EARTHQUAKE HAZARD CENTRE
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ROBINSON

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Contents

Editorial: When will we ever learn?

I write about two weeks after the shorelines of Samoa were devastated by tsunami and Padang, Indonesia, was struck by a Magnitude 7.6 quake. The losses in Padang are particularly heavy. Thousands of people were killed and injured, and thousands of buildings and houses collapsed.

As I reflect on the Padang tragedy, I recall how that in the early 1980s when I was living in Indonesia for over two years, I headed up a week-long course on earthquake resistant design in Padang. The course content was based upon the then new Indonesian seismic code, newly prepared by a team of New Zealand structural engineers in conjunction with local counterparts.

This was Indonesia's first code to incorporate the philosophy of Capacity Design. Now, for the first time Indonesian engineers had the potential to design buildings that, when experiencing seismic overload, would not collapse. Some of the key concepts that were communicated included:

- columns to be stronger than beams,
- columns and beam-column joints must never fail in shear,
- stirrups and ties should have 135 rather than 90 degree hooks to guarantee their effectiveness after cover concrete has spalled off, and
- the dangers of infill walls and methods to design and construct them safely.

As I reflect upon that course and the recent destruction I am reminded of the famous song "Where have all the flowers gone?" popularised by Peter, Paul and Mary in the early 60's. The chorus contains the haunting refrain "Oh, when will we ever learn, oh, when will we ever learn?"

In the context of earthquake engineering, the question is "When will we learn to design and build so that our buildings are safe in earthquakes?" or expressing it another way, "When will the very structures, designed and constructed to provide shelter, no longer be agents of harm?"

These thoughts are not intended to criticise design and construction practices in Indonesia, but rather to acknowledge the challenge of changing the way we do things; the ways we design and build. Resistance to change seems a deeply embedded characteristic of the human condition. It is tragic when what is being resisted has the potential for improved safety and human well-being.

May those of us in the world of earthquake engineering keep pushing for and introducing changes that lead to increased building safety. May there be learning about how to improve seismic safety and may it be applied.

Virtual Site Visit No. 18: An Apartment Building, Wellington, New Zealand

In this eight-storey apartment building, steel framing supports all suspended floors and the roof, as well as resisting transverse wind and seismic forces. Longitudinal forces are resisted by shear walls that are constructed from strongly connected precast concrete panels on both sides of the building (Fig. 1).

Six steel moment frames are placed along the building length. They support floors and resist lateral forces. Near the middle of the building two of these frames are transformed into eccentrically braced frames by the addition of inclined struts (Fig. 2). While these are stiffer than the pure moment frames, under torsion effects the end moment frames resist similar amounts of force. Due to the narrowness of the site and the relative flexibility of the frames it was necessary to limit the amount of lateral drift. So they were designed for elastic rather than ductile response.

In the longitudinal direction, three concrete shear walls provide resistance. The large wall (Fig. 1) is supplemented by two shorter walls on the other side of the building (Fig. 3). The walls are constructed from 175 mm thick precast panels joined along their vertical edges by plates welded to cast-in steelwork. Horizontal connections between the storey-high panels take the form of grouted-in deformed steel rods. The structural walls were also designed for elastic response resulting in the stiffest and strongest structural solution. The walls rise up as vertical cantilevers from pile caps connected to the tops of two or three steel screwed-in piles. The structural walls are seismically separated by narrow sealant-filled gaps from the bottom two floors of reinforced concrete masonry exterior walls. To keep the building weight to a minimum, exterior cladding and interior walls are light-weight.

Fig. 1 The building under construction showing the one-bay steel moment frames and an RC shear wall.

Fig. 2 One storey of an eccentrically braced frame.

Fig. 3 The finished building with the two narrower shear walls.

Selected excerpts from "Implementation of Structural Earthquake-Disaster Mitigation Programs in Developing Countries"

by Roberto Mel and Sergio M. Alcocer from Natural Hazards Review, February 2004, pp. 29 - 39

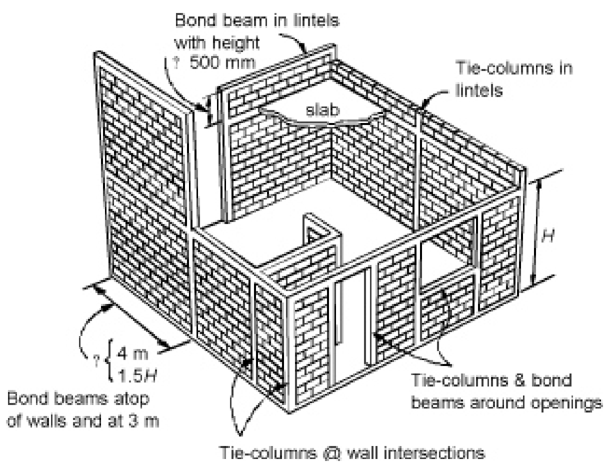

Fig. 4 Main characteristics of confined masonry.

NON-ENGINEERED CONSTRUCTION

In general, in the aftermath of an earthquake where vast destruction of unreinforced masonry houses has occurred, the original construction processes, and even the debris, have been used to reconstruct dwellings without any positive modification to increase their safety. In contrast, the reconstruction program developed after the 1993 Maharashtra, India, earthquake is an example of a recent success (Nikolic-Brzev et. al. 1999). The reconstruction of destroyed buildings using superior structural layouts and materials, as well as the enthusiastic and committed participation of beneficiaries from the initial planning to the post-implementation evaluation of the program, are key features that made this program successful. A significant contribution of this program was the qualification of the victims as beneficiaries of the aid. Additionally, the Maharashtra earthquake reconstruction actually promoted, on a major scale, training and education programs for masons at a local level. Thousands of local masons and artisans were trained, as were many hundreds of engineers. It is convenient to carefully study these examples where significant improvements of seismic safety have been attained, in order to identify the factors that contributed to the total or partial success and to apply those factors in new migration programs.

Confined Masonry and Reinforced Masonry

The use of some type of reinforcement is probably the single most effective means of reducing earthquake damage of masonry construction. Confined masonry and reinforced masonry are prime examples (Figs. 4 and 5). Both types of masonry systems are commonly used in engineering construction of dwellings. Analysis, design, and construction methods and requirements are available for those systems, based on structural mechanics and experimental evidence. Confined masonry and reinforced masonry are also found in non-engineered construction with the aim of overcoming the seismic deficiencies of unreinforced masonry. In this case, as is characteristic of non-engineered construction, wall reinforcement and detailing typically depart from code requirements. The evolution of the two types of masonry have been quite different, giving rise to distinct conditions of vulnerability in non-engineered construction.

Since the beginning of last century, walls confined with vertical and horizontal reinforced concrete elements, bond beams, and tie-columns around the perimeter were included in the reconstruction of some cities that were practically destroyed by earthquakes such as in Messina, Italy, after 1908. The initial objectives of the confining elements were to tie the walls, floors and roof together and to provide out-of-plane flexural strength.

This led to the development of the confined masonry structural system. Over the years, its use in non-engineered construction has steadily increased, not because of organized and systematic promotional efforts, but because of its satisfactory performance under successive moderate and intense earthquakes. Since then, confined masonry has been adopted in several countries, especially in southern Europe and Latin America. The system was adopted in Mexico City in the 1940s to control the wall cracking caused by large differential settlements in the soft soil of the central portion of the city. Several years later, after examining its excellent seismic performance, this system became popular even outside the soft soil area and in other villages in the zones of highest seismic hazard.

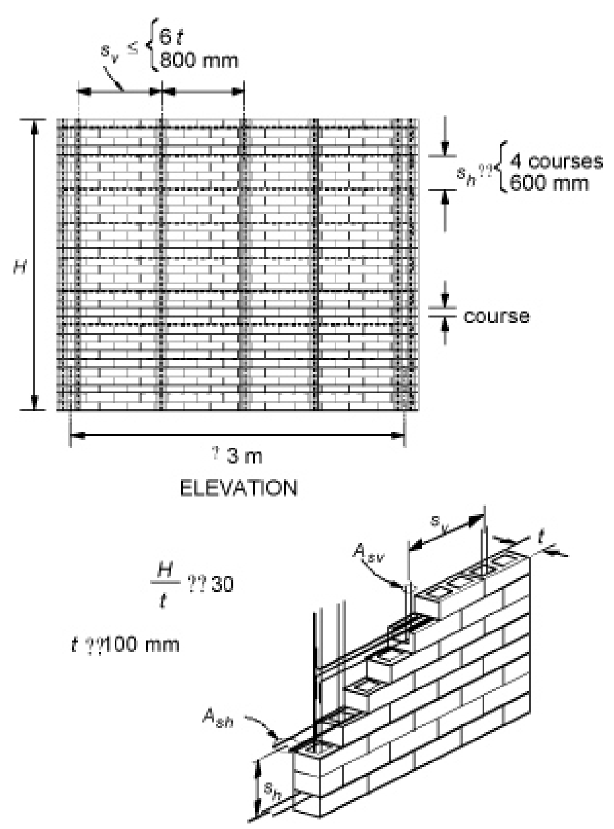

Fig. 5 Schematic view of masonry with internal reinforcement.

It must be pointed out the confined masonry has evolved essentially through an informal process based on experience and that present code requirements and design procedures are mostly rationalizations of the established practice, even after thus has been validated by structural mechanics principles and experimental evidence. In this situation, non-engineered constructions are not intrinsically more vulnerable than engineered construction. In general terms, a larger number, and more robust and more heavily reinforced tie-columns and bond beams, are found in non-engineered construction than in engineered construction.

To illustrate the positive effects of some minimum confinement reinforcement in masonry houses in reducing their vulnerability, two case studies are described, each quite distinct from an organisational and decision-making point of view.

In the south of Chile, after repeated earthquakes that had destroyed adobe houses, mainly in rural villages, adobe was forbidden as a construction material. In lieu of adobe, confined brick or block masonry was promoted. The new construction practice was rapidly disseminated and widely applied. The result was a noticeable reduction in the damage inflicted by subsequent earthquakes (Monge 1969). In this example, earthquake engineering specialists and government authorities decided upon and implemented a reliable construction practice through an organized effort.

The second case is that of Huajuapan, a village located in central Mexico that suffered extensive destruction during a local earthquake in 1980. Apparently as a spontaneous result of the good performance of a few confined masonry structures nearby, a large number of destroyed adobe houses were replaced mainly by dwellings made of confined masonry.

In June 1999, an earthquake of equal magnitude occurred in the same region, causing severe damage to houses in several villages. Damage recorded in Huajuapan, however, was substantially smaller than that observed in neighbouring towns, where traditional unreinforced masonry was still in use. This case illustrates the importance of promoting superior structural systems when damaged or destroyed houses are to be rehabilitated or rebuilt.

Several characteristics of the Huajuapan case study on confined masonry should be emphasized and considered in the development and implementation of disaster-reduction programs: (1) The dissemination of the confined masonry system was based on clear evidence of its superior performance under severe earthquakes; (2) it was easily accepted because previous construction practices were not significantly modified, because its execution was relatively simple, and because its impact on the cost was small and (3) the advantages of the system were rapidly understood by users, with no need for arguments clear only to specialists.

Unlike confined masonry, unreinforced masonry (Fig. 5) has been developed on an engineering basis, where quantitative design procedures (consistent with structural mechanics), as well as efficient and almost industrialized construction processes have been followed. As in confined masonry construction, masonry's intrinsic weaknesses are addressed through the use of vertical and horizontal internal grouted reinforcement. Such bars additionally increase in-plane wall shear strength and deformation capacity, and help tie the transverse walls and floors together.

Although reinforced masonry is the prevalent system for new masonry construction in some developed countries (such as the United States, Japan, and New Zealand), its technology has not been properly transferred to developing countries, particularly in non-engineered construction, where several major failures have been documented as a result.

Examples of inadequate performance of reinforced masonry in developing countries cannot be attributed to any shortcoming of the system itself, but rather to substandard construction practice, and (in few cases) to gross construction errors. Common examples of substandard practice are low percentages of vertical and horizontal reinforcing bars (as typically observed in non-engineered structures) and, more often, incomplete filling of grout in hollow blocks. In this regard, it is important to recognized that reinforced masonry is not a construction system amply suitable for inspection, because deficiencies cannot be easily detected and isolated.

Inadequate or substandard construction has more to do with a lack of understanding or conviction as to the positive role of reinforcement on wall behaviour, than with negligence or cheating. This again suggests that the effectiveness of a construction system depends on cultural or social factors, in addition to technical merits. In this regard, awareness programs focussing on the need and benefits of key structural features (such as the proper placement of wall reinforcement) should be implemented at the local level.

The earthquake in Techuacan, Mexico, in 1999 confirmed that, while widespread damage or collapse occurred in masonry houses with internal reinforcement, confined masonry behaved much better (Alcocer et. al. 2001).

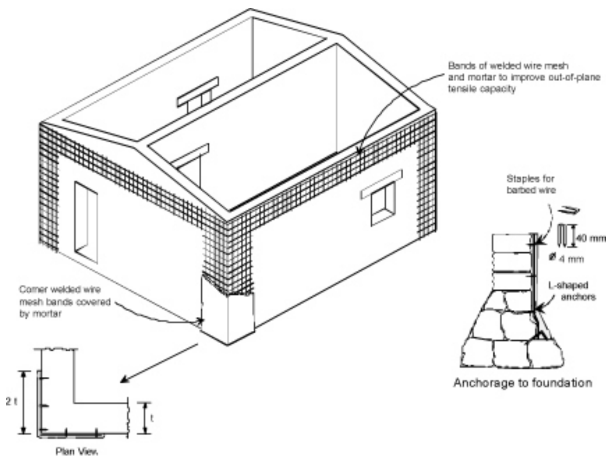

Fig. 6 Strengthening of unreinforced masonry houses with wire mesh bands.

Seismic Rehabilitation of Rural Construction

All methods previously discussed for reinforcing masonry walls are applicable to new construction. However, many of them are also appropriate for building rehabilitation. Many efficient and inexpensive procedures have been developed for upgrading existing houses that either have been damaged by an earthquake or, as with most masonry construction, are clearly unsafe. Although these rehabilitative procedures vary in complexity and cost, most are based on improving the in-plane tensile strength of walls and on tying them together to avoid out-of-plane failure. One efficient and cost-effective technique is the addition of steel welded wire meshes, ether completely jacketing the walls or placed along the wall edges in the form of bands (Klingner 2000) (Fig. 6).

Despite many attempts, rehabilitation of vulnerable houses has been successfully implemented at a larger scale in only a few cases. There are many reasons for this. In developing countries, urban design professionals who are unaware of local materials and practices have typically developed seismic vulnerability-reduction programs. One lesson that could be drawn from this is that vulnerability-reduction programs should be organized at the local level and should promote solutions similar to local practice and materials, with clearly understandable and advantageous structural behaviour.

The Encyclopedia of Housing Construction Types in Seismically Prone Areas of the World (EERI 2002), which is being co-developed by the Earthquake Engineering Research Institute and the International Association for Earthquake Engineering, is expected to be an important asset in this regard. This electronic document is a database accessible via Internet that includes key structural, architectural, and socio-economic features of typical seismically vulnerable housing throughout the world. Damage statistics and experiences with rehabilitation schemes in different parts of the world are of importance to decision makers, the insurance industry, international aid agencies and banks, civil protection authorities, and urban planners interested in vulnerability reduction.

Conclusions and Recommendations

1. In general, poor performance of buildings in major earthquakes can be partially attributed to insufficient transfer of knowledge, technology, and expertise to designers, contractors, and construction practitioners. Lessons learned over time seem to remain in the custody of academics and a few practitioners.
2. For non-engineered buildings, mere code enforcement cannot be considered as a viable solution to reduce their seismic vulnerability. Dissemination and training programs must be designed, as proposed in conclusion 3.
3. To mitigate the seismic vulnerability of non-engineered buildings, the following recommendations are made:
   - Encourage the participation of housing owners (beneficiaries) as stakeholders in different stages of the vulnerability-reduction program, with emphasis on the construction process itself.
   - Promote the use of structural solutions akin to the local practice, but with superior performance based on their improved layout, materials, and structural features.
   - Develop training and educational programs for masons at the local level, and encourage the participation of local universities and professional associations.
   - Take advantage of periods of hyperreceptivity immediately following severe earthquakes.
   - Develop pilot studies on a small-scale level, where conditions and results can be used as feedback.
   - Disseminate case studies of success attained in similar areas and conditions to potential beneficiaries of this program.
   - Implement economic incentives, mostly related to supplying suitable materials at reduced prices and to temporary employment programs for masons, tied to organized educational programs intended to improve quality and construction knowledge.
   - Link vulnerability-reduction efforts to other efforts aimed at improving housing habitability and durability, and at reducing poverty. In all cases, it is important to remember that safety is an ethereal concept, not easily understood and even more difficult to sell to a population with serious unmet needs in their everyday lives. Nevertheless, it can be better sold if it is companied by tangible daily benefits.

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Summary of "Handbook of good building design and construction – Aceh and Nias Islands" published by the Secretariat of the International Strategy for Disaster Reduction (www.unisdr.org) and the UNDP Regional Center in Bangkok (http://regionalcentrebangkok.undp.or.th), 2007

Introduction

The Handbook of good building design and construction was based on concrete reconstruction experiences in tsunami hit in Aceh and Nias in Indonesia. It provides useful information to home owners, house designers, builders and construction monitors. It explains how to design and build houses in such a way as to resist major natural hazards such as earthquakes and floods.

It is hoped that the handbook will not only be useful in Indonesia but also in other disaster vulnerable countries. As well, the handbook explains eight design principles and eight construction and material principles in a simple language, supported by photos of good and bad practices in housing construction. The handbook is a contribution to the ongoing international effort in guiding communities to integrate risk reduction in reconstruction process.

Fig. 7. Concrete foundations which have been well drained and well laid on sand using sufficient cement.

Fig. 8 Ends of steel reinforcing bent at 135 degrees for earthquake resistance.

Fig. 9 A good example of wall ties which are inserted into columns before they were made.

The handbook can be used as an easy tool to increase understanding and knowledge of those individuals and organisations that will be involved in the post-disaster rehabilitation and reconstruction of individual houses and public facilities, such as schools and health centres.

Design Principles

The handbook clearly explains eight design principles for quality construction in terms of building back better and stronger. The eight principles are; foundations, coherent building structure, joining walls to roof structure, tying walls to building structure, roof truss ties, cross bracing of walls and roof, drainage principles and house elevation.

Construction and Materials Principles

The handbook also explains eight construction and material principles imperative to the safety of building dwellers. These principles are; foundations, sand and gravel, mixing concrete, making columns, reinforcement, roofing, tying walls to structure, and wells and septic tanks.

Announcement: Third International Earthquake Symposium, Dhaka, Bangladesh, March 5-6, 2010

The Bangladesh Earthquake Society jointly with Bangladesh University of Engineering and Technology will be organising the Third International Earthquake Symposium, Bangladesh (IESB-3) to be held in Dhaka on March 5-6, 2010.

Since its inception in 2002, the Bangladesh Earthquake Society has organised two symposiums. The First Bangladesh Symposium (BES-1) was held in 2005, and the Second International Earthquake Symposium (IESB-2) was held in 2007.

The Third International Earthquake Symposium aims to bring together professionals from different regions to present and discuss various topics related to earthquake engineering, seismology and earthquake disaster management. The objectives of the symposium are to promote activities related to preparedness against, and mitigation of, earthquake risk.

The organisers of the symposium expect participation from a wide group of professionals including engineers, geologists, planners, architects, disaster managers, government officials as well as social scientists. Accordingly, the organising committee invites you to participate in this conference which will address a wide range of topics related to earthquake disaster mitigation. For further information, contact Raquib Ashan, Organising Secretary, IESB-3 on iesb3dhaka@gmail.com. The deadline for submissions is December 31 2009.

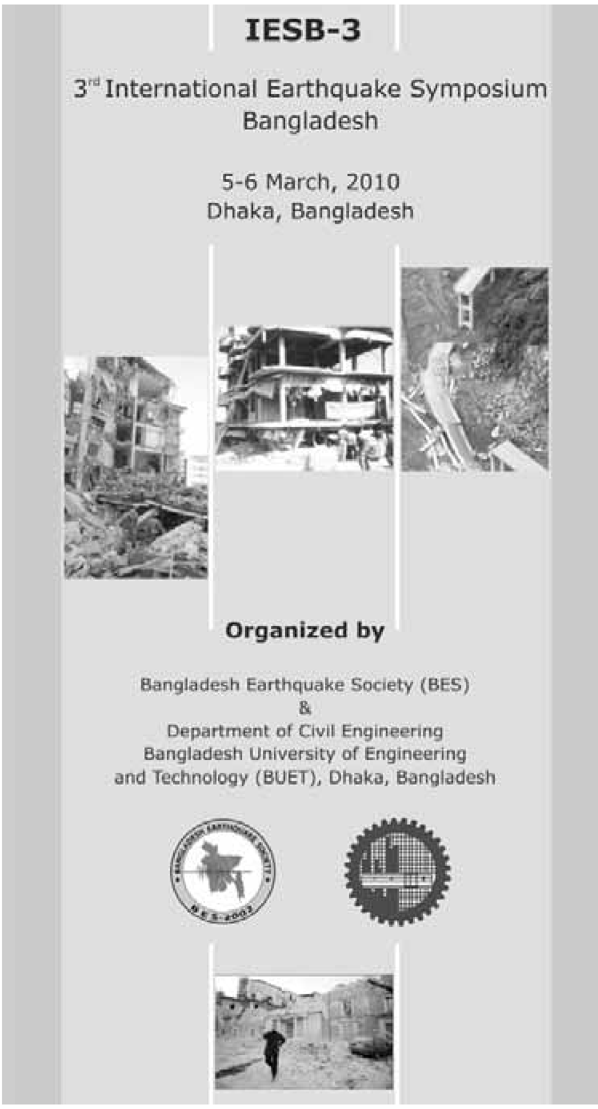

Fig. 10 Cover of the circular promoting the 3rd International Earthquake Symposium in Bangladesh.

Earthquake Hazard Centre
Promoting Earthquake-Resistant Construction in Developing Countries

The Centre is a non-profit organisation based at the School of Architecture, Victoria University of Wellington, New Zealand. It is supported financially by Robinson Seismic Ltd.

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