Reconstructing Schools in Post-Earthquake Haiti

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SUMMARY:
Canadian firms joint ventured to offer Structural aid in the reconstruction of schools in the earthquake damaged Haiti.

The paper presents a study of a volunteer effort successfully providing benefit post-earthquake. The project was facilitated by FCA Finland. The paper includes Building Code options applicable to construction in locations where traditional enforcement does not exist. Application of the National Building Code of Canada to the design of prototype schools using appropriate climatic and seismic data and local construction materials and methods is presented. Prototypes have been adapted for the local requirements for construction of several school sites. Opportunities to overcome challenges to construction in remote rural areas are outlined. Sustainability initiatives including reuse of rubble material and non-toxic preservative treatments for lumber are examined. The program will see 50 new schools constructed in Haiti. Local engineers will be trained to administer design and construction of on-going new schools.

Keywords: Schools, Haiti, Remote Rural Construction

1. GENERAL INTRODUCTION

On January 12, 2010, a Magnitude 7.0 earthquake destroyed the capital of Haiti, Port au Prince, and large parts of the built environment across the country. It left around 1.5 million people homeless, destroying over 100,000 homes and leaving another 200,000 severely damaged. It also destroyed or damaged around 4,000 schools, including 80% of schools in Port-au-Prince and 60% of schools in a large area in the southwest of the country.

2. PROJECT OVERVIEW

Following the earthquake, four Canadian Structural Engineering Consulting firms - Blackwell Bowick, Halsall Associates, Quinn Dressell, and Read Jones Christoffersen - collaborated in a pro-bono project to assist in rebuilding schools in Haiti. The four companies committed to having at least one field engineer present in Haiti for a total term of 18 months, with a team of designers backing up the field presence. Together the joint venture firms have made significant donations of time and expertise to design and build robust, sustainable school structures and to transfer important skills and expertise to local professionals.

The reconstruction of the schools was administered through Finn Church Aid (FCA) who undertook a long-term mandate to construct approximately 50 permanent schools over a 5 year period. FCA was responsible for the management of the project, securing the funding and engaging the technical expertise for all project activities. The owner of the school sites worked on to-date is the Bureau

Anglican d'Education en Haiti (BAEH) of the Episcopal Church, who has worked with FCA as their local partner.

The project's primary goal was to use durable, locally sourced materials to build permanent schools rather than temporary or transitional ones. Each of the companies involved pledged to contribute to an adaptable design for school buildings, to oversee the construction of the prototype schools and to transfer skills to Haitian engineers that would equip them to take over the design and review of future schools.

Following initial reconnaissance it became clear that the extensive earthquake damage in the Zone extending from Port au Prince west to Leogane and south to Jacmel (Fig 2), presented communities and terrain which ranged from reasonably flat and accessible by road to extremely rugged terrain only accessible by foot. To respond to both of these conditions, the four firms designed two structural prototypes concepts for new schools. A heavyweight structure (Fig 3,8,9,10) incorporating reinforced concrete columns, beams, and shear walls with rubble masonry infill walls, was designed for areas accessible by road (e.g., St. Matthieu School in Leogane). Also, an alternative, lightweight structure was designed (Fig 4,5,11) for rural areas where there is no road access and building materials must be transported on foot. The lightweight structure relies on timber stud wall construction with plywood shear walls (e.g., St. Joseph School).

Materials for construction were selected based on local availability with a goal of illustrating how conventional readily available local materials can be used to construct robust, durable and safe structures. To this end the materials selected as load bearing structural elements include timber, and reinforced concrete, with masonry only used for non-loadbearing elements. Steel sections available in Haiti are limited to small angles and tubes so these have been used only where they can be used effectively.

In building the new schools, numerous challenges unique to Haiti had to be overcome. These included scarcity of materials, a narrow supply chain, limited infrastructure for transportation of material and communications, and the limited availability of construction equipment. Typically in Haiti, for example, workers crush stones by hand to produce gravel. In addition, at one of the prototype sites, an inaccessible rural site, building materials had to be carried on foot or by donkey for approximately 2 1/2 hours down a hillside and along a riverbed, (Fig 5) significantly slowing the construction process. Also the Haitian contractor's site staff and the local engineering staff had little experience reading drawings and little knowledge of good construction practices.

Throughout the project, efforts were made to make all designs as simple as possible for local contractors to follow. To assure the success of the project, an experienced Canadian field engineer was sent to Haiti, whose role was not only to oversee the structural work but also to help coordinate the many different elements of the project. The field engineer assisted with project layout, demolition, scheduling, safety issues, quantity calculations, building envelope details, civil works, plumbing, electrical work, quality control, training of the site staff and paperwork issues.

To ensure that the schools were built properly, site supervisors and tradespeople had to be trained in good practices. Language barriers and illiteracy were both issues and the local workers tended to build more or less what the drawings illustrated. The structural drawings had to be adapted so they could be easily understood, for example, if the designs called for 33 nails in a connection, all 33 nails had to be illustrated in the correct locations on the drawing to avoid construction errors. The lesson learned is that success depends on keeping the design simple, clearly communicating the requirements, then making sure those responsible for the construction at all levels understand the need and expectation, that the actual work follows the design details.

3. CODES AND STANDARDS

The new school buildings were designed to resist earthquakes using US Geological Survey data, with interpretation from the Geological Survey of Canada (Fig 1), and to resist hurricanes to which Haiti is naturally vulnerable, using Caribbean Wind Speed Maps compatible with ASCE7.

In the absence of a Haitian national building code, and with the “informal” agreement of the Haitian government, the team provided designs compliant with the National Building Code of Canada (NBCC).

4. PROTOYPE CONCEPTS

Construction standards in Haiti are typically low and buildings are unable to withstand large seismic forces. Haitian buildings traditionally have reinforced concrete roof slabs and poorly defined lateral-load-resisting systems. The lateral load resisting systems are often based on unreinforced masonry or confined masonry, recent earthquake experience proved that this does not stand up to the high seismic levels prevalent in the area. For the new schools, the types of construction were carefully chosen to fulfil the requirements of the NBCC and enable the team to use locally available construction materials. For both Prototype concepts the designs included timber truss roof structures with well-connected plywood roof diaphragms that attract lower seismic loads because of their small masses and have demonstrated high resistance to lateral loads. In addition, well defined, uniformly distributed systems of shear walls made of either timber or reinforced concrete were used to support the roofs.

Masonry is a widely used material for construction in Haiti. As a result stone rubble is in abundant supply from buildings destroyed by the earthquake. By using rubble masonry in a nonloadbearing role, and ensuring that the masonry is well anchored to the surrounding structure, a sound structural example that makes good use of the skills and materials readily available was developed.

Where timber construction was employed on the projects a borate solution treatment was applied to the timber on site rather than using pressure treated lumber. This simple precaution allowed all of the untreated scrap lumber to be used by the communities as fuel for cooking, as is the common practice in Haiti. This avoided having people exposed to potentially toxic fumes from burning pressure treated lumber scraps.

Geotechnical conditions vary somewhat from site to site in Haiti. There are soils engineers in Haiti but the equipment and expertise to carry out deep soils investigation to quantify a site classification consistent with the requirements of the NBCC is not available. The prototype designs were prepared based on a generic site class D. At one specific site the soils engineer recommended a site class E and the shear wall design was verified for this site specific condition.

5. MATERIAL TESTING

No access to conventional material testing facilities was available in Haiti, so the team had to be resourceful and develop simple alternatives (for example, using local materials to perform a modified concrete slump test). In addition, material availability in Haiti varies widely, necessitating continual innovation to compensate for shortages.

6. CONCLUSIONS

In a country where 50% of the population is illiterate, the new schools give numerous children access to an education that they would not otherwise have. By contributing to increased child literacy levels, the hope is to enable Haitian people to gain the skills and education that will be necessary to rebuild not just their homes and communities, but an entire economy.

Many Haitians lost their livelihoods after the earthquake. The school-building projects provide badly needed employment for local builders, and many of the labourers which were hired for the school construction are parents of the children that will be attending the schools. As part of the project, the team was able to help local labourers learn valuable new skills ranging from properly mixing concrete to carpentry and masonry work as well as allowing members of the community to feel a pride of ownership in the project by being involved in the construction.

Wherever possible, construction materials were sourced and recycled locally. For example, in the heavyweight prototype school, rubble masonry infill walls were designed, using recycled rubble from buildings destroyed by the earthquake.

This project has had a tremendous positive social and economic impact in Haiti and beyond. It has given Haitian children and young people safe and comfortable buildings in which to learn and has provided work and income to Haitian builders. It has also established connections between Haitian and Canadian engineers, offering a model of cooperation to a domestic engineering industry that typically focuses on competition rather than collaboration among companies.

An engineer-training program was incorporated into the project, which has helped to develop the skills of local engineers. By sharing knowledge and expertise, and setting examples of good construction practices, the hope is to ensure that future projects built in Haiti are better designed to resist earthquakes and hurricanes.

Throughout the project, Canadian engineers liaised not just with local construction professionals but also with church leaders, school principals, teachers and many other members of the local community to ensure that their needs were met. In collaboration with the partnering firms, two schools were completed during the first year, opening their doors to almost 600 local children in time for the beginning of the Haitian school year. In addition three schools were taken into construction, with three more out for tender and three other schools prepared for tender.

A suite of classroom modules for each construction prototype has been prepared which can be easily adapted to future sites and soil conditions.

The Haiti schools project demonstrates how, through creativity and innovation, buildings of quality and excellence can be produced even in the aftermath of one of the world’s largest natural disasters and in the absence of any locally established, adopted or enforced building code.

The team of Canadian Engineers which collaborated in the project conclude that the experience of participating in a small grass root Pro Bono volunteer effort can create real benefit to the community in need. A significant additional benefit appreciated by the engineering team was the opportunity for engineers from different firms to work cooperatively without the need for competition to achieve a collective goal.

7. ILLUSTRATIONS, DIAGRAMS AND PHOTOGRAPHS

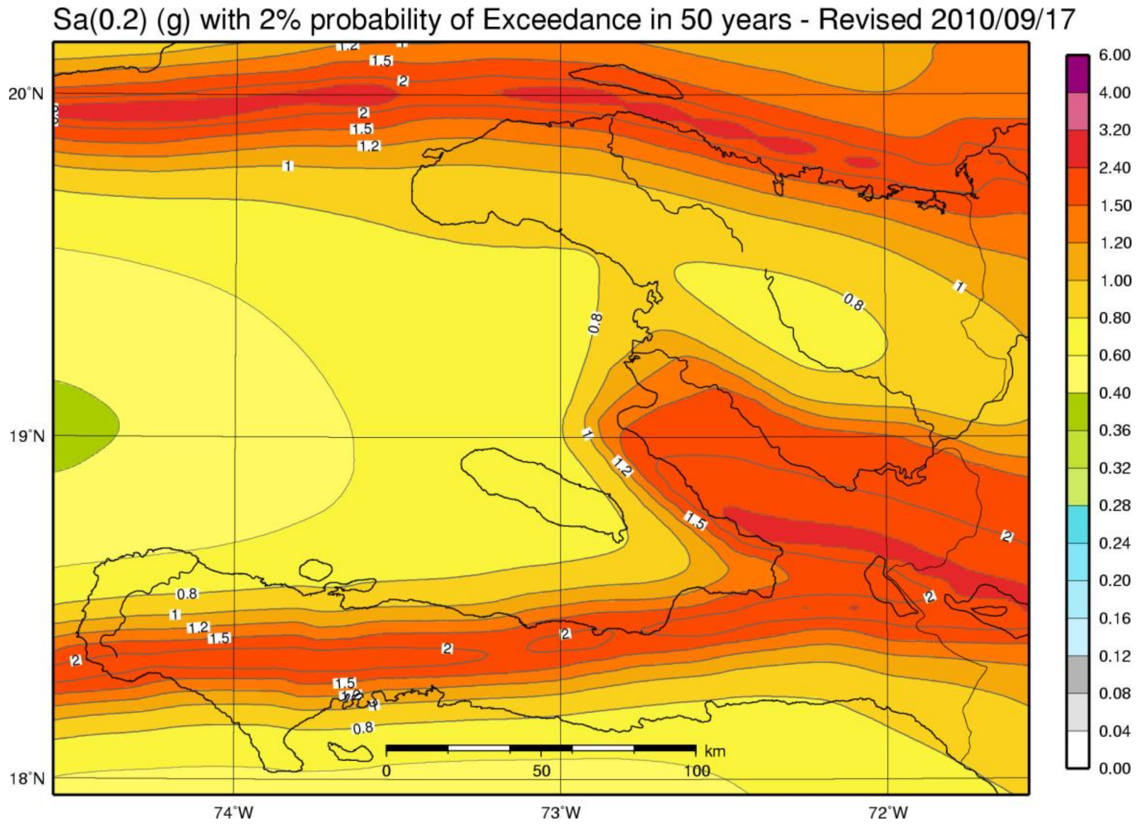

Figure 1. Seismic hazard map for Haiti, for the mean value of Sa(0.2) at a 2% probability of exceedance in 50 years on Class B/C rock (contoured by the GSC from data points provided by the USGS on 2010 09 21).

Figure 2. Major damage zone.

Figure 3. St. Matthieu School Concrete Shear wall Prototype.

Figure 4. St. Joseph School timber Frame Prototype.

Figure 5. Plywood trekking and taking material by donkey.

Figure 7. St. Joseph and St. Matthieu School Children

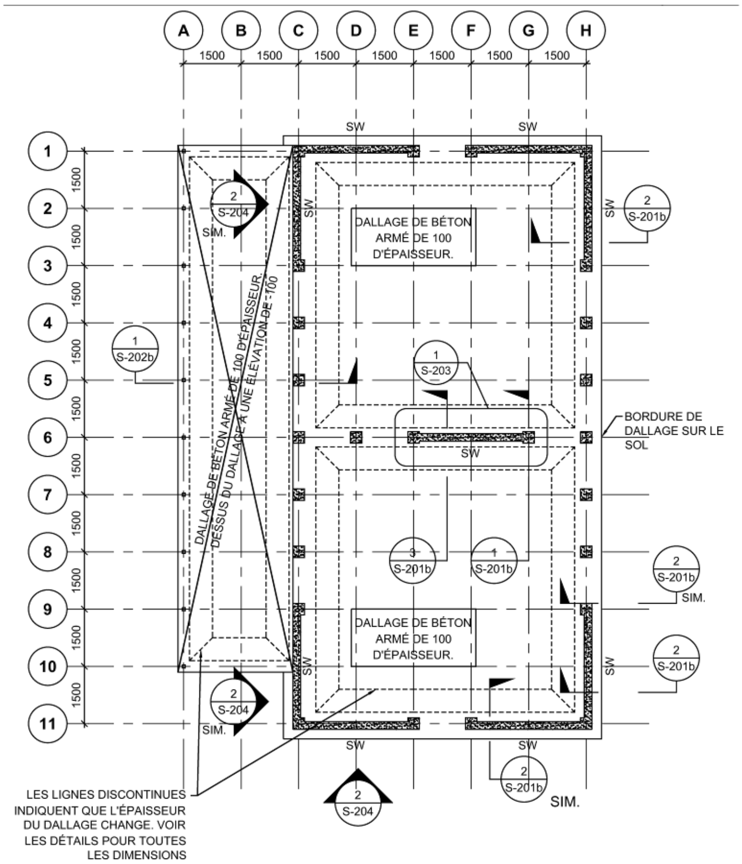

Figure 8. Typical 2 classroom module

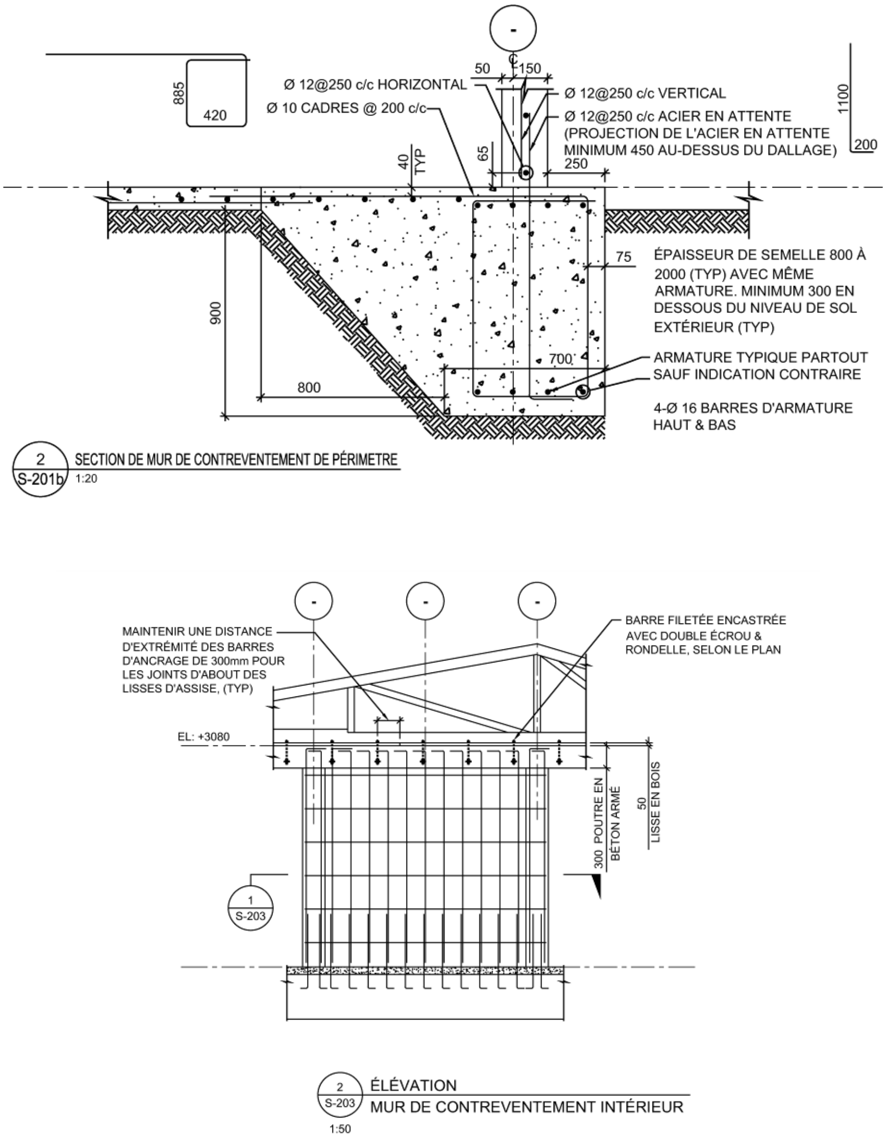

Figure 9. Typical Concrete Shear wall Details

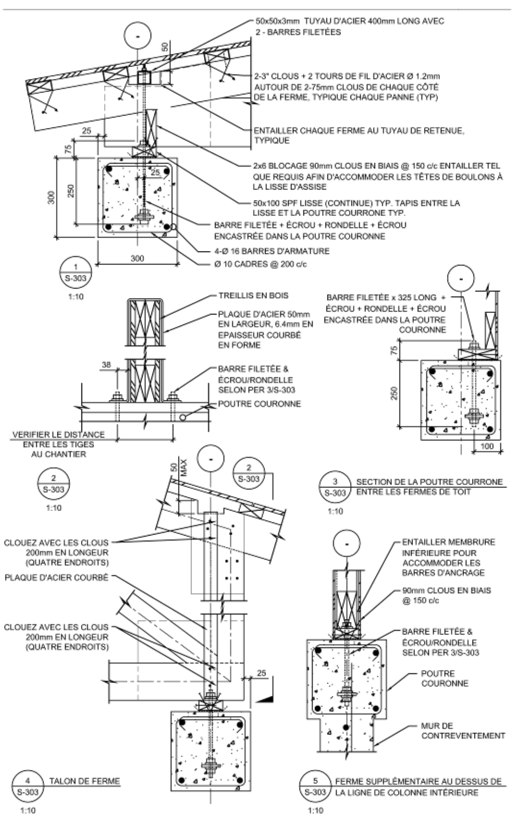

Figure 10. Typical Concrete Frame details

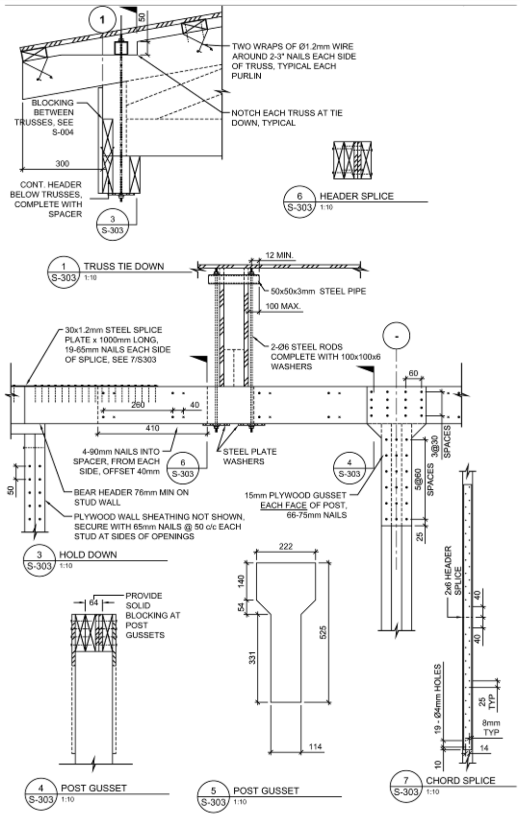

Figure 11. Typical Timber frame details

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