EARTHQUAKE HAZARD CENTRE
NEWSLETTER

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Editorial

Wake-up call

While earthquakes and other natural disasters are often perceived as wake-up calls by professionals in the building industry particularly if building damage is not too severe, it's not often that such a call comes from within the industry. However, exactly that happened in New Zealand last week. An experienced Auckland structural engineer had become so frustrated at problems in the building design and construction industry that he released a one hundred page report outlining his concerns. As one would expect, the press latched onto the more sensational aspects of his criticisms in a manner that reduced his credibility, but nevertheless his pessimistic assessment of the problems within the industry must be taken very seriously.

In essence his concern is about slipping of standards or reduction in technical quality in just about every area of the industry: design checking, construction, and construction supervision. Blame is laid on a very competitive market among structural engineers that leads to such low fees that firms don't do a proper job. They take shortcuts that lower quality and result in design errors. This was probably a far lesser problem in the days when structural engineers' fees were based on fee scales endorsed by a national body.

However other negative factors are contributing to lower design and construction standards as well. A Building Act that accepts self-certification doesn't help. How can genuine mistakes, incompetence or dishonesty be remedied under such a system? And then there is the need for construction workers to be more highly trained and responsible for their work. The report cites many examples where workmanship is so poor it could lead to unsafe buildings in the event of a damaging earthquake.

Fortunately, the Institution of Professional Engineers of New Zealand is taking the report seriously and it is likely it will set up a committee of experts to investigate the claims made in the report and initiate improvements.

I admire the report's author for the effort taken to document his concerns. His motivation is sound. He is worried that not only will the engineering profession lose its credibility but that public safety will be compromised, and even suggests how the profession might respond to his criticisms.

So, what about your and my professional standards? For the sake of our profession, clients and the wider society and even ourselves, we must improve them. Imagine if we were to lose some family members after a building collapse during an earthquake and later discover that collapse was due to errors in either design or construction! We have a vested interest in keeping standards high. We can't do it just by ourselves, but need to support and encourage leaders in our professions to do so. We must also accept technical checking of our work positively with a view to learning and improving from any feed-back, and at the least, welcome any wake-up calls!

Earthquake Hazard Centre
Promoting Earthquake-Resistant Design in Developing Countries
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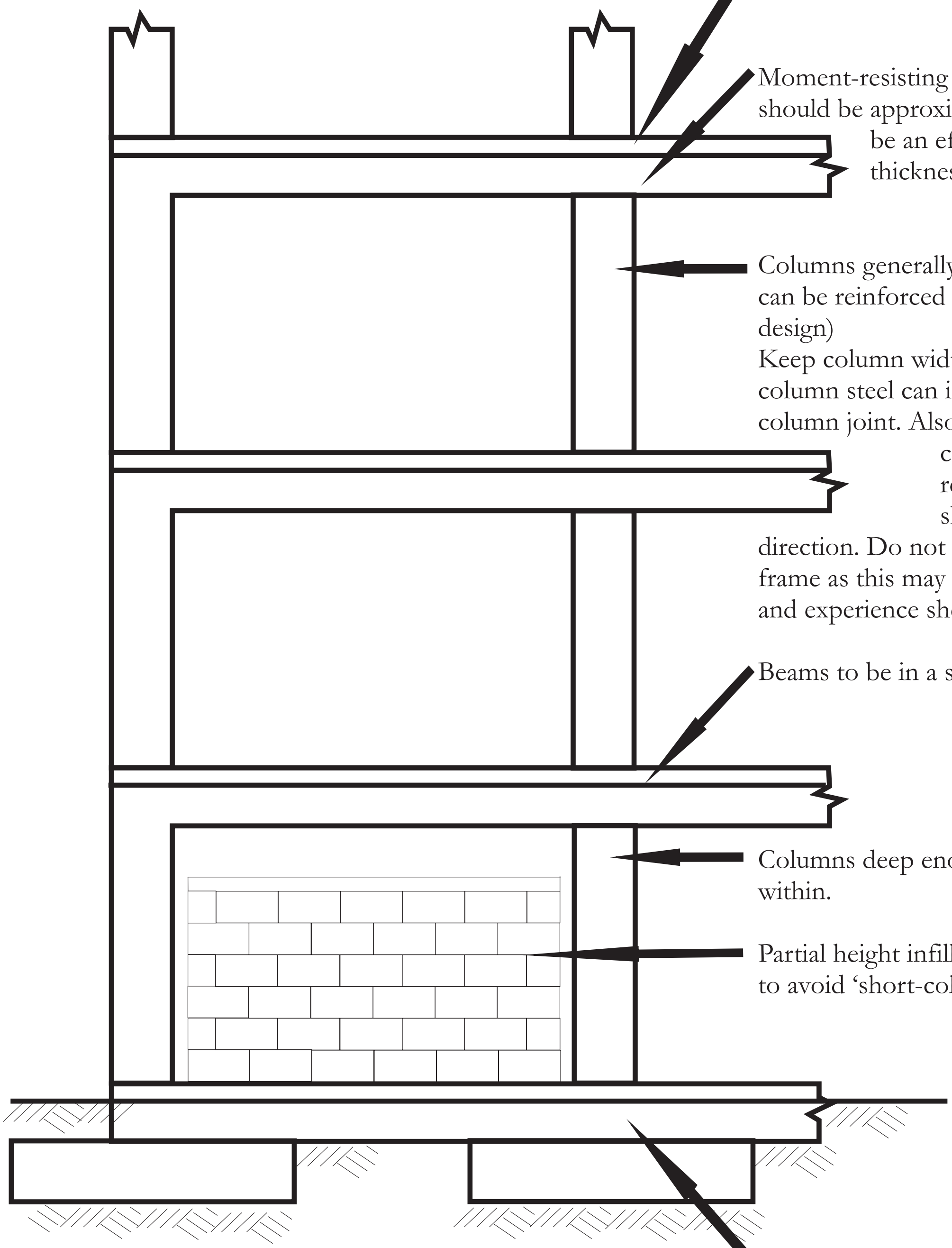
Principles of Building Earthquake Resistance No. 24

An exterior check-up of moment-resisting frames



Flooring reinforced to form a floor diaphragm

Moment-resisting beam. It's depth including slab depth should be approximately 1/12 to 1/10 of the span to be an effective frame member. Beam thickness>span/25.

Columns generally to be as deep as beams so as they can be reinforced to be stronger than beams (capacity design)
Keep column width close to beam width so that all column steel can interact with beam steel in the beam-column joint. Also avoid large eccentricity beam and column centre-lines. If columns are rectangular, the larger dimensions should be parallel to the frame direction. Do not change orientation of columns in a frame as this may cause other columns to be over laden and experience shear bending problems.

Beams to be in a straight line (no off-sets)

Columns deep enough to anchor horizontal beam steel within.

Partial height infill walls to be separated from columns to avoid 'short-column' effect.

Ground beams approximately same depth as columns to limit damage below ground level.

In the next newsletter we check up on frame reinforcing details.

Summary of a paper "Improved seismic resistance of adobe buildings-corner specimen testing"

by Dominic Dowling, from the 17th Australasian Conference on the Mechanics of Structures and Materials (ACMSM 17).

Introduction

The earthquakes which rocked El Salvador, Central America on January 13 and February 13, 2001 registered M_w 7.8 and M_w 6.6 respectively. The loss of life and livelihood was drastic. The degree of destruction was certainly exacerbated by the extensive use of structurally inadequate adobe buildings and has highlighted the need for further research into methods to improve the seismic resistance of such vulnerable buildings.

A key component of this study was the manufacture and testing of adobe blocks, both as individual elements (structural properties) and as collective components in corner elements (Shake table testing of 1m high, 1m length corner specimens) representing 'traditional' and 'improved' design and construction techniques. The 'improved' specimen performed significantly better than the 'traditional' specimen and this study concludes that significant improvement in seismic resistance can be achieved, with minimal additional cost and complexity.

Experimental analysis

In order to experimentally assess some of the improved seismic design concepts, two corner elements were constructed (Fig. 1). These elements were built on separate concrete supporting slabs and subjected to various earthquake simulations. It was acknowledged that the testing would be unable to determine the degree of influence of each of the proposed improvements. This study sought to assess whether the use of such aseismic design features would improve the overall seismic resistance of the building.

Soil and block testing

A total of 170 bricks were fabricated by hand and subsequently air dried. The bricks were of varying sizes and configurations. Most of the bricks were used to construct the corner test specimens. Some of the bricks were tested individually to determine various material properties.

Cement stabilised block performance

This study considers both regular (non-stabilised) and cement-stabilised blocks. Cement-stabilisation refers to the addition of cement to the mud prior to the formation of the blocks. The performance of the cement-stabilised blocks was significantly worse than expected. In all cases (except erosion resistance) the structural properties of the stabilised blocks were lower than those of the non-stabilised blocks. This discovery provides an important 'reality check' relating to the use of 'the magic white powder'. There is a widespread misconception that cement is an essential ingredient in improved mud brick fabrication. Various studies have concluded that the capacity of cement to improve the structural integrity of a mud brick is directly related to the clay content of the soil used, and is not an all-purpose strengthening agent.

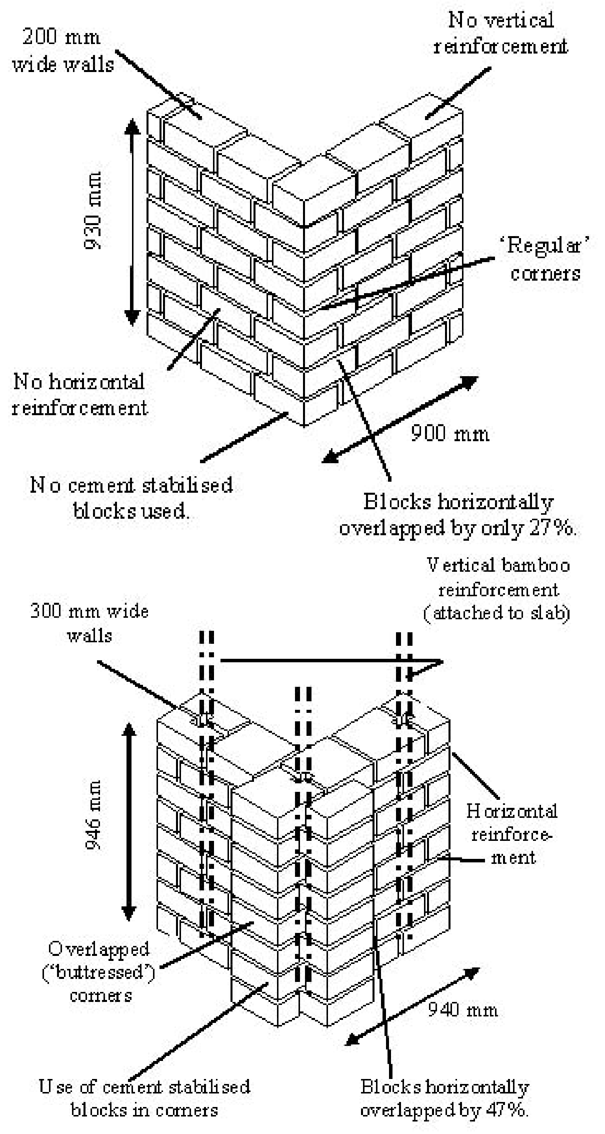


Fig. 1 Comparison between 'traditional' and 'improved' corner specimens

Assessment

A qualitative assessment was undertaken for this study. The MSK Intensity scale (7) was adopted as a benchmark means of assessing the degree of damage to the corner elements when subjected to earthquake loading. It is acknowledged that for effective use of the MSK scale a significant quantity of a range of building types (considering materials and reinforcement used, as well as construction quality) must be assessed. In this study, the MSK scale was used as a comparative tool when considering the impact of the earthquakes on the traditional and improved corner specimens.

Severe structural damage of a 'traditional' element (Fig. 2) occurred at 65% of the intensity of the January 13, 2001 event. The major failure of the specimen occurred at the intersection of the walls, with the cracking essentially creating two distinct walls. The damage was consistent with MSK scale VII (Damage of Buildings) or VIII (Destruction of Buildings) type earthquakes.

Fig. 2 'Traditional' element damage

Overall, it can be stated that the improved element (Fig. 3) performed better than the traditional element in the series of earthquake simulations. This statement is based on an assessment of the risk of causing injury posed by each structure. The walls of the traditional corner were independent and unstable. Any additional force, such as another tremor or a strong wind or impact, could cause either wall to topple over, in an inward or outward direction. This represents an unacceptable level of risk.

The improved element exhibited significantly better structural stability. The major threat comes from the high probability that the 'wedge' in the buttress will separate from the corner if a further force is applied. This represents an acceptable level of risk because the 'wedge' is on the outside of the building, and is relatively small. Some form of barrier should be erected around this area to prevent injury. Although the main structure was significantly damaged it is still relatively stable and the risk of wall collapse is greatly reduced.

Conclusion

A number of simple and cheap amendments can be made to existing construction practices to improve the seismic resistance of an adobe structure. These include:

- Tieing the structure together
- Use of vertical and horizontal reinforcement
- The inclusion of buttressed corners
- Construction of wide walls with good horizontal overlap of bricks.

Fig. 4' Improved' element damage

This study supports these recommendations.

The main objective of improved seismic design is to preserve life and minimise injury. If preservation of housing occurs too, it should be regarded as a bonus. This report does not suggest that an improved adobe structure will survive a major earthquake undamaged; in fact, the structural properties of adobe render such feat highly unlikely. This report, however, does support the notion that an adobe structure may be made to better resist seismic loading with minimal additional cost and complexity.

"The Bloom Hospital, Disaster Mitigation and Preparedness Yield Valuable Lessons,"

by Víctor Rojas from PAHO's Emergency Preparedness and Disaster Relief Area. Based on a presentation by Dr. Carlos Alvarenga, Bloom Hospital, El Salvador 15-16 August 2002, San Pedro Sula, Honduras at the meeting of Central American Hospital Committees on Prevention, Mitigation and Care in Emergencies and Disasters.

In October 1986, an earthquake measuring 7.5 on the Richter scale struck El Salvador, killing more than 1000 people, injuring or displacing many thousands more and causing millions of dollars worth of damage. The Benjamin Bloom Children's Hospital suffered structural damage to its 12-story tower, and three floors that offered outpatient services were destroyed. The damage caused the complete evacuation of the hospital. Health-care for patients and victims was provided in tents (Fig. 4).

Fig. 4 Health services provided in tents following the 1986 earthquake

As a result of the earthquake, disaster mitigation measures were incorporated into the reconstruction of damaged facilities. The tower was retrofitted and the exterior walls surrounding the structure were strengthened. Outpatient facilities were also rebuilt. The reconstruction took several years, and during this time a temporary facility was prepared to provide hospital services (Fig. 5).

In 1993, all services were transferred back to the retrofitted and rebuilt Benjamin Bloom Hospital. Over the next several years, the hospital stepped up disaster preparedness efforts, reorganizing the hospital emergency committee and reviewing and modifying the hospital's emergency manual, based on experience from the 1986 quake. Simulation exercises were also conducted to review evacuation and mass casualty management procedures.

Fig. 5 Temporary facilities 1987-1993

Fast forward to January 2001. Another major earthquake strikes, seriously affecting the health infrastructure in El Salvador. However, the Bloom Hospital suffered no apparent damage. As a precautionary measure, patients and personnel were evacuated from the tower, but all returned 15 days later when it was determined that the earthquake had not compromised the safety of the building. When a second earthquake occurred in February 2001, patients were again evacuated according to hospital plans, but services were restored in just hours this time (Fig. 6).

El Salvador's valuable experience over a 15-year period clearly demonstrates the effectiveness of disaster mitigation measures and hospital preparedness-both of which help ensure that natural disasters need not cripple a country's health services.

Thanks to Tracy Rudne from the Emergency Preparedness and Disaster Relief Coordination Program, Pan American Health Organization, for her help in sourcing information for this article.

Fig. 6 Current view of the Benjamin Bloom Hospital

Summary of "Preliminary Observations on the October 31-November 1, 2002 Molise, Italy, Earthquake Sequence."

From EERI Special Earthquake Report, January 2003.

Introduction

On October 31, 2002, a magnitude M_w5.7 earthquake struck the inland part of Moise, a small rural region in the south-eastern part of the Italian peninsula. This earthquake caused widespread damage in 50 villages and killed 30 people, 27 of whom were children trapped in the collapse of the elementary school in San Giuliano di Puglia.

The next day, an aftershock of similar magnitude, M_w5.7, hit the same area. The aftershock seriously damaged many buildings whose stability was already impaired by the main shock, but it did not cause any additional casualties.

Building performance

All the towns in this area are located on hilltops, ridges, and steep sloping hills. The older, medieval buildings are almost always located on outcropping rock formations, while the newer developments are often on looser materials. The building stock in this area is rather homogenous, but the building types are significantly different in the medieval and the newer parts. The older buildings have stone-bearing walls and are usually 2-4 storeys high. The stone walls are usually carefully crafted with local materials; reinforcing details, such as iron tie-rods or buttresses, are often seen in the facades of larger buildings. Small and far apart openings in the facades are common. The first floor is often vaulted either in stones and mortar, or bricks of different types. The roofs have a wooden structure with joists and purlins that often carry a grille of bamboo canes acting as roof sheathing for supporting clay tiles.

At the margin of the old towns, new developments arose mainly in the 20th Century. Most of the buildings were constructed in the first part of the century as one or, more rarely, two-story bearing-wall structures. The stones were often cut in small regular blocks for the exterior and interior parts of the walls, while the middle was filled with loose material. The mortar is either absent or scarce and of very poor quality. There are frequent cases of bearing walls of poorly cut 250-500mm stones mixed with smaller irregular stone pieces and no mortar. Less common are buildings with regular blocks of "tufa" or filled bricks.

After World War II one or two additional stories were added to many of these buildings. Often the additions were made either by hollow brick-bearing walls with elements of different shapes and dimensions, or by reinforced concrete frames with hollow brick infills with heavy precast or cast-in-place ribbed slab with ribs at approximately 500-600mm on centre, and not more than 300mm in depth with a flange depth of not more than 75-100mm, with hollow clay tile infill between the ribs. Minimal or no provisions were made to ensure continuity with the already existing storey. These buildings of mixed construction proved to be extremely vulnerable, as shown below.

The more recent structures are almost all engineered reinforced concrete frames with hollow brick partitions. Often the ground floor consists of pillars with no infill walls, a classic soft-storey condition. The construction practice and materials used were observed to be fairly poor compared to modern standards, but, with a few exceptions, concrete buildings experienced minimal damage.

Stone bearing wall buildings and buildings of mixed construction

All the damage mechanisms typical of stonewall and brick-wall buildings were observed in the relatively newer structures located in the developments outside of the old town. Figs. 7, 8, 9 and 10 show some typical examples.

Fig. 7 San Giuliano. Failure of the exterior wall not properly connected to the slab

Churches

The observed damage caused to the monumental heritage building stock has confirmed, yet again, that churches are particularly vulnerable to seismic forces. The intrinsic vulnerability was often exacerbated by questionable recent retrofits that proved incompatible with the natural vibration mode of the original masonry walls. Roofs made of reinforced concrete or steel, and the addition of very thick reinforced concrete tie beams and floors, dramatically increased the inertial forces that could not be accommodated by the original structure.

Fig. 8 San Giuliano. Degraded mortar and poor construction material in foreground wall.

Fig. 10 Collapsed school in San Giuliano di Puglia. Note the very heavy slab of the second storey and the roof that was supported by a first storey bearing wall of poor-quality stone, now collapsed.

Reinforced Concrete Frame Buildings
Overall damage to reinforced concrete frame buildings was minor throughout the region. Damaged buildings were located on soft-soil basins. Three concrete buildings in the surrounding regions were observed to have sustained structural damage, while approximately 50 concrete frame buildings were observed to have had significant non-structural damage to hollow clay tile and plaster infill walls.

Fig. 9 San Giuliano. Large diagonal shear cracks in the proximity of the large openings. The two storeys above built more recently in reinforced concrete and hollow-brick infills are unscathed. The bottom storey essentially acted as a base-isolation system. The building is going to be demolished.

Concrete construction in this region is similar to that found in Turkey, consisting of poorly detailed, mildly reinforced concrete columns, beams, and slabs with hollow clay masonry tile infill walls between column lines. Concrete frame buildings suffered tremendous damage and collapse during the 1999 Izmit, Turkey earthquake, but the Italian concrete structures suffered little damage, as they typically have fewer storeys (four or less) and the ground motions in the Molise events were substantially shorter and less severe than those in Turkey.

Two buildings of particular interest were a pair of concrete frame residential apartment structures located in Bonefro (Figs. 11 and 12). The two buildings, constructed in 1984, were founded in a valley, at the base of the historic portion of the town. Both structures were identical in plan and structural composition, but vary in height, one with three storeys and the other with four. The four-storey structure suffered substantial structural damage at the ground level, focused mainly along the east elevation. The three-story structure suffered no structural damage and only minor cracking in the exterior plaster finishes.

The damage to the four-story structure is likely due to the additional mass of the fourth floor level.

Conclusions
The extensive damage to buildings observed in Molise can be attributed mostly to poor quality construction practices and materials. Many of the buildings that suffered extensive damage or collapse (including the school) were not adequately engineered to withstand the

seismic forces. The extensive damages to poor quality non-engineered buildings were caused by the lack of seismic regulations for construction in this region. Amplification of ground motion due to soft soil conditions and topographic effects seem to have played an important roles as well.

Fig.11 Two concrete frame apartment buildings in Bonefro. Construction of each building was identical, with the exception of the additional floor. The four-storey building sustained major damage in the two events, resulting in a major collapse hazard.

The older medieval parts of towns that were built on surface hard rock formations sustained much less damage. Another contributing factor was the strong aftershock on November 1, which exploited the weaknesses of already damaged buildings.

Fig. 12 Interior of concrete frame apartment building in Bonefro. Extensive damage at the ground level of the four-storey building after the aftershock of November 1.

New Publications

Housing Encyclopedia updated

The EERI/IAEE Housing Encyclopedia web site (www.world-housing.net) is being updated continually. More information is being added for many of the country sections in the encyclopedia including many new links to documents and other web sites. Some of the publications in the FEMA yellow-book series are now available, as well as documents on strengthening and repairing non-engineered construction.
Focusing upon housing types, the Encyclopedia provides comprehensive information on construction, seismic resistant features and problems. Country reports are laid out clearly with information presented under the following headings:

1. General information
2. Architectural features
3. Socio-economic issues
4. Structural features
5. Evaluation of seismic performance and seismic vulnerability
6. Earthquake damage patterns
7. Building materials and construction processes
8. Construction economics
9. Insurance
10. Seismic strengthening techniques
11. Contributers
12. Figures

The encyclopedia is very useful for comparing your own housing construction vulnerability with that of other countries. It is also an excellent resource for both engineering and architecture student projects. It provides opportunities to learn from other countries and gain fresh ideas. If need be, you can request further information from country contributors.

School Maintenance Manual

The Organization of American States General Secretariat Unit of Sustainable Development and Environment has published a "Maintenance Manual for School Buildings in the Caribbean" which has been developed in an attempt to reduce the vulnerability of school buildings to natural hazards. It contains easy to follow information and charts, allowing the examination of existing school buildings in order to prolong their life expectancy. It is a systematic and pro-active approach that aims to prevent the need for repairs and identify problems as they arise.
This manual has been developed for school personnel who need to have a maintenance programme without the usual technical language, and is for use in conjunction with existing school maintenance programmes.
Obtain a copy at:
http://www.oas.org/en/cdmp/document/schools/maintman.htm