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A Full Scale Rubble-House Construction and Testing Project Powered by Undergraduate Student Volunteers Workforce

Abstract

In January 2010, a devastating earthquake destroyed several concrete and masonry structures, killed more than 200,000 people, and left thousands of families homeless in Haiti. As part of the relief work, replacement homes have been built by U.S. non-profit organizations in areas severely hit by the earthquake. Considering the vast availability of post-earthquake rubble, a house built with walls comprised of welded wire baskets filled with loose rubble seemed to be an inexpensive and immediate solution for the needy. Conscience International, Inc. has used a unique construction technique and built more than 70 rubble houses over the last two years. In August 2011, Southern Polytechnic State University (SPSU) in collaboration with Conscience International, Inc. (CI) initiated a preliminary research effort to assess the seismic resistance of such rubble houses. The first phase of this research project was to build a full-scale (14 ft. wide, 20 ft. long and 8 ft. tall) rubble house and subject it to static load testing. The project started under the limited sponsorship of both parties and largely depended on donations, student volunteers and unpaid faculty time. In order to increase exposure to the university community and promote student involvement, a full-scale rubble house was built in the middle of SPSU campus. During construction, more than 600 hours of engineering and non-engineering student labor time were spent. This paper focuses on undergraduate student involvement during construction and testing phases. Results of survey administered among volunteered students are also presented. It appears that volunteers enjoyed this humanitarian hands-on project activity, and expressed a strong desire to see similar opportunities on the campus. Overall, the project has made positive impacts on students’ approach to community issues, interest in volunteer activities, and team-work skills.

1. Introduction

A 7.0 magnitude earthquake struck Haiti on January 12th, 2010. The Haitian government estimates 200,000 have died as a result of this sad incident, 2,000,000 people have been left homeless and 3,000,000 people are in need of emergency aid. The United States Geological Survey (USGS) reported that the earthquake was the strongest earthquake to hit the area since 1770.

Shortly after the earthquake, relief organizations from around the world joined their forces to support the devastated communities in carrying out rescue operations and supplying food, shelter, medical aid and providing sanitation, etc. The most challenging issue was providing shelter to millions of people who lost their homes. In 2011, despite government and international efforts, the UN reported over 1 million individuals still living in temporary structures. New building methods have been developed for rapid, low cost, construction. Studies have yet to be conducted to determine the effectiveness of these solutions

CI, a Georgia non-profit humanitarian and advocacy organization, started building homes for the Haitians using welded wire baskets and rubble. Rubble is still plentiful in Haiti and a major obstacle for new construction. Oxfam indicates that only 5% of the rubble was removed one
year after the earthquake. Two years after the earthquake 50% of the rubble is still sitting on the streets and more rubble is to come due to demolition of heavily damaged structures.

Rubble houses help removal of the rubble from the streets and recycle the concrete generated by the collapsed buildings. The method used to make the walls of a rubble house is relatively simple. A single wire basket is prepared for each wall, and loose rubble, with varying sizes, is poured into the basket from the top. Finally, both interior and exterior surfaces are covered with mortar, and a simple A-frame roof is installed.

A similar approach has been used in the “gabion basket” concept, especially in retaining wall business, except that crushed rock or river gravel is used to fill the baskets made out of chain link fencing material with varying strengths. These baskets are then stacked on top of each other to form a wall with an inclined base, leaning toward the retained soil. However, in a home construction the walls need to be vertical and free standing. Oxfam, a U.K. based relief organization, applied the “stackable gabion basket” concept to build homes and named them “gabion homes”. Hart has developed a “rubble bag houses” concept to build shelters in Haiti. Natural fiber bags are filled with rubble and stacked on top of each other to make walls. The wall of the rubble house studied in this paper is made out of one single wire basket, and this is what sets it apart from other “gabion” and “bag” approaches.

Another important feature of a rubble house is that it can be built with simple hand tools and non-educated volunteer work force. No power tools are needed. Simple tools such as, wire cutter, simple wire bending tool, and hammer are all you need to build a rubble house.

In August 2011, a collaborative research effort between SPSU and CI was initiated to assess the seismic resistance of such rubble houses. The literature survey revealed no significant study on the response of such houses to both static and dynamic loads. Therefore, as the first phase of this study, it was decided to build a prototype of original rubble house built in Haiti, and subject the walls to a series of in-plane and out of plane static loads. SPSU administration proposed to make the construction and testing activities in the middle of the campus so that students could see the entire progress. This proposal has triggered other ideas, such as encouraging student involvement in volunteer activities including construction, testing and publicity. Therefore, in addition to research objectives, a whole new set of “campus objectives” has emerged. Figure 1 shows the completed rubble house next to a student residence building.

The overall research objectives were:

(a) Evaluate current construction techniques and propose cost-effective improvements
(b) Perform static load testing on a full-scale Rubble-House
(c) Create computer models for static and dynamic analyses
(d) Make recommendations for future seismic shake table experiments
(e) Draft construction and design guidelines based on experimental and numerical findings,

and the campus objectives were:

(a) Increase awareness of the rubble house project amongst the students and the local community
(b) Promote engineering and non-engineering student involvement
(c) Increase students’ sensitivity to community issues
(a) Provide students an opportunity to improve their teamwork skills
(b) Nurture an environment where students can apply their knowledge to real-life problems

Figure 1 Rubble house built next to a student residence building.

The following section briefly covers the construction method. Next, student involvement and survey results are discussed, and evaluation of campus objectives is presented.

2. Construction Method of a Rubble House

Rubble houses are inexpensive and easy to build without power tools and skilled labor. A six inch deep foundation was first excavated and filled with rubble and concrete. Next, a single wire basket was prepared for each wall separately. A wire basket consists of 10-Gauge 6 inch X 6 inch welded wire mesh and 23-Gauge flexible wire mesh fabric. As shown in Figure 2, the sides of the basket are formed by tying 10-Gauge and 23-Gauge wire mesh together, then the sides are connected to each other by 12 in wide 10-Gauge cross tie at every foot along the length of the wall. Connections are done by bending wires using a simple tool called “Bailey’s tool”. A Bailey’s tool is named after the person who invented it while building rubble houses in Haiti. It has two components, a 12 in long bent rebar, and about 3 in long steel tube attached to the rebar as shown in Figure 3.

Once two sides are connected with cross ties, it creates 8 feet tall compartments with 12 inch by 12 inch cross-sectional areas as illustrated in parts (a) and (b) of Figure 4.

After erecting all four wire baskets, one for each wall, they are filled with rubble. Finally, the walls are covered with 1.5-2.0 in thick mortar. Each rubble house measures 14 feet by 20 feet in foot print area and contains no bathroom, which is not uncommon in Haiti.
Figure 2 Preparation of the wire basket.

Figure 3 Bailey’s tool used to bend wires.
(a) Demo Wall partially filled with rubble.

(b) Illustration of a wire basket

Figure 4 Wire basket.
Students from various majors actively worked during the construction process. Figure 5 shows students working on different stages of construction: (a) foundation installation, (b) , (c), and (d) preparation of wire baskets, (d), and (e) breaking concrete into smaller pieces to be used in filling wire baskets.

![Student volunteers working on foundation installation, preparing wire baskets, and busting concrete.](image)

**Figure 5** (a) Student volunteers working on foundation installation, (b, c, d) preparing wire baskets, (e, f) busting concrete.

The construction of the walls was done with the same construction method and tools used in Haiti. However, the quality of concrete rubble was better than the Haitian rubble. Figure 6 shows the construction stages of a typical rubble house built in Haiti, and Figure 7 shows the same construction process followed by the project team on SPSU campus.
Figure 6 Construction of a rubble house in Haiti
(a) Foundation installation

(b) Wire basket installation

(c) Wire baskets being filled with loose rubble.

(d) Applying cement finish

(e) Final look of the rubble house on SPSU campus. The picture was taken by the webcam before the static load testing.

Figure 7 Construction of the rubble house on SPSU Campus.
3. Student Involvement in Construction

A premium location was proposed by the University administration to increase exposure to the campus community and student involvement.

Volunteerism was a key for the success of this project. In order to promote the university’s spirit of maintaining a hands-on learning environment, faculty advisors complemented research efforts with a volunteer program for the project. The rubble house project was able to rally over 100 students for the project, including engineering and non-engineering students. Volunteers spent a total of 600 labor hours to successfully build a live model of the rubble house using Conscience International’s unique building method.

Civil engineering technology and architecture faculty also incorporated the project into relevant coursework, using the ongoing construction to demonstrate field application of in-class learning.

Engineering and architecture students were not only involved in construction but also participated in brainstorming sessions to propose cost-effective rubble-house construction techniques.

4. Student Involvement in Instrumentation and Measurements

In order to understand the mechanical behavior of the rubble walls, the displacement response of the walls was recorded using displacement gauges (part (a) of Figure 8), a 3D laser scanning technique (part (b) of Figure 8), and total stations (part (c) of Figure 8).

3D laser scanner was operated by a team that consists of one faculty and two graduate students from the Construction Management department. Total stations were operated by a team of faculty and students from the Surveying and Mapping program. Instrumentation frames and displacement gauges were fully designed and manufactured by undergraduate civil engineering technology students and worked very well during testing.

5. Student Involvement in Publicity and Outreach

In addition to the official web site, http://www.spsu.edu/rubble-house, a Facebook page was created by students which provided another way for people to follow the rubble house project. The page was updated with photos and status updates as they were made available.

In order to increase awareness and promote student involvement, informational seminars were scheduled on the campus. Additionally, faculty members delivered short lectures on the construction site at several instances.

In collaboration with SPSU’s human resources office, students worked on reaching out to local TV channels and newspapers. Rubble house related news appeared several times on local media.
Figure 8. Displacements were measured by three different methods.

(a) Displacement gauges.  
(b) 3D Laser scanner. 

(c) Total stations.
6. Survey Questions and Responses

A survey was conducted among volunteer students. A total of 38 responses were received from 100 students. Survey results showed that the rubble house construction and testing project was a positive experience for most students, and 89.5% showed interested in participating in a similar project should an opportunity comes up.

More than 80% strongly support the idea that the University should provide more hands-on learning opportunities on the campus.

Survey questions and collected response are presented in Appendix 1.

7. Conclusions

This article discusses the student involvement in a full-scale construction and testing project of a rubble house that received more than 600 labor hours of help from engineering and non-engineering undergraduate student volunteers.

The rubble house project gave SPSU students the opportunity to be exposed to an alternative technology based on hands-on, practical, and humanitarian purposes.

Survey results show that the rubble house project increased students’ sensitivity on community issues and interest in solving problems regarding international community as well.

Survey results also show great satisfaction by the student volunteers. Majority of them want to see more hands-on opportunities on the campus similar to the rubble house project presented in this paper.

Contributions from students and faculty from various majors helped to create a learning environment across the campus.

Acknowledgement

The authors acknowledge gratefully the support of this study by SPSU Administration, Conscience International, Inc., Atlanta Technical Services, Steel, Inc., Atlanta Demolition, Paul Lee and by the volunteer efforts of many students, faculty, and community partners. Thanks to all the faculty members who have encouraged students for participating in this project. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of Southern Polytechnic State University or other project sponsors.
Bibliography


Appendix 1 Student Survey Results

1. What is your gender?
   - Female
   - Male

2. What is your academic status?
   - Freshman
   - Sophomore
   - Junior
   - Senior
   - Graduate
   - Other
3. What is your major?

- Civil Engineering Technology
- Civil Engineering
- Construction Management
- Construction Engineering
- Architecture
- Mechanical Engineering Technology
- Mechanical Engineering
- Electrical Engineering Technology
- Electrical Engineering
- Industrial Engineering Technology
- Industrial Engineering
- Computer Science
- Information Technology

Participation by Major

- Business Administration: 2.9%
- Computer Engineering Technology: 5.95%
- Information Technology: 2.95%
- Computer Science: 2.9%
- Industrial Engineering: 8.8%
- Industrial Engineering Technology: 2.9%
- Electrical Engineering: 2.9%
- Electrical Engineering Technology: 2.9%
- Mechanical Engineering Technology: 11.8%
- Architecture: 5.9%
- Construction Engineering: 2.9%
- Construction Management: 2.9%
- Civil Engineering: 23.5%
- Civil Engineering Technology: 29.5%
4. On average, how many hours did you spend working on the Rubble-House Project?

- Less than 2 hours
- 2-5 hours
- 5-10 hours
- 10-15 hours
- 15-20 hours
- 20-25 hours
- 25-30 hours
- More than 30 hours

Participation by Labor Hours

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5. What role did you assume while working on the Rubble House Project?

- I was in a leadership role
- I was involved as a team member
- I was involved in field construction activities
- I was involved in research activities
- I was involved in public relations

Other (please specify):

- I was involved in public relations: 7.9%
- I was involved in research activities: 18.4%
- I was involved in field construction activities: 78.9%
- I was involved as a team member: 47.4%
- I was in a leadership role: 5.3%

6. I volunteered in Rubble House Construction and Testing Project because:

- I am concerned about community issues
- It is important to me to be part of projects that involve helping people
- I want to have an impact on solving problems that face under-served communities internationally
- I learn more with hands-on activities
- I like building things
- I needed some volunteer work activity for my course/program
- My instructor encouraged me to get involved
- It seemed like an interesting project to me

Other (please specify):

Participation by Intention:

- It seemed like an interesting project to me: 56.8%
- My instructor encouraged me to get involved: 21.6%
- I needed some volunteer work activity for my course/program: 5.4%
- I like building things: 59.9%
- I learn more with hands-on activities: 45.9%
- Solving problems that face under-served communities internationally: 58.8%
- It is important to me to be part of projects that involve helping people: 54.1%
- I am concerned about community issues: 32.4%
7. Based on your experience with Rubble-House Project, do you agree with the following?

1) In this project, I learned how engineers/architects/construction managers apply the concepts I learned in class to real-life problems

2) In this project I learned how to work with others effectively
Question 7 cont’d.

3) This project increased the likelihood that I would continue in engineering

4) This project increased my commitment to being involved in community issues as a professional
5) This project increased my belief that I can make a difference in the community

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<td>28.51%</td>
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6) This project improved my leadership skills

<table>
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<td>11.43%</td>
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Question 7 cont’d.
7) This project increased my interest in volunteer activity

8) This project increased my school pride
Question 7 cont’d.

9) The school should provide more opportunities for students to get involved in similar real-life projects.

10) Working on this project had negative impact on my coursework.
8. Would you like be involved in a similar project again?

- Yes
- No
- Not sure

9. Please include your additional feedback here. Thanks...

- Well it was working on the rubble house, and it actually turns out pretty nice. Testing was fun to watch, plus this was a convenient activity as it occurred right outside our dorm.

- Great project! Hope to be involved in something like this again

- had fun!!

- It was an amazing experience.

- it was a pleasure to be involved in this project ..... thank for helping to students .......

- I think more projects like this should be mandatory for students to take as part as a requisite for a SPSU Degree.

- We need projects like this every semester! It allowed us to have hands on training. Hands on training is what we need!

- The test results should be presented in a final paper/lecture to all involved which explains: research goals and which of those goals were met, along with the next steps. This should be done in an official SPSU forum to have the student body (including students who didn't participate in the project) learn about this research project. I think students will want to become involved in future research projects if they can understand the process a project like this takes: from concept to execution