EARTHQUAKE HAZARD CENTRE NEWSLETTER

The Commonwealth Network for Earthquake-Resistant Construction in Developing Countries

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Editorial

Seismic initiative in Nepal

The major article in this newsletter reports on the Kathmandu valley seismic safety of schools project. The paper, from which the article has been summarized, was first presented at the 2002 annual New Zealand Society for Earthquake Engineering Technical Conference. It was well received by delegates. They appreciated the considerable social, technical and financial difficulties faced by the authors and others attempting to upgrade hundreds of seismically vulnerable schools.

As the article points out, the seismic vulnerability assessment of the school buildings portrays a frightening situation. Over 29,000 teachers and children are at risk of losing their lives, with another 61,000 likely to be severely injured. This scenario is not unrealistic either. It is based on expected damage from an earthquake with a reasonably low return period of 100 years. (Most developed country codes are based on design earthquakes with a return period in the order of 450 years!)

It would be interesting to know if any Nepalese politicians were made aware of these statistics, and if so, what was their response? No doubt the schools' disseminate information. Hospitals and health clinics play a similar but smaller role due to their lesser impact on people's daily lives.

The Earthquake Hazard Centre congratulates the authors on their initiative. We belief the approach outlined in the paper is excellent. It is worthy of further study and possible replication in other seismically active developing countries.

Base-isolation

Another article describes the base-isolation of the new Bhuj Hospital, India. The former building was destroyed in the devastating January 2001 quake. The principles of base-isolation are quite simple; increase the natural period of the building so that short period ground vibrations have little effect, and increase damping to reduce ground floor displacements and wind movements. Lead rubber bearings are also reasonably unsophisticated in that they are 'passive' devices, requiring virtually no maintenance.

From a philosophical view, base-isolation is the best possible method of providing seismic resistance. It is particularly suited for buildings needing to function immediately after an earthquake. The relatively small additional cost of the hospital bearings will surely be saved many times over during the next quake to hit Bhuj.

vulnerability mirrors that of most surrounding buildings in the Katmandu valley. But to their credit, the authors concentrated on just one building type - schools, in the knowledge that lessons learned from upgrading them can be transferred to other building types. Their choice of school buildings is very strategic. Not only do societies value children's needs greatly, but schools are often the foci of communities and hence are ideal institutions from which to

EHC Future

In the previous newsletter, January 2002, the Centre’s financial uncertainty was outlined. Since then a New Zealand company has offered some financuial support. However, there is still a long way to go before the Centre can be certain of its survivial. So we would like to hear from you if you have any suggestions that might enable the Centre to continue.

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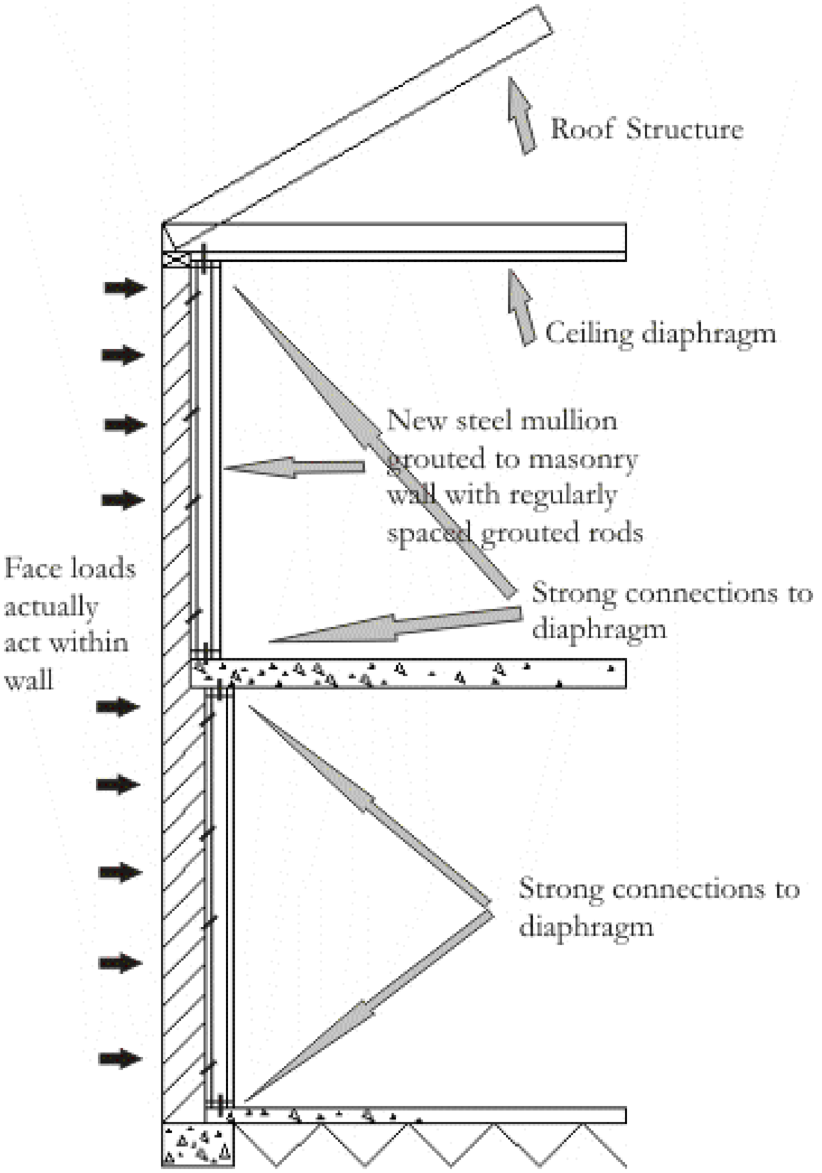
NEWSLETTER INDEX

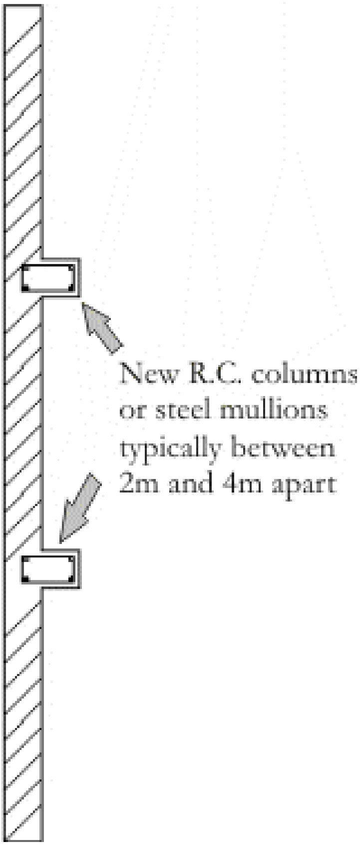
Principles of Building Earthquake Resistance No. 20

Providing face load resistance of masonry walls in existing buildings

If an evaluation of walls suggests they might fail under earthquake face loads then provide the following load path:

1) Inertial face loads caused by earthquake accelerations are resisted by short lengths of existing wall and transferred to new vertical members
2) These new practical columns or steel mullions resist horizontal wall loads and transfer them up and down to be resisted by floor or ceiling diaphragms
3) Diaphragms resist horizontal column or mullion forces and transfer them to (new?) vertical structure resisting horizontal loads





Typical section through an upgraded building

Plan of a face load upgraded wall

Notes:

1) If possible, place new columns or mullions directly on top of each other. If the wall becomes badly damaged, the new members will help transfer gravity loads and might prevent collapse.

2) Columns or mullions are necessary on all vulnerable walls, both exterior and interior. Due to the random directionality of earthquake shaking, each length of wall can expect inertial face loads.

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Base-isolation technology in the rebuilding of a hospital in Bhuj, India.

A hospital destroyed in January last year in India is being rebuilt using New Zealand engineering skills and technology. Base-isolation of the new building will protect not only the building, but also the equipment within. This means that after a serious earthquake, the hospital will be able to continue functioning in its vital capacity.

Construction commenced in October to rebuild the destroyed Bhuj Hospital, in the state of Gujarat. The hospital was one of many buildings in the area that collapsed in the January 26 earthquake. Doctors who staff the hospital survived because they were taking part in an Independence Day parade, but nurses and patients were killed.

Engineering advice and technology is being provided to the project under the auspicious of the Wellington Earthquake Cluster. This is a collaboration of local consultants, researchers and manufacturers.

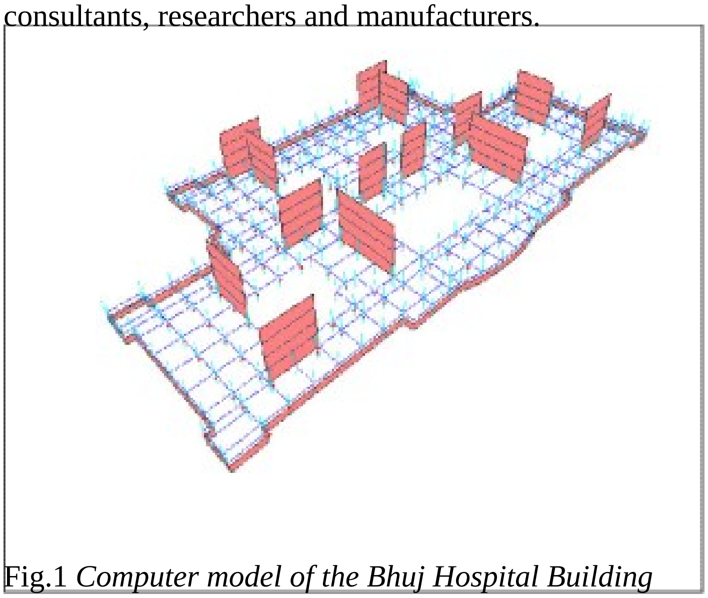

Fig.1 *Computer model of the Bhuj Hospital Building with Floors removed so that bracing walls can be seen.*

Base Isolation

The inclusion of base isolation means that a building is cushioned against the shocks of earthquakes. Instead of designing the building to resist high earthquake forces, the isolation system is designed to allow the building to stay more or less still while the ground moves

equipment are often left in piles on the floor.

Bearings

At the heart of most base-isolation systems are lead and rubber bearings. These are designed and manufactured specifically for each building project so that the whole system can be “tuned” for optimum earthquake performance. The rubber in the bearings allows sideways flexibility which cushions the shaking, while the lead flows like hot liquid as the rubber deforms during shaking and absorbs energy, further reducing potential damage from the earthquake. Lead/rubber bearings were invented in the seventies by New Zealander Dr Bill Robinson, and his company, Robinson Seismic, manufactures them today.

The hospital when constructed will have a total floor area of about 50,000 square metres, with a basement area in addition. The bearings will be placed under the ground floor, on top of the basement columns. The basement area is used as habitable space, so the detailing of the building around the bearings has to provide for treating the bearings aesthetically.

The building has 280 columns, of which 180 are supported on lead-rubber bearings with the balance on sliding bearings. The isolation system was designed to provide the same level of seismic protection to the building that would be expected of a New Zealand design, at the lowest cost.

The building is generally constructed of reinforced concrete, although thin precast concrete floor panels are used for the upper-level floors. These are covered with a mesh-reinforced structural topping and supported on a system of steel trusses and beams. At ground-floor level, where diaphragm stresses are higher, an in situ concrete floor slab is being used. The building will be braced by reinforced concrete walls distributed around the floor plate. (Fig.1) underneath it in strong earthquakes. As a result the building need only be designed for much smaller forces.

Crucially, because the building isn't shaking much, neither are the things inside it. That means that normal operations in the building can continue. By contrast, in most conventional buildings, even if the building survives strong shaking the furniture, files and

Fig. 2 Appearance of finished building

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Summary of the paper: Seismic Safety of Schools in Kathmandu Valley, Nepal: Problems and Opportunities,

by J.K. Bothara, A.M Dixit, M. Nakarmi, S.B. Pradanang, and R.C. Thapa.

This paper was presented at the New Zealand Society for Earthquake Engineering Annual Conference, Napier, 15-17 March, 2002

Introduction

There are 643 public schools in the Kathmandu, Lalitpur and Bhaktapur districts of Kathmandu Valley. These range from pre-primary to higher-secondary levels, with multiple buildings in most school campuses. The Kathmandu Valley School Earthquake Safety Program (KVSESP), a component of KVERMP, collected information on some 60% of these schools and assessed vulnerability of more than 900 buildings. Seventy-eight percent of these buildings used typical Nepali construction techniques. The rest are standardized two-room steel sheds constructed by the Earthquake Affected Area Reconstruction and Rehabilitation Project (EAARRP) after the magnitude 6.4 Udaypur earthquake of 1988.

School safety has been considered as a path to the safer community, with the greater goal of introducing seismic safety as a culture. The methodology seeks maximum involvement of the local community in the overall school earthquake safety programme. Technical and logistic support comes from KVERMP (and presently from NSET-Nepal) for technology transfer to local craftsman, and awareness raising of the community.

School Buildings

Nepalese school buildings are mostly procured by the community itself, employing a local skilled artisan to direct operations. The process is characterized by the high degree of informality-community members make decisions on even the strength factors. In urban areas, some input from technicians is also common because of building permit processes. However, even these

Construction materials for school buildings fall into two groups: traditional and modern (Fig.3). Traditional materials such as earth, stone, timber and bamboo are naturally occurring, and are used with very limited processing or quality grading. These types of buildings, mostly constructed out of municipal areas, tend to be beyond the control of urban building regulations and planning requirements. Cement and steel bars are the modern materials. These were introduced in the late seventies in abundance. The use of these materials is more concentrated in dense urban areas (the valley floor) and in urban fringes where affordability and accessibility to the materials, information and transport is comparatively easy. Traditional materials are common in old buildings in urban areas, and on the outskirts and the valley rim, or wherever affordability and accessibility is low (Figs. 4, 5)

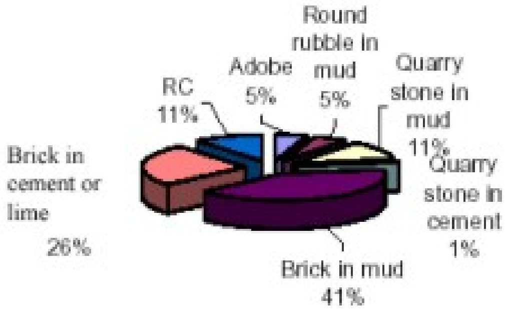

Fig.3 *Walling materials*

A visual inspection of buildings showed that at least 10-15% of them are in a severely bad condition-to an extent that even their use in normal times is hazardous. Crumbling of walls, floors, loss of integrity, and distortion in shape are the common problems. These buildings need immediate demolition and reconstruction. The next 25% are in fair condition, either because of weak construction materials, material degradation, old age, and a low levelof repair and maintenance. These buildings have not lost their integrity and shape. Such buildings can be rehabilitated with some effort if immediate action is taken. The rest of the buildings are in relatively good condition and are safe for vertical loads.

urban buildings do not incorporate earthquake-resistant features. Even those schools funded by foreign donor agencies are not required by the donors to be earthquake-resistant. The larger part of the funds for construction of school buildings also comes from the community. The buildings in rural areas are constructed with very little capital input as the local community provides labour and collects materials, e.t.c.

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The seismic vulnerability assessments done for these school buildings show a very grim situation. Over 66% of the school buildings are likely to collapse, and the next 11% will be beyond repair, if the valley experiences MSK intensity IX shaking. Such shaking during school hours could kill more than 29 000 students and teachers and severely injure a further 61 000. An earthquake producing at least this intensity of the shaking has been experienced every 100 years in the valley, the last time in 1934 (MMI intensity X)

Fig.

Improvement of Building Stock

The fatal earthquake scenario of school buildings could cripple the national economy for not only years, but also possibly decades. However, the loss scenario can be greatly reduced if proper programmes to construct new earthquake safe buildings and upgrade existing are actioned. If the Nepalese do not act now, it could cost thousands of lives and the reconstruction cost may even exceed tens of millions of dollars (Table 1). If we act today, it will have the much longer benefit of improving the overall seismic safety of the community.

Table 1: Benefits of intervention

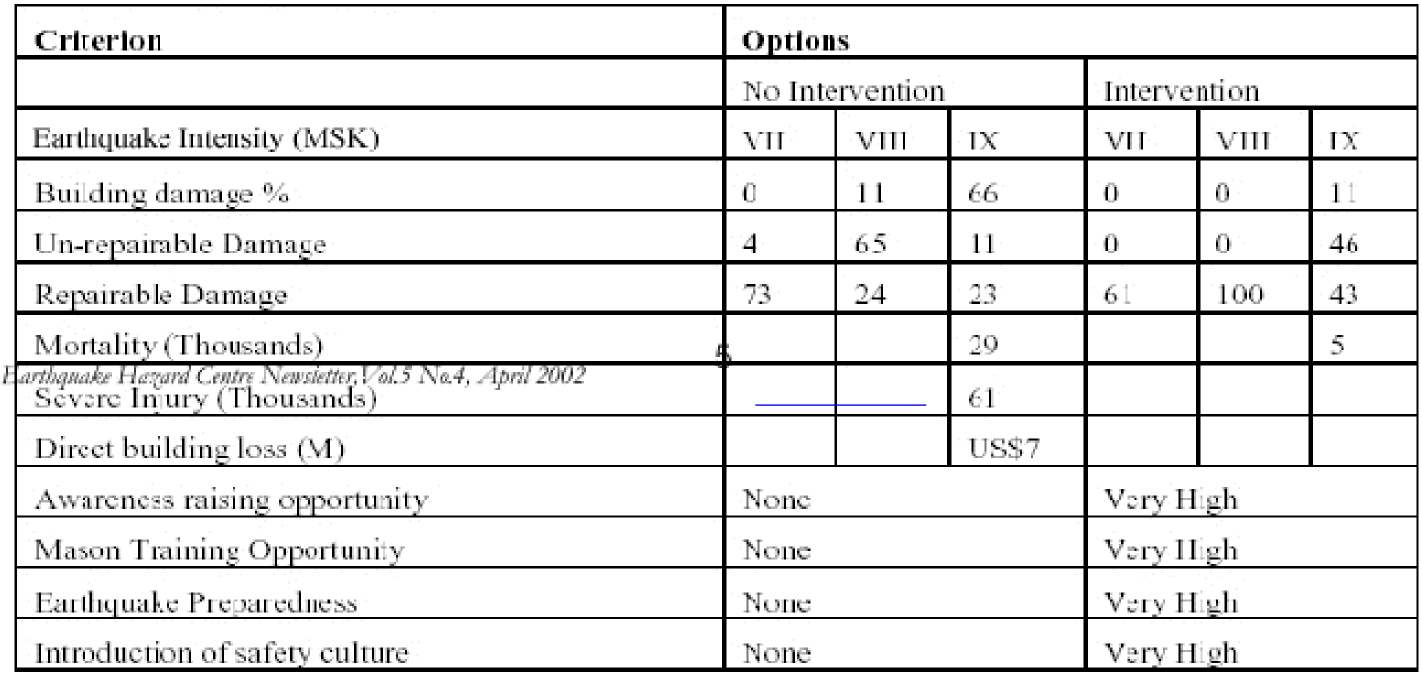
Opportunities

Economic front: The vast majority of the existing school buildings in the Valley will be in use continuously for decades to come. Fortunately, for 70% of the existing buildings in the Valley, retrofitting is a cost effective option. For new construction, seismic safety can be introduced at an affordable cost

Community participation: The work done by NSET-Nepal for improving the seismic safety of school buildings by involving the local community as a major stakeholder has a large impact on the community. People have accepted the technology, as is reflected by the replication of earthquake-resistant construction introduced in school building construction

Craftsman: Artisans could be used as messengers. They can easily bridge the gap between owner-builders and technicians. It is observed that masons are quite receptive to retrofitting and seismic construction. Earthquake-resistant design/construction and the associated quality control and technology can be easily transferred to them. Their lack of an academic background is not a problem. Of course, training needs to be on-the-job, and more interactive and informal rather than through rigid classroom sessions. Such training could be conducted at a very nominal cost as part of construction activity.

Awareness raising: Introducing seismic safety in schools is a great tool to make the student/local community aware. This is because knowledge imparted to children is more sustainable as it will be reflected some 10-20 years later. Furthermore, it has been observed that people who used to take a fatalistic approach now like to discuss issues on seismic safety. This can be considered as a big step forward.



Criterion	Options					
	No Intervention			Intervention		
Earthquake Intensity (MSK)	VII	VIII	IX	VII	VIII	IX
Building damage %	0	11	66	0	0	11
Un-repairable Damage	4	65	11	0	0	46
Repairable Damage	73	24	23	61	100	43
Mortality (Thousands)			29			5
Severe Injury (Thousands)			61			
Direct building loss (M)			US$7			
Awareness raising opportunity	None			Very High		
Mason Training Opportunity	None			Very High		
Earthquake Preparedness	None			Very High		
Introduction of safety culture	None			Very High		

Formal training: Few engineering colleges and polytechnics are eager to have courses on earthquake-resistant design and construction. The problem is they do not have manpower to run courses. They are trying to develop staff who can deliver them.

Building code: The building code is ready for use. It is purposely made incremental in nature so it can encompass both formal and informal construction. It has ready-to-use guidelines for both non-engineered and pre-engineered construction. Similar guidelines have also been prepared for school building construction by NSET-Nepal

Government initiative: The Nepalese government is constructing school buildings as part of some specific projects. There is enough room for the projects to develop their construction activity as a model for dissemination of the technology and information. Of course, it will require much more innovation. Furthermore, the government could require the incorporation of earthquake resistance to be a prerequisite for funding of any school building construction

International initiative: The construction of 43% of school buildings has been funded all or in part by an international organization. In no case did that international involvement translate into making the building safer. In the future, international organizations that support school construction must make sure that all of the schools they fund should incorporate earthquake resistance.

Conclusions

- No radical change is possible. Radical changes will cause unfavorable repercussions on overall construction activity
- Schools are good places to be developed as models for the transfer of technology, dissemination of information, mason training e.t.c., as they are places of common interest, and a large percent of he population affected.
- A back-up training system for the upgrading of masons is necessary in the long term. A similar program for professional designers is also an immense need.
- Involving the community means more sustainable work in the long term.

Preliminary Observations on the Southern Peru Earthquake of June 23, 2001.

A Summary of EERI Special Earthquake Report- November 2001.

Introduction

On June 23, 2001, a Mwe 8.3 earthquake struck near the coast of south-central Peru along the subduction zone between the Nazca and South America plates. There were dozens of strong aftershocks in the region. The southern coastline was affected by a tsunami following the main event.

The National Institute for Civil Defense of Peru reports 77 dead, 68 missing, 2 713 injured, 213 430 people affected, 33 570 houses damaged, and 25 399 houses destroyed.

Structural Damage

Initial surveys indicated that most damage occurred in areas to the east and southeast of the epicenter of the main event and that historic structures and old houses sustained the most severe damage. Adobe houses were most vulnerable. School buildings also performed poorly, except for the few new ones designed to the 1999 code. Most of the damage could be attributed to configuration problems such as soft stories or short-column effects. Both new and older schools with short column problems performed poorly. Schools designed according to the 1999 Peruvian code had isolation details between infill masonry walls and the concrete framing, and thus avoided the short column failures.

Moquega

Moquega was the city hardest hit by this earthquake. The damage there is mainly to old and new adobe houses. Numerous adobe buildings collapsed in the downtown area, and many others sustained heavy damage to the point of being almost unstable. In the area of San Fransisco, the hillside was nearly totaled due to collapse of new adobe houses. One school had a partial collapse due to short columns (Fig.6)

Arequipa

Primarily historical buildings and older stone masonry structures sustained damage. An estimate of 0.10g appears reasonable for the peak ground acceleration in

§ Bottom-up and top-down approaches should be undertaken simultaneously.

Contact EHC for a copy of the complete paper

Arequipa, based on observed damage patterns. Many cathedrals and religious monuments sustained damage. Many traditional domed and vaulted structures were extensively damaged. Most of the historical monuments are made with blocks of sillar (consolidated volcanic ash) laid with lime or cement mortar.

Fig.6 *School building in Moquega. Partial collapse due to short column failure*

Tacna
The University Jorge Basadre in Tacna has two campuses, and some damage was observed in both. In the old campus building, some parapet walls at the fourth floor had to be demolished, since they were unstable in the out-of-plane direction. On the new campus, a three storey building had moderate damage to the infill masonry in the form of diagonal cracking. However, the infill was strong enough to form diagonal compression struts between the beam-column joints, which cracked the corner-column joints in shear on the first and second floors. The poorly detailed columns of the elevated tank located on the roof (fifth floor) had significant damage but did not collapse. The Colegio Nacional Mariscal Caceres sustained extensive damage to approximately 60 short columns in the typical campus buildings. The school principal was building temporary wooden classrooms following the earthquake.

A municipality building outside Tacna suffered severe damage to the short columns and the few masonry walls that existed. The building had typical poor short-

Technical support for repair and rehabilitation of the damaged historic structures, an important part of its international cultural heritage.

Health care system
Hospitals and health centers were damaged in the earthquake. While some of the damage was structural, a great deal of nonstructural and functional damage created problems in providing health care to the affected population. Five hospitals in the region were damaged to some extent. The adobe hospital in the community of Aplao in the Province of Castilla was significantly damaged and completely out of operation.

Plans are currently being studied to replace the hospital in Aplao with a seismically resistant one, and to establish one or two other hospitals in these isolated provinces. In all, 169 health care centers (hospitals and health centers) were damaged or destroyed in the four departments.

Not only were health care buildings damaged and closed by the earthquake, but health care personnel column configuration without any transverse reinforcement, which caused these columns to crush and lose several inches of height. The building is not readily repairable and will be demolished.

The Peruvian National Institute for Civil Defense reports that distribution of relief material is ongoing. Peru may need long-term international financial and

were affected as well. It was estimated that approximately half of the health care personnel in Moquega were victims of the earthquake. Similar numbers of affected personnel are expected in the other four departments

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New Publications

Designing or evaluating steel moment resisting frames?

In the eight years since the 1994 Northridge, Los Angeles Earthquake researchers have been developing more reliable beam column joint details for structural steel members. FEMA has just released research findings on CD ROM.

A new CD-ROM, Seismic Design Criteria for Steel Moment-Frame Structures (FEMA 355), is now available free of charge from the FEMA Distribution Centre, PO Box 2012, 823 Stayton Drive, Jessup, MD 20794-2012, (fax: 301-362-5335). This CD-ROM contains a library of technical reports on the seismic design criteria, evaluation, repair, and specifications of steel moment-frame buildings. They are in pdf format. Produced by the SAC Joint Venture and FEMA as part of the *Program to Reduce the Earthquake Hazards of Steel Moment-frame Structures*, the first four reports are primarily intended as resource documents for organizations engaged in the development of building codes and standards for regulation of the design, construction, repair and upgrading of steel moment-frame structures that may be subject to the effects of earthquakes:

FEMA 350 Recommended Seismic Design Criteria for New Steel Moment-Frame Building

FEMA 351 Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings

FEMA 352 Recommended Post earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings

FEMA 353 Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications

Additionally, the CD-ROM contains six state of the art reports prepared in parallel with these resource documents. The reports provide detailed explanations of the basis for the design criteria and evaluation recommendations for base metals, welding, systems performance, connection performance, and past and

Repair and Strengthening Guide for Earthquake Damaged Low-rise Domestic Buildings in India

Download it free of charge from the Internet at: http://www.arup.com/geotechnics/HTML/Articles/DesignGuide.htm

This Guide was created by a small group of professional engineers in the U.K. called the Gujarat Relief Engineering Advice Team (GREAT), in response to the devastating Gujarat, India earthquake, January 26, 2001 in which over 20,000 people died, 167,000 were injured and countless buildings were weakened. GREAT has made the 91 page Guide available free of charge in pdf format on the Arup website listed above.

Concerned that many buildings had been weakened in the Gujarat event, the authors intend this publication for owners who build their own houses, builders, local engineers and architects, local authorities, relief agencies and other parties. The Guide explains in simple terms why earthquakes happen in India, which regions are seismically active, how buildings respond in an earthquake, and how to safely carry out good repair and strengthening techniques to earthquake damaged buildings. While acknowledging Professor A. S. Arya's book *Guidelines for Earthquake Resistant Non-Engineered Construction*, 1986, produced in conjunction with the International Association for Earthquake Engineering (IAEE), the authors caution that the Gujarat Guide does not address retrofit/repair of earthen and adobe, wooden, rubble maonry buildings, but rather refers readers to Arya's publication for those topics. Both the Gujarat guide and the *Guidelines for Earthquake Resistant Non-Engineered Construction* can also be accessed from EQNET, Earthquake Information Network at http://www.eqnet.org, under the category non-engineered construction. (From MCEER News, Oct. 2001)

Earthquake Hazard Centre
The Commonwealth Network for Earthquake - Resistant Construction in Developing Countries

The Centre is a non-profit organisation supported by predicted performance included in the resource reports.

(From MCEER News, Oct. 2001)

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