GUIDELINES ON RETROFITTING OF RURAL HOUSES IN MYANMAR









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This manual provides guidelines and information on various causes and effects of a disaster. It targeted for school teachers, students, parents, Civil Society Organizations, individuals, households, communities and practitioners in the field of Disaster Management to prepare for and respond to future disaster.

This manual would not have come into fruition without the technical and financial support from the individuals, organizations and agencies mentioned above.

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



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 causalities.

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 nonengineering 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.

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

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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-helped 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-helped 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



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.



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



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



*Dan*i 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



2.4.2 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.



Pulling By Two People

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 ft2		160 ft2	
		Outside wall height	7 ft above the plinth level			
		Roof slope/pitch	30 degree from horizontal			
		Roof design and construction	Household Rainwater Sche	eme sensitive		
		Roof projection	18 inch from the outside wa	all		
		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	ervices 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.



Guidelines on Retrofitting of Rural Houses in Myanmar

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





Roofing

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

Wall and Framing-

- Frame tilted
- Wall opened, loosen
- Loose connections

Floor and Footing

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

4.1.2 DISASTER RESISTING FEATURES AT A GLANCE



4.2 RETROFITTING BRICK NOGGING

4.2.1 VULNERABILITY AT A GLANCE



- 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



$4.3.2 \ Retrofitting with \ Disaster \ Resisting \ Features \ at \ a \ Glance$



4.4 PREPARATION FOR RETROFITTING

4.4.1 VISUAL SURVEY





Assessing the building before retrofitting



Removing loose plaster

Floor cracks



Crack between post and wall





Rusted steel in column

Removing loose bricks and plaster

4.4.2 Selecting Good Timber



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







Reinforcement preparations

4.4.5 PREPARING GOOD MORTAR AND CONCRETE



4.5 RETROFITTING FOUNDATION AND FLOOR STRUCTURES

4.5.1 ERECTING THE TILTED BUILDING





Pulling 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.

Shoring the building for verticality

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



Installing ground beam belt around the existing building

4.5.4 INSTALLING ADDITIONAL BRICK PIER SUPPORT





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







Providing Knee Bracing



Bracing at every panel



Sill and stud connection detail



Diagonal bracings



Bracing of a bamboo building



Sill and stud connection detail

4.6.2 INSTALLING STEEL STITCHING TO THE BRICK WALL





Installing Mesh



Plastering back stitching



4.6.3 INSTALLING LINTEL BEAMS AND TIES TO THE BRICK WALL



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



Casting concrete

Open-up for corner repair

Concreting and plastering

4.6.5 Adding Lintel Tie Beam Around the Reinforced Concrete Building





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



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







RC lintel wrap around the gable end

Holding with steel bracket



Preparing reinforcement for roof tie beam

$4.7.4 \ Connecting \ Trusse \ to \ Building$



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



Wire tie between purlin and rafter



Metal tie 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:

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



Metal tie between purlin and rafter



Metal tie (Earl Lain) for purlin and rafter

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, bitumin 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 leafs (Dani of 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 clay 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.

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Developed by UN-HABITAT, Myanmar

For further information: UN-HABITAT, Myanmar No.6, Natmauk Road Tamwe Township, Yangon Myanmar desk@unhabitat-mya.org