DISSIMINATION OF EARTHQUAKE RESISTANT TECHNOLOGIES FOR NON-ENGINEERED CONSTRUCTION

B.H. Pandey[1], K. Okazaki[2] and S. Ando[3]

[1] *Student, Dept. of Civil Engineering, University of British Columbia, Vancouver, Canada*
[2] *Professor, National Graduate Institute for Policy Studies, Tokyo, Japan*
[3] *Coordinator, Disaster Management Planning Hyogo Office, UNCRD, Kobe, Japan*

Email: bishnuhp@gmail.com, okazakik@grips.ac.jp, andos@hyogo.uncrd.or.jp

ABSTRACT :

It is observed in the past that high rate of casualty in earthquakes is due to prevailing practice of unsafe construction. Despite the efforts of reducing risks, loss of life is increasing in earthquakes in developing countries. Most of the victims are being killed by collapse of their own houses. It shows that the current state of technologies either has not reached to the communities those need them the most or it is lacking in addressing the problems appropriately. In these countries, local governments have poor institutional and technical capacity for implementing earthquake safety related provisions of building codes. Under such circumstances, promoting earthquake safe construction could not be achieved only through efforts on controlling by codes and regulations but also through an approach where house-owners are convinced on earthquake safety issues and are provided with easy and affordable technologies. Case studies of developing countries in Asia-Pacific region show that integrating seismic safety in housing construction requires a strategy that incorporates technological awareness of common people, consultation on housing technology by local governments to home owners and trainings and education programs at community level. The paper discusses about some initiatives on housing safety in communities of Asia-pacific countries. Lessons from implementation led to devise comprehensive approach of housing safety of non-engineered construction. It is concluded that a sustainable earthquake safe housing could be achieved by integrating result of the technology demonstration, capacity building and actions to motivate people safety practices.

KEYWORDS: Non-engineered construction, Technology dissemination, Education, Risk perception

1. INTRODUCTION

Any good technology can be help of society only if it is accepted by and penetrated to its people. This also applies in case of earthquake technology for safe housing since decision of individual home owners on choice of building typology and construction affects the risk of building to earthquakes. In communities where building production is based on owner-built system where construction of house is controlled by home-owners, earthquake technologies need to be trickled down to the community and individual level for effective applications. The continuous loss of lives of people in developing countries in recent earthquakes implies that the current state of earthquake technologies has not reached to the communities those need them the most. However, the technology can not be simply imposed but rather any efforts for earthquake risk reduction requires understanding of community safety culture, their intelligence and integrating that with knowledge tools. This approach needs an effective dialogue between “experts” and “common people” which forms into translation and transfer of modern research outcomes and knowledge of earthquake technology into non-technical language.

It is increasingly acknowledged that the non–engineered construction prevailing in seismic area of developing countries is one of the important sectors to intervene to reduce the loss of the lives in earthquakes, where the need of community education is more obvious. Surveys on community risk perception are carried out and action research projects are implemented in pilot basis in some communities of Asia–Pacific countries. The objectives of the survey and demonstration projects on housing safety are to get better understanding of how technological tools can be passed to the communities and to devise appropriate system of earthquake technology dissemination for safer housing. Results of research project of Housing Earthquake Safety Initiative (HESI) of United Nations Centre for Regional Development (UNCRD) and study on seismic risk perception coordinated by National Graduate Institute for Policy Studies (GRIPS) are taken for the study to identify the contributing factors for effective community education for earthquake safe houses. Pilot implementation of community based housing safety initiatives included demonstration of simple and cost-effective earthquake technologies, awareness programs to homeowners, training of technicians and masons as apart of technology dissemination. Observations, experiences and lessons are analyzed to establish linkage between hazard context, socio-economic status and priority for earthquake risk reduction at individual and community level. Based on the survey results and lessons from pilot works, conclusions are drawn in respect to guiding elements in planning and implementing technological awareness on earthquake safe housing to communities.

2. NON-ENGINEERED CONSTRUCTION

It has been repeatedly observed that people are killed in earthquakes mostly due to the failures of the non-engineered buildings (Boen, 2001). High human casualties in recent earthquakes in Kashmir, Bam (Iran) and Gujarat (India) are attributed to the collapse of traditional adobe and masonry houses (EERI 2006, Zahrai et al, 2007, EERI, 2002). These houses are mostly built informally by homeowners themselves with input from local masons and do not have the engineering input during the construction phase. There is large stock of such residential buildings in seismically active part of the world and people, particularly, in developing countries, continue practice to build and live in such houses because of various socio-economic and technical reasons. People in such area may not have access to modern materials and technical service. In such cases, owners make decision regarding planning and construction of their houses with the help of the local artisans. Figure 1 shows the level of contribution by stakeholders in building delivery process in Nepal (Pandey, 2006). In community surveys carried out in Indonesia and Pakistan with 800 households for this study, it was found that 61% and 90% of houses are built by local masons with no input and interventions from professional and contractors. As observed in the survey result, professional advice is rarely sought and, if solicited, is limited to the preparation of submission drawings for municipality permits. Home owners and local masons take care in all stage of building delivery process i.e. planning, design and construction. The building code enforcement is not effective in these constructions as there is very limited access to professional experts and governments also do not have capacity to monitor and enforce the code provisions.

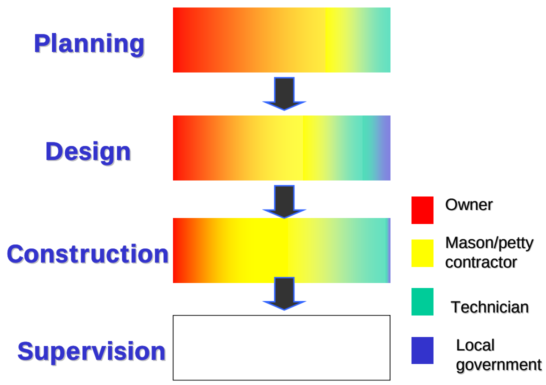

Figure 1 Contribution of stakeholders in building delivery process

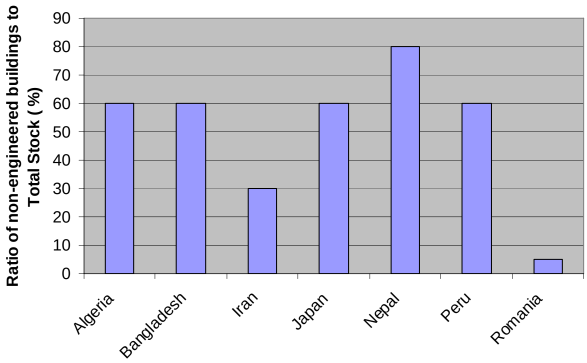

Figure 2 Prevalence of non-engineered building in seismic countries

Non-engineered buildings that kill most people in earthquakes attract the least attention from the engineering profession (Davis, 2002). It is claimed that resource distribution in terms of building engineering research and education is unbalanced to the proportion of the building production. In a questionnaire survey with building officials of various countries under HESI program of UNCRD, ratio of the non-engineered buildings to the total stock of the building is found more than 50 % in most of the countries (Fig 2). As sophisticated analytical tools for analysis and design of such buildings for earthquakes may not be readily available, lessons from past earthquakes which come from the analysis of the cause and effect of the damages make it now possible in pointing weaknesses of such buildings and help identify the solutions to avert the collapses against earthquakes Boen(2001). Earthquake resistant solution to these non-engineered buildings is mostly based on "observed behavior of such buildings during past earthquakes", and engineering judgment.

3. CASE STUDIES ON ROLE OF TECHNOLOGY DISSEMINATION IN SAFE HOUSING

Implementation studies of earthquake technology dissemination had objectives of creating awareness of earthquake risk and providing means to reduce the risk by making houses resistant to future earthquakes; enhancing people's knowledge, understanding and motivation to go for adopting the earthquake technologies and developing skill of local masons and craftsmen for implementing the safe techniques in construction. Community earthquake education incorporated the aspects of:

i) Public involvement in model earthquake projects
ii) Mass awareness through demonstration of existing risk and use of earthquake safe techniques
iii) Communications and social marketing of technology
iv) Education and training for earthquake resistant construction techniques

Case studies of Afghanistan India, Iran and Nepal are described here as examples of technology dissemination

3.1 Earthquake safe construction awareness and trainings in Afghanistan

During 2002-2004, earthquake technology dissemination activities for safe construction were carried in Afghanistan, which emerged out of decades of conflict. The objective of the pilot activities were to increase capacities of the national and local governments with technical support for safer construction practices in recovery process and to disseminate safer construction practices through trainings, dissemination and demonstration programs in communities. The intervention with earthquake technology dissemination was aimed specifically to incorporate seismic safety in rehabilitation process where millions of new houses were to be constructed to fulfill the national housing need. The program included developments of guidelines in Persian language for non-engineered construction targeting to local masons and craftsman, training of technicians/ masons on use of guideline, exhibition of earthquake safe construction method through real scale model wall and reinforced bar layout for beam-columns in Kabul University and simple improvised shake table demonstration for typical Afgan houses. In the entire process, the Ministry of Urban Development and Housing (MUDH), Ministry of Rural Rehabilitation and Development (MRRD) were engaged for national capacity building. The training guidelines developed were later adopted as recommended construction practice by MUDH.

3.2 Community based reconstruction of Patanka village in Gujarat, India

The earthquake of January 26, 2001 hit the state of Gujarat, India causing extensive loss of life and property. In response to this earthquake, UNCRD, along with other international organizations, initiated the Patanka Navjivan Yojna (Patanka New-Life Plan) project that aimed to provide affordable means of reducing future risk from earthquakes in the village of Patanka with focus on capacity building of communities to adopt the technology for safe housing. It has been observed from past experiences that the lessons of earthquakes are often forgotten, especially in case of rural construction, where buildings are most often rooted in traditional culture and constructed to suit to the local climatic conditions. However, in most cases, modern construction practices have been adopted without having been considered within the local context, making many places more vulnerable than prior to such adoption.

The technology dissemination activities included field demonstrating testing by making two half-size models of typical rural construction: one normal and other improved (retrofitted), and testing them with shocks, and conducting training programs. Study of impact of demonstration and training in the community shows significant increase in level of confidence among masons and carpenters on use of earthquake technology after the demonstrations. This led to institutionalization the mason training for earthquake safety of housing in India. In Gujarat, trained masons on earthquake safe construction form association to expand the role and create social marketing in the communities.

3.3 Earthquake technology demonstration in Bam, Iran

Over 70% of the houses in Bam are reported to be destroyed in the earthquake that occurred on 26th December 2003 (JSCE, 2004). The huge loss of lives in the earthquake, which was moderate in scale of intensity, was considered owing to unsafe houses. The UNCRD organized shake table demonstration and trainings in Bam aiming to influence the reconstruction of the city so that risk of the natural hazard is well taken care of in the process. The intervention through the trainings and demonstration was timely for effective reconstruction as it was to commence after about 10 months long temporary housing since disaster. The activities aimed to show people how they can reconstruct their houses maintaining the earthquake resistant system with due respect to their culture of housing system. Improvised shake table demonstration, on-the job training of masons during the construction of the model houses and training workshop on safer housing were the major activities of technology dissemination targeting technicians. The most significant impact of the activities in Bam was the realization of effectiveness of simple affordable technology based on local materials for safe housing by Housing Foundation, the government entity looking after housing reconstruction of Bam city.

3.4 Multi-front approach of earthquake technology dissemination in Kathmandu, Nepal

In Kathmandu Nepal, where big earthquake is considered long due in Himalayan zone (Bilham, 2001), efforts are made for earthquake awareness with a simultaneous activities in multi-front through a number of programs. The leading role of an NGO- National Society for Earthquake Technology (NSET) in technological and policy awareness for earthquake safety demonstrates role to be played by civil society for earthquake risk management where formal sector is not effective. The awareness activities target most of the stakeholders and use all available means of communication for seismic safety. The targets of activities are people of all sections of the society: officials and decision-makers at the central and local government level, the influential members of the private sector, school family, and professionals besides prime targets of housing construction stakeholders-homeowners and masons. Tools and channels of disseminations include radio and TV shows, public lectures, shake table demonstration and exhibitions, drills and simulations, vulnerability tours, earthquake safety clinics, homeowners' orientations, paper based publications, rallies and street shows, student art competitions on earthquake safety, engagement of engineering students in development of vulnerability database of buildings in cities etc. Besides achievements in social awareness and education for seismic safety, impact of these activities is visible in formal sectors too where building codes are now enacted at city government level, central government put building safety in its major policy and program paper, international agencies are active in earthquake risk management programs.

4. TOWARDS MOTIVATION AND ACTION FOR SAFE HOUSING

A risk perception survey on seismic safety of buildings was carried out by GRIPS in Nepal, Indonesia, Pakistan and Turkey targeting residents. The survey is conducted in 2 kinds of communities in each country with approximately 400 households selected randomly in each community. The surveyors visited selected houses to conduct an interview with each householder and fill in the questionnaire through the interview. Results of the survey have been analyzed from the perspective of contributing factors to motivate individual homeowners towards seismic safety of houses they own or built.

Most interviewees, more than 50%, don't know when the next big earthquake is going to occur in their area, except in Turkey where only 30% respondents have no guess about timing of next earthquake. Where as more than 80% of respondents in Turkey are confident that their house are safe from earthquakes, most of the residents (more than 60%) in Nepal, Pakistan and Indonesia feel that their houses are unsafe from earthquakes. A 62% of the residents in Nepal, who feel unsafe, responded "No" to the question when they were asked whether they do have plan for safer house in future. It is in spite of overwhelming response by 86% who think their weak house would be collapsed in earthquakes. In Indonesia and Turkey, only 33 % respondents who feel their house is unsafe have no plan for safer housing. A significant portion of residents in Nepal (42%) would blame to themselves followed by to the God (17%) for any damages in future earthquakes where as more than one third of respondents in Turkey would blame to house builders and 20% would blame to the God. In contrary, in Indonesia and Pakistan, only less than 4% would blame to god, where most of them don't know

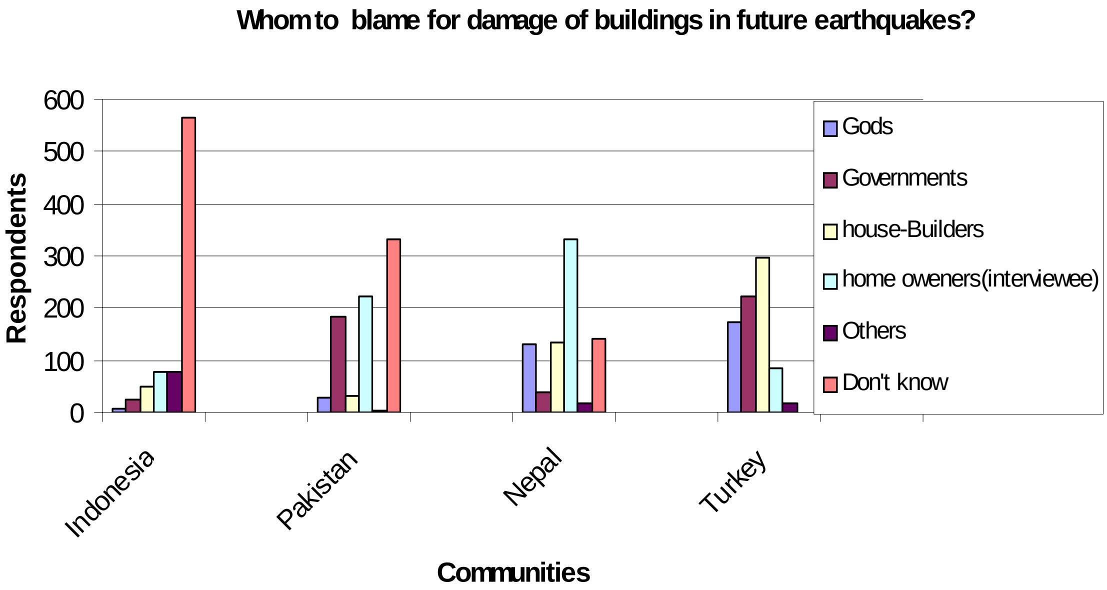

Figure 3 Response of residents on whom to blame for damage of their buildings in earthquakes

In all countries, poor construction material is considered a major factor for weak houses and most of the residents, more than 95 % in all countries, consider threat from neighboring houses. A significant portion of residents in Turkey (38%) said that they can invest maximum one months salary for protecting their houses from earthquakes where as in Indonesia and Pakistan, 45% and 80% responded they can spend salary of more than 5 years for this. In contrary to the expected concept that loss of life would be considered more terrible than loss of housing property, only 31% and 29% respondents in Indonesia and Pakistan said they can invest salary of 5 years for protecting family members in earthquakes.

With analysis of data of questionnaire survey and lessons from pilot case studies of community based initiative of earthquake safe housing in developing countries of Asia pacific, following factors are found mostly contributing in determining the motivation of individual for seismic safety of their houses

4.1. Economic consideration

Poverty creates strain to the livelihood and people tend less priority to the far distant risk of earthquake disaster than their immediate needs in poverty situation. In respect to the investment for increased safety, the issue of livelihood always comes first for them. Even aware of the risk, people don't hesitate to take risk of life if that is distant like in earthquakes. In case of seismic retrofitting, it is usually difficult to convince homeowners to have full fledged retrofitting as it is usually costly and complex in nature. However, some model retrofitting works would give message of importance of incorporating the earthquake safety measures at the time of construction, which act as motivational tools for earthquake measures. In case of post earthquake rehabilitation, retrofitting can go well with the repair. It's the best window of opportunity for intervention.

4.2. Knowledge of buildings and availability of technology

Unless the homeowners have knowledge on the basic weakness of their houses, there will be no actions from their side to make their houses safe. The risk communication should target at individual level as action comes from the threat to individual or own family rather than threat at community level. A homeowner acts only when he or she knows the risk of own house and basic idea of what should be done to eliminate such weakness. Some aspects of housing safety are difficult to understand by homeowners and some others are easy to follow. The basic design and construction concept in relation to earthquake forces are important to be conveyed to home owners as they are simple to understand and they are the most influencing factors in earthquake resistant systems. Earthquake education should accompany with the accessibility to technology. The effect of earthquake education vanishes if there is no service available to people when they seek to retrofit their houses or make new houses earthquake resistant. If community does not have regular access to engineering services, training of local craftsmen should be the part of program to empower and educate communities for the seismic risk reduction

4.4.Building construction delivery process

In case of owner built system, homeowner themselves take care and decide on construction matter and there is usually no check and regulation from formal sector. Technical input in configuration and construction is sought from local masons and petty contractors. In owner-built non-engineered construction, developing the house model is a joint product of owner and masons. Basic knowledge of housing safety to home owners makes a big difference in making the earthquake resistant housing.

4.5. Housing as cultural reflection in the neighborhood

The motivation to individual family to adopt better technology and safety also comes through observation of the same in the neighborhood. It is a human culture that one wants to imitate and compete with the same ranks. This social psychology could be applied to encourage for better safety by initiation of some member communities. Experiences are that if a well respected member of neighborhood adopts the safe technology, chances are high that it spreads to other households.

5. TOOLS FOR EARTHQUAKE EDUCATION

The most important part of the earthquake education is to design methods, tools and techniques of communication to the public on earthquake risk and safety measures to be employed in house. The appropriateness of education method(s) should be checked against the need of target groups. Mostly two or more methods are effective to disseminate the technologies.

Video of past earthquake in the same region or in other areas of similar housing condition are very effective to create imagination to the people on what may happen in the future earthquakes in their communities. Photos exhibition of the past earthquakes in the same community are very effective means for convincing people on the risk. Awards to encourage and recognize the contribution can be a useful method of motivating and supporting for the cause of earthquake safety in community. Certification of masons trained on earthquake resistant construction gives moral boost and also helps in social marketing of the skill to them. This method is extensively used in India and Nepal for social marketing of skilled masons in the communities (SEEDS India, 2007)

There are innovative tool developed to show the effectiveness of the earthquake safety elements in houses through the demonstrations like shake table test demonstration. An improvised shake table demonstration can be carried out with pair of scaled building model made of sub-standard material like adobe, brick. The building models are placed on tabletop of a improvised shake table. Twin building models, look alike, but having differences that one is constructed in a conventional method without using any earthquake resistant elements in construction and another with same material but with simple quake- resistant technology will be given vibration manually. Upon the shaking, it is expected to observe the performance of the both model at a time. The show will reveal the weaknesses of the conventional construction model whereas it also shows, in same shaking, the mechanism of resistance and the effectiveness of the earthquake resistant features in the other model. Comparing the damages, one can easily be convinced on the simple techniques of safer construction The demonstration earthquake technology can be made with real scale exhibition of techniques to be used for safe construction of different type of houses. When it is combined with training and other tools, the demonstration tools are very effective to convey the message.

Counseling service like 'earthquake clinics" would be another effective tool for technological awareness. The term "earthquake clinics" are derived from the medical concepts to use in technology service for earthquake safety that solution in the form of cure and prevention is provided to the weakness of the houses. A group of experts give consultations to perspective home owners who want to build houses. The earthquake clinics are more effective if they are combined with municipal building permit process so that all aspiring homeowners can go the consultation service provided to them before construction of houses. Another form of earthquake clinic is also devised in Nepal called "mobile earthquake clinic" where an expert team visits to the sites of the house construction and provides on-site consultation to the masons and petty contractor upon their requests. Print material like flyers, guidebook and other resource material are distributed to the masons, homeowners and contractors for later reference. This method is very effective to intervene in the construction at the real time.

Other common tools in disseminating earthquake technology in communities could be mass media, print materials, trainings, talks etc.

6. APPROACH FOR EFFECTIVE DISSIMINATION OF EARTHQUAKE TECHNOLOGY IN COMMUNITIES

Figure 4 illustrates a comprehensive approach for effective dissemination of the earthquake technology for safer housing in communities of developing countries. It is a integration of technology demonstration, capacity building of communities to use the technology and educational and motivational activities to make individuals in communities take earthquake safety measures of their houses. Examples of technological intervention for safety of houses against earthquakes are physically visible elements that provide community a sense of confidence on use of those techniques. Community facilities like schools, heath posts etc are found the best places to demonstrate the earthquake safe technology in communities. The technological improvements over the traditional construction for earthquake resistance should be simple and understandable to adopt locally so that local craftsmen can easily get the know-how and implement it. As the local community people have strong attachment to the traditional cultures and building practices the building forms and layout resembling the traditional style to the possible extent provided that they follow the simple configuration rules are most effective.

The communities need to be equipped with necessary knowledge and skills to adopt the safer construction practices by their own. As masons are the technical service providers for the most of house construction in developing countries, they are the key stakeholders in transferring the technology at the root level. As capacity building of the community for safer technology, training to these groups is must. The aspects of simplicity and ownership of technology by these groups of people is important for sustainable capacity building of communities on use of technology. Use of demonstration model like seismic retrofitting of school building is effective to provide on-job training to the masons and technicians. Awareness of the home-owners and motivation is also critical for safer construction of individual houses in the communities. As opposed to the common skeptics, common people are found very receptive and interested on such technological issues.

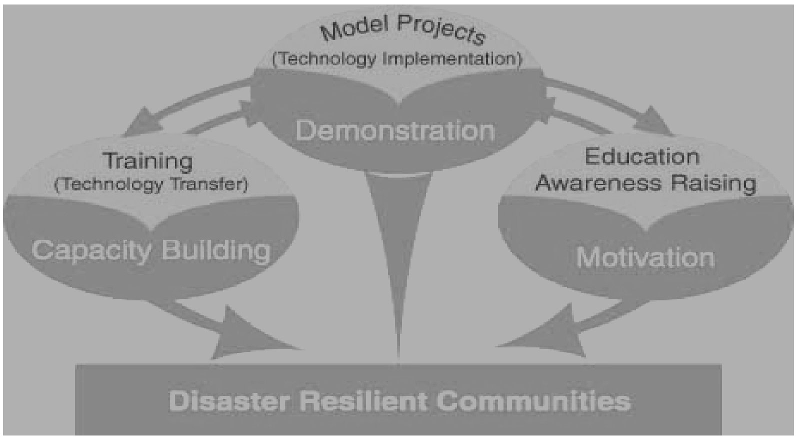

Figure 4 Community based approach for technology dissemination and application

REFERENCES

Bilham, R. Gaur, V. K. and Molnar, P. (2001). Earthquakes: Himalayan seismic hazard. *Science* Vol. 293. no. 5534, pp. 1442 – 1444

Boen, T.(2001). Earthquake resistance design of non-engineered buildings in Indonesia, EQTAP Workshop IV Proceedings, Kamakura, Japan. Published by EDM Japan

EERI. (2002). 2001 *Bhuj*, India Earthquake Reconnaissance Report. *Earthquake Spectra*. Vol. 18

EERI. (2006). The Kashmir earthquake of October 8, 2005: impacts in Pakistan. *EERI Newsletter* 40:2

Davis I. (2002). Key note paper on earthquake mitigation for 12th European conference on earthquake engineering, 9-13, September 2002. Published by Elsevier Science Ltd. Paper Reference 841

JSCE. (2004). Preliminary Report on December 26, 2003 Iran Bam Earthquake

Pandey, B.H. (2006) Community based approach to promote earthquake resistant technology in developing countries. Proceedings of Annual symposium, JAEE Japan

SEEDS India, (2007) http://www.seedsindia.org/SMA/sma.htm (accessed on 4th April 2007)

Shaw R., Britton N., Gupta M. (eds).(2003). PNY: Towards Sustainable Community Recovery. UNCRD, Kobe Japan.

Zahrai,S.M. and Heidarzadeh, M.(2007). Destructive effects of the 2003 Bam Earthquake on structures. *AJC(Building and Housing),* Vol. 8, No. 3 pp. 329-342