Compliance Catalogue

Guidelines for the Construction of Compliant Rural Houses

EARTHQUAKE RECONSTRUCTION AND REHABILITATION AUTHORITY
ERRA

ERRA Build Back Better for a safer future

Including New Compliance Updates and Remedial Measures

Version: March 06, 2008

It is very encouraging to see how well the rural housing reconstruction activities are progressing across the affected areas.This reflects on the hard work put in by all involved in the Rural Housing Sector as well as the courage and determination of the affected people who have not let this disaster put them down, but have rather turned it into an opportunity for construction of safer housing for their loved ones. ERRA, with technical support of UN-Habitat and NESPAK, on its part continues to strive for providing all facilitation measures for construction of safer houses in the affected areas. The launch of the compliance catalogue is yet another measure aimed at assisting the affected population to achieve this objective.

It is my sincere hope that all affectee's will benefit from this document as well as from the continued support of ERRA, Housing Reconstruction Centers (HRCs), Partner Organizations (POs) and Assistance and Inspection (AI) Teams who will continue to help them in making their houses compliant, safer and therefore eligible for receiving the remaining tranches of the rural housing subsidy.

Altaf Mohammad Saleem
Chairman ERRA

Introduction

The earthquake of 8th October 2005 resulted in the collapse of hundreds of thousands of houses, causing deaths, injuries, homelessness and destruction or damage of household and personal belongings.
The reconstruction of houses in the earthquake affected districts is intended to **'build back better',** to ensure people and property are safer in the event of any future earthquakes.
The policy for rural housing reconstruction is **'owner driven',** whereby owners themselves are responsible for the reconstruction of their own homes and meeting the standards required to be eligible for financial assistance.
In order to support owners meeting these standards, **ERRA** has published and disseminated information on safer construction, reinforced through training, technical advice and the Assistance and Inspection process.
ERRA has responded to variations between areas, conditions, traditions, access to salvaged materials and new materials, and owner preferences by endorsing a range of approved construction techniques and materials.

Nonetheless the tasks of reconstruction and information dissemination have been enormous and many householders, as well as masons, carpenters and others involved in rebuilding are unfamiliar with new materials and techniques and may have been confused or unsure about requirements for seismic resistance. This has resulted in instances of construction of houses failing to meet basic safety standards, and thereby failing to be certified for approval for financial assistance.

This document is aimed to improve the knowledge base of engineers, technical trainers and advisors in the affected districts. It focuses on key technical issues in earthquake resistant construction and provides agreed solutions to substandard work, to assist the engineers' task of providing solutions and advice in training and on site.
The document should provide an easily accessible reference and overview for all those involved in managing the reconstruction process.
It is not intended to be used by masons or householders, but to form a basis for further shorter and simpler documents for these audiences.
It is not intended to be used as a retrofitting guideline for buildings damaged in the earthquake, it targets defects in new construction.

The very basic requirement of building back better and safer construction is that the owner of the house should be convinced that his house needs to be built safely and if it is not, to strengthen it in order to save himself, his family and the next generations in any future earthquakes.
If the owner is not convinced, he may not take the necessary care during execution of construction, or of remedial measures. This may result in houses that are weaker than the original ones which collapsed in 2005.
The efforts involved to construct to the required standards of safety, and carrying out remedial works when necessary, should be rewarded by the confidence of residing in a house, which is safe against severe ground shaking.

When a serious earthquake occurs, most of those who die will be in their own homes. Please place maximum care and effort into making the new homes safer homes.

Introduction

WHO IS THIS BOOK FOR ?

This guideline is for engineers, sub engineers and all those involved in providing technical training and advice for housing reconstruction.

WHAT IS IT FOR ?

- A single source of information on all ERRA compliant construction standards.
- Identification of problems of non compliance and instructions to carry out remedial measures.

WHAT DOES IT CONTAIN ?

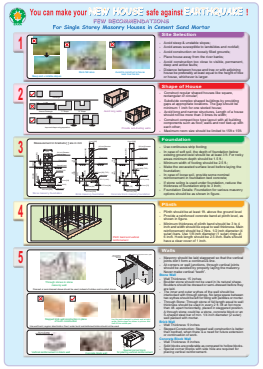
A. General Guidelines	*Principles that apply in all techniques. The basis for safer houses.*
B. Construction Standards	*Summary of technical specifications for the 5 techniques approved by ERRA*
C: Common Defects	*Outline of common problems in current construction.*
D. Remedial Measures	*Detailed specifications of remedial works and step by step procedure.*
E. Site Works	*Recommendations for site improvements and mitigation measures.*
F. New Compliance Measures	*Compliance updates and remedial measures (November 2007 to January 2008)*
Appendices	*A. Posters of construction guidelines.* *B. Technical drawings of remedial works (NESPAK).* *C. Questions and answers related to safe and compliant construction (NESPAK)*

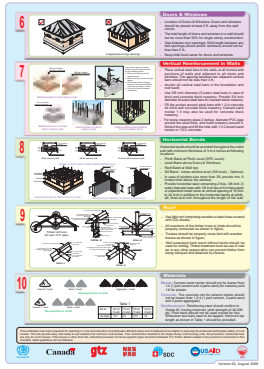
WHERE TO GET MORE INFORMATION ?

The detailed guidelines and posters are available from Housing Reconstruction Centres (HRC) and Partner Organisations (PO) and AI- Teams (Assistance and Inspection Teams)
For training or advice on any information in this book, contact UN Habitat.

This guideline is a summary of information contained in more detailed specifications already available in the following ERRA approved posters, guidelines, booklets and in training

NESPAK Book of earthquake area rural house plans





Reinforced Masonry 10 Point Poster

Confined Masonry 12 Point Poster

Timber Frame / Dhajji 10 Point Poster

Timber Frame / Dhajji Simple Poster

Bhatar / Timber Reinforced Masonry Handbook

Leepa

Guidelines for the compliant construction of Leepa-type timber post and beam houses

Leepa-type Timber Post and Beam Houses Handbook

For the posters **See Appendix- A**

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GENERAL GUIDELINES

1 Site
2 Shape
3 Foundation
4 Masonry
5 Concrete and Reinforcement
6 Openings Windows and Doors
7 Roof

1 Site

Many people do not have an alternative but to build in locations that are not ideal.
Plan the house to be safe within the constraints of the site.
Take measures to improve the site and protect the house.








Hazardous Sites

- Avoid steep and unstable slopes.
- Avoid areas at risk of landslides.
- Avoid construction close to faults.
- Avoid construction close to river banks.

Stable Sites

- Avoid construction on loose or filled ground.
- Construct the house on solid stable ground.
- An uneven base will mean the house will be weakened/damage due to settlement.

Retaining Walls

- Build the house away from the retaining wall uphill.
- Build the house away from the edge of the retaining wall downhill.
- Ensure all retaining walls are constructed properly, with adequate strength and stability.

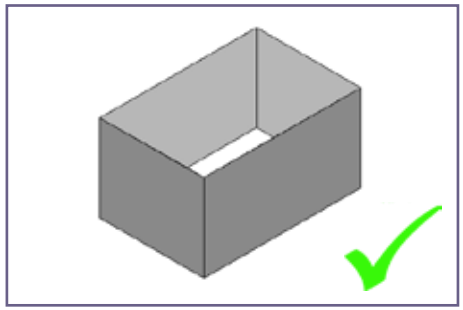
SEE SITE WORKS (Section E)
For advice on Retaining Walls and Site Drainage

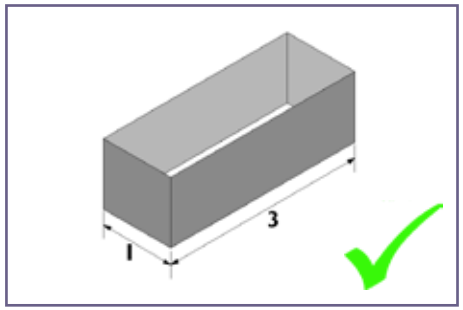
Site Improvements

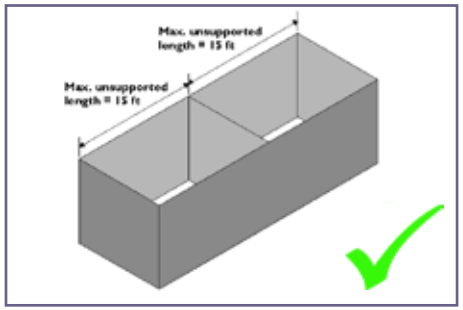
- Divert site surface water away from the building with a land drain uphill.
- Improve all land retaining walls.
- Plant trees to stabilise slopes.
- Manage site surface water drainage to protect the building and to avoid site erosion.

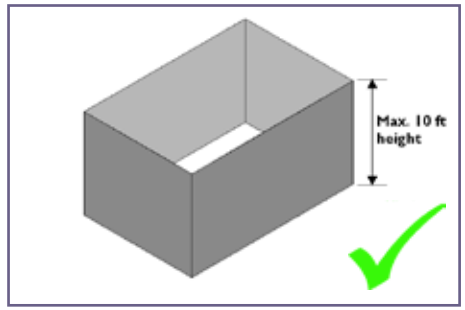
2 Shape

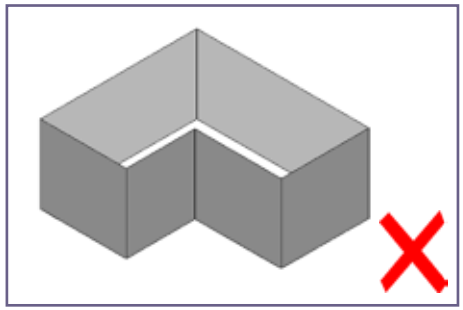
**The shape of the house affects how it behaves in earthquakes.
Eccentric shapes and unrestrained walls increase the stress on parts of the building.
Plan to reduce the stress and distribute forces evenly.**

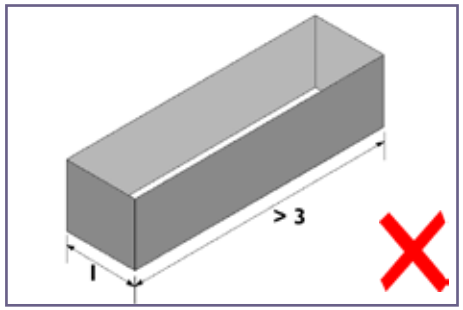


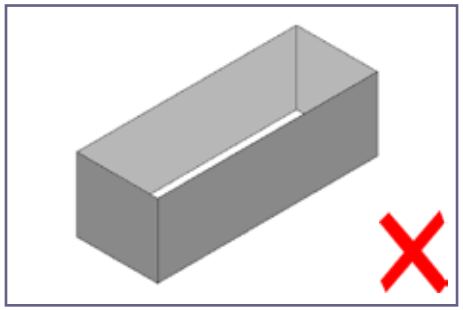


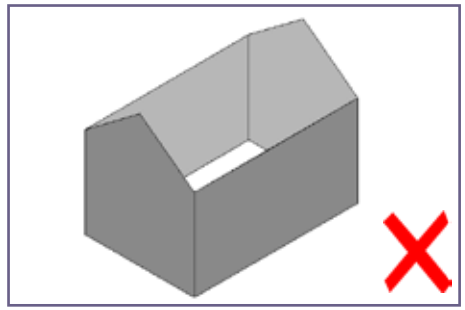






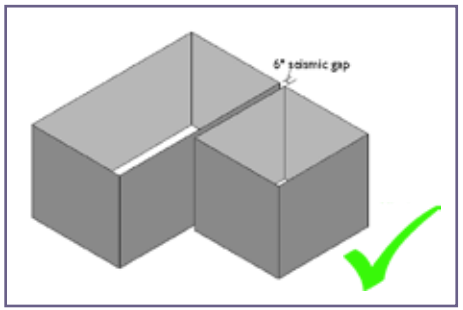






Shape

- Construct regular simple shapes (e.g. rectangular, square).
- Avoid L-shape, U-shape or more complex shapes.



Proportion

- Avoid long and narrow shapes.
- The length of the house should not be more than 3 times the width.

Cross walls

- Provide cross walls to strengthen the building.
- Make sure all walls are connected to each other.
- Maximum room size should be 15ft x 15 ft.

EXCEPTION
Room size up to 16 x 16 ft is acceptable if all other requirements are fulfilled.

Height

- Maintain equal wall heights for all the walls.
- Avoid gable walls.
- Limit all buildings to one storey in high risk areas.

3 Foundations

Poor foundations weaken the walls due to settlement.
Poor protection of the wall from moisture will mean that the base of the wall is weakened.
Both effects reduce the building's strength and resistance to earthquakes.

Anchorage

- Foundations should start from below ground for all walls: depth and width according to construction type and soil conditions. (Section B)
- All vertical reinforcement, columns, etc, should start below natural ground level and be well anchored.

Soft Soil : Hard Soil

- Soft soil is a greater risk in earthquakes. Good foundations are more important in soft soil conditions.

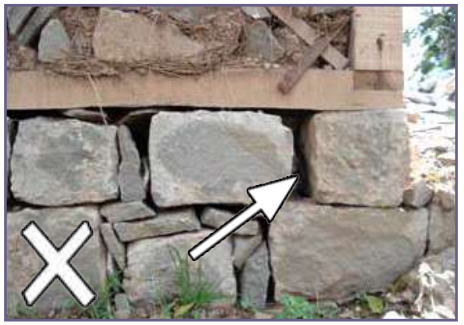
For timber frame/ dhajji construction the bolts should be fixed in foundation below natural ground level.

Ground level

- Prepare and level the site.

Plinth

- Protect the base of the wall from ground water and site surface water.
- Do not construct the plinth higher than 3 ft above natural ground level.
- Make sure the plinth is constructed with well packed masonry using long stones or blocks to strengthen the corners.



Plinth should not have gaps.

4 Masonry

In design for earthquakes, load bearing masonry must have sufficient stability and strength to withstand lateral forces. Substandard walls may fail by cracking or aggregating.

Stonework

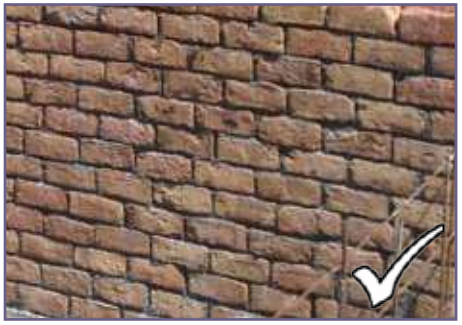
15 inches wide (minimum)

- Stones to be dressed or flat.
- No round or friable stones.
- Stones should be well packed.
- Use large stones to strengthen corners and junctions.

Through Stones

- All stone work should have through stones at every 2 ft vertically and 4 ft horizontally.

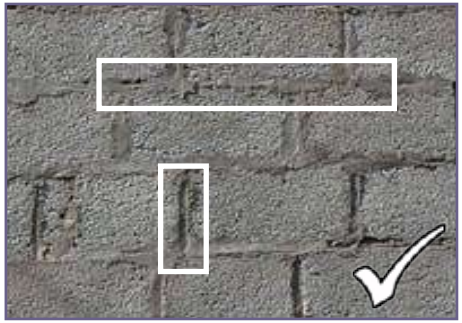
Length of stone should be equal to the wall thickness.



Brickwork

9 inches wide (minimum)

- Bricks to be made from good brick earth, free from saline deposits.
- Aggregating strength min. 1000 psi.



Blockwork

8 inches wide (minimum)

- Blocks to be solid or hollow.
- Solid blocks are preferable to hollow blocks.
- Aggregating strength min. 1700 psi at 28 days curing.
- Blocks should be cured for 10 days.

EXCEPTION
6 inch **solid** concrete blockwork is acceptable if all other requirements are fulfilled.

Workmanship

- All bricks and blocks should be laid in 1:4 cement: sand mortar in all vertical and horizontal joints.
- All brick and blockwork should be coursed and bonded correctly without continuous vertical joints.

In Situ Concrete

8 inches wide (minimum)

- Mix 1: 3: 6. (cement : sand : aggregate).
- Max stone size 5 inches.
- Concrete should be well compacted.
- Aggregating strength: min. 1000 psi.
- Concrete should be cured for 10 days.
- For in situ concrete use confined masonry methodology, with additional #4 bars at 4 ft spacing along the wall. The vertical bars should be anchored in foundations.

For Timber Construction

Timber Frame (Dhajji)
Minimum Wall Thickness: 4 inches.

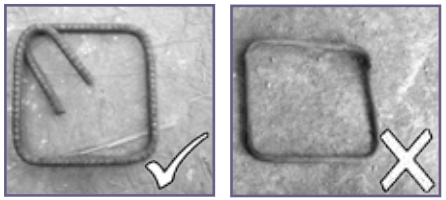
Timber Reinforced Masonry (Bhatar)
Minimum Wall Thickness: 18 inches

5 Concrete & reinforcement

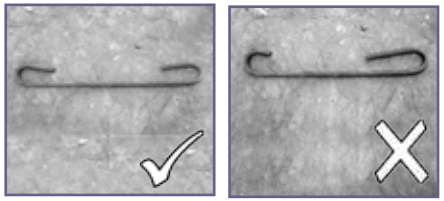
Reinforcement is used with masonry to improve the integrity of the walls, to tie the walls together, and to tie the building to the foundation.
Substandard reinforcement and fixing means this tying action will fail in an earthquake.

Steel

- Deformed steel shall have a minimum yield strength of 40,000 psi (40 ksi).
- Vertical reinforcement should always start from the foundation.
- Steel reinforcement for columns should have a 12" horizontal foot at the base.
- Horizontal reinforcement should be continuous to connect perpendicular walls.
- Steel reinforcement bars should have a 60Db (diameter of bar) minimum overlap.
- All column and beam stirrups should be fixed with seismic hooks at 45 degrees, otherwise the stirrups may open and fail in an earthquake.
- Stirrups should be spaced at the required distance.



Proper hooks in the rings keep the reinforcement bars in-line in columns/ beams during earthquakes.



Stirrups with proper hooks at the ends, make the bands strong in earthquakes.

Concrete

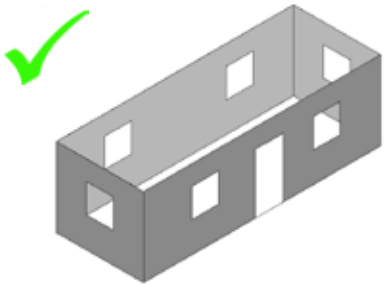
- Concrete for foundations, columns, bands and beams should be 1:2:4 mix (cement : sand : aggregate), with maximum aggregate size 3/4 inch.
- Cement shall be fresh, dry and free from lumps.
- Sand should be well graded, dry, hard, durable, granular, clean and free from clay dirt, organic matter and adherent coating.
- Fine and coarse aggregates shall be clean and free from clay, loam, silt or other organic matter.
- Aggregate shall be dry, hard, durable material free from laminated structure.
- Concrete should be compacted with a vibrator, or stick to release trapped air.
- Concrete shall be poured in stages but ensuring no cold joints.
- Concrete shall be cured for 10 days.
- Steel reinforcement bars must have one inch concrete cover to avoid rust and failure.

Bar Dia	1/4"	3/8"	1/2"	5/8"	3/4"
Bar No	#2	#3	#4	#5	#6

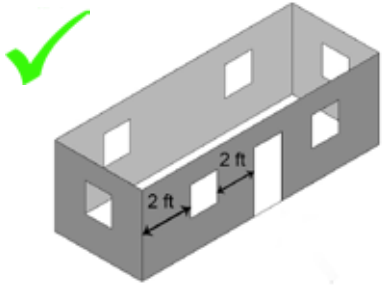
See **Section B** for reinforcement requirements for each construction type.

6 Openings: Windows & Doors

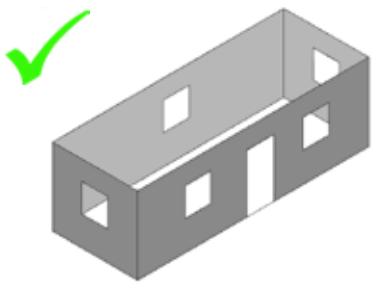
Openings reduce the strength and stability of the wall.
The location and size of openings throughout the house must be planned carefully.
Reinforce the openings to add strength.



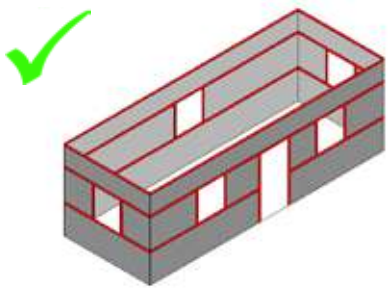
Openings should be evenly distributed around all sides of the house.



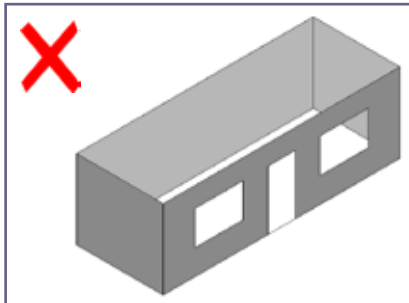
Openings should be kept at right distance from corners and each other



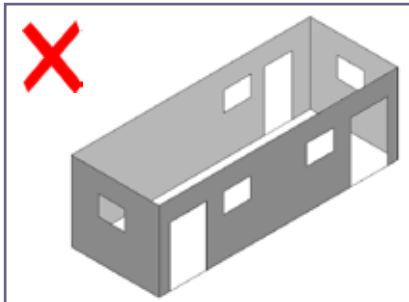
Openings should be small in size.



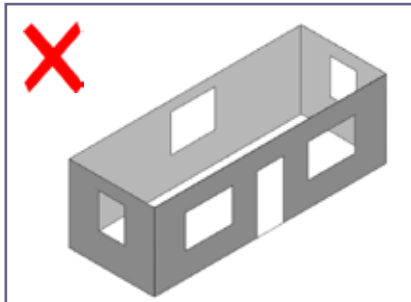
Roof, lintel and sill bands should be continuous.



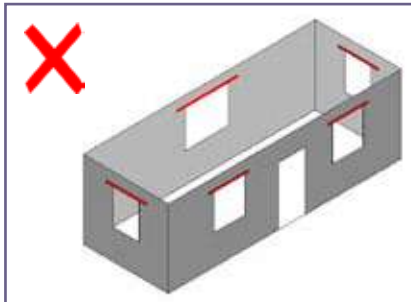
All openings in front wall will make the wall weak.



Openings too close to corners will make the corners weak.



Very large openings will make the walls weak.



No roof band and short lintels will not hold the walls together during an earthquake.

Balance

- Distribute the openings evenly around all sides of the house.
- If this is not possible, avoid putting all openings on one side only.

Location

- Keep openings away from corners:
  Generally: 2 ft minimum
  For stone walls: 3 ft minimum
- Keep openings away from each other:
  Generally: 2 ft minimum
  For stone walls: 3 ft minimum

EXCEPTION
Solid portion between openings of less than 2 ft is acceptable if constructed as an RCC column.

Size

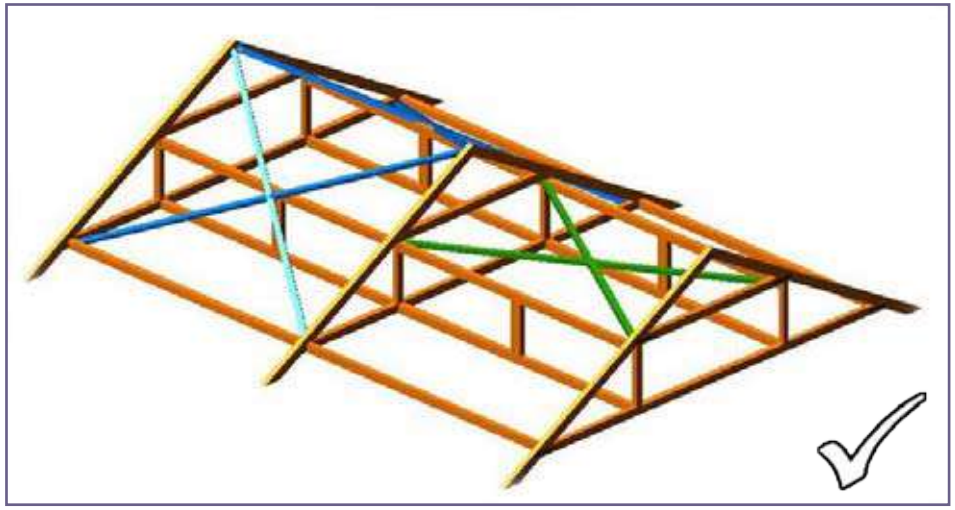
- Keep opening sizes small.
  Generally: 4 ft wide maximum
  For stone walls: 3 ft wide maximum
- Total length of openings should not exceed 50% of the length of wall between consecutive cross walls.

Reinforcement

- Always provide continuous lintel band and roof band.
- Best to provide continuous sill band also.
- Provide vertical reinforcement to make a continuous reinforcement frame around openings.

7 Roof

The roof should be stable and secure, tied well together and tied well to the walls. It should not fall off the walls in high winds or in an earthquake causing the walls to be damaged.



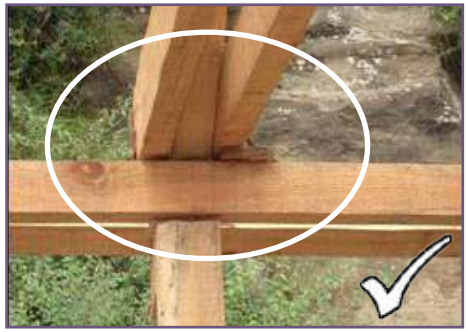
Roof Type

- Lightweight roofs are recommended for all houses.
- Hipped roofs are better than A-pitched roof.
- A ceiling structure adds bracing and stiffness.
- Storage in the roof space should be evenly distributed.

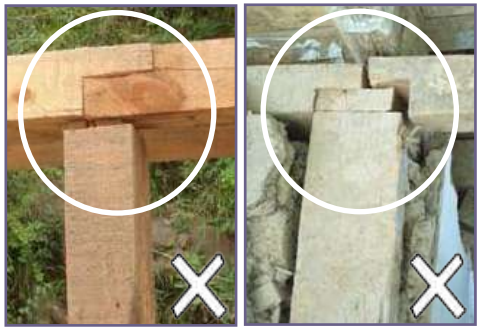
Roof Structure

- Use timber or steel truss construction for the roof.
- The connections are most important.
- Proper timber joints are recommended for timber connections.
- If using nails, screws and metal straps, make sure they are galvanised or protected from rust.
- Use seasoned timber free from defects.
- Use a continuous wall plate to tie all trusses / rafters together and to fix the roof to the walls.
- Fix roof trusses over posts in timber frame construction.
- Brace the roof timbers diagonally to avoid distortion and to resist wind load.
- Minimum 26 gauge (1.26mm) CGI sheets shall be used.

Truss should be over the post.



Use a capital to support a joint.



Do not put a joint directly over a post..

CONSTRUCTION STANDARDS

1 Reinforced Masonry

2 Confined Masonry

3 Timber Frame / Dhajji

4 Timber Reinforced Masonry / Bhatar

5 Exceptions

I Reinforced Masonry

General Description

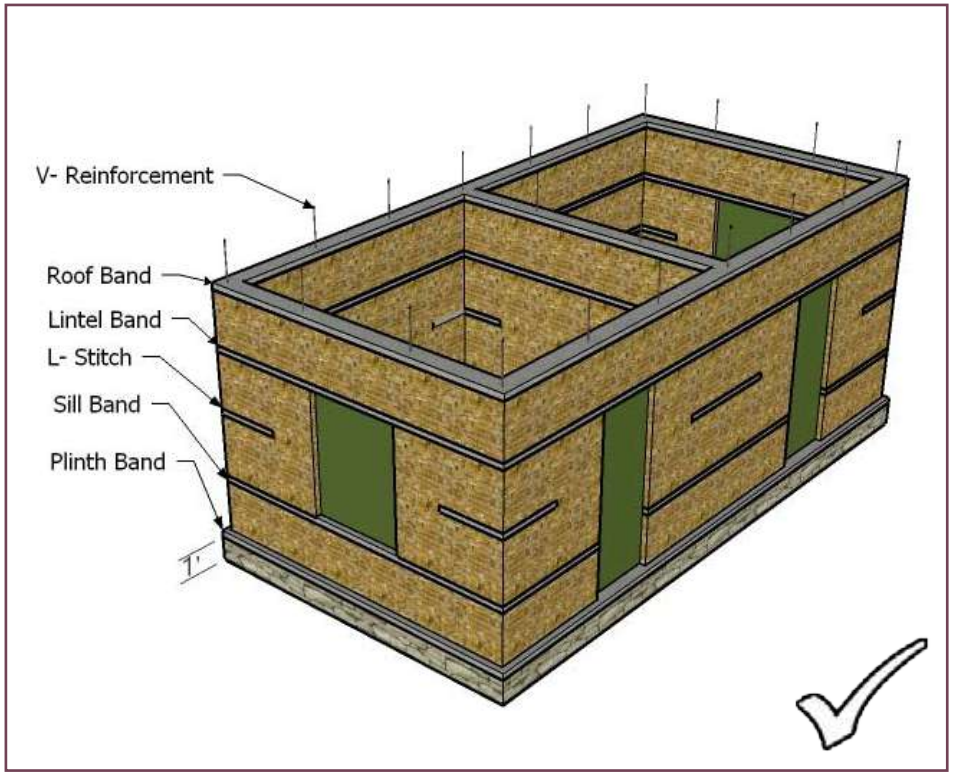
- Reinforced masonry consists of stone, brick or block masonry with vertical and horizontal steel reinforcement bars.
- Reinforcement is located at all junctions and is evenly spaced throughout the wall tying the masonry and the walls together.
- Vertical reinforcement starting from the foundation is placed at wall junctions, openings and at 4ft spacing along the wall.
- Vertical reinforcement should be placed in the centre of the wall thickness.
- Horizontal reinforcement consists of reinforced concrete bands (with 2 longitudinal rebars) at plinth, sill, lintel and roof levels.
- Additional stitches are provided to reinforce corners.

Permitted

- Reinforced masonry may have 4 vertical reinforcement bars at corners and junctions, but must also have vertical bars every 4ft along the wall.
- Without the bars every 4ft, construction must be considered as confined masonry and should meet the confined masonry standards.
- If four bars are used at corners, additional care must be taken to ensure that horizontal reinforcement is correctly placed to ensure the perpendicular walls are tied together and ties are provided to enclose the bars. Plinth, lintel and roof band reinforcement is extended into the four bars column.
- Due to height limitations, a single beam may be cast instead of separate lintel and roof band

Not Permitted

- Do not use timber posts in reinforced masonry.



1 Reinforced Masonry | Specifications

Walls	**Wall Materials**	Stone, brick, concrete block, in situ concrete.	**Important Note:** Concrete for foundations, columns, bands and beams should be 1:2:4 mix (cement : sand : aggregate), with maximum aggregate size 3/4 inch.
	Wall Thickness (min.)	15" Stone 9" Brick 8" Concrete Block 8" In Situ Concrete	
	Wall Length	15 ft Maximum unsupported length	
Vertical Reinforcement	**Location**	Vertical reinforcement bars at corners, junctions, wall openings and at 4 feet to max. 5 feet spacing along walls	
	Reinforcement	1 # 4 or # 5 bar (brick or block) / 1 # 5 or # 6 bar (stone). (Reinforced concrete columns (with 4 bars) in corners are also acceptable if the vertical bars at max. 5 feet spacing along the wall are also used)	
Horizontal Reinforcement	**Foundation**	Material	Masonry
		Depth (below ground)	36" (soft soil) / 18" (hard soil)
		Height (above ground)	8" - 12"
		Width	30 inches
		Reinforcement	None
	Plinth Band	Depth	Min. 3"
		Reinforcement	2 # 4 bars (stirrups: #1 or #2 bars @ 6")
	Sill Band	Depth	Min. 3"
		Reinforcement	2 # 4 bars (stirrups: #1 or #2 bars @ 6")
	Lintel Band	Depth	Min. 3" (if <3 ft wide opening) OR Min. 6" (if >3 ft wide opening) Band may be locally thickened at the openings.
		Reinforcement	2 # 4 bars (stirrups: #1 or #2 bars @ 6")
	Roof Band	Depth	Min. 3"
		Reinforcement	2 # 4 bars (stirrups: #1 or #2 bars @ 6")
	Corner strengthening	Location	Stitches @ 18" - 24" vertical spacing and embedded min. 2 ft into connecting walls
		Reinforcement	2 # 3 bars, (stirrups: #1 or #2 bars @ 6") OR wire mesh
Roof		Lightweight (timber truss frame / steel frame with CGI sheet covers)	
Other Features		In case of stone masonry: provide through stones (Dosalu) at every 2 ft spacing vertically and 4 ft spacing horizontally.	
		Cement sand mortar mix: For Masonry - 1:4 ; For Plaster - 1:6	

2 Confined Masonry

General Description

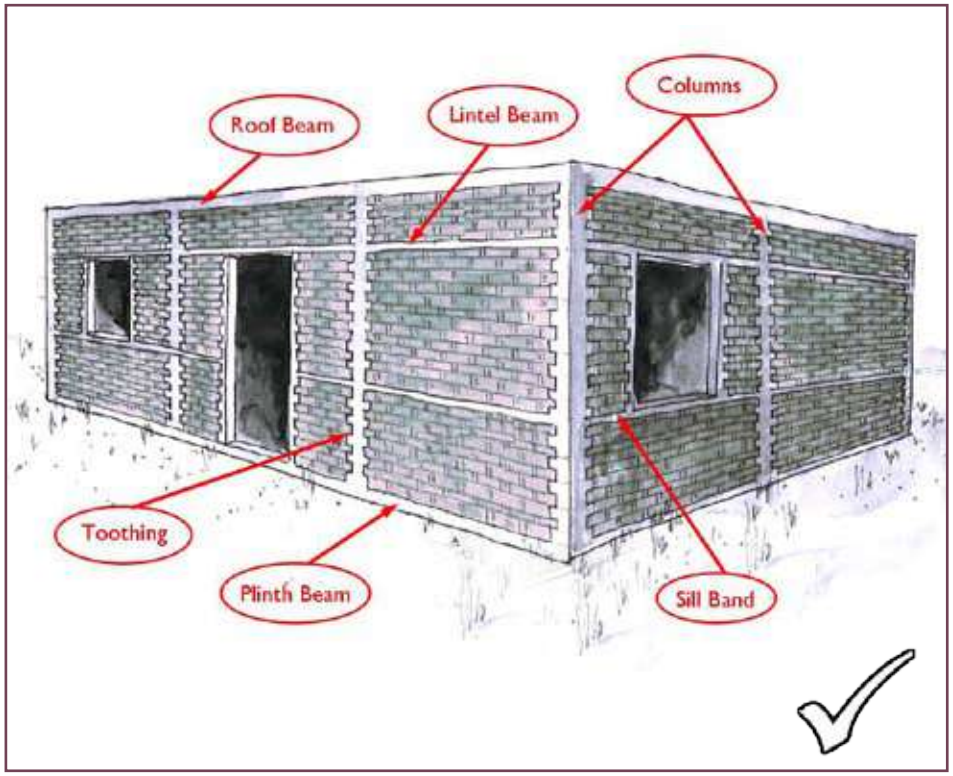
- Confined masonry consists of load bearing brick, or block masonry or in situ concrete panels surrounded by horizontal and vertical 'confining' elements made from reinforced concrete.
- Wall panels are built first, and then the reinforced concrete columns poured afterwards. The wall should be built with toothing to ensure a good connection with the concrete column. Walls should also be tied to columns with horizontal reinforcement.
- Horizontal reinforcement consists of reinforced concrete beams (with 4 longitudinal rebars) at plinth, lintel and roof levels. Additional reinforcement may be provided at sill level or with corner stitches.
- Vertical reinforcement consists of reinforced concrete columns (with 4 longitudinal rebars) at wall junctions (corners) and max. 15 ft spacing.
- Reinforced concrete frames (with 2 rebars) should be provided around window and door openings.

Permitted

- Masonry with 4 bar vertical reinforcement at corners and junctions and vertical bars at every 4 ft along the wall, can comply with reinforced masonry standards.
- Without vertical bars every 4 ft, construction must be considered to be confined masonry and meet the confined masonry standards.
- Due to height limitations, a single beam may be cast instead of separate lintel and roof beam.

Not Permitted

- Do not use timber posts with concrete blocks or in situ concrete.



2 Confined Masonry | Specifications

Walls	**Wall Materials**	Brick, concrete block, in situ concrete.	**Important Note:** Concrete for foundations, columns, bands and beams should be 1:2:4 mix (cement : sand : aggregate), with maximum aggregate size 3/4 inch.
	Wall Thickness (min.)	9" Brick 8" Concrete Block 8" In Situ Concrete	
	Wall Length	15 ft maximum unsupported length	
Vertical Reinforcement	**Location**	Reinforced concrete columns at wall junctions / corners	
		Reinforced concrete frames around wall openings.	
	Reinforcement	Junctions: 4 # 4 bars (stirrups: #3 bars @ 6")	
		Openings: 2 # 3 bars (stirrups: #3 bars @ 6")	
Horizontal Reinforcement	**Foundation**	Material	Masonry / Concrete
		Depth (below ground)	36" (soft soil) / 18" (hard soil)
		Height (above ground)	9"
		Width	30"
		Reinforcement	#3 bars @ 8" spacing (longer direction); #3 bars @6" spacing (shorter direction) Or 32" wide strip foundation is also acceptable
	Plinth Beam	Depth	Min. 9"
		Reinforcement	4 # 4 bars (stirrups: #3 bars @ 6")
	Sill Beam (Optional)	Depth	Min. 3"
		Reinforcement	2 # 3 bars (stirrups: #2 bars @ 6")
	Lintel Beam	Depth	Min. 6"
		Reinforcement	4 # 3 bars (stirrups: #3 bars @ 6")
	Roof Beam	Depth	Min. 9"
		Reinforcement	For <12 ft span: 4 #4 bars (stirrups: #3 bars @ 6" or 8" spacing) For >12 ft span: 4 #6 bars (stirrups: #3 bars @ 6" spacing)
	Corner strengthening	Location	Stitches @ 18" - 24" vertical spacing and embedded min. 2 ft into all connecting walls
		Reinforcement	2 # 2 bars or 1/8" x 1" flat iron or wire mesh
Roof		Lightweight (wooden truss frame / steel frame with CGI sheet covers)	
Other Features		In case of situ concrete: provide additional #4 vertical bars at every 4 ft along the wall. Cement sand mortar mix: For Masonry - 1:4 ; For Plaster - 1:6	

3 Timber Frame / Dhajji

General Description

- Two types of timber frame construction are considered compliant:
  a. Timber frame with sheet cladding.
  b. Timber frame with infill masonry (Dhajji).
- The timber frame in both cases should be constructed as a well-connected box with adequate bracing in all directions for stiffness.
- The base plate and wall plate act as plinth and roof beams and should be continuous.
- The masonry infill provides additional compressive strength.
- The panels should be small and even-sized.
- The timber should be good quality, with joint connections.
- All timber should be well protected from moisture, especially from the ground.

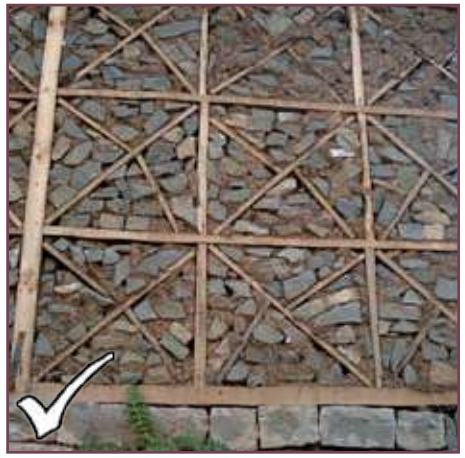
Apply termite proofing agents before using the timber in construction works.

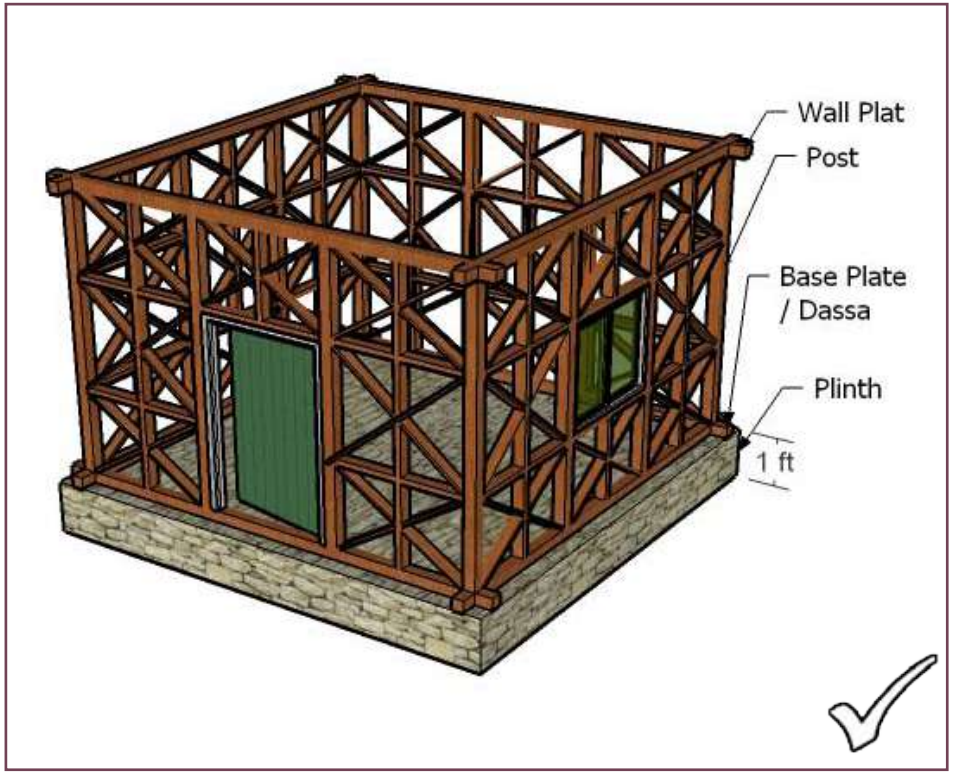
Permitted

- Timber frame (Dhajji) construction is traditional in parts of the affected district. There are regional variations in the technique including different bracing patterns.
- The posts, sub posts and spacing should be considered to allow versions that provide equivalent structural strength: 4" x 4" at 4 ft spacing, equals to 4" x 2" at 2 ft spacing.
- Bracing should be balanced in both directions, making small even-sized panels.

Not Permitted

- Do not use concrete blocks or in situ concrete as infill.
- Do not use large unbraced panels.
- Timber should not be in direct contact with the ground.





3 Timber Frame / Dhajji | Specifications

Walls	**Wall materials**	Timber framework with cladding sheeted material, (CGI sheets or ply-wood) Timber framework with infill masonry (stone/ brick with mud or lime)	
	Wall thickness	Min. 4”	
	Unsupported wall length	Max. 15 ft	
	Wall height	Max. 8 ft	
Timber Structure	**General**	Use good quality, well-seasoned wood (e.g. Kail, Chir)	
	Base plate / ‘dasa’ (horizontal)	Min. 4” x 4” Beam	
	Main posts (vertical)	4” x 4” Posts @ 4-6 ft spacing Or equivalent (e.g.: 4” x 2” @ 2 ft spacing)	
	Top wall plate (horizontal)	4” x 4” Wall plate continuous + connected to posts	
	Cross bracing (diagonal)	4” x 2” Bracing for > 2 ft spacing. Brace in both directions 4” x 1” Bracing for < 2 ft spacing. Brace in both directions	
Foundation and Plinth	**Foundation**	Material	Concrete or stone masonry
		Depth Below Ground	30” (soft soil) / 18” (hard soil)
		Width	24” - 30”
	Plinth beam	Location	Min. 12” above ground level. Base plate / ‘dasa’ acts as plinth beam.
			Additional concrete DPC / plinth beam optional.
			Base plate fixed to foundations with anchor bolts / metal straps at 6 ft spacing
Roof		Lightweight (wooden truss frame / steel frame with CGI sheet covers)	
Other Features	**Connections**	Strong connections are critical for strength. Strengthen joints with metal straps.	
	Infill	Infill should not have stones larger than 4” x 4”.	

4 Timber Reinforced Masonry / Bhatar

General Description

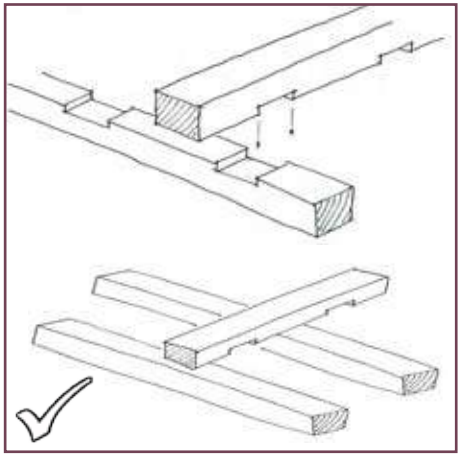
- This technique consists of stone masonry reinforced with horizontal ladders (bands) to improve the integrity of the wall and to tie the walls together.
- The timber bands are provided at regular interval of maximum 2 ft.
- The timber bands must have cross pieces at every 3 ft horizontally and good joints and overlapping.
- Stone masonry must be constructed with through stones and well packed, using flat or dressed stones.

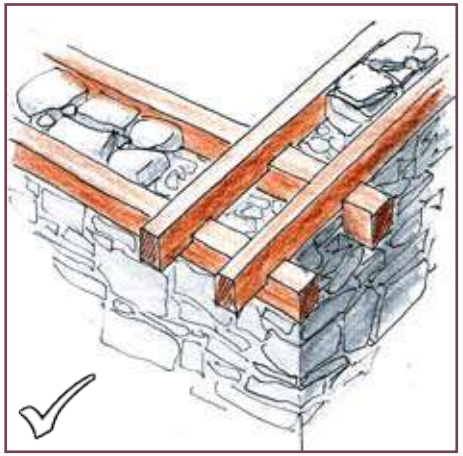
Permitted

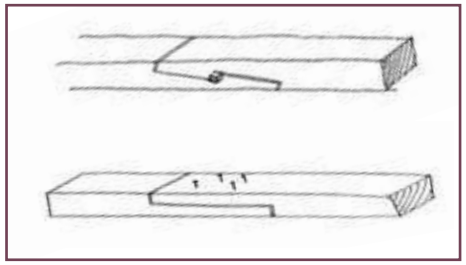
- Timber reinforced masonry construction is traditional in parts of the affected district.
- The timber reinforcement indicated here is minimum. In some areas closer spacing of timber bands may be found.

Not Permitted

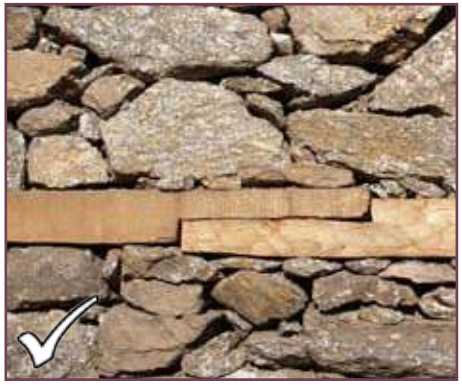
- Do not use timber bands with concrete blocks or in situ concrete.
- Timber should not be in direct contact with the ground.

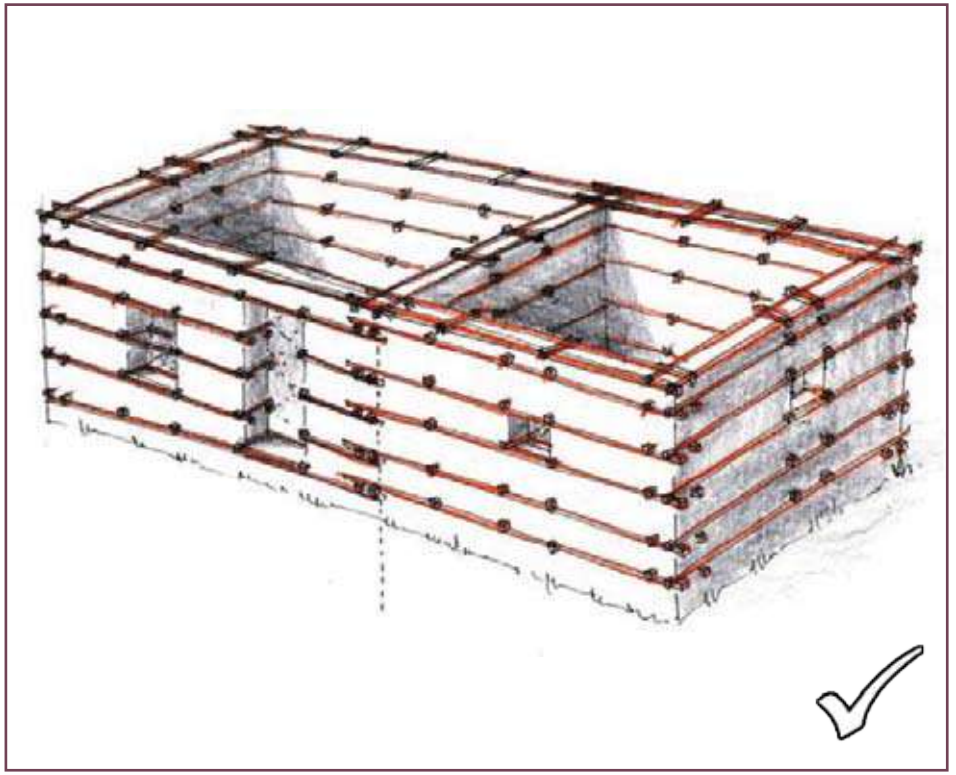






Apply termite proofing agents before using the timber in construction works.





4 Timber Reinforced Masonry / Bhatar | Specification

Walls	**Wall materials**	Stone masonry with timber reinforcement	
	Wall thickness	18”	
	Unsupported wall length	Max. 12 ft	
	Wall height	Max. 8 ft	
Reinforcing Elements	**General**	Use good quality, well-seasoned wood (e.g. Kail, Chir) Use timber joints for connections.	
	Timber Bands	4” x 3” long pieces, 4” x 3” cross pieces Cross pieces at 3 ft spacing horizontally, notched and overlapped. Continuous bands at 2 ft spacing vertically	
Foundation and Plinth	**Masonry**	Use through stones at every 2 ft vertically and 4ft horizontally	
	Foundation	Material	Concrete or stone masonry
		Depth (below ground)	36” (soft soil) / 24” (hard soil)
		Width	30”
	Plinth band	Location	Min. 12” above ground level. May be timber band. Recommended to use an RCC plinth band
		Depth	4”
		Reinforcement	2 #4 bars (stirrups: #1 bars @ 6”)
Other Features	**Openings**	Max opening size 3ft Minimum distance from corners 3ft.	
	Horizontal Joints	Min. 1 ft overlap should be provided.	

5 Leepa - Timber Post and Beam Type Houses

General Description

- Leepa-Timber Post and Beam Construction is based on large timber section sizes.
- It differs from Dhajji frame construction which has small timber section sizes in a fully braced structure.

- The building should be heavier on the lower storeys and lighter above.
- The total building height should not be more than its plan length
- The building should have equal number of bays and openings on all sides.
- The openings should not be large or numerous.
- The building should have adequate walls in both directions to provide enough stiffness.
- The building should be retrofitted if it does not have adequate stiffness.

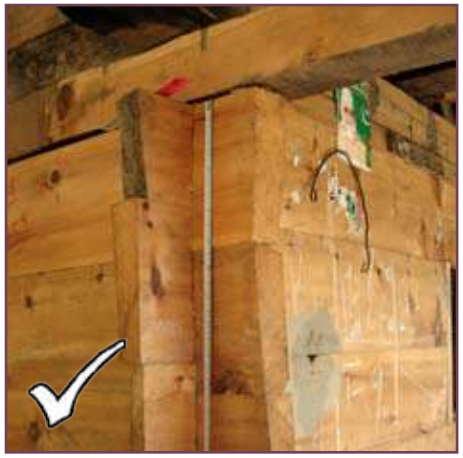
See APPENDIX- A for Leepa type construction guidelines and standards.

Permitted

- The plinth can be a basement floor of up to 8 ft constructed in reinforced stone masonry.
- The main building may have walls of timber planks or dhajji infill panels.
- Timber planks should be interlocked.
- The building can be more than 1 storey.

Not Permitted

- Do not use concrete blocks or in situ concrete as infill.
- Do not use large unbraced panels.
- Do not use RCC columns or beams combined with the timber frame.
- Do not make very large or numerous openings in any wall.
- The roof should follow the traditional shape and not introduce new imported styles.

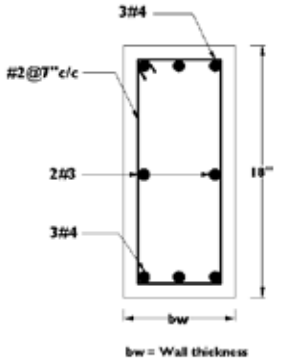


Leepa - Timber Post and Beam Type Houses | Specifications

Walls	**Wall materials**	**Timber Plank**	**Dhajji Infill**	**Stone Masonry. Bhatar reinforcement. (ground floor only)**
	Wall thickness	1 1/2“	Min 6”	24”
	Unsupported wall length	**15’**	**15’**	**15’**
	Wall height	**10’**	**10’**	**8’**
Timber Structure	**General**	Use good quality, well-seasoned wood.		
	Base plate / ‘dasa’ (horizontal)	Min. 6” x 5” Base plate.		
	Posts (vertical)	6” x 5” Posts at maximum 6 ft spacing		
	Top wall plate (horizontal)	6” x 5” Wall plate continuous + connected to posts		
	Flooring	Solid floor boards 3/4’ thick.		
Foundation and Plinth	**Foundation**	Material	Concrete or stone masonry	
		Depth Below Ground	36” (soft soil) / 24” (hard soil)	
		Width	30”	
	Plinth / Basement	Height	Min. 12” above ground level. Max 8’ above ground. Base plate / ‘dasa’ acts as a plinth beam. Basement / plinth wall must not retain a height greater than 8 ‘.	
Roof		Timber frame with CGI sheeting or timber shingles		
Other Features	**Configuration / Openings**	Openings should not be more than 25% of overall wall area. Openings should be equally distributed. Openings should not be located less than 5’ from corners. Wall length between openings not less than 2.5’.		
	Connections	Posts should be connected to base plate and wall plate with mortice and tenon joints.		

5 Exceptions

Exceptions are those which are also technically acceptable, in addition to the standards published earlier.

No.	Items	Poster Text	Exceptions
1	**Shape of House**	Avoid long & narrow structures. Length of house should not be more than 3 times its width.	Houses comprising more than two rooms are acceptable as long as the aspect ratio and plan configuration is as per poster requirements.
		Maximum room size should be limited to 15 ft x 15 ft.	Room size upto 16 ft x 16 ft is acceptable instead of 15 ft x 15 ft if all other requirement of poster are fulfilled. In larger rooms additional horizontal cross bracing shall be provided at the top chord level.
2	**Foundation**	Foundation details: Foundation for various masonry options should be as shown in Figure No.3 in reinforced masonry poster (Appendix-A). Minimum width of footing should be 2.5 ft.	Foundations without steps are also acceptable. Foundation size of 2 ft instead of 2.5 ft are acceptable only if the strata below the foundation is hard and all the other requirements of the poster are fulfilled. For soft soils the foundation width shall be 2.5 ft.
3	**Windows & Doors**	Gap between two openings, wall length between two openings (doors and windows) should not be less than 2 ft.	Solid portion between windows and door is less than 2 ft is acceptable if constructed as R.C column.
4	**Horizontal RCC Bands**	Lintel band over window & doors. Roof band at wall top.	Due to height limitation or ease of construction one single deep beam is casted instead of separate lintel and roof band is also OK. 

5 Exceptions

No.	Items	Poster Text	Exceptions
5	**Walls**	Concrete block wall thickness: 8 inches	For single storey construction, 6" thick walls constructed using solid cement concrete blocks are acceptable provided: 1. All other requirements of poster are met including horizontal and vertical reinforcement and seismic band. 2. The height of wall is not more than 9 ft. 3. Number of storeys is limited to one only. 6" solid reinforced block may be used for room sizes 12 ft x 12 ft or less. **For future construction walls less than 8" thick shall not be accepted.**
6	**Vertical Reinforcement in foundation & walls**	Place vertical steel bars in foundation and walls at all corners & junction of walls & adjacent to all doors & windows. The max. spacing between two adjacent vertical bars should not be more than 4 ft. Use 5/8 inch diameter (5 sutar) steel bars in case brick and concrete block masonry. Provide 3/4 inch diameter (6 sutar) steel bars for stone masonry.	More than one bar provided at corners & T-junction (For example 4 bars is acceptable, provided all other requirements of poster are fulfilled and ties are provided to enclose the bars and plinth, lintel and roof band reinforcement is extending into the confining element. The spacing between two vertical bars may be increased to 5 ft provided all the other requirements of poster are fulfilled.
7	**Not covered**	Not applicable	Situ (8 inch thick) and confining elements i.e (lintel, roof, plinth bands /beams and columns) cast and bonded together using stitches are acceptable if the reinforcement provided is at least equal to the reinforcement specified in confined masonry poster using concrete mix of (1:2:4) and maintaining a w/c ratio of 0.6. Situ in which timber posts are embedded are not acceptable.

See **APPENDIX - C** For any further queries related to safe and compliant construtions

INTRODUCTION

ERRA guidelines for safer construction include

a) familiar traditional techniques and materials like brick, timber frame and stone, but introducing essential new measures to improve the seismic resistance of the construction and
b) less familiar imported materials and techniques like reinforced concrete and blockwork, also with essential specific details to improve seismic resistance.

The principles of seismic design and the detailed specification and correct implementation of reinforcement measures to ensure seismic resistance, is new information for many engineers, sub engineers, and for most masons and carpenters.
It is not only new information, but complex to understand properly and to execute correctly, especially on a first attempt.
There is a wide range of information for people to try to learn and understand and inevitably many householders, masons and engineers are confused and unsure about both the general principles and the specific details.

Section C attempts to show the types of errors which have commonly occurred in the field, some due to lack of understanding, some due to lack of good workmanship.

It explains what the effect of these deficiencies in the building will be in terms of earthquake resistance. It explains which defects are major and require dismantling, and which defects can be remedied.

The guidance for carrying out remedial works is detailed in **Section D.**

While almost every household placed vertical reinforcement bars at plinth level, due perhaps to the tranches of financial assistance contingent at plinth inspection, a large number of households did not understand the greater importance of constructing continuous horizontal reinforcement bands, particularly at roof level. Section C sets out to discuss the importance of all of the key seismic improvement measures in terms of safety, to help ensure that buildings are fully completed as intended, and to avoid a situation of householders neglecting essential requirements when closer to completion, or when their budget is nearly spent.

COMMON DEFECTS

I Shape and configuration

Irregular plan shape, L, U and T shapes

Problem

- *Complex shapes increase the stress on parts of the building during earthquakes and will cause damage or failure.*

Recommendations

- Complete the house to regularise the plan and balance the mass.
- Split the complex shape into box shapes by constructing an additional wall with 6" seismic gap from existing wall of the house.

Long walls - unrestrained length >15ft

Problem

- *Long or high unrestrained walls will deflect in earthquakes*

Recommendations

- Use cross walls to divide the building into smaller rooms.
- Make sure all cross walls are well connected to the long walls.
- Use buttresses to add strength and stiffness to long walls.
- Use additional columns to add strength and stiffness to long walls.
- Make sure long walls do not have large openings.
- Limit the height of long walls.

SEE REMEDIAL MEASURES # 3 (Section D)
For advice on how to add cross walls.

Room sizes too big

Problem

- *Similar to long walls*

Recommendations

- Subdivide large rooms, with additional cross walls.
- Use buttresses or additional columns to add strength and stiffness to long walls.

SEE REMEDIAL MEASURES # 3 (Section D)
For advice on how to add cross walls.

Gable walls

Problem

- *Masonry in gable walls means unbalanced mass in the building. This masonry is also vulnerable as it is high and not restrained.*

Recommendations

- Replace the gable masonry above the lintel with lightweight infill.
- Provide additional reinforcement band over gable.

SEE REMEDIAL MEASURES # 9 (Section D)
For advice on how to add reinforced band at roof level over the existing walls.

SEE REMEDIAL MEASURES # 8 (Section D)
For advice on how to add external reinforced bands to the existing walls.

2 Foundations and site

Site on fill

Problem

- *The building will settle unevenly causing damage or failure. In earthquakes, the base will behave unevenly causing strain on the building.*

Recommendations

- Keep the main house only on solid ground.
- Use filled ground from verandah or ancillary use.
- Use a strong plinth beam if the site is on soft ground or fill.

SEE SITE WORKS # 1 PAGE-73, (Section E)
For advice on how to improve plinth.

Plinth too high / unequal

Problem

- *An unequal or loosely packed plinth will not provide a base of sufficient stability in an earthquake. High plinth reduces overall stability*

Recommendations

- Limit the height of a plinth to 3 ft.
- Stabilise the plinth with horizontal reinforcement RCC bands.
- If the plinth is already built, strengthen it with buttresses and a horizontal reinforcement band at the top.

SEE SITE WORKS # 1 PAGE-73, (Section E)
For advice on how to improve plinth.

No anchorage to columns

Problem

- *If the vertical reinforcement / columns do not have foundations, they do not anchor the building back to the ground and are not sufficiently stable.*

Recommendations

- Excavate to approximately 3ft below ground level. Extend the steel reinforcement below ground and fix in concrete.

SEE REMEDIAL MEASURES # 6 (Section D)
For advice on how to improve vertical reinforcement

No foundation

Problem

- *Good foundations are necessary to evenly transmit the load of the building to the ground. Soft ground causes more settlement and distortion in earthquakes.*

Recommendations

- Use a strong plinth beam.
- Excavate and provide foundations to the vertical reinforcement.
- Make sure the rising wall is protected from ground and site surface water.

3 Weak masonry

No mortar in vertical joints

Problem

- *Block and brick masonry needs to be well bonded to act as a shear plane. The wall will fail and crack along the open joints.*

Recommendations

- Dismantle all masonry as far as possible and rebuild with correct mortar in all joints.
- Avoid continuous vertical joints in all masonry.

NOTE
Mortar should be 1:4 cement : sand.
Weak mortar will fail.

SEE REMEDIAL MEASURES # 2 (Section D)
For advice how to strength weak masonry

Substandard stonework

Problem

- *Stone needs to be well selected and well laid to act as a homogenous wall with sufficient integrity.*

Recommendations

- Round or friable stones should not be used.
- Loose fill should not be used in the centre of the wall.
- If the wall does not have the required through stones carefully remove stones at 4 ft intervals and cast a through stones or reinforcement bars in the replaced stonework.
- Use long stones at corners and junctions for additional strength.

Substandard in situ concrete

Problem

- *In situ concrete must meet minimum requirements of mix and placement.*

Recommendations

In situ not permitted:

- With large boulders:
  i- > 40 % ratio,
  ii- > 5 inch stone size
- With large air pockets and gaps
- Less than 8 inch width
- With timber post vertical reinforcement

In-situ recommendations

Recommendations

- In situ of 8 inches wide is acceptable if it is good quality and all reinforcement and other requirements are fulfilled
- In situ should be cured for at least 10 days.

Vertical Reinforcement

- #4 bars should be placed at every 4ft spacing vertically.

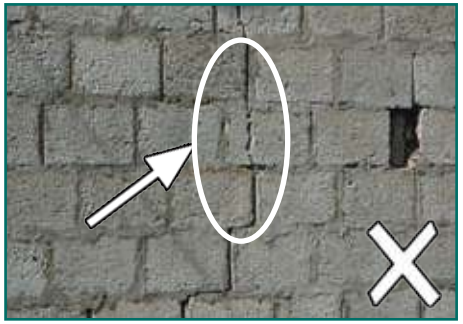
Horizontal Reinforcement

- In situ should have reinforced bands/ beams at sill, lintel and roof levels.
- All horizontal reinforcement should be correctly fixed to vertical confining reinforcement.

Dismantle

- In situ with timber post reinforcement should be dismantled.
- In situ less than 6 inches wide should be dismantled.

3 Weak masonry : Blocks



Substandard concrete blocks

Problem

- *Concrete blocks must meet minimum standards of strength. For the stability of load bearing walls they should meet minimum dimensions.*

Recommendations

Concrete blocks not permitted:

- 6 inch hollow
- 4 inch hollow
- Less than 1700 psi strength
- Cured for less than 10 days
- Do not use timber posts as vertical reinforcement with blocks

Solid Blocks

Recommendations

- 6 inches thick **solid concrete blocks** are acceptable for single storey construtions if all reinforcement and other requirements are fulfilled and the wall height is not more than 9ft.

Horizontal Reinforcement

- Blockwork should have plinth, sill, lintel and roof band horizontal reinforcement.

Vertical Reinforcement

- Blockwork should have vertical bars at 4 ft to max. 5ft spacing along the length of the wall, corners and at wall junctions.

WARNING

For 6" thick solid blocks room size should not be greater than 12 ft x 12 ft.

Fill hollow blocks to make solid wall

Recommendations

- Hollow 6 inch or 8 inch blocks can be filled with 1: 3: 6 mix while under construction.
- This will assist the placing of vertical and horizontal reinforcement.
- Filling blocks after the wall is already constructed or partially constructed is not advised as the concrete will not fill evenly, it will get trapped in the upper courses and will make the wall top heavy.
- It will be better to dismantle the wall if construction is below lintel level.

SEE REMEDIAL MEASURES #1 (Section D)

For filling the hollow blocks before use

Increase wall thickness

Recommendations

- Fix steel reinforcement or wire mesh to both faces of the blocks and cover with 1" shot-crete or plaster applied to entire face of both sides of the wall.

SEE REMEDIAL MEASURES #2 (Section D)

For using the wire mesh

4 Reinforcement defects

Non-seismic rings

Problem

- *Proper rings reinforcement is essential to make columns or beams act as single elements.*

Recommendations

- Stirrups should be made with 45 degree hooks on both ends to ensure they do not open when shaken in an earthquake.
- These hooks are called seismic hooks.
- The hooks should be alternated along the column or beam so the connections are not all on one side.
- Stirrups should be spaced according to the construction standard, generally at 6 inch spacing.

No connection at corners

Problem

- *Horizontal rebars should be placed to strengthen corners and junctions. Incorrect placement will mean this critical location is weak and will fail.*

Recommendations

- Joints in horizontal rebars should never meet at the corners or junctions.
- Rebars should continue at least 24" past all junctions into the walls.
- Make sure the reinforcement is correctly placed at corners and junctions in the beams to ensure it act as complete bands.
- If the roof band or beam is missing or has incorrectly fixed steel, cast an additional beam with correct steel reinforcement.

Anchorage

Problem

- *Columns should have feet to securely anchor the building to the ground.*

Recommendations

- Columns and vertical reinforcement bars should start from the foundation, minimum 3 feet below natural ground level.
- Columns should have feet extending 12 inches horizontally and placed on lean mix concrete
- If the vertical reinforcement does not start from below ground, dismantle part of the concrete, excavate the foundation and splice additional vertical bars. Pour new concrete to complete column. For more details see **Remedial Measures No. 6.**

Insufficient overlaps for vertical reinforcement

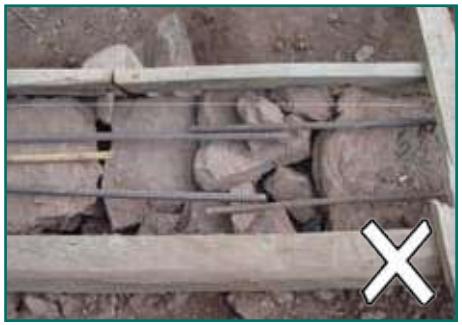
Problem

- *The location and length of overlap of rebars is important to ensure the strength of reinforced concrete members.*

Recommendations

- Rebar overlaps should be located at least 2ft away from the joints vertically..
- The length of overlap required depends on the diameter of the rebar. The recommended overlap is 60 x diameter of bar.
  e.g.: 60 x 1/2 inch : 30 inches

4 Reinforcement defects



Insufficient overlap of reinforcement bars

Problem

- *The location and length of overlap of rebars is important to ensure the strength of reinforced concrete members.*

Recommendations

- Rebar overlaps should be located at least away from joints.
- The length of overlap required depends on the diameter of the rebar. The recommended overlap is 60 x diameter of bar.
  e.g.: 60 x 1/2 inch : 30 inches.

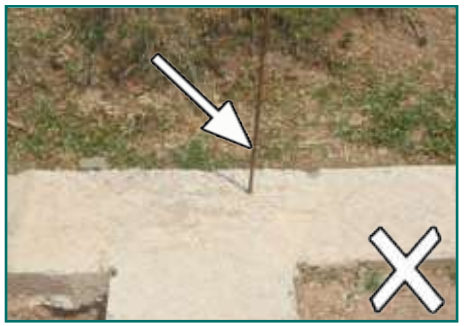
Wrong placement of vertical bars

Problem

- *Vertical reinforcement bars not located in the center of the walls, corners and T-junctions.*

Recommendations

- If the construction is at plinth level: partially dismantle plinth and place the reinforcement in the center of the wall and reconstruct.
- The vertical reinforcement should be aligned and in the center of the wall



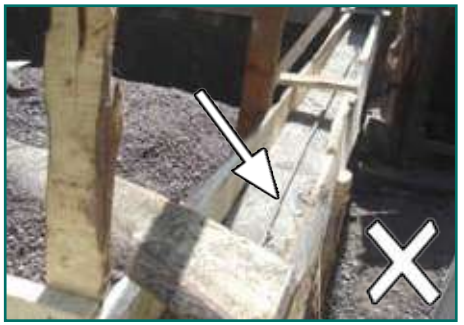
Exposed reinforcement bars

Problem

- *Exposed steel reinforcement is vulnerable to rusting and the structure weak.*

Recommendations

- Ensure proper compaction when placing concrete. Use a rod or vibrator for compacting concrete.
- If already constructed and very poor concrete cover, dismantle and reconstruct.
- If already constructed and minor problems with concrete cover, fill the holes with grout. Use 1:1 cement sand mix.



Insufficient reinforcement in bands

Problem

- *Only one bar placed in horizontal bands.*

Recommendations

- Place required number of bars (two bars for reinforced masonry; four bars (or confined masonry), with stirrups as per requirements (Section B).

5 Openings

> 50% openings in a wall. Openings too large

Problem

- *Openings reduce the strength and stability of the wall.*

Recommendations

- If openings form >50% of a wall, consider blocking up some openings.
- If all openings are on one wall, consider partial blocking up and relocation of openings, to another wall.
- If openings are larger than 4 ft wide, consider partial blocking up.
- If blocking up is not feasible in the above cases, make sure the openings are well framed with vertical and horizontal reinforcement.
- Maximum length of the opening could be 65% of the total wall length if all opening are properly framed.

WARNING: Openings larger than 65% length of the walls with proper framing would not be acceptable.

SEE REMEDIAL MEASURES # 4 (Section D)
For advice on how to reduce the opening sizes.

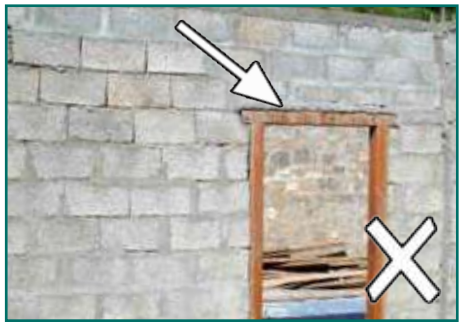
Openings too close to corner/ other openings

Problem

- *Openings too close to each other and corners reduce the overall strength of masonry.*

Recommendations

- Consider partial or full blocking up of openings.
- Make sure all openings are well framed with vertical and horizontal reinforcement.
- Increase the strength of portion between openings by constructing as an RCC column.



Openings without lintels

Problem

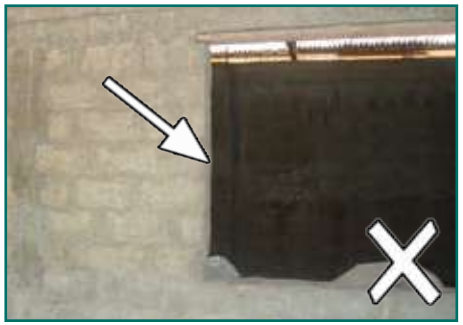
- *Masonry above openings should be supported by a strong lintel.*

Recommendations

- All openings should have an appropriate lintel. A continuous lintel band or beam is essential.
- If no lintel is provided, dismantle masonry above opening and construct a lintel.
- Timber beams are not recommended for use as lintels in brick and block masonry.

SEE REMEDIAL MEASURES # 7 (Section D)
For advice on how to add lintel band / beam. If the wall is constructed with roof beam/ band and only lintel is missing, then:

SEE REMEDIAL MEASURES # 8 (Section D)
For advice on how to add external lintel band.



Openings without framing reinforcement

Problem

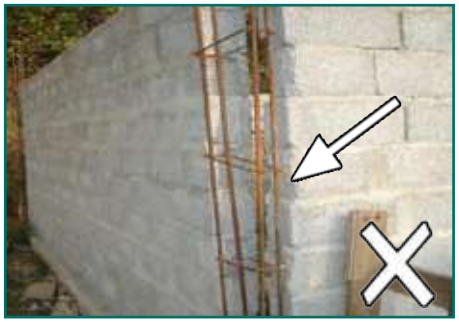
- *Reinforcement around openings improves the strength of a wall.*

Recommendations

- Openings should always have lintels.
- Windows should preferably have sill bands.
- Openings should have reinforced vertical framing on both sides from the sill band.
- If reinforcement is missing, dismantle the masonry below the opening and cast a reinforced concrete sill.
- Provide vertical reinforcement, connected to the sill and lintel.

SEE REMEDIAL MEASURES # 5 (Section D)
For advice on how to add reinforcement around openings.

Connection defects



No toothing

Problem

- *The walls should be constructed before pouring concrete for columns. The edge should be toothed to ensure a good bond to the column.*

Recommendations

- If the column is not cast, partially dismantle along the edge to improve the toothing effect.

No connection between cross walls

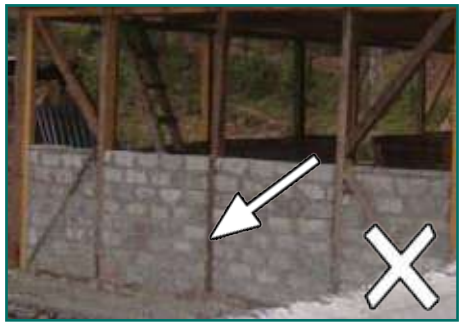
Problem

- *Perpendicular walls need to be connected through bonded masonry and strengthened with horizontal and vertical reinforcement. Without connection there is no box effect, the walls are free standing.*

Recommendations

- If the column is not cast, partially dismantle at the junction and reconstruct with correct toothing, bonding and correctly placed reinforcement.
- If no column is required, partially dismantle and rebuild with improved bonding and correct reinforcement.

SEE REMEDIAL MEASURES # 12 (Section D)
For advice on how to connect the cross walls.



Timber posts in masonry

Problem

- *Timber posts used in block and brick masonry reduce the connection between walls, and do not confine masonry panels.*

Recommendations

- Timber posts should be removed and replaced with RCC columns with horizontal bands and stitches connecting to the walls.

SEE REMEDIAL MEASURES # 10 (Section D)
For advice on how to replace timber post with RCC column.

Substandard columns

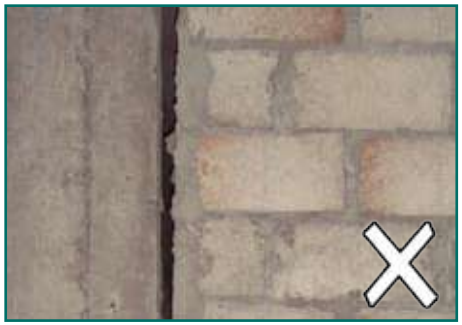
Problem

- *If the columns are substandard consider dismantling them to allow correct construction. This may be an easier and more cost effective solution.*

Recommendations

- If column concrete is of poor quality, and major honey combs (voids) are exposed then consider dismantling and re-doing the concreting. If the problem is only mild fill the holes with grout (1:1 cement sand mix).
- If the column has exposed reinforcement bars, due to the use of poor quality concrete, dismantle the column and pour again with adequate concrete cover for reinforcement bars.

6 Connection defects



RCC columns cast first No connection to walls

Problem

- *Casting columns first means the horizontal reinforcement is not properly connected to the columns and the masonry is not well bonded with the concrete.*

Recommendations

- The columns need to be connected to the walls. The cross walls need to be connected to each other through the column.
- The horizontal bands need to be made and placed correctly and columns adjusted to achieve this connection.
- If the walls and columns are already constructed, it may be possible to construct a splint/external bandage to strengthen the connection.
- If the columns and wall panels have visible gap, fill the gap with 1:2:4 concrete and connect walls and column with splint/external bandage.

SEE REMEDIAL MEASURES # 11 (Section D)
For advice on how to improve the connection between column and walls.

Free standing columns No connection to roof beam

Problem

- *Casting columns first and providing timber wall plate as roof beam/band to connect columns at roof level results in weak onnection between the column and walls.*

Recommendations

- The RC columns need to be connected at top with a roof band/ beam.
- A timber wall plate is not adequate to tie the top of the walls together.
- To connect the columns with roof beam/band, remove the concrete from the top of the column to expose steel bars and place reinforcement for roof beam with proper connection to the column reinforcement.

SEE REMEDIAL MEASURES # 8 (Section D)
For advice on how to add roof beam with proper connection to columns.

Horizontal bands missing

Problem

- *Horizontal bands and beams are essential to tie the building together to act as a box.*

Recommendations

- Where a roof band or beam is missing, dismantle the top of the wall and support the roof to add appropriate band/beam.
- Where a lintel band or beam is missing, dismantle the top of the wall down to the openings and reconstruct correctly.
- Horizontal bands, stitches and splints are explained in more detail under remedial measures.

SEE REMEDIAL MEASURES # 7 & # 9 (Section D)
For advice on how to add lintel band / beam and roof band / beam respectively.

Mixed materials

Problem

- *Construction of walls or parts of the building in different materials results in poor connections and requires additional detailing to tie the building together.*

Recommendations

- Where all walls are constructed of different masonry at different levels e.g. stone to 4 ft then blocks or lighter material above. Construct a complete RCC horizontal band or beam as a ring where the change in material occurs.
- Where walls are completely different materials, make sure there is horizontal reinforcement tying both walls. Avoid very large differences in mass between different walls in the same building.

SEE REMEDIAL MEASURES # 13 (Section D)
For advice on how to improve connection between different types of materials.

7 Timber frame / Dhajji

Keep the timber dry

Problem

- *Timber frame buildings will remain strong only if the timber is protected from moisture and rotting. Rotten timber will fail in an earthquake.*

Recommendations

- Timber should be protected from ground water and site surface water by constructing a plinth of 12 inches minimum height above natural ground level.
- If the height of plinth is less than 12 inches, excavate around the plinth and improve site drainage.
- Do not use a timber frame as a rear retaining wall.
- Use an overhang or verandah to protect the walls and base plate.
- Apply used engine oil or other preservative to improve the water resistance of timber.

Frame stable on plinth

Problem

- *The plinth should not be at risk of collapse. The timber frame should not be at risk of falling off the plinth. Both cases risk the frame failing to perform as a secure box.*

Recommendations

- The maximum height of plinth above the existing ground should not exceed 3 ft.
- The plinth should be constructed of well packed masonry (no large gaps) with strong corners and retaining wall specifications where required.
- The frame should not be placed directly on the edge of the plinth, to allow for slight movement without failure.
- Substandard plinths should be improved to meet these criteria.
- Fixing the frame to the base can improve the stability. This is done with bolts drilled through the base plate and anchored below ground.
- Fixing can be done as retrofit, by using 18" long anchor bolt and concreting in.

Base plate and wall plate

Problem

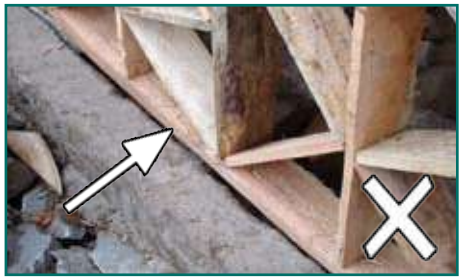
- *The base and wall plates act as ring beams are must be continuous and strong to tie the building together.*

Recommendations

- The base plate should be minimum 4 x 4 inch good quality seasoned timber.

Horizontal joints

- All horizontal joints should be well made with lapped, or kashmiri joints.
- For 4 x 4 base plate the joint should be 12 inches long.
- Strengthen horizontal joints with horizontal metal straps.
- Do not fix nails in a single line in case of splitting the timber.



Base plate and wall plate

Recommendations

- **Corners**
- The corner joints should be overlapped in both directions.
- If the joint is flush add a metal strap extending minimum 18 inches on each side. Fix with staggered nails.
- Make sure posts are well fixed to both base and wall plates.

7 Timber frame / Dhajji

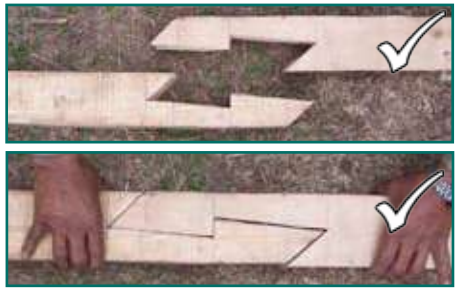
Joints

Problem

- *Joints should be located correctly and well made.*
  The frame is most likely to fail at these connection points.

Recommendations

- Horizontal joints should be placed over a post with a capital. Otherwise the post will push and open the joint in an earthquake.
- Do not drill a bolt through a joint.
- Do not use too many or too large nails, they may split the timber.
- Mortice and tenon joints are recommended for post to beam connections.
- If a joint is poorly made, add an overlapping timber.



Stiffen the frame

Problem

- *There should be adequate bracing to stiffen the main frame.The bracing should help distribute the force from an earthquake equally through the building.*

Recommendations

- Use small panels. If the masonry panels are larger dismantle back to main frame and reconstruct with more bracing to make smaller panels.
- Make sure all bracing is well fixed and will not fall out in an earthquake.
- Stiffen the building with cross walls or struts to reinforce corners.
- Add timber blocks to fix posts, trusses or other members in place.

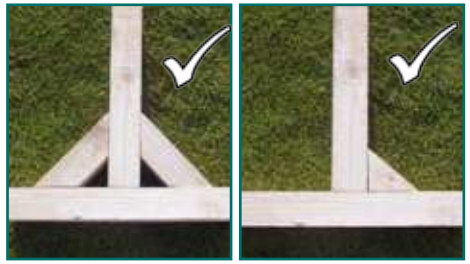
Stiffen the roof

Problem

- *The roof needs to be framed as a box to add stiffness to the main frame and to resist wind loads.*

Recommendations

- Hipped roofs are more stable
- Use a continuous wall plate, ridge and purlins to tie the rafters or trusses together.
- Use rafters or trusses at no greater than 6 ft cc horizontal spacing.
- Add diagonal timbers to brace between trusses.
- Add a ceiling to stiffen the roof.
- Add timber blocks to fix the trusses or rafters in place.



Substandard infill

Problem

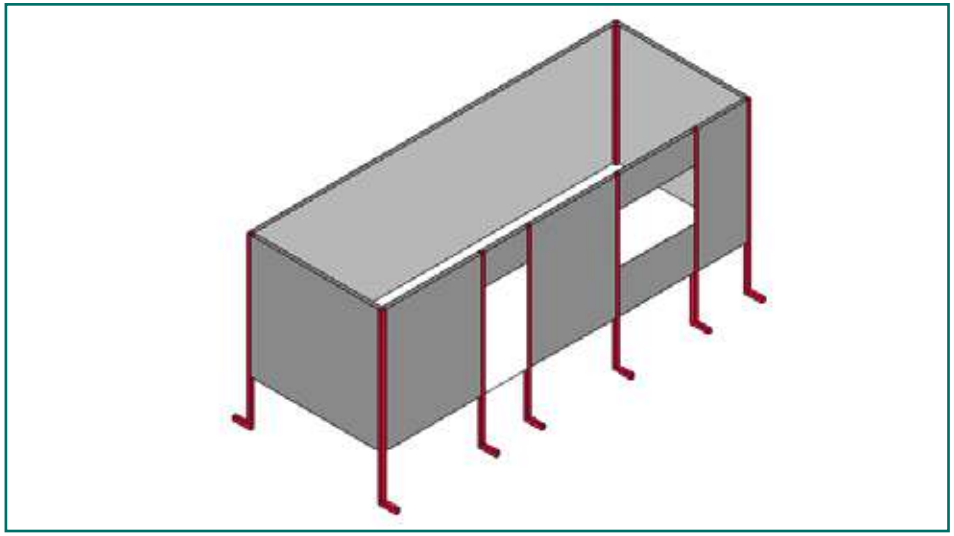
- *Infill provides compressive strength for the wall. It must be the correct mix and well fixed so it does not fall out in an earth-quake.*

Recommendations

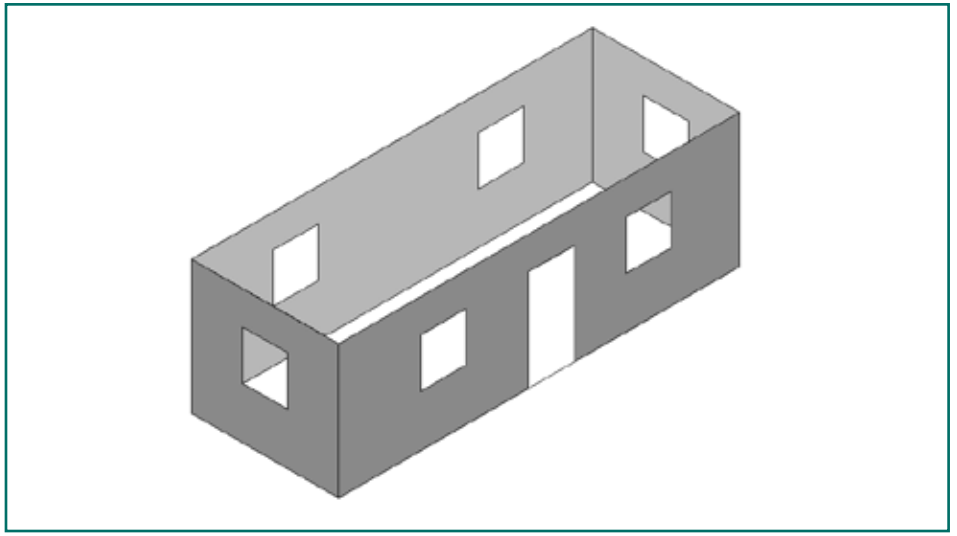
- Infill should not have large stones (no larger than 4 x 4 inches).
- If larger stones have been used dismantle the infill and replace.
- In situ concrete is not permitted, dismantle and replace with correct infill.
- The mix should have 50% mortar..
- Completely fill the shrinkage gaps with infill materials.

8 Summary: Tie the Box

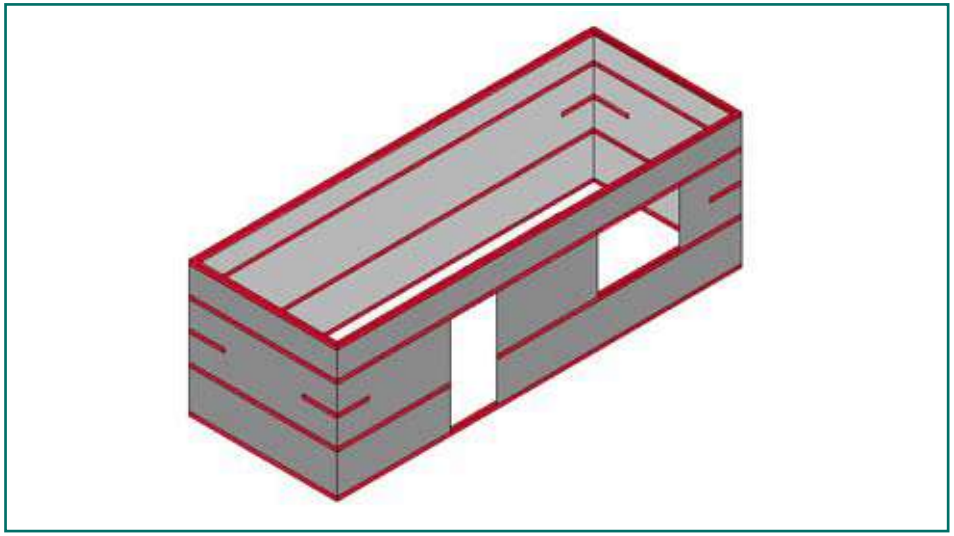
This applies to all construction types.



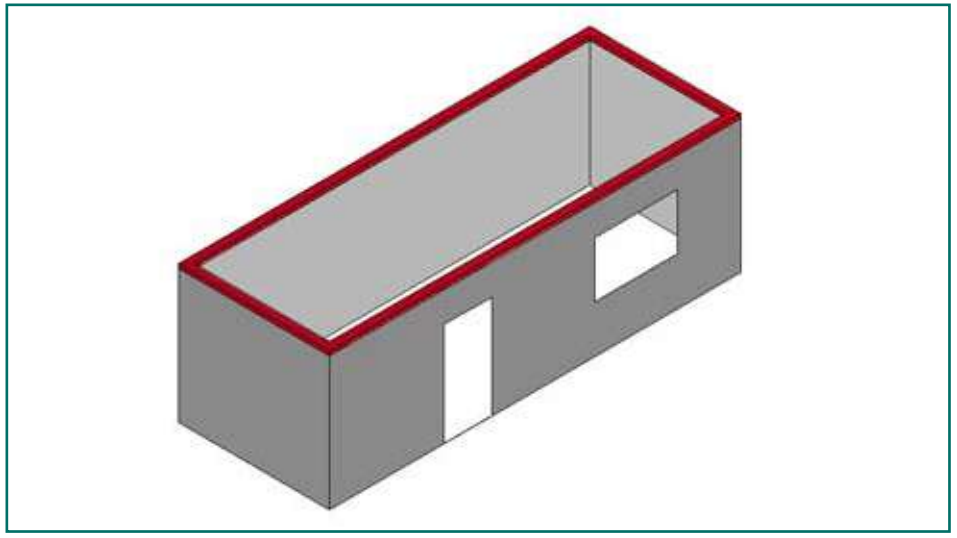
Anchorage: Vertical reinforcement should be fixed below the ground to anchor the building firmly in place and to ensure the reinforcement can withstand tension.



Stiffness: Masonry should be of adequate wall thickness and strength. Openings should be planned and constructed to avoid weakening the integrity of the wall.



Horizontal Connections: Horizontal bands and corner stitches make the walls and junctions stronger and ensure the walls are connected to each other like a box system. The greater risk in masonry is poor connections between walls.



Roof Beam: Providing a continuous ring beam at the top of the wall connects all the walls together. This is the most important horizontal band. The walls deflect more at the top so it is critical to tie them in place at this point.

D Remedial Measures

INTRODUCTION

The remedial measures section defines the solutions that could make the house seismically resistant and compliant for receiving ERRA's approved grant for house construction. These solutions require additional money and skills. By applying these guidelines, house owners will not only qualify to receive the remaining tranches of housing subsidy from ERRA but will also lead a safer life in their new ERRA compliant house.

It is not intended to be used as a retrofitting guideline for buildings damaged in the earthquake, it targets defects in new construction.

This section contains step by step proedures with practical photographs for each remedial measure. See **Apendix-B** for detailed technical drawings.

REMEDIAL MEASURES

1	Strengthening weak masonry:	Filling hollow concrete blocks
2	Strengthening weak masonry:	Increasing wall thickness
3	Oversized rooms:	Adding cross walls (Reinforced Masonry)
4	Strengthening openings:	Reducing opening size
5	Strengthening openings:	Adding reinforcement
6	Improving anchorage:	Extending reinforcement to the foundation
7	Adding horizontal reinforcement:	Lintel and roof beams
8	Adding horizontal reinforcement:	Adding bandages
9	Adding horizontal reinforcement:	Roof beams only
10	Adding vertical reinforcement:	Confined masonry
11	Connecting columns and walls:	External mesh
12	Connecting cross walls	
13	Connecting walls of different construction materials	
14	Strengthening weak masonry:	Widening of Lintel and Roof bands

I Strengthening weak masonry: Filling hollow concrete blocks

Construction Types

- Reinforced masonry and confined masonry

Problem

- 6" thick hollow concrete blocks do not have sufficient strength or stability to resist earthquake forces.

Reason

- Thin and weak walls do not have sufficient strength and stability to resist earthquake forces.
- For 9 ft and higher walls, 8" blocks are more stable and strong compared to 6" blocks.

Solution

- In case of partially constructed walls (below sill level), or where construction has not yet started, fill hollow blocks with concrete before constructing walls.
- Provide vertical bars are present at every 4 ft spacing. and limit the height of the wall maximum 9 ft.

Methodology

- Prepare concrete using a mix of 1: 3: 6 (cement : sand : aggregate) with a water-cement ratio not more than 0.6.
- Thoroughly wet the inner surface of concrete blocks by sprinkling water.
- Pour concrete in layers in block cavities
- Compact concrete in layers with roding.
- Cure the filled blocks for at least 15 days before using.

Warning:

- Filling blocks in only high sections of walls will result in heavy and unbalanced top courses, which will make the wall unbalanced and it will topple over easily. It is better to dismantle the wall and re-lay the masonry, filling each block with concrete.

Precautions:

- In case of partially constructed walls , ensure the concrete filling reaches the base/ plinth.
- Fill one course at a time.
- Compact the concrete in layers to avoid voids.
- Maximum aggregate size should be 1/4".
- Follow **Section A : General Guidelines**.

I Step-by-step Procedure

Mix 1:3:6 (cement:sand:aggregate) for filling the blocks.

Wet the internal sufaces of the cavities in the blocks.

Pour 1:3:6 concrete mix in layers in the cavities (fill one cavity at a time).

Compact concrete in layers with rodding.

Level the surface after roding.

Repeat the procedure for filling all cavities..

2 Strengthening weak masonry: Increasing wall thickness (wire mesh)

Construction Types

- Reinforced masonry and confined masonry

Problem

- 6" thick hollow concrete blocks do not have sufficient strength or stability to resist earthquake forces.
- Masonry walls with poor quality and/or no mortar in joints.

Reason

- Thin and weak walls do not have sufficient strength and stability to resist earthquake forces.
- For 9 ft and higher walls, 8" blocks are more stable and strong compared to 6" blocks.
- Proper mortar joints hold the blocks together and keep the masonry intact during earthquakes.

Solution

- In case of fully constructed walls and also for masonry with insufficient mortar between the joints, provide wire mesh or light reinforcement on both sides of the wall and cover with 3/4" or 1" thick plaster each face.

Methodology

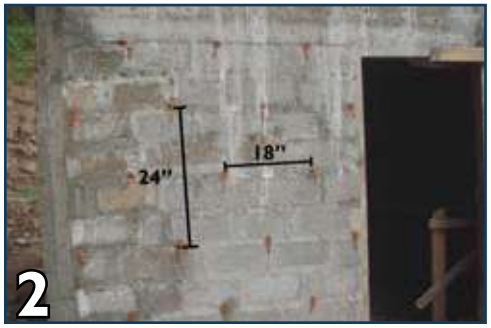
- Clean the surface on which steel wire mesh is to be attached.
- Rake the joints carefully to ensure good key between wall and proposed plaster.
- Fix steel wire mesh on both faces of the wall, and also conect it to all horizontal seismic bands (i.e.: plinth, lintel and roof band) using stainless steel nails (or #10 screws and 1/2" long).
- Connect the wire mesh on both sides of the wall using 1/8" diameter steel wire/bars passed through the bed joint at every third course vertically and at a spacing of 18" to 24" horizontally in masonry and 9" horizontally in seismic bands. These cross ties shall be staggered. Both ends of bars shall be hooked at 90 degrees and lapped with steel mesh equal to 3".
- Wet the wall surfaces and plaster it on inside and outside in two layers.
- Cure the plaster for at least 10 days.

Precautions:

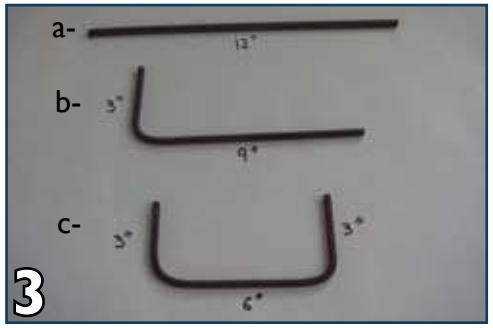
- The lap of the mesh shall be min. 12".
- Wire mesh should be 20 gauge, 1/2" x 1/2" (or 1" x 1").
- For cement plaster:
  a. Use 1:4 or 1:5 (cement:sand) plaster mix.
  b. Wet the surface of the wall prior to applying the plaster.
- Follow **Section A : General Guidelines**.

2 Step-by-step Procedure

Rake the joints and drill holes in staggered form.

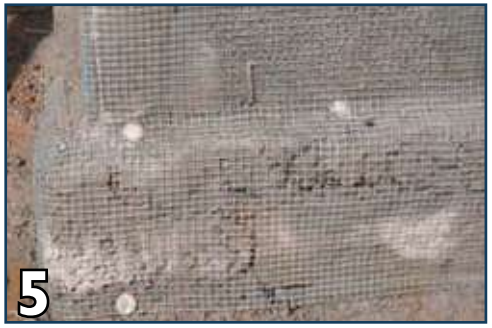


Holes should be at 24" vertical and 18" horizontal distances in staggered form in masonry and at 9" horizontal spacing in seismic bands.



Take 1/8" dia bar and bend it in the U-form following the above steps showed in the picture for fixing the wire mesh.

Place the wire mesh on both sides of the wall.



Fix wire mesh on concrete (beams and bands) with steel nails using bottle caps or #10 screws with 1" dia washers.

Fix 1/8" dia. L-bar in the holes and turn the bar from other end in U-shape as shown in Step -3.

Provide min. 12" lap in wire mesh, where required.

Apply 1" thick 1:4 (cement: sand) plaster on both faces of the wall.

Cure the plaster at least for 10 days.

3 Oversized rooms: Adding cross walls

Construction Types

- Reinforced masonry

Problem

- Unsupported wall length is greater than 15ft.

Reason

- Long, unsupported walls are vulnerable to damage during earthquakes. Cross walls, provide stability to long walls. If rooms are too large, internal cross walls may be added. These should be properly reinforced and connected to the existing walls.

Solution

- Provide cross walls, with proper masonry bonding, reinforcement and stitches. Cross walls are internal walls, which cross through the middle of the room, and connect with the opposite wall. The cross wall should include vertical reinforcement (at 4ft spacing) and horizontal reinforcement (plinth, sill, lintel and roof bands, plus stitches at 2ft vertical spacing).

Methodology

- Support the roof properly with timber props.
- In existing walls, dismantle the masonry 3 ft wide, from the roof beam to the foundation where cross wall will be constructed. Leave a toothed pattern in the masonry.
- Carefully remove the concrete in the foundation, sill, lintel and roof bands to expose the reinforcing bars. Place one #4 or #5 bar in center of corner/junction, with an 12" L-shape foot in the foundation.
- For cross walls, include vertical reinforcement (at 4 ft spacing) and horizontal reinforcement (plinth, sill, lintel and roof bands, plus stitches at 2 ft vertical spacing).
- Excavate and construct a foundation for the cross wall, as per the foundation requirements for reinforced masonry.
- Construct the cross wall, as per the requirements in the reinforced masonry standards (including through-stones, vertical reinforcement, horizontal reinforcement, key-hole blocks, and proper masonry jointing, as required).
- For cross walls, provide horizontal stitches (2 ft long), consisting of two #3 bars, with #1 stirrups at 6" spacing, at 2 ft vertical spacing (between the plinth and lintel bands). Provide a strong connection between the existing and new horizontal beams.
- Cure the masonry properly.

Precautions:

- During toothing ensure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Wear safety goggles during chiselling. Take care not to damage existing reinforcement bars.
- Use 1:3 (cement:sand) mortar for filling around cavities for block/brick masonry.
- Use maximum 1/4" size aggregate if concrete is used in filling around cavities.
- Follow **Section A : General Guidelines**.

3 Step-by-step Procedure

Dismantle masonry 3 ft wide where cross wall will be added.

Chisel plinth band without damaging reinforcement and excavate/remove foundation.

Place #4 or #5 vertical bars over P.C.C. Passing through all bands. Place shuttering and pour concrete.

Lay masonry with 24" long stitches with 2- #3 bars after every third course (or max. 24").

Ensure vertical bar passes through lintel and roof bands.

Place shuttering and pour concrete in existing chiselled and new lintel beam/band.

Embed vertical bars upto 8" in roof beam/band

Place shuttering and pour concrete to replace dismantled portion of roof beam/band.

Cure the concrete for at least 10 days.

4 Strengthening openings: Reducing opening size

Construction Types

- Reinforced Masonry and Confined Masonry

Problem

- Total length of the openings in a wall is greater than 50% of the wall length, and/or openings are less than 2ft from corners or from other openings.

Reason

- Openings reduce the strength of solid walls and their resistance to earthquakes. Openings should be as small as possible. Strengthening around openings is required to reduce cracking and potential collapse during an earthquake.

Solution

- Reduce the total length of openings and ensure minimum 2 ft solid wall each side of openings. This can be done by reducing the size of some openings, and/or completely blocking up some openings.
- Provide reinforced concrete framing around the opening.

Methodology

- Provide toothing in the wall on each side of the opening by removing the half block in block masonry (or header in brick masonry) in alternate courses.
- Lay bricks/blocks to reduce opening size, or close opening completely. Use proper masonry techniques as detailed in Section A.
- If reducing the opening size, it is necessary to provide reinforcement around the opening, so leave toothing in the wall on each side of the opening.
- Place continuous reinforcement at the sill and vertical faces of the opening. Reinforcement consists of two #4 bars, with #2 stirrups at 6" spacing.
- Place shuttering on two sides of the sill. Pour 3" thick concrete to make the sill.
- After a minimum of three days, support the lintel with masonry or timber struts. Partly dismantle the lintel (using a chisel) for a minimum length of 12" from each end (for anchoring of vertical reinforcement). Remove some bricks/blocks above the chiselled portion of the lintel (to facilitate pouring of concrete).
- Provide reinforcement (two #4 bars with #2 stirrups at 6" spacing) lapped with the existing vertical and lintel reinforcement.
- Erect shuttering about 12" in height on both vertical faces. Pour 3" thick concrete on both faces. Repeat this process up to 9" below existing lintel. (Pour concrete upto lintel top from its dismantled portion and compact it by roding).
- Erect shuttering for final portion of frame and for lintel. Pour concrete.
- Cure concrete for at least 10 days.

Precautions:

- During toothing make sure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Lintel should be properly supported during partial dismantling. Take care not to damage existing reinforcement bars.
- Use 1:2:4 (cement: sand: aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag). Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

NOTE:

Using reinforced concrete frame around openings, the total width of the openings may be increased to 65% between two cross walls.

4 Step-by-step Procedure

Window opening is greater than 65% of the wall length.

Remove half blocks/ header in brick masonry to form toothing.

Provide toothing on either/both ends to reduce the opening or increase the distance from the corner.

Lay blocks course by course with 1:4 cement sand mortar.

Opening size has been reduced and distance from center has been increased

Toothing left for providing the RCC frame around the opening.

See **Remedial Measure No. 4** for providing adequate reinforcement.

5 Strengthening openings: Adding reinforcement

Construction Types

- Reinforced Masonry and Confined Masonry

Problem

- Absence of reinforcement around openings.

Reason

- Openings reduce the strength of solid walls and their resistance to earthquakes. Openings should be a small as possible. Strengthening around openings is required to reduce cracking and subsequent collapse during an earthquake.

Solution

- Provide reinforced concrete framing around the opening.

Methodology

- Provide toothing in the wall on each side of the opening by removing the half block in block masonry (or header in brick masonry) in alternate courses.
- Lay bricks/blocks to reduce opening size, or close opening completely. Use proper masonry techniques as detailed in Section A.
- If reducing the opening size, it is necessary to provide reinforcement around the opening, so leave toothing in the wall on each side of the opening.
- Place continuous reinforcement at the sill and vertical faces of the opening. Reinforcement consists of two #4 bars, with #2 stirrups at 6" spacing.
- Place shuttering on two sides of the sill. Pour 3" thick concrete to make the sill.
- After a minimum of three days, support the lintel with masonry or timber struts. Partly dismantle the lintel (using a chisel) for a minimum length of 12" from each end (for anchoring of vertical reinforcement). Remove some bricks/blocks above the chiselled portion of the lintel (to facilitate pouring of concrete).
- Provide reinforcement (two #4 bars with #2 stirrups at 6" spacing) lapped with the existing vertical and lintel reinforcement.
- Erect shuttering about 12" in height on both vertical faces. Pour 3" thick concrete on both faces. Repeat this process up to 9" below existing lintel.
- Erect shuttering for final portion of frame and for lintel. Pour concrete.
- Cure concrete for at least 10 days.

Precautions:

- During toothing make sure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Lintel should be properly supported during partial dismantling. Take care not to damage existing reinforcement bars.
- Use 1:2:4 (cement: sand: aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag). Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

5 Step-by-step Procedure

Provide toothing in the wall on both side of the openings.

Place 2- #4 main bars with #2 @6" spacing stirrups.

Place shuttering and pour 3" thick 1:2:4 concrete at sill level.

Prop the lintel band/beam and chisel 12" concrete of beam/ band for embedment of reinforcement.

Reinforcement embedment in lintel beam/band.

Place shuttering and pour concrete.

6 Improving anchorage: Extending reinforcement to foundation

Construction Types

- Confined Masonry

Problem

- Lack of proper anchorage of vertical confining elements

Reason

- Confined masonry houses in which vertical confining elements are not anchored to the foundation may slide (shear) or overturn at ground floor level under lateral loads generated during an earthquake.

Solution

- Extend the vertical confining elements to the foundation.

Methodology

- Support the roof with temporary timber props in the area around the confining column to be treated/extended.
- Remove the brick/block upto 3 ft height above plinth in arching/ toothing pattern in a manner that 18" at the top and 30" at the bottom. on both sides. Remove the concrete of the column (using a chisel) up to the same level.
- Remove the masonry/concrete down to the base of the foundation 18" on each side of the column. Do not remove the P.C.C. at the base of the foundation.
- Clean the surface of the existing P.C.C. and place footing reinforcement (using #3 bars at 8" spacing in both directions). Place new vertical column reinforcement (four #4 bars with #3 stirrups at 6" spacing), over the footing reinforcement and lap it with the existing reinforcement.
- Place 12" deep concrete in the foundation.
- Lay masonry (or situ concrete) above the footing up to plinth level, leaving an 8" wide toothed gap around the column reinforcement.
- Pour concrete in the column up to plinth level. (If required, erect shuttering around the column reinforcement.)
- Erect shuttering around the dismantled portion of plinth beam, and pour concrete.
- Re-lay the dismantled portion of masonry, leaving a toothed gap on each side of the column reinforcement.
- Pour concrete in the column. For the top 6" of the new portion of the column, use a comparatively dry mix and pack it tightly under the existing concrete.
- Repeat procedure for each column, as required.
- Cure concrete for at least 10 days.

Precautions:

- During toothing make sure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Wear safety goggles during chiselling. Take care not to damage existing reinforcement bars.
- Use 1:2:4 (cement: sand: aggregate) concrete mix Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag). Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

6 Step-by-step Procedure

Prop the roof properly and dismantle the foundation in arch

Remove the masonry in toothing pattern

Chisel the existing plinth beam/band without destroying the existing reinforcement

Dismantle the foundation 18" on both sides of the column

Clean the surface of the P.C.C. and place #3 bars @ 8" pacing on both ways in the form of mesh over P.C.C. surface

Extend column reinforcement with proper lap and proper foot to reinforcement pad in foundation

Place shuttering for plinth for pouring concrete

Pour 1:2:4 concrete in the foundation trench and the plinth band/beam

Pour 1:2:4 concrete in the columns with proper compaction

7 Adding horizontal reinforcement: Lintel and roof beams

Construction Types

- Confined Masonry

Problem

- Absence of continuous lintel and roof beams.

Reason

- Continuous horizontal reinforcement ties the structure together, and significantly improves integrity and performance during an earthquake. Lintel and roof beams/ bands are most critical elements for integrity of the building.

Solution

- Remove existing masonry and lintels over doors and windows and provide new continuous lintel and roof bands/beams.

Methodology

- Support the roof with timber props. (This is only viable for light weight roofs made of timber and CGI sheeting.)
- Remove all existing masonry above lintel level, including any short lintels over doors and windows. In case of confined masonry, chisel the concrete in confining columns above the lintel level to provide a good connection between beams (lintel and roof) and column.
- Add a proper, continuous reinforced concrete lintel band (for reinforced masonry) or beam (for confined masonry), as per the relevant requirements (see Section B). Ensure adequate connection with existing vertical reinforcement.
- After a minimum of three days, construct masonry above the lintel. For confined masonry, leave a toothed gap adjoining the columns, then fix shuttering and pour concrete in the confining columns.
- Construct a proper, continuous reinforced concrete roof band (for reinforced masonry) or beam (for confined masonry), as per the relevant requirements (see Section B).
- Cure concrete for at least 10 days.

Precautions:

- Wear safety goggles during chiselling. Take care not to damage existing reinforcement bars.
- Use 1:2:4 (cement: sand: aggregate) concrete mix Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag). Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

7 Step-by-step Procedure

Continuous lintel and roof beam is missing.

Support the roof with wooden props.

Remove masonry above lintel level and short lintel over the door.

Place 4-#4 continuous reinforcement with #3 @ 6" spacing stirrups for lintel beam with adequate connection with vertical reinforcement bars and confining columns.

Pour 1:2:4 (cement:sand:aggregate) concrete for new lintel band and cure for at least 7 days.

Lay masonry over newly casted lintel beam, in case of confined masonry provide toothing at the corners and provide roof beam at the top.

NOTE:

For reinforced masonry see Section B (Construction Standards) for relevant specifications.

See **Remedial Measure No. 8** for providing roof beam.

8 Adding horizontal reinforcement: Adding bandages

Construction Types

- Reinforced Masonry and Confined Masonry

Problem

- Absence of beams/bands below roof level.

Reason

- Continuous horizontal reinforcement ties the structure together, and significantly improves integrity and performance during an earthquake. Bands and beams are critical.

Solution

- Provide external bands on both faces of the wall.

Methodology

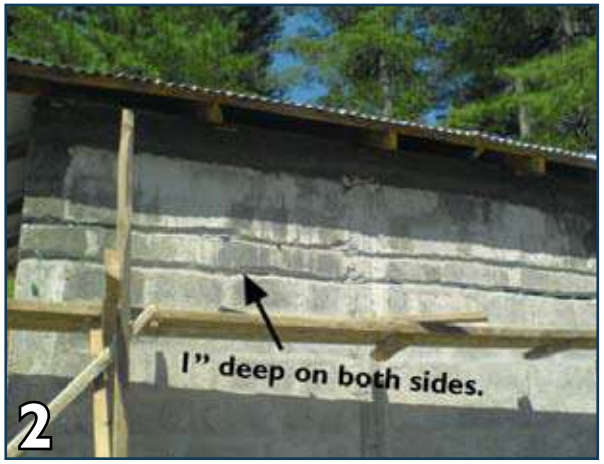
- Rack the joints and clean the surface.
- Drill holes in masonry at every 1 ft spacing.
- Make 1/8" dia connectors.
- Place two #4 bars with #2 stirrups @ 6" spacing on both faces of the wall over concrete layer of 3/4" or 1".
- Tie the bars with 1/8" dia connectors.
- Ensure the bars are held firmly with the wall surface.
- Place shuttering and pour 1:2:4 concrete or short-crete.
- Cure concrete for at least 10 days.

Precautions:

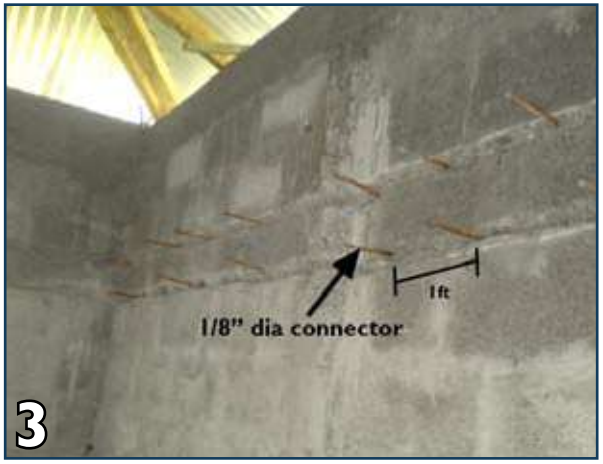
- Use 1:2:4 (cement: sand: aggregate) concrete mix.
- Maximum aggregate size shall be 1/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag).
- Minimum thickness of band should be 3".
- Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

8 Step-by-step Procedure

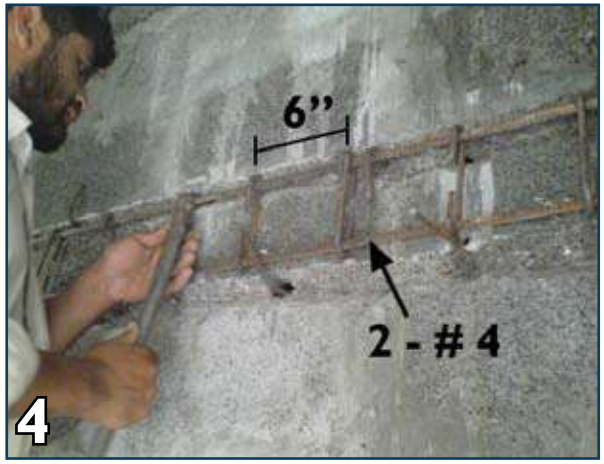
Clean the surface and drill holes.



Make grooves on both faces to place reinforcement.



Insert connectors at every 1 ft.



Place reinforcement at both faces and fix them firmly with 1/8" dia connectors.

Place shuttering and pour concrete.

Cure concrete for at least 10 days.

9 Adding horizontal reinforcement: Roof beam only

Construction Types

- Reinforced Masonry and Confined Masonry

Problem

- Absence of continuous roof beams

Reason

- Continuous horizontal reinforcement ties the structure together, and significantly improves integrity and performance during an earthquake. A roof beam is critical.

Solution

- Provide a continuous roof beam.

Methodology

- Support the roof with timber props. (This is only viable for light weight roofs made of timber and CGI sheeting.)
- If required, remove the top course of masonry. For confined masonry, chisel the concrete in the confining columns 12" below the proposed roof beam.
- Construct a proper, continuous reinforced concrete roof band (for reinforced masonry) or beam (for confined masonry), as per the relevant requirements (see Section B). Ensure adequate connection with existing vertical reinforcement.
- Cure concrete for at least 10 days.

Precautions:

- Wear safety goggles during chiselling. Take care not to damage existing reinforcement bars.
- Use 1:2:4 (cement: sand: aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag). Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

9 Step-by-step Procedure

Continuous roof beam is missing.

Support the roof with wooden props.

Remove last course of masonry to provide roof beam.

In case of confined masonry chisel the upper part of the columns to have proper connection between roof beam reinforcement and columns.

Place 4-#4 continuous bars with #3 @ 6" spacing stirrups for roof beam with adequate connection to vertical reinforcement bars and confining columns.

Place shuttering and pour 1:2:4 concrete in roof beam and cure for 10 days.

10 Adding vertical reinforcement: Confined masonry

Construction Type

- Confined masonry

Problem

- Lack of reinforced concrete columns at key locations (corners and wall junctions).
- Timber posts are provided at the wall junctions having no connection with walls.

Reason

- Vertical reinforcement resists lateral loads induced during an earthquake. When properly connected to the horizontal reinforcement they help to distribute stresses throughout the structure and reduce damage.
- Timber posts have no structural connection with walls which means the walls are free standing walls which are vulnerable to earthquakes, and easily fall down.

Solution

- Remove and replace timber post with reinforced concrete column/s.

Methodology

- Support the roof with temporary wooden props and remove the timber post.
- Remove 18" masonry around the location of the removed timber post from the top of the wall to the foundation in a toothed pattern and chisel off the concrete from the lintel and roof beams.
- Excavate 30" deep below plinth level. Compact and clean foundation bed having a plan area of 3' x 3'.
- Provide 3" thick 1:4:8 P.C.C. and place footing reinforcement (using #3 bars at 8" spacing in both directions). Place new vertical column reinforcement (four #4 bars with #3 stirrups at 6" spacing), with 1 ft L-shaped feet over the footing reinforcement.
- Pour 12" thick 1:2:4 concrete for footing pad.
- Ensure beam/bands reinforcemnet is properly anchored in column reinforcement.
- Lay masonry over the footing to plinth level leaving 8" toothed gap for column.
- Erect shuttering for new column, and pour concrete in layers not exceeding 2 ft.
- Lay masonry upto lintel level leaving a 8" gap for column. Place two #2 stitches 24" long at every third course (or max. 24" vertically).
- Pour concrete in layers not exceeding 2 ft up to column top.
- Repeat procedure for each missing column.
- Cure concrete for at least 10 days.

Precautions:

- During toothing make sure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Use 1:2:4 (cement: sand: aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag).
- Properly compact the concrete while pouring.
- Follow **Section A : General Guidelines**.

10 Step-by-step Procedure

Prop the roof and excavate the foundation 18" on each side of corner/junction.

Remove 18" masonry around the location of the timber post from the top of the wall to the foundation in a toothed pattern.

Dismantle plinth band/beam without damaging the reinforcement and remove the masonry from the foundation.

Place reinforcement mesh and vertical column reinforcement with proper feet over P.C.C.

Provide #3 stirrups at 6" spacing

Pour 12" thick concrete for footing pad. Place shuttering for pouring column upto plinth.

Place two #2 bars 24" long at every third course (or max. 24"vertically).

Re-lay masonry and leave toothing.

Place shuttering and pour 1:2:4 concrete in columns.

11 Connecting columns and walls: External mesh

Construction Type

- Confined masonry

Problem

- Lack of adequate connection (toothing and/or stitches) between masonry walls and confining columns results in unsupported wall panels which may easily fall over in an earthquake. This is most common when the concrete column has been poured before the walls were constructed.

Reason

- In confined masonry, earthquake loads are carried by the confining elements (reinforced concrete columns and beams), plus the infill masonry walls. In order to achieve this, an adequate connection is required between these components.

Solution

- Provide external wire mesh connecting the walls and confining elements (columns and beams), and cover with cement plaster.

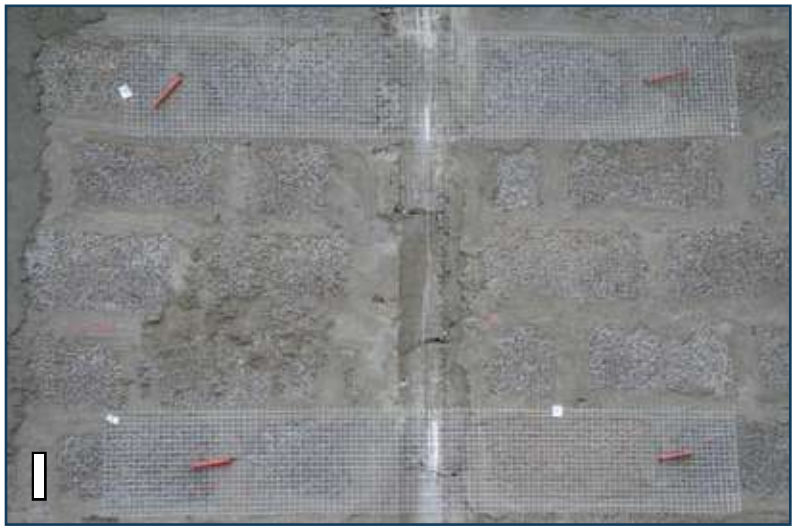
Methodology

- Clean the surfaces on which the wire mesh is to be placed.
- Place the wire mesh in strips (min. 4ft wide and 9" thick) evenly balanced on each side of the column where column and walls have no connection. The mesh should be placed on both internal and external surfaces of the wall. Place wire mesh strips after every three courses.
- Rake the joints and drill holes (through mortar joints). Pass 1/8" dia bar through the holes and bend it to firmly attach wire mesh with wall.
- Where the mesh crosses the reinforced concrete confining elements (columns and beams), use special galvanised steel nails 3" long to attach the mesh to the confining elements. Use bottle caps to provide a stronger connection between wire mesh, confining elements and walls (or use 1/2" long, #10 screws with 1" dia washers).
- Cover the wire mesh reinforcement with cement plaster, on the inside and outside.
- Cure the cement plaster for at least 10 days.

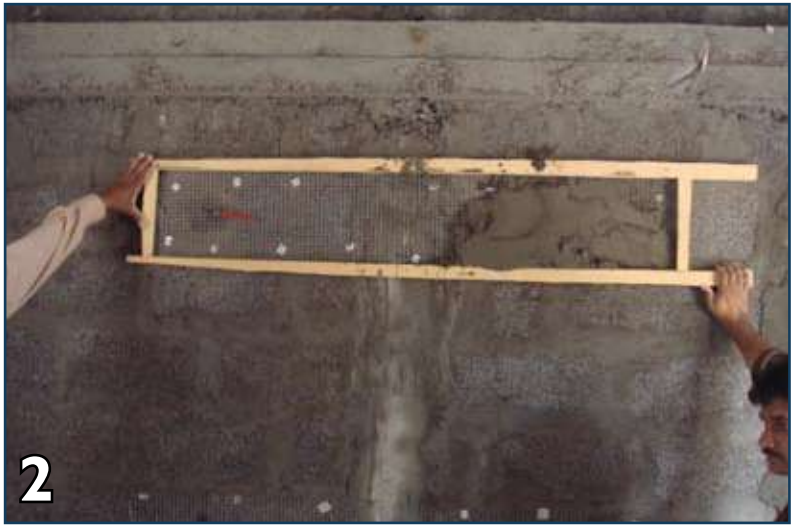
Precautions:

- Ensure wire mesh should be held tight against the wall.
- Wire mesh should be 20 gauge, 1/2" x 1/2" (or 1" x 1").
- For cement plaster:
  a. Use 1:4 or 1:5 (cement:sand) plaster mix.
  b. Wet the surface of the wall prior to applying the plaster.
  c. Minimum plaster thickness should be 3/4" (or 1").
- Follow **Section A : General Guidelines**.

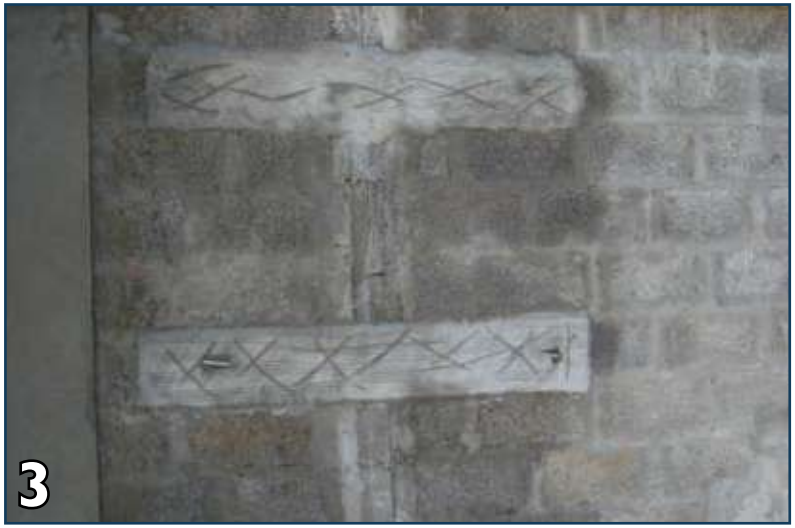
11 Step-by-step Procedure



Drill holes and fix mesh after every three courses on both faces of the wall with 1/8" dia connectors.



Bottle caps with steel nails are used to firmly fix the wire mesh to the confining elements.



Apply first layer of plaster, rough the surface for second layer.

After final layer of plaster cure it for at least 10 days.

12 Connecting cross walls

Construction Type

- Reinforced masonry

Problem

- No connection between cross walls.

Reason

- Absence of structural connection between intersecting cross walls make them free standing walls. Free standing walls are vulnerable to earthquake and easily fall down during ground shaking.

Solution

- Dismantle the junction and reconstruct with proper masonry bonding, and stitches (at 2 feet vertical spacing). Include vertical reinforcement at the corner, if this is absent.

Methodology

- Support the roof with temporary timber props at the corner to be treated.
- Dismantle the masonry 18" on each side of the corner, from the roof beam to the foundation. Leave a toothed pattern in the masonry.
- If there is no vertical reinforcement at the corner, carefully remove the concrete in the foundation, sill, lintel and roof bands to expose the reinforcing bars. Place one #4 or #5 bar in the corner, with an 12" foot in the foundation.
- If horizontal bands (plinth, sill, lintel, roof) are absent in one or both connecting walls, see Remedial Measure no. 7 and No. 8 (Adding horizontal reinforcement: Lintels and roof beams) to resolve this problem.
- Rebuild the masonry, as per the requirements in the reinforced masonry poster (including through-stones, concrete around the reinforcement, key-hole blocks, and proper masonry jointing, as required).
- At 2ft vertical spacing (between the plinth and lintel bands), provide horizontal stitches (2ft long), consisting of two #3 bars, with #1 stirrups at 6" spacing (OR wire mesh stitches).
- Repeat procedure for each corner, as required.
- Cure the cement plaster for at least 10 days.

Precautions:

- During toothing make sure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Wear safety goggles during chiselling. Take care not to damage existing reinforcement bars.
- Use 1:2:4 (cement: sand: aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water-cement ratio shall be 0.6 (i.e. 30 litre water in one cement bag). Properly compact the concrete while pouring.
- Handle one wall junction at a time.
- Use 1:3 (cement:sand) mortar for filling cavities around reinforcement.
- Follow **Section A : General Guidelines**.

12 Step-by-step Procedure

Dismantle masonry 3 ft wide where cross wall will be added.

Chisel plinth band without damaging reinforcement and excavate/remove foundation.

Place #4 or #5 bars over P.C.C. passing through bands. Place shuttering and pour concrete.

Lay masonry with 24" long stitches with two #3 bars after every third course.

Ensure vertical bar passes through lintel band.

Place shuttering and pour concrete replace dismantled portion of lintel beam/band.

Embed vertical bars upto 8" in roof beam/band

Place shuttering and pour concrete to replace dismantled portion of roof band.

Cure the concrete for at least 10 days.

13 Connecting walls of different construction materials

Construction Type

- Reinforced masonry and confined masonry

Problem

- Use of two different construction methods in intersecting / orthogonal / adjacent walls, which results in a lack of structural connection between these walls.

Reason

- Absence of structural connection between intersecting cross walls make them free standing walls. Free standing walls are vulnerable to earthquakes and easily fall down during ground shaking.

Solution

- Dismantle the junction and reconstruct with a reinforced concrete column, proper masonry bonding, and stitches.

Methodology

- Support the roof with temporary timber props at the corner to be treated.
- Dismantle the masonry 18" on each side of the corner, from the roof beam to the foundation. Leave a toothed pattern in the masonry.
- Carefully remove the concrete in the foundation, sill, lintel and roof bands to expose the reinforcing bars.
- Remove the masonry/concrete down to the base of the foundation 18" on each side of the proposed column. Do not remove the P.C.C. at the base of the foundation. (If there is no P.C.C., provide one consisting of 3" thick concrete, using 1:4:8 mix.)
- Place footing reinforcement (using #3 bars at 8" spacing in both directions). Place new vertical column reinforcement (four #4 bars with #3 stirrups at 6" spacing), connected and lapped with the footing reinforcement.
- Place 12" deep concrete (1:2:4 mix) in the foundation.
- Lay masonry (or in situ concrete) above the footing up to plinth level, leaving an 8" wide toothed gap around the column reinforcement.
- Erect shuttering around the column reinforcement up to plinth level and pour concrete in the column and the plinth.
- Re-lay the dismantled portion of masonry, leaving a toothed gap on each side of the column reinforcement. Place horizontal stitches (2ft long), consisting of two #3 bars, at 2 ft vertical spacing (between plinth and lintel bands/beams).
- Pour concrete in the column, up to lintel, then roof beam level. Cure concrete for at least 10 days.
- Repeat procedure for each corner, as required.

Precautions:

- During dismantling ensure that blocks or bricks are not damaged. Provide additional support to the walls, as required.
- Use 1:2:4 (cement:sand:aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water:cement ratio shall be 0.6. Compact all concrete by rodding.
- Reinforcing steel should conform to deform grade 40, having minimum yield strength of 40,000 psi. Plain steel shall not be used.
- Splice length of steel bars shall be at least 60 times diameter of bar.
- Follow **Section A : General Guidelines**.

13 Step-by-step Procedure

Excavate the foundation 18" on each side of corners/junctions..

Dismantle the masonry (18") aronud the connection creating a toothed gap.

Dismantle plinth band/beam without damaging the reinforcement. Place reinforcement mesh and vertical column bars with proper feet.

Place two #3 bars 24" long at every 24" spacing vertically..

Re-lay masonry in both walls and leave a toothing.

Place shuttering and pour 1:2:4 concrete in column and cure for 10 days.

14 Strengthening weak masonry: Widening of Lintel & Roof Bands

Construction Type

- Reinforced masonry and confined masonry

Problem

- 6" thick hollow cement concrete block walls are used instead of 8" thick wall.

Reason

- 6" thick hollow concrete blocks do not have sufficient strength or stability to resist earthquake forces.

Solution

- Use 10" wide seismic bands at lintel and roof level instead of 6" wide band. The extra width may project inside the room and may be used as shelf for small household items.

Methodology

- If the house is constructed upto roof level, dismantle block masonry (including roof band if already poured) to the lintel band. Lintel band need not to be removed.
- Erect bottom planks of shuttering for extending lintel band with 2" offset on both (inside and outside) faces of the wall.
- Clean the top surface of the wall
- Fix 2- #4 bars in longitudnal direction for the widened lintel with #2 stirrups at 6" spacings.
- Erect the vertical planks of eth shuttering on boh sides and ensure the inner distance between the vertical shutterings is not less than 10".
- Pour 1:2:4 concrete and cure it for at least 14 days. Construction above the lintel may however be started after three days.
- Construct the masonry upto bottom of the roof band.
- Repeat steps 2 to 4 to construct roof band.

Precautions:

- During dismantling ensure that blocks or bricks are not damaged. Provide additional support to the walls, if required.
- Use 1:2:4 (cement:sand:aggregate) concrete mix. Maximum aggregate size shall be 3/4" and water:cement ratio shall be 0.6. Compact all concrete by rodding.
- Reinforcing steel should conform to deform grade 40, having minimum yield strength of 40,000 psi. Plain steel shall not be used.
- Splice length of steel bars shall be at least 60 times diameter of bar.

Step-by-step Procedure

Dismental the masonry above the existing lintel band.

Fix 2- #4 longitudnal bars with #2 stirrups @ 6” specings.

Fix the bottom planks of shutteirng on both sides of the walls and fix reinfrcement properly.

Fix shuttering on vertical faces and ensure the internal distance bewteen vertical planks is 10”.

Pour 1:2:4 Concrete in lintel band and cure for atleast 14 dyas.

After intial 3 days of curing, construction above lintel band can be started. Repeat the same procedure for roof band.

INTRODUCTION

Many sites in the earthquake affected district pose difficulties for construction, with steep slopes, constrained dimensions and other problems.

This section gives guidance for improved site works and mitigation measures, including retaining walls and site drainage. Safer sites will contribute to safer housing.

This advice is not a basis for assessment of compliance, but is intended to answer common requests for technical advice in the field.

SITE WORKS

1 Retaining walls: General

2 Retaining walls: Plinth

3 Site Drainage

I Retaining walls: General

Construction Type

- **Retaining Wall**

Reason

- Many sites in the affected districts are located on steeply sloping land. Retaining walls are part of the construction of terraces to create level agricultural and building lands and are sometimes integrated into the construction of buildings.

  In an earthquake, retaining walls may themselves fail, or their collapse may trigger landslides or slope failure. Improved retaining wall design and construction reduces risks to the stability and strength of both buildings and site.

Key Points

Geometry

- The geometry of the wall determines the stability. The width of the wall is related to the retained height. The most stable geometry is an inclined front face and vertical rear face, or both faces inclined towards the retained slope.

Back Fill

- Retaining walls must resist the force of retained fill. This force is increased when water pressure builds up behind the wall. The provision of drainage behind and through the wall will reduce the risk of failure.

Shear Strength / Workmanship

- The shear strength of the masonry is a major factor in the strength of the wall. Careful placement of stones, rearward sloping, and use of through stones are important. Use of horizontal reinforced concrete bands will also reduce failure.

Foundation

- The foundation of the wall should be started from below ground level to ensure good anchorage, to avoid slippage or overturning at ground level.

Notes

The following guidelines refer to mass gravity retaining walls which are not engineered structures.

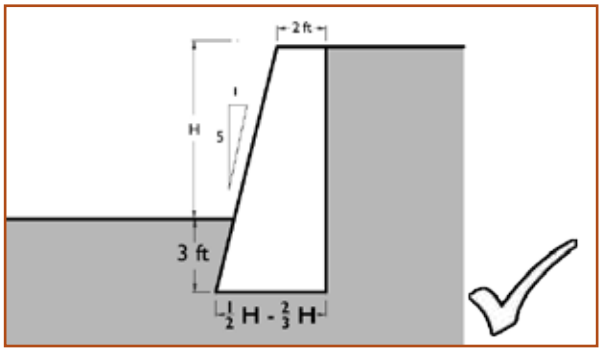
Traditional construction of retaining walls is generally from stone available on site, laid as dry stone or in cement sand mortar.

The following guidelines apply to both stone masonry and in situ concrete construction.

Warning

Gabion construction is not described or recommended without engineering input and supervision.

1 Retaining Walls: General

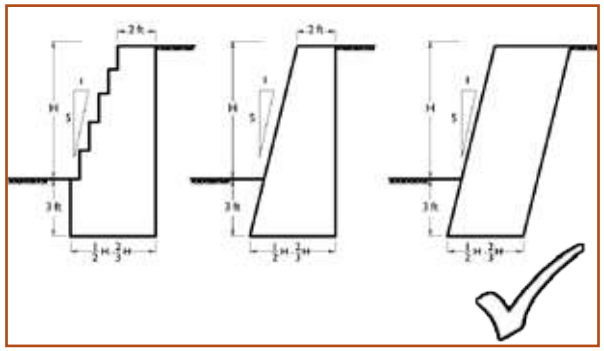


Geometry: Dimension

The base width of the wall should be minimum 1/2 of the retained height, ideally 2/3rd of the retained height.

The top of the wall should be 2 ft wide.

Terracing of the site can reduce the retained height of the wall and therefore the required width and total volume of masonry.



Geometry: Slope

The front face of the wall should be inclined at a slope of 1: 5, either in a slope or in steps.

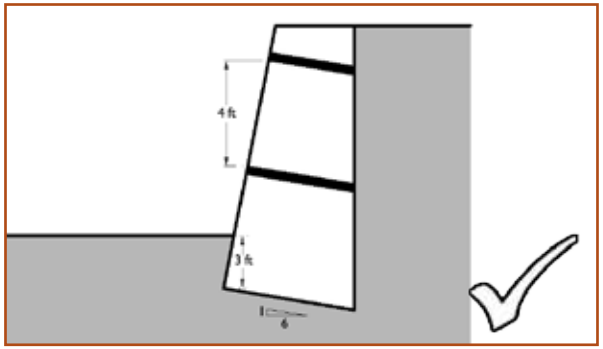
The rear face should be vertical or slope parallel to the front face.

Foundation

The base of the wall should be minimum 3 ft below existing ground level.

Lay 6 inch thick PCC to make an even base for wall construction.

Lay foundation with slope 1: 6 toe to heel, masonry courses should also follow this slope



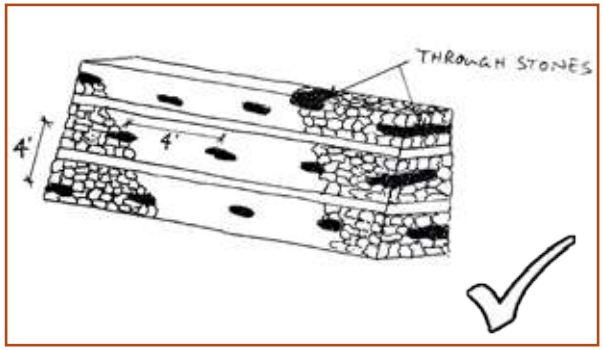
Workmanship

Stones should be laid coursed, at an incline to the vertical, sloping downwards towards the retained slope.

Stone should be placed tightly to ensure good interlocking and friction.

Use flat field stones, do not use round stones.

Mortar should not be a substitute for good masonry.



Workmanship

Through stones, should be laid every 4 ft vertically and horizontally, perpendicular to the length of the wall.

Workmanship

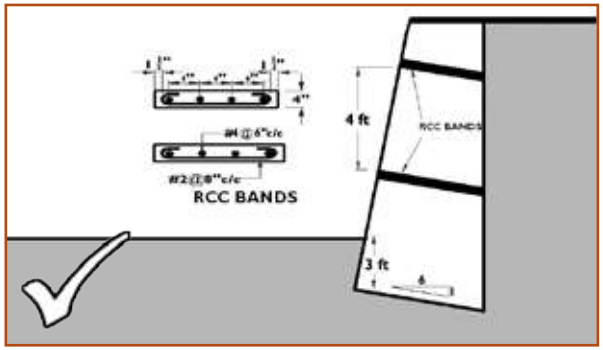
A wall with dressed stones on either face and with a gravel core is extremely unstable and should never be used.

A thin wall of stones used as facing on the retained slope has no strength and should never be used.

1 Retaining walls: General

Horizontal Bands

Horizontal bands should be provided to the full width of the wall consisting of 4 inch thick reinforced concrete.



Horizontal Bands

The horizontal bands should be reinforced with #4 longitudinal steel bars at 6 inches spacing with stirrups of #2 stirrupsat 8 inches spacing

Concrete should be 1: 3: 6 cement: sand: aggregate.

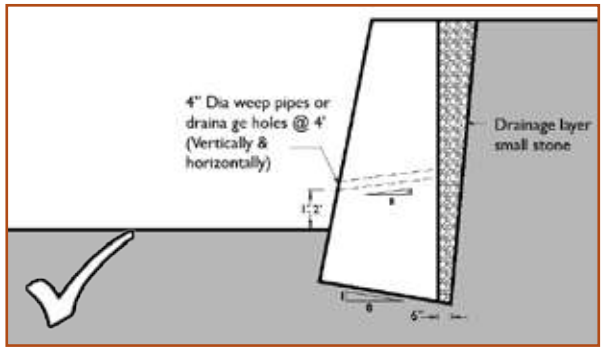
Bands should be spaced at 4 ft intervals vertically.

Columns

Columns protect the wall from delamination failure.

They help in resisting against bending.

They distribute the load evenly and hold the wall together.



Drainage

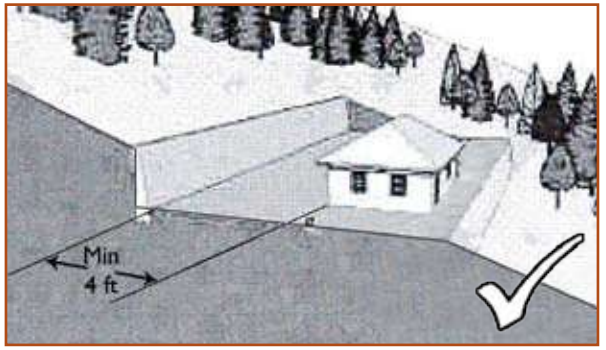
Provide a drainage layer of minimum 6 inches thickness made of small stones, behind the retaining wall.

If the wall is mortared provide weep-holes of 4 inch diameter at 4 ft spacing or provide a drainage channel (half pipe 4 inch diameter) behind the wall at the base of the drainage layer, at a 1: 100 slope to drain away.

Drainage

Dry stones will drain themselves.

If the wall is mortared, provide weep holes at 4ft spacing vertically and horizontally.



Distance

There should be a minimum distance of 4 ft between a retaining wall and any adjacent structure.

Ideally the distance should be equal to the height of the wall.

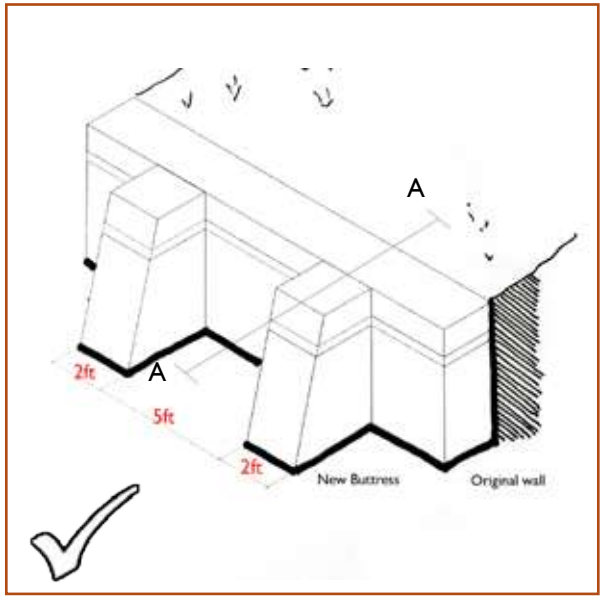
2 Retaining Walls: Plinth

Problem

If a house has been constructed on a high plinth or built up ground, the front must be constructed as a retaining wall.

If the wall is not strong enough there is a risk it will collapse, and therefore cause the collapse or serious damage to the house.

If the wall is not strong enough, it may cause settlement defects in the house which will weaken it and make it less resistant to earthquakes.



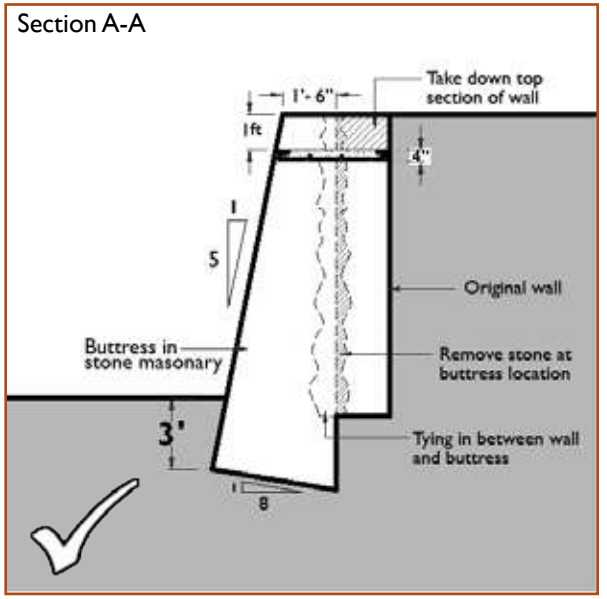
Solution

Construct an additional new retaining wall in front of the plinth as per the specifications on page 71

or

The retaining wall can be strengthened by the addition of buttresses along the front face.

These should be well connected to the existing wall, by tying in masonry and provision of an RCC band connecting the wall and the buttresses.



Solution

The foundation of the buttresses should be minimum 3 ft below ground.

Provide a 2 ft wide buttress every 7 ft along the face of the wall (5 ft gap between buttresses). The wall masonry should be partially dismantled at buttress locations to enable the buttress to be tied in to the wall.

The buttress should slope at 1: 5 and be minimum 1 ft 6 inches wide at the top of the wall.

Take down the top of the wall in order to construct an RCC band at 1 ft below the top of the wall.

Construct an RCC band 4 inches thick concrete 1: 3: 6, with #4 bars at 6 inches spacing.

Reconstruct the masonry above the band.

3 Site Drainage and Stabilisation

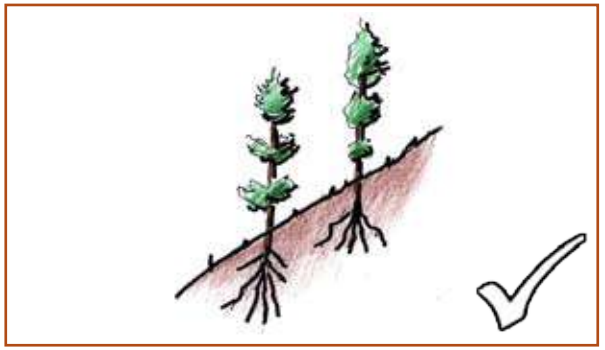
Drainage

A cut off drain must be provided on the uphill side above any retaining wall to divert ground water.

Drains should be provided around the house to collect and divert surface water and rain-water run-off from the roof.

Slope Instability

Slope instability and soil erosion by water are major environmental hazards. The risk of slope failure particularly in monsoons rains, is increased when the vegetation cover is removed.



Plants and roots.

Trees and other vegetation may be used to reinforce the soil.

The roots act as anchors and to knit the soil together.

This contributes to slope stabilisation and erosion control.

Fine roots contribute most to soil reinforcement.

Drainage

Drains should be provided around the house to collect and divert surface water and rain-water run-off from the roof.

The stone pathway around the house in the photograph above will drain very well.

Gabions

Gabions may be used as retaining walls on roadside slopes or other locations.

They require maintenance over time.

They are a relatively expensive option for private works.

SEEK ENGINEERING GUIDANCE

Trees

Use plants and trees to match the ecological and site conditions.

Some tree species can also play a role in reducing the water content in the soil, This can reduce the risk of landslide.

Contact your local Government Forestry Department for advice on all selection, planting and management of trees.

Planting trees is important for future generations.

Compliance Updates and Remedial Measures

Guidelines for construction of Rural Houses

EARTHQUAKE RECONSTRUCTION AND REHABILITATION AUTHORITY
ERRA

ERRA Building Back Better for a safer future

November 2007 to January 2008

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5 GENERAL

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I REINFORCED MASONRY | Masonry

ISSUE

I- Mixed Construction

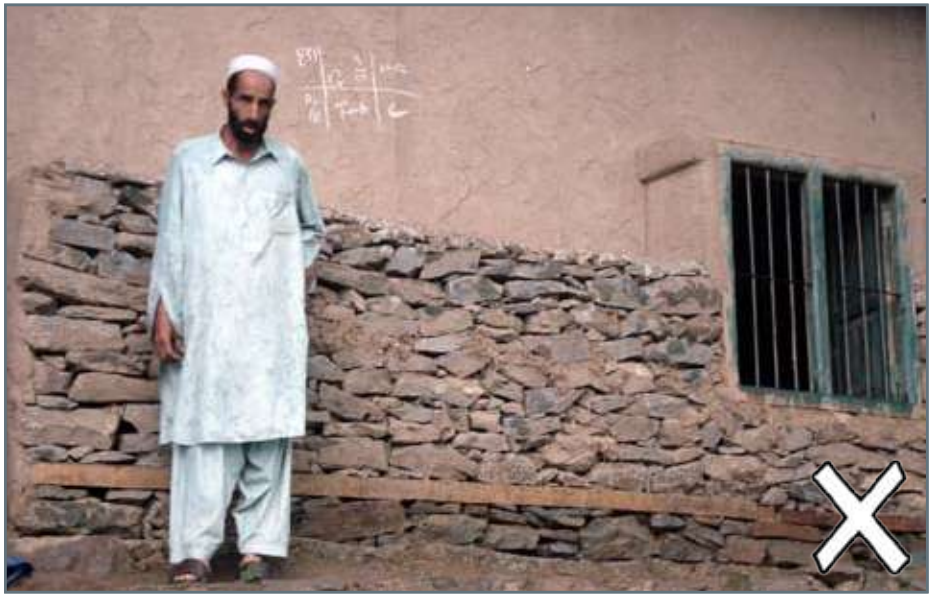
CASE - A:

- Houses where lower portion of walls (say up to sill level) is built using one type of masonry units or in-situ and upper part is built using different masonry units.

SOLUTION

Such houses shall be considered compliant subject to the condition that:

- Heavier material is placed in lower portion of wall,
- A seismic band of RCC should be provided at the change in materials.
- For example hollow block wall above situ is acceptable but in-situ above hollow blocks is inappropriate and non-compliant.
- No need to reiterate that all seismic resisting elements such as RCC bands/ beams and vertical reinforcement/ confining elements shall be in place as specified in ERRA guidelines.



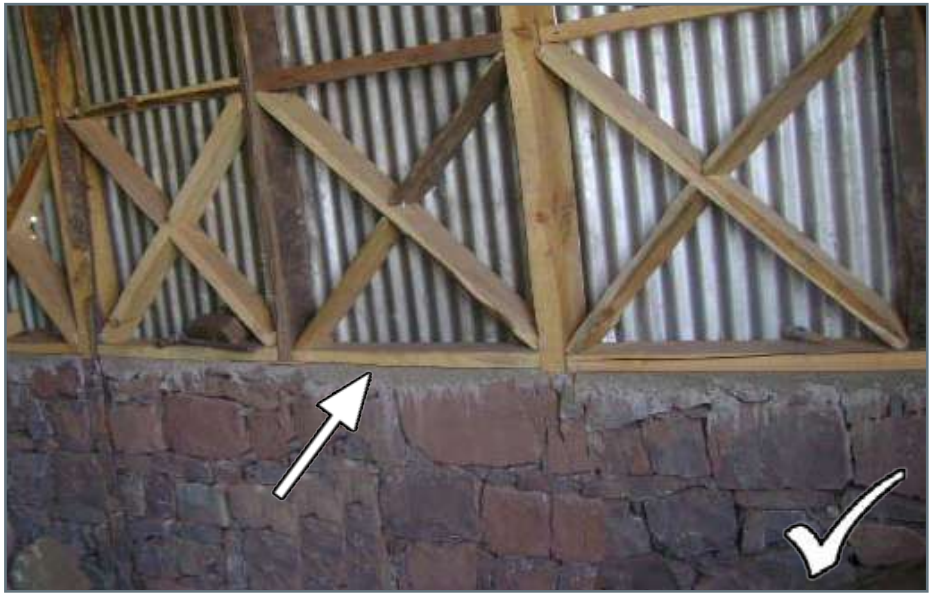
ISSUE

1- Mixed Construction

CASE - B:

- Stone masonry wall is provided up to four feet height and the rest of structure is Dhajji House.

SOLUTION



- If the stone masonry wall is constructed using dressed or semi-dressed stone using 1:4 C/S mortar and an RCC band is provided at top of it (i.e. between base plate (Dassa) and stone wall) such houses may be regarded as compliant.
- Presence of reinforced concrete band, in accordance with reinforced masonry guidelines, at top of wall is vital for such houses and should be added where missing.

Futher Explanation

- The Dhajji section of the wall should have a Dassa.
- See under Dhajji remedial measures how to carry out remedial measures in the case of missing or substandard Dassa.

1 REINFORCED MASONRY | Masonry

ISSUE

1- Mixed Construction

CASE - C:

- Houses with full height of one wall made up using one type of masonry units and the other wall with a different type of masonry. Houses with full height of one wall made up using one type of masonry units and the other wall with a different type of masonry.

SOLUTION

Houses where solid concrete blocks, bricks and or semi dressed stones are mixed should be considered compliant if;

- A concrete column is provided at the junction of different materials. This is essential as due to the difficulty of achieving adequate interlocking bonding at the junction when different masonry sizes are used.
- Houses where in situ is mixed with masonry unit shall be dealt with as per "Non-Compliance Referral System".
- Houses where light and heavy materials are mixed. (for example hollow block walls mixed with solid blocks, bricks or stone) shall be checked for symmetry of walls in plan with regard to type of masonry units in addition to column at junctions. Symmetrical houses may be considered compliant.
- For houses with the back wall acting as a retaining wall and constructed of a different material to the rest of the house refer to separate clarification on "Retaining Wall / Backwall Issues".

Futher Explanation

- Also consider the proportion of openings in the wall when assessing symmetry of mass.
- A wall of lighter masonry units with many openings is even lighter.

ISSUE

2- Stone Masonry

- Thickness of stone masonry wall is 10" to 12" instead of 15".

SOLUTION

- Min. 10" thick stone masonry wall if constructed with dressed stones laid in regular courses using 1:4 - Cement: Sand mortar as per ERRA guidelines may be considered compliant.
- For semi dressed to roughly dressed stones, the min. wall thickness of 15" will not be relaxed.

ISSUE

4- In-Situ Masonry

- In-Situ Masonry construction done with the standards of reinforced masonry instead of confined masonry standards.

SOLUTION

- Houses fulfilling requirements of reinforced masonry but using in-situ concrete instead of blocks may be accepted.
- In case of 8" thick in-situ with sill, lintel and roof band well executed, the stitches may be exempted.
- 6" thick in-situ may considered equivalent of 6" thick solid block construction is eligible for exemptions allowed for such construction.

I REINFORCED MASONRY | Masonry

ISSUE

4- 6" Hollow Blocks Construction

- Hollow blocks are used in walls instead of 8" solid or hollow blocks.

SOLUTION

- Previously there were two methods to correct 6"inches block problem are disseminated in the field.

  1- Plaster with wire mesh on both sides of the wall

  2- Widening of lintel and roof bands up to 10"

In addition to these two solutions:

- An external band in the form of reinforced concrete strips, on inside and outside face of wall; connected together by cross ties is also acceptable.

Further Explanation

- The external band should consist of 2- #3 (3-sutar) longitudinal steel bars on the inside and outside face of the wall with ties of #2 (2-sutar) at every 12inches through the wall to tie the longitudinal bars together. The tie bars should be tied with binding wire.
- The steel reinforcement band should have 2inch concrete cover.
- This band should be fixed on the course of blockwork directly above the lintel.
- Corner and junction stitches of the same specification should also be added where required.

Method- 1: Plaster with wire mesh on both sides of the wall.
For further details see Compliance Catalogue Section D (Remedial Measurse)

Method- 2: Widen the lintel and roof bands up to 10”
For further details see Compliance Catalogue Section D (Remedial Measurse)

Method- 3: An external reinforced concrete band on both sides of the wall connected together by cross ties.
For further details see Compliance Catalogue Appendix- A (External Band Flyer)

See Appendix-A for further details

2 REINFORCED MASONRY | Horizontal Reinforcement

ISSUE

1- Single Band for Lintel and Roof

- House is finished at lintel level. **OR** Roof is provided over lintel band.

SOLUTION

- Houses where no masonry is built over the lintel band and the roof is placed at lintel level may be considered compliant.
- In cases where lintel level is more than 7ft no exemption for corner stitches shall be granted.

ISSUE

2- Local Thickening of Lintel Band

- Lintel band is not thickened over openings more than 3ft wide. **OR** Thickness of lintel band is not being increased over the lintels longer than 3ft.

SOLUTION

- The requirements of thickening of band for openings more than 3ft may be relaxed up to 5ft.
- Therefore, houses having windows opening up to 5ft without locally increased thickness of lintel band may be considered compliant if the window is fixed in the opening.
- For bare openings the relaxation does not apply.
- The thickening of the lintel band is required for gravity loads.

ISSUE

3- Discontinuous Lintel Band

- Lintel band has been provided at different level over the door and window opening. OR Un even heights of Doors and Windows lintel levels.

SOLUTION

- Lintel band plays the most important role in earthquake resistance of a house.
- Lintel band shall be continuous and at the same level to perform its intended function.
- Partial external bands connected to existing band could be a solution to this problem.
- However, these cases are very few in number, hence will be dealt on case to case basis under Non-Compliance Referral system (NCRS).
- Additional solution is to provide an external band as per solution for 6 inch hollow block work.

ISSUE

4- Lintel Band at Different Levels

- In-Situ Masonry construction done with the standards of reinforced masonry instead of confined masonry standards.

SOLUTION

- Continuous seismic band at lintel level is essentially required. Where this is inappropriate correct the situation as per instructions and details of "Compliance Catalogue".

Further Explanation

- Additional solution is to provide an external band as per solution for 6 inch hollow blockwork.

ISSUE

1- Vertical Reinforcement Missing (Hollow Block Masonry)

- 8" hollow block is used in the walls of the house. There is no reinforcement in the wall. Columns are provided in the corner and all bands are placed in position.

2- Vertical Reinforcement Missing (Stone Masonry)

- Vertical bars are missing in stone masonry laid in 1:4 C/S mortar. There are R.C columns and beams.

SOLUTION

1- Vertical Reinforcement Missing (Hollow Block Masonry)

- Vertical reinforcement is required for both reinforced and confined masonry around openings. Where this reinforcement is not provided correct the situation by adding necessary steel as outlined in "Compliance Catalogue."
- For confined masonry no other vertical steel is needed.
- It is important that the vertical reinforcement should start from the foundation. The vertical reinforcement bars starting from the plinth level may not be acceptable.

Further Explanation

- For reinforced masonry vertical steel is also required at corners and T-Junctions. The procedures to correct situations involving absence of such bars are also included in compliance catalogue.

2- Vertical Reinforcement Missing (Stone Masonry)

- Stone masonry must be considered as reinforced masonry. Vertical bars are required at corners, T junctions, openings and at every 4 feet.

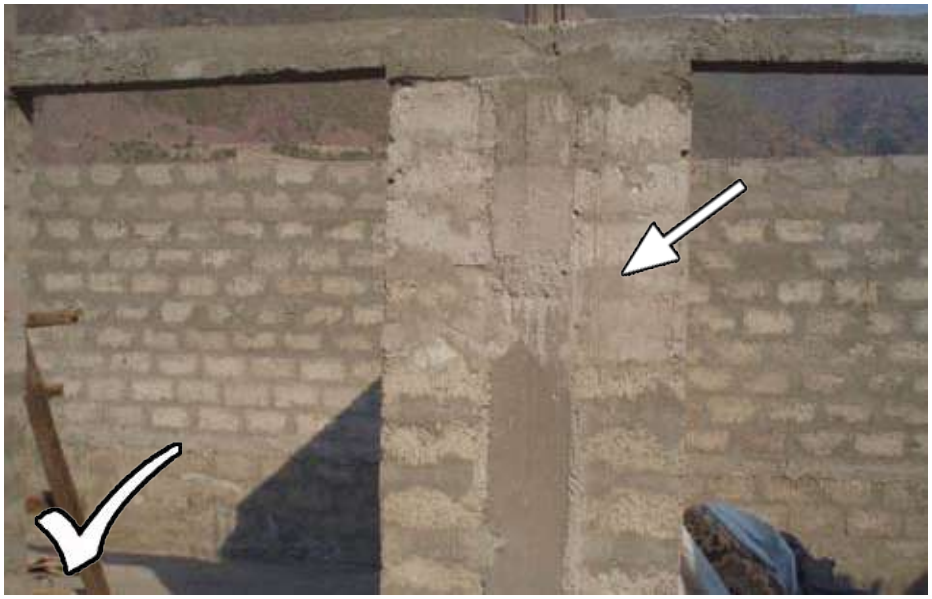
ISSUE

1- Combined Window and Door Openings

- Doors and window are located adjacent to each other.

SOLUTION

- Such a situation is not acceptable and is non-compliant.
- Relocate door or window opening ensuring at least 24" masonry or R.C Column in between.



ISSUE

2- Width of Wall Between Doors and Windows Openings

- Doors and window openings have been provided adjacent to corner. The distance between the corner and opening or between two openings is equal to one block length i.e. 16" which is less than specified width of 2ft.

SOLUTION

- Where R.C columns are provided at corners or between two openings and all other requirements of ERRA guidelines are met, masonry width of 16" from corner or between two openings may be accepted.
- Where R.C columns are not present the openings shall be re-arranged to fulfill requirement of minimum 24" wall length. Refer to "Compliance Catalogue" for procedures.

5 REINFORCED MASONRY | General

ISSUE

1- 6" Solid Block - Maximum Room Size

- Length of unsupported wall is more than 12' specified.

SOLUTION

- The Maximum length of unsupported wall for the houses constructed with 6" solid blocks was limited to 12' as per the exemptions published earlier in the compliance catalogue.
- In good quality construction with 6" solid blocks a relaxation of 3' may be granted as an exemption (i.e. unsupported wall length of 15' is acceptable) if all other specifications of particular type of construction are fulfilled

ISSUE

2- Intermmediate Vertical Bars Missing

- If four bars are provided at each corner with one vertical bar at each face of opening, without any intermediate vertical bars?

SOLUTION

- As per the approved design and specifications for reinforced masonry construction the verticals bars should be provided at 4ft spacing and on both sides of the openings. But as an exemption it can be relaxed from 5ft to 6ft distance.
- It's necessary to provide the vertical bars at specified distance in the solid walls (walls without openings) for making the house safe and compliant.

1 HORIZONTAL REINFORCEMENT

1- 6” Hollow Blocks Construction (Confined Maosnry)

2- Plint Band - Confined Masonry

1 CONFINED MASONRY

Horizontal Reinforcement

ISSUE

1- 6" Hollow Block - Confined Masonry

- Can 10" x 3" lintel and roof bands be provided with reinforcement detailed in Reinforced Masonry Standards to avoid concentrated mass at the top by providing beam of 10" x 9"?

SOLUTION

- It's recommended not to mix the specifications of Reinforced Masonry and Confined Masonry.
- The beam height may be reduced from 9" to 6" for the sake of economy without any compromise on safety. However, concrete band provided as per requirement of reinforced masonry system may also be accepted as a relaxation

These are only exceptions, however the original standard are unchanged.

ISSUE

2- Plinth Band- Confined Masonry

- If four bars are provided at the corner, with plinth band (without a four bar beam) can it be considered as "Confined Masonry".

SOLUTION

- If someone has already constructed; the plinth band (instead of plinth beam with four bars) with four bars columns at the corners and wall junctions will be accepted as an exemption under Confined Masonry but not as a rule.

WARNING:

- This should not be promoted as a revised standard.

C TIMBER FRAME (DHAJJI)

1 BASE PLATE (DASSA)

1- Missing Base Plate (Dassa)

2- Discontinuous Base Plate (Dassa)

3- Undersize Base Plate (Dassa)

2 FRAME

1- Poor Jointsl

2- RCC Columns in Timber Construction

3- Undersize Timber members

4- Large Room Sizes in Dhajji Construction

3 GENERAL

1- Use of Metal Straps in Timber Frame

2- Dhajji Double Storey Construction

1 TIMBER FRAME (DHAJJI) | Base Plate (Dassa)

ISSUE

1- Missing Base Plate (Dassa)

- Base plate (Dassa) is not provided under timber frame (Dhajji Construction).

SOLUTION

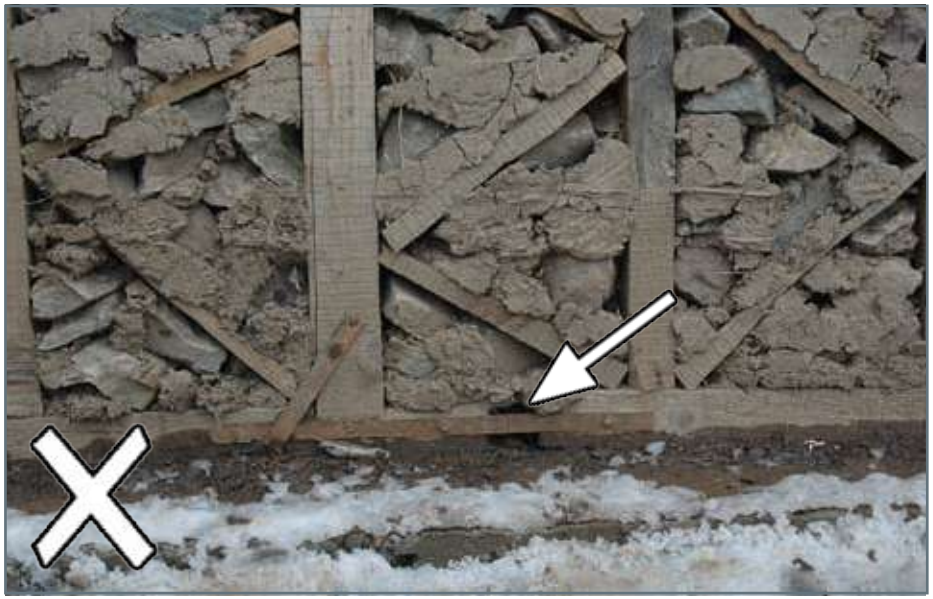
- The base plate is important element of timber frame (Dhajji Construction) and shall be provided in all structures.
- It is recommended that if the base plate is missing, the solution should be to use long flat timber planks to provide an internal and external band close to the base of the wall. This should provide stability to the bottom part of the posts and tie between the panels in a way similar to the base plate.
- The timber planks should be face nailed and strapped to the posts, and to any existing base plate sections. Metal plates or straps could be used to improve the connection from one plank to the next as they are in the same plane.
- The pieces should be as long as possible and the joints internally and externally should be staggered. They should also be fixed at different heights to avoid too many nails together which may split the timber.
- The planks should be 4" x 2" but should be as long as possible, preferably over 10 ft long to avoid frequent joints and to optimize the number of posts connected by the same plank.
- The safety of such houses against sliding shall be ensured by proper anchorage into adequately built plinth or providing a wide level plinth that can accommodate the slight house movements associated with ground shaking.

Further Explanation

- The base plate has two purposes:

  1- It ties the building together as a box

  2- It can be used to fix the building to the ground.
- The first purpose is more important. Once the building is a secure box and the plinth is a secure plinth the building may move slightly but not fail in an earthquake.
- The long planks used where baseplate is missing or substandard may be 1 inch thick if they are at least 6 inches wide.
- This solution may also be used where the base plate is discontinuous.



ISSUE

2- Discontinuous Base Plate (Dassa)

- Base plate of size 2" x 4" and 3" x 4" has been provided at plinth level.

SOLUTION

- TProper connection of posts with base plate is improbable when the latter has a thickness less than 4".
- Replace undersize base plate where feasible.
- The other alternative may be to nail additional 2" thick timber over existing plate between columns: At columns provide additional timber plates 2" x 30" long on each vertical face of improved base plate. These plates shall be nailed to columns and base plate.
- Where infill is in place the extra planks as discussed in item 8 above may be used on sides of base plate.
- Where infill is in place the extra planks solution proposed for missing base plate may be used.
- (long flat planks to be face nailed to posts).

I TIMBER FRAME (DHAJJI)

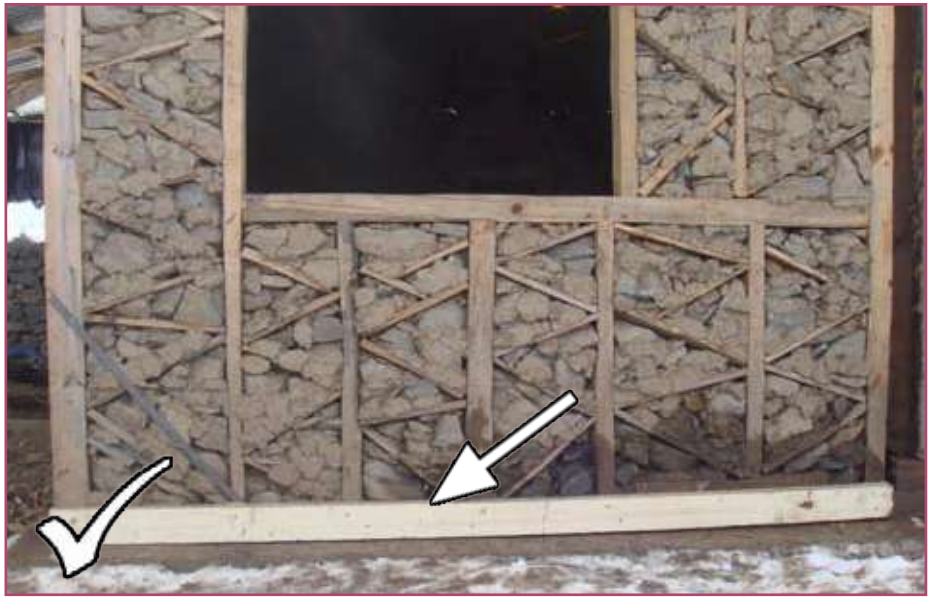
Base Plate (Dassa)

ISSUE

3- Undersize Base Plate (Dassa)

- Base plate of size 2" x 4" and 3" x 4" has been provided at plinth level.

SOLUTION



- Proper connection of posts with base plate is improbable when the latter has a thickness less than 4".
- Replace undersize base plate where feasible.
- The other alternative may be to nail additional 2" thick timber over existing plate between columns: At columns provide additional timber plates 2" x 30" long on each vertical face of improved base plate. These plates shall be nailed to columns and base plate.
- Where infill is in place the extra planks as discussed in item 8 above may be used on sides of base plate.
- Where infill is in place the extra planks solution proposed for missing base plate may be used.
- Long flat planks should be face nailed to posts.

ISSUE

1- R.C. Columns in Timber Construction

- R.C columns are used in place of timber posts in Timber Frame / Dhajji Construction. In some cases all posts are of concrete whereas in others some posts are of R.C and some are of timber.

SOLUTION

- All construction using fully or partially reinforced concrete columns in-filled with Dhajji is non-compliant.

The house shall be converted to complete timber frame or confined masonry based on economic considerations and choice of the owner.

ISSUE

2- Poor Joints

- Poor joints and connections:

SOLUTION

- If wooden members are not properly tied together at the joints: Nail or screw at least 8 mm (3/8") thick plywood sheet on the inside face of each wall for the relevant area.
- A poorly planned timber frame with inappropriate connections has a little resistance against the earthquake as compared to properly braced frame with well connected members.
- Compliance catalogue has solution for base and wall plate joint improvement. Use an external metal strap min 3 ft. long.

2 TIMBER FRAME (DHAJJI) | Frame

ISSUE

3- Undersize Timber Member

- Base plate of size 2" x 4" and 3" x 4" has been provided at plinth level.

SOLUTION

- If structural members are undersized:
- Nail or screw at least 8 mm (3/8") thick plywood sheet on the inside face of each wall for the relevant area.

Further Explanation

- A poorly planned timber frame with inappropriate connections has a little resistance against the earthquake as compared to properly braced frame with well connected members.

ISSUE

4- Large Rooms in Dhajji Construction

- Size of room is more than 16'x16' in timber frame / Dhajji construction.

SOLUTION

All corners in the room should be stiffened with corner struts of 2-3 ft at wall plate level.

In fact better is to fix the strut on top of the wall plate.

- An exemption of up to 15ft x 20ft should be permitted under the following conditions:
- All horizontal members are adequate and well fixed. All vertical posts are adequate and well fixed. All bracing is adequate and well fixed. No undersized members, or large spacing between posts is acceptable.
- All corners and junctions in the building should be strengthened and stiffened with minimum 2 ft struts.
- A full ceiling is provided and well fixed on top of the wall plate, with adequate strength and stiffness to act as a diaphragm for the walls.
- All roof trusses are well framed and well fixed to the wall plate and posts. The spacing should not be more than 6ft cc. An additional bracket strut may be added from the truss tie beam to the post to improve the stiffening effect.

3 TIMBER FRAME (DHAJJI) | General

ISSUE

1- Dhajji Double Storey

- 2 storey houses in Dhajji Construction.

SOLUTION

- The specifications already issued for Dhajji houses are good for single story construction only.
- Therefore, double story houses using same specifications are non-complaint.
- However, the houses using improved specifications i.e. large sizes of timber members and stronger connection may be referred through Non-compliance Referral System with proper documentation.

ISSUE

2- Use of Metal Starps in Timber Framed Masonry

- Can the iron/steel plates (L,T or I shapes) to strengthen joints of undersize timber?

SOLUTION

No.

- Strengthening of only joints will not help. Stress levels in various timber elements do matter and they depend on cross-sectional area of the timber.

Further Explanation

- A poorly planned timber frame with inappropriate connections has a little resistance against the earthquake as compared to properly braced frame with well connected members.

1 SLAB

2 STRUCTURE

1- Single Band for Roof and Lintel

2- Local Thickening of Lintel Band

3- Lintel Bands at Different Levels

4- Discontinuous Lintel Band

1 R.C.C. Construction

Flat Slab

ISSUE

1- RCC Flat Slab

- RCC Flat slab construction over reinforced masonry structure and confined masonry structure.

SOLUTION

- R.C.C. flat slab will be considered compliant over Confined Masonry, and
- Also over Reinforced masonry if reinforced masonry construction comprising of burnt clay bricks or solid concrete blocks.
- Reinforced concrete or parapets upto a height of 3' may be accepted if adequately integrated with slab.
- Parapets or other decoration made of masonry units shall be strictly rejected.

General Guidelines

- These guidelines are limited to slabs supported on all four sides by load bearing masonry.
- RCC slab should be cast monolithically with the roof beam.
- All other Earthquake resistant measures must be present in the building.
- Determine Ratio of longer side to the shorter side of the room. There will be two cases;

  1- If the ratio is more than 2,

  2- If the ratio is lee than 2

R.C.C. Construction

RCC slab should be cast monolithically with the roof beam.

Reinforced concrete parapets up to 3ft height adequately integrated with RCC slab may be acceptable.

Avoid heavy cornices.

Parapets made of masonry units will not be acceptable.

Decorative parapets will also not be acceptable.

2 R.C.C. Construction

Structure

ISSUE

1- RCC Double Storey House

- Is it acceptable to construct second story over Confined Masonry Structure?

SOLUTION

- The second storey may be allowed in case of Confined Masonry Construction only., under the following terms & conditions:
- Where column dowels project above first floor slab and new walls are constructed exactly over the walls below.
- Confining elements and their reinforcement shall be as per guidelines for lower storey.
- Roof shall comprise steel or wooden truss with CGI sheets.

See Appendix A for detailed Drawings

ISSUE

2- RCC Construction

- The houses built as reinforced concrete frame structures, which neither fall in reinforced masonry nor in category of confined masonry.

SOLUTION

- There is a little chance, if any, that such construction qualifies the requirements of "Special Moment Resisting Frame" (SMRF) essentially required for seismic zones 3 and 4.
- However, such structures may be made compliant easily by adding missing confined masonry elements as per details already provided in compliance catalogue.

E GENERAL

1 PLINTH HEIGHT

2 OPENINGS

3 USE OF ANGEL IRON IN COLUMNS

4 L & U SHAPED HOUSES

5 TIMBER STORAGE AS INTERNAL PARTITION WALL

1 GENERAL

This section is valid for all types of constructions

ISSUE

1- Openings in Cross Walls

- If all the doors are at proper locations i.e. located at a distance of 2 ft from the corner, except for doors of partition walls?

SOLUTION

- All the doors should be at the specified distance away from corners and junctions.
- Where it is not possible to keep the door at the specified location, an RC Column may be provided at the corners & junctions with same amount of reinforcement specified for vertical confining elements in Confined Masonry.

ISSUE

2- PLinth Height

- The height of plinth is more than 3ft.

SOLUTION

- For plinth heights more than 3ft the wall shall be constructed as a retaining wall.

ISSUE

3- Use of Angel Iron Columns

- Some people use angle iron columns at joints and junctions in block, stone and Dhajji Houses. Are they acceptable?

SOLUTION

- There is a very little chance that such reinforcement is properly anchored and bonded to masonry. Therefore, they should be considered non-complaint.

1 GENERAL

This section is valid for all types of constructions

ISSUE

4- L and U Shaped Houses

- What is the policy about L shaped and U shaped houses? Lintel level inspection is being carried out at this stage?

SOLUTION

- L and U shaped houses with light flexible roof are comparatively less prone to additional stresses due to torsional effects because of two reasons.

  i) Mass of roof is negligible as compared to that of wall. Hence major earthquake forces are developed in walls due to their own mass and transferred directly to foundation with minimal secondary affect on other walls.

  ii) The roof is not rigid enough to "Constrain" the wall lateral movement and force each point at top of wall to undergo same lateral deflection. In other words rigid floor diaphragm action, responsible for creating torsional affects, is almost absent.

- The above two consideration indicate sufficient room for relaxation on the plan configuration for single storey houses with light roof. However, fixing a general limit for the length of projections allowed can only be based on engineering judgment due to a large number of variables involved.

- L and U shaped houses with concrete slab are subjected to torsional affects. Longer walls will attract large lateral forces and may crush due to in-plane stresses. Walls made of hollow (usually substandard) blocks are likely to fail in this manner.

- Solid concrete blocks are burnt clay bricks are likely to offer a higher level of resistance. Obviously confined masonry will perform better than reinforced masonry. The uneven distribution of forces will also cause stress concentrations at corners.

- For larger projections it appropriate to convince the owner to carryout additional construction in such a manner to achieve symmetry as this is the best and direct way of enhancing earthquake resistance.

ISSUE

5- Timber Storage as Intenal Partition Wall

- A number of houses have used timber storage as the full or part of the internal partition wall. This may be open shelving or closed cupboards / wardrobes. It may be a few inches deep or up to 2 feet deep. In general the back of the unit is made from solid timber boards.

SOLUTION

- Use of timber partition walls in Dhajji timber frame construction, should be considered compliant if it has adequate strength and stiffness.
- It should be considered also as a timber frame and part of the structural system.
- If it is substandard it can be braced from the rear or have additional structural members added to improve it.
- The use of solid boards is preferable to use of thin fiber-board in terms of providing shear strength.
- The partition wall should be well connected with the external walls.
- Further corner bracing can be added at wall plate level improve this connection.
- The partition wall should preferably have a base plate, also connected to the external base plate.
- Use of timber partition walls in masonry houses is not adequate and should not be considered compliant,
- If the length of unrestrained masonry wall is greater than 15 ft. The owner should plan to add a masonry partition wall with a proper connection to the existing walls.
- Meanwhile the timber partition wall should be strengthened and well connected to the external walls.

F RETAINING/BACK WALL

1 WHERE RETAINING WALL IS NOT A PART OF THE HOUSE

1- Distance Between Retaining Wall and Backwall of the House

2 WHERE RETAINING WALL IS A PART OF THE HOUSE

1- Back wall is the retaining wall

2- Back wall is the retaining wall

3 REMEDIAL MEASURES

1- Adding Vertical and Horizontal Reinforcements

2- Improvement of Retaining Wall

3- Retaining Wall Connection to Cross Walls of the House

2 RETAINING/BACK WALL | Where Retaining Wall is not a Part of the House

ISSUE

1- Distance Between Retaining Wall and House

- What should be the distance between the retaining wall and the building?
- In case of space constraint can the distance be reduced?

SOLUTION

- Ideally the distance between the rear/ back wall of the house and the retaining wall shall be equal to the height of retaining wall.
- Where this ideal situation is not feasible due to steep slopes, the distance shall be based on functional requirements and space limitations.
- A distance of 3ft to 4ft is recommended to keep the area clean and well ventilated. The snow accumulated in this area may also be conveniently removed.
- The distance may be further reduced without any effect of structural response during an earthquake. The owner of the house shall however satisfy himself that the narrow space behind the house may not be a problem in his daily life.
- In case of severe limitations the distance may be as little as a few inches just to ensure that the response of the house is not modified by the moving soil or rock mass behind the house.
- Where space is too tight, it is functionally better to build abutting the retaining wall. This situation is not ideal but fairly acceptable particularly in rocky areas.

Further Explanation

- This advice applies to the distance between back wall of the house and the retaining wall or slope behind or rock face behind. Consider the stability of the slope behind. Rock is more stable.

2 RETAINING/BACK WALL | Where Retaining Wall is a Part of the House

ISSUE

1- Retaining Wall is the Backwall of the House

- In some cases the back wall of the house serves the purpose of the retaining wall also. OR The retaining wall is used as back wall of the house. The height of retained soil varies from a few feet to full height of the house and the soil or rock mass behind the wall may have a level or sloping surface. What is the status for this issue?
- Can the back wall of a house be a retaining wall?

SOLUTION

1. Height of retaining: < 5 ft.

- This may be considered compliant:
- Where the height of retained earth is not more than 5ft and the area behind the wall is fairly level, if wall thickness is not less than 2 feet 6 inches and all seismic bands are anchored in it.

2. Height of retaining: 1 storey / approx 8 ft.

- This may be considered compliant:
- Where full height of a single storey house is retained i.e. the height of retained soil is around eight feet and the area behind the house is fairly level, if wall thickness is 3 feet 6 inches and all seismic bands are anchored in it.

In both cases:

- The ground behind must be fairly level.
- The room sizes must be within limits (maximum room size: 15 x 15 ft)
- The stone masonry should have sand cement mortar.
- Where already constructed, dry stone masonry walls shall be pointed ensuring filling of as many voids as possible.

NOTE:

- If bands are not present in the wall see Remedial Measures.

ISSUE

2- Retaining Wall is the Backwall of the House

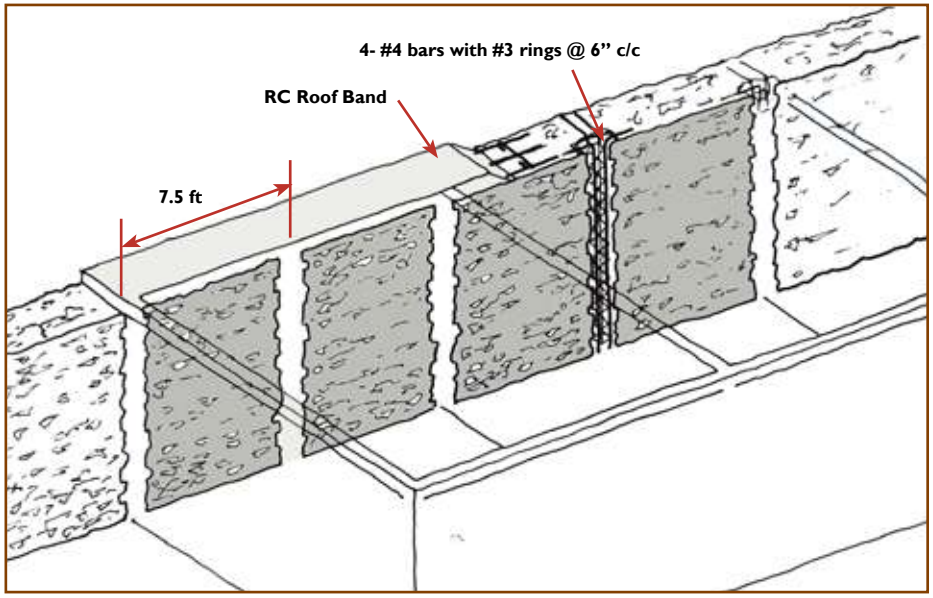
- Can back wall of a house be a retaining wall if there is a steep slope retained?.

SOLUTION

No.

- In situations where the surface of the retained soil has a steep slope it is not advisable to use retaining wall as the back wall of the house, unless the retaining wall is designed by a qualified engineer.

3 RETAINING/BACK WALL | Remedial Measures



ISSUE

1- Adding Horizontal & Vertical Reinforcements to Improve the Retaining Wall connected to House

- In some cases the back wall of the house serves the purpose of the retaining wall also. OR The retaining wall is used as back wall of the house. The height of retained soil varies from a few feet to full height of the house and the soil or rock mass behind the wall may have a level or sloping surface. What is the status for this issue?
- Can the back wall of a house be a retaining wall?

SOLUTION

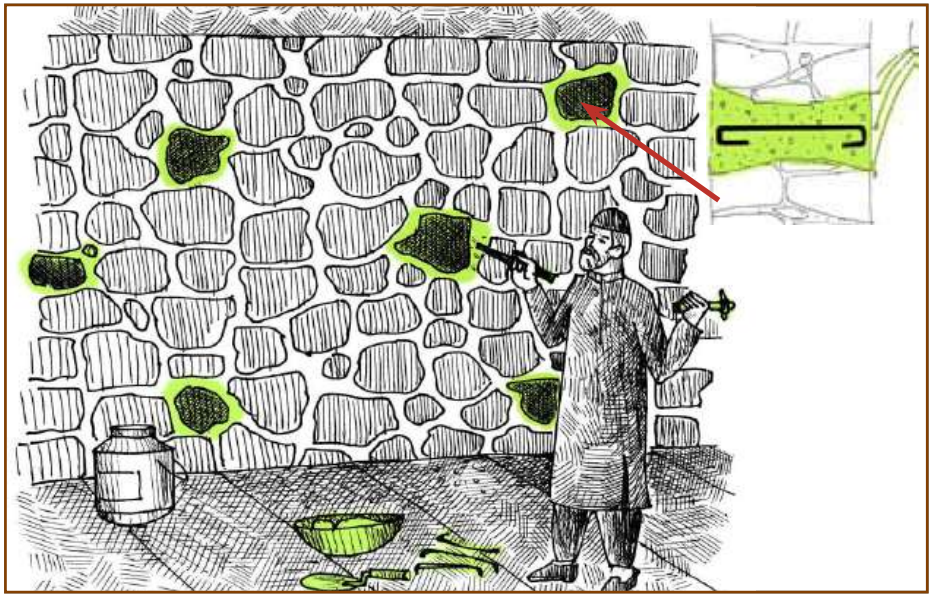
- The wall should have both a horizontal band provided at the top (RCC roof band) and should have vertical confining elements (RCC columns) combined to ensure desired safety.
- Roof band or vertical confining element alone may not be adequate.
- These measures apply where the area behind the house is fairly level.

To provide horizontal reinforcement / RCC roof band:

- Prop the roof where already constructed and remove the top layer of stones (minimum 4 inches) to make space for casting a new roof band.
- The width of the band should be the same as the width of the wall.
- Provide #4 (4-sutar) longitudinal bars at 6" spacing leaving 1-1/2" (1.5") concrete cover on both sides with #2 (2-sutar) stirrups at every 8" spacing.
- The concrete should be 1:2:4 mix.
- Where possible, the new roof band section should be tied in to the existing roof band at the top of the other three walls.
- To provide vertical reinforcement / RCC columns:

Vertical reinforcement must be provided at max 7 ½ ft centers (room sizes of 15 ft).

- Remove stones along a vertical line of the new column, and Provide 4- #4 vertical bars with #2 stirrups at 6" spacing. The vertical bars shall have a 90o bend at top and bottom.
- The concrete should be 1:2:4 mix.
- The column should be taken down to and integrated with the wall foundation.
- The width of the column at the face of the wall should be minimum 9 inches. The depth should be as much as possible. The column should be fully embedded in the wall.
- Where possible tie the new vertical reinforcement in to the new roof band.



ISSUE

1- Improvement for Retaining Wall

- If the retaining wall is not fully constructed or loosely constructed. What could be the additional improvements to make the house safe and compliant?

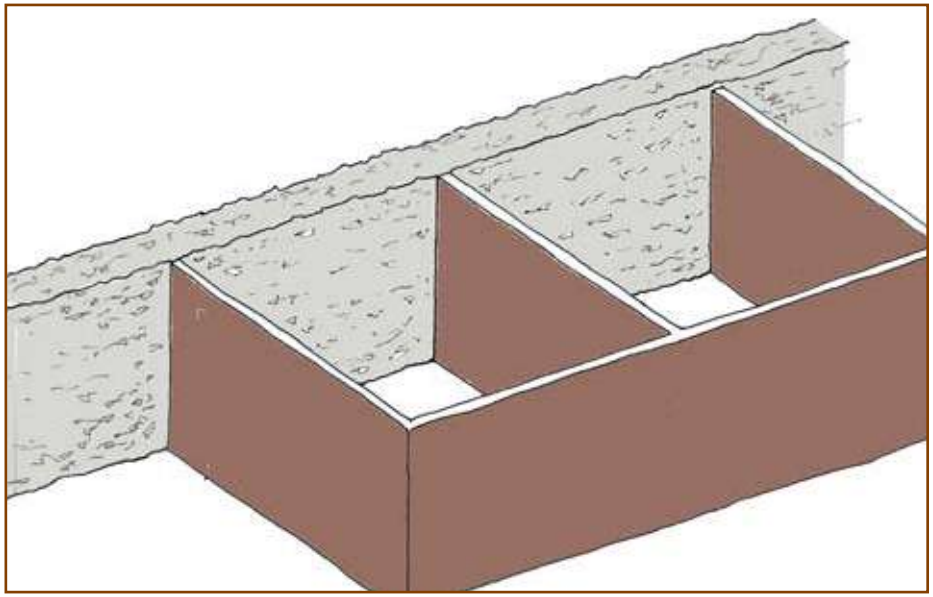
SOLUTION

- Where the wall is not yet fully constructed or loosely constructed it is important to improve the stability of the stone work and the anchorage of the front face to the rest of the masonry behind.
- The provision of seismic bands or horizontal and vertical reinforcement remedial measures are required for the wall to be compliant.
- The alternative may be to create a horizontal void across the wall width (by removing stones) and fill it with concrete mix 1:2:4. The concrete mix may be pushed into the irregular cavity by rodding. This will be more effective with steel reinforcement.
- All of these measures would improve stability more than simply pointing the front face of the wall with mortar.

Further Explanation

- If available use long through stones perpendicular to the face of the wall.
- Solid concrete blocks of length equal to wall thickness may be used. S or Z shaped #6 or #4 bars may be used encased in mortar or concrete by at least 2" on all sides.
- It may be practically difficult to insert through stones, blocks, or steel in an existing wall.

3 RETAINING/BACK WALL | Remedial Measures

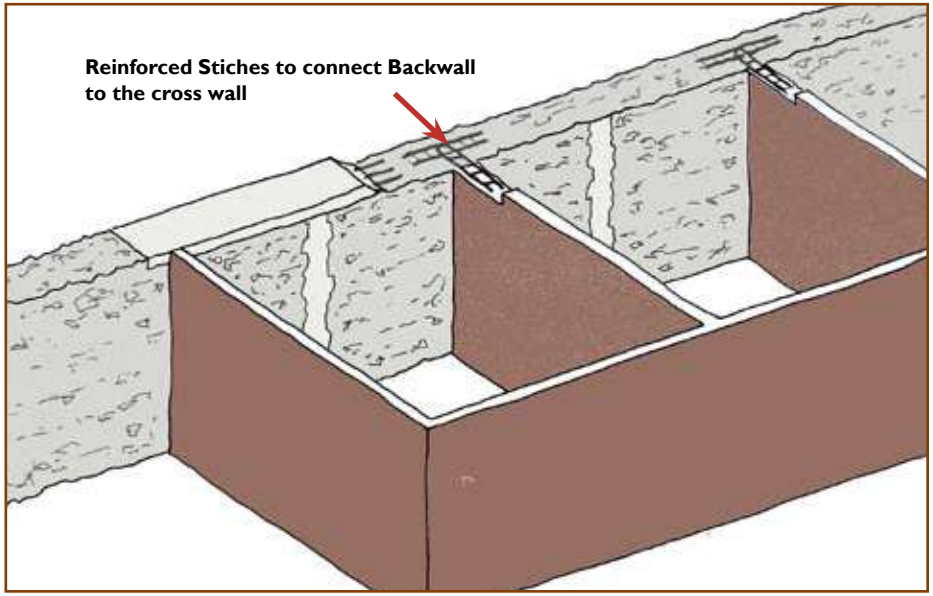


ISSUE

1- Retaining Wall Connection to Cross walls of the House

- Where retaining walls have been constructed as part of a house, the other walls often have poor connections to the retaining wall. What could be the remedy?

SOLUTION



- Improve cross wall connections to improve the potential for the cross walls to provide restraint or buttressing action to the back wall.
- The provision of seismic bands or horizontal and vertical reinforcement remedial measures are required for the wall to be compliant.
- This can be improved by tying the perpendicular walls in to the back wall with better keying or bonding, or with horizontal stitches or constructing RCC columns at the junctions.

APPENDICES

Appendix - A: Posters for construction standards

Appendix - B: Technical drawings for remedial measures by NESPAK

Appendix - C: Questions and answers by NESPAK

APPENDIX - A

APPENDIX - A

POSTER FOR CONSTRUCTION STANDARDS

A-1: Reinforced Masonry Poster

A-2: ERRA Dhajji Poster

A-3: UN-Habitat Dhajji Poster

A-4: External Band Flyer

A-5: Confined Masonry Poster

A-6: Bhattar/ Timber Reinforced Masonry Handbook

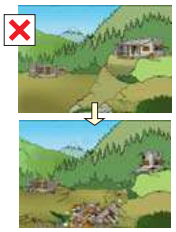
A-7: Leepa-Type Timber Post and Beam Houses Handbook

You can make your NEW HOUSE safe against EARTHQUAKE !

FEW RECOMMENDATIONS

For Single Storey Masonry Houses in Cement Sand Mortar

1 Site Selection



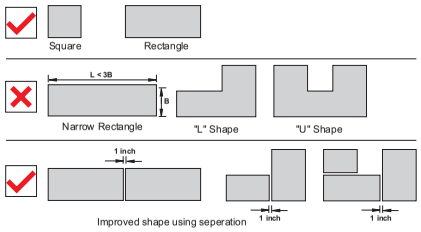
Steep and unstable slopes

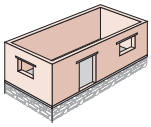
Rock fall area

Avoid to construct a house near river banks

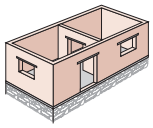
- Avoid steep & unstable slopes;
- Avoid areas susceptible to landslides and rockfall;
- Avoid construction on loosely filled grounds;
- Place house away from the river banks;
- Avoid construction too close to visible, permanent, deep and active faults;
- Distance between house and tree or with adjoining house be preferably at least equal to the height of tree or house, whichever is larger.

2 Shape of House





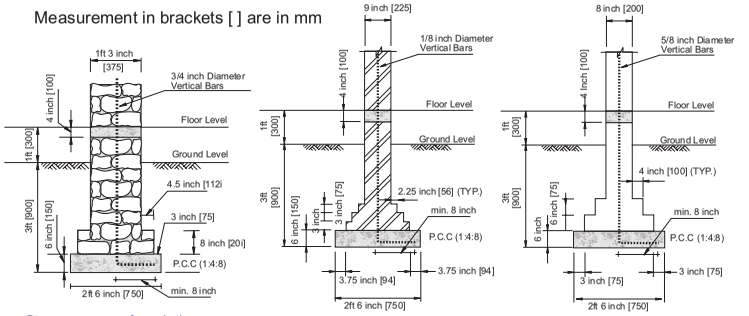
Avoid long walls



Provide sub-dividing walls

- Construct regular shaped houses like square, rectangular or circular;
- Subdivide complex shaped buildings by providing gaps at appropriate locations. The gap should be minimum 1 inch for one storied house;
- Avoid long and narrow structures. Length of a house should not be more than 3 times its width;
- Construct compact box type layout with all building components such as floor, walls and roof tied-up with each other;
- Maximum room size should be limited to 15ft x 15ft.

3 Foundation



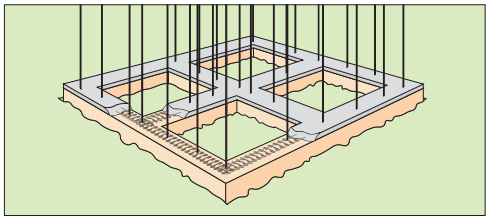
Stone masonry foundation

Brick masonry foundation

Concrete block masonry foundation

- Use continuous strip footing;
- In case of soft soil, the depth of foundation below existing ground level should be at least 3 ft. For rocky areas minimum depth should be 1.5 ft.;
- Minimum width of footing should be 2.5 ft.;
- Make the excavated surface level before laying the foundation;
- In case of loose soil, provide some nominal reinforcement in foundation bed concrete;
- If stone soling is used under foundation, reduce the thickness of foundation strip to 3 Inch;
- Foundation Details: Foundation for various masonry options should be as shown in figure.

4 Plinth

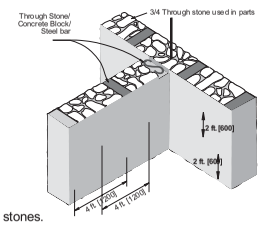


Plinth band and vertical reinforcement

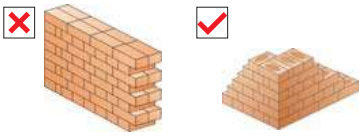
- Plinth should be at least 1ft. above the ground level
- Provide a reinforced concrete band at plinth level, as shown in figure.
- Minimum thickness of plinth band should be 3 to 4 inch and width should be equal to wall thickness. Main reinforcement should be 2 Nos. 1/2 inch diameter (4 sutar) bars. Use 1/8 inch diameter (1 sutar) rings at 6 inch. Hook length should be 2.5 inch. Bars should have a clear cover of 1 inch.

5 Walls

Through stones in stone masonry wall



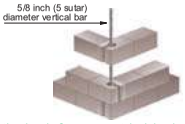
Dressed or semi dressed stones should be used, instead of rubbles and rounded stones.



Stepped brick wall construction in place of tooth construction

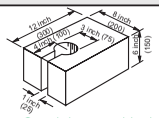
Lay the walls straight in plumb and at right angle. Make steps as shown in picture and then fill the middle part

Use well burnt, regular sized bricks. Over/ under burnt and deformed bricks should not be used.



Vertical reinforcement in block wall

Concrete block wall



Special corner block for placing vertical reinforcement

- Masonry should be laid staggered so that the vertical joints don't form a continuous line.
- At corners or wall junctions, through vertical joints should be avoided by properly laying the masonry. Never make vertical "teeth".

Stone Wall

- Wall Thickness: 15 inches
- Boulder stone should not be used in its natural shape. Boulders should be dressed or semi-dressed before they are laid.
- The inner and outer wythes of the wall should be interlocked with through stones. No large space between two wythes should be left for filling with pebbles or mortar.
- Through Stone: Through stone of full length equal to wall thickness should be used in every 2 ft. lift at not more than 4ft. apart horizontally, placed in staggered position. A through stone could be a stone, concrete block or an S-shaped steel bar of min. 1/4 inch diameter (2 sutar) well packed with mortar.

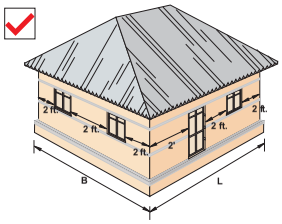
Brick Wall

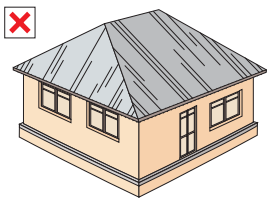
- Wall Thickness: 9 inches
- Stepped Construction: Stepped wall construction is better than toothed, when there is a need for future extension or continuation of work.

Concrete Block Wall

- Wall Thickness: 8 inches
- Solid blocks are preferable as compared to hollow blocks.
- Special corner blocks with side hole are required for placing vertical reinforcement.

6 Doors & Windows

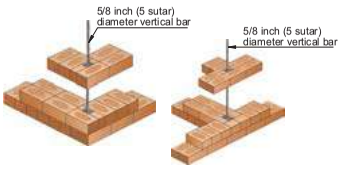




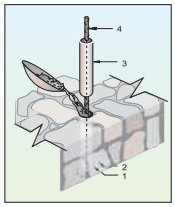
Inappropriate & large openings

- Location of Doors & Windows: Doors and windows should be placed at least 2 ft. away from the wall corner;
- The total length of doors and windows in a wall should not be more than 50% for single storey construction;
- Gap between two openings: Wall length between any two openings (doors and/or windows) should not be less than 2 ft.;
- Keep lintel level same for doors and windows.

7 Vertical Reinforcement in Walls

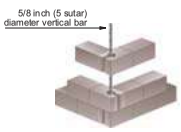


Reinforcement in brick masonry wall

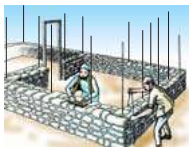


Use of pipe sleeve to create uniform void for reinforcement as per following steps:

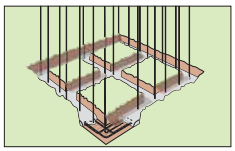
1. *Place pipe sleeve around reinforcement*
2. *Build masonry around the pipe sleeve*
3. *Lift the pipe sleeve leaving hollow in masonry and fill the void with concrete or mortar.*
4. *3/4 inch (6 sutar) diameter vertical bar*



Reinforcement in concrete block masonry wall



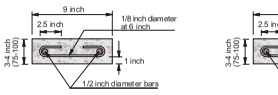
Reinforcement in stone masonry wall



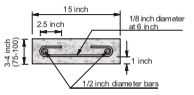
Vertical reinforcement starting from foundation band

- Place vertical steel bars in the walls, at all corners and junctions of walls and adjacent to all doors and windows. The spacing between two adjacent vertical bars should not be less than 4 ft.;
- Anchor all vertical steel bars in the foundation and roof band;
- Use 5/8 inch diameter (5 sutar) steel bars in case of brick and concrete block masonry. Provide 3/4 inch diameter (6 sutar) steel bars for coursed stone masonry;
- Fill the pocket around steel bars with 1:2:4 concrete for brick and concrete block masonry. Cement sand mortar 1:3 may also be used for concrete block masonry;
- For stone masonry place 2 inches diameter PVC pipe around the steel bars, and build masonry around it. Extract the pipe and fill the hole with 1:3 Cement sand mortar or 1:2:4 concrete.

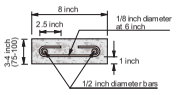
8 Horizontal Bands



Brick masonry wall

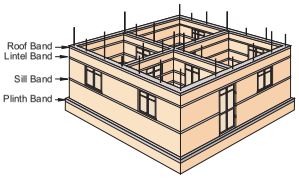


Stone masonry wall

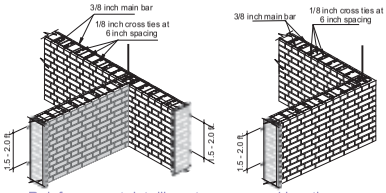


Concrete block masonry wall

Details of RCC bands at Plinth/Sill/Lintel/Roof level



Horizontal bands at different levels of wall

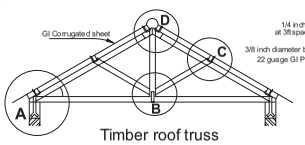


Reinforcement detailing at corners and junctions

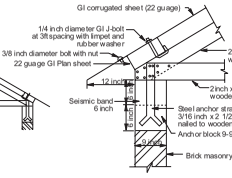
Horizontal bands should be provided throughout the entire wall with minimum thickness of 3 to 4 inches at following locations:

- Plinth Band at Plinth Level (DPC Level);
- Lintel Band above Doors & Windows;
- Roof Band at Wall top;
- Sill Band - below window level (Sill level) - Optional;
- In case of window size more than 3ft, provide min. 6 inches lintel above the window;
- Provide horizontal steel comprising 2 Nos. 3/8 inch (3 sutar) diameter bars with 1/8 inch ties at 6 inches apart or expanded metal mesh at vertical spacing of 18 inch to 24 inch in addition to the horizontal bands at plinth, sill, lintel and roof; throughout the length of the wall.

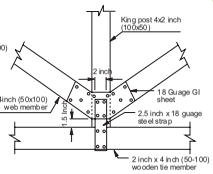
9 Roof



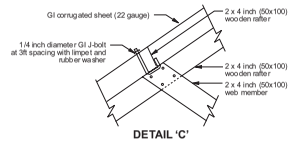
Timber roof truss (for upto 12 ft. span)



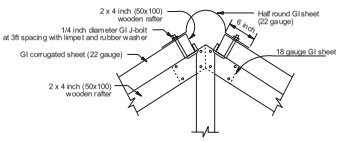
DETAIL 'A'



DETAIL 'B'



DETAIL 'C'



DETAIL 'D'

- Use light roof comprising wooden or steel truss covered with CGI sheets;
- All members of the timber truss or joists should be properly connected as shown in figure;
- Trusses should be properly cross-tied with wooden braces as shown in figure;
- Well seasoned hard wood without knots should be used for roofing, Timber treatment such as use of coal tar or any other preservative can prevent timber from being decayed and attacked by insects.

10 Materials

Cement =1 part Sand = 2 part Aggregate = 4 part

Mix proportion for concrete

Cement = 1 part Sand = 4 part

Mix proportion for mortar

Table 1

Bar dia.	3/8 inch (3 sutar)	1/2 inch (4 sutar)	5/8 inch (5 sutar)	3/4 inch (6 sutar)
Lap length	1.5 ft	2 ft.	2.5 ft.	3 ft.

Mortar: Cement sand mortar should not be leaner than 1:4 (1 part cement and 4 parts sand) for masonry and 1:6 for plaster.

Concrete: The concrete mix for seismic bands should not be leaner than 1:2:4 (1 part cement, 2 parts sand and 4 parts aggregate)

Reinforcement: Reinforcing steel should confirm to Grade 40, having minimum yield strength of 40,000 psi. Plain steel should not be used except for ties. Whenever two bars need to be lapped, minimum lap length as shown in Table 1 should be provided.

This publication has been prepared for assisting in rural reconstruction of earthquake affected areas and is believed to be helpful in assuring the enhanced earthquake safety of rural houses. This will provide easy and ready to use solutions for common rural houses. This construction checklist is for single storey rural housing units, the provisions mentioned here are only for such houses. If the house is other than this, standard provisions for those specific types should be followed. For further details related to the provisions mentioned in this checklist, detail guidelines can be followed.

UN-HABITAT Canada gtz NESPAK SDC USAID FROM THE AMERICAN PEOPLE NSET

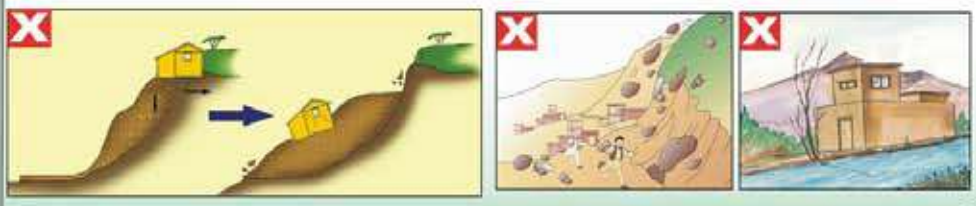
Version 02, August 2006

اپنے نئے گھر کو زلزلے سے مزاحم بنائیں !

لکڑی سے بنائے گئے ڈھانچے اور ہلکی چھت والے گھروں کے لئے ہدایات

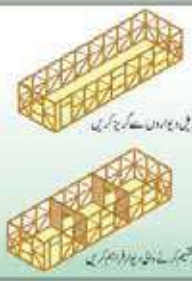
لکڑی کے ڈھانچے سے تعمیر شدہ گھر میں اگر بنیاد اور ڈھانچے کے درمیان جوڑ اچھے ہوں، مضبوط ڈھانچہ اور ترچھے سہارے بہترین ہوں۔ تمام جوڑ اور میخیں کی بھرائی اچھی طرح کی گئی ہو۔ تو ایسا گھر بہت اچھے طریقے سے زلزلے کو برداشت کرسکتا ہے۔ لہذا آپ اس پوسٹر میں دی گئی تعمیری ہدایات پر عمل پیرا ہو کر لکڑی کا استعمال کرتے ہوئے مزاحم گھر بنا سکتے ہیں۔ تاہم ایرا کی ہدایات کے مطابق بنائے گئے بیسمنٹ اور سریے والے گھروں کو فوقیت دیں۔ لکڑی کے گھر صرف ان علاقوں میں بنائیں جہاں بیسمنٹ اور سریہ کٹنا مشکل ہو۔

1 جگہ کا انتخاب



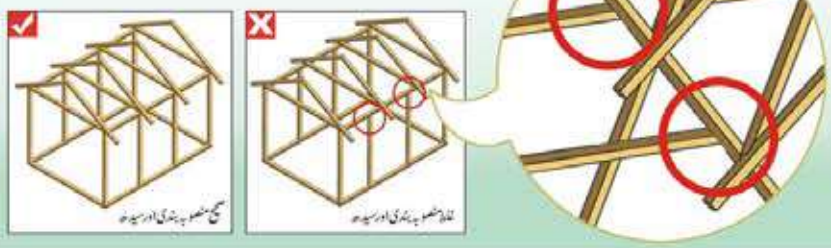
- غیر مستحکم ڈھلوان سے گریز کریں۔
- ایسے علاقے سے گریز کریں جہاں لینڈ سلائیڈز اور چٹانیں گرنے کا احتمال ہو۔
- بھرتی کی گئی نرم زمین پر تعمیر کرنے سے گریز کریں۔
- ڈھلوان کو دریا کے کنارے سے دور رکھیں۔
- ظاہری مستقل، گہرے، واضح اور فطرتاً کم زمینی ضدوحال کے زیادہ قریب تعمیر سے گریز کریں۔

2 گھر کی بناوٹ



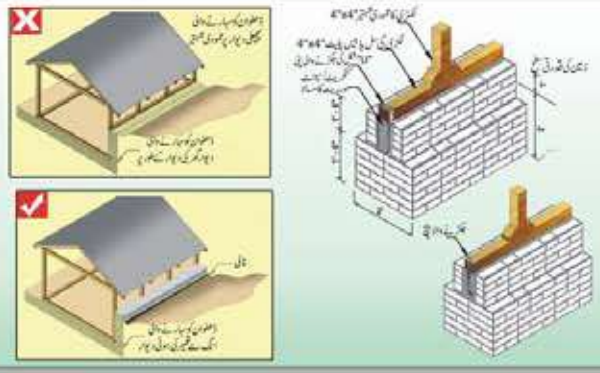
- باقاعدہ بناوٹ والے گھر تعمیر کریں جیسا کہ مربع، مستطیل اور گول۔
- طویل اور کم چوڑائی والے ڈھانچوں سے پرہیز کریں۔
- باکس کی مانند ایسا عمارتی ڈھانچہ بنائیں جس میں فرش، دیواریں اور چھت ایک دوسرے سے اچھی طرح منسلک ہوں۔
- کمرے کے زیادہ سے زیادہ سائز کو 5x15 فٹ تک محدود رکھیں۔
- شہتیر کی اونچائی 8 فٹ تک محدود رکھیں۔

3 معیار اور مہارت



- گھر کا پلان احتیاط سے بنائیں اور ستونوں کے درمیان باہمی فاصلہ ایک جیسا رکھیں۔
- عمارت بنانے سے پہلے زمین کو اچھی طرح ہموار کرلیں۔
- اس بات کی یقین دہانی کرلیں کہ تمام ستون ایک سیدھ میں اور مکمل طور پر گھنے میں ہیں۔
- قینچی نما چھت اور لکڑی کے بالے ستونوں پر رکھے جائیں۔
- مضبوط اور پائیدار غیر گانٹھ کے لکڑی استعمال کریں مثلاً کیل یا پیچ۔
- عمارتی ڈھانچے کو خشک رکھنے کے لیے تمام عمارتی جزیات اور نکاسی آب کا مناسب انتظام کریں۔
- لکڑی پر حفاظتی چیز کا لیپ کریں تاکہ یہ کھوکھلے پن اور حشرات کے حملے سے محفوظ رہے۔

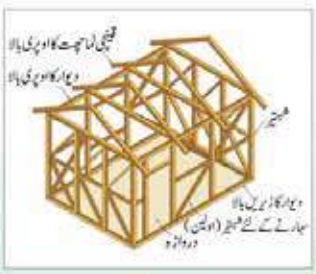
4 بنیاد اور پلنتھ

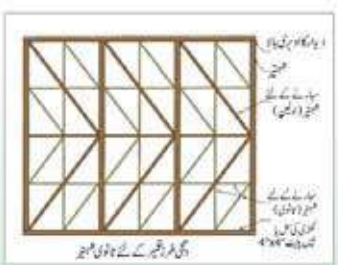


- کنکریٹ یا پتھروں کی (1:4 کے تناسب سے سیمنٹ اور ریت کے مسالے میں) پٹی نما بنیاد مسلسل سے استعمال کریں۔
- مٹی نرم ہونے کی صورت میں بنیادی گہرائی موجود زمینی سطح سے کم از کم 2.5 فٹ نیچی ہونی چاہیے۔ پتھریلی سطح میں یہ گہرائی کم از کم 1.5 فٹ ہونی چاہیے۔
- بنیادی چوڑائی کم از کم 2 فٹ رکھیں۔
- پلنتھ لیول زمین کی قدرتی سطح سے کم از کم 1 فٹ اوپر ہونا چاہیے 2 فٹ سے اوپر پلنتھ لیول رکھنے سے اجتناب کریں۔
- ڈھلوان سے متصل تعمیر نہ کریں۔ لیکن جہاں کہیں ایسا کرنا ناگزیر ہوں وہاں گھر کے پیچھے ڈھلوان کو سہارنے کے لئے اس سے متصل ایک دیوار بنائیں اور اس دیوار کو گھر کی دیوار کے طور پر استعمال نہ کریں۔

5 لکڑی کا ڈھانچہ

لکڑی کا ڈھانچہ درج ذیل ارکان پر مشتمل ہونا چاہیے۔

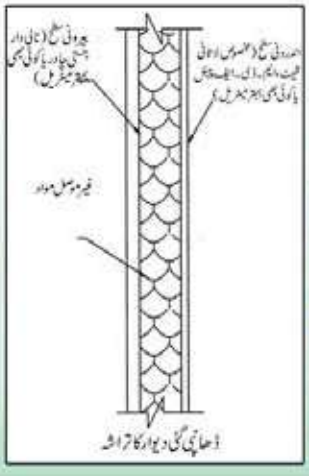




- "4x4" کے عرضی تراشے والی لکڑی کی ایسی پلیٹ کو بنیاد میں پلنتھ لیول پر اچھی طرح جوڑیں اور اس مقصد کے لئے بہترین لکڑی استعمال کریں۔
- "4x4" کے عرضی تراشے والے لکڑی کے عمودی شہتیر کو ایس پلیٹ سے جوڑیں اور ان شہتیروں کے درمیان فاصلہ 4 سے 6 فٹ تک رکھیں۔
- لکڑی کے شہتیروں کو آپس میں جوڑنے کے لئے عمارت کے اطراف میں لکڑی کی مسلسل افقی پٹیاں شہتیروں کے اوپری حصے پر جوڑیں ان پٹیوں کا سائز "4x4" ہونا چاہیے۔
- سہارنے کے لئے ترچھے شہتیر کم از کم "2x4" کے عرضی تراشے کے ہونے چاہیں اور ثانوی اہمیت کے ترچھے شہتیروں کا سائز کم از کم "1x4" ہونا چاہیے۔ ثانوی اہمیت والے ترچھے شہتیر کی طرورت صرف پتھروں سے بھرائی والی دیوار میں ہے۔ (دگی تعمیر) ثانوی اہمیت کے سہارے کے لئے ترچھے شہتیر کی مثال شکل میں واضح ہے۔ تاہم برت سے دوسرے طریقے بھی اپنائے جاسکتے ہیں۔
- قینچی نما چھت اور اس کے تمام ارکان کو عمودی شہتیروں پر رکھیں اور اوپری پٹیوں کے ساتھ مضبوطی سے جوڑیں۔ (ہدایت نمبر 9 ملاحظہ کریں)۔

6 بھرائی اور حفاظتی سطح

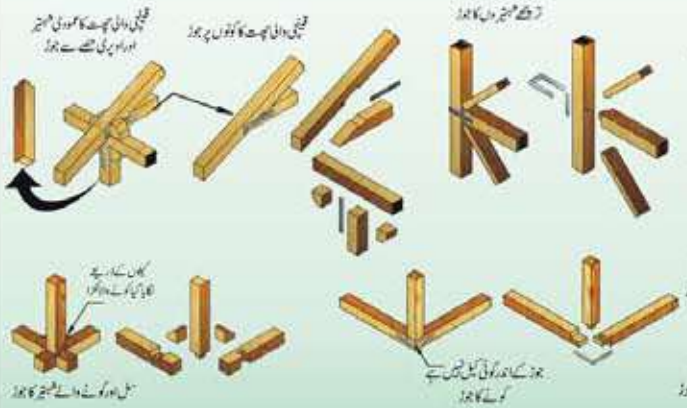
- دیواروں کی اندرونی اور بیرونی حفاظتی سطح کے لئے مقامی دستیاب مٹیریل استعمال کریں اور اسے کیلوں اور پیچوں سے اچھی طرح جوڑ دیں۔ لکڑی کے تختوں کو اس مقصد کے لئے استعمال نہ کریں۔
اندرونی اور بیرونی حفاظتی سطحوں اور دیوار کے درمیان خلاء کو کسی مناسب غیر موصل مواد سے بھر دیں۔



- حفاظتی سطح کے بجائے لکڑی کے عمارتی ڈھانچے کو پتھروں سے بھی بھرا جا سکتا ہے (دیکھی تصویر) جس کی موٹائی "4 سے زیادہ نہ ہو۔ لکڑی کے تمام ارکان کی چوڑائی دیوار کی موٹائی کے برابر رکھیں تاکہ پتھر لکڑی کے فریم میں اچھی طرح مقید ہو جائیں۔ تمام پتھروں کا سائز ایک جیسا ہونا چاہیے اور سیمنٹ اور ریت یا مٹی کے مسالے میں اچھی طرح بھرے ہوئے ہونے چاہئیں۔

پتھروں کی بھرائی کے معیار کو بہتر بنانے کے لئے دیوار کے اندرونی اور بیرونی اطراف پر دھاتی جالی کا استعمال ضرور کریں جو کہ لکڑی کے ڈھانچے اور سہارنے والے ترچھے شہتیروں سے کیلوں کے ذریعے مضبوطی سے جوڑی گئی ہو۔

7 لکڑی کے ڈھانچے میں جوڑوں کی تفصیل



- ڈھانچے کے دوران عمارتی ڈھانچے کی اچھی کارکردگی کے لئے اسکے تمام ارکان کو آپس میں اچھی طرح سے جوڑیں۔
- بنیاد سے ساتھ لکڑی کے ڈھانچے کی اچھی طرح پیوستگی کے لئے درج ذیل میں سے کسی ایک طریقے کو اپنائیں۔ (شکل کے لئے ملاحظہ ہو نمبر 4 اختیار کریں)
- 1/2 انچ کے "J"، "L" شکل کے 15 انچ لمبے چوڑی دار بولٹ 6 سے 8 فٹ کے باہمی فاصلے پر کم از کم 9 انچ بنیاد میں پیوست کریں اور لکڑی کی نچلی پٹی یا سل کے ساتھ فٹ اور واشر کے ساتھ اچھی طرح کس دیں۔ لکڑی اور واشر کے درمیان سٹیل کی ایک پلیٹ بھی مہیا کریں۔
- اگر بولٹ شہتیر ہوں تو 1/8 سے 13/16 انچ تک کی موٹائی اور 1 سے 1.5 انچ چوڑائی کی U شکل کی دھاتی پٹی بنیاد میں پیوست کریں۔ اس دھاتی پٹی کو سل یا نچلی پلیٹ کے گرد اچھی طرح موڑنے کے بعد اچھی طرح مضبوطی سے کیلیں اور سل یا نچلی پلیٹ کے اوپر اور اطراف سے پیچوں اور کیلوں سے جوڑ دیں۔
- تمام افقی اور عمودی جوڑوں پر لکڑی کا تکونہ ٹکڑا یا ترچھا سہارا مہیا کریں اور کناروں کو کاٹ کر جوڑ کے ساتھ اچھی طرح فٹ کر دیں۔
- ہر جوڑ کو کیلوں اور پیچوں کی مدد سے مضبوط بنائیں۔
- جہاں کہیں بھی کیلوں کا استعمال کرنا ہو تو ان کیلوں کی لمبائی اتنی رکھیں کہ وہ جوڑ کے دوسری طرف سے کچھ باہر نکل آئیں۔ پھر اس باہر نکلی ہوئی زیادہ لمبائی کو اس جوڑ کے عمودی رخ پر موڑ کر مزید مضبوط کر لیں۔
- ہر جوڑ پر "1.5 x 3/32" کی سٹیل کی پٹی استعمال کی جا سکتی ہے جس کی دونوں طرف کم از کم دو کیل لگائے جائیں۔ اس پٹی کو زنگ سے بچانے کے لئے پینٹ کر لیں۔
- سہارنے کے لئے ترچھے شہتیر (بریسز) مناسب طریقے سے کاٹ کر عمارتی ڈھانچے کے ساتھ برابر کر دیں اور افقی اور عمودی ارکان سے بہتر جوڑ کی یقین دہانی کر لیں۔

8 دروازے اور کھڑکیاں

- دروازوں کو کھڑکیوں کو دیوار کے کونے سے کم از کم 2 فٹ دور رکھنا چاہیے۔
- دروازوں اور کھڑکیوں کی کل لمبائی کسی ایک دیوار کے لئے دیوار کی نصف لمبائی سے زیادہ نہیں ہونی چاہیے۔
- دروازوں اور کھڑکیوں کا باہمی فاصلہ 2 فٹ سے کم نہیں ہونا چاہیے۔
- لکڑی کے ڈھانچے میں دروازوں اور کھڑکیوں کو چاروں اطراف مناسب طریقے سے رکھیں اور اس بات کی تصدیق کر لیں کہ یہ ڈھانچے سے جدا نہیں ہیں۔

9 چھت

- ایسی ہلکی چھت کا انتخاب کریں جس میں لکڑی کی قینچی والی چھت کا استعمال ہو اور یہ ٹائل دار جستی چادر سے ڈھانپی گئی ہو۔
ڈھلوانی چھت کو بالنسبت تکونی چھت کے زیادہ ترجیحی دینی چاہیے۔
- لکڑی کی قینچی والی چھتوں کو ترچھے شہتیروں سے اوپر اور نیچے سے اچھی طرح سے باندھنا چاہیے۔
- زیادہ سے زیادہ مضبوطی کی یقین دہانی کے لئے چھت کے اوپری حصے کا اسکی چوٹی کے ساتھ مضبوط جوڑ ہونا چاہیے۔
- بارش کے پانی سے بچاؤ کے لئے چھت کو کم از کم 1.5 سے 2 فٹ تک دیواروں سے باہر کو بڑھائیں۔
- چھت کی ڈھلوان 20 سے 35 درجے رکھیں اور یہ ڈھلوان برفانی علاقوں میں مزید زیادہ کر دیں۔

10 غسل خانہ اور کھانا پکانے کی جگہ

- نمی اور آگ کے خطرات کو کم کرنے کے غرض سے غسل خانہ اور کھانا پکانے کی جگہ کو گھر کی اصل عمارت سے الگ بنایا جائے۔
- غسل خانہ، کھانا پکانے کی جگہ اور آتش دان کو نمی اور آگ کے اثرات سے بچانے کے لئے عمارتی ڈھانچے پر دھاتی جالی لگا کر سیمنٹ اور ریت کے مسالے کا پلستر کر دینا چاہیے۔
- آگ سے بچاؤ کے لئے کیمیکل کا استعمال بھی کیا جا سکتا ہے۔ بشرطیکہ خرچ زیادہ نہ ہو۔

Recommendations for ERRA approved Dhajji Timber Frame House Construction.

Not all types of timber frame are compliant. The frame must be Dhajji type to the following standards. The Dhajji frame is stronger than other timber and stone houses if the frame is well fixed and the wall sections are small.

Kacha ✗

Big timber
No bracing
Thick stone walls
Flat heavy mud roof

Mixed Material ✗

4ft walls
Plywood / Tin / Dhajji above

Dhajji Timber Frame ✔

Small timber sizes
Bracing in small sections
Frame goes from ground to roof
Small stones and mud infilled thin wall
Light CGI roof

Main Standards of Dhajji for Compliance

Foundation

- Plinth may be stone or concrete
- Frame should be attached to the plinth, with bolt or strap.
- Dasa (Base Plate) should be kept dry above the ground.

Roof

- The roof should be lightweight (CGI).
- Rafters should be well fixed to the wall plate.
- The roof should extend 1.5 feet beyond the wall to protect from rainwater or use verandahs.
- Hipped roofs are better than gables.

Frame

- Dasa, posts and wallplate should be fixed well together.
- Main frame of timber should be 4 inch x 4 inch.
- Frame should be divided in equal sections, maximum 6ft post to post.
- Doors and windows should have lintel and sill frames.

Infill

- Stone and mud is recommended for infill.
- Other materials like straw, sand, cement, lime, may be added.
- Smaller stones are best.

Bracing

- Different bracing systems are allowed.
- Smaller sections are recommended.

- Bracing should be symmetrical or balanced with pieces going in both directions.
- Bracing is essential to make the wall strong.

General Standards

- Max room size 15 x 15ft.
- Max height of post 8 ft.

Canada SDC USAID UN-HABITAT

How to make 1 Dhajji Room 15 ft x 12 ft

1. Plinth

- Foundation should be minimum 1½ ft deep depending on soil conditions.
- Plinth should be minimum 1 ft above ground. Avoid a very high plinth.
- Use a bolt 3ft long ½ inch diameter (4 sutar) to fix the Dasa to the foundations.
- Space the bolts at every 6 ft. Do not fix the bolt at joints.
- Fix the bolts in sand cement mortar or concrete.

2. Base Plate

- The corner joints for Dasa and wall plate are the most important connections in the frame and need to be strong.
- Dasa should be made from the best available timber.
- To keep Dasa dry, keep it above the ground level.

✔ Strong

✘ Weak

3. Frame

- Fix the posts at regular spacing.
- Doors and windows should have a frame around all sides.
- Bracing pieces should be the same width as the wall. 4 inch wall, needs 4 x 3, 4 x 2, 4 x 1 bracing, to hold the infill properly.
- Add extra triangular pieces to make the frame stronger.

4. Wall Plate

Connections

- The strength of the house depends on the strength of the connections.
- Metal straps give additional strength to joints.
- Screws work better than nails in tension.
- Timber joints make the frame stronger.
  Eg: Kashmiri joint for wall plate.

5. Bracing & Infill

- Infill should be made with small stones and mud in equal proportion.
- Infill can have straw, pine needles, lime, cement or other material to make it stronger.
- Bracing should be well fixed.

Large Stones ✘

Small Stones ✔

Good use of Timber

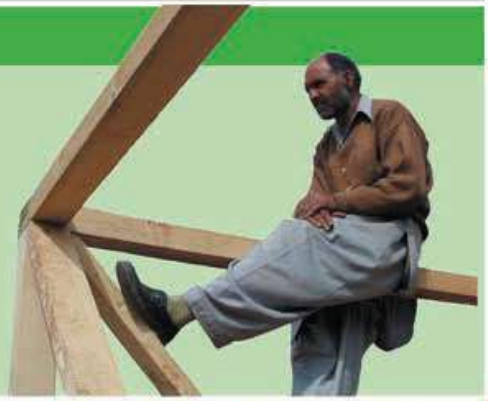
- **All timber should be preserved with eg: mobiloil treatment.**
- **Timber should be kail or pine without knots.**
- **Young and fresh timber must not be used.**
- **Be careful to install all electrical fittings safely in timber houses.**

Quantity of Timber Required for 1 Room

1 Room in Dhajji Construction 15 ft x 12 ft

	Size	Length	Volume
Wall Frame			
Dasa, Wall Plate and Main Posts.	4 x 4	188 ft	
Frame	4 x 2	272 ft	
Dhajji infill pieces	4 x 1-1½	360 ft	50 cubic ft
Roof			
Trusses or rafters	4 x 2	132 ft	13 cubic ft
Battens	3 X2	128 ft	
Window and Door			3 cubic ft

Note:
These calculations are only for 1 Room, you can construct any number of rooms according to your needs.

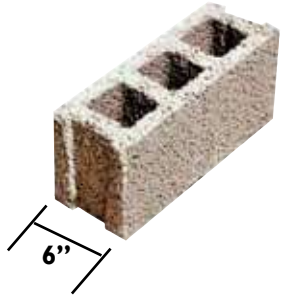


- Training and guide lines for how to construct a Dhajji House and standard for ERRA compliance are available from your local HRC.
- If you have already constructed your house in Dhajji system you may be eligible for financial assistance, if it meets the required standards. Please check with your local HRC

مجھے بیرونی بینڈ کی ضرورت کیوں ہے؟

مسئلہ نمبر۔۱

"6 بلاک زلزلے میں زیادہ مضبوط نہیں ہوتے اور کسی بڑے زلزلے میں گھر کا گرنا یقینی ہے۔



مسئلہ نمبر۔۲

گھر میں لنٹل بینڈ موجود یا متسلسل نا ہونے کی وجہ سے دیواروں کا آپس میں مضبوط جوڑ نہیں بنتا اور دورانِ زلزلہ دیواریں گر جاتی ہیں۔

حل

لنٹل کی سطح پر ایک اضافی بیرونی بینڈ دیواروں کو آپس میں جوڑے رکھے گا اور اس طرح کمزور دیواروں کو مضبوط کرے گا۔

یہ بینڈ آپ کے گھر کو محفوظ بنانے کا بہترین اور سستا طریقہ ہے۔

مجھے کن چیزوں کی ضرورت ہے؟

مٹیریل

سریا: 3 سوتر تقریباً 555 فٹ یعنی تقریباً 95 کلوگرام
2 سوتر تقریباً 400 فٹ یعنی تقریباً 32 کلوگرام
= 127 کلوگرام

سیمنٹ: 7 بیگ ۔ عام پورٹلینڈ (Portland) سیمنٹ

ریت: 17.5 مکعب فٹ (cft) (14 بیگ کے برابر)

بجری: 35 مکعب فٹ (cft) (28 بیگ کے برابر)

1:2:4 کنکریٹ

شٹرنگ: 210 مربع فٹ (چوڑے لکڑی کے پھٹے)
210 مربع فٹ (چوڑے لکڑی کے پھٹے، نچلی سطح کے لئے)

لوہے کی تار: تقریباً 5 کلو

اوزار (Tools)

سوراخ کرنے کے لئے، اگر ڈرل مشین موجود ہو تو "8 لمبے برمے کا استعمال کریں۔ دوسری صورت میں کنکریٹ میں لگنے والی لمبی کیلیں یا چھینی کا استعمال کریں۔

سریا موڑنے کے لئے باری (۲، ۳، ۴ سوتر)، ہتھوڑا، پلاس، پیلچہ، کرنڈی، سَنی، گٹر، وغیرہ۔

درکار وقت اور مزدور

ایک مستری (کنکریٹ کے کام کے لئے)، ایک سٹیل فکسر (سریے کے کام کے لئے)، اور ایک کارپینٹر (شٹرنگ کے کام کے لئے) ۳ سے ۴ دنوں میں مکمل کر سکتے ہیں۔

دو کمروں کے گھر پر کتنی لاگت آئے گی؟

کُل لاگت (مٹیریل + مزدوری) تقریباً

Approx. Rs. 18,000/-

مزید معلومات کیلئے مندرجہ ذیل تعمیراتی تربیتی مراکز 's (HRC) سے رابطہ کیجیے:

آزاد جموں کشمیر: مظفر آباد HRC۔ (058810-34994-5)، ہٹیاں HRC۔ (058830-42589)، پٹکہ HRC۔ (058811-42944)، راولاکوٹ HRC۔ (058710-81096)، باغ HRC۔ (058720-72529)، دھیرکوٹ HRC۔ (0992-506302)، حویلی HRC۔ (058720-32321)، عباس پور HRC۔ (058710-52073)

شمالی مغربی سرحدی صوبہ: بٹگرام HRC۔ (0997-311900)، بالاکوٹ HRC۔ (0997-360656)، آبل HRC۔ (0997-330585)، بنہ HRC۔ (0997-319388)، ایبٹ آباد HRC۔ (0992-383860)

مجھے بیرونی بینڈ لگانے کے لئے کیا کرنا ہوگا ؟

دیوار کی سطح کو صاف کر کے، دیوار کے دونوں جانب درزیں کھرچیں اور ہر ایک فٹ کے فاصلے پر سراخ کریں۔ (بیرونی بینڈ لنٹل لیول پر لگانا ہوتا ہے، اور اگر لنٹل بینڈ پہلے سے موجود ہو تو بیرونی بینڈ موجودہ لنٹل بینڈ کے اُوپر والے ردے میں لگائیں)

لمبائی کے رُخ 3 سوتر کے دوسریے لگائیں اور دیوار کے دونوں جانب سے دو سوتر کے U شکل کے رنگ (پہلا دیوار کے باہر سے اندر کی جانب اور دوسرا دیوار کے اندر سے باہر کی جانب) دیوار سے گزار کر لگائیں۔ U شکل کے رنگ کو بائنڈنگ وائر (لوہے کی تار) کی مدد سے اچھی طرح باندھیں۔

▲ آپ بیرونی بینڈ کی بھرائی کیلئے شٹرنگ بھی لگا سکتے ہیں **یا**

صرف نیچے سے لکڑی لگا کر کرنڈی کی مدد سے بھی کنکریٹ کر سکتے ہیں۔ ▼

بینڈ میں 1:2:4 کنکریٹ کرتے وقت اس بات کو یقینی بنائیں کے سریا پوری طرح کور ہو جائے۔

◀ بیرونی بینڈ کے ساتھ، بیرونی ٹانکے آپکے گھر کو اور بھی زیادہ محفوظ بنا دیتے ہیں۔

اپنے نئے گھر کو زلزلے سے محفوظ بنائیں!

اینٹوں/ بلاکوں کی چنائی اور آر سی سی کے ڈھانچے سے جکڑے ایک منزلہ مکانات کی تعمیر کے لئے ضروری ہدایات

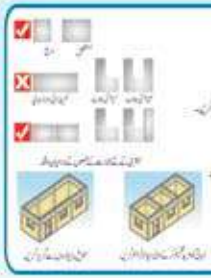
UN-HABITAT SDC USAID Canada gtz NESPAK ERRA

۱ آر سی سی ڈھانچے کی تعمیر سے پہلے اور بعد کی چنائی کا فرق

- آر سی سی ڈھانچے سے پہلے کی چنائی
- آر سی سی ڈھانچے کی تعمیر کے بعد کی چنائی

۲ جگہ کا انتخاب

۳ گھر کی بناوٹ

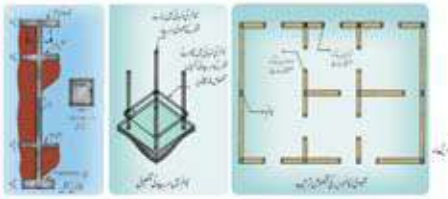


۴ آر سی سی ڈھانچے کے ارکان

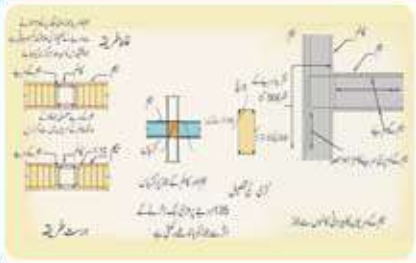
۵ بنیادیں

۶ بیم

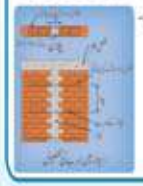
۷ کالم



۸ بیم اور کالم کا جوڑ

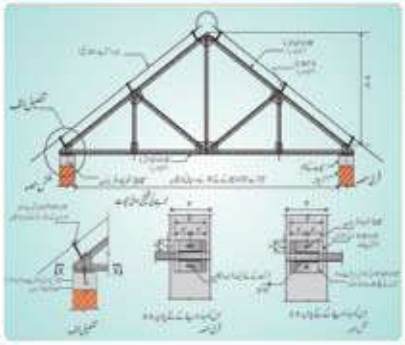


۹ دیواریں اور چھت



۱۰ میٹریل/ معیار اور مہارت

۱۱ چھت کی تفصیل



۱۲ تعمیر کے مراحل

Bhatar construction

Timber reinforced masonry

An illustrated guide for craftsmen

Bhatar is a traditional construction system consisting of stone masonry with horizontal timber reinforcement bands.
These bands (with cross pieces) act as seismic bands which prevent the walls from falling apart in an earthquake.
Proper connection of the timber elements is critical for safety.

Contemporary Bhatar construction
Tarand - NWFP - Pakistan

Traditional Bhatar construction
Besham Fort (c. 1750) NWFP - Pakistan

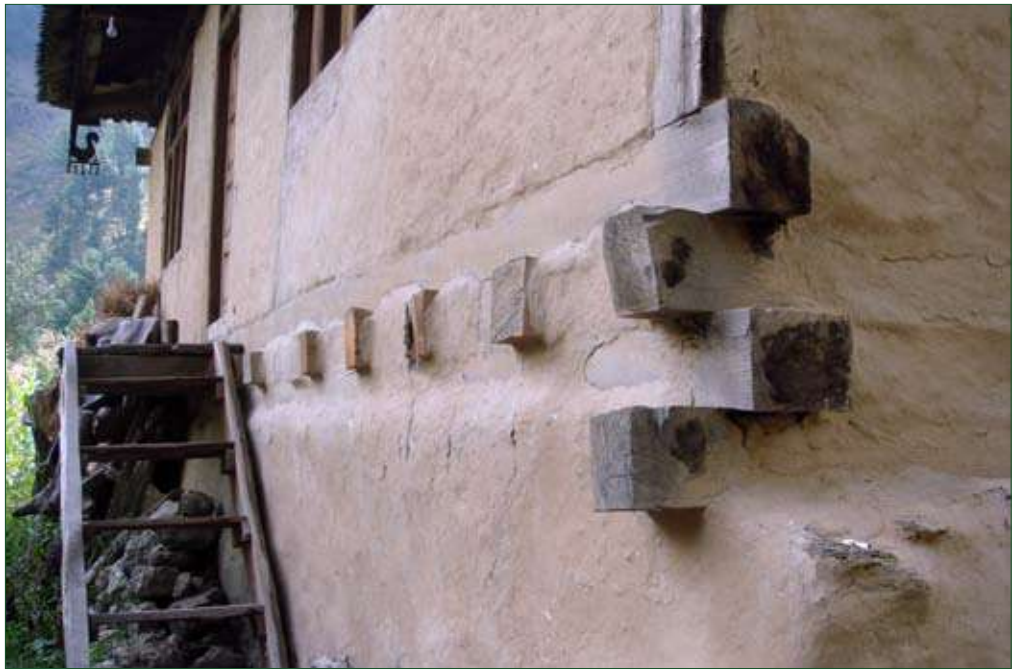
Leepa

Guidelines for the compliant construction of Leepa-type timber post and beam houses

Leepa

Plinth and back wall

A good plinth protects the base plate and ensures it dries quickly.



Plinth

- The plinth should be stable and well packed.
- The base plate and frame should be kept dry.
- The plinth may be raised above ground level, for protection from snow. In this case the ground floor should be maximum 8 ft high.
- The plinth or back wall may be constructed as retaining walls, but should not retain a height greater than 8 ft.

Plinth and back wall

Traditional practice is to have back wall of stone.

RCC bands can strengthen the wall.

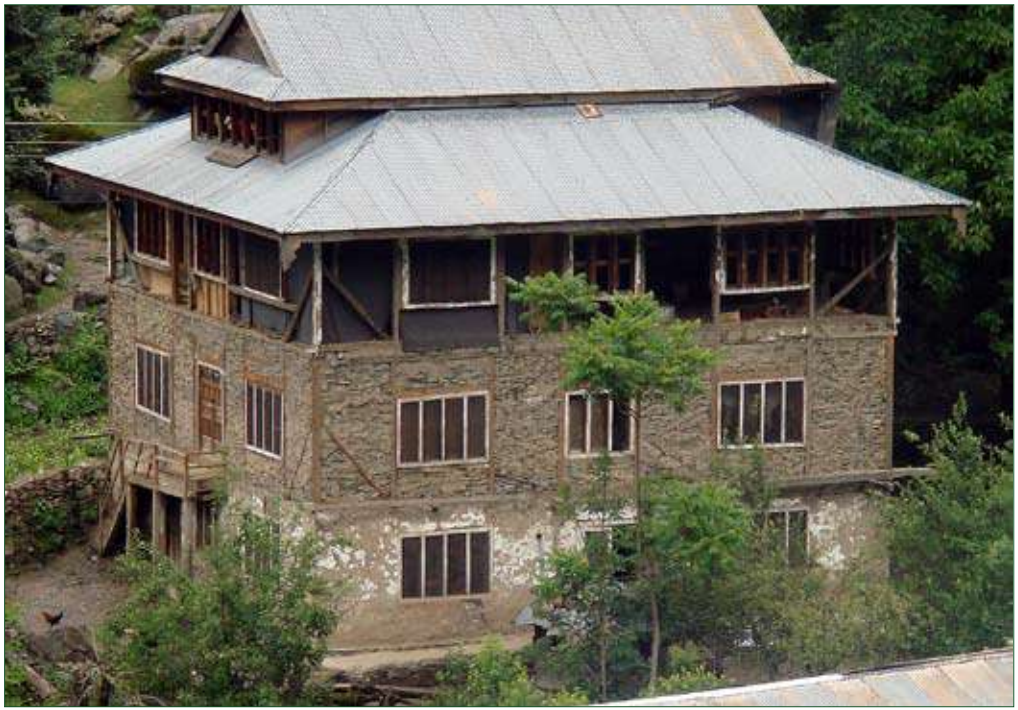
Timber posts inside and separate to the wall. RCC bands between well laid dry stone masonry.

Back wall

- A rear wall may be constructed of good quality stone masonry with through and corner stones.
- The wall should be min 24 inches at top and wider at base, the wall may be stepped or sloped on rear side.
- The posts supporting the upper floor must be separate and inside the wall.

Upper storey frame is fixed to top of the wall.

Leepa Configuration



Configuration / Plan

- The building should be symmetrical and balanced.
- The best plan shape is square.
- The traditional layout of 3 equal bays wide x 3 equal bays long is recommended.
- The external walls should be balanced in weight, with all sides equal.
- The building length should not be greater than 3 times its width.

Core and stiffness

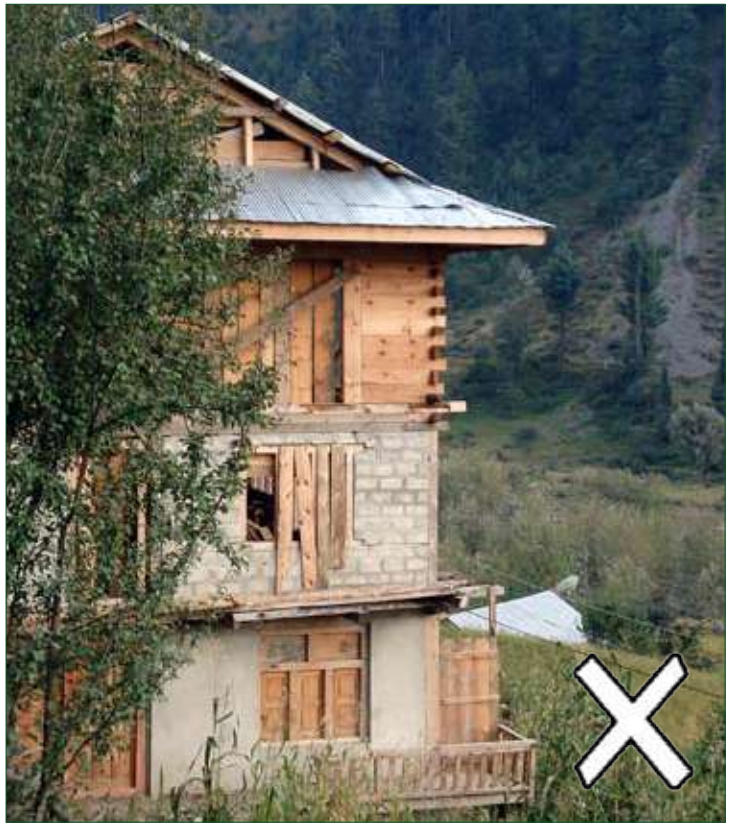
- There should be full height walls provided in both plan directions.
- Load bearing walls should be placed over each other.

Configuration

More than 1 storey retaining wall. Plan area not same for each storey.

Section

- The building should be heavier in lower storeys and lighter in upper storeys.
- Max storey height 10 ft. Storey heights should be equal.
- Stone basement storey height max 8 ft. Stone masonry walls should follow Bhatar construction principles.
- The total building height should not be greater than the plan length.



Building height greater than length or width.

Leepa

Timber Frame Sizes

Horizontal

- Each storey should be a box with its own top and bottom plates and posts.
- The building is a series of separate boxes stacked on top of each other.
- Base plate should be provided under all posts and wall plates above all posts.
- Base and wall pates minimum size 6 x 5 inches.
- Plates should be long continuous good quality seasoned timber.
- Floor joists should be spaced at maximum 2 ft cc and may be overlapped over the floor beam.
- These timber sizes are good for double storey construction.

Timber Frame Sizes

Vertical

- Posts should provided at maximum 6 ft spacing.
- Posts min section size: 6 x 5 inches.
- Posts should be made of a single piece.
- Where there are larger clear spans the posts should be larger section or closer spaced.
- All timber sizes recommended are good for double storey construction.

Walls and openings

Walls

- External walls may be constructed of load bearing timber planks, timber boarding or dhajji infill.
- The maximum unrestrained wall length is 15 ft.
- The building should be divided into small regular rooms.
- The walls should be constructed of dhajji infill in lower storeys and solid timber planks in upper storeys.

Floors

- Floors and ceilings add stiffness to the frame.
- It is recommended to use solid floor boards minimum 3/4 inch thick.

Verandahs

- Verandah frames may be constructed of smaller timber sections. The frames may be stiffened with balustrades or other infilled sections.
- Knee braces can also be used from the post to the wall plate.

Walls and openings

Distance from the corner to opening must be minimum 5 ft.

Large opening

Large window frames should have sub frames like this.

Corners and Openings

- Openings should not be greater than 25% of the overall wall area.
- Plan length of the wall between the corner and nearest opening should not be less than 5 ft.
- Plan length between any other two openings should not be less than 2.5 ft.
- Openings should not be larger than 5 ft wide.
- Openings should distributed equally in the plan.
- Openings should be fully framed.
- Frames greater than 2 ft wide should have sub frames.

Joints and Framing

Vertical

- Posts should be fixed to base plates and wall plates with mortice and tenon joints.
- Joints should also be nailed.
- In new construction the timber sizes have been reduced making it more difficult to make a correct joint.

  Timber section sizes should be minimum 5 x 6 inches in the main frame.
- Tenon size and location should be correct to avoid breaking off.

Joints and Framing

Horizontal

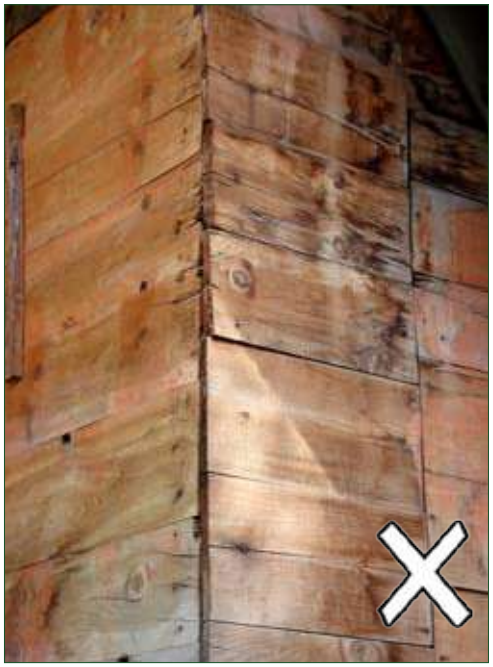
- Base and wall plates should be connected at the perpendicular joint with an overlap cross halved joint.
- Bases and wall plates should be spliced with a scarf joint or Kashmiri joint. These joints should be pegged.
- In new construction the horizontal joints are butt or lap jointed, these need to be improved.
- The timber section used in the base plate should be best quality seasoned heartwood. It carries the load of the building and is most exposed to weathering.

Leepa

Joints and Boarding

Joints and Boarding

Boards ends not protected, nailed at weak location.



Thin boards may split or warp, nailed at weak location.

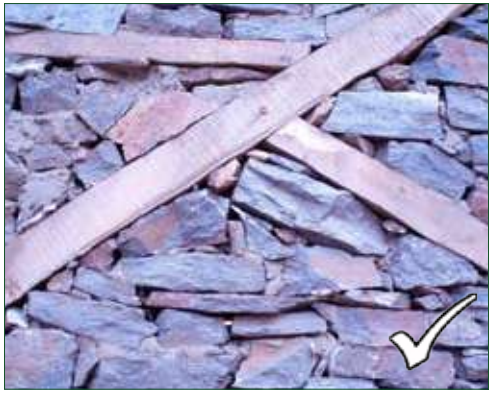
Timber Boarding

- Use timber planks of approximately 1 1/2 inches thick to make timber load bearing walls, or as cladding to a timber frame.
- The boards should be interlocked at the corners to provide excellent earthquake resistance.
- The boards should be fixed to each other by pegging to the board above and below.
- The fixing method and board thickness ensures the boards do not warp or weather..
- At intermediate posts, boards should be inserted in grooves for better fixing.

- Boards should not be cut off without proper interlocking. This is a weaker detail.
- Boards should not be nailed close to the end grain weakening the planks at the corners.
- Boards overlapped but not interlocked at the corners are not sufficient.
- Thinner boards and poor fixing by face nailing means increased warping and weathering.
- Boarding should not be used as only short wall lengths.

Leepa

Dhajji and Infill



Dhajji

- Previous construction used well packed dhajji infill masonry of minimum 6 inch usually 8-10 inch thickness.
- Flat boards were used between the main posts to hold the infill and brace the frame.
- The infill performed well in the earthquake, with minor loosening or falling out of infill stones. The mortar should be weak.
- The earthquake energy is shed by the Dhajji. This protects the main timber frame.

Dhajji and Infill

In situ concrete infill.

Even small areas of in situ may weaken the frame.

Masonry with sand cement mortar.

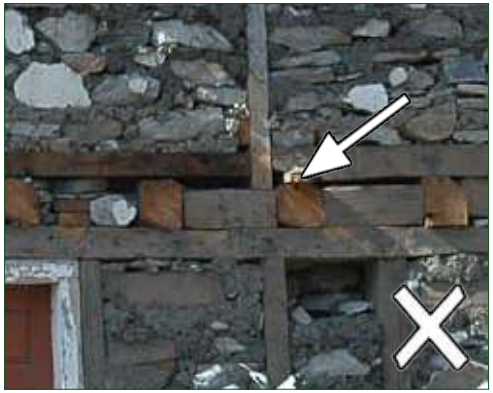
New Infill

- In new construction, in situ concrete, stone masonry with sand cement mortar and concrete blocks are being used.
- All of these are too stiff and will not perform as well as weaker Dhajji infill. They may fall out as entire panels or break the timber frame.
- They also provide no timber bracing for the timber frame.
- Stone masonry laid dry or with weak mortar may not be used without Dhajji bracing in upper floors.
- Sand cement mortar is not good for timber durability.

Stonework with no bracing.

Leepa

Mixed Construction



Base plate not continuous, posts fixed on wall plate below.

Platform Frame

- Each storey should be constructed as a box with its own base plate, posts and wall plate. This is a platform frame.
- In new construction some houses do not have continuous plates, and posts are bearing on the wall plate of the storey below.
- The plates are necessary to act as continuous bands and to allow each storey to act independently.

Mixed Construction

RCC column fixed to timber beam. This is not permitted.

RCC beam has no connection to the timber posts. The frame is not well connected. Framing must be all timber

RCC frame members

- RCC beams and columns should not be used in combination with timber framing.
- They do not have proper connections with the timber and they will not perform well in earthquakes, as they are a different weight, and unrestrained.

Insulation

- Use of heavy mud or concrete in the floors or roof for insulation should be discouraged. It adds to the load of the building. The roof should be light.
- Lightweight insulation options should be developed.

Heavy insulation in the roof is dangerous.

APPENDIX - B

APPENDIX - B

TECHNICAL DRAWINGS FOR REMEDIAL MEASURES BY NESPAK

B-1: Strengthening of large openings

B-2: Adding external bandages

B-3: Strengthening weak masonry

B-4: Improvement of connections

B-5: Improving anchorage

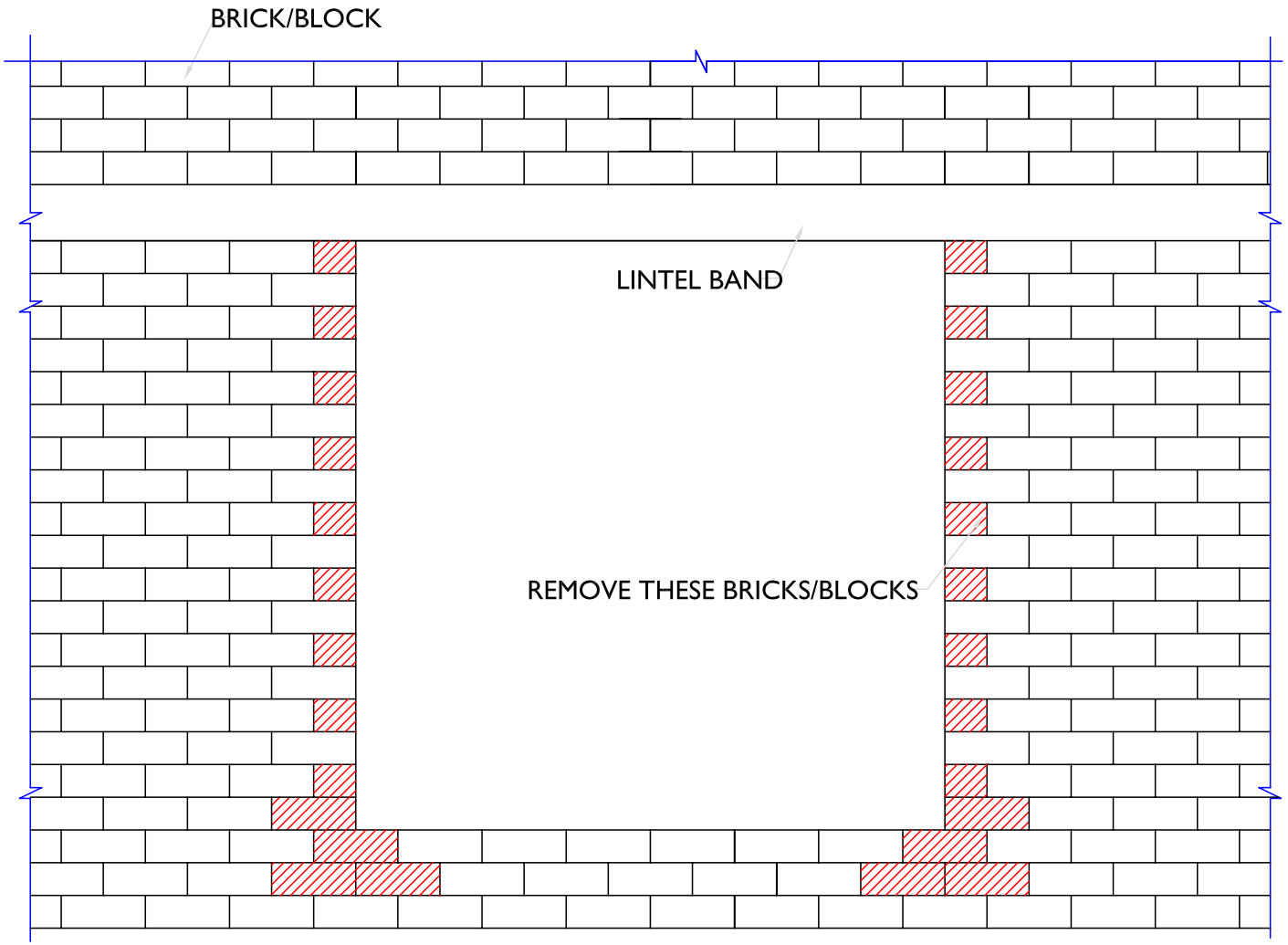
B-6: Connecting cross walls: Option - A

B-7: Connecting cross walls: Option - B

B-8: Strengthening of undersize foundations

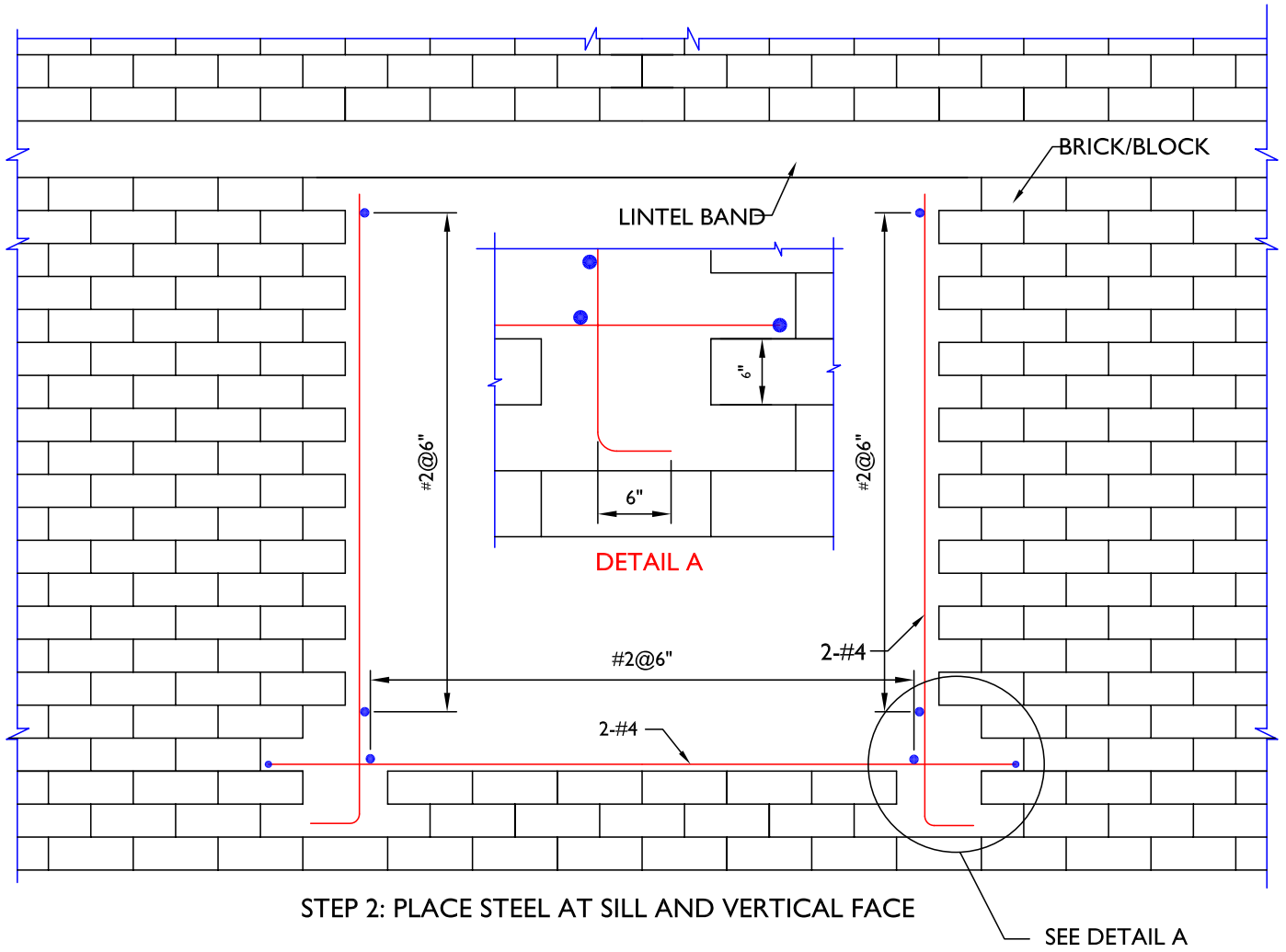
B-9: Connecting walls of different construction materials

I Strengthening of large openings



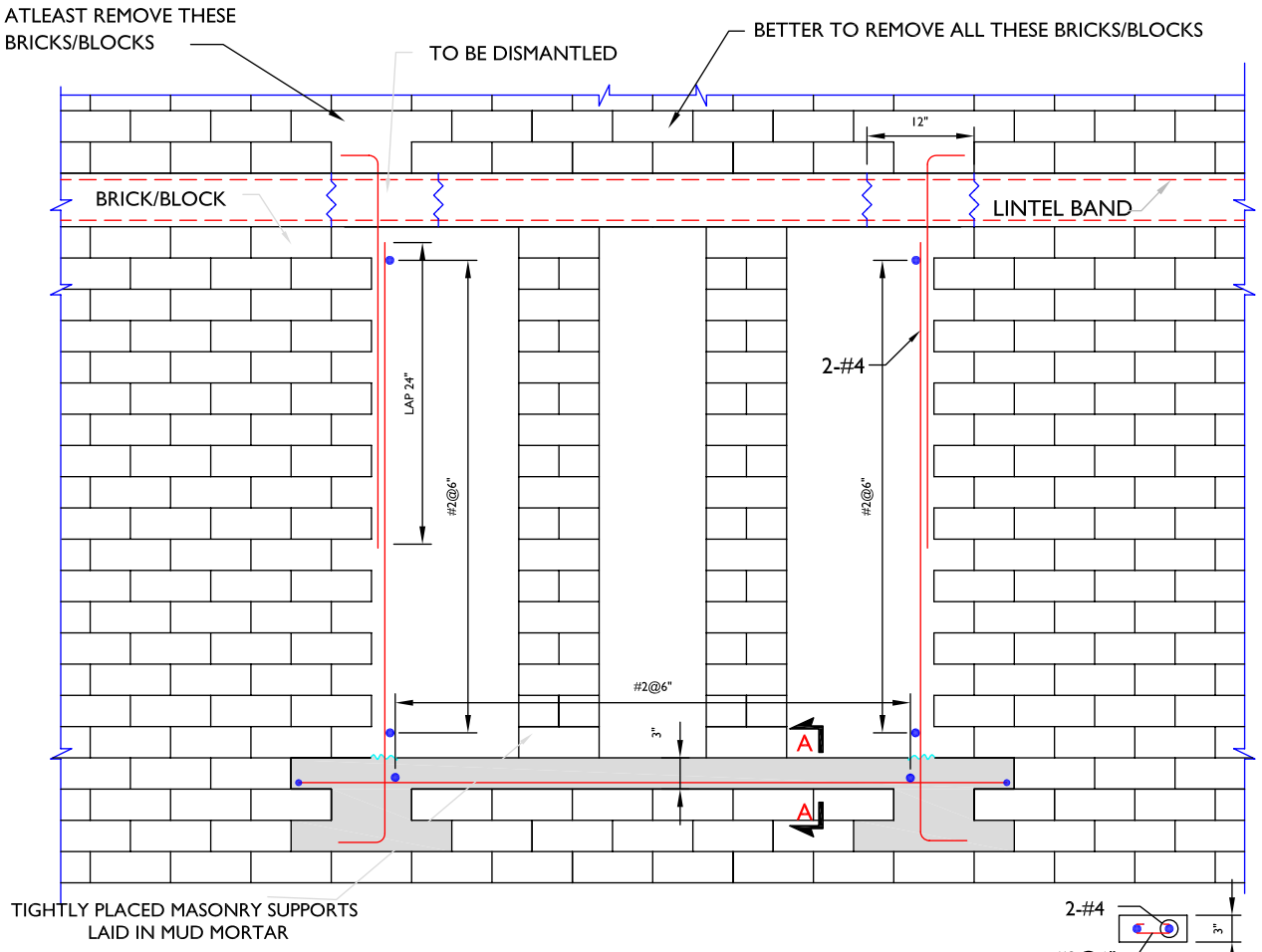
STEP 1: REMOVE BLOCKS AND PROVIDE TOOTHING

I Strengthening of large openings



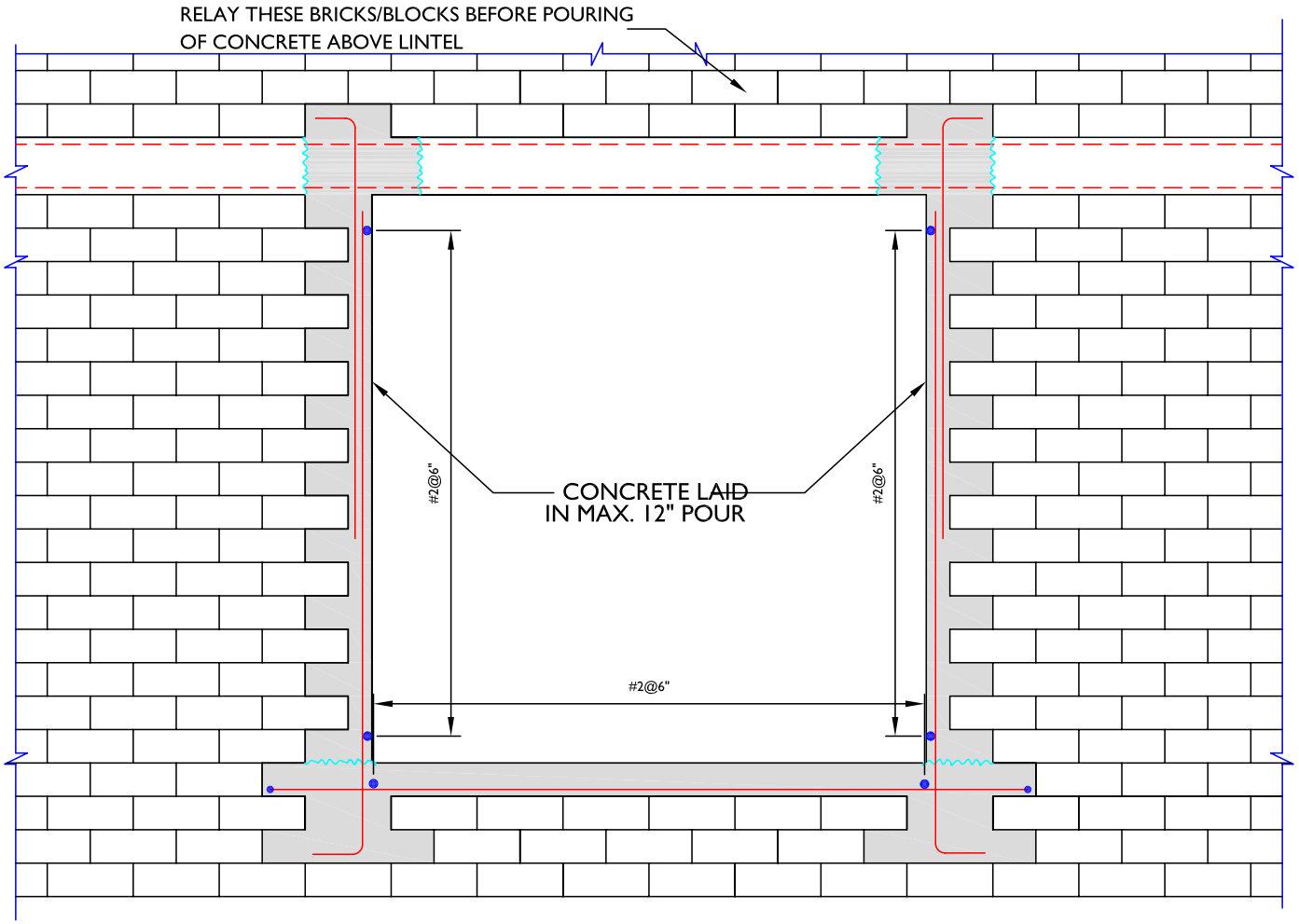
STEP 2: PLACE STEEL AT SILL AND VERTICAL FACE

Strengthening of large openings



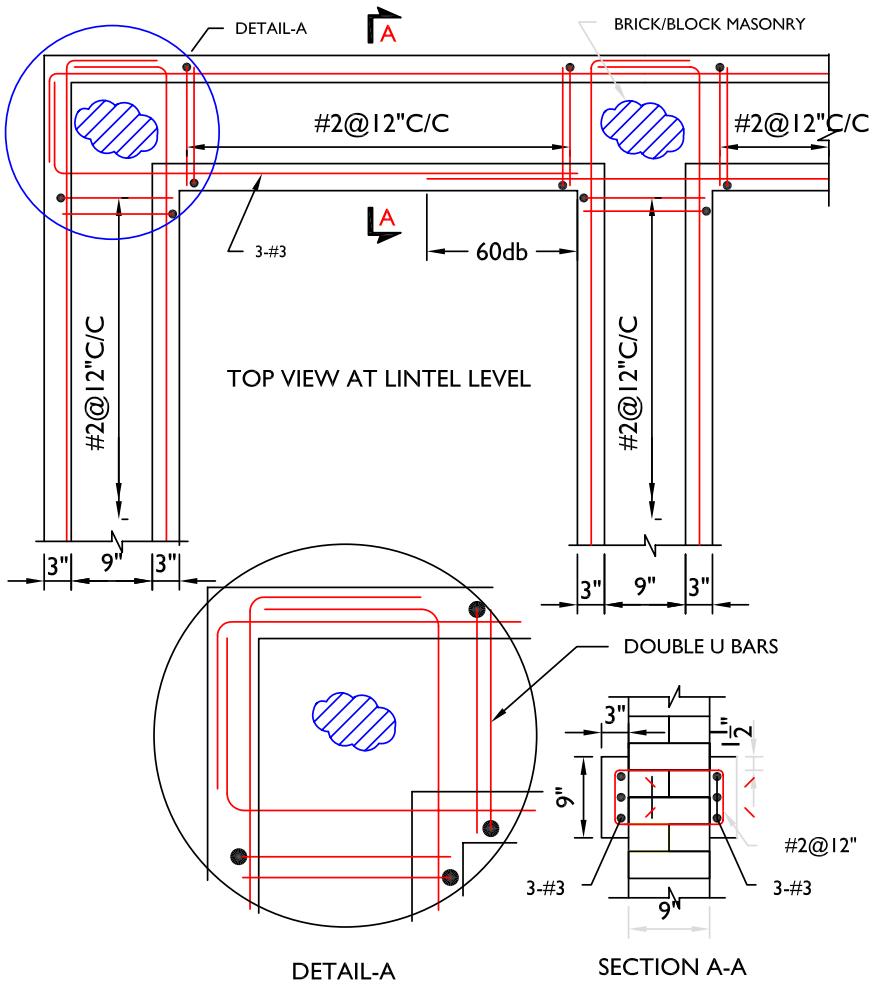
STEP 3: POUR CONCRETE AT SILL, SUPPORT LINTEL,
CHISEL LINTEL AND EMBEDED REINFORCEMENT IN LINTEL BAND/ BEAM

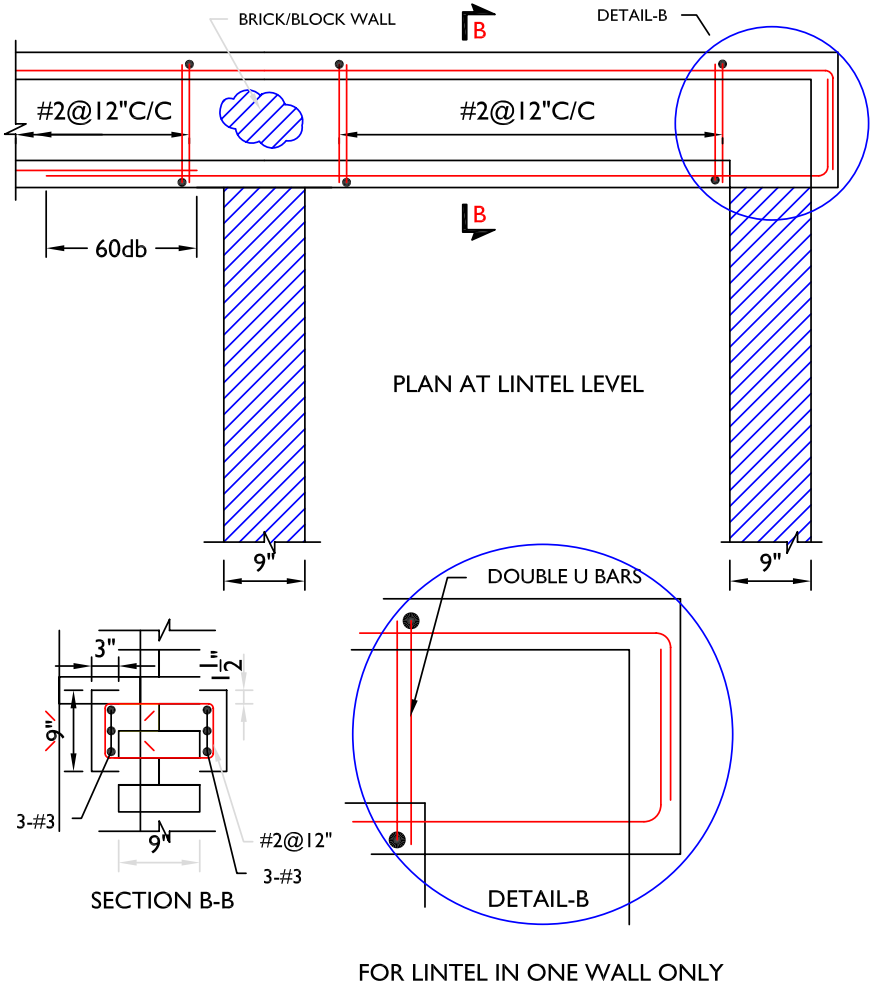
I Strengthening of large openings



STEP 4: PLACE SHUTTERING AND POUR CONCRETEEL BAND/ BEAM

2 Adding external bandages



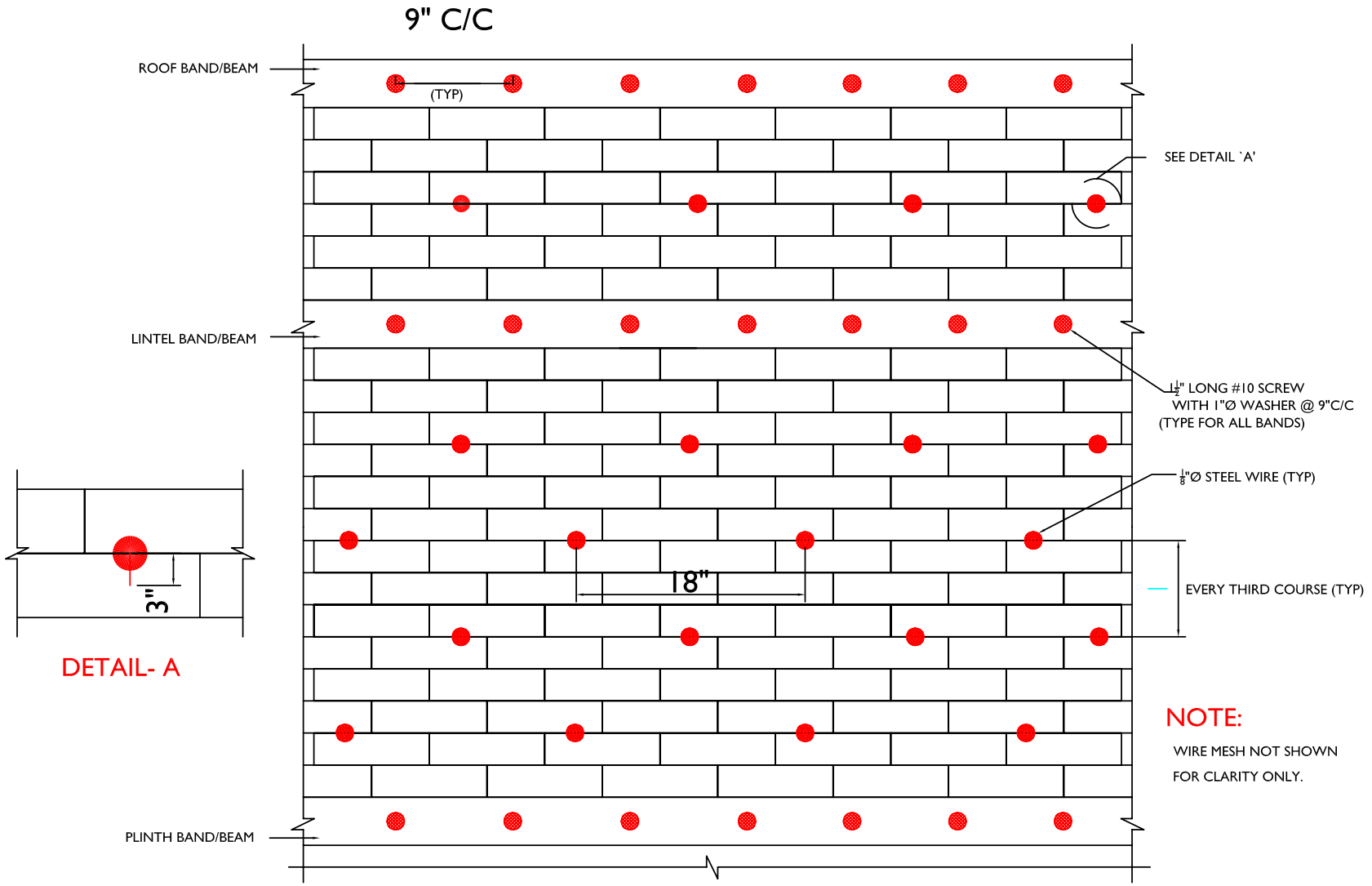


FOR LINTEL IN ONE WALL ONLY

STEP 1: PLACE STEEL OUTSIDE THE WALLS AND HOLD THEM U BARS

STEP 2: EXTERNAL BANDAGES ON BOTH SIDES

3 Strengthening weak masonry



DETAIL- A

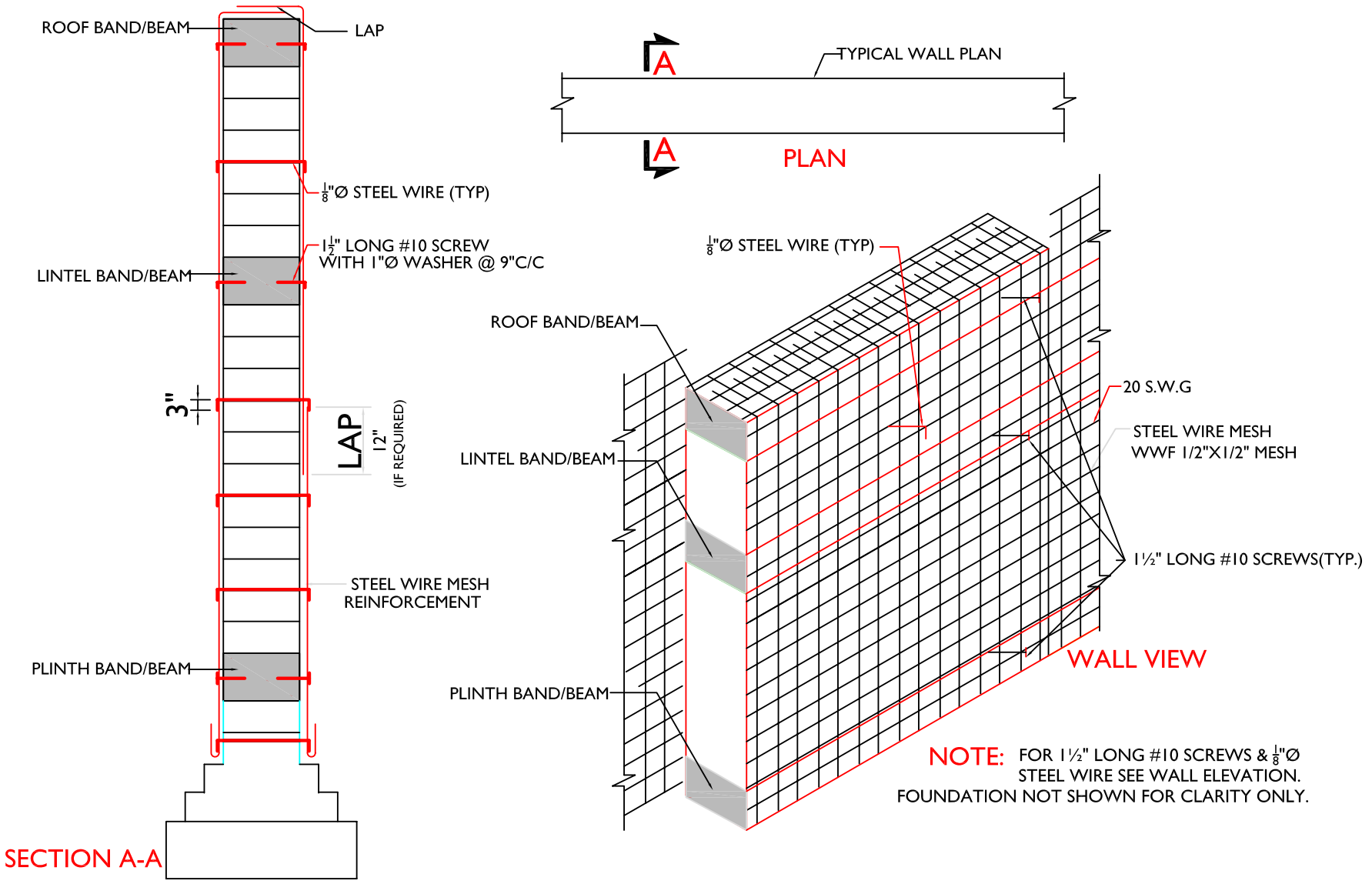
NOTE:

WIRE MESH NOT SHOWN FOR CLARITY ONLY.

WALL ELEVATION

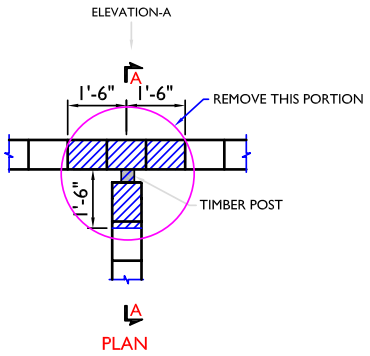
DRILL HOLES IN STAGGERED FORMAT

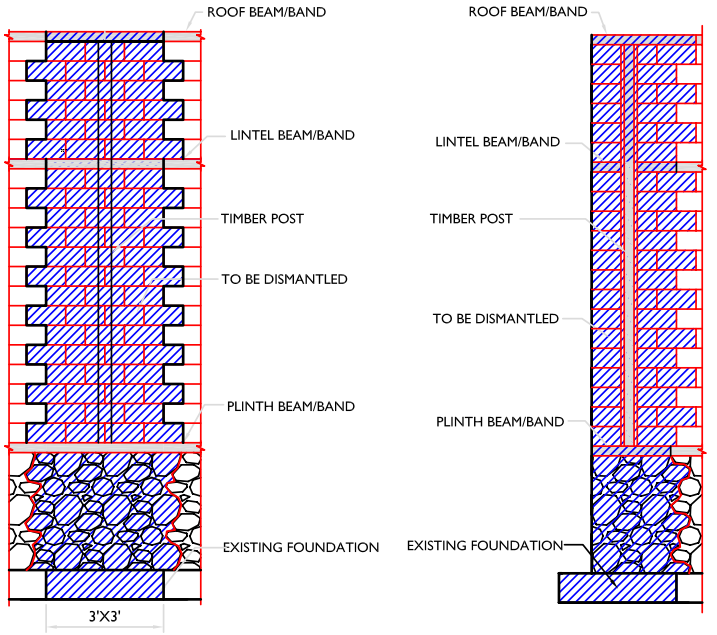
Strengthening weak masonry



STEP 1: FIXING OF WIRE MESH

4 Improvement of connections





ELEVATION A

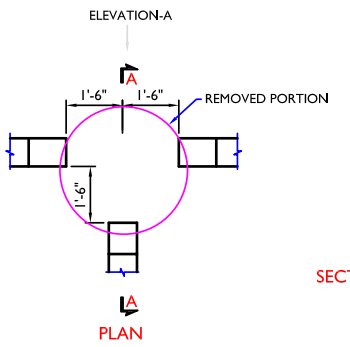
SECTION A-A

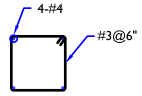
STEP 1: PROVIDE TOOTHING IN MASONRY

TO BE DISMANTLED

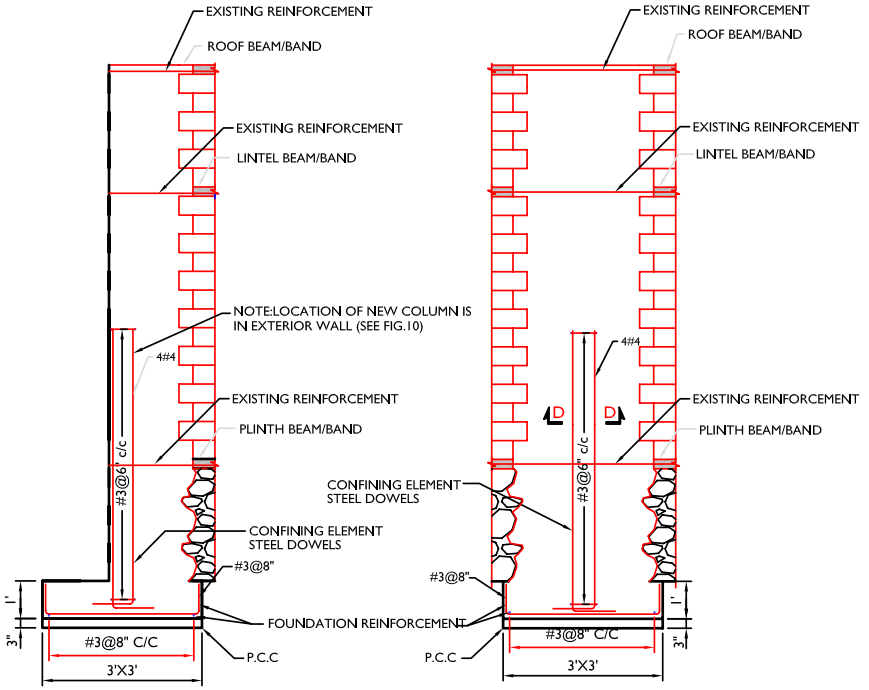
NOTE:

SEE RELEVANT LITERATURE IF ANY ESSENTIAL BAND IS MISS





SECTION D-D



SECTION A-A

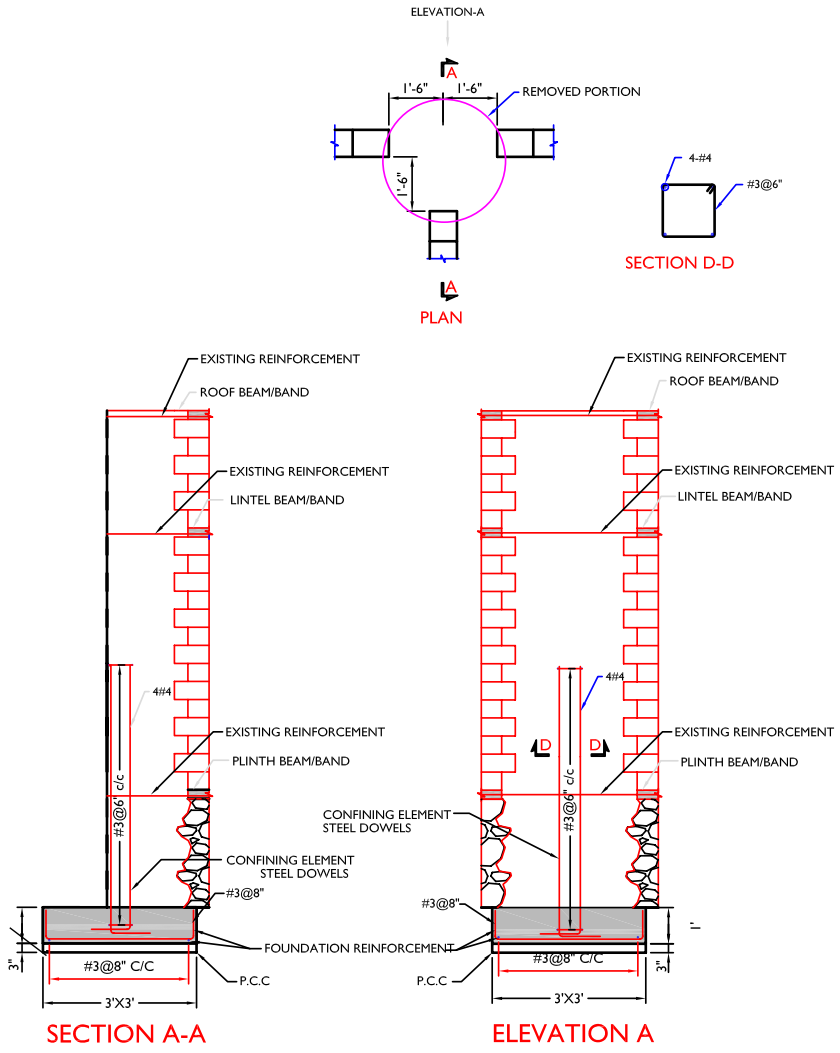
ELEVATION A

STEP 2: EXCAVATE AND PLACE COMUMN STEEL

NOTE:

CROSS WALL NOT SHOWN FOR CLARITY ONLY

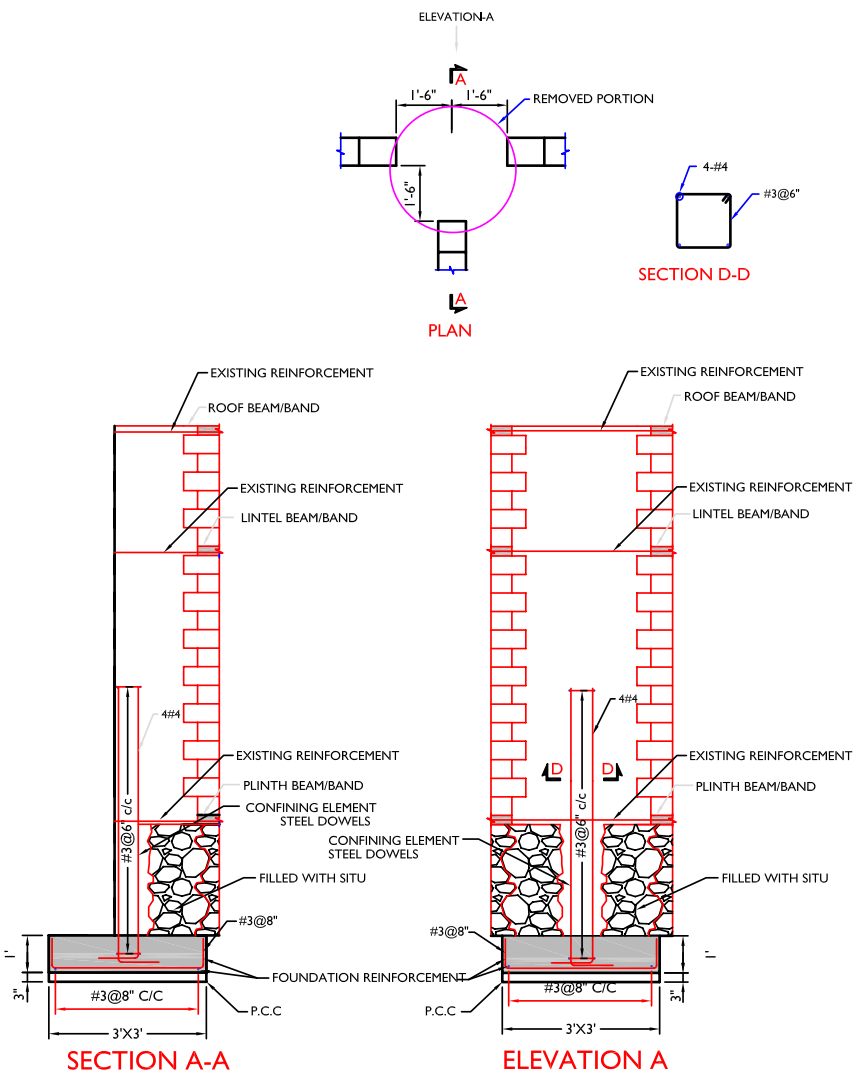
Improvement of connections



STEP 3: POUR FOOTING IN CONCRETE

CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

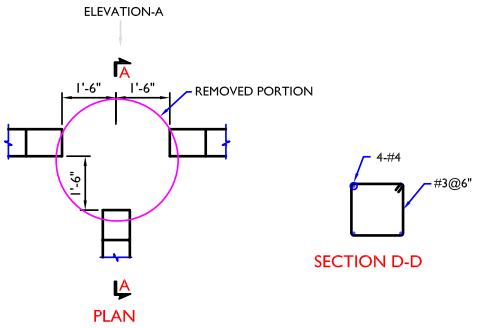


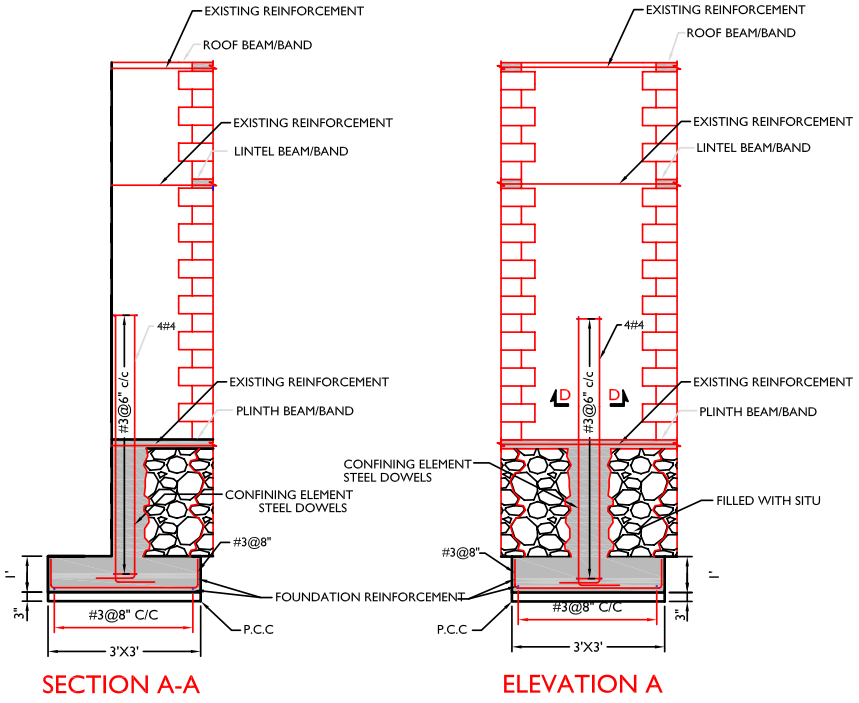
STEP 4: POUR FOOTING IN CONCRETE

CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

4 Improvement of connections

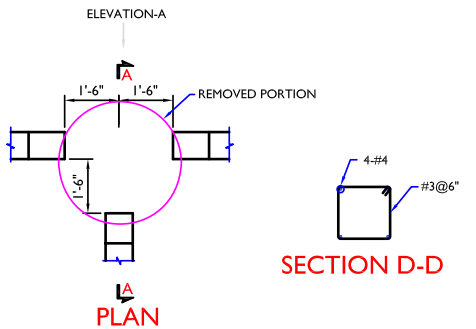


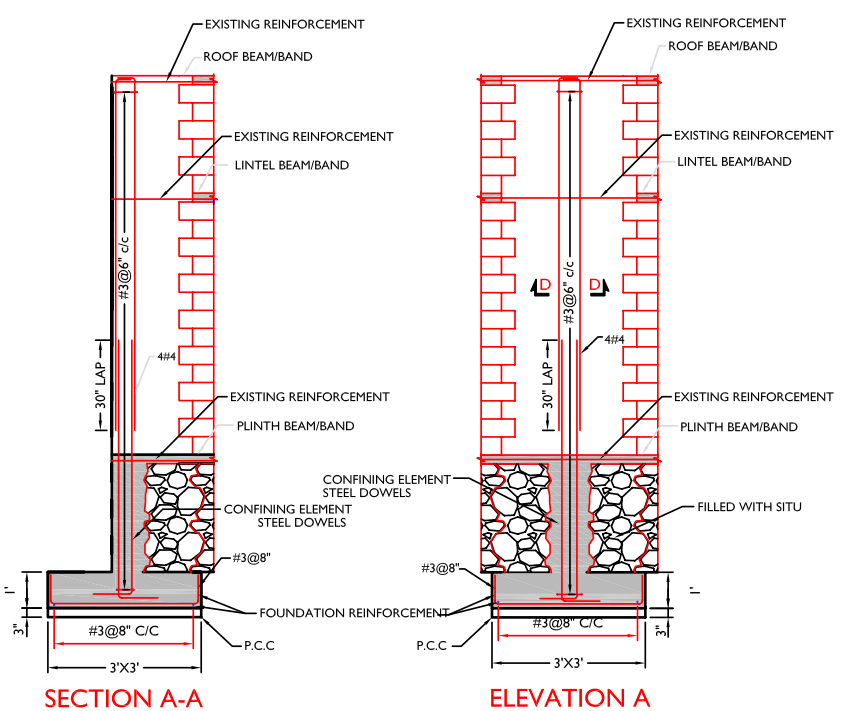


STEP 5: POUR CONCRETE UP TO PLINTH

CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY



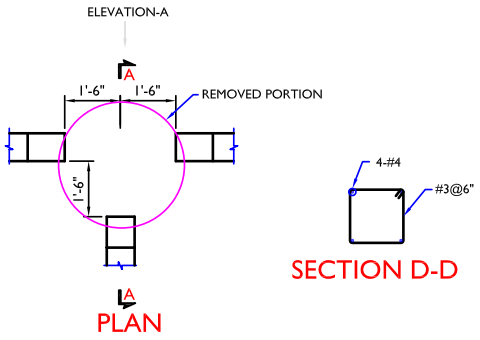


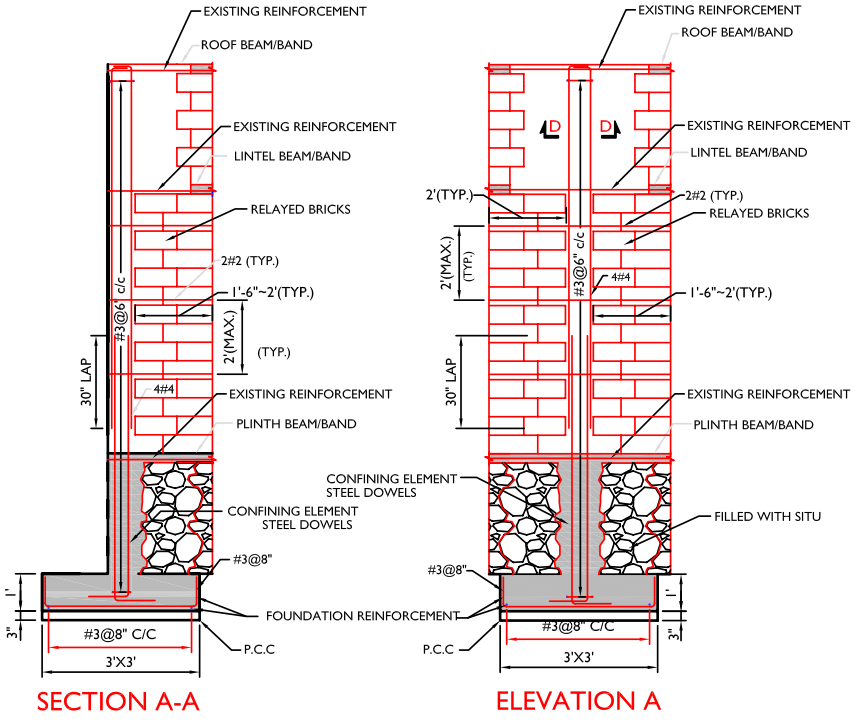
STEP 6: EXTEND COLUMN UPTO ROOF LEVEL (PROVIDE LAP)

CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

Improvement of connections



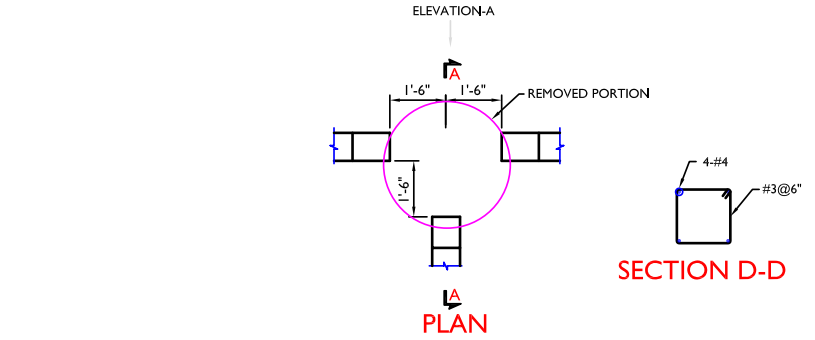


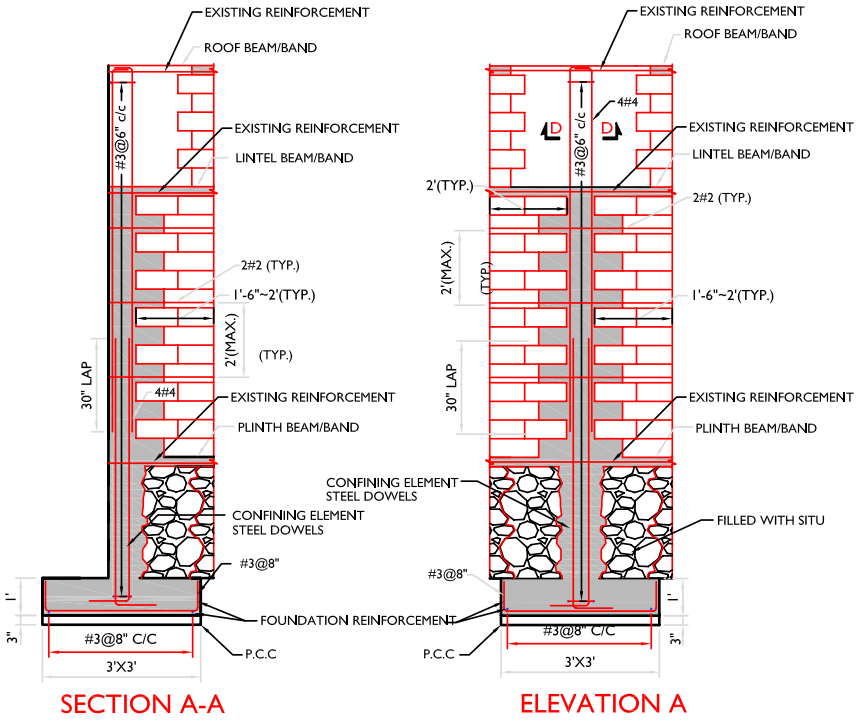
SECTION A-A ELEVATION A

STEP 7: BUILD MASONRY UPTO LINTEL WITH TOOTHING

CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY





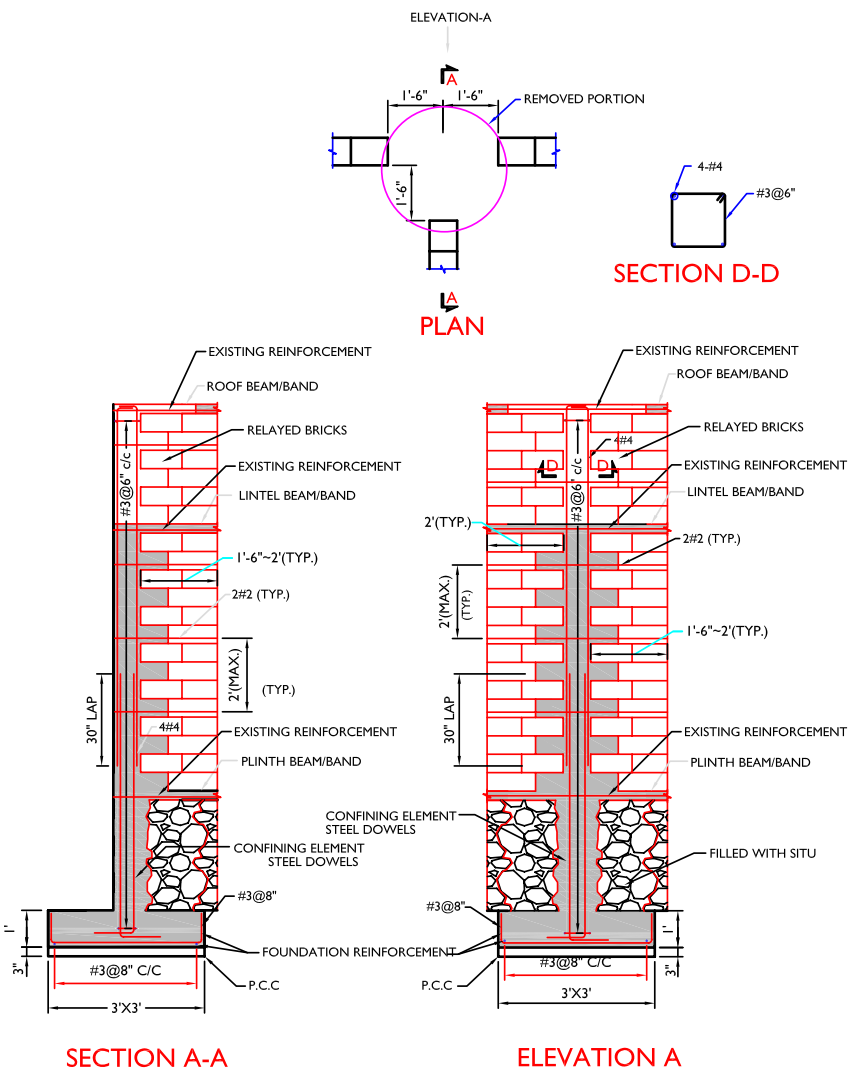
SECTION A-A ELEVATION A

STEP 8: POUR COLUMN AND LINTEL

CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

4 Improvement of connections



STEP 9: BUILT MASONRY UPTO ROOF WITH TOOTHING

CONCRETED PORTION

NOTE:
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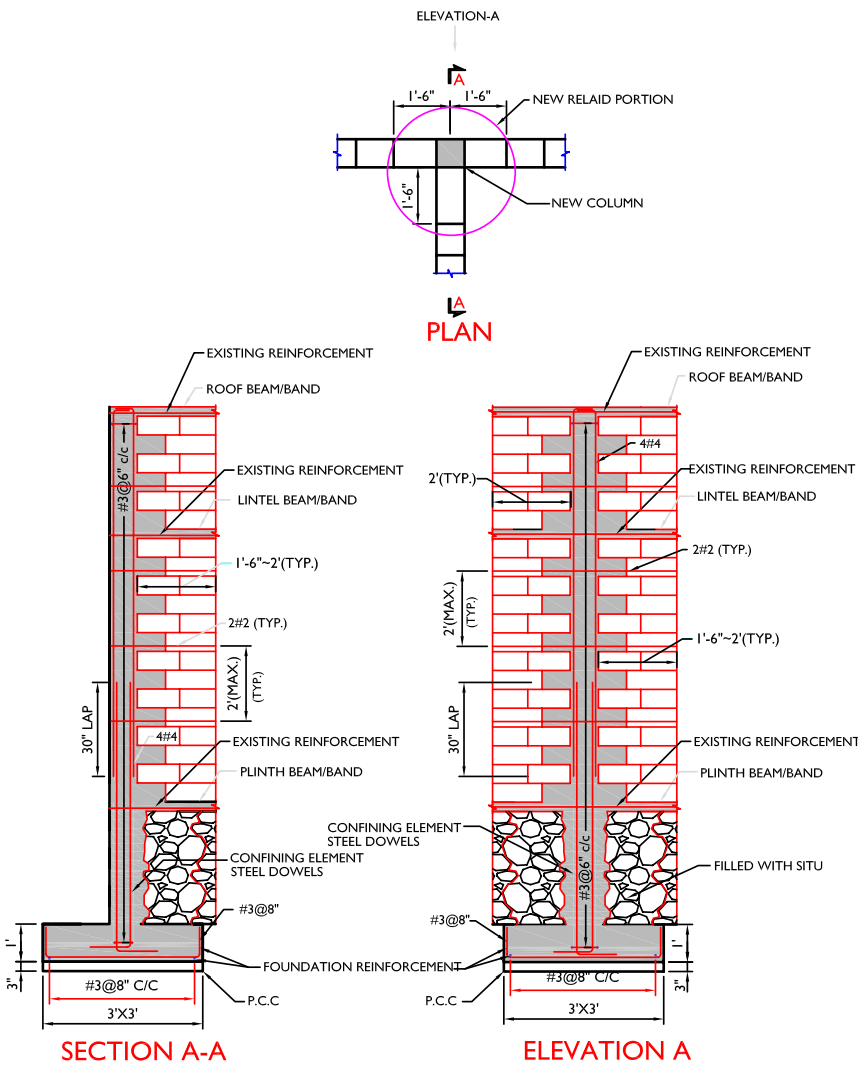
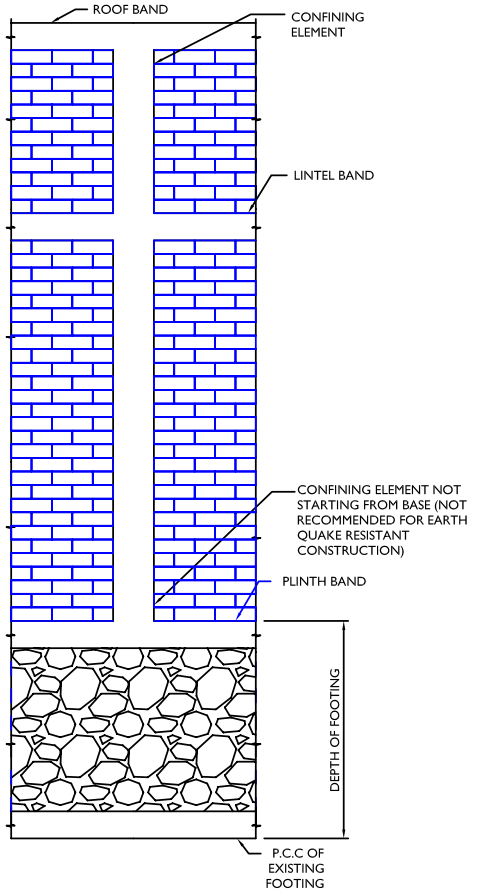


STEP 10: POUR CONCRETE IN COLUMN AND ROOF BEAM

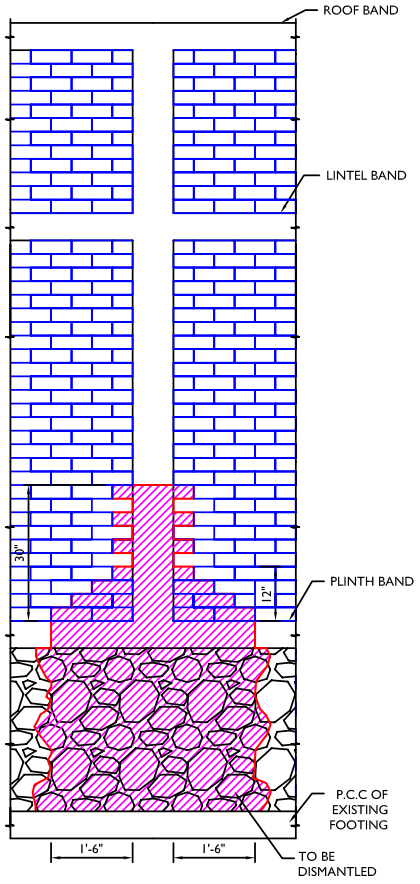
CONCRETED PORTION

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

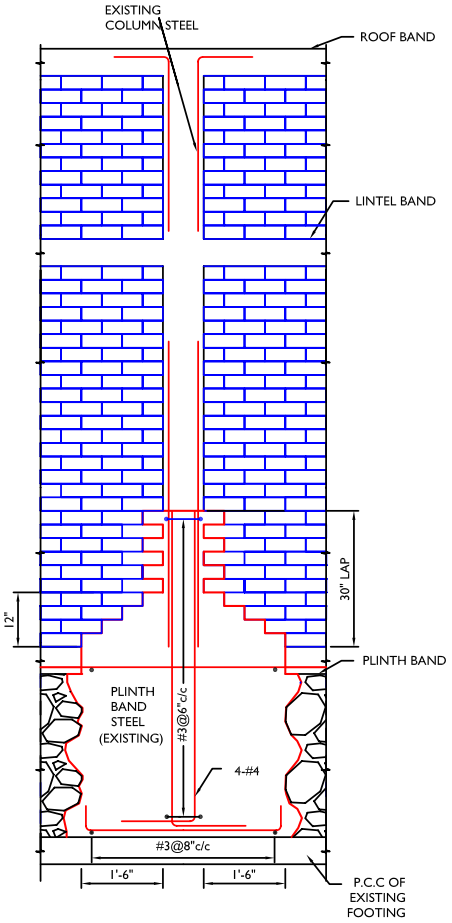
Improving anchorage



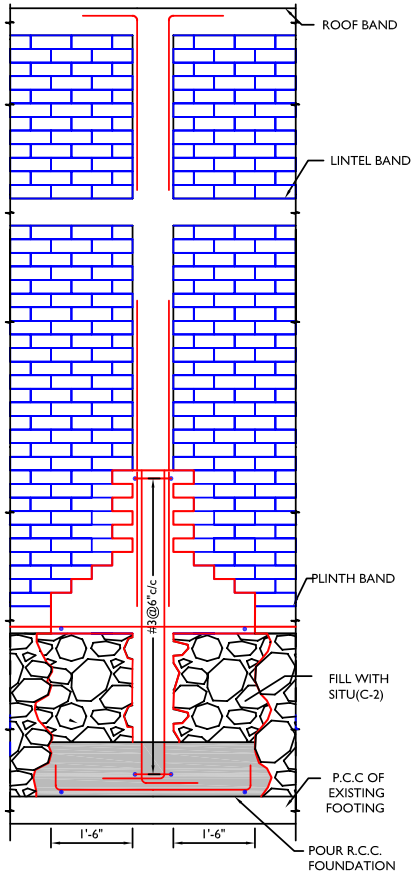
WALL ELEVATION
ACTUAL CONDITION
(STEP 1A)



WALL ELEVATION PORTION
TO BE DISMANTLED
(STEP 2 A)

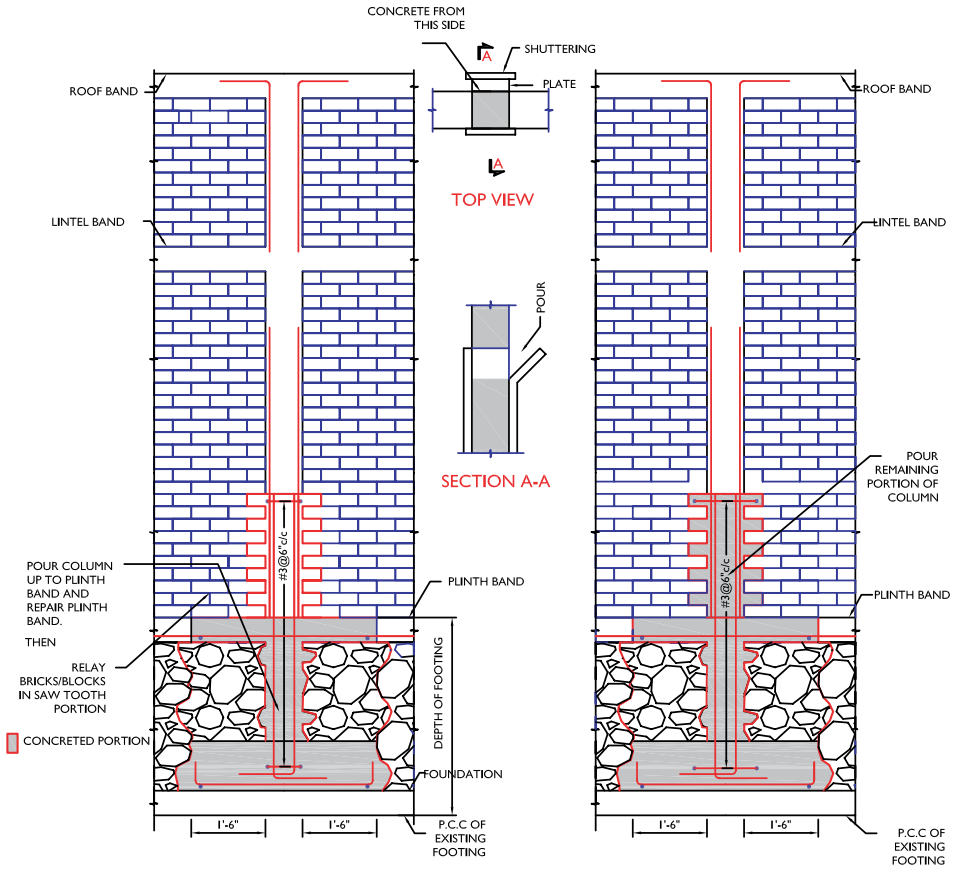


WALL ELEVATION
REINFORCEMENT DETAIL
(STEP 3A)



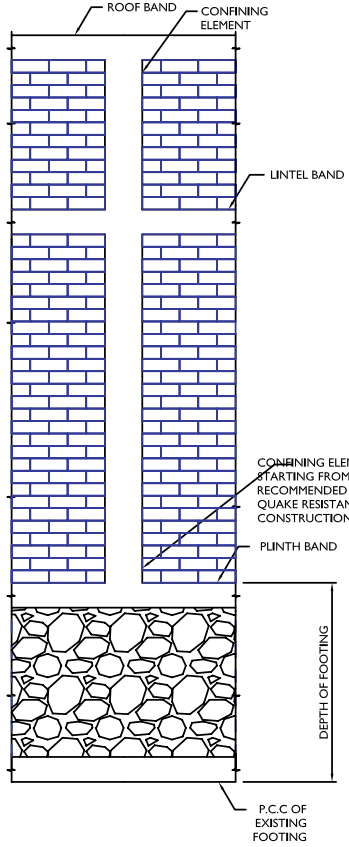
ELEVATION OF WALL
CONCRETING SEQUENCE
(STEP 4A)

5 Improving anchorage



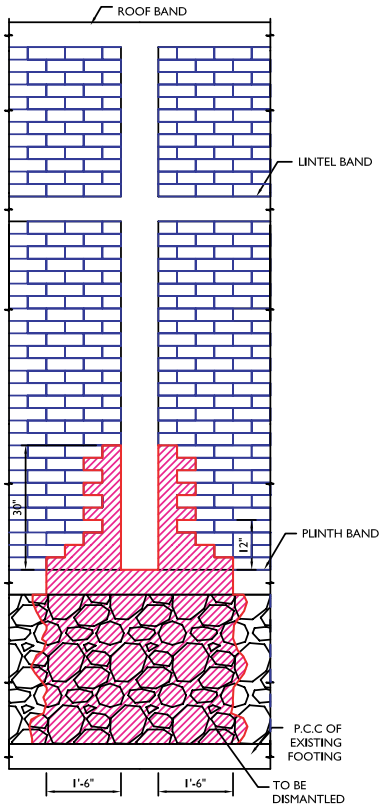
CONCRETING OF COLUMN UPTO PLINTH
(STEP 5A)

FINAL FORM AFTER CONCRETING UPTO THE DISMANTLED CONCRETE PORTION
(STEP 6A)



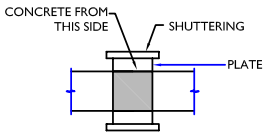
WALL ELEVATION ACTUAL CONDITION

(STEP 1b)

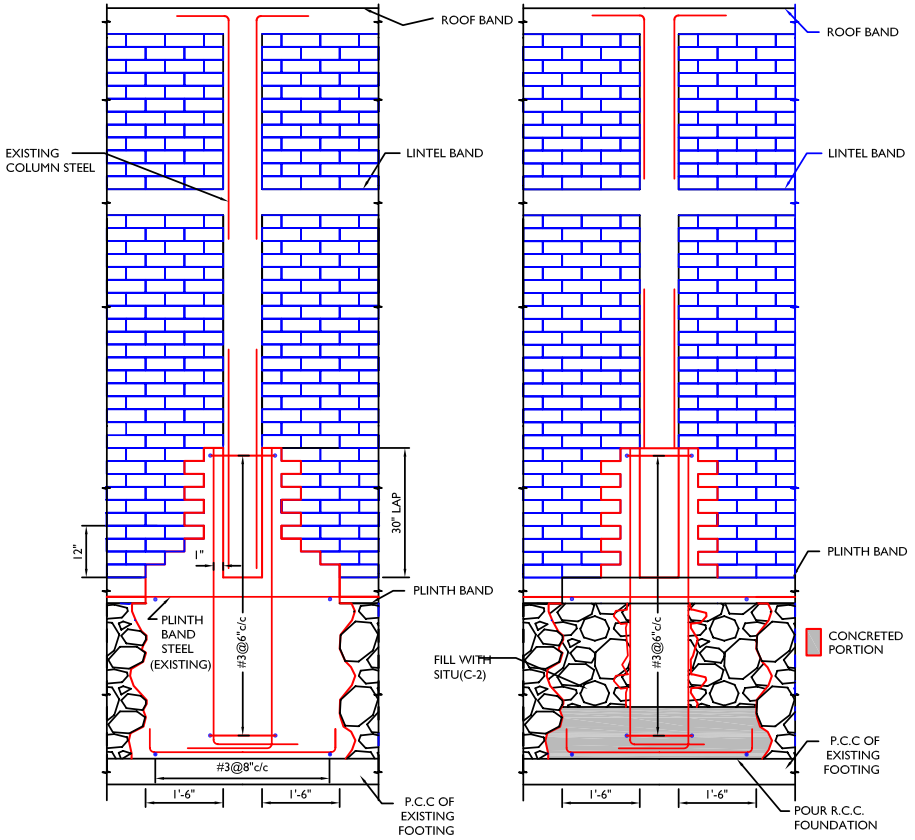


WALL ELEVATION PORTION TO BE DISMANTLED
(STEP 2b)

Improving anchorage

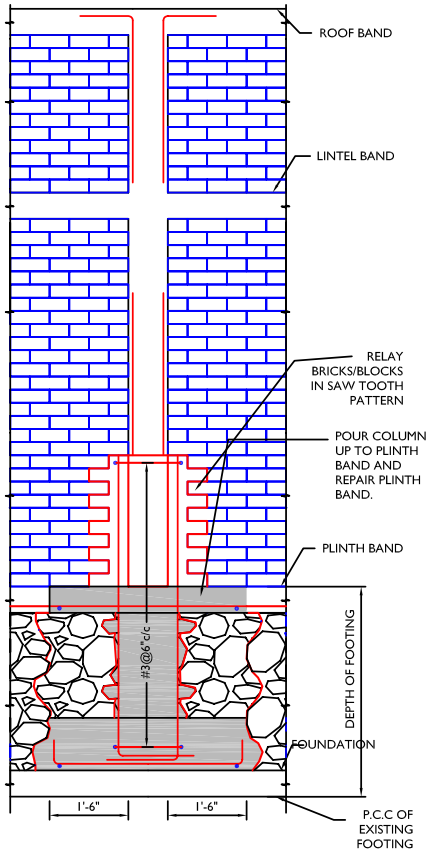


TOP VIEW

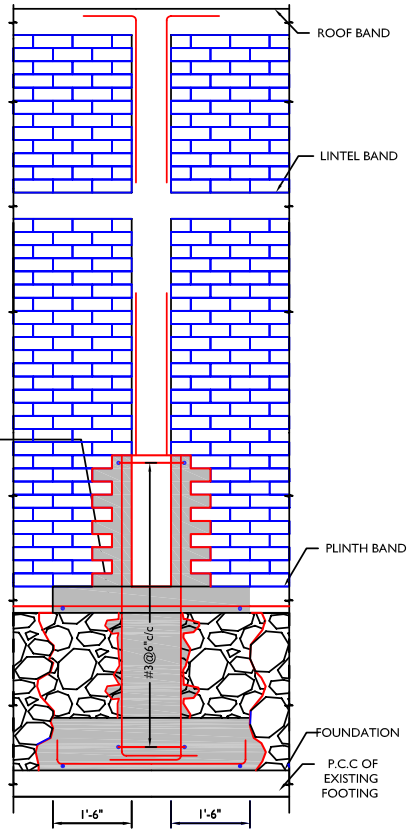


WALL ELEVATION
REINFORCEMENT DETAIL
(STEP 3b)

ELEVATION OF WALL
CONCRETING SEQUENCE
(STEP 4b)

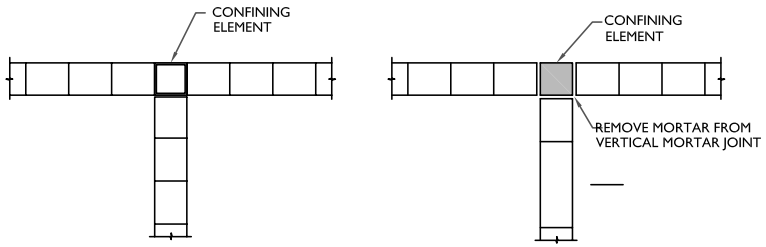


CONCRETING OF COLUMN UPTO PLINTH
(STEP 5b)



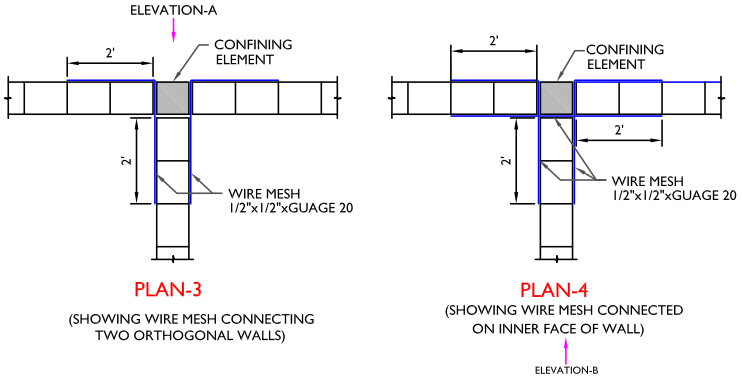
FINAL FORM AFTER CONCRETING UPTO THE DISMANTLED CONCRETE PORTION
(STEP 6b)

6 Connecting cross walls - Option A



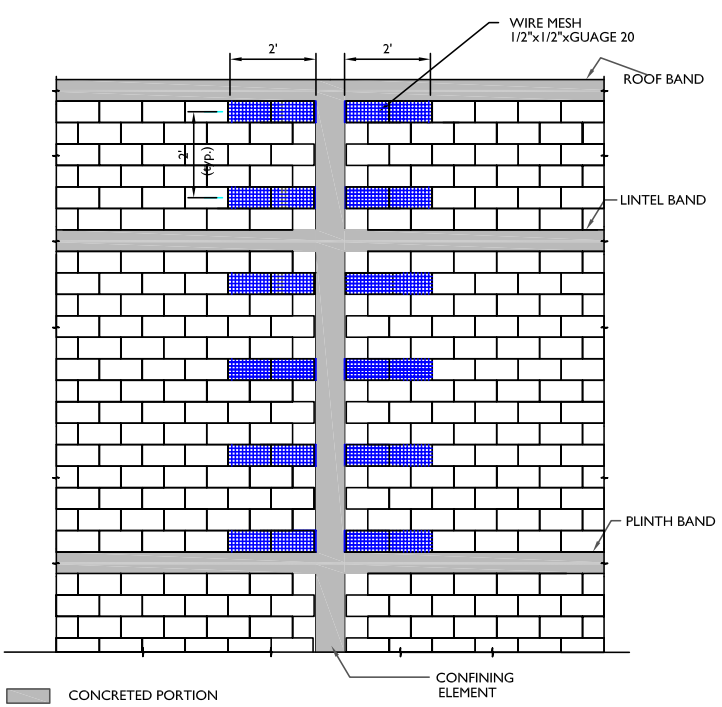
PLAN-1
(SHOWING ACTUAL CONDITION)

PLAN-2
(SHOWING MORTAR REMOVED FROM VERTICAL MORTAR JOINT)

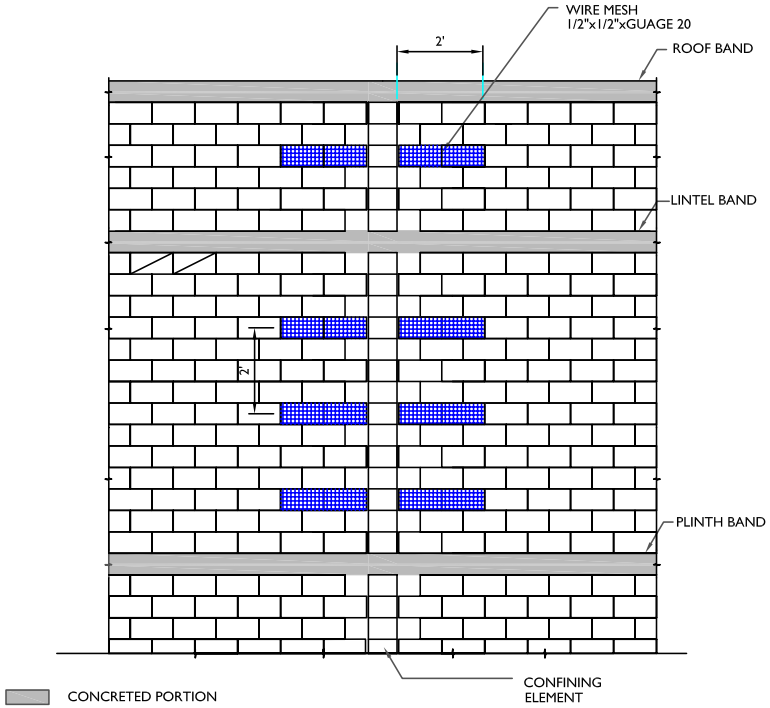


PLAN-3
(SHOWING WIRE MESH CONNECTING TWO ORTHOGONAL WALLS)

PLAN-4
(SHOWING WIRE MESH CONNECTED ON INNER FACE OF WALL)

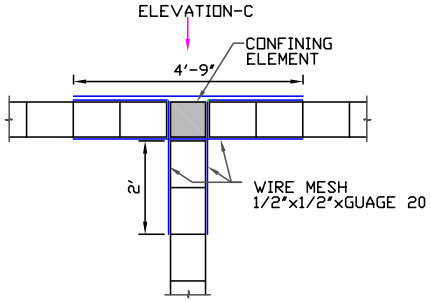


ELEVATION-A

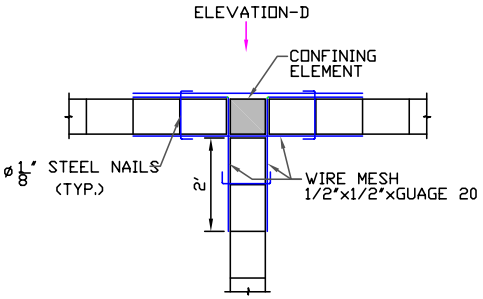


ELEVATION-B

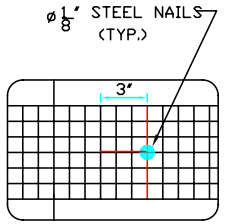
Connecting cross walls - Option A



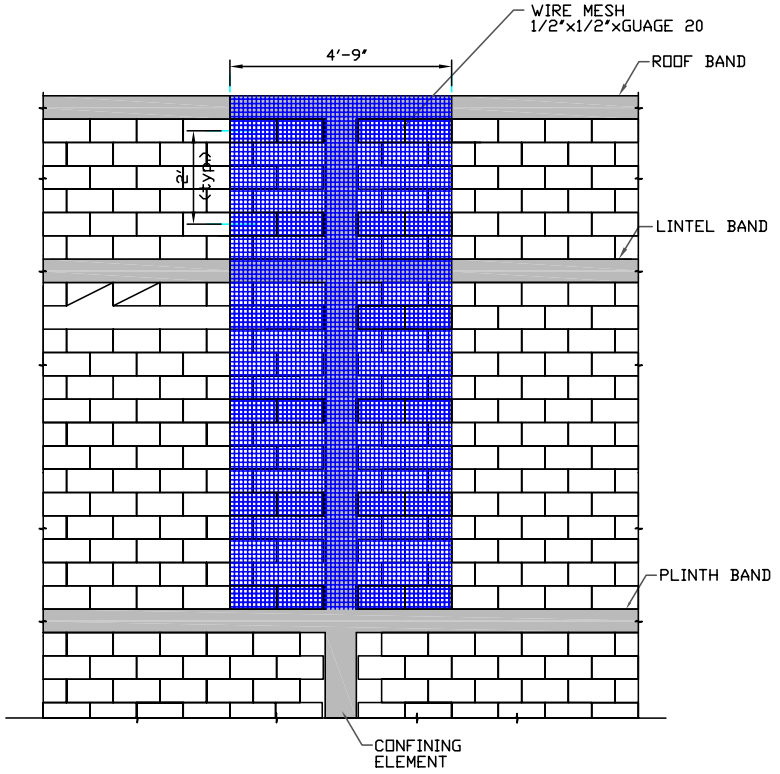
PLAN-5
(SHOWING WIRE MESH CONNECTED ON OUTER FACE OF WALL)



PLAN-6
(SHOWING WIRE MESH CONNECTED ON EACH FACE THROUGH STEEL NAILS)

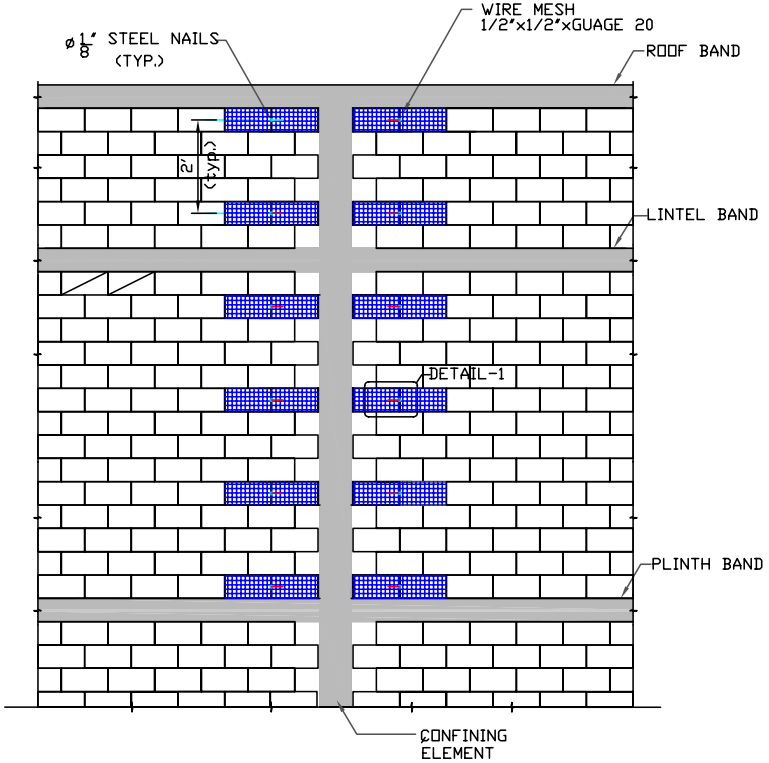


DETAIL-1



ELEVATION-C

CONCRETED PORTION

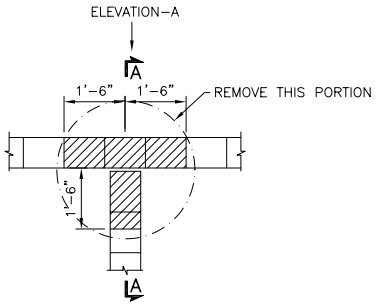


ELEVATION-D

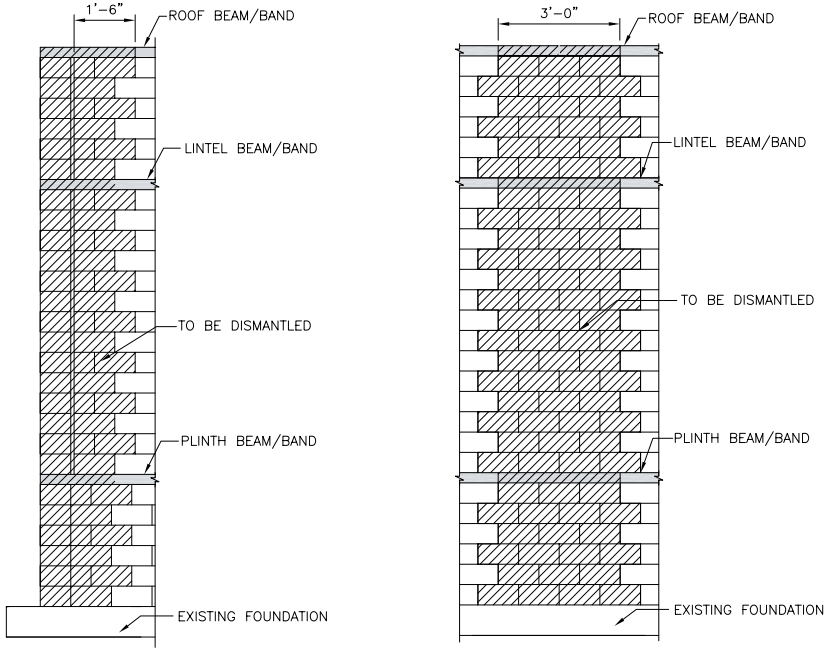
CONCRETED PORTION

NOTE: TOP WIRE MESH NOT SHOWN FOR CLARITY ONLY

7 Connecting cross walls - Option B



PLAN



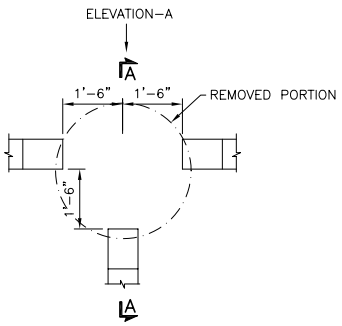
SECTION A–A

ELEVATION–A

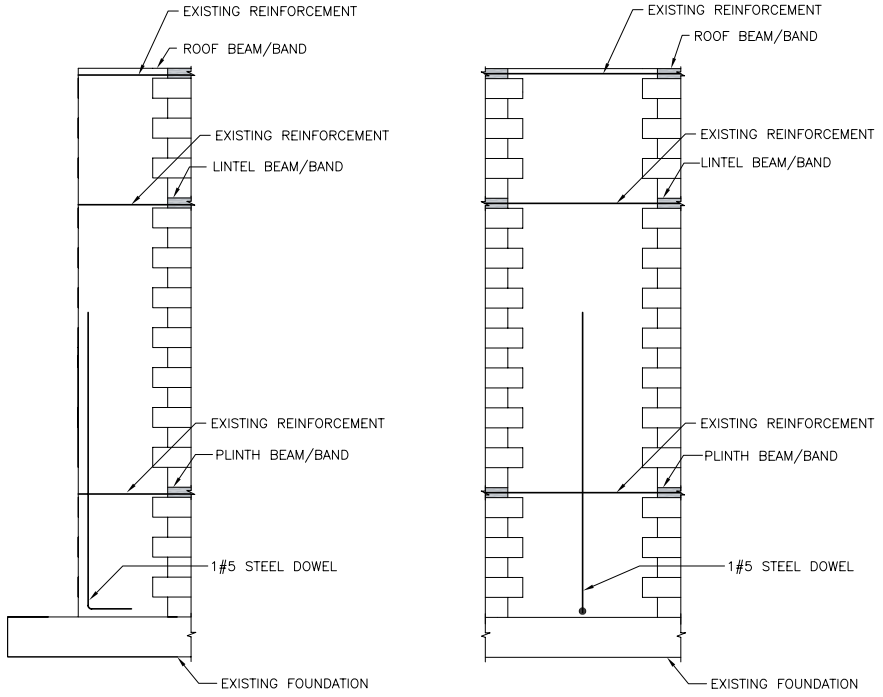
TO BE DISMANTLED

NOTE:
SEE RELEVANT LITERATURE IF ANY ESSENTIAL BAND IS MISSING

STEP 1: REMOVE MASONRY BY PROVIDING TOOTHING



PLAN



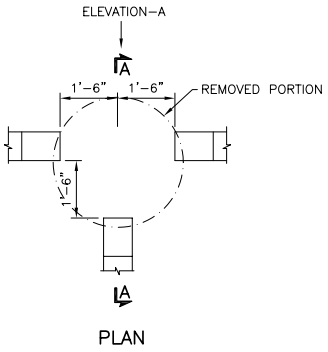
SECTION A–A

ELEVATION A

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

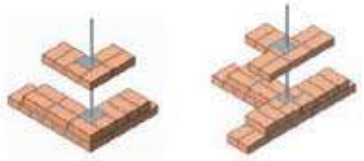
STEP 2: PLACE VERTICAL BAR

Connecting cross walls - Option B

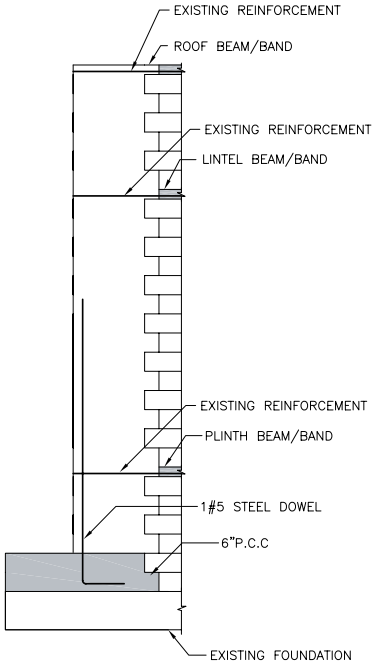


PLAN

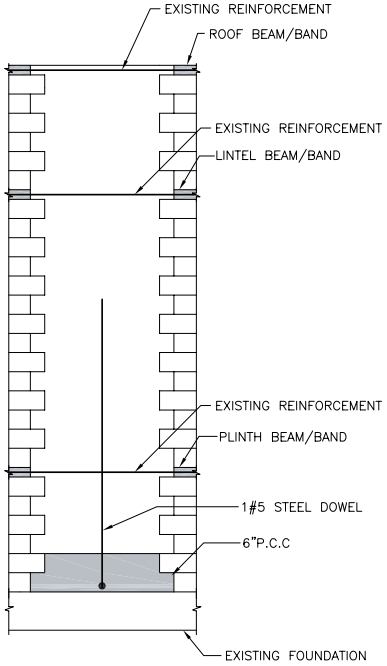
JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF CONCRETE BLOCK MASONRY WALLS



JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF BRICK MASONRY WALLS



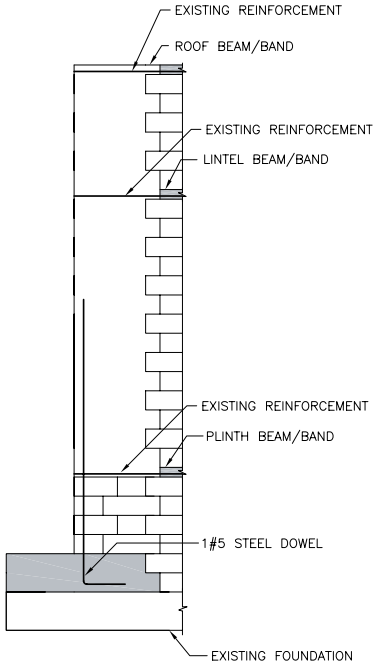
SECTION A–A



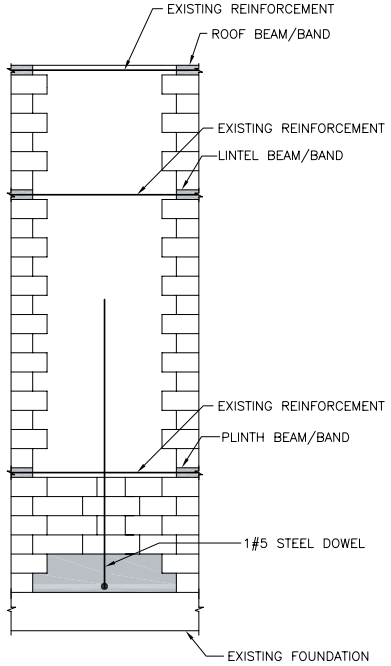
ELEVATION A

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

STEP 3: POUR CONCRETE IN FOUNDATION



SECTION A–A



ELEVATION A

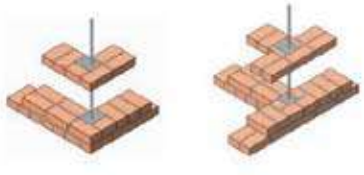
NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

STEP 4: BUILD MASONRY UPTO PLINTH

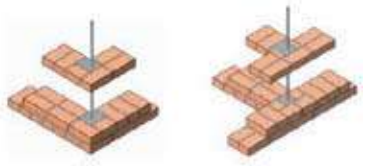
7 Connecting cross walls - Option B

JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF CONCRETE BLOCK MASONRY WALLS

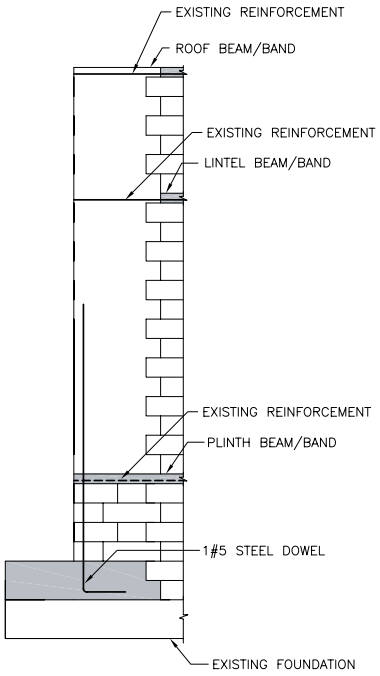


JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF BRICK MASONRY WALLS

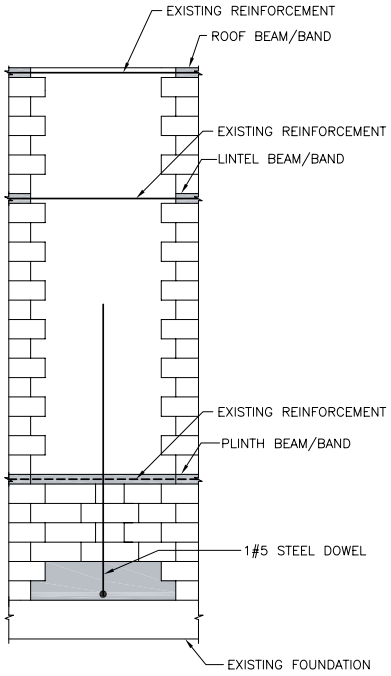
JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF CONCRETE BLOCK MASONRY WALLS



JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF BRICK MASONRY WALLS



SECTION A–A

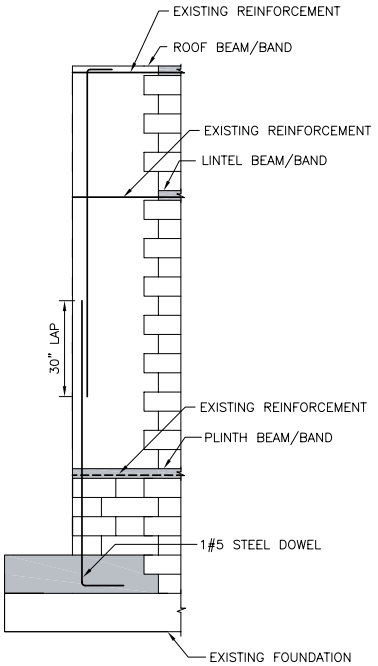


ELEVATION A

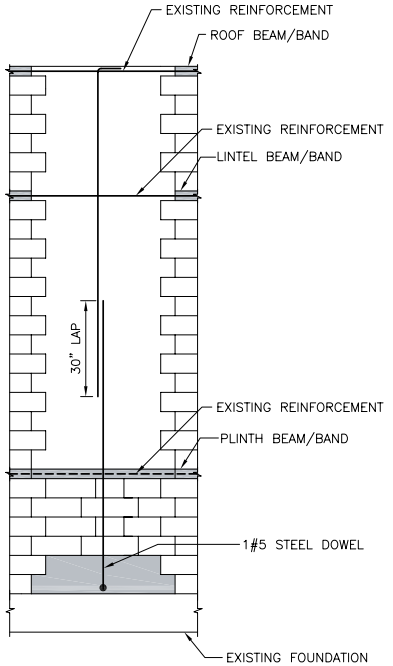
NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

STEP 5: POUR CONCRETE IN PLINTH



SECTION A–A



ELEVATION A

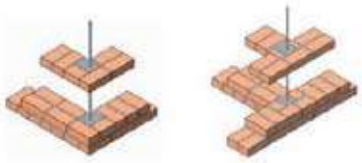
NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

STEP 6: EXTEND BAR UP TO ROOF

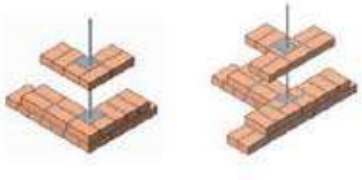
7 Connecting cross walls - Option B

JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF CONCRETE BLOCK MASONRY WALLS

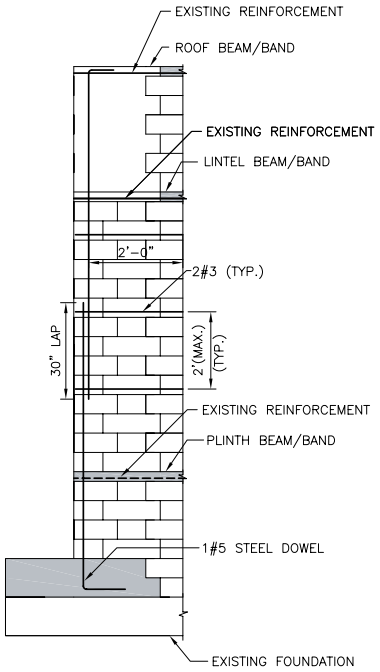


JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF BRICK MASONRY WALLS

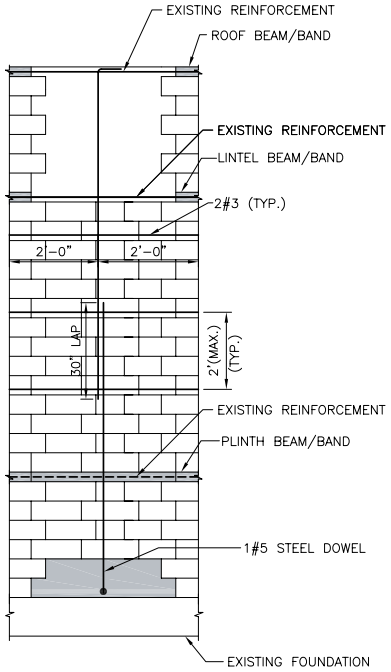
JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF CONCRETE BLOCK MASONRY WALLS



JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF BRICK MASONRY WALLS



SECTION A–A

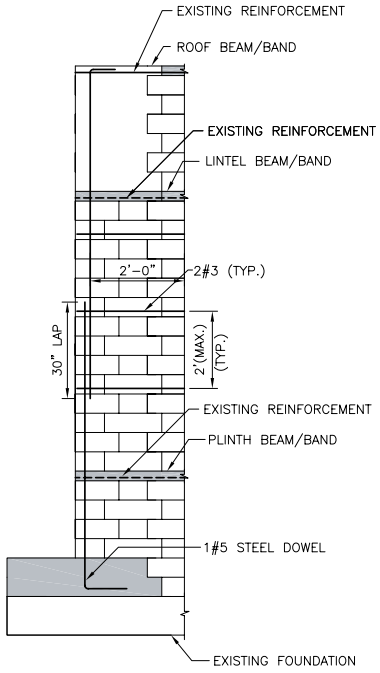


ELEVATION A

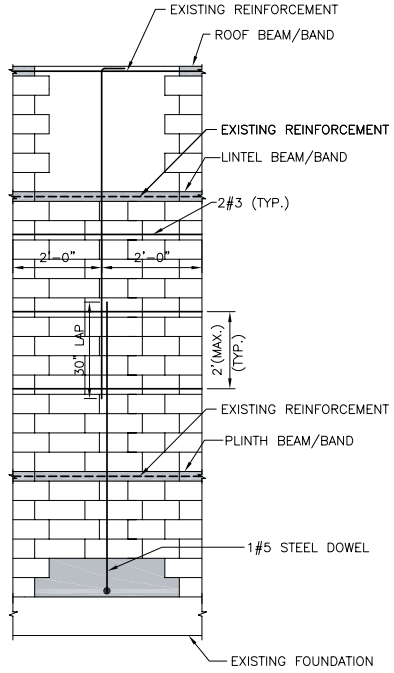
NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

STEP 7: BUILD MASONRY UP TO LINTEL



SECTION A–A



ELEVATION A

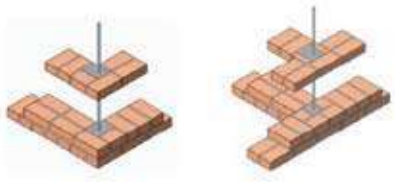
NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

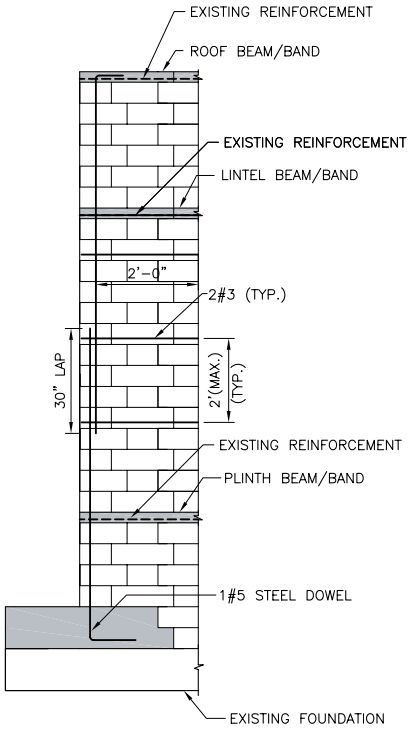
STEP 8: POUR CONCRETE IN LINTEL BAND

7 Connecting cross walls - Option B

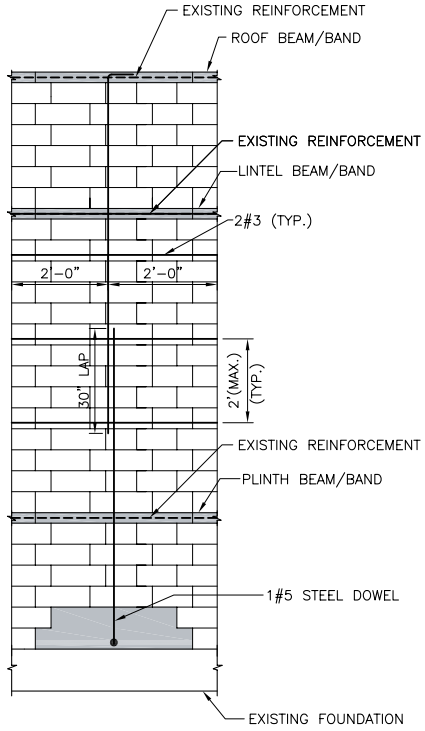
JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF CONCRETE BLOCK MASONRY WALLS



JOINT DETAILS WITH THE VERTICAL REINFORCEMENT AT CORNER OF BRICK MASONRY WALLS



SECTION A–A



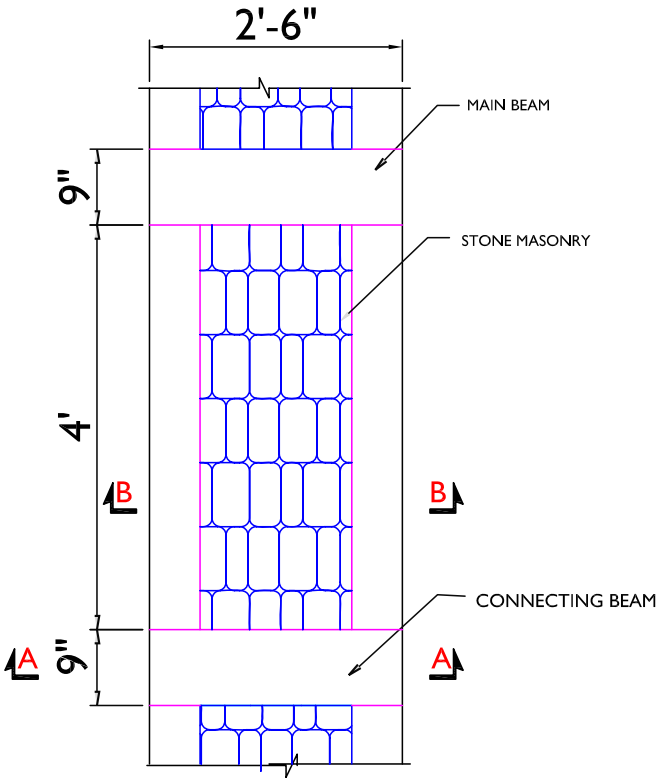
ELEVATION A

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

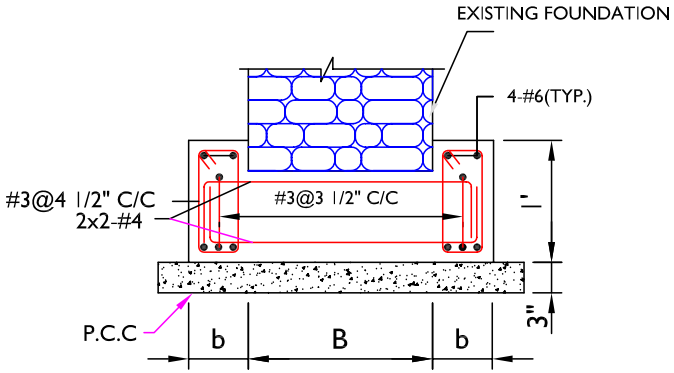
CONCRETED PORTION

STEP 9: BUILD MASONRY UP TO ROOF AND POUR CONCRETE IN ROOF BAND

Strengthening of undersize foundation



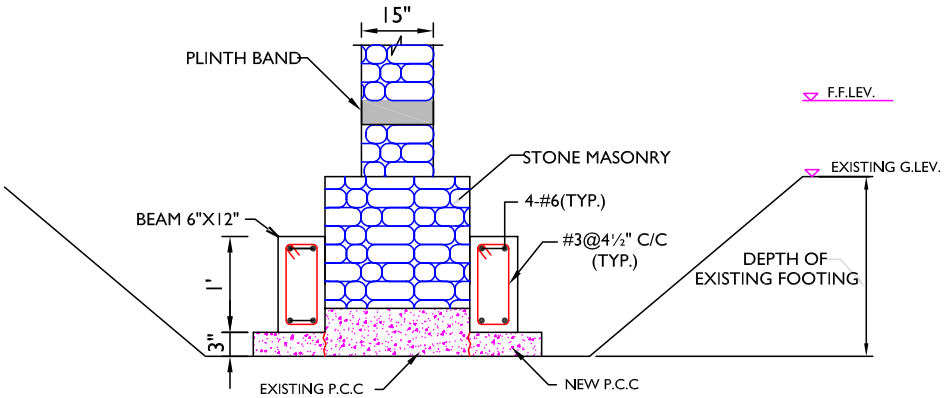
PLAN OF STONE MASONRY FOUNDATION



SECTION A-A

P.C.C (1:4:8)

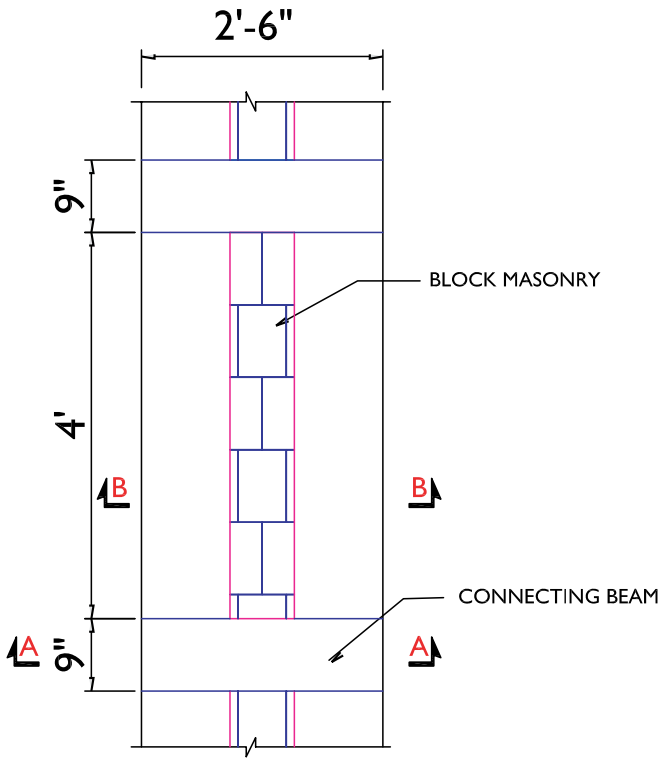
B+2b = 30" (POSTER MIN)
2b = SUM OF WIDTH OF 2 FOUNDATION BEAMS
B = WIDTH OF EXISTING FOUNDATION



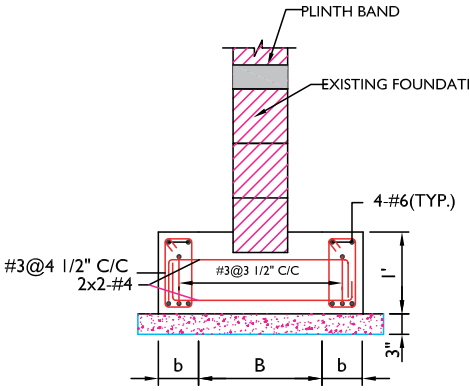
SECTION B-B

P.C.C (1:4:8)

8 Strengthening of undersize foundation



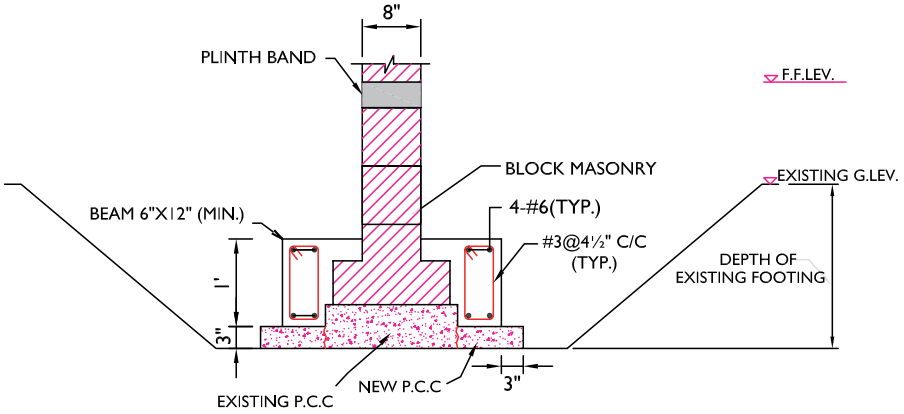
PLAN OF BLOCK MASONRY FOUNDATION



SECTION A-A

P.C.C (1:4:8)

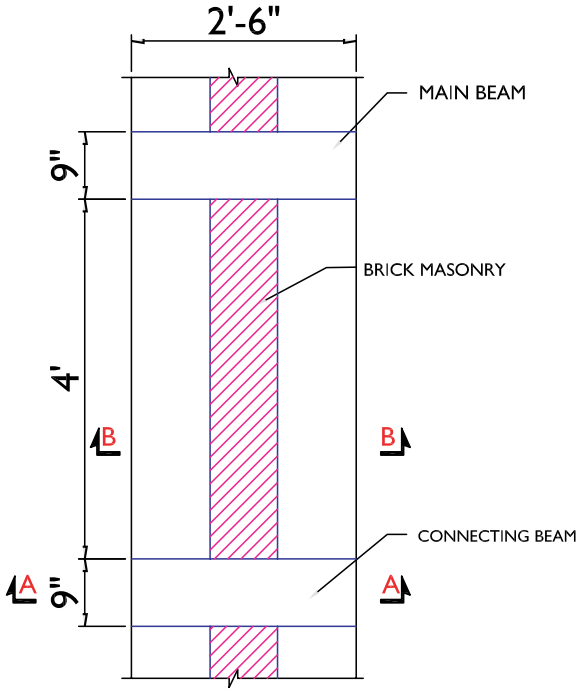
B+2b = 30" (POSTER MIN)
2b = SUM OF WIDTH OF 2 FOUNDATION BEAMS
B = WIDTH OF EXISTING FOUNDATION



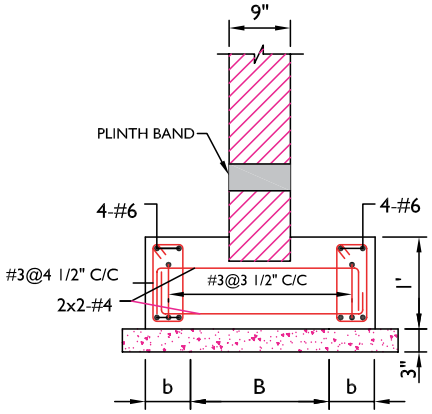
SECTION B-B

P.C.C (1:4:8)

Strengthening of undersize foundation



PLAN OF BRICK MASONRY FOUNDATION



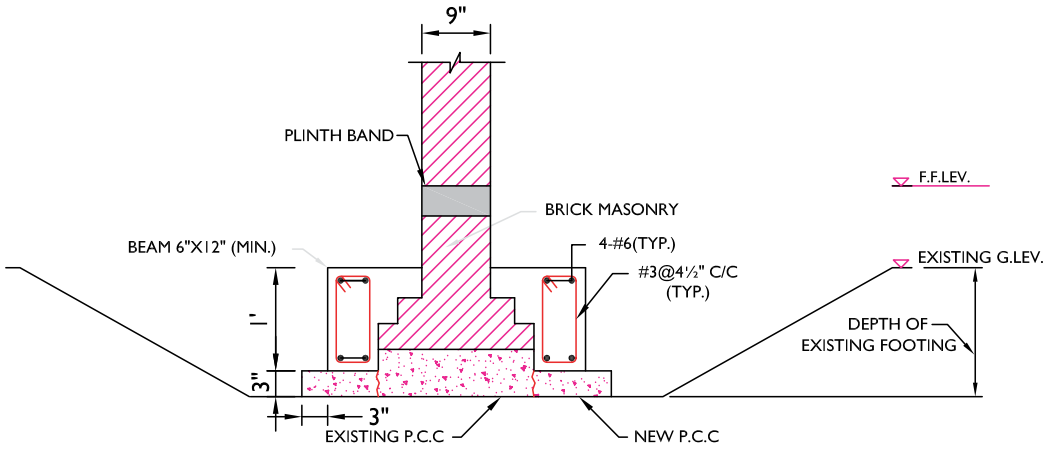
SECTION A-A

P.C.C (1:4:8)

B+2b = 30" (POSTER MIN)

2b = SUM OF WIDTH OF 2 FOUNDATION BEAMS

B = WIDTH OF EXISTING FOUNDATION



SECTION B-B

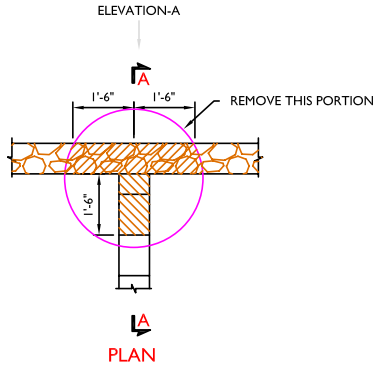
P.C.C (1:4:8)

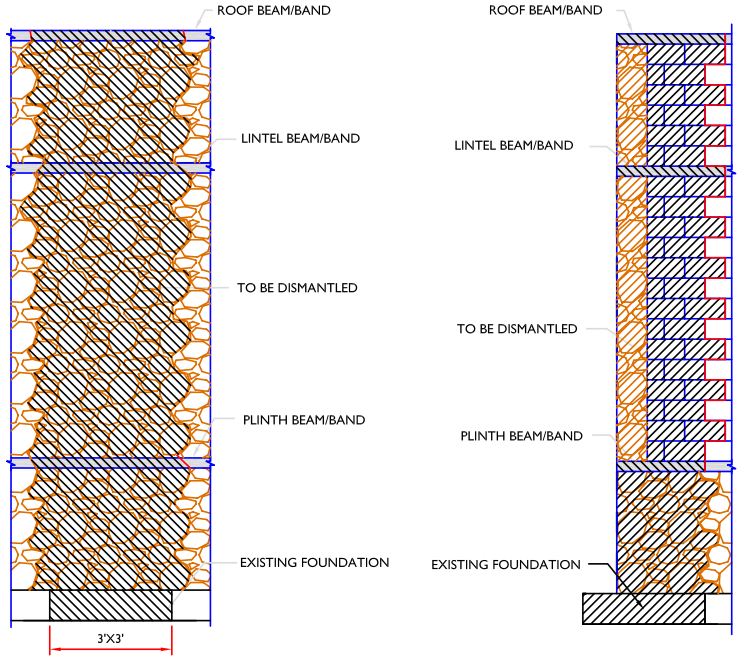
8 Strengthening of undersized foundation

Step by Step Procedure

1. Excavate the soil at least 2 ft wide on each side of the footing equal to the depth of existing foundation.
2. Maintain a stable slope for excavation. In case of unstable slope provide protective apron to stabilize the slope.
3. Make 9" wide and 12" deep openings at the base of the footing.
4. Clean the bed of created opening and place PCC (1:4:8) of 3" thickness in the created opening..
5. Make connection beam of 9" x 9" size and 2ft 6" length. Fix 1/2 " dia bars (2 top and 2 bottom) hooked at ends.
6. Repeat steps 3, 4, 5 along the length of the footing at intervals of 4 ft. Concrete the portion of connecting beams using (1:2:4) concrete mix, into the foundation leaving both the reinforcement of open edges unconcreted.
7. Place PCC (1:4:8) of 3" thick and 9" wide on each side of the footing.
8. Place 4 #6 (2 top and 2 bottom) steels for 6" x 12" beam on each side of footing and fix #3 bar ties at at spacing of 4 1/2" cc.
9. Bend the steel of foundation connecting beam at the end as shown in section AA.
10. Provide shuttering on one side of foundation beam and use other side of foundation as shuttering.

Connecting cross walls of different materials



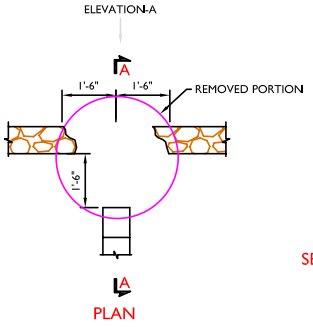


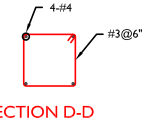
STEP - I

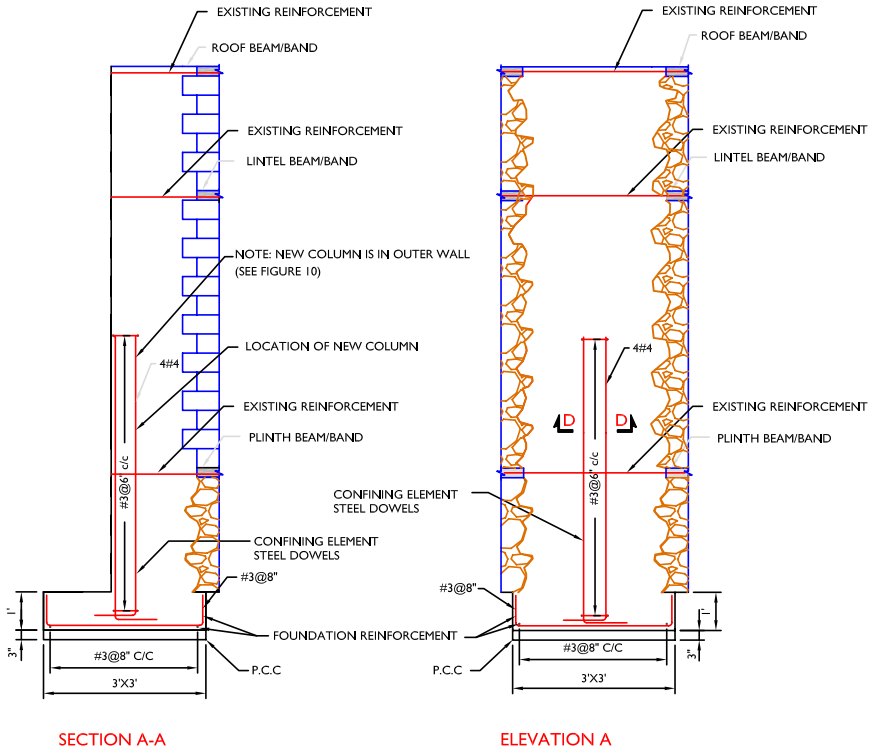
TO BE DISMANTLED

NOTE:

SEE RELEVANT LITERATURE IF ANY ESSENTIAL BAND IS MISSING





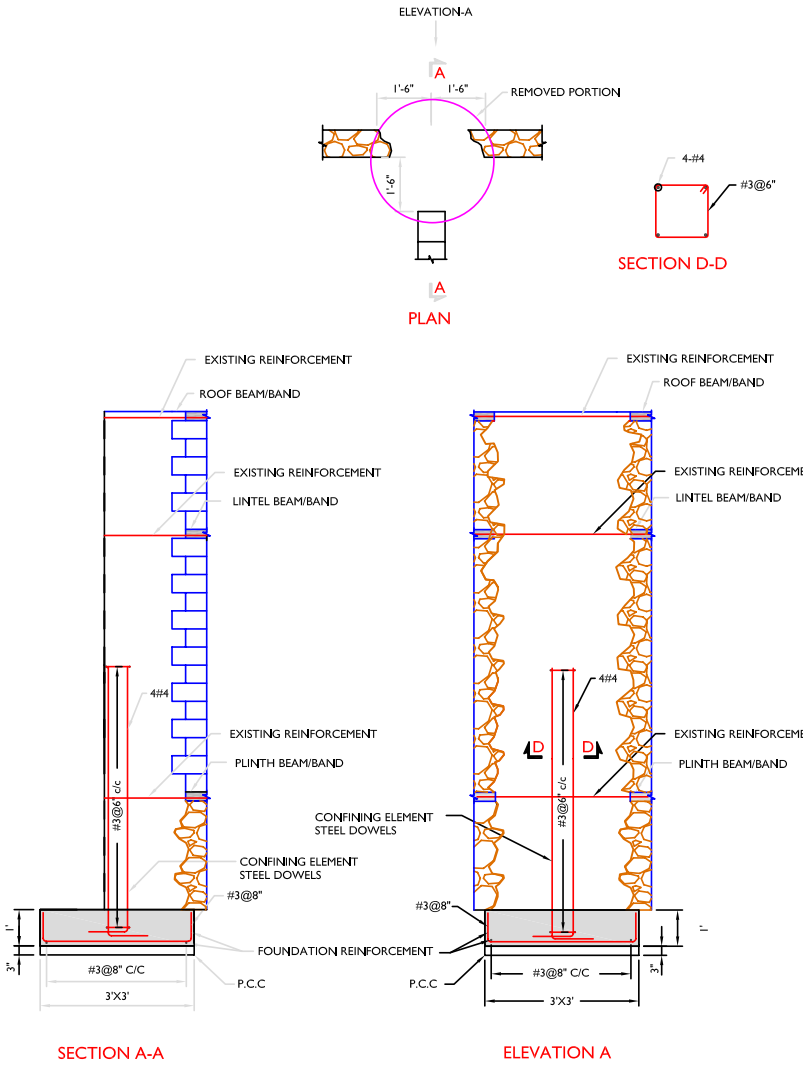


STEP - 2

NOTE:

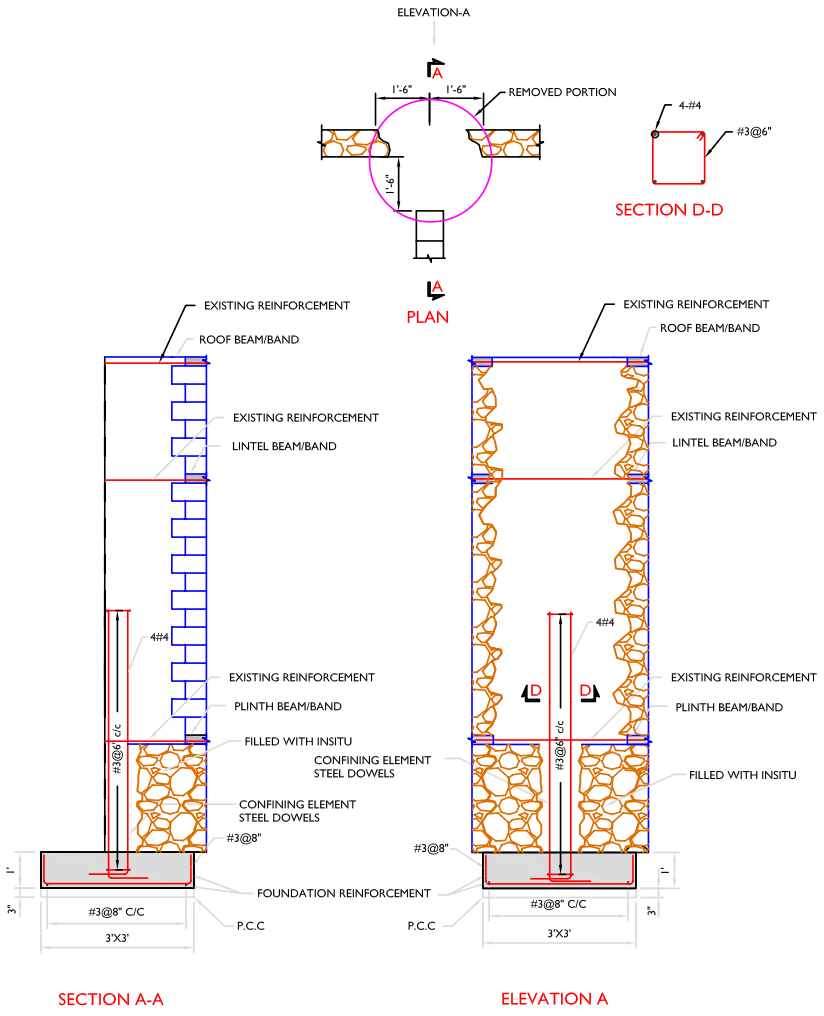
CROSS WALL NOT SHOWN FOR CLARITY ONLY

9 Connecting cross walls of different materials



STEP - 3

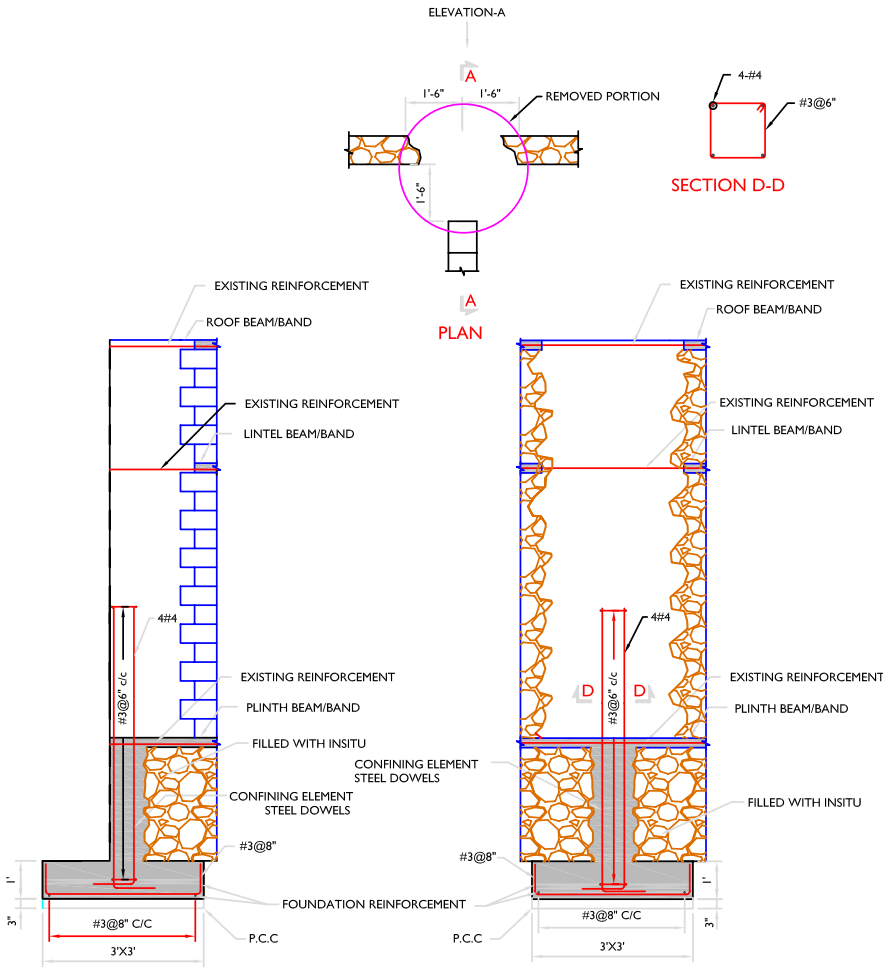
NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY



STEP - 4

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

Connecting cross walls of different materials

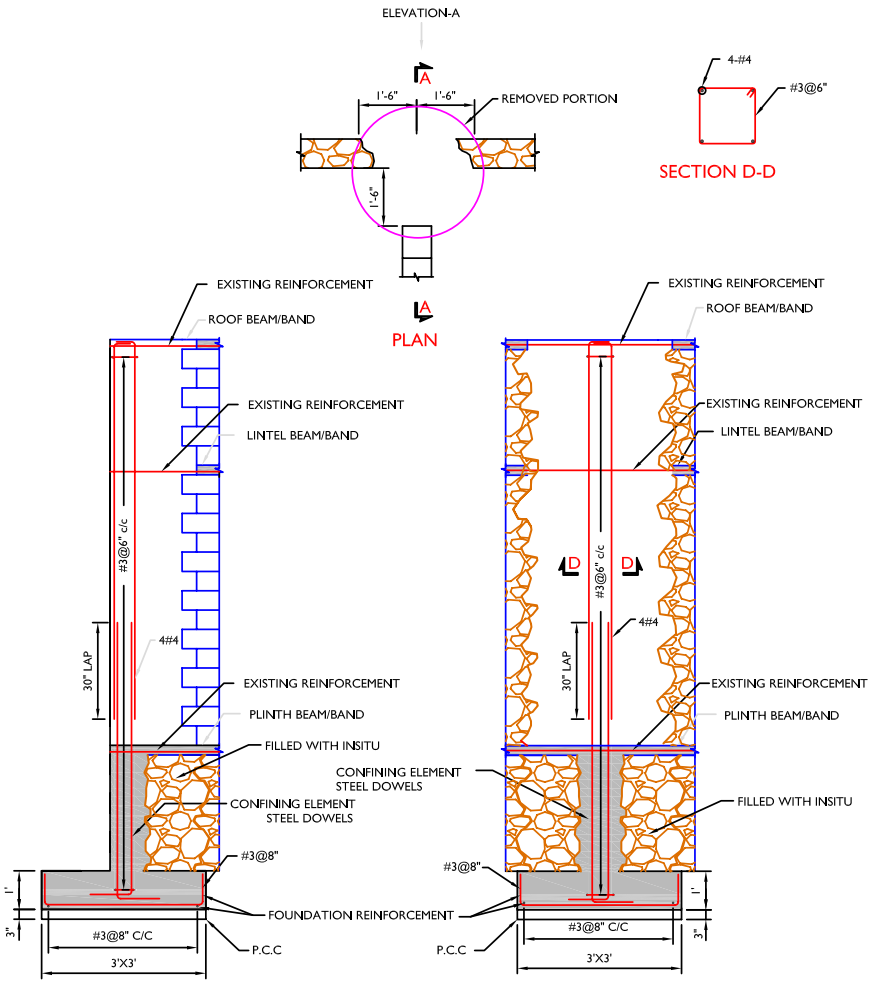


SECTION A-A ELEVATION A

STEP - 5

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION



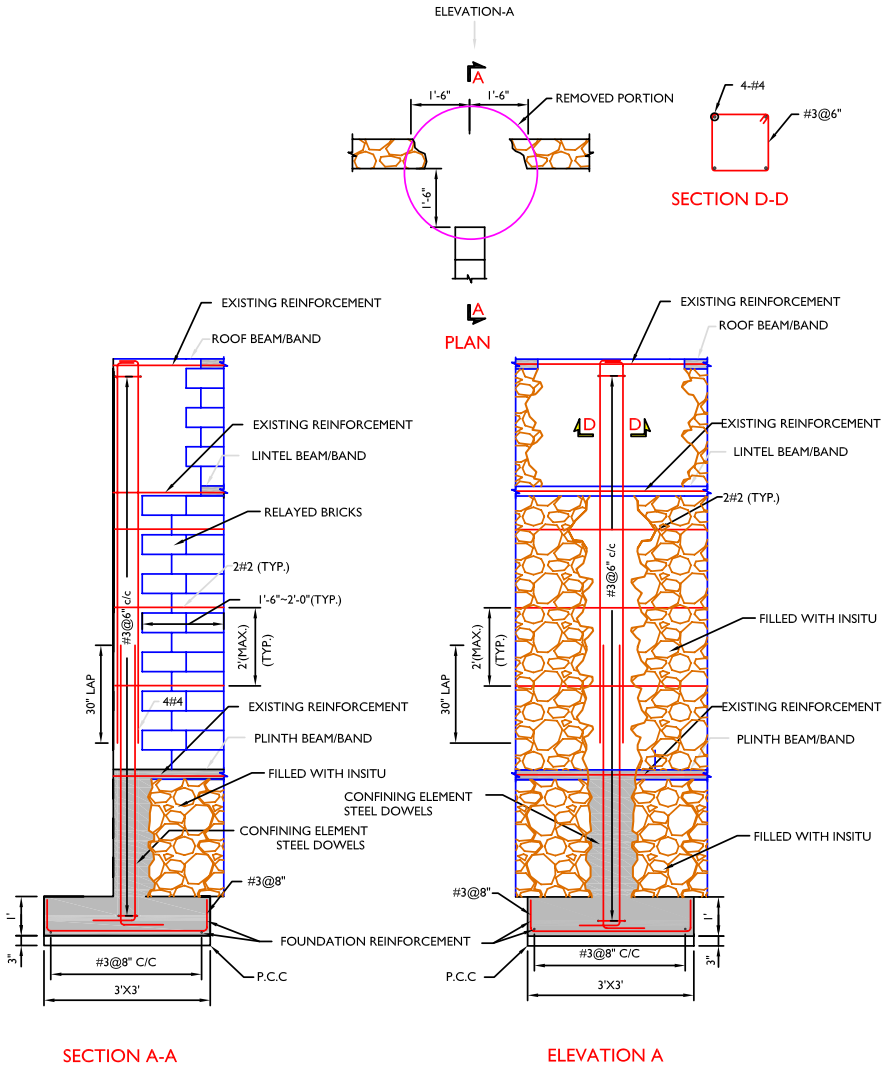
SECTION A-A ELEVATION A

STEP - 6

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

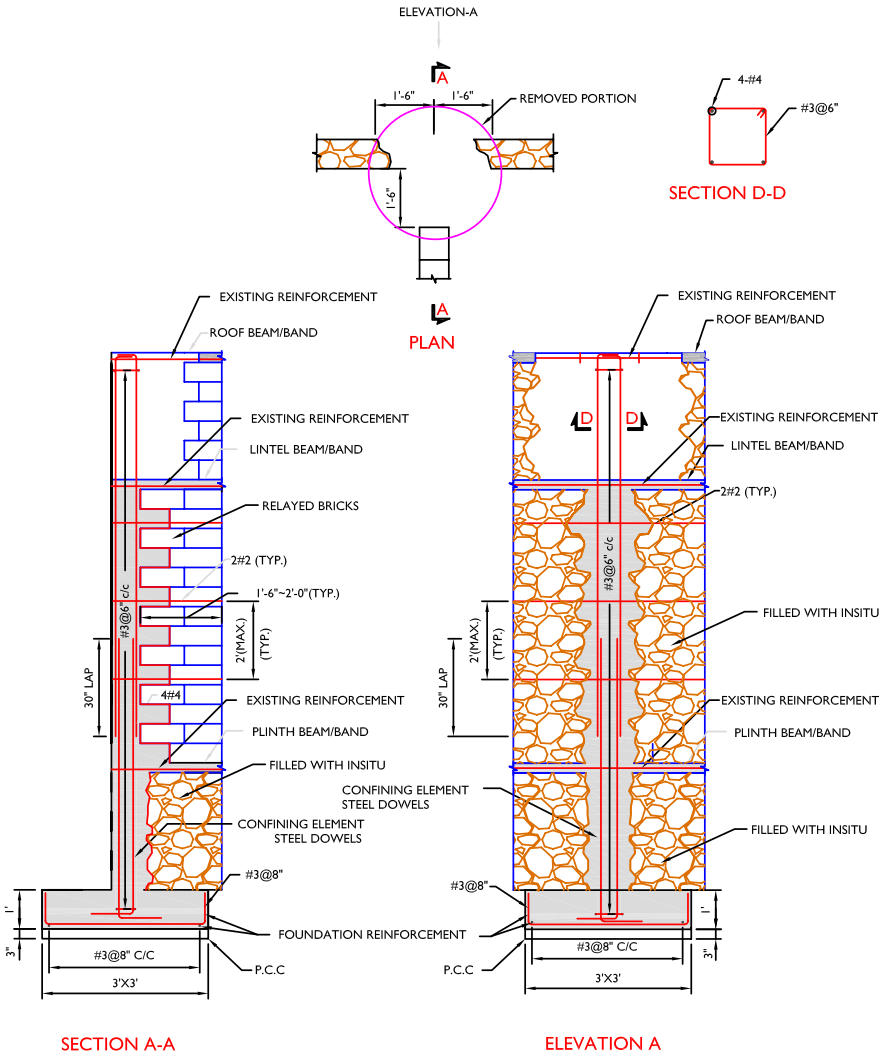
9 Connecting cross walls of different materials



STEP - 7

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

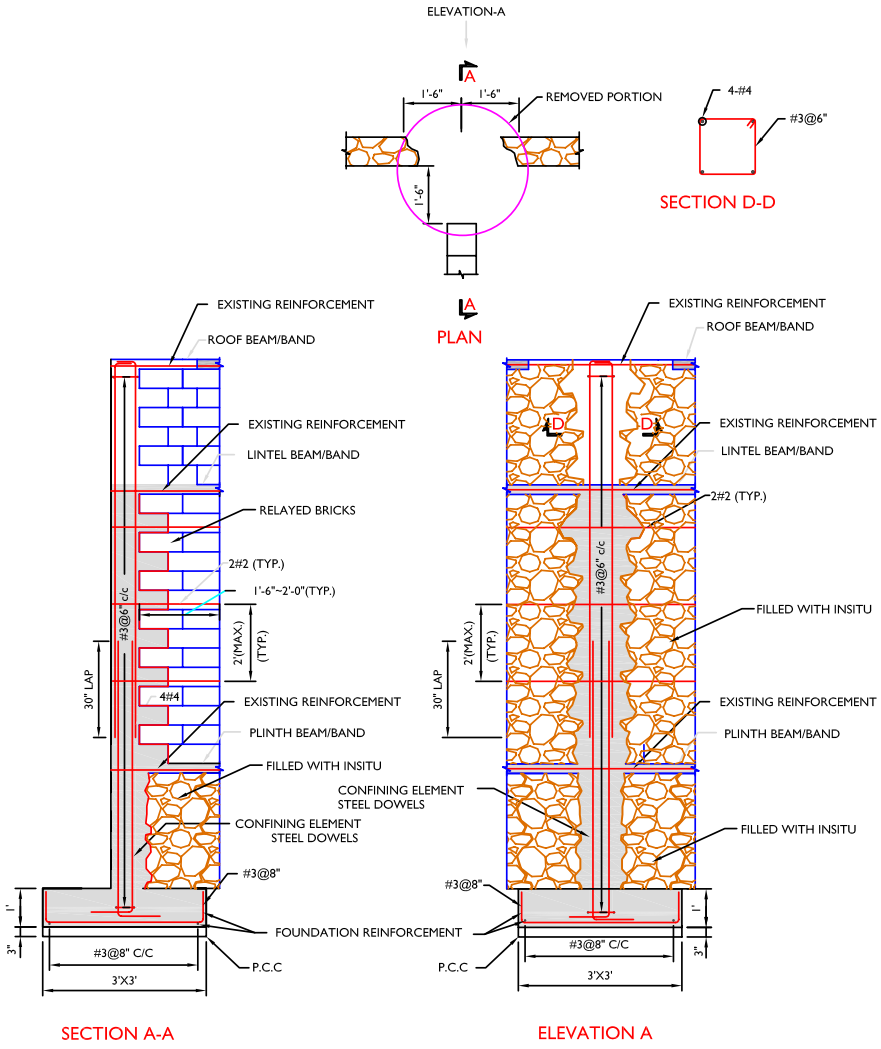


STEP - 8

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

Connecting cross walls of different materials



STEP - 9

NOTE:
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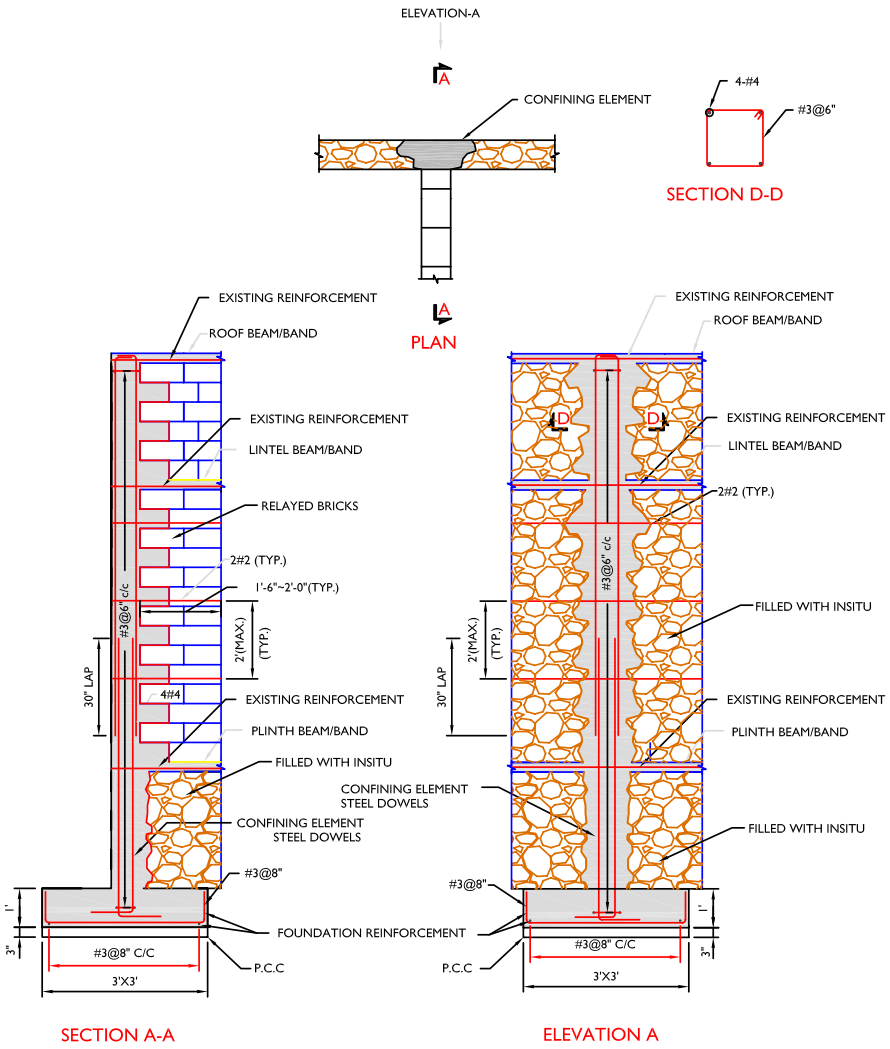
CONCRETED PORTION



STEP - 10

NOTE:
CROSS WALL NOT SHOWN FOR CLARITY ONLY

CONCRETED PORTION

APPENDIX - C

APPENDIX - C

QUESTIONS AND ANSWERS RELATED TO SAFE & COMPLIANT CONSTRUCTION BY NESPAK

C-1: Questions and answers

1 Questions and answers

No	Questions	Construtcion Type	Answers
1	If you have; Provided concrete columns at each corner of the house having four #4 bars used as main reinforcement with #4 vertical reinforcement bars instead of #5 bars (recommended in guidelines) at 4 feet spacing along the length of the wall, at the corners and T-junctions. a- Is it technically safe to use #4 bars instead of #5 bars in such case? b- Will they be safe and compliant?	Reinforced masonry	The resistance of the building against earthquake is dependant on a number of seismic elements, including reinforced plinth, sill, lintel & roof bands,stitches and vertical reinforcement. So providing #4 bars in the place of #5 bars as vertical reinforcement in walls particularly when RC columns are provided at corners of the building does reduce the resistance against earthquakes but not to an alarming extent, if the house comply with all other specifications listed in Section B for Reinforced Masonry are fulfilled. In such case the house will be potentially safe against earthquakes and shall be considered as compliant.
2	Before earthquake Situ foundations were used in building construction. Still some people are using the same technique. Is it a feasible option?	General	Yes. Situ foundations are technically acceptable. Provide at least minimum reinforcement into the foundation as specified in confined masonry poster.
3	In some cases it is observed that different materials are used for masonry construction. For example, back wall is constructed in stone masonry, and rest of the walls are constructed in brick /block masonry. Are such situations acceptable?	General	One of the main technical problems related to such type of mixing is poor connection at junction of two different materials. Due to different size of masonry units adequate interlocking at junctions is very difficult or almost impossible to achieve. The situation is worst if the different material meet at corner or T-junction. The situation is not desirable but may be corrected by adding columns at locations where different materials meet. Dowels and stitches shall be used to tie the masonry with columns. The procedure for adding columns is detailed in case #10 in this catalogue. The field inspector should record reason for use of different materials in back wall and inspect that back wall should not be working as retaining wall. In this case currently the house may not be declared as complaint.
4	In some cases of Timber frame houses, as these are being constructed at high altitudes, various structural elements like base plate and posts are not available in the required dimensions of 4" x 4". So if someone used 4" x 3" or 5" x 3" members then are these houses compliant?	Timber Construction	The 4" x 4" size is the minimum required size. Sizes smaller than this shall be considered non-compliant. The house may be considered complaint for base plate if equivalent (e.g. 2 nos. 2"x4" with actual cross- sectional area equal to 4"x4") or larger member is substituted

I Questions and answers

No	Questions	Construtcion Type	Answers
5	As most of the houses to be constructed are very near to each other so what is the requirement of the shared wall. Either a separate foundation is to be provided for the wall or above plinth the walls may be separated.	General	Both the situations have their pros and cons. Technically, a common footing with separate walls above plinth is superior. However, separate foundations are also acceptable.
6	ERRA guidelines specify horizontal bands at plinth level, sill level, lintel level and roof level. If someone provides all bands except sill level, can it be declared as compliant?	General	Yes. Provided all other specifications of the guidelines are met and sill band is added locally (as per poster requirements) extending 2 ft. beyond the opening in each direction , embedded in 1:4 cement sand mortar set in chase cut along each face of wall. See Case#1 for detail.
7	In some cases a big tree or electric pole is present adjacent to the plinth. It is very difficult for the owner of the house to cut the tree as it is government property and shifting of the poles is very costly. Houses built on such sites shall be considered compliant or non-compliant?	General	It is injustice to the house owner to declare his house non-compliant for reasons beyond his control. However, the owner shall be educated to take up the matter with the relevant authorities. A large tree or electric pole are always vulnerable to strong wind /earthquake and may fall onto the house and damage it during wind storm/ earthquake .The house owner should discuss the matter with concerned authority as he can neither cut the tree nor change location of electric pole.
8	**NEW: ISSUE DATE: 20- SEPTEMBER - 2007** Some of the people in field are using R.C slab over of the confined masonry wall. Is it acceptable. If yes, whether the second storey over this construction is allowed or not?	Confined Masonry	R.C slab cast monolithically with roof beam is acceptable provided all requirements laid down in ERRA's poster are fulfilled. The second storey may be allowed where column dowels project above first floor slab and new walls are constructed exactly over the walls below. Confining elements and their reinforcement shall be as per guidelines for lower storey. Roof shall comprise steel or wooden truss with CGI sheets. **For design guidleines for Reinforced Concrete Slab see the attached drawings**

GUIDELINES FOR REINFORCED CONCRETE SLABS FOR SMALL HOUSES

NOTE:

THESE GUIDE LINES ARE LIMITED TO SLABS SUPPORTED ON ALL FOUR SIDES BY LOAD BEARING MASONRY WALLS.

PROCEDURE:

1. DETERMINE RATIO OF LONGER SIDE TO THE SHORTER SIDE OF THE ROOM.

   IF THE RATIO IS MORE THAN TWO USE INSTRUCTION OF CASE 'A'. IF THE RATIO IS LESS THAN 2 USE INSTRUCTIONS OF CASE 'B'

2. USE 3/8"ø BARS @ 12" c/c AS BINDING/SUPPORTING STEEL.
3. AT DISCONTINUOUS EDGE OF SLAB PROVIDE 3/8"ø BARS @ 9" c/c.

CONCRETE: THE CONCRETE MIX SHOULD NOT BE LEANER THAN 1:2:4 (1 PART CEMENT, 2 PARTS SAND AND 4 PARTS AGGREGATE)

REINFORCEMENT: REINFORCING STEEL SHOULD CONFORM TO GRADE 40, HAVING MINIMUM YIELD STRENGHT OF 40,000 psi. PLAIN STEEL SHOULD BE USED.

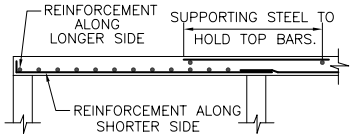
WATER: ONLY WATER THAT IS FIT FOR DRINKING SHALL BE USED TO PREPARE CONCRETE.

SAND: USE CLEAN COARSE SAND FREE FROM IMPURITIES, LIKE CLAY DUST, TREE LEAVES AND SIMILAR FOREIGN MATTER.

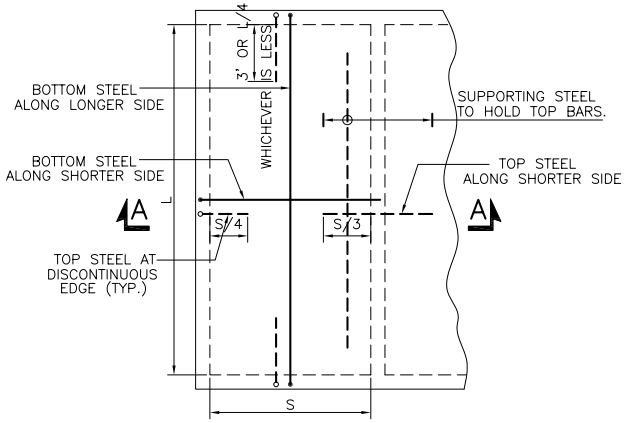
COARSE AGGREGATE: COARSE AGGREGATE SHALL BE CLEAN AND WELL GRADED i.e. THEY SHALL HAVE GOOD REPRESENTATION OF VARIOUS PARTICLE SIZES.

CASE 'A'

LENGTH OF SHORTER SIDE ROOM	SLAB THICKNESS (INCH)	BOTTEM REINFORCEMENT ALONG SHORTER SIDE	BOTTEM REINFORCEMENT ALONG LONGER SIDE	TOP REINFORCEMENT AT CONTINUOUS EDGE ALONG SHORTER SIDE
6' or Less	4	3/8"ø@9"	3/8"ø@12"	3/8"ø@9"
8'	5	3/8"ø@9"	3/8"ø@12"	3/8"ø@9"
10'	6	1/2"ø@8"	3/8"ø@9"	1/2"ø@8"
12'	7¼	1/2"ø@6"	3/8"ø@9"	1/2"ø@6"

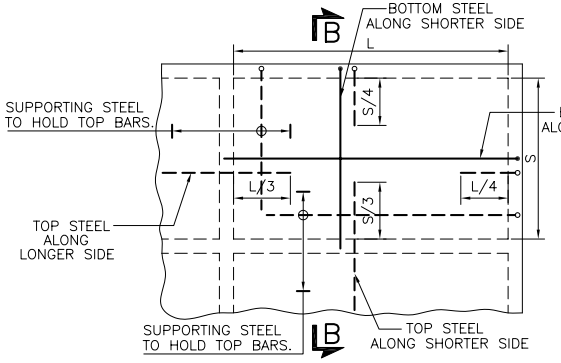


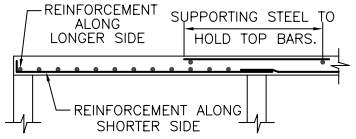
SECTION A-A



CASE 'B'

SHORTER SIDE OF ROOM	LONGER SIDE OF ROOM	MINIMUM SLAB THICKNESS	BOTTEM STEEL ALONG SHORTER SIDE	BOTTEM STEEL ALONG LONGER SIDE	TOP STEEL ALONG SHORTER SIDE	TOP STEEL ALONG LONGER SIDE
8'	8'	4"	3/8"ø@8"	3/8"ø@8"	3/8"ø@8"	3/8"ø@8"
	10'	4"	3/8"ø@8"	3/8"ø@8"	3/8"ø@7"	3/8"ø@7"
	12'	4"	3/8"ø@8"	3/8"ø@8"	3/8"ø@7"	3/8"ø@7"
	14'	4"	3/8"ø@8"	3/8"ø@8"	3/8"ø@7"	3/8"ø@7"
10'	10'	4"	3/8"ø@8"	3/8"ø@8"	3/8"ø@6"	3/8"ø@6"
	12'	4"	3/8"ø@8"	3/8"ø@8"	1/2"ø@8"	1/2"ø@9"
	14'	4"	3/8"ø@6"	3/8"ø@6"	1/2"ø@7"	1/2"ø@8"
12'	12'	4"	3/8"ø@6"	3/8"ø@6"	1/2"ø@8"	1/2"ø@8"
	14'	5"	3/8"ø@5½"	3/8"ø@6"	1/2"ø@6"	1/2"ø@6"
14'	14'	5"	3/8"ø@5"	3/8"ø@6"	1/2"ø@5"	1/2"ø@5"

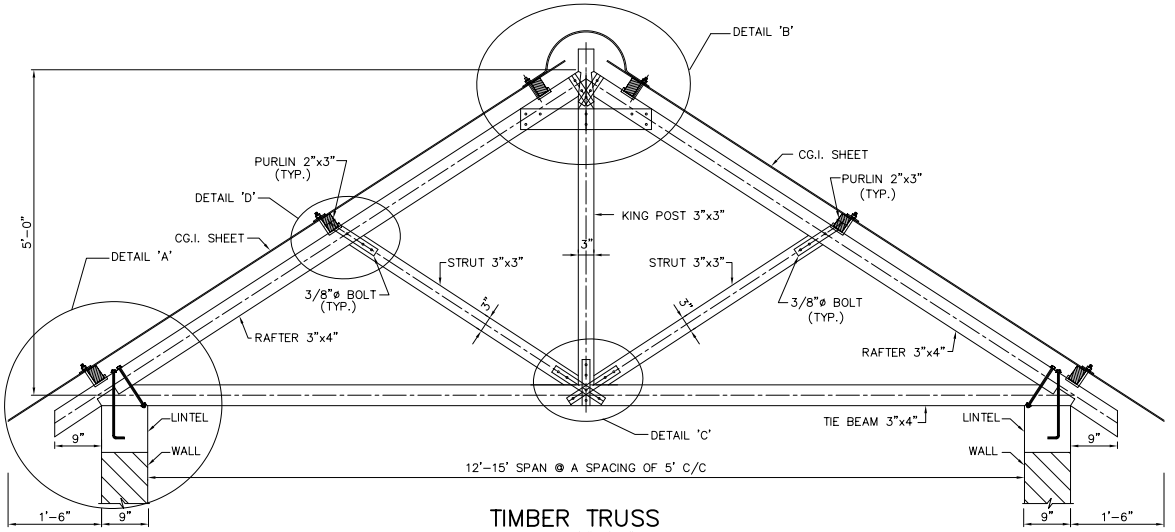




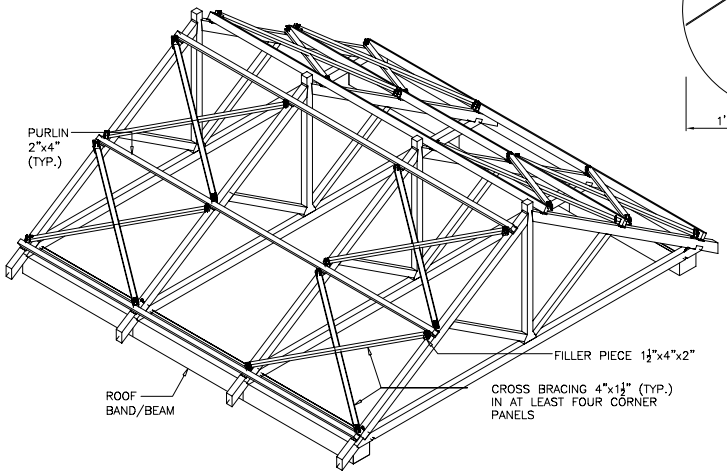
SECTION B-B

TIMBER ROOF FOR SMALL RURAL HOUSES

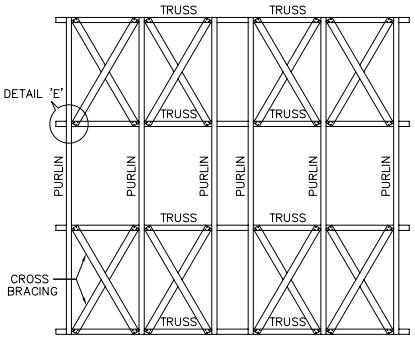
1. USE GOOD QUALITY WELL REASONED TIMBER FOR ROOF TRUSS.
2. CENTER TO CENTER SPACING BETWEEN TRUSSES SHALL BE FIVE TO SIX FEET.
3. TRUSSES SHALL BE TIED DOWN TO THE ROOF BAND/BEAM USING 1/2"ø ANCHOR BOLTS.
4. STRAPS MAY BE PROTECTED FROM RUST BY PAINTING.
5. FIX STEEL STRAPS ON BOTH FACES OF TRUSS.



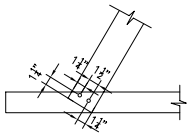
TIMBER TRUSS
SCALE 3/4"=1'-0"



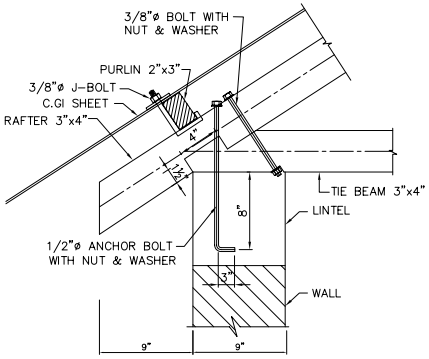
ISOMETRIC VIEW



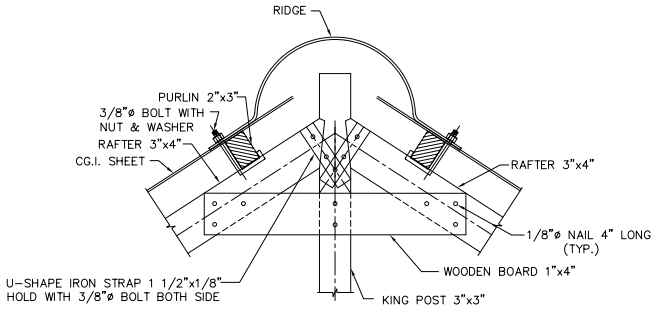
ROOF PLAN



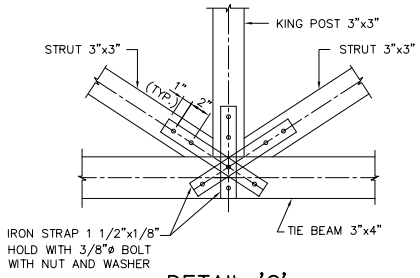
DETAIL 'E'



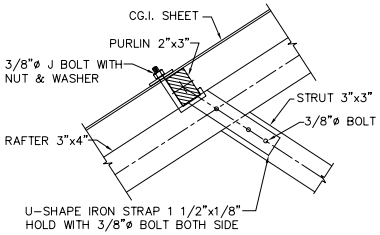
DETAIL 'A'
SCALE 1 1/2" = 1'-0"



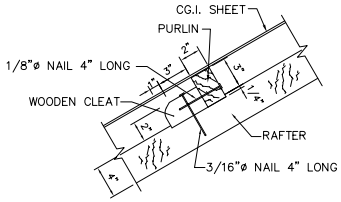
DETAIL 'B'
SCALE 1 1/2" = 1'-0"



DETAIL 'C'
SCALE 1 1/2" = 1'-0"



DETAIL 'D'
SCALE 1 1/2" = 1'-0"



CONNECTION OF PURLIN WITH TIMBER TRUSS
SCALE 1 1/2" = 1'-0"

The step by step photographs in Section D are taken at model buildings constructed to test the remedial measures at Dhirkot HRC, District Bagh, AJK.

For advice on any information in this book, contact:

UN-HABITAT Islamabad Office, House No. 6, Street-20, F-7/2, Islamabad. Tel. 051-825 5230

UN-HABITAT

For further information regarding rural housing reconstruction contact the following ERRA Housing Reconstruction Centres, (HRC)'s:

Azad Jammu and Kashmir

Muzaffarabad HRC
Hse No. B-10, Upper Chattar housing Scheme,
Near State Bank, Muzaffarabad.
Ph: 058810- 34994-5
Email: hrc.muzaffarabad@unhabitat.org.pk

Hattian HRC
Tehsil Compound Hattian Bala
Ph: 058830- 42589
Email: hrc.hattian@unhabitat.org.pk

Patika HRC
Sere Culture Office Compound, Nokot, Patika
Ph: 058811-42944
Email: hrc.patika@unhabitat.org.pk

Rawalakot HRC
Industrial Area, Eid Gah darek, Rawalakot
Ph: 058710- 81096
Email: hrc.rawalakot@unhabitat.org.pk

Bagh HRC
Behind Income Tax Office, District Headquarters,
Bagh
Ph: 058720- 72529
Email: hrc.bagh@unhabitat.org.pk

Dhirkot HRC
Neelabut Road, Tourist Rest House, Dhirkot
Ph: 0992- 506302
Email: hrc.dhirkot@unhabitat.org.pk

Haveli HRC
Towards Boys College, Kahuta.
Ph: 058720- 32321
Email: hrc.haveli@unhabitat.org.pk

Abbaspur HRC
In front of Degree College for Girls, Abbaspur
Email: hrc.abbaspur@unhabitat.org.pk

North West Frontier Province

Battagram HRC
In front of District Headquarters Hospital,
Battagram.
Ph: 0997- 311900

Balakot HRC
Near Govt. Middle School, Shohala Najaf Khan.
Balakot
Ph: 0997- 360656

Ahal HRC
Near Nazir hospital, Ahal
Ph: 0997- 330585

Bana HRC
CNW Guest house, Bana
Ph: 0997- 319388

Abbottabad HRC
Awan Lodge, Near North Haven Hotel,
Mansehra Road, Mirpur,
Abbottabad.
Ph: 0992- 383860

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