as stucco, or it may be large and be used as most lay people envision the word concrete.

What Is a Monolithic Dome?

A monolithic dome is a method of construction where an air form is inflated (picture a balloon in the shape of a hemisphere) on a foundation. The inside of the balloon is sprayed with nominally 3 inches (7.6 cm) of polyurethane insulation, then a network rebar is installed, and concrete made with fine aggregate is sprayed. This concrete is often called shotcrete or high-strength stucco. Domes built in this manner range from about 200 square feet (18.5 square meters) to well over 150 feet (46 meters) in diameter. The domes are used as homes, schools, churches, hospitals, storage of agricultural produce, and storage of industrial chemicals and minerals. Doors and windows can be installed. For most of the housing needs in Haiti, at this point it appears that the 20 foot in diameter (6 meter) EcoShell would be appropriate. This provides 3oo square feet (27.9 square meters) of living space.

Since the dome is one piece of reinforced concrete, the standard construction results in a structure which can easily withstand earthquakes, hurricanes, and even F-5 tornados. While windows may be sucked out or blown out during a tornado, the occupants remain safe inside the structure.

The air form stays in place and protects the polyurethane insulation. At a later date, the exterior of the air form may be painted or coated with stucco or other coating to protect the polyurethane insulation beneath it. This places the insulation to the outside of the structure, which from a thermodynamic standpoint is the most efficient place for the insulation. The temperature inside of a Monolithic Dome tends to stabilize close to the ground temperature.

The air form is used only once. While this type of construction is more economical than conventional construction, it would not be appropriate for the large volume of low-cost housing that is needed in Haiti.

What Is an EcoShell?

An EcoShell looks much like a small Monolithic Dome, but there are some substantial differences. First, the concrete is applied from the outside and thus, the air form can be removed and used again. Second, since the dome is sprayed from the outside, it would be much more difficult to install a layer of polyurethane foam in the dome. Based on the building codes, since polyurethane can burn, it needs to be separated from living areas by a fire-resistive barrier. If this were done, the advantages of the EcoShell would be lost.

Traditionally, an EcoShell was built by inflating the air form on a foundation, and painting the air form with a primer. The primer helps the concrete to stick to the air form during application of the concrete. Rebar was then bent and installed outside the air form, and often touching the air form. The structure was sprayed, and after curing, the air form was deflated and removed. Since the rebar that was in contact with the air form was exposed, a layer of concrete would be applied to the inside of the dome. The exterior of the dome should be white to reflect solar radiation. This can be a white paint, or it could be produced by using white cement in the final layer of concrete.

The EcoShell is not insulated like the Monolithic Dome, so it is not as practical for living in cold climates. In tropical climates, it is much better than living under a tin roof.

The Enhanced EcoShell

In an attempt to develop an EcoShell which would be impervious to the problems of the rebar (exposed rebar and corroding rebar due to chlorides, moisture penetration, and oxidation), Monolithic started experimenting with basalt fiber, basalt rebar, and basalt rope. Each of these products is made from the volcanic rock called basalt. It is melted and formed into fibers. Further processing converts it into rebar or into rope.

During the same time period, I was experimenting with basalt fibers, and I had basalt rope and basalt mesh that I was preparing to experiment with. I had found that no matter what the basalt sales staff said, fine basalt fibers needed to be protected from the high-alkaline interstitial water in fresh concrete. This could either be done with a coating or by controlling the pH of the concrete mix. I had concluded that controlling the pH of the concrete was doable to protect the fiber, but the window where quality concrete could be produced and the fibers would not dissolve was narrow. From a practical standpoint, coating the fibers was the only practical way to limit dissolving of the basalt. Theoretically, using the basalt rebar and the basalt rope would be sidestepping the fiber problems, since it was easier to protect them with a coating.

When I heard that Monolithic was reinforcing domes with basalt rope, I knew that they had combined excellent engineering with chemistry that would work in areas where rebar corroded.

Several other advantages occurred which I did not fully appreciate until I spent time at the workshop. Steel rebar needs to be covered with concrete to protect it; and if it does corrode and expand, the rebar needs to be buried far enough into the concrete so the concrete is not cracked when exposed to tension. As a result, the thickness of the skin of a dome is engineered based on the need to protect the rebar and not on the strengths needed for the dome to function under disaster conditions. This results in more concrete being used in the dome than is needed to provide disaster resistance. Basalt rebar and basalt rope do not need extra concrete to protect them, so a dome with adequate strength can be built with about half of the concrete needed for a steel-reinforced dome.

Another advantage which I had not considered was that the inside of the dome did not need to be sprayed to cover rebar. This was another savings in building with the basalt rope.

After the air form is inflated, and forms for the windows and doors are attached, it is sprayed with about one-half inch (1.3 cm) of concrete. After the concrete has cured so it is stable, the basalt rope is looped over the dome with a spacing of about 10 to 12 inches (25.4 to 30.5 cm) at the base. Then the dome is wrapped with the basalt rope, starting at the bottom and each horizontal wrap is about 10 to 12 inches (25.4 to 30.5 cm) above the previous wrap. The vertical rope and the horizontal rope do not need to be tied to build structural strength, but it needs to be tied to hold the rope in place, as the rope is wrapped around the top of the dome. Bread wrapper ties work well for this job. Would everyone reading this report please start saving their bread wrapper ties so we can provide low-cost housing to Haiti?

After the basalt rope is in place, the structure is sprayed with a second half-an-inch (1.3 cm) layer of concrete. Near the base, the concrete is sprayed to a total thickness of about two inches (5 cm). Close to the top of the dome, the thickness can be dropped to one to one-and-a-half inches or so.

As with the original EcoShell, the air form is deflated, removed, and used again, and the exterior of the EcoShell should be painted white to impact heating from solar radiation.

During the day, the EcoShell will absorb solar radiation and heat up. I will need to discuss the potential of installing a thermal chimney to the top of an EcoShell structure. It could not be installed dead center where the basalt rope is crossing, but it should be safe to install it within about two feet (0.6 meters) of dead center. Venting at the base of the dome should be about the same area as the cross section of the thermal chimney. Rate of air movement would be related to the cross section of the thermal chimney and the height of the thermal chimney.

Based on one day to pour a slab and footings, one day to install & inflate the air form and install the door & window forms, one day to spray the first coat of concrete, and another day to add the basalt rope and spray the second coat, a small crew could complete a house per week. Theoretically, if two crews were coordinated, the air form could be used twice per week; however, we should not plan on that occurring.

Life of the air form is based on the weight of the fabric used to produce it and the care that is taken in handling it. A wild guess is that it can be reused 10 to 20 times.

Imison Construction

The Imison Construction system is based on steel-reinforced Neopor panels which are faced with steel reinforcing mesh. After the panels are placed, rebar is placed in hollow cavities and a high-flow concrete is added. Then the Neopor panels are coated on each side with a high-quality stucco. This results in a highly insulated structure which can withstand winds associated with major categories of hurricanes. The panels can be used for walls, roofs, and floors on upper levels of the structure. While their system is used to construct massive structures, it is also used to build residences. They have a model aimed at the low-cost market in third world countries and is approximately 400 square foot (37.1 square meters) in size.

Metrock SCIP

Jim Farrell, President of BlastCrete and of Metrock SCIP, has developed a structural concrete insulated panel which can be assembled on site with a trailer-mounted system using face mesh with built-in screeds for easier leveling of the stucco, and Warren trusses which provide separation between the two sheets of face mesh. One advantage of this type of SCIP is it can be assembled on site and the investment in the trailer-mounted system is in the neighborhood of $100,000. One to one-and-a half-inches of stucco is required on each side of each panel for most applications. Roof trusses can be designed and built which allow up to twenty-six feet of clear span. A disadvantage is that if EPS is not available in

Haiti, it would need to be imported or an EPS expansion plant would need to be installed.

Advanced Structural Panels

Dave Stevenson, president of Advanced Structural Panels, has designed and constructed a structural concrete insulated panel plant in Los Angeles, California, which uses various gauges of wire to produce the panels rather than premade wire mesh and Warren trusses. Unlike previous wire feed plants which have been built, adjusting the machinery to make different configurations of panels is easy and the investment to build such a plant is about 1.3 million dollars US, rather than over 5 million dollars US. Panels can be ordered from the Los Angeles plant, or a plant could be built in Haiti. As with the Metrock SCIP, there needs to be a source of EPS, and the concrete coating needs to be about one to one-and-a-half inches on each side of each panel.

Concrete Quality

The huge problem in Haiti is getting concrete and especially getting good-quality concrete.

Many of the wells in Haiti, especially in the lowlands, are brackish. High chloride levels will degrade the cement portion of the concrete to some extent, but the amount of degradation is not significant when compared with the quality of concrete which is currently being used.

The significant problem is that the chlorides in the water attack steel rebar that is used in the concrete to give it tensile strength. As the steel rebar corrodes, it increases in volume and places the concrete around it under tension. This leads to cracking of the concrete.

The problem can be addressed by using water that is low in chlorides and placing a moisture barrier below any concrete in contact with the ground, so chloride-laden water does not wick up, or by replacing all steel in the building that can be attacked by chlorides with a product that is not attacked by chlorides. Basalt rebar is an appropriate substitute; and for the EcoShell, basalt rope is even better, since it can be placed precisely where it is needed.

I have a kit for testing water for chlorides which I will bring to Haiti on my next trip, and we will train people to test the water and develop a map of where good water is located.

Much of the aggregate used contains large amounts of clay. This produces a trowelable concrete without the addition of hydrated lime or mortar fats, but it substantially weakens the mix. There are some aggregates that would be good for stucco work in some of the stream beds. A stucco-type concrete is really all we need for the building types addressed in this report. The EcoShells gain their strength from their curves. SCIP gain their strength from their face mesh and from the truss wires between the two sheets of face mesh. The Imison system gains its strength from the face mesh, galvanized steel reinforcing, and from reinforced concrete columns in the system.

In those locations where basalt reinforcement can be used, chlorides will not degrade the reinforcing. This results in structures which will have a life span of hundreds of years. By not having to rebuild every few years, more housing will be available for the people who need housing.

To produce a flat concrete roof with current technology used in Haiti, a lot of concrete is required. Additionally, to produce a roof that will not degrade with time, the quality of the aggregate needs to be improved and the amount of chlorides in the concrete needs to be reduced. Alternate methods of producing roofs need to be explored. Structures built in a rectangular configuration are not conducive for installing a roof consisting of an EcoShell. Other technologies include, but are not limited to:

- Replacing the steel rebar with basalt rebar. This will require the same amount of concrete as is currently used, but will produce a roof with a longer life span. We need to compare the cost and availability of basalt rebar to the cost of steel rebar.
- Using Structural Concrete Insulated Panels (SCIP) and limiting the chlorides in the concrete (stucc0) to prevent degradation of the mesh and reinforcing wire used in the system. Such a roof would provide significant amounts of insulation and would require only two to three inches of concrete (stucco).
- Using Imison technology with Neopor insulation and galvanized steel reinforcing would use about as much concrete as SCIP and would provide an equal amount or more insulation. Again, the amount of chlorides in the concrete would need to be limited.

Concrete Mixer Trucks

Conventional ready-mix trucks have limited value when one gets off the major roads in Haiti because of their weight and especially because of delays that regularly occur with traffic.

An alternative we have been looking at involves the use of volumetric mixer trucks. They are about the same weight as the conventional ready-mix trucks, but the components are maintained in a dry state until the concrete is needed. Then it is batched and blended through an auger blender.

An alternative, especially during start-up, and especially for the mixing of stucco-type concrete to apply to EcoShells might be the use of a skid steer loader outfitted with a Monolithic Mixer. The mixer is used to scoop up the appropriate volume of aggregate, then Portland cement is added to the mixer. After the components are dry mixed, water is added. The mixer will mix 0.3 yards (0.0084 cubic meters) in about three minutes. With an experienced operator this equates to about 2 to 3 cubic yards (1.5 to 2.3 cubic meters) of concrete per hour. A 20 foot diameter (6 meter) EcoShell would need about 3 cubic yards (2.3 cubic meters) of concrete for the shell and about the same amount of concrete for the base. I need to determine the maximum aggregate size that can be used in this mixer.

Hand Mixing of Concrete

Most concrete in Gonaives, Haiti, is mixed by hand at the job site. This leads to cases where the concrete has not been adequately blended. An alternative is to use a piece of plastic tarp with handles on each corner. Aggregate, cement, and water are added. Two workers shake it back and forth a few times, and a cubic foot (0.28 cubic meters) of concrete is mixed. Even though this requires a lot of energy, it can result in faster mixing on the job site and better mixing of the concrete.

Future Trips to Haiti

I will leave home on November 1, 2013 and return on November 8.

I will not be traveling to Haiti in December, 2013.

Plans are not finalized for trips in 2014.

Arrangements are being made so I will have internet access while in Haiti.