CONSTRUCTION OF SAFE AND HEALTHY ADOBE HOUSES AFTER THE PISCO 2007 EARTHQUAKE IN PERU

Marcial Blondet[1], **Julio Vargas**[2], **Álvaro Rubiños**[3]
Catholic University of Peru (PUCP)
Av. Universitaria. 1801, San Miguel, Lima 32, Peru
Tel: +511 626 2000
E-mail: mblondet@pucp.edu.pe, jhvargas@pucp.edu.pe, arubinos@pucp.edu.pe

Theme 3: Techniques, Construction, Research and Development
Key words: Earthquake, training, safe and healthy adobe houses

Abstract
On August 15th, 2007, a great earthquake of magnitude 7.9 Mw affected the southern area of Peru. Almost 76 thousand houses were destroyed and more than 319 thousand persons were affected. The majority of the destroyed constructions were made with adobe and the reason for their collapse was the lack of seismic reinforcement. Without any knowledge of healthy and earthquake resistant technologies, the affected families would rebuild their houses in a seismically vulnerable and unhealthy way.

This paper presents the actions taken in the affected zones by the Catholic University of Peru (PUCP) in a joint effort with several cooperation agencies and NGOs to develop capacities and train dwellers on the construction of healthy and earthquake-resistant adobe houses. The improved adobe houses include seismic reinforcement based on a geomesh which completely covers all adobe walls. The geomesh reinforcement increases the stiffness and strength of the walls and, more importantly, maintains the integrity of the house after the adobe walls have cracked, thus avoiding collapse (Blondet et al., 2008). The sanitary conditions of the new adobe houses are enhanced by including an external dry hole latrine and an improved kitchen made with local materials.

Training was provided to the dwellers of three cities in the affected area, including the construction of three improved adobe houses. It is hoped that the training program contributed to reduce the seismic risk and to improve the quality of life of many families in the areas affected by the Pisco earthquake. Furthermore, it is expected that these positive results will help disseminate the improved technologies for the construction of safe and healthy adobe houses in other seismic regions of Peru.

1. SAFE AND HEALTHY ADOBE CONSTRUCTION

In many developing countries around the world adobe construction is prevalent because the material is cheap and readily available, the construction technology is relatively simple, and adobe houses can be quite comfortable because of the material's excellent acoustic and thermal properties. Traditional adobe dwellings, however, are extremely vulnerable to earthquakes because the adobe walls are weak, heavy and brittle. Also, due to the lack of economic resources of the dwellers, most adobe construction is performed informally, without any seismic reinforcement, adequate technical supervision or quality control. As a result, every strong earthquake that has occurred in areas where adobe construction is common has caused enormous destruction and loss of life. Figure 1 shows several adobe houses which collapsed or suffered significant damage during the Pisco earthquake in Peru, and a confined masonry house (in the background) which did not suffer any damage.

Furthermore, the sanitary conditions of most adobe houses in rural areas of Peru are very poor, as there are no sanitation systems, and kitchens are primitive and without proper ventilation. These deficiencies cause respiratory infections and unnecessary illnesses in their occupants.

Fig. 1 – A street in Pisco after the earthquake (Credits: M Blondet)

During the past 35 years, the Catholic University of Peru (PUCP) has devoted considerable effort to the development of seismic reinforcement systems for adobe constructions (Vargas et al., 2005). A successful system developed and tested recently is based on a polymer mesh commonly used in geotechnical applications (geomesh).

The geomesh must be anchored to the concrete foundation and tied firmly to both sides of the adobe walls using a plastic string placed across the wall during construction. The mesh should also be attached to the wooden crown beam on top of each wall. The idea is that during seismic shaking the mesh will absorb the tensile stresses that the adobe masonry is unable to resist. Several seismic simulation tests were performed on the PUCP's shaking table and the reinforced models showed excellent performance (Fig. 2). The geomesh reinforcement increases the stiffness, strength and deformation capacity of the adobe walls. Furthermore, since the walls are completely surrounded by the mesh, even if they break into large pieces during very strong shaking, the mesh will keep the pieces from falling apart, thus avoiding collapse (Blondet et al., 2006). The mesh studied at PUCP costs about 1,5 US dollars per square meter and has a tensile strength of 22 kN/m (Madueño, 2005).

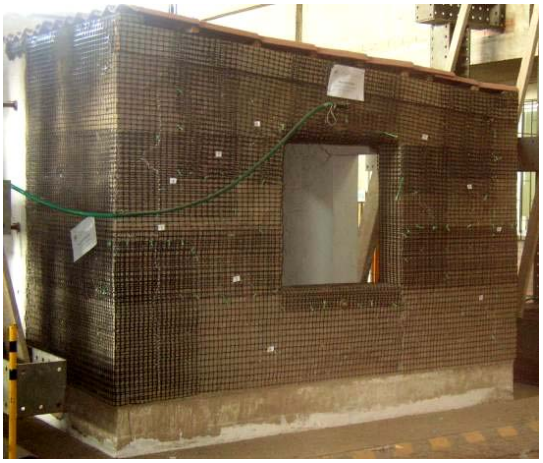

Fig. 2 - Reinforced adobe house after shaking test (Credits: Unknown)

In order to provide basic sanitation for low income families, CarePeru has developed a simple dry hole latrine and an improved adobe stove. CarePeru is an NGO with significant experienced in implementing training programs aimed at rural communities. Their approach is to develop the capability in the inhabitants to learn new technologies which will help improve their quality of life. The dry hole latrine is used to contain

human excreta. It prevents the users from illnesses due to poor hygiene and sanitation, and avoids environmental contamination. The improved adobe stove uses less firewood than traditional stoves and can be easily built with local materials. It can be built inside or outside the dwelling and has good ventilation. It therefore prevents respiratory infections common in adobe house dwellers, where the stove is inside the house without external ventilation.

The use of geomesh reinforcement to build seismic-resistant adobe houses and the dry hole latrine and adobe stove are important improvements, which will provide low income families with the possibility to live in safe and healthy houses.

2. THE PISCO EARTHQUAKE AND THE EMERGENCY RESPONSE

On August 15th, 2007, a strong earthquake occurred around 145 km south of Lima, near the city of Pisco. The earthquake had a magnitude of 7,9 Mw and intensity of VIII MM (Tavera et al., 2008). According to the Statistics and Informatics National Institute of Peru almost 600 persons died, around 300,000 were affected, and more than 75,000 dwellings were destroyed (INEI, 2007). Most of the damaged or collapsed houses were made with adobe. The cities most affected by the earthquake were Chincha, Pisco and Huancavelica.

One of the first actions taken by the Peruvian government after the earthquake was to create the Fund for the Reconstruction of the South (FORSUR), in order to manage the reconstruction process in the affected zones. The government also created housing programs based on the offer of a reconstruction bonus of around two thousand US dollars to those persons who demonstrated ownership of a destroyed house. This bonus could be used in three ways:

- Persons with adequate financial resources could use the bonus as partial payment towards the purchase of new (and relatively expensive) confined masonry houses.

- Persons of less economic means living in urban areas would get the equivalent of 1800 US dollars in construction materials from the Bank of Materials (BanMat). The remaining funds would be given in local currency to pay for qualified persons to build a confined masonry house.

- Persons living in rural areas would receive a materials kit to build a reinforced adobe house.

3. TRAINING PROGRAM ON SAFE AND HEALTHY ADOBE CONSTRUCTION

A training program to build improved adobe houses in the areas affected by the Pisco earthquake was conceived and implemented by the PUCP, CarePeru, FORSUR and SENCICO (government agency in charge of construction codes and training). The program was inspired by the human development capacity approach (Sen, 2000), which claims that development is achieved through the expansion of the capabilities of the people to have the freedom to live a good life. The participants of the training program would learn how to build, by themselves, better adobe houses. Thus, they would not be mere recipients of external aid, but they would be agents of their own development.

The PUCP and CarePeru professionals developed two booklets to explain the construction of safe and healthy adobe houses in a simple way, with many detailed illustrations. These booklets, designed for arid or highlands zones, were published by the PUCP Editorial Fund (Vargas et al., 2007a, b). The adobe houses described in the booklets have 50 m2 of floor plan and have four rooms. They have geomesh

reinforcement on all walls, and include an improved stove and a dry hole latrine. Figure 3 shows the illustrations of the proposed adobe house for highland zones, the geomesh placement, the improved kitchen and the dry hole latrine.

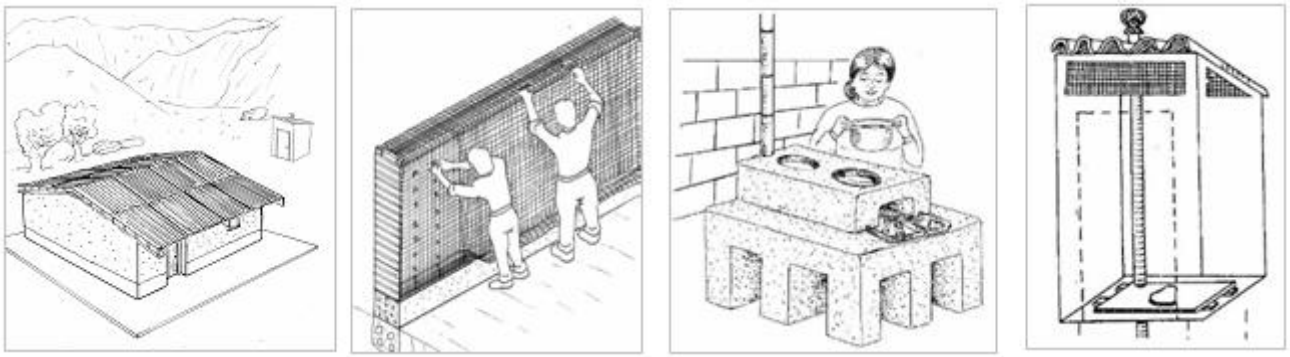

Fig. 3 - Illustrations from the construction booklet (Vargas et al., 2007a, b)

Professionals from the PUCP, CarePeru and the Swiss and German cooperation agencies also designed a smaller adobe house reinforced with geomesh that could be built in rural zones with the 6000 soles (2000 US dollars) reconstruction bonus offered by the Peruvian government. The Bono6000 house has 19 m2 of floor plan, two rooms, and better finishings than the house proposed in the booklets. The technical file includes the list of the materials required to build the house (Araujo et al., 2008). Figure 4 shows the floor plan view and the Bono6000 adobe house.

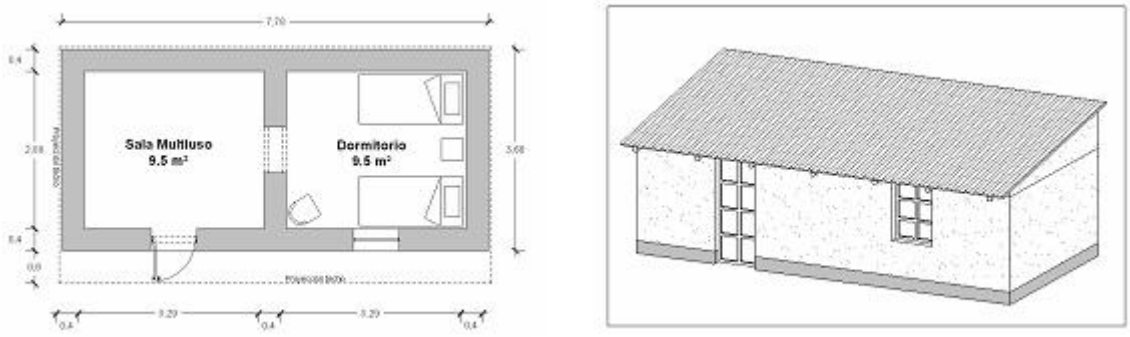

Fig. 4 – Floor plan view and Bono6000 adobe house (Araujo et al., 2008)

The training program was conceived as a “cascade” process, in which first some people are trained. Then, they would train more persons, and so on until the actual dwellers of adobe houses receive training.

The first phase of the program was developed in Lima, at the PUCP campus. A hundred persons were trained. The participants were builders, masons, construction technicians, civil engineers, architects and NGO members (Blondet et al., 2008). The program consisted of classroom lectures and practical lessons. An adobe wall was used to teach the participants how to tie the geomesh and how to plaster the wall with mud (Fig. 5). A demonstration adobe module, consisting of a portion of the reinforced adobe house proposed in the booklet was also built. One of the walls showed its different layers: adobe blocks joined with mud mortar, with plastic strings embedded in the mortar, geomesh, and mud plaster. The wooden roof, covered with crushed cane and mud, can also be clearly appreciated. Construction of the module, which closely followed the instructions given in the booklets, was videotaped to produce an educational video showing each step for the constructions of better adobe houses.

Fig. 5 - Geomesh placement training wall (Credits: Álvaro Rubiños, 2007)

The second phase of the training program was developed in the cities of Cañete, Chincha and Pisco, which were severely affected by the Pisco earthquake. The program was aimed at all citizens. The goals were to train 360 persons (120 persons in each city) and to build 9 model houses following the guidelines proposed in the booklet for arid zones (Vargas et al., 2007b).

Training included lessons in the classroom and in the field. Classroom lessons consisted of detailed explanations of the concepts and instructions included in the booklet. At the end of the course, the educational video was projected. A six hours class was given to all citizens and a three hours class was given to the different associations working in the intervention zone. All persons who completed the classroom courses received a certificate. The field lessons followed the “learning by doing” training methodology. The participants helped in the construction of a model reinforced adobe house in their neighborhood. A model house was built in three neighborhoods, in order to reach more persons. At the end of the course a test was given to those participants who wanted to be certified as reinforced adobe builders. The finished houses were donated to the most needed family in each neighborhood. Figure 6 shows the model house.

Fig. 6 – Model reinforced adobe house (Credits: Álvaro Rubiños, 2008)

The training program was successful: 883 persons attended classroom lessons, 276 received practical training, 102 persons were certified as construction technicians in reinforced adobe, and 9 families received new and improved adobe houses.

The Peruvian government has declared it a priority to implement new housing programs in rural areas. An economic incentive has been offered to build new adobe houses or reinforce existing ones using the geomesh technology. Accordingly, new training programs on improved adobe construction will be implemented. It is expected that these actions will contribute towards a better quality of life for many families who are now living in inadequate conditions.

4. CONCLUSIONS

- Millions of families living in traditional adobe dwellings located in seismic areas are at unacceptable risk. Furthermore, many times their homes are built in unhealthy and unsanitary conditions. It is possible, however, to build safe and healthy adobe houses at moderate cost.

- Successful reconstruction programs require the joint and coordinated efforts of many individuals and organizations, such as governmental institutions, professional associations, development and cooperation agencies, and universities.

- In economically depressed areas, external resources, such as the government reconstruction bonus, are indispensable because the inhabitants do not have the means to acquire the materials required for constructions of reasonable quality.

- The human development capacity approach provides an efficient framework for the design and implementation of training programs in which the participants learn how to build better homes and thus improve the quality of their lives.

5. REFERENCES

Araujo, J.; Krüger, F.; Vargas, J. (2008). *Basic adobe module reinforced with geomesh*. (In Spanish). Lima (Peru): CARE Peru. Technical file.

Blondet, M.; Torrealva, D.; Vargas, J.; Villa Garcia, G.; Ginocchio, F. (2006). *Reinforcing adobe constructions with industrial elements: seismic simulation tests.* (In Spanish). Lima (Peru): Catholic University of Peru (PUCP).

Blondet, M.; Vargas, J.; Patron, P.; Stanojevich, M.; Rubiños, A. (2008). *A Human development approach for the construction of safe and healthy adobe houses in seismic areas*. Beijing (China): 14th World Conference on Earthquake Engineering.

INEI (Statistics and Informatics National Institute). (2007). *Census of areas affected by the August 15, 2007 earthquake*. (In Spanish). Available on: http://www1.inei.gob.pe/sismo2007/Resultados1.asp?resultado=6. (Access: June 2009)

Madueño, I. (2005). *Reinforcing adobe constructions with industrial elements: preliminary study*. (In Spanish). Lima (Peru): Catholic University of Peru (PUCP).

Sen, A. (2000). *Development as freedom*. New York (USA): Anchor books (Random House).

Tavera, H.; Salas, H.; Jimenez, C.; Arredondo, L.; Parillo, R.; Millones, J. (2008). *Regional intensities associated to the Pisco earthquake of August 15, 2007*. (In Spanish). Lima (Peru); Geophysical Peruvian Institute.

Vargas, J.; Blondet, M. (2005). *35 years of SismoAdobe research at the Catholic University of Peru. SismoAdobe 2005: International Conference on Architecture, Conservation and Construction of Adobe Buildings in Seismic Areas*. (In Spanish). Lima (Peru): Catholic University of Peru (PUCP).

Vargas, J.; Torrealva, D.; Blondet, M. (2007a). *Building hygienic and earthquake-resistant adobe houses using geomesh reinforcement. For arid zones*. (In Spanish). Lima (Peru): Catholic University of Peru Editorial Fund.

Vargas, J.; Torrealva, D.; Blondet, M. (2007b). *Building hygienic and earthquake-resistant adobe houses using geomesh reinforcement. For highland zones*. (In Spanish). Lima (Peru): Catholic University of Peru Editorial Fund.

Curricula

Marcial Blondet: Professor of Civil Engineering (PUCP), Civil Engineer (PUCP, 1973), PhD in Engineering (University of California at Berkeley, 1981).

Julio Vargas Neumann: Professor of Civil Engineering (PUCP, 1963), Researcher on earthen construction in seismic areas (PUCP, 1971), Vice Minister of Housing (Peru, 1985), National Award in Culture, Science and Technology (1986), President of the Specialized Committee NTE E-080 Adobe (Peru, 2007).

Alvaro Rubiños: Research Assistant (PUCP, 2008), Civil Engineer (PUCP, 2009).