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EARTHQUAKE SAFER NON-ENGINEERED CONSTRUCTION PRACTICES: PROBLEMS AND PROSPECTS

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SUMMARY

Several recent earthquakes in different parts of the world have pointed out the importance and need to promote a culture of earthquake safer building practices. This is specifically relevant to the context of developing countries, where the application of building codes and regulations are often neglected. A specific problem occurs for the non-engineered buildings, which are made by informal construction sectors, without any monitoring and inspection process during construction. The success of the earthquake safer construction of non-engineered buildings is often attributed to the awareness and involvement of the house owners and masons.

A unique approach is adopted in the reconstruction program after the Gujarat Earthquake of India in 2001. Initiated by a diverse group of organizations, the approach focuses on the confidence building of masons and house owners through shake table demonstration testing. A shake table was designed in the field to test two half-size models at a time using different construction technologies. Two tests were performed for the rubble masonry using mud and cement mortar, and one test was performed for the concrete block masonry. Use of retrofitting technologies using traditional practices was demonstrated in one model, and was tested simultaneously with the normal model.

The test was observed by a diverse group of people, including government decision makers, representatives of non-government organizations, engineers and practitioners, masons and house owners. An impact analysis was made before and after the testing to study the effectiveness of demonstration testing to build confidence and raise awareness. The approach was found to be successful to: (1) build peoples' confidence in earthquake resistant building technologies including the retrofitting of existing houses, (2) enhance understanding of

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performance of simple structures, and (3) incorporate people and communities in the process of transferring earthquake safer technology in a participatory way.

INTRODUCTION

Two major issues related to earthquake disaster pose the real challenge to the earthquake professionals. The first one is the nature of the event, which, unlike flood or typhoon, cannot be predicted in advance. The other issue is its frequency, which, unlike other events, occurs once in 10 or 50 or even 100 years. Thus, the priorities of preparing for the earthquake disaster in advance is relatively low in many countries. For the developing countries, while the post-disaster reconstruction exercise provides an opportunity for development, pre-disaster preparedness and mitigation measures are the only solution for earthquake risk reduction (Shaw 2003). However, the painful question is: 'how to motivate an individual and/or community to take pre-disaster risk reduction actions'?

This question is not only critical for the developing countries, but also found to be relevant for the developed country like Japan, which has a high risk of earthquake, experiences of major earthquake disasters, and significant technical expertise and resources. Still the question arises: 'Is Japan prepared for the next big one?' The same question will possibly be valid for other developed countries, and obviously for the developing countries as well.

Several recent earthquakes in different parts of the world have pointed out the importance and need to promote a culture of safer building practices. This is specifically relevant to the developing countries, where the application of building codes and regulations are often neglected. A specific problem occurs for the non-engineered constructions, which are constructed by the informal construction sectors, without any monitoring and inspection process during construction. The success of the earthquake safer construction for the non-engineered buildings are often attributed to the awareness of the house owners and masons, training and transferring the proper technical skills to the masons, and providing confidence to the community for the effective use of technology for non-engineered construction. In this paper, a case study is presented as a model reconstruction program after the 26th January 2001 Gujarat earthquake, with specific focus on the non-engineered construction practices of India.

BUILDING STOCKS OF INDIA

In case of India, building stocks can be divided into four categories (Vulnerability Atlas of India, 1997): Category A (buildings made of field stones, un-burnt bricks and clay structures), Category B (mainly brick buildings), Category C (reinforced concrete buildings and well-constructed wooden buildings), and Category X (made up of informal materials like grass, thatch etc.). Out of these, Category A and X can be considered as non-engineered, Category B as 'less-engineered', and Category C as engineered. The most vulnerable types for earthquakes are Category A and B, since the materials are heavy, with stones, mud or brick walls, with RC slabs as the roof in some cases. The buildings stocks show that almost 50% of Indian houses fall under category A, 35% in B, 4% in C and 11% in X respectively.

In India, the rural and the urban construction have its characteristic features. A typical representative of the rural housing can be: 60% is made up of Category A, 35% of B, 2% of C and 3% of X. In contrast, for the urban housing (e.g., in Ahmedabad in Gujarat), 24% is made up of Category A, 71% of B, 4% of C and 1% of X. Thus, the rural and urban structures have their distinct characteristics, and are reflected in the existing building stocks. For the rural areas, the building materials are mostly local and/or indigenously produced. In most cases, the construction is done by the house-owner, and sometimes by the local masons. In contrast, for the urban areas, the construction is done by the contractor, with mason and helper from different areas, with very little or no involvement of the house owner. The involvement of the house owner is regarded as one of the key factor for the non-engineered housing (Shaw 2001).

LATUR EARTHQUAKE OF SEPTEMBER 30, 1993

The catastrophic earthquake of September 30, 1993 left a large trail of devastation and destruction in Latur and Osmanabad districts, quite unprecedented for an earthquake of magnitude 6.4 on Richter Scale. The number of casualty was more than 8,000. Government of Maharashtra (GOM) had undertaken a massive rehabilitation program to re-establish the livelihood of the survivors of the quake. The GOM implemented the shelter component of the rehabilitation program from 1994 to 1999, with three categories of assistance to the earthquake-affected people, which are as follows (Vatsa, 2001):

- Category A: Relocation of 52 completely devastated villages including reconstruction at new sites;
- Category B: Reconstruction of houses and basic amenities in another 22 severely damaged villages; and
- Category C: In-situ reconstruction, repairs and strengthening in over 2000 affected villages spread over 13 districts in Maharashtra.

The shelter component had a scope of approximately 228,500 houses, which included 28,000 houses from the Category ‘A’, 10,500 houses from Category ‘B’ and 190,000 houses from Category ‘C’. A recent survey in Latur revealed that the participation of the house owner in the reconstruction process made a significant difference in the understanding of the safer building practices and its future implementation into practices. The original construction practices of the rural housing were stone masonry with heavy mud-timber roof, which is well suited with the climatic condition and local culture and tradition.

The relocation has been conducted by the formal construction industries, with very little or no involvement of the community and house owners. The relocation has its positive side, with the improvement of the living condition, better livelihood, better opportunity for the women, and relatively less discrimination of the caste system. A shake table demonstration has been performed after the completion of the relocation, and thus was not so effective in the rehabilitation process. However, it was useful to provide confidence to the people on the overall building practices, employed in the rehabilitation program. The shake table was also useful in demonstrating the earthquake safer construction practices. In contrast to the relocation site, the in-site repair and rehabilitation program was more effective in incorporating people and community in to the process, where the earthquake safety features were well understood within the community and the house owners. Therefore, for a successful reconstruction program, following are the essential requirements as evident from the Latur experiences: 1) involvement of house owner in the construction process, 2) ownership of the problem and solution with the communities, 3) conduct confidence building testing and awareness raising programs, and 4) link the efforts to the existing schemes and/or institutions for its sustainability.

EXPERIENCES OF GUJARAT EARTHQUAKE

Background

The earthquake of 26 January 2001 (magnitude 7.7, USGS) devastated the Gujarat State in Western India with unprecedented and widespread loss of lives and properties. More than 13,000 people lost their lives, and thousands were injured (GSDMA, 2002). The earthquake affected an area stretching more than 400 km, including urban, semi-urban and rural areas. Several villages close to the epicenter were completely destroyed. Over 300,000 buildings were collapsed and more than twice the number were severely damaged. This was a tragic blow to the region that was suffering from a drought conditions and the aftermath of cyclone in last 3 years. The devastation affected the area socially, economically and physically (Shaw et al., 2001).

There was an overwhelming response from all quarters to offer support for relief and reconstruction of the quake hit areas. Such support both material and in kind brought together several institutions/organizations concerned with disaster management to launch a combined effort in the post earthquake response. One such consortium was formed among government, non-government, academic and international organizations from India, Japan and Nepal. United Nations Centre for Regional Development (UNCRD), Earthquake Disaster Mitigation Research Centre (EDM), and NGOs-Kobe, three organizations from Japan joined hands with Sustainable Environment and Ecological Development Society (SEEDS), National Society for Earthquake Technology (NSET)-Nepal and others in India to implement a small-scale project in the affected area in Gujarat, India.

The purpose was to put together the group's strengths and past experiences to help the people of Gujarat in the best possible manner. Patan district, located to the east of Kuchchh district in Gujarat State, and one of the hardest hit districts was chosen as the area of intervention. The village name was Patanka, which was located approximately 270 km north west of Ahmedabad. The area was 70 km west of the epicenter of the earthquake. An initiative called Patan Navjivan Yojna (PNY) was formulated, which had two major components: rehabilitation of a model village, and a shake table demonstration testing for earthquake safer construction.

Model Rehabilitation

The needs for a model approach in community rehabilitation are felt more than ever before. The reasons contributing to this need are obvious. Disasters in recent decades are causing more deaths than it did earlier in the century. The worse still, same areas get affected by disasters over and over, and yet the relief and rehabilitation carried out following one disaster does little to protect them against the subsequent ones. In the areas vulnerable to recurrent disasters, the approach of not learning from past experiences, has led to a miserable disaster-poverty cycle (Bhatt, 1998). Limited education and awareness among the stakeholders, and lack of confidence in disaster-resistant practices such as construction are regarded as two major reasons for the repetition of the same mistakes and tragedy.

Over many years, attempts are being made to develop sustainable disaster management models that can effectively reduce risk. This has been a rather difficult exercise. Experience shows that most 'models' exist as long as there is external support to the local community (Twigg, 2000). The initiative fails soon after external assistance is withdrawn. Ultimately, this results in the vulnerability of the community increasing to it previous levels. It has also been felt that, increased coordination and capacity building among aid agencies, long-term planning and a greater understanding of the recovery and rehabilitation issues can potentially improve post disaster actions at the community level. Thus, the urgency and need for developing a model approach was strongly felt after the earthquake.

PNY was conceived as a model program right from its inception stage. It sought to empower the affected community to such an extent that they are sufficiently resilient against any future disasters. It attempted to link immediate response in form of relief to mainstream development. An important aspect of the initiative was to establish a framework of mutual cooperation among different stakeholders in the post-disaster scenario. Most importantly, it aimed at successively reducing the role of external agency in local rehabilitation action until a point wherein the local community completely takes over the functions insofar performed only by the external agency. The work was done by a Project Team, which consisted of representatives of different organizations mentioned above.

The Process of Rehabilitation (Shaw et al. 2003a) had three major stages: I: Principles and Planning, II: Implementation and III: Ensuring Sustainability (Figure 1). The first thing was setting up the basic principles for planning the rehabilitation intervention. Rehabilitation was not just a short term, gap filling exercise. In most cases, the community faced threat of recurrent disasters and therefore rehabilitation should be aimed at reducing their vulnerability. This would imply building communities assets, achieving sustainability of their livelihood, building houses that could protect them against future earthquakes and an infrastructure that potentially improved the quality of life of the community to a level better than it was before the disaster.

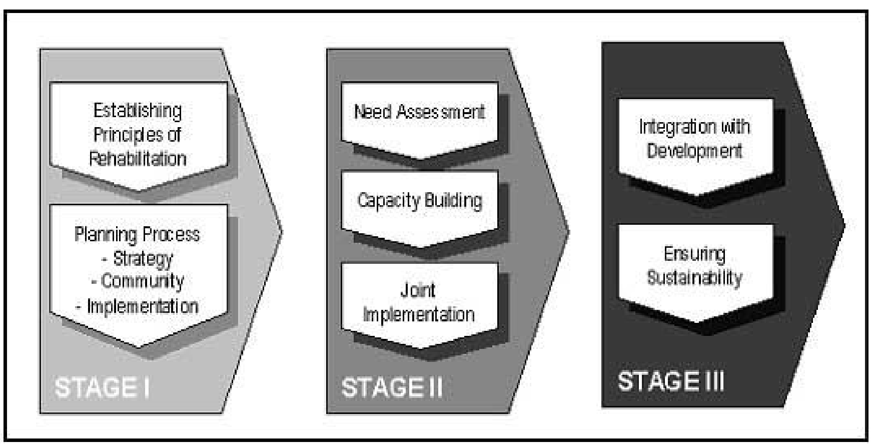

Figure 1. Model of Rehabilitation and Reconstruction

Rehabilitation should be empowering. The Project Team would not, and should not, remain with the community forever. In such a case, the community who were the first responders should be sufficiently equipped to cater to their immediate needs. A well-planned rehabilitation exercise could significantly increase the capacity of the community for a more effective response. Social, economic and psychological aspects were integral part of the rehabilitation program. It was to be understood that the proper rehabilitation was not only to build earthquake resistant houses, but also the restoration of the livelihood, and to restore the normal life with sustainable economic activities. "Livelihood" could not be ensured only by safer housing and suitable income, but would need to include issues such as welfare, health care, medical service, educational facilities, labor condition, disaster prevention and others maintained in good balance.

Rehabilitation should also incorporate the local cultural aspects and should try to inculcate safer construction culture to the community. The rehabilitation program should try to establish a strong bond within the community and also within different related stakeholders. The success of the rehabilitation exercise was judged by the degree to which action were replicated by the community, without intervention from the aid agency. Inputs on capacity building were therefore important. Additionally, the Project Team needed to ensure that conditions would continue to exist for easy replication.

The role of the Project Team was to facilitate the reconstruction process. The composition of the team was therefore very important. Getting appropriate staff members with suitable motivation and skills was difficult, however suitable training and encouragement could help. Establishing good relationship with the community was the foremost responsibility for the Project Team, skills and knowledge came next. The Project Team had to have an attitude of helping the community so that they can help themselves. Maintaining professional and ethical standards while performing amidst the community earns respect and trust of the community. The skills of the Project Team in being able to translate their own knowledge into community acceptable practice was the crucial testing point. Besides, the team would have to ensure transparency in their accounting system and working methods. This helped in establishing credibility for the team.

The most significant part of the project was involvement of house-owners and communities in the reconstruction and decision making process. The Project Team provided know-how, training and building materials, and prepared a model house for the most needy person in the village. However, the construction of houses was done by the family members. Thus, the essential seismic features of the houses were deep-rooted in the persons, and the house-owners were the best quality controller of their own buildings. Thus, an auto-monitoring system was developed within the village, which would be sustainable, even after the completion of the project.

Shake Table Demonstration Testing

In general, there was lack of confidence in traditional construction methods, lack of available lost cost and affordable technology, and lack of trained, skilled masons.

Figure 2. Shake table demonstration testing (building types: stone with mud mortar)

The important aspects of rural non-engineered constructions therefore needed to be identified by demonstration and training that involved the local community in order to provide them with confidence in existing building materials. The main message of this demonstration and training program was that damage was done to rural constructions mainly due to the lack of proper use of technology, not to poor construction materials. The important steps were to build awareness, confidence, and capacity among the people of the local communities, masons and local engineers. A preliminary training program was conducted in the village so that people would understand the importance of earthquake-resistant construction at little additional cost.

Two identical half-size models of rural houses were constructed on a locally built shaking table in the field and tested to underscore the importance of earthquake safety elements. The experiment and training programs were carried out in the presence of the local masons and people in order to engender confidence in the earthquake-resistant construction techniques to be used. Figure 2 shows the first of the test series, in which two models were constructed from stones and mud mortar, after which one was retrofitted with locally available materials. At the end of testing, the retrofitted building had minor cracks, whereas the other building had collapsed. This visual experiment, with explanations, inspection, and measurements gave immense confidence to the community. Four such testing was conducted on houses built with different construction materials and construction techniques (Shaw et al. 2003b). For Test 2, two models of un-coursed rubble masonry (UCRM) will be used, using the cement mortar. One of the models will be made using the traditional methods, and the other will be made using improved seismic elements like through-stones, RC Seismic Bands at different levels, RC lintel connection, and corner reinforcement. For Test 3, two models, one of burnt brick masonry and the other of concrete block masonry will be made using cement mortar. Both models will be made using seismic elements like lintel band, vertical corner reinforcement. For Test 4, two models of concrete blocks will be made using cement mortar. One of the models will use the conventional method, without frog, and the other will use the frog and seismic elements.

Another important aspect of the training program was mason training, in which trained masons from Kathmandu, Nepal provided training for local masons from the affected villages. Through that program, the PNY masons had the chance to visit Nepal and see the work of the Nepalese masons. This also gave great confidence and experience to the local masons.

DISSEMINATION OF EXPERIENCES

Dissemination of PNY experiences was one of the important aspects of the project. The dissemination could be within the state, in the country and outside the country. To disseminate the experiences within the state of Gujarat, different schemes of cooperation were formulated.

Figure 3. 1:10 scale shake table testing with rural construction in Northern India (Left) and Kabul, Afghanistan (Right). The photo in the right shows Nepalese mason and engineer with Afghani masons

These include: cooperation with NGOs working in the Kachchh area for the mason exchange program, new project with GSDMA for sharing the experiences with other parts of Kachchh, proposed training programs in the disaster management resource centers in Gandhidham. All these could be made feasible through constant lobbying, and networking. The PNY video (shake table testing) was broadcasted in the state-wise television, and was used as a training kit for different parts of Gujarat.

The most important dissemination of PNY experiences was in the light of mitigation and preparedness efforts for future earthquakes in northern parts of India. A comprehensive program was conceptualized and implemented by SEEDS, in cooperation with national government (NCDM), NGOs-Kobe and UNCRD. The program was termed as 'Parvat Yatra' (A journey to the mountain), in response to the International Mountain Year of 2002. It was planned to cover the whole north and northeastern part of the country. Figure 3 shows one example of this training program in northern hill town in the Kangra Valley in the Himachal Pradesh. NSET-Nepal has helped in this program with technical expertise.

The same exercise was conducted by UNCRD in Kabul, Afghanistan with the technical assistance from NSET-Nepal (Figure 3). This was aimed to train masons and engineers in the post-conflict reconstruction program in Afghanistan.

IMPACT ASSESSMENT

Since the project has several components, the impact should be evaluated in different work with different each target groups. Needless to say, the project had several target groups. The first target group was at the local level, the community, the masons and local engineers. The impact of the rehabilitation program had two aspects: training and capacity building, and the improvement of livelihood and living condition. A detailed impact analysis was performed on training aspects, and the results are described in the next section. There has been significant upgrading of building conditions, and related infrastructures in Patanka. The residents have a great sense of ownership and pride over the houses and reconstructed infrastructure, primarily because they themselves decided the designs (there were no imposed prototype designs, and each family decided on its house design), they provided most of the material, they paid for the skilled labor, they themselves served as the unskilled labor, and had a central role in all stages of the process. The important aspect was the process, through which the people underwent in the rehabilitation program. All members of respective families were involved in the rehabilitation process, and thus the reconstructed house gave lots of satisfaction to all.

The socio-cultural attributes of the community were preserved since the village was redeveloped along the same organic pattern and houses were built in similar layouts using the same material as types typical of traditional villages and houses in the region. The settlement did not look like an alien cement concrete city neighborhood, as many other rehabilitated villages in the region do. This feature made the villagers very happy and proud of their project.

The construction process had, as a by-product, created a pool of trained masons out of the villagers. Those farmers whose livelihood were destabilized due to ongoing drought had, through the process of building their own houses, assisting their masons, and participating in the mason training workshops, learnt skills of earthquake resistant construction. In view of the large-scale construction activity that would go on in the region's towns and villages in the coming years, this had created significant employment opportunities for these villagers.

The main elements of success of the project can be contributed to the following factors:

Participation: People from the villages participated and contributed in the rehabilitation program spontaneously, which made the project a holistic one.

Empowerment: The local community was empowered with the knowledge and technology, which was the ultimate goal of the project activities.

Flexibility: The Project Team was flexible to the need and priorities at the local level, which contributed to the smooth running of the project.

Teamwork: The total project is a joint cooperative work of all different organizations and stakeholders. The output could be best viewed with a solid teamwork among different parties, with equal ownership of the stakeholders.

Time-frame: Different activities were planned in specific time frames, and feasibility was initially assessed within the specified period.

Sustainability: The framework of sustainability was formulated in consultation with the community, and thereby a feasible recommendation was evolved.

The second target group was the policy makers and the decision makers in central and local government. It was needed to add value to the strategic decision made by the policy makers for formulating effective risk reduction process. The Gujarat State Disaster Management Authority (GSDMA), the nodal agency of rehabilitation in the Gujarat Government recognized PNY as 'one of the very few on-going activities in Gujarat, which specifically focuses on community involvement and participation as the core element of project with a clear-cut target to achieve safe and sustainable livelihood'. The National Center for Disaster Management (NCDM) of Government of India commented that 'the participatory approach adopted by the PNY was exemplary, and formed a true national best practice. This kind of work needed to be disseminated at the highest and widest levels possible to upscale it from a model project to a national approach". This was good recognition from the central government, which proposed to make PNY an example of best practice and a model for future rehabilitation initiatives. The project has evolved dissemination mechanisms at various levels, using appropriate methods. The experiences of the project were documented in video, and presented in different national and international workshops.

A third target group of this project was the international community, including research organizations and international donor agencies. While doing the work at the local level, it was necessary to disseminate information and experiences globally, and make sure that the model of implementation technology would be applicable to a wider community in other vulnerable locations of the world. The United Nations International Strategy for Disaster Reduction (ISDR) recognized the PNY as a successful case study, and incorporated in its World Disaster Report. Also, regional disaster centers such as Asian Disaster Preparedness Center (ADPC) recognized the mason exchange program as a successful south-south cooperation on community based disaster mitigation.

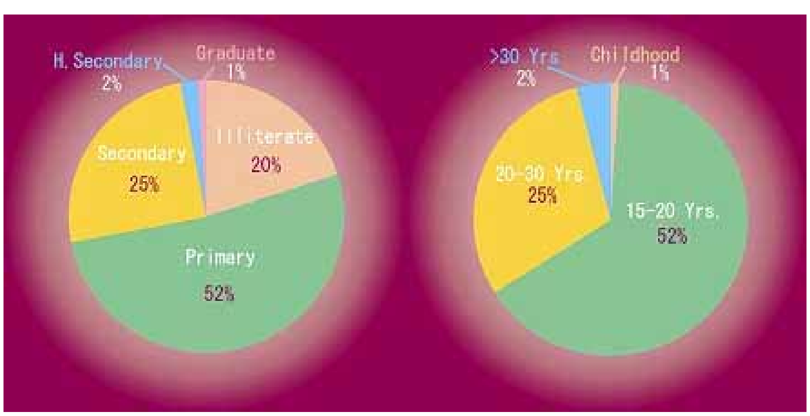

Figure 4. Data on trained masons (left: education, and right: age of starting of mason's work)

An assessment of the effects of the shake table demonstration needed close monitoring of participants to understand specific aspects of the effects. This was done through a survey-conducted questionnaire. In fact, there were two questionnaires, one is before and another is after the demonstration testing. Pre-test questionnaires tried to understand the general perspective of masons about seismic safety, while post-test questionnaires aimed to understand the impact of testing.

General observations on the background of the masons were as follows (Figure 4):

- 28% of the masons were from urban areas, while 78% were from rural areas,
- Average age was 32 years, with a variation from 19 to 50 years,
- Approximately half of the masons completed primary education, while 20% of them did not go to school at all,
- 84% of the masons were main earning members of the family,
- 67% of the masons had an annual income of 240-720 $, 21% had an annual income of 720 $, and 12% had an annual income of more than 240 $,
- Average employment days for masons are 160 per year. However, 44% has employment for more than 180 days per year, 36% between 120-180 days, and 20% less than 120 day per year,
- 72% of the masons were engaged in other activities, apart from mason work (42% in agriculture, 46% as labor, 14% in miscellaneous activities),
- The majority (65%) of masons started their work in the age group 15-20 years, and 30% started their work between 20-30 years, and
- 88% of masons were trained by fellow masons during their work, 12% accepted this as family professions.

Regarding the types of work, the following information was collected:

- 58% of the masons were engaged in masonry work (brick, stone, concrete blocks), 27% is specialized in brick masonry, and 5% in stone masonry, and
- 80% masons preferred brick and cement as the building materials, and tiles as roof materials. Stone as a building materials had a low preference.

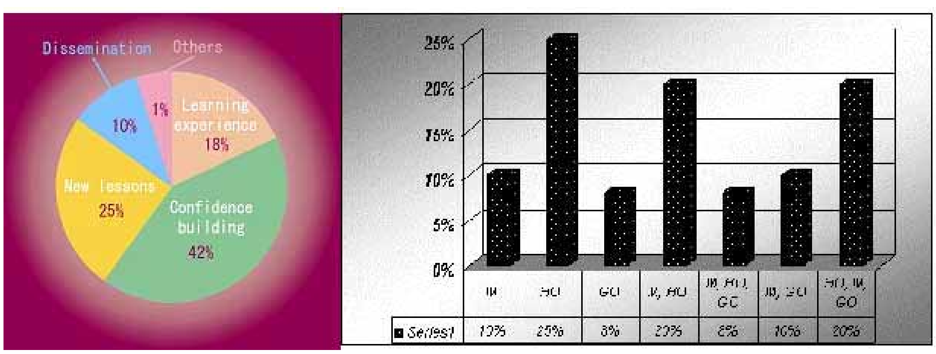

Figure 5. Mason's survey results (Left: impression of masons after Test 1, and Right: suggested ways of dissemination of shake table experiences)

Thus, it can be said that there was a high preference of cement-based building materials, and most of the masons referred to building materials as the prime cause of damages due to earthquake. This was relevant to the first and second tests, where the aim was to build confidence for stone and rubble masonry with both mud and cement mortar.

In Test 1**,** 105 completed pre-test forms were selected after scrutiny, and 85 post-test questionnaires were analyzed. Although statistical figures should not be used as a yardstick to measure qualitative characteristics such as confidence building, type of learning experience, however through the questionnaire survey an attempt was made to understand the overall impact. Some of the major observations after Test 1 are (Figure 5):

- 25% masons came to learn new lessons, 62% come with the idea of "worth seeing". Hence, for most of these people it was a learning experience, and confidence building and also suggested to demonstrate the test in other parts of Gujarat,
- The show was a confidence building in earthquake technology to 42%, gave a new lesson to 25%, learning experiences to 18%, and need for dissemination for 10%,
- Before the test, 78% had faith in retrofitting, and 22% was not sure, which changed to a unanimous agreement that retrofitting was a useful and necessary tool,
- 57% of the masons were convinced that retrofitting was cheaper than new construction, 36% thought that it would be costlier, and 7% did not answer. Thus the majority believed in the cost-effectiveness of retrofitting, and
- Among the retrofitting elements, 42% of masons had confidence in headers and vertical reinforcement, 27% had confidence in the previous two elements plus bracings and gable strengthening, and the rest was a combination of different elements.

There was no post-test analysis after Test 2. In Test 3, 27 completed questionnaires were collected and analyzed. The reason for a relatively low number of questionnaires was attributed to the volatile situation at the aftermath of communal violence in Gujarat. The major observations were as follows:

- 65% of the masons told that it was worth seeing, and learning experiences,
- 65% answered that their confidence increased in seeing the test, while 35% answered that there was no change,
- 45% had confidence in header, vertical reinforcement and gable strengthening, while 35% had confidence in above the three elements plus the band, and the rest opted for a combination,
- More than 65% of masons remarked that gable strengthening, header and vertical reinforcements are relatively easier and convenient, while seismic band seemed to be more difficult, and
- 60% of masons wanted to see the shake table test for concrete blocks and brick in cement mortar.

In Test 4**,** 72 forms were collected and analyzed. Major observations were as follows:

- The test was a confidence building in earthquake resistant construction technology to 78% masons. 96% of masons believed that earthquake resistant practices should be followed in Gujarat,
- Only 20% of masons followed the new technology, while 80% used conventional methods,
- Most of the masons wanted the test is shown in the other parts of Gujarat,
- Masons were asked about the best way of dissemination of technology. The answer was: 10% for mason's training, 25% for information to the house owners, 8% for government training, and rest suggested the combination of all different process. 73% felt that house owners should be informed, 48% believed in mason training and 36% felt government training as important ways of dissemination,
- Among different seismic elements, 80% masons believed in reinforced concrete band, 85% believed in vertical reinforcement, and 59% believed in a combination of different elements for concrete blocks buildings,

- As for the causes of damages: 31% believed it was caused primarily by materials, 24% in quality, 9% in age, and 36% in the construction types, and

28% masons stated that additional cost for earthquake resistant features would be 10% of total construction cost, 70% told that it would be 20% of the total cost, and 2% suggested it would be more than 50% of the total cost.

CONCLUSION

The demonstration testing and the model village reconstruction exercise are considered as useful tools to demonstrate and disseminate safer building practices for rural housing to the community and house owners. Latur earthquake showed that the involvement of the house owners during the construction and rehabilitation process is the key factor for the sustainability and adoptability of the transferred technology. It also pointed out that the testing should be done along with the rehabilitation process, so that people turns the knowledge into practice. These lessons are useful for the future testing and confidence building process of the community. Thus, the timely interventions through the shake table testing in Gujarat have been found to be fruitful and appropriate. To study the adaptation and adoption process, a close monitoring is required, which will be done through on-site inspection, questionnaires and interviews of the different stakeholders.

In most cases, the non-engineered housings are deep rooted in the local culture, tradition and climate. Any drastic change in the construction practice is not possible or advisable for the sustainability. Therefore, any remedy should be simple, affordable, and linked up to the economic activities. There should be an appropriate level of incentives for introducing earthquake resistant features within the non-engineered constructions. The center is a joint initiative of the government and non-government sectors, where the government provides initial resources and technical input. The non-government sector has to run the center, make prescribed profit, and pay back to the government for a certain specified time period. The center acts a training center for the local masons, and thus the safer building practices are disseminated through the wider communities with the appropriate incentives. This system has been able to generate a local economy and small-scale industry. Mason training and incentives to the masons is found to be a useful approach in this regard. For the rural construction, awareness raising among the house owners and local community is found useful. For the urban structures, the problem is more complex and needs strong government involvement. This approach, coupled with the shake table confidence building testing can be a possible tool for the dissemination of culture of safer building practices.

ACKNOWLEDGEMENTS

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