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INTERNATIONAL SUSTAINABILITY THROUGH KNOWLEDGE TRANSFER CONSIDERING CULTURE AND RESOURCES – SLEDGEHAMMER ATTACKS ON ADOBE MASONRY WALLS.

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Abstract

In terms of knowledge and technology innovation, sustainability is defined as the ability for a society or culture to develop, incorporate and maintain knowledge and technology in a long term manner without continued outside input. In rural East Africa, the prevalence of low-cost building materials and unskilled labor produce buildings that provide poor security for charitable groups working to improve the quality of life for communities and individuals there. Medicine and other medical supplies are targeted by thieves for their high value. Buildings constructed of the most common building material in the region, adobe masonry, are easily broken into by using sledgehammers to destroy a portion of a wall, circumventing many security measures. The people associated with Nyumbani Village (a project located in a rural area of Kenya) asked for help in mitigating this problem. The question was asked if local resources (low cost and high availability) could be used in a manner that could be easily and affordably reproduced. This paper will present, in a qualitative manner, how a sustainable solution was found for sledgehammer attacks on adobe masonry walls.

Introduction

The current AIDS pandemic continues to decimate an entire generation of Sub-Saharan Africa's population. This portion of the population with the highest infection and death rate leaves behind two demographics, their young children and elderly parents, often referred to as the Two Forgotten Generations of this AIDS pandemic. In 2001, the United Nations

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Program on HIV/AIDS issued a report (UNAIDS 2001) that stated that 90% of the world's AIDS orphans live in Sub-Saharan Africa, roughly 12.2 million children. With so much attention paid to the disease and its direct consequences, the secondary effects of HIV and AIDS on societies have only recently begun to be noticed. Orphaned children of AIDS are left to fend for themselves. Even if the parents are survived by extended family, the children are rarely accepted in the family due to the severe stigma associated with the disease in this part of the world. Abandoned and alone, these children are sentenced to a horrific life.

In the Republic of Kenya, Nyumbani Children's Home, a US registered charitable group, has been working to care for AIDS orphans since 1992 (Nyumbani 2010). Nyumbani (Swahili for "home") has several programs including an orphanage, slum community outreach centers, and a medical diagnostic laboratory. It's most recent undertaking is the construction and operation of a self-sustaining model facility, called Nyumbani Village, which will care for up to 1,000 children and 200 elderly in the rural Kitui area of Kenya's Eastern Province. The intent is for the Village to produce enough revenue through the production and processing of food and cash crops to offset the cost of care for the inhabitants.

Starting with an undeveloped plot of land approximately 1,000 acres in size, Nyumbani needed to plan and construct all the necessary buildings and civil infrastructure. To ensure the success and longevity of the Village's operation, the design of the buildings considered all the probable demands or forces that could be imposed on the structures. This included environmental demands from wind, scouring rains, and seismic events along the East African Rift System. Additionally, the design of the buildings needed to consider security.

One of the primary facilities in the Village will be the medical clinic. The clinic will be fully staffed by doctors and nurses with access to medical equipment, supplies and pharmaceuticals. Although available at the Village and other Nyumbani facilities, these items are not readily available to the majority of the population making them highly valuable in the region. With the severe levels of poverty in Kenya, the risk of theft to these valuable items is very high. The remoteness of the Village's location required that large stockpiles of all the medical supplies will be on site, making the facility a prime target for theft. Therefore, the design of the medical clinic and storehouses needed to consider security.

Adobe blocks are the primary building material in rural East Africa. Adobe is inexpensive to manufacture and the technology and methods for construction are relatively simple. Adobe has disadvantages including low compressive strength, tensile strength and abrasion resistance. This makes adobe structures particularly susceptible to impact loading. While typical features for securing items inside a building include sturdy doors and windows with frames integrated into the building structure, these are easily circumvented in adobe masonry buildings. The common method thieves in East Africa use to gain entry into adobe masonry buildings is to penetrate through the masonry walls with a sledgehammer. A typical man swinging a sledgehammer with a standard 9-10 lb head can easily break through a single wythe adobe masonry wall, producing a hole large enough for entry, in matter of minutes.

In an attempt to provide an appropriate solution (in terms of using local materials and labor) to this security issue, Nyumbani's founder, Father Angelo D'Agonstino, partnered with

Cal Poly – SLO through then student David Lambert: working with Associate Professor Craig Baltimore, SE. The solution was to create a double wythe adobe masonry wall with the cavity filled with a force damping material, thus mitigating the energy wave of each hammer blow. While this system will still not able to fully withstand the repeated blows of a sledgehammer, it does significantly prolong the required time to penetrate the wall making entry more difficult and allowing security personnel at the Village time to respond to a threat. This paper summarizes how the wall system was constructed and tested at Cal Poly – SLO.

The Making of Traditional Adobe Bricks

The walls were made using methods that duplicated the processes in rural Kenya for making Adobe bricks. The high pressure presses, precise machinery, controlled curing rooms, and advanced chemical stabilizers used in adobe manufacturing in the U.S. were not used. In a developing nation such modern mechanisms are not readily available. Considering the processes used in rural Kenya, the materials used were a hand brick press, adobe clay, potable water, sand, and cement.

The labor force in rural Kenya is largely unskilled. To reproduce the unskilled labor force, volunteers from the incoming freshman class in the College of Architecture and Environmental Design made the bricks. To help assure the labor remained unskilled, students were asked to limit their efforts to 4 hours in total. Nearly 100 incoming students participated in making over 1000 adobe bricks.

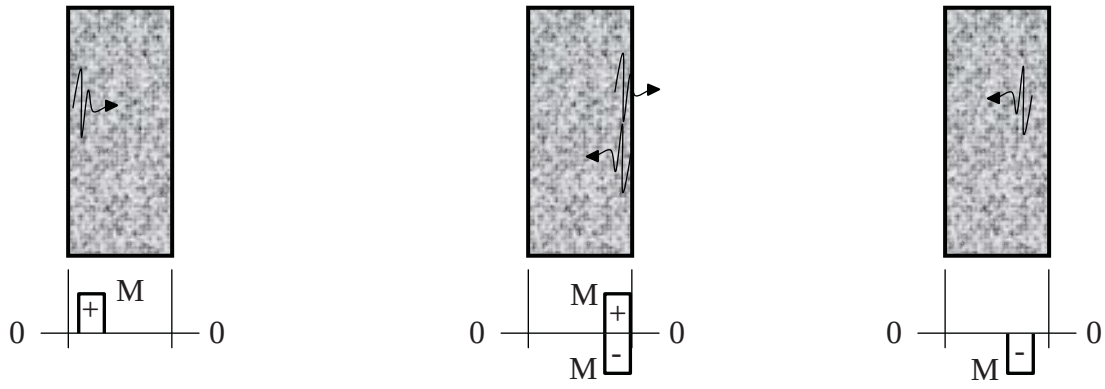
The students were given a lesson in adobe brick making and then left to themselves to make bricks. The mixture consisted of 30% clay, 60% sand, 10% cement (dry mix), and enough water to give the proper consistency (Blondet 2003) (U.S.D.A. 1999). Measuring of the materials was done by volume with ½ gallon plastic water pitcher (Figure 1). Since the goal was to mimic the conditions in a developing nation, (minimal quality control), the students were unsupervised and relied on each other for assuring quality of product. The mixture was placed in a brick press and compressed. (Figure 2). The bricks were then laid out in open air to cure. The bricks were sprayed with water during the first 3 days.

Figure 1. Students measuring and mixing dry materials of adobe mix.

Figure 2: Hand brick press and bricks air curing.

The Sledgehammer Resistant Adobe Wall

The solution for improved adobe wall performance to resist sledgehammer impact was based on energy wave transmission (Hinrose 1991). When a solid is impacted with a hammer, an energy wave is set into motion. When the wave travels to the end of the material, the air acts as an insulator and the wave is reflected back within the wall. At the instance of reflection, the energy wave is doubled in magnitude; often breaking the material (see Figure 3).



Wall is hit with hammer and energy wave travels to right with magnitude “M”

Energy wave hits the air and is reflected back. For the instance of reflection the magnitude is “2M”

The reflected energy wave travels to the left with magnitude “M”

Figure 3. Energy wave transmission sequence

To reduce the doubling in the magnitude of the energy wave, at the instant of reflection, another material can be attached such that the new material will allow the wave to continue (not reflect); the new material will have damping properties (dissipate the energy). By providing a two wythe wall with a cavity, the damping material can be added in the cavity. Considering the local resources (sustainability), sand was chosen as the energy dissipating material.

The investigation consisted of constructing adobe walls similar to the walls of rural East Africa and impacting the walls with a sledgehammer until penetration. The investigation was qualitative to see if there would be a significant difference in time (effort). The number of hammer blows and the total elapse time were recorded.

Adobe Wall Construction

Each wall was constructed from adobe bricks 6”x12”x2.5”. The mortar mix used was 7 parts sand to one part cement (characteristic proportions for the rural area) . Because foundations vary in the rural regions, from no foundation to a foundation of stone and mortar; an intermediate foundation was constructed by building the wall in contact with the ground, but starting the wall 5 courses below grade (Figure 5).

Figure 4: Bricks made by students

Figure 5: Brick wall laid directly on ground starting 5 course below grade

To represent the typical roof construction of wood framing with sheet metal, a wooden brace system was used to give similar flexibility in the top of wall support (Figure 6).

In constructing the double wythe wall, chicken wire at every 5th course was used to tie the withes together. At every 5th course, prior to the placement of chicken wire, the cavity was filled with sand (Figures 7 and 8). The ends of the wall were capped with adobe brick.

Figure 6: Flexible top of wall support

Figure 7: Chicken wire used to tie double wythe wall together.

Figure 8: Placement of sand in cavity of double wythe wall

Results of Sledgehammer Impacts

9 hammer blows were needed to break through the single wythe wall and the result was an explosive penetration. The 9 swings took less than 2 minutes to complete. The sledgehammer penetrated the front face (side of the wall being impacted by the hammer) by one inch at which time the back face exploded outward creating the hole (Figures 9 and 10).

Figure 9: Single wythe wall and penetration, front face

Figure 10: Single wythe wall and penetration, back face

The double wythe wall took well over 100 hammer blows (139) to penetrate and the result was a chipping out of the wall with the hammer head. It took over 20 minutes to completely

break through the wall. The process of chipping away of the wall is non-explosive. During the process, the hammer head would occasionally become lodged in the hole or the sledgehammer shaft would hit the wall before the hammer head -- extending the amount time needed to penetrate. The hammerhead had to dig through the major part of the wall. There was approximately two inches of wall remaining when the hammer impact penetrated the wall (Figures 11 and 12)

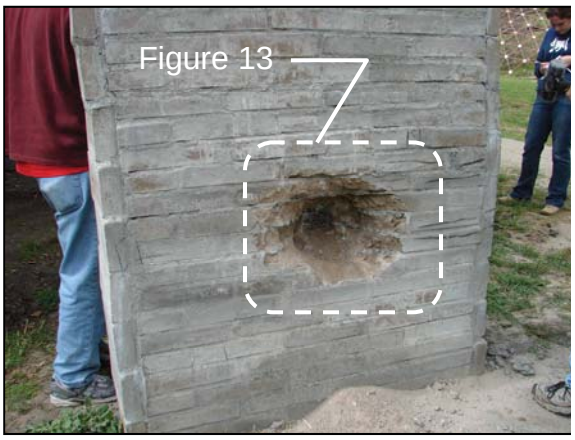


Figure 11: Double wythe wall and penetration by a chipping action of the hammer head, front face

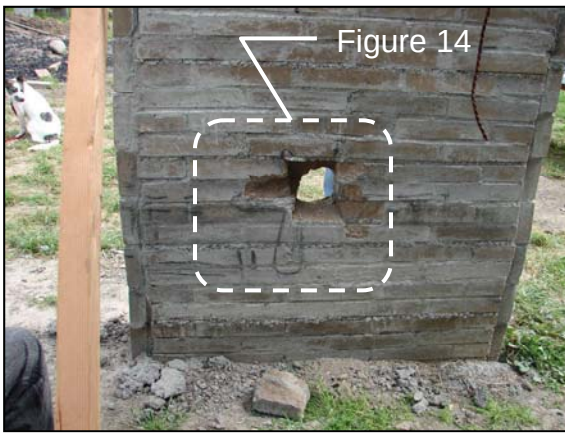


Figure 12: Double wythe wall and penetration, back face

Figure 13: Double wythe wall and penetration by a chipping action of the hammer head, front face

Figure 14: Double wythe wall and penetration, back face

Conclusion

Building sand cavity double wythe adobe walls was demonstrated to be an effective system to mitigate the effect of sledgehammer impacts. The increased time needed to penetrate the wall was of significant magnitude (approximately 10 times longer) thus making entry more difficult and allowing security personnel at the Village more time to respond to a threat. Through the use of resources common to rural East Africa (adobe, sand, and cement), a long term transfer of knowledge and technology innovation can be sustainability accomplished. The sustainable solution was low-cost; it could be easily duplicated by unskilled labor; and it could be carried forward without continued outside input. Such sustainable solutions allow for charitable groups working in rural East Africa to improve the quality of life for communities and individuals there.

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