Teaching Building Professionals Design of Earthquake Resistant Buildings: Haiti Experience

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Abstract

When the strongest earthquake in over two hundred and sixty years struck the Caribbean island nation of Haiti in January 2010, part of the devastation was measured in hundreds of thousands of human lives lost as a result of the hundreds of thousands of buildings that were totally destroyed or severely damaged.

Investigation as to why the buildings failed revealed that building professionals were not familiar with design and construction of buildings to resist earthquake loadings. Most of the buildings (some as tall as five stories) were not engineered, were built using poor quality materials and built by unskilled contractors. No official building code was (and is) available in Haiti and no inspection of building construction was ever conducted by the authority in charge of buildings. As the reconstruction and repair of the damaged homes had to start soon after the earthquake, it was important to educate all the stakeholders on the design and construction of earthquake resistant buildings in order to avoid such a catastrophe recurring in the next earthquake.

This paper presents unique teaching methods used to teach Haitian practicing building professionals (architects, engineers and contractors) as well as home owners, government building officials and engineering students at the state university and other professional trade schools the basic but important aspects of design and construction of earthquake resistant one- and two-story concrete and concrete masonry un-engineered confined masonry buildings.

The classes were offered in form of one-week workshops that had both classroom setting and three days of hands-on learning that included field visits and hands-on experience in the construction procedures. Graduates of the program were given jobs to construct new homes or repair damaged homes and then tested after a few projects in order to assess the success of the training program. The trainings as presented were found to be very successful.

Introduction

Haiti, located on the western one-third portion of the Hispaniola Island in the Caribbean attained her independence on January 1, 1804 from France. Since independence, Haiti has been plagued by political instability that has led to social and economic hardships placing this country of ten million people\(^1\) as the poorest in the Americas\(^2\). Although French is the official language, only about ten percent of the population is proficient in speaking, reading and writing in French. The general population communicates, but most cannot read or write in the second official language; the Haitian Creole, a French based creole with African influences.

The public education system in Haiti suffers from lack of funding from the government and private schools (primary, secondary and universities) dominate the education sector with very little if any control on education standards. Presently, there is one state university and a few
professional (trade) schools in the country. More than half of children aged between five and seventeen years do not attend school due to lack of school fees\textsuperscript{1}.

Over the years, Haiti has suffered devastating economic and human loss of life as a result of hurricanes and tropical storms that lead to flooding and mud slides originating from land left bare by man-made deforestation activities. On October 18, 1751, Haiti experienced a Magnitude 8.0 earthquake that completely destroyed Port-au-Prince (PaP), the capital city\textsuperscript{3}. Since then, the next earthquake, a Magnitude 7.0 struck Haiti on January 12, 2010. Ground shaking that lasted for 35 seconds resulted in more than 230,000 deaths, as many people injured, more than 105,000 buildings totally destroyed, 208,000 buildings damaged and more than 1.3 million people left homeless\textsuperscript{4}. The reasons for the building failures were investigated over a two week period starting immediately after the earthquake as the author conducted building evaluations for structural safety. Building materials, construction procedures, qualifications and competency of building professional (architects, engineers, contractors) and government building regulations were investigated. It was found that each of the investigated items and including the home owners all contributed to the catastrophe. In a country where construction grade lumber, cement, structural steel, steel bars for concrete reinforcement, galvanized iron sheets, etc. are all imported, the only sustainable solution for the reconstruction is the continued use of masonry and reinforced concrete buildings. This however requires immense training and re-training of building professionals on construction technics of hurricane and earthquake resistant building.

**Workshop Preparations**

The author attended meetings in PaP organized by the Government of Haiti (GoH) and other shelter cluster stakeholders like UN-HABITAT, UNOPS, etc. in hope to gather as much information on the training, licensure of building professionals (architects, engineers, contractors) and enforcement of building codes. It was clear from the onset that the faculty of science at the State University of Haiti (UEH) lacked qualified personnel to teach design of earthquake resistant concrete and masonry buildings, predominately built in Haiti. It also came to light that, the legal licensing body, the College of Haitian Architects and Engineers (CNIAH) had not met in over 25 years leading to the January 2010 earthquake. It was also learned that Haiti had never had a specific building code. Designers had been using whatever building code they were familiar with which included the French Code, Canadian Code, The Euro Codes and the International Building Codes. Building plans were never submitted for plan check by the Ministry of Public Works, Transport and Communications (MTPTC) or building construction inspected as required by Ministry of the Interior and Local Government (MICT). Quality of building materials had also to be addressed. Since most of the buildings were not engineered, the workshops were developed to address all building professionals and also the home owners in preparation of home repairs and new constructions.

**Workshop Pilot**

The first step was to get in touch with the target audience. This was done through religious based non-governmental organizations (NGOs) both international and national. The first (pilot) workshop was held for two days in Kenscoff’s mayor’s office. The participants included architects, civil engineers, contractors (bos masons) and some home owners. The workshop
covered one day of classroom activities that included theory on earthquakes and behavior of concrete and masonry buildings during earthquakes, quality of buildings materials and safe building practice for un-engineered two-story family dwellings. The participants were also taken around the neighborhood for explanation as to why the buildings failed as shown in Figure 1.

Figure 1: Pilot Workshop (a) Classroom Setting and (b) Site Visit

The second day of the workshop was a hands-on concrete and masonry home repair techniques. Figure 2 shows hands-on activities.

Figure 2: Pilot Workshop (a) Re-bar Cutting and (b) Wall Crack Repair

The purpose of the pilot workshop was to establish a protocol so that the workshop could be replicated in other parts of the country and may also be offered by other engineers and not just the author. The lessons learned from the pilot workshop included but not limited to:

- Haitian Creole and not French was to be used as the language of instruction for the workshops.
- The participants were to be separated in future workshops. Engineers and architects may be mixed but their workshops need not exceed two days.
• Workshops for contractors to be held for five days and include three days of supervised home repair projects.
• The number of participants in contractor workshops to be limited to sixteen so that there are no spectators in the hands-on activities.
• There should be an incentive for the community to participate in the workshops.

Workshop Execution

After two weeks in Haiti following the earthquake and having concluded the pilot workshop and two other two day workshops, the author took a one year sabbatical leave from the department of Architectural Engineering at California Polytechnic State University (Cal Poly) in order to implement the lessons learned from the pilot workshop and heed to the community’s request for the workshops. The project was funded by the Mennonite Central Committee (MCC), Church World Service (CWS) and the Christian Labour Association of Canada (CLAC) as the international NGOs. Two Haitian national NGOs, Christian Service of Haiti (SCH) and Christian Center for Integrated Development (SKDE) provided the local contacts and sites for the workshops. The theoretical portion of the workshop was given at various settings depending on the availability of space in the community neighborhoods as shown in Figures 3, 4 and 5.

Figure 3: Workshop Classroom Setting (a) and (b) for Engineers and Architects

Figure 4: Workshop Classroom Setting (a), (b) and (c) for Contractors
After one day of classroom presentation, the participants were taken around the neighborhood for explanations of the different building failure mechanisms and their causes. Repair methods were also addressed during the site visits. Figure 6 shows the workshop participants on the site visits.

The learn-by-doing portion of the workshop consisted of supervised selection of quality of construction materials, mixing of concrete, proper placement and tying of steel reinforcement, proper laying of concrete masonry and proper construction of reinforced concrete columns and beams for confined masonry building construction as shown in Figure 7.

A total of twelve workshops whose duration ranged from one day to one week were offered over the period of one year. The majority of the workshops were held in Port-au-Prince where most
Workshop Assessment

The trained contractors were offered contracts to repair damaged concrete buildings or build new earthquake and hurricane resistant buildings where inspections were conducted by the author leading a team of Haitian engineers that formed the “technical team”. The lessons learned from the workshops were implemented wholesome. To ensure that the graduates could execute the lessons learned from the workshops as leaders of their own construction crews, the contractors were given a checklist (Appendix A) of construction inspection items that the technical team would check at random during the construction. No construction would proceed or be complete unless all the relevant activities were performed to the satisfaction of the inspecting engineer. 100% compliance was hence expected as the outcome of this assessment as failure was not an option. Of the 126 homes constructed or repaired, only one contractor at one building site failed to place concrete beam reinforcement as required. His team was instructed to demolish it and do it “right”.

The participants were also given a written assessment quiz shown in Appendix B. For those participants who could not read or write in Haitian Creole, an oral quiz was given. Figure 8 shows assessment in progress. The quiz was graded in form of an oral presentation by the participants where a discussion took place to reinforce any deviation from the materials covered in the workshops. Overall, the author gave a 100% pass in the quiz for the tested participants. One of the workshops was held at trade school where the students were preparing to take the government contractor license examination. All the twelve students who participated in the workshop passed their contractor licensing examination.

Figure 8: Workshop Assessment (a) Home Repair Inspection Checklist, (b) Written Assessment Quiz and (c) Oral Assessment Quiz

The final assessment of the training program was carried out by Church World Service. The assessment was in form of observable benefits. The home repair program was found to be the only program in Haiti that was providing permanent housing for people with disabilities having...
repaired 213 houses in Port-au-Prince and trained over 200 Haitian masons in earthquake-resistant building practices. One other task was to disseminate the training information nationally as a feedback request by the participants of the workshops. Meetings were held with the programming director of the Haiti National Radio and Television (RTNH) in which the workshop materials were provided for national broadcast through the radio and television media. The principles of construction covered in the workshops have now been taken over by the government in collaboration with NGOs (like USAID, etc.) using print media (flyers, bill boards, calendars, etc.) besides radio and television programming. Examples of government of Haiti safe building construction campaign flyers are shown in Appendix C.

As an incentive for the workshops, all workshop participants were given a certificate of completion. Contractors who participated in the workshop were also given a construction tool kit to help them apply the knowledge of the workshop correctly as shown in Figure 9.

Figure 9: Workshop (a) Certificate Presentation, (b) Construction Tools in Tool Kit and (c) Presentation of Tool Kits

Conclusion

Conducting workshops for building professionals to build earthquake and hurricane resistant buildings, some of whom do not know how to read or write is an enormous task for a university professor. It gets even more complicated if you have to learn a new language and then use it in the workshops and in construction in a foreign third world country outside your comfort zone. This is exactly what happened to the author as he had to learn French Creole within two months and then use it for the remaining ten months of the project. The following can be concluded from this experience:

- This type of project is not for everyone and was purely driven by need to help humankind and especially the marginalized in the society. It was driven by the norm that, if you give a man fish, you feed his family for that day, but, if you teach him how to fish, then you will feed his family for life.
- The program is a good lesson for faculty who would be willing to work with students on the most common projects through Engineers Without Borders or other NGOs.
- The concept of inspection during construction of buildings was new in Haiti when first introduced by the author and it is currently being used by engineers from other international and national NGOs.
• Although the workshop participants came from different backgrounds and different academic and professional levels, the workshops succeeded in teaching building professionals how to design and construct safe hurricane and earthquake resistant un-engineered confined masonry buildings as evidenced by the inspections and the assessment quiz.

• Liaison with the government and other NGOs was crucial in the success of the project. The success here was measured by the awareness campaign on construction of masonry “small” un-engineered buildings. In the absence of an official building code, the government produced guidelines on building repairs\(^7\) and new construction\(^8\) besides flyers, bill boards and calendars with information similar to Appendix C.

• The workshops continued to be offered by other engineers even after the author left Haiti using the author’s template. The template is also being used by the government of Haiti and other NGOs as a training tool.

• Follow up observation after two or so years will be necessary to fully assess the true success of the program as the construction principles continue to be repeated by the government. This will entail going back to Haiti and “shadowing” the workshop participants.

Bibliography

Appendix A:

STRUCTURAL QUALITY CONTROL CHECKLIST

Home Address: ____________________________ GPS: _______________________

Home Owner: ______________________________ Telephone: __________________

Check all that applies and dates when items were observed

Materials

☐ Clean river sand
☐ Clean crushed river gravel
☐ Portland cement Type I
☐ Clean water
☐ Clean good quality blocks
☐ Clean new deformed ½” Φ bars
☐ Clean new ¼” Φ bars
☐ “Readymix Block” for mortar
☐ “Readymix Normal” for mortar

Column and beam steel cages

☐ 4 - ½” Φ bars used for each column and beam
☐ All ½” Φ bars with only 90° hooks with 25cm long tails in columns and beams
☐ All ¼” Φ ties with only 135° hooks with 7.5cm long tails in columns and beams
☐ Spacing of ¼” Φ ties from floors in columns and from ends of beams as follows:

1 @ 5 cm
4 @ 10 cm
Rest @ 25 cm maximum

☐ ½” Φ column bars splice length of 60 cm located in middle 3rd of column height (between floors)
☐ ½” Φ beam bars splice length of 60 cm located in end 3rd of beam length

Block wall

☐ Blocks used in wet condition (dip in bucket)
☐ Mortar laid on block face shells of block only
☐ Mortar bed and head joint thickness between 1.0 and 1.5 cm (finger width)
☐ Stagger blocks at columns and plumbing and electrical conduits (zigzag pattern)
☐ Not more than 1.2 m (6 courses) of wall height built in one day
☐ Wall erected plumb as checked by a plumb bob
☐ Where “Readymix Block” not used, mortar mixed in ratio of 1 part Portland cement to 5 parts river sand and adequate amount of water
Concrete

Concrete mixed in ratio of 1 part Portland cement to 2 parts of river sand to 4 parts of crushed river gravel (2 cm max) and 1 part of water
Concrete well vibrated and compacted in column and beam formworks
Concrete formworks removed not earlier than two days after concrete placement
Concrete columns and beams watered three times a day for seven days after formwork is removed

Crack repairs

Observed cracks in wall after removal of plaster
Damaged mortar removed and surface cleaned with water prior to application of new cement paste
Repaired crack area patched with “Readymix Normal”
Where “Readymix Normal” not used, plaster mixed in ratio of 1 part Portland cement to 5 parts river sand and adequate amount of water

Reinforcement steel repairs in columns, beams and floors

Rusted reinforcement cleaned with wire brush followed by sand paper and area cleaned with water prior to patching with concrete

New corrugated galvanized iron sheet roof system

Main roof framing members tied to columns or perimeter masonry walls for cyclone resistance
Each iron sheet adequately fastened to framing members
All iron sheet fasteners extending beyond framing member depth to be bent at 90° and flat below the framing members for cyclone resistance

Engineer’s name and signature: ____________________________________________
Date work completed: _________________________________________________
Appendix B:

BOS MASON TRAINING WORKSHOP EXIT QUIZ

Last Name: ______________________    First Name(s): _____________________
NIF: __________________________         Telephone: _______________________

Please answer all the questions to the best of your ability

1. **Materials**

Since attending the workshop from MCC what changes have you made in use of the following materials?

☐ Sand
☐ Gravel
☐ Cement
☐ Water
☐ Blocks
☐ Steel reinforcement

2. **Column and beam steel cages**

What changes have you made in preparation of steel reinforcement cages for columns and beams since you attended the workshop from MCC to make buildings seismic resistant?

**Block wall and concrete**

Describe how you are laying block walls since you attended the workshop from MCC. Please include how you prepare the blocks, and how tall a wall you have been placing in a day’s work.

Describe the proportions you are now using for mortar and for concrete

3. **New corrugated galvanized iron sheet roof system**

Since attending the workshop from MCC, describe what changes you have made on the attachment of the roofing iron sheets to make the roof cyclone resistant.

Signature: __________________________________________________________
Date: ________________________________
Appendix C:

EXAMPLE OF GOVERNMENT OF HAITI PUBLIC AWARENESS CAMPAIGN FLYERS

"Zanmi m yo! Lè nou gen bon materyo, lè nou itilize bon pratik konstriksyon yo epi bòs ki kalifye sa ap pèmèt nou gen yon kay moun ka fè konfyans"
Ann Rebati Byen Epi San Danje

“Itilize kantite siman, sab, gravye ak dlo ki rekòmande a lè n’ap brase beton epi n’ap gen yon kay ki solid”

ENPÒTAN

Pa bliye: Si sab la mouye mete mwens dlo lè n’ap brase beton.

BETON

Siman + Sab rivyè lave + Gravye + Dlo =

BLÒK an BETON

Siman + Sab rivyè lave + Dlo =

MÒTYE

Siman + Sab rivyè lave + Dlo =
Lè a rive pou nou chanje jan n’ap konstwi

Yon mi ki solid ki mare ak poto epi pout yo ap pwoteje w kont tranblemantè

Wi! Sévi ak bon blòk epi fè jwen kwaze epi mete motye nan toulède pwent blòk yo.

Non! Jwen file ap fè mi yo pa solid

Non! Machwè blòk fè mi yo pa solid

Non! Jwen yo twò pre youn ak lòt epi pa gen motye nan pwent blòk yo

Non! Jwen yo twò epè. Fè jwen yo anvìwon ½ pou.
MELANJ POU BETON

1. RESET:
   1. BONT
   2. BOKIT
   3. BONIT

2. MELANJ A SEK (SAN DLO):
   ETAP 1: BRASSE ER PEL DE PLI.
   ETAP 2: DEPLIJE PLI LA PEL.

3. AJOUTE DLO:
   MAKING KE J BOKIT DLO.

TES:
   BOH BETON DAE REWS AN SOUL.
   MEN PA TWA KOLLE.

TRÉ ENPOTAN:
   SEV BONIT AWA NIN DLE.
   PA DI DROG J IN D SAU?
   SE N PA N BU PA LE BONIT.

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