Concrete and Building in Haiti

Report 1

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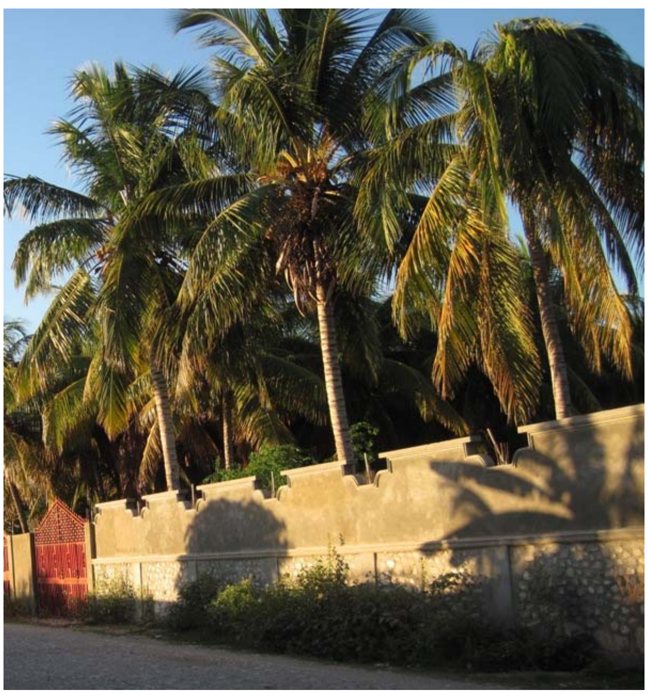
Introduction

On September 7, 2013, I traveled to Gonaives, Haiti, with a mission team from Shepherd of the Hills Lutheran Church in San Antonio, TX. On September 14, we returned to San Antonio. This report is a brief summary of what I learned during that trip.

1 A wall in front of a residence



Most structures in Haiti are constructed of concrete. The quality of the concrete varies greatly, and the concrete used in the residences of the wealthy is usually of much better quality than the concrete used in the residences of average citizens. This is especially true of the residences of Haiti's poor.

This report does not address the quality of construction for Haiti's wealthy. Instead, it focuses on the quality of construction for the rest of the population. When I taught a seminar on concrete during my trip to Haiti, I explained to my students that I knew about cement and concrete, but I did not know about Haiti. In order for me to help them improve the quality of the concrete that they produce, they would have to teach me about Haiti. I would need to learn both what could be done and what could not be done in their locale. They took this request seriously, and I probably learned more than my students.

On January 12, 2010, a 7.0 earthquake occurred just west of Port-au-Prince, Haiti. The estimated death toll ranged from 100,000 to 316,000. It is estimated that 250,000 residences and 30,000 commercial buildings were either destroyed or severely damaged. October 2010 ushered in a cholera epidemic, and November

2010 saw Hurricane Tomas. Both of these events severely hampered earthquake relief efforts.

While Gonaives was not damaged by the earthquake like Port-au-Prince, it did sustain considerable damage in a flood that occurred in September 2008, which resulted in more than 2,500 deaths. That flood and the mudslide that followed were triggered by Tropical Storm Jeanne.

One of the long-term outcomes of my trips to Haiti will be a detailed construction manual that will enable builders in Haiti to construct low-cost, disaster-resistant homes. Such a manual will require the assistance of both the technically savvy contacts I have in the US and hands-on, practical builders in Haiti. If both groups do not have an equal voice in developing the manual, the finished product will be of limited value.

One of the limiting factors in building quality homes in Haiti is money. If there is not enough money to build a small, high-quality concrete home, a small, low-quality concrete home is built.

A second limiting factor in building quality homes in Haiti is that there are no building codes or standards in Haiti. Experts have estimated that it will be at least ten years before codes can be developed, and after they are developed, it will take still more time to implement them.

During the rebuilding of Port-au-Prince, many of the structures that were built to replace the ones that had been destroyed were of the "same" quality as the structures that they replaced. As a result, when the next hurricane or earthquake comes, many of them will need to be replaced yet again. This is not a criticism specific to the people of Haiti or those who brought relief to Haiti. It is an issue that concerns people all over the world.

Following Hurricane Ike in Galveston and the Bolívar Peninsula, rebuilding was completed to the same quality as the destroyed structures. There was a SCIP home (Structural Concrete Insulated Panel - a three dimensional wire frame with EPS infill. Both sides of the panel are coated with a stucco. Structurally it reacts similar to a reinforced concrete wall.) on the Bolívar Peninsula-that had cost about the same as the surrounding homes. It survived both the hurricane and another home floating into it. This is technology that could have been used when rebuilding Galveston and the Bolivar Peninsula, but people and governments chose to ignore the facts and replace rather than improve. When the next "Hurricane Ike" arrives, builders will have to replace those replacement homes. We need to figure out how to change the mindset of people faced with rebuilding after a disaster.

Standard Construction Practices in Gonaives

Most concrete in Haiti is mixed by hand. Unlike in the US where people mixing by hand use hoes, most of Haitian builders use round-nosed shovels to mix concrete. An area is cleared off, and dry Portland cement and aggregate are blended. Then the mixture is shaped into a bowl and water is added to the center. The cement/aggregate mix is then brought into the water in the center until it achieves the desired consistency. It is then shoveled into five-gallon plastic buckets and delivered to the location where the concrete is to be poured.

Foundations are often built with large stone and mortar It is common to see a foundation of this type with a small shack built on top of it. The Lutheran Church in Jubilee consists of a foundation. On top of the foundation is a palm-leaf-sided structure. When the owner of the foundation can afford to continue building and replace the shack with a more permanent structure, he does so.

Vapor barriers are used under concrete when the budget will allow their use. Eliminating the vapor barriers is one of the first cost-cutting operations for many builders.

In areas with a high water table, if there is water in the trenches for the footings, a dry mix of Portland cement and aggregate is shoveled into the trench to bring the foundation's level up ~~to~~ above the water level. Rebar is not placed in the area below the water table. As the foundation comes up higher, rebar is incorporated. If the builder's budget can afford a vapor barrier, a vapor barrier is added before the section of the foundation containing rebar is poured.

2 After a few years, many concrete foundations start to deteriorate.

Often the concrete in foundations starts to deteriorate within a few years. This can be caused by the clay in the sand, the lack of Portland cement in the concrete, or a number of other factors.

3 Typical lightly-reinforced framework with masonry infill.

Most walls for houses and fences consist of a lightly reinforced frame with concrete block infill. Normally there are eight to twelve block between the vertical columns. The reinforced columns consist of four pieces of nominally No. 2 rebar coming out of the footing. Longer pieces are then attached; the four pieces of rebar are held into position with heavy wire placed about every meter along the column. A board is attached to each side of the proposed column and extends over the block wall. Any gaps are stuffed with paper.

4 Regularly, the columns are not rodded enough to get the concrete adequately consolidated.

Concrete is poured in from the top and is usually rodded. However, the rodding is frequently insufficient to fill all of the voids in the column. After the concrete cures, the boards are removed. The columns are usually 10 cm or 15 cm square for fences and 15 cm square for single story houses.

There is usually a reinforced beam at each floor plate, and sometimes there is an additional reinforced beam halfway between the floor plates. For fences, the reinforced beams fall in about the same position, but many fences never get the top beam installed.

5 The capping beam on this wall did not remain in place.

Sometimes when the capping beam is installed, it does not stay in place.

Reinforced beams usually have three nominally No. 2 rebar positioned with two below and one centered about 4 cm higher. The beams are approximately 15 cm wide (the width of the block) and 10 cm high, but there is quite a bit of variation between jobs. The beams are formed by attaching boards on each side of the top of the wall.

In some cases, the horizontal rebar pass through the vertical columns. There were some fences where a column extended above the top block of fence, so the rebar for the beam would have to be cut. There were other fences where the concrete in the vertical column stopped at the top of the fence and the rebar continued up. In such cases, it would be easy to have both vertical and horizontal rebar at the junction.

Most of the concrete block are laid with mortar joints that are about 2 cm thick and contain an aggregate coarser than US masonry sand. The mortar consists of sand (containing clay) and Portland cement. Most of the interfaces between the mortar joints and the block show hairline cracks. This indicates that there is little bonding at these joints.

Few of the block have tooled joints. Usually the excess mortar was scraped off with the trowel.

Cement bags are torn up and used to fill gaps in the forms. One individual told me that cement bags are also often torn up and added to the mix.

The concrete block walls are finished with stucco. The stucco, consisting of sand and Portland cement, is thrown at the wall with a mason's trowel. The first coat is left rough, and after it has cured to some extent, a second coat is thrown at the wall and then smoothed with the mason's trowel.

To cast a roof, a lightweight rebar frame is installed. Using floor jacks, bottom form boards are placed slightly below the rebar. If there are gaps in the form boards, the gaps are usually filled with paper.

Roof panels are usually between 15 cm and 25 cm in thickness. To limit the amount of concrete that needs to be used, concrete block are often set on the bottom form boards. Bonding between the block and the concrete tends to be limited. After the concrete in the roof has cured, supports are removed and the bottom form boards are removed. The ceiling is often stuccoed.

6 Inadequate bedding mortar resulted in ceramic tile failure.

Floor tile are used to hide imperfections in concrete floors. If an adequate bedding mortar is not used, the tile are likely to break.

Factors Impacting Concrete Quality

7 Chlorides are attacking the rebar on the underside of this concrete roof.

Much of the well water in lower elevations of Haiti is brackish. This brackish water is used to produce much of the concrete. The chlorides in the water attack the steel rebar and cause the rebar to corrode. As a result of the corrosion, the rebar expands, which in turn causes the concrete to crack.

The water table under Gonaives is high, so the chlorides in the ground water are often in direct contact with concrete footings and slabs.

8 Some of the sands that are commonly used contain as much as 20% clay.

Another factor that impacts the quality of the concrete is the fine aggregate. Much of it has not been washed, and I observed some sand that contained up to 20% clay.

Most of the aggregate available is pit run, or it has only been run through a grizzly to take out the oversized particles.

When there is not enough money, the amount of Portland cement may be reduced, which results in not having enough cement paste to fill the voids between the aggregate particles.

Most of the concrete in Gonaives is mixed by hand using round-nosed shovels. While it is possible to produce quality concrete in this manner, the concrete is often not as well mixed as it should be, and the water/cement ratio is higher than optimum.

9 The rebar on the underside of this roof was not covered adequately.

Placement of rebar is often not optimal.

Many times the rebar is exposed on the surface rather than being imbedded in the concrete at a depth of three times the diameter of the rebar.

Most rebar is tied with steel wire, and chloride-induced corrosion results in the rebar not being adequately tied.

To reduce the amount of concrete that needs to be mixed and bucket-brigaded to roofs, concrete block are set between the rebar runs. Since the block are often made with aggregate that is high in clay, they are not very stable. This results in a roof with a plethora of cracks.

Most of the concrete roofs examined showed signs of once having had a roof coating, but in most cases the roof coating was no longer effective. As a result of sags in the roof, water would pond and seep through the concrete, leading to further degradation.

10 Peeling paint caused by water in the walls is common, even in more expensive structures.

Many of the concrete walls had peeling paint, which indicated that water was coming out of the wall.

11 Many walls had strong angle cracks.

Many of the concrete walls had strong angle cracks, indicating that there was probably foundation movement.

Many of the cracks on the upper surface of the roofs occurred where the roof passed over an internal wall.

12 Exposed rebar and spalling on the ceiling of a classroom.

Many of the ceilings have exposed rebar and spalling concrete. Each time there is significant rainfall, more concrete spalls, and the rebar corrodes a little more.

13 Exterior stairways with unconsolidated concrete and no guard rails are common in Haiti.

Many of the stairways have exposed rebar, spalling concrete, and unconsolidated concrete. These stairways often rely on columns to provide support. Usually, the support columns are not constructed to a higher standard than the stairway itself.

14 A concrete column supporting a flight of stairs shows signs of degradation.

Conclusion

The people of Haiti are hard-working, and with adequate training and materials, they can construct safe and disaster-proof housing. Those builders who attended the concrete technology seminar were eager to learn why failures were occurring and to learn techniques which would limit such failures in future construction.