

# **A Full Scale Rubble-House Construction and Testing Project Powered by Undergraduate Student Volunteer Workforce**

## **Abstract**

In January 2010, a devastating earthquake in Haiti destroyed several concrete and masonry structures, killed more than 200,000 people, and left thousands of families homeless. As part of the relief work, U.S. non-profit organizations have built replacement homes 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 few 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. More than 600 hours of engineering and non-engineering student labor time were spent on the construction. This paper focuses on undergraduate student involvement during the construction and testing phases. Results of a survey administered among student volunteers are also presented. It appears that volunteers enjoyed this humanitarian hands-on project and many expressed a strong desire to see similar opportunities on the campus in the future. Overall, the project has made a positive impact on students' approach to community issues, interest in volunteer activities, and teamwork skills.

## **1. Introduction**

A 7.0 magnitude earthquake struck Haiti on January 12th, 2010. The Haitian government estimates 200,000 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 efforts from around the world joined forces to support the devastated communities in carrying out rescue operations, supplying food, shelter, medical aid and providing sanitation facilities, 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 that more than one million individuals were 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<sup>1</sup>.

CI<sup>2</sup>, 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<sup>3</sup> 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 with more rubble to come due to the demolition of heavily damaged structures.

Rubble houses help with the removal of 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 of varying size, 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 the retaining wall business, except that crushed rock or river gravel is used to fill the baskets that are made out of chain link fencing material of 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 freestanding. Oxfam, a U.K. based relief organization, applied the “stackable gabion basket” concept to home construction and named them “gabion homes”<sup>3</sup>. Hart<sup>4</sup> has developed a “rubble bag house” concept to build shelters in Haiti. This concept uses natural fiber bags that 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 the “gabion” and “bag” approaches.

Another important feature of a rubble house is that it can be built with simple hand tools and a non-educated volunteer work force. No power tools are needed. Simple tools such as, wire cutters, simple wire bending tools, and hammers are the only tools needed 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 an 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 construct the prototype and conduct the test procedures in the middle of the campus so that students could see the entire process. This proposal has triggered other ideas, such as encouraging student involvement in volunteer activities including the construction, testing and publicity for the project. 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 as follows:

- (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

The campus objectives were as follows:

- (a) Increase awareness of the rubble house project amongst the students and the local community
- (b) Promote involvement of both engineering and non-engineering students
- (c) Increase student 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 foundation six inches deep was first excavated and filled with rubble and concrete. Next, a single wire basket was separately prepared for each wall. 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 the 10-gauge and 23-gauge wire mesh together, then the sides are connected to each other by 12 inch wide 10-gauge cross tied 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 inch long bent rebar, with a steel tube about 3 inches long attached to the rebar as shown in Figure 3.

Once two sides are connected with cross ties, 8-foot tall compartments with 12 inch X 12 inch cross-sectional areas are created. This is illustrated in parts (a) and (b) of Figure 4.

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



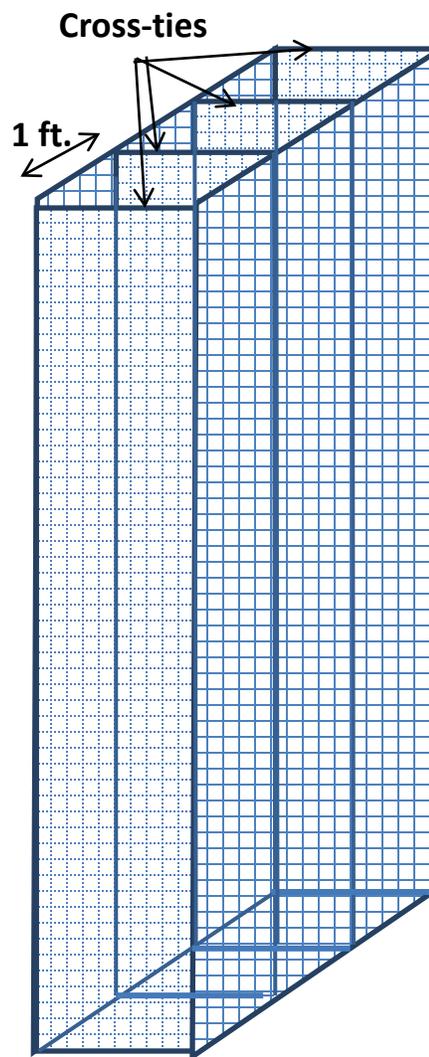
**Figure 2** Preparation of the wire basket.



**Figure 3** Bailey's tool used to bend wires.



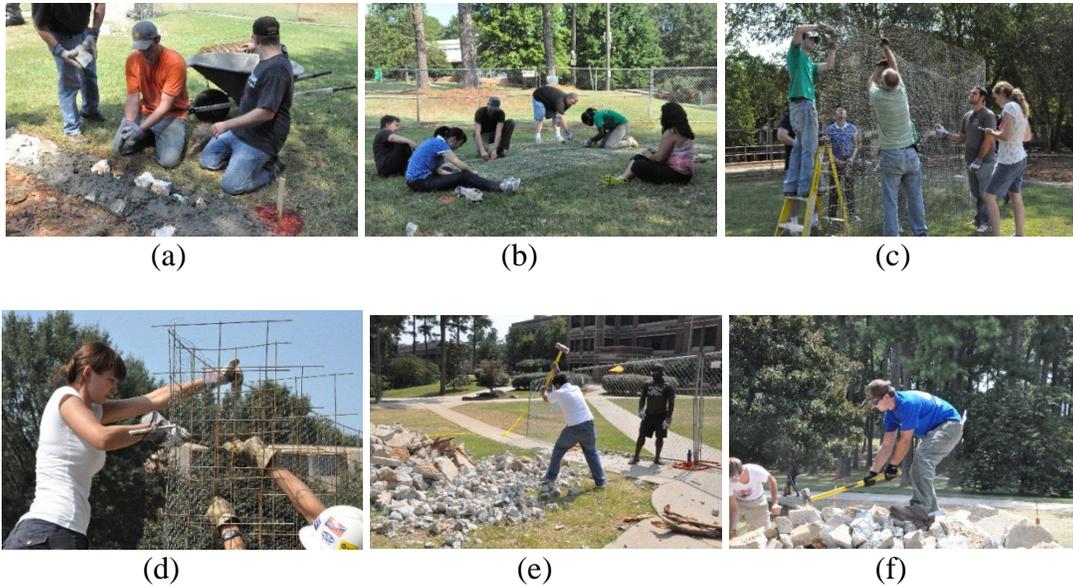
(a) Demo Wall partially filled with rubble.



(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, and (e) and (f) breaking concrete into smaller pieces to fill the wire baskets.



**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.



(a) Foundation installation



(b) Wire basket preparation



(c) Baskets filled with loose rubble



(d) Adjusting window and door openings



(e) Applying cement finish



(f) Roof installation



(g) Final look of a typical Rubble-House in Haiti

**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).

The 3D laser scanner was operated by a team that consisted 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 the 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, there were several instances when faculty members delivered short lectures at the construction site.

In collaboration with SPSU's human resources office, students worked on reaching out to local television stations and newspapers. Rubble house related news appeared several times on local media.



(a) Displacement gauges



(b) 3D Laser scanner



(c) Total stations

**Figure 8.** Displacements were measured by three different methods.

## **6. Survey Questions and Responses**

A survey was conducted among volunteer students. Thirty-eight responses were received from 100 students surveyed. The 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 in the future should an opportunity arise.

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

Survey questions and collected responses 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 felt by the student volunteers. The majority of responses showed that participants want to see more hands-on opportunities on the campus similar to the rubble house project.

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

## **Acknowledgement**

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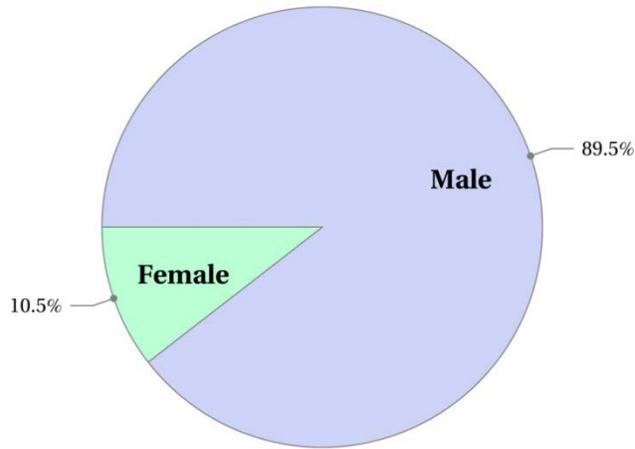
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2. Conscience International, I. (n.d.). Retrieved 12 20, 2011, from <http://www.conscienceinternational.org/>
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4. Kelly Hart, D. O. (2010). *Home*. Retrieved 01 09, 2012, from EarthbagBuilding.com: <http://www.earthbagbuilding.com/aboutus.htm>

# Appendix 1 Student Survey Results

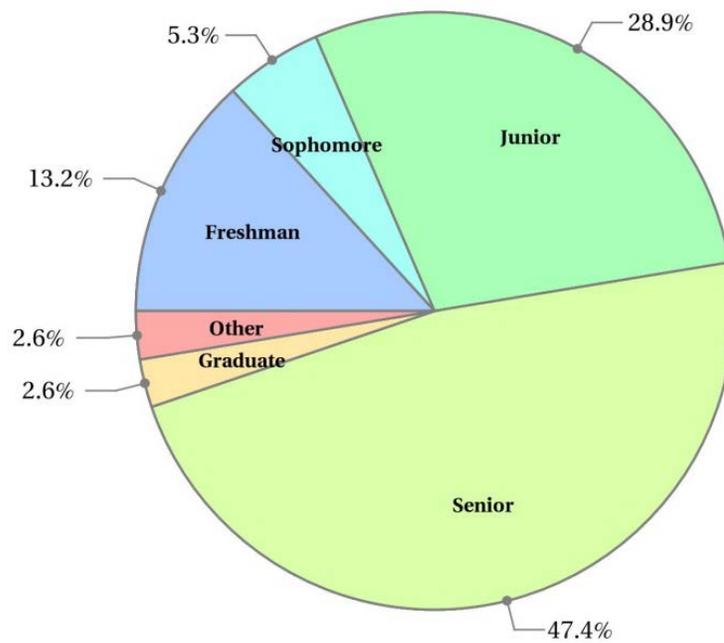
## 1. What is your gender?

- Female
- Male



## 2. What is your academic status?

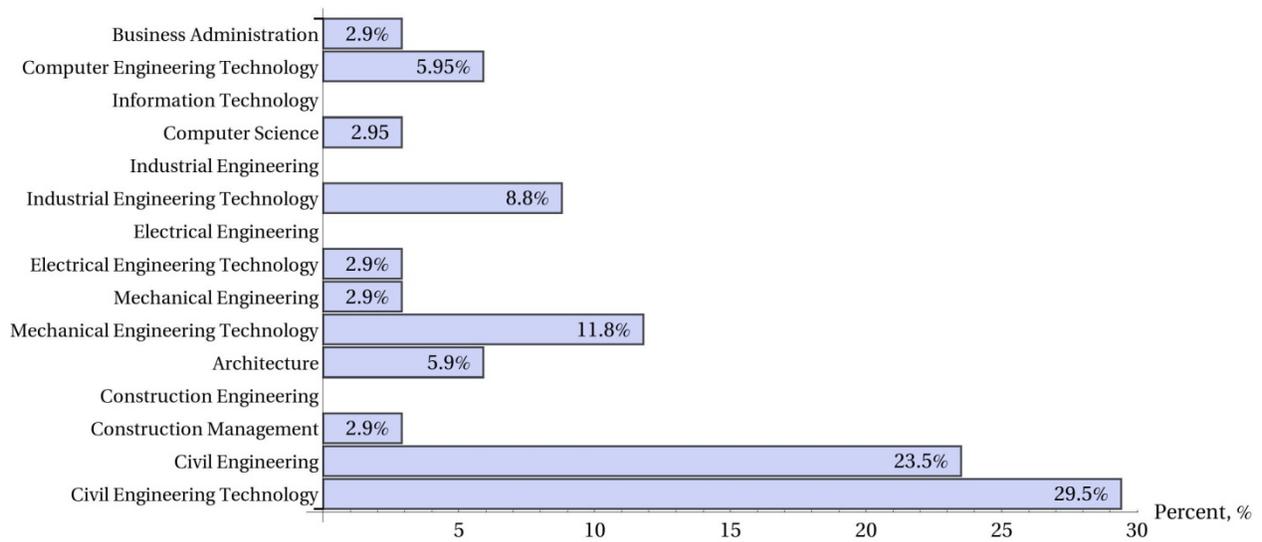
- Freshman
- Sophomore
- Junior
- Senior
- Graduate
- Other



### 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 Technoloav

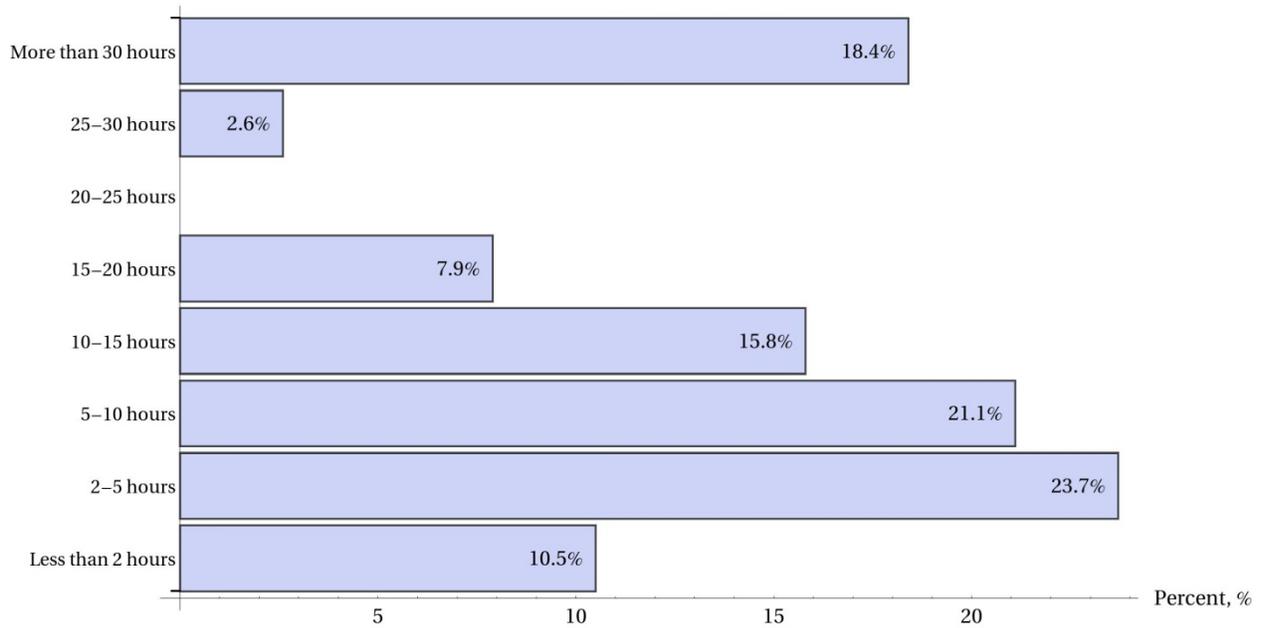
Participation by Major



**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

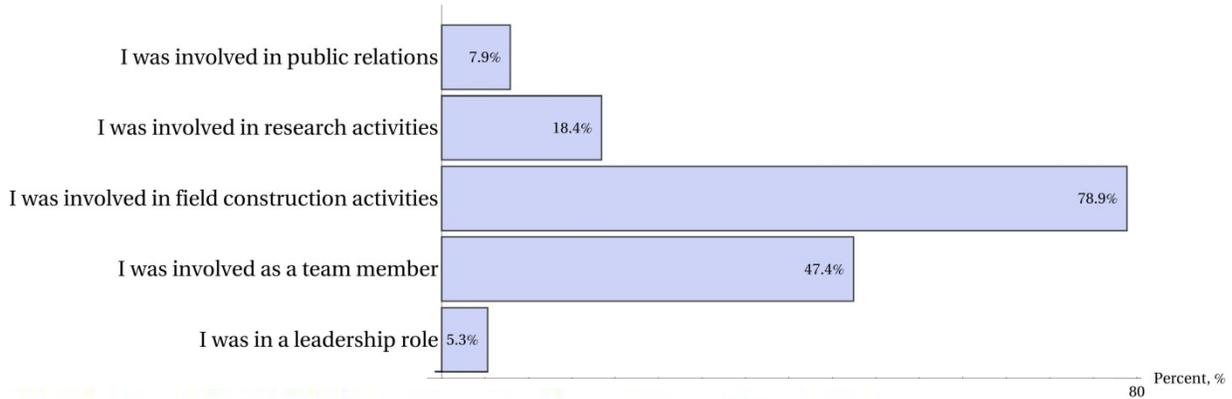
Participation by Labor Hours



**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

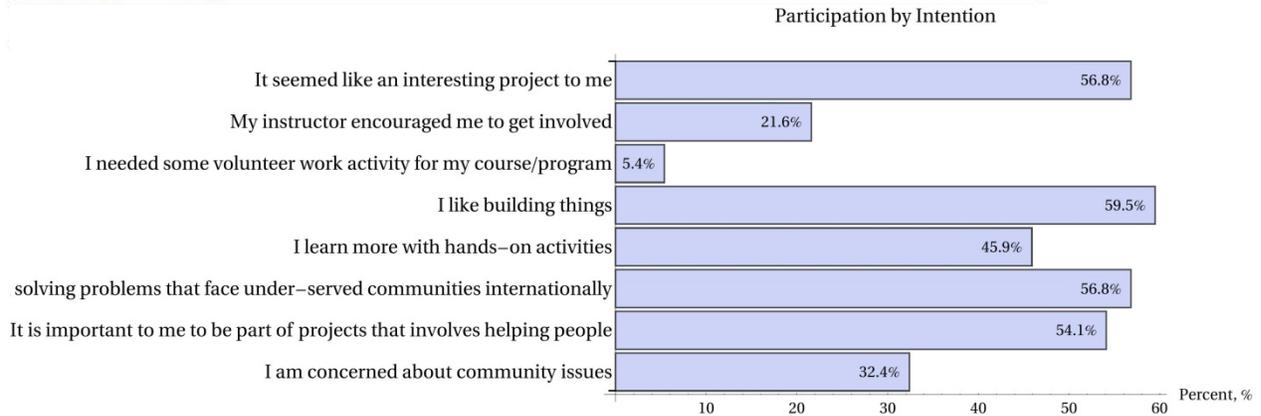
Other (please specify)



**6. I volunteered in Rubble-House Construction and Testing Project because;**

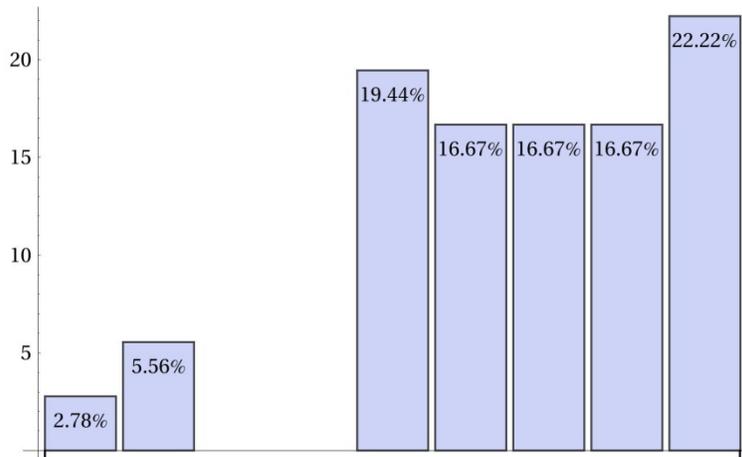
- I am concerned about community issues
- It is important to me to be part of projects that involves helping people
- I want to have an impact on solving problems that face under-served communities internationally
- I learn more with hands-on activities
- I like building things
- I needed some volunteer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

Other (please specify)



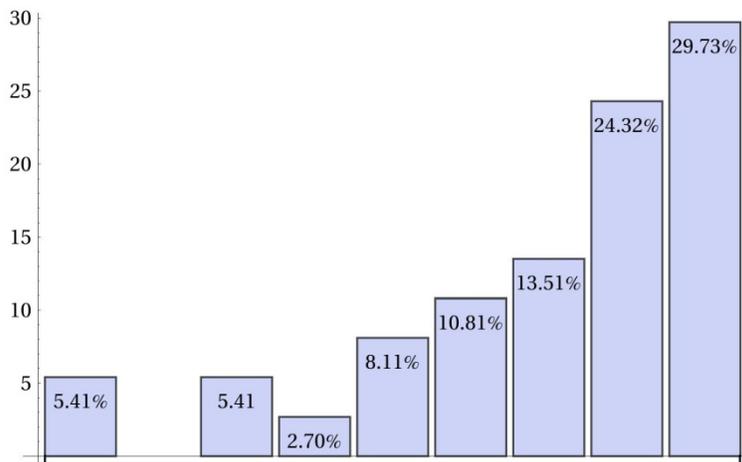
**7. Based on your experience with Rubble-House Project, do you agree with the following?**

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



Strongly Disagree <----- Neutral -----> Strongly Agree

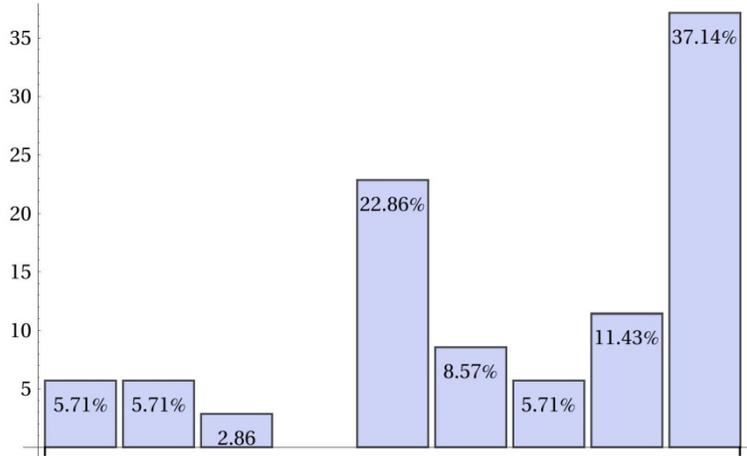
2) In this project, I learned how to work with others effectively.



Strongly Disagree <----- Neutral -----> Strongly Agree

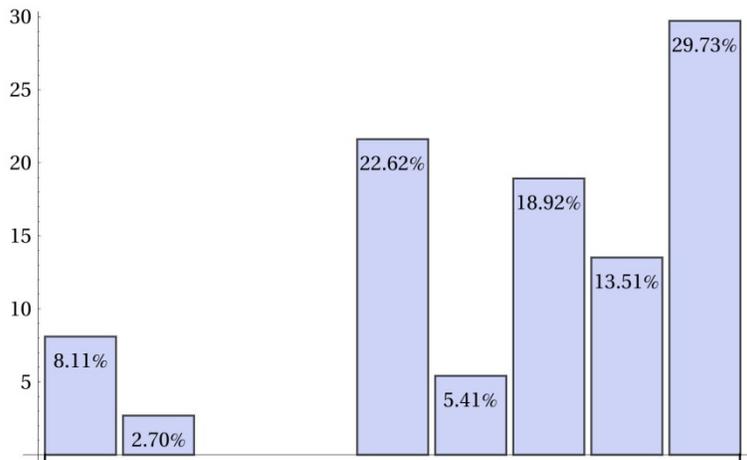
Question 7 cont'd.

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



Strongly Disagree <----- Neutral -----> Strongly Agree

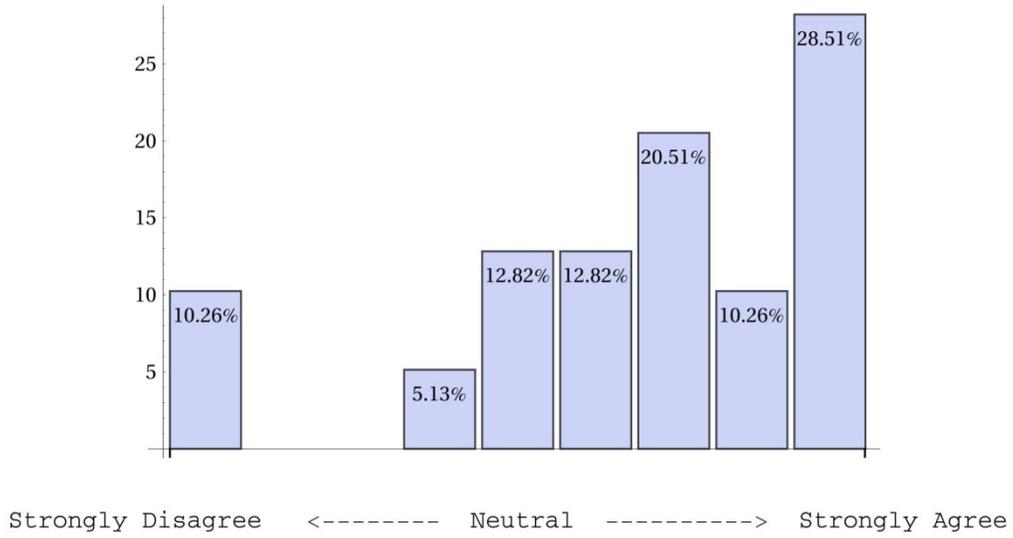
4) This project increased my commitment to being involved in community issues as a professional.



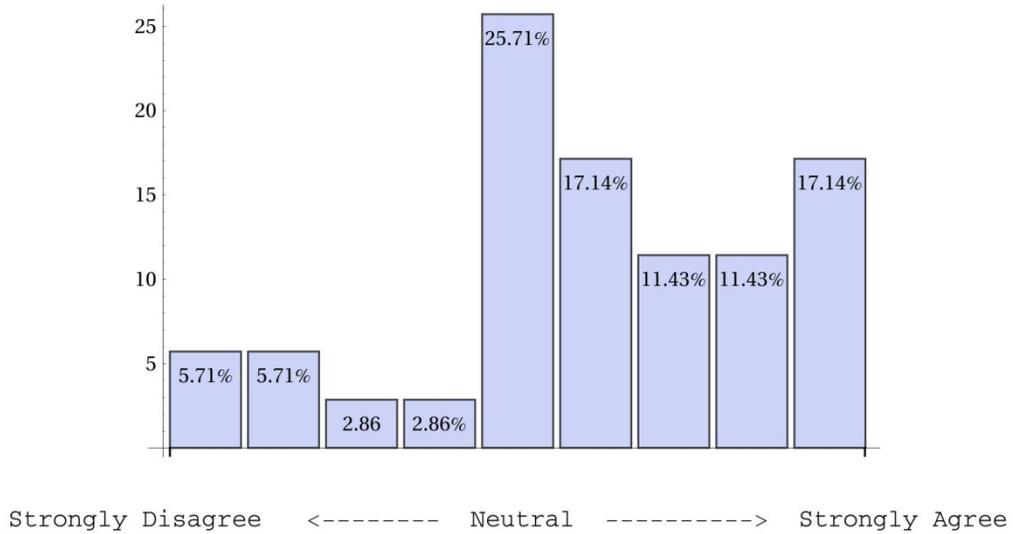
Strongly Disagree <----- Neutral -----> Strongly Agree

Question 7 cont'd.

5) This project increased my belief that I can make a difference in the community.

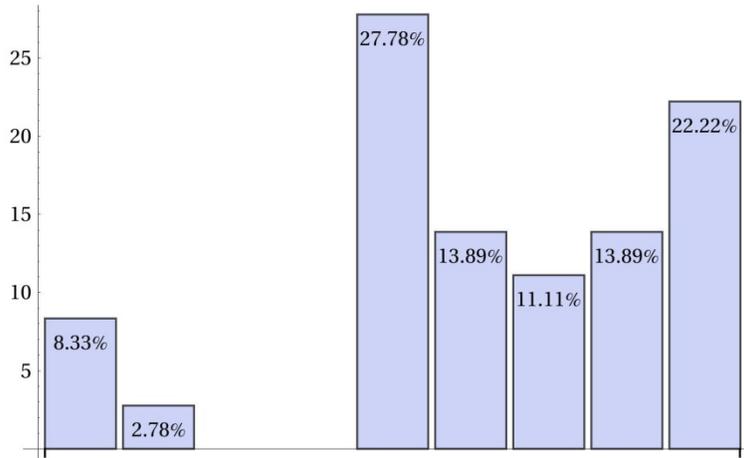


6) This project improved my leadership skills.



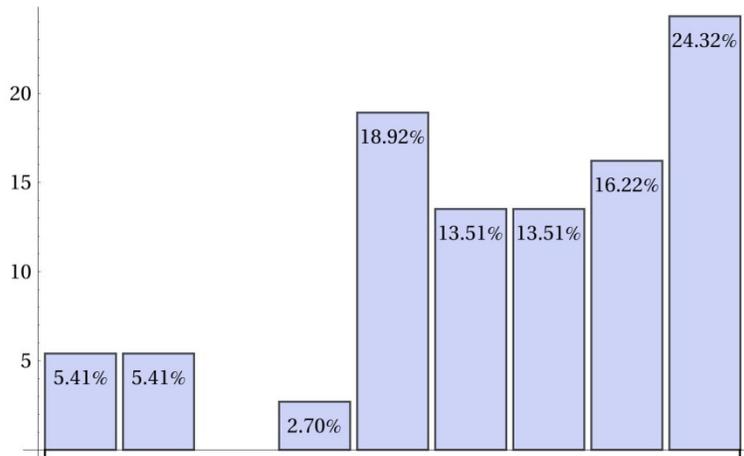
Question 7 cont'd.

7) This project increased my interest in volunteer activities.



Strongly Disagree <----- Neutral -----> Strongly Agree

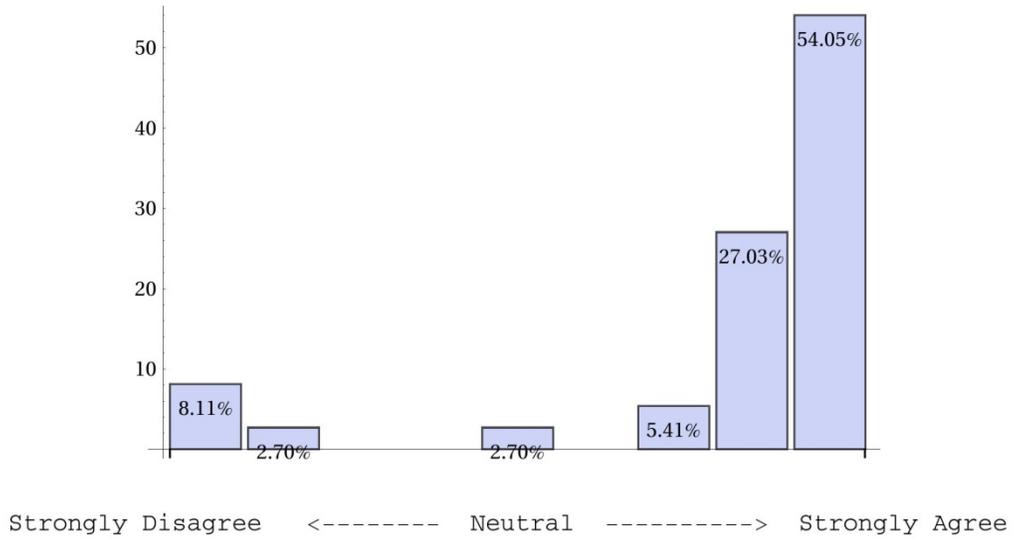
8) This project increased my school pride.



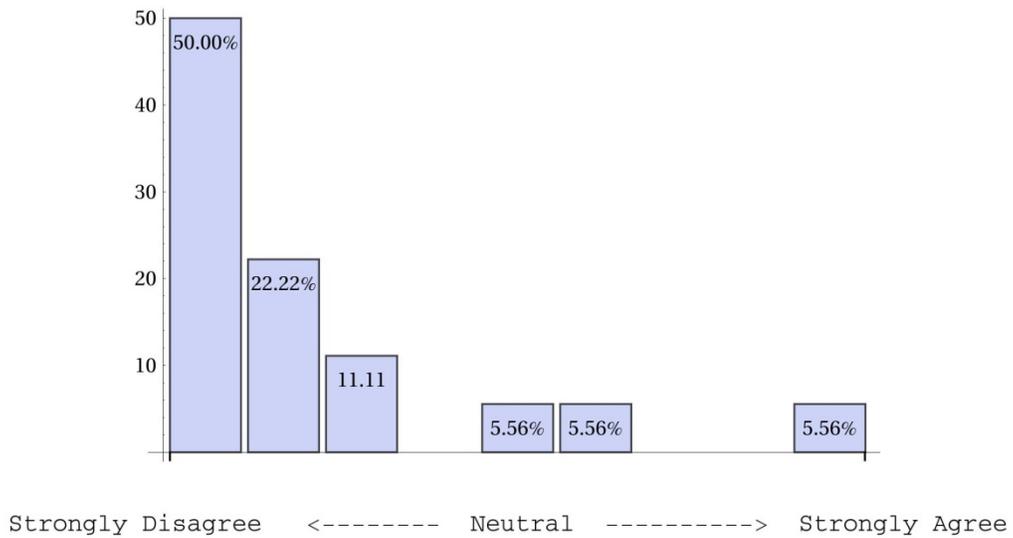
Strongly Disagree <----- Neutral -----> Strongly Agree

Question 7 cont'd.

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

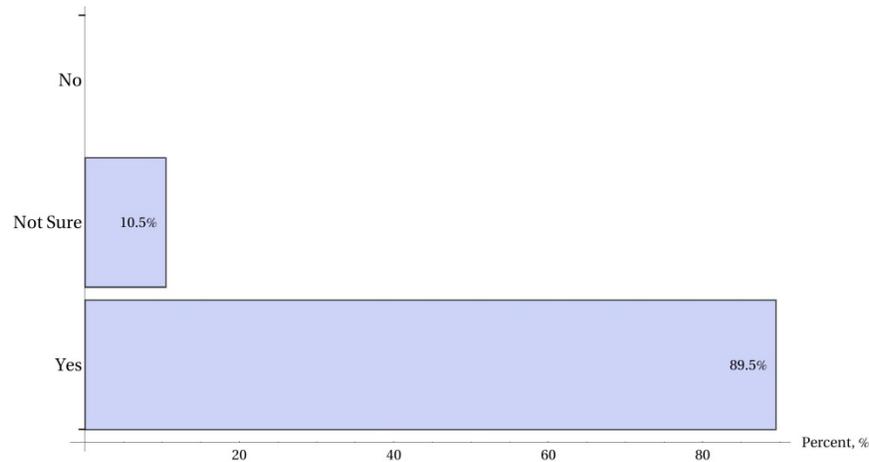


10) Working on this project had negative impact on my coursework.



## 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*