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LESSONS ON DISSEMINATION OF TECHNOLOGIES OF SEISMIC NON-ENGINEERED HOUSES -A CASE STYDY OF A TRAINING PROGRAM IN PERU-

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ABSTRACT

Dissemination of seismic technologies to people and community is a key issue to reduce earthquake disasters as well as development of appropriate technologies. JICA (Japan International Cooperation Agency) has been conducting a well designed training program on seismic adobe houses through construction of model houses in several towns and villages in Peru from 2005. During the program, Pisco Earthquake occurred and hit wide areas including the project sites in August 2007. We found that all the model houses performed well against the shaking motion. We also found quite interesting results of the training program in the reconstruction procedures from the disaster. In one village, the participants of the program work actively to construct seismic adobe houses with their knowledge and skills they learned in the training program for reconstruction from the disasters. In contrast, in other towns and villages, no one construct the seismic adobe houses. It shows a successful dissemination program does not necessarily function to diffuse the technologies to communities automatically.

This experience provides us with useful and informative lessons on dissemination of technologies in the case of non-engineered houses in developing countries, which has many aspects different from those of engineered houses and in industrialized countries. The first one is the different situations of communication in communities both by the media and word-of-mouth communication compared with those in developed countries. The second one is that some kind of encouragement and support is necessary for people to take action. This paper reports the outline and evaluation of the training program, survey results of physical performance of model houses in the Pico Earthquake, results of field studies after the earthquake including interviews to participants of the training programs and people in affected areas and lessons learnt from the experience.

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Background, objectives and overview of the research

Background

Every large-scale earthquake causes widespread social damages and most tragically human casualties. The main cause of human casualties is the collapse of houses, often called "non-engineered" because they are built with little or no intervention of engineers. Most of these houses are built with locally available materials by local workers or inhabitants themselves who do not have sufficient knowledge of engineering (Anand 1986). To reduce the damage by earthquakes, it is necessary to develop affordable and feasible seismic technology that could be employed under the considerable constraints of non-engineered houses in the materials, workers, financial resources and other factors. Furthermore, efforts to disseminate technologies to people and communities are necessary (Shoichi 2008).

In industrialized countries, technologies concerning housing construction are disseminated mainly through publications and workshops, etc by private sector. Efforts by enterprises and professional associations in housing sector for their employees/members are also actively promoted. Administrative systems concerning building permits also contribute to disseminate them. On the other hand, in developing countries, activities on commercial basis are not available because of economical reasons. We could not expect efforts by the housing sector since there is no large business or organizations/associations for non-engineered houses that can take this role. Dissemination of technologies in industrialized countries relies on engineers in the housing sector who have engineering knowledge, but in the case of non-engineered houses in developing countries, there is no professional housing sector. In addition, administrative services in developing countries are usually limited and prioritize less on non-engineered houses because of its small size and impact to surrounding areas.

Under these difficult circumstances, people in the countries concerned, international organizations, donor agencies, and NGOs have been working on dissemination of the technologies. However, they have not succeeded to disseminate them so as to be widely adopted for house other than model/pilot houses. Thus dissemination of technologies remains to be an acute issue for reduction of disasters.

Objectives and overview of the research

This research is to study on approaches to disseminate seismic technologies for non-engineered houses based on a case study of a project on seismic adobe (sun-dried brick) houses in Peru. Japan International Cooperation Agency (JICA) has been implementing a project on the dissemination of seismic adobe house technology through constructing model houses. First this research summarizes the project and evaluates its achievements. On August 15, 2007 (local time), while the project was in progress, a magnitude 8.0 (USGS: United States Geological Survey) earthquake occurred and caused huge damage over a wide area including the project sites. We conducted a field survey on damages to houses and detailed examination on model houses as well as interview survey to investigate the effects/influences of the project. Based on the results of these surveys we discuss and study on problems and approaches on dissemination of technologies for non-engineered houses.

Summary and evaluation of the case study project

Summary of the case study project

The objective of the case study is dissemination of seismic adobe house technology with reinforcement of canes inside the walls (Figure 3 and 4), which was developed in Peru. The project is a kind of training programs for construction workers consisting of workshops on the seismic deign (Figure 1) and construction works of model houses under technical guidance by experts (Figure 2). The program was designed and managed by SENCICO (National Service for Normalization, Training, and Research for Construction Industry) and CIDAP, Peruvian NPO working for improvement of living environment of low income people, with support of municipalities in provision of housing sites and management service. Three model houses were constructed in 2005 and four in 2006.

The workshops for two or three days were organized before each phase of construction work such as manufacturing of adobe bricks, earthworks, foundation construction, adobe laying,

Figure 1 A workshop before each phase of construction work

Figure 2 Construction of a model house by participants under technical guidance of experts

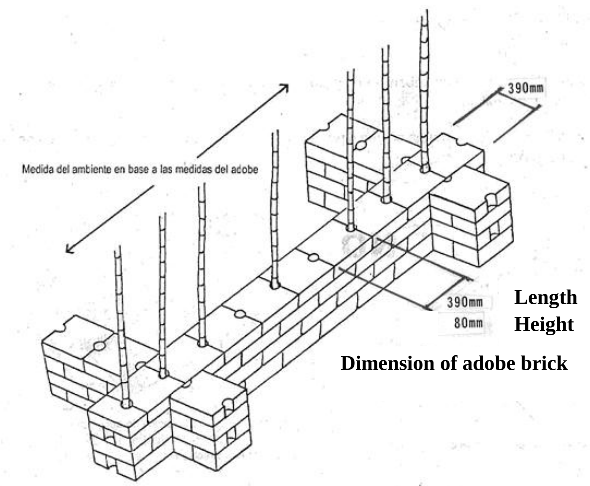


Figure 3 Adobe bricks and canes for vertical reinforcement

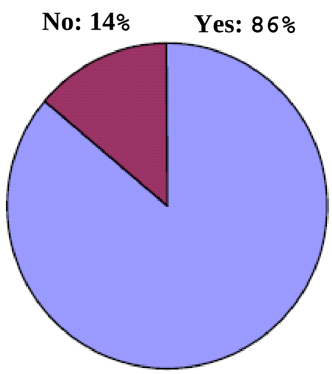
Figure 4 Installation of horizontal reinforcement of crashed canes

wood work (beam construction), finishing work. After that participants (habitants who want to learn the construction method) were encouraged to construct model houses by themselves under technical guidance of experts. Total number of participants in 2006 is eighty five in three sites. Peru has a long history of research and development of seismic deigns for adobe houses starting from 1970s with financial support of several donor organizations. The design with reinforcement of cane employed in the project is one of these designs developed by Peruvian researchers. The major structural members are vertical and horizontal reinforcement cane inside the wall, ring beams placed on top end of adobe walls and foundation of reinforced concrete (RC).

Evaluation of the case study project

S. Matsuzaki, one of the co-authors, monitored all the construction procedures of the model house in Huangascar, one of the project sites in 2006. She reports all the participants of the project worked sincerely and eagerly following the guidance of the engineers in exact manner, and even cheerfully in spite of hard job handling heavy adobe bricks. She observed all the participants understand the design and construction work of the seismic adobe house, which is proved by answers of a questionnaire in which 86 percent of the participants responded “yes” to the question “Can you build a whole adobe house?”(Figure 5).Although several construction works such as “earth work”, “foundation”, “adobe laying”, “electricity” have a certain percentage of response “difficult”, we can conclude participants have learned the construction method fairly well (Figure 6). In addition, all of them expressed satisfaction at acquiring knowledge of safe housing construction and indicated that they were willing to use this method for their own houses in future. This is also supported by the results of the questionnaire in which all 85 respondents answered “yes” when asked “Are you interested in building a house similar to the model house?”

Based on the results of the above-mentioned questionnaire and interviews, the program consisted of workshops and construction work for dissemination of technology to construction workers can be evaluated to be effective and successful.



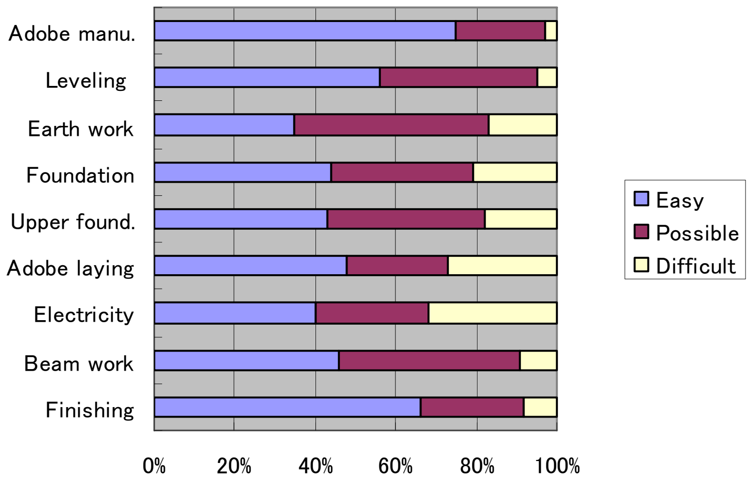


Figure 5 Answer to Question “Can you build a whole adobe house?”

Figure 6 Answers to Questions on understanding of each phase of construction work

Field survey after Pisco Earthquake in 2007

Damages to houses

It was reported that more than 50,000 houses collapsed by the Pisco Earthquake. According to a detailed investigation conducted by JICA, adobe houses, in particular, were subject to extensive damage and they accounted for 82.7% of the houses categorized to "collapsed or heavily damaged" in the region investigated (Ica state, the most seriously damaged state). Situation was same in Lima state, which locates adjacent to Ica state and most of construction sites of the case study projects locate at. Figure 7 and 8 show the situation in the central area of Zuniga, Canete Province, Lima State, which is one of the project site. You can see a church and many houses were heavily damaged.

Figure 7 Heavily damaged church in Zuniga
Wall: adobe, Vault roof: Quincha

Figure 8 Central area of Zuniga
Many adobe houses collpased

Situation of model houses

The Model house constructed under this project at a distance of about 300 meters from the central area of Zuniga got no damage in structural members (Figure 9). On the other hand, a

Figure 9 The model house in Zuniga
No structural damage

Figure 10 A house adjacent to the model house in Zuniga

Figure 11 Broken walls of the adobe house of Figure 10

Figure 12 Heavy cracks in the adobe house of Figure 10

house just next to it suffered severe damage (Figure 10, 11 and 12). The situations are same with all other model houses. This demonstrated that the seismic design employed for model houses is strong enough to endure the seismic motion that caused adobe houses serious damages.

Interview survey in areas surrounding the project site

We also conducted interviews to people in Lunahuana, Canete Province, which is one of this project sites in 2005 near Zuniga. The results are shown in Table 1. Interviewee No. 1, who resides adjacent to the model house in Lunahuana and had opportunity to see procedures during the construction, acknowledged that the model house employs seismic design and got no structural damage by the earthquake. However, other interviewees showed that about half of the people in the same community are not aware of the objective of model house or even not recognize existence of the model house. This fact is far from expectation of JICA that the construction of the model house in a small town like Lunahuana would be known among people.

Table 1 Results of interview survey in Lunahuana, Canete Province, Lima State

Interviewee	Gender and age	Awareness of model houses
No. 1	Female, senior	She knew that it is a seismic design house and it did not suffer damage. (She resides adjacent to the model houses)
No. 2	Female, senior	She knew that it is a seismic design house but did not know that it did not suffer damage.
No. 3	Female, middle aged	She knew of the model house, but did not know that it is a seismic design house.
No. 4	Male, young	She knew of the model house, but did not know that it is a seismic design house.
No. 5	Female, young	She did not know of the model house.

A project by NGOs for rural area development including housing supply

Summary of the NGO project

Caritas and the CRS (Catholic Relief Society), both international NGOs, have implemented rural area development projects consisting of agricultural productivity improvement, construction of irrigation facilities, community governance, and housing improvement, in five mountainous towns and villages including Huangascar, Yauyo Province, Lima state, one of the project sites of the JICA project in 2006. They adopted the seismic design of the JICA model houses for the houses included in their project as participants of the JICA project proposed it. One house was completed while 3 units were under construction under this project in Huangascar as of December 2008. They said they were constructing 12~15 housing units in total. The seismic design of the JICA project was applied houses other than model houses of the JICA project, which is exactly what the JICA expects.

Application and modification of the technology/construction method

Many of the participants of the JICA project are playing important role in the above-mentioned housing construction in the NGO program. They modified the technology in several aspects to be easier and more practical including 1) enlarging space in adobe brick for vertical cane so as to accept larger canes (Figure 13), and 2) changing anchorage method of vertical canes from direct placing to foundation to preparing composite of a cane and an empty can filled with cement mortar in advance (Figure 14) for easier construction work. Though they are confidence in their modification, Regarding to 2), it is not verified that modified method has enough strength to prevent the canes come off foundation, since the original method uses five nails in fifteen cm long for the purpose (Figure 15). We found a serious problem on the construction site.

Figure 13 Adobe bricks manufactured in Huangascar. Space for vertical cane is larger than that of the original method

Figure 14 Modified method of anchorage in Huangascar. Vertical canes are fixed to empty cans in advance

Figure 15 The original method of anchorage
Nails are attached to canes to prevent coming off

Figure 16 The original method of anchorage
Measuring spacing is done precisely

We pulled vertical canes by hands and found that around half of them coming off easily. The workers said that position of anchored canes was often not according to space in adobe bricks, therefore they have to cut them and place another cane without anchorage. Placement of vertical canes must be precise (Figure 16) as it penetrates through the entire wall from foundation to top end, otherwise they could not lay adobe bricks because position of canes does not accord to space in adobe bricks. This is very crucial situation as vertical canes are one of the most important structural members.

Discussions on key issues

Discussions on dissemination of technologies

JICA expected that the construction of model houses attracts interests of people in each of the local communities as most of the construction sites locate in small towns and mountainous villages where topical events are not often and information on the model houses will diffuse by word-of-mouth communication and local media automatically. It seemed to be supported by facts that each of events related construction of model houses such as groundbreaking ceremonies, completion ceremonies attracted 50-100 attendants in small communities. However, the results of the interview survey described in the previous chapter (Table 1) indicate that the expectation was not reality as only one person who resides in a adjacent house knew about the project objective and seismic design of the model house while others do not know that the objective is dissemination on seismic design nor even recognize the construction of model house. We assume several reasons. First one is that difference of interest and response of people to events in their own community in developing countries is not the same as that of industrialized countries. Some Peruvian people point out there might be remaining influence of a way of life during time of terrorism when people were afraid of talking on neighbors and communities. Another possibility is that dwellers of non-engineered houses in Peru have less recognition on earthquake risks than people in industrialized countries like Japan where earthquakes happen more often and mass media are active to report on these. We had better to have in mind that influence of media in local communities in developing countries might be not as strong as industrialized countries. These discussions lead us to lessons that it is necessary to take the difference of social circumstances into consideration such as interest and response of people to events in local communities, recognition of earthquake risks, function and influence of local media when we figure out a project for dissemination of technologies in developing countries.

We also get a lesson from our experiences that it is effective to let people see actual things, just the same as the old saying of “Seeing is believing”. The neighbor of the model house who had opportunities to see construction work, especially reinforcement members, understand the seismic design well. The participants of the JICA project who construct the model house by themselves believe the seismic design is effective and useful. It is recommendable to show the actual things for better understanding.

Discussions on encouragement and supports

As previously mentioned, the participants of the JICA project adopted the seismic design for the project by NGOs in Huangascar. On the other hand, four other project sites where same scheme projects were conducted and participants in the areas are also willing to apply the design for their houses, have no similar movements. It implies that it is not enough only to let people know the design and convince its effectiveness but also necessary to provide some kind of encouragement and supports like the NGO activities in Huangascar for further diffusion of the design other than the model houses. We observe NGOs prepared opportunities for the people to remind the tragedy by the earthquake and prioritize safety against next earthquakes and offer financial support for houses which require big investment for low income people.

Discussions on modification of technology/design

Designs of houses are always modified based on demands from construction sites. It is a natural movement which has both positive and negative effects. During our monitoring activities of construction procedures in Huangascar, it seemed that the adopted design is theoretically well designed by researchers, but needs modification to be more practical from view point of construction sites. The people in Huangascar ran exactly on this track to modify the design for more practical construction work. As we indicated there is a serious problem in vertical reinforcement caused by modification of the method of anchorage which was done without support or advice by engineers. Since most of these modifications are matters of engineering, it is necessary to provide support of engineers to these movements. Collaboration of engineering and practice is the way for a new design to evolve to be “soundly matured”.

Conclusion

This paper studies on dissemination of seismic technologies, which is one of the keenest issues for safer non-engineered houses based on the case study of the JICA seismic adobe house project in Peru. The project got good achievement as a training program for the participants but still not enough for the final goal to widely diffuse the technology and encourage people to adopt it to their houses. We learn that further efforts are necessary to diffuse the technology to people out side of the training program with consideration of social circumstances specific in each country. In addition, some kind of encouragement and support is required for people to construct houses of seismic design. We observe natural modification activities by people in Huangascar which needs support of engineers to evolve to be “soundly matured”.

During our study, Pisco earthquake hit wide area in Peru. We extend our deepest condolence to the affected people and resolve to work further for safer house.

Acknowledgments

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