EARTHQUAKE RISK REDUCTION TO NON-ENGINEERED BUILDINGS: A STUDY OF PRACTICE IN INDONESIA

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In recent years the lethal effects of earthquake events in and around Indonesia have been all too real. Tens of thousands of buildings have been destroyed and the death toll considerable. Many such buildings are classified as 'non-engineered' - in simple terms, unsystematically designed and poorly built structures. The application of earthquake-resistant, or seismic, building codes to non-engineered construction is paramount to ensuring safety against earthquake events. Risk reduction through the implementation of appropriate codes involves not merely technical intervention but involves a plethora of societal responses. This paper reports on a PhD research programme, funded by the Government of Indonesia, which has explored technical and societal elements which are significant to the seismic risk reduction of non-engineered buildings (SRRNEB). The overarching aim of the research was to examine the potential for reducing earthquake risk of non-engineered buildings within the context of current practices in Indonesia. The research methodology involved a triangulated qualitative-quantitative approach underpinned by the detailed review of literature from the Asia-Pacific region together with primary data gathered by a questionnaire survey and in-depth interviews with the stakeholders involved in Indonesian construction. Fifty-seven elements of effective risk reduction were identified, fifteen reflecting technical interventions and forty-two reflecting societal dimensions. Identifying, understanding and applying the appropriate combination of technical and societal responses to earthquake events will enable a new generation of risk reduction measures to be developed in Indonesia where the effective implementation of building codes can be achieved through regulatory and voluntary initiatives.

Keywords: building codes, earthquakes, non-engineered buildings, risk reduction.

INTRODUCTION

Almost two-thirds of Indonesia's major cities are located in zones of 'relatively high' to 'very high' earthquake risk (IUDMP, 2001). In and around these cities, tens of thousands of buildings have been destroyed in recent earthquake disasters. Such events and their consequential effects have been exacerbated because many buildings and structures have not been designed and constructed to be earthquake resistant (CEEDEDS, 2004). Many collapsed or heavily damaged buildings, and in particular domestic dwellings, are of medium to low cost construction (BAPPENAS, 2006) with the building techniques employed classified as 'non-engineered' - in simple terms, unsystematically designed and poorly built structures. A paramount contribution to maximising the earthquake resistance of buildings in Indonesia is to ensure that

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earthquake, or seismic, related building codes are applied rigorously in their design and that construction techniques are effective and robust in practice.

The aim of the research reflected in this paper was to examine the potential for reducing the earthquake, or seismic, risk of non-engineered buildings within the context of current construction practices in Indonesia. This involved the exploration of : (1) key elements within the regulatory, technical and social dimensions of existing building practices that generate risk to non-engineered buildings in earthquake situations; (2) the perspectives of key stakeholders in relation to the importance of the identified elements to be implemented to reduce risk to non-engineered buildings; (3) the principal reasons why seismic-related building codes are not applied more readily to non-engineered buildings; and (4) the actions which might be taken to improve practices in the design and construction of non-engineered buildings.

BACKGROUND AND CONCEPTUAL DEVELOPMENT OF THE RESEARCH

Non-engineered buildings proliferate in most residential areas of the major cities of Indonesia (CEEDEDS, 2004). Such construction has increased to meet the direct demand of local populations (Sarwidi, 2001) and been delivered by speculative builders whose activities may often go unregulated. While seismic-related building codes have existed in Indonesia for many years (Boen, 1978), as in other countries there is a broad divide between the existence of appropriate building codes and their widespread utilisation (Comartin *et al.,* 2004). With each earthquake-related disaster more and more questions are being asked as to how and why the design and construction processes fail to protect Indonesia's buildings, infrastructure and people.

Petak (2002) suggested that the principal problem with implementing seismic-related codes did not directly relate to the codes themselves but to an absence of awareness of their availability and the inadequate understanding of their application. Wenzel (2006) suggested that the slow evolution of risk reduction measures following each earthquake disaster is due to five predominant failings: (i) poor structures of national and, specifically, local governance; (ii) absence of an inter-disciplinary work culture; (iii) inefficient and ineffective use of resources; (iv) lack of awareness and low knowledge of risk and its management; and (v) poor professional standards and ethics. Winarno et al (2007) examined recent thinking and suggested that a framework for risk reduction was needed directed specifically toward non-engineered construction. This should focus on a systematic risk management approach which embraces all the many different and diverse dimensions to the subject. This is considered essential because risk reduction through the implementation of appropriate seismic-related building codes involves not only the technical interventions surrounding building specifications and practices but a plethora of non-technical, predominantly societal, responses. Moreover, it requires the input of a great many stakeholders each with their own levels of awareness, understanding, capabilities and commitment.

Furthermore, a prominent line of thought is also emerging where earthquake resistant design and construction should contribute an intrinsic part in promoting sustainable development (UN-ISDR, 2002: UNDP, 2004). Most disaster management actions in Indonesia, as indeed they are elsewhere, tend to be response mechanisms following an earthquake-related event. Little consideration has been given to risk reduction during the development-planning and regulation of non-engineered construction. Likewise, little has been done to raise awareness and understanding of the need for better design and construction among community stakeholders, participants, owners and occupiers

(Comfort, 2002: Ngoedijo, 2003: ISDR, 2003). The importance of ultimately developing a well configured and well recognised integrated framework for risk reduction, in the widest possible sense, has been emphasised in recent years (Petak, 2002: Shah, 2002: IDEA, 2005) although current practice is somewhat distant from this at this time.

This paper reports on research (Winarno, 2007) which examined, in detail, key aspects surrounding seismic risk reduction of non-engineered buildings using a risk management approach. This allows the concept, principles and practice of risk reduction within the perspective of wider decision making for planning and regulation, essential if the many and varied facets of the particular construction type are to be accommodated. Understanding these important dimensions will enable better risk reduction measures to be developed and possibly lead, in the future, to an integrated framework of systematic risk reduction for non-engineered buildings in Indonesia.

RESEARCH AIM, OBJECTIVES AND METHODOLOGY

Aim

The overarching aim of the research study was to examine the potential for reducing the seismic risk of non-engineered buildings within the context of current construction practices in Indonesia.

Objectives

Underpinning this aim, the main objectives of this study were to:

1. Identify the key elements within the regulatory, technical and social dimensions of existing building practices that generate risk to non-engineered buildings in earthquake situations;
2. Examine the perspectives of key stakeholders in relation to the importance of the identified elements to be implemented to reduce risk to non-engineered buildings;
3. Highlight the principal reasons why seismic-related building codes are not applied more readily to non-engineered buildings;
4. Suggest what actions might be taken to improve practices in the design and construction of non-engineered buildings.

Methodology

The methodology involved a triangulated qualitative-quantitative approach. Information and data was gathered from secondary and primary sources. This involved the review of a wide range of literature from the Asia-Pacific region and wider international sources together with a detailed structured questionnaire survey of building practice in Indonesia, a series of in-depth interviews with multidisciplinary stakeholders and the acquisition of case studies. The approach to questioning within these data groups enabled each of the research objectives to be explicitly fulfilled. Quantitative data was collated and analyzed using the Statistical Package for the Social Sciences (SPSS) while qualitative data was processed using NVivo software. From this, trends in the quantitative and qualitative data could be established and integrated to highlight those key elements central to answering the questions posed.

Respondent groups

It was essential that appropriate respondents were identified within the data acquisition methods used to secure the primary data. The input of the key multidisciplinary stakeholders was necessary to reflect an accurate and reliable sense of involvement and engagement in the design and construction of non-engineered buildings together with experience of the impacts upon these types of buildings from earthquake events. Literature from research in Indonesia suggested that appropriate participants should include nine groups of multidisciplinary stakeholders: (i) researchers/scientists; (ii) small and medium contractors; (iii) construction supervisors; (iv) government officials; (v) business leaders; (vi) academics/educators; (vii) non-government organizations; (viii) community leaders; and (ix) media reporters (IUDMP, 2001; GREAT, 2001; SCEC, 2002; Dixit, 2003; CEEDEDS, 2004). The appropriateness of each respondent was determined by their role, responsibilities and normal activities within their own organization and the level of experience in the specific subject.

The questionnaire survey asked respondents to consider and value 57 pairs of characteristic-indicators, presented as statements, which they considered to be important to the effective seismic risk reduction of non-engineered buildings. These were rated on a five-point Likert scale as follows: 5 for very important to 1 for absolutely not important. From a total of 875 questionnaires distributed to respondents throughout Indonesia, 305 usable completed questionnaires were acquired, reflecting a 35% response rate. The researchers-scientists group and contractors' group responded best with a 62% and 44.5% return respectively. This was due, principally, to close contact with these particular respondent groups. The questionnaire survey was followed by a series of semi-structured interviews with 9 respondents, reflecting each of the 9 groups of stakeholders and allowed detailed discussion of individual experiences and a more enhanced understanding of events, issues and concerns.

FINDINGS

The findings from the research data address each of the objectives stated previously, as follows:

Key elements within the regulatory, technical and social dimensions of building practice in Indonesia that generate risk to non-engineered buildings in earthquake regions

The data highlighted fifty-seven elements, or characteristics, associated with the effective implementation of seismic risk reduction for non-engineered buildings, or SRRNEB. These included fifteen technical interventions and forty-two non-technical aspects, predominantly human responses. These elements formed sensibly into twelve groups of elements: (i) hazard analysis; (ii) risk assessment; (iii) policy and planning; (iv) legal and regulatory framework; (v) organization structure; (vi) resources; (vii) information management and communication; (viii) education and training; (ix) public awareness; (x) research; (xi) social and economic development practices; and (xii) physical measures. The data obtained reflected the respondents' views and opinions of the importance of the characteristics within and across the groups, highlighting elements requiring particular attention when considering risk reduction.

Prominent 'technical' elements include: information on earthquake occurrence, scenario and impacts which falls into the group denoted hazard analysis; inventory data on geology which falls within the risk assessment group; the development and enforcement of building codes which comes in the legal and regulatory framework group; and development planning within the policy and planning group of elements. Prominent 'non-technical', or human response, elements include: resource mobilization which falls into the resources group; coordination of government bodies which comes within organization structure; awareness enhancement within the group education and training; and dissemination of indigenous knowledge which comes within the public awareness grouping.

Respondents were clear that while the technical elements were vitally important yet well known and understood the non-technical elements were also considered prerequisite but were generally less well appreciated and understood. When considered as groups of elements it was seen that respondents assigned higher priority to technical interventions than non-technical human orientated elements. This occurs, probably, due to their familiarity with those elements, their previous experiences of those elements and also that respondents likely felt more comfortable highlighting elements for which they had less direct responsibility.

Perspectives of key stakeholders in relation to the importance of the identified elements to be implemented to reduce risk to non-engineered buildings

The data highlighted a number of influential perspectives of the key stakeholders, as follows:

- Limited knowledge
- Inability or unwillingness to share knowledge
- Reliance on tradition and familiar viewpoints

Developing links between scientific, subject-specific and personal knowledge develops a capacity to shift latent knowledge to dynamic action and disseminate experiences to a wider audience. It became clear from the respondents that this was not happening but rather that understanding and activity was locally based in terms of geography and people with little, if any, widespread dissemination. As such, a piecemeal approach was being taken in all respects with no sharing of lessons at community, local or national levels, which confirmed the study by Comfort (2002). This means that technical interventions were considered first and foremost because of familiarity and tradition and non-technical aspects ignored really through lack of knowledge and understanding. Many respondents reported that technical knowledge and capabilities rested with the building contractors' tradesmen and that there was a natural reluctance to share information with other stakeholders in the building process. As such, inappropriate practices would go unnoticed or unregulated, essentially earthquake resistance was not in-built at all but either consciously or unconsciously left out.

Principal reasons why seismic-related building codes are not applied more readily to non-engineered buildings

The data highlighted three key factors of influence explaining why appropriate building codes are not applied more readily to non-engineered buildings:

- Lack of knowledge by building contractors
- Lack of earthquake data
- Lack of understanding of the Government's role

Respondents suggested that a prominent reason for not applying seismic building codes more readily was that those tradespersons involved in constructing residential dwellings simply do not know how to build an earthquake resistant structure. The quality of workmanship was largely dependent upon the inherent practices of individuals who relied upon custom and tradition for their input rather than reference to building standards and specifications. The lack of technical knowledge matched by appropriate abilities was highlighted as a major shortcoming. This triangulates with the views of Petak (2002) and Wenzel (2006) as outlined in the literature reviewed earlier.

It was also clear that difficulties emerged from the lack of general information on earthquake likelihood and location. Scientific information on local geological conditions and seismic history clearly exists yet its availability was lacking and inclusion into local planning absent. This meant that community and regulatory awareness was at a low level and ignored when planning residential building development. This is consistent with the views of Comfort (2002), Ngoedijo (2003 and ISDR (2003).

A lack of awareness of the specific and wider roles of government bodies was also highlighted. Regulation and control of building activity was seen to be weak such that compliance with building codes is not well monitored and enforced. Also, government policies appeared to be far removed from those difficulties explicitly associated with non-engineered construction and the activities of the stakeholders involved. Because government bodies have tended to remain somewhat distant from the real issues, information management and communication, and organization structure has tended to be understated and widespread education and training has become stifled.

All of this has meant that awareness, knowledge and understanding of building codes has really remained at a low level and their application to design and enforcement during construction has not been widespread and effective.

Actions which might be taken to improve practices in the design and construction of non-engineered buildings

The data highlighted many key areas where positive action might be taken to improve practice. These involve important contributions from each and all of the stakeholder groups and the careful and comprehensive consideration required for and across the many elements identified. The prominent actions are that:

- The Government (local and national) must take a prominent, stronger and leading role in ensuring pre-emptive management of earthquake-resistant design and construction;
- There must be frequent, timely and reliable information on earthquake risk available to building stakeholders through effective communication mechanisms;
- A robust framework of risk assessment must be a part of building legislature and regulation;
- Risk reduction for non-engineered buildings, and indeed for all construction, must become an intrinsic part of development policies;
- Designers and builders must have the necessary knowledge and competences to deliver earthquake-resistant construction end-products;
- Earthquake-related technology and practice must evolve through appropriate education and training routes;
- Greater awareness of earthquake-related matters must be ensured by all stakeholders to the building processes, and from a broader perspective there must be greater owner, occupier and widespread public awareness;
- Research must form the core of interrelated interests in building-related earthquake science, technology, policy, legislature, procedures and practices.

It is apparent that the role of government is becoming increasing critical to the matter of earthquake response. Also, the role of the builder in non-engineered construction was seen to be vitally important. Seismic risk is a real fact for those who live in earthquake-prone areas and the occurrence of a seismic event is not always predictable or avoidable. People have no option but to live as harmoniously as one can with the risk. In this sense, a good awareness of those risks together with a better understanding of earthquake phenomena and characteristics is of the highest importance, underlying those initiatives which seek to reduce apparent risk. Such approach would go some way to answering the questions raised by Comfort (2002), Shah (2002) and IDEA (2005).

Earthquake data in Indonesia is available to key government staff, select researchers, and subject specialists, but it is not widespread among local building practitioners or community stakeholders. Public institutions, the wider population and local communities appear to have a low level of awareness of risk and do not have an affordable means to reduce it and negate the risk, leading to un-preparedness toward disaster.

Moreover, the primary data highlighted that to break the reluctance of communities to implement seismic codes, the decision makers cannot simply give seismic code manuals or practical training to local builders and expect them to be rigorously implemented. If local populations have a greater awareness of potential risk, equipped with better understanding of appropriate data, they will be in a position to strive to implement building codes voluntarily as suggested by Winarno et al (2007).

CONCLUSIONS

Earthquakes are a feared yet accepted phenomenon, posing a real threat for almost all Indonesian communities. This threat is related intrinsically to the susceptible geology of the region and therefore the inevitability of earthquake risk is ever present. Indonesia can but live as harmoniously as possible with such risks as earthquakes can occur at any time and without any warning. When earthquakes do occur their effects are catastrophic, bringing destruction and loss of life. Although earthquakes cannot be prevented, modern science and engineering provides building techniques which can be used on a wide range of construction types to reduce their effects. As reflected in this paper, many buildings in Indonesia are particularly susceptible due to a severe lack of robustness in design and construction. In highly populated communities where such non-engineered building is the indigenous and most widespread form of construction for residential dwellings effective action to reduce earthquake effect is absolutely essential. The application of earthquake-resistant, or seismic, building codes to non-engineered construction is a positive step to improving the safety of property and people in earthquake regions.

Much of the problem is exacerbated by a clear lack of awareness for and understanding of basic earthquake-resistant design and construction applied within the Indonesian building industry. This is true not only to builders of self-built domestic homes but extends to those organisations who plan, design and build residential provision on a commercial scale. The research confirms much of the literature in this regard and augments those calls for much greater community and stakeholder understanding of and involvement with the issues highlighted in both research and government studies conducted over the last decade.

This paper has shown that a detailed understanding of non-engineered design and construction together with a greater appreciation of the underlying dynamics of stakeholder perspectives and actions will allow the elements significant to earthquake risk reduction to be better understood. Applying the appropriate combination of technical and human interventions to earthquake events will, over time, facilitate the development of better risk reduction measures where the effective implementation of earthquake compatible building codes can become intrinsic to Indonesian construction practice. In addition, some elements of the knowledge and experiences reflected in this paper will also be of interest to other countries within the SE Asia region where earthquake events pose an ever present risk.

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