International Video Conference: Reconstruction of Safer Houses after Earthquake Disasters

Earthquake Damage to Non-Engineered Houses and the Guidelines by IAEE

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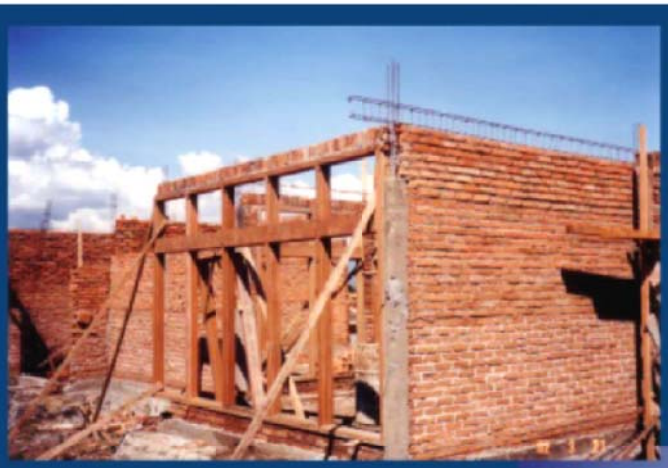
Non-Engineered Construction

- Non-engineered buildings are spontaneously and informally constructed in the traditional manner without intervention by qualified architects and engineers in their design.
- Non-engineered construction is most common construction technique in the world and also most vulnerable against earthquakes.

Un-reinforced brick masonry

Un-reinforced brick masonry with no columns and beams (Java, Indonesia)



Confined masonry

Un-reinforced brick wall farmed with RC columns and beams

Wood frame for door sash can support brick wall.

Damage to Adobe (sundried mud block) construction (1996 Nazca, Peru EQ)

Damage to Adobe (2001 Atico, Peru EQ)

Damage to Tapial construction (1990 Peru EQ)

Tapial is cast-in-place mud (rammed earth) construction (1990 Peru EQ)

Damage to Japanese traditional wooden houses (1995 Kobe EQ)

Narrow boards nailed to frame cannot resist lateral forces (1995 Kobe EQ)

GUIDELINES FOR EARTHQUAKE RESISTANT NON-ENGINEERED CONSTRUCTION

Revised Edition of "Basic Concepts of Seismic Codes" Vol. I, Part 2, 1980

THE INTERNATIONAL ASSOCIATION FOR EARTHQUAKE ENGINEERING

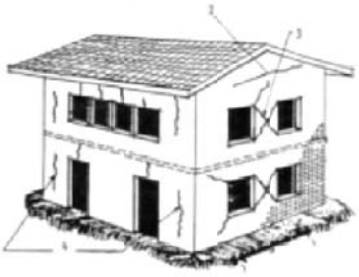
October 1986

International Association for Earthquake Engineering (IAEE)

Guidelines for Earthquake Resistant Non-Engineered Construction

(1986 Edition)

Easy to understand with many illustrations



1-1 Earthquake motion, 2-Horizontal crack in gables, 3-Diagonal cracks due to shear, 4-Cracks due to bending of wall.

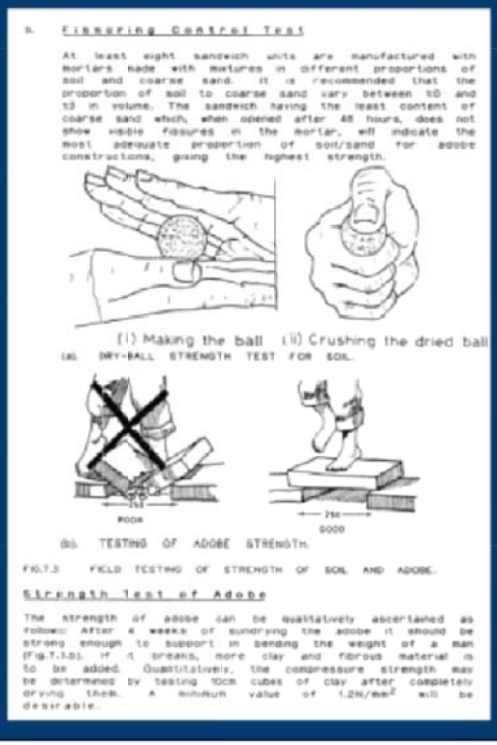
FIG.4.1 CRACKING IN BEARING WALL BUILDING DUE TO BENDING AND SHEAR.

i) A wall can fail as a bending member loaded by seismic inertia forces on the mass of the wall itself in a direction, transverse to the plane of the wall. Tension cracks occur vertically at the centre, ends or corners of walls. Longer the wall and longer the openings more prominent is the damage (Fig.4.1.). Since earthquake effects occur along both axes of a building simultaneously, bending and shearing effects occur often together and the two modes of failure are often combined. Failure in the piers occurs due to combined action of flexure and shear.

ii) Unreinforced gable and masonry walls are very unstable and the strutting action of purlins imposes additional force to cause their failure. Horizontal bending tension cracks are caused in the gables.

iv) The deep beam between two openings one above the other is a weak point of the wall under lateral in-plane forces. Cracking in this zone occurs before diagonal cracking of piers (Fig.4.2.). In order to prevent it and to enable the full distribution of shear among all piers, either a rigid slab or r.c. band must exist between them.

Applicable at construction site



5. Fissuring Control Test

At least eight sandwich units are manufactured with mortars made with mixtures in different proportions of soil and coarse sand. It is recommended that the proportion of soil to coarse sand vary between 1:0 and 1:3 in volume. The sandwich having the least content of coarse sand which, when opened after 48 hours, does not show visible fissures in the mortar, will indicate the most adequate proportion of soil/sand for adobe constructions, giving the highest strength.

(i) Making the ball (ii) Crushing the dried ball

(a) DRY-BALL STRENGTH TEST FOR SOIL.

POOR GOOD

(b) TESTING OF ADOBE STRENGTH.

FIG.7.3 FIELD TESTING OF STRENGTH OF SOIL AND ADOBE.

Strength Test of Adobe

The strength of adobe can be qualitatively ascertained as follows: After 4 weeks of sundrying the adobe it should be strong enough to support in sending the weight of a man (Fig.7.1.b). If it breaks, more clay and fibrous material is to be added. Quantitatively, the compressive strength may be determined by testing 10cm cubes of clay after completely drying them. A minimum value of 1.2N/mm^2 will be desirable.

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In 1984 during WCEE in San Francisco

Revision for 2012 Version

26 and 27 years after the previous picture

Anand S. Arya
Teddy Boen
Yuji Ishiyama

Latest version (Feb. 2012)

41 CHAPTER 4 MASONRY BUILDINGS IN FIRED-BRICK AND OTHER MATERIALS

4.9 Confined Masonry

4.9.1 Understanding confined masonry construction

Confined masonry construction is a building technology that offers an alternative to "Masonally reinforced masonry" with "RC Bonds and Vertical Bars" as per Sec. 4.5 and Sec. 4.6 in this Chapter and "RC Frame Construction". It consists of masonry walls (made either of clay brick or concrete block units) and horizontal and vertical R.C "confining members" built on all four sides of the masonry wall panels. Vertical members are called "tie-columns" or "practical columns" and though they resemble columns in RC frame construction they are of much smaller cross-section. Horizontal elements, called "tie-beams", resemble beams in RC frame construction, but also of much smaller section. It must be understood that the confining elements are not beams and columns in the way these are used in RC frames. Rather they function as horizontal and vertical ties or bands for resisting tensile stresses and many better be termed as such (see Fig 4.18).

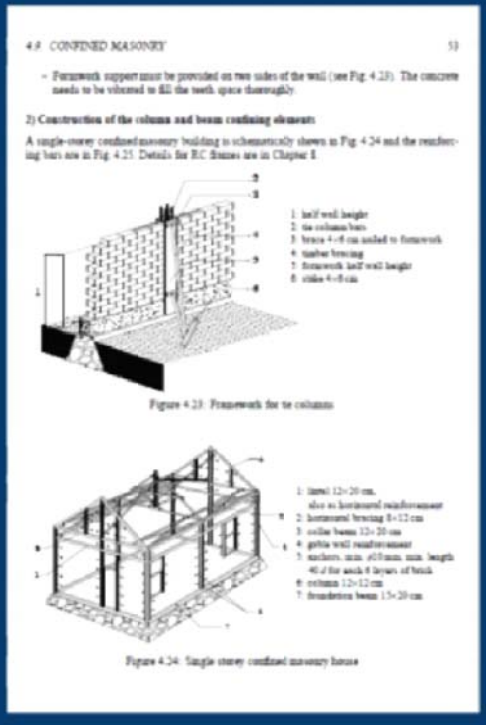
Single storey house (Aceh, Indonesia)

Two storey house under construction (Java, Indonesia)

Figure 4.18 Confined brick masonry

The structural components of a building using confined masonry walls are as follows (see Figs. 4.19, 4.20 and 4.21):

- **Masonry walls** are load bearing elements, and transmit the gravity loading from the slab(s) and walls above down to the foundation. The "confined" walls also work as bracing panels acting due to the confining tie elements which enable the walls to resist the horizontal earthquake forces.
- **Confining elements** (horizontal and vertical tie elements) provide the necessary tensile strength and ductility to the masonry wall panels and protect them from disintegration in the major earthquakes.
- **Floor and roof slabs** transmit both vertical gravity and lateral loads to the confined masonry walls. In an earthquake the slabs behave like rigid horizontal diaphragms.



4.9 CONFINED MASONRY 53

- Formwork support must be provided on two sides of the wall (see Fig. 4.23). The concrete needs to be vibrated to fill the teeth space thoroughly.

2) Construction of the column and beam confining elements

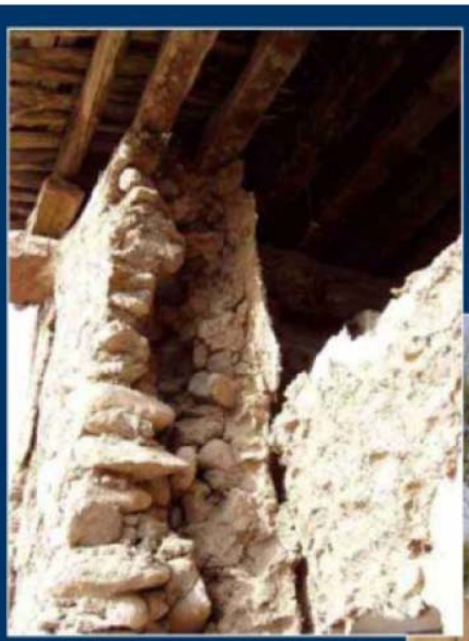
A single-storey confined masonry building is schematically shown in Fig. 4.24 and the reinforcing bars are in Fig. 4.25. Details for RC frames are in Chapter 8.

Figure 4.23: Framework for tie columns

Figure 4.24: Single storey confined masonry house

Pictures of various types of earthquake damage

Damage to Stone Masonry



Damage caused by Tsunami of 2011 Great East Japan Earthquake

New Figures to be understood easily

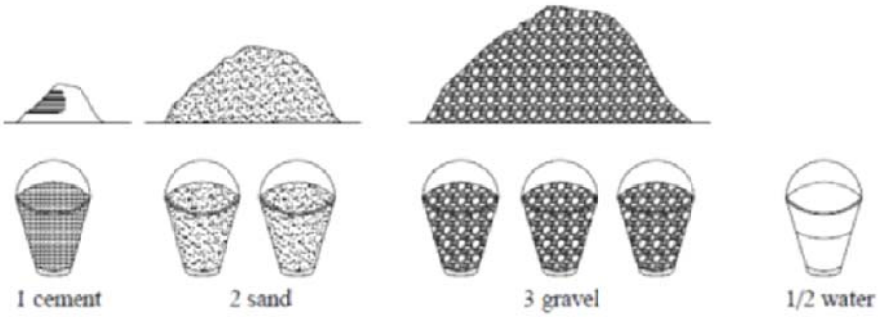
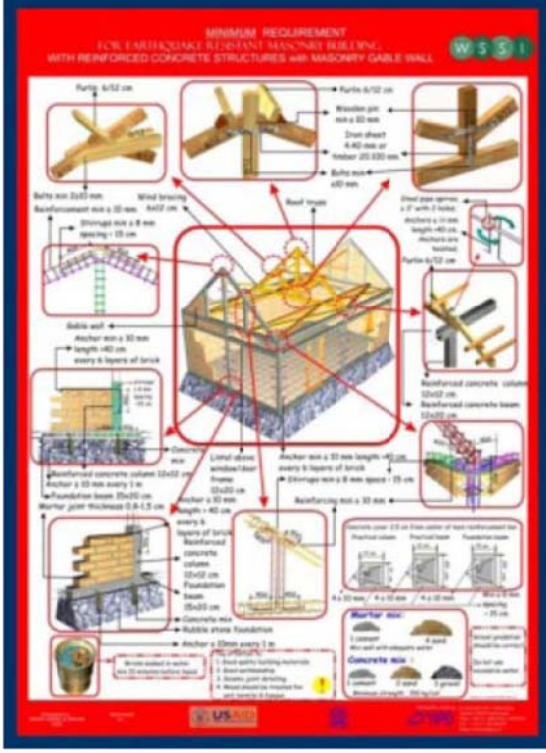


Figure 8.6: Simple measurement of concrete mix "1 cement : 2 sand : 3 gravel"

Figure 8.7: Test of concrete mix consistency by making a soft ball of concrete mix in hand

Poster for Minimum Requirements



- Quality of materials
- Structural members
- Connection of structural members

(After 2006 Central Java, Indonesia EQ)

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1. Problems, Objective & Scope
2. Structural Performance during EQs
3. General Concept of EQ Resistant Design
4. Masonry Buildings in Fired-Brick and Other Materials
5. Stone Buildings
6. Wooden Buildings
7. Earthen Buildings
8. Non-Eng. RC Buildings
9. Repair, Restoration and Strengthening
10. Appendices

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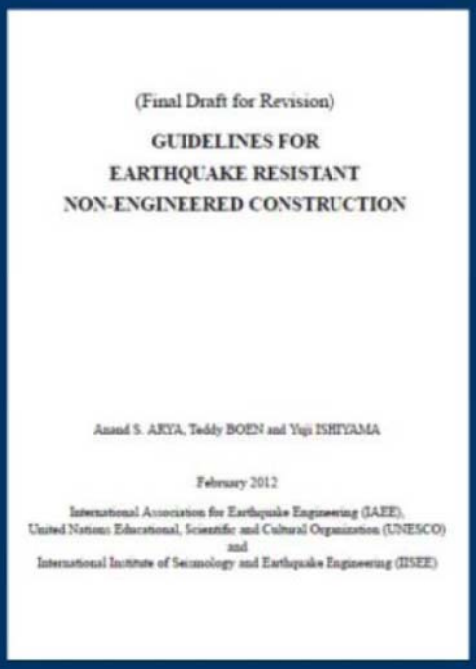

(Final Draft for Revision)

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February 2012

International Association for Earthquake Engineering (IAEE),
United Nations Educational, Scientific and Cultural Organization (UNESCO)
and
International Institute of Seismology and Earthquake Engineering (IISEE)

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Thank you
for your attention