Earthquake Resistant Design of Non-Engineered Buildings In Indonesia

by
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Abstract

Almost every year earthquake disasters occur in various areas in Indonesia and despite of the severe impact on the regional economy and development, it seems that relatively little is being done to prepare for, prevent or mitigate, the effects of future earthquakes.

This paper discusses about rural and urban non-engineered buildings and try to get information that is useful to correlate the actual damage with analysis.

1. Introduction

Throughout the centuries earthquakes have taken a high toll of human lives and caused great property losses throughout the world and unfortunately mostly in developing countries. All the catastrophes are due to the collapse of man made buildings/structures.

In general, buildings can be divided into two main categories, namely engineered buildings and non-engineered buildings, their percentages being quite different in developed, developing, and underdeveloped countries. Past destructive earthquakes showed that most of the disasters occurred to non-engineered buildings. In Indonesia, most dwellings (non-engineered buildings) constructed in small towns and villages are built according to tradition, their types suiting the culture and materials available in that area. The traditional houses generally have a good record or performance in past earthquakes. However, as the economic condition is prospering, there is a strong trend towards the construction of masonry houses and measure of status is associated with the owners of such masonry houses. Poor people tend to adopt such new habits and built “look like masonry” houses. Most of such masonry houses are built without considering the requirements for appropriate masonry construction.

With the extreme pressures of a great demand for new masonry houses together with a limitation on the resources available, including finance, skills, and building materials, resulting in poor workmanship and poor quality of construction. The general tendency has been for the standards to fall year by year. World experience in damaging earthquakes has shown that these types of construction are dangerous to human life, often in a relatively small earthquake. It is quite apparent that it will be difficult to do away with this kind of construction in seismic areas, particularly in developing countries.

2. Non-Engineered Buildings

Non-engineered buildings can be divided into two main categories. The first category of non-engineered buildings is those built according to tradition, their types suiting the culture and materials available in that area.

1 Presented during EQTAP Workshop IV, Kamakura Dec 3-4,2001.
This type of buildings is generally also called indigenous or vernacular buildings. Indigenous buildings are gradually fading and replaced with the second category of non-engineered buildings, namely either city type masonry construction or a combination of traditional look only but not adopting the traditional skills and crafts in detailing, material use, etc. As mentioned earlier, the rapid increase in numbers of the second category of buildings is among others due to population growth and its increasing concentration in urban areas and the prospering economic condition.

North Sulawesi (Manado) (1980)
Tasikmalaya (1979)
Sumbawa (1977)
Lombok (1977)
North Sumatera (Batak) (1975)
West Java (Sukabumi) (1978)
Tasikmalaya (1979)
North Sulawesi (Manado) (1980)
West Lampung (Liwa) (1994)

Center Sulawesi (Palu) (1995)

Irian Jaya (Biak) (1996)

Bengkulu (2000)

Bengkulu (2000)
The traditional buildings generally have a good record or good performance in past earthquakes. This is due to the fact that man and nature have co-existed on the planet of earth for a long time. Since the primitive days man has tried to adjust himself to the conditions of environment and made feeble attempts to cope with the fury let loose by forces of nature. The pattern of human settlements and traditional methods and materials for traditional buildings on regional basis embody the accumulated traditional wisdom, experience, skill, and craft evolved through the ages. Some of the buildings which have existed for centuries have withstood the onslaughts of earthquakes. However, due to urbanization, the trade of building those traditional, vernacular houses is not being transferred. Almost all young people from villages are moving to cities in search for a better living. As soon as they are successful, they return to their respective villages and tend to build masonry houses as a show off of their success.

The second category of non-engineered buildings considered are single family residences and smaller commercial structures in developing countries which are built by landowners or local artisans without the benefit of engineering or architectural help. Specifically, such buildings will include load bearing masonry wall buildings, stud wall and brick nogged constructions in timber, and composite constructions using combinations of load bearing walls and piers in masonry, reinforced concrete, timber, and the like. The buildings which do not follow the requirements for masonry construction and which are built with poor workmanship and poor quality of materials, have very poor performance during past earthquakes and have taken a high toll of human lives and caused great property losses throughout the world. Unfortunately, all catastrophes in developing countries are mostly due to the collapse of such type of non-engineered buildings. In developing countries, such condition of vulnerability that produces so many disasters is in most cases a result of the poverty that exists in these places. This situation is actually increasing because of the following reasons, some of which vary in intensity from country to country.

These are:
- uncontrollable population growth.
- mass urbanization.
- political instability.
- debt crisis.
3. Design Basis of Non-Engineered Buildings

Until few years ago, the design of non-engineered buildings is based on:
1. Observed behavior of such buildings during past earthquakes and
2. Trained engineering judgement.
3. However, with the rapid advancement of the computing power and speed of PCs as well as laptops and the availability of the softwares, in these last years, it is possible to model non engineered buildings and perform dynamic analysis.

3.1. Earthquake Damage

It is said that “Earthquake damage is the mother of earthquake engineering” and that represents the true expression since it gives a good opportunity to learn from observation of the damages. Observation of structural performance of buildings during an earthquake can clearly identify the strong and weak aspects of the design as well as the desirable qualities of materials and techniques of construction and site selection. Therefore, the study of damage provides an important step in the evolution of strengthening measures for different types of buildings. Every damaging earthquake provides new lessons to be learned.

The development of man’s understanding of the causes and effects of earthquakes has been a gradual process over many centuries. Through careful observation and study of the earth and the damage resulting to his works from earthquakes, man had come to recognize how the great forces of earthquakes act upon his structures. The information which has been obtained bit by bit over the years helps today’s engineers to assess the ability of their works and those of their predecessors to withstand this great, destructive force of nature. Without such accumulated information it would not be possible to design modern structures with any reasonable assurance of safety in many parts of the world. All past earthquakes damage reports are another step on the way to a better understanding of earthquakes and their influences.

An earthquake is remarkably effective in pinpointing out structural weaknesses. Most of the structural failures that we observed in past earthquakes were associated with deficiencies in the structure as built, whether caused by design, by lack of supervision, or by improper construction practices (poor materials, poor workmanship).

The investigation of past earthquakes and their effects on various types of structures have contributed significant information to engineers, architects, building officials, and others engaged in extending the knowledge of earthquake engineering. The advancement of theoretical and empirical methods of earthquake resistant design of structures depends upon full-scale tests of structures. Currently the most productive method of obtaining full-scale test information for structures subjected to earthquake motion is field inspection and investigation of structures actually subjected to earthquakes. The field inspection of earthquake damaged buildings is one of the most effective means of obtaining such information. This is particularly true for non-engineered buildings since their earthquake resistant design is mostly based on “observed behavior of such buildings during past earthquakes”, and engineering judgement.
In the mass of evidence from past earthquakes (local and abroad), a few facts stand out and although they may be elementary, they are worth reiterating. The typical damages to non-engineered buildings are as follows:

1. Roof covering tends to be dislodged.
2. Roof tends to separate from its supports.
3. Walls tend to tear apart.
4. Walls tend to shear off diagonally in direction.
5. Walls tend to collapse.
6. Additional shear due to twisting or warping for unsymmetrical building.
7. Failure at corners of openings.
8. Concentration of stresses in openings.
9. Failure at corners of walls.
10. Hammering/pounding between two adjacent buildings.
11. Failure due to sudden change in mass or stiffness.
12. Weak connection between wall and wall, wall and roof, wall and foundation.
13. Excessive column bending.
14. Failure of rigid and insufficient strength of structural elements and connections.
15. Large seismic forces are not properly transferred into the supporting walls and frames.
16. Poor quality of construction (poor material and poor workmanship).
17. Unreinforced gable wall.
18. Plan of building (symmetry and simplicity).

Those typical damages to non-engineered buildings are confirmed by observing damages of earthquakes (in Indonesia and other countries) during the past 25 years.

**Typical Damages**

1. Roof covering tends to be dislodged.
2. Roof truss tends to separate from its supports.

3. Walls tend to tear apart.
4. Walls tend to shear off diagonally in direction.

Liwa 1994

Kerinci 1995

Biak 1996

Bengkulu 2000

5. Failure at corners of walls.

Flores 1992

Kerinci 1995

Bengkulu 2000

Sukabumi 2000
6. Walls tend to collapse

Liwa 1994  
Bengkulu 2000

Kerinci 1995  
Biak 1996

7. Weak connection between wall and wall, wall and roof, wall and foundation.

Liwa 1994  
Kerinci 1995

Biak 1996  
Bengkulu 2000
8. Unsymmetric plan of buildings.

9. Failure at corners of openings.

10. Hammering/pounding between two adjacent buildings.
11. Failure due to sudden change in mass or stiffness.

Flores 1992

12. Poor quality of construction (poor material and poor workmanship).

Liwa 1994

Biak 1996

Bengkulu 2000

Sukabumi 2000
3.2. Observed Behavior of Buildings during past Earthquakes and Engineering Judgement

The subsequent step in designing non-engineered buildings to analyze the typical damages and come up with the structural mechanics explanations of each failure mechanism.
3.3. Failure Mechanism of Structures

As outlined in chapter 3.1 and 3.2 regarding Earthquake Damage and Typical Damage, it is observed that during an intense earthquake, certain effects are seen to occur, the roof tends to separate from the supports, the roof covering tends to be dislodged; the walls tend to tear apart and if unable to do so they tend to shear off diagonally in the direction of motion; infill walls within steel, reinforced concrete or timber framing tend to fall out bodily unless properly tied to the framing members. From those facts, an analysis of the mechanism of damage is performed.

3.3.1. Free Standing Masonry Wall

Consider the free standing masonry walls shown in Fig. 1. In Fig. 1(a), the ground motion is acting transverse to a free standing wall A. The force acting on the mass of the wall tends to overturn it. The seismic resistance of the wall is by virtue of its weight and tensile strength of mortar and it is obviously very small. This wall will collapse by overturning under the ground motion.

The free standing wall B fixed on the ground in Fig. 1(b) is subjected to ground motion in its own plane. In this case, the wall will offer much greater resistance because of its large depth in the plane of bending. Such a wall is termed a shear wall. The damage modes of an unreinforced shear wall depend – on the length-to-width ratio of the wall.

A wall with small length-to-width ratio will generally develop a horizontal crack due to bending tension and then slide due to shearing. A wall with moderate length-to-width ratio and bounding frame diagonally cracks due to shearing as shown at (c).

A wall with large length-to-width ratio, on the other hands, may develop diagonal tension cracks at both sides and horizontal cracks at the middle as shown at (d).

Figure 1. Failure Mechanism of Free Standing Walls

| A=Wall A | B=Wall B | F=Framed | 1=Earthquake force | 2=Overturning | 3=Sliding | 4=Diagonal cracking | 5=Horizontal cracking |
3.3.2. Wall Enclosure without Roof

Now consider the combination of walls A and B as an enclosure shown in Fig.2. For the X direction of force as shown, walls B act as shear walls and, besides talking their own inertia, they offer resistance against the collapse of wall A as well. As a result walls A now act as vertical slabs supported on two vertical sides and the bottom plinth. The walls A are subjected to the inertia force on their own mass. Near the vertical edges, the wall will carry reversible bending moments in the horizontal plane for which the masonry has little strength. Consequently cracking and separation of the walls may occur along these edges shown in the figure.

It can be seen that in the action of walls B as shear walls, the walls A will act as flanges connected to the walls B acting as web. Thus if the connection between walls A and B is not lost due to their bonding action as plates, the building will tend to act as a box and its resistance to horizontal loads will be much larger than that of walls B acting separately. Most unreinforced masonry enclosures, however, have very weak vertical joints between walls meeting at right angles due to the construction procedure involving toothed joint which is generally not properly filled with mortar. Consequently the corners fall and lead to collapse of the walls. It may also be easily imagined that the longer the walls in plan, the smaller will be the support to them from the cross walls and the lesser will be the box effect.

![Figure 2. Failure Mechanism of Wall Enclosure without Roof](image)

1 = Earthquake force  
2 = Bending of Wall A  
3 = Bending cracks at ends of wall A
3.3.3. **Roof on Two Walls**

In Fig.3, a roof slab is shown to be resting on two parallel walls B and the earthquake force is acting in the plane of the walls. Assuming that there is enough adhesion between the slab and the walls, the slab will transfer its inertia force at the top of walls B, causing shearing and overturning action in them. To be able to transfer its inertia force to the two end walls, the slab must have enough strength in bending in the horizontal plane. This action of slab is known as diaphragm action. Reinforced concrete or reinforced brick slabs have such strength inherently and act as rigid diaphragms. However, other types of roofs or floors such as timber or reinforced concrete joists with brick tile covering will be very flexible. The joists will have to be connected together and fixed to the walls suitably so that they are able to transfer their inertia force to the walls. At the same time, the walls B must have enough strength as shear walls to withstand the force from the roof and its own inertia force. Obviously, the structure shown in Fig.3, when subjected to ground motion perpendicular to its plane, will collapse very easily because walls B have little bending resistance in the plane perpendicular to it. In long barrack type buildings without intermediate walls, the end walls will be too far to offer much support to the long walls and the situation will be similar to the one just mentioned above.

![Diagram of Roof on Two Walls](image)

1 = Earthquake force  

B = Wall B

**Figure 3.** Roof on Two Walls
3.3.4. Roof on Wall Enclosure

Now consider a complete wall enclosure with a roof on the top subjected to earthquake force acting along X-axis as shown in Fig.4. If the roof if rigid and acts as a horizontal diaphragm, its inertia will be disturbed to the four walls in proportion to their stiffness. The inertia of roof will almost entirely go to walls B since the stiffness of the walls B is much greater than the walls A in X direction. In this case, the plate action of walls A will be restrained by the roof at the top and horizontal bending of wall A will be reduce. On the other hand, if the roof is flexible, the roof inertia will go to the wall on which it is supported and the support provided to plate action of walls A will also be little or zero. Again the enclosure will act as a box for resisting the lateral loads, this action decreasing in value as the plan dimensions of the enclosures increase.

![Figure 4. Roof on Wall Enclosure](image)

1 = Earthquake force  
A = Wall  
B = Wall B
3.3.5. Roofs and Floors

The earthquake-induced inertia force can be distributed to the vertical structural elements in proportion to their stiffness, provided the roofs and floors are rigid to act as horizontal diaphragms. Otherwise, the roof and floor inertia will only go to the vertical elements on which they are supported. Therefore, the stiffness and integrity of roofs and floors are important for earthquake resistance. The roofs and floors, which are rigid and flat and are bonded or tied to the masonry, have a positive effect on the wall, such as the slab or slab and beam construction directly cast over the walls or jack arch floors or roofs provided with horizontal ties and laid over the masonry walls through good quality mortar. Others which simply rest on the masonry walls will offer resistance to relative motion only through friction, which may or may not be adequate depending on the earthquake intensity. In the case of a floor consisting of timber joists placed at a center to center spacing of 20 to 25 cm with brick tiles placed directly over the joists and covered with clayey earth, the brick tiles have no binding effect on the joists. Therefore, relative displacement of the joists is quite likely to occur during an earthquake, which could easily bring down the tiles, damaging property and causing injury to people. Similar behavior may be visualized with the floor consisting of precasts reinforced concrete elements not adequately tied together. In this case, relative displacement of the supporting walls could bring down the slabs.

3.3.6. Long Building with Roof Trusses

Consider a long building with a single span and roof trusses as shown in Fig. 5. The trusses rest on the walls A. The walls B are gabled to receive the purloins of the end bays. Assuming that the ground motion is along the X-axis, the inertia forces will be transmitted from sheathing to purloins to trusses and from trusses to wall A.

The end purloins will transmit some forces directly to gable ends. Under the seismic force the trusses may slide on the walls unless anchored into them by bolts. Also, the wall A, which does not get much support from the walls B in this case, may overturn unless made strong enough in the vertical bending as a cantilever or other suitable arrangement, such as adding horizontal bracing between the trusses, is made to transmit the force horizontally to end walls B.

![Figure 5. Long Building with Roof Trusses](image)

1 = Earthquake force, 2 = Gable end, A = Wall A, B = Wall B

Figure 5. Long Building with Roof Trusses
When the ground motion is along Y direction, walls A will be in a position to act as shear walls and all forces may be transmitted to them. In the case, the purling act as ties and struts and transfer the inertia force of roof to the gable ends.

As a result the gable ends may fail. When the gable triangles are very weak in stability, they may fail even in small earthquakes. Also, if there is insufficient bracing in the roof trusses, they may overturn even when the walls are intact.

3.3.7. Shear Wall with Openings

Shear walls are the main lateral earthquake resistant elements in many buildings. For understanding their action, let us consider a shear a shear wall with three openings shown in Fig.6. Obviously, the piers between the openings are more flexible than the portion of wall (sill masonry) or above (spandrel masonry) the openings. The deflected from under horizontal seismic force is also sketched in the figure 6.

The sections at the level of the top and bottom of opening are found to be the worst stressed in tension as well as in compression and those near the mid-height of piers carry the maximum shear. Under reserved direction of horizontal loading the sections carrying tensile and compressive stresses are also reserved. Thus it is seen that tension occurs in the jambs of openings and at the coiners of the walls.

![Figure 6 Deformation of a shear wall with openings](image-url)
3.4. Analysis

The computing power and speed of desktop /laptop computers has increased at a breathtaking rate over the last ten years. The availability of software makes it practical for engineers to perform static and dynamic analysis of structures quickly and efficiently.

Recently we tried to model non-engineered masonry buildings and utilize SAP 2000

The wall panels are modeled as shell elements. Shell elements behavior is a combination of a plate bending behavior plus a membrane behavior. The purpose of the analysis is not to simulate the actual behavior, but to get reliable information that there is a correlation between the observed damages and the results of the analysis. The correlation is not perfect, but is good enough to get a good idea to build appropriate non-engineered buildings that can withstand earthquakes.

The results of a non-engineered houses and school building in Indonesia are shown below. From the results of analysis it can be seen that there is a good correlation between actual earthquake damage and results of analysis.

3.4.1. Dwelling House (Perumnas) RSS 21/54

3.4.1.1. Dwelling House (Perumnas) RSS 21/54 (Gable wall with practical column)

3-D Model

Soft soil; PGA=0.22 g; UBC 97; Importance Factor=1; Return Period = 200 yrs
• Reinforced Concrete Column Evaluation

Reinforced Concrete Ring Beam Evaluation

Required Reinforcing
Longitudinal Reinforcing = 1.44 cm²
Shear Reinforcing = 0.089 cm²

Available Reinforcing
Longitudinal Reinforcing = 4.5216 cm²
Shear Reinforcing = 1.0048 cm²

Required Reinforcing
L. Reinforcing(top) = 1.577 cm²
L. Reinforcing(bot) = 1.485 cm²
Shear Reinforcing = 0.084 cm²

Available Reinforcing
L. Reinforcing (top) = 2.2608 cm²
L. Reinforcing (bot) = 2.2608 cm²
Shear Reinforcing = 1.0048 cm²
- **Wooden Rafter Evaluation**

  ![Axial Force](image1)
  ![Shear](image2)
  ![Moment](image3)

  **Maximum Existing Stress**
  - Axial stress = 5.92 kg/cm²
  - Shear stress = 2.29 kg/cm²
  - Bending tensile stress = 5.54 kg/cm²

  **Allowable Stress**
  - Axial stress = 81 kg/cm²
  - Shear stress = 10.8 kg/cm²
  - Bending tensile stress = 91.8 kg/cm²

- **Masonry Wall Evaluation**

  ![Axial Stress](image4)
  ![Shear Stress](image5)
  ![Bending Tensile Stress](image6)

  **Maximum Existing Stress**
  - Compression stress = 4.39 kg/cm²
  - Shear stress = 2.54 kg/cm²
  - Bending tensile stress = 8.75 kg/cm²

  **Capacity Stress**
  - Compression stress = 12 kg/cm²
  - Shear stress = 3 kg/cm²
  - Bending tensile stress = 12 kg/cm²
3.4.1.2. Dwelling House (Perumnas) RSS 21/54 (Gable wall with no practical column)

3-D Model

Soft soil; PGA=0.22 g; UBC 97; Importance Factor=1; Return Period = 200 yrs

- **Reinforced Concrete Column Evaluation**

  - **Axial Force**
  - **Shear Force**
  - **Moment**

  **Required Reinforcing**
  - Longitudinal Reinforcing = 1.44 cm$^2$
  - Shear Reinforcing = 0.089 cm$^2$

  **Available Reinforcing**
  - Longitudinal Reinforcing = 4.5216 cm$^2$
  - Shear Reinforcing = 1.0048 cm$^2$

- **Reinforced Concrete Ring Beam Evaluation**

  - **Shear Force**
  - **Moment**
Required Reinforcing
Top Longitudinal Reinforcing = 1.335 cm²
Bottom Longitudinal Reinforcing = 1.259 cm²
Shear Reinforcing = 0.077 cm²

Available Reinforcing
Top Longitudinal Reinforcing = 2.2608 cm²
Bottom Longitudinal

- Wooden Rafter Evaluation

Axial Force
Shear Force
Moment

Maximum Stress
Compression stress = 5.36 kg/cm²
Shear stress = 2.53 kg/cm²
Bending tensile stress = 23.08 kg/cm²

Allowable Stress
Compression stress = 81 kg/cm²
Shear stress = 10.8 kg/cm²
Bending tensile stress = 91.8 kg/cm²

- Masonry Wall Evaluation

Axial Stress
Shear Stress
Bending Tensile

Maximum Existing Stress
Compression stress = 5.81 kg/cm²
Shear stress = 3.64 kg/cm²
Bending tensile stress = 5.26 kg/cm²

Capacity Stress
Compression stress = 12 kg/cm²
Shear stress = 3 kg/cm²
Bending tensile stress = 12 kg/cm²
3.4.1.3. Dwelling House (Perumnas) RSS 21/54 (Gable wall without column)

3-D Model

Soft soil; PGA=0.22 g; UBC 97; Importance Factor=1; Return Period = 200 yrs

- **Masonry Wall Evaluation**

<table>
<thead>
<tr>
<th>Maximum Existing Stress</th>
<th>Capacity Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression stress = 8.30 kg/cm²</td>
<td>Compression stress = 12 kg/cm²</td>
</tr>
<tr>
<td>Shear stress = 3,28 kg/cm²</td>
<td>Shear stress = 3 kg/cm²</td>
</tr>
<tr>
<td>Bending tensile stress = 4.75 kg/cm²</td>
<td>Bending tensile stress= 12 kg/cm²</td>
</tr>
</tbody>
</table>

- **Masonry Wall Damage (Shear stress exceeded)**
3.4.2.1. School Building (Gable Wall with Practical Column)

3-D Model

Hard soil; PGA=0.22 g; UBC 97; Importance Factor=1.5; Return Period = 200 yrs

- Reinforced Concrete Column Evaluation

<table>
<thead>
<tr>
<th>Axial Force</th>
<th>Shear Force</th>
<th>Moment</th>
</tr>
</thead>
</table>

**Required Reinforcing**
- Longitudinal Reinforcing = 6.726 cm$^2$
- Shear Reinforcing = 0.104 cm$^2$

**Available Reinforcing**
- Longitudinal Reinforcing = 6.7824 cm$^2$
- Shear Reinforcing = 1.0048 cm$^2$
• Reinforced Concrete Ring Beam Evaluation

Maximum Existing Stress
Compression stress = 1.30 kg/cm$^2$
Shear stress = 1.81 kg/cm$^2$
Bending tensile stress= 1.02 kg/cm$^2$

Capacity Stress
Compression stress = 21 kg/cm$^2$
Shear stress = 3.90 kg/cm$^2$
Bending tensile stress= 2.5 kg/cm$^2$

Required Reinforcing
Longitudinal Reinforcing = 4.5 cm$^2$
Shear Reinforcing = 0.145 cm$^2$

Available Reinforcing
Longitudinal Reinforcing = 6.09 cm$^2$
Shear Reinforcing = 1.0048 cm$^2$

• Brick Masonry Wall Evaluation

Maximum Existing Stress
Compression stress = 1.30 kg/cm$^2$
Shear stress = 1.81 kg/cm$^2$
Bending tensile stress= 1.02 kg/cm$^2$

Capacity Stress
Compression stress = 21 kg/cm$^2$
Shear stress = 3.90 kg/cm$^2$
Bending tensile stress= 2.5 kg/cm$^2$
- Wooden Rafter Evaluation

  Maximum Stress
  Compression stress = 13.05 kg/cm$^2$
  Shear stress = 1.99 kg/cm$^2$
  Bending tensile stress = 77.48 kg/cm$^2$

  Allowable Stress
  Compression stress = 81 kg/cm$^2$
  Shear stress = 10.8 kg/cm$^2$
  Bending tensile stress = 91.8 kg/cm$^2$

3.4.2.1. School Building (Gable Wall with No Practical Column)

  3-D Model

  Hard soil; PGA=0.22 g; UBC 97; Importance Factor=1.5; Return Period = 200 yrs

- Reinforced Concrete Column Evaluation
**Reinforced Concrete Ring Beam Evaluation**

- **Required Reinforcing**
  - Longitudinal Reinforcing = 5.33 cm²
  - Shear Reinforcing = 0.099 cm²

- **Available Reinforcing**
  - Longitudinal Reinforcing = 6.7824 cm²
  - Shear Reinforcing = 1.0048 cm²

**Brick Masonry Wall Evaluation**

- **Maximum Existing Stress**
  - Compression stress = 7.82 kg/cm²
  - Shear stress = 1.60 kg/cm²
  - Bending tensile stress = 3.38 kg/cm²

- **Capacity Stress**
  - Compression stress = 21 kg/cm²
  - Shear stress = 3.90 kg/cm²
  - Bending tensile stress = 2.5 kg/cm²

From observations of the past 25 years it can be identified that a “new” culture is emerging all over Indonesia, namely a culture of building masonry houses, reinforced or unreinforced and mostly built with poor quality. This new culture is the product of lifestyles, which again are a result of occupational pattern, social dependency, local believes and practices. Therefore efforts must be emphasized on how to make such masonry houses earthquake resistant and information dissemination on how to appropriately build masonry houses.

In the Indonesian case, the damage and collapse of the “new culture” non engineered masonry buildings are mostly caused by the poor quality materials and poor workmanship, resulting in, among others poor detailing, poor concrete quality, poor brick laying. However, in almost all rural areas, one good earthquake resistant design feature can be identified, namely almost all masonry buildings all over Indonesia are built with reinforced concrete framing, consisting of a so called “practical columns” of 12 x 12 cm with 4 rc bars of dia 0.8 cm and “practical beams” of 12 x 20 cm with 4 rc bars of dia 0.8 cm at the foundation level and on top of the walls. As shown in the pictures, such masonry buildings if correctly built were undamaged or suffered negligible damage in past earthquakes. Most of the damage observed were caused by poor quality of concrete, wrong detailing of rc bars, particularly at column – beam connections and connections of wall to columns and roof trusses were not properly anchored to the top beams. In those cases, for rural areas, the efforts on how to make the buildings earthquake resistant will be emphasized on the enhancement of the current practice to produce good quality buildings as a culture.

Another major factor contributing to the damage and collapse of such buildings is the lack of maintenance, resulting in deterioration, thus reducing the structural strength.

As is known, for non engineered buildings, 90 % of the vulnerability reduction related issues are social, cultural, ethnological, economical and political since it is closely linked to poverty. Only 10 % is technical. Having identified the technical problem, simplistic notion says that technical assistance, supervision, training and different forms of information and communication will be the measures that help to the improvement of quality of construction and the resistance to earthquake. The solution is not as simple as that because it is interlocked with poverty. An effective solution to solve this problem must be sought. The solution must be socially acceptable utilizing traditions which already exist, e.g. the concept of communal activity and mutual self help (gotong royong) which is part of the Indonesian traditional society in rural areas. Community participation provides an effective means of contributing to upgrading activities of existing buildings and for the adoption of correct methods in constructing masonry buildings. The emphasis must also include the comprehensive improvement of infrastructural facilities and income generating. The training for such activities shall be as practical as possible and based on learning by doing and utilizing local materials and local craftsmen. However, it is not suggested to provide prototypes buildings during such trainings.

For such purpose, there is a need to train an intermediate group of technicians who will be stationed in the villages and would serve as problem solvers at the local level and train local masons and craftsmen in quality control. However, all these requires concerted
efforts from many different players, the integration of all sectors and levels of national and local development efforts in the implementation of social and economic development with the aim to alleviate poverty.

The problems are different for rural non-engineered buildings and shanty town non-engineered buildings. In the shanty town dwellers case, the situation is more difficult because the dwellers are too immersed in their misery to initiate a change. Shanty town dwellers mostly have surrendered to their condition, to their cramped and stunted view of life. They could not help themselves. Almost anything which they cannot acquire by their own labor from their own neighborhood cannot be acquired at all. They dragged out their short, diseased and ugly lives in the dirt and discomfort to which they had been born.

More efforts must be made in looking for an appropriate solution on how to upgrade non-engineered buildings in shanty towns correctly. For the purpose, sociologist, economists, ethnographers, technicians and the government must work in a concerted effort.

Conclusion

- A new masonry building culture has emerged in Indonesia, unfortunately most of them are of poor quality and inappropriately built.
- Reducing negative effects of this new culture should be anticipated not only by technical approach but also cultural-social approach continuously and simultaneously.
- It is recommended to encourage the practice of the good earthquake resistant feature in rural areas, the use of RC framing for masonry buildings, the so called (“practical columns and beams”) in urban shanty towns areas.
- The preliminary results of the analysis showed a good correlation with the actual damages observed during past earthquakes. It can be observed that most of the damaged buildings are caused by poor quality and if appropriately built, can meet the expectations: that in a major earthquake, the buildings may suffer heavy damage but do not collapse.

It is suggested to include the following research in EQTAP Phase II:

1. Indonesia
   a. Perform more analysis to reconfirm the above findings.
   b. Perform a random full scale laboratory tests utilizing each individual area’s material and workmanship. This is to reconfirm the analysis results and findings
   c. To study the possibilities for an appropriate, effective and workable solution and measures that help to the improvement of quality of construction and the resistance to earthquakes.

2. Other Countries
   a. Identify the predominant types of non-engineered buildings built in other Asia Pacific countries and identify the new “culture”.
   b. Find solutions to make those buildings earthquake resistant utilizing locally available materials and workmanship and suiting the local social, cultural, ethnographical, economical as well as political conditions for each individual country and or area, whenever necessary.
References


