

GUIDELINES ON RETROFITTING OF RURAL HOUSES IN MYANMAR



SCOPE OF THIS MANUAL

This manual is developed with wider consultations and inputs from various relevant stakeholders, professional organizations including some independent experts. This is intended to give basic information on techniques of construction of disaster resilient houses and retrofitting of community shelters. It is expected that this will be used for carpenters, artisans and construction workers with agencies involved in shelter construction, which will enable in reducing disaster risks.

Don't Wait for Disaster

No country can afford to ignore the lessons of the earthquakes in Chile and Haiti. We cannot stop such disasters from happening. But we can dramatically reduce their impact, if the right disaster risk reduction measures are taken in advance.

A week ago I visited Chile's earthquake zone and saw how countless lives were saved because Chile's leaders had learned the lessons of the past and heeded the warnings of crises to come. Because stringent earthquake building codes were enforced, much worse casualties were prevented. Training and equipping first responders ahead of time meant help was there within minutes of the tremor. Embracing the spirit that governments have a responsibility for future challenges as well as current ones did more to prevent human casualties than any relief effort could.

Deaths were in the hundreds in Chile, despite the magnitude of the earthquake, at 8.8 on the Richter Scale, the fifth largest since records began. In Haiti, a less intense earthquake caused hundreds of thousands of deaths. Haiti had non-existent or un-enforced building codes, and very poor preparedness.

The lessons are universally applicable. No country is immune from disaster, be it earthquakes or floods, storms or heat waves. More and more intense natural disasters are affecting all five continents, we believe as a result of climate change. Many of the world's poorest people live in high-risk densely populated cities in flood or earthquake zones, or both.

The culture of disaster risk reduction must spread. I am encouraged that we already have a head start in this regard. The Hyogo Framework for Action, a 10-year plan to make the world safer from disasters triggered by natural hazards, was adopted by 168 governments in 2005. Hyogo gives national authorities a blueprint to assess and reduce risks through planning, training, and better public education. For example, making sure that school, hospitals, and other key public infrastructure meet certain safety standards.

There has been progress. Bangladesh lost more than **500,000** people during Cyclone Bhola in 1970. It subsequently built 2,500 cyclone shelters on elevated concrete platforms and trained more than 32,000 volunteers to help in evacuations. When Cyclone Sidr struck in 2007 with an enormous sea surge, the death toll was less than **4,000**. Cyclone Nargis, a similar event in unprepared Myanmar in May 2008, cost **140,000** lives. Cuba weathered four hurricanes in 2008. It sustained \$9 billion of physical damage but very few lives were lost.

The evidence is overwhelming. Yet the lessons of these disasters are forgotten with depressing speed. We know prevention actually saves governments money in the long run. When China spent \$3.15 billion on reducing the impact of floods between 1960 and 2000, it averted losses estimated at about \$12 billion. Similar savings have been recorded in Brazil, India, Vietnam and elsewhere.

Everyone has a role to play.

Governments, central and local, have to do what it takes to make communities able to cope with both continuing challenges and sudden shocks. The Chile and Haiti earthquakes showed us once again why action **before** disasters makes all the difference. To prevent natural hazards turning into disasters, we must all act sooner and act smarter.

***Excerpts from the speech of Ban Ki-moon,
Secretary-General of the United Nations***



Issued in public interest by UN-Habitat

FOREWORD

Natural disasters are most common and frequent in Myanmar, causing enormous loss of lives and properties and environmental damage. It is prone to multiple natural hazards including cyclones, storm surge, tsunami, earthquake, fire and land slide. The Cyclone Nargis which hit Myanmar coast in May 2008 has been so far the major disasters affecting the Ayerrawady delta and other coastal regions of the country.

The recent disaster has given an opportunity to focus on a comprehensive disaster risk reduction strategy and programme in the most hazard prone locations of the country.

In any disaster situations most lives and properties are lost due to lack of proper awareness and knowledge on preparedness and effective response in a systematic manner. The Cyclone Nargis has reiterated the fact that lack of awareness of the people living in the disaster risk prone areas cause more human casualties.

Following the Cyclone Nargis there were various recovery and reconstruction efforts taken up by various agencies including government, donor communities, UN, INGOs, Local NGOs including individuals. One of the major actions taken up in construction of various individual shelters in the concepts of build back better to save the lives and livelihoods of the vulnerable populations in the delta.

The manual on "*Guideline on retrofitting of rural houses in Myanmar*" is one step forward to provide basic knowledge, guidance in order to enable the rural community to retrofit their houses to withstand any future disasters. As the main purpose of this guideline is to promote sustainable disaster risk reduction at the community level, I hope this guideline will meet its specific objectives of ensuring safer habitation by giving the knowledge on best practices of retrofitting through engineering and non-engineering methods.

I congratulate UN-Habitat for developing this manual in collaboration with Myanmar Engineering Society to come up with this initiative. I am hopeful that this guideline will provide the basic techniques of empowering the people, enable them to improve the existing rural houses through retrofitting and ensuring a safer tomorrow.


U Than Myint
Immediate Past President (MES)
Chairman of Natural Disaster Mitigation Committee
Myanmar Engineer Society

TABLE OF CONTENTS

| | |
|-------------------------------------|---|
| Goal..... | 4 |
| Objectives..... | 4 |
| Target users of this Guideline..... | 4 |
| How to use this Guideline..... | 4 |

Chapter 1 Introduction

| | |
|--|---|
| 1.1 What is retrofitting?..... | 5 |
| 1.2 The different between retrofitting and repair..... | 5 |
| 1.3 Why is retrofitting needed?..... | 6 |
| 1.4 When is retrofitting needed?..... | 6 |
| 1.5 Advantages of retrofittings..... | 7 |
| 1.6 Summary..... | 7 |

Chapter 2 Myanmar and Rural Buildings

| | |
|---|----|
| 2.1 Disasters in Myanmar..... | 8 |
| 2.1.1 Drough..... | 8 |
| 2.1.2 Earthquake..... | 8 |
| 2.1.3 Cyclones, Floods, Landslides, Storm Surges and Tsunami..... | 9 |
| 2.1.4 Fire and Forest Fire..... | 9 |
| 2.2 Rural Buildings in Myanmar..... | 10 |
| 2.2.1 Bamboo..... | 10 |
| 2.2.2 Timber..... | 10 |
| 2.2.3 Brick Noggin..... | 10 |
| 2.2.4 Brick Pier..... | 11 |
| 2.2.5 Reinforced Concrete..... | 11 |
| 2.3 Types of Rural Buildings System..... | 12 |
| 2.3.1 Foundation..... | 12 |
| 2.3.2 Floor..... | 12 |

| | | |
|-------|---|----|
| 2.3.3 | Frame and Wall..... | 13 |
| 2.3.4 | Roof..... | 13 |
| 2.3.5 | Joints and Connections..... | 14 |
| 2.4 | Testing resistance of the building..... | 14 |
| 2.4.1 | Soil Test..... | 14 |
| 2.4.2 | Footing Uplifting Test..... | 15 |
| 2.4.3 | Sway Test..... | 15 |
| 2.5 | Summary..... | 15 |

Chapter 3 DRR Requirement and the Process of Retrofitting

| | | |
|-----|---|----|
| 3.1 | Disaster Risk Reduction Compliance..... | 16 |
| 3.2 | Systematic Approach..... | 17 |
| 3.3 | ABC Principle..... | 17 |
| 3.4 | Disaster Preventive Guidelines..... | 18 |
| 3.5 | Maintenance..... | 19 |
| 3.6 | Summary..... | 20 |

Chapter 4 Retrofitting Rural Buildings

| | | |
|-------|--|----|
| 4.1 | Retrofitting Bamboo and Timber Buildings..... | 21 |
| 4.1.1 | Vulnerability at a Glance..... | 21 |
| 4.1.2 | Disaster Resisting Features at a Glance..... | 21 |
| 4.2 | Retrofitting Brick Nogging..... | 22 |
| 4.2.1 | Vulnerability at a Glance..... | 22 |
| 4.2.2 | Disaster Resisting Features at a Glance..... | 22 |
| 4.3 | Retrofitting Brick Pier Building..... | 23 |
| 4.3.1 | Vulnerability at a Glance..... | 23 |
| 4.3.2 | Retrofitting with Disaster Resisting Features at a Glance..... | 23 |
| 4.4 | Preparation for Retrofitting..... | 24 |
| 4.4.1 | Visual Survey..... | 24 |

| | | |
|----------------------------------|---|----|
| 4.4.2 | Selecting Good Timber..... | 25 |
| 4.4.3 | Treating Bamboo and Timber..... | 25 |
| 4.4.4 | Preparing Steel Reinforcement..... | 26 |
| 4.4.5 | Preparing Good Mortar and Concrete..... | 27 |
| 4.5 | Retrofitting Foundation and Floor Structures..... | 27 |
| 4.5.1 | Erecting the Tilted Building..... | 27 |
| 4.5.2 | Replacing Column Base..... | 28 |
| 4.5.3 | Installing Ground Beam around the Building..... | 29 |
| 4.5.4 | Installing Additional Brick Pier Support..... | 29 |
| 4.5.5 | Re-leveling Floor..... | 30 |
| 4.6 | Retrofitting Frame and Wall Structures..... | 30 |
| 4.6.1 | Adding Bracings..... | 30 |
| 4.6.2 | Installing Steel Stitching to the Brick Wall..... | 32 |
| 4.6.3 | Installing Lintel Beams and Ties to the Brick Wall..... | 33 |
| 4.6.4 | Installing Lintel Column Ties to the Brick Wall..... | 34 |
| 4.6.5 | Adding Lintel Tie Beam Around the Reinforced Concrete Building..... | 34 |
| 4.7 | Retrofitting Roof Structures..... | 35 |
| 4.7.1 | Adding Truss Bracing..... | 35 |
| 4.7.2 | Reinforcing Trusses..... | 36 |
| 4.7.3 | Adding Gable End Lintel Ties..... | 36 |
| 4.7.4 | Connecting Trusses to Building..... | 37 |
| 4.7.5 | Connecting Purlin to Truss and Rafter..... | 38 |
| 4.7.6 | Connecting Roofing to Purlin..... | 38 |
| 4.8 | Summary..... | 39 |
| Chapter 5 Recommendations | | |
| 5.1 | Disaster Risk Reduction Guidelines..... | 40 |
| 5.2 | Conclusion..... | 42 |
| | References..... | 43 |

GOAL

- To promote sustainable disaster risk reduction in the community

OBJECTIVES

- Ensure safer habitat by giving the knowledge on best practices of retrofitting
- Improve earnings on their livelihood by providing capacity building of the local artisans and self-help group
- Strengthen the capacity and improve skills for local carpenters and artisans on construction and retrofitting on non-engineered structures

TARGET USERS OF THIS GUIDELINE

- Self-help groups, communities living in the disaster prone areas of rural regions in Myanmar
- Local carpenters, masons and artisans
- Trainers, technical workers involved in rural housing development activities.

HOW TO USE THIS GUIDELINE

Most of the retrofitting methods are simple, easy to work and economical. Retrofitting can be done with available local resources in most of the case. However, it shall be done correctly to be effective for which the understanding of basic concepts and ideas are essential. This guideline tried to relay those basic facts to the community levels.

This guideline shall be use as a guideline. The detail works shall be adjusted as necessary. It is advisable to seek assistance and ideas from the local artisans to carry out proper retrofitting work.



CHAPTER 1. INTRODUCTION

1.1 WHAT IS RETROFITTING?

Retrofitting is the process of introducing specific elements or features into an existing structure so as to improve its resistance against natural disasters.

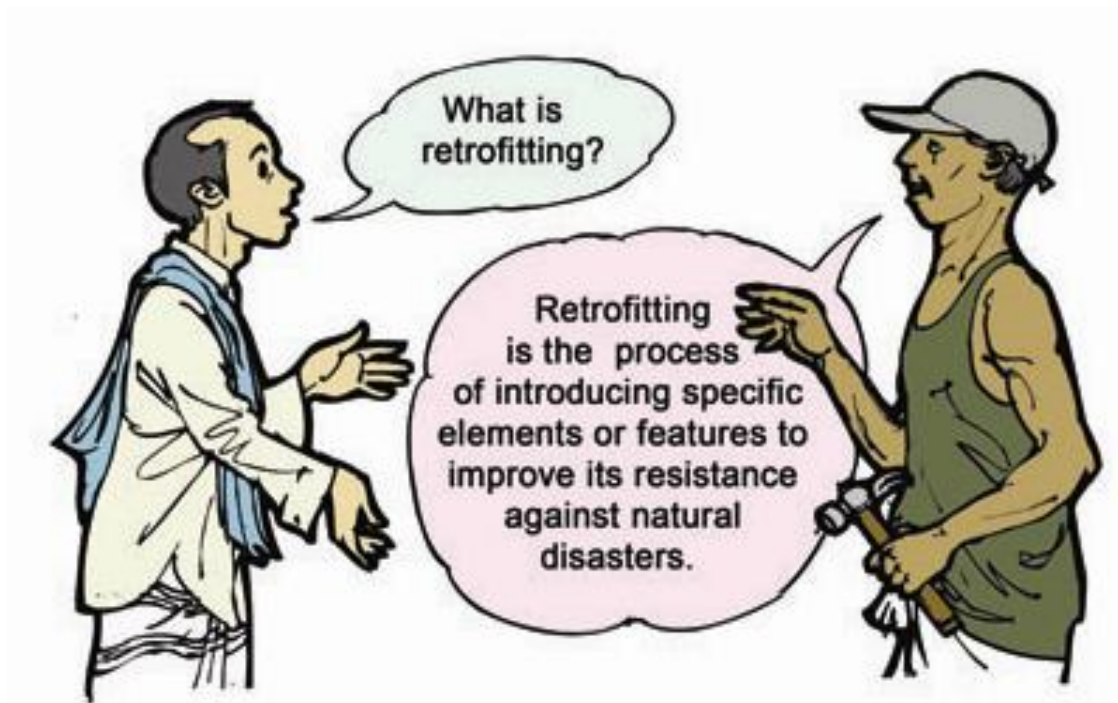
1.2 THE DIFFERENCE BETWEEN RETROFITTING AND REPAIR

Repairing is restoring a building back to its original condition. For example-

- Repairing cracked wall
- Repairing damaged columns and beams
- Repairing or replacing roof truss elements

Retrofitting is structural improvement to enhance the multi-hazard resistance of a building. For example-

- Adding seismic bands
- Adding shear wall
- Adding bracing
- Improve joint connections along load path



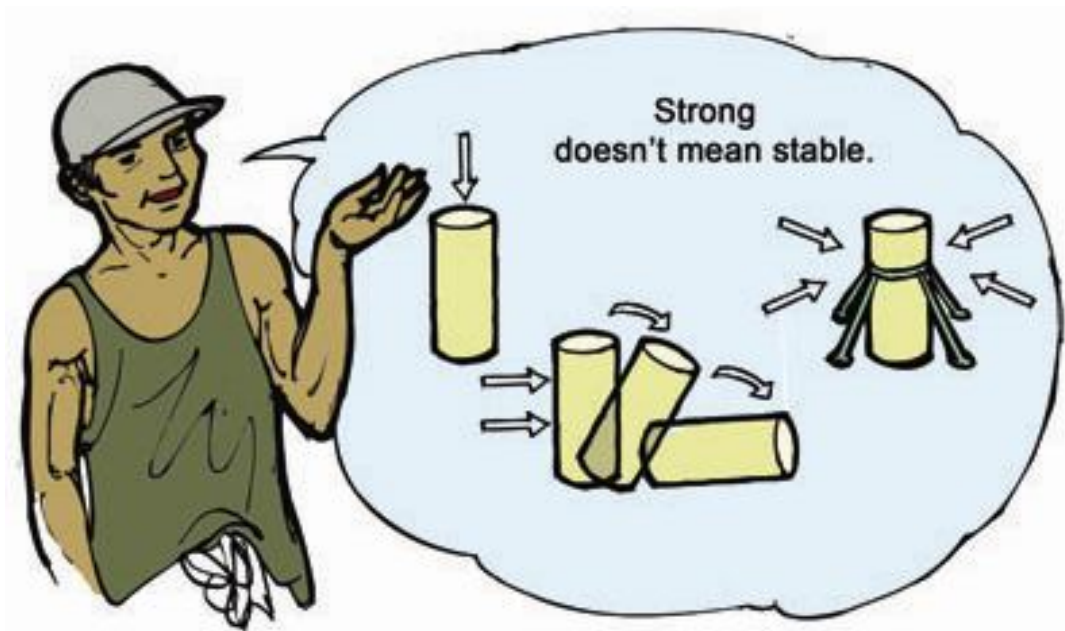
1.3 WHY IS RETROFITTING NEEDED?

Structure may be strong but may not be stable. For example, a log wood piece of 8 inch diameter and 2 ft in height is very strong and it can take a heavy load. However, it will topple down easily even if you push it lightly. That log wood piece is strong but not stable.

To make this log wood piece more stable, a couple of simple wires tied at the top and anchored to the ground will increase its ability to resist horizontal forces.

Retrofitting is therefore not just adding strength to the structures but is strengthening the whole structural system to impart needed stability under and disaster-induced loading conditions.

Traditionally rural buildings are built to resist gravity load only. Normally, they are not strong enough to resist lateral load system as most of natural disasters forces apply laterally for which retrofitting is necessary to improve their performance during disaster.



1.4 WHEN IS RETROFITTING NEEDED?

- Old and deteriorated buildings
- New structure not designed properly
- Use of inferior material, poor construction, and poor workmanship
- Laid foundation or building on soft soil

1.5 ADVANTAGES OF RETROFITTING

- Retrofitting can be done in phased manner depending upon availability of funds and time. So it is not necessary to retrofit the whole in one time.
- Retrofitting eliminates the need for temporary shelter for the occupants since retrofitting can be taken up in a few rooms at a time.
- Retrofitting eliminate the cost of total demolition and removal of debris from demolition of the building

1.6 SUMMARY

Retrofitting is the process of introducing specific elements or features to improve its resistance against natural disasters. Retrofitting is most cost-effective way to improve the resilience of your building. Most of the retrofitting ideas are simple, easy and economical but very effective to strengthen the structure.

Points to Remember

- Retrofitting is improving the resistance of an existing building against natural disasters
- Retrofitting enhances the hazard resistance unlike normal repairing work
- Strong member alone may not be enough. The whole structural system need to be stable
- All weak buildings (may or may not be damaged) need to be retrofit.
- Retrofitting can be done step-by-step
- Retrofitting doesn't need for temporary shelter
- Retrofitting is cost effective

CHAPTER 2: MYANMAR AND RURAL BUILDINGS

2.1 DISASTERS IN MYANMAR

2.1.1 DROUGHT

CHARACTERISTIC OF HAZARD

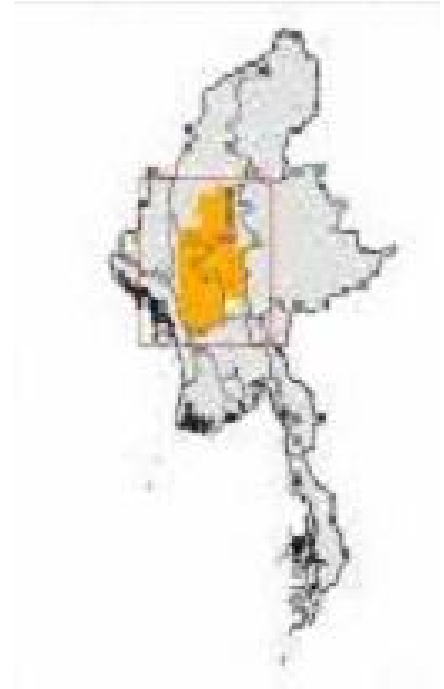
- Location - Central part of the country
- Seasons - Summer, from March to May
- Intensity - Up to 47° C

RISK TO BUILDING

- No direct damage
- Heat related health problem to user
- Heat related secondary hazard such as fire

PREVENTIVE MEASURES

- Use thermal lightweight material
- Provide ventilation
- Provide heat shades such as providing ceiling, extend roof projection, grow trees to avoid direct sun light, etc.



2.1.2 EARTHQUAKE

CHARACTERISTIC OF HAZARD

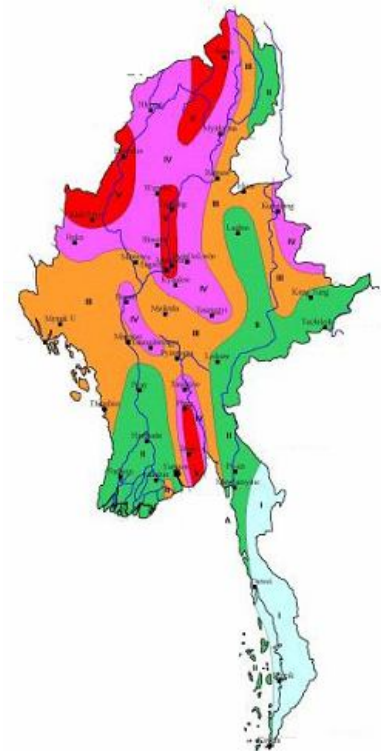
- High Risk- Sagaing division and Central Myanmar
- Moderate Risk - Rest of the country except Thinnintharyi division
- Seasons - Not seasonal, impossible to predict
- Intensity - Up to MMI IX

RISK TO BUILDING

- Direct damage from ground shaking
- Secondary hazard such as landslide, fire

PREVENTIVE MEASURES

- Use lightweight material
- Avoid hazardous locations such as near mountain cliff, soft ground, etc.
- Tie every structural elements together
- Provide lateral resistance features such as bracing, shear wall, etc.



2.1.3 CYCLONES, FLOODS, LANDSLIDES, STORM SURGES AND TSUNAMI

CHARACTERISTIC OF HAZARD

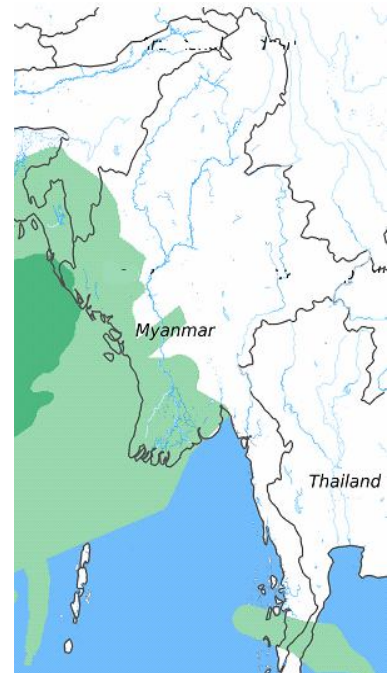
- Location - Rakhine state, Ayeyarwaddy and Yangon divisions
- Seasons - Rainy season (from May to August)
- Intensity - Up to 150 mph

RISK TO BUILDING

- Direct damage from wind, flood, wave
- Secondary hazard such as landslide

PREVENTIVE MEASURES

- Use strong material
- Avoid hazardous locations such as near mountain cliff, soft ground, etc.
- Tie every structural elements together
- Provide lateral resistance features such as bracing, shear wall, etc.



2.1.4 FIRE AND FOREST FIRE

CHARACTERISTIC OF HAZARD

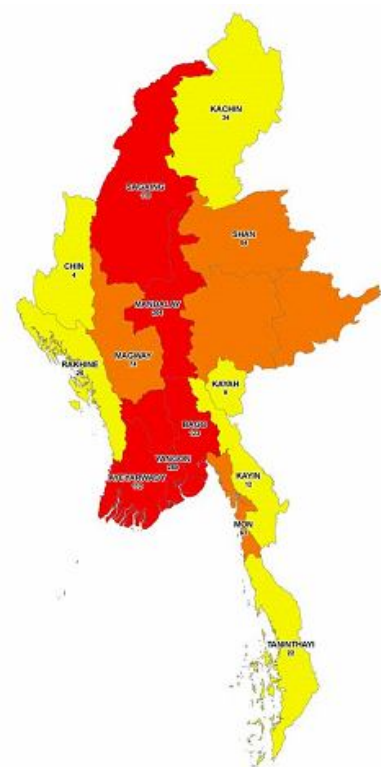
- High Risk Locations - Sagaing, Mandalay, Bago, Ayeyarwaddy and Yangon divisions (More than 100 average annual fire cases)
- Moderate Risk Locations - Magwe, division, Shan and Mon states. (Between 100 and 50 average annual fire cases)
- Seasons - Forest fires are seasonal. Mostly occurs in summer, from March to May

RISK TO BUILDING

- Direct damage from fire

PREVENTIVE MEASURES

- Use fire resistant material
- Cover oven and kitchen properly with fire-proof material
- Provide fire fighting facilities
- Educate users and fire fighting trainings



2.2 RURAL BUILDINGS IN MYANMAR

2.2.1 Bamboo

- Foundation - Earth
- Floor - Earth/ Bamboo
- Frame - Bamboo
- Wall - Bamboo
- Roof - Leaves/ CGI sheet
- Life - 2 to 5 years
- Vulnerable to - Fire, Wind, Flood



2.2.2 Timber

- Foundation - Earth/ Brick/Precast
- Floor - Timber/Concrete
- Frame - Timber
- Wall - Timber
- Roof - Leaves/CGI sheet/ Tile
- Life - 10 to 25 years
- Vulnerable to - Fire, Wind, Flood



2.2.3 Brick Noggin

- Foundation - Brick/ Precast
- Floor - Timber/ Concrete
- Frame - Timber
- Wall - Brick
- Roof - CGI sheet/ AC sheet/ Tile
- Life - 20 to 30 years
- Vulnerable to - Earthquake



2.2.4 Brick Pier

- Foundation - Brick
- Floor - Timber/ Concrete
- Frame - Brick pier and lintel beams
- Wall - Brick
- Roof - CGI sheet/ AC sheet/ Tile
- Life - 20 to 40 years
- Vulnerable to - Earthquake



2.2.5 Reinforced Concrete

- Foundation - Reinforced Concrete
- Floor - Timber/ Reinforced Concrete
- Frame - Reinforced Concrete
- Wall- Brick
- Roof - CGI sheet/ AC sheet/ Tile
- Life - 30 to 60 years
- Resistant to - Earthquake, Fire, Wind, Flood



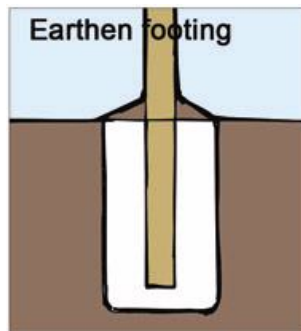
2.3 TYPES OF RURAL BUILDING SYSTEM

2.3.1 Foundation

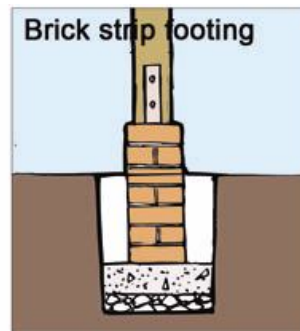
Foundation is essential part of a building where all the forces from the building transfer to the underlying ground. Therefore, not only foundation structure must be strong but also the underlying ground must be firm.

Foundation must be well protected and strong enough to resist-

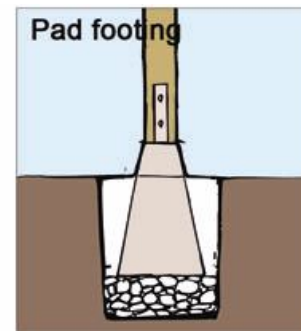
- Ground shaking due to earthquake
- Lateral forces due to earthquake, wind and flood
- Uplifting due to earthquake, wind and flood
- Ground weakening due to flood.
- In heavy buildings, most of the foundation loads are compressive loads only.
- In light buildings, uplift load to the foundation can also be possible sometimes.



Earthen footing



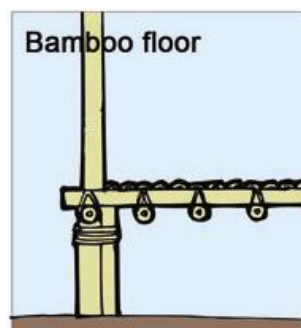
Brick strip footing



Pad footing

2.3.2 Floor

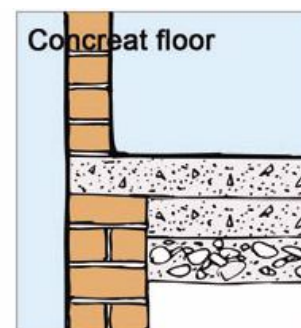
Floor receives gravity loads. In case of elevated floor, loads are transferred to the foundation through floor structural frame. In case of floor resting on ground, loads are transferred directly to the ground.



Bamboo floor



Timber floor



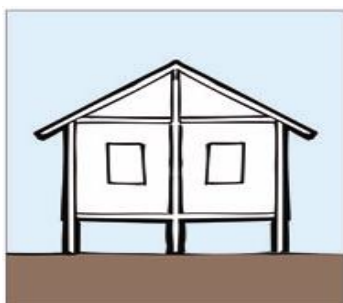
Concrete floor

2.3.3 Frame and Wall

Frames are the skeleton of the buildings. Loads from the surfaces like roofs, walls and floors are transferred to the foundation through frames along the load path. Traditional rural buildings are built to resist vertical gravity load only. Therefore, it is very important to retrofit the buildings to resist disaster induced lateral forces.

Preventive measure against disaster-

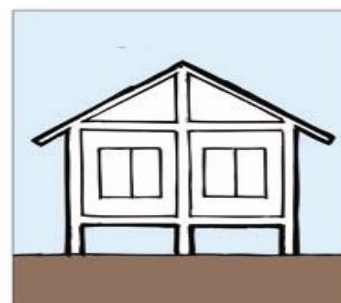
- Frames and walls must be strong enough to resist lateral forces due to earthquake, wind and flood.
- Provide diagonal bracings for each grid line especially for timber and bamboo buildings.
- Opening in walls such as doors and windows must be ensured to prevent cracks and deformation.



Timber/ Bamboo frame



Brick Nogging



Concrete frame

2.3.4 Roof

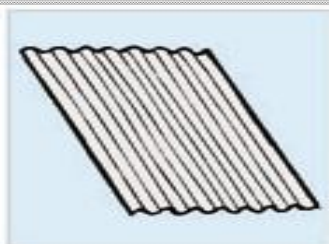
Loads from the roof transfer to the frame through roof structure. Roof structure must be braced both horizontally and vertically. Loads on the roof can be either pushing or pulling. Therefore, it is important all part of roof system must be connected to each other firmly.

Preventive measure against disaster-

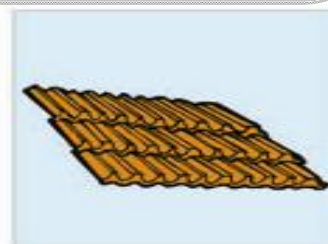
- Roofing must be connected to the underlying roof system to prevent blown away in the event of cyclone and storm.
- Roof slope shall be around 30\degree
- Roof projection shall not be longer than 2 feet
- Use the roof fasteners twice at the edges



Dari roof



CGI roof



Tile roof

2.3.5 Joints and Connections

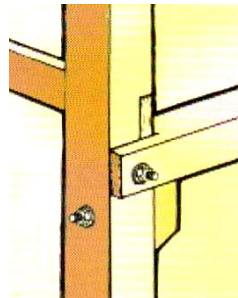
Joints are essential part of every structure. Building members are connected by joints and member forces transfer each other through the joints along the load path. Therefore, joints and connections not only provide continuity but also must be strong enough to be able to withstand member loads.

Preventive measure against disaster-

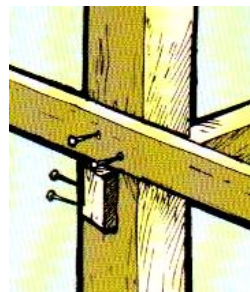
- Make sure joints are connected properly
- Use good, adequate and reliable fasteners
- Use at least two nail points to prevent rotations



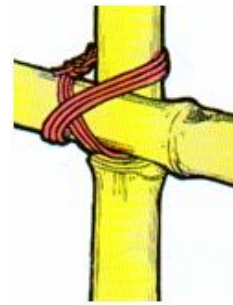
Cast in place



Bolt and Nut



Nail

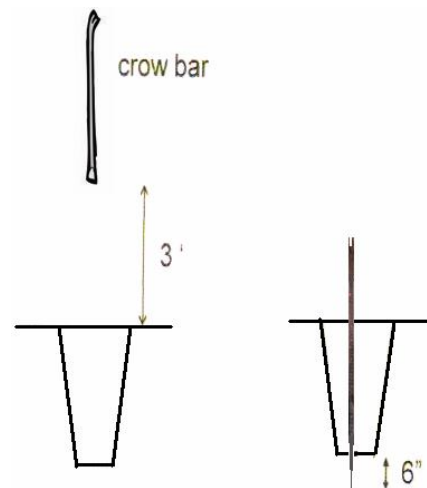


Ties

2.4 TESTING RESISTANCE OF THE BUILDING

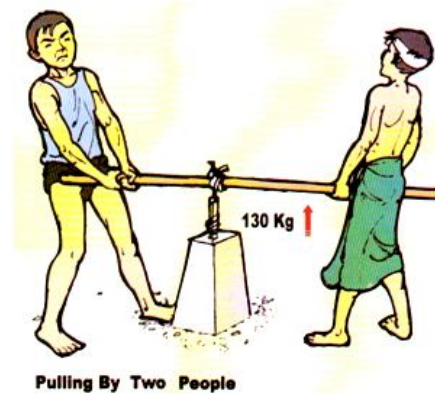
2.4.1 Soil Test

- To test soil at the bottom of the post footing, hold a 5 kg crow bar 3 feet above the ground, directly above the pit, with its pointed end downwards.
- Drop it freely to the bottom of the pit.
- If the penetration of the crow bar is less than 6 inches, the soil is hard enough for the foundation.
- If not, it should be improved by more compaction or new filling.



2.4.2 Footing Uplifting Test

- Post footing of light weight structure like bamboo and timber building must be well anchored in the ground.
- Take a strong bamboo or timber piece. Tie it to the footing and pull it up by two people.
- If it comes out, the anchorage is not enough. It should be compacted again or increase tie down weight.



2.4.3 Sway Test

- To test ability of the building to resist high winds.
- Tie a strong rope to the top of the column post and pull by two person.
- If the building move less than 2" only, it can be considered to withstand normal wind forces.
- If not, the building need lateral bracing at the direction of the rope.
- This test must be carried out at every column grid in both front to back and side to side directions.



2.5 SUMMARY

Being a multi-disaster prone country, the types of hazards are different according to the geographic locations. On the other hand, depending on the type of building vulnerabilities are different. Therefore, it is important to understand both the nature of the hazards and resilience of the building type. The buildings have to be resistant to every possible hazard types.

Points to Remember

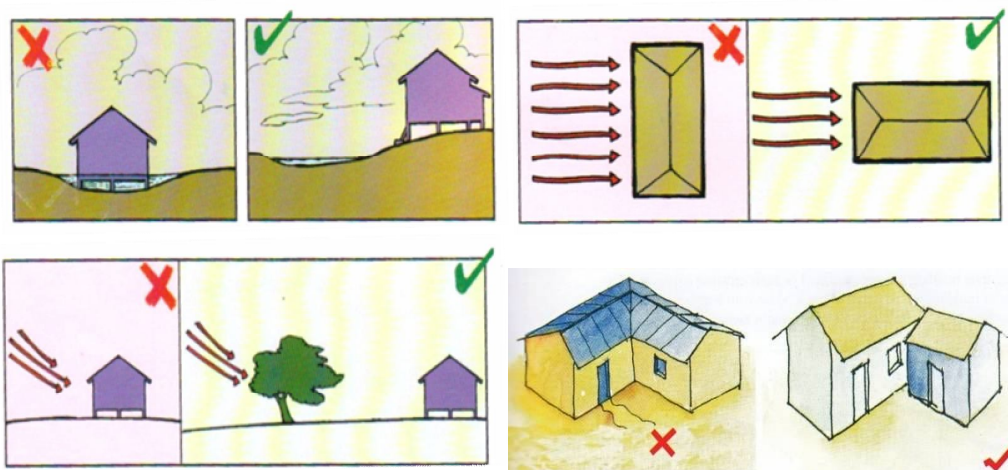
- Myanmar is multi-hazard prone country
- Bamboo, timber, brick nogging and brick pier buildings are most common in Myanmar
- It is important to understand functions of each component of the building structure
- Building stability can be tested by simple ways.

CHAPTER 3: DRR REQUIREMENT AND THE PROCESS OF RETROFITTING

3.1 DISASTER RISK REDUCTION COMPLIANCE

In order to reduce the risks of loss of lives, livelihood and assets caused by heavy rains, strong storms, high floods and earthquakes, some main points must be observed and follow important technical guidelines throughout the retrofitting process.

| Points to observe | Disaster Risk Reduction |
|--|--|
| Build on higher/safer ground | Safer to floods |
| Short face of the house to windward direction | More stability against wind |
| Roof pitch-minimum 30 degree | Prevents roof blowing away |
| Roof projection-not more than 18" from all sides | Prevents roof blowing away |
| Roof cover firmly fixed to rafters and purlins | Keep roof cover intact |
| Rafters, purlins, tie beams and post plates have to be securely fixed to posts | Prevents structural failure |
| Provide bracings | Make structure wind resistant |
| Posts firmly anchored to ground | Prevent the posts from tilt, sway or be blown away |
| Maintain/repair regularly | Extends the durability of shelter |
| Repair/upgrade before monsoon | Ensures shelter remains resistant and safe |

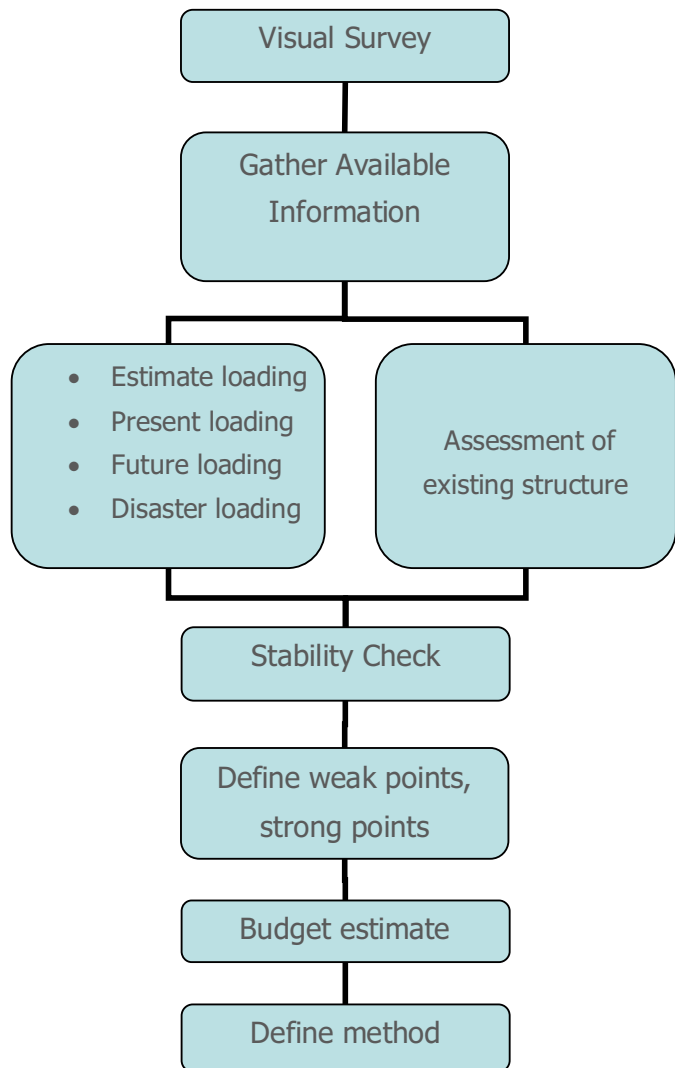


3.2 SYSTEMATIC APPROACH

There are a range of retrofitting methodologies and techniques available. The choice of particular methodology or technique is depend on various factors like-

- Type of building
- Usage of building
- Material used in construction
- Instant of damage
- Future use and exposure condition
- Availability of skill, man, material and tools to carry out the work
- Extent of work

Diagnosis is the first step of retrofitting. This requires systematic documentation and understanding of the possible behavior of buildings during natural disasters.



3.3 ABC PRINCIPLE

The general requirements in shelter construction in regard of DRR compliance is summarized in a simple abbreviation: the ABC principle.

A=Anchoring

Every part of the structure must be tied back to some secure point which is capable of resisting all applied forces.

B=Bracing

Every part of the structure must be held rigid so that it cannot tilt, slide or rotate.

C=Continuity

Every part of the structure must be properly connected to every other member.

3.4 DISASTER PREVENTIVE GUIDELINES

During emergency response period after the Nargis cyclone disaster, several implementing agencies come together and developed minimum requirements for rebuilding shelters in disaster affected areas.

| S N | Design Criteria | Sub-criteria | Limiting Values/Aspects - Minimum | |
|--------|--|---|---|---------------------|
| 1 | General | Internal plinth area | 160 ft ² | |
| | | Outside wall height | 7 ft above the plinth level | |
| | | Roof slope/pitch | 30 degree from horizontal | |
| | | Roof design and construction | Household Rainwater Scheme sensitive | |
| | | Roof projection | 18 inch from the outside wall | |
| | | Roofing material and connection to main frame | Water tight, durable; rainwater scheme sensitive, preferably locally available, easily and cheaply repairable, and properly fastened to the frame | |
| | | Wall material and connection to main frame | Water tight, durable; easily and cheaply repairable, preferably locally available and properly fastened to the frame | |
| | | Floor material | durable, locally available such as Split bamboo | |
| 2 | Life expectancy and resistance to hazards | Life span | 4 years | As much as possible |
| | | Resistance to wind | Limiting wind speed - 80 miles per hour; high speed wind resistant frame, building materials and connections | |
| | | Resistance to Earthquake | 6.5 richter scale; Seismic Factor = 0.150; the house abide by general EQ resistant standard | |
| | | Resistance to flooding | 1 m above normal high tide level of that particular area | |
| 3 | services in the house | Privacy/interior partition | interior partition to generate at least one private space inside the house | |
| | | Steps to plinth level | 2 means of egress/stairs | |
| | | Doors and window opening | 2 doors and 2 windows | |
| 4 | Other Provision | Water and sanitation provision | Space provision for individual Household latrine within 5 m of core house; Provision for Household RW collection system | |
| | | Core house expandability | Flexible enough core house for future expansion | |

3.5 MAINTENANCE

You can extend the life of your shelter with regular maintenance. A shelter can protect your family for many years when you perform regular maintenance during every dry season, especially before the monsoon rain. Protect shelter against earthquakes, storms, floods and fire.

EXTEND THE LIFE OF YOUR SHELTER WITH REGULAR MAINTENANCE

A shelter can protect your family for many years when you perform regular maintenance during every dry season, especially before the monsoon rains.

We Protect our shelter from Rains, Storms & Floods

Let's be prepared before the rains come

Let's do it before the storms come

I cut branches.

This house is fire-safe.

I tighten joints and ropes and add braces.

I repair our roof and shelter top mat.

I tighten nuts, bolts and nails.

I tighten window hinges.

I check the stability of my house with a skilled person (carpenter).

I clean all drains and clean underneath of my house.

I clean the column base and fill it with good soil.

I can save my family because the path to a safe place is clear.

I can save my family because I have cleared the attic where they can escape to.

SHelter CLuster, Myanmar Handout

UN HABITAT FOR A BETTER URBAN FUTURE

DFID Department for International Development

Let's be prepared before the floods come

TEL 951 242361 FOR MORE INFORMATION CONTACT UN-HABITAT www.un-habitat.org/shelter shelter@unhabitat.org

Shweboonthee Shweboonthee's Construction Group

3.6 SUMMARY

Retrofitting the building following the DRR guidelines will decrease its vulnerability in the event of natural disasters. By this, the means of livelihood will be less damaged; the risk of serious setback of the development of the economy and society is reduced. This is true Disaster Risk Reduction.

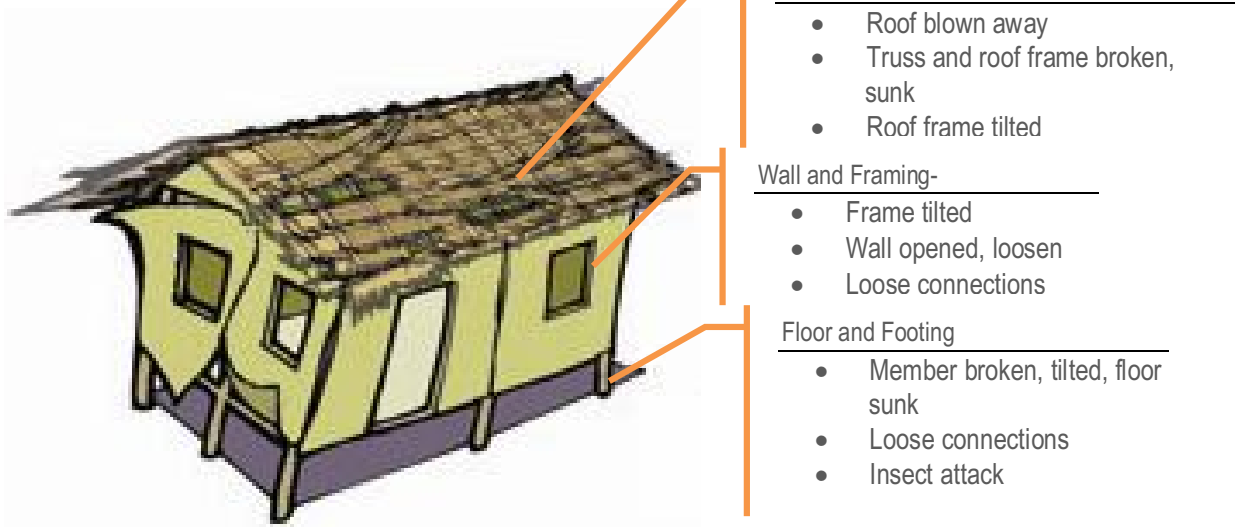
Points to Remember

- Disaster risks can be reduce by following technical guidelines throughout the retrofitting process
- Retrofitting shall be done in systematic approach
- Remember “Anchoring, Bracing, Continuity” principles
- Follow disaster preventive guidelines
- Do regular maintenance

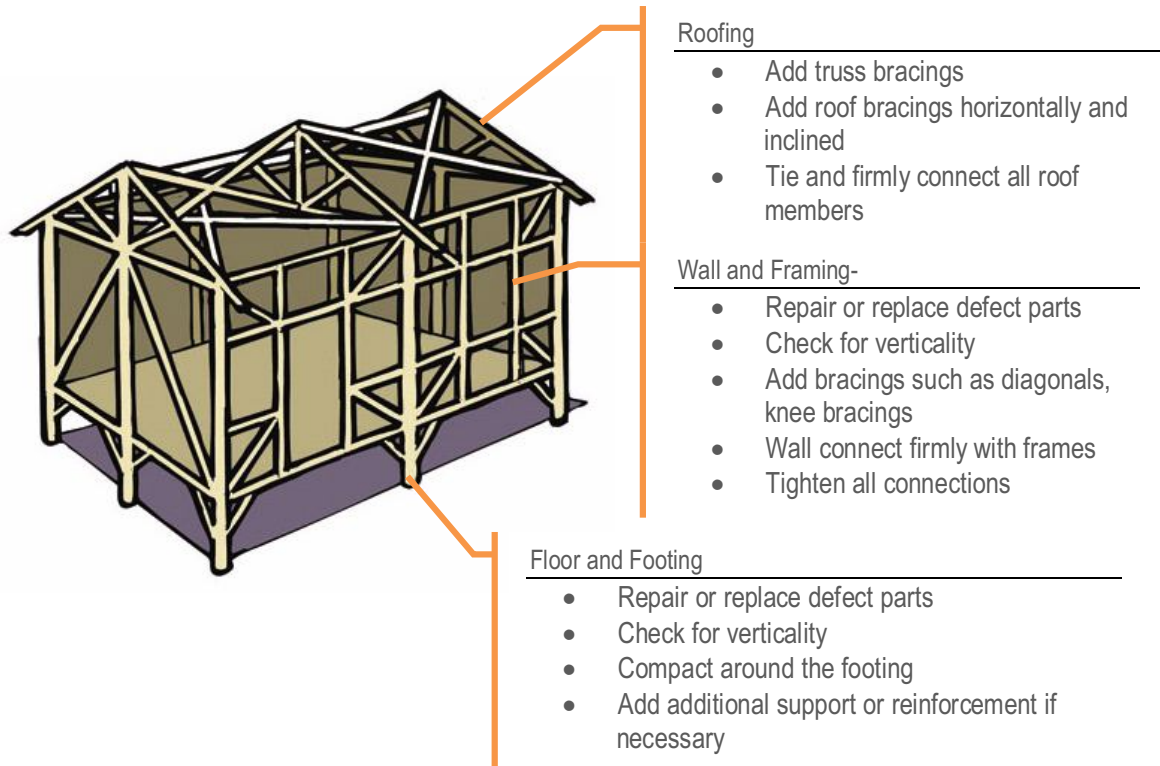
CHAPTER 4: RETROFITTING RURAL BUILDINGS

4.1 RETROFITTING BAMBOO AND TIMBER BUILDINGS

4.1.1 VULNERABILITY AT A GLANCE

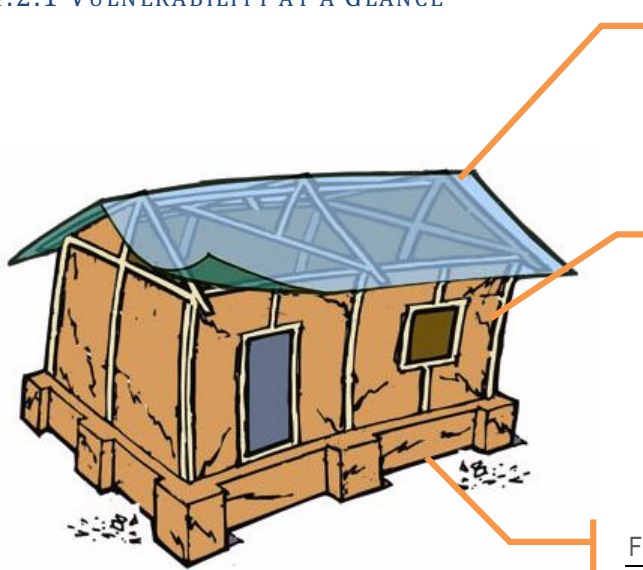


4.1.2 DISASTER RESISTING FEATURES AT A GLANCE



4.2 RETROFITTING BRICK NOGGING

4.2.1 VULNERABILITY AT A GLANCE



Roofing

- Roof blown away
- Truss and roof frame broken, sunk
- Roof frame tilted
- Loose connections

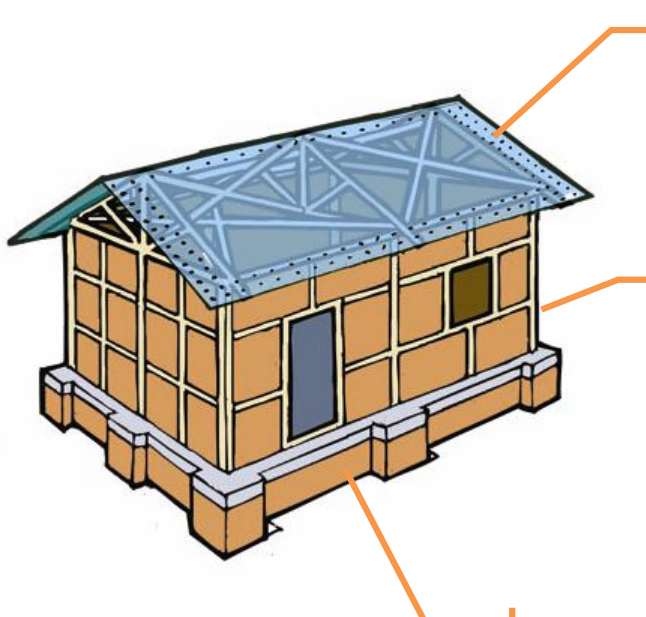
Wall and Framing-

- Frame tilted
- Wall opened, loosen
- Wall strut and rails are missing
- Diagonal wall cracks appear
- Large cracks between timber members and brick walls appear

Floor and Footing

- Member broken, tilted, floor sunk
- Loose connections
- Insect attack

4.2.2 DISASTER RESISTING FEATURES AT A GLANCE



Roofing

- Add truss bracings
- Add roof bracings horizontally and inclined
- Tie and firmly connect all roof members
- Nail closely at the edges

Wall and Framing-

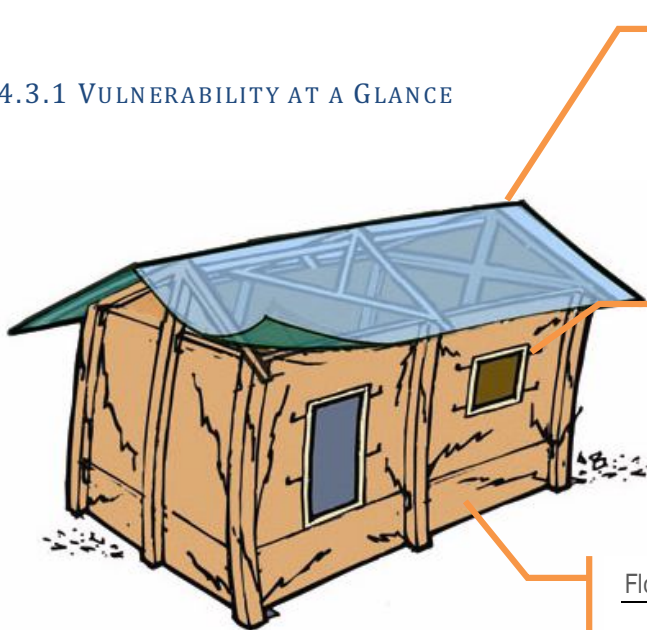
- Repair or replace defect parts
- Check for verticality
- Add wall struts and rails
- Add brackets to connect brick walls to the timber frames
- Tighten all connections
- Paint timber members with preservatives

Floor and Footing

- Repair or replace defect parts
- Check for verticality
- Compact around the footing
- Add additional support or reinforcement if necessary

4.3 RETROFITTING BRICK PIER BUILDING

4.3.1 VULNERABILITY AT A GLANCE



Roofing

- Roof blown away
- Truss and roof frame broken, sunk
- Roof frame tilted
- Loose connections

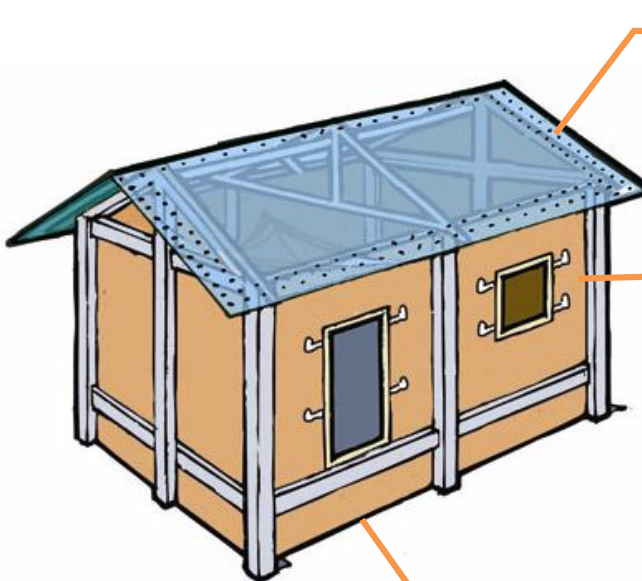
Wall and Framing-

- Frame tilted
- Wall opened, loosen
- Wall strut and rails re missing
- Diagonal wall cracks appear
- Large cracks between timber members and brick walls appear

Floor and Footing

- Member broken, tilted, floor sunk
- Loose connections
- Insect attack

4.3.2 RETROFITTING WITH DISASTER RESISTING FEATURES AT A GLANCE



Roofing

- Add truss bracings
- Add roof bracings horizontally and inclined
- Tie and firmly connect all roof members

Wall and Framing-

- Repair or replace defect parts
- Check for verticality
- Add wall struts and rails
- Add brackets to connect brick walls to the timber frames
- Tighten all connections
- Paint timber members with preservatives

Floor and Footing

- Repair or replace defect parts
- Check for verticality
- Compact around the footing
- Add additional support or reinforcement if necessary

4.4 PREPARATION FOR RETROFITTING

4.4.1 VISUAL SURVEY

When:

- Before retrofitting work
- Get assistant from village

Why:

- To assess level of danger
- To select best retrofitting method
- To prepare budget

How:

- Remove covers and loose particles such as old paint, old plasters, old ceiling
- Check the overall building deformation- verticality, leveling, etc.
- Look for defective members
- Look for cracks in foundation, floor, wall, beam and column
- Look for truss member and joints defects



Assessing the building before retrofitting



Floor cracks



Removing loose plaster



Crack between post and wall



Rusted steel in column



Removing loose bricks and plaster

4.4.2 SELECTING GOOD TIMBER

When:

In preparing material before retrofitting

Why:

Timber is natural material proper selection is important to get a required quality

How:

- Uniform in color
- Free from cracks and knots
- Straight and uniform size
- Correct size

4.4.3 TREATING BAMBOO AND TIMBER

When:

In preparing material before retrofitting

Why:

Properly treated materials will last longer and substantially reduce maintenance and replacement activities.

How:

- Submerge in seawater for two weeks
- Soak with preservatives (diesel or tar oil) or mixed for two weeks
- Submerged in a tank of preservatives and heated for 3 to 4 hours then allowed to cool overnight.
- Paint with preservatives after installations.



Soaked in preservatives



Heat treatment with preservatives

4.4.4 PREPARING STEEL REINFORCEMENT

When:

Before retrofitting

Why:

Installation of steel must be in right location in right connection. Improper installation of steel bars is useless and very dangerous.

How:

- Steel bars or wire mesh must be free from rusting
- If possible, use new and assured quality materials
- If possible, use deformed bars
- Steel bars ends must be at least 135°
- Steel bar lapping must be 40 times its diameter at least



Reinforcement preparations

4.4.5 PREPARING GOOD MORTAR AND CONCRETE

When:

Preparing before concreting and plastering

Why:

Proper concrete mix greatly effect to its strength.

How:

- All reinforced concrete mix shall be 1:2:4 (Cement:Sand:Stone)
- All plain concrete mix shall be 1:3:6
- Do not use fine sand and clayey sand
- Wash and screen sand and stone if dusty
- Use stone size between 1/8" and 3/4"
- Mix cement, sand and stone thoroughly before adding water
- Use portable water to mix concrete
- Use 5 gallons of water maximum for a cement bag to mix.
- After adding water, concrete must be used within 1 hour
- Allow 1" minimum concrete cover
- Spray the new concrete and mortar surface with water for 3 days

4.5 RETROFITTING FOUNDATION AND FLOOR STRUCTURES

4.5.1 ERECTING THE TILTED BUILDING

When:

When the building is tilted

Why:

Tilted buildings are not stable - easy to collapse

How:

- Tie the top of the column of the incline building to the anchor
- Pull the building slowly till it achieves its verticality
- Secure the position by diagonal bracings and knee bracing as necessary (See bracings ideas)



Pulling the building for verticality



Shoring the building for verticality

4.5.2 REPLACING COLUMN BASE

When:

When the column base is deteriorated

Why:

The whole weight of the building is supported by columns. Columns must be strong and firmly connected to the ground.

How:

- Level the floor.
- Make temporary support and replace the column
- Fix the column with strong strap and two bolts
- Apply preservatives



Metal angle bracket



Replacing defected member



Applying preservatives

4.5.3 INSTALLING GROUND BEAM AROUND THE BUILDING

When:

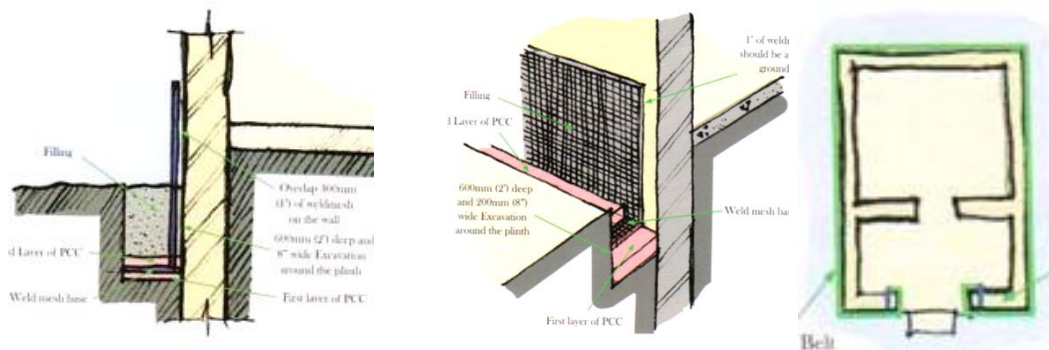
Found cracks in foundation

Why:

Brick buildings are heavy, foundation must be strong

How:

- Repair the cracks
- Dig a trench around the foundation
- Install reinforcement (with iron bars and wire mesh)
- Cast concrete
- Plaster and paint as necessary



Installing ground beam belt around the existing building

4.5.4 INSTALLING ADDITIONAL BRICK PIER SUPPORT

When:

Column post of brick pier is sunk

Why:

Foundation is weak at a particular point

How:

- Dig a hole next to the weak pier or column
- Lay brick
- Plaster and paint as necessary



Preparation for additional column foundation



Making new brick foundation

4.5.5 RE-LEVELING FLOOR

When:

When floor is sagging

Why:

Sagging floor is weak and easy to collapse

How:

- Replace defective members
- Make level and provide temporary support
- Add Knee bracings or additional intermediate support
- Connect all joints firmly.
- Apply timber members with preservatives



Remove floor panels and replace defects



Leveling the floor girder

4.6 RETROFITTING FRAME AND WALL STRUCTURES

4.6.1 ADDING BRACINGS

When:

Building frame is weak

Types:

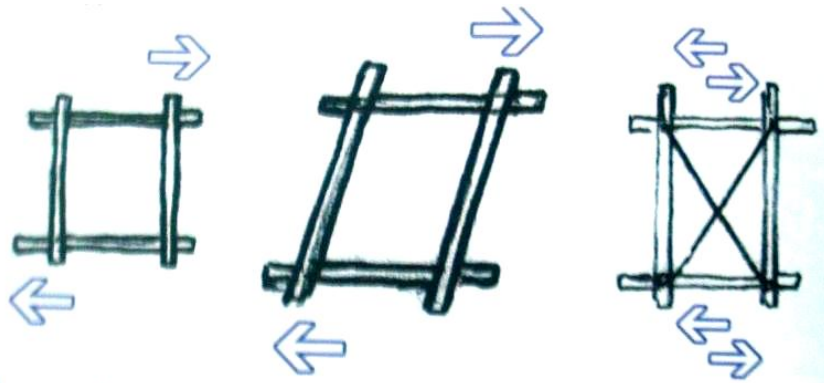
- Diagonal wall bracing
- Knee bracing below floor
- Cross bracing below floor

Why:

Bracings are essential to resist lateral forces like earthquake, wind and flood.

How:

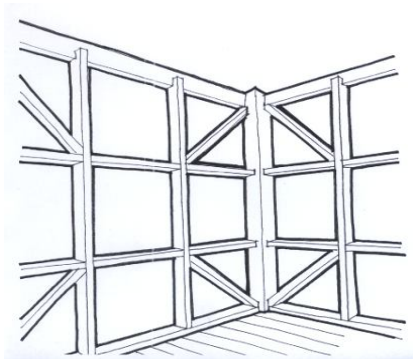
- Pull back the member to vertical.
- Add bracings properly.
- Fix the bracing connections firmly.
- Apply preservatives.



Providing Knee Bracing



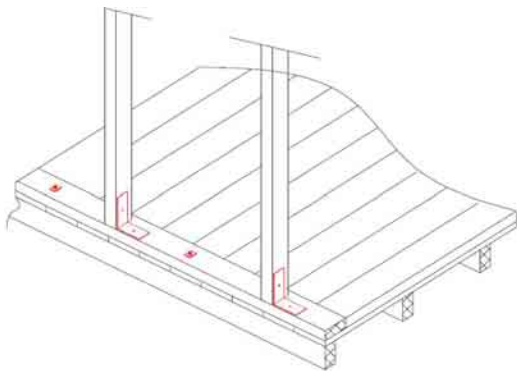
Diagonal bracings



Bracing at every panel



Bracing of a bamboo building



Sill and stud connection detail



Sill and stud connection detail

4.6.2 INSTALLING STEEL STITCHING TO THE BRICK WALL

When:

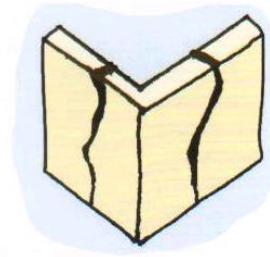
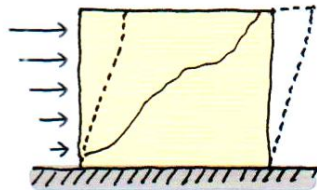
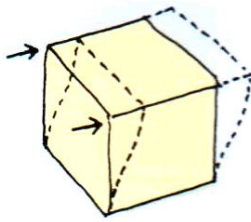
Found cracks in the brick wall

Why:

Cracks appear due to lateral force or weak foundation

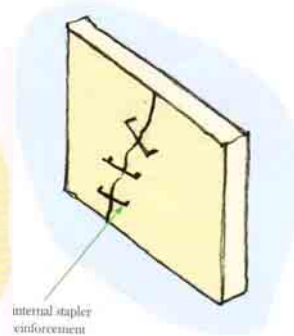
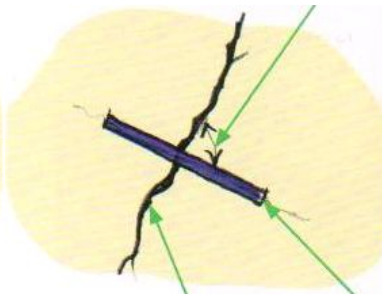
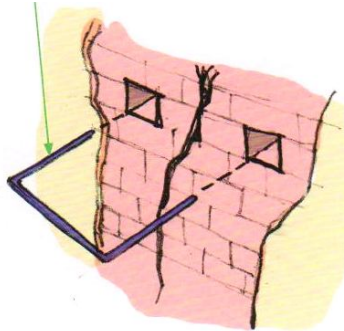
How:

- Remove old paint, plaster and loosen bricks
- Mark and make holes along the crack
- Install steel ties
- Apply plaster



Diagonal wall cracks due to lateral force

Corners are also weak points



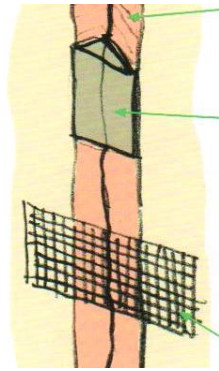
Installing steel stitching into the brick wall



Open-up for stitching

Installing Mesh

Plastering back stitching



How: (Alternative)

- Remove old paint, plaster and loosen bricks
- Trim the brick into V shape line along the crack
- Install wire mesh
- Apply plaster

4.6.3 INSTALLING LINTEL BEAMS AND TIES TO THE BRICK WALL

When:

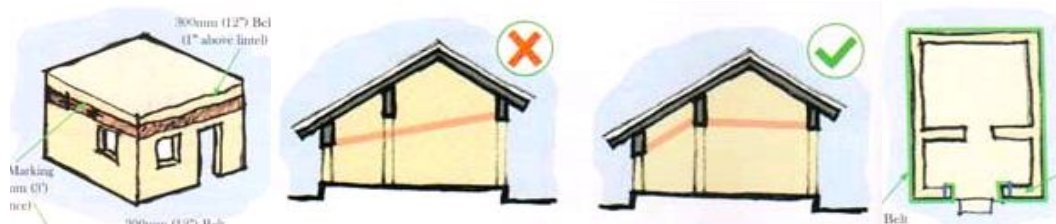
- Found cracks in the brick wall
- Building is tilted

Why:

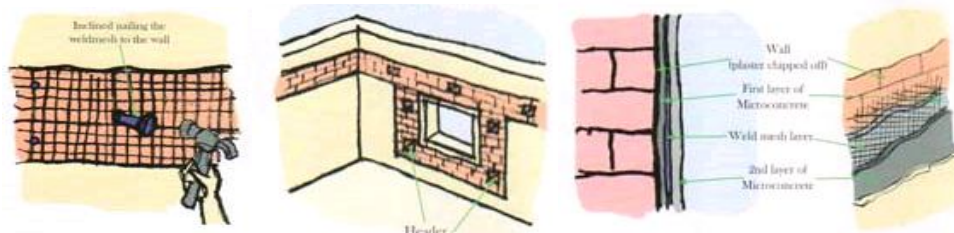
Cracks appear due to lateral force or weak foundation

How:

- Mark the lintel line around the building
- Remove old paint, plaster and loosen bricks
- Install reinforcements (steel bars, steel ties and wire mesh)
- Install nails and ties
- Apply plaster

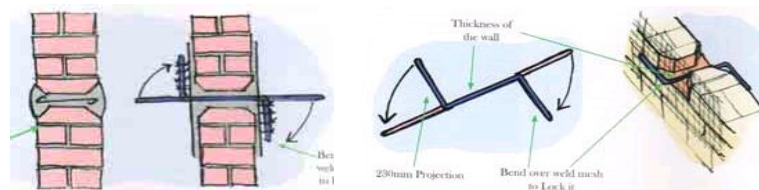


Tie around the building



Installing wiremesh and nail to the brick wall

Plastering over the wire mesh



Installing steel ties across the brick wall

4.6.4 INSTALLING LINTEL COLUMN TIES TO THE BRICK WALL

When:

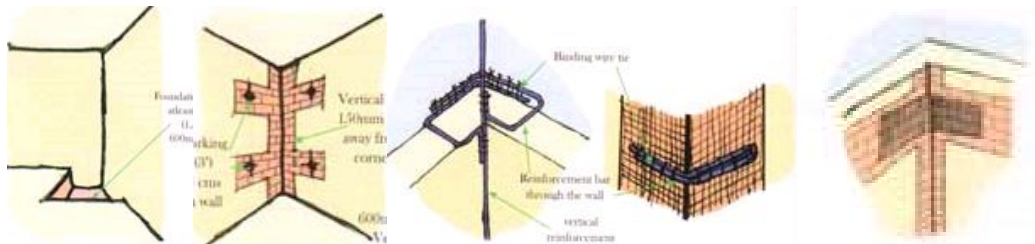
Found cracks in the brick wall near the columns and corners

Why:

Columns are essential part of building structure. Columns have to be strong.

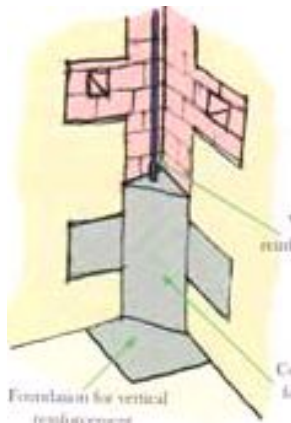
How:

- Mark the column and foundation
- Dig the foundation below the column point
- Install reinforcements (steel bars, steel ties and wire mesh)
- Install nails and ties similar to stitching



Digging footing

Add reinforcement inside, outside and ties



Casting concrete



Open-up for corner repair



Concreting and plastering

4.6.5 ADDING LINTEL TIE BEAM AROUND THE REINFORCED CONCRETE BUILDING

When:

Wall cracked or tilted

Why:

Building will be much stronger and resist better to lateral force when tie beam wrap around the building.

How:

- Mark the lintel line
- Make temporary shoring
- Cut brick wall
- Install reinforcement. Make sure all the steel bars are connected firmly.
- Cast concrete



Lintel positions (at gable top, at ceiling level, above window top and below window sill)

4.7 RETROFITTING ROOF STRUCTURES

4.7.1 ADDING TRUSS BRACING

When:

When trusses and frames are weak

Types:

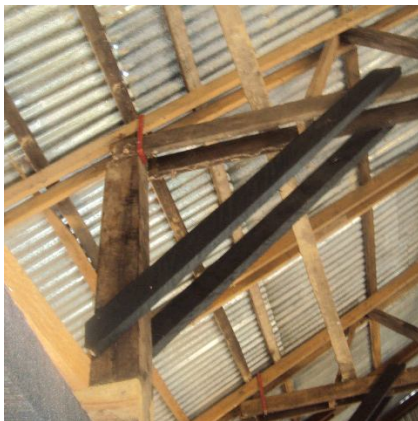
- Horizontal cross bracing
- Vertical cross bracing
- Cross bracing in roof plane
- Knee bracing to truss

Why:

The whole building must act as a one piece. Therefore, trusses and frames must be connected one another firmly to resist the external forces as a one piece.

How:

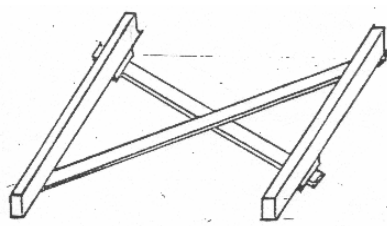
- Check verticality and truss levels
- Reposition trusses to the correct position
- Add temporary ties
- Add bracings and connect properly
- Remove temporary ties



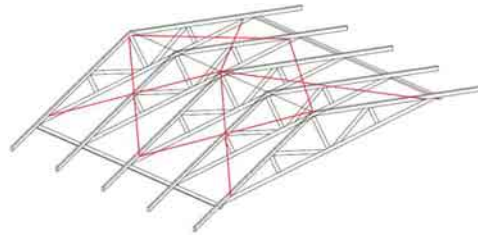
Knee bracing to roof truss



Vertical cross bracing between trusses



Horizontal cross bracing



Cross bracing in roof plane

4.7.2 REINFORCING TRUSSES

When:

When trusses are weak (tilting or sagging)

Types:

- Add web members closely
- Add collar ties

Why:

Truss has to be strong since it is the primary member that transfers the forces from the roof to frames of the building.

How:

- Type of reinforcements-
- Replace defective members
- Reposition truss to correct position
- Add reinforcement (adding web members or collar ties or both)



Strengthening truss by providing additional web members



Strengthening truss by providing additional collar ties

4.7.3 ADDING GABLE END LINTEL TIES

When:

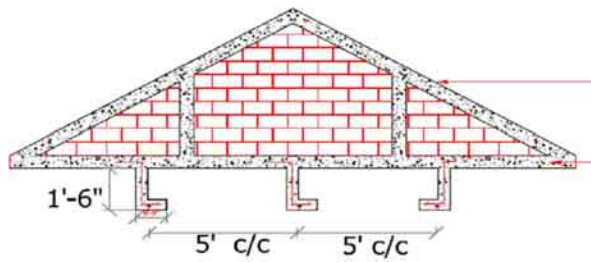
Brick gable end wall is cracked or inclined

Why:

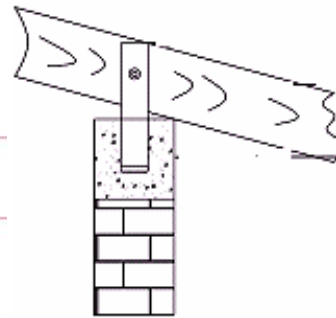
Brick gable ends are heavy and high. It can damage the building greatly if it falls.

How:

- Mark the gable edge line
- Install forms
- Install reinforcement
- Cast concrete



RC lintel wrap around the gable end



Holding with steel bracket



Preparing reinforcement for roof tie beam



4.7.4 CONNECTING TRUSSE TO BUILDING

When:

When trusses connections are loosen

Why:

To hold trusses so that trusses will not to be blown away during high wind

How:

- Replace defected member
- Tie with metal strap and connect with bolt and nut
- Or, hold down the truss with reinforcing steels or GI wire



Timber cleat tie between rafter and roof plate



Metal tie between roof cords

4.7.5 CONNECTING PURLIN TO TRUSS AND RAFTER

When:

Purlins are loosen

Why:

To hold purlin so that purlin will not be blown away during high wind

How:

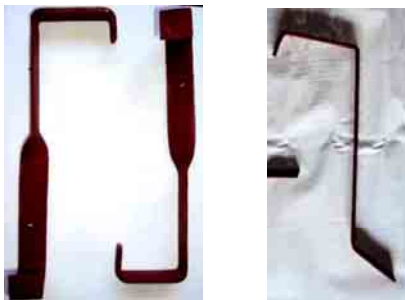
- Replace defected member
- Tie with metal strap and connect with wood screw or, tie down with GI wire



Wire tie between purlin and rafter



Metal tie between purlin and rafter



Metal tie for purlin and rafter



Metal tie (Earl Lain) for purlin and rafter

4.7.6 CONNECTING ROOFING TO PURLIN

When:

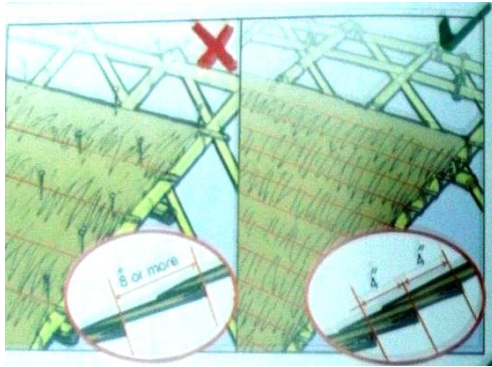
Roofing sheets are loosen

Why:

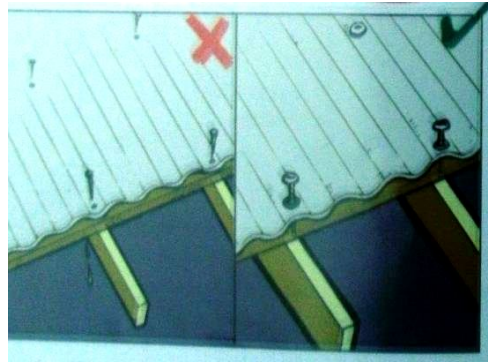
Roofing will be blown away easily if the connections to roofing sheet to purlin are not properly made.

How:

- Nailed or screwed firmly
- Nail or screw spacing shall be closer at the edges
- Use roofing nail with cap and washer
- Tie thatch roofing strips closely (about 4" spacing)
- Roof projection shall not be larger than 18"



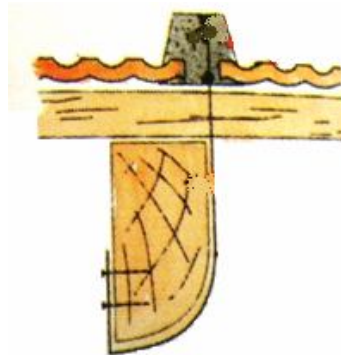
Tie roofing strips closely



Use screw or nail with cap and washer



Metal tie between roof cords



RC strip to tie clay tile edges

4.8 SUMMARY

Majority of Myanmar traditional rural buildings are bamboo and timber buildings which are lightweight and flexible structures. They perform very well against earthquake but very much vulnerable against wind, storm and flood. On the other hand, majority of Myanmar population are located in cyclone prone coastal and Ayeyarwaddy delta area.

Therefore, it is important to strengthen this type of rural buildings to be able to resist disasters like cyclone and storms.

Points to Remember

- Review vulnerability according to your building type
- Study disaster resisting feature according to your building type
- Prepare before action
- Select best fit retrofitting ideas and following the steps

CHAPTER 5: RECOMMENDATIONS

5.1 DISASTER RISK REDUCTION GUIDELINES

General:

Prior to planning any retrofitting work, check for the stability with assistance from the village carpenter.

- Are any of the post bases weak or decayed?
- Is any part of foundation or floor is cracked or sunk?
- Is any part of wall or corner cracked?
- Is shelter tilted more than 5 degrees?
- Is the roof sagging?
- Are bracings provided sufficiently?

Materials Selections and Preparations:

Proper material preparation is essential to ensure to get successful result as retrofitting is strengthening particular parts of the building that had already weaken.

- Use only good material
- If possible apply proper treatment to bamboo and timber before using them
- All the material must be clean and exact in dimension
- Install the material in exact location in proper manner
- Use proper finishing

Foundation:

With strong footings, your shelter will not sway and will resist better to storms, floods and earthquakes. Each foundation posts must be checked. Following activities are recommended.

- Check verticality and make pulling and shoring as necessary.
- Replace defective members.
- Compact the soil under the entire shelter.
- Ensure the footings are at least 2'6" deep.
- Compact the holes around the footing.
- Provide proper drainage under the floor so that water does not pool around the footings.
- On concrete footings, fix timber with 2 bolts through a L shaped bracket.
- Provide ground beam belt at the plinth level around the building.
- Tighten all the bolts and fix all the nail points.
- To prevent joints from rotations, provide extra nail point to every nail or bolt connections.

Floor:

For this type of buildings, floors are generally made of either bamboo or timber. Floor must be strong and level. Any defected member must be replaced. Following activities are recommended.

- Check floor level and make adjustments and shoring as necessary.
- Replace defective members
- Tighten all the bolts and fix all the nail points.
- To prevent joints from rotations, provide extra nail point to every nail or bolt connections.
- Protect floor members against fungi and insects by painting with earth oil, bituminous paint, etc.

Frame and Wall:

Since this type of building is lightweight and flexible, it is necessary to provide sufficient bracing so that the building can resist lateral forces induced in the disaster event.

- Check verticality and make adjustments and shoring as necessary.
- Replace defective members.
- Post, frame and wall members must be connected firmly.
- Tighten all the bolts and fix all the nail points.
- To prevent joints from rotations, provide extra nail point to every nail or bolt connections.
- Protect frame members against fungi and insects by painting them with earth oil, bituminous paint, etc.

Roof:

With Roof systems for bamboo and timber buildings are generally made of timber frame with CGI or natural leaves (Dani or Thetch) which are lightweight and flexible. Therefore, it is necessary to provide bracings to every plain and ties to every point. Following activities are recommended for roof structure retrofitting.

- Check inclination and verticality. Make adjustments as necessary.
- Replace defective members.
- Tie firmly every part of the roof system- roofing sheet to purlin, purlin to rafter and truss, truss and rafter to post and roof plate, etc.
- Tighten all the bolts and fix all the nail points.
- To prevent joints from rotations, provide extra nail point to every nail or bolt connections.
- Anchor tiles with RC strips and tie to the underlying roof structure or wall frames.
- Protect roof members against fungi and insects by painting them with earth oil,

Connections:

Most of the connections in timber buildings are bolt and nuts and/or nail connection. In bamboo framed buildings, natural ties such as coconut coil or fiber ties (Hnee) are commonly used. Each and every connection must be strong in order to transfer forces from one member to another. Following activities are recommended for connections.

- Check every connection and replace deteriorating connectors and fasteners.
- For nail connection, provide at least two nail points in order to prevent against rotation as well as to act as a spare.
- Add at least one additional nail point to each bolt connection to prevent joint rotations.
- All metal parts shall be galvanized or painted to avoid rusting

5.2 CONCLUSION

Disaster preparedness and planning in the past have been too dependent on massive financial, technical and infra-structural input by Government & NGO's. While such interventions are necessary, these steps must be accompanied by local people's participation as well as incorporating the age old wisdom of the people. This will have the double advantage of empowering the people, drawing them into plans which will no longer merely be injected from the outside, and will result in a more thought out, user and environment friendly response to extreme natural calamity.

It is important to note that traditional houses can only be disaster resistant with a comprehensive approach for the implementation of all the recommendations in the guidelines for cyclone resistant houses.

REFERENCES

1. Rajendra Desai and Rupal Desai, "Manual on Hazard Resistant Construction in India", 2008, Guidelines for "Reducing vulnerability in buildings built without engineers"
2. Dipan Shah, "Manual on Retrofitting of Non-Engineered Structures", UNDP India.
3. A.S.Arya Dr. Principal Seismic Advisor, NDMA, Ministry of Home Affairs, Government of India, 2005, Guidelines for "Repair, Restoration and Retrofitting of Masonry Buildings in Earthquake Affected Area of Jammu&Kashmir". and Guidelines for "Earthquake Resistant Reconstruction and New Construction of Masonry Buildings in Jammu and Kashmir State".
4. Dr.K.Iftekhar Ahmed, "Handbook on Design and Construction of Housing for Flood-prone Rural Areas of Bangladesh, January 2005.
5. ASAG, 1994, "Repaires and Retrofitting The Marathwada Houses".
6. BRE 1988 "Cyclone-Resistant Houses for Developing Countries".
7. "Repair & Seismic Strengthening of Building-Guidelines", IS:13935:1993.
8. Professor Anand S.Arya, "Disaster risk management-document series"
9. Bashirul Haq , "Battling the storm" study on cyclone resistant housing, Dec 1999.
10. "Handbook on good building design and construction" Aceh and Nias Island .
11. "Handbook on good building design and construction" Philippines .
12. A guide for village carpenters on How To Build A Safer Shelter".

GUIDELINES ON RETROFITTING OF RURAL HOUSES IN MYANMAR

Developed by UN-HABITAT, Myanmar

For further information:

UN-HABITAT, Myanmar

No.6, Natmauk Road

Tamwe Township, Yangon

Myanmar

desk@unhabitat-mya.org