My Don Quixote Quest

Herb Nordmeyer

Notes for a presentation on January 12, 2017

Photos in this document will be will be shown to provide visual explanations during the presentation. Brief comments will be made about the photos.

Introduction

I would like to thank the President of the American University of the Caribbean for asking me to come and say a few words to you today. I would also like to thank each of you for coming. More than anything else, I would like to bring the message to you that no matter what happens in life, we are all together, and we need to help each other.

In listening to the introduction, I learned how great I am. I wish my wife could have heard that introduction.

While you were experiencing an earthquake on January 12, 2010, I was doing a forensic analysis of a building in Florida which was having serious problems. Due to improper waterproofing, moisture was getting into the walls, and mold was growing there. Due to the building being air conditioned, there was no ventilation, and the mold spores were making people sick. That was a minor inconvenience compared to what you were experiencing that day.

We need to address the construction problems in Haiti so that when another hurricane or earthquake strikes that it is an inconvenience, not a major disaster. As a result, I will be talking about what we can do related to construction to reduce the devastation when the next one comes, rather than speak about all of your sufferings and all of the assistance that poured into Haiti after the earthquake.

Coming to Haiti

In September, 2013, I came to Haiti for the first, and what I thought would be my only, time. Riding down many streets, I could see construction defects which would cause even newly-built buildings to fail in a disaster.

Pastor Benoit took me to the slum of Jubilee, and in a home that was about 7.5 m^2, where 11 people lived, he challenged me to develop technology to build disaster-resistant homes for a materials cost of not more than $1,000 US.

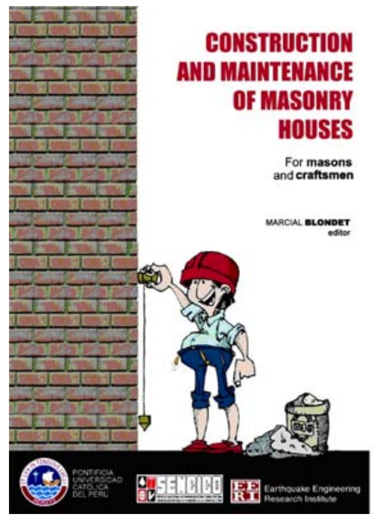
I came back to Haiti in November, 2013, and started to learn about construction in Haiti, especially concrete construction. More importantly, I started to learn about the culture of Haiti and the reasons why it is difficult to build a home in Haiti which will survive a hurricane or an earthquake.

Joe Warnes, probably the leading disaster-resistant engineer in the world, took the time to talk to me on several occasions about building in Haiti. We became acquainted because both of us taught classes at World of Concrete.

For those who haven't read the book **Don Quixote**, it's a story about a man, Don Quixote, who was so fixated on an issue that it drove him crazy. He sets off on his quest to right wrongs

To this day Joe calls me Don Quixote and maintains that building disaster-resistant structures in Haiti is about as successful as Don Quixote's quest to right all wrongs. Joe Warnes is very opinionated. Because I chose not to believe him, I am here today.

Don Quixote's quest ended when he died. I hope and pray that each of you will adopt my quest as your quest and carry it on until it is successful.



Dr. Richard Klingner, who had recently retired as a structural engineering professor from the University of Texas and is an expert in disaster-resistant construction, mentored me in disaster-resistant construction. He was part of the Blondet Team and introduced me to Blondet. This was a payback for my years of mentoring him in cement technology. He once introduced me at an American Society of Testing and Materials Symposium where I was to present a paper, as the only person he had ever met who knew 200 cement chemicals by their first names.

David South with Monolithic Dome Institute mentored me in dome construction and why it has many advantages when building low-cost, disaster-resistant structures. This was payback for my mentoring him and his staff in thin-wall concrete technology.

I helped them reach their goals, so they are helping me reach my goals. Invest in one another, even if you do not see any immediate gain.

2014, 2015, and 2016 were spent learning, documenting, and writing. People whom I knew and people whom I did not know heard about my Quest, and made money available to defer my expenses. Some gave $5.00 US. Others gave more. Each gave to bring hope to Haiti.

After all of that effort, we have not gotten the cost of materials down to $1,000 US. Currently we are at $2,800 US for a disaster-resistant home which meets the UN standards. Even though this is lower in cost than any other disaster-resistant structure we are familiar with, we are still working to reduce the cost.

Concrete Problems

Let's move on to look at a few of the problems concerning concrete that are prevalent here in Haiti and the causes of those problems.

High clay content

Much of the aggregate I have observed in Haiti has not been washed, and as a result, there is a high content of clay and other fines. In Leogane I observed a plaster failure which contains a high content of limestone fines. Besides clay and other fines in the aggregate, clay is often added to plaster or stucco to give it body so it will stay on the wall. When there are non-reactive fines in the mix, they interfere with the concrete developing strength. They are as bad for the concrete as adding extra water. Non-reactive fines can also be incorporated into the concrete by mixing the concrete on the ground.

If the concrete is the color of the local clay rather than gray like ordinary concrete, there is a strong likelihood that excessive clay is in the mix. If the paste in the concrete erodes with time, there is a strong likelihood that excessive clay is in the mix.

I have found 29% clay in sand which was being sold for making concrete. If that sand were used at a ratio of 1 Portland, 2 parts of sand, and 3 parts gravel, the ultimate strength with a 6.5 bag per cubic meter batch would be 41% of the strength if the clay had not been in the mix. But seldom can you make one change without causing other changes. In all probability one would need to add more water if highly absorbent clay were used. That would lower the strength even more.

We need sand and gravel operations where the clay is washed out of the mix.

Aggregates in many areas do not meet a standard.

They may simply be rock that has been mined and passed through a crusher without any screening or washing. They may be passed through a screen but not washed. They may be passed through a crusher and screen and washed, but one or more of the screens may have worn out. This results in aggregate that has a poor gradation to make good concrete, or it contains fines which interfere with the strength gain of the concrete.

When facilities are added to wash the sand and gravel, we need to incorporate a screening facility to ensure that the aggregate is sized to meet the needs of the concrete which will be produced with it.

Unsound aggregate

Some aggregate is unsound. This may be soft limestone which will disintegrate with time. In the US I am familiar with aggregate which reacts with the cement paste and expands with time, or contains sulfates and causes the hardened cement paste to disintegrate. I have not determined whether these last two problems occur in Haiti.

It is easy to determine whether a limestone is too soft to use as concrete aggregate. If it is too soft, eliminate it.

Low cement content

The strength of concrete is determined by a number of things. One of the most important is the amount of cement used per cubic meter. A common standard is 6.5 bags of Portland cement per cubic meter of concrete. If 20% of the Portland cement is removed, and all other factors remain the same, the ultimate compressive strength would be only 88% as much as it would be if 6.5 bags were used.

If half the Portland cement were removed, the ultimate compressive strength would be only 62% as much as it would be if 6.5 bags were used.

This is a problem which can be eliminated with education and inspection.

High water/cement ratio

Portland cement needs water to hydrate. To produce the maximum strength, the water/cement ratio needs to be 0.35. That is 15 liters of water per bag of Portland cement. A concrete with a water/cement ratio of 0.35 is hard to work. As a result, water-reducing agents are added. Even then, additional water is often added. This reduces the strength of the concrete. Some water-reducing agents act by adding entrained air. This reduces the strength of the concrete as much as if extra water were added.

This is a problem which can be eliminated with education and inspection.

High chloride content

Chlorides have little impact on the cementitious portion of concrete. They attack the steel in the concrete. Specifically, they enhance the rate of oxidation when there is moisture in the concrete adjacent to the steel. When steel oxidizes, it expands. When it expands, it stresses the solidified concrete paste and leads to cracking of the concrete. This usually leads to more water in contact with the steel and more oxidation of the steel.

Much of ground water near the coasts of Haiti contains elevated levels chlorides. There are lakes which are at higher elevations which also have elevated levels of chlorides. If there is a chloride problem, either the steel rebar needs to be protected or a non-corrosive substitute needs to be used. Not all protection of steel rebar provides long-term protection.

Problems with high chlorides are usually most evident on the underside of concrete roofs when the plaster coating of the ceiling starts to slough off. It is very dangerous on unsupported beams that carry large amounts of weight.

If quality concrete is used, and if vapor barriers are used, the oxidation of the rebar is substantially slowed. In areas of marginal chloride content, that would be enough to give a building an extended life span.

In areas of higher chloride content, more drastic methods are needed. To implement these methods, we need to educate the public about the problem and solutions; we need to educate building contractors and building inspectors about how to eliminate the problem. We need to import basalt rebar or other substitute in quantities so the cost will be reduced substantially.

Failure to consolidate concrete

When concrete is poured, it has a tendency to bridge on rebar. Sometimes it seems to have a mind of its own and will bridge when there is nothing for it to bridge on. Another problem is that when concrete flows or is poured, the larger aggregate often separates from the paste. This results in a weak and porous concrete. To prevent these problems, all concrete needs to be consolidated. This can be accomplished by vibration, by rodding with a piece of rebar in a column, and by using a jitterbug on a slab. On small pours, a trowel can be effectively used to vibrate the concrete. There are devices that can be inserted into the concrete to vibrate it. If the concrete is over-vibrated, the concrete can separate as well.

The best judge of how well concrete has been vibrated is to examine the sides of the concrete after the forms have been removed. If there are any air pockets, vibrate more on your next job.

Oxidation of rebar is usually enhanced with unconsolidated concrete.

With education, each building contractor can be familiar with the problems of failure to consolidate the concrete and failure to check that it's done as listed on the job's checklist.

Inadequately mixed concrete

This is a problem which does not need to happen. A little instruction on a job site can teach a crew to eliminate the problem. We can divide the problem into hand-mixed concrete and mechanically mixed concrete.

With hand-mixed concrete the mixing should be done in a wheelbarrow or in a mortar trough. Mixing on the ground often incorporates extraneous materials into the mix and often results in inadequate mixing. If the concrete is being mixed by hand, it is difficult to mix it well if the ingredients are not well-mixed while in the dry state.

If a mechanical mixer is over-filled (more than 50% full), the mixing rate is reduced. When using a mechanical mixer, if most of the mix water is not added before the cement, clumps of the cement will form, and it will be difficult to produce an even mix without adding excess water. For best mixing with a mechanical mixer, add most of the water. Then with the mixer running, add 1/3 of the aggregate, then the fines (cement, admixtures, and fibers). After these components are well mixed, slowly add the remaining aggregate and add a little more water if needed.

With a little on-the-job training, we can eliminate this problem.

Construction Problems

Even if excellent concrete has been produced, there are a few construction techniques used here in Haiti which can lead to problems.

Inadequate foundations

The soil underneath a building holds it up. Some soils are very stable, while the stability of other soils varies with the moisture content of the soil. The foundation needs to be sized so it will hold up the weight of the building, whether the soil is dry or soaked.

If you see a wall with an angle crack, there is a good chance that the area below the crack has an inadequate foundation and that the foundation has been depressed a small amount.

The Blondet Manual has an illustrated guide for sizing foundations. Building inspectors need to be involved so they can sign off on the foundation needs.

Building to add a second and third story

Many people have the resources to build the first story of their two- or three-story home. They leave rebar trusses sticking out so the next story can be added. Every place I have been in Haiti where concrete construction takes place, I have seen this. There are a couple of problems. The rebar trusses sticking up are exposed to the wind and may move back and forth and weaken the concrete where the rebar emerges.

This opens a hole for water to enter the roof or wall, which accelerates the oxidation of the rebar.

The most active area for the oxidation of the rebar is at the air/concrete interface.

If rebar is going to be left exposed, it needs to be protected. One of the most effective ways is to paint the exposed rebar with an anti-rust paint and encase the lower 45 cm of each rebar truss in a low-grade concrete. This moves the area of the rebar degrading to a less critical location and reduces the oxidation of the rebar.

Insufficient reinforcement

Rebar is expensive; so if the job calls for 4 pieces of No. 4 rebar, a contractor might assume that no one will notice the substitution of 4 pieces of No. 3 rebar. The No. 3 rebar provides only 56% of the tensile strength that the No. 4 rebar does.

Failure to place the rebar in the proper elevation of a concrete pour also results in insufficient reinforcement. This is especially true with concrete roofs where the rebar needs to be high in the slab over support structures and low in the slab between support structures.

If the rebar is placed too close to the surface of the concrete, the rebar can fail to bond adequately to the concrete. This results in inadequate reinforcing.

Another problem is when rusty rebar is used. The concrete cannot bond to it, so it does not provide the reinforcement which it should.

Again, education and on-the-job training can eliminate these problems.

Failure to understand the functions of beams and columns

Columns support vertical loads on them and transfer the load to the foundation.

Beams take vertical loads and transfer them laterally to columns.

For them to work, the rebar in the column must be tied to the rebar in the beam.

Failure to consolidate all concrete in all beams and columns is asking for premature failure.

Beams need to be sized based on the span they cover and on the weight they are required to support. An engineer can do calculations and size the beams for the contractor.

Incorporating elements weak elements into the building

Earthquakes and hurricanes attack corners, overhangs, and unsupported walls. With our domes, we have removed corners and overhangs. If a building has a long wing to funnel a breeze into it, it is a handle for an earthquake or a hurricane to break that wing off the building. If a building has a roof with long eaves to provide shade for the walls to keep the walls cool, it is a handle for a hurricane to tear the roof off. If the upper stories have interior walls but the lower stories do not have corresponding interior walls providing support to the upper story walls, in a hurricane or an earthquake the upper story will move up and down and that upper wall can plunge down to the lower story. An upper story extending out over a porch provides a wonderful place to sit and visit, but it provides a handle for either a hurricane or an earthquake to tear that portion of the upper story away from the rest of the structure.

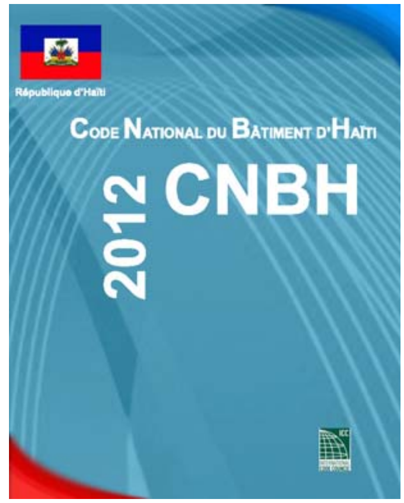
These are not just problems in Haiti. They are problems found around the world. Haiti has more major disasters than most other places in the world, so building design becomes more critical.

As a side note, Frank Lloyd Wright was a famous American architect whose structures were works of art, but every one of them had a leaky roof and water intrusions in many of the walls. About 15 years ago I was part of a team to help one of his last students, who was 86 at the time, design a home with a Frank Lloyd Wright design which did not have the problems inherent in Wright's designs.

Other Problems

Other factors which contribute to building failures:

The building code



Building codes are adopted to provide safe structures for people to live, work, and play in. Haiti adopted the ICC building code a few years ago. It is difficult for most builders to comply with it since aggregates and other items specified in the building code are not available in many parts of Haiti. Where they are available, many of the building contractors do not know how to effectively use them.

Currently the building code is available in French. Since many building contractors are more fluent in Haitian Creole than French, having it translated to Haitian Creole would make it easer for the contractors to comply with it.

Holding workshops and classes will help both building contractors and building inspectors understand the building codes better.

Inadequately trained contractors

Many contractors learned on the job from other contractors, who did not know the proper techniques to build a safe and long-lasting building. They are doing their best. Many do not understand how to build a disaster-resistant home. If they knew the techniques, many of them would encourage their clients on building disaster-resistant homes.

This is an opportunity for the American University of the Caribbean to train its engineering students to go out and train building contractors and to work with them when they have problems.

Inadequately trained building inspectors

The building code is a massive and complex document. Few inspectors ever have a grasp of all aspects of the building code. This is a new document to Haiti, so few of the building inspectors grasp all that they need to in order to effectively enforce the code. Even fewer understand that there are construction techniques, which a professional engineer can certify to, which do not follow the letter of the code, but are as effective as what is written in the code.

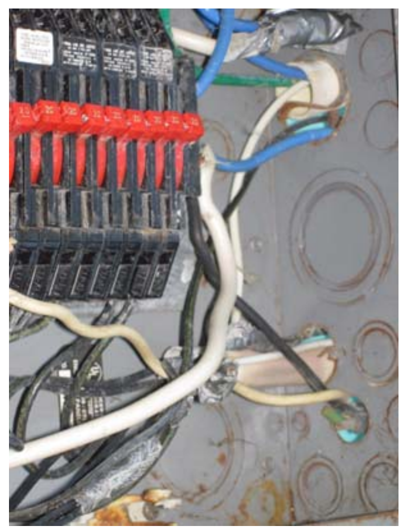
In most developed countries, each year the building inspectors need to take refresher classes and also classes which cover new items in the code.

Gold-Plated Slums

Coming in and building a house or two, or even thousands of houses, but without them being part of a community, will accomplish little. If communities are built, they must be built so they are self-sustaining. Building houses where a living cannot be earned, even if the homes are gold-plated, will not help the people living there. I have visited a complex funded by USAID before the earthquake and a complex funded by USAID after the earthquake. The streets are well laid out. The buildings are well-designed and constructed, but there are no jobs in the area. There is no public transportation. To live there, one needs to have a car to drive to work. The rent is higher than most people who would live there can afford. As a result, the complexes have about 10% occupancy. They were built with good intentions, but many people did not do their homework. Whatever we do, we need to study the problem so we help people, not hurt them.

How can we bring jobs to that area?

Utilities



Roads are needed to provide access to homes which are built.

Many areas do not have access to water, electricity, or sewage disposal. While I am not going to discuss these items, they are items which need to be addressed. There are engineers who can address these areas.

Money

Many of the above problems are related to not having enough money to build an adequate structure, in a timely manner, using quality concrete, and designed so it will endure. These problems could be addressed to some extent if an adequate mortgage system were developed and financed.

People

Working with people complicates the problem. Since this is not a problem dealing with concrete, I have no solutions to offer.

Disaster-Resistant Building Technologies

Structures can be built using the following technologies and be designed to survive disasters:

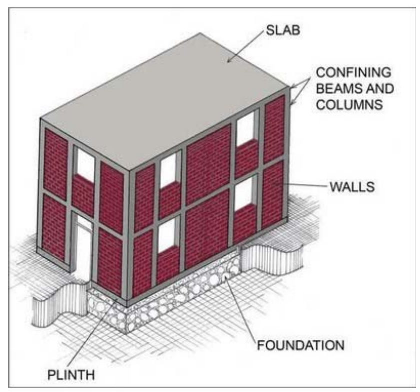
Reinforced concrete boxes

With limited openings, these structures can be built with poured-in-place or tilt-wall construction.

Structures without corners or overhangs

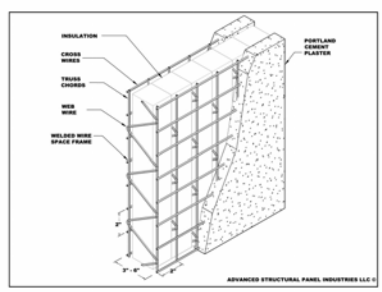
They do not give the forces a place to grab hold of. Concrete domes are a classic example. With domes, it is more difficult to add a second story than some of the other methods, but they are the lowest cost method for building disaster-resistant housing.

Confined masonry structures



This is the indigenous method of construction in Haiti, so many people know the basics, but few know the techniques to make them disaster-resistant. With training, inspection, and adequate documentation, disaster-resistant structures could be built. A modification of this technique is to build a one-story structure and place a metal roof on it. If beams are installed between the tops of the walls, it can be made earthquake-resistant. If the truss system is adequate and the overhangs of the metal roof are limited, it can be made hurricane-resistant.

Structural concrete insulated panel structures



This is used in much of the third world, but there are no plants available in Haiti. It can be used to build structures up to 5 stories high. A panel consists of two sheets of reinforcing steel separated by Warren Trusses, with the inside filled with sheet Styrofoam and the outside plastered with 1 or 2 inches of a cement stucco. The panels can be used for walls, roofs, or floors. Except for areas where oxidation of the galvanized mesh eliminates its use, it is an excellent product.

Insulated concrete form structures

Building blocks produced from Styrofoam or other material are stacked and then filled with rebar and concrete. If there is a Styrofoam expander in Haiti, it would be a simple matter to build the block. The walls, inside and out, have to be plastered, otherwise they provide a fire hazard. While roofs can be built from these blocks, a metal roof or a flat concrete roof would be better.

Underground structures

Underground structures are disaster-resistant and are often cooler than other structures, but are not practical in much of Haiti.

Solving the Problems

Many years ago I took my car to my brother, who is a mechanic, and asked him if he could fix it so it would run good and be reliable. After looking it over he suggested that I needed a new key. That did not make sense to me, but he explained that he would jack the key up and put another car under it. Solving the construction problems in Haiti are like that. We can solve one problem, but numerous other problems will destroy what we have done.

We need a group of people who can develop coordinated solutions to the problems. Rather than having to comply with the building code, we need some documents which if followed will meet the requirements of the building code. An example would be the Blondet Manual for building confined masonry construction.

The documents should be available in Haitian Creole, so the maximum number of contractors can read and understand them.

As each building technology is approved, instructors need to start teaching building contractors and building inspectors.

None of this will help if the people do not demand that buildings be built to a better standard. How can we accomplish that?

There is a massive job ahead of us but we can meet the challenge. It is time to start organizing and building a better Haiti. We can be sure of one thing: in a few years we will have another earthquake or another hurricane. If we are prepared, it will be more of an inconvenience. If we continue to build in the traditional way, it will be another disaster.

The American University of the Caribbean has taken a first step, in that they invited me to come and teach a two-week class in disaster-resistant construction for engineering students. Other classes will be held here, and the same classes should be held in all other parts of Haiti. I am one old man and cannot do much.

What would it take to equip the engineering students who are taking my class to go out and teach a class or two in some other part of Haiti? What would be the benefit for Haiti? It would be a good place to start.

Do other universities have engineering students who could be trained to do the same thing?

If people know something can be done, they can then make it happen,

If we work together, we can make Haiti great. Let’s do it.

Thank you.

Mr. Chairman, do we have time for a few questions?

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