







Government of Nepal  
**National Reconstruction Authority**  
Singhadurbar, Kathmandu

## Ready-to-Use Manuals for Repair and Retrofitting of Masonry Structures



March 2021



# PREAMBLE

This 'Repair and Retrofitting Manual for Masonry Structures' is an important achievement in the field of the Nepal's Post-Earthquake Reconstruction Programme. To date, 70,439 retrofit beneficiaries have been identified in 32 earthquake-affected districts of Nepal. As safety of the occupants is a crucial requirement of the reconstruction programme, the best option is to retrofit these partially damaged buildings with the support of the retrofitting grant.



The development of this manual was completed in conjunction with the retrofitting of several houses in earthquake-affected districts, which made it possible to ensure the practical viability of all the approaches. This has also made it possible to address the most commonly observed vulnerabilities in the vernacular buildings in the region. This technology, I believe, will not only strengthen the structural integrity of the buildings but also will help to preserve the valuable vernacular architectures both of rural and urban Nepal. Such ready-to-use retrofitting manuals are the way forward for implementing large scale retrofitting in the country post disaster, as well as for the prevention of future damage.

This manual can be used by all engineers and sub-engineers who are working on retrofitting at central and local levels all over Nepal. The manual will be a valuable reference in academia for learning and sharing of knowledge, not just in Nepal but in other countries that, like ours, suffer from naturally-triggered disasters.

## **Sushil Gyewali**

Chief Executive Officer

National Reconstruction Authority



# ACKNOWLEDGEMENTS

This 'Repair and Retrofitting Manual for Masonry Structures' is dedicated to all personnel involved in the field of academia and practitioners of the construction industry. The manual provides insight into affordable, contextualized and replicable technologies for the repair, restoration and retrofitting of houses, in a way that is ready to use.



I appreciate the contribution of the Central Level Project Implementation Unit (Building) for taking the lead, together with partner organizations UNOPS, Build Change, NSET, UNDP and CRS for their support on the production of the manuals.

NRA CEO Mr Sushil Gyawali deserves a special thanks for encouraging such a crucial manual with tireless energy and commitment. Without his leadership of the NRA, this kind of solidarity and smooth operation of activities and knowledge sharing would not be possible.

A special note of cordial thanks to respected senior experts Dr Hari Ram Parajuli, Prof. Dr Prem Nath Maskey, Prof. Dr Gokarna Bahadur Motra, Mr Tim Hart and Mr Jitendra Bothara for their comments and guidance in the finalization of the manual.

I would also like to show my appreciation to Mr Bipin Kumar Gautam, Ms Liva Shrestha and Dr Ramesh Guragain for their work on the compilation of the manual and Mr Manohar Ghimire, NRA's Under Secretary & ICNR Secretariat's Member Secretary and Mr Sandeep Gurung, the Assistant Conference Expert for facilitating and expediting the process.

Finally, I hereby make the most of the opportunity to express my sincere thanks to all personnel involved, both directly and indirectly, for their valuable contribution to the preparation of this manual. I am confident that it will be a valuable reference for all the practitioners of Nepal's retrofitting activities.

**Mani Ram Gelal**

Secretary

National Reconstruction Authority



# FOREWORD

I would sincerely like to congratulate everyone involved in the development of the 'Repair and Retrofitting Manual for Masonry Structures' which has been published by the National Reconstruction Authority. This manual is one of a series of publications intended to record the NRA's experiences for future generations of Nepalis and for other countries facing similar problems. These documents will be presented at the International Conference on Nepal's Reconstruction (INCR-2021).



This manual is prepared to provide guidance specifically on masonry houses and offers pre-engineered retrofitting solutions using the strong back and splint & bandage approaches for retrofitting of typical masonry houses, particularly the traditional SMM houses common in the midhills of Nepal. These approaches and designs are based on laboratory testing and analytical modelling, as well as numerous iterative calculations for all critical conditions that may occur in these types of buildings in the field.

The step-by-step pictorial descriptions in these manuals shall aid engineers to understand the repair and retrofitting techniques and help them to guide and provide technical assistance to homeowners and masons.

As retrofitting is different from constructing a new house, it requires that existing masons and engineers gain new knowledge of new techniques. This is a hands-on manual that translates the complexity of designing retrofits for each house to a simpler format with the ready-to-use designs.

I look forward to seeing the retrofitting techniques implemented across earthquake-affected districts and all vulnerable houses in the country. This represents another positive step forward in the construction process, and will support homeowners to retrofit their homes so that they are safe, compliant, and resilient in the face of future disasters. Additionally, I trust that this manual will contribute to the complete guidance of retrofitting and will continue to pave the way forward toward safe housing. In future, the Ministry of Urban Development (MoUD) will consider consolidating various approaches under one guideline, which will be instrumental for further replicating to all local governments of Nepal.

## **Dr Chandra Bahadur Shrestha**

NRA Executive Member & ICNR Convener  
National Reconstruction Authority

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## BACKGROUND

Earthquakes are one of the most devastating natural disasters that can cause large-scale loss of life and property. Earthquakes can destroy entire cities. Earthquakes can induce secondary hazards including aftershocks, landslides, liquefaction, tsunamis and avalanches. Sometimes the earthquake-induced secondary effects are more dangerous than the quake itself. On April 25th 2015, a 7.8-magnitude earthquake struck Nepal. More than 8,800 people were killed and 23,000 were injured. About 299,588 homes were destroyed and 269,107 were partially damaged. Under the housing reconstruction programme, homeowners of houses that are partially damaged, and fall under damage grade 2 (major) and grade 3 (minor), were eligible to receive a 100,000 NPR grant to retrofit their home. For the household to receive the housing retrofit grant, their home must comply with a two-step verification process, at the start of retrofitting and right before plastering.

The retrofit manuals and designs that are approved for use have been formulated based on the Nepal National Building Code and Indian Standard codes. The retrofitting elements are proposed based on structural deficiencies causing local and global failures. The manuals propose retrofitting solutions for deficiencies that were observed in rural SMM houses in the past earthquake. Three manuals were used extensively to retrofit houses during the reconstruction phase post the Nepal Gorkha earthquake in 2015:

- Repair and Retrofit Manual for Masonry Structures (Annex 1)
- Retrofitting Manual: Type Design for Retrofitting Stone Masonry in Mud Mortar (SMM) Houses using Strong Back Approach (Annex 2)
- Field Guide for Repair and Retrofitting for up to 2½-storey Masonry Buildings in Mud Mortar (Annex 3)

This document is a collection of these three manuals (Annexes 1–3) that provides a menu of pre-engineered and ready-to-use retrofitting solutions for masonry houses. The manual collectively recommends approaches such as the strong back approach, the splint and bandage approach using galvanized iron wire mesh, welded wire mesh, timber and containment reinforcement using wire mesh for typical masonry houses that follow specific eligibility criteria. The eligibility criteria may differ with the different retrofitting methodology adopted.

Designing a retrofit solution for a house is a long process that starts with the detailed assessment of the structure followed by a detailed structural calculation and design

method by an experienced engineer. After the 2015 earthquake, more than 60,000 homeowners were categorized as eligible for a retrofitting grant. Designing each and every one of these houses in a bespoke manner would be very expensive to the homeowners and to the Government. Hence, it was of utmost importance that the retrofitting process be simple to implement as well as simple to check by engineers. These manuals provide retrofit options in this simplified manner, given that the houses were similar, and thus that they all met the same eligibility criteria. This was achievable because most of the houses in the mid-hills of Nepal have similar geometrical and structural configurations, so it was possible to create retrofitting solutions that would be applicable to a large subset of the houses.

The retrofitting approaches prescribed by the manuals can be used in a preventative setting as well to improve performance of these building in future earthquakes.

## Target Groups

These manuals are designed to be used by engineers and sub-engineers who are going to provide technical assistance to homeowners who wish to reduce vulnerability by retrofitting their houses.

## Deficiencies in Masonry Buildings

The damages observed in these traditional masonry houses were found to be very similar and repetitive throughout different earthquake-affected locations in Nepal. This was expected, as the construction practices observed were also found to be similar throughout the earthquake-affected regions. Damage due to out-of-plane loading was found to be most prominent. The deficiencies in the buildings can be clearly outlined by observing the damages induced in by the earthquake:

### **Delamination of walls:**

This damage was mostly seen in stone masonry in mud mortar houses where the width of the walls is very thick. The walls are built with two faces, and the lack of connection between the inner and outer wythes, causes the wythes to behave as two separate slender walls under out-of-plane shaking. This resulted in frequently observed delamination and led to subsequent damage or even out-of-plane collapse in some houses.

Deficiency: Lack of connection between outermost layers of walls



Figure 1: Cross section of a damaged SMM house showing the dual layer of stones

(Photo credit: NRA)



Figure 2: Damaged gable wall in an SMM house

(Photo credit: NRA)

### Gable wall collapse:

The stone masonry in the short walls is typically extended up to the roof line, forming the triangular gable walls, which directly support the outermost roof trusses at each end of the house. This gable wall, although adequate for gravity loads, is unbraced and unreinforced. During the Gorkha earthquake this unreinforced wall was prone to collapse due to the out-of-plane lateral shaking. Gable wall collapse often initiated or facilitated the subsequent collapse of the transverse walls below.

Deficiency: unsupported, tall gable walls



Figure 3: Short wall out-of-plane damage in SMM building

(Photo credit: NRA)



Figure 4: Collapsed gable wall

(Photo credit: NRA)

### **Short wall out-of-plane damages:**

There was a high occurrence of damage to the short walls of masonry buildings. The floor diaphragm is only connected to the short walls through the girder beam at the middle point of the walls, while it is connected to every embedded joist along the longitudinal walls, leaving the short walls significantly less braced out-of-plane than the longitudinal walls. This led to a concentration of out-of-plane damage observed on the short walls of the building. In addition, the wall corners did not have sufficient capacity to transfer forces from one wall to the adjacent wall, which also caused wall separation at the corners, leaving the short wall with even less bracing against out-of-plane loads.

Deficiency: Lack of adequate connection of short walls to the diaphragm

### **Attic wall out-of-plane damages:**

The top of the attic walls, which are essentially a tall perimeter parapet above the attic floor, are usually not tied together nor are they directly connected to the roof framing. The lack of bracing for these cantilevering unreinforced walls led to observed out-of-plane failure in the earthquake.

Deficiency: Unsupported attic walls



**Figure 5: Attic wall out-of-plane damage**  
(Photo credit: NRA)

### **Diaphragm deficiency:**

The floor joists are directly embedded in the walls and there is typically no element to serve as the perimeter diaphragm chord. Due to the lack of a tension-carrying chord element at the edges of the diaphragm, significant diaphragm deflection likely occurred, leading to vertical cracks at the face of the walls or in some cases collapse of the floor.

Deficiency: Lack of chord element in diaphragm edges



**Figure 6: Diaphragm deficiency**

(Photo credit: NRA)

**In-plane damage in walls:**

This type of damage was mostly observed in brick masonry in mud mortar buildings and brick in cement mortar buildings in wall piers between openings.



**Figure 7: In-plane damage in wall**

(Photo credit: NRA)

## RETROFIT APPROACHES

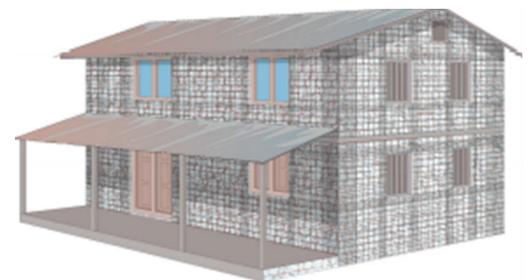
All three manuals take similar approaches to providing retrofit solutions. Based on the damages observed in these types of buildings in the past earthquake and the deficiencies associated with it, the manuals apply the following strategies but use different approaches to achieve the retrofit target:

- Configuration and load path improvement
- Wall-to-wall connection improvement
- Wall-to-floor connection improvement
- Wall-to-roof connection improvement
- Diaphragm improvements
- Roof improvements
- Bracing parapet walls
- Securing gable walls
- Capacity improvement of structural walls

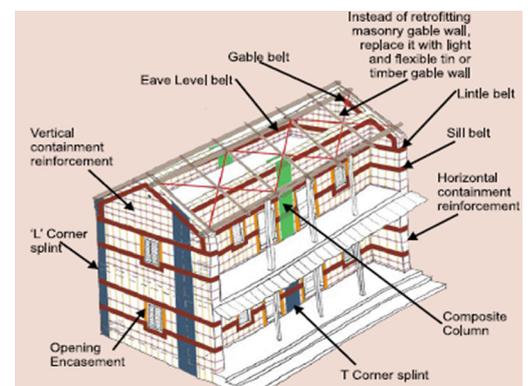
The manuals use two major approaches in providing retrofitting solutions. These two approaches are as follows:

### Splint and Bandage Approach

The splint and bandage approach consists of vertical splints at building corners, at wall intersections and on either side of openings, plus horizontal bandages at sill, lintel and floor levels. The wall areas not covered by the splints and bandages are covered by wire mesh that confines the walls. Various materials are recommended for use for the splints and bandages. The function of the splints is to add in-plane capacity and stiffness to the walls. The splints at the edge of the piers provide tension capacity to the walls. The splint is fixed at the bottom by a plinth beam. The function of the bandage is to tie the walls together to provide box action. The bandages are similar to splints in terms of materials used and details but are horizontal instead of vertical bands. Bandages



**Figure 8: Splint and bandage approach**  
(Source: NRA's Repair and Retrofitting Manual)



**Figure 9: Key elements in splint and bandage approach**  
(Source: UNDP)

are provided at the top and bottom of floors and openings. Cement sand plaster is applied on the outside and inside of the walls to cover all the reinforcement.

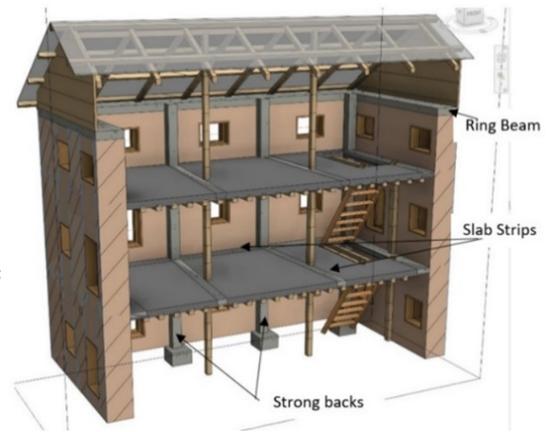
## Strong Back Approach

The strong back design comprises a system of reinforced concrete strong backs placed at corners and at locations along the length of the wall, connected at the floor level by slab strips and a ring beam at the top of the walls. The strong back is connected to the walls with the help of through anchors. The function of the strong back is to brace the walls against out-of-plane forces, as well as to provide connectivity to the various elements of the system.

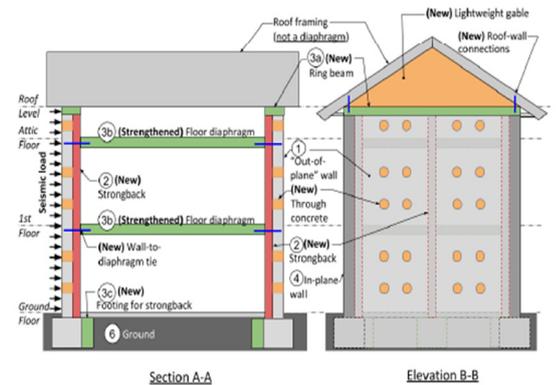
At the floor levels, a slab strip is provided around the inside perimeter of the wall and across, connecting opposite strong backs. This slab strip acts as the chord element at the edges of the floor. A reinforced concrete ring beam is provided at the top of the walls to provide connectivity and restraint to the walls at the top.

Through concrete is provided all over the walls. The through concrete connects the inner and outer wythes of the thick walls, preventing delamination and hence increasing the overall out-of-plane capacity of the walls. Finally, a cement sand plaster is applied to the walls on the internal and external surfaces.

In both approaches, heavy gable walls made of heavy masonry are dismantled and a light CGI or timber gable is provided with good connection to the roof and the ring beam. In addition, improvements to the connections with the existing timber elements are provided with the help of CGI straps.



**Figure 10: Strong back approach**  
(Source: Build Change)



**Figure 11: Key elements of Strong back approach**  
(Source: Build Change)



**Figure 12: Light gable**  
(Photo credit: Build Change)

The Repair and Retrofit Manual for Masonry Structures and the Field Guide for Repair and Retrofitting for up to 2½-storey Masonry Buildings in Mud Mortar both use the splint and bandage approach, whereas the Engineering Manual: Standard Type Design Retrofits for SMM Structures uses the strong back approach as a retrofit solution.

# REPAIR AND RETROFITTING MANUAL FOR MASONRY STRUCTURES

**See Annex 1.**

This manual is applicable to masonry buildings that are residential and fall under categories C and D of the Nepal National Building code:

**Category C:** Buildings with plinth area of up to 1,000 square feet, with up to three floors including the ground floor or with structural span of up to 4.5 metres.

**Category D:** Small houses, sheds made of baked or unbaked brick, stone, clay, bamboo, grass, etc.

The manual is divided into four parts:

**Part A:** Seismic Damage and Intervention: deals with various damages that were observed in masonry buildings and intervention options that can be adopted for different elements or different damage grades.

**Part B:** Seismic Deficiencies and Interventions: deals with various deficiencies in connections in masonry buildings.

**Part C:** Ready-to-use Seismic Retrofit Designs: simplified and ready-to-use designs are provided that are applicable to those buildings that meet the eligibility criteria.

**Part D:** Construction Sequences: explains the construction sequence for repair of buildings and the general retrofitting process.

The manual provides the following options as retrofitting solutions:

**Option 1:** Retrofitting using RC splint-bandage and GI wire jacketing

**Option 2:** Retrofitting using welded GI wire mesh splint-bandage and GI wire jacketing

**Option 3:** Retrofitting using welded GI wire mesh splint-bandage and PP band jacketing

**Option 4:** Retrofitting using wooden splint-bandage and GI wire mesh jacketing

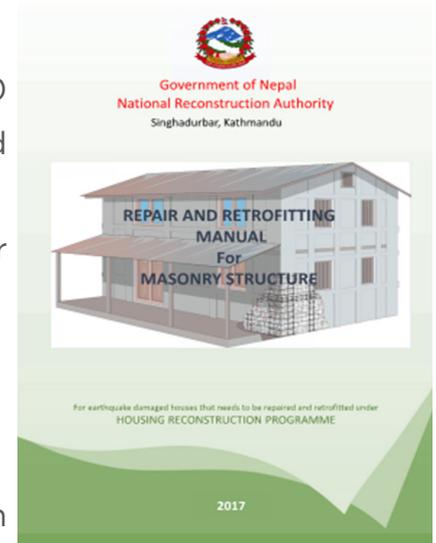


Figure 13: Repair and Retrofitting manual for masonry structures

# RETROFITTING MANUAL: TYPE DESIGN FOR RETROFITTING STONE MASONRY IN MUD MORTAR (SMM) HOUSES USING STRONG BACK APPROACH

**See Annex 2.**

This manual is valid for the retrofit of buildings constructed in the traditional Nepali practice using SMM construction. This building system is assumed to have the following properties:

- Exterior walls are SMM construction
- Floor framing consists of wood joists and planking supporting a mud slab
- Wood posts providing support for the joists at the diaphragm centerline
- Roof consists of wood beams, rafters and purlins with CGI roofing or roof tiles.

These guidelines do not apply to stone masonry buildings constructed with reinforced concrete slabs at any floor or roof level.

The manual applies to buildings as described above and that meet a set of eligibility criteria on shape, size, location and other features.

The manual provides two options of strong backs:

- reinforced concrete strong back
- timber strong back

Either can be selected, based on availability of quality materials.

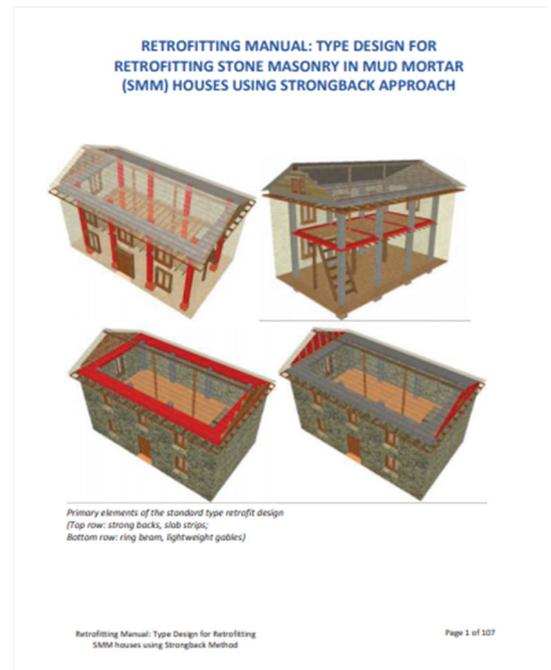


Figure 14: Retrofitting manual: strong back approach

# FIELD GUIDE FOR REPAIR AND RETROFITTING FOR UP TO 2½-STOREY MASONRY BUILDINGS IN MUD MORTAR

*See Annex 3.*

This guide focuses specifically on retrofitting masonry buildings in mud mortar that are up to 2½ storeys high using the containment reinforcement technique. This technique is suitable in Nepal since it is simple, cost effective, uses easily available materials and is simple to implement. Furthermore, most common types of stone masonry observed in the earthquake-affected regions allow for making the 15mm-diameter holes that are necessary in the CR system for the insertion of the cross-links for the anchoring of different retrofitting elements. It is equally applicable to houses built with brick masonry in mud mortar.

The guidebook is divided into two parts:

**Part 1:** Explains repairing various damages to the buildings, restoring them to their original condition

**Part 2:** Explains retrofitting measures for further strengthening the buildings

This approach consists of welded wire mesh splints and bandages with a containment mesh basket to prevent disintegration of the masonry walls. It also includes floor bracing by galvanized iron wires.

This retrofitting approach can be done in 5 incremental phases. Based on affordability, the homeowners can choose to carry out the first few phases at a time.

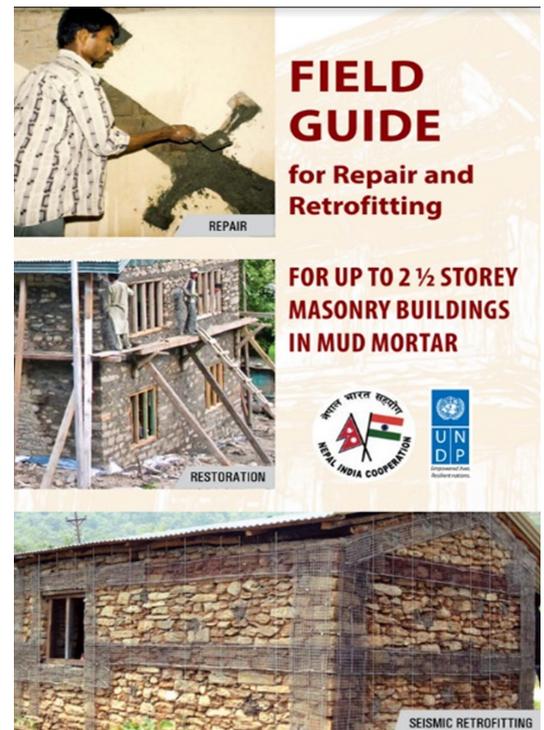


Figure 15: Field guide for repair and retrofitting

## IMPLEMENTATION OF THE APPROACHES

The strong back retrofitting approach has been successfully implemented in around 250 private SMM houses spanned over 20 districts, whereas around 100 private SMM houses have been retrofitted using the splint and bandage approach.

The learnings from that implementation are well documented and are transferred in this manual. Step-by-step pictorial descriptions are shown for different retrofitting techniques, which enables engineers to guide homeowners and masons to implement the techniques with some technical assistance.



Figures 16 & 17: Strong back approach retrofitted houses  
Left: ongoing retrofitting; Right: after retrofit



Figures 18 & 19: Splint & bandage approach retrofitted houses  
Left: ongoing retrofitting; Right: after retrofit

(Photo credits for Figures 16–19: NRA)

## **WAY FORWARD**

The manuals are based on NBC 105: 1995. The details and design in these manuals need to be checked and upgraded as per the new NBC105:2020.

The manuals have common parts such as damages and deficiencies in masonry buildings, repair methods, etc. It would be better if these three manuals could be consolidated into one manual so that the users can access the information more easily without repetition of information.

To scale up retrofitting in Nepal, more pictorial guides, mason training materials, etc. need to be produced based on these manuals.

More ready-to-use manuals need to be produced to aid the engineers to provide technical assistance to homeowners who want to retrofit their houses.

# ANNEXES

## Annex 1: Repair and Retrofitting Manual for Masonry Structures



Government of Nepal  
National Reconstruction Authority  
Singhadurbar, Kathmandu

# Repair and Retrofit Manual for Masonry Structures

FEBRUARY 2021

## **Preface**

This document is a compilation of repair and retrofit manuals for masonry houses developed based on retrofit designs and methods approved by the National Reconstruction Authority.

After the Nepal-Gorkha earthquake in 2015, some pre-engineered designs and approaches for retrofitting were developed and some of the previously developed approaches were implemented. These retrofitting resources are compiled into one document so that it will serve as a complete reference document for future retrofitting purpose. The compilation has been done for use of these designs and methods in post disaster and/or preventative retrofitting of residential houses in the future.

There are three manuals compiled in this document. The first is the Repair and Retrofit Manual. The second is the Engineering Manual for Standard Type Design Retrofits of Stone Masonry with Mud Mortar houses using the strong back approach. The third is the Field manual for repair and retrofitting for upto 2 ½ storey Masonry Buildings in Mud Mortar. These manuals have been used in implementation of retrofits after the 2015 earthquake and can be a valuable resource for retrofitting in the future.

This document can be used by engineers to propose retrofit solutions or give advice to homeowners who want to retrofit their homes.

# **REPAIR AND RETROFITTING MANUAL for MASONRY STRUCTURE**

For earthquake damaged houses that needs to  
be repaired and retrofitted under  
**HOUSING RECONSTRUCTION PROGRAMME**



**Government of Nepal  
National Reconstruction Authority**

Singhadurbar, Kathmandu

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## FOREWARD



I would sincerely like to congratulate everyone involved in the development of the “Repair and Retrofitting Manual for Masonry Structures” which has been published by the National Reconstruction Authority. This manual will support the implementation of the 100,000 NPRs retrofitting grant for partially damage houses that need seismic retrofitting under the GoN housing reconstruction programme.

Thirty-one districts have been identified by the GoN Post Disaster Needs Assessment (PDNA) as being earthquake affected. To date, almost 25,000 households across these districts have been identified as eligible to receive the 100,000 NPRs housing retrofit grant. The grant will be disbursed in two tranches based on compliant construction.

Every effort is required to support households to retrofit unsafe structures so that they can receive the grant amount. This manual has been developed for technical staff to support them to guide households through the retrofit process, and to manage the inspections of completed retrofits.

I look forward to seeing the manual implemented across the earthquake affected districts and to seeing the impact that it will have. This represents another positive step forward in the reconstruction process, and will support households to retrofit their home so that it is safe, compliant, and resilient in the face of future disasters.

Dr. Govind Raj Pokharel  
Chief Executive Officer, NRA

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## PREFACE



Under the housing reconstruction programme, houses that are partially damaged, and fall under damage grade 2 (major) and 3 (minor) are eligible to receive a 100,000 NPRs grant to retrofit their home. For the household to receive the housing retrofit grant, their home must comply with all the specifications detailed in the inspection check sheet, which were formulated based on the Minimum Requirements (MRs). This manual has been prepared to introduce the inspection standards for the housing retrofit grant, and their associated step by step procedures for construction.

This manual will be used by all the engineers who are working for the reconstruction, and have been deployed by the GoN to carry out inspections.

The manual has been divided into four parts and two annexes:

- PART- A: Seismic damage and intervention
- PART- B: Seismic deficiencies and intervention
- PART- C: Ready to use seismic retrofit designs
- PART- D: Construction Sequences
- Annex 1: Typical structural drawings
- Annex 2: Annex 2 : EMS Damage Grade

Dr. Hari Ram Parajuli  
Executive member, NRA

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### **ACKNOWLEDGEMENTS**

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We also thank senior structural engineers Er. Hima Gurubacharya, Er. Rajani Prajapati, Er. Kuber Bogati and Er. Kirty Tiwari for their continuous work during the preparation of this manual. Also thanks to Chandan Ranamagar and Rachana Kansakar for preparing the graphics and drawings respectively. Thanks to Ar. Sabika Mastran, Ar. Ambu Chaudhary, Er. Siobhan Kennedy, Er. Jyotimani Bhattarai and Er. Nabin Paudel.

We appreciate Partner Organisations' (POs) work to review and contribute to the draft manual, especially Build Change, Catholic Relief Services, World vision Nepal, and so on .

We would like to congratulate all personnel involved, both directly and indirectly, for their valuable contribution to the preparation of this manual.

Standardization Committee, NRA  
for Reconstruction of Earthquake Resistant Houses

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## BACKGROUND

The damage assessment carried out by the NRA and the Central Bureau of Statistics (CBS) categorised damaged houses by damage grade and technical solution. Almost 25,000 households across the 31 earthquake affected districts were categorised as damage grade 2 and major technical solution or damage grade 3 and minor technical solution. Under the Government of Nepal (GoN) housing reconstruction programme, a housing retrofit grant of 100,000 NPRs will be available to these households if their retrofit complies with the relevant standards and specifications.

This manual outlines these standards and specifications as well as the minimum intervention works required to carry out the retrofitting.

The manual discusses two levels of intervention works which are necessary for damaged buildings and that ensure a life safety level of performance under the standards set out in the Nepal National Building Code, NBC 105: 1994.

There are various methods of repair and retrofitting for earthquake damaged masonry structures in different categories. Where repair methods are applied it is expected that the structure will be restored to its pre-earthquake condition, whereas the application of retrofitting methods is expected to increase the strength and ductility of the structure beyond its original condition. This manual incorporates repair and retrofit methods considering their suitability in terms of material availability, affordability, and ease of construction.

This manual has been developed to support the engineers responsible for the compliance inspection process. The engineers will use this manual to provide advice and guidance to households for the implementation of required repair and retrofitting strategies.

### Objectives of this manual:

- To set the minimum criteria to provide the tranches under the retrofitting grant
- Cover policies for distribution of tranches with minimum technical intervention options (economical and 31 district orientated.)
- References are taken from published documents and recent researches
- To support engineers for inspection, help them to provide advice and guidance to households

**Repair and retrofitting works, carried out using approved and published GoN documents, are also considered as a part of this manual.**

## SCOPE

### □ Applicability

The repair and retrofitting strategies set forth in this manual are applicable only for residential houses categorised as damage grade 2 (major) or 3 (minor) after Gorkha earthquake 2015 under the GoN housing reconstruction programme. The manual intends to achieve the minimum acceptable structural safety envisioned in NBC 105: 1994 after completing two levels of intervention.

The designs mentioned in the manual are ready-to-use designs for all structural components, but some provisions mentioned are set as advisory measures.

### □ Limitations

***The repair and retrofitting strategies are only for damaged non-engineered residential buildings.***

This manual has certain limitations and is only relevant for buildings which are:

- I. Residential and fall under category 'C' and 'D' of NBC.

- ✓ Category "A": Modern building to be built, based on the international state-of-the-art, also in pursuance of the building codes to be followed in developed countries.
- ✓ Category "B": Buildings with plinth area of more than One Thousand square feet, with more than three floors including the ground floor or with structural span of more than 4.5 meters.
- ✓ Category "C": Buildings with plinth area of up to One Thousand square feet, with up to three floors including the ground floor or with structural span of up to 4.5 meters.
- ✓ Category "D": Small houses, sheds made of baked or unbaked brick, stone, clay, bamboo, grass etc., except those set forth in clauses (a), (b) and (c).

*\* If the intervention has already been completed as per, or similar to, the strategies outlined in this manual, Government of Nepal published documents, or as per international practices, and are based on codal provision ensuring life safety with quality construction, then applications can be forwarded only after thorough engineering judgement*

## Few definition

### Seismic Damage

According to post earthquake damage assessment carried out as per EMS 98 scale, level of damages found in masonry buildings are of grade 1 to grade 5 (refer annex 2). The structural components which helps in smooth transmit of loads in masonry building are (i) foundation, (ii) structural masonry walls, (iii) roof/floor and (iv) connections (are vital which maintains integrity of the structural systems) where as remaining components such (i) partition walls, (ii) gable walls, (iii) Chimney, (iv) false ceiling, (v) decorative components etc. are non-structural components of the building. The damages in structural and non-structural components of buildings due to earthquake are seismic damage. Repair shall be done to the non-structural components against damage and retrofitting shall be done to the structural components against damage.

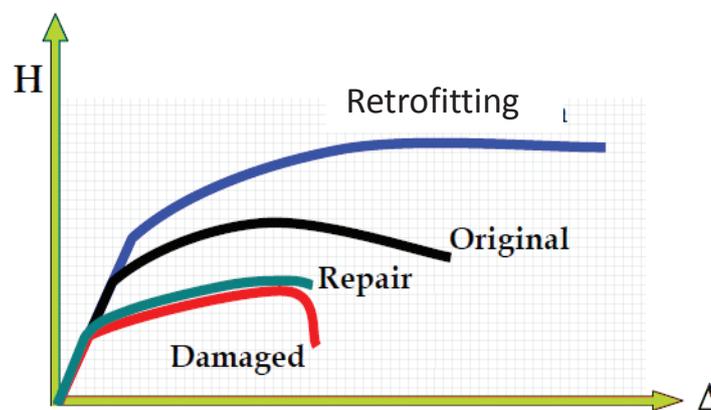
### Seismic Deficiencies

Building system, configuration, lateral force resisting system are basic vulnerability factors to the seismic performance to the building in future earthquake. Retrofitting can be done to overcome seismic deficiencies of buildings. The masonry buildings which are partially damaged due to Gorkha earthquake, which comes under DG2-major and DG3-minor and are eligible to get housing grant under “repair and retrofit” category shall have life safety level of performance envisioned by NBC 105:1994 to complete the tranches.

### Intervention works

Repair and retrofitting are intervention works in seismic damaged or capacity deficient structures:

- **Repair** : Repair does not improve the structural strength of the building and very deceptive for meeting the strength requirements of the next earthquake.
- **Retrofitting** : This removes the seismic deficiencies and improves the response of existing un-reinforced masonry buildings to both gravity and seismic loads it improves the “box type” behavior and increases the flexural strength of un-reinforced walls and piers. Improvement in configuration, load path, redundancy, connections, ductility and capacity etc falls under this.



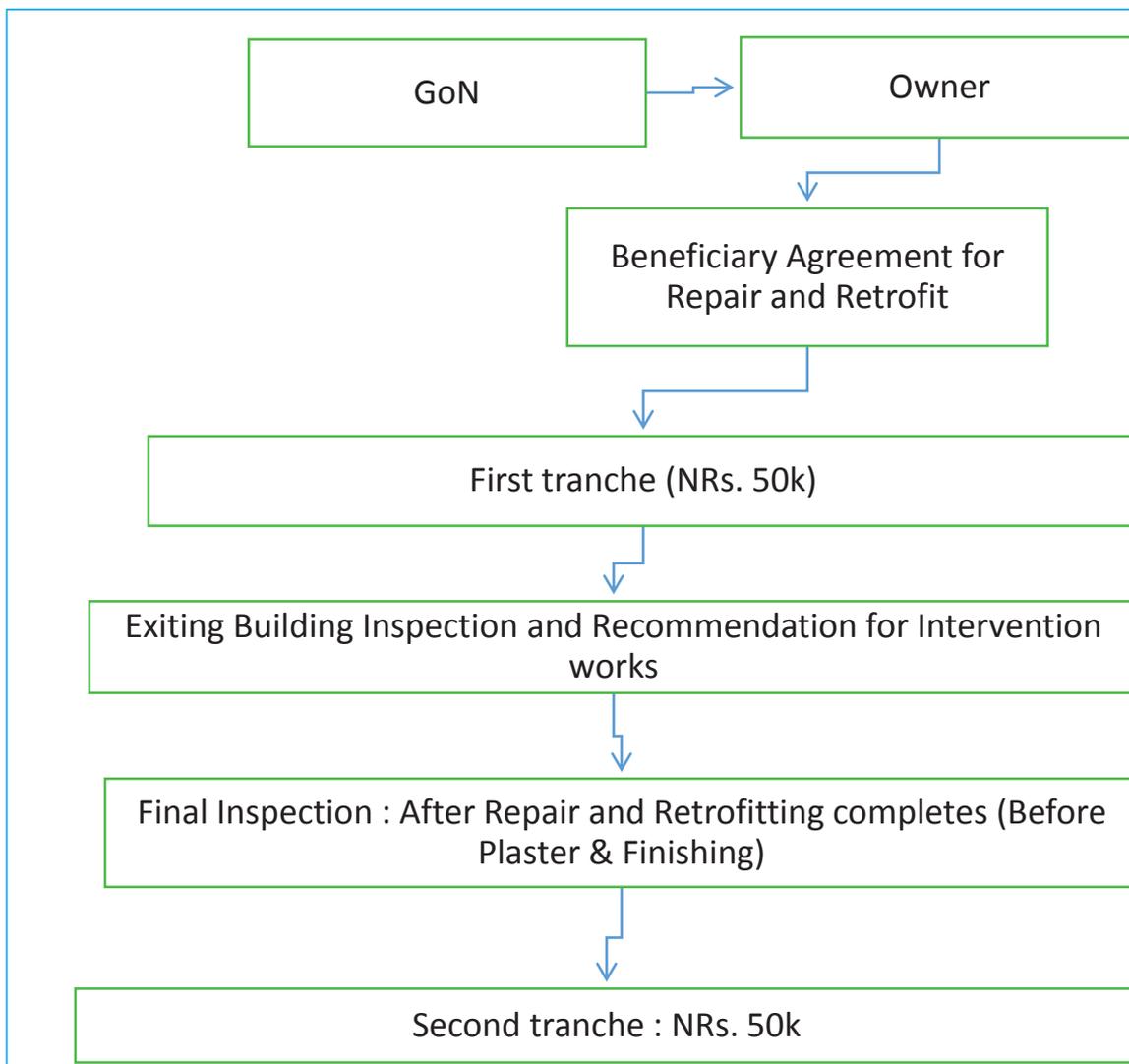
**Comparison of Repair/Retrofitting**

## Level of Intervention

### Level of Interventions required to receive the grant:

This guideline presents repair and retrofitting methodologies for stone masonry and brick masonry buildings. For retrofitting, it consists of retrofitting design and outcomes of the sample buildings taken from the earthquake effected areas. Also for those building which can be modified to match with sample buildings, modification methodologies are given. For those buildings which are not within the scope of the manual (such as span restrictions, height restrictions, number of storey etc.), this manual is not applicable however, grant will be given if detail retrofit analysis and design is carried out.

### Grant distribution process:



Flow chart of Grant Distribution of Repair and Retrofitting

## PART-A: Seismic damage and intervention

This part deals with seismic damages and possible intervention that needs to turn the building in to pre-earthquake condition.

## 1. Foundation damage and mitigation work

### [Key Problem]

Potential damages in foundation are as follows :

F.1 Cracked stone masonry

F.2 Settlement of Foundation

F.3 Bulged Stone Walls

F.4 Dislocations and Loose Stone

F.5 Stone foundation wall interruption, removal of portions of the wall, & loss of structural integrity

### [Repair Solution]

Repair solution on corresponding damages in foundation listed above, are :

F.1 For Minor cracks : **action #01**

F.2 Settlement of Foundation : May be possible with grouting if it is only minor to moderate crack (**Action #04**), Else more soil intervention may require

F.3 Bulged Stone Walls : **action #04**

F.4 Dislocations and Loose Stone : **Action #04**

F.5 Stone foundation wall interruption, removal of portions of the wall & loss of structural integrity : **Action #04**

### [Retrofitting Solution]

FR.1 Foundation improvements : if the existing foundation size is not sufficient then improvement in foundation is required, else repair or restore of damaged works as above is sufficient. Foundation improvement can be done as explained (**Refer part B**).

**[Note] : Level/extent of damage can be quantify on the basis of post earthquake damage assignment knowledge and appropriate repair/retrofit solution can be recommended accordingly.**

# 1.1 Foundation Damage and mitigation work

## Problem

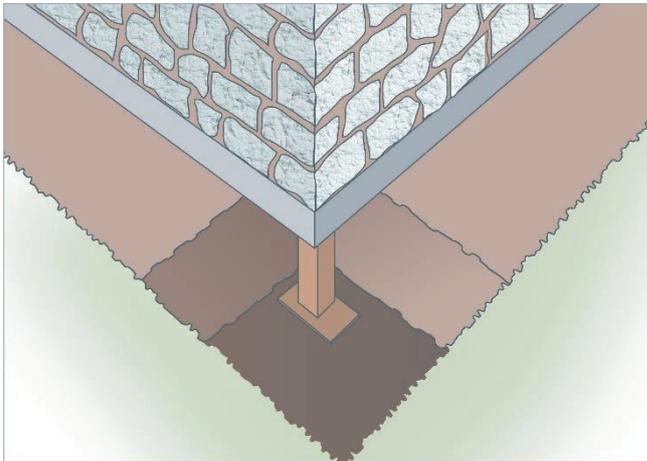


F.3 Bulged and leaning stone Foundation



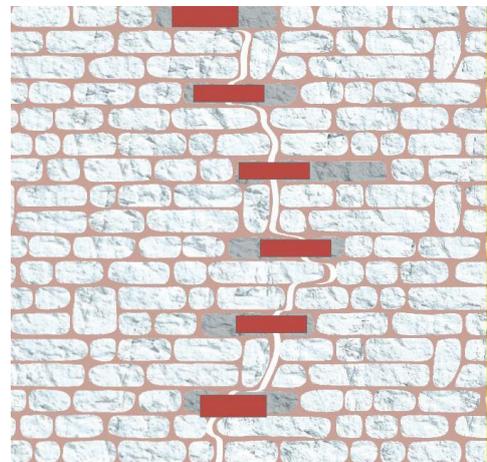
F.2 Settlement of Foundation

## Solution: Repair works



Reconstruction of Foundation with proper safety

Note : Provide sufficient props and temporary support, reconstruct the wall footing as new. Also, increase soil bearing capacity or provide additional retaining structures if needed.



Repair Foundation

Note : Depending upon size of cracks, apply appropriate solution discussed on part B1. Also ensure the sufficiency of foundation size, if yes, then no improvement is required in foundation.

## 2. Roof/floor partial collapse and mitigation works

### [Key Problem]

Potential damages in floor and/or roof are as follows :

- R.1 : Partial to heavy damage on gable wall
- R.2 : Sliding of roof materials (stone slate or clay tiles)
- R.3 : Roof connections failure
- R.4 : Floor connection
- R.5 : Floor to wall connection
- R.6 : Roof to wall connection
- R.7 : Wall to wall connection

### [Repair Solution]

Repair solution on corresponding damages in floor and/or listed above, are :

- R.1 : Remove heavy material replace with lighter materials
- R.2.: Replace damaged tiles and anchor all the tiles
- R.3: Provide new appropriate roof/floor connection

### [Retrofit Solution]

F(RF).2 Improve Roof-to-Wall connection, Floor-to-Wall connection, improve connections in Roof/Floor (stiffening the Roof/Floor), provide bracing at Roof/Floor. Improvements are described in part B.

## R1. Partial to heavy damage of Gable wall

### Problem : Gable wall collapse



R1.1 Gable wall toppling



R.1.2 Gable wall toppling

### Solution : Remove heavy material replace with the lighter materials



Use of C.G.I. sheet at Gable part



Use of timber planks at Gable part

## R.2: Sliding of Roofing materials

### Problem : Sliding of roof tiles (stone slate or clay tiles)



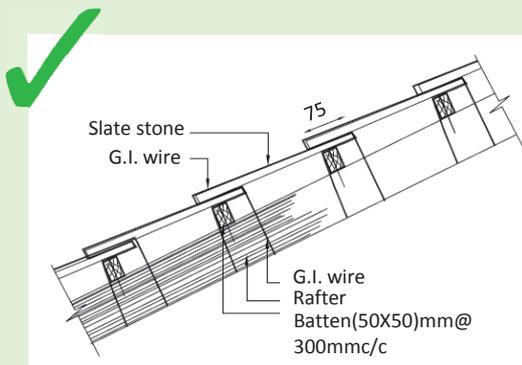
R.2.1 Slate stone roof



R.2.2 Clay tile roof

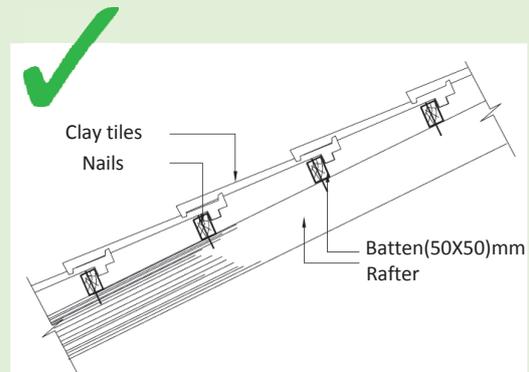
### Solution

- Replace damaged tiles.
- Using appropriate correct fixing method for roofing materials.
- Connect the roof with the roof band by inserting reinforcement or GI sheet.
- Slatestone and clay tiles should be properly anchored to purlin as NBC.



Detail of anchoring slate stone

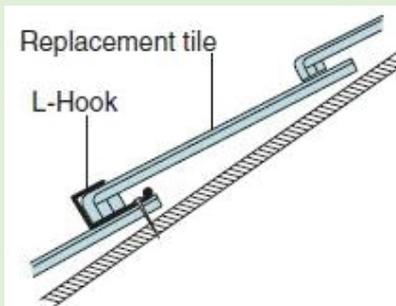
Source: NBC203 2015, P44



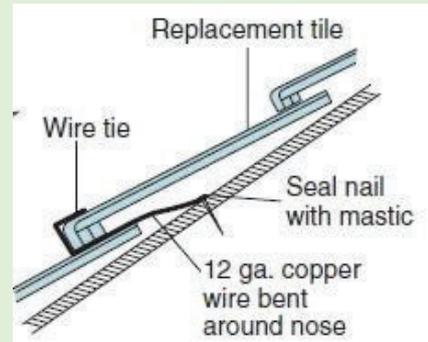
Detail of fixing clay tile

Source: NBC203 2015, P45

#### L-hooks



#### Wire ties



Gently lift the overlapping tile and twist loose the damaged tile.

After filling any nail holes, slip in a new tile and secure with an L-hooks (left) or bent copper wire (right)

## R.3:Roof connection failure

Problem : Inadequate roof connections or connections failure



R.3.1 Purlin detached from rafter due to inadequate nailing

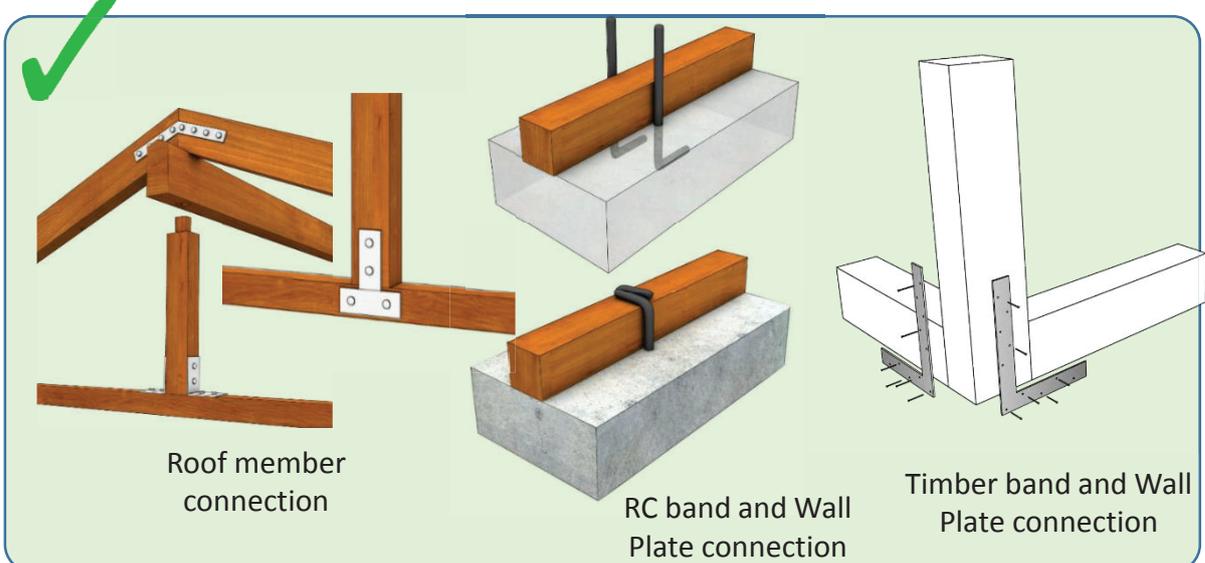


R.3.2 Connection of wooden truss

### Solution

- Use a continuous wall plate, ridge and purlins to tie the rafters or trusses together.
- Stiffening of roof
  - Diagonal straps with steel nut bolts or metal nails
  - Diagonal steel truss with steel nut bolts or metal nails
  - Timber bracing with metal nails or timber nails

Refer Part B



## R.3:Roof connection failure

### Problem :Roof/floor bracing missing



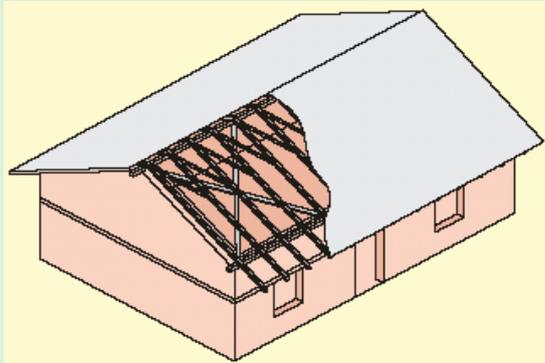
Refer Part B

R.3.3 Bracing missing in inclined roof

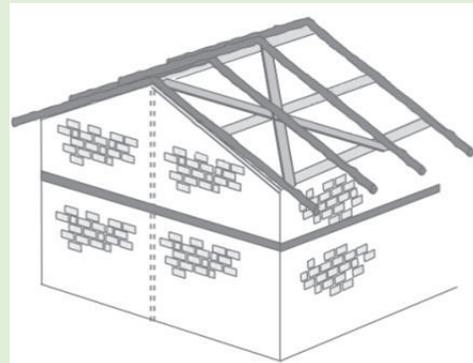
### Solution

- Provide X-bracing at end bays on each sloppy side
- Provide additional roof/floor member as needed

Diagonal Bracing to roof



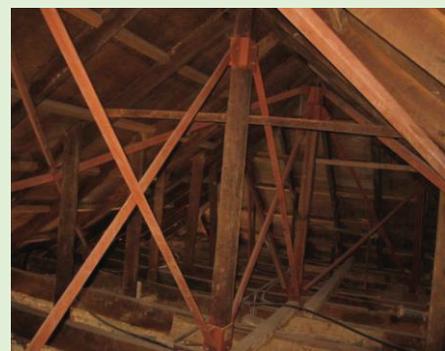
Stiffening of the floor with diagonal timber planks



Diagonal Steel bracing to roof



Steel bracing to roof



Flexible diaphragm improvements

## R.4: Floor connection

### Problem : Inadequate roof connections or connections failure



R.4.1 view inside the attic showing the rafters and the absence of collar beams and joist connections to the rafters

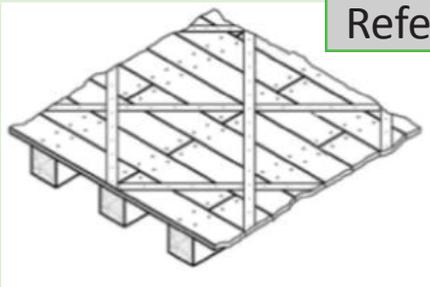


R.4.2 Inadequate and poor floor members

### Solution

- Use a continuous wall plate, ridge and purlins to tie the rafters or trusses together.
- Stiffening of roof
  - Plywood overlay
  - Diagonal straps
  - Nailed sheeting
- Concrete overlay
- Plank overlay
- Diagonal steel truss
- Timber bracing
- New RC floor

Diagonal straps

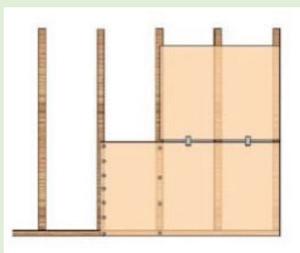


Refer Part B

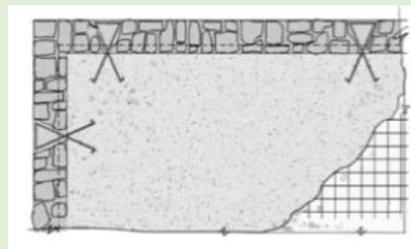
Connectivity of roof member



Nailed sheeting

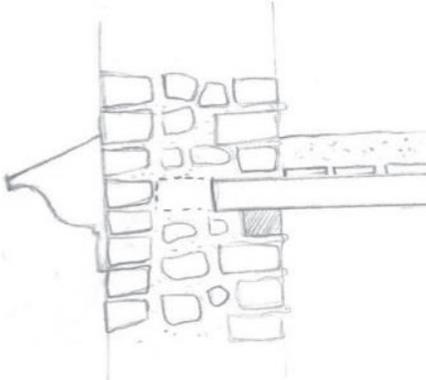


New RC Floor

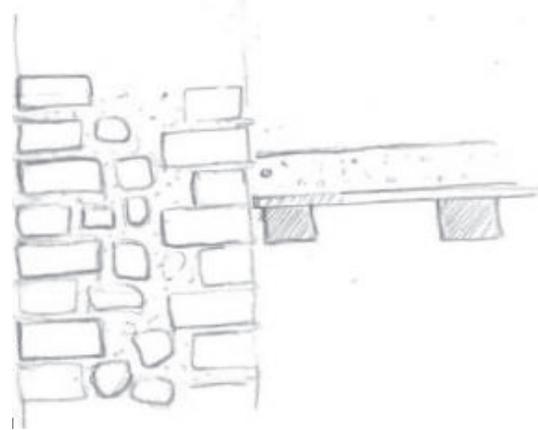


## R.5: Floor to wall connection

### Problem : Inadequate roof connections or connections failure



R.5.1 Floor joists supported by half of the wall width (insufficient anchorage)



R.5.2 Wall-to-floor connection *parallel to the joists* (insufficient anchorage)

### Solution



Steel Strap

Anchored with splint and bandage at floor level



Timber block

Refer Part B

## R.6:Roof to wall connection

Problem : Inadequate roof connections or connections failure



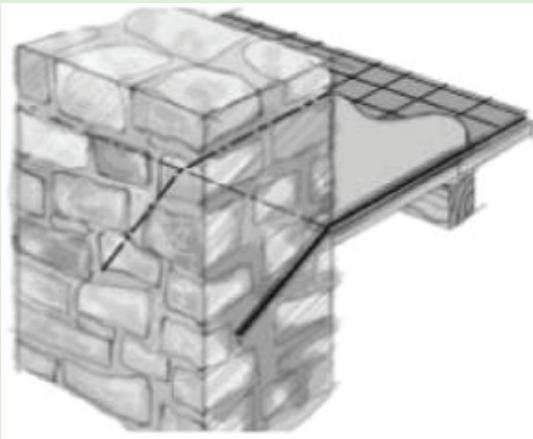
R.6.1 Damaged buildings showing wall-to-floor(joist) connection in Bungamati

### Solution

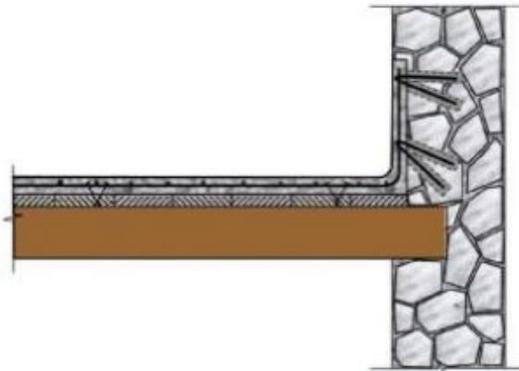
- Anchors ties
  - Anchor to joist
  - Wall anchors
  - Connector element
  - Combined methods

Refer Part B

Anchor inlay into wall



Anchors in wall fold overlay



## R.6:Roof to wall connection

Problem : Inadequate roof connections or connections failure

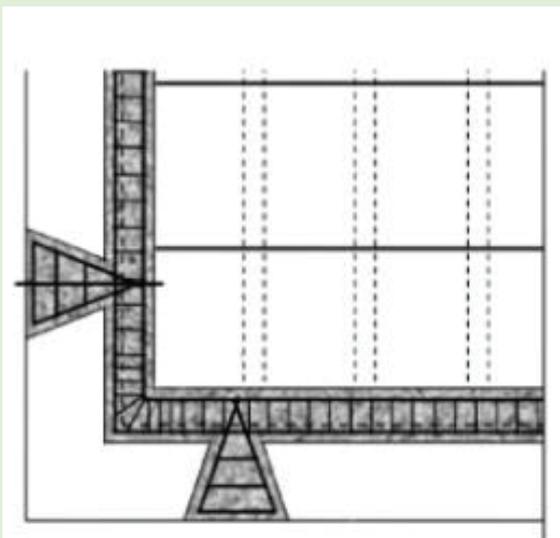


Solution

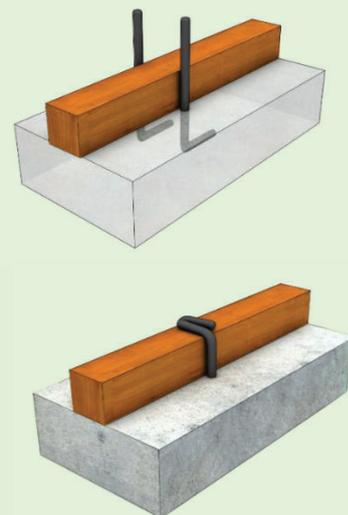
- Use a continuous wall plate, ridge and purlins to tie the rafters or trusses together.



RC-diaphragm chord with shear locks



Anchor joist with rebar embedded in roof band



Refer Part B

### 3. Cracks in wall and mitigation works

#### **Seismic damage pattern**

Potential damages in structural and non-structural wall are as follows :

- C.1 : Minor cracks
- C.2 : Major cracks
- C.3 : Heavy cracks
- C.4 : Out-of-plane failure of walls
- C.5 : Wall to wall connection

#### **Repair Solution**

Repair solution on corresponding damages in wall listed above, are described in repair mitigation **part D (D.1)**. From repair mitigation, apply appropriate options depending upon extend of damage.

#### **Retrofit Solution**

R.C.1. : For improvement in capacity of wall, retrofitting options are described in retrofitting Part-C and Part D (D.1) . Relevant options can be selected and apply in the building according to building typologies

## Common types of earthquake induced damages in masonry building

### Problem :



#### Diagonal Cracks:

Diagonal cracks on the walls are the result of in plane bending and shear force. When the in plane bending and shear capacity of the walls are exceeded, such diagonal X cracks are formed.



#### Corner Separation:

The lack of proper connection between the orthogonal walls result in Corner separation



#### Failure of Gable wall:

Lack of proper anchorage of gable wall with the roof results into failure of gable wall. This is the most common type of failure pattern in masonry buildings.

## Common types of earthquake induced damages in masonry building

### Problem :



#### Delamination:

Stone masonry walls have two exterior vertical layers (called wythes) of large stones, filled in between with loose stone rubble and mud mortar. There is no any connection between the two wythes of the wall. This causes bulging/separation of walls in the horizontal direction into two distinct wythes during earthquake. Delamination is very common in stone in mud buildings



#### Collapse of wall:

When the out of plane bending capacity of wall is exceeded, partial or complete collapse of wall happens.



#### Diaphragm failure:

Lack of proper connection of diaphragm: floor/ roof with the wall result in failure of floor/ roof.

Also Inadequate size of column and beam

## C.1: Minor Cracks

PART-A: Seismic damage and intervention

### Problem : Minor In-Plane Cracks in the building



C1.1 Low strength masonry :  
Stone Masonry in Mud mortar



C.1.2 Low strength masonry :  
Brick masonry in mud mortar



C.1.3 Brick masonry in  
cement mortar

## C.1: Minor Cracks

### Definition of Damage

Damage Grade	Damage level	Description of damage
DG1	Slight damage	Hairline cracks

### Repair and Retrofitting

#### Repair Solution

- Pressure injection of cement grout or mixture of cement and mud : or  
Action #1

## C.2: Moderate Cracks

Problem : Moderate In-Plane Cracks in the building



C2.1 Low strength masonry :  
Stone Masonry in Mud mortar



C.2.2 Low strength masonry :  
Brick masonry in mud mortar



C2.3 Brick masonry in cement  
mortar

## C.2 :Moderate Cracks

### Definition of Damage

Damage Grade	Damage level	Description of damage
DG2	Moderate damage	Cracks up to 5 mm wide

### Repair and Retrofitting

#### Repair Solution

- Grouting : **Action #1**
- Stitching

## C.3 :Heavy Cracks

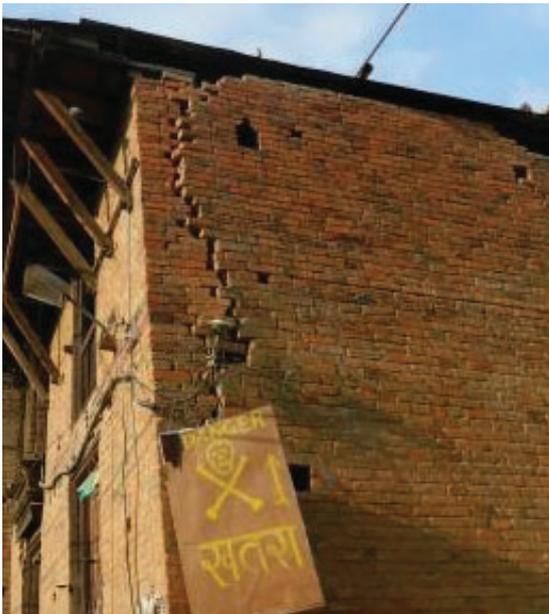
### Problem : Heavy In-Plane Cracks in the building



C.3.1 Low strength masonry :  
Stone Masonry in Mud mortar



C.3.2 Low strength masonry :  
Brick masonry in mud mortar



C.3.3 Brick masonry in  
cement mortar

## C.3 :Heavy Cracks

### Definition of Damage

Damage Grade	Damage level	Description of damage
DG3	Heavy damage	Cracks greater than 5 mm wide or wall material dislodge

### Repair and Retrofitting

#### Repair Solution

- Through stones and Cement grouting in cracks : **Action #4**
- Rebuilt the portion of wall or wall cracked

## C.4 :Delamination of walls

### Problem : Wall-wythes separation



C.4.1 Low strength masonry : SMM



C.4.2 Low strength masonry : BMM

### Solution

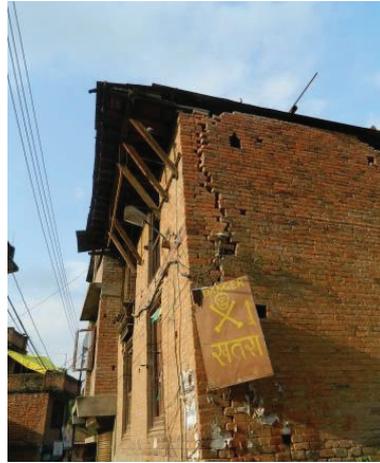
- Rebuilding / wall overlay
- Through wall-anchors

## R.7: Wall to wall connection

### Problem : Corner separation



R.7.1 Low strength masonry : SMC

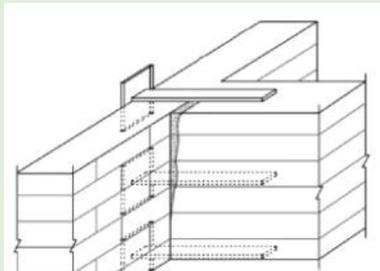


R.7.2 Low strength masonry : SMM

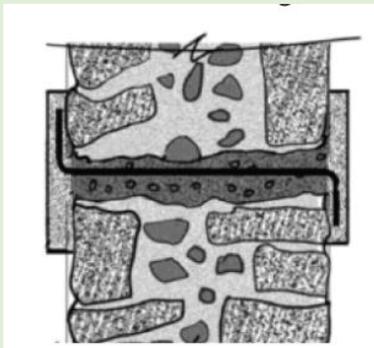
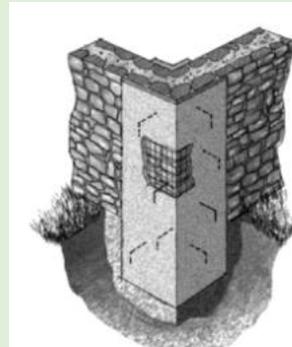
### Solution

- Provide additional stiches

Metal stitching



Anchored splint overlay



Through wall anchor



Through wall anchor

## PART-B : Seismic deficiencies and intervention

Additional intervention may required with respect to inherent structural deficiencies after turning the building in to pre earthquake condition as per part A. This part deals with possible deficiencies in the masonry buildings and possible improvement measures. Probable intervention are as follows:

- 1) Foundation improvement
- 2) Configuration and load path improvement
- 3) Connection improvement between wall to wall
- 4) Connection improvement between wall to floor
- 5) Connection improvement between wall to roof
- 6) Stiffening of floor in their plane
- 7) Stiffening of roof in their plane
- 8) Tying of parapet wall
- 9) Tying of gable wall
- 10) Capacity improvement of structural wall with splint and bandage using:

Opti on	For preventing global failure (Splint & bandage)	For present local failure control (to avoid effects due to lack of through stone etc.)	Remarks
01	Welded GI wire mesh	GI wires in remaining part	<b>The following chapter covers brief about sketches and drawings which are informative only. For more details and clarity, refer annex 1 (separate volume in A3 paper sheets).</b>
02	GI wire mesh	PP band in remaining part	
03	Wooden section	GI wires in remaining part	
04	RCC	GI wires in remaining part	



## 1.1 Foundation improvement...

### Problem



No foundation

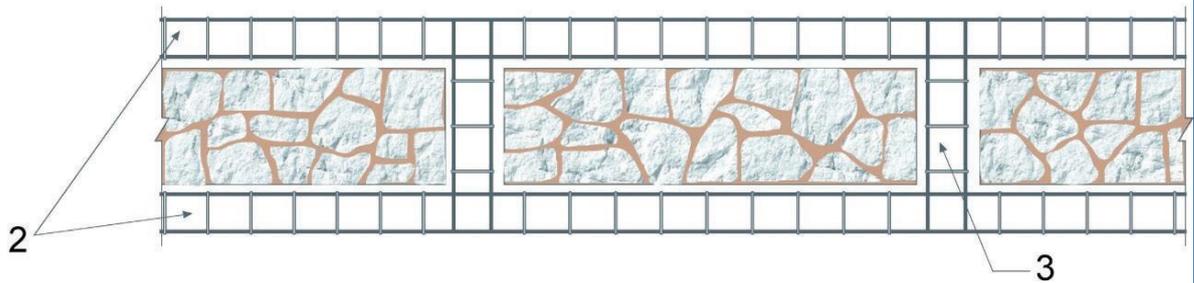


Insufficient foundation

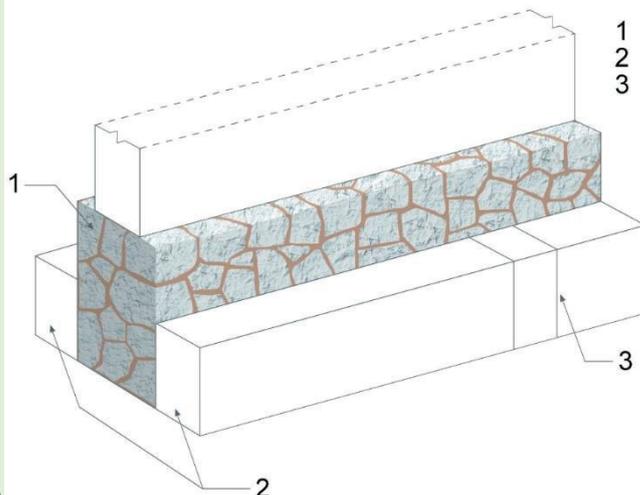
### Solution

Addition of RCC foundation beam with proper connection

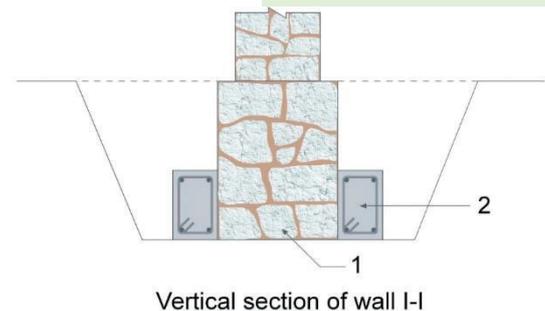
Schematic view of foundation strengthening with RC :



Horizontal section of wall through new RC beams



- 1 - Old foundation
- 2 - New concrete beams
- 3 - Connecting lateral concrete beams



Vertical section of wall I-I

## 2.0 Configuration and load path improvement

### Configuration :

The configuration of a building will influence the seismic performance of a building, particularly regarding the distribution of the seismic loads.

**Architectural configuration** : related to geometry, shape and size of building.

- The building shall be in rectangular in plan shape, ratio of maximum dimension to minimum dimension is three (3), in other case provide seismic gap.
- The projected length up to (one fifth : 1/5) of building length is acceptable.
- For small residential buildings not exceeding 100 sq.m. in plinth area with flexible floor and cross walls, the shape criterion of building can be ignored.
- The cantilever-projection of roof/floor, where provided, is acceptable but load bearing wall shall be replaced with lighter material over such cantilever-projections.
- If the load bearing wall continues from ground floor to first floor on the same vertical line, vertical setback is allowable.
- The maximum storey of building is two plus attic.

**Structural configuration** : related to size and location of structural members in the building

- Number of wall : there shall be two wall in each direction or equivalent system.
- Minimum wall thickness : equal or more than 230mm and 350mm for stone and brick respectively.
- Clear span of un supported wall : The span of wall up to 12 times of wall thickness is acceptable in one direction, in case where wall thickness is more than 350mm. Else, new wall or buttress walls should be constructed.
- Size of room : The size of room is restricted to 13.5 sq.m only for those houses with RCC slab. The thickness of RCC slab should be 115mm -125mm
- Height of wall : The height to wall thickness ratio of a wall shall not be more than 1:8 for stone masonry and 1:12 for brick masonry.

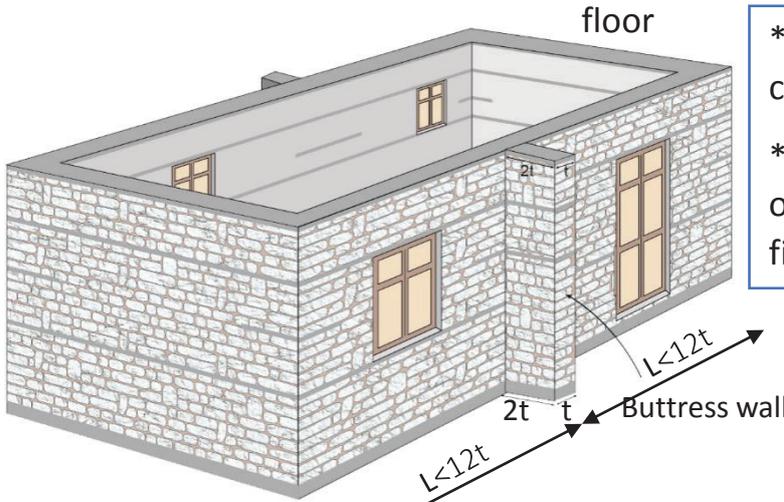
### Load Path :

The structure shall contain at least one rational and complete load path for seismic forces from any horizontal direction so that they can transfer all inertial forces in the building to the foundation.

- To improve load path, size of opening can be reduced or closed with proper connection between new and old walling materials.

## 2.1 Configuration and load path improvement...

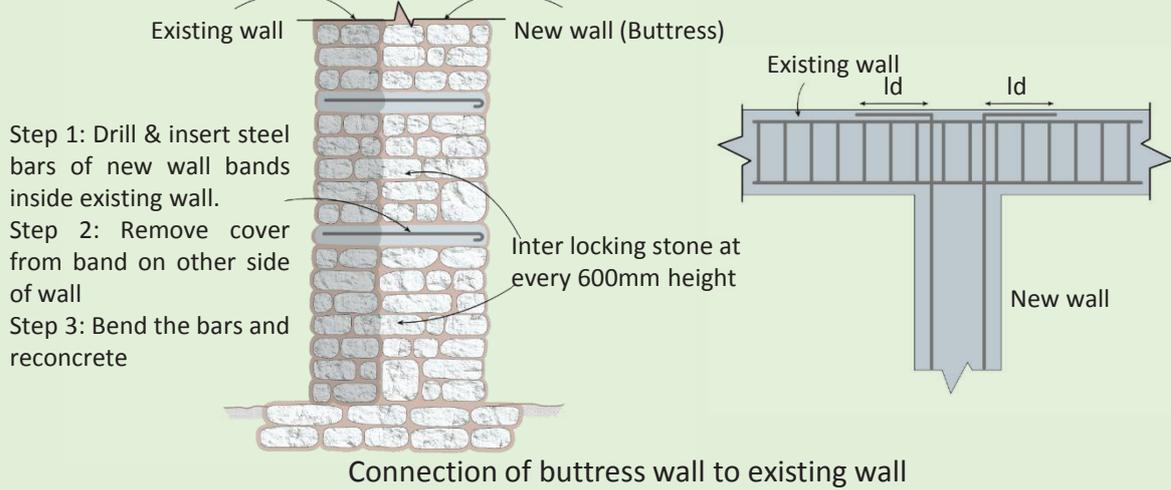
Example 1 : Construction details of Buttrissing in mud mortar with flexible floor



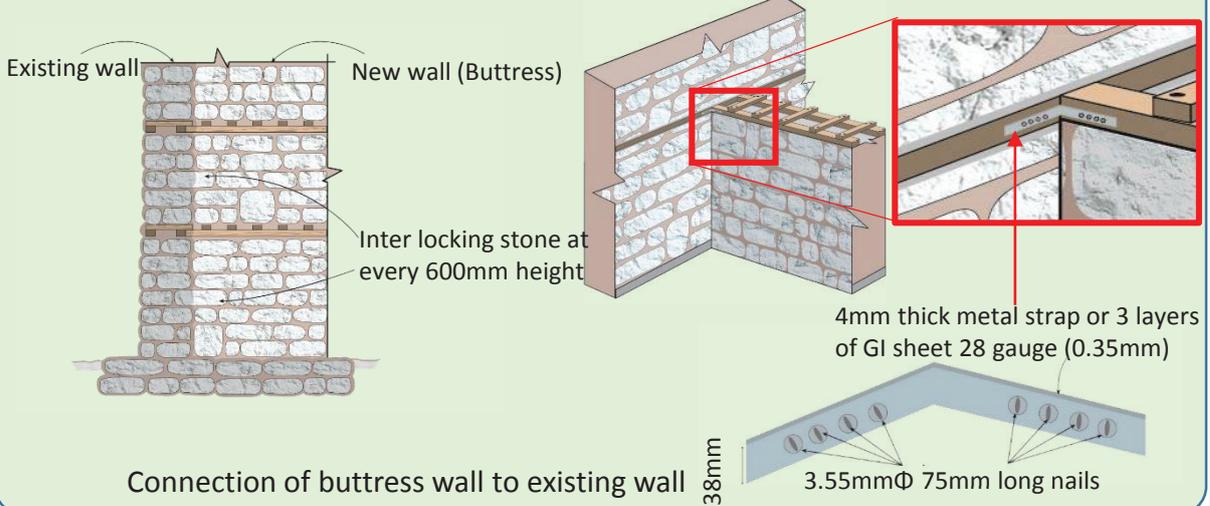
- \* For other typology of construction, see NBC.
- \* Provide buttress either outside of wall as shown in figure or inside the room.

\*Addition of buttress wall when length of wall is greater than 12t (mud mortar)

### RC horizontal band



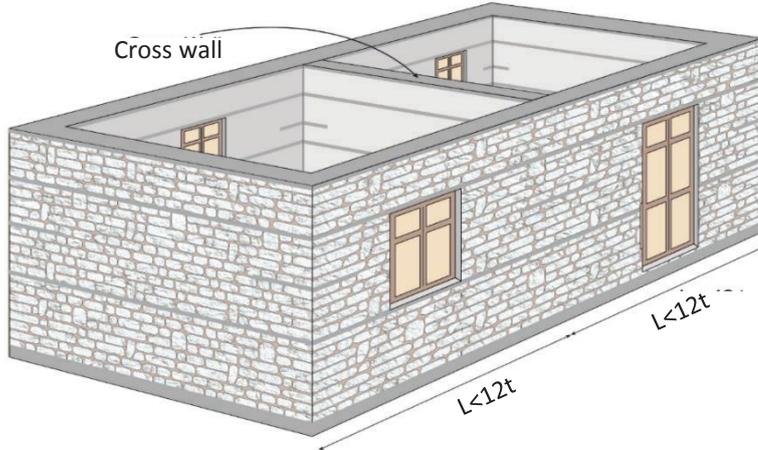
### Wooden horizontal band



## 2.2 Configuration and load path improvement...

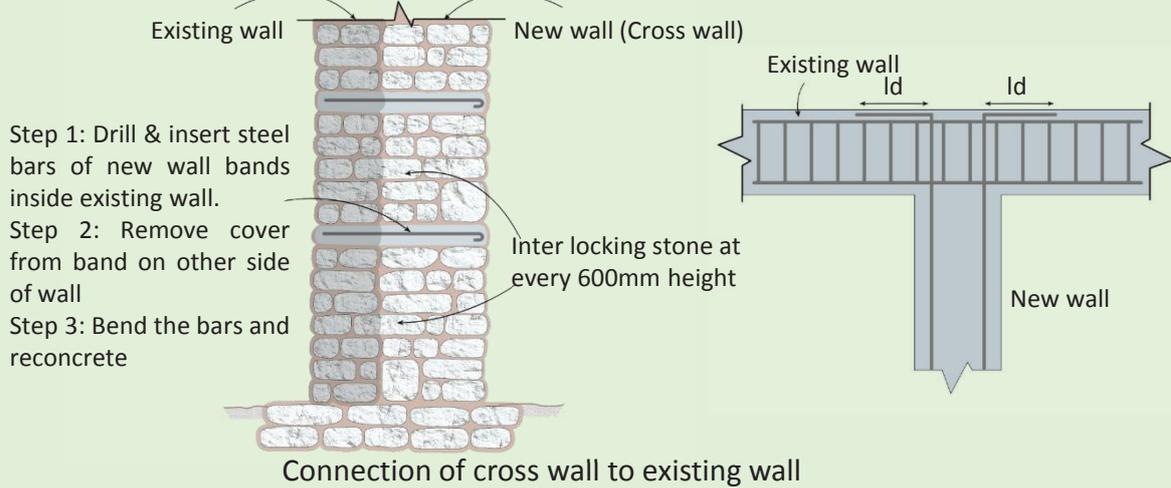
Example 2 : Construction details of New Cross wall in mud mortar with flexible

\* For other case, see NBC

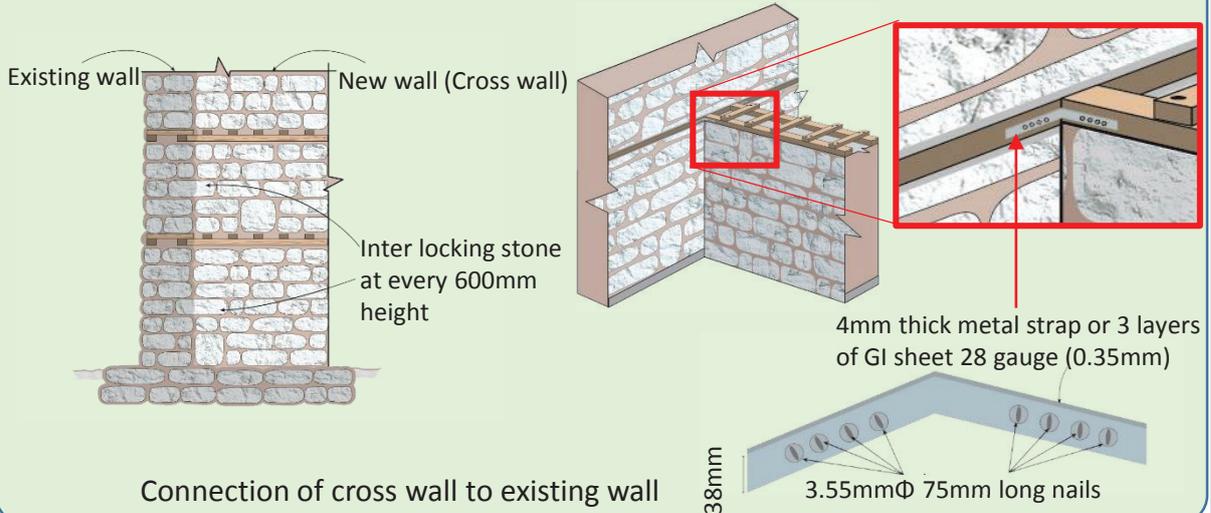


Addition of cross wall when length of wall is greater than 12t.

### RC horizontal band



### Wooden horizontal band



### 3.0 Connection improvement between wall - to – wall

Option 1: anchored splint (using RC elements with rebar or G.I. wire mesh) at corner or T-Junction in both side of wall with proper connection between new and existing walling material should be done.

Rebar anchored R C splint



G I wire mesh anchored R C splint



\*See details in ready to use seismic retrofit designs, summary

### 3.1 Connection improvement between wall-to-wall...

Option 2: anchored splint (using wooden elements) at corner or T-Junction in both side of wall with proper connection between new and existing walling material should be done.

Installation of wooden vertical member from inside of the wall



\*See details in ready to use seismic retrofit designs, summary

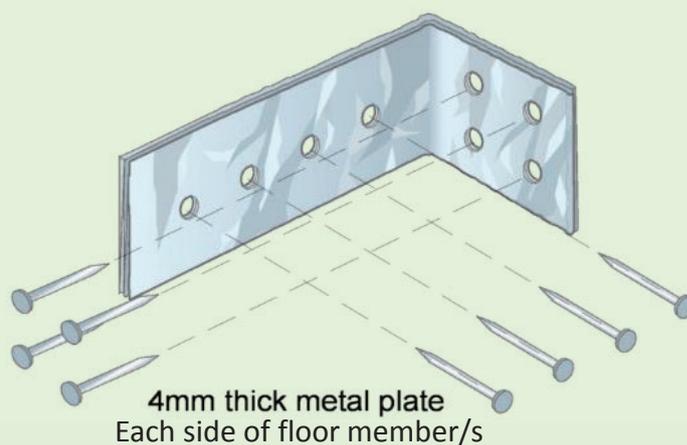
## 4.0 Connection improvement between wall-to- floor

### Option 1: Metal Strap :

When it is not possible to transport concrete and steel to the site:



Details of metal strap

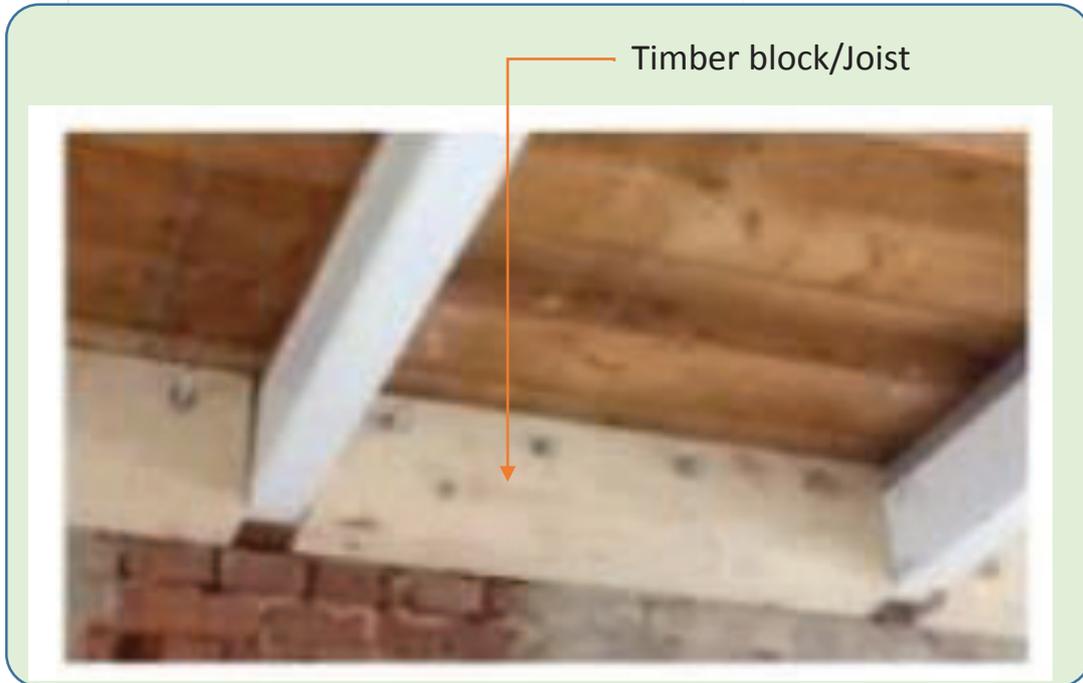


Note : Minimum four numbers of 50 mm long nails (Fe250) with Floor member and Minimum four numbers of M16 grade expansion bolts with walling material

## 4.1 Connection improvement between wall-to-floor...

### Option 2: Timber block :

When it is not possible to transport concrete and steel to the site:



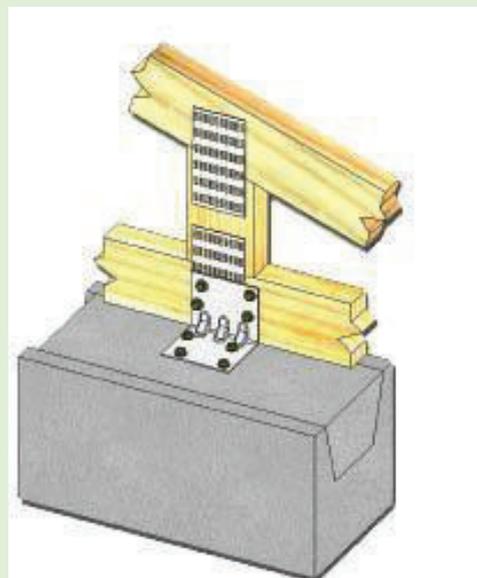
Timber block/Joist : Depth x width = 50 mmx30 mm (Hard wood) with required length and 75 mmx45 mm (Other wood) with required length

Details of timber block

## 5.0 Connection improvement between wall - to - roof

### Option 1: Metal Strap at the top of wall:

Note : This is not required separately if retrofitting is done simultaneously. Splint is connected to the floor joist and roof rafters.



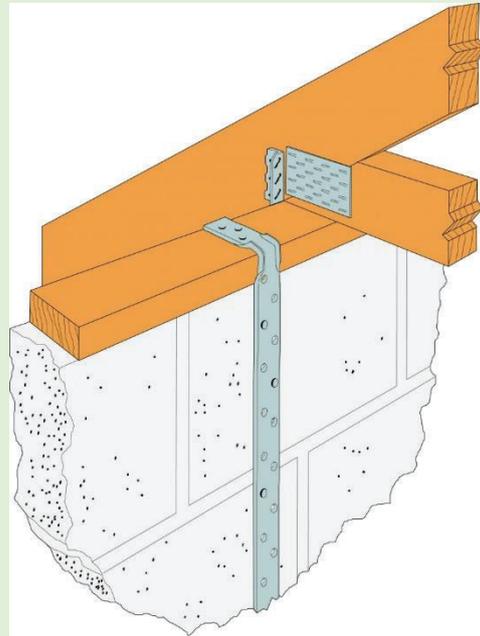
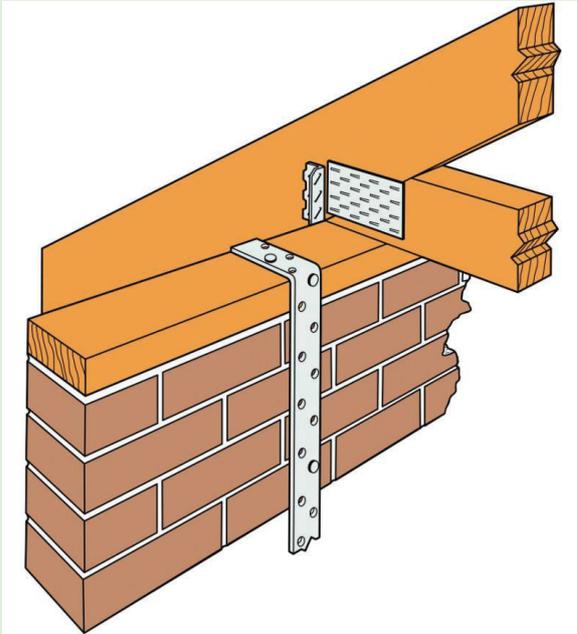
3 mm thick Height and depth : 45mmx45mm, M12 of 4 number, M16 of one number in each face @ 3.00 mat centres

Details of Anchor plate

## 5.1 Connection improvement between wall-to-roof...

### Option 2: Metal Strap at side of wall:

Note : This is not required separately if retrofitting is done simultaneously. Splint is connected to the floor joist and roof rafters.

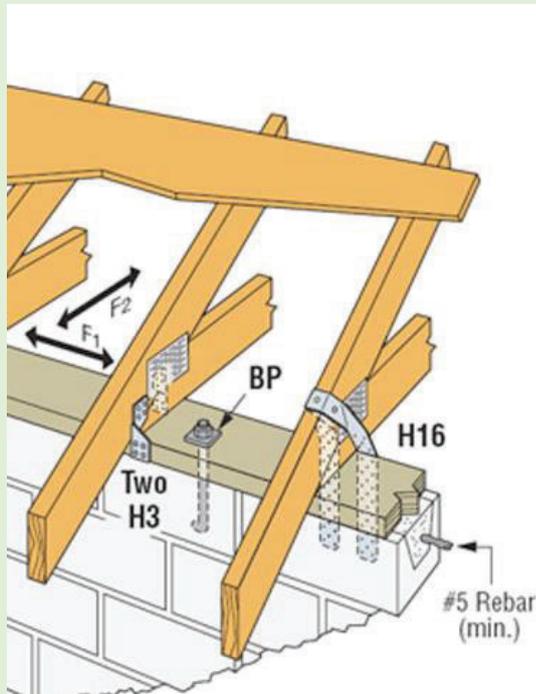


3 mm thick width and depth :  
115mmx300mm, M8 of 4 number,  
(width side) and M8 of 8 numbers  
depth side face @ 4.5 m at centres

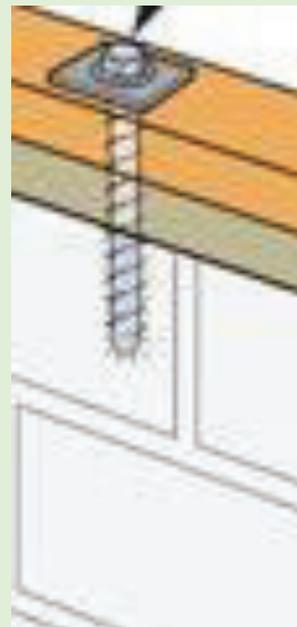
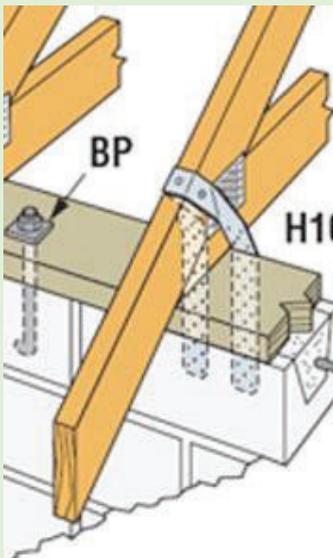
Details of Anchor plate

## 5.2 Connection improvement between wall-to-roof...

### Option 3: Metal Strap with Screws :



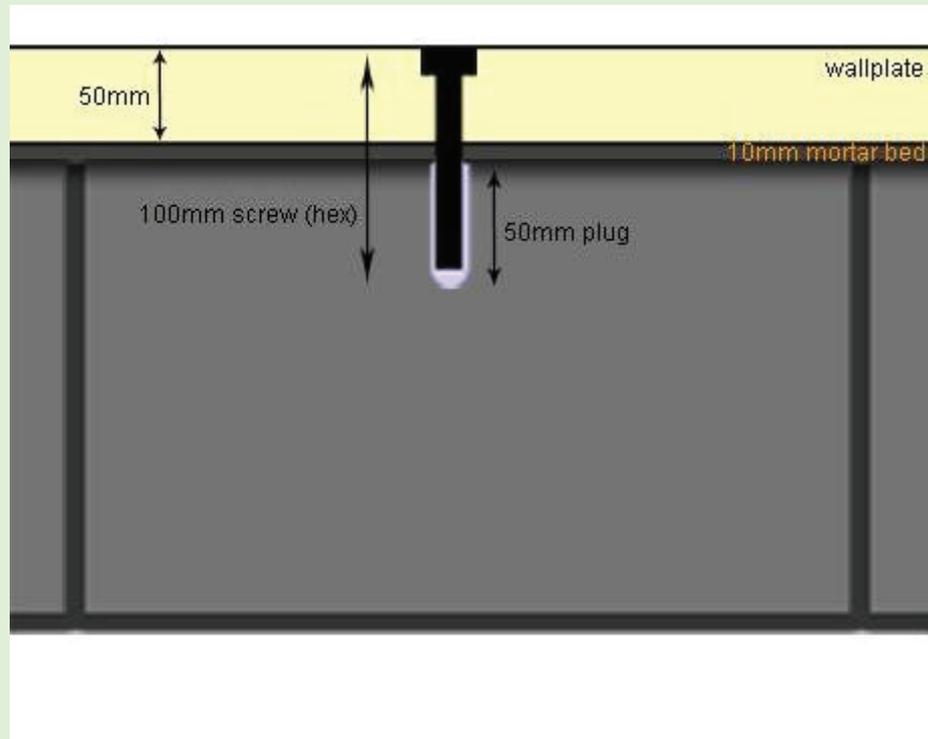
Note : 3 mm thick metal strap, Minimum four numbers of 50 mm long nails (Fe250) with Floor member and Minimum four numbers of M16 grade expansion bolts with walling material



Details of Anchor plate

## 5.3 Connection improvement between wall-to-roof...

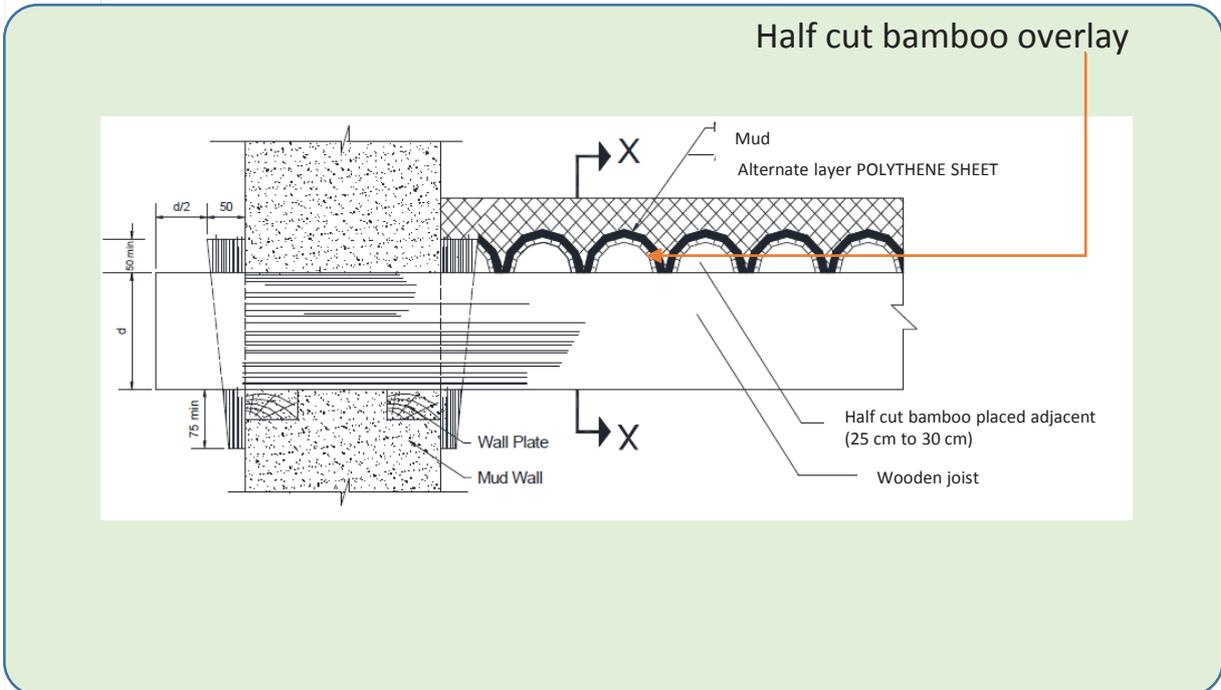
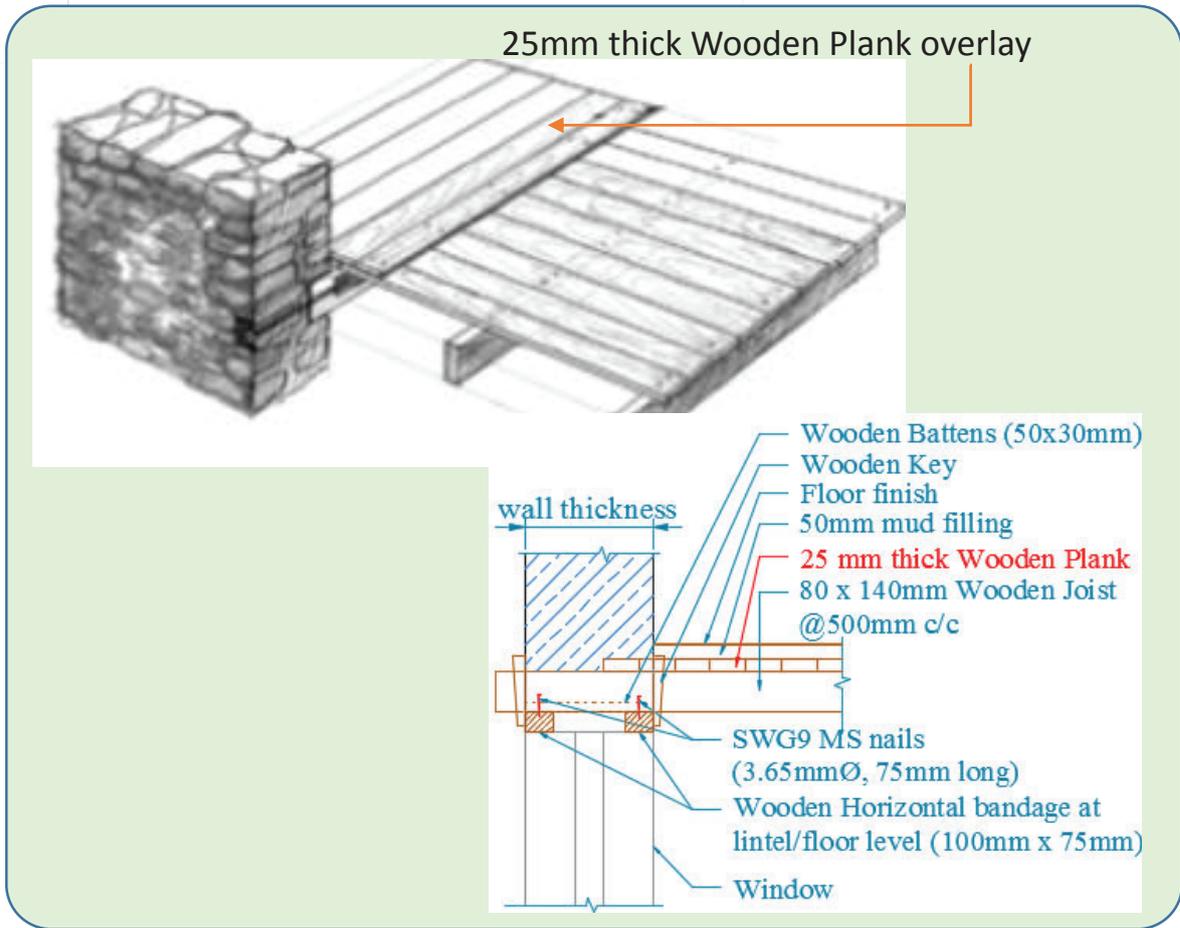
Option 4: Use of metal screw :



Note : Minimum four numbers of 50 mm long nails (Fe250) with Floor member and Minimum four numbers of M16 grade expansion bolts with walling material

## 6.0 Stiffening of floors in their plane

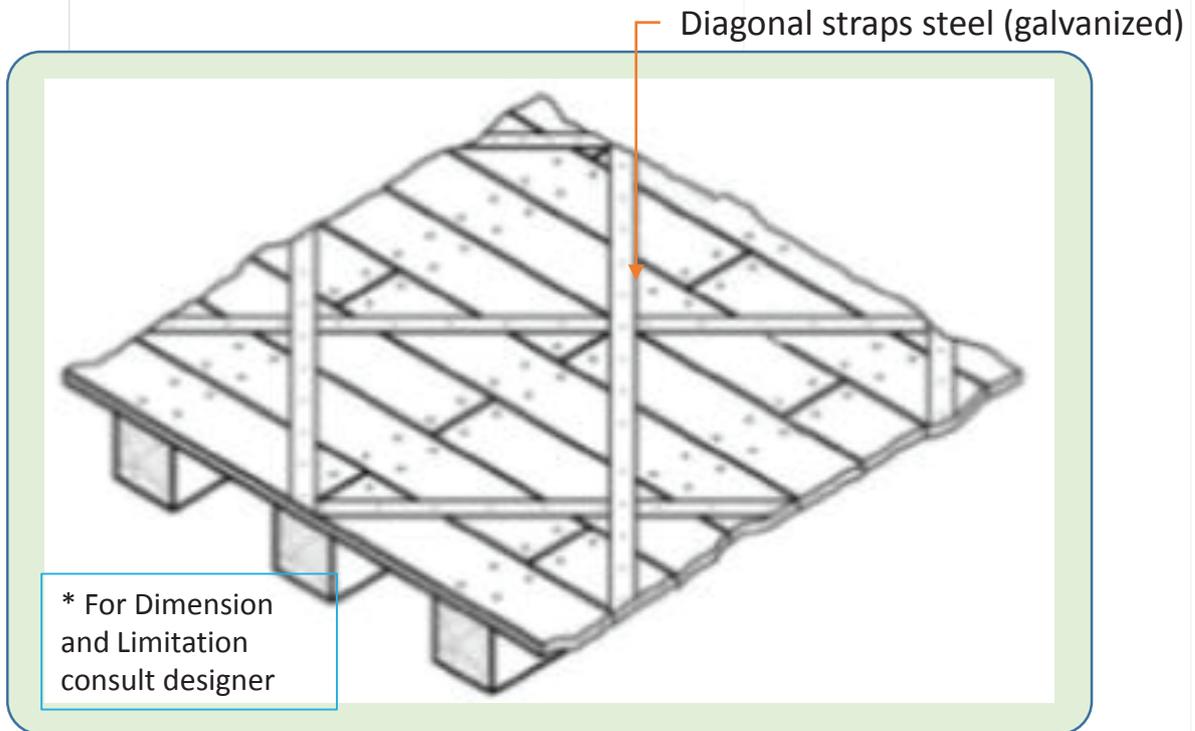
Option 1: Wooden plank overlay or half cut bamboo overlay:



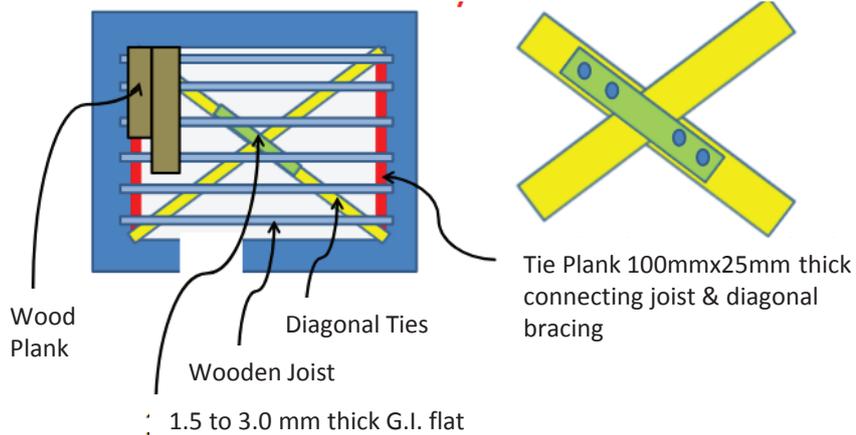
## 6.1 Stiffening of floors in their plane...

### Option 2: Diagonal straps steel (galvanized):

When it is not possible to transport concrete and steel to the site:



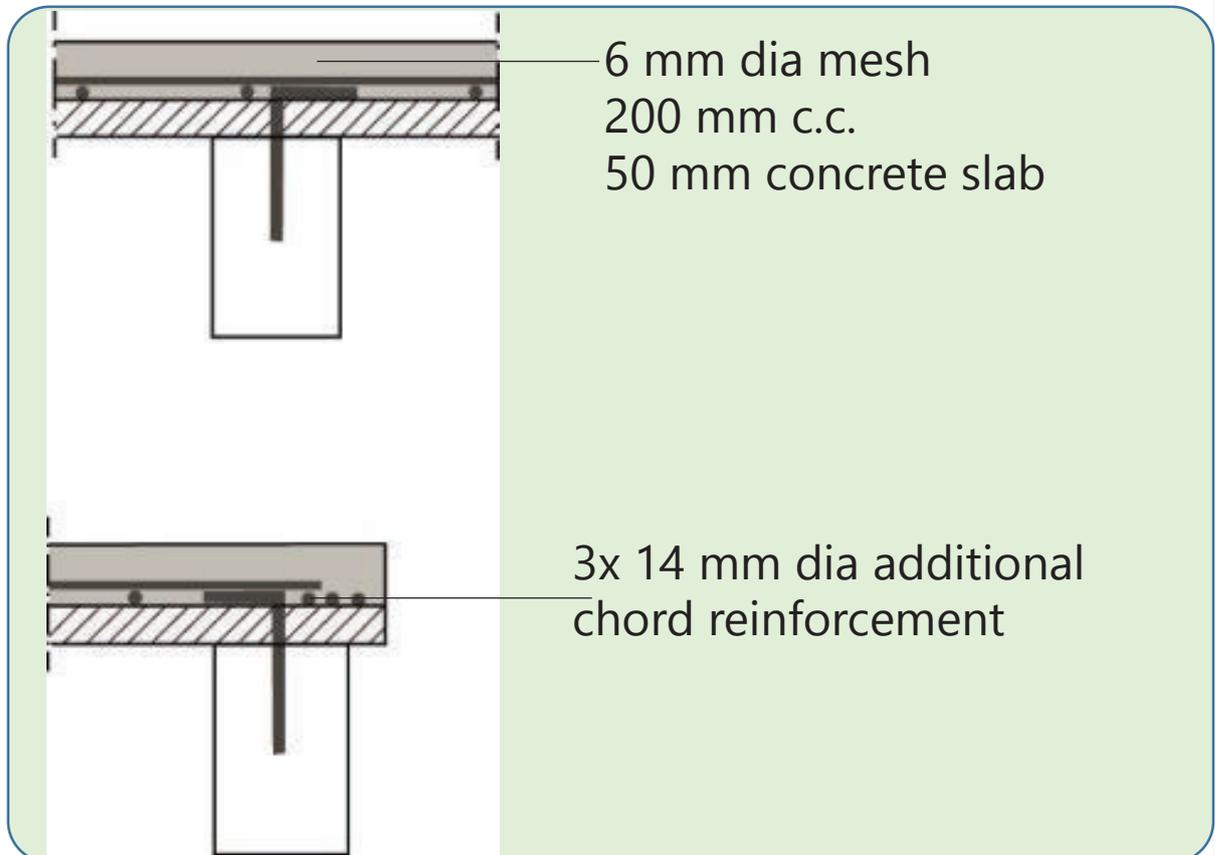
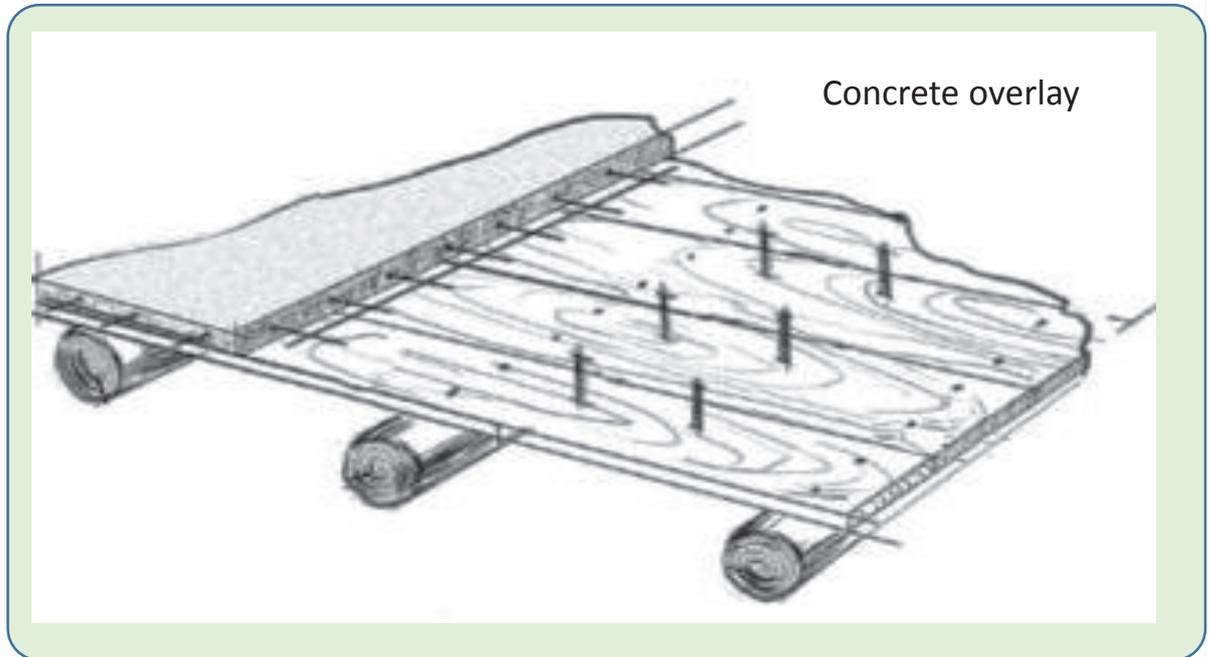
Stiffening flat wooden floor/roof resting on stone or brick masonry



Details of diagonal straps steel (galvanized) plate

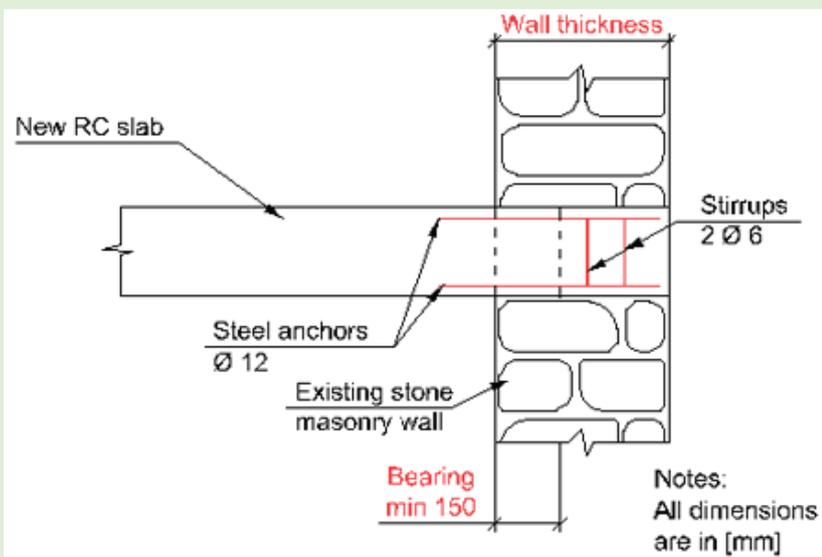
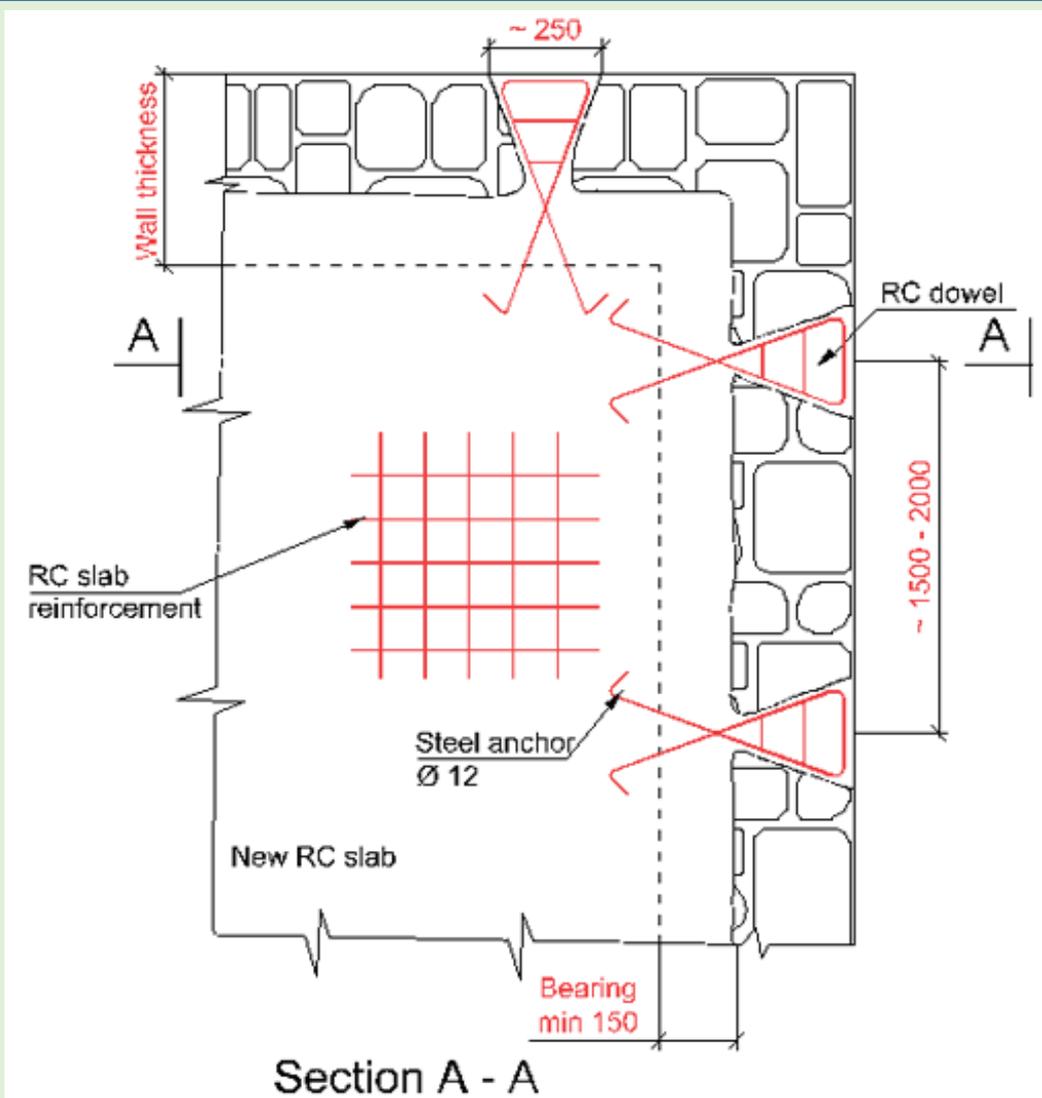
## 6.2 Stiffening of floors in their plane ...

### Option 3: Concrete overlay:



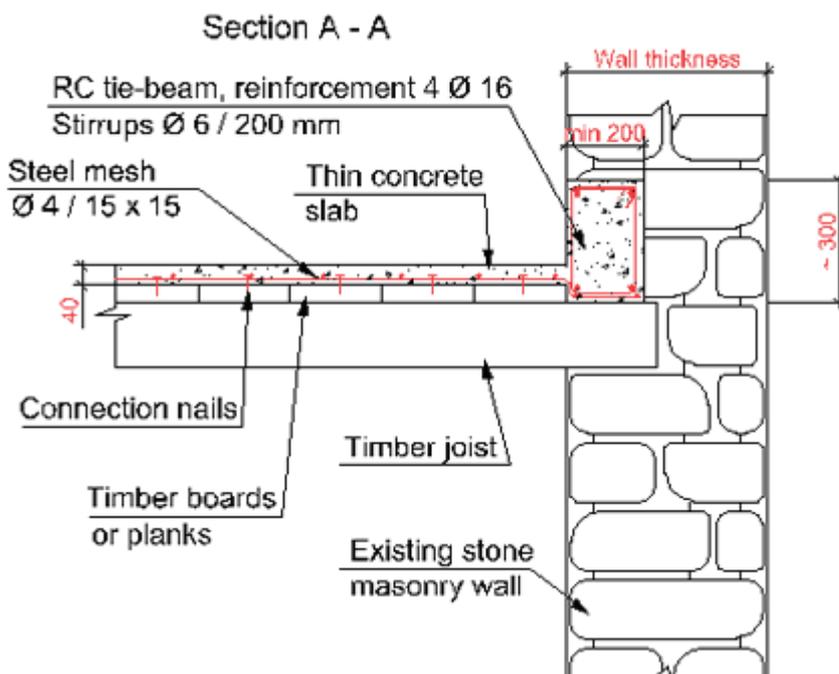
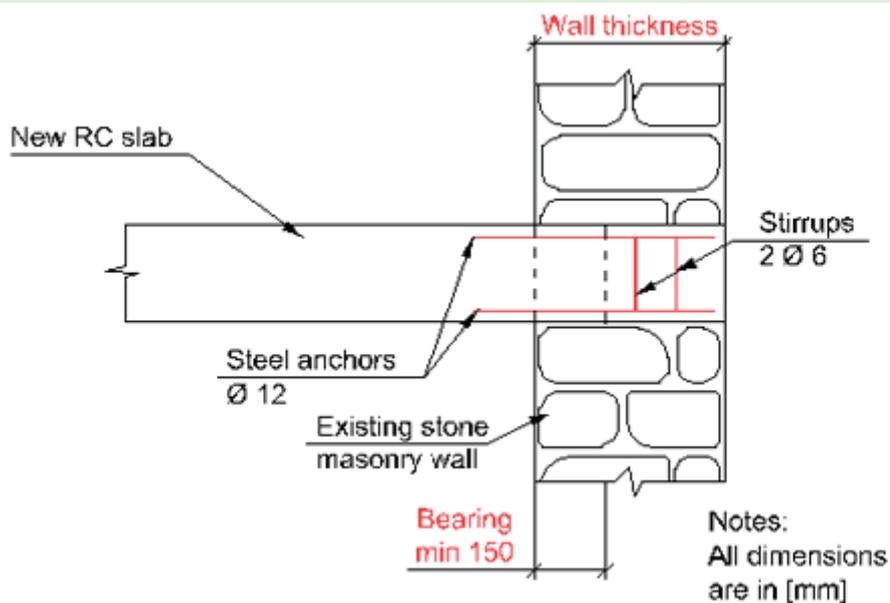
## 6.3 Stiffening of floors in their plane...

Option 4: New RCC slab :



## 6.3 Stiffening of floors in their plane...

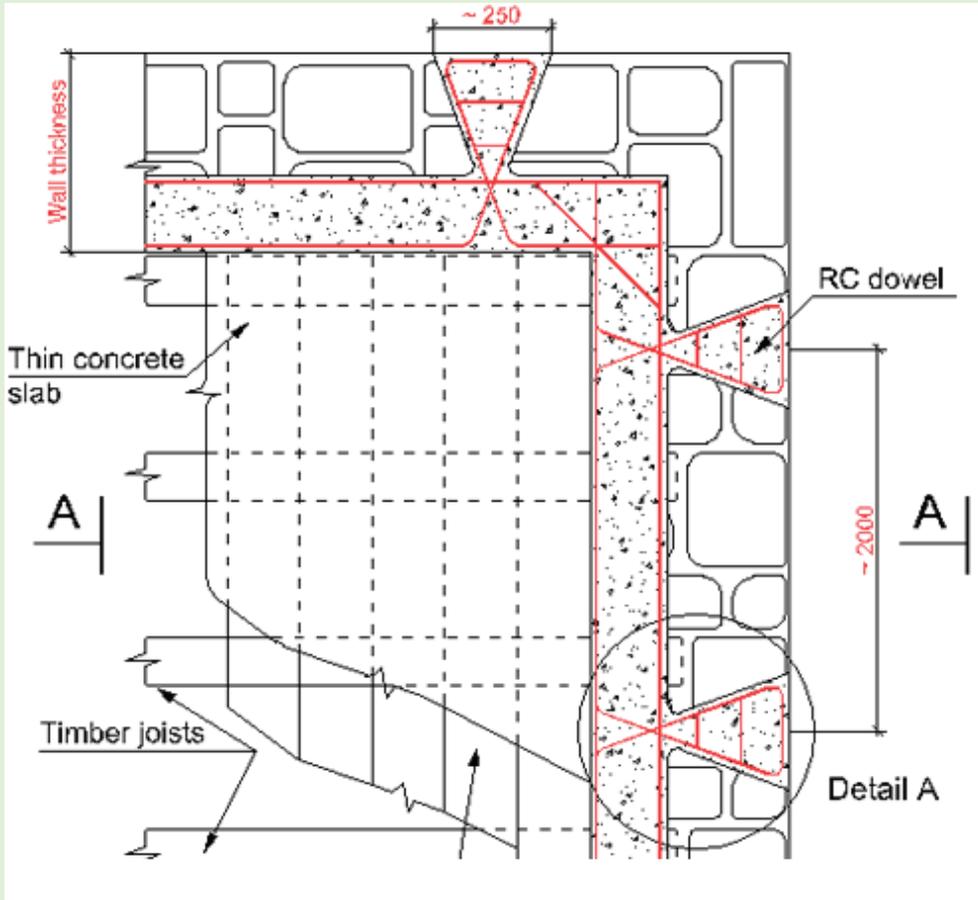
Option 4: New RCC slab :



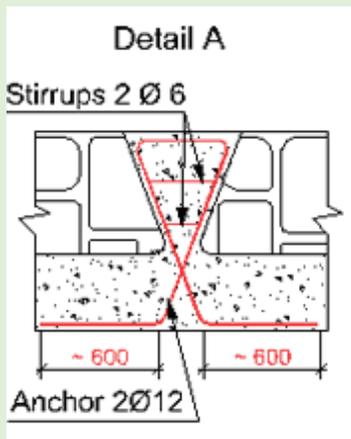
Details of new RC

## 6.3 Stiffening of floors in their plane...

Option 4: New RCC slab :



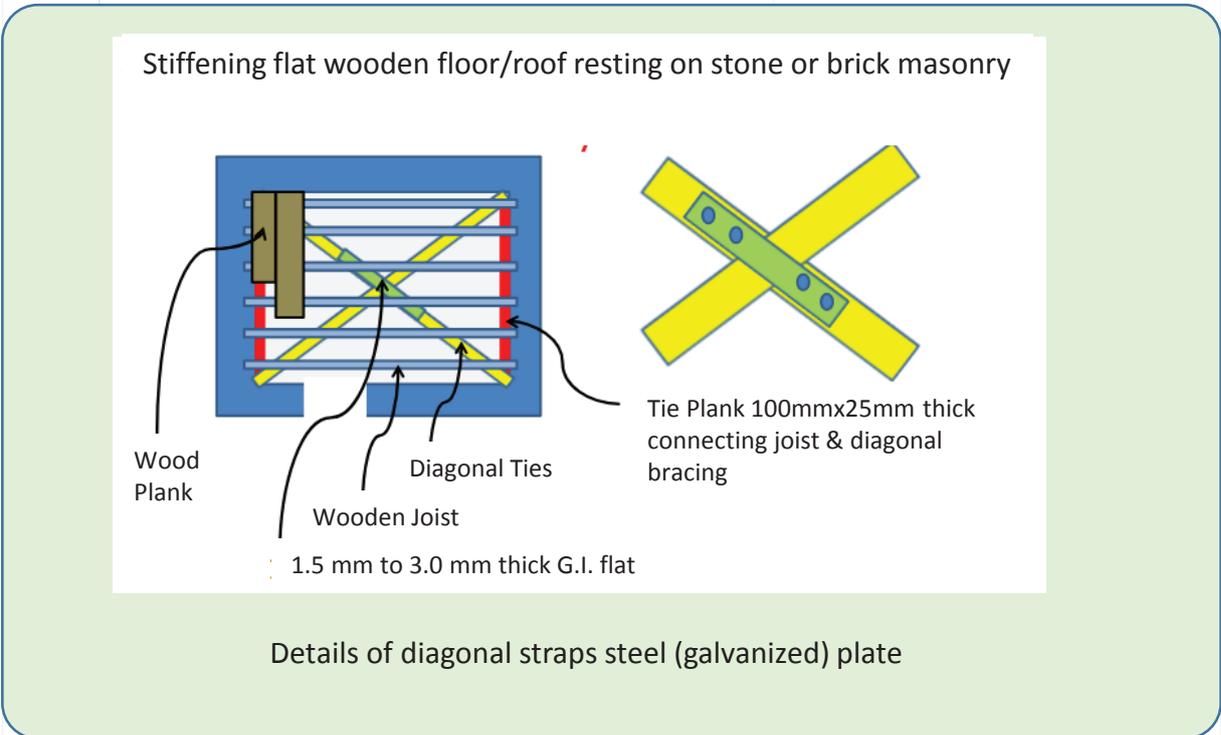
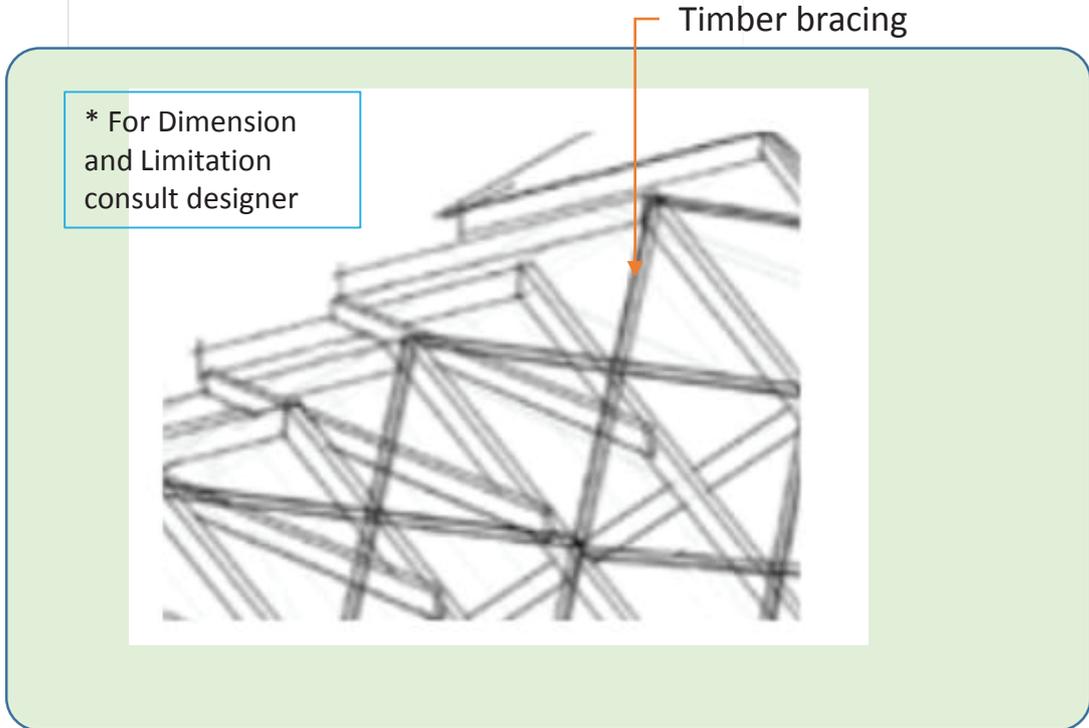
Details of new RC



## 7.0 Stiffening of roofs in their plane

### Option 1: Timber bracing :

When it is not possible to transport concrete and steel to the site:

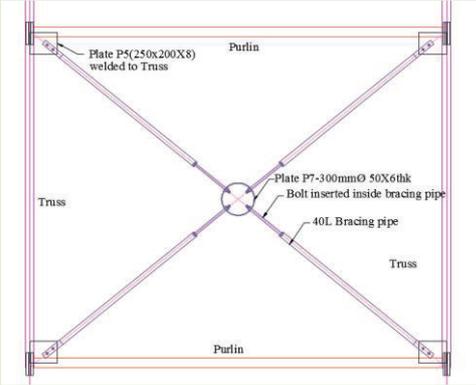
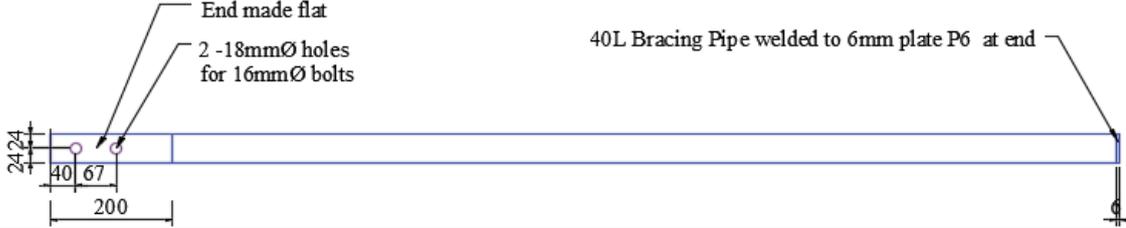
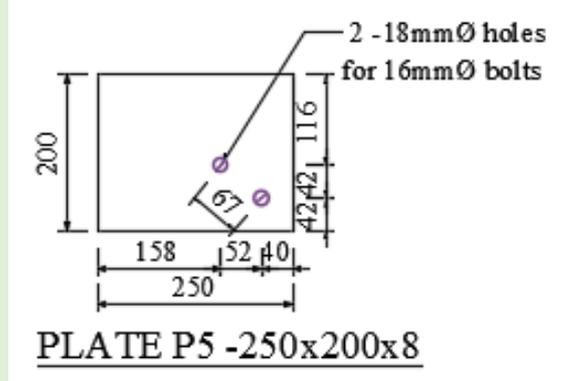
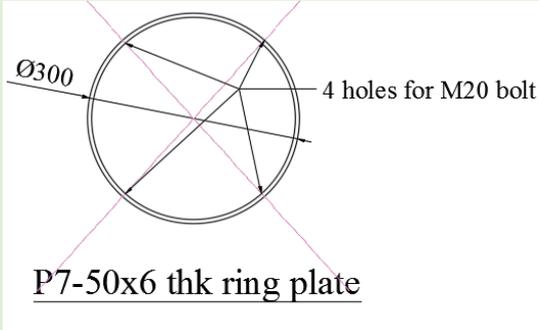
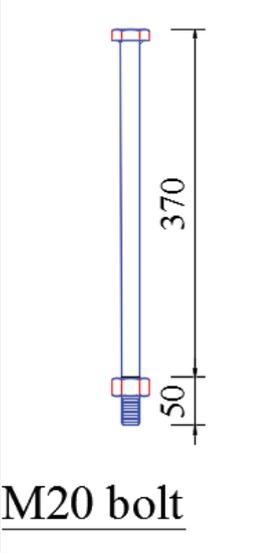


## 7.0 Stiffening of roofs in their plane ...

### Option 2 : Steel bracing :

When it is not possible to transport concrete and steel to the site:

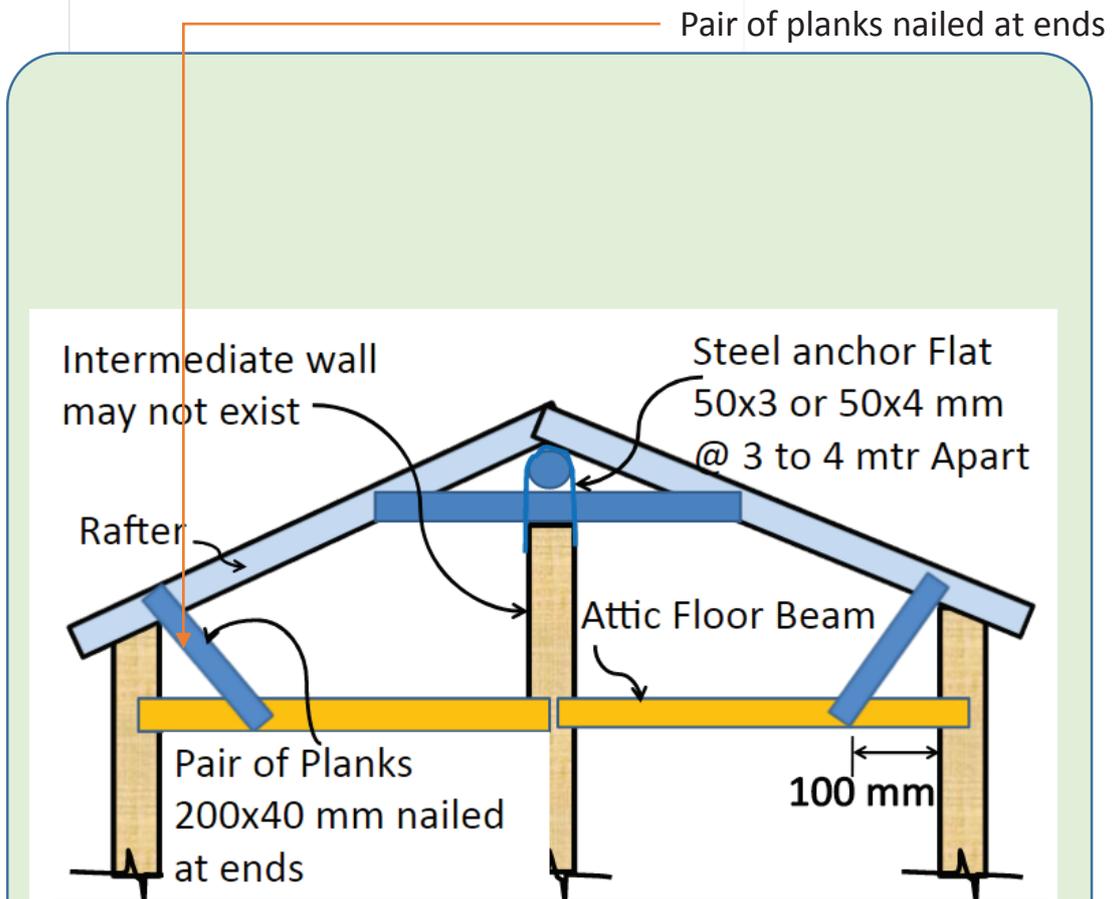
**Steel bracing**

**Details of steel bracing**

## 7.0 Stiffening of roofs in their plane ...

### Option 3 : Strengthening of Rafter roof having attic :



Details of Strengthening of Rafter roof having attic

## 8.0 Tying of parapet walls

- Replace heavy masonry with lighter material such as steel, wooden or bamboo elements with proper connection Or
- Provide bracing or parapet band with proper connection with existing walling/floor/roof material.

URM masonry parapet wall



Steel parapet with proper connection with slab or beam



Parapet wall with RC band & vertical RC post as per NBC practices



Wooden parapet with proper connection with floor joists



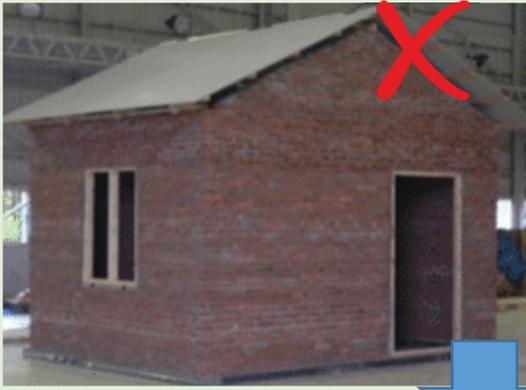
Masonry parapet braced with steel section with proper connection with slab or beam



## 9.0 Tying of gable walls...

### Intervention

URM gable wall



Replace the gable walls by light-weight materials such as galvanized iron sheets or wood panels. Where it cannot be done, confine the wall materials properly by complete jacketing or Bandages at roof and eaves level and Splint with span not exceeding 2.0m.

Replace with Light weight material (CGI sheet or wooden plank)



Provide external splint & bandage



## 10.0 Capacity improvement of structural wall

Note : This page give informative knowledge regarding the given retrofitting techniques. For more details and clarity, refer annex 1 (separate volume in A3 paper sheets).

Option 1: Retrofitting using RC splint-bandage (For preventing global failure) and GI wires in remaining part (for Local failure)



Retrofitting using rebar with concrete Splint-bandage and GI wire mesh Jacketing (Brick Masonry)

Option 1: Retrofitting using RC splint-bandage (For preventing global failure) and GI wires in remaining part (for Local failure)

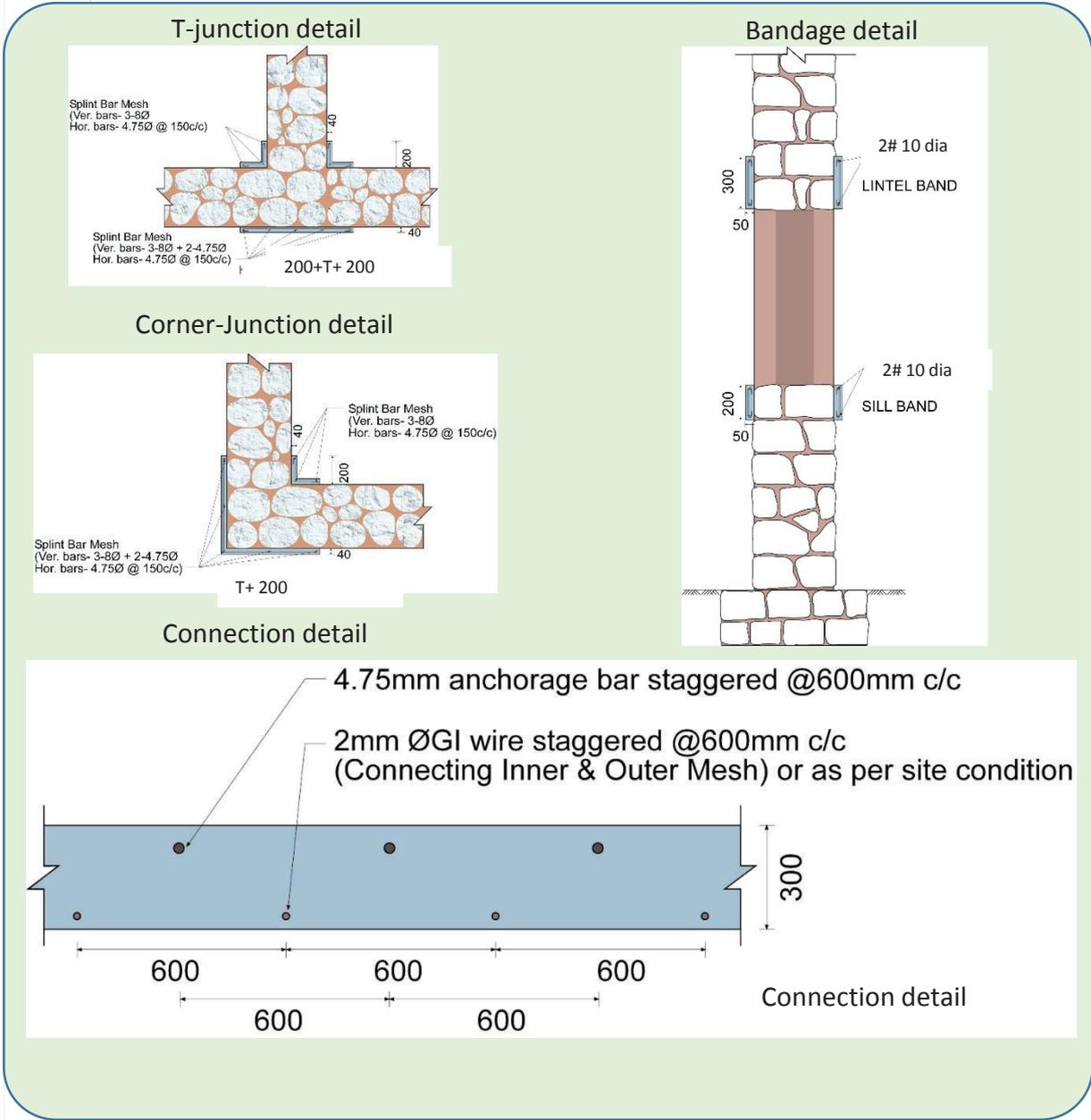


Retrofitting using rebar with concrete Splint-bandage and GI wire mesh Jacketing (Stone Masonry)

# 10.1 Capacity improvement of structural wall...

## Option 1: Typical details at T- & Corner junction, and anchorage details

PART-B : Seismic deficiencies and intervention

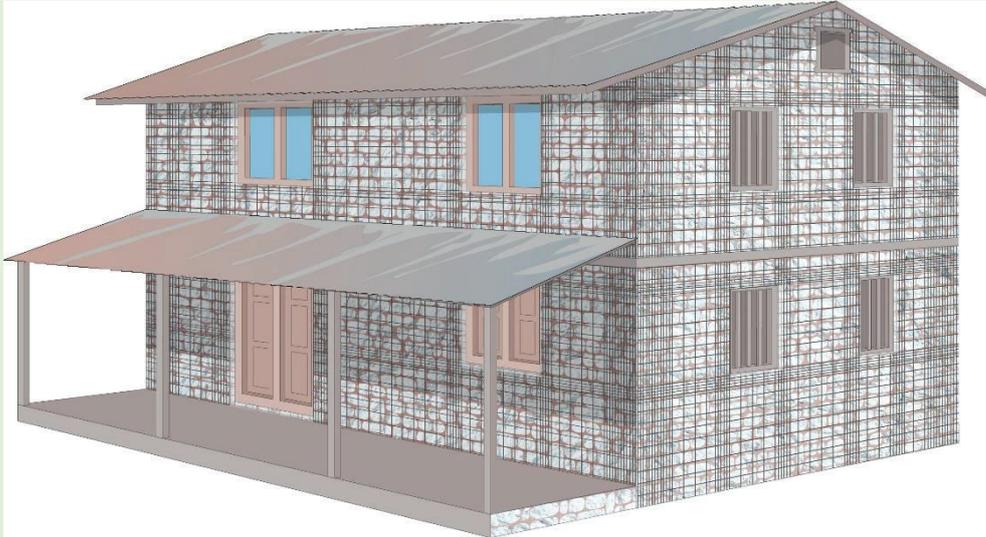


Note : This page give informative knowledge regarding the given retrofitting techniques. For more details and clarity, refer annex 1 (separate volume in A3 paper sheets).

## 10.2 Capacity improvement of structural wall...

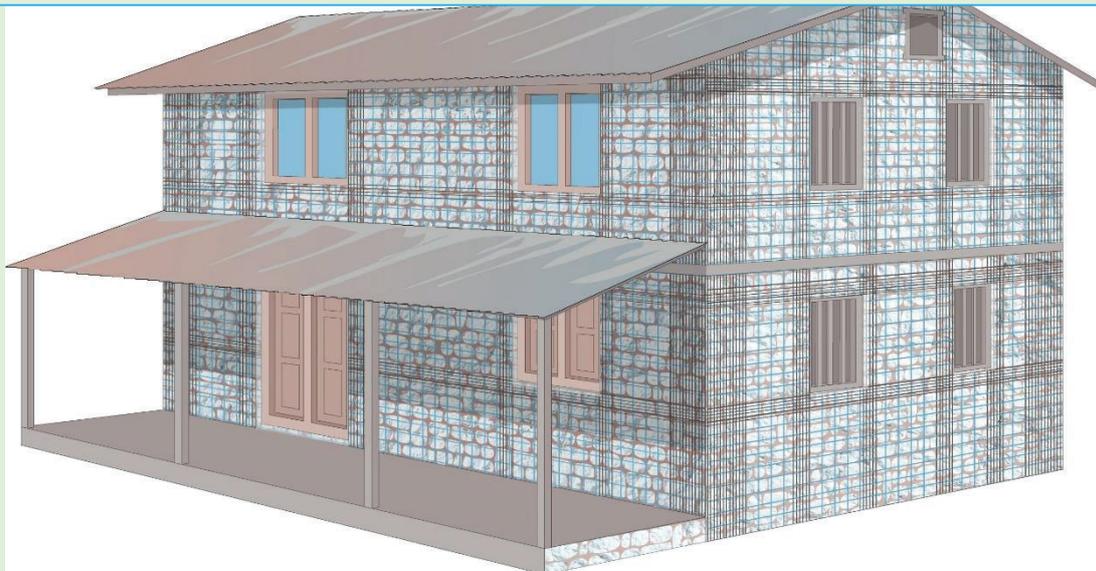
Note : This page give informative knowledge regarding the given retrofitting techniques. For more details and clarity, refer annex 1 (separate volume in A3 paper sheets).

Option 2: Retrofitting using Welded GI wire mesh Splint –bandage (For preventing global failure) and GI wire jacketing (for Local failure)



Retrofitting using Welded wire mesh Splint-bandage and GI wire mesh Jacketing  
(Stone Masonry)

Option 3: Retrofitting using Welded GI wire mesh Splint –bandage (For preventing global failure) and PP band in remaining part (for Local failure)



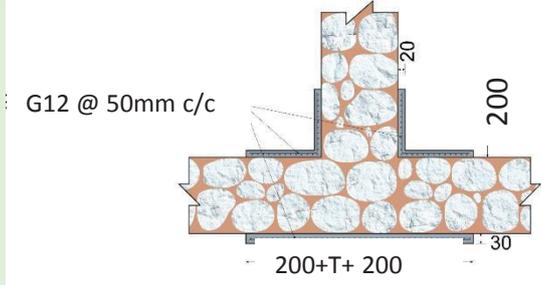
Retrofitting using Welded wire mesh Splint- bandage and P.P. wire mesh Jacketing  
(Stone Masonry)

## 10.3 Capacity improvement of structural wall...

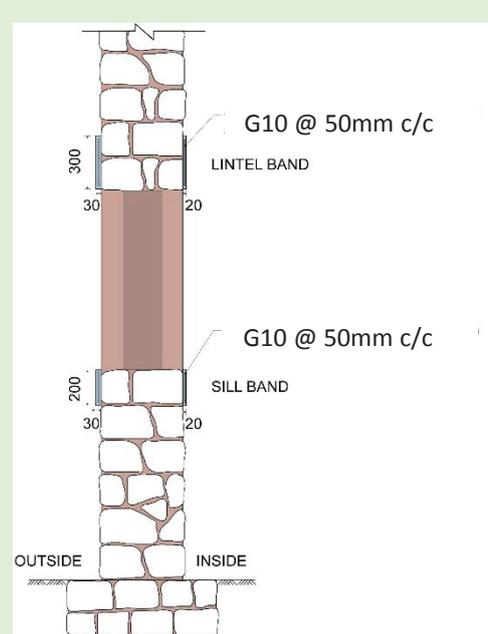
Option 2 & 3 : Typical details at T- & Corner junction, and anchorage details

PART-B : Seismic deficiencies and intervention

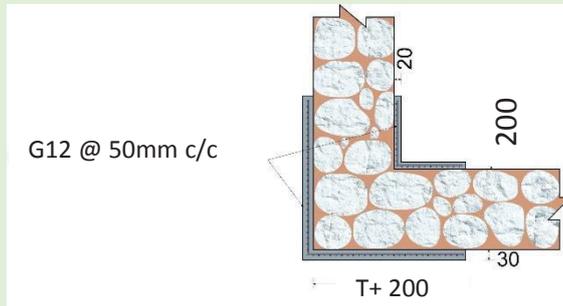
T-junction detail



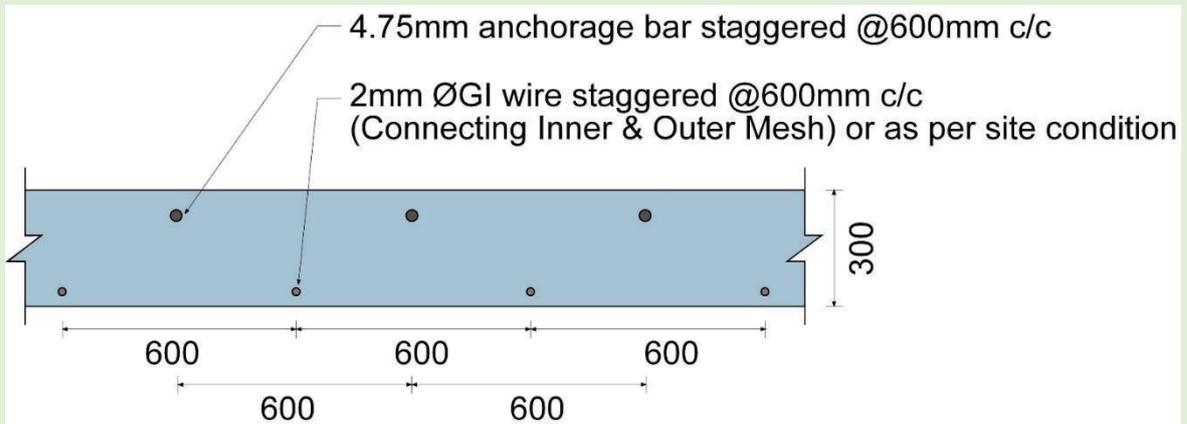
Bandage detail



Corner-Junction detail



Connection detail

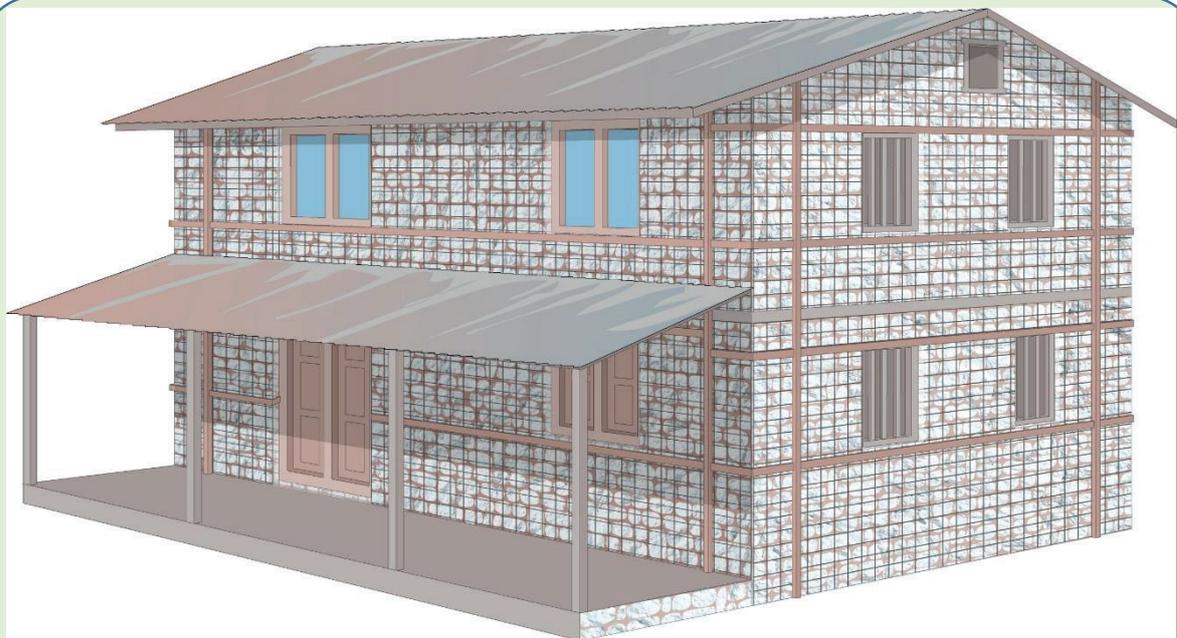


Connection detail

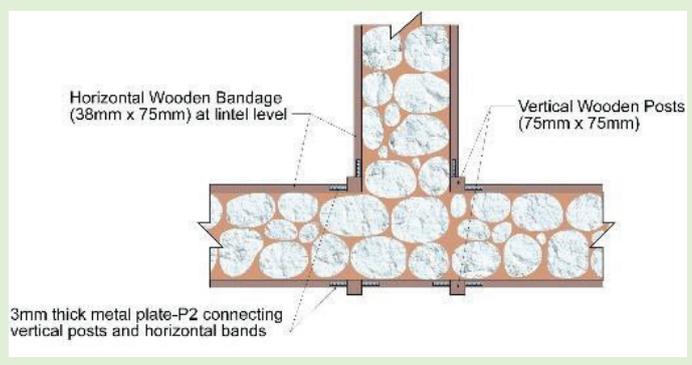
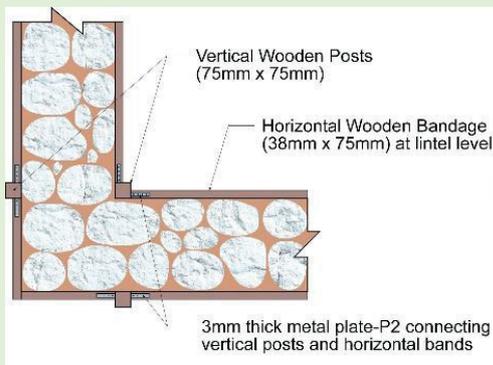
Note : This page give informative knowledge regarding the given retrofitting techniques. For more details and clarity, refer annex 1 (separate volume in A3 paper sheets).

## 10.4 Capacity improvement of structural wall...

Option 4: Retrofitting using wooden splint-bandage (For preventing global failure) and GI wires in remaining part (for Local failure)



Retrofitting using wooden section and GI wire mesh Jacketing



Note : This page give informative knowledge regarding the given retrofitting techniques. For more details and clarity, refer annex 1 (separate volume in A3 paper sheets).

## PART-C : Ready to use seismic retrofit designs

This section presents summary of retrofit designs which are applicable in following cases :

- ❖ Retrofitting Stone masonry building
  - 1) Retrofitting stone masonry building in mud (RSMM)
  - 2) Retrofitting dry stone masonry building (RDSM)
- ❖ Retrofitting brick masonry building
  - 1) Retrofitting brick masonry building in mud with flexible floor (RBMM)
  - 2) Retrofitting brick masonry building in cement with flexible floor (RBMC1)
  - 3) Retrofitting brick masonry building in cement with rigid floor (RBMC2)

[Typical description of building]

- Number of storey : 2 plus attic (maximum), except RBMC2 which is three storey
- Storey height : 3.00 m (maximum)
- Total height : 7.0m (2 plus attic) and 9.0 m (three storey)
- Unsupported wall length: 5.40 m (maximum)
- Plinth area : 100.00 sq.m.
- Configuration and load path : is similar as mention in part B : Seismic deficiency and intervention)
- Redundant : Yes
- Material condition : Good or replaced with new material in case of damaged.

[Note:] : the design given in this section are applicable to those building which meets the description mentioned above under typical description of buildings. In other case, structural design shall be done.

# Capacity improvement of structural wall : Design Summary

## Option 1 : Summary of design : For RC splint & bandage

Table 3: Summary of retrofit design (applicable to RSMM, RDSM, RBMM RBMC1 : 2 plus attic storey & RBMC-2\* : three storey)

S.N.	Length or Wall	Rebars Reinforcement in seismic belts with overlapping of Ld mm	
	In meter	Concrete Size (mm)	Rebar (No & diameter)
1.	≤ 5.40	300 x 40	2#10 $\varnothing$

Note : Material grade : M20 and Fe 500 or 415 , ties 4.75 mm diameter bars @ 150 m spacing.

Split : Rebar in RC seismic splint with overlapping of Ld mm,									
SN	No. of storey	Storey	Concrete size (Width x thickness)	At T-Junction		At Corner Junction		At near opening	
Concrete Grade M 20, Rebar Grade Fe 500				No	Bar $\varnothing$ (mm)	No	Bar $\varnothing$ (mm)	No	Bar $\varnothing$ (mm)
1	One		200x40	3	8	3	8	2	8
2.	One plus attic	attic	200x40	3	8	3	8	2	8
		Ground	200x40	3	8	3	8	2	8
3.	Two	First	200x40	3	8(10)	3	8	2	8
		Ground	200x40	3	8 (10)	3	8	2	8
4.	Two plus attic/s econd	Attic/S econd	200x40	3	10	3	8	2	8
		First	200x40	3	10	3	8	2	8
		Ground	200x40	3	10	3	8	2	8

Note :1) Material grade : M20 and Fe 500 or 415 , ties 4.75 mm diameter bars @ 150 mm spacing.

: 2) The splints which is provided to out side of the room shall be of 200+2\*wall thickness and 200+wall thickness at T –junction and at corner respectively with 2 Numbers of 4.75 diameter vertical bars additionally.

Provide G.I. wire mesh at 100 mm at centres in horizontally and vertically to prevent local failures.

: values in parenthesis is RBMC -2

# Capacity improvement of structural wall : Design Summary

## Option 2 & 3 : Summary of design : For Welded G.I. Mesh splint & bandage

Table 1: Summary of retrofit design (applicable to RSMM, RDSM and RBMM)

S.N.	Length or Wall	G.I. Mesh Reinforcement in seismic belts with overlapping of 300mm		
	In meter	Gauge	No.	Wide
1.	≤ 5.40	10	12 (5)	300 (200)

Gauge, G10 = 3.25mm.

- Value in parenthesis is for sill band, remaining in lintel band
- concrete thickness 20mm & 30mm for inner and outer section.

Split : G.I. Mesh Reinforcement in seismic splint with overlapping of 300mm,(applicable to RSMM, RDSM and RBMM)

SN	No. of storey	Storey	G	At T-Junction		At Corner Junction		At near opening	
				No	W	No	W	No	Wide
1	One		12	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
2.	One plus attic	attic	12	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
		Ground	12	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
3.	Two	First	10	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
		Ground	10	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
4.	Two plus attic	attic	10	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
		First	10	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)
		Ground	10	18 (5)	2X200 +T (200)	14 (5)	200 +T (200)	5 (5)	200 (200)

Values in parenthesis ( ) is for splint in side of the room and remaining value is for splint outside the room.

Gauge, G10 = 3.25mm, G12 = 2.64mm

Note : provide PP band or G.I. wires (G12) at 100 mm at centers vertically and horizontally to prevent local failures in remaining portion of the walls.

- concrete thickness 20mm & 30mm for inner and outer section.

# Capacity improvement of structural wall : Design Summary

## Option 4 : Summary of design : For wooden splint & bandage

Table 2: Summary of retrofit design (applicable to RSMM and RDSM)

S.N.	Length or Wall	Wooden member in seismic belts with proper overlapping.		
	In meter	size	No.	Wide
1.	$\leq 5.40$	38mmX75mm	2 (each face)	

Note : Connection using MS plate.

Split : wooden member in seismic splint with proper overlapping .						
SN	No. of storey	Storey	Size	At T-Junction	At Corner Junction	At near opening
				No	No	No
1	One		75x75	4	3	4
2.	One plus attic	attic	75x75	4	3	4
		Ground	75x75	4	3	4
3.	Two	First	75x75	4	3	4
		Ground	75x75	4	3	4
4.	Two plus attic	attic	75x75	4	3	4
		First	75x75	4	3	4
		Ground	75x75	4	3	4

Note : Connection using MS plate. Provide G.I. wire mesh of 12 gauge @100 mm at centres in horizontally and vertically to prevent local failures.

## PART-D: Construction Sequences

[This section deals with construction sequences regarding repairs measures and retrofitting measures.]

### PART-D.1: Repair Process

Repair does not improve the structural strength of the building and very deceptive for meeting the strength requirements of the next earthquake. Repair measures presented are :

- a) Action # 1: repair minor to cracks using grouting
- b) Action # 2: repair major cracks by fixing wire mesh
- c) Action # 3 : repair major cracks by using stitching elements
- d) Action #4: repair of damaged wall by rebuilding

### PART-D.2: General Retrofitting Process

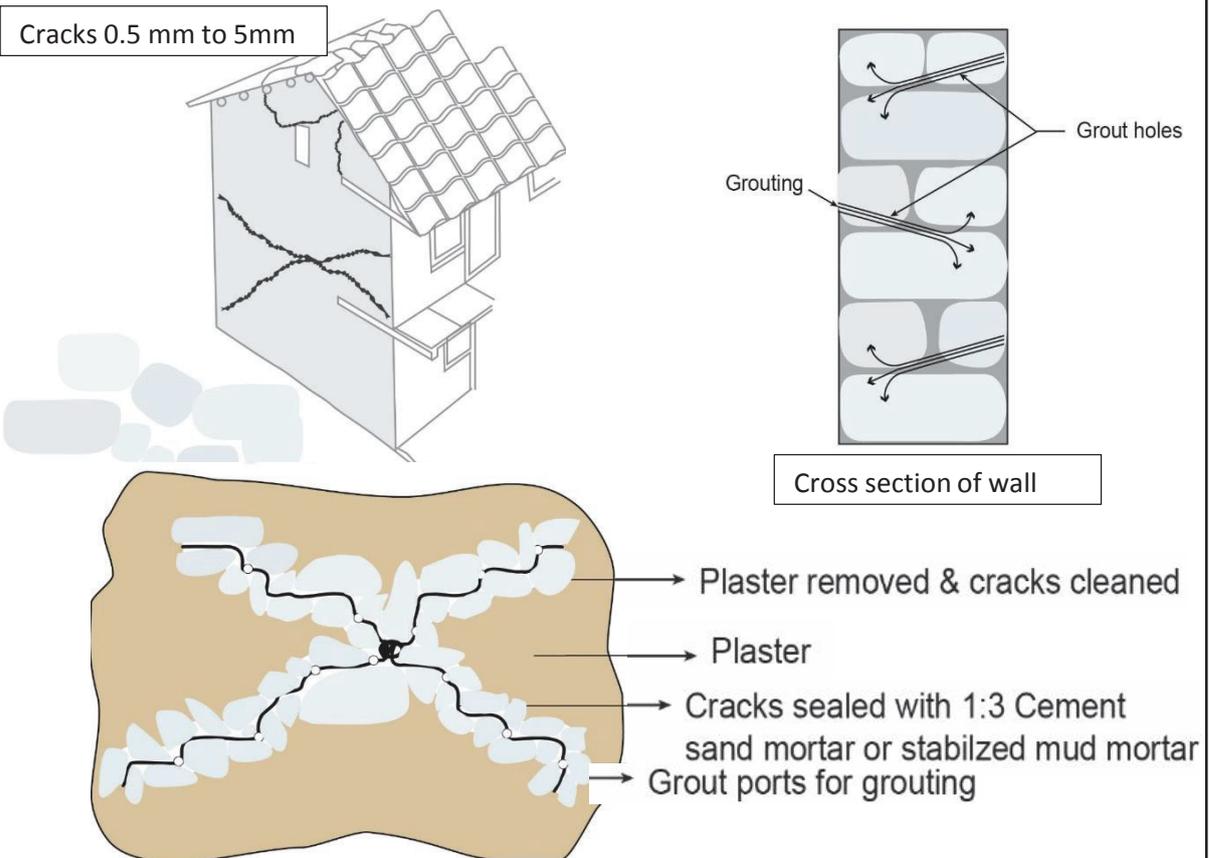
[Retrofitting measures are meant for increasing the capacity of structural components of the building. This sub section gives typical construction process of retrofitting]

## Action # 1: Repair Minor To Cracks Using Grouting

## Material and Equipment

- Plastic or aluminum nipples of  $\frac{1}{2}$  inches in diameter and 1 to 1  $\frac{1}{2}$  inches long in length.
- Grouting materials: the grout may be made using cement, sandy soil and fine sand mix in the proportions in 1:1:3 with enough water to make it into slurry. The soil and sand should be passing through  $\frac{1}{2}$  mm sieve.
- Cement and sand mortar of 1:3 for sealing the cracks.
- Container for injecting slurry at a height of 4 feet to 5 feet above the cracks with flexible hose pipe for flow of grout by gravity.

Cracks 0.5 mm to 5mm



Steps : Grouting can be done as following:

Remove plaster in the vicinity of crack exposing the cracked bare masonry.

Make the shape of crack in V-shape by chiseling out.

Fix the grouting nipples in the V-groove on the faces of the wall at spacing of 6 to 8 inch c/c.

Clean the crack with compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed (Water injection should not be done in case of mud mortar masonry).

Seal the crack on both faces of the wall with 1:3 ratio cement mortar and allow to gain strength.

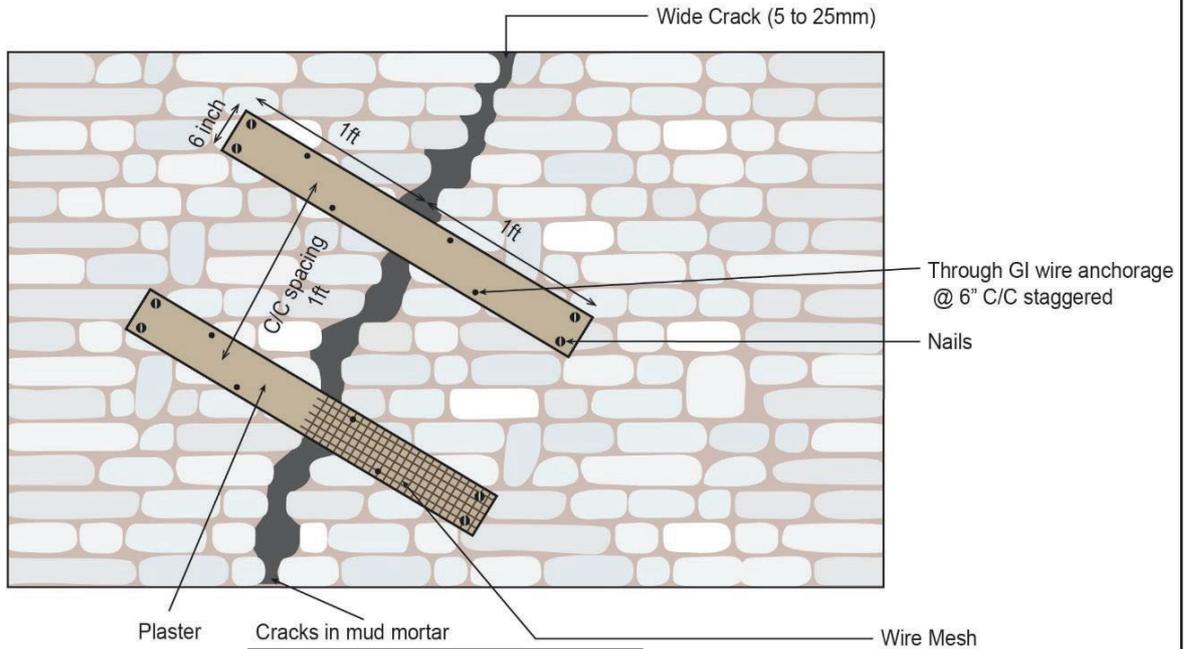
Inject the grout from lower most nipple till it comes out from the next higher nipple and then move to next higher nipple.

After injection of grout through all the nipples is completed, re-plaster the surface and finish as required.

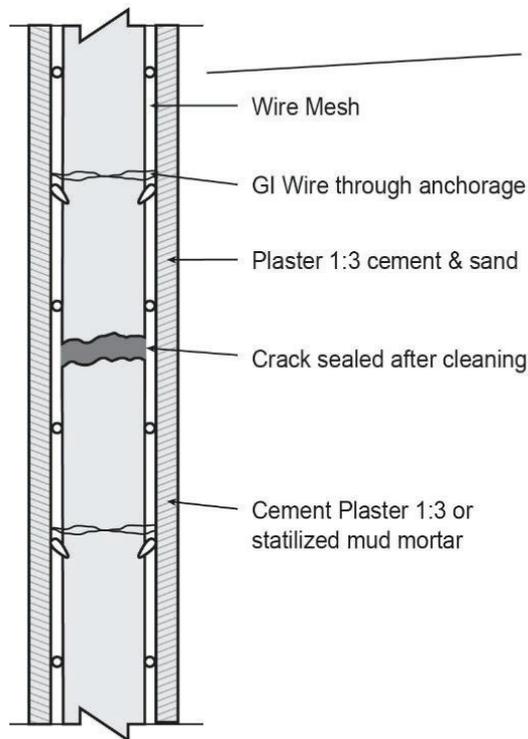
## Action # 2: Repair Major Cracks By Fixing Wire Mesh

### Material and Equipment

- 1:3 cement-sand mortar for sealing of cracks and plastering.
- Galvanized steel wire mesh (with wires of 16 to 14 gauge i.e. 1.5mm to 2.03 mm diameter) 1 inch x 1 inch mesh size.
- Galvanized steel wire of 12 gauge i.e 3.15 mm diameter, 4 inch long nails.



Stone Masonry : Elevation



Stone Masonry : Section View

## Action # 2: Repair Major Cracks By Fixing Wire Mesh...

### Construction steps:

Steps : Major Cracks (crack width greater than 5 mm) can be repaired by wire mesh as following .

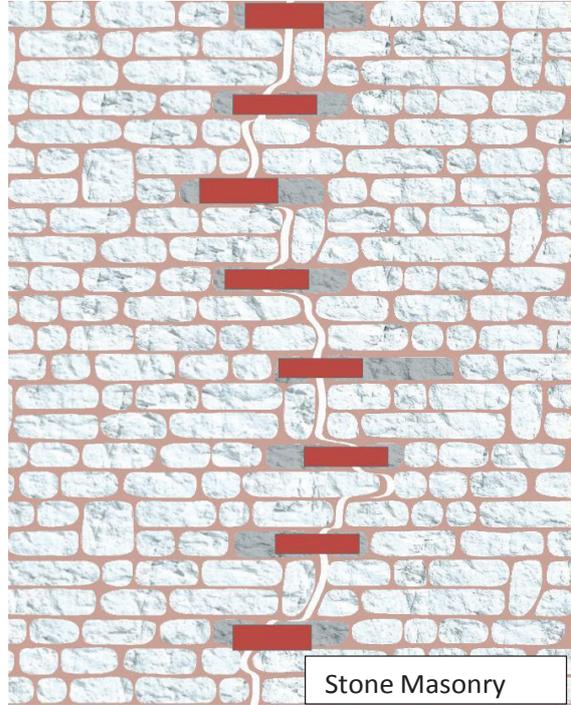
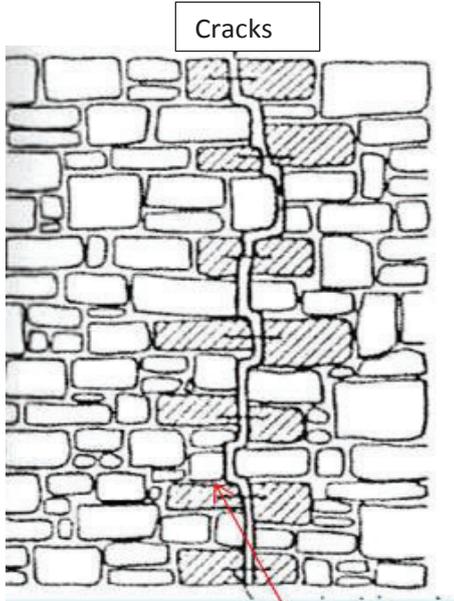
- Remove the plaster in the vicinity of crack exposing the cracked bare masonry upto around 6 inch width at both sides of the crack.
- Make the shape of crack in the V-shape by chiseling out.
- Make the throughout hole on wall by drilling on planned area of wire mesh at spacing of 6" c/c staggered.
- Clean the crack with compressed air.
- Fill the crack with 1: 3 ratio cement mortar with necessary water from both sides as deep as feasible.
- Provide wire mesh on both the faces of wall to a minimum width of 6 inch on each side of the crack and in the entire length of the crack. if it is not possible to provide in the entire length, then provide pieces of wire mesh (width not less than 6 inch) at spacing of about 1 ft.
- Clamp the mesh with the wall using nails.
- Connect the both side of mesh by galvanized wire through the throughout holes of wall.
- Plaster the meshed area with cement sand mortar of 1:3 with minimum of 1/2 inch thickness.

### Action # 3 : Repair Major Cracks By Using Stitching Elements

#### Material and Equipment

- 1:3 cement-sand mortar for sealing of cracks and plastering.
- Stitching dogs or steel bars with concrete

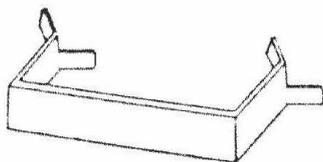
Cracks greater than 5 mm



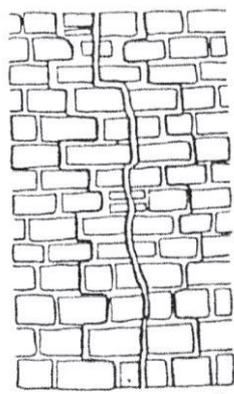
Removal of stones

Stone Masonry

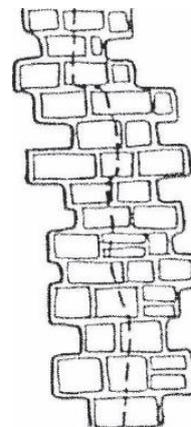
**Stitching up the crack by inserting stitch on both side of wall**  
(source: UNIDO 1983)



**Stitching dog** (source: UNIDO 1983)



Removal of stones



**Stitching up the crack by rebuilding the wall over its entire thickness**  
(source: UNIDO 1983)

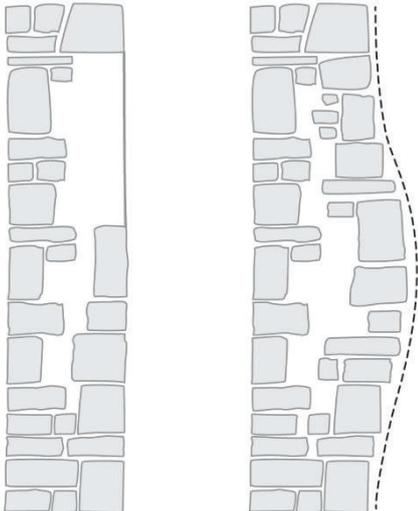
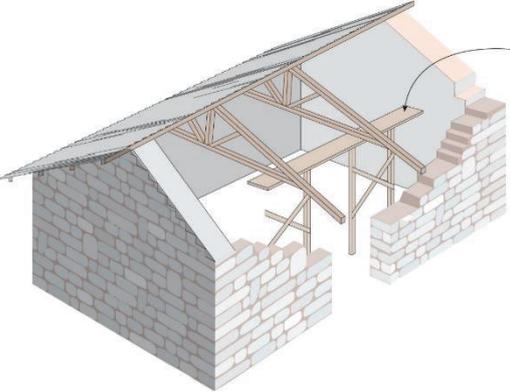
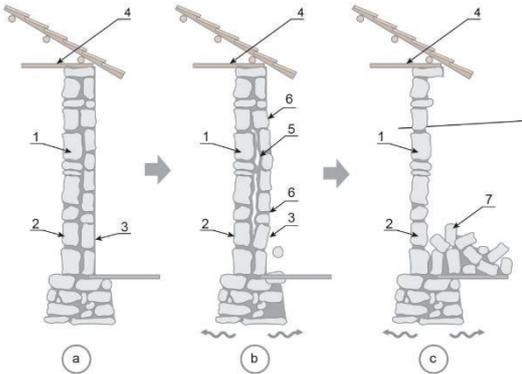
### Action # 3 : Repair Major Cracks By Using Stitching Elements...

Steps : Major Cracks (crack width greater than 5 mm) can be repaired by stitching as following :

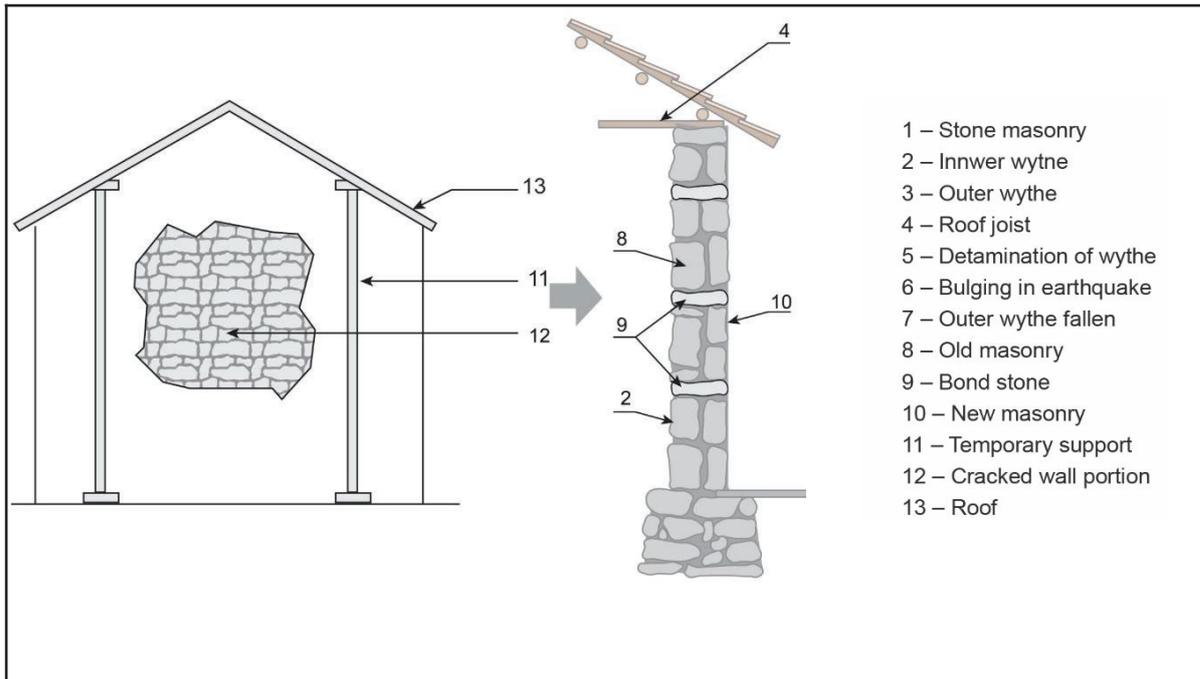
- Remove the plaster in the vicinity of crack exposing the cracked bare masonry upto around 6 inch width at both sides of the crack.
- Make the shape of crack in the V-shape by chiseling out.
- Remove the alternate loose stones adjacent to the cracks.
- Clean the crack with compressed air.
- Add stitching dogs or steel bars with concrete on removed loose stones.
- Alternatively, stones can be removed from a zone about 6" to 9" along a vertical cracks and the wall can be reconstructed using elongated stones.
- Fill the crack with 1: 3 ratio cement mortar with necessary water from both sides as deep as feasible.
- Plaster the exposed area with cement sand mortar of 1:3 with minimum of 1/2 inch thickness.

Action #4: Repair Of Damaged Wall By Rebuilding

PART-D: Construction Sequences : PART-B.1: Repair Process

Material and Equipment	
Same as new construction with scaffolding sets	
 <p>Wall is rebuilt and the void filled with concrete or cement grout</p> <div style="border: 1px solid black; padding: 2px; display: inline-block;">Stone Masonry</div>	
<p><b>Wall that need completely removed and reconstruction</b> (source: UNIDO 1983)</p>	<p>Only humped side need removed and reconstruction (source: UNIDO 1983)</p>
 <p>Temporary roof support</p> <p>Dismantle the wall in the form of a staircase until it is completely vertical.</p>	
<p><b>Rebuilding the partial collapsed wall or tilted walls(adapted from: )</b></p>	
	<ul style="list-style-type: none"> <li>1 - Stone masonry</li> <li>2 - Inner wythe</li> <li>3 - Outer wythe</li> <li>4 - Roof joist</li> <li>5 - Detamination of wythe</li> <li>6 - Bulging in earthquake</li> <li>7 - Outer wythe fallen</li> <li>8 - Old masonry</li> <li>9 - Bond stone</li> <li>10- New masonry</li> <li>11- Temporary support</li> <li>12- Cracked wall portion</li> <li>13- Roof</li> </ul>

## Action #4: Repair Of Damaged Wall By Rebuilding..

**Rebuilding the delaminated wall(source: IAAE 1986)**

Steps : Major Cracks (crack width greater than 5 mm) can be repaired by rebuilding as it as following :

- Extensive damage may occur to stone walls which require a portion of the wall to be removed and reconstructed.
- In such case, it is important to promptly install temporary shoring to support the floors and walls above that depends on the extent of damage of wall.
- When portions of the walls have permanent lateral distortion or humping throughout the width of the wall, the distressed portion of the wall must be completely removed and reconstructed.
- If the wall has a spread or humped on only one face, complete reconstruction can be avoided if the vertical face is stable enough to be used as formwork after the humped side has been taken down. Header are placed in the rebuilt wall using concrete or cement grout to completely fill all voids.
- The new portion of the wall should be constructed using the same mortar as that used in the existing construction.

a) General retrofitting process

- Following gives over view of construction steps, activities and description of retrofitting process.

Steps	Activities	Description
1	Remove plaster	Plaster removed from walls in the area only where splint and bandage is to be added, dust cleaned, any holes patched up for consistent wall surface. Mud mortar raked to 25mm in case of mud mortar and 12 mm to 15 mm in case of cement plaster.
2	Clean, repair and prepare walls	Cracks cleaned with water and grouted, thin cement slurry for cement based construction or mud (mud-cement mix) for mud based construction, applied over the area of wall where splint and bandage is to be added with water bottle.
3	Excavate tie beam	Excavation as per drawing, soling installed to correct level. Foundation wall brushed and washed with water to remove all mud.
4	Tie beam ties installed	Holes drilled or cavities located as per required spacing, reinforcement installed as per diagram to length of half of wall width plus 50mm (2").
5	Tie beam ties grouted	Grout all reinforcement ties using 1:3 mortar mix, firm in place.
6	Install splint and bandage	GI wire ties placed as per required spacing. Wire mesh rolled horizontally, with corners of room at the middle of the panel. Wire mesh secured in place with tightened loops of GI wire ties, wire mesh panels bound together using binding wire with 50mm (2") overlap.
7	Demolish walls and replace frames	Replace any damaged timber frames and install new lintel.
8	Reconstruct wall, truss mounts, bracing mounts, install jacketing	Wall constructed using stone and mud to 2400mm (8'), installing wire ties and wire mesh as height increases. 20mm pipe 600mm long (2') for bracing brackets installed in corners and centre of long walls (total 6 per classroom) for bracing bolts.. Leave 300mm x 300mm ( 1'x1' ) gaps at top of wall where trusses will be mounted.
9	Truss mounts	Fill 300mm x 300mm (1'x1') gaps in wall with stones /concrete, cast GI wire ties and fold wire mesh on both sides of wall across the top of wall. Cast 4x 10mm bars 600mm (2') long. 2 bars on each side of where truss beam will be located, 150mm (6") apart or as required depending on timber width.

## General retrofitting process...

10	Secure wire mesh, install reinforcement	Wire mesh installed tight against stone wall, wire tie loops tightened and tied, corners of wire mesh flattened, and tie beam anchors tight, 12mm dia rod in place with lap lengths 500 mm. Install vertical reinforcement at splint location midway along external end walls as per drawing. Formwork constructed for tie beam, tight with no leaks.
11	Concrete tie beams	Concrete tie beams with 1:1.5:3 concrete mix. Ensure good compaction using rod. When hardening fill hole with water or cover with wet jute immediately, cover with material or tarpaulin for shade to prevent evaporation.
12	Plastering internal	Plastering to inner walls using 1:3 mortar mix. Plaster applied in two layers. Ensure depth and good bond with wall. To depth 30mm or 20mm where specified in drawings. Smooth finish. Stop near top of wall. Upon completion cover with wet jute material and tarpaulin to stop evaporation. Apply water to jute several times a day or as needed to maintain wetness.
13	Plastering external	Plastering to outer walls using 1:3 mortar mix. Plaster applied in two layers. Ensure depth and good bond with wall. To depth 30mm as specified in drawings, and 50mm thickness at splint location as per drawing. Smooth finish. Stop near top of wall. Upon completion cover with wet jute material and tarpaulin to stop evaporation. Apply water to jute several times a day or as needed to maintain wetness.
14	Plaster top of wall	Plaster top of wall to minimum 50mm thickness using 1:3 mortar mix or micro concrete 1:1.5:3 mix as advised by technical supervisor. Upon completion cover with wet jute material and tarpaulin to stop evaporation. Apply water to jute several times a day or as needed to maintain wetness.
15	Roof installed	Roof truss timber cut, fabricated, placed and secured. Truss constructed as per drawing.
16	Install bracing	Install bracing.

## Annex 1 : Typical structural drawings

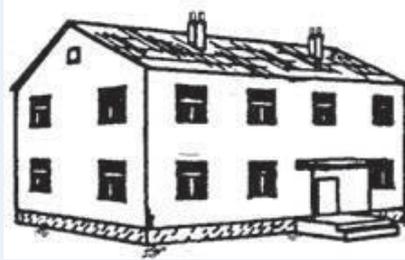
[Annex 1 is compiled in A3 sheets, separate volume which is detail retrofitting drawings for type design of particular buildings. Further structural drawing can be prepared for ready to use designs presented in Part : C with study of these drawings. The drawing are of following building typologies:

- ❖ Retrofitting Stone masonry building
  - 1) Retrofitting stone masonry building in mud (RSMM)
  - 2) Retrofitting dry stone masonry building (RDSM)
  
- ❖ Retrofitting brick masonry building
  - 1) Retrofitting brick masonry building in mud with flexible floor (RBMM)
  - 2) Retrofitting brick masonry building in cement with flexible floor (RBMC1)
  - 3) Retrofitting brick masonry building in cement with rigid floor (RBMC2)

[Note:] : The preparation of detail drawing shall not be mandatory where ready to use design are applicable. In case of detail design submitted, only typical drawing shall be prepared.

## Annex 2 : EMS Damage Grade

### Classification of damage to masonry buildings



Grade 1: Negligible to slight damage

Structural damage : No  
Non-structural damage: Slight

- Hair-line cracks in very few walls.
- Fall of small pieces of plaster only.
- Fall of loose stones from upper parts of buildings in very few cases.



Grade 2: Moderate damage

Structural damage : Slight  
Non-structural damage: Moderate

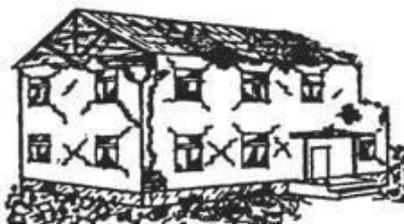
- Cracks in many walls.
- Fall of fairly large pieces of plaster.
- Partial collapse of chimneys.



Grade 3: Substantial to heavy damage

Structural damage: Moderate  
Non-structural damage: Heavy

- Large and extensive cracks in most walls.
- Roof tiles detach.
- Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).



Grade 4: Very heavy damage

Structural damage: Heavy  
Non-structural damage: Very heavy

- Serious failure of walls; partial structural failure of roofs and floors.



Grade 5: Destruction

Structural damage: very heavy

- Total or near total collapse.

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नेपाल सरकार  
राष्ट्रिय पुनर्निर्माण प्राधिकरण  
आवास पुनर्निर्माण कार्यक्रम  
सिंहदरवार, काठमाडौं  
फोन नं.: ०१४२००२६६, ४२१११०३  
इमेल: info@nra.gov.np

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN ON  
THREE STOREY BRICK MASONRY BUILDING IN CEMENT  
USING RC BARS**

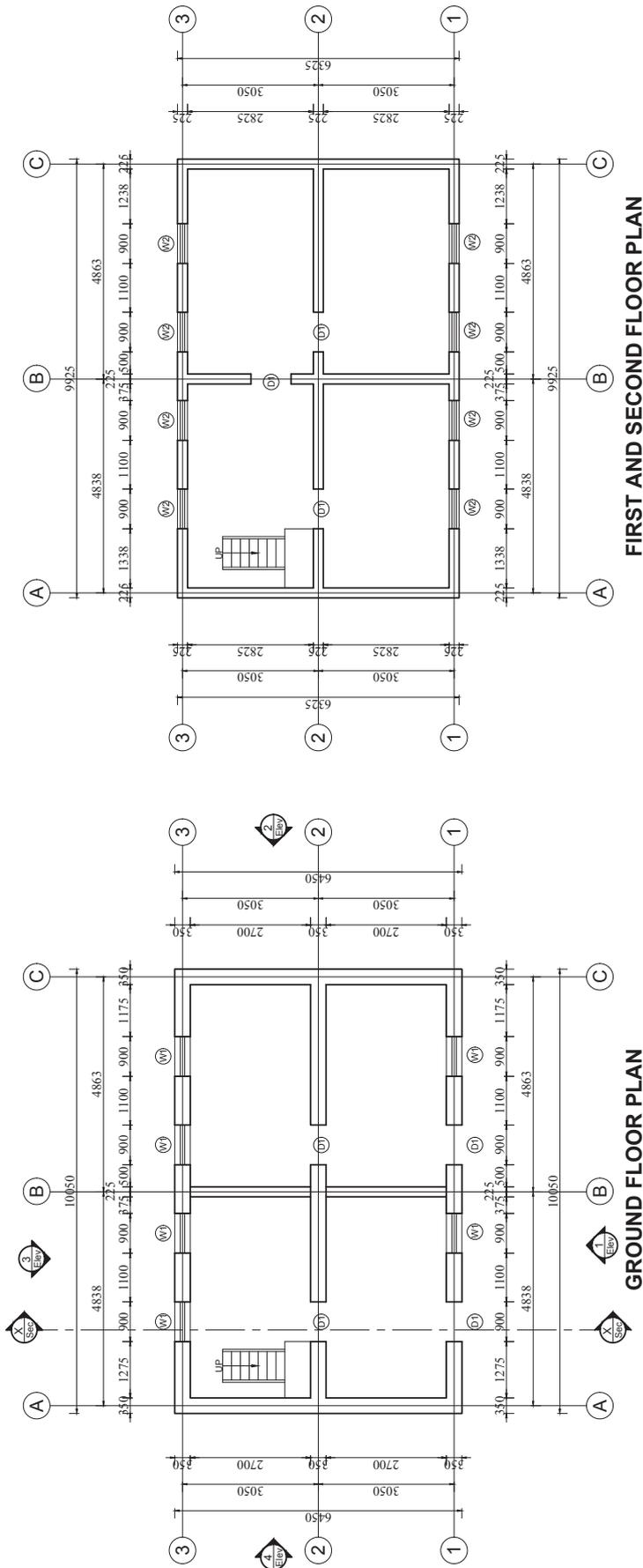
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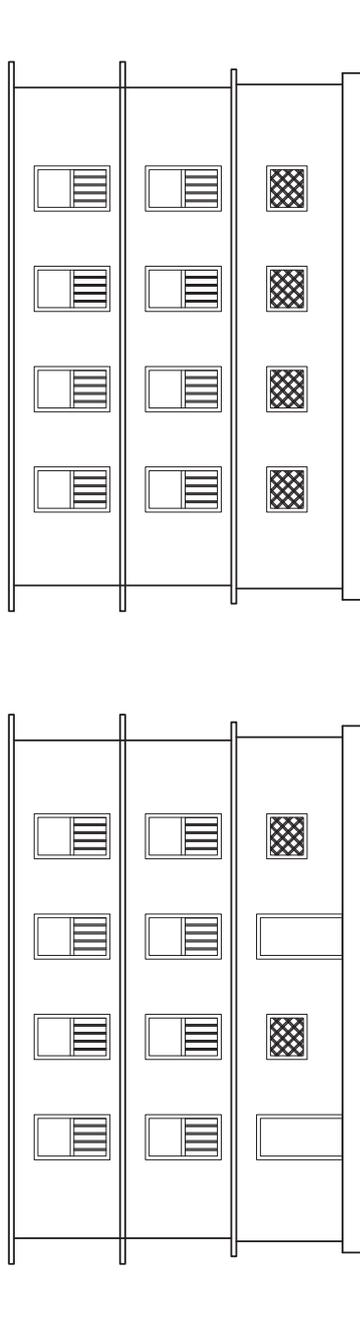
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DATE :- JULY, 2017

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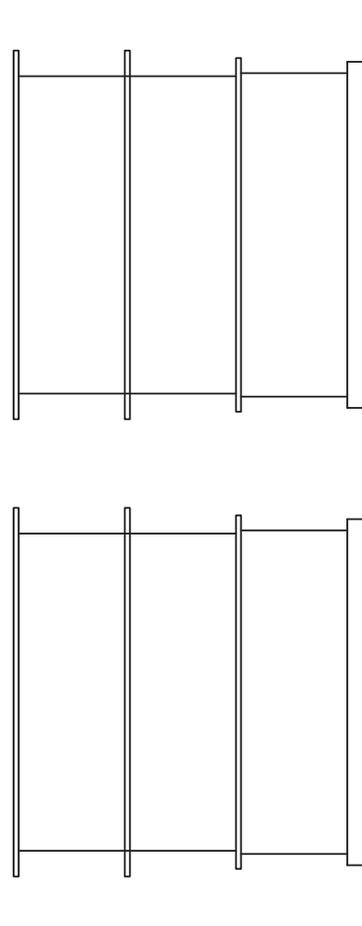
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**





ELEVATION-1

ELEVATION-3



ELEVATION-2

ELEVATION-4

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**

SHEET TITLE :-

**ELEVATIONS OF EXISTING BUILDING**

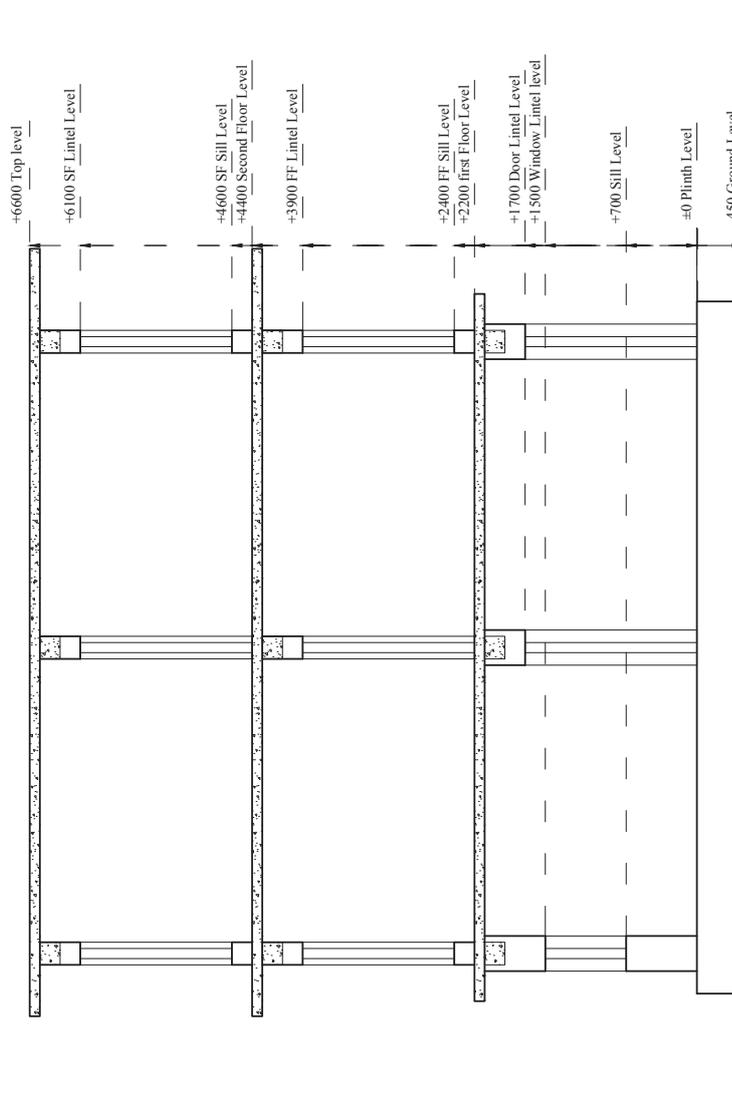
SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

**02**

**OPENING SCHEDULE**

S.N.	SYMBOL	NOS.	SIZE	SILL HEIGHT
1.	DOOR-D	10	900 x 1700	---
2.	WINDOW-W1	6	900 x 800	700
3.	WINDOW-W2	16	900 x 1500	200



**SECTION AT X-X**

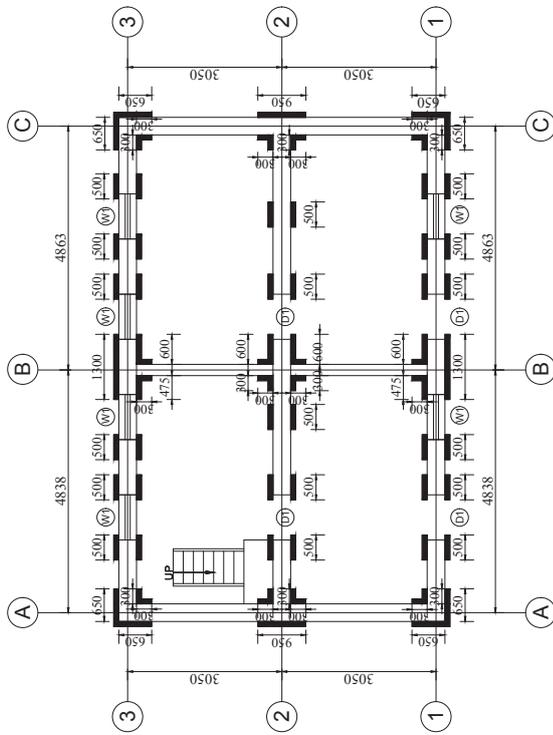
PROJECT TITLE :- **STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**

SHEET TITLE :- **SECTION OF EXISTING BUILDING AND DETAILS**

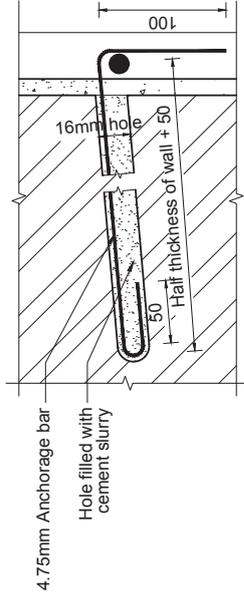
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DATE :- JULY, 2017

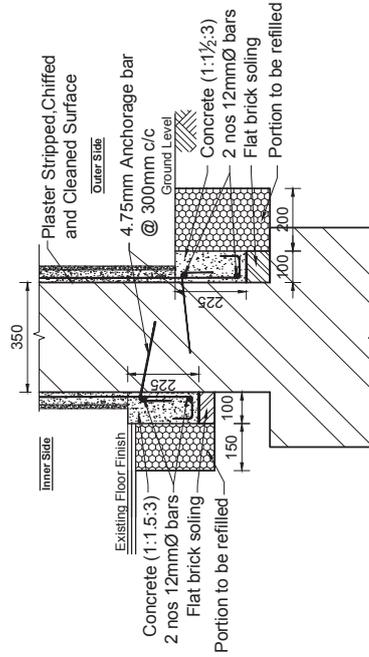
**Notes:**  
 Tie beam for Splint on walls using  
 RC Bars of 10mmØ



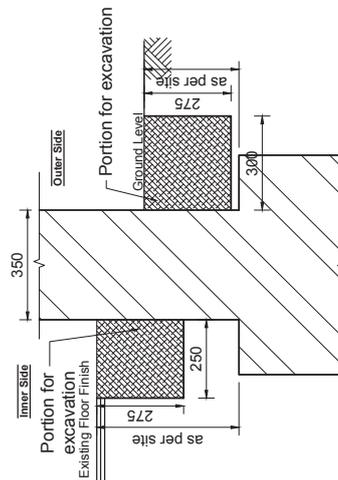
**GROUND FLOOR PLAN SHOWING TIE BEAM FOR SPLINT ON WALLS**  
 SCALE = 1:100



**4.75 MM ANCHORAGE BAR DETAILS**  
 SCALE 1:4



**DETAILS OF TIE BEAM (FOR RC BARS) FOR INNER AND OUTER SIDE OF THE WALL**  
 SCALE = 1:16



**SECTION SHOWING THE PORTION TO BE EXCAVATED FOR TIE BEAM**  
 SCALE = 1:16

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**

SHEET TITLE :-

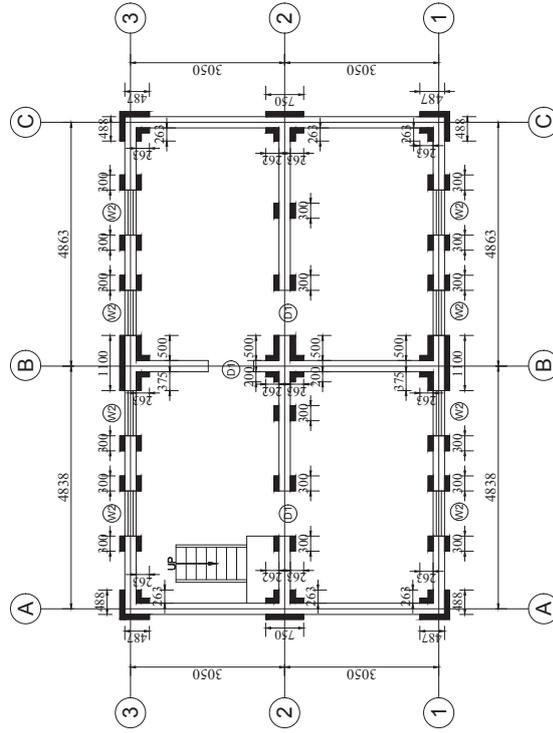
**TIE BEAM AND DETAILS**

SCALE :- AS SHOWN FOR A3 PAPER

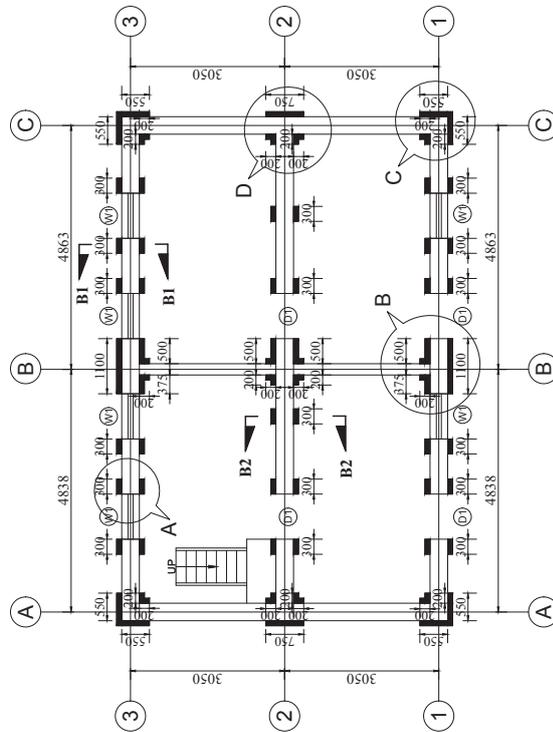
DATE :- JULY, 2017

**Notes:**

- Splint
- 200mm width on each sides of corners and junctions using 3-10mmØ bars
- 300mm width for sides of openings and on walls using 3-10mmØ bars



**FIRST AND SECOND FLOOR PLAN SHOWING LOCATION OF SPLINT ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF SPLINT ON WALLS**

SHEET TITLE :-

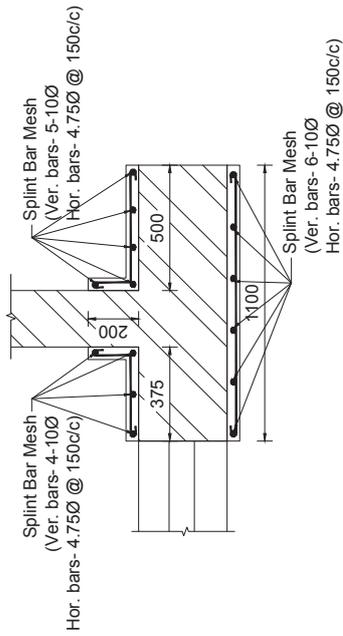
FLOOR PLANS SHOWING LOCATION OF SPLINT ON WALLS

SCALE :- 1:100 FOR A3 PAPER

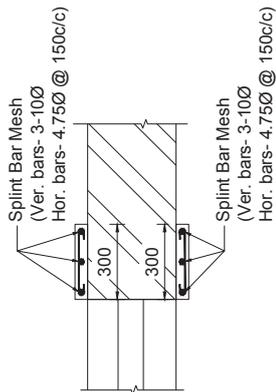
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PROJECT TITLE :-

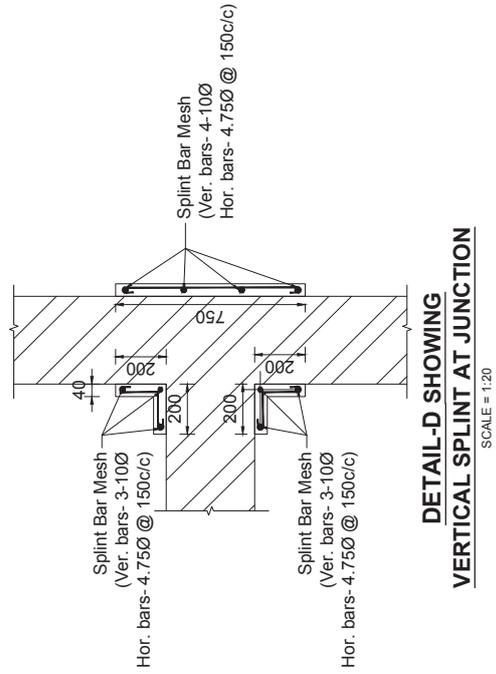
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS



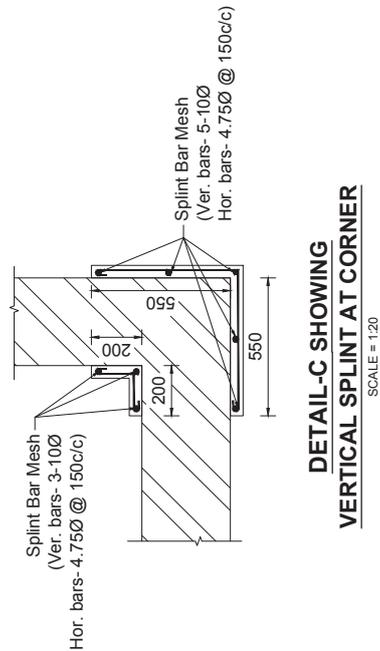
**DETAIL-B SHOWING  
VERTICAL SPLINT AT JUNCTION**  
SCALE = 1:20



**DETAIL-A SHOWING  
VERTICAL SPLINT AT SIDES OF OPENING**  
SCALE = 1:20



**DETAIL-D SHOWING  
VERTICAL SPLINT AT JUNCTION**  
SCALE = 1:20

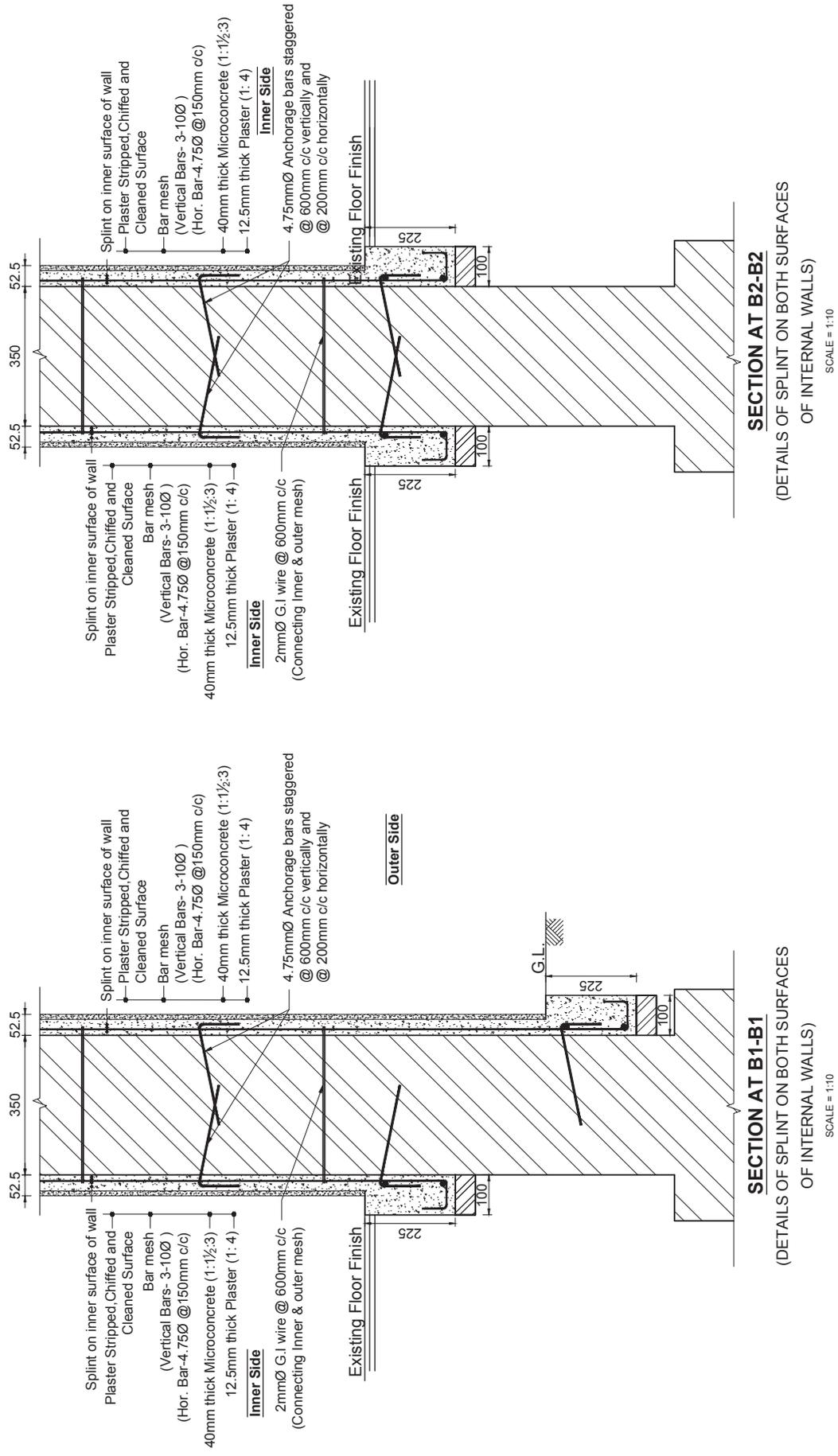


**DETAIL-C SHOWING  
VERTICAL SPLINT AT CORNER**  
SCALE = 1:20

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**

**DETAILS OF SPLINT**  
DATE :- JULY, 2017

SCALE :- 1:20 FOR A3 PAPER

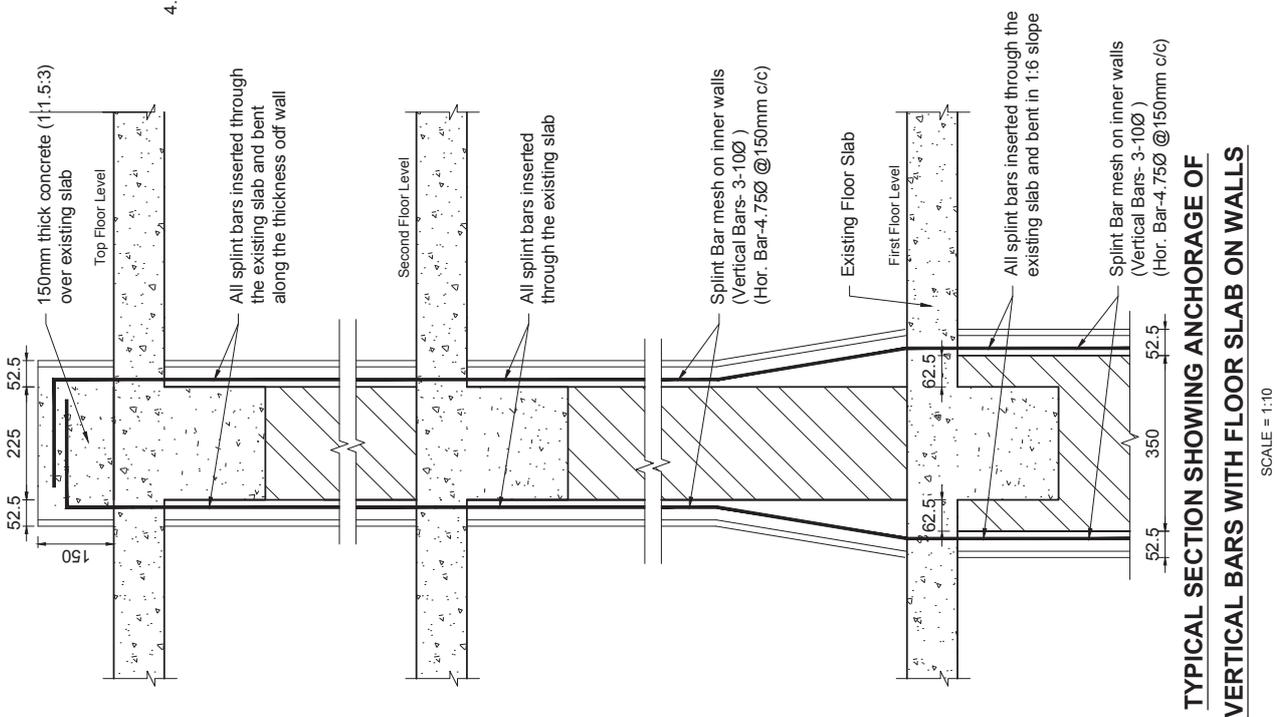


**SECTION AT B2-B2**  
(DETAILS OF SPLINT ON BOTH SURFACES OF INTERNAL WALLS)  
SCALE = 1:10

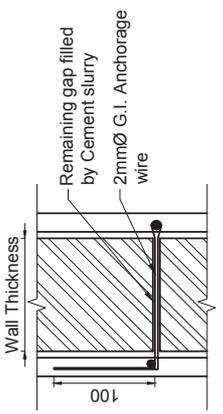
**SECTION AT B1-B1**  
(DETAILS OF SPLINT ON BOTH SURFACES OF INTERNAL WALLS)  
SCALE = 1:10

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**

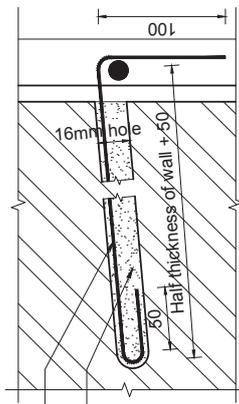
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**DETAILS OF SPLINT**  
DATE :- JULY, 2017  
SCALE :- 1:10 FOR A3 PAPER



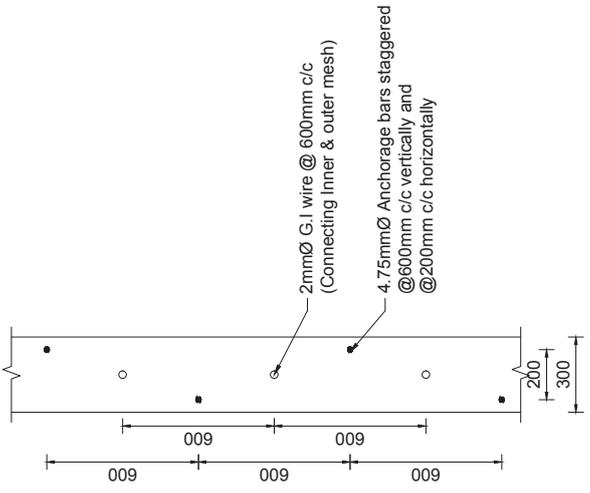
**TYPICAL SECTION SHOWING ANCHORAGE OF VERTICAL BARS WITH FLOOR SLAB ON WALLS**  
SCALE = 1:10



**G.I. WIRE DETAILS**  
SCALE 1:10



**ANCHORAGE BAR DETAILS**  
SCALE 1:4

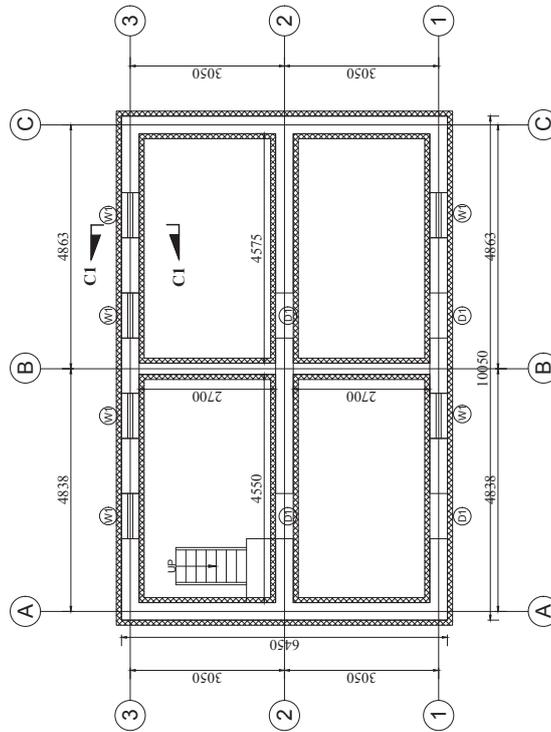


**LAYOUT OF ANCHORAGE BARS FOR CONNECTING SPLINT BANDS ON BOTH SIDES OF WALLS**  
SCALE 1:20

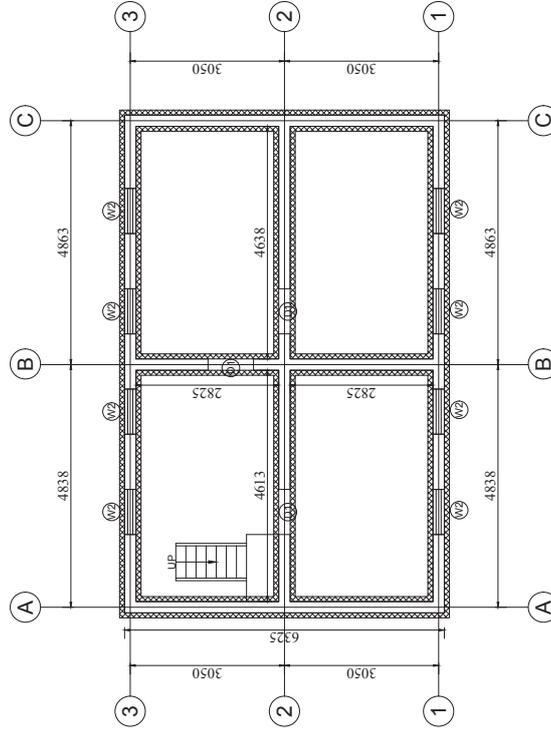
**Notes:**

Horizontal Bands

- 200mm width using 2-4.75mmØ bars at mid level
- 300mm width using 2-4.75mmØ + 1-8mmØ bars at lintel level



**GROUND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**FIRST AND SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**

SHEET TITLE :-

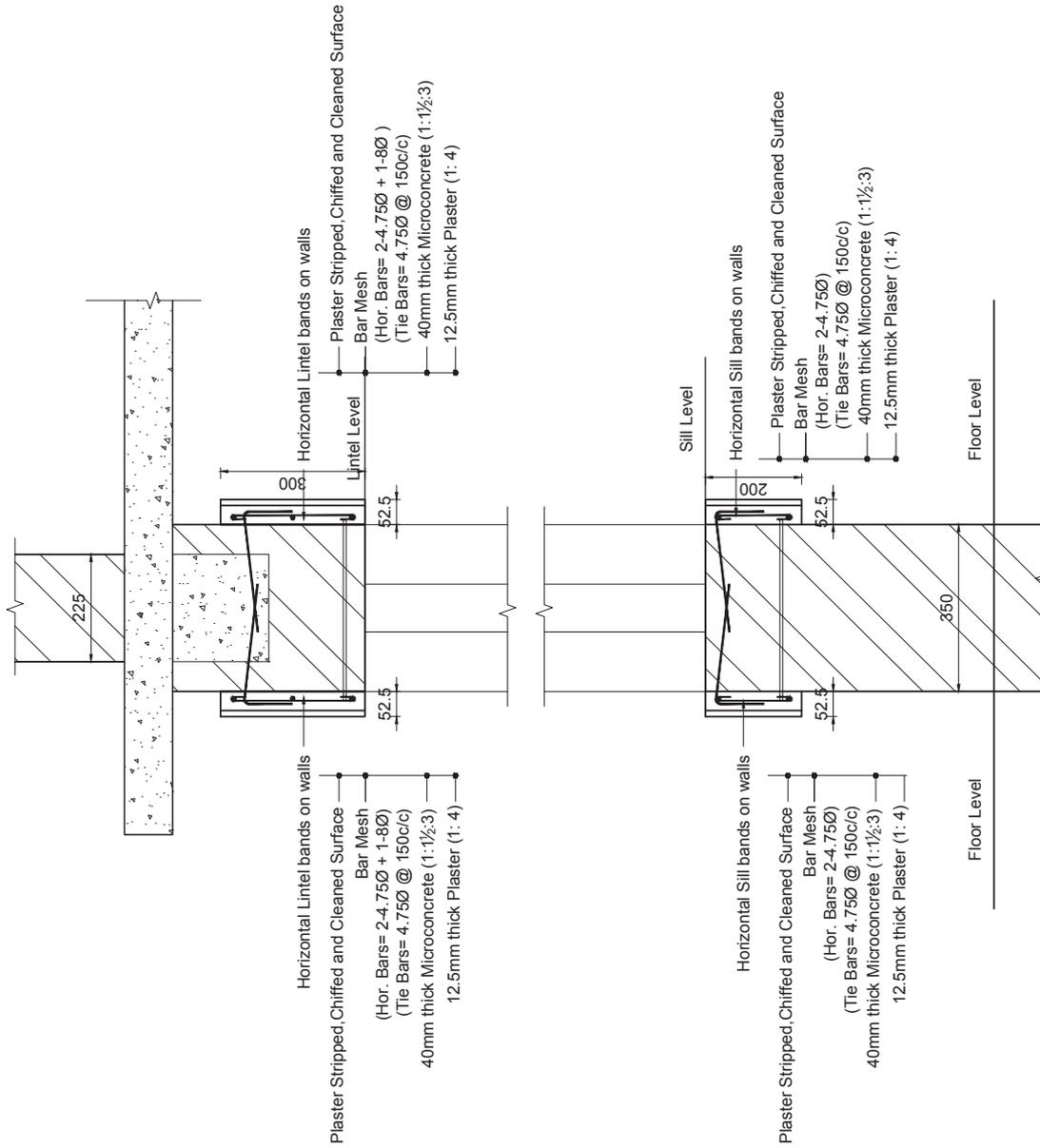
FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL BANDAGES AT FLOOR AND SILL LEVEL

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

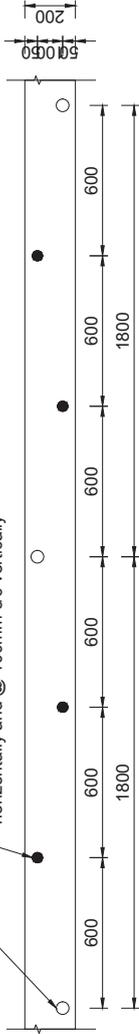
PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS



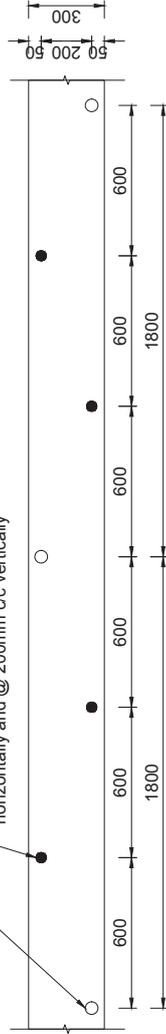
**SECTION AT C1-C1**  
(DETAILS OF HORIZONTAL BANDAGES  
ON BOTH SURFACES OF WALLS)  
SCALE = 1:10

2mmØ G.I wire staggered @ 1800mm c/c horizontally and 200mm c/c vertically (after every two 4.75mm Ø Anchorage bars) (Connecting inner & outer mesh)  
 4.75mmØ Anchorage bars staggered @ 600mm c/c horizontally and @ 100mm c/c vertically

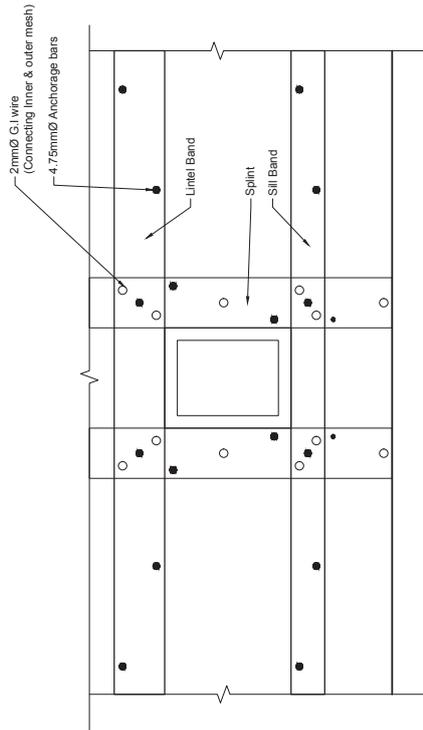


**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT SILL/MID LEVEL ON BOTH SIDES OF WALL**  
 SCALE = 1:20

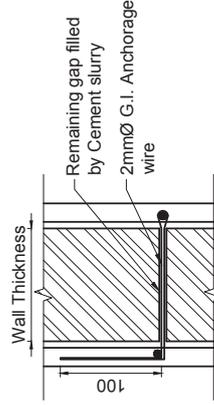
2mmØ G.I wire staggered @ 1800mm c/c horizontally and 200mm c/c vertically (after every two 4.75mm Ø Anchorage bars) (Connecting inner & outer mesh)  
 4.75mmØ Anchorage bars staggered @ 600mm c/c horizontally and @ 200mm c/c vertically



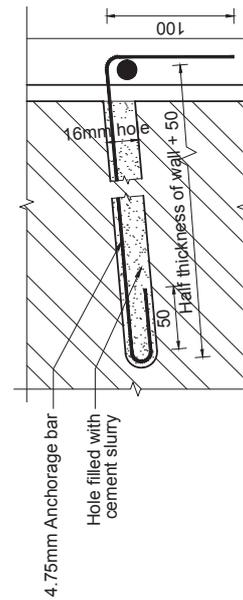
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT LINTEL LEVEL ON BOTH SIDES OF WALL**  
 SCALE = 1:20



**TYPICAL LAYOUT OF ANCHORAGE FOR CONNECTING SPLINT AND HORIZONTAL BANDAGE ON BOTH SIDES OF WALLS**  
 SCALE 1:30



**G.I. WIRE DETAILS**  
 SCALE 1:10



**ANCHORAGE BAR DETAILS**  
 SCALE 1:4

PROJECT TITLE :-

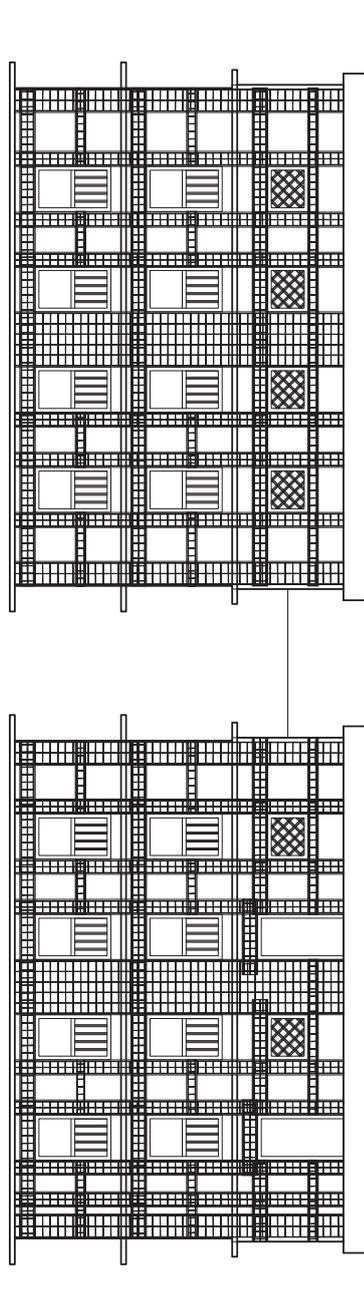
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS**

SHEET TITLE :-

**DETAILS OF HORIZONTAL BANDAGES**

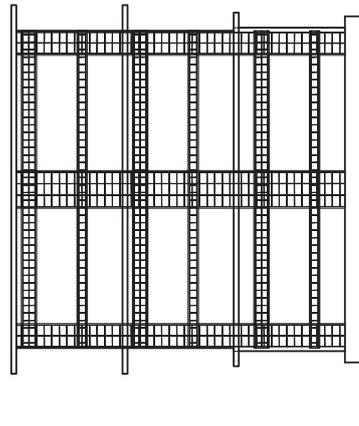
SCALE :- AS SHOWN FOR A3 PAPER

DATE :- JULY, 2017

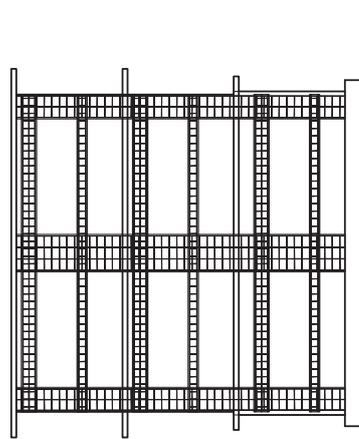


ELEVATION-1

ELEVATION-3



ELEVATION-2



ELEVATION-4

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF THREE STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN CEMENT USING RC BARS

SHEET TITLE :-

ELEVATIONS OF EXISTING BUILDING AFTER RETROFIT

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

# STRUCTURAL DRAWINGS FOR RETROFIT DESIGN ON TWO STOREY BRICK MASONRY BUILDING IN MUD USING RC BARS

0

SHEET TITLE :-

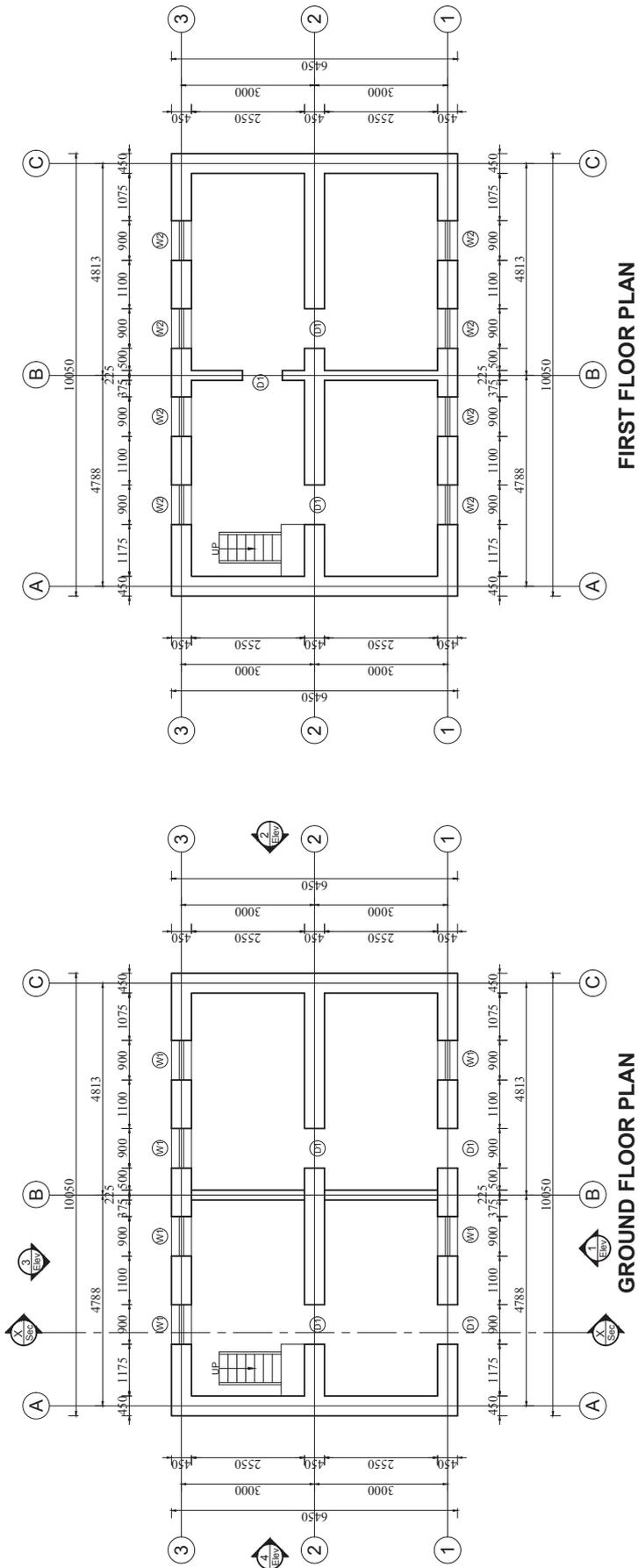
COVER PAGE

SCALE :- N/A

DATE :- JULY, 2017

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS



SHEET TITLE :-

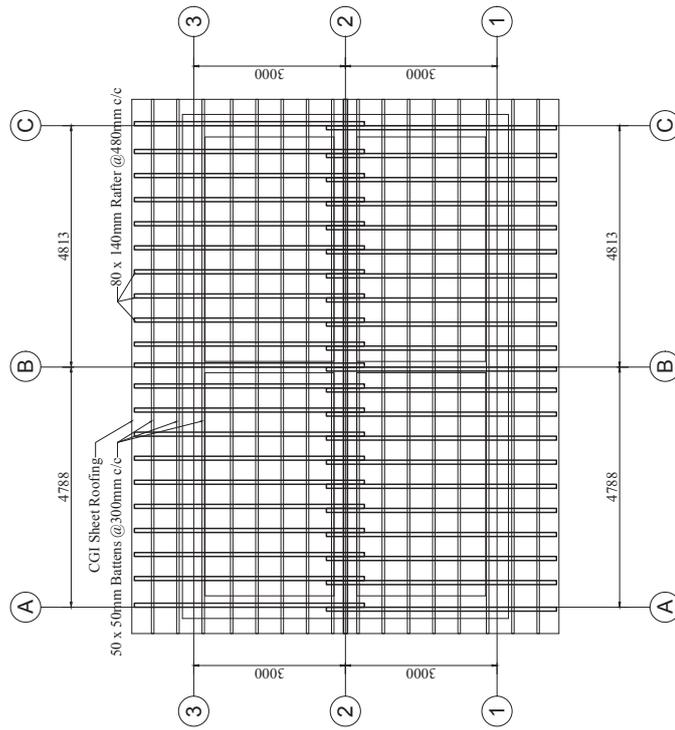
FLOOR PLANS OF EXISTING BUILDING

SCALE :- 1:100 FOR A3 PAPER

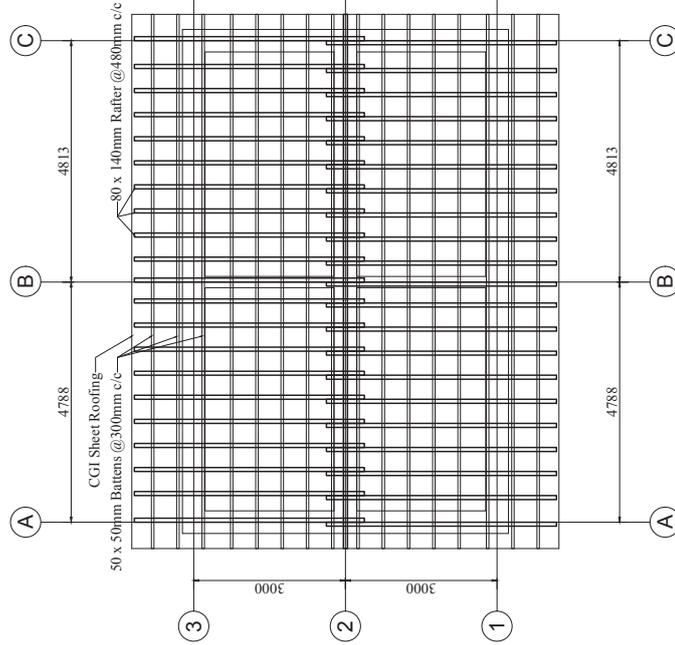
DATE :- JULY, 2017

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS

PROJECT TITLE :-



**FLOOR PLAN SHOWING LAYOUT OF JOIST**



**ROOF PLAN SHOWING LAYOUT OF RAFTER**

PROJECT TITLE :-

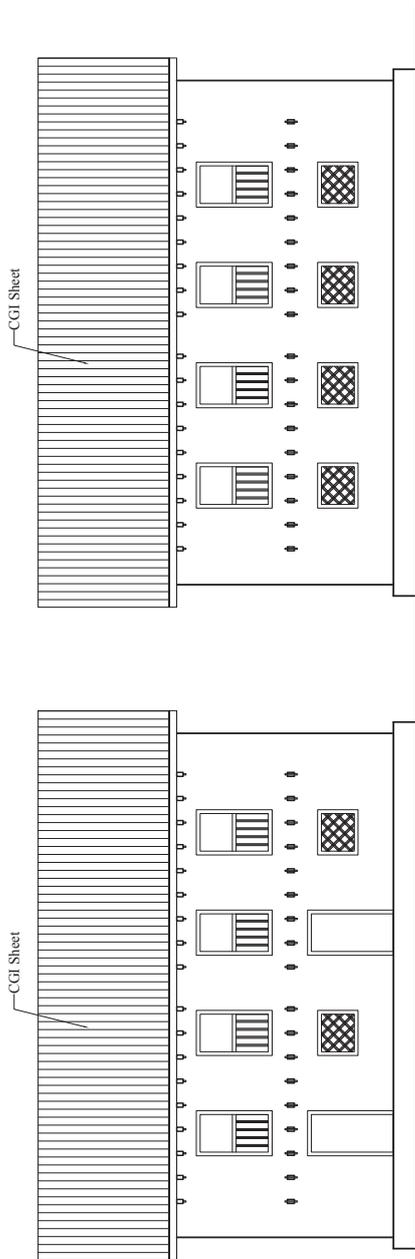
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS**

SHEET TITLE :-

**FLOOR PLANS OF EXISTING BUILDING**

SCALE :- 1/100 FOR A3 PAPER

DATE :- JULY, 2017

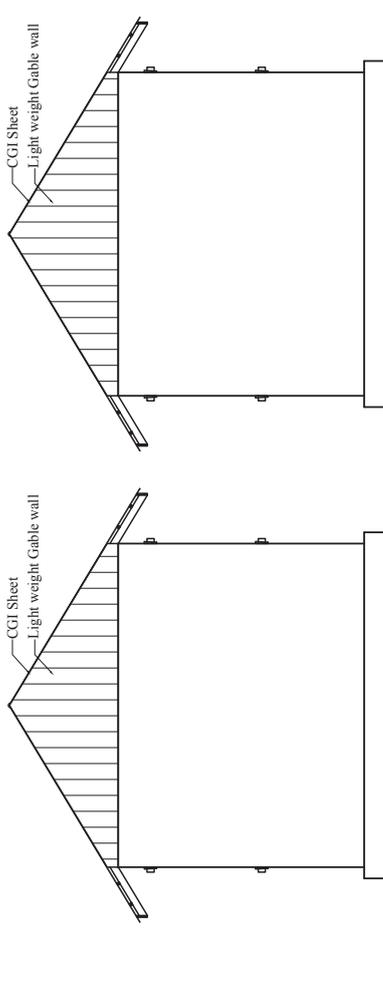


**ELEVATION-3**

**ELEVATION-1**

**OPENING SCHEDULE**

S.N.	SYMBOL	NOS.	SIZE	SILL HEIGHT
1.	DOOR-D	7	900 x 1700	---
2.	WINDOW-W1	6	900 x 800	700
3.	WINDOW-W2	12	900 x 1500	200

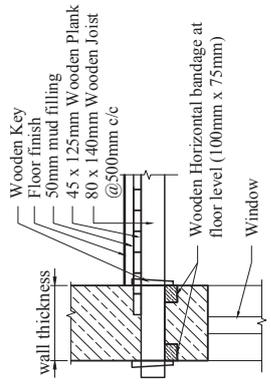


**ELEVATION-4**

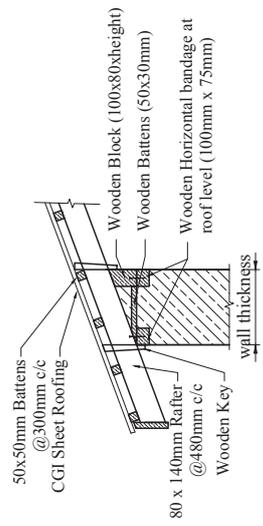
**ELEVATION-2**

PROJECT TITLE :-  
**ELEVATIONS AND OPENING SCHEDULE OF EXISTING BUILDING**  
 SCALE :- 1/100 FOR A3 PAPER  
 DATE :- JULY, 2017

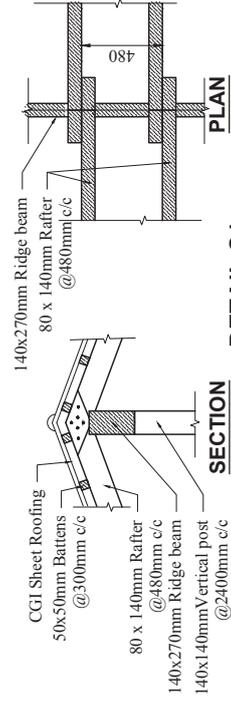
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
 LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS**



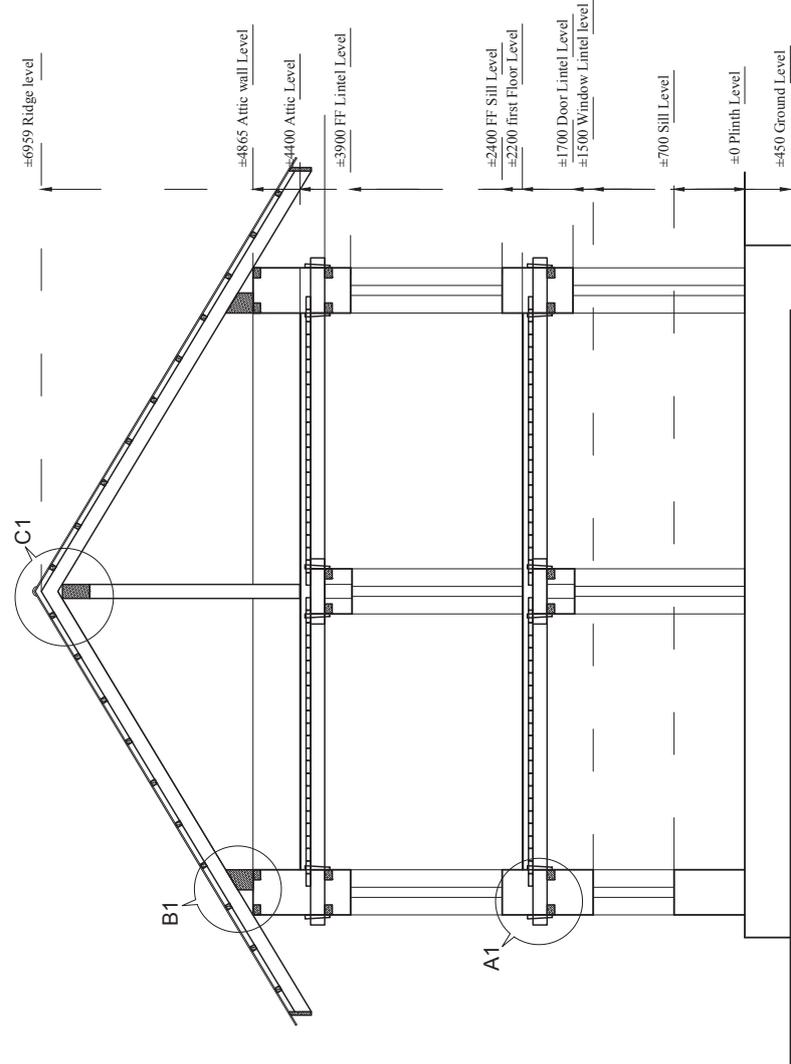
**DETAIL A1**  
**SHOWING CONNECTION OF**  
**FLOORING MEMBERS WITH WALL**  
 SCALE = 1:30



**DETAIL B1**  
**SHOWING CONNECTION OF**  
**ROOFING MEMBERS WITH WALL**  
 SCALE = 1:30



**DETAIL C1**  
**SHOWING ROOF DETAILS AT RIDGE LEVEL**  
 SCALE = 1:30



**SECTION AT X-X**  
 SCALE 1:50

SHEET TITLE :-

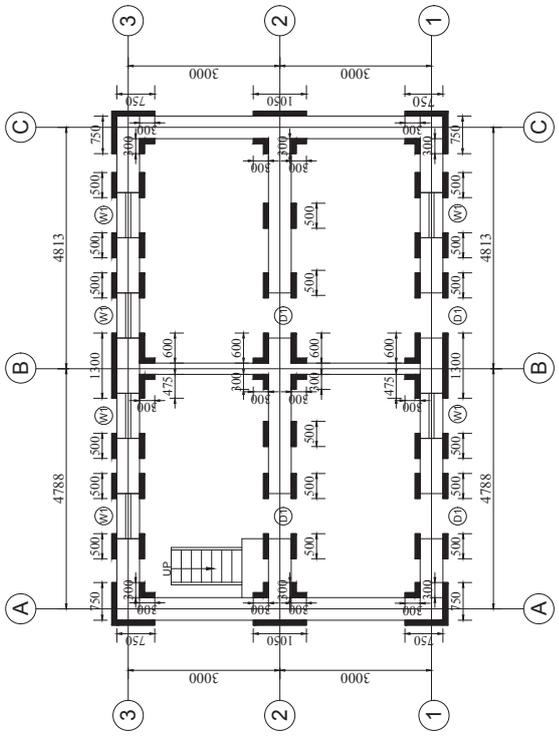
SECTION AND DETAILS OF EXISTING BUILDING

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS

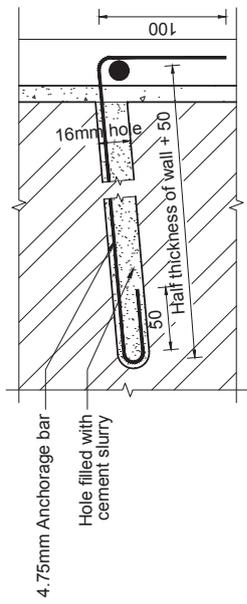
SCALE :- AS SHOWN FOR A3 PAPER

DATE :- JULY, 2017

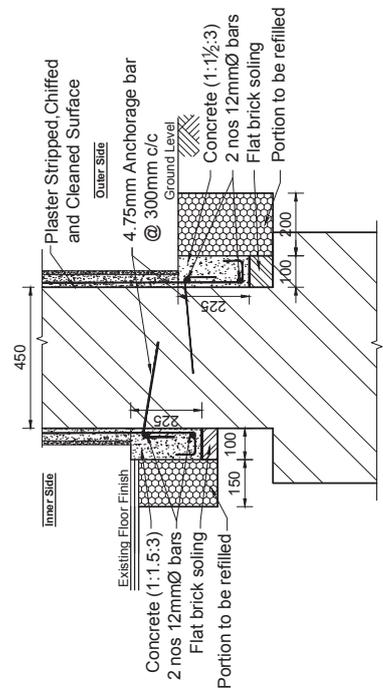
**Notes:**  
 Tie beam for Splint on walls using RC Bars of 10mmØ



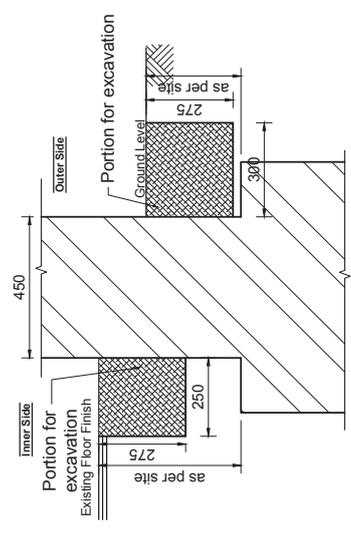
**GROUND FLOOR PLAN SHOWING TIE BEAM FOR SPLINT ON WALLS**  
 SCALE = 1:100



**4.75 MM ANCHORAGE BAR DETAILS**  
 SCALE 1:4



**DETAILS OF TIE BEAM (FOR RC BARS) FOR INNER AND OUTER SIDE OF THE WALL**  
 SCALE = 1:16

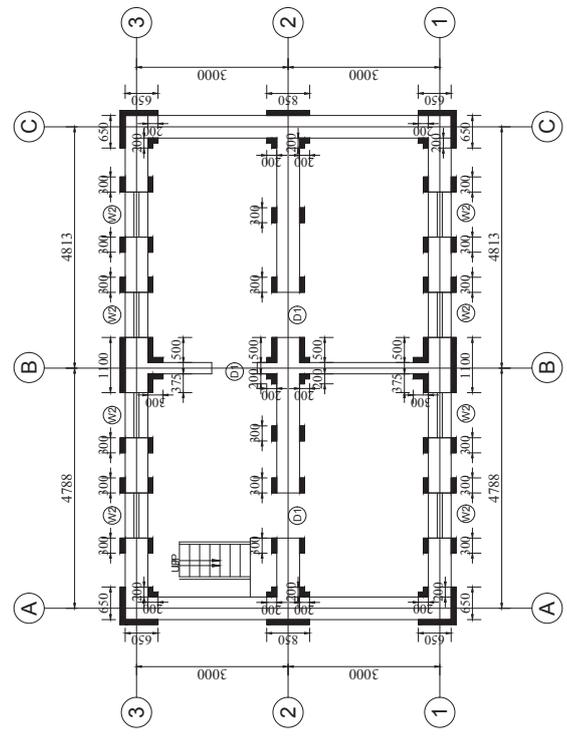


**SECTION SHOWING THE PORTION TO BE EXCAVATED FOR TIE BEAM**  
 SCALE = 1:16

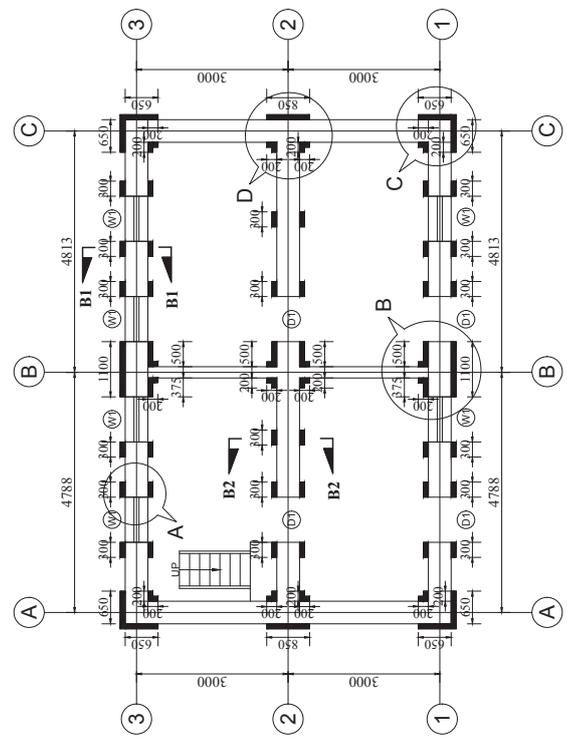
PROJECT TITLE :-  
**TIE BEAM AND DETAILS**  
 SCALE :- AS SHOWN FOR A3 PAPER  
 DATE :- JULY, 2017

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS

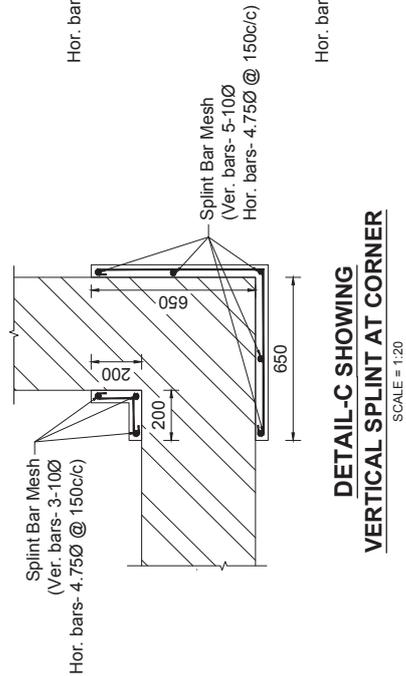
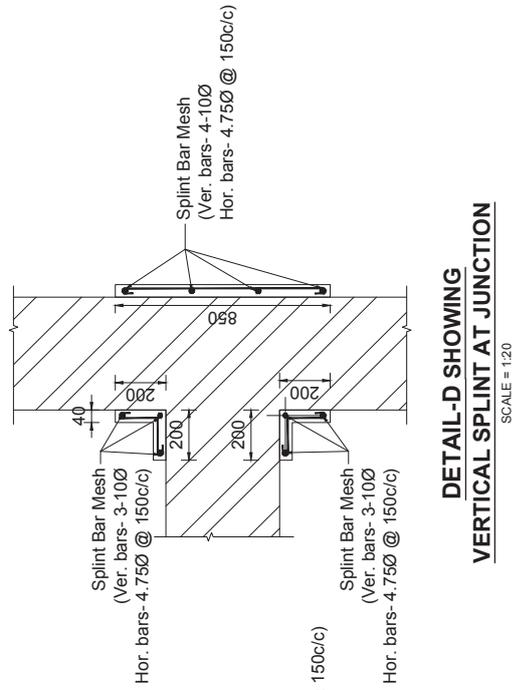
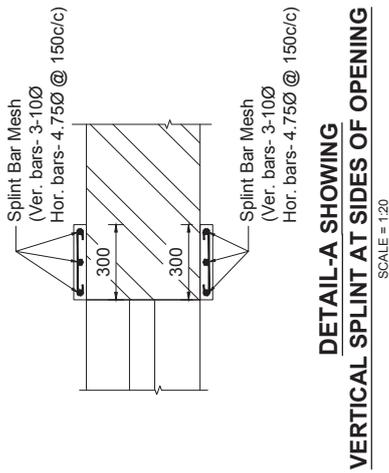
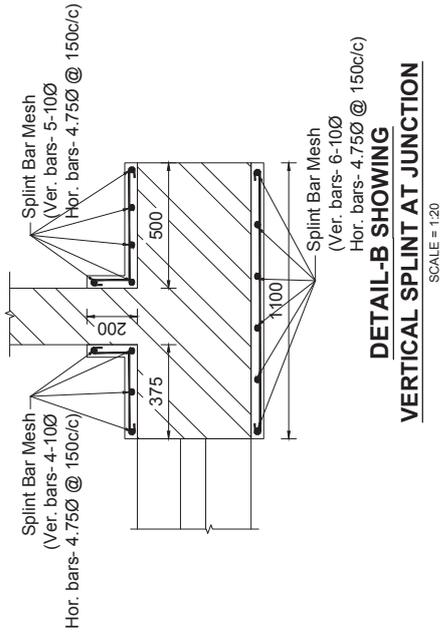
- Splint**
- 200mm width on each sides of corners and junctions using 3-10mmØ bars
  - 300mm width for sides of openings and on walls using 3-10mmØ bars



**FIRST FLOOR PLAN SHOWING LOCATION OF SPLINT ON WALLS**

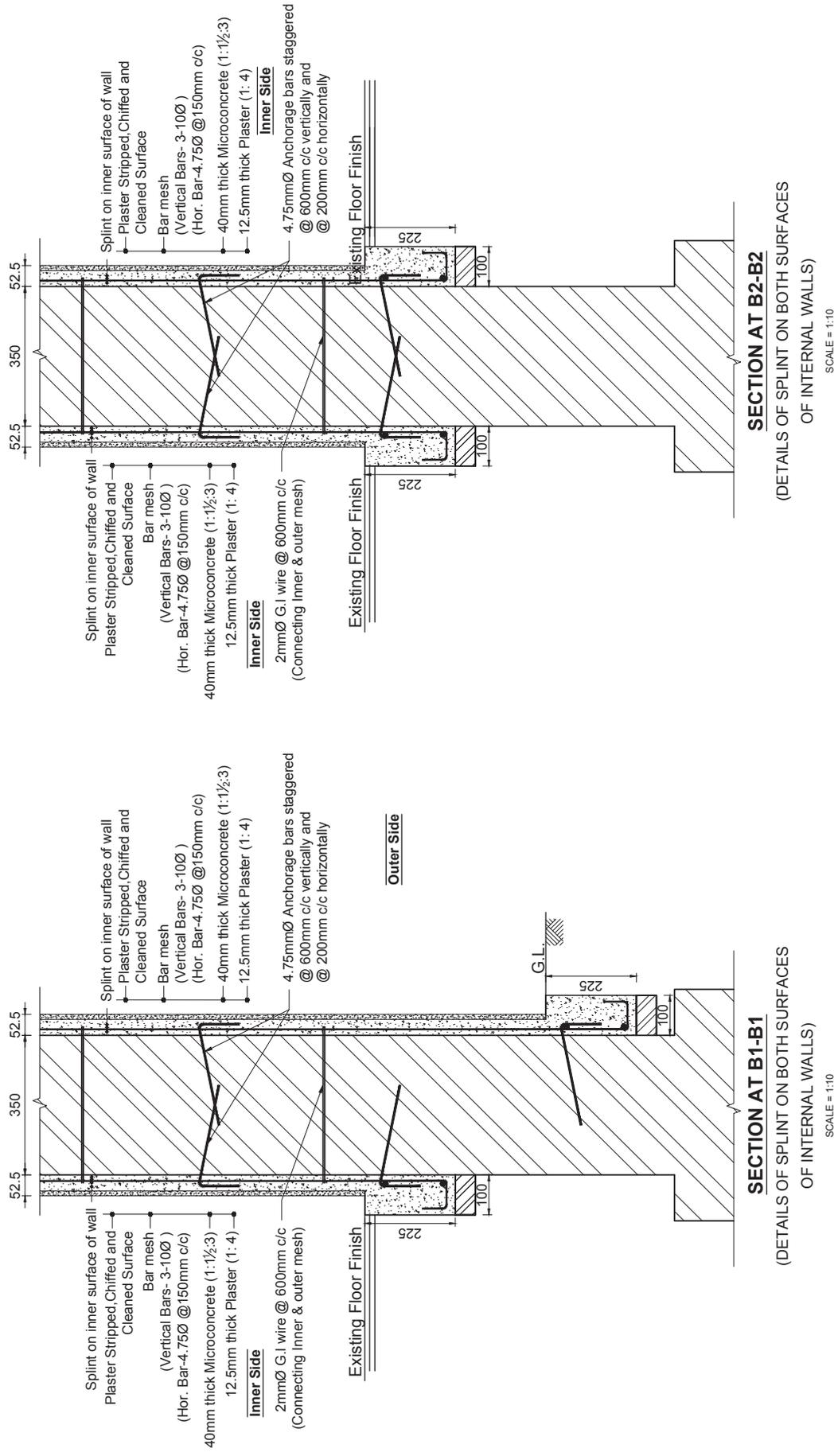


**GROUND FLOOR PLAN SHOWING LOCATION OF SPLINT ON WALLS**



PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
 LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS**

SHEET TITLE :-  
**DETAILS OF SPLINT**  
 SCALE :- 1:20 FOR A3 PAPER  
 DATE :- JULY, 2017

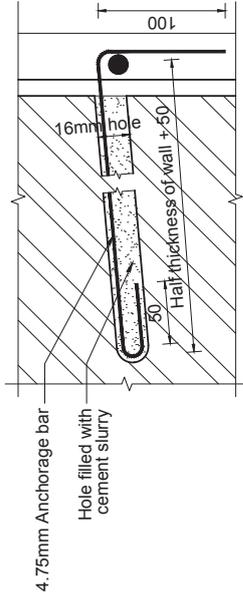


**SECTION AT B2-B2**  
(DETAILS OF SPLINT ON BOTH SURFACES OF INTERNAL WALLS)  
SCALE = 1:10

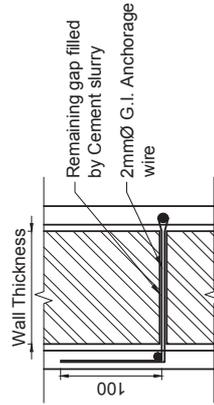
**SECTION AT B1-B1**  
(DETAILS OF SPLINT ON BOTH SURFACES OF INTERNAL WALLS)  
SCALE = 1:10

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS**

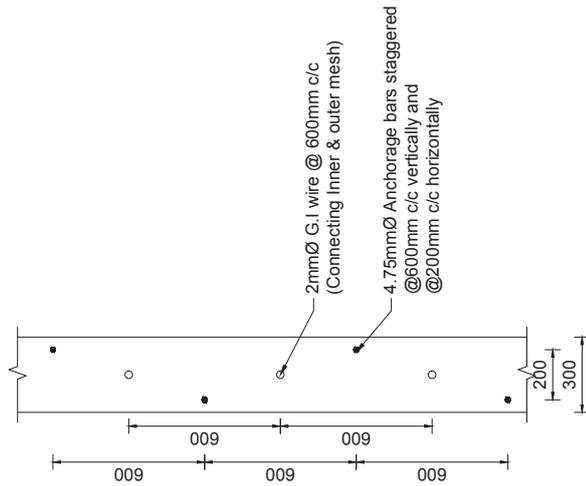
SHEET TITLE :-  
**DETAILS OF SPLINT**  
DATE :- JULY, 2007  
SCALE :- 1:10 FOR A3 PAPER



**ANCHORAGE BAR DETAILS**  
SCALE 1:4



**G.I. WIRE DETAILS**  
SCALE 1:10



**LAYOUT OF ANCHORAGE BARS FOR CONNECTING  
SPLINT BANDS ON BOTH SIDES OF WALLS**  
SCALE 1:20

SHEET TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS

DETAILS OF SPLINT

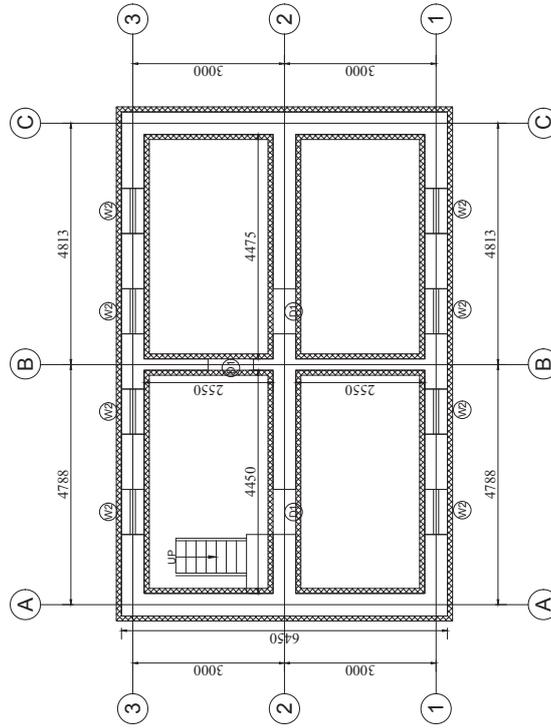
SCALE :- 1:20, 1:10, 1:4 FOR A3 PAPER

DATE :- JULY, 2017

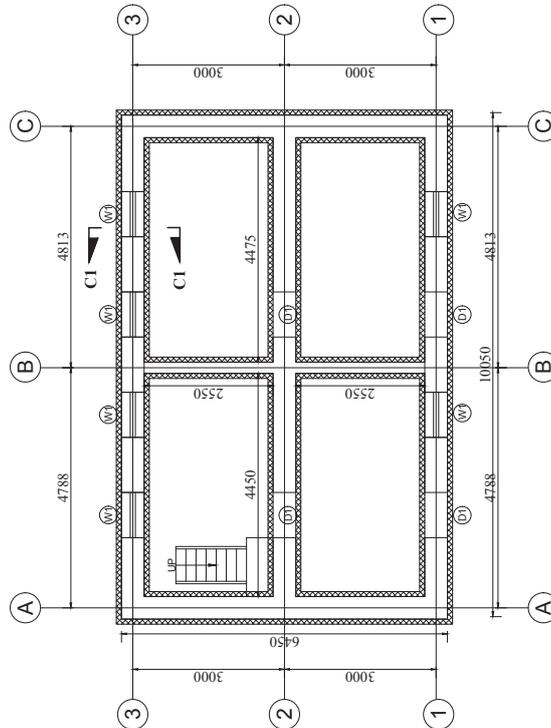
**Notes:**

Horizontal Bands

- 200mm width using 2-4.75mm $\varnothing$  bars at sill and mid level
- 300mm width using 2-4.75mm $\varnothing$  + 1-8mm $\varnothing$  bars at lintel level



**FIRST FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**

SHEET TITLE :-

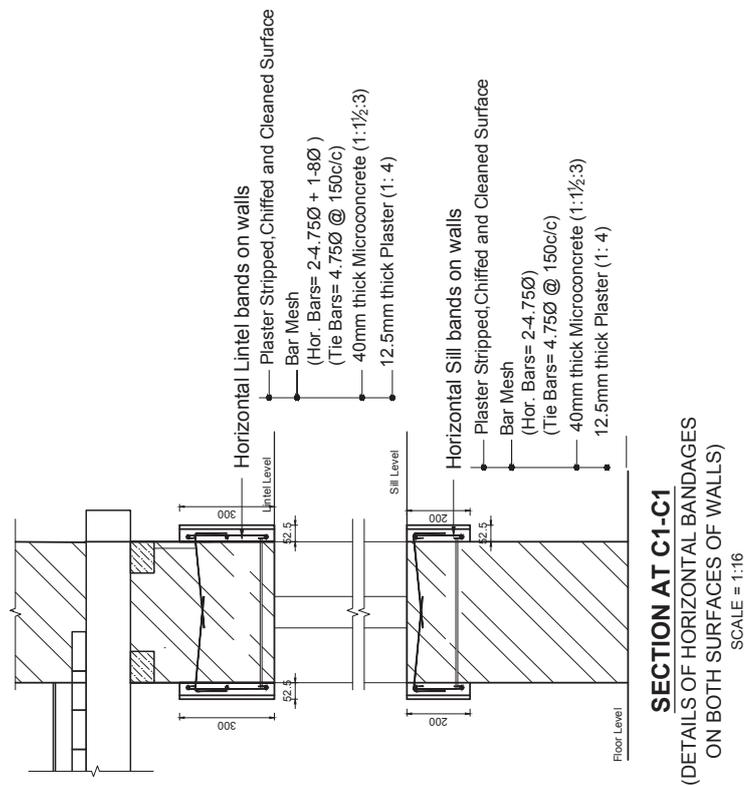
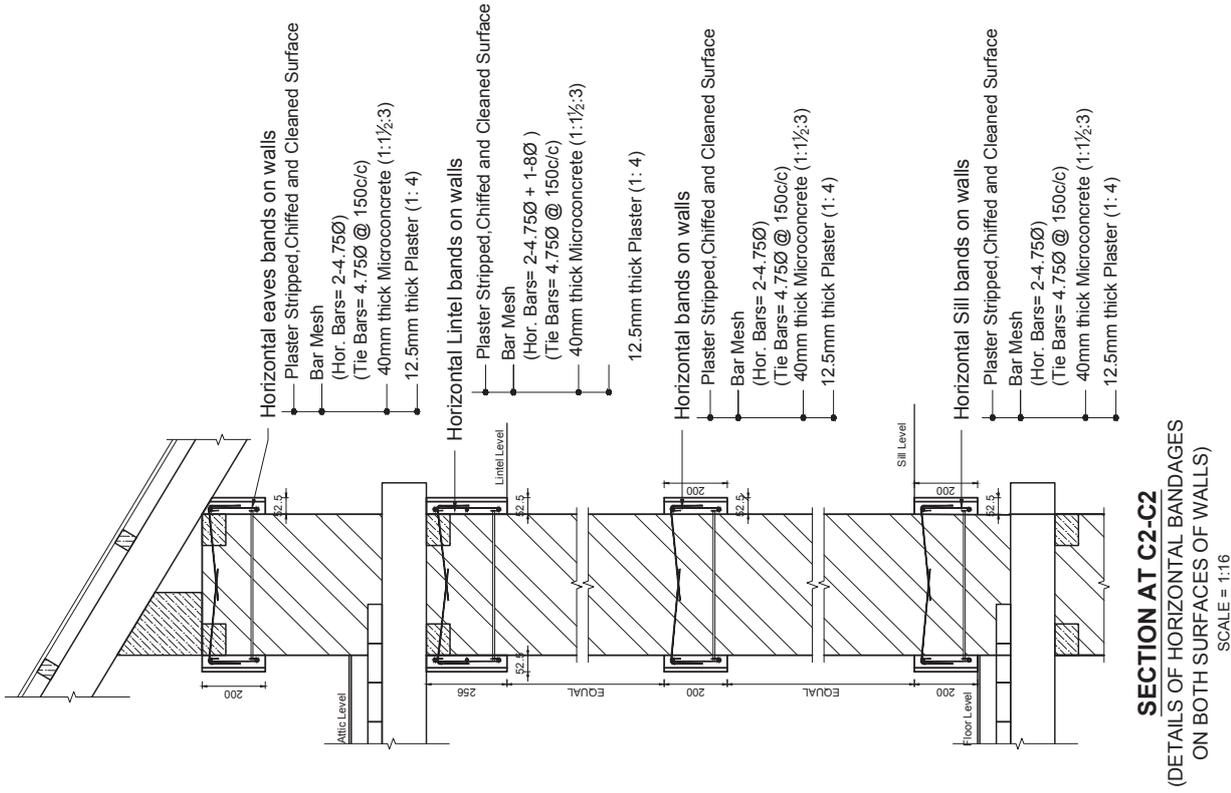
FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL BANDAGES AT FLOOR AND SILL LEVEL

SCALE :- 1/100 FOR A3 PAPER

DATE :- JULY, 2017

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS



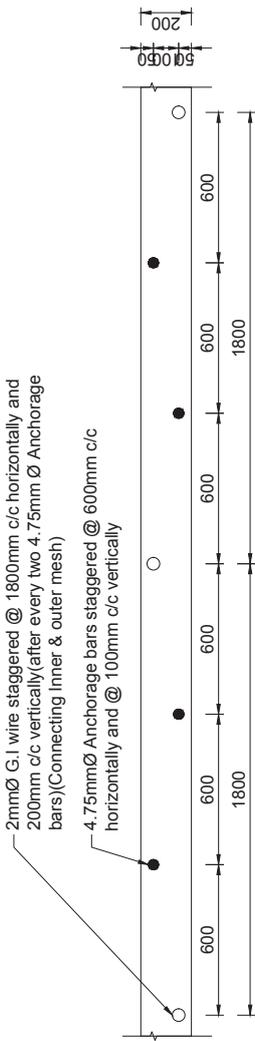
SHEET TITLE :-

DETAILS OF HORIZONTAL BANDAGES

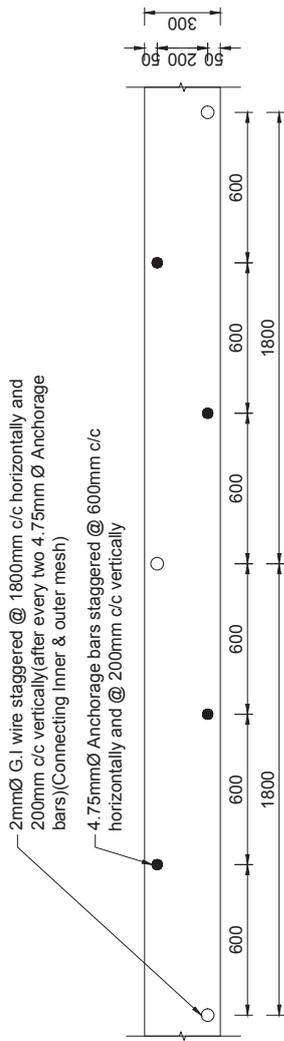
SCALE :- 1:16 FOR A3 PAPER

DATE :- JULY, 2017

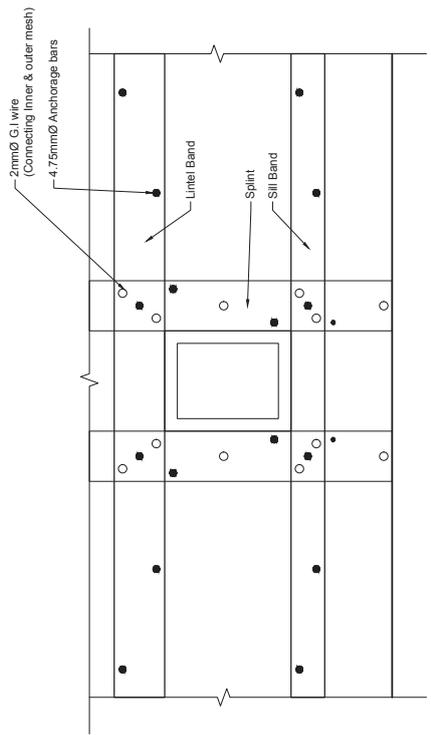
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY  
LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS



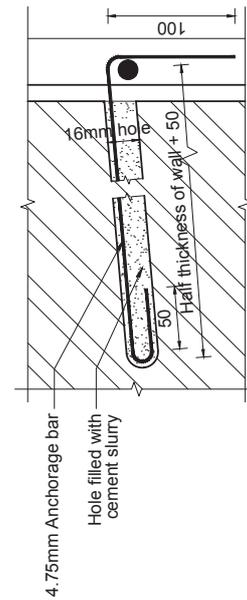
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT SILL AND MID LEVEL ON BOTH SIDES OF WALL**  
 SCALE = 1:20



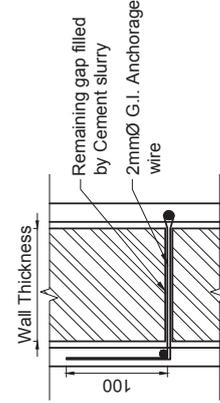
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT LINTEL LEVEL ON BOTH SIDES OF WALL**  
 SCALE = 1:20



**TYPICAL LAYOUT OF ANCHORAGE FOR CONNECTING SPLINT AND HORIZONTAL BANDAGE ON BOTH SIDES OF WALLS**  
 SCALE 1:30



**ANCHORAGE BAR DETAILS**  
 SCALE 1:4



**G.I. WIRE DETAILS**  
 SCALE 1:10

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH BRICK MASONRY BUILDING IN MUD USING RC BARS

SHEET TITLE :-

DETAILS OF HORIZONTAL BANDAGES

SCALE :- AS SHOWN FOR A3 PAPER

DATE :- JULY, 2017

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN ON  
TWO STOREY STONE MASONRY BUILDING IN MUD  
USING RC BARS AND G.I. WIREMESH**

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

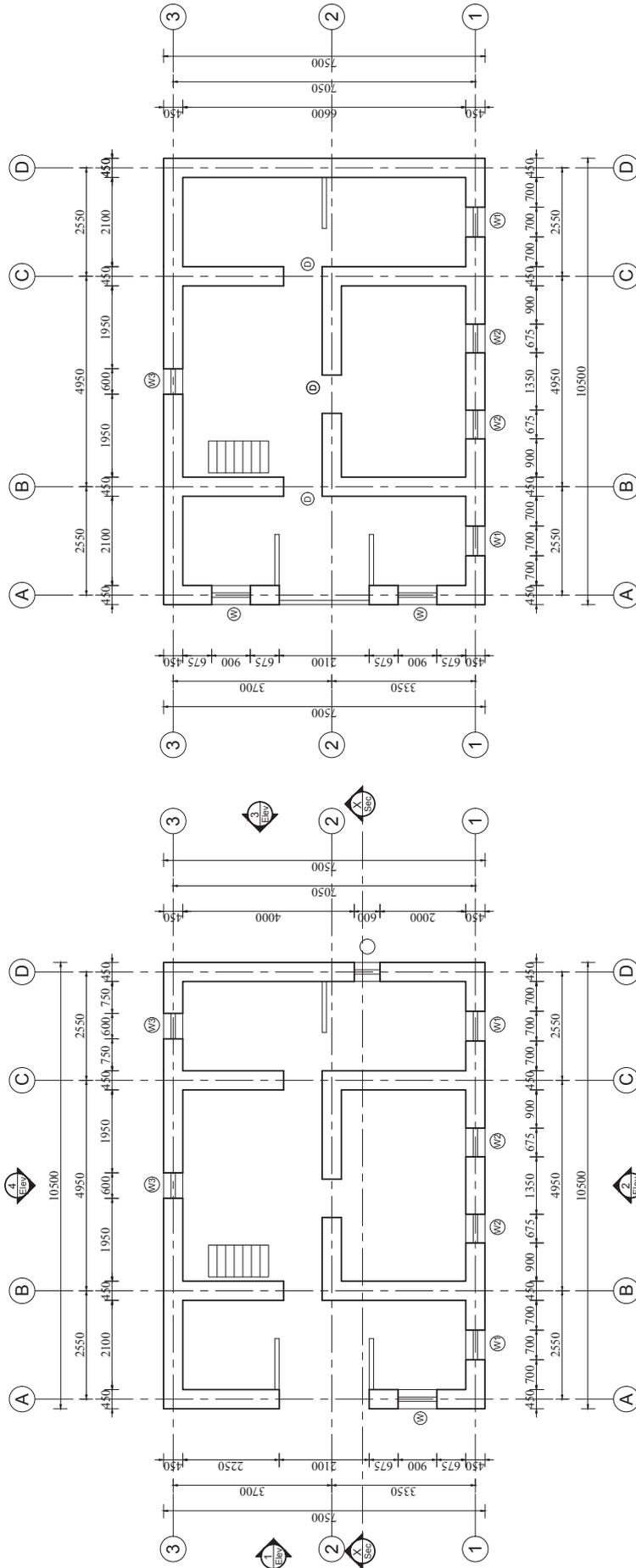
SHEET TITLE :-

**COVER PAGE**

SCALE :- N/A

DATE :- JULY, 2017

**0**



**FIRST FLOOR PLAN**

**GROUND FLOOR PLAN**

SHEET TITLE :-

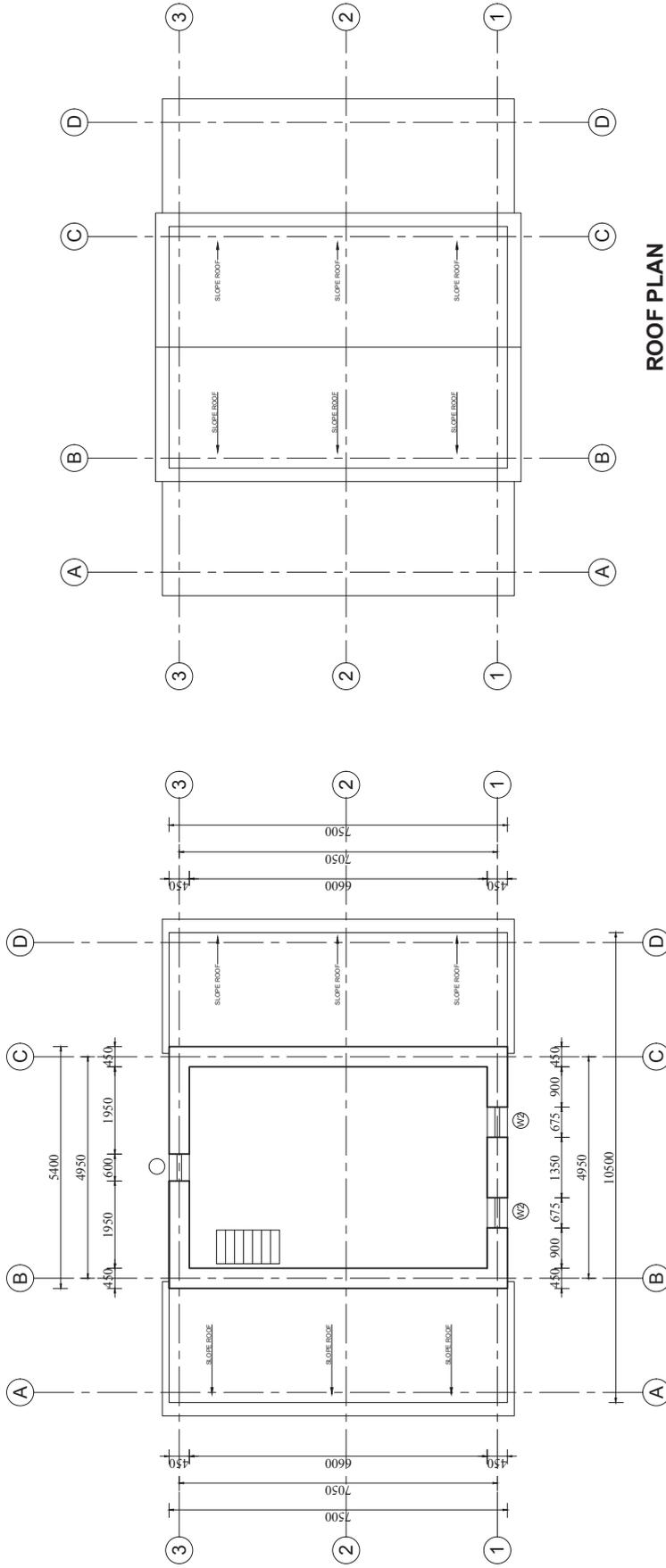
FLOOR PLANS OF EXISTING BUILDING

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH

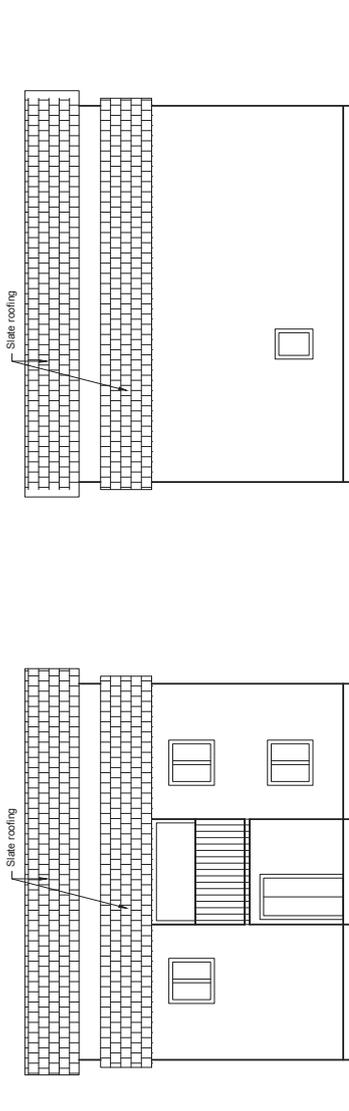


PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

SHEET TITLE :-  
**FLOOR PLANS OF EXISTING BUILDING**

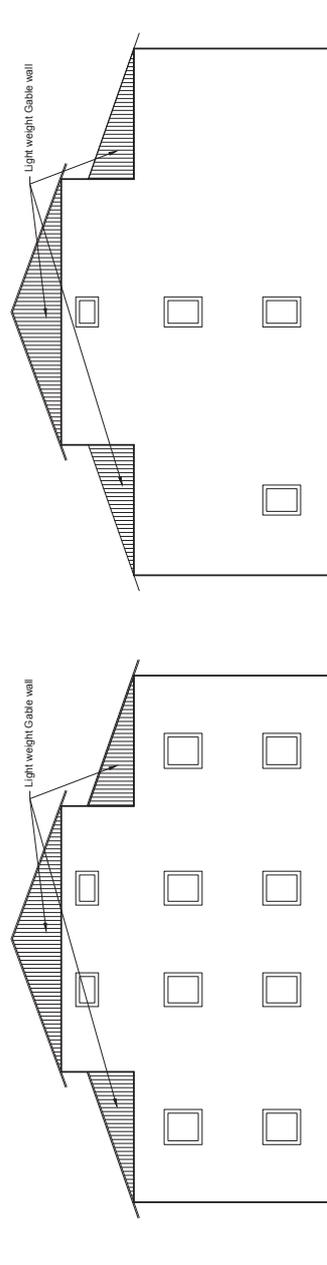
SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017



**ELEVATION-3**

**ELEVATION-1**



**ELEVATION-4**

**ELEVATION-2**

PROJECT TITLE :-

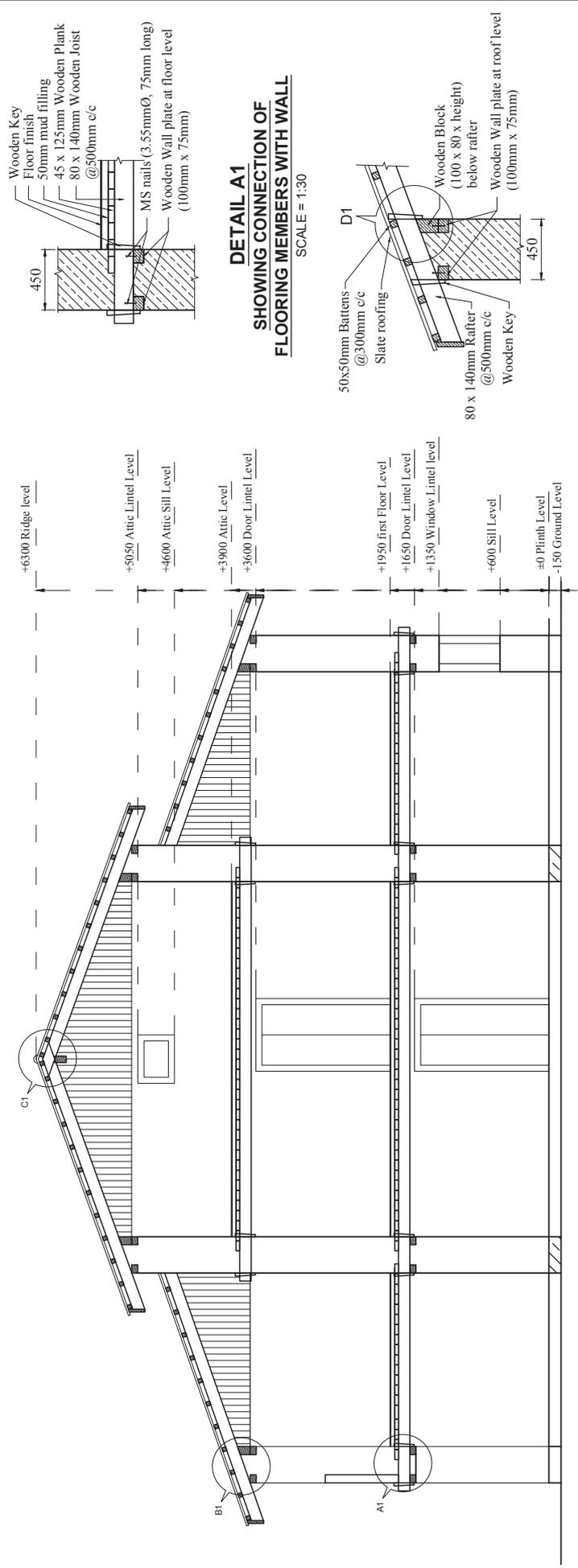
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

SHEET TITLE :-

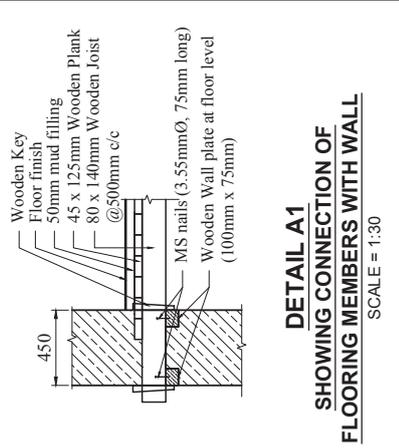
**ELEVATIONS OF EXISTING BUILDING**

SCALE :- 1/100 FOR A3 PAPER

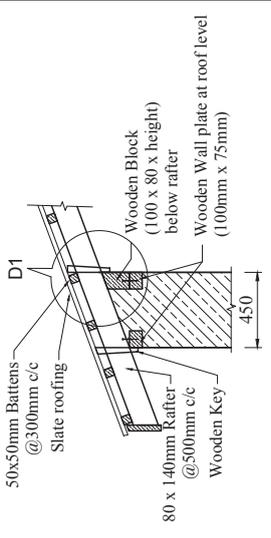
DATE :- JULY, 2017



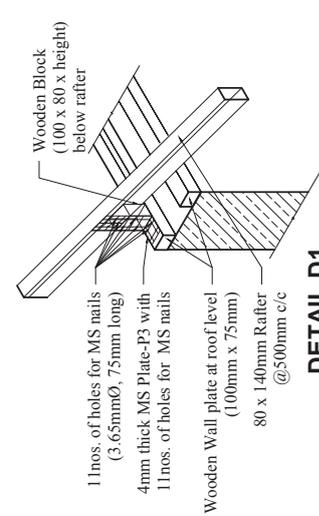
**SECTION AT X-X**  
SCALE = 1:50



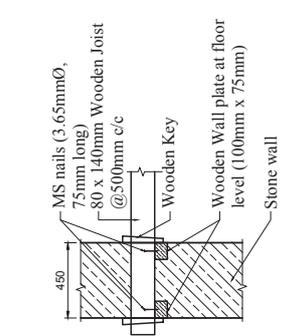
**DETAIL A1**  
**SHOWING CONNECTION OF FLOORING MEMBERS WITH WALL**  
SCALE = 1:30



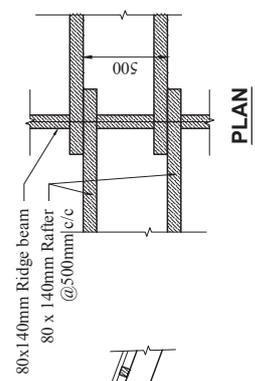
**DETAIL B1**  
**SHOWING CONNECTION OF ROOFING MEMBERS WITH WALL**  
SCALE = 1:30



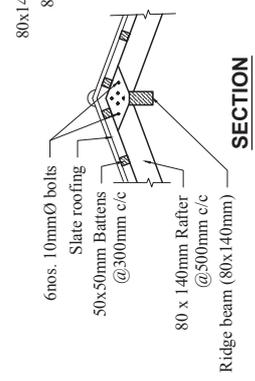
**DETAIL D1**  
**SHOWING CONNECTION OF RAFTER WITH ROOF BAND**  
SCALE = 1:30



**FIXING OF JOISTS**  
SCALE = 1:30



**DETAIL C1**  
**SHOWING ROOF DETAILS AT RIDGE LEVEL**  
SCALE = 1:30



**SECTION**  
SCALE = 1:30

SECTION OF EXISTING BUILDING AND DETAILS

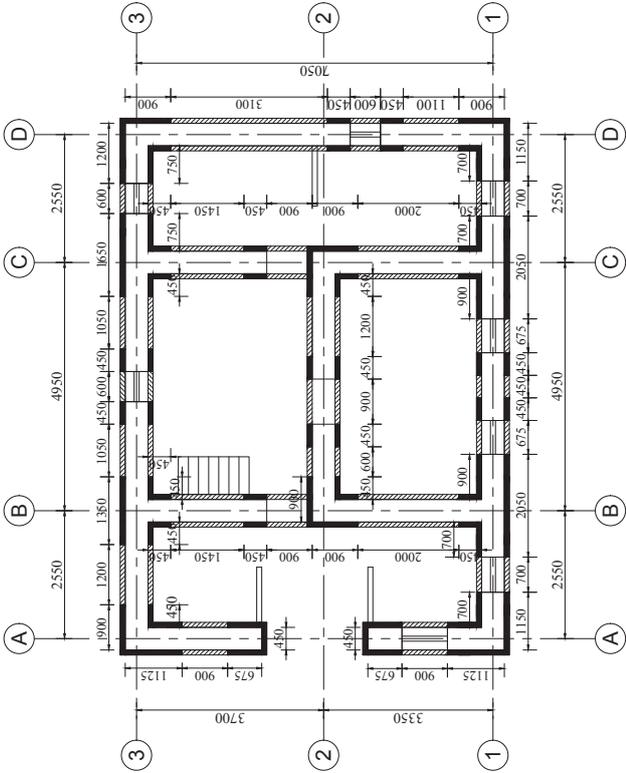
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

DATE :- JULY, 2017

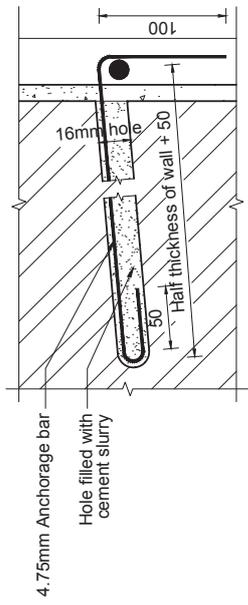
SCALE :- AS SHOWN FOR A3 PAPER

**Notes:**

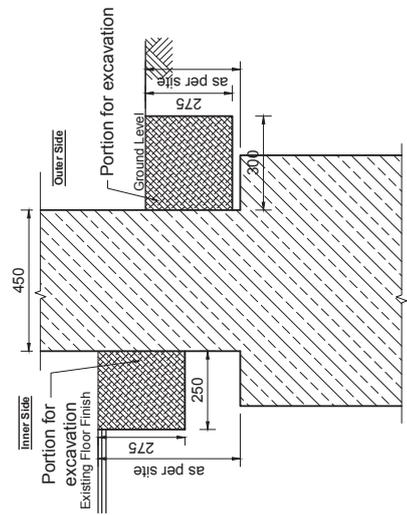
- Tie beam for Splint on walls using RC Bars of 8mmØ and/or 4.75mmØ
- ▨ Tie beam for Jacketing on remaining walls using G.I. wire of 14SWG (2.03mm Ø) @ 100mm c/c both horizontally and vertically



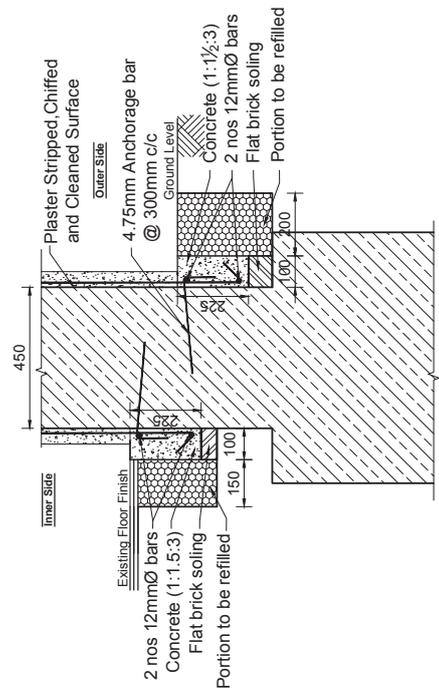
**GROUND FLOOR PLAN SHOWING TIE BEAM FOR SPLINT AND JACKETING**  
SCALE = 1:100



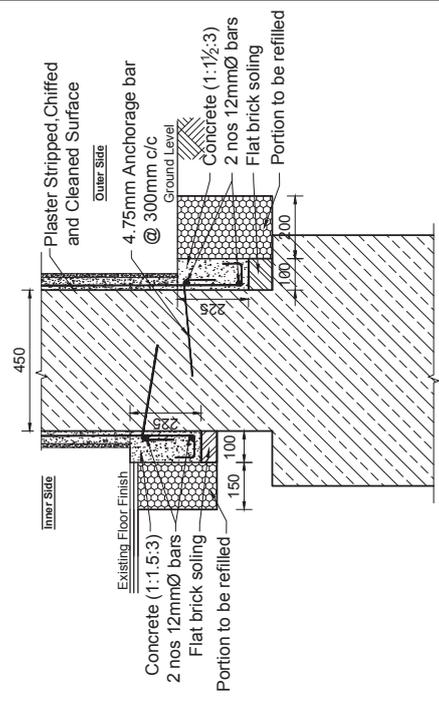
**4.75 MM ANCHORAGE BAR DETAILS**  
SCALE 1:4



**SECTION SHOWING THE PORTION TO BE EXCAVATED FOR TIE BEAM**  
SCALE = 1:16



**DETAILS OF TIE BEAM (FOR G.I. WIRE MESH) FOR INNER AND OUTER SIDE OF THE WALL**  
SCALE = 1:16



**DETAILS OF TIE BEAM (FOR RC BARS) FOR INNER AND OUTER SIDE OF THE WALL**  
SCALE = 1:16

SHEET TITLE :-

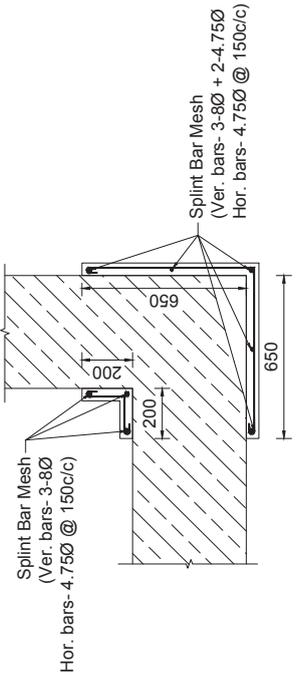
TIE BEAM AND DETAILS

SCALE :- AS SHOWN FOR A3 PAPER

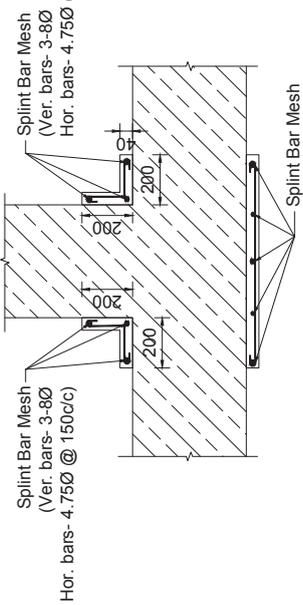
PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH

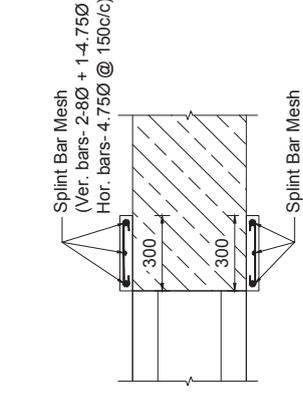




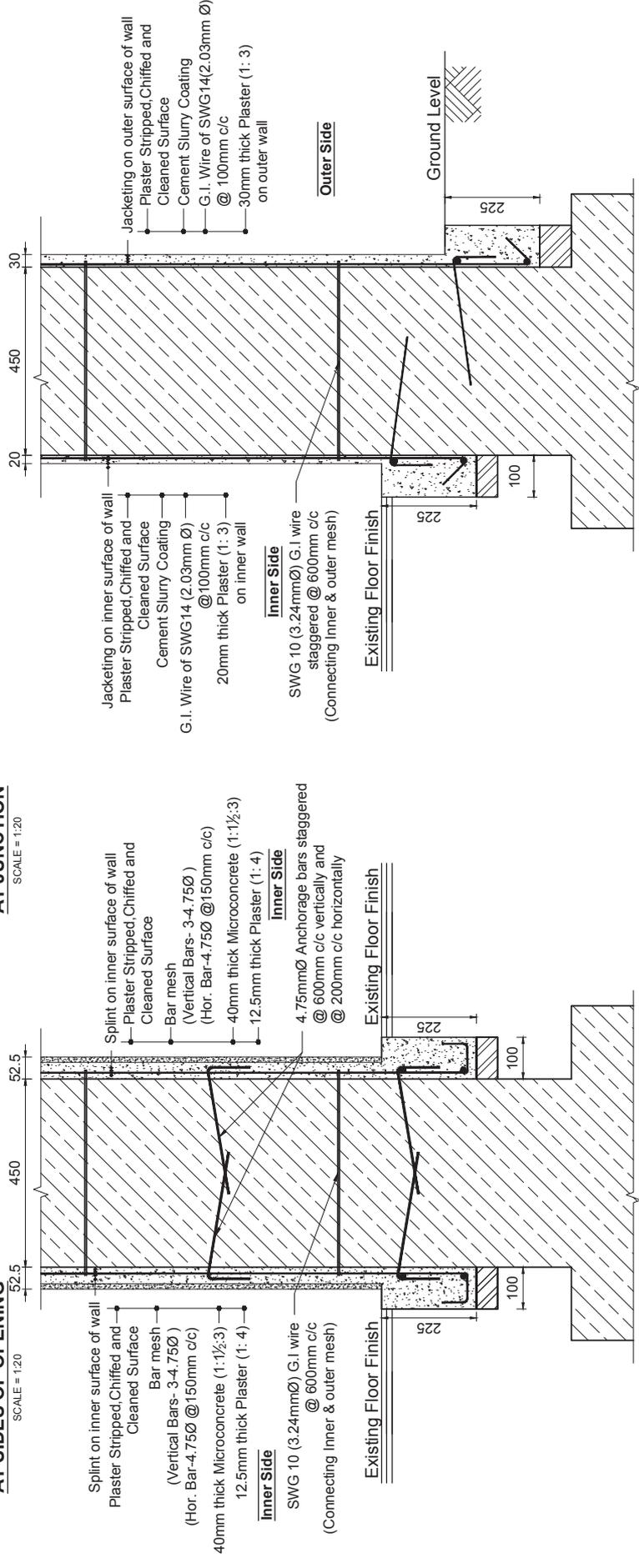
**DETAIL SHOWING VERTICAL SPLINT AT CORNER**  
SCALE = 1:20



**DETAIL SHOWING VERTICAL SPLINT AT JUNCTION**  
SCALE = 1:20



**DETAIL SHOWING VERTICAL SPLINT AT SIDES OF OPENING**  
SCALE = 1:20



**SECTION AT B1-B1**  
(DETAILS OF SPLINT ON BOTH SURFACES OF INTERNAL WALLS)  
SCALE = 1:10

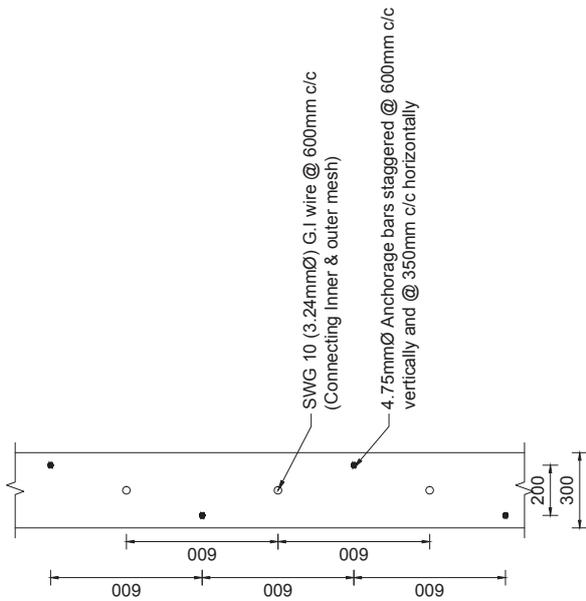
**SECTION AT B2-B2**  
(DETAILS OF JACKETING ON BOTH SURFACES OF PERIPHERAL WALLS)  
SCALE = 1:10

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

SHEET TITLE :-  
**DETAILS OF SPLINT AND JACKETING**

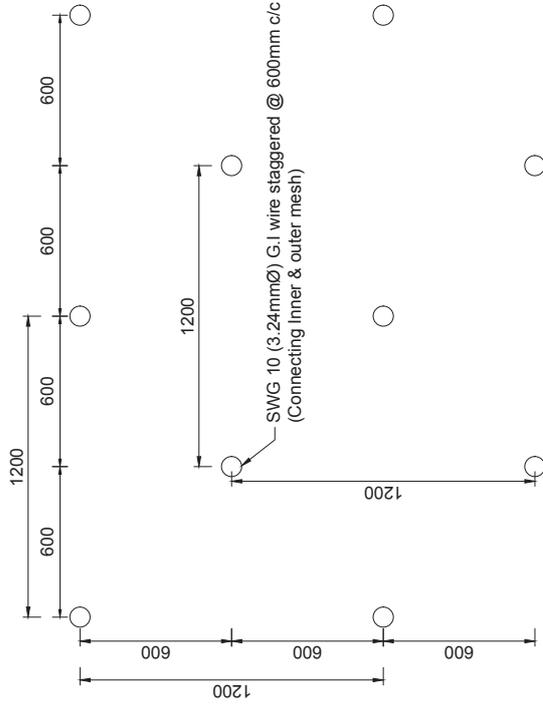
SCALE :- 1:20, 1:10 FOR A3 PAPER

DATE :- JULY, 2017



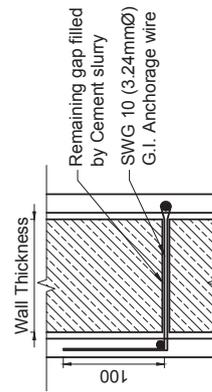
**LAYOUT OF ANCHOR BARS FOR CONNECTING SPLINT BANDS ON BOTH SIDES OF WALLS**

SCALE 1:20



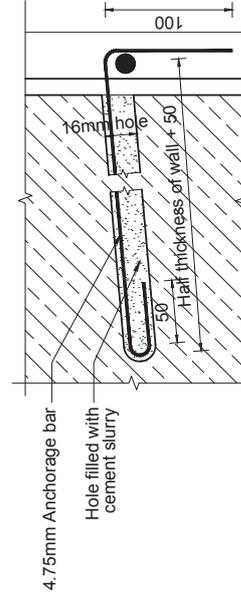
**LAYOUT OF G.I. WIRE ANCHORAGE FOR CONNECTING JACKETING MESH ON BOTH SIDES OF WALL**

SCALE 1:20



**G.I. WIRE DETAILS**

SCALE 1:10



**ANCHORAGE BAR DETAILS**

SCALE 1:4

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

SHEET TITLE :-

**DETAILS OF SPLINT AND JACKETING**

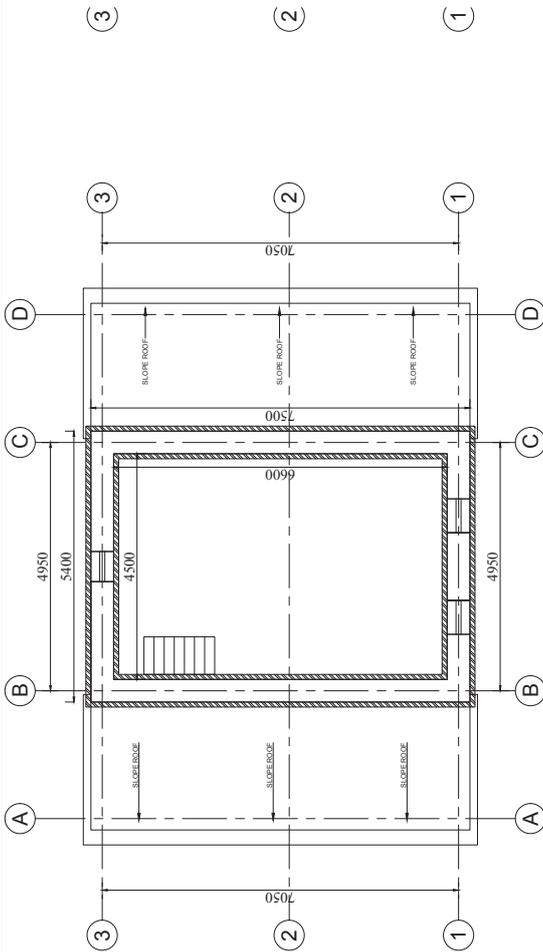
SCALE :- 1:20, 1:10 FOR A3 PAPER

DATE :- JULY, 2017

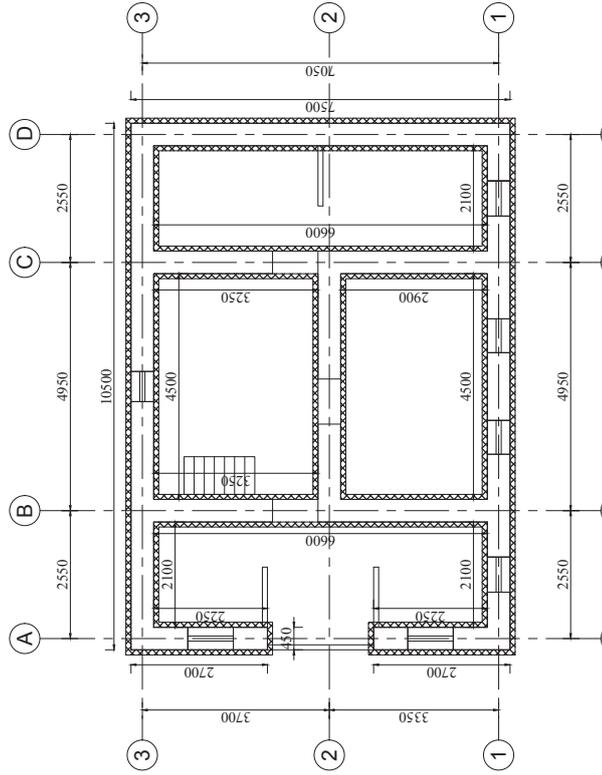
**Notes:**

Horizontal Bands

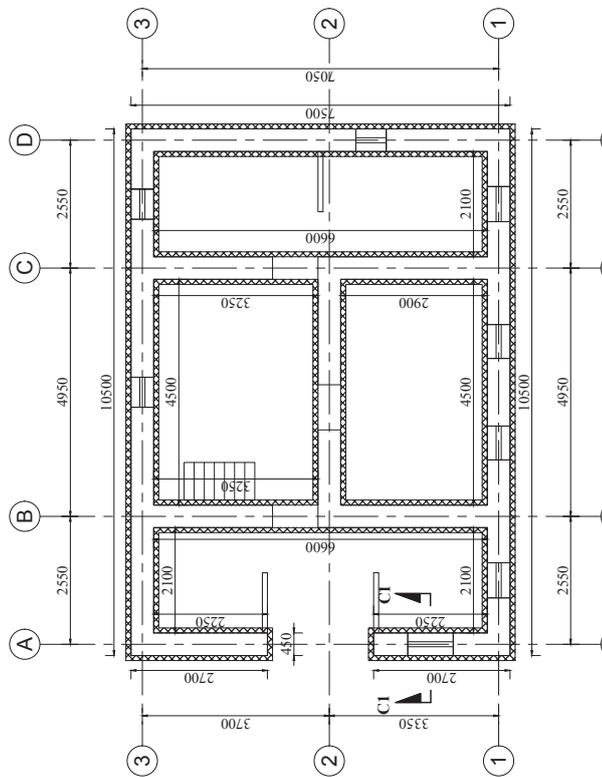
- 200mm width using 2-4.75mm $\varnothing$  bars at sill level
- 300mm width using 3-4.75mm $\varnothing$  bars at lintel level



**SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**FIRST FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**

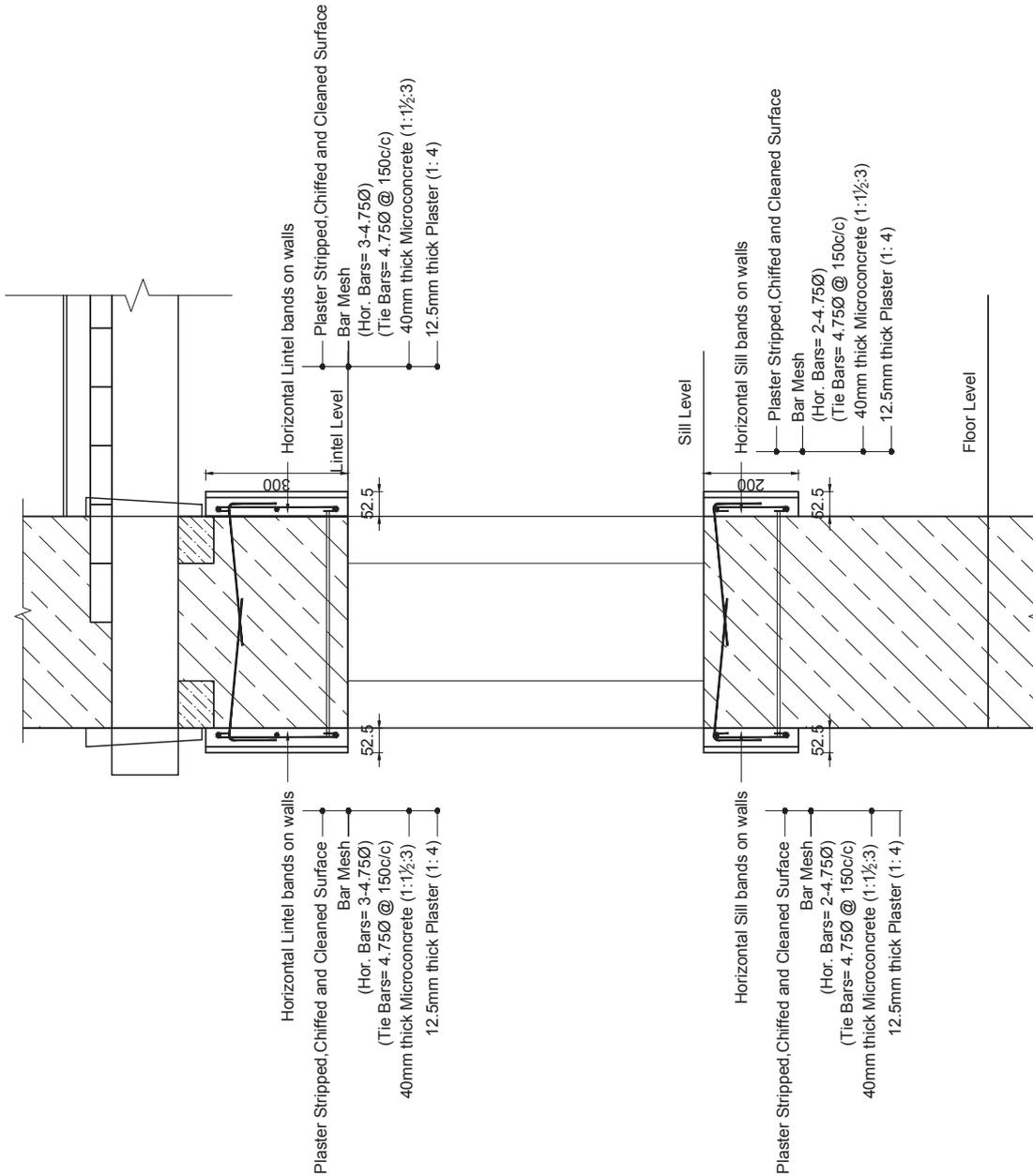
SHEET TITLE :-

FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL BANDAGES AT FLOOR AND SILL LEVEL

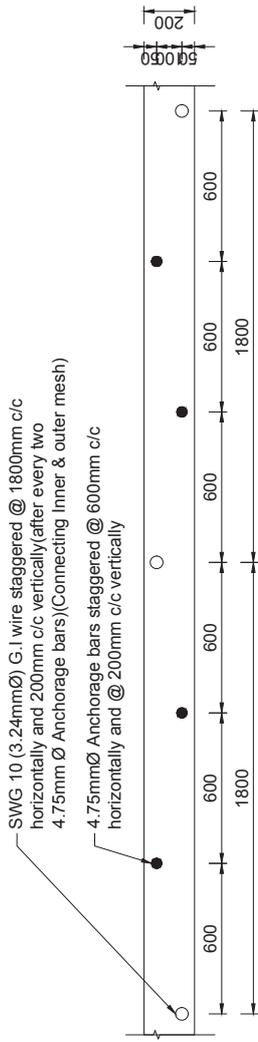
SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

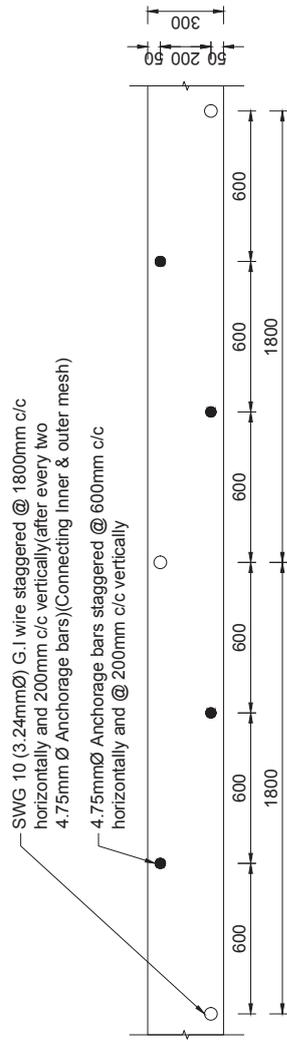
PROJECT TITLE :-  
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH



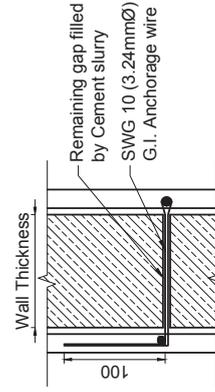
**SECTION AT C1-C1**  
 (DETAILS OF HORIZONTAL BANDAGES ON  
 BOTH SURFACES OF WALLS)  
 SCALE = 1:10



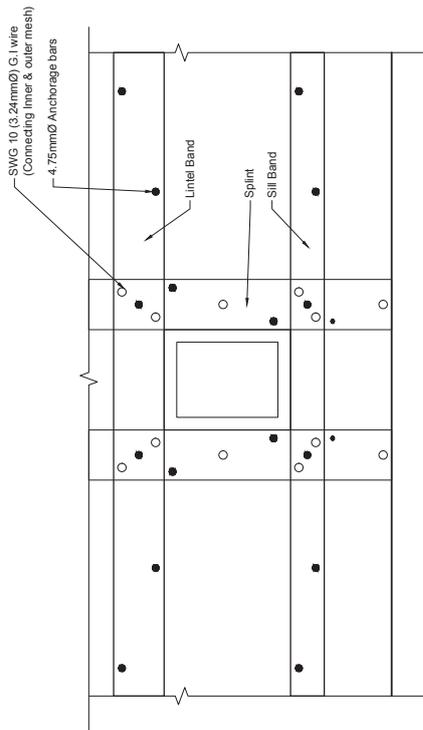
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT SILL LEVEL ON BOTH SIDES OF WALL**  
SCALE = 1:20



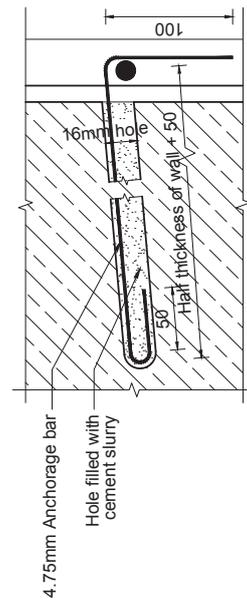
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT FLOOR LEVEL ON BOTH SIDES OF WALL**  
SCALE = 1:20



**G.I. WIRE DETAILS**  
SCALE 1:10



**TYPICAL LAYOUT OF ANCHORAGE FOR CONNECTING SPLINT AND HORIZONTAL BANDAGE ON BOTH SIDES OF WALLS**  
SCALE 1:30



**ANCHORAGE BAR DETAILS**  
SCALE 1:4

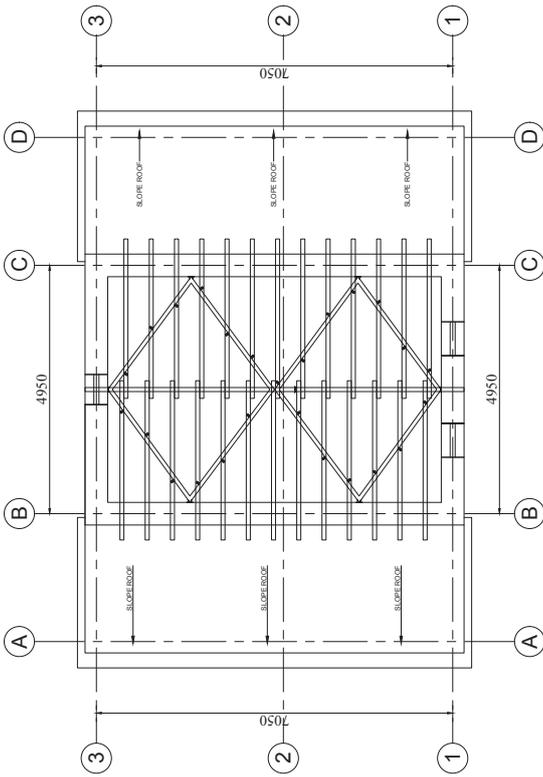
SHEET TITLE :-

DETAILS OF HORIZONTAL BANDAGES

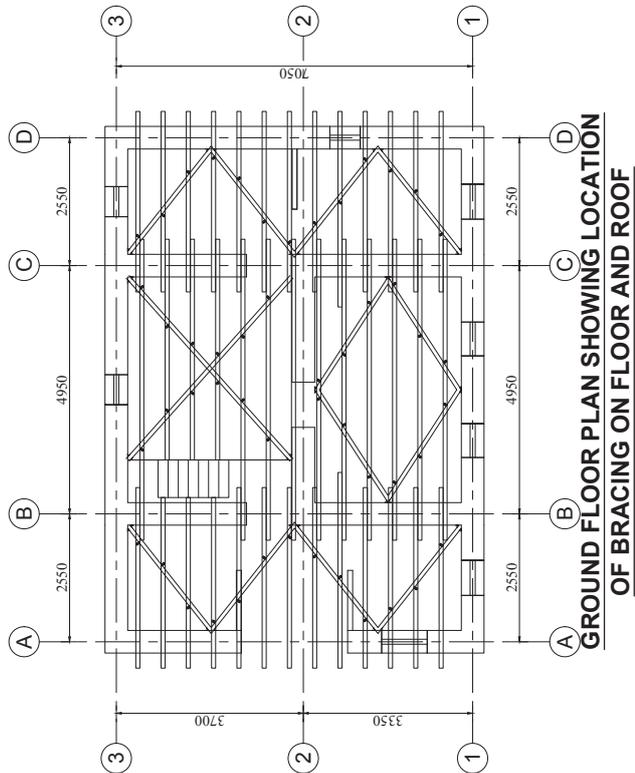
SCALE :- AS SHOWN FOR A3 PAPER

DATE :- JULY, 2017

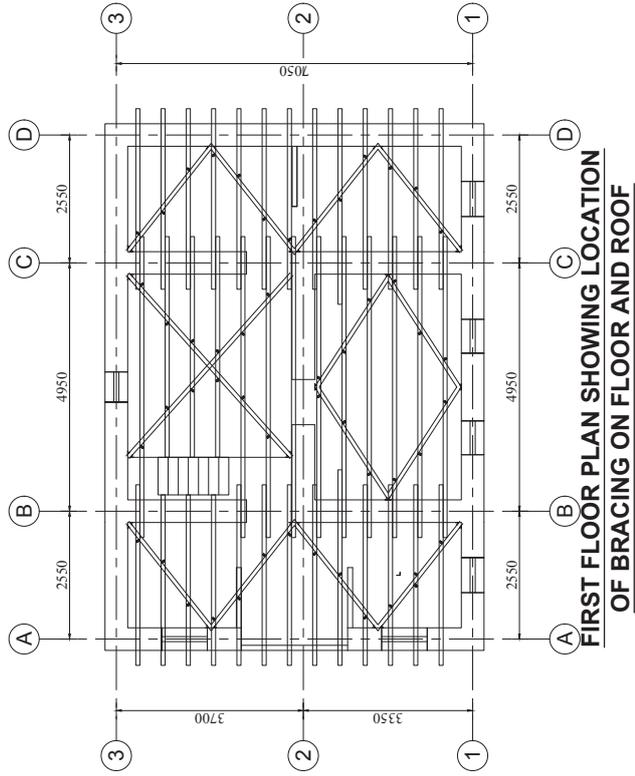
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**



**SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF BRACING ON FLOOR AND ROOF**



**FIRST FLOOR PLAN SHOWING LOCATION OF BRACING ON FLOOR AND ROOF**

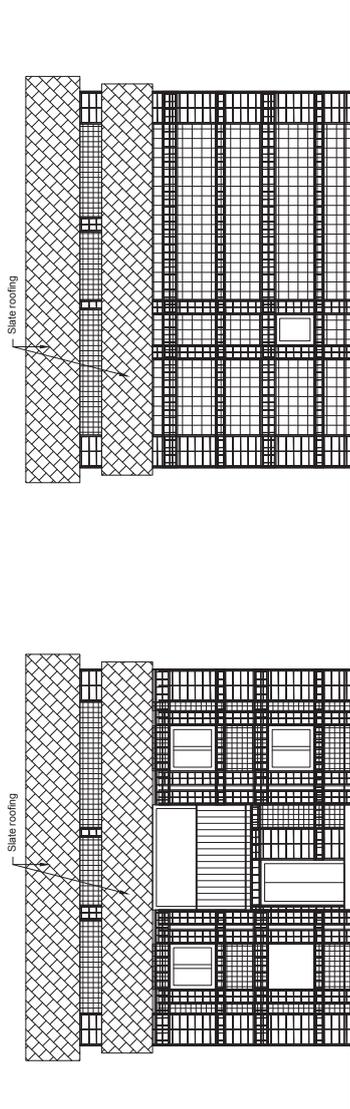
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

SHEET TITLE :-  
**FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL**

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017





ELEVATION-3

ELEVATION-1

ELEVATION-4

ELEVATION-2

SHEET TITLE :-  
**ELEVATIONS OF EXISTING BUILDING AFTER RETROFIT**  
 SCALE :- 1:100 FOR A3 PAPER  
 DATE :- JULY, 2017

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
 STRENGTH STONE MASONRY BUILDING USING RC BARS AND G.I. WIRE MESH**

# STRUCTURAL DRAWINGS FOR RETROFIT DESIGN ON TWO STOREY STONE MASONRY BUILDING IN MUD USING G.I. WIREMESH

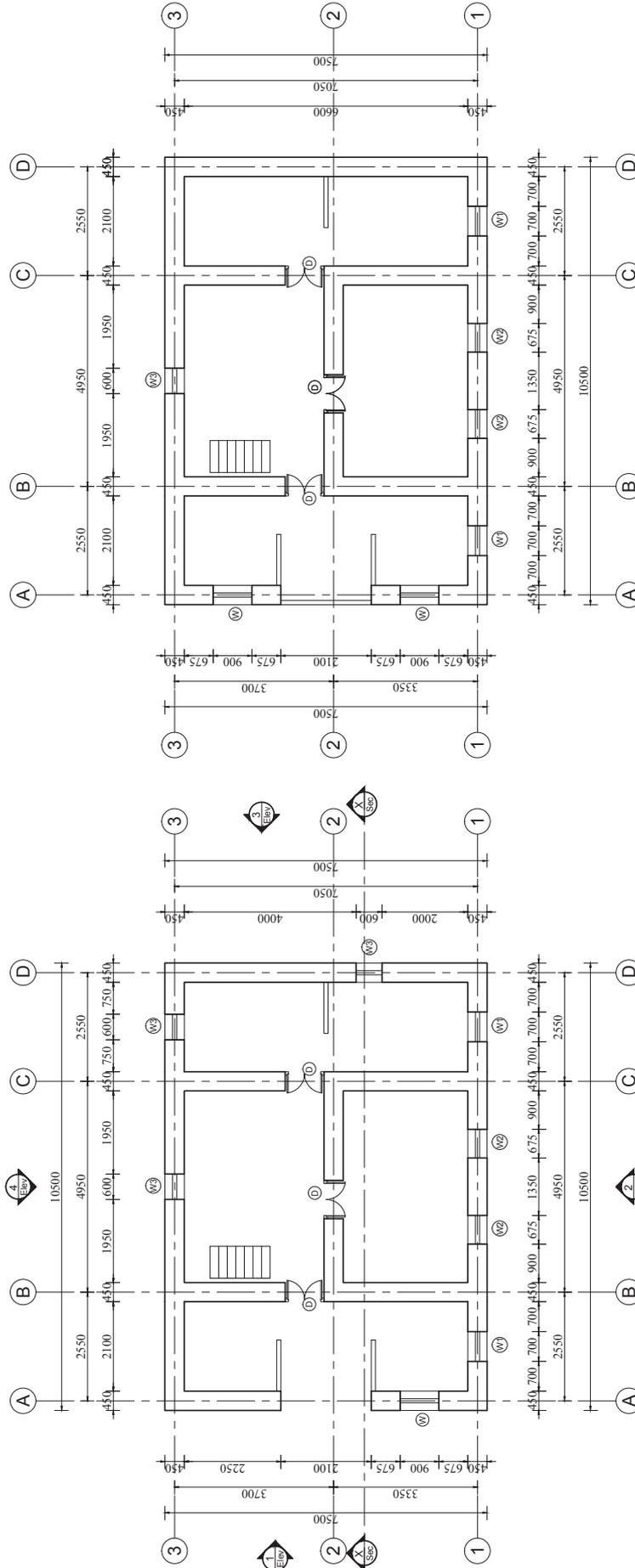
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SHEET TITLE :- COVER PAGE  
SCALE :- N/A  
DATE :- JULY, 2017

PROJECT TITLE :-  
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING USING G.I. WIRE MESHING

OPENING SCHEDULE

S.N.	SYMBOL	NOS.	SIZE	SILL HEIGHT
1.	DOOR-D	6	900 x 1660	---
2.	WINDOW-W	3	900 x 900	600
3.	WINDOW-W1	4	700 x 750	600
4.	WINDOW-W2	6	675 x 750	600
5.	WINDOW-W3	6	600 x 750	600



FIRST FLOOR PLAN

GROUND FLOOR PLAN

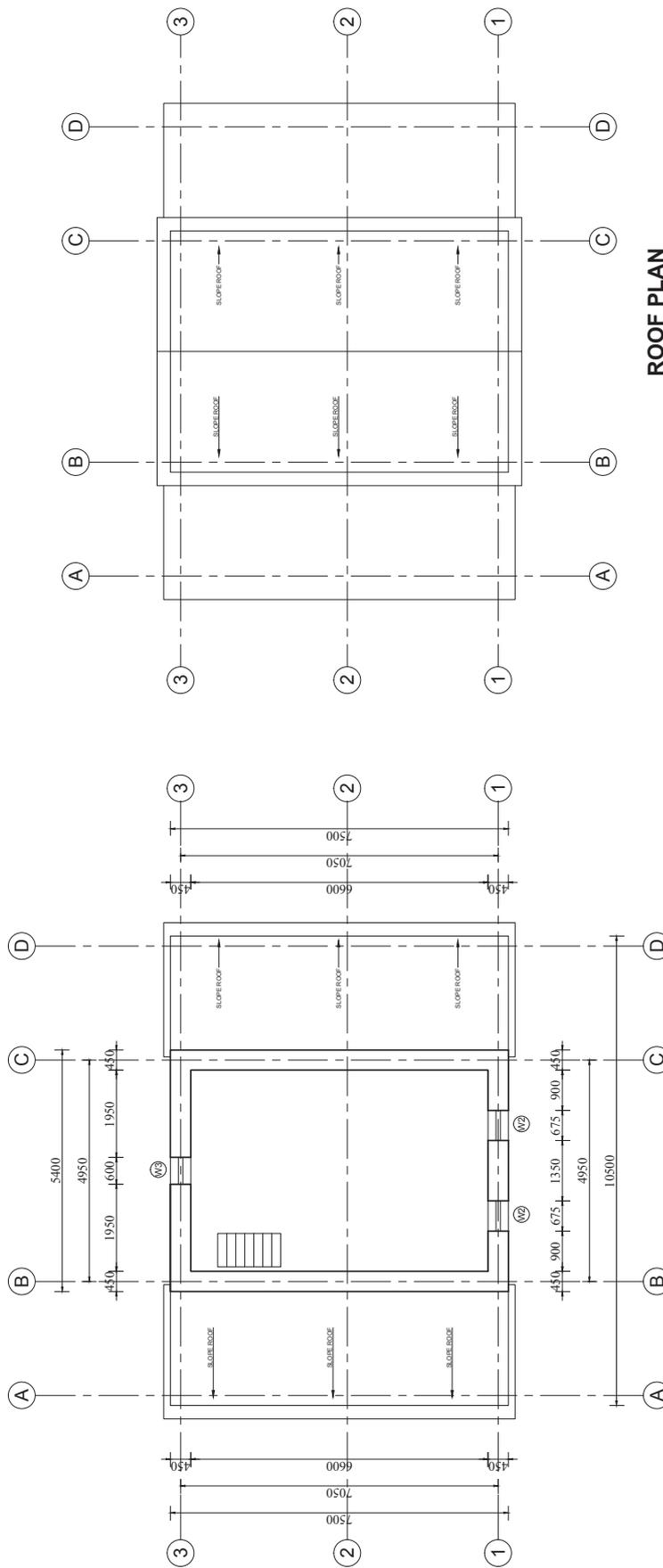
01

FLOOR PLANS OF EXISTING BUILDING

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING

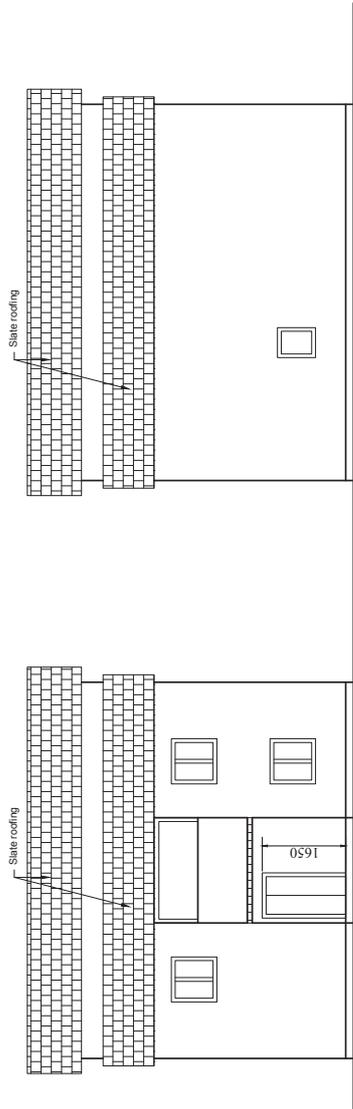
DATE :- JULY, 2017

SCALE :- 1:100 FOR A3 PAPER



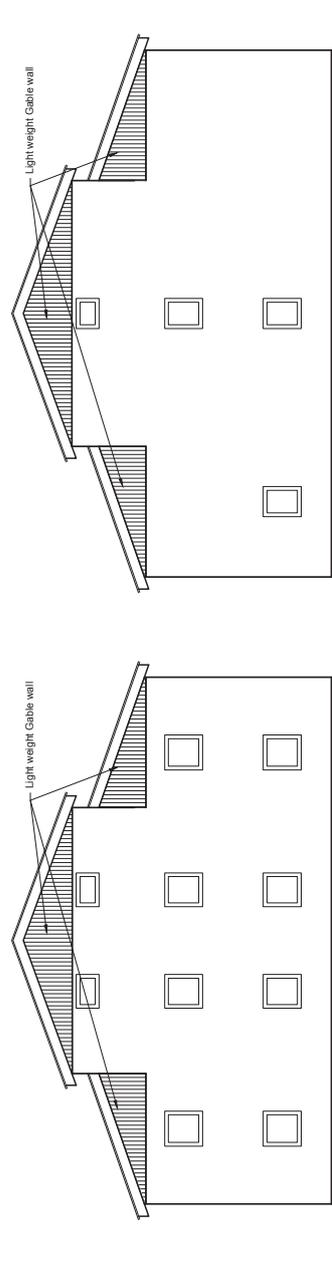
**ROOF PLAN**

**SECOND FLOOR PLAN**



**ELEVATION-3**

**ELEVATION-1**



**ELEVATION-4**

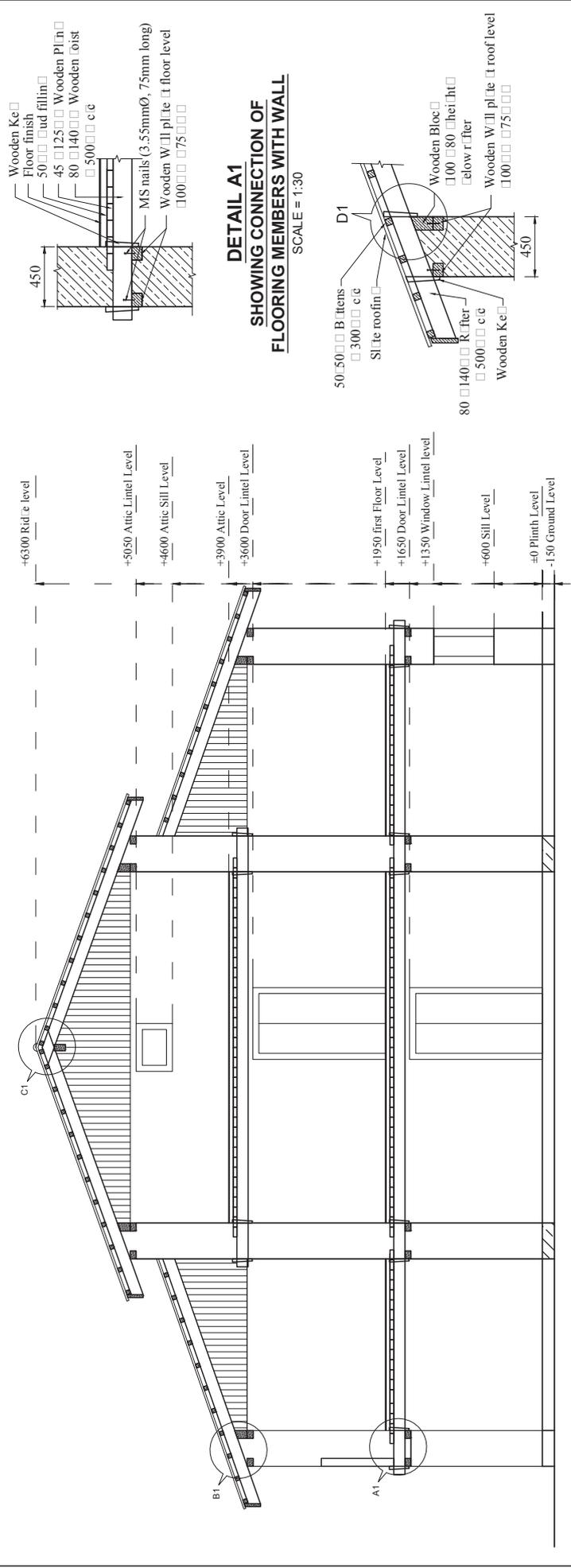
**ELEVATION-2**

SHEET TITLE :- ELEVATIONS OF EXISTING BUILDING

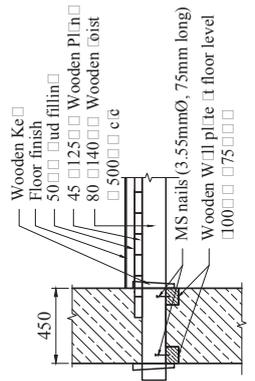
DATE :- JULY, 2007

SCALE :- 1:100 FOR A3 PAPER

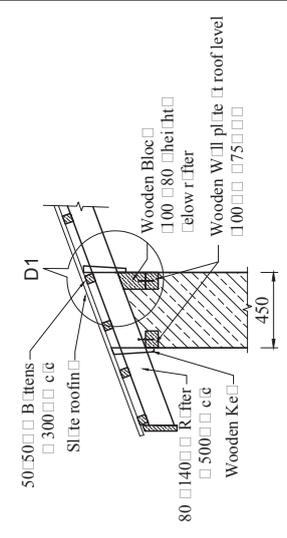
PROJECT TITLE :- STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING



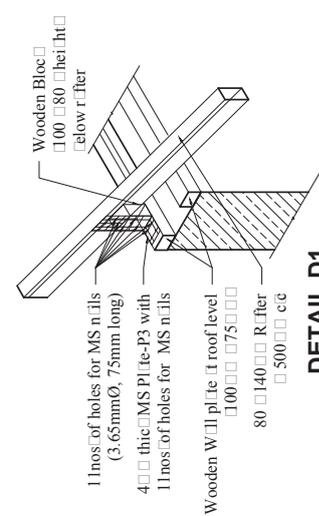
**SECTION AT X-X**  
SCALE = 1:50



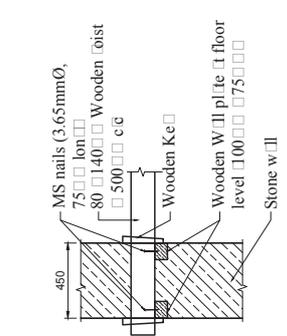
**DETAIL A1**  
**SHOWING CONNECTION OF FLOORING MEMBERS WITH WALL**  
SCALE = 1:30



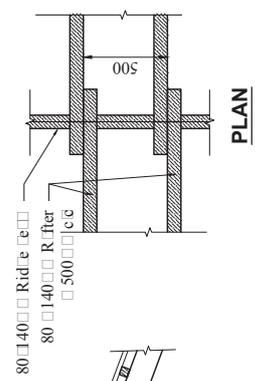
**DETAIL B1**  
**SHOWING CONNECTION OF ROOFING MEMBERS WITH WALL**  
SCALE = 1:30



**DETAIL D1**  
**SHOWING CONNECTION OF RAFTER WITH ROOF BAND**  
SCALE = 1:30



**FIXING OF JOISTS**  
SCALE = 1:30



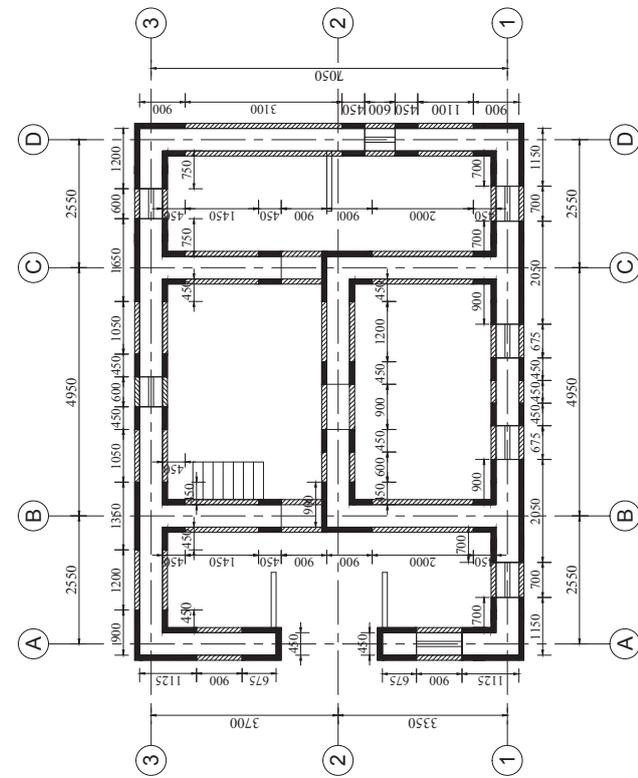
**DETAIL C1**  
**SHOWING ROOF DETAILS AT RIDGE LEVEL**  
SCALE = 1:30

SECTION OF EXISTING BUILDING AND DETAILS

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING**

DATE :- JULY, 2017

SCALE :- AS SHOWN FOR AS PAPER

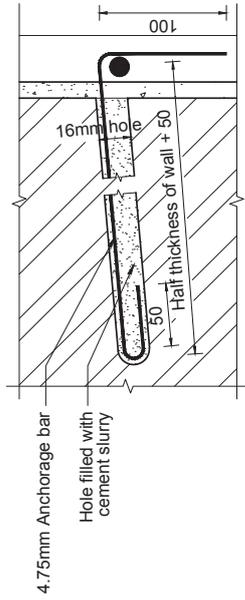


**GROUND FLOOR PLAN SHOWING TIE BEAM FOR SPLINT AND JACKETING**

SCALE = 1:100

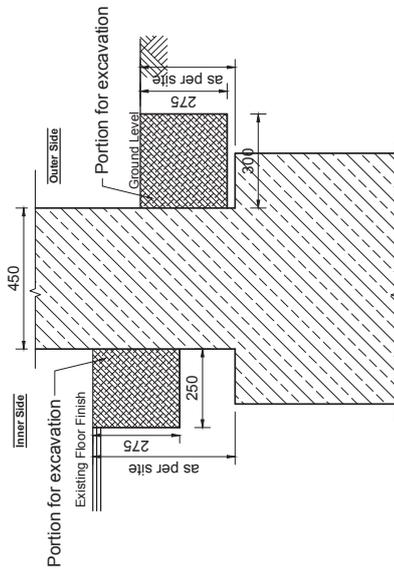
**Notes:**

- Tie beam for Splint of 450mm width on walls using G.I. welded wiremesh of 14SWG (2.03mm Ø) and size 25x25mm.
- ▨ Tie beam for jacketing on remaining walls using G.I. wire of 14SWG (2.03mm Ø) @ 100mm c/c both horizontally and vertically



**4.75 MM ANCHORAGE BAR DETAILS**

SCALE 1:4



**DETAILS OF TIE BEAM FOR INNER AND OUTER SIDE OF THE WALL**

SCALE = 1:16

**SECTION SHOWING THE PORTION TO BE EXCAVATED FOR TIE BEAM**

SCALE = 1:16

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING**

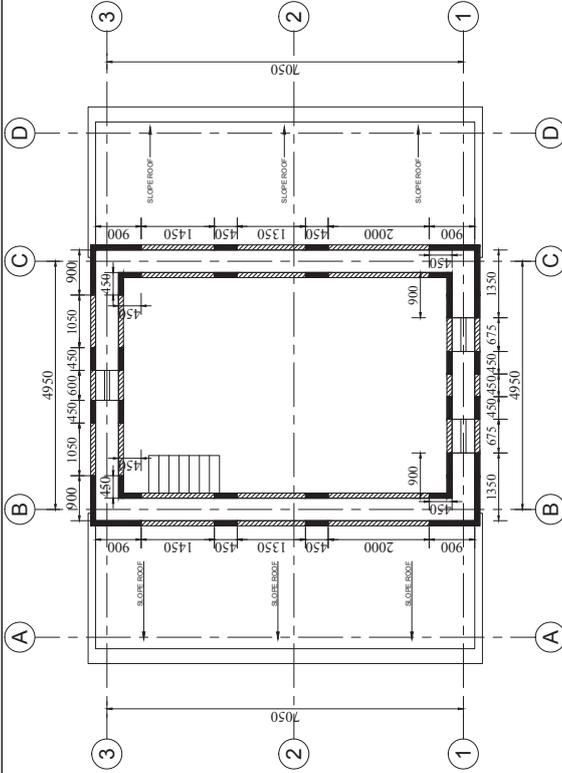
**TIE BEAM AND DETAILS**

SCALE :- AS SHOWN FOR A3 PAPER

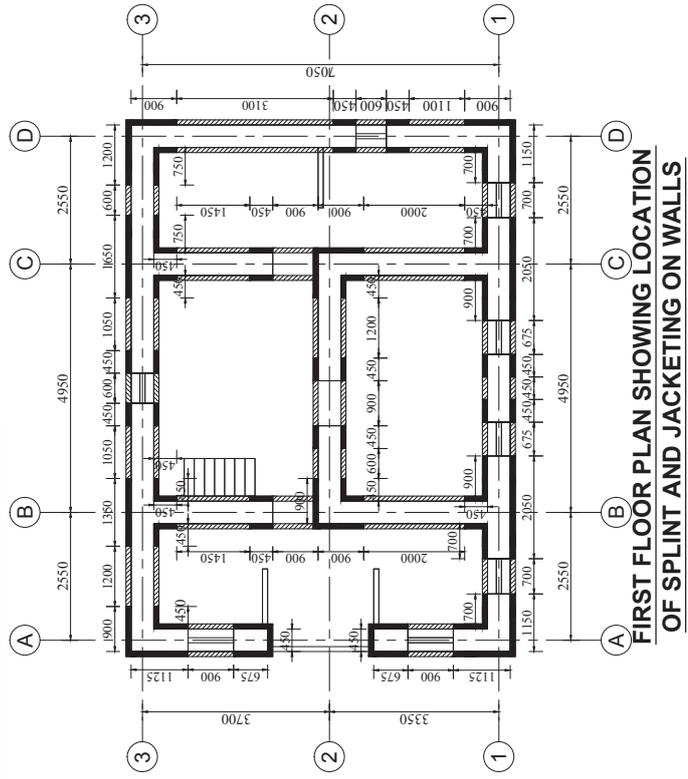
DATE :- JULY, 2017

**Notes:**

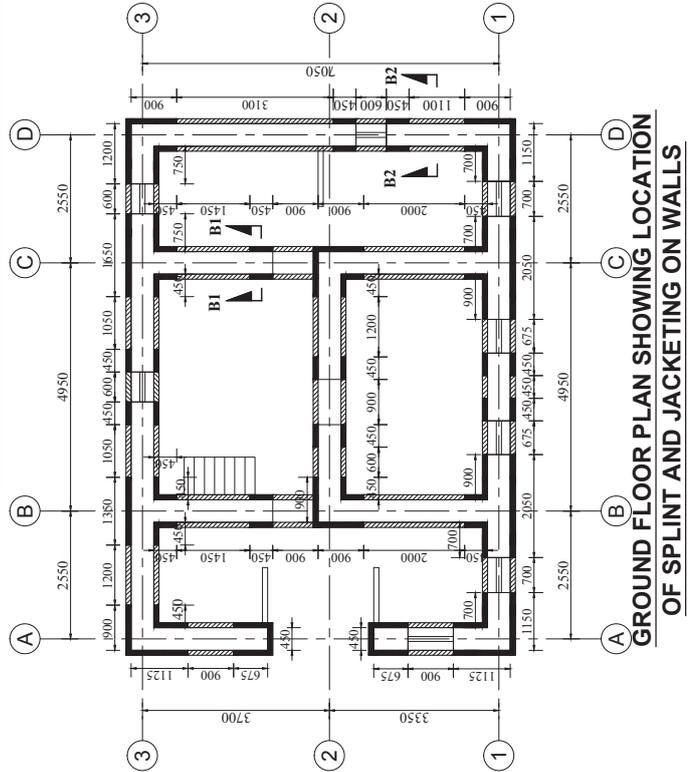
- ▬ Splint of 450mm width on walls using G.I. welded wiremesh of 14SWG (2.03mm Ø) and size 25x25mm.
- ▨ Jacketing on remaining walls using G.I. wire of 14SWG (2.03mm Ø) @ 100mm c/c both horizontally and vertically



**SECOND FLOOR PLAN SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS**



**FIRST FLOOR PLAN SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS**

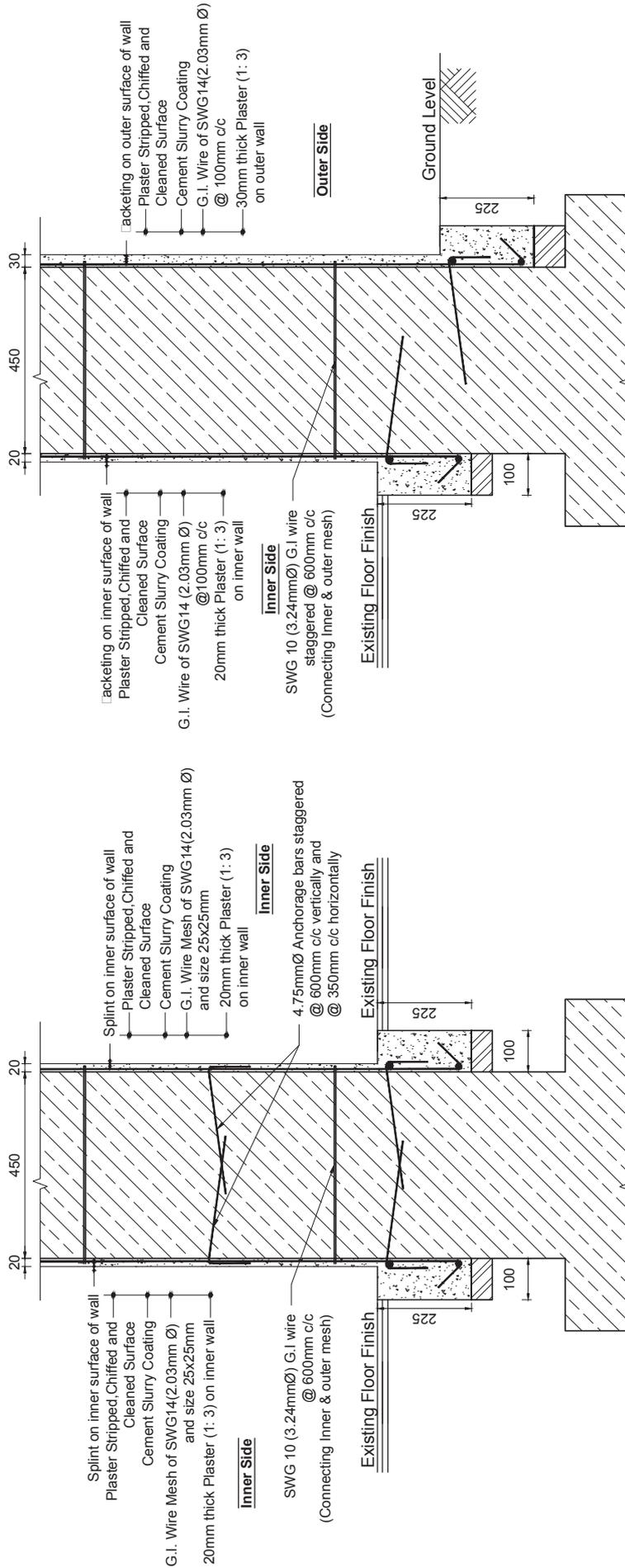
SHEET TITLE :-

FLOOR PLANS SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

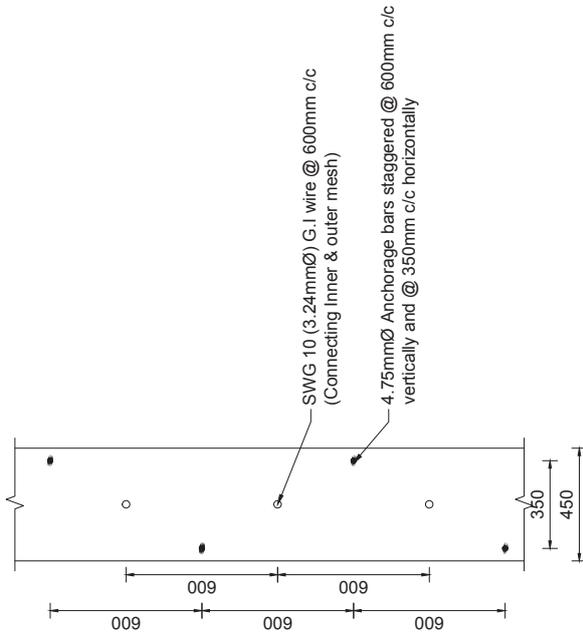
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING G.I. WIRE MESHING**



PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING G.I. WIRE MESHING**

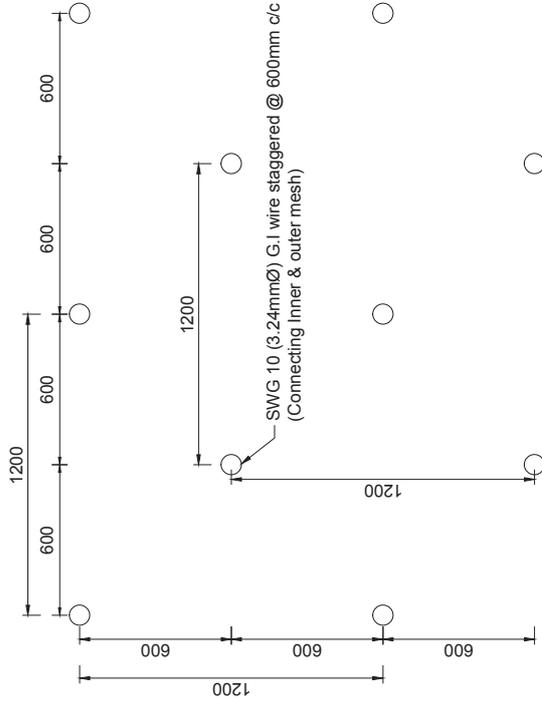
SHEET TITLE :-  
**DETAILS OF SPLINT AND LACKEYING**

SCALE :- 1:10 FOR A3 PAPER  
DATE :- JULY, 2017



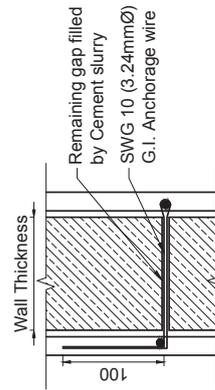
**LAYOUT OF ANCHOR BARS FOR CONNECTING  
SPLINT BANDS ON BOTH SIDES OF WALLS**

SCALE 1:20



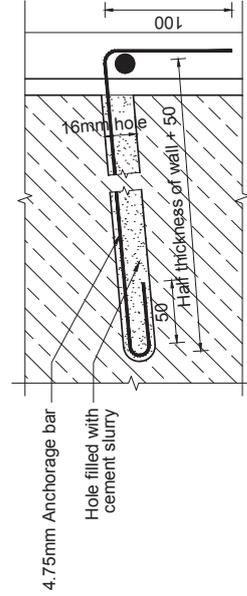
**LAYOUT OF G.I. WIRE ANCHORAGE FOR CONNECTING  
JACKETING MESH ON BOTH SIDES OF WALL**

SCALE 1:20



**G.I. WIRE DETAILS**

SCALE 1:10



**ANCHORAGE BAR DETAILS**

SCALE 1:4

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING USING G.I. WIRE MESHING**

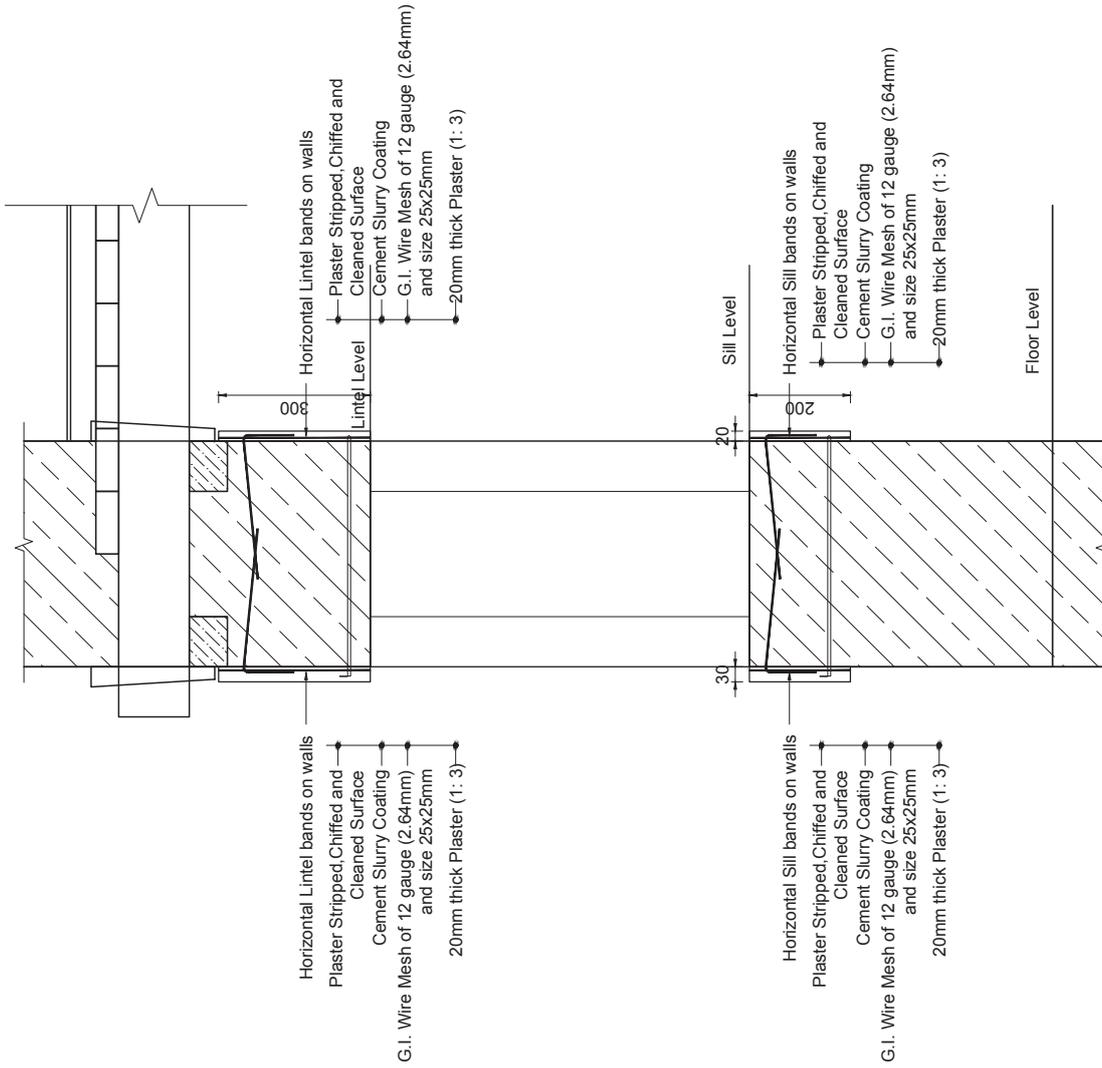
SHEET TITLE :-

**DETAILS OF SPLINT AND JACKETING**

SCALE :- 1:20, 1:10 FOR A3 PAPER

DATE :- JULY, 2017





**SECTION AT C1-C1**  
 (DETAILS OF HORIZONTAL BANDAGES ON BOTH SURFACES OF WALLS)  
 SCALE = 1:10

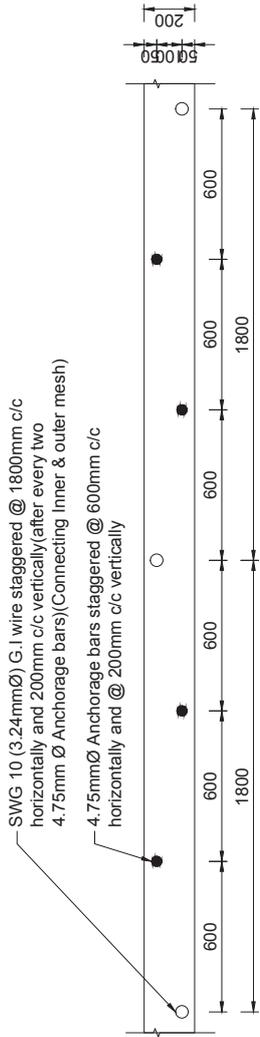
DETAILS OF HORIZONTAL BANDAGES

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING**

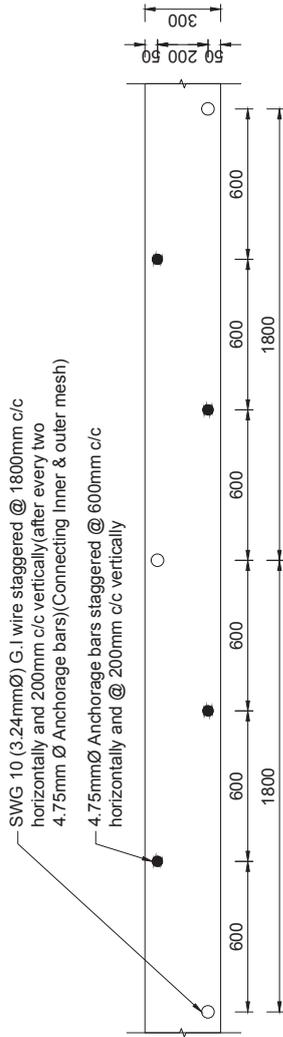
DATE :- JULY, 2017

SCALE :- 1:10 FOR A3 PAPER

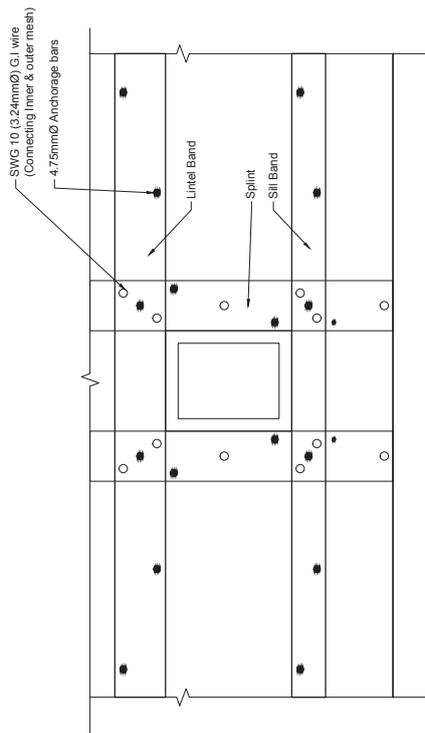
SHEET TITLE :-



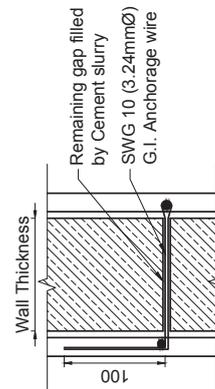
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT SILL LEVEL ON BOTH SIDES OF WALL**  
SCALE = 1:20



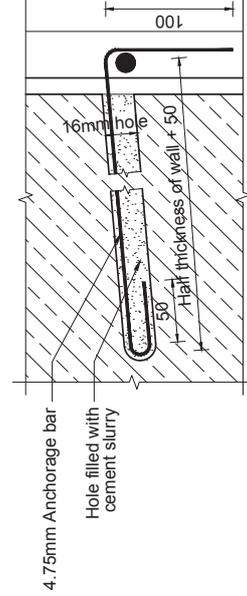
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT LINTEL LEVEL ON BOTH SIDES OF WALL**  
SCALE = 1:20



**TYPICAL LAYOUT OF ANCHORAGE FOR CONNECTING SPLINT AND HORIZONTAL BANDAGE ON BOTH SIDES OF WALLS**  
SCALE 1:30



**G.I. WIRE DETAILS**  
SCALE 1:10



**ANCHORAGE BAR DETAILS**  
SCALE 1:4

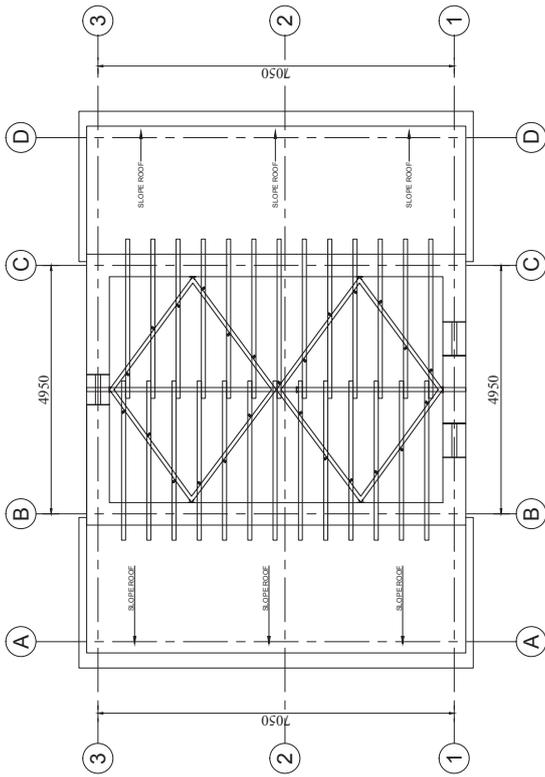
SHEET TITLE :-

DETAILS OF HORIZONTAL BANDAGES

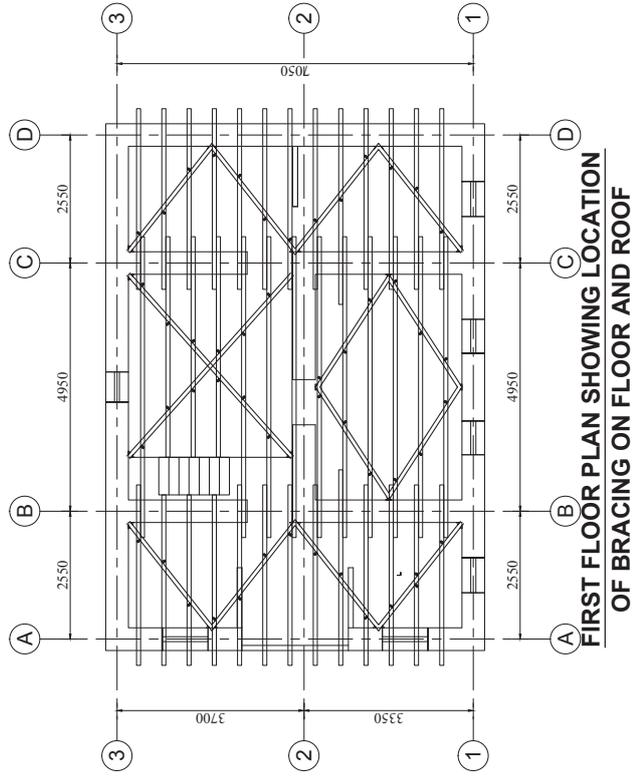
SCALE :- AS SHOWN FOR A3 PAPER

DATE :- JULY, 2017

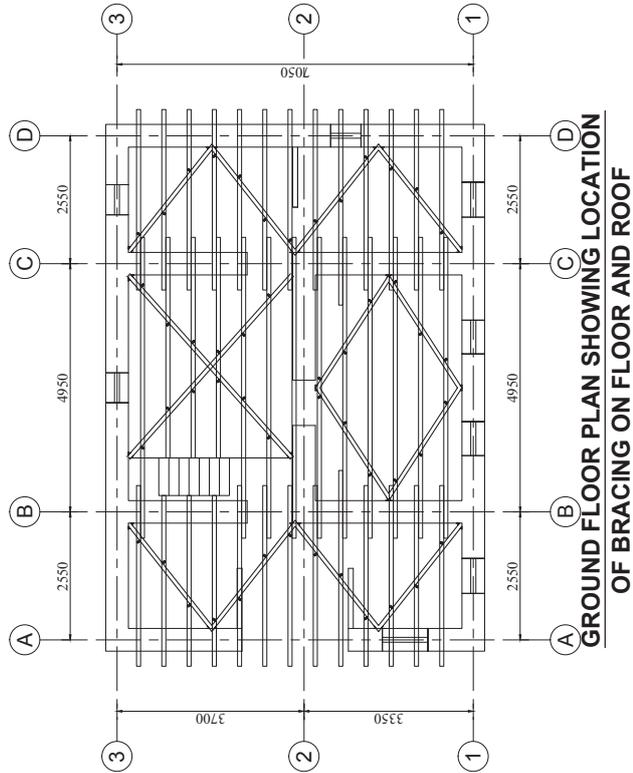
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING G.I. WIRE MESHING



**SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



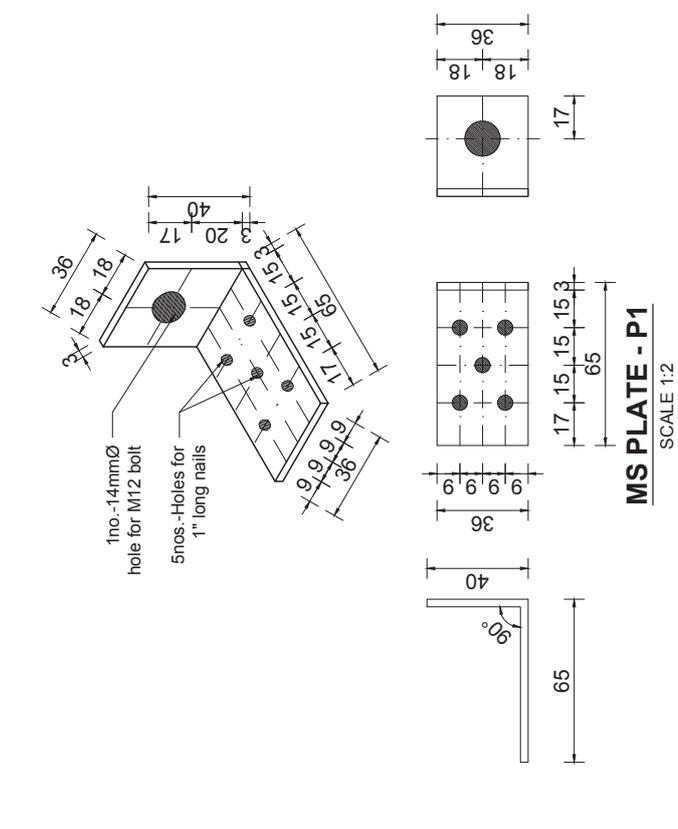
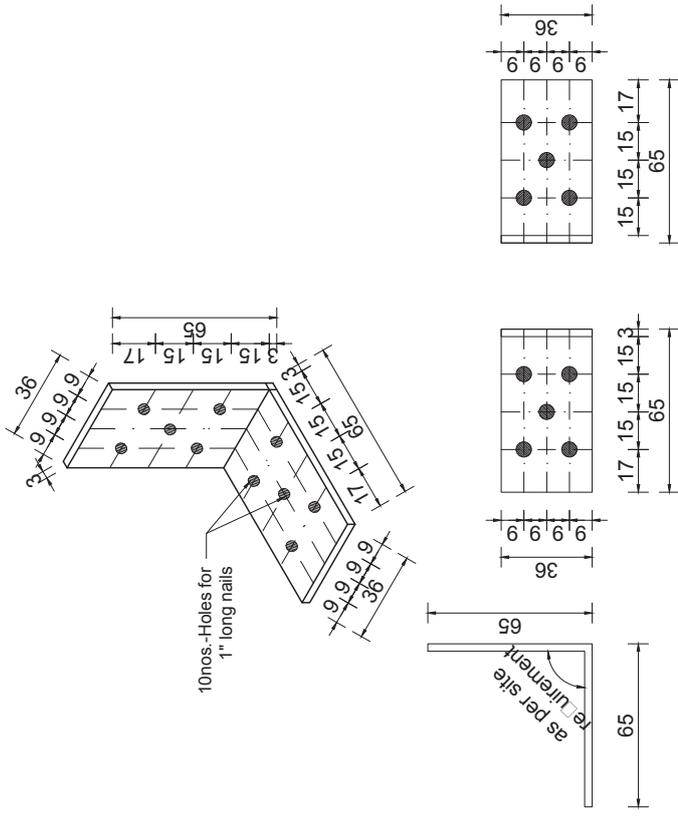
**FIRST FLOOR PLAN SHOWING LOCATION OF BRACING ON FLOOR AND ROOF**



**GROUND FLOOR PLAN SHOWING LOCATION OF BRACING ON FLOOR AND ROOF**

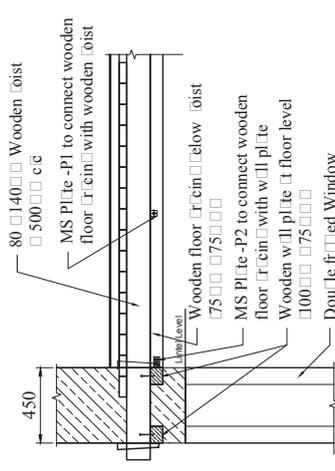
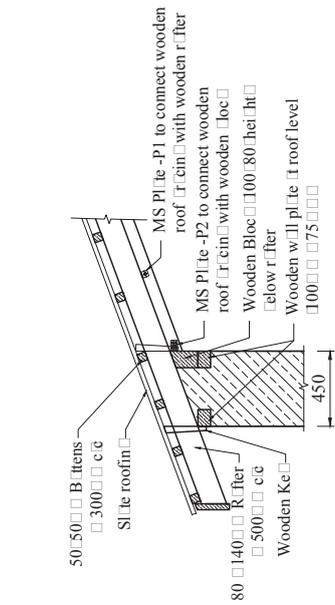
SHEET TITLE :- FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL  
 SCALE :- 1:100 FOR A3 PAPER  
 DATE :- JULY, 2017

PROJECT TITLE :- STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING



**MS PLATE - P2**  
SCALE 1:2

**MS PLATE - P1**  
SCALE 1:2

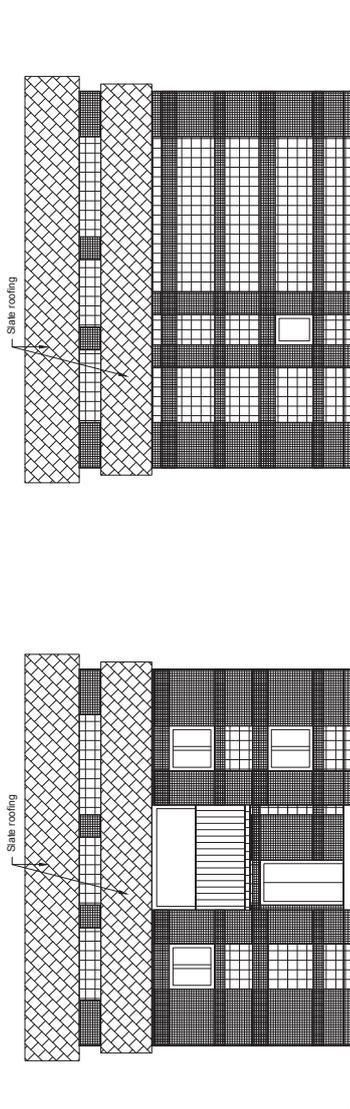


**FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL**

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING**

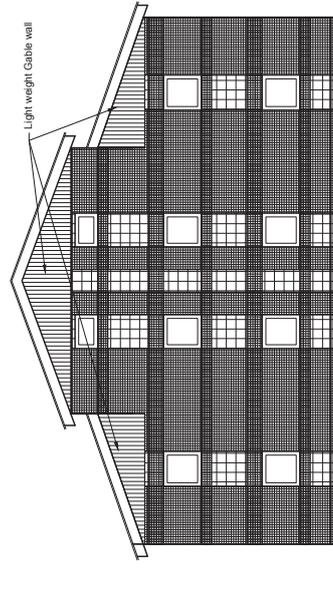
SHEET TITLE :-  
SCALE :- 1:30, 1:2 FOR A3 PAPER  
DATE :- JULY, 2017

PROJECT TITLE :-  
SCALE = 1:30

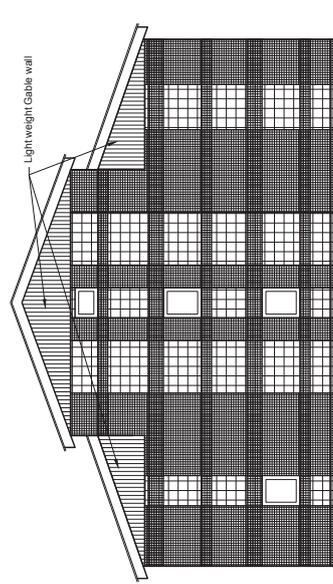


**ELEVATION-1**

**ELEVATION-3**



**ELEVATION-2**



**ELEVATION-4**

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING GI WIRE MESHING**

SHEET TITLE :-

**ELEVATIONS OF EXISTING BUILDING AFTER RETROFIT**

SCALE :- 1:100 FOR A3 PAPER

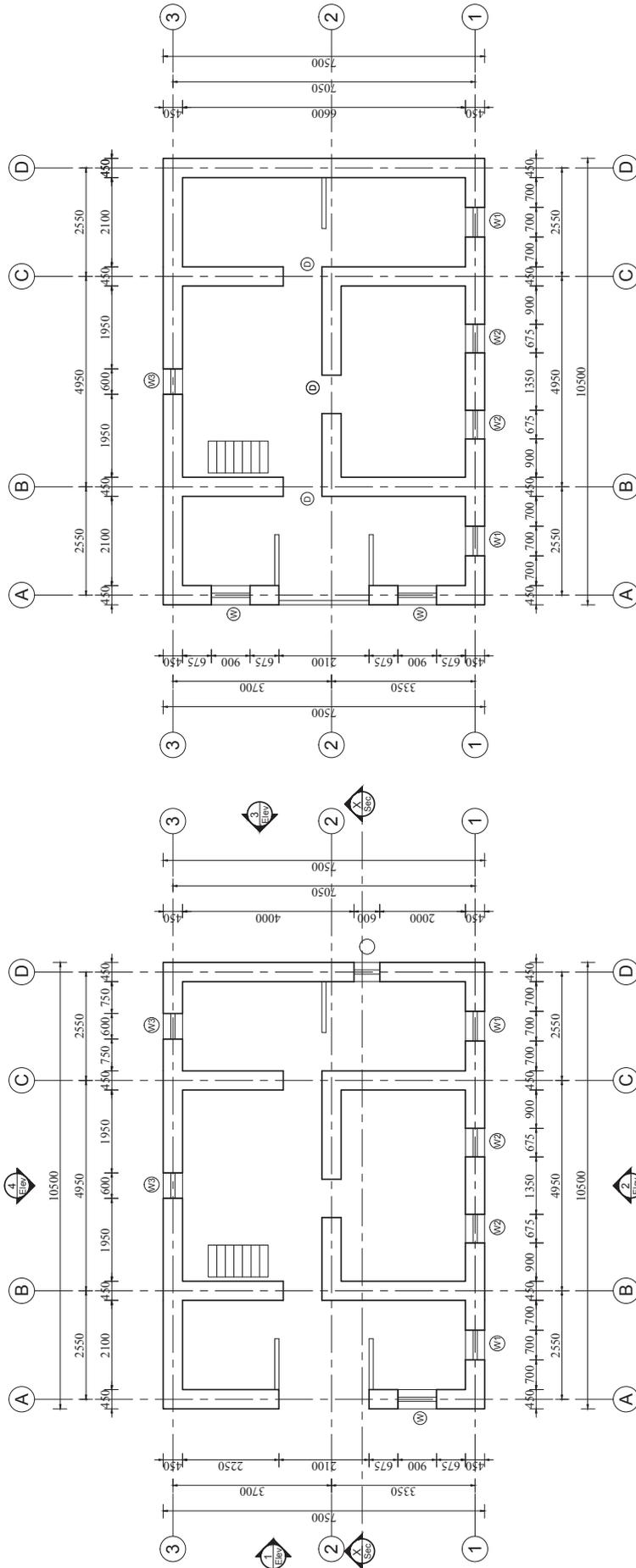
DATE :- JULY, 2017

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN ON  
TWO STOREY STONE MASONRY BUILDING IN MUD  
USING G.I. WIREMESH AND PP BANDS**

0

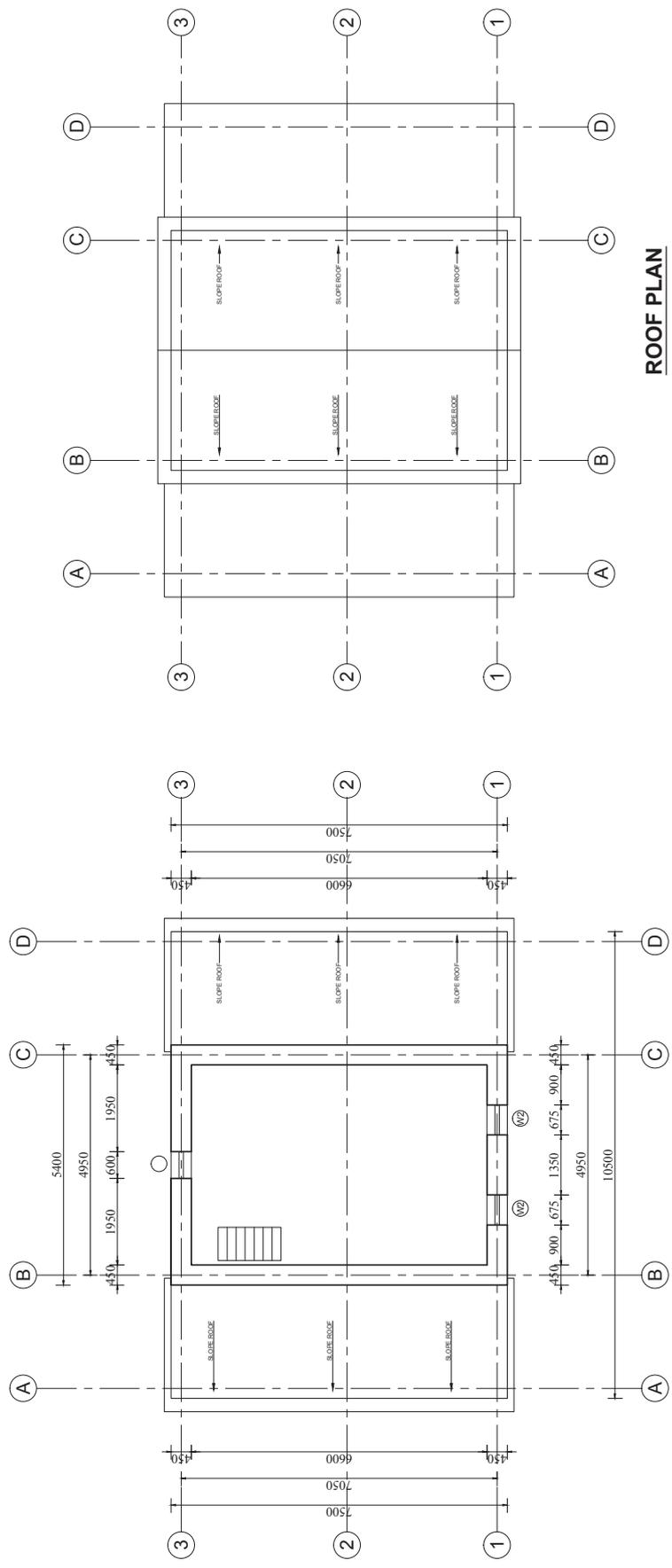
SHEET TITLE :- COVER PAGE  
SCALE :- N/A  
DATE :- JULY, 2017

PROJECT TITLE :-  
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING WITH G.I. WIRE MESH AND PP BAND



**FIRST FLOOR PLAN**

**GROUND FLOOR PLAN**

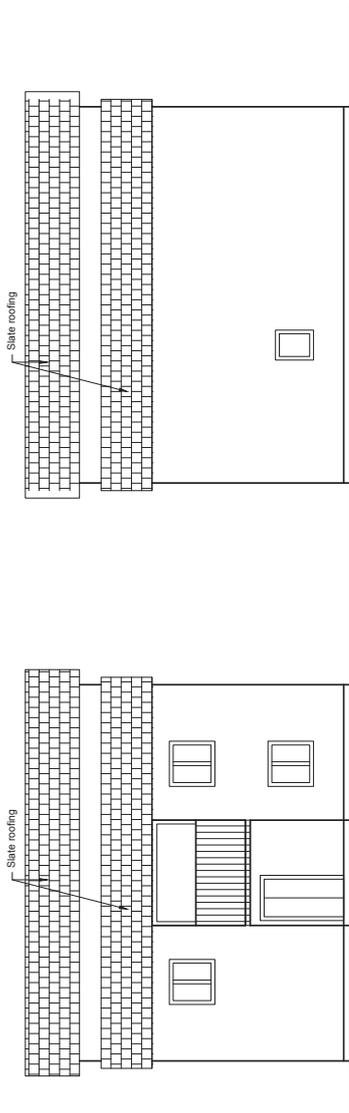


**ROOF PLAN**

**SECOND FLOOR PLAN**

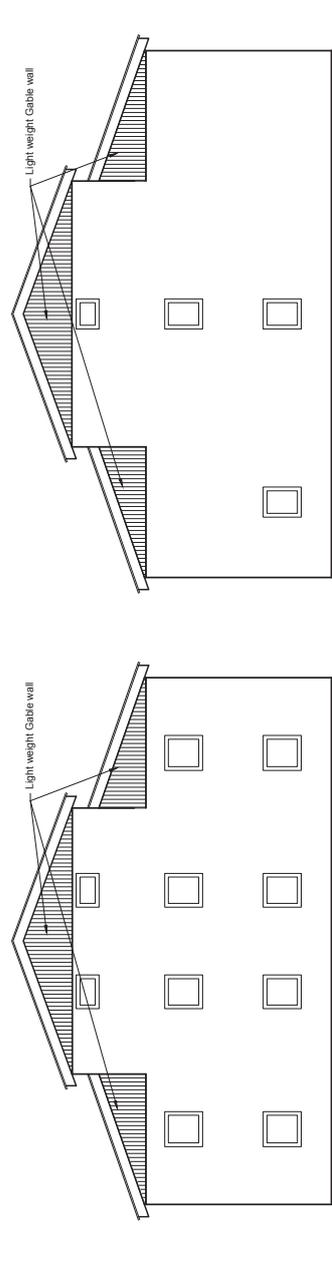
SHEET TITLE :- **FLOOR PLANS OF EXISTING BUILDING**  
 SCALE :- 1:100 FOR A3 PAPER  
 DATE :- JULY, 2017

PROJECT TITLE :- **STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH GI WIRE MESH AND PP BAND**



**ELEVATION-3**

**ELEVATION-1**



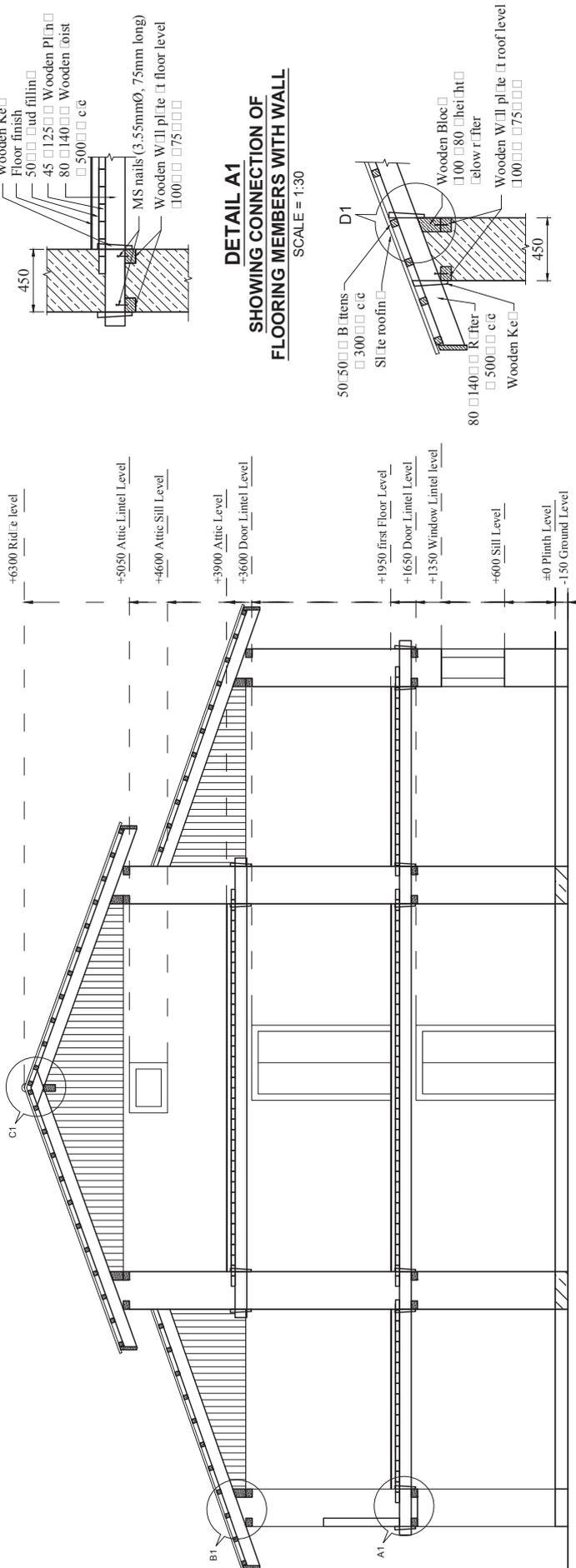
**ELEVATION-4**

**ELEVATION-2**

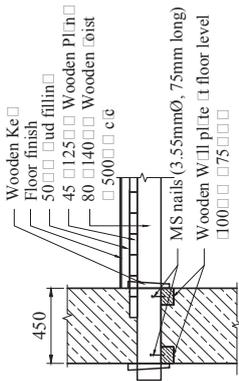
03

SHEET TITLE :- ELEVATIONS OF EXISTING BUILDING  
DATE :- JULY, 2017

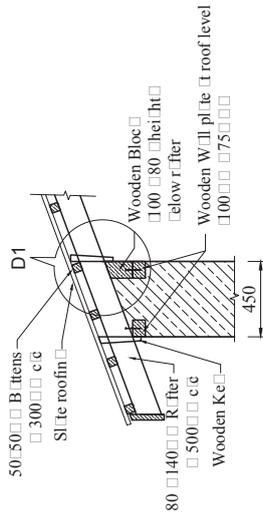
PROJECT TITLE :- STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH GI WIRE MESH AND PP BAND  
SCALE :- 1:100 FOR A3 PAPER



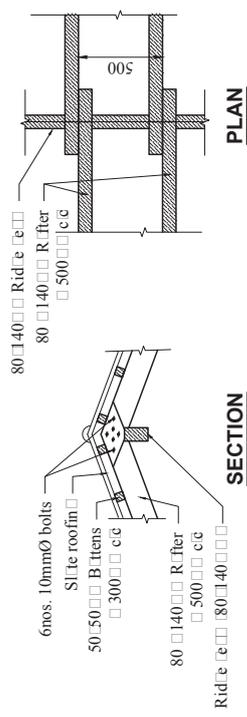
**SECTION AT X-X**  
SCALE = 1:50



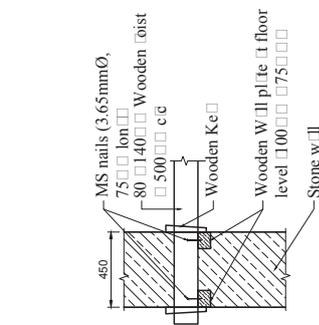
**DETAIL A1**  
**SHOWING CONNECTION OF FLOORING MEMBERS WITH WALL**  
SCALE = 1:30



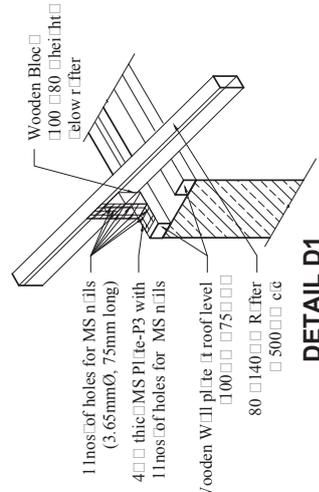
**DETAIL B1**  
**SHOWING CONNECTION OF ROOFING MEMBERS WITH WALL**  
SCALE = 1:30



**DETAIL C1**  
**SHOWING ROOF DETAILS AT RIDGE LEVEL**  
SCALE = 1:30



**FIXING OF JOISTS**  
SCALE = 1:30



**DETAIL D1**  
**SHOWING CONNECTION OF RAFTER WITH ROOF BAND**  
SCALE = 1:30

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH G.WIRE MESH AND PP BAND

SHEET TITLE :-

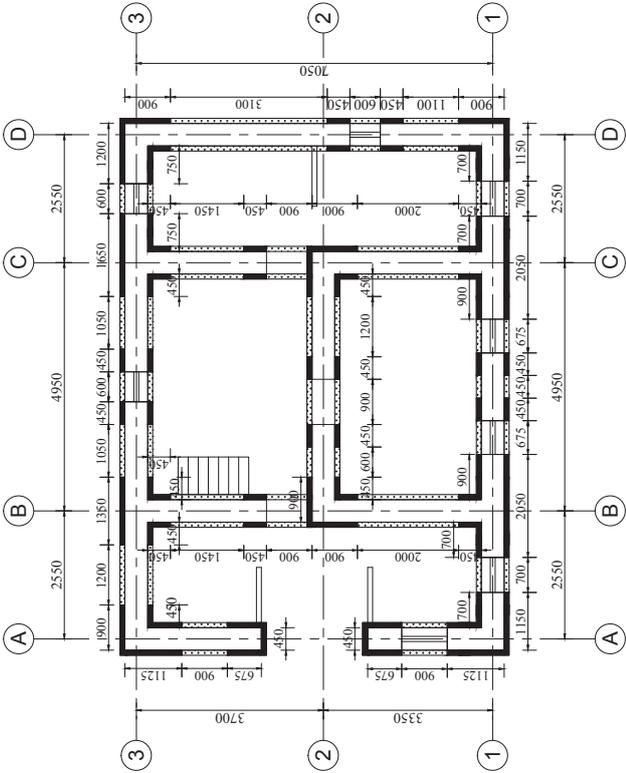
SECTION OF EXISTING BUILDING AND DETAILS

SCALE :- AS SHOWN FOR AS PAPER

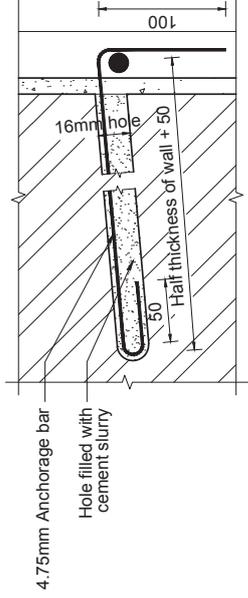
DATE :- JULY, 2017

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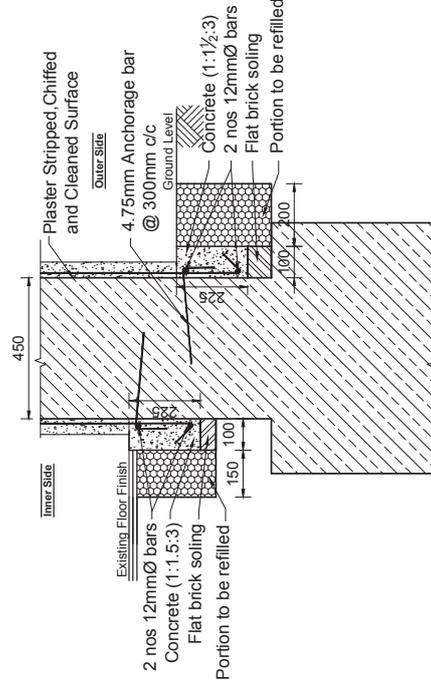
-  Tie beam for Splint of 450mm width on walls using G.I. welded wiremesh of 14SWG (2.03mm Ø) and size 25x25mm.
-  Tie beam for Jacketing on remaining walls using 10mm wide PP band @ 100mm c/c both horizontally and vertically



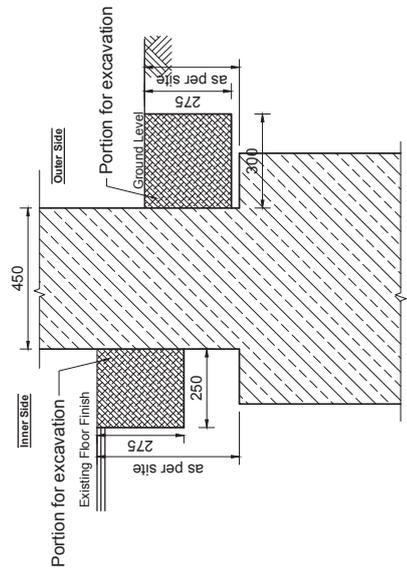
**GROUND FLOOR PLAN SHOWING TIE BEAM FOR SPLINT AND JACKETING**  
SCALE = 1:100



**4.75 MM ANCHORAGE BAR DETAILS**  
SCALE 1:4



**DETAILS OF TIE BEAM FOR INNER AND OUTER SIDE OF THE WALL**  
SCALE = 1:16



**SECTION SHOWING THE PORTION TO BE EXCAVATED FOR TIE BEAM**  
SCALE = 1:16

SHEET TITLE :-

TIE BEAM AND DETAILS

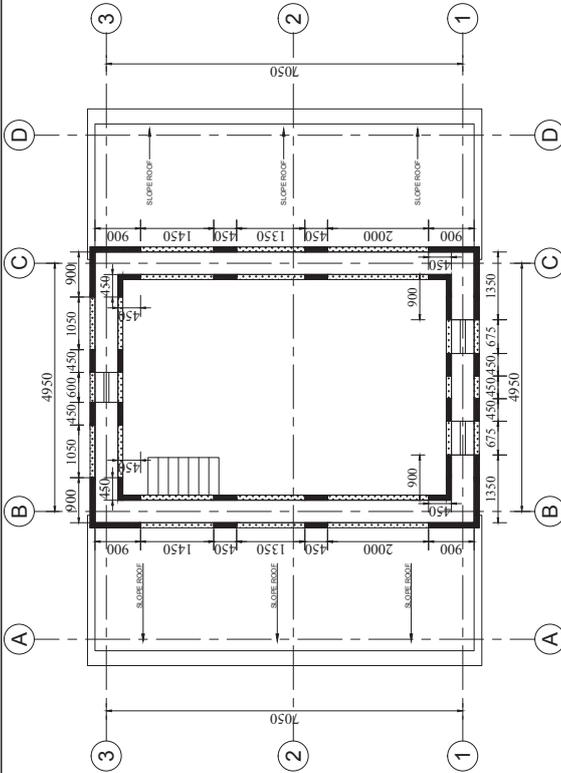
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH G.I. WIRE MESH AND PP BAND

SCALE :- AS SHOWN FOR A3 PAPER

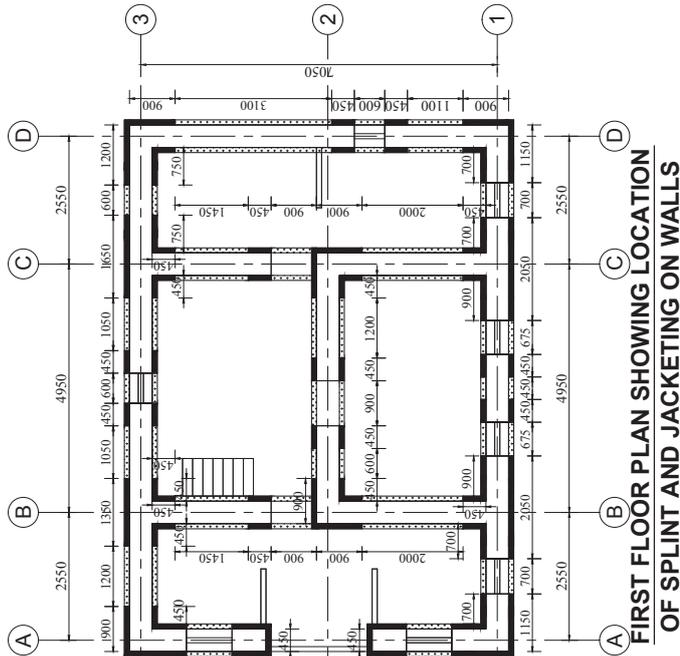
DATE :- JULY, 2017

**Notes:**

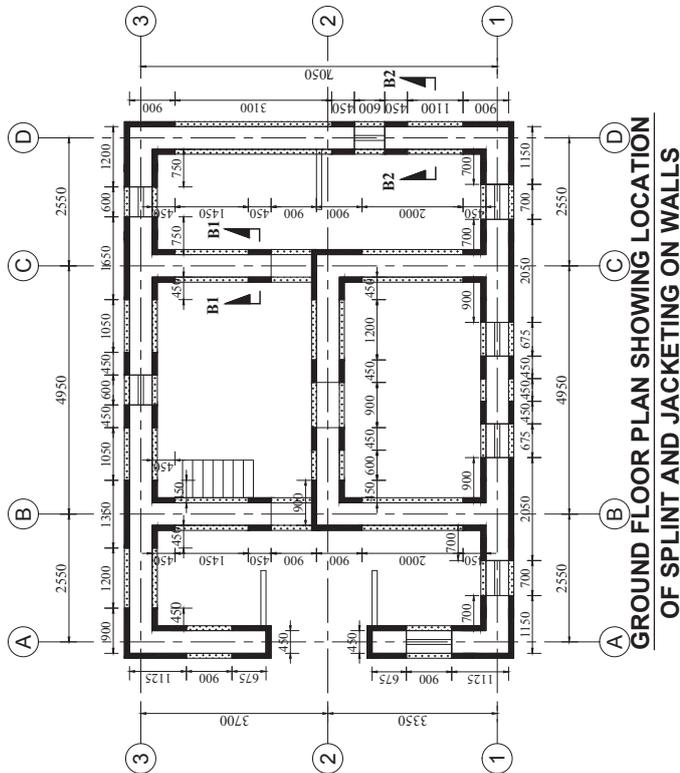
- Splint of 450mm width on walls using G.I. welded wiremesh of 14SWG (2.03mm Ø) and size 25x25mm.
- Jacketing on remaining walls using 10mm wide PP band @ 100mm c/c both horizontally and vertically



**SECOND FLOOR PLAN SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS**



**FIRST FLOOR PLAN SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS**

SHEET TITLE :-

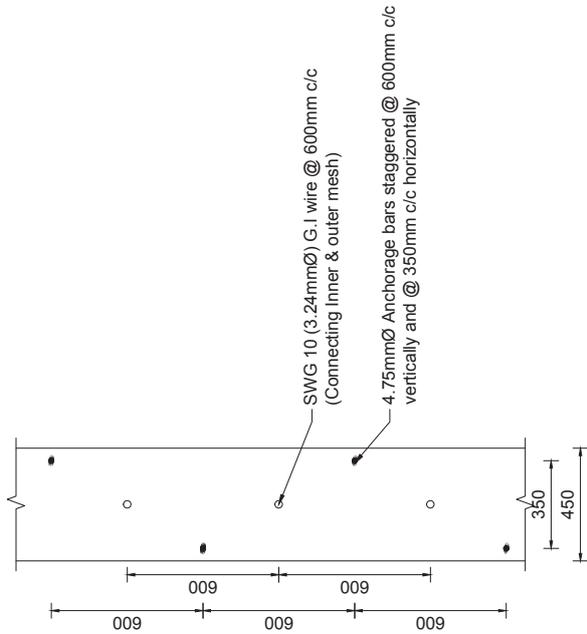
FLOOR PLANS SHOWING LOCATION OF SPLINT AND JACKETING ON WALLS

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

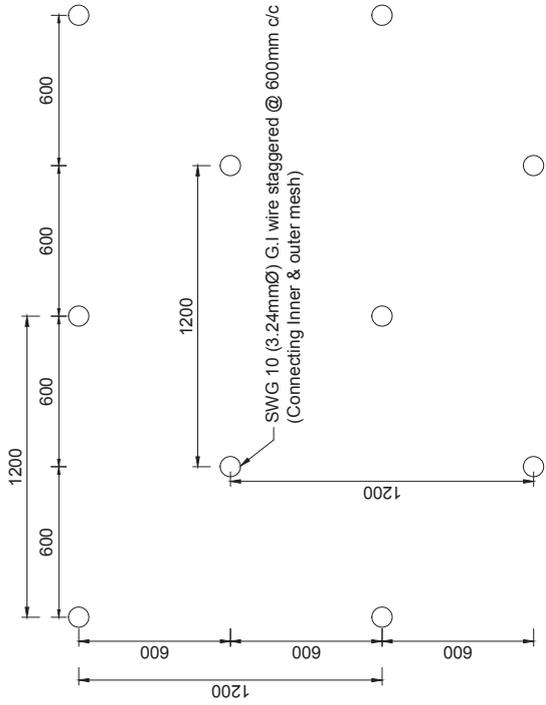
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH GI WIRE MESH AND PP BAND**





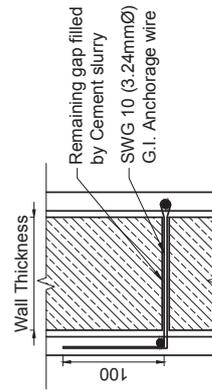
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING SPLINT BANDS ON BOTH SIDES OF WALLS**

SCALE 1:20



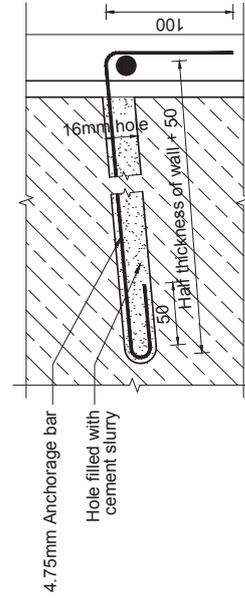
**LAYOUT OF G.I. WIRE ANCHORAGE FOR CONNECTING JACKETING MESH ON BOTH SIDES OF WALL**

SCALE 1:20



**G.I. WIRE DETAILS**

SCALE 1:10



**ANCHORAGE BAR DETAILS**

SCALE 1:4

PROJECT TITLE :-

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH G.I. WIRE MESH AND PP BAND**

SHEET TITLE :-

**DETAILS OF SPLINT AND JACKETING**

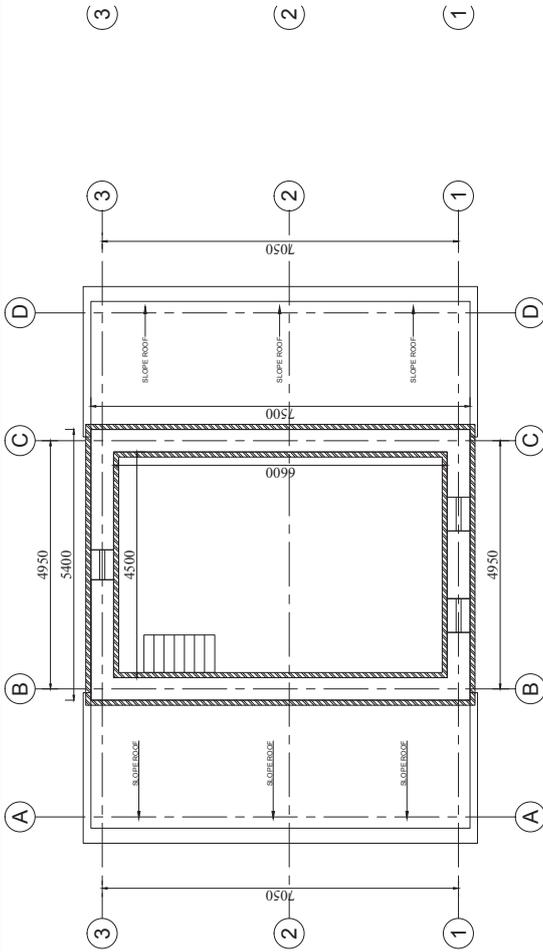
**08**

SCALE :- 1:20, 1:10 FOR AS PAPER

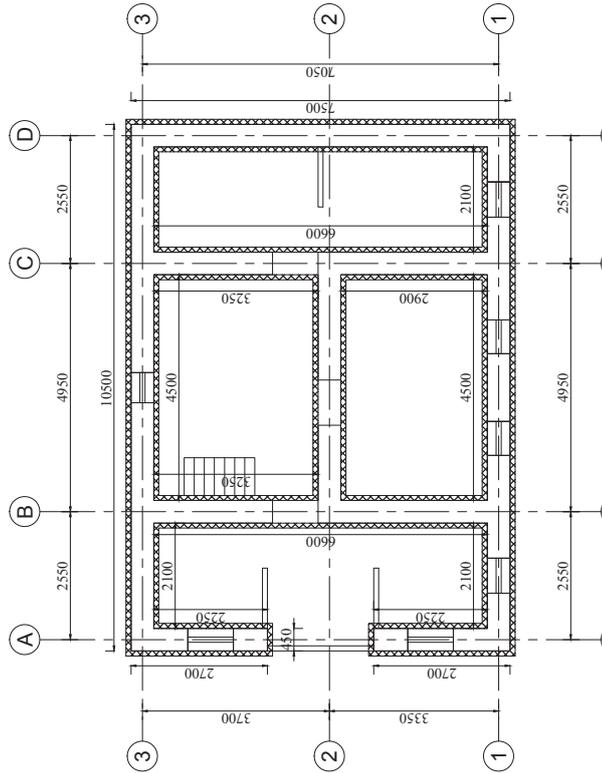
DATE :- JULY, 2017

**Notes:**

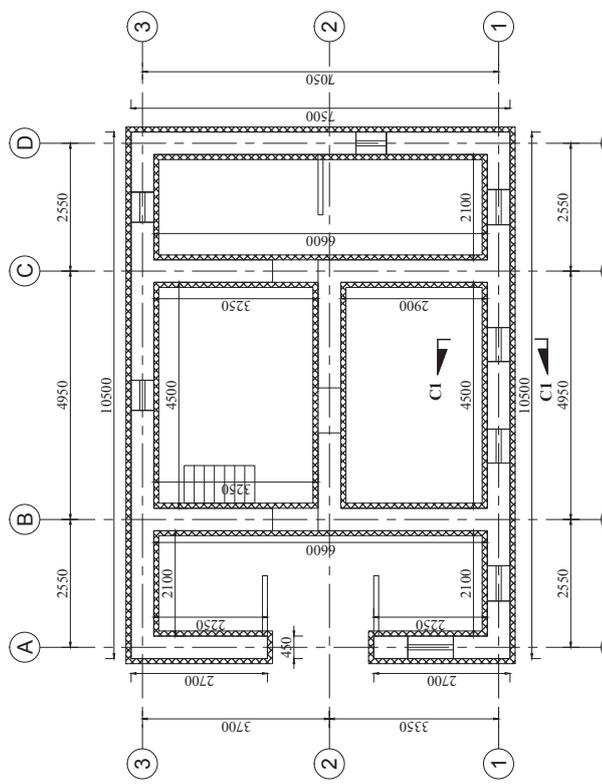
- Horizontal Bands with G.I. wire mesh of 12SWG (2.64mmØ) and size 25x25mm at Sill and Lintel level.
- A layer of cement slurry with bonding chemical (brick wall with plaster) shall be applied in wall after erecting wire mesh for horizontal bandage.
- Apply plaster of 20mm thick on internal wall over Galvanised wire mesh with cement sand mix (1:3)



**SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**FIRST FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**

SHEET TITLE :-

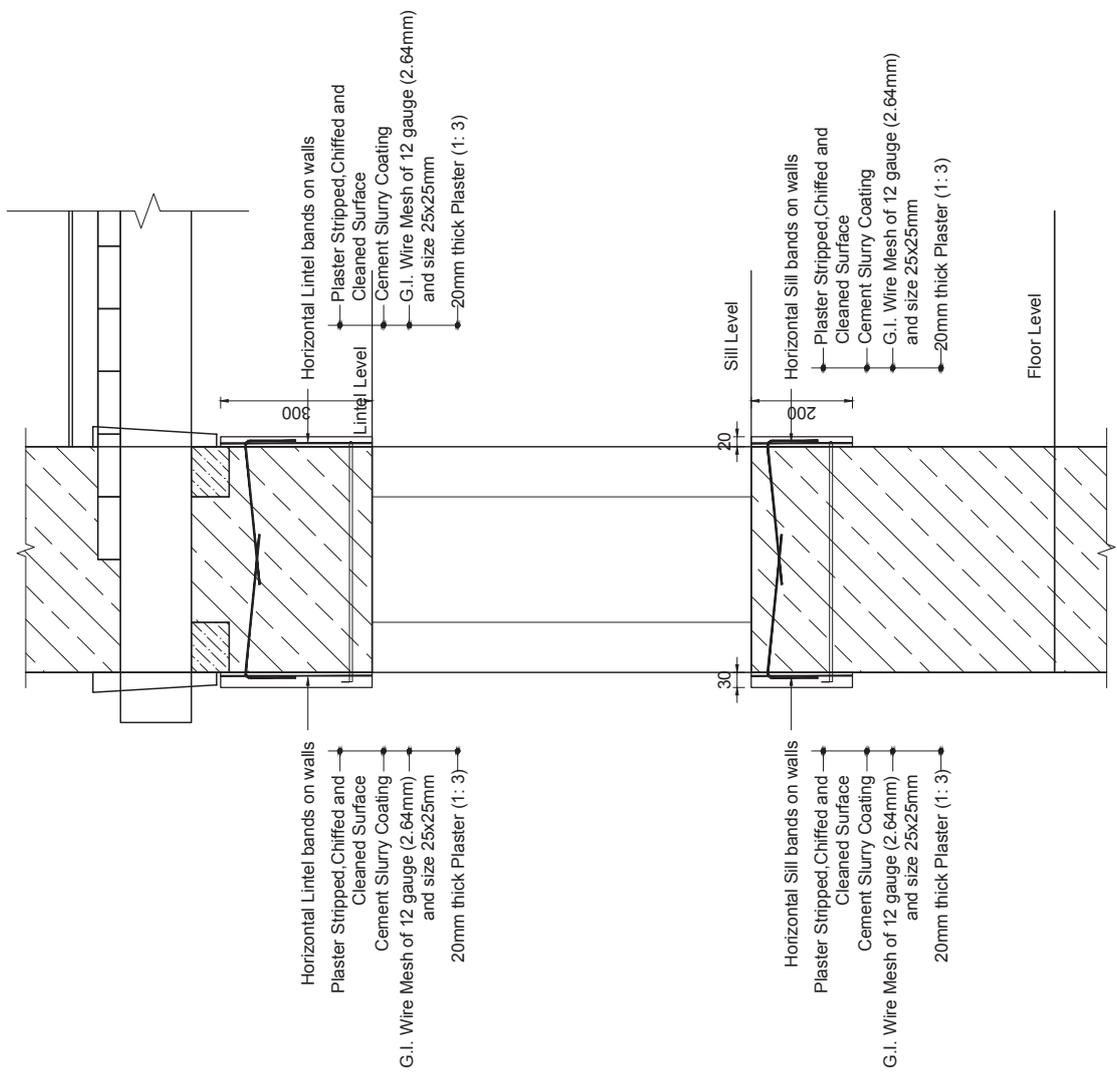
FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL BANDAGES AT FLOOR AND SILL LEVEL

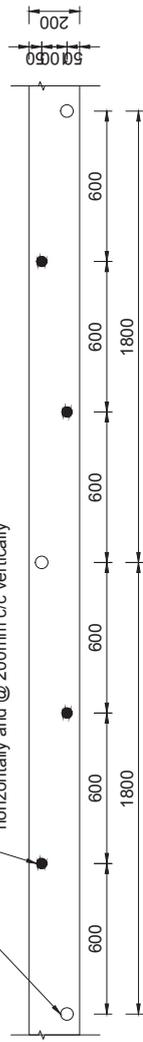
SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

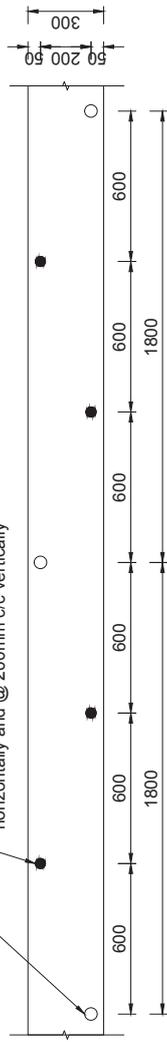
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH G.I. WIRE MESH AND PP BAND**

**SECTION AT C1-C1**  
 (DETAILS OF HORIZONTAL BANDAGES ON BOTH SURFACES OF WALLS)  
 SCALE = 1:10

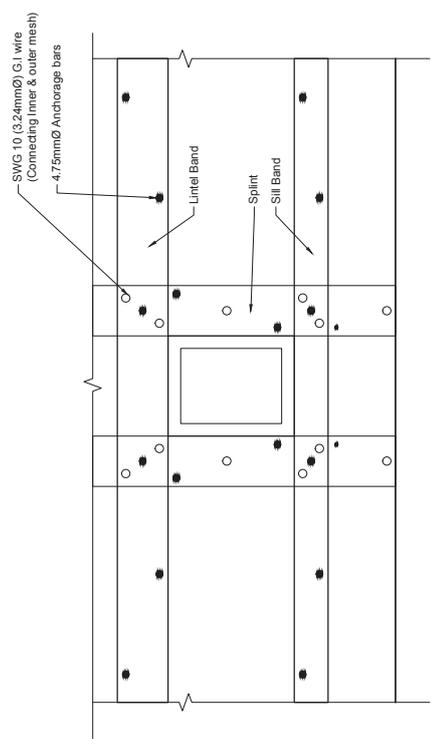




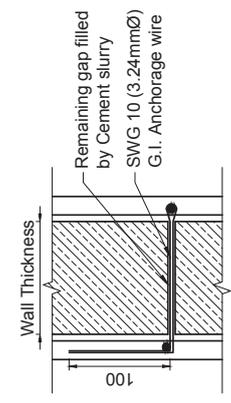
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT SILL LEVEL ON BOTH SIDES OF WALL**  
SCALE = 1:20



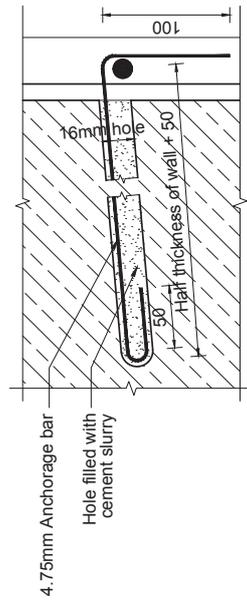
**LAYOUT OF ANCHORAGE BARS FOR CONNECTING HORIZONTAL BANDAGES AT FLOOR LEVEL ON BOTH SIDES OF WALL**  
SCALE = 1:20



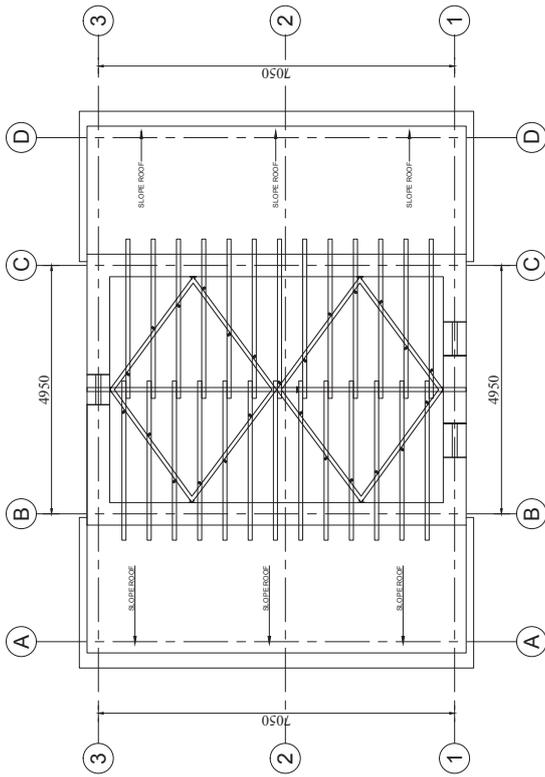
**TYPICAL LAYOUT OF ANCHORAGE FOR CONNECTING SPLINT AND HORIZONTAL BANDAGE ON BOTH SIDES OF WALLS**  
SCALE 1:30



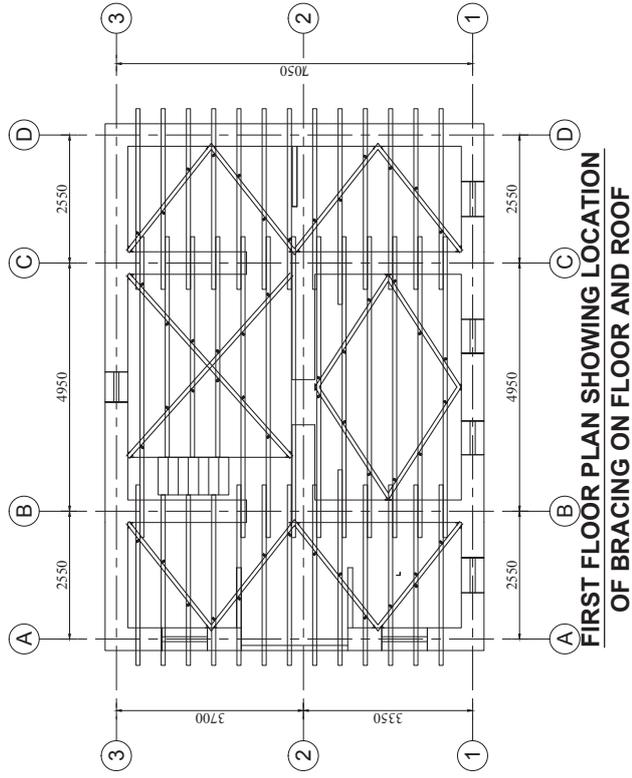
**G.I. WIRE DETAILS**  
SCALE 1:10



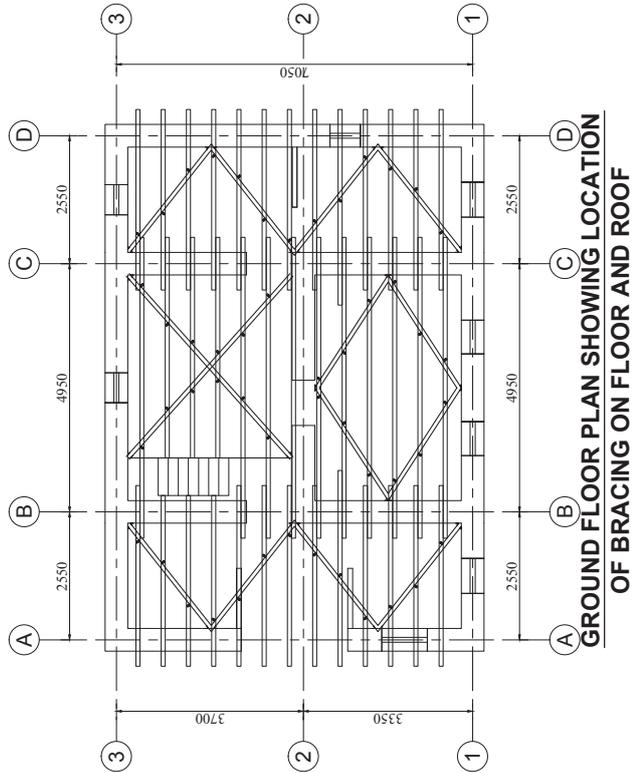
**ANCHORAGE BAR DETAILS**  
SCALE 1:4



**SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



**FIRST FLOOR PLAN SHOWING LOCATION OF BRACING ON FLOOR AND ROOF**



**GROUND FLOOR PLAN SHOWING LOCATION OF BRACING ON FLOOR AND ROOF**

SHEET TITLE :-

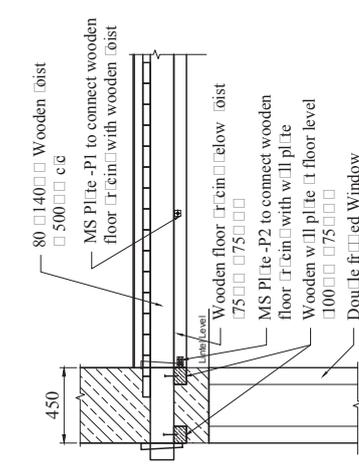
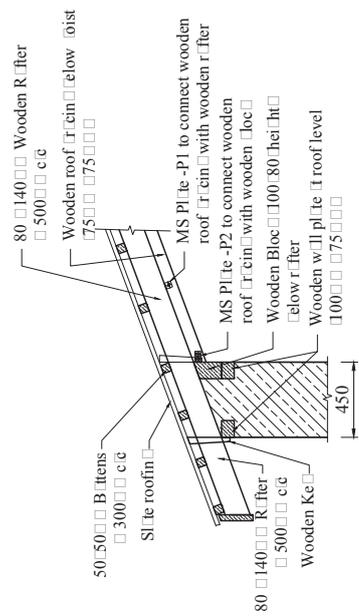
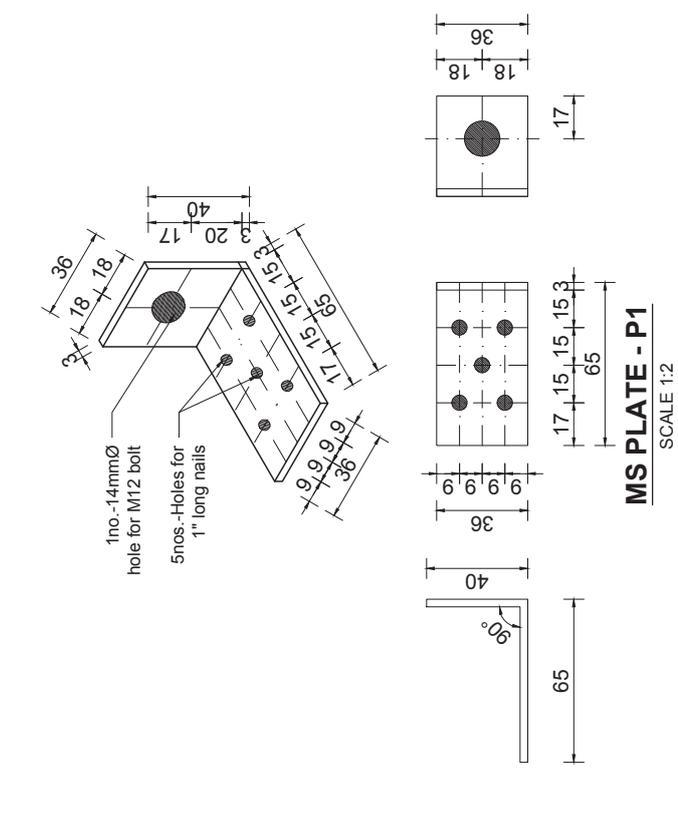
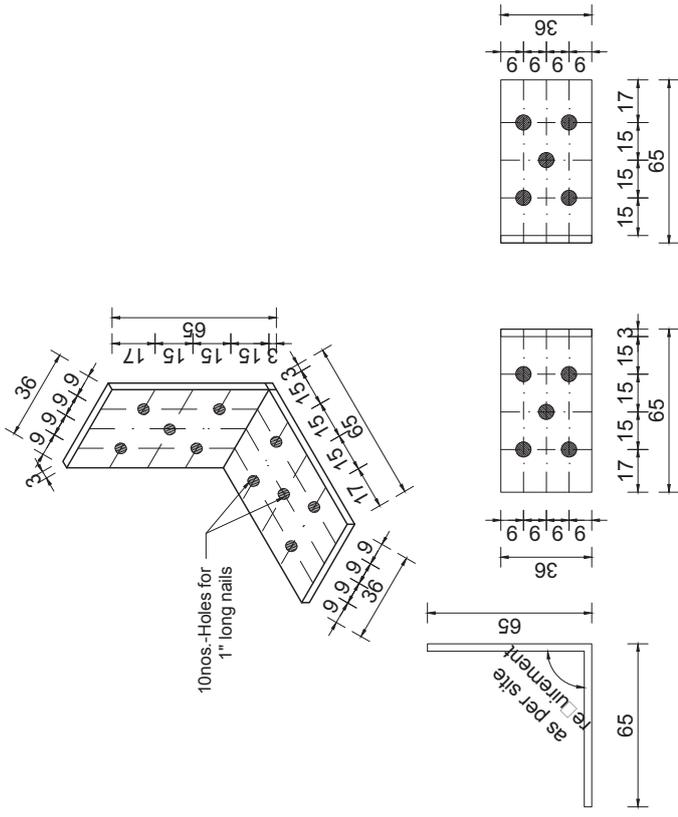
FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH GI WIRE MESH AND PP BAND

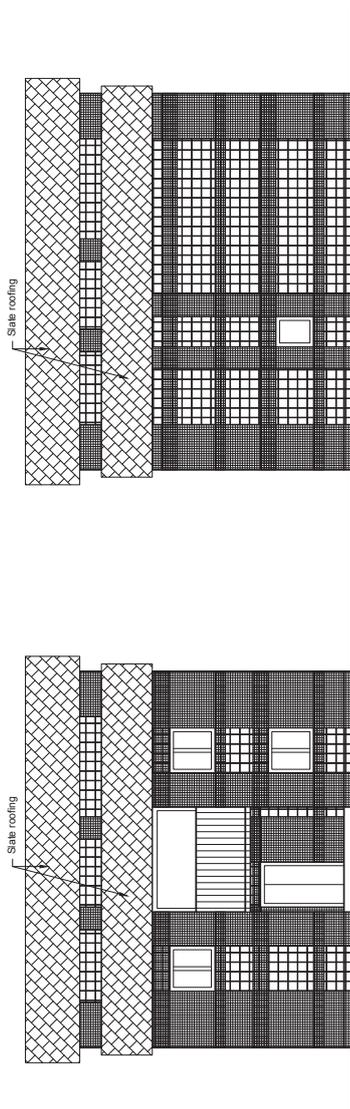


PROJECT TITLE :- FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL

DATE :- JULY, 2017

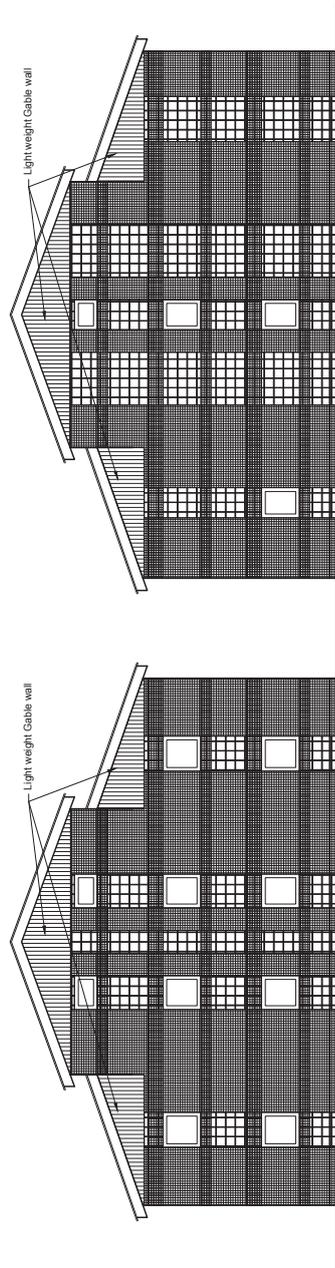
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING WITH GI WIRE MESH AND PP BAND

SCALE :- 1:30, 1:2 FOR A3 PAPER



ELEVATION-1

ELEVATION-3



ELEVATION-2

ELEVATION-4

SHEET TITLE :-

ELEVATIONS OF EXISTING BUILDING AFTER RETROFIT

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

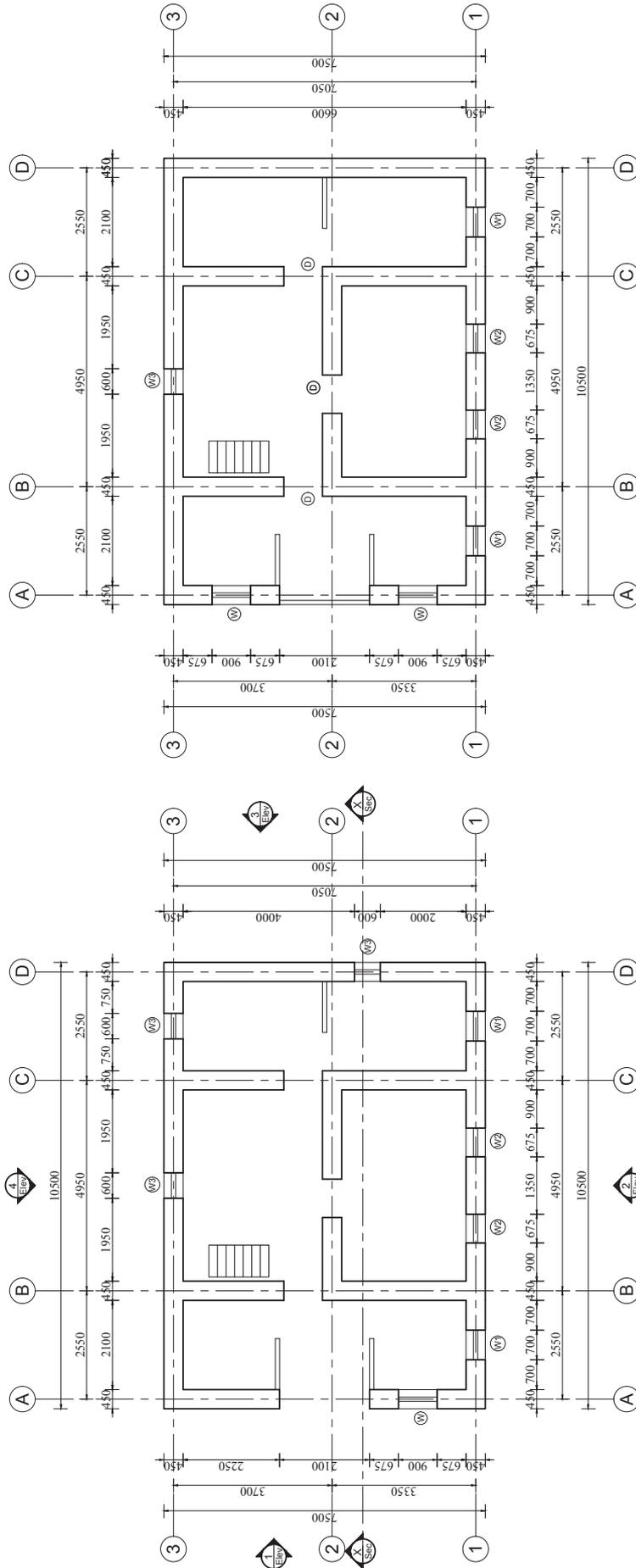
PROJECT TITLE :-  
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING WITH GI WIRE MESH AND PP BAND

**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN ON  
TWO STOREY STONE MASONRY BUILDING IN MUD  
USING TIMBER AND G.I. WIREMESH**

0

SHEET TITLE :- COVER PAGE  
DATE :- JULY, 2017  
SCALE :- N/A

PROJECT TITLE :-  
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH



**FIRST FLOOR PLAN**

**GROUND FLOOR PLAN**

SHEET TITLE :-

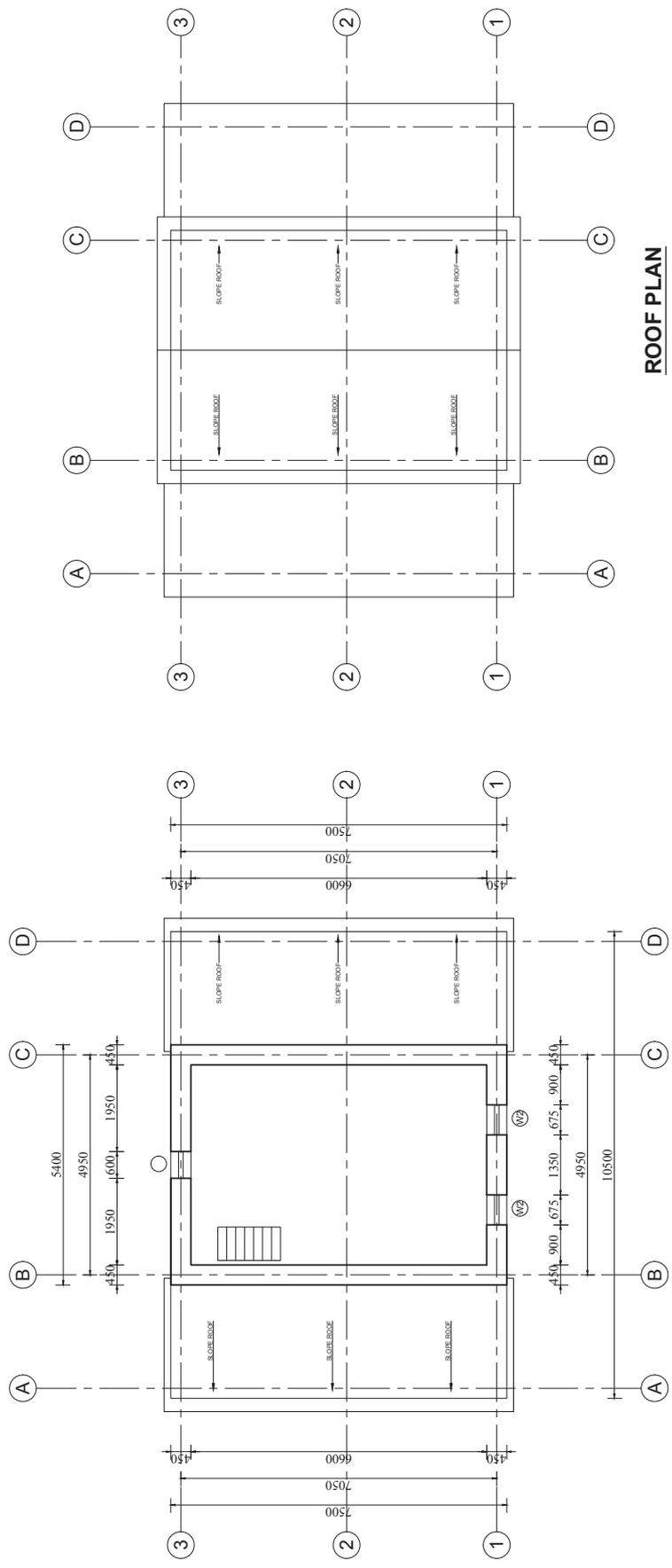
FLOOR PLANS OF EXISTING BUILDING

SCALE :- 1:100 FOR A3 PAPER

DATE :- JULY, 2017

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH

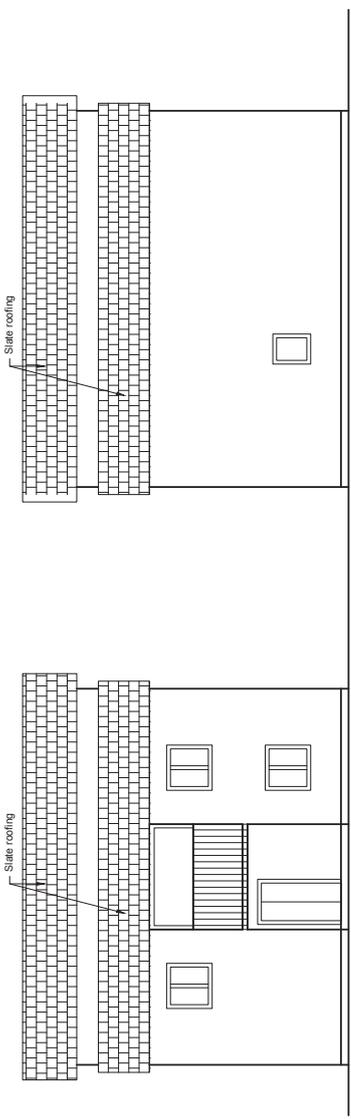


**ROOF PLAN**

**SECOND FLOOR PLAN**

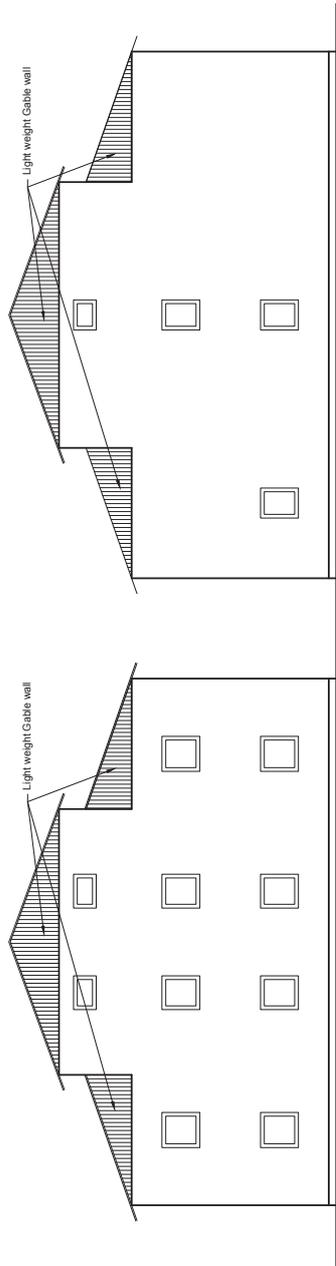
SHEET TITLE :-  
**FLOOR PLANS OF EXISTING BUILDING**  
 SCALE :- 1:100 FOR A3 PAPER  
 DATE :- JULY, 2017

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
 STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH**



**ELEVATION-3**

**ELEVATION-1**

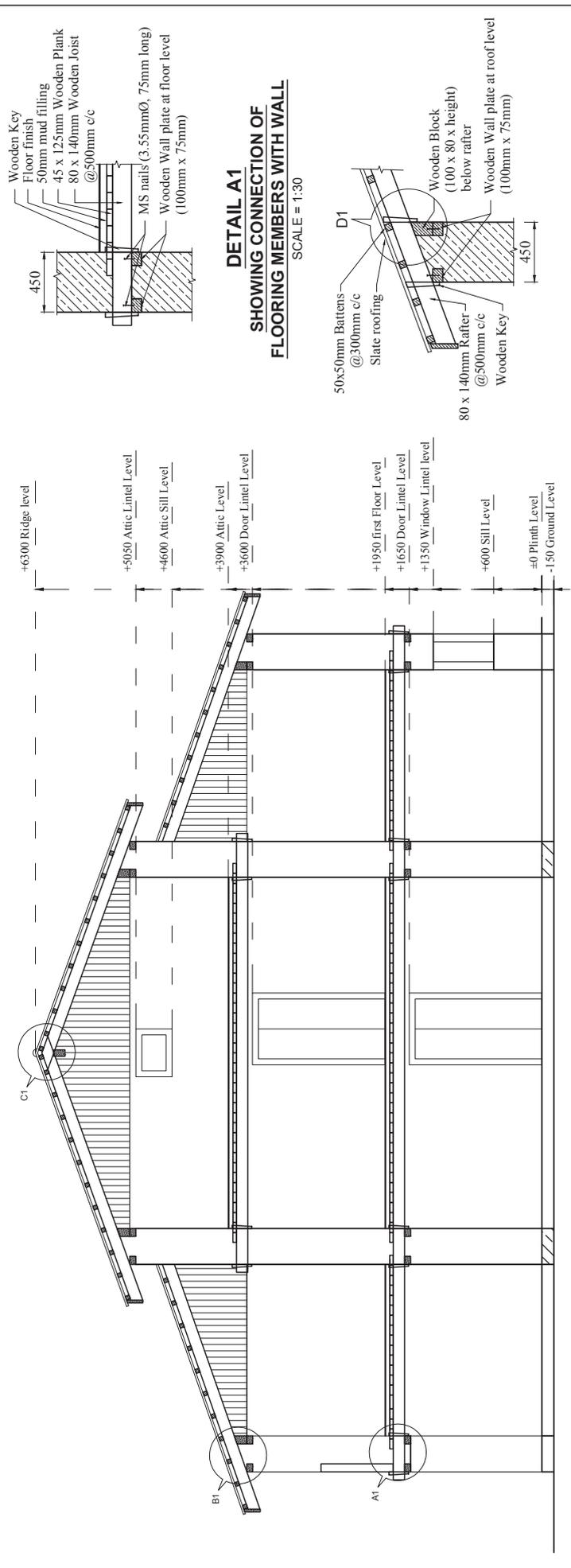


**ELEVATION-4**

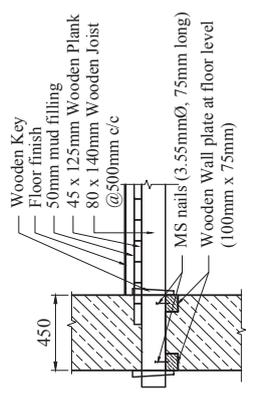
**ELEVATION-2**

SHEET TITLE :-  
**ELEVATIONS OF EXISTING BUILDING**  
SCALE :- 1:100 FOR A3 PAPER  
DATE :- JULY, 2017

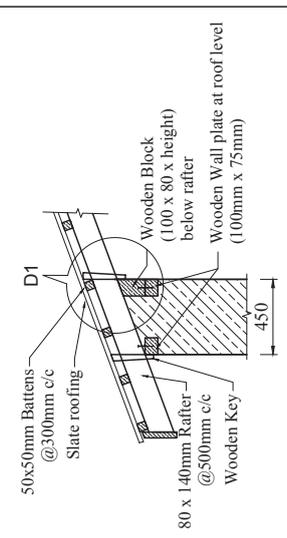
PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW  
STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH**



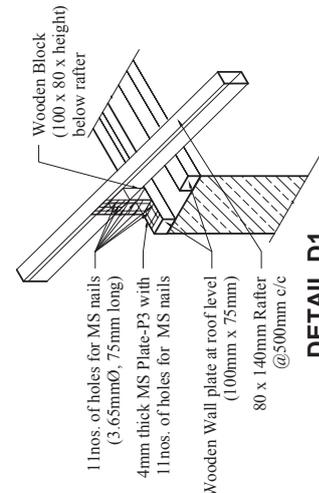
**SECTION AT X-X**  
SCALE = 1:50



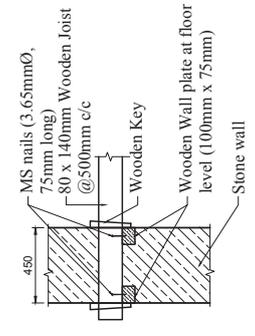
**DETAIL A1**  
**SHOWING CONNECTION OF FLOORING MEMBERS WITH WALL**  
SCALE = 1:30



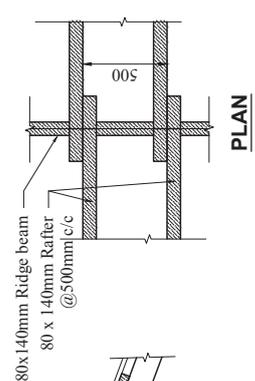
**DETAIL B1**  
**SHOWING CONNECTION OF ROOFING MEMBERS WITH WALL**  
SCALE = 1:30



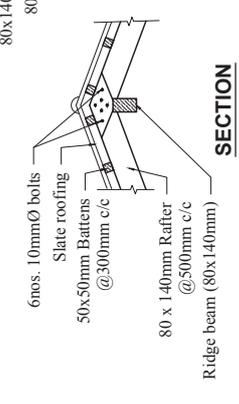
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**SHOWING CONNECTION OF RAFTER WITH ROOF BAND**  
SCALE = 1:30



**FIXING OF JOISTS**  
SCALE = 1:30



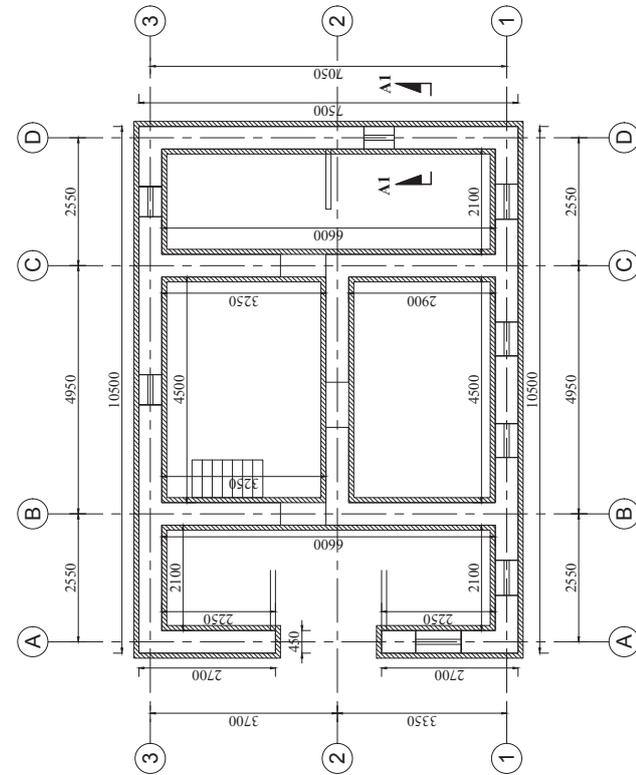
**DETAIL C1**  
**SHOWING ROOF DETAILS AT RIDGE LEVEL**  
SCALE = 1:30



**SECTION**

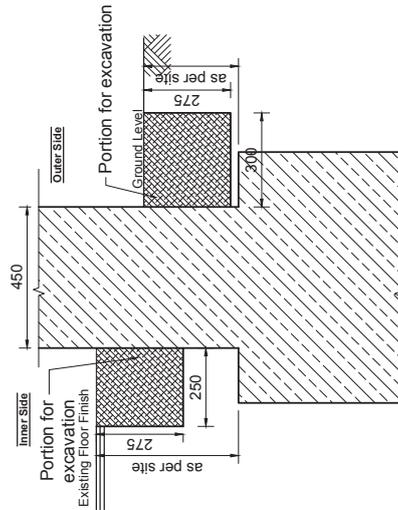
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**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH**

SHEET TITLE :-  
**SECTION OF EXISTING BUILDING AND DETAILS**  
SCALE :- AS SHOWN FOR A3 PAPER  
DATE :- JULY, 2017



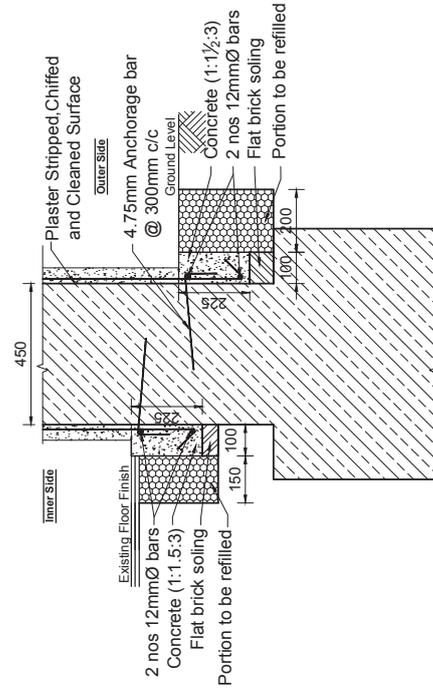
**GROUND FLOOR PLAN SHOWING TIE BEAM FOR G.I. WIRE JACKETING**  
SCALE = 1:100

**SECTION SHOWING THE PORTION TO BE EXCAVATED FOR TIE BEAM**  
SCALE = 1:16



SCALE = 1:16

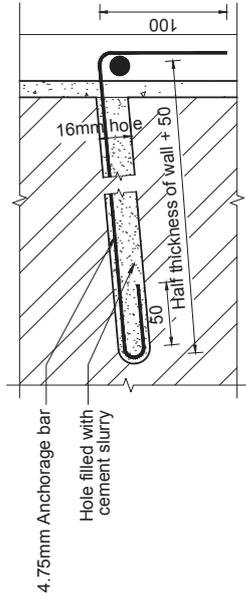
**SECTION AT A1-A1 SHOWING DETAILS OF TIE BEAM (FOR G.I. WIREMESH) FOR INNER AND OUTER SIDE OF THE WALL**  
SCALE = 1:16



SCALE = 1:16

**Notes:**

Tie beam for Jacketing on walls using G.I. wire of 12SWG (2.64mm Ø) @ 150mm c/c both horizontally and vertically



**4.75 MM ANCHORAGE BAR DETAILS**  
SCALE 1:4

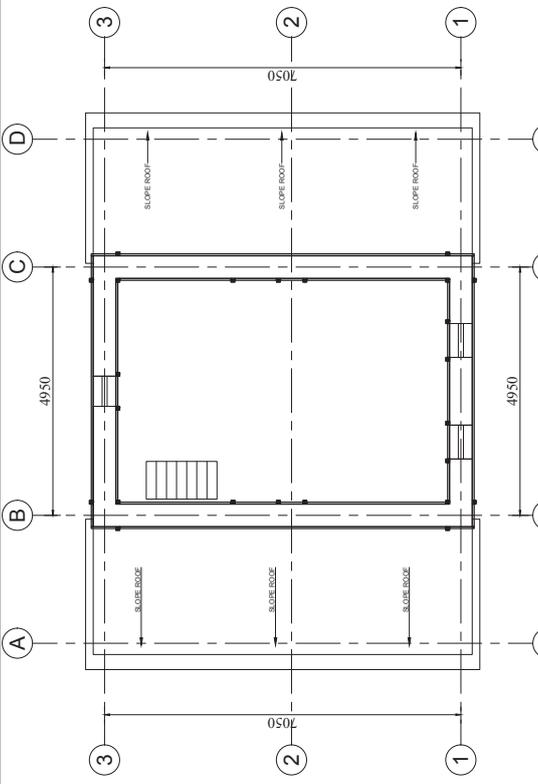
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**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH**

SHEET TITLE :-  
**TIE BEAM AND DETAILS**

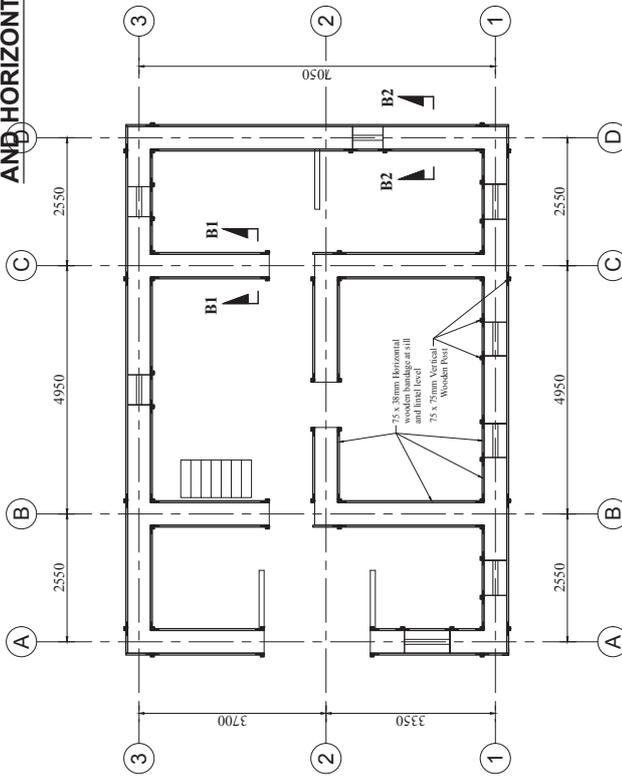
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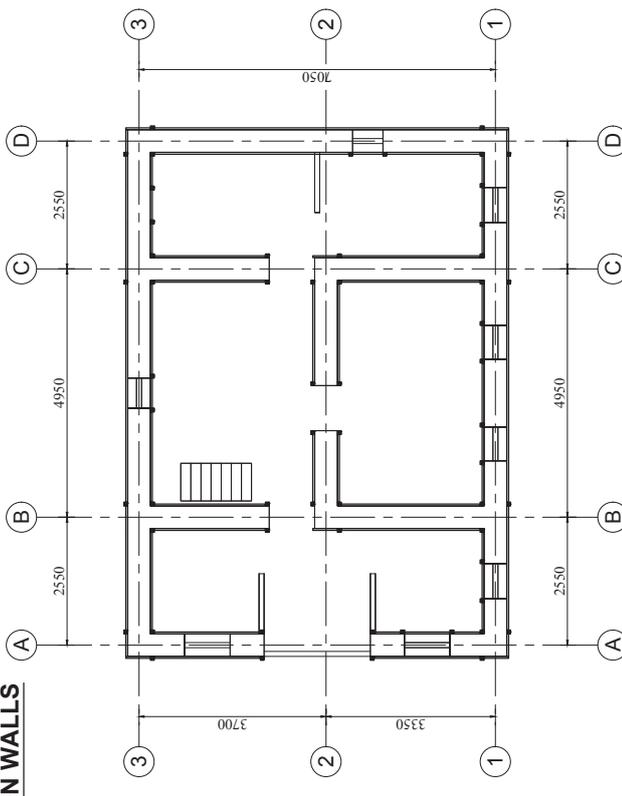
- Notes:**
-  Wooden Vertical Posts (75mm x 75mm)
  -  Jacketing on walls using G.I. wire of 12SWG (2.64mm Ø) @ 150mm c/c both horizontally and vertically



**SECOND FLOOR PLAN SHOWING LOCATION OF VERTICAL POSTS AND HORIZONTAL BANDS ON WALLS**



**GROUND FLOOR PLAN SHOWING LOCATION OF VERTICAL POSTS AND HORIZONTAL BANDS ON WALLS**

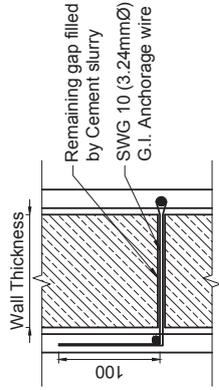


**FIRST FLOOR PLAN SHOWING LOCATION OF VERTICAL POSTS AND HORIZONTAL BANDS ON WALLS**

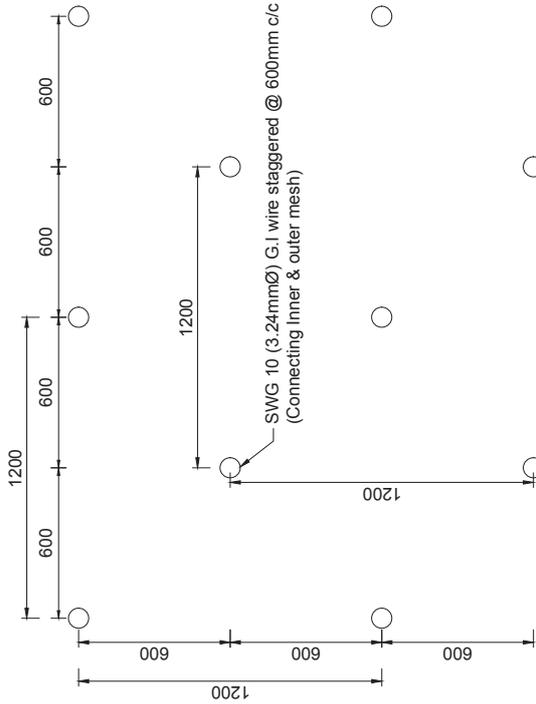
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SHEET TITLE :-  
**FLOOR PLANS SHOWING LOCATION OF WOODEN VERTICAL POSTS AND HORIZONTAL BANDAGE ON WALLS**

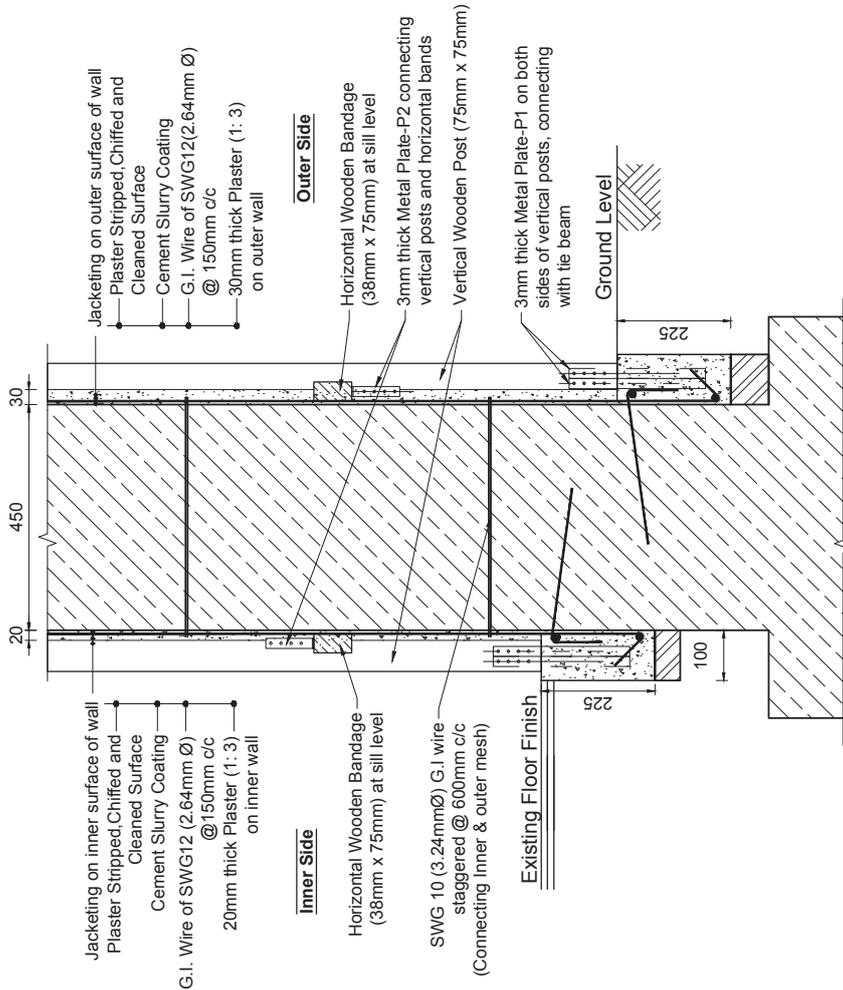
SCALE :- 1:100 FOR A3 PAPER  
 DATE :- JULY, 2017



**G.I. WIRE DETAILS**  
SCALE 1:10



**LAYOUT OF G.I. WIRE ANCHORAGE ON BOTH SIDES OF WALL**  
JACKETING MESH ON BOTH SIDES OF WALL  
SCALE 1:20



**SECTION AT B2-B2**  
(DETAILS OF JACKETING ON BOTH SURFACES OF PERIPHERAL WALLS)  
SCALE = 1:10

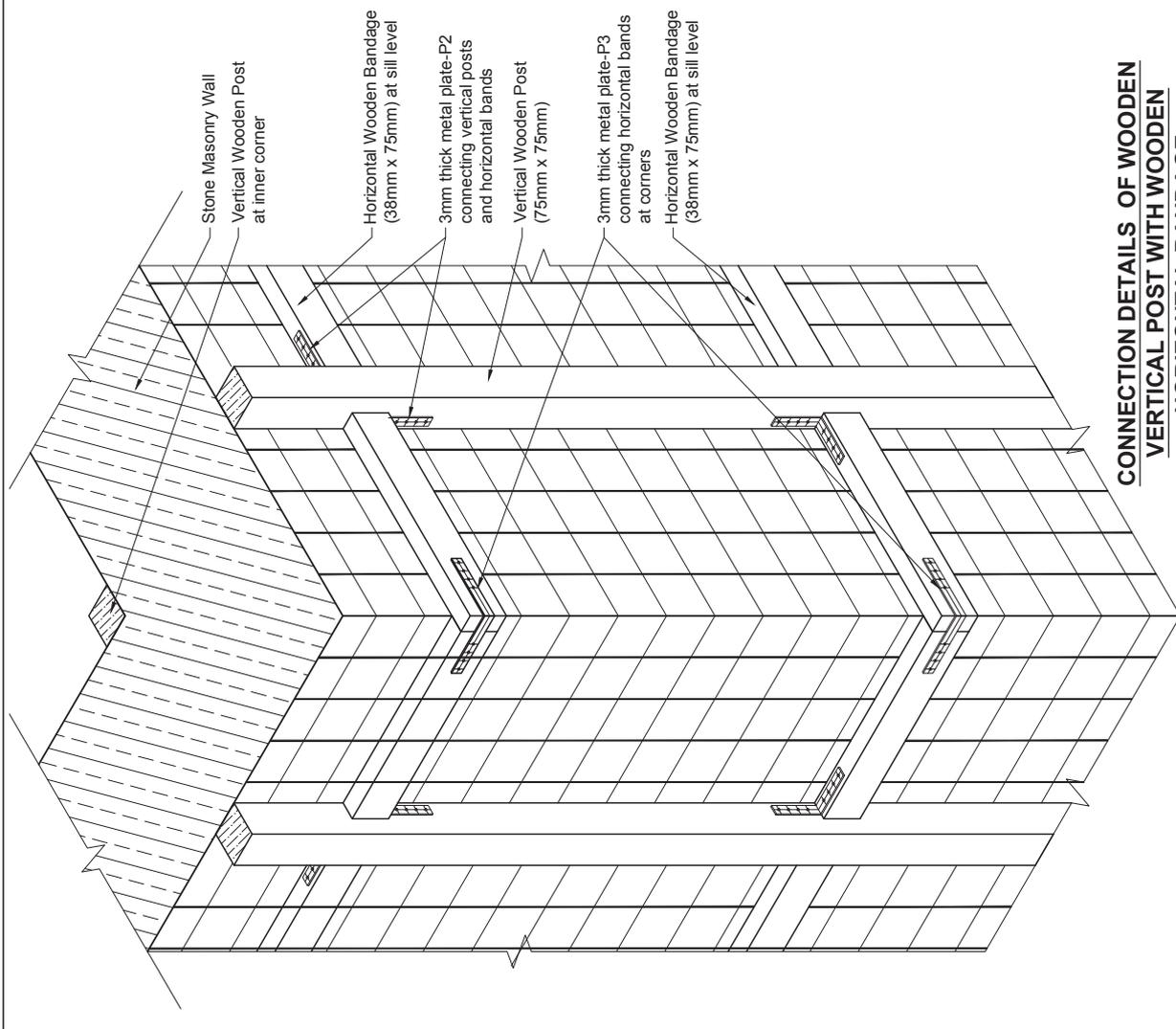
SHEET TITLE :-

DETAILS OF JACKETING ON WALLS

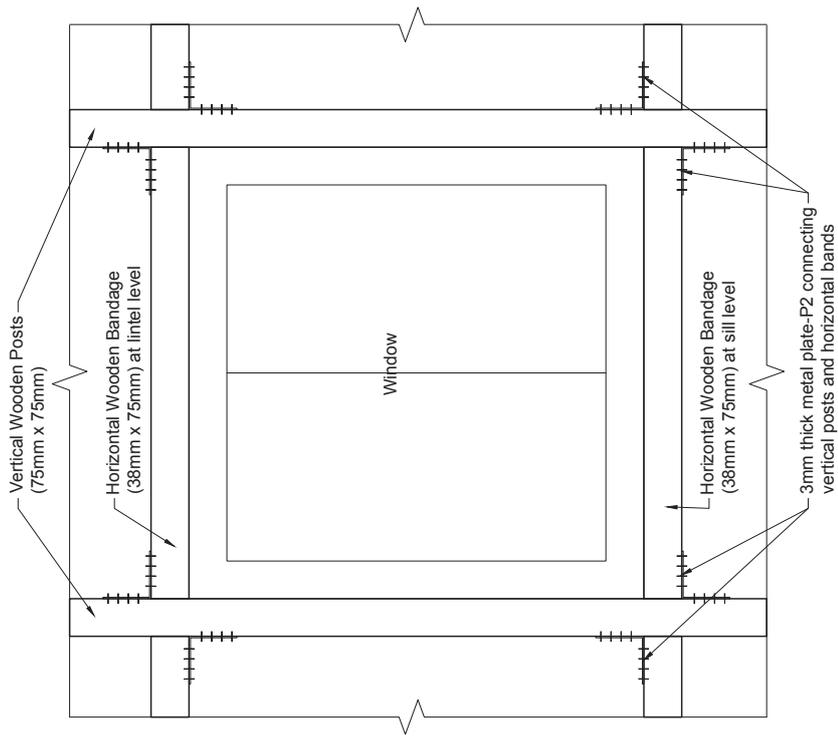
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DATE :- JULY, 2017

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH



**CONNECTION DETAILS OF WOODEN VERTICAL POST WITH WOODEN HORIZONTAL BANDAGE**  
SCALE 1:10



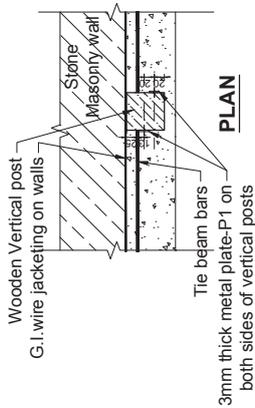
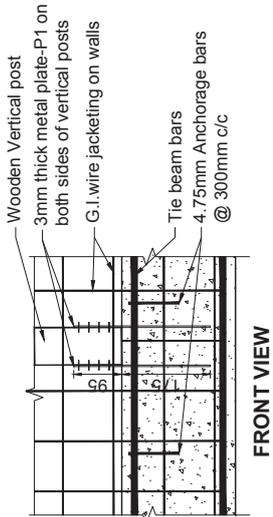
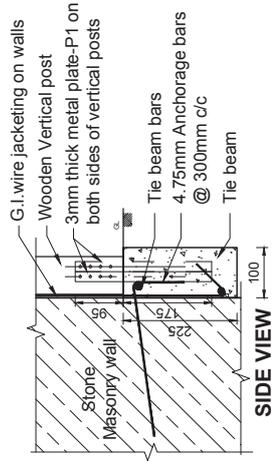
**CONNECTION DETAILS OF WOODEN VERTICAL POST WITH WOODEN HORIZONTAL BANDAGE**  
SCALE 1:10

PROJECT TITLE :-  
**STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH**

SHEET TITLE :-  
**DETAILS OF WOODEN VERTICAL POSTS AND HORIZONTAL BANDAGES**

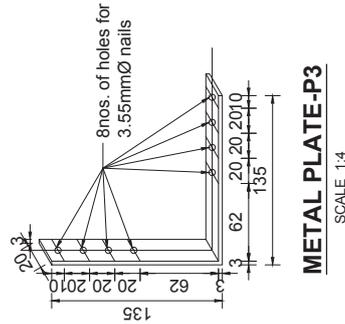
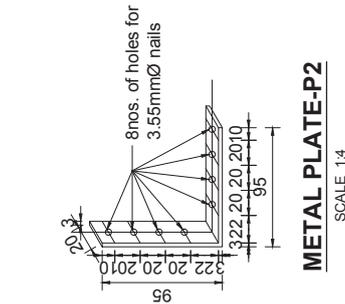
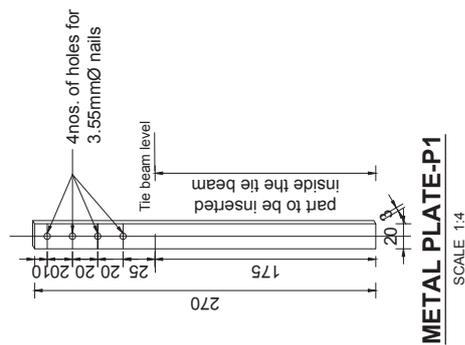
DATE :- JULY, 2017

SCALE :- 1:10 FOR A3 PAPER



**CONNECTION DETAILS OF WOODEN VERTICAL POST WITH TIE BEAM**

SCALE 1:10

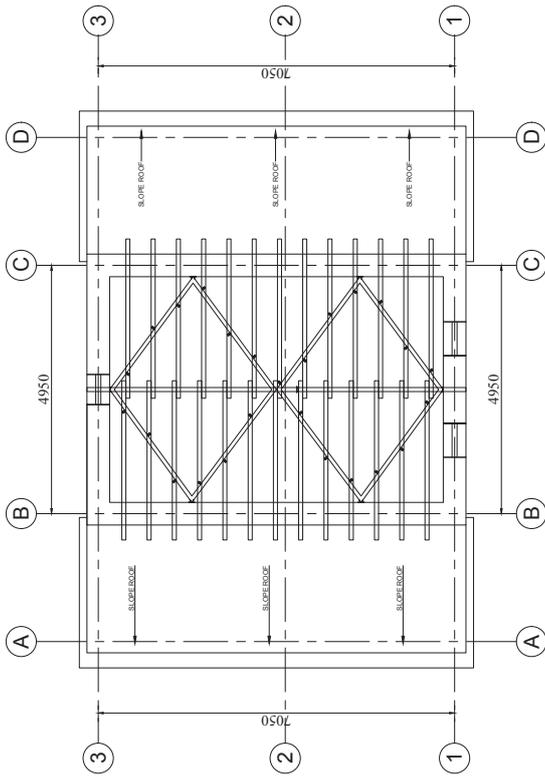


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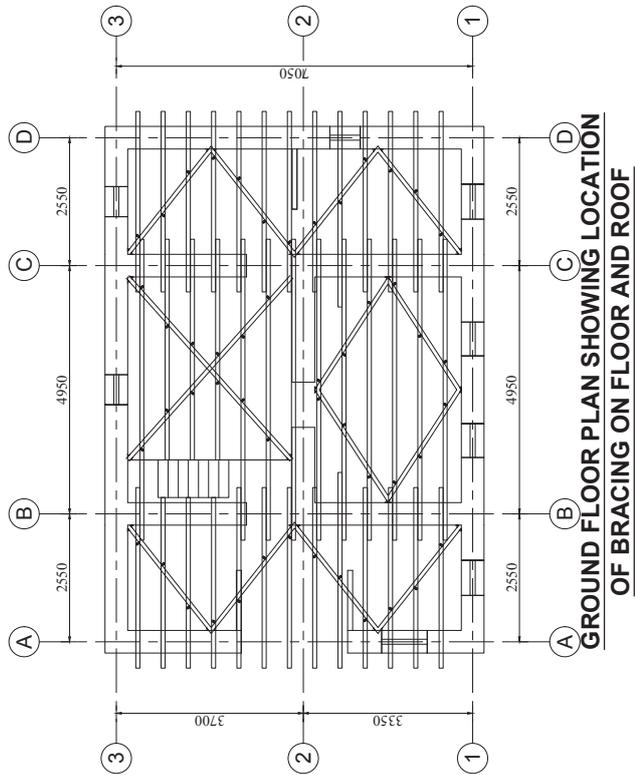
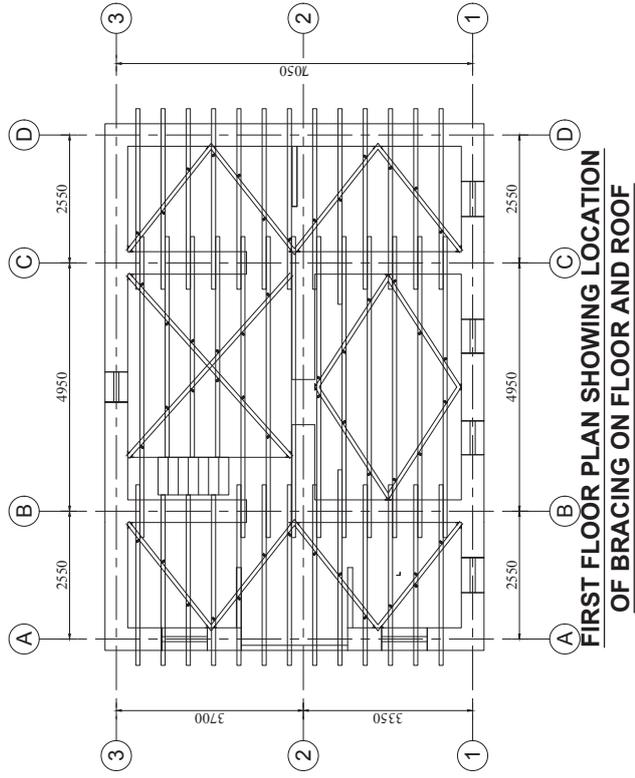
SCALE :- 1:10, 1:4 FOR A3 PAPER

DATE :- JULY, 2007

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH



**SECOND FLOOR PLAN SHOWING LOCATION OF HORIZONTAL BANDAGE ON WALLS**



SHEET TITLE :-

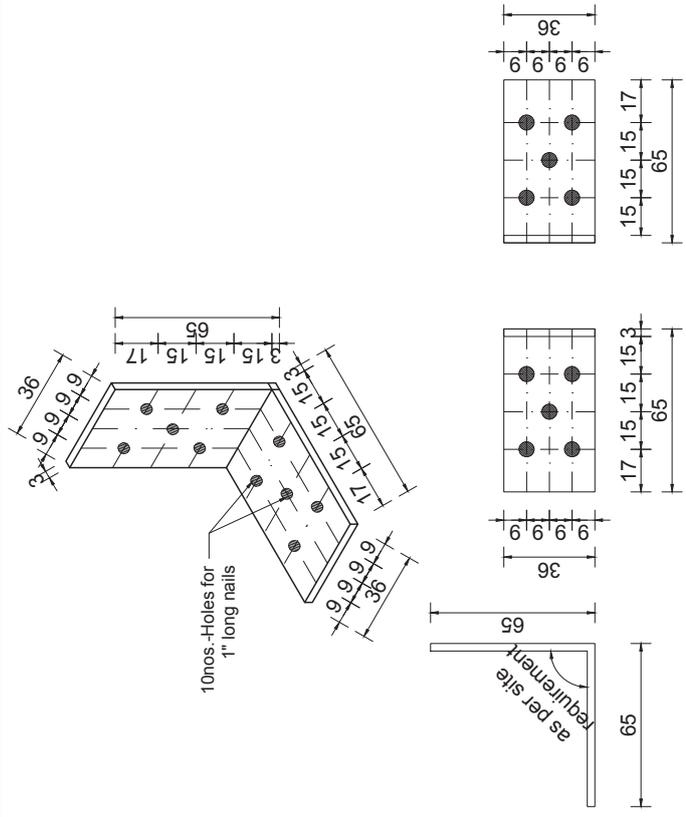
FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL

SCALE :- 1:100 FOR A3 PAPER

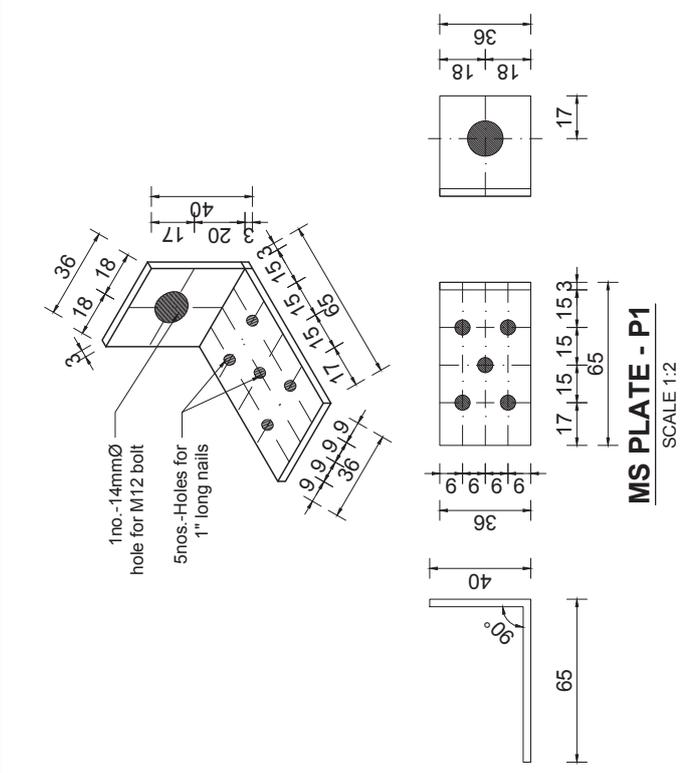
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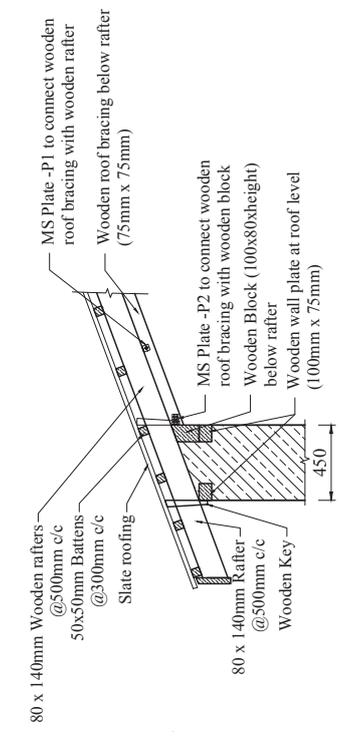
STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH



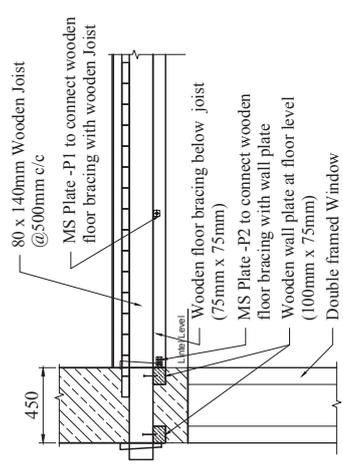
**MS PLATE - P2**  
SCALE 1:2



**MS PLATE - P1**  
SCALE 1:2



**DETAIL B1**  
**SHOWING CONNECTION OF ROOFING MEMBERS WITH WALL**  
SCALE = 1:30



**DETAIL A1**  
**SHOWING CONNECTION OF FLOORING MEMBERS WITH WALL**  
SCALE = 1:30

SHEET TITLE :-

FLOOR PLANS SHOWING LOCATIONS OF HORIZONTAL AND INCLINED BRACING AT FLOOR AND ROOF LEVEL

SCALE :- 1:30, 1:2 FOR A3 PAPER

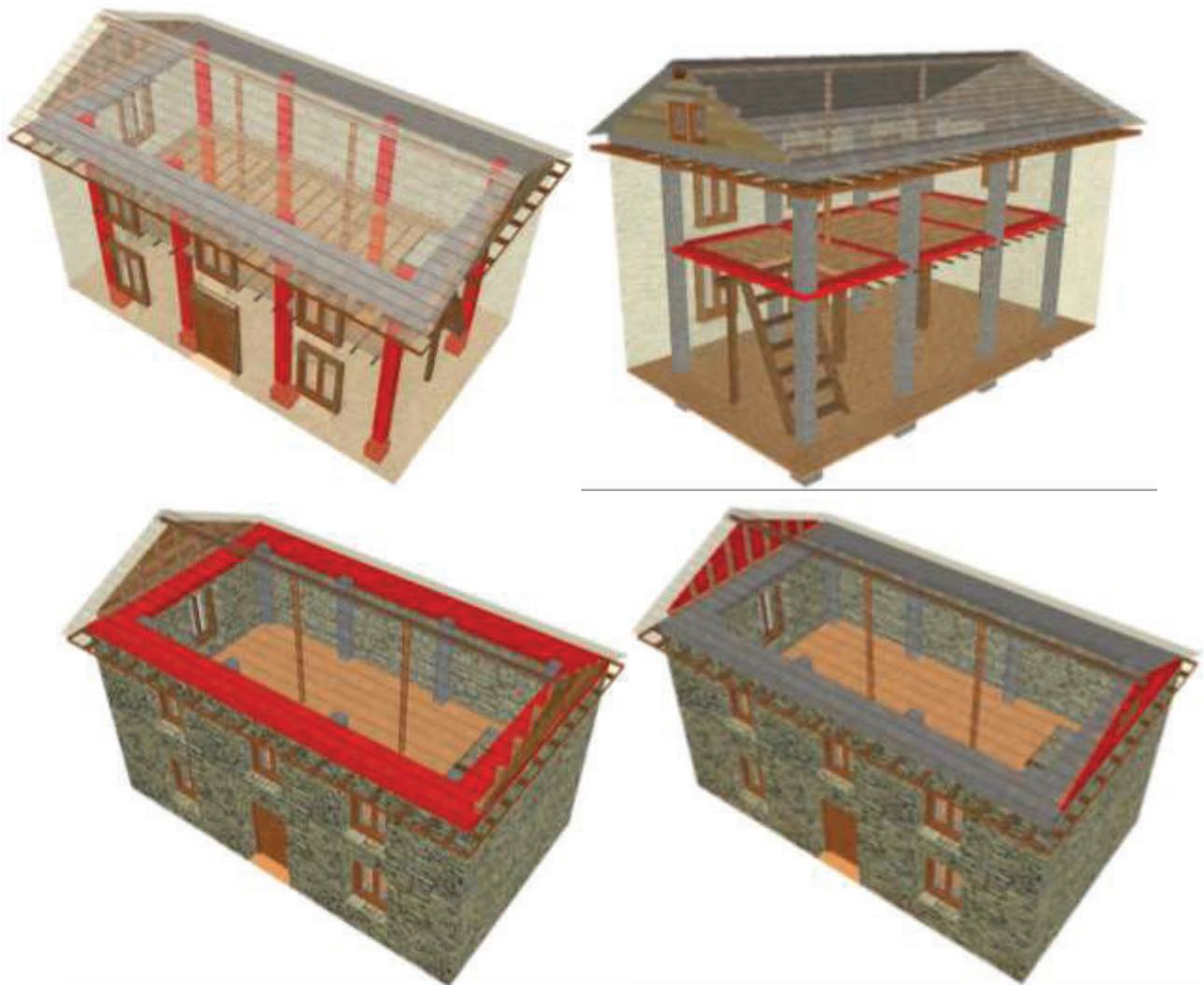
DATE :- JULY, 2007

PROJECT TITLE :-

STRUCTURAL DRAWINGS FOR RETROFIT DESIGN OF TWO STOREY LOW STRENGTH STONE MASONRY BUILDING USING TIMBER AND G.I. WIRE MESH

## Annex 2: Retrofitting Manual: Type Design for Retrofitting Stone Masonry in Mud Mortar (SMM) Houses using Strong Back Approach

### RETROFITTING MANUAL: TYPE DESIGN FOR RETROFITTING STONE MASONRY IN MUD MORTAR (SMM) HOUSES USING STRONGBACK APPROACH



*Primary elements of the standard type retrofit design  
(Top row: strong backs, slab strips;  
Bottom row: ring beam, lightweight gables)*

## **PREFACE**

This Engineering Manual was prepared to document the engineering basis, limitations, and design of the Standard Type Design Retrofit for Stone Masonry with Mud Mortar (SMM) Buildings using the strong back approach, as implemented by the UNOPS consortium consisting of Build Change, BBC Media Action and UNOPS under the Seismic Retrofitting of Unsafe Housing in Nepal project with funding support from the Foreign, Commonwealth and Development Office (formerly Department for International Development). This manual is based on the type designs approved by Central Level Project Implementation Unit (CLPIU) and National Reconstruction Authority (NRA).

The Standard Type Design is a pre-engineered system for improved earthquake-resistance of existing SMM buildings. The design described in this standard is subject to minimum requirements described in this Manual and applicable only to existing buildings with characteristics that meet the requirements described in this Manual.



*Figure 1 SMM house before and after implementation of Standard Type Retrofit*

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## 0. FOREWORD

### 0.1 Introduction

Stone masonry with mud mortar is the most common building type in rural areas of Nepal. Nearly all of existing SMM buildings in Nepal are non-engineered, and they are not capable of withstanding code-level seismic forces. SMM buildings have structural deficiencies that make them vulnerable to damage or collapse in earthquakes. Occupants of SMM buildings are at risk of injury and death in earthquakes.

The dissemination of seismic-resistant construction practices for SMM buildings can improve the seismic resistance of new construction in Nepal, but this work does not address the vulnerability of the existing rural building inventory. Retrofitting is a way to reduce the vulnerability of existing buildings by addressing the inherent deficiencies of the building type. A retrofit is designed by structural engineer to make the building perform better in earthquakes and reduce the risk of death, injury, and building damage.

Retrofitting an existing building is less expensive than demolishing and rebuilding it. Thus, an approach which favors retrofitting over rebuilding results in a larger area of safe, occupiable space for the same cost. There are additional benefits to preserving the existing building, such as: a shorter disruption to building occupancy, the option to phase the work as funding becomes available, and the preservation of existing architectural elements.

SMM buildings are constructed using traditional construction practices and their structural and architectural designs are similar across Nepal. Access to engineering services is limited to non-existent in rural areas, but the consistency of the building configurations and materials make rural SMM building ideal for pre-engineered retrofit design.

In this application, a pre-engineered retrofit has several advantages over project-specific design. Pre-engineering makes seismic engineered construction accessible to a larger population and reduces the time and work required to generate a design that meets the code's seismic performance requirements. Consistency between designs makes construction training and oversight more straightforward, thus easing the adoption of new construction technologies by builders.

### 0.2 Objectives of this Manual

The main objectives of this Manual are:

- To clearly communicate the restrictions on the applicability of the design
- To provide ready-to-use dimensions and details for seismic retrofits of SMM buildings
- To document the engineering basis and methodology for the retrofit design
- To provide guidelines for adapting retrofit details to common existing conditions

### 0.3 What is a Pre-Engineered Retrofit?

A pre-engineered retrofit is one which uses the sizes and detailing of structural and non-structural elements, including the amounts of reinforcement, which have been pre-established using standard design procedures for a given condition. All retrofits constructed by following the requirements of this Manual could, in future, be called pre-engineered retrofits.

Design guidelines for pre-engineered retrofits take the form of prescriptive requirements, but have been validated by structural calculations.

### 0.4 Limitations

The requirements set forth in this Manual shall be applicable only for buildings complying with the specified restrictions provided in [Eligibility Requirements](#) section.

Buildings that are retrofit using this standard without meeting the eligibility requirements shall not be considered engineered unless project-specific engineering analysis is completed to confirm that the design is acceptable.

### 0.5 Interpretation

- In this standard the word "shall" indicates a requirement that must be adopted in order to comply with the Manual, while the word "should" indicates recommended practice.
- References to 'Code' indicate the Nepal Building Code or Indian Standard. 'Code-level seismic forces' indicate seismic forces as calculated using IS

### 0.6 Terminology

**Chord** means an element that resists tension and compression forces that form at the extreme edges of the *diaphragm*.

**Code** means Nepal Building Code (*NBC*) and Indian Building Code (*IS*), which are both acceptable design standards in Nepal.

**Delamination** means collapse or bulging of a wall *wythe* during *out-of-plane* loading. Delamination occurs when wythes are not sufficiently interconnected.

**Diaphragm** means a horizontal structural element (such as a floor) capable of transmitting lateral loads from *out-of-plane* walls to *in-plane* walls.

**Important buildings** are ones that have one or more of the following properties:

- contain critical facilities which are essential before and immediately after a disaster (e.g. hospitals, fire and police stations, communication centres etc),
- by their very purpose have to house many persons at a time (e.g. cinema halls, schools, convention centres, etc)
- have national and international importance (e.g. historical palaces, monuments, etc)
- are to be used for storage of toxic or explosive materials.

**In-plane wall** mean those that run parallel to the direction of seismic loading. These walls are the primary lateral force resisting system for the building in that seismic loading direction, and they are responsible for safely transferring the inertial load for the entire building to the ground.

**IS** means Indian Standard, the Indian building code.

**“Go/No-Go”** means the process for determining whether an existing building is eligible for pre-engineered retrofit or not.

**Longitudinal wall** means the wall on the longer side of the building. Typically, floor framing spans to this wall. Also called “long wall”.

**NBC** means National Nepal National Building Code (NBC) by the Department of Urban Development and Building Construction (DUBUC), 1994 edition.

**Opening percentage** means the total length of horizontal openings along an exterior wall divided by the overall length of that wall (including the openings), expressed as a percentage.

**Ordinary buildings** are ones that are not required to be classified as *important buildings*. Residential, commercial, and office buildings are typically ordinary buildings.

**Out-of-plane wall (OOP)** means a wall that runs perpendicular to the direction of loading. Typically, these walls resist only the inertial forces associated with their own self weight (including any appendages connected to them). These walls resist the inertial load like a beam in bending before transferring them to the in-plane walls via the diaphragms or similar elements.

**Partition** means a non-load bearing masonry wall (carrying only its own self weight). Partitions do not serve as a part of the lateral-force resisting system.

**Pier** means a wall section between openings in a load bearing masonry wall.

**Positive connection** means a connection that does not rely on gravity or friction to resist uplift and lateral loads. Positive connections are typically fasteners embedded in the objects they connect. Examples of positive connections include bolts, nails, and cast-in-place straps. Examples of connections that are not positive include ballasts and clamps.

**Project-specific** describes analysis or design that is done for a specific building.

**Strongback** is a vertical structural element that provides out-of-plane bracing for a wall.

**SMM** means stone masonry walls with mud mortar as a binder.

**Transverse wall** means the wall on the shorter side of the building. Also called “short wall”.

**Wall** means a load bearing masonry wall. Walls serve as part of the lateral-force resisting system of SMM buildings.

**Wythe** is one vertical layer of masonry units stacked on top of each other in a wall.

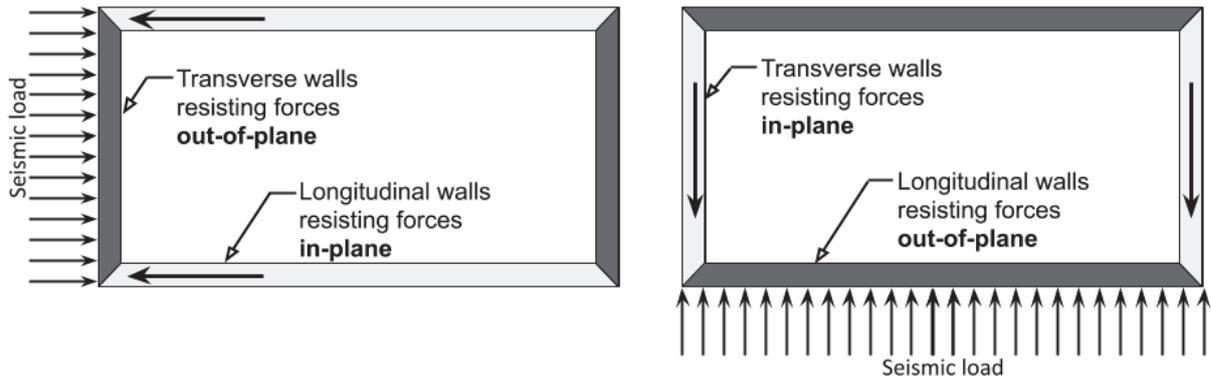


Figure 0-1 Plan diagram depicting in-plane loading of a wall versus out-of-plane loading of a wall

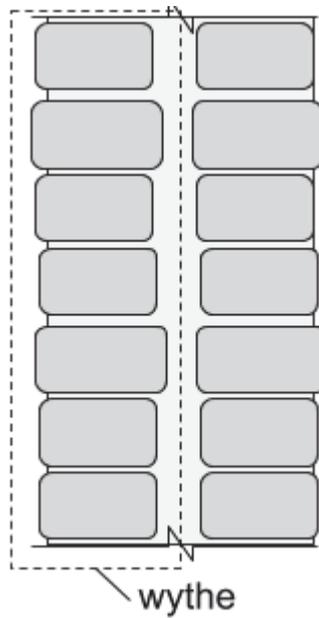


Figure 0-2 Cross section of a wall depicting a masonry wythe

## 1. SCOPE

### 1.1 Type of Building System Covered

This Manual is valid for the retrofit of buildings constructed in the traditional Nepal practice using stone masonry in mud mortar (SMM) construction. This building system is assumed to have the following properties:

- Exterior walls are SMM construction.
- Floor framing consists of wood joists and planking supporting a mud slab.
- Wood posts provide gravity-load support for the joists at the building centerline.
- The roof consists of wood beams, rafters, and purlins with CGI (corrugated galvanized iron) roofing or roof tiles.

These guidelines do not apply to stone masonry buildings constructed with suspended reinforced concrete slabs at any floor or roof level.

Buildings must meet all requirements in [Eligibility Requirements](#) section.



Figure 1-1 Rendering depicting a typical SMM house in Nepal

### 1.2 Occupancy Types Covered

The pre-engineered design is applicable for typical housing and other buildings that can be classified as ordinary, as defined in the [Terminology](#) section.

Unless justified by project-specific analysis, these guidelines shall not be applied to schools or other buildings that can be classified as important, as defined in the [Terminology](#) section.

### 1.3 Locations Covered

The pre-engineered design is applicable to all geographic locations in Nepal. The design is based on Zone V, as defined in IS 1893, which is the highest seismic zone in Nepal.

The design is based on soft soil, as defined in Table 4-1 of NBC 202. It is therefore applicable to all soil conditions except weak soil, as defined in that table.

The guidelines are not applicable to all site locations. See [Eligibility Requirements](#) section for site condition requirements.

## 1.4 Damaged Buildings

These guidelines apply only to existing buildings in good condition. The pre-engineered design is valid for structurally damaged buildings only if they are repaired before the retrofit or as part of the retrofit construction.

During the initial site investigation, any existing damage shall be noted. A retrofit shall not be considered pre-engineered until all structural damage is repaired.

This Manual does not include guidance on stabilization or repair of damaged structural elements. See the [References](#) section for applicable documents that address repair of damaged masonry buildings.

## 1.5 Outside of scope

The pre-engineered retrofit design is limited to addressing the common seismic deficiencies of SMM buildings and providing an adequate primary seismic resistance system.

During the initial site investigation, any existing falling hazards must be should be noted. A retrofit shall not be considered “pre-engineered” until all falling hazards addressed.

The following items are outside the scope of this guidelines, but should be considered by the owner-builder or their representative where applicable:

- Shoring of damaged buildings
- Repair of existing damage
- Renovation unrelated to the retrofit
- Porches and balcony construction
- Mitigation of falling hazards such as unbraced architectural elements, rooftop equipment without positive attachment

Any new construction done as part of the retrofit project should meet the requirements of NBC 203. Where walls are rebuilt or new, follow NBC 203, Section 7.1.

## 1.6 Alternative designs

The design procedures here are simplified in order to save design time and make earthquake-resistant design and details more accessible. The retrofit for any building can be designed using the conventional design process for strengthening of existing structures. Tailor-made detailing from a project-specific engineering design may result in better economy.

Naturally, there is nothing preventing designers/builders exceeding the standards set out in this standard.

## 1.7 Eligibility Requirements

### 1.7.1 Background

The pre-engineered retrofit is based on building properties that are typical to existing SMM houses in rural Nepal. In reality, however, no two existing SMM buildings are completely identical. Due to practical limitations, prescriptive retrofit design per this Manual is not feasible for all SMM buildings. The pre-engineered design seeks to address the largest number of rural SMM buildings without creating a design process that too difficult to apply correctly or efficiently.

Existing buildings retrofitted using the pre-engineered design shall meet the limitations outlined in this section. In some cases, a building may not meet a particular eligibility requirement, but it is feasible to repair or make alterations to meet the requirement.

To determine if the building is eligible, review the existing conditions (observed during the site investigation phase) and determine if the each statement in [Section 1.7.3 Eligibility checks \(“Go/No-Go”\)](#) is true or false.

- If all statements are true, the building meets the criteria for pre-engineered retrofit.
- If all statements could be made true after alterations and/or repairs\*, then the building meets the criteria for pre-engineered retrofit once those alterations/repairs are completed.
- If any of the statements are false and alterations/repairs cannot feasibly be made to address them, the building does not meet the criteria for pre-engineered retrofit.

\*See [Section 1.7.4 Alterations and repairs to meet eligibility requirements](#) for more about alterations and repairs to address ineligibility.

Example “Go/No-Go” sheets are included in [Appendix A](#).

### 1.7.2 Conventions

“Go/No-go” refers to the process for determining if a building is eligible (“Go”) or ineligible (“No-Go”) for pre-engineered retrofit.

References made in this Manual to the “longitudinal wall” refer to the wall side with the longer plan dimension. Typically, floor framing joists span to the longitudinal walls, though this is not an eligibility requirement. The plan dimension for longitudinal wall is referred to as the “building length” and abbreviated as “L”. The building length is measured from outside end to outside end.

References made to the “transverse wall” refer to the wall side with the shorter plan dimension. The plan dimension for transverse walls is referred to as the “building width” and abbreviated as “B”. The building width is measured from outside end to outside end.

Any openings with height less or equal to 1.2 meters (3.9 feet) shall be considered as a window. Any opening between the heights of 1.2 to 1.9 meters (3.9 to 6.2 feet) shall be considered as a door.

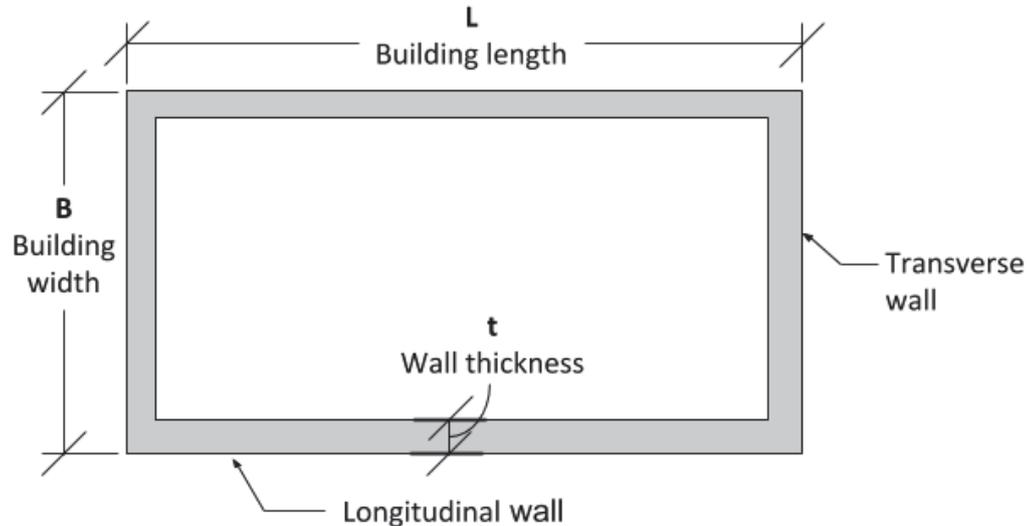


Figure 1-2 Plan depicting wall terminology and abbreviations

### 1.7.3 Eligibility checks (“Go/No-Go”)

#### 1.7.3.1 Shape and size

The shape of the building shall be regular and meet all dimensional requirements outlined herein, or else the building shall be altered to meet the requirements, as described in [Section 1.7.4 Alterations and repairs](#) to meet eligibility requirements.

- Review the building plans. Confirm the following statements are true.**
  - The floor plan on each level is rectangular.
  - Walls are present along the entire perimeter of the building.
  - Maximum overall length of the **longitudinal wall** is less than 10.7 meters (35 feet).
  - Maximum overall width of the **transverse wall** is less than 6 meters (19.5 feet).
  - Perpendicular walls appear to intersect at a 90 degree angle, with maximum deviation of 500 mm over the wall length (see Figure).
  - The wall thicknesses at least 450 mm (1.5 feet).
  - Floor, attic, and roof framing are timber construction.
  
- Review the building elevations. Confirm the following statements are true:**
  - The building is no more than two stories plus attic.
  - The floor-to-floor height (including floor framing) is less than or equal to 2.1 meters (6.9 feet) at each level.
  - The height of any attic walls (measured from top of attic floor) shall be less than or equal to 1.2 meters (3.9 feet).
  - Perimeter walls are continuous along the entire building height (i.e. no setbacks or cantilevers, or other vertical discontinue)
  - The walls of the building shall be true to plumb line.
  - See also Openings section.*

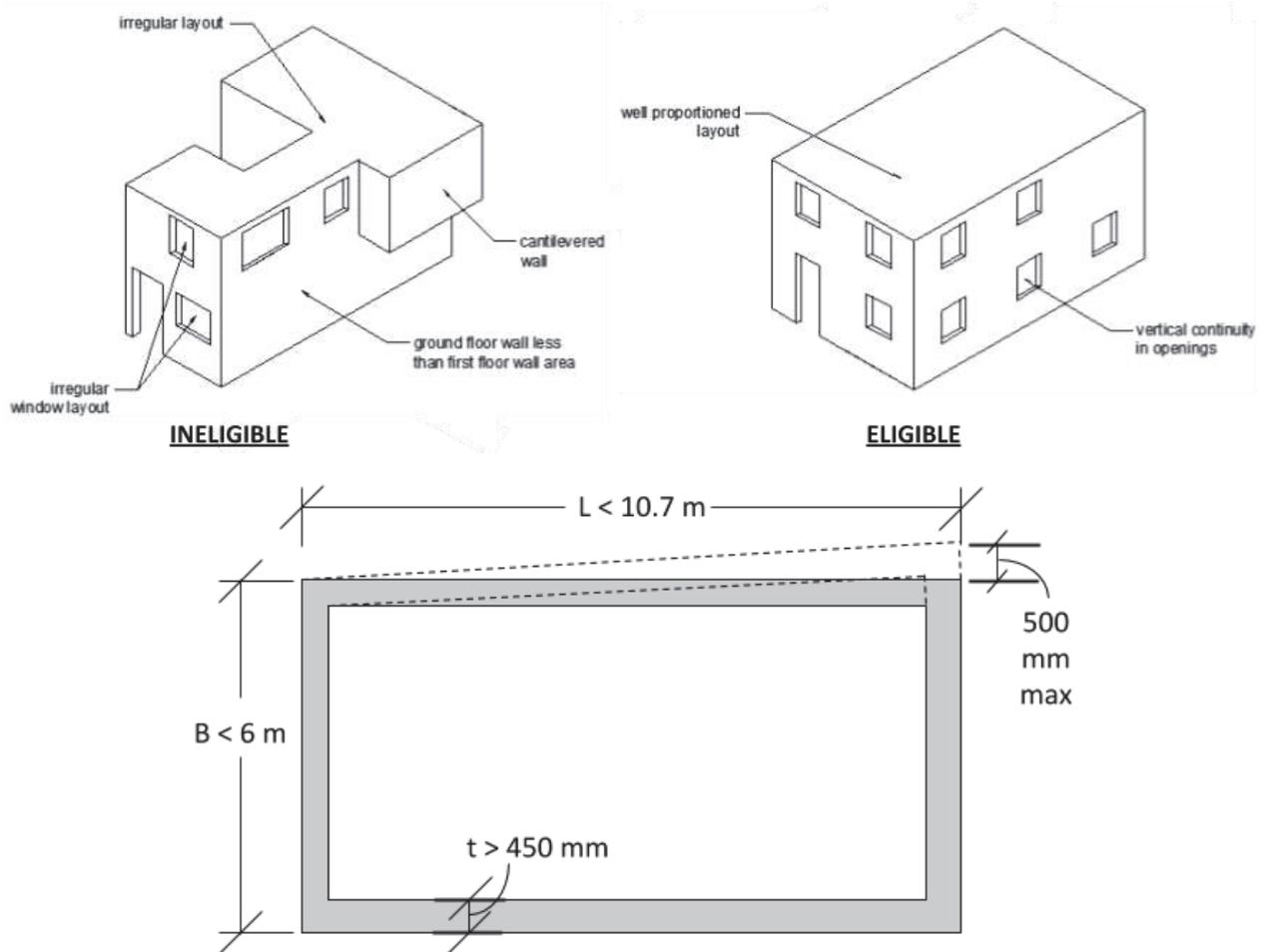


Figure 1-3 Plan depicting dimensional eligibility requirements

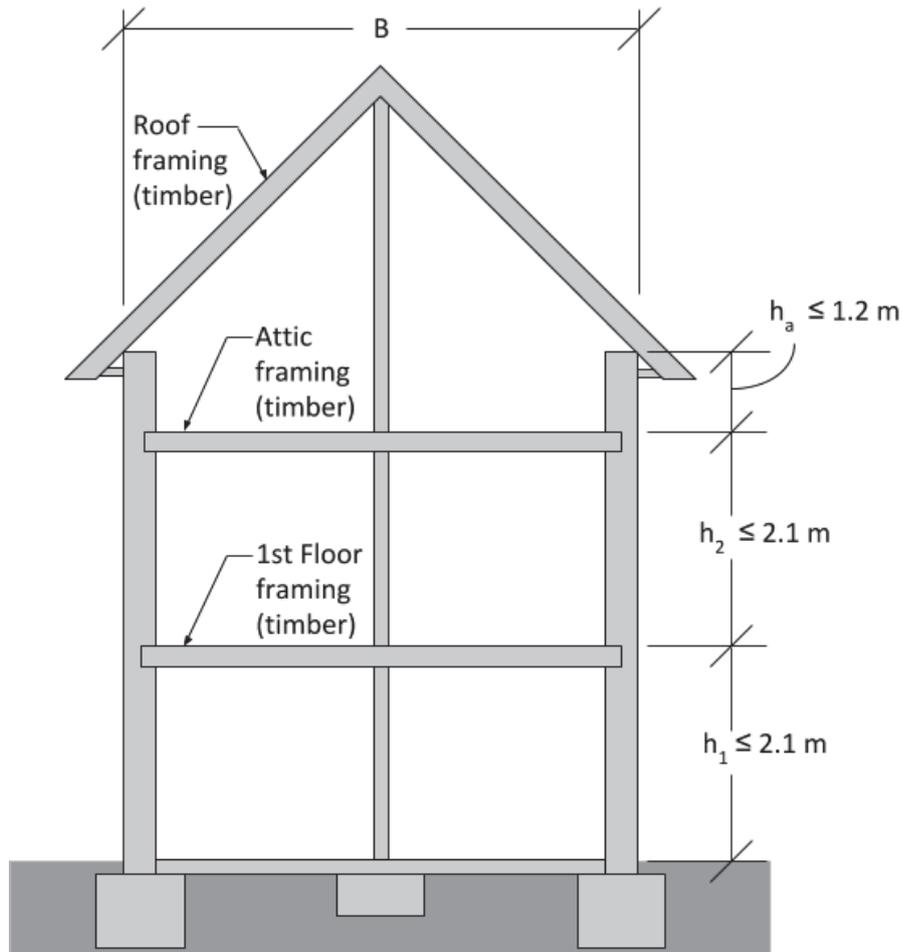


Figure 1-4 Section depicting eligibility requirements

### 1.7.3.2 Exterior Wall Openings & Piers

The wall openings and piers in exterior walls shall meet all dimensional requirements outlined herein, or else the building shall be altered to meet the requirements, as described in [Section 1.7.4](#) Check all levels including the attic level.

- Review the wall elevations. Confirm the following statements are true:**
  - Openings on the upper floors are aligned with openings on lower floors. (Piers are continuous along height of the building to the foundation.)
  - Along each of the four exterior walls, the percentage of openings do not exceed the maximum allowable percentages provided in the table. Percentage of openings for a wall is calculated using the following equation:

$$\text{Percentage of openings} = \frac{\Sigma \text{Length of openings in the wall}}{\text{Length of the wall}}$$

Length of longitudinal wall (meters)	Length of transverse wall (meters)	Allowable percentage of openings	
		Along longitudinal Wall	Along transverse walls
$L \leq 8.3$	$B \leq 6$	$\leq 35\%$	$\leq 25\%$
$8.5 < L \leq 10.7$			$\leq 20\%$

- There are no openings taller than 1.9 meters (6.2 feet).
- Each pier length (distance between adjacent wall openings), meets the requirements in the this table:

Building length (meters)	Building width (meters)	Minimum pier length, P, required (meters)			
		Longitudinal walls		Transverse walls	
		Door-to-window	Window-to-window	Door-to-window	Window-to-window
$8.5 \leq L < 10.7$	$4.5 \leq B < 5$	0.925	0.6	1.6	1
	$5 \leq B \leq 6$			1.35	0.95



Figure 1-5 Photo depicting pier lengths

### 1.7.3.3 General Condition

The general condition of the building shall meet the requirements outlined herein, or else the building shall be repaired to meet the requirements, as described in [Section 1.7.4](#)

- Review the condition of the building. Confirm the following statements are true:**
  - The structural elements do not have observable damage.
  - The structural elements do not have observable deterioration
  - Based on observations, the foundation is observed to be intact and stable.
  - Based on observations, the foundation is not affected by settlement, consolidation or cracks.

### 1.7.3.4 Building Site and Location

The site properties and location of the building shall meet the requirements outlined herein.

- Observe the building site. Confirm the following statements are true:**
  - None of the building walls are retaining soil.
  - The building is not attached to other buildings or additions.
  - The slope of the ground is less than 20 degrees.
  - The soil is not weak (as defined in NBC 202, Table 4-1).
- Observe the area around the building site. Confirm the following statements are true:**
  - The area (ward) has not been affected by landslides, cracks in the ground, fault line or other types of ground movement.
  - There are no adjacent retaining walls or slopes that have been subjected to movement or damage.
  - The ward is not subject to floods for the nearby watercourses (including flash flood).
  - The distance between the building and nearest water course is at least 20 meters (66 feet).
  - If located in the vicinity of sloping terrain (exceeding 20 degrees), the building site meets minimum distances from toe and top of slope, as required by NBC 108 (figure below), or adequate slope stability measures have been taken (i.e. retaining walls).

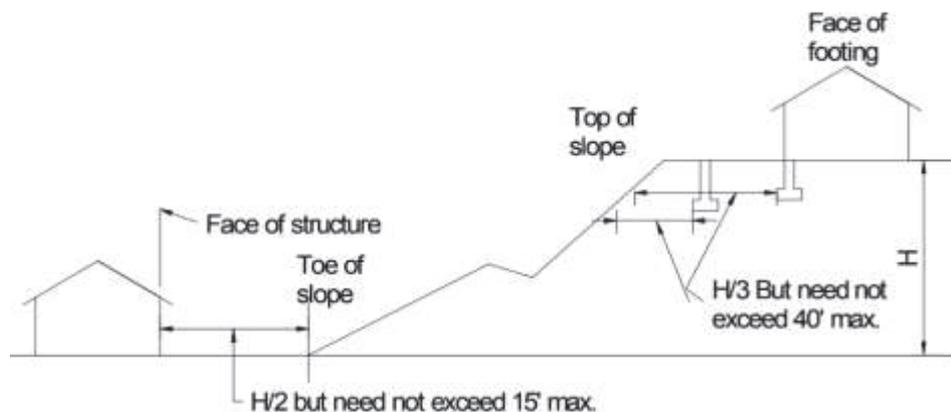


Figure 1-6 Requirements for buildings sited on sloping terrain (Source: NBC 108)

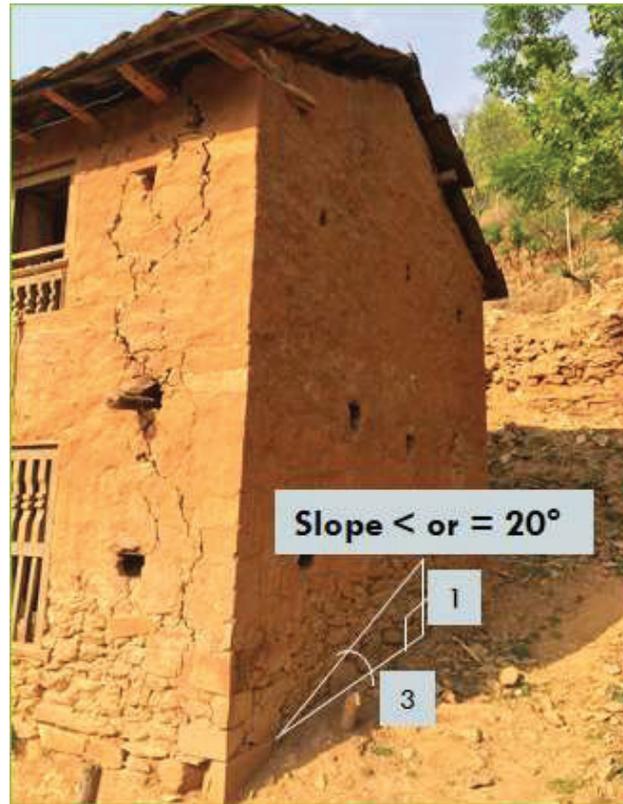


Figure 1-7 Requirements for buildings sited on sloping terrain

### 1.7.4 Alterations and repairs to meet eligibility requirements

When buildings do not meet an eligibility criterion, but the building can feasibly be altered or repaired to meet the criterion, the building may be retrofit using the pre-engineered design, provided that the alterations and/or repairs are implemented during construction.

Examples of eligibility issues and alterations and repairs that may be practical are provided in the table below. These alterations and repairs are outside the scope of this Manual.

Eligibility issue	Alteration or repair to make eligible
Pier elements are not vertically continuous.	Relocate an existing opening so that it aligns with openings above and/or below.
Wall exceeds the maximum allowable percentage of openings.	Infill an opening such that the maximum allowable percentage is met.
A pier length does not minimum allowable lengths.	Infill an opening or relocate an existing opening so that all pier lengths meet minimum allowable lengths.

Attic wall exceeds maximum allowable height.	Reduce height of attic wall to meet maximum allowable height.
Structural elements are damaged or deteriorated.	Repair the damaged or deteriorated elements. See Additional Resources section for repair methods.
The building has a horizontal addition which is structurally connected.	Create a structural separation between the building to be retrofit and the addition.

### 1.7.5 Ineligible Buildings

Retrofit design per this standard of buildings not meeting the eligibility criteria shall not be considered as pre-engineered per this Manual.

## 2 BASIS OF DESIGN

### 2.1 Seismic Performance Objective

The pre-engineered retrofit meets an equivalent level of seismic safety to that provided by the current Code for new engineered construction of ordinary buildings.

The retrofit includes global interventions to form a stable load path in the primary structure for seismic loads. It also provides local interventions to address weak connections and nonstructural elements.

The design is based on a linear static analysis carried out per IS 1893, Part 6, Section 1, Paragraph 5. The design seismic coefficients used in the pre-engineered design are per clause 6.4.2, IS 1893:2002.

$$A_h = \frac{Z I S_a}{2 R g}$$

Where the following parameters are used:

Parameter	Value	Code Reference ( <i>IS 1893, Part 6, Section 1</i> )
Zone factor, $Z$	0.36	Table 31, Zone V - "Very severe"
Importance factor, $I$	1.0	Table 35, "All other buildings"
Response acceleration coefficient, $S_a/g$	2.5	Figure 12, 5% damping, Soft soil, $T \leq 0.67$ s
Response reduction factor, $R$	2.5 for in-plane	Table 36, "Unreinforced masonry with horizontal bands"
	1.5 for out-of-plane	Table 36, "Unreinforced masonry"

### 2.2 Architectural Design Objective

The retrofit design seeks to minimize the architectural impact of the retrofit by selection of a scheme that minimizes the aesthetic impact and loss of living space.

As much as feasible, the retrofit avoids altering the exterior appearance of the building. As a result, the primary strengthening elements are located on the interior of the building. This is to preserve the unique architectural heritage of traditional Nepali construction, which is considered an asset to both the building owners individually, and to the country as a whole.

As much as feasible, the original functionality of the building is maintained. The primary strengthening elements use a small footprint of the building. New interior wall are not required.

## 2.3 Construction Objectives

The retrofit seeks to be as affordable as possible while still meeting the performance objectives in Section 2.1 and 2.2.

All materials used in the design are widely available throughout rural areas of Nepal.

Elements and their detailing seeks to be easily and quickly constructed using skills of available masons.

## 2.4 Related standards and guidelines

Existing resource documents (i.e. in the Nepal Building Code and Indian Standards) do not specifically address engineered design of seismic retrofit for buildings of stone masonry in mud mortar.

The requirements of this Manual are based on the following standards. Compliance with this Manual will, therefore, result in compliance with these Standards, where applicable.

NBC 105:1994, "Seismic Design of Buildings in Nepal".

NBC 108:1994, "Site Consideration for Seismic Hazards".

NBC 112:1994, "Timber".

NBC 202:1994, "Mandatory Rules of Thumb, Load Bearing Masonry".

NBC 203:1994, "Guidelines for Earthquake Resistant Building Construction, Low Strength Masonry".

IS 1893:2002 Criteria for Earthquake Resistant Design of Structures

IS 456:2000 Plain and Reinforced Concrete Code of Practice

The requirements of this Manual are based on the following guideline documents:

Guidelines for the Seismic Assessment of Stone-Masonry Structures, 2000- Public Works and Government Services Canada

IITK-GSDMA Guidelines for Seismic Evaluation and Strengthening of Buildings

Seismic Retrofitting Guidelines of Buildings in Nepal-Masonry (2016)

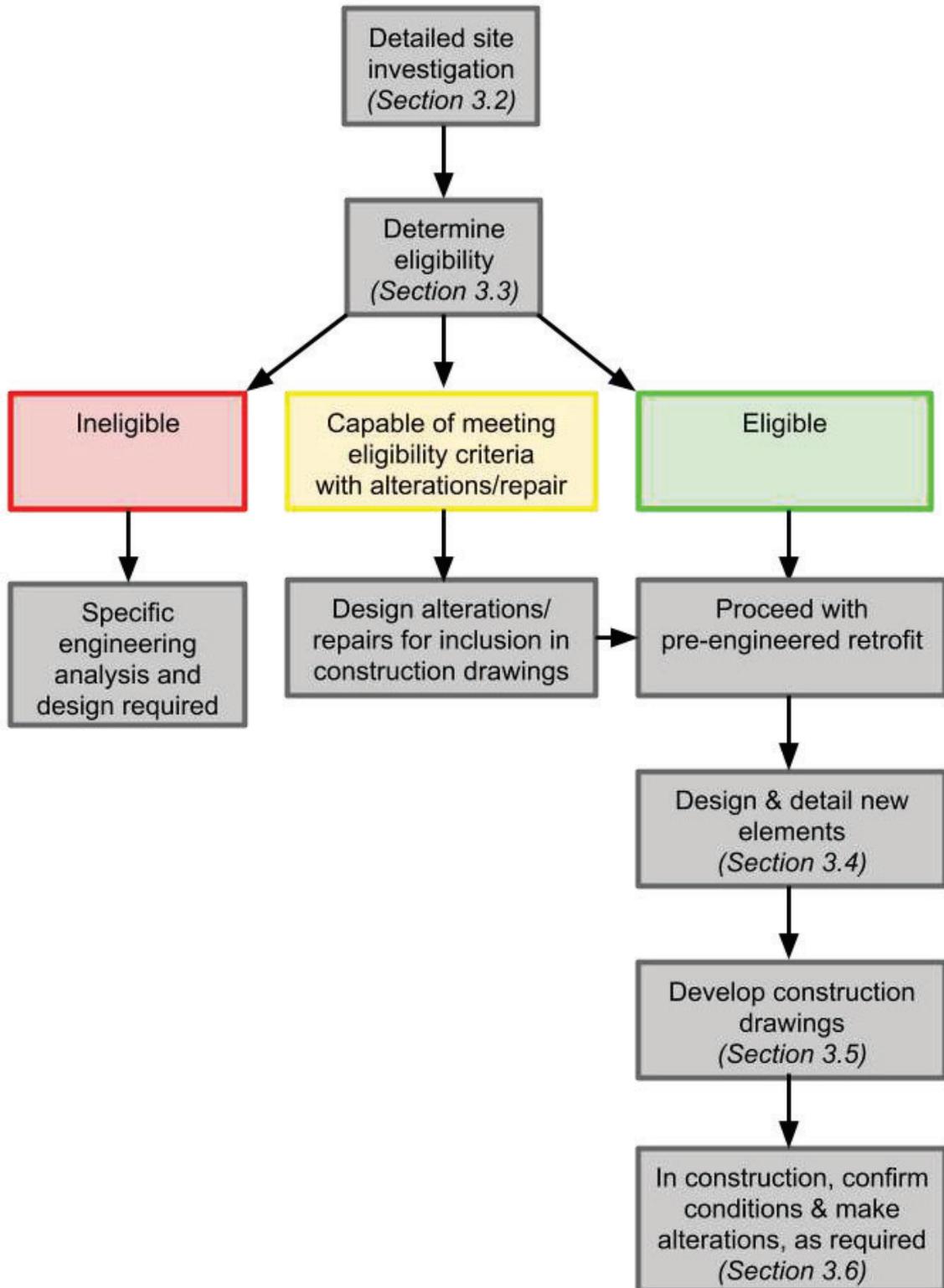
### **3. DESIGN PROCEDURE**

#### **3.1 Outline**

This section provides an overview of the design procedure for a pre-engineered SMM retrofit. The procedure comprises of the following steps:

- 2.5 Conduct a detailed site investigation (Section 3.2)
- 2.6 Determine the eligibility of the building for pre-engineered retrofit (Section 3.3)
- 2.7 Design and detail structural elements (Section 3.4)
- 2.8 Produce construction drawings (Section 3.5)
- 2.9 Perform field alterations for existing conditions, as required (Section 3.5)

The process is summarized in the flowchart below.



### 3.2 Detailed site investigation

A detailed site investigation shall be conducted to gather basic properties of the building that are used to determine if the building is eligible for pre-engineered retrofit and to be used in the prescriptive design of strengthening elements.

At a minimum, the following information shall be recorded:

- a) Plan sketch at each floor level and roof, including:**
  - i) Overall dimensions
  - ii) Wall locations and thickness(es), including non-loadbearing partitions
  - iii) Floor/roof framing (spacing, materials) and post locations
  - iv) Location of stairs
- b) Elevation sketch at each side of the building, including:**
  - i) Number of stories
  - ii) Floor-to-floor heights
  - iii) Attic parapet height and peak roof height
  - iv) Dimensions and locations of all openings (i.e. door, windows)
  - v) Gable construction material
- c) General condition observations**
  - i) Are the walls plumb?
  - ii) Do walls appear to be perpendicular?
  - iii) Are there observable signs of existing damage?
  - iv) Are there any falling hazards, such as unbraced appendages, heavy equipment, or other nonstructural elements?
  - v) Is the foundation intact and stable?
  - vi) Is the foundation affected by settlement, consolidation and cracks?
- d) Site observations:**
  - i) Has the area (ward) been affected by landslides, cracks in the ground, fault line or other types of ground movement?
  - ii) Have any adjacent retaining walls or slopes been subjected to movement or damage?
  - iii) Is the ward subjected to floods from the nearby watercourses or flash flood?
  - iv) Does the building have any additions or adjacent buildings attached?
  - v) What is the slope of the ground at the building?
  - vi) If the building located in the vicinity of a slope > 20 degrees, what is the distance from the toe of slope and/or top of slope?
  - vii) Is the soil weak (as defined in NBC 202 Table 4-1)?
  - viii) Is the distance between the building and the nearest water course less than 20 meters?

### 3.3 Determine eligibility

A review of eligibility criteria, as outlined in [Section 1.7](#), shall be conducted for each building before proceeding with the retrofit design.

- If the building **meets all eligibility criteria**, proceed to pre-engineered design.
- If the building **does not meet all eligibility criteria, but could meet the criteria after repair and/or alteration**, make plans for these repairs and alterations. Then, proceed to pre-engineered design.
- If the building **does not meet eligibility criteria and cannot be made eligible through repair and/or alteration**, the pre-engineering retrofit is not applicable and project-specific design is required to meet Code level requirements. If the retrofit design described herein is applied to the building, the seismic resistance will be improved, but the building cannot be considered to be engineered.

### 3.4 Design and detail the structural elements

Pre-engineered retrofits designed per this Manual shall meet the requirements in [Section 6: Retrofit Design & Detailing](#). New structural elements and their connections to the existing structure shall meet all requirements outlined in that section. Additional guidance to adapt details to common existing conditions is included in [Section 7: Addressing Common Existing Conditions](#).

### 3.5 Produce construction drawings

During design, construction drawings shall be developed which at a minimum include the following:

1. **General notes**, including minimum standards for materials
2. **Plans & elevations**, depicting existing conditions, required demolition, and new elements
3. **Details**, depicting all new elements and their connections to the existing structure
  - a. Use **typical details** provided in this standard, adapted to suit conditions of the existing building.
  - b. As required, provide special details for repairs, alterations, or unique conditions.

### 3.6 Construction monitoring & field alterations

During construction, demolition may expose existing conditions that do not match the project drawings. There shall be adequate monitoring during construction to identify these cases and bring them to the attention of the engineer. The engineer shall be responsible for adapting the details to meet unforeseen conditions that arise during construction.

## 4 PRINCIPLES OF PRE-ENGINEERED SMM RETROFIT

### 4.0 Introduction

This section describes the load path of lateral seismic forces in an SMM building retrofitting using this Manual. Specific deficiencies of typical SMM buildings and the retrofit elements used to mitigate them are described. Assumptions used in the analysis and design of the retrofit are included.

### 4.1 Lateral force resisting system

The primary lateral force resisting system for SMM buildings is masonry shear walls. The floor systems at the 1st floor and 2nd floor serve as diaphragms. The roof is not assumed to act as a diaphragm.

A typical load path for lateral forces in a retrofitted SMM building are described below. Where elements contribute significant inertial forces due to large self-weight (e.g. diaphragms), their addition into the load path system is noted. Where elements do not contribute significant inertial forces due to relatively low self-weight (e.g. ring beam), their addition is neglected. Spans described act as simply supported beams, unless otherwise noted.

The load path is also shown diagrammatically below.

- [1] **Out-of-plane masonry walls** resist the inertial forces associated with their own self-weight in flexure (bending). The masonry wall spans horizontally between new **strongbacks** [2]. (See Note 1 for associated assumptions.) New **through-concrete** reduces the risk of delamination during wall bending.
- [2] **Strongbacks** receive the OOP wall load tributary to them. Strongbacks span vertically over the full height of the building, with support points (reactions) at the new attic **ring beam** [3a], the strengthened **floor diaphragm(s)** [3b], and the new **strongback footing** [3c].
- [3] The load path then splits between the strongback support points:
  - [3a] **Ring beams** at the top of the OOP walls receive the reaction force at the top of the strongback via rebar dowels. Ring beams span horizontally between **in-plane walls** [4].
    - + *Added loads:* When longitudinal walls serve as OOP walls, the ring beam also carries the inertial force associated with the roof via new **roof-wall connections**. When transverse walls serve as OOP walls, the ring beam also carries the seismic load associated with the gable wall.)
  - [3b] **Floor diaphragm(s)** receive the reaction force(s) at the interior of the strongback span via **diaphragm-to-wall ties**. The diaphragm spans horizontally between **in-plane walls** [4]. (New **slab strips** strengthen the floor diaphragm so that the diaphragm has adequate flexural strength to safely carry the loads to the in-plane walls.)
    - + *Added loads:* Each floor diaphragm also carries the inertial forces associated with its own self-weight.
  - [3c] **Strongback footings** receive the reaction force at the base of the strongback span via rebar dowels. The footing transfers the lateral load into the **ground** [6].
- [4] **In-plane walls** receive the loads from the ring beam and diaphragms. Piers in the wall resist the loads as shear walls cantilevering from a fixed base at ground level. At the base of each wall pier, shear and moment (when applicable) are transferred into the **shear wall footing** [5]. (Where

required, piers and their foundation connections are strengthened to meet the demands.) (See Note 2.)

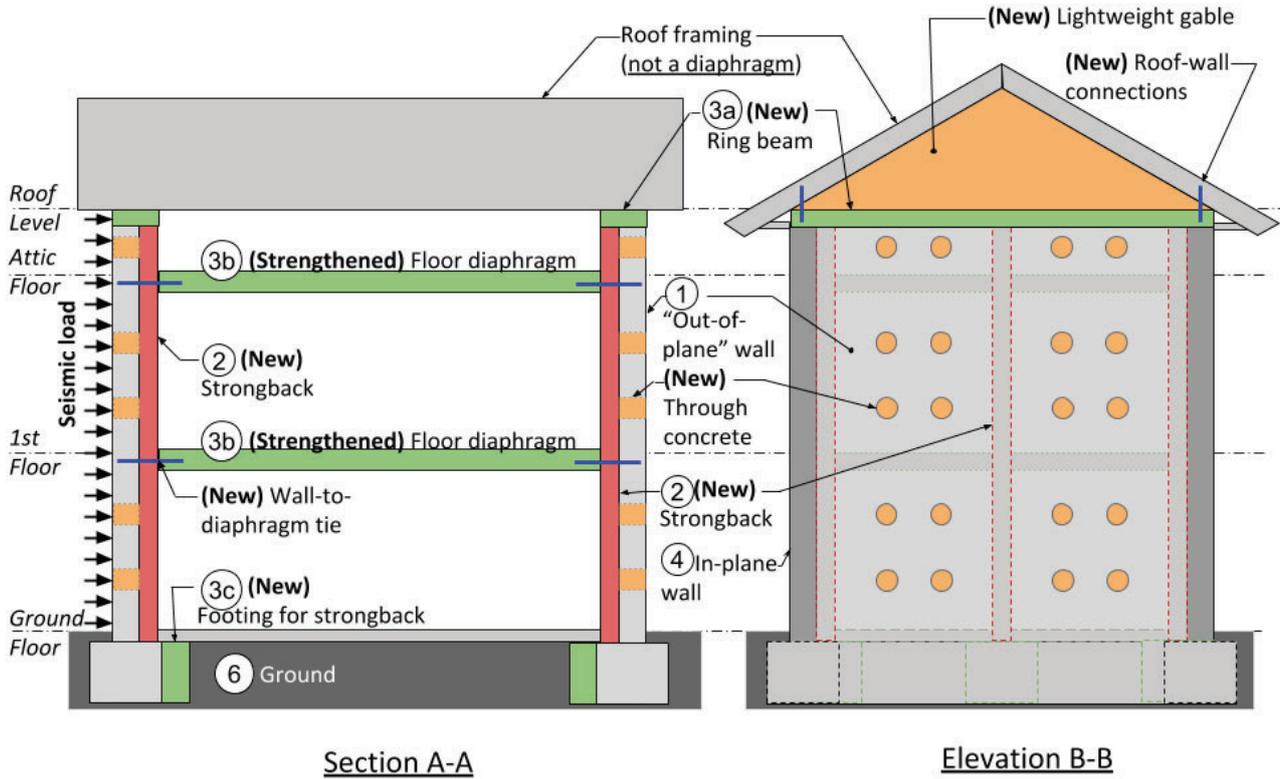
+ *Added loads*: Each in-plane wall also carries the inertial forces associated with its own self-weight. When longitudinal walls serve as in-plane walls, the inertial force associated with the roof is added directly to the in-plane wall (i.e. bypasses the ring beam).

**[5] Footings for shear walls** receive shear reactions from the in-plane wall piers. Where overturning of the pier occurs, the footings also resist moment reactions. If uplift occurs, it is resisted by self-weight of the footing. The footing transfers the forces into the ground.

**[6] The ground** receives lateral and vertical loads from the footings. The stresses on the soil are adequately resisted provided that allowable bearing pressures are not exceeded.

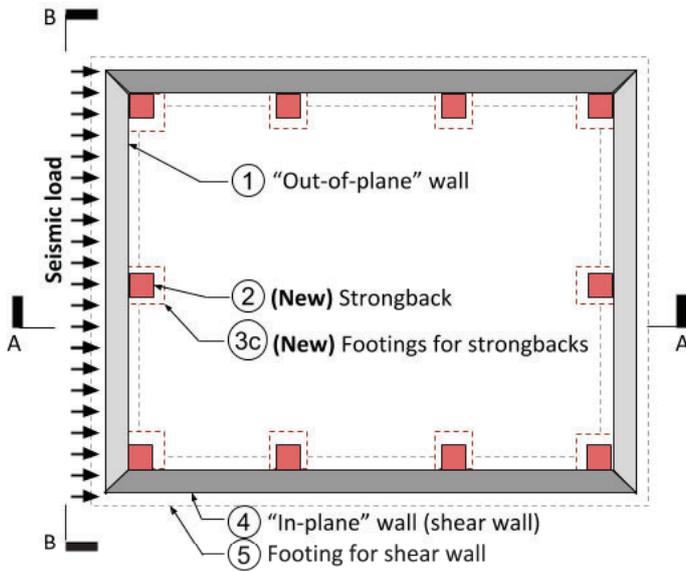
**Notes:**

1. In reality, the walls have two-way action when loaded out-of-plane: spanning horizontally to strongbacks and vertically to diaphragms/ring beams/the ground. In this analysis, it is conservatively assumed that the OOP walls only span horizontally to strongbacks.
2. Strongbacks are assumed to provide out-of-plane resistance only. Any impact on in-plane strength or stiffness is neglected.



Section A-A

Elevation B-B



Plan at Ground Floor

**Notes:**

1. Drawing is diagrammatic and not drawn to scale.
2. In Elevation B-B, direction of seismic load is into the page.
3. Openings are not shown (for clarity).
4. Not all gravity members are shown (for clarity).
5. In some cases, in-plane walls are strengthened with wire mesh.

Figure 4-1 Diagram of SMM building lateral force resisting system with pre-engineered retrofit. In the seismic load direction considered, the transverse walls are depicted as the out-of-plane walls, and the longitudinal walls are depicted as the in-plane walls. Note that both directions of horizontal seismic load should be considered.

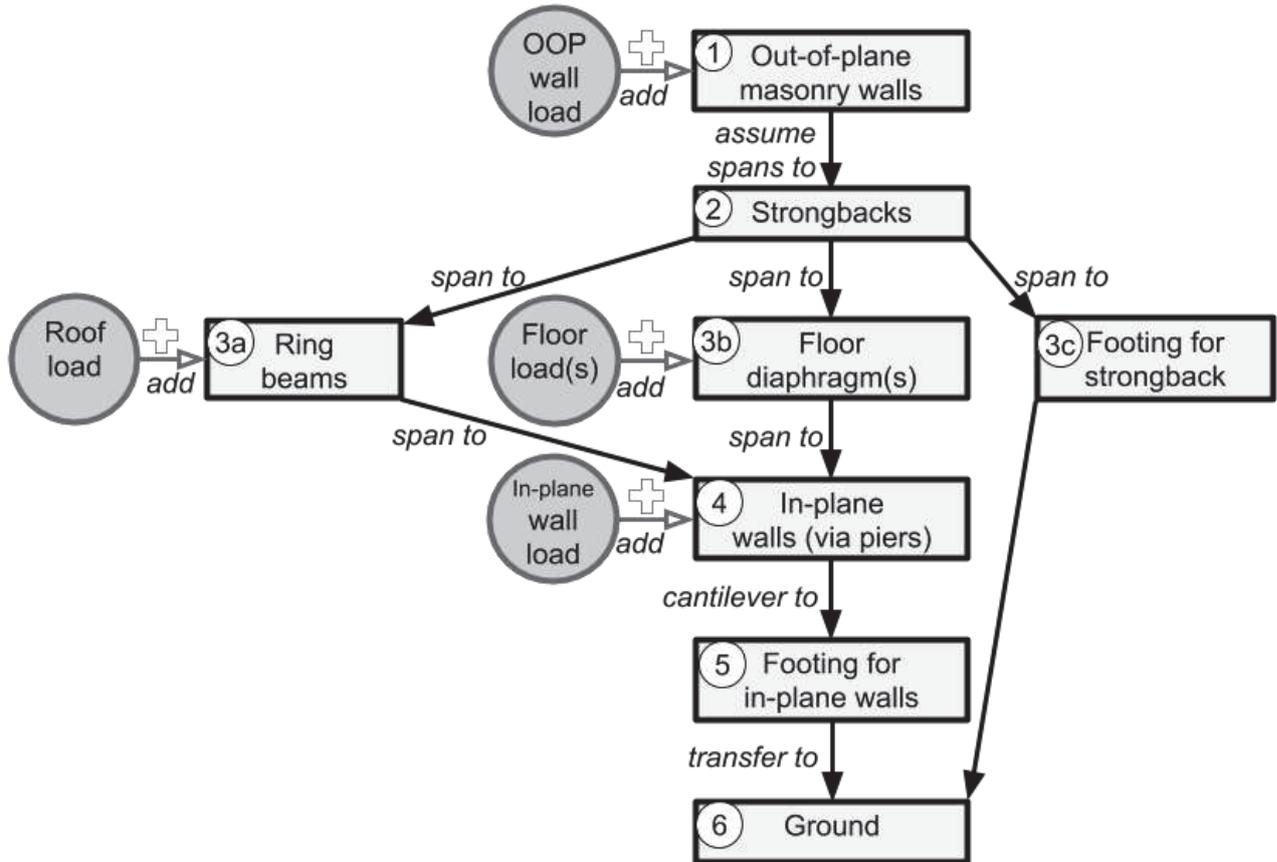


Figure 4-2 Chart depicting the load path of pre-engineering SMM retrofit

## 4.2 Existing Seismic Deficiencies of SMM Buildings

Common seismic deficiencies of SMM buildings and their mitigation measures are summarized in the table below. Section 5.3 to 5.10 provide an overview of these deficiencies and how they are addressed in the pre-engineered retrofit. [Section 5](#) provides the design and detailing requirements for these mitigation measures.

Category	Deficiency	Mitigation	Relevant section	
			Principles	Design
Out-of-plane (OOP) forces	Walls prone to delamination	Through concrete	5.3	6.3
	Low OOP wall strength	Strongbacks	5.4	6.4
	Low OOP attic wall strength	Ring beam	5.5	6.5
	Heavy, unbraced gable walls	New lightweight gable	5.6	6.6
	Weak diaphragm-to-wall connections & weak diaphragms	Improved diaphragm-to-wall ties & slab strip diaphragm strengthening	5.7	6.7
In-plane forces	Inadequate shear strength	Limited openings, or added shear strength	5.8	6.8
General	Weak roof framing connections and bracing	Improved connections and add bracing	5.9	6.9
	Weak connections at wall intersections	Corner strongbacks, ring beams, slab strips	5.10	N/A

Note: Vulnerable site locations are also a common seismic issue for SMM buildings. However, this issue is not addressed in the Manual, because buildings with this issue are not eligible for pre-engineered retrofit. Addressing this issue is typically not practically feasible.

### 4.3 Masonry wall construction

#### 4.3.1 Engineering requirements

The integrity and strength of SMM walls are closely related to the bond between stones. There must be interconnecting elements between wythes in order for them to behave as single unit. Where each wythe behaves separately because these interconnecting elements do not exist, the out-of-plane bending capacity of the wall is lower and risk of failure is higher.

#### 4.3.2 Deficiency: Walls prone to delamination

SMM walls are generally more than 450 mm thick. Larger stones are sometimes unavailable or difficult to shape. Walls are typically constructed with smaller stones that do not span the entire width of the wall. The lack of interconnecting elements makes the wall prone to delamination of the wall during OOP

loading. Partial loss of the wall weakens its capacity of the wall to carry gravity loads and further lateral loads. Thus, delaminated walls are very susceptible to further collapse.

### 4.3.3 Remediation: Through concrete

In the retrofit, through concrete elements are provided at a spacing that ensures the stone wythes will behave together when the wall is subjected to bending. The through concrete element is made by removing a small area of the wall and infilling the hole with rebar ties in concrete. After the through concrete is installed, the wall has the capacity to span out of place to the new strongbacks.

Deficiency	Remediation
<p><i>Masonry wythes are not sufficiently interconnected</i></p>	<p>Installation of through concrete</p>
	

## 4.4 Out-of-Plane (OOP) Strength of Walls

### 4.4.1 Engineering requirements

Walls should have adequate out-of-plane strength. To achieve this, the wall must have adequate bending capacity to span between brace points along its height. Brace points typically occur at each diaphragm and the foundation level. The connection of the diaphragm to the wall must be adequate to transfer the out-of-plane load from the wall into the diaphragm. The diaphragm then delivers the load into the perpendicular walls, which resist the load in in-plane shear.

### 4.4.2 Existing deficiency: Insufficient OOP strength

A typical SMM building has two issues with out-of-plane wall capacity:

1. The wall has insufficient bending strength to span between brace points.

- The diaphragm-to-wall ties are too weak to transfer the out-of-plane wall load to the diaphragm. As a result, the wall span is lengthened and bending demand is increased.

Out-of-plane wall failures are more commonly observed in transverse walls. Longitudinal walls are typically less susceptible to out-of-plane wall failures, because floor joists spans to those walls. The joist to wall connections are better diaphragm-to-wall ties than the connections along transverse walls at the diaphragm.

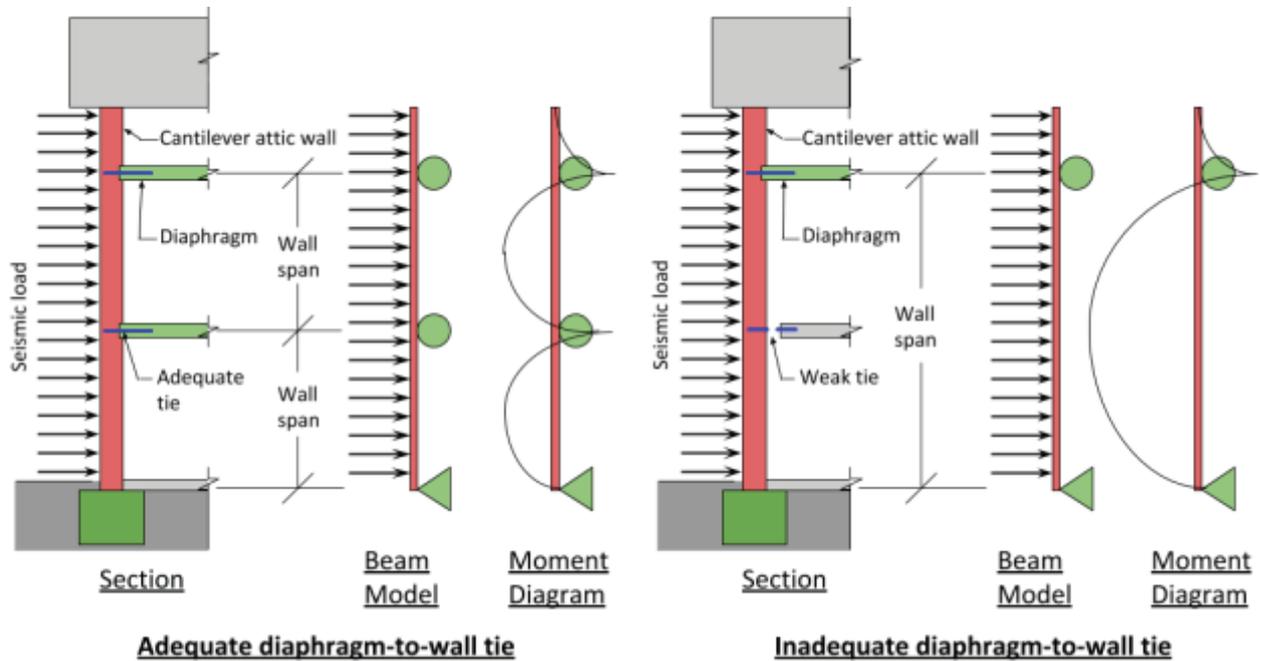


Figure 4-3 Weak diaphragm to wall ties result in longer wall spans and larger bending moment demands

#### 4.4.3 Remediation: New strongbacks

In the retrofit, strongbacks are installed to strengthen the flexural capacity of the wall for out-of-plane bending. It achieves this in two ways.

- The strongbacks decrease the span of the masonry wall, thus decreasing the demand. Before installation of the strongbacks, the masonry wall spans from floor-to-floor vertically. After installation of the strongbacks, the masonry wall spans two-ways: from strongback-to-strongback horizontally and floor-to-floor vertically (though the analysis conservatively assumes it spans only horizontally between strongbacks). The strongback spacing is set to provide a span size adequate for the masonry wall strength.
- The strongbacks provide adequate flexural strength to span vertically between from floor to floor brace points.

Strongbacks located at the wall corners also provide added interconnectedness between the perpendicular walls. This helps with transferring the out-of-plane load into the in-plane walls.

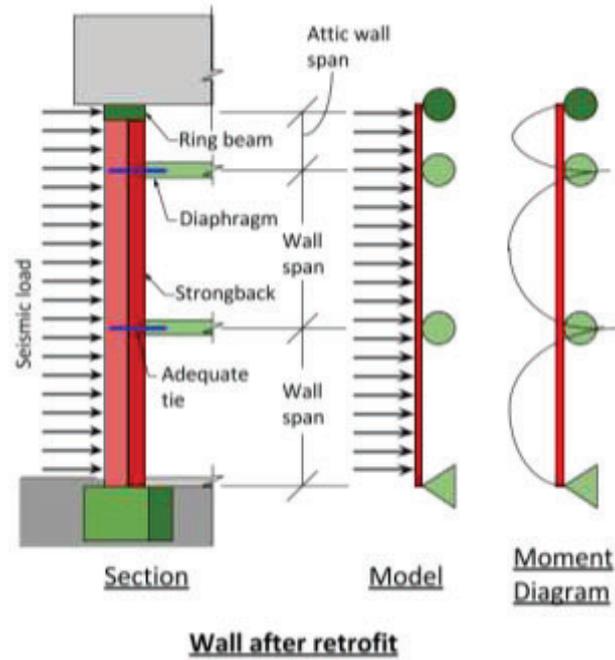


Figure 4-4 After the retrofit: (1) the strongback spans vertically; (2) The ring beam creates an additional support point at the top of the attic wall (see Section 4.5); (3) Improved wall-to-diaphragm ties (see Section 4.7) ensure that the diaphragm acts as a support point



Figure 4-5 From left: timber strongback (typical at midspan of transverse walls); reinforced concrete corner strongbacks; reinforced concrete mid-wall strongbacks (typical along longitudinal walls)

Deficiency	Remediation
<i>Insufficient OOP strength of walls</i>	Installation of strongbacks
	

## 4.5 Attic Walls

### 4.5.1 Engineering requirements

In SMM buildings, lightweight roofs do not have adequate strength or stiffness to serve as diaphragms. Thus, SMM attic walls typically resist out-of-plane lateral loads as cantilevers.

The walls carry the seismic loads associated with their self-weight. When the longitudinal walls are loaded out-of-plane, the attic walls also carry the roof's seismic load.

Attic walls should be strong enough to resist their seismic demands.

### 4.5.2 Existing deficiency: Weak strength & cantilevered

The cantilevered attic walls are typically unreinforced and unbraced. Typically, they do not have adequate strength to cantilever under seismic loading.

### 4.5.3 Remediation: New ring beam

In the retrofit, continuous reinforced concrete ring beams are installed at the top of the attic wall (below the roof) around the perimeter of the building. The ring beam improves the out-of-plane performance of the attic wall.

After installation of the ring beam, the attic wall is no longer assumed to cantilever from the floor below. Instead, the wall spans between the floor below and the ring beam. (The ring beam serves as a new support point at the top of the attic wall.)

The ring beam is designed to span between the walls perpendicular to it (which always serve as in-plane walls when the ring beam is engaged OOP). Intersecting ring beams are interconnected, and the load resisted by the ring beam is delivered to the in-plane walls through their interconnecting elements.

The masonry attic wall has the flexural capacity to span simply supported between the floor below and the ring beam. Strongbacks continue to the ring beam, and thus provide strengthening to the flexural capacity of the attic walls. However, their contribution is neglected in analysis for the retrofit design.

Deficiency	Remediation
<p><i>Unbraced cantilever attic walls have insufficient OOP strength</i></p>	<p><i>New ring beam at top of attic wall</i></p>
	

## 4.6 Gable walls

### 4.6.1 Engineering requirements

In SMM buildings, lightweight roofs do not have adequate strength or stiffness to serve as diaphragms. Thus, gables walls typically resist out-of-plane lateral loads as cantilevers.

Gable walls should have sufficient out-of-plane strength to resist their own inertial force. Their connections should be capable of transferring their inertial force into the transverse wall and the roof framing.

#### 4.6.2 Existing deficiencies: Heavy and unbraced

Gable walls are typically a continuation of the SMM wall up to the roof ridge level. Masonry is heavy and creates proportionally large inertial load. Gables are unreinforced and unbraced.

Typically, they do not have adequate strength to cantilever under code-level seismic loads. When SMM gable walls fail, falling hazards result, and there is a high risk of injury.

#### 4.6.3 Remediation: Remove and replace gable

In the retrofit, masonry gable walls are removed and replaced with lightweight wood framing. The lighter materials reduce the inertial force generated and reduce the risk of falling hazards

Positive connection to the roof framing and transverse wall below are provided, sufficient to transfer the seismic load into the structure.

Deficiency	Remediation
<i>Gable walls are heavy and unbraced</i>	<i>Installation of lightweight gables</i>
	

### 4.7 Floor Diaphragms

#### 4.7.1 Engineering requirements

Diaphragms carry the seismic loads associated with their own self-weight and any out-of-plane wall areas tributary to them. Diaphragms resist these loads as flexural elements and deliver them to the in-plane walls. Typically, the shear forces are resisted by a continuous topping (such as sheathing or concrete overlay) and the tension/compression generated at the extreme edges of the diaphragm are resisted by a chord.

In each direction of lateral loading, an adequate diaphragm has (1) OOP wall-to-diaphragm connections capable of delivering the OOP wall load into the diaphragm, (2) a topping adequate to resist the shear stresses generated in the diaphragm, (3) chord elements capable of resisting the tension and compression loads generated at the extreme edges of the section, (4) In-plane wall-to-diaphragm connections capable of delivering the load into the in-plane walls.

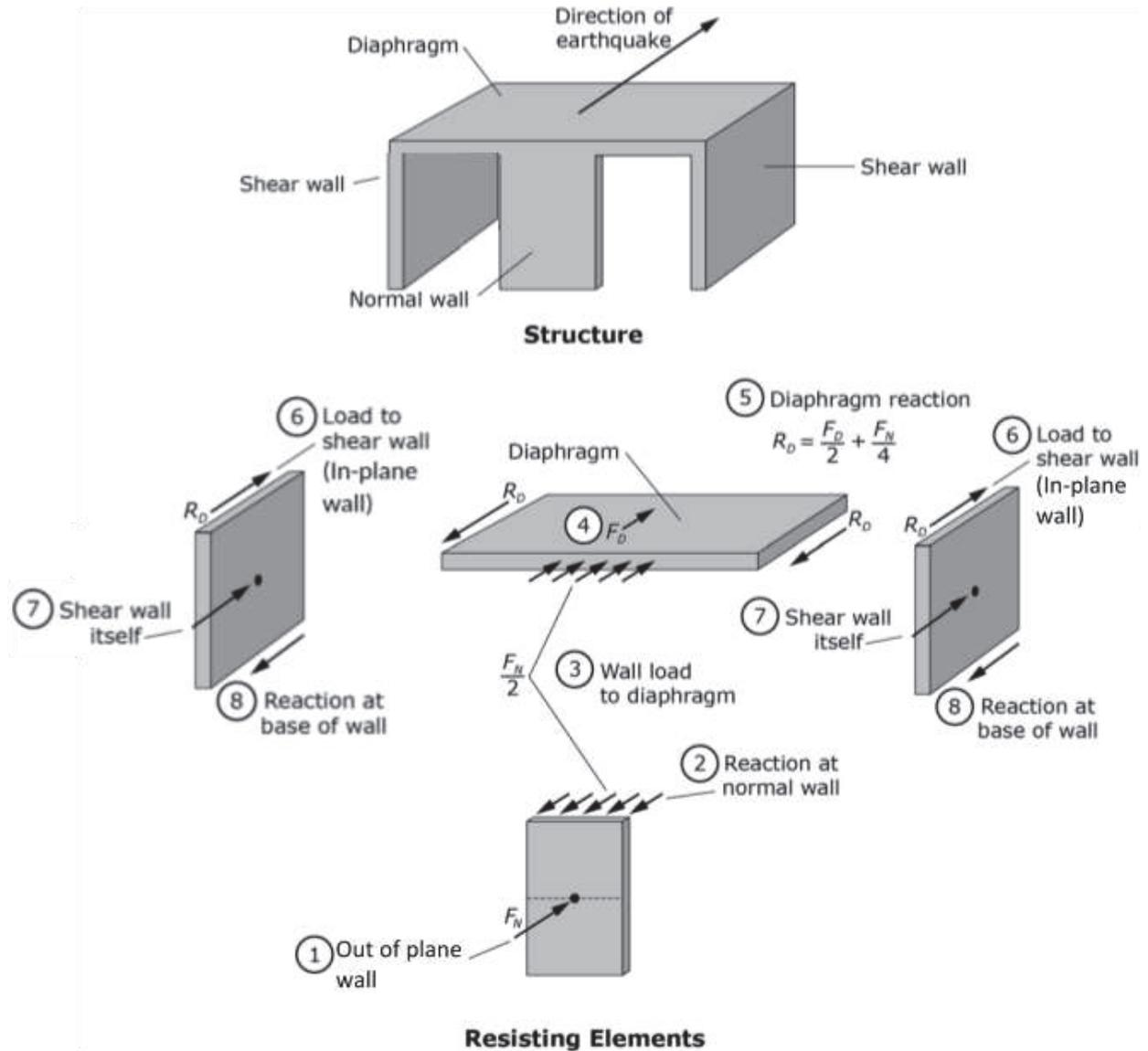


Figure 4-6 Diagram depicting how the diaphragm delivers OOP wall loads to in-plane walls (Source: Seismic Design Review by Stephen Hiner, with revisions)

#### 4.7.2 Deficiency: Weak diaphragm system and ties

SMM buildings typically have wood framed floors with a mud overlay. The floor construction has several issues which impair its ability to serve as a diaphragm:

- **Wall-to-diaphragm connections** are inadequate to transfer out-of-plane loads from the walls into the diaphragms and transfer shear forces from the diaphragm into the in-plane walls. On the longitudinal side, the floor joists connect to the wall and serve as ties. On the transverse side, there are few if any framing elements connected to the wall, and as a result the wall-to-diaphragm connection ties are weak or nonexistent.
- **Shear strength** of the mud overlay is inadequate to provide the necessary shear resistance to transfer the OOP loads into the in-plane walls.
- **Chord elements** do not exist in the floor system. As a result the OOP walls act to resist the tension and compression generated at the extreme edges of the diaphragm section. Vertical cracks at the joists have been observed in earthquake damage and are assumed to be a result of tension in the wall (which the wall is unable to withstand due to low tensile capacity).

#### 4.7.3 Remediation: Diaphragm strengthened with slab strips

In the retrofit, the floor systems are strengthened so that they can serve as adequate diaphragms. Reinforced concrete slab strips are installed. These slab strips serve as chords and are connected to the walls with dowels in concrete that are adequate to transferring:

- out-of-plane forces from the wall into the diaphragm (dowels in tension)
- Shear forces from the diaphragm into the in-plane walls (dowels in shear)

Diaphragm strengthening is done by providing reinforced concrete slab strips along the perimeter and at midspan in each floor level. This strip connects with the existing timber floor and provides connection of the diaphragm to the short walls, which was non-existent previously. Rebar cross bracing is installed where the slab strips intersect. This cross bracing allows the slab strips to behave compositely.

Deficiency	Remediation
<i>Weak diaphragms and connections to walls</i>	<i>New slab strips, cross bracing, and improved interconnection between elements</i>



## 4.8 In-plane wall strength

### 4.8.1 Engineering requirements

In-plane SMM walls are the lateral force resisting system for the entire SMM building. The piers in the wall are shear walls which carry the inertial force of the entire building to the foundation. They are assumed to behave as cantilevers from the ground level. Piers should be strong enough in shear and bending to resist the demand. Wherever the overturning moment caused by the shear exceeds the resisting moment from the weight tributary to the pier, tie down connections and foundations should be capable of withstanding the uplift force.

### 4.8.2 Existing deficiency: Inadequate pier strength

The material properties of SMM walls make the in-plane strength low compared to other materials commonly used in shear walls (such as stone masonry with cement mortar, reinforced masonry, or reinforced concrete). Despite their thickness, SMM walls have insufficient shear strength to resist shear demands.

Walls with higher opening percentages have higher shear stresses than walls with lower opening percentages and have inadequate pier strength to meet the demands.

### 4.8.3 Remediation: Pier strengthening

In the retrofit, cement sand plaster is applied to the interior and exterior of all loadbearing masonry walls. For walls with lower opening percentages, this is sufficient strengthening to resist the shear demands.

Walls with higher opening percentages require the installation of GI wire mesh in cement sand plaster with firm connections at the top and bottom.

Deficiency	Remediation
<p><i>Insufficient in-plane strength</i></p>	<p><i>In-plane strengthening of wall piers with cement plaster or wire mesh with mortar overlay (Pictured below: Wire mesh before cement plaster installation)</i></p>
	

## 4.9 Roof framing and wall connections

### 4.9.1 Engineering requirements

Roof framing members should have adequate positive connections and lateral bracing.

Roof-to-wall connections should be sufficient to transfer inertial loads of the roof to the attic walls via the ring beams. They should also be able to resist lateral and uplift forces generated by wind loading.

### 4.9.2 Existing deficiency: Weak or lack of positive connections

Connections between roof framing elements (purlins to rafters) are often insufficient and lateral bracing or rafters is typically nonexistent.

Connections between the roof framing and wall often lack positive connections or are insufficient to transfer lateral and uplift loads from the roof to the ring beam.

### 4.9.3 Remediation: New connections and lateral bracing

In the retrofit, positive connections between rafters and purlins are provided.

Cast-in-place straps are installed to connect the rafters to the ring beam. The strap provides uplift and lateral load resistance.

Deficiency	Remediation
<p><i>Weak or lack of positive connections between roof framing elements and structure</i></p>	<p><i>Improved connections between roof framing elements and structure</i></p>
	

### 4.10 Interconnection of walls and diaphragms (“Box Effect”)

#### 4.11 Engineering requirement

Where perpendicular walls intersect, the interconnection should be sufficient to transfer any tributary load for the OOP wall into the in-plane wall. The interconnecting elements prevent the walls from separating during seismic loading.

#### 4.12 Deficiency: Insufficient interconnection between elements

The interconnection between perpendicular walls is insufficient to transfer out-of-plane loads to in-plane walls.

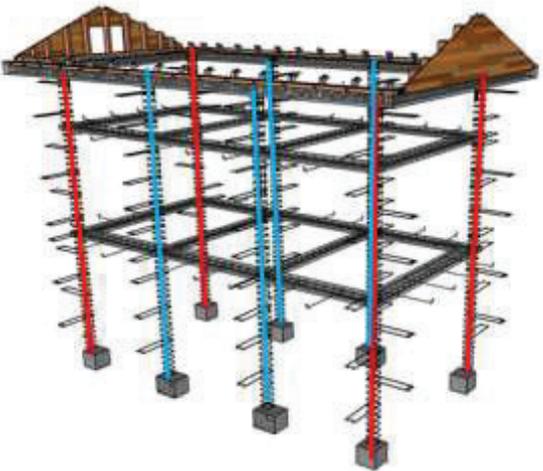
In earthquakes, separation between perpendicular walls have been observed.

### 4.12.1 Remediation

Several elements provide interconnection between the walls to create a “box effect”. Each of these previously mentioned elements are connected to both walls and ensure that forces from the out-of-plane wall are adequately transferred into the in-plane walls.

- Strongbacks at each wall corner
- Ring beams
- Slab strips

These elements are addressed under their individual sections. Therefore, there is no separate section devoted to the detailing for interconnection of walls.

Deficiency	Remediation
<p><i>Insufficient connection between perpendicular walls and between walls and diaphragms</i></p>	<p><i>Strongbacks, ring beams, slab strips</i></p>
	

## 5 RETROFIT DESIGN & DETAILING

### 5.1 Overview

This section provides instructions and details for elements of the retrofit design. Most retrofit elements are required for all eligible buildings. For some elements, review of existing conditions is required to determine if the remediation measure is required or to determine what type of remediation measure is required.

In order to be considered pre-engineered by this Manual, the retrofit must meet all design and detailing requirements provided in this section.

### 5.2 Summary table

An overview of all seismic-resistant components in a typical pre-engineered retrofit building is provided below.

Retrofit element	When remediation is required	Detailing section
Through concrete	Always required	6.3
Strongbacks	Always required	6.4
Ring beam	Always required	6.5
Gable replacement	Required where gables are SMM	6.6
Diaphragm strengthening	Always required	6.7
Cement plaster pier strengthening	Where wire mesh pier strengthening is not required (see Section 5.8.1)	6.8.2
Wire mesh pier strengthening	As determined by opening percentage in Section 5.8.1	6.8.3
Roof framing strengthening	Required where existing roof is in poor condition or will be replaced	6.9
Positive connection of roofing tiles to roof framing	Required where roofing tiles are used	NBC 203, 9.2.3

## 5.3 Through concrete

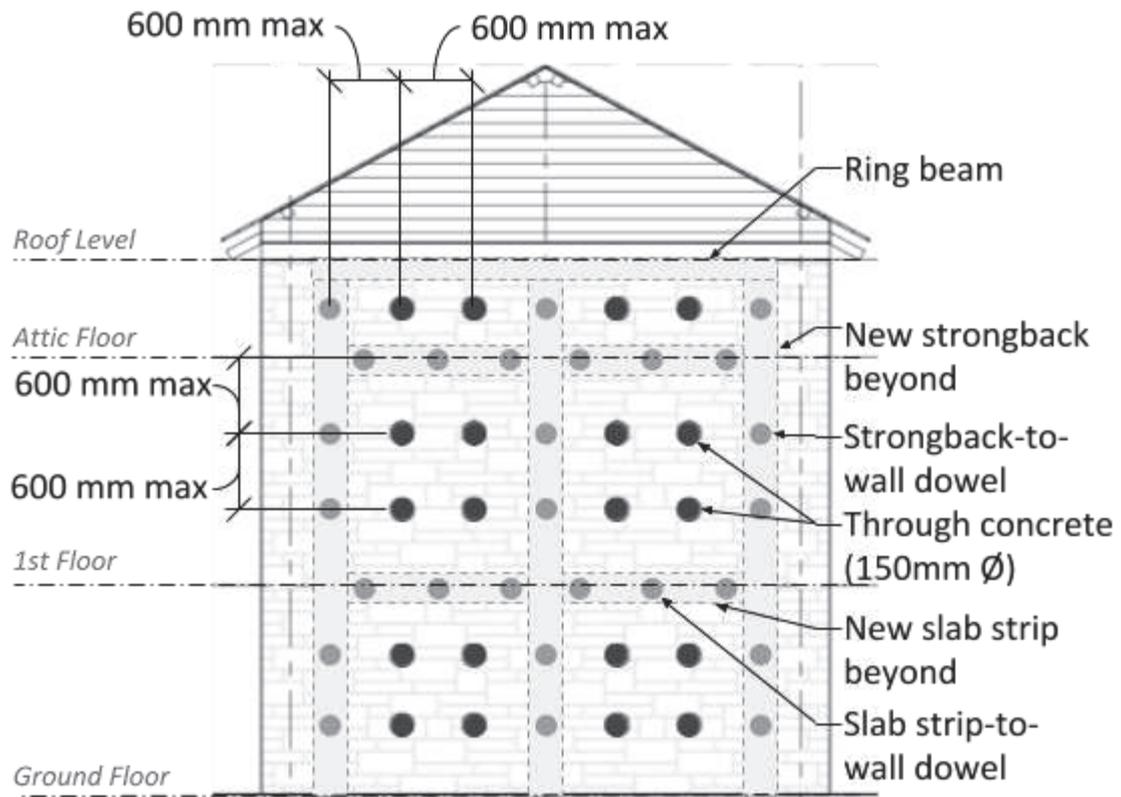
### 5.3.1 Description

Through concrete is a reinforced concrete element installed in an existing SMM wall to provide interconnection between wythes of the wall. See Section 4.3 for more information.

### 5.3.2 Design

Through concrete is required on all exterior SMM walls. The spacing of through concrete shall not exceed 600 mm (2 feet) center-to-center vertically or horizontally over the entire wall area (including the attic walls). Interconnection elements are integral to the design of slab strips and strongbacks. Thus, additional through concrete elements are not required along slab strips and strongbacks. Maximum spacing can be measured from the center of the slab strip or strongback to the through concrete. See the figure below for a graphical summary of the spacing requirements. Install per details in the detailing section.

<b>Overall Diameter</b>	<b>Allowable maximum spacing</b>
150 mm (6 inches)	600 mm (2 ft)



## Elevation

*Figure 5-1 Elevation depicting maximum spacing for through concrete*

### 5.3.3 Detailing

Through concrete elements shall be minimum 150 mm (6 inches) in diameter and be continuous through the entire width of wall. Remove stones as required to create hole for the new element. As much as practical, do not oversize hole. Remove mud, clean hole, and wet the entire surface of the hole before installing through concrete element. At the center of the hole, provide one 7 mm diameter rebar with hooks each end and adequate cover. See the figure below for a detail of the new through concrete element.

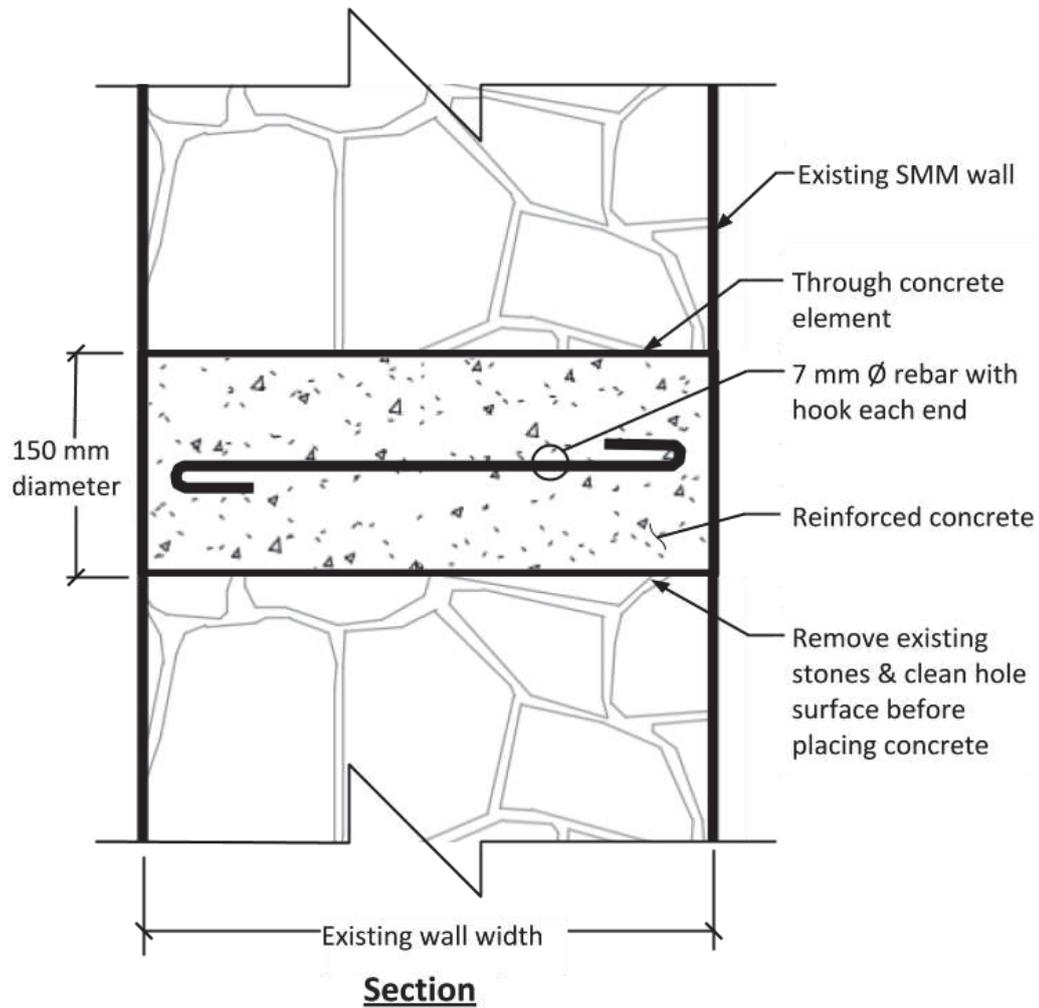


Figure 5-2 Section (or plan) through the SMM wall at a new through concrete element

## 5.4 Strongbacks

### 5.4.1 Description

Strongbacks are vertical elements that run from ground level to the ring beam. Strongbacks in corners and along longitudinal walls are reinforced concrete, and strongbacks along the transverse walls are timber. Strongbacks provide out-of-plane strengthening to SMM walls.

### 5.4.2 Design

Strongbacks shall be located (1) in each corner where exterior walls intersect; (2) at the midpoint of the transverse walls; and (3) along the longitudinal walls at 2800 mm maximum center-to-center spacing. Strongbacks shall be located at least 150 mm from all openings.

At each corner and along the longitudinal walls, strongbacks shall be reinforced concrete with a 200 mm by 200 mm cross section. At midpoint in plan along both exterior transverse walls, the strongback shall be timber meeting these minimum properties:

Strongback timber type	Transverse wall length, B	Minimum cross section dimensions (see Note)
Soft timbers	$B \leq 5 \text{ m}$	150 mm x 150 mm (6"x6")
	$5 \text{ m} < B \leq 6 \text{ m}$	160 mm x 160 mm (6.3"x6.3")
Hard timbers	$B \leq 5 \text{ m}$	115 mm x 115 mm (4.5"x4.5")
	$5 \text{ m} < B \leq 6 \text{ m}$	125 mm x 125 mm (5"x5")

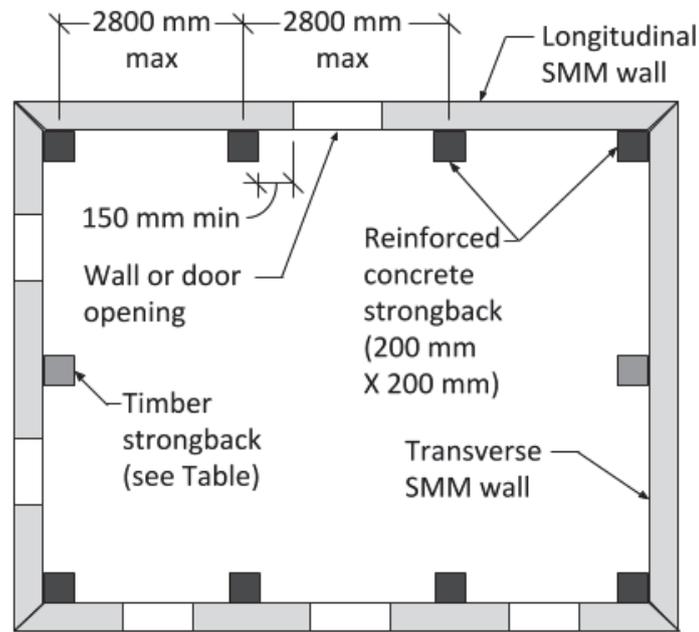
Note: Any other section equivalent to above mentioned can be used.

The strongbacks shall run continuously with no offset from the ground floor to the top of the ring beam. A new footing (450 mm by 450 mm) shall be provided at each strongback. Along the height of the strongback, dowels penetrating the entire SMM wall width shall be provided. In corner locations, dowels shall connect to both walls. At each diaphragm level, dowels connected to the new slab strips shall be provided.

The requirements for strongback layout design are provided in the table below. Install per details in the detailing section.

Location in plan	Material	Minimum size of cross section	Allowable max spacing (center-to-center)	Notes
Corners	Reinforced concrete	200 mm x 200 mm (8"x8")	N/A	
Along longitudinal walls	Reinforced concrete	200 mm x 200 mm (8"x8")	2800 mm (9.2 ft)	Shall be at least 150 mm from edge of opening.
Midpoint of transverse wall (2 locations)	Timber	Per timber strongback table	N/A	Acceptable to reuse existing posts that meet minimum dimensions and are in good condition

The requirements for strongback layout design are provided graphically in the figure below.



**Plan**

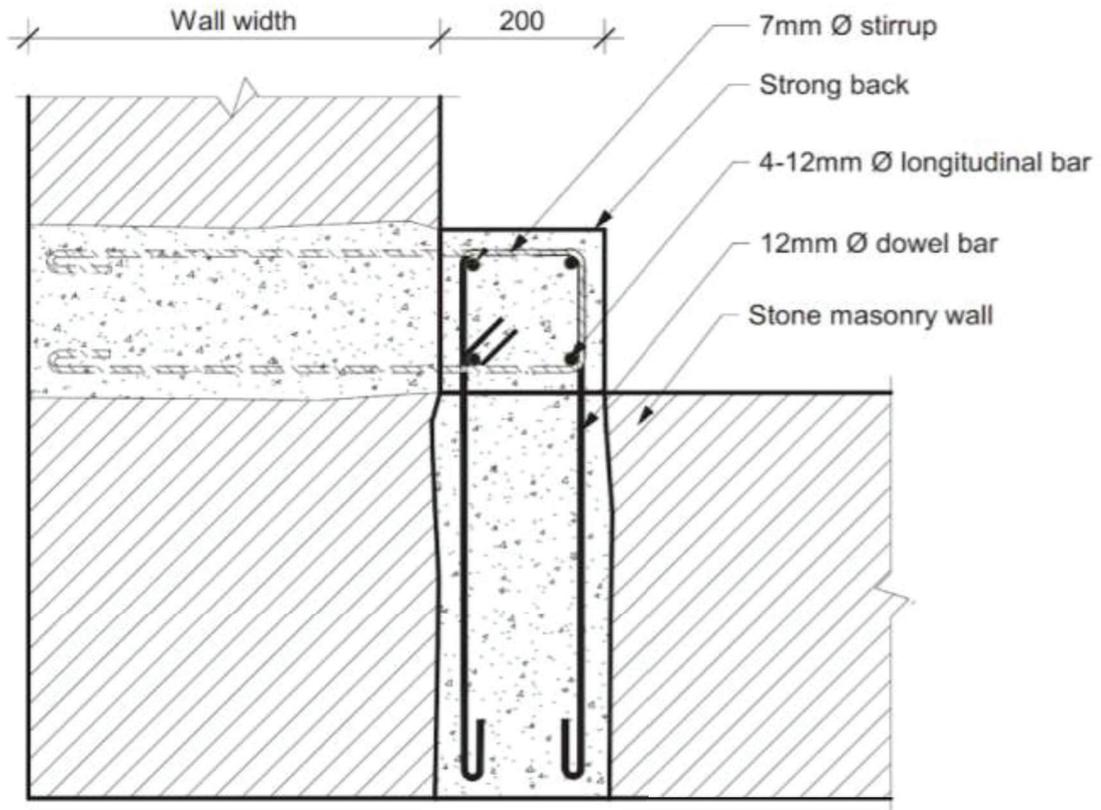
Figure 5-3 Plan depicting strongback layout requirements (NTS)

**5.4.3 Detailing**

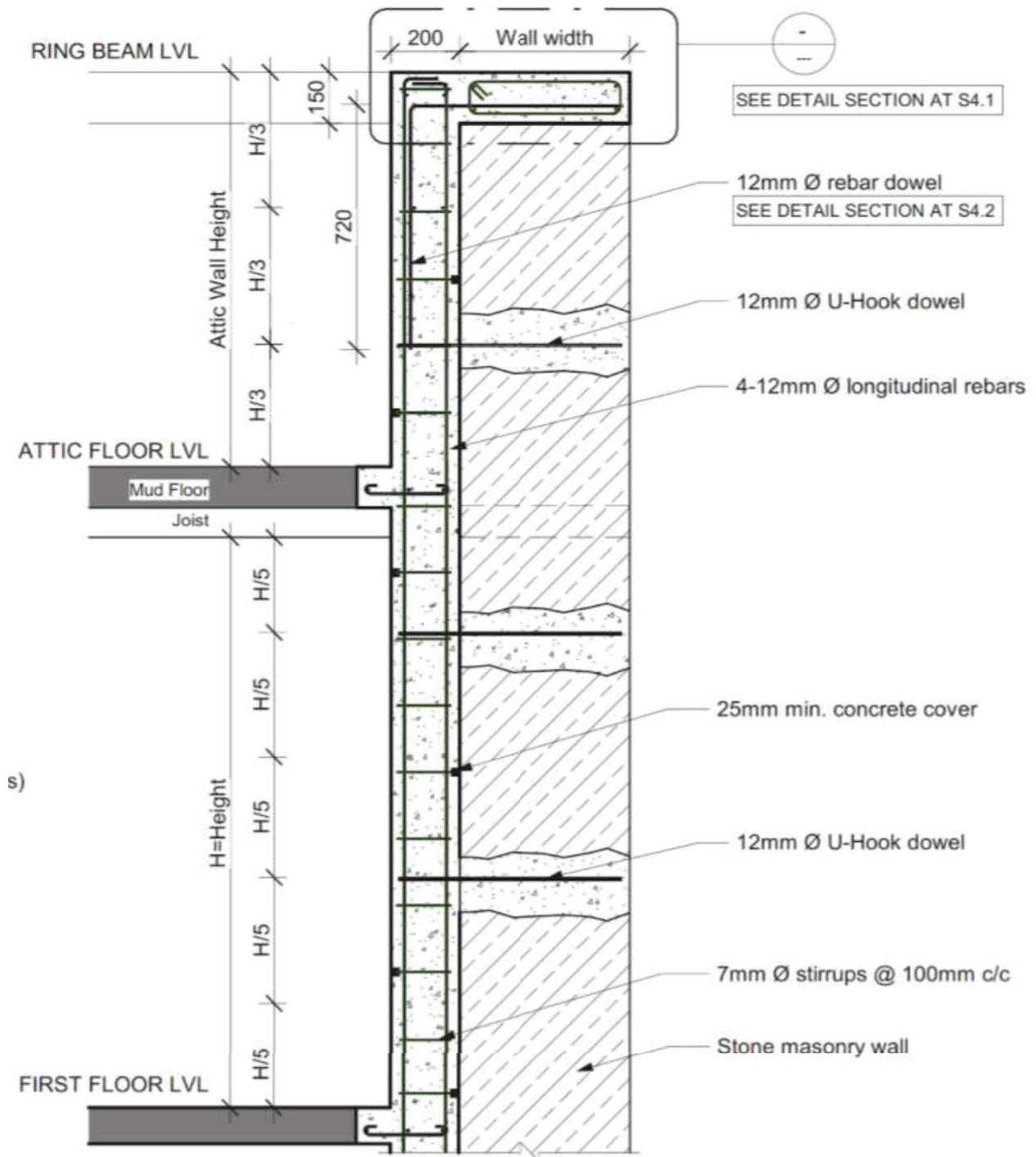
**5.4.3.1 Corner strongbacks (reinforced concrete)**

Typical details for corner strongbacks and their connections are located are below.

Details for connection of strongback to ring beam are provided in Section 5.5.

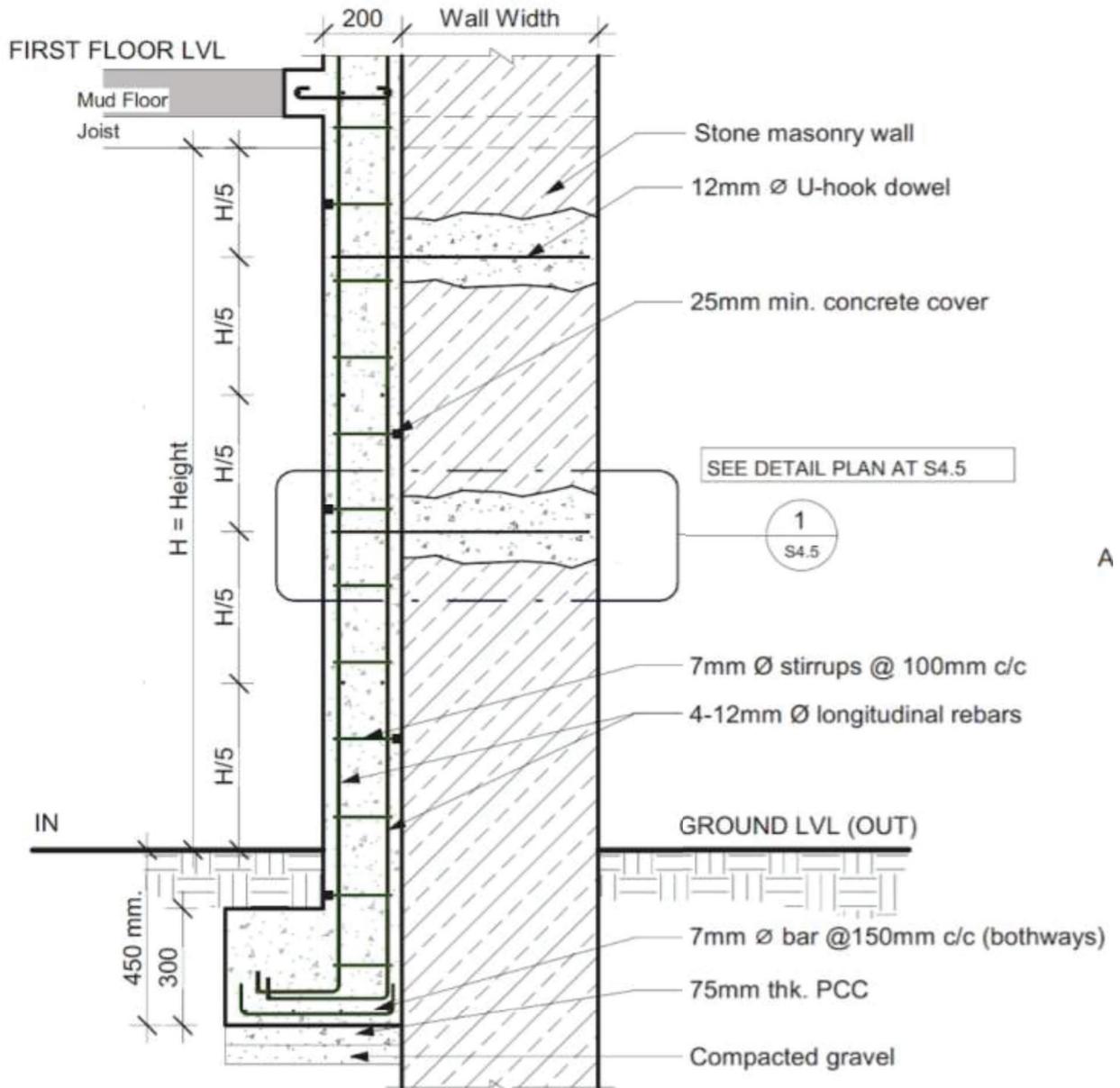


1 CORNER STRONG BACK CONNECTION DETAIL  
1 : 8



s)

3 CORNER STRONG BACK SECTION (FIRST & ATTIC FLOOR)  
 1 : 15  
 Designed By: (Signature)



1 CORNER STRONG BACK SECTION (GROUND FLOOR)  
1 : 15



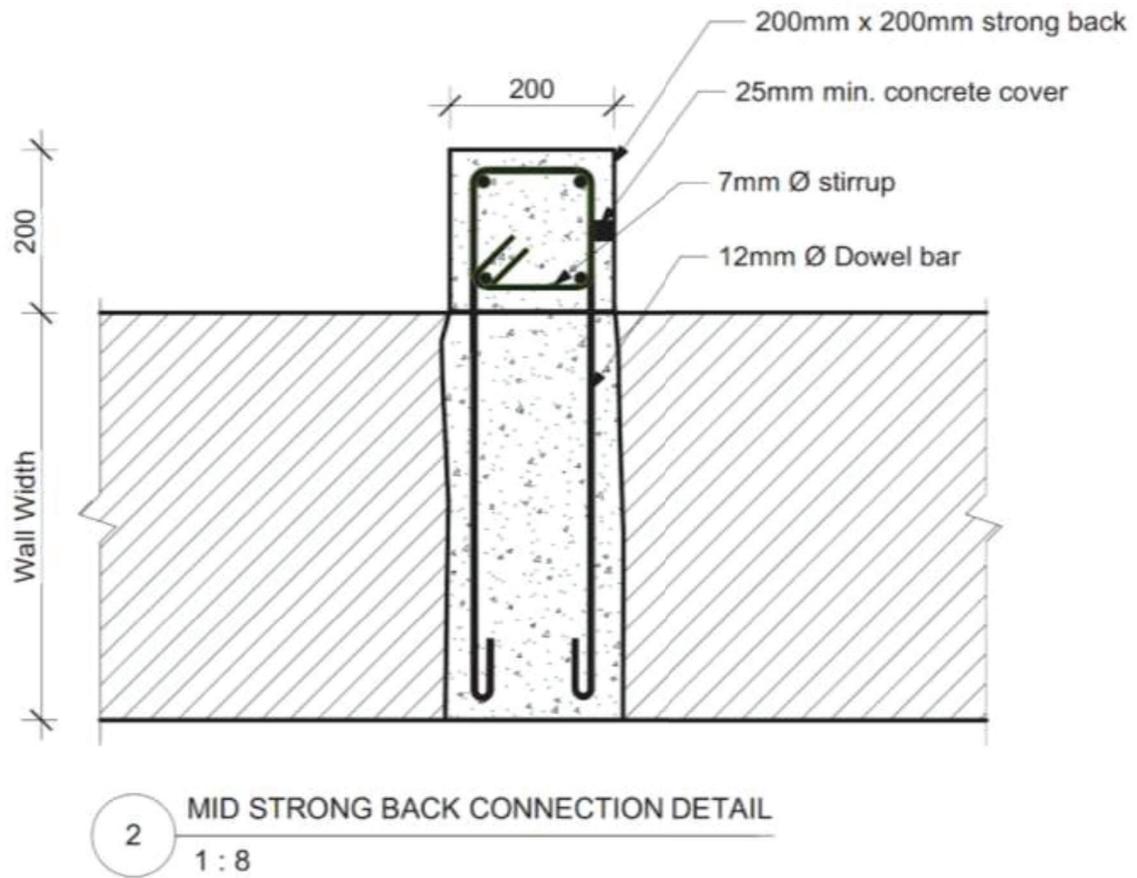
2 CORNER STRONG BACK FOUNDATION PLAN  
1 : 15

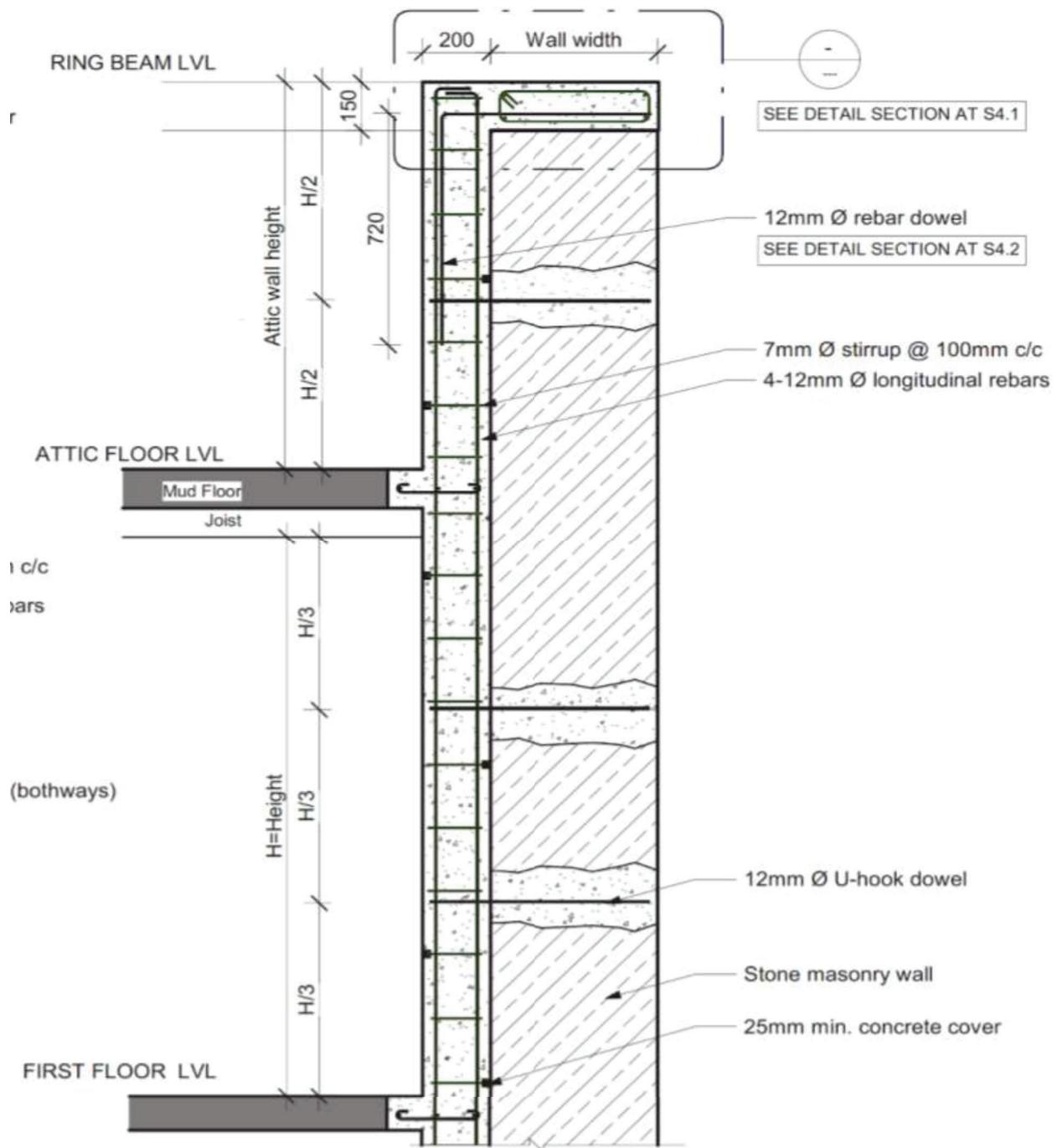
Approved By (Signature):

### 5.4.3.2 Longitudinal wall strongbacks

Typical details for longitudinal wall strongbacks and their connections are located are below.

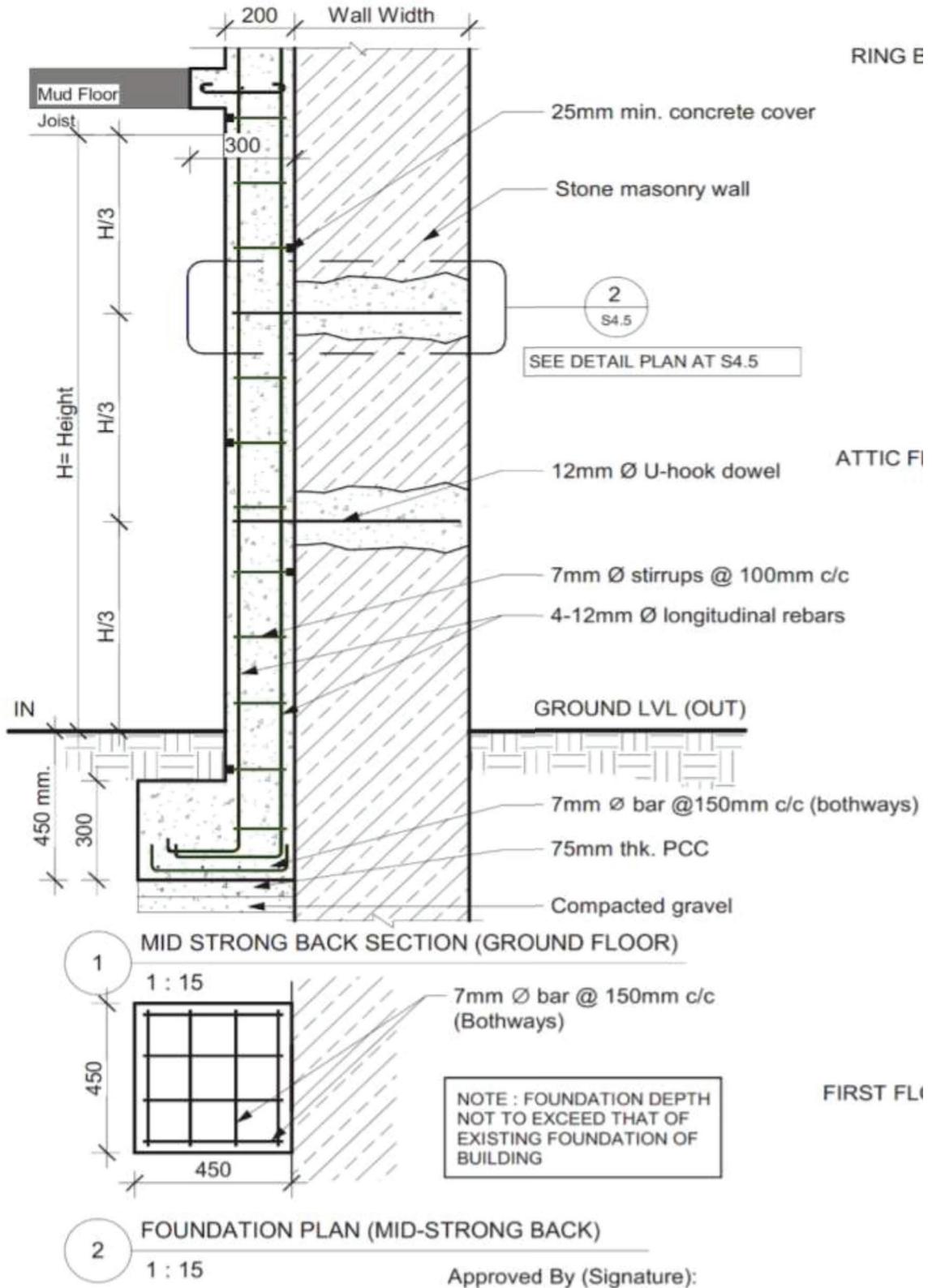
Details for connection of strongback to ring beam are provided in Section 5.5.





3 MID STRONG BACK SECTION (FIRST & ATTIC FLOOR )  
1 : 15

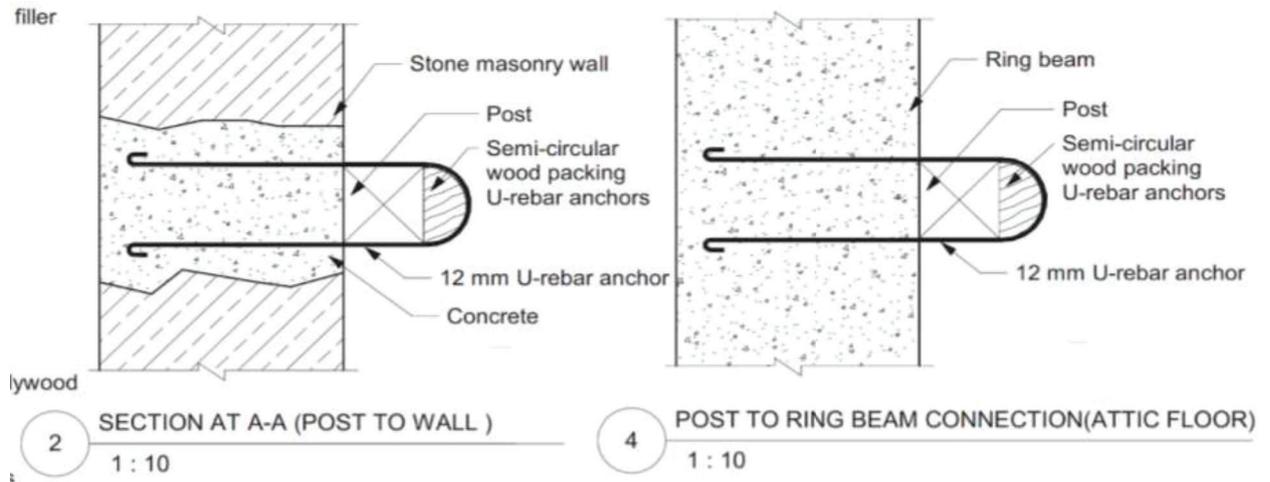
Designed By (Signature):



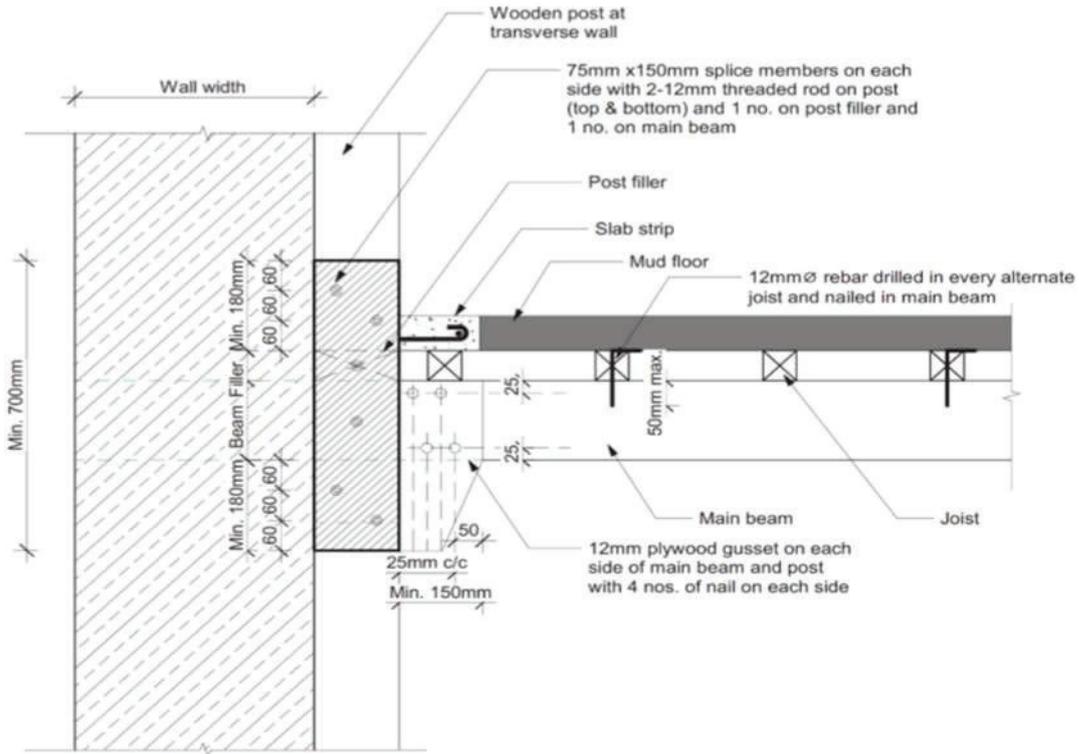
### 5.4.3.3 Transverse wall strongbacks (timber)

Typical details for transverse wall strongbacks and their connections are below.

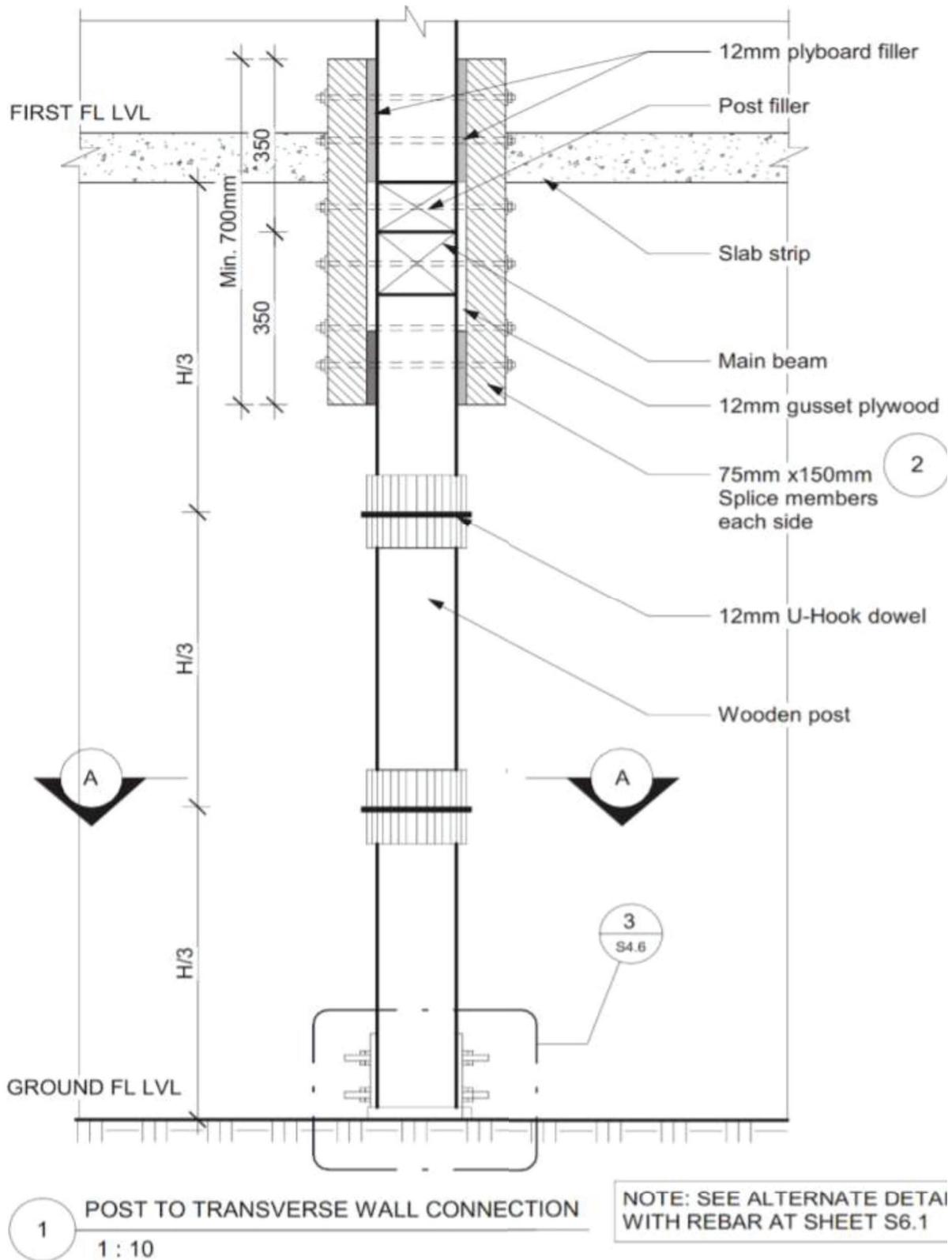
Details for connection of strongback to ring beam are provided in Section 5.5.

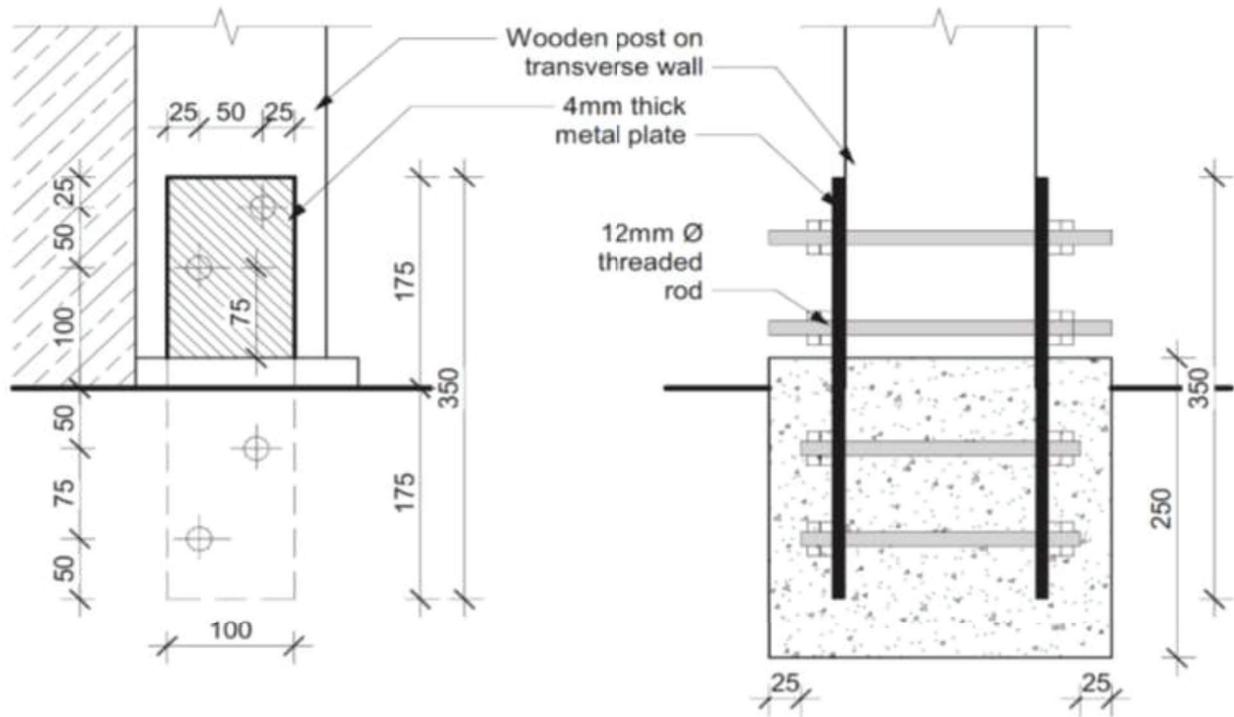


5.4.3.3.1 Option 1: Threaded Rod Connections



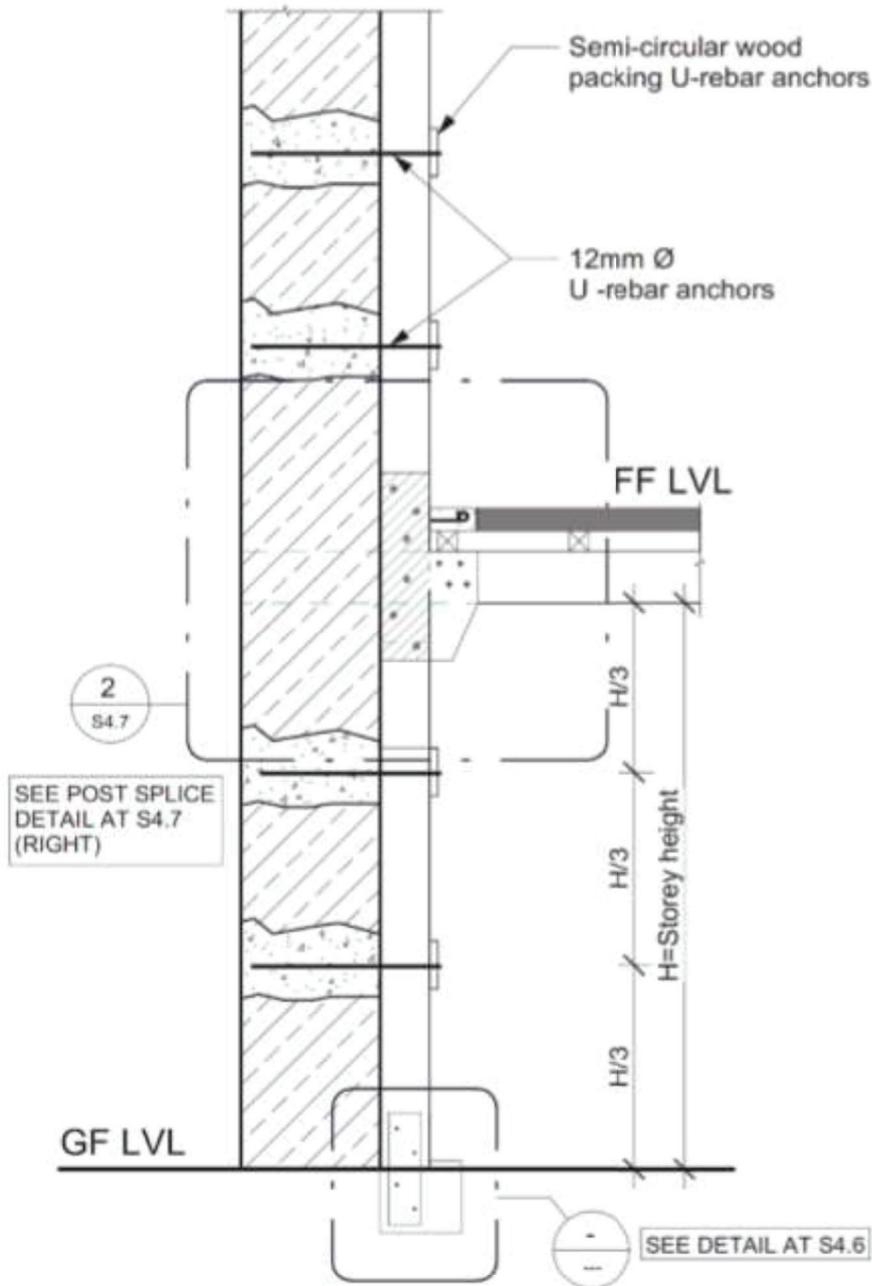
2 POST SPLICE DETAIL.  
1 : 8





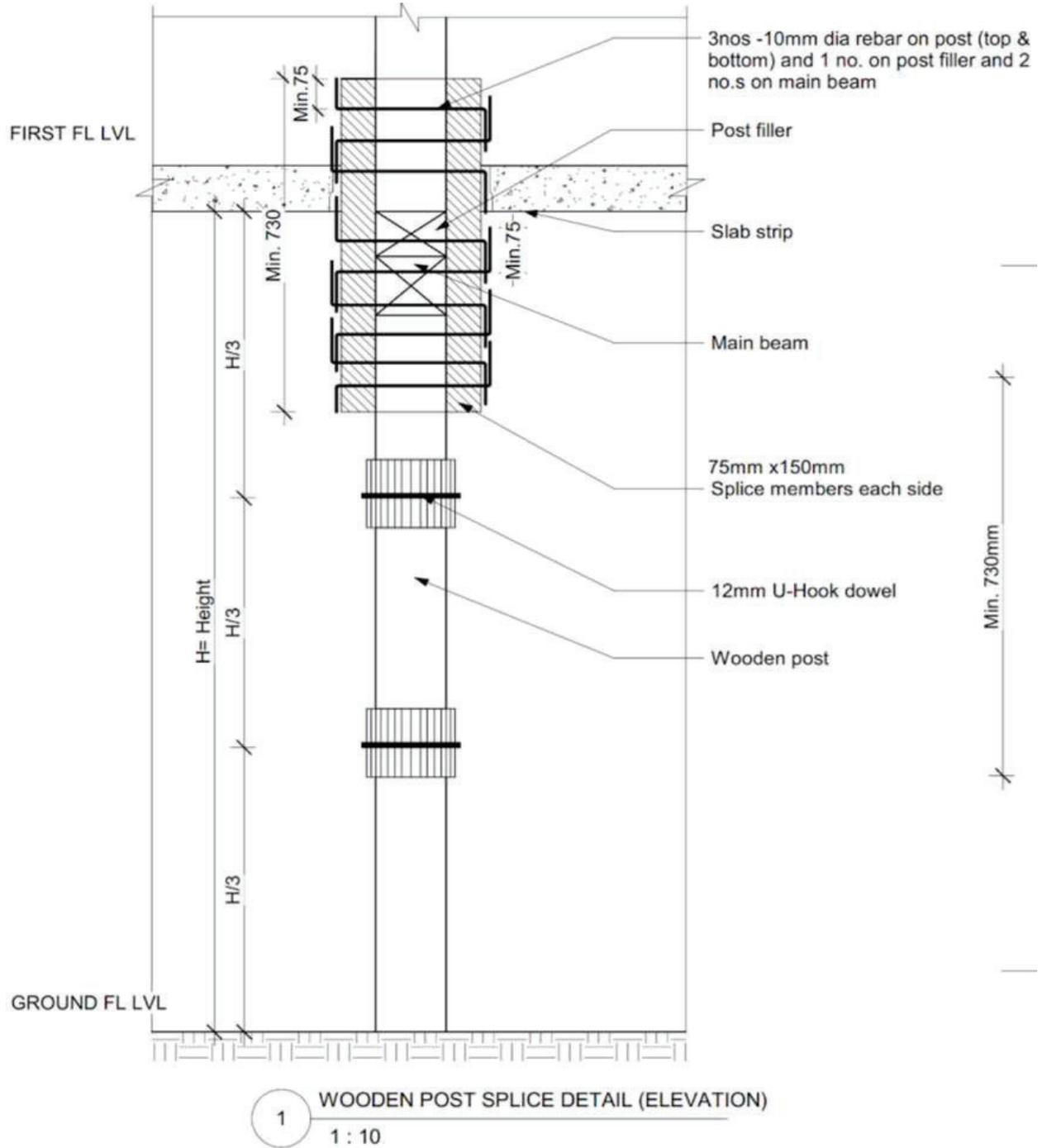
NOTE: SEE ALTERNATE DETAIL OF FOUNDATION WITH REBAR AT SHEET S6.2

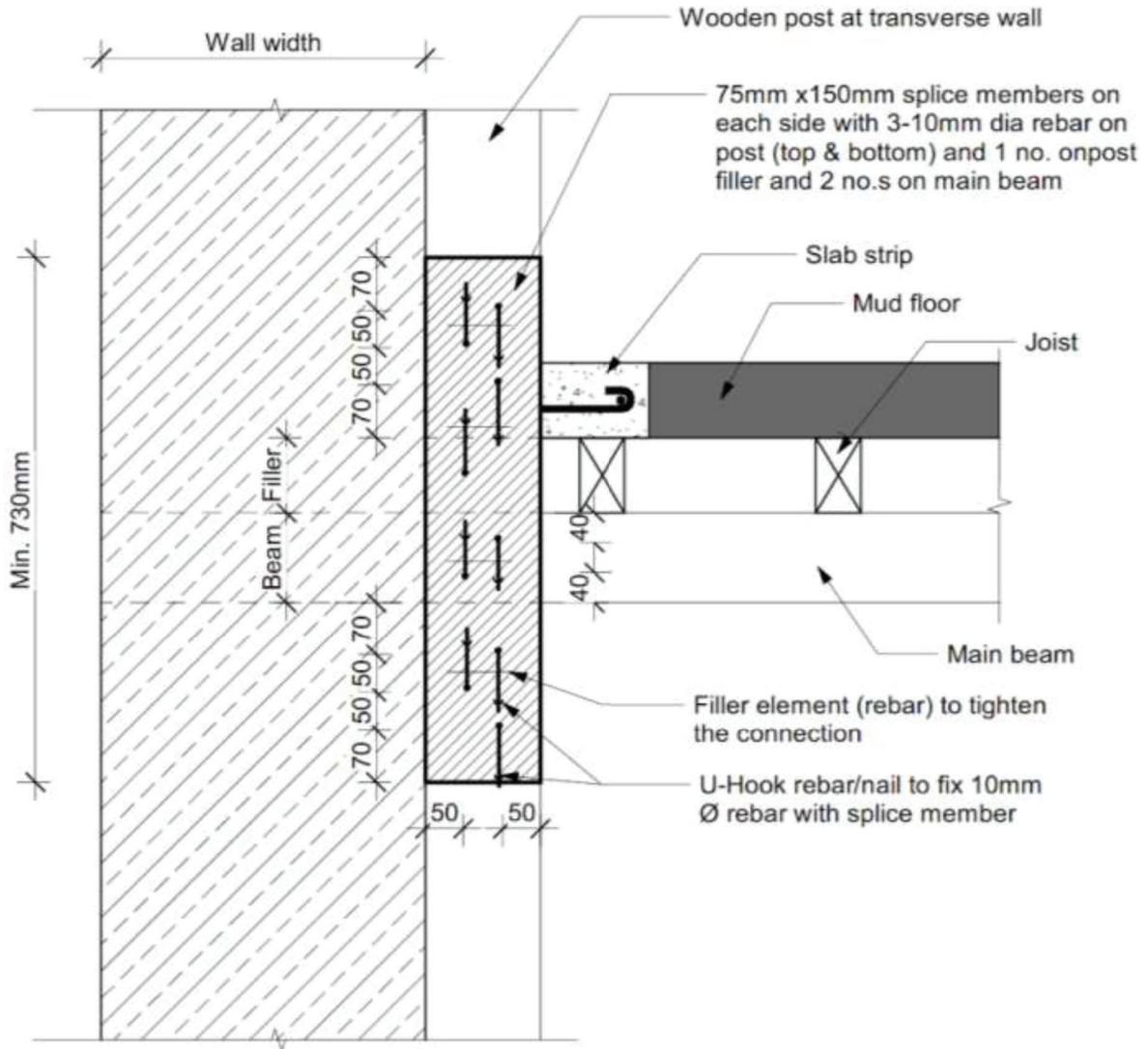
3 POST FOUNDATION DETAIL(SIDE VIEW & SECTION)  
1 : 5



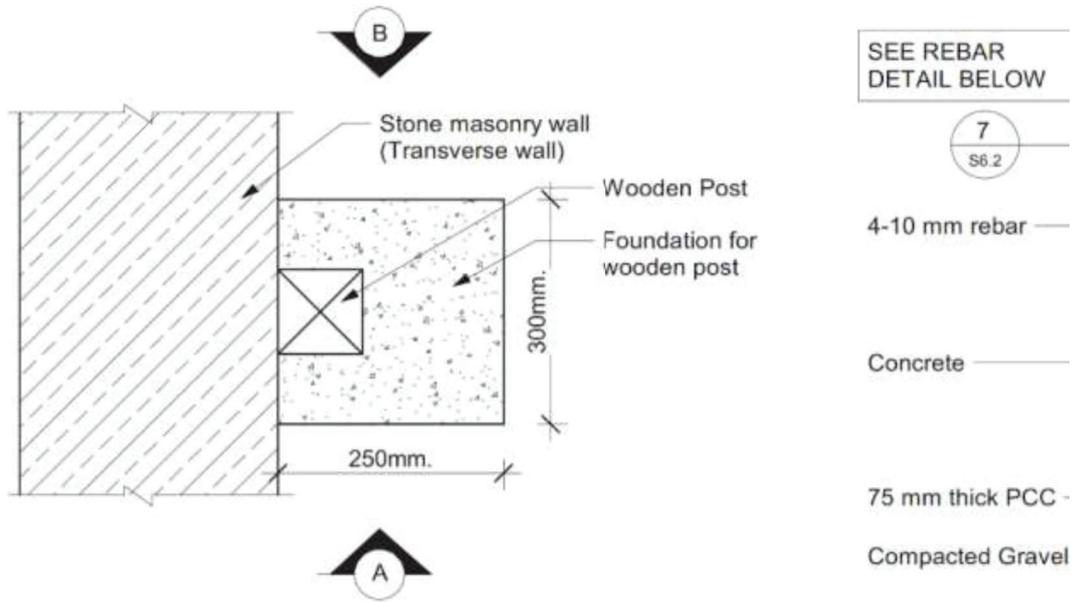
1 WOODEN POST SIDE ELEVATION.  
1 : 20

5.4.3.3.2 Option 2: Steel Reinforcement Connections



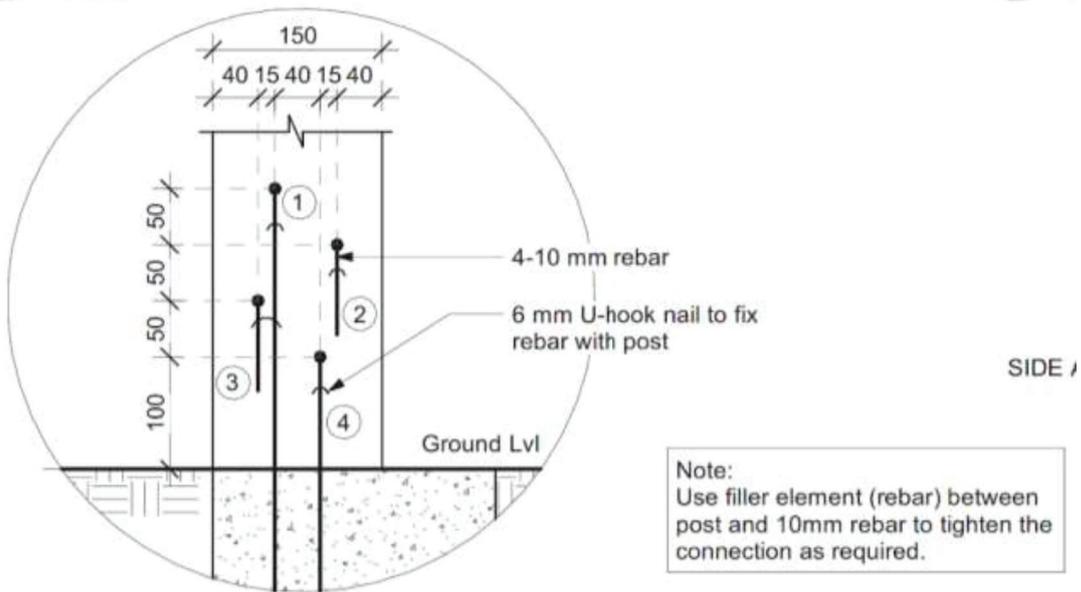


2 POST SPLICE DETAIL  
1 : 8



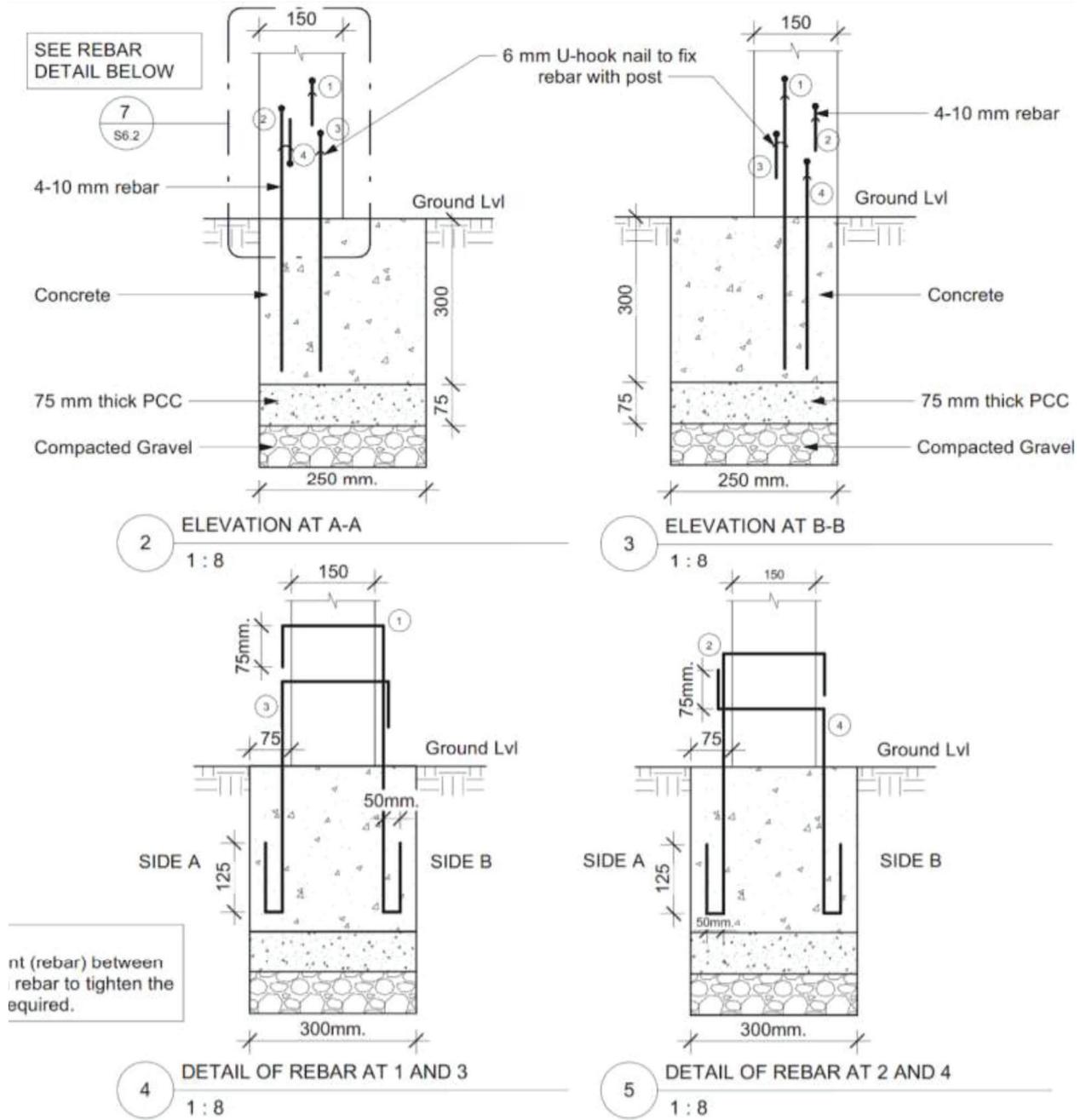
1 POST TO TRANSVERSE WALL CONNECTION (PLAN)  
1 : 10

2 E  
1



7 REBAR DETAIL  
1 : 5

4 C  
1



## 5.5 Ring Beams

### 5.5.1 Description

Ring beams are reinforced concrete elements installed at the top of an existing SMM wall to provide out-of-plane support for attic walls.

### 5.5.2 Design

Ring beams must be continuous and without offset. The attic wall with the ring beam may not exceed 1.2 meters.

Install per details in the detailing section.

### 5.5.3 Detailing

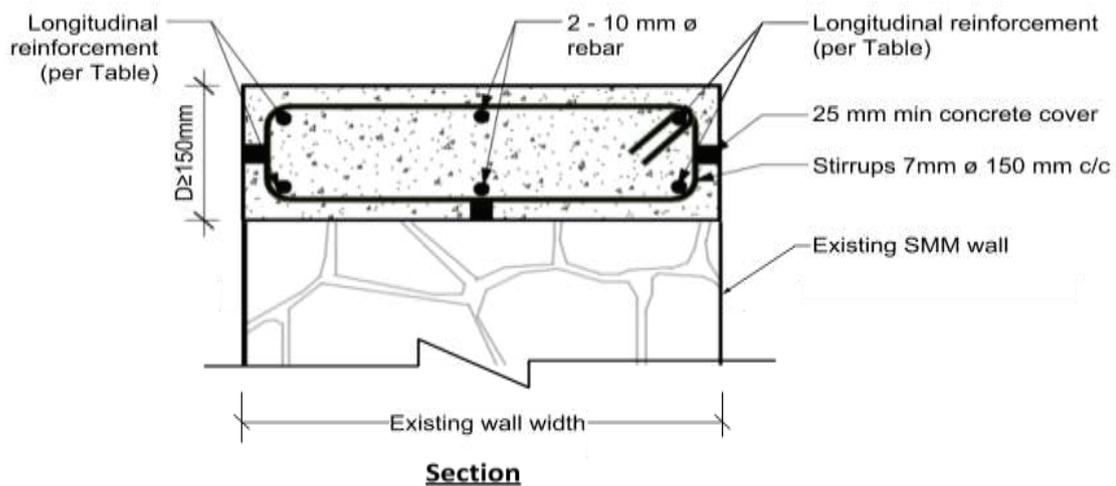
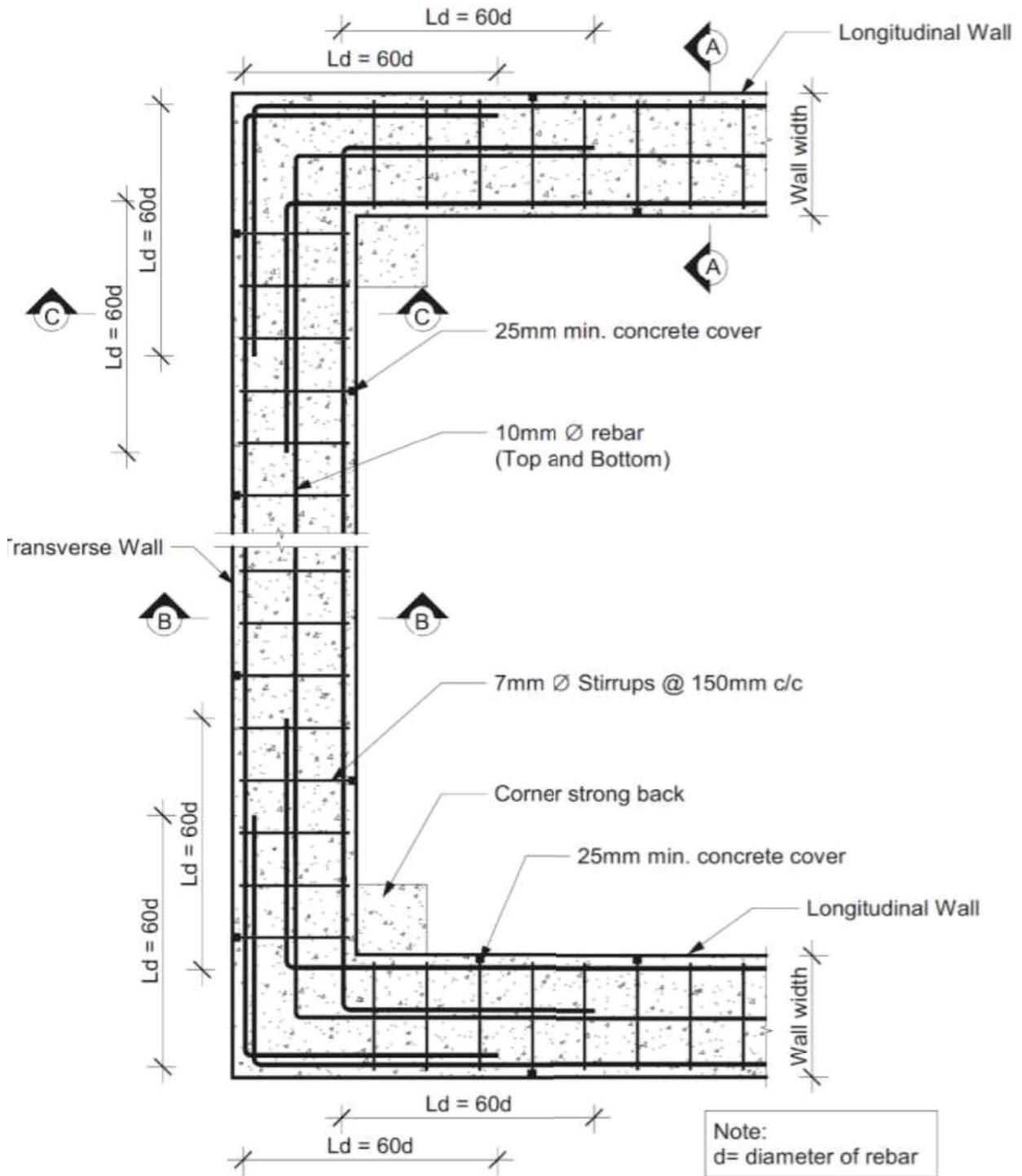
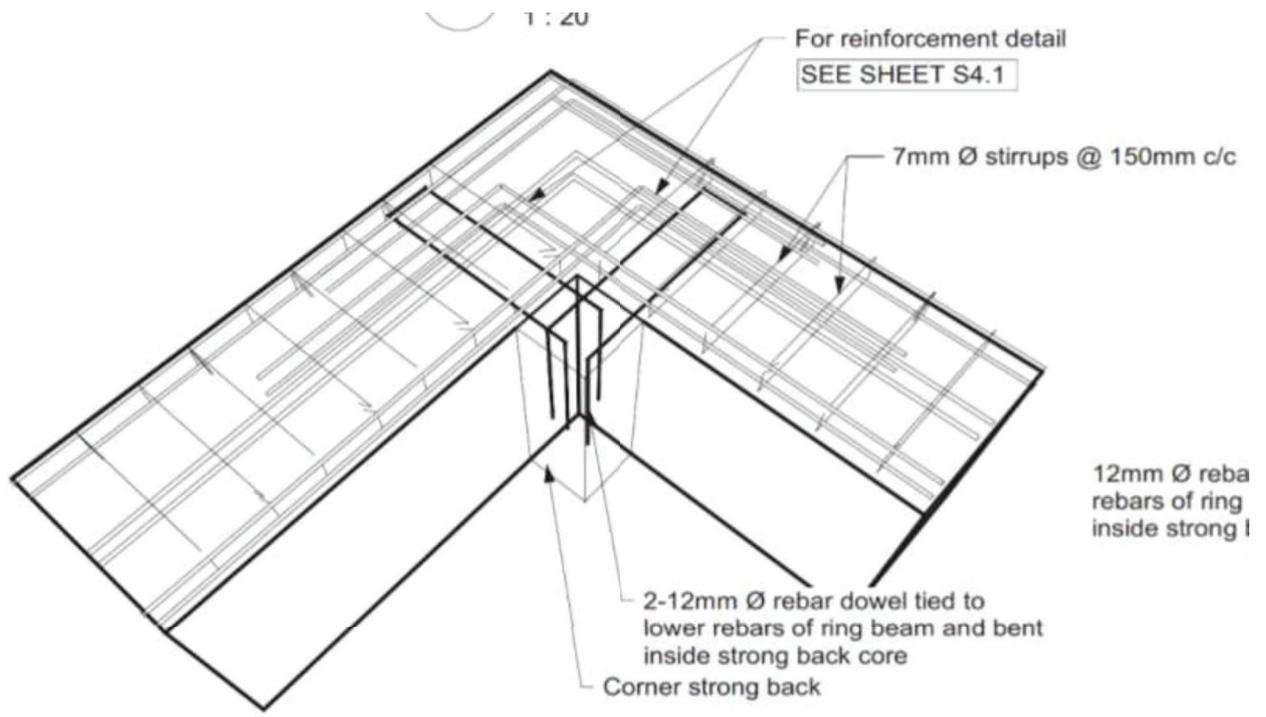


Figure 5-4 Ring beam section

Length of ring beam, L	Longitudinal reinforcement (provide each side)	Stirrups
$10.7 \text{ m} \geq L > 10 \text{ m}$	(3) 16 mm	7 mm @ 150 c/c
$10 \text{ m} \geq L > 9.5 \text{ m}$	(2) 16 mm + (1) 12 mm	
$9.5 \text{ m} \geq L > 9 \text{ m}$	(2) 16 mm + (1) 8 mm	
$9 \text{ m} \geq L > 8.3 \text{ m}$	(2) 16 mm	
$8.3 \text{ m} \geq L$	(2) 12 mm	

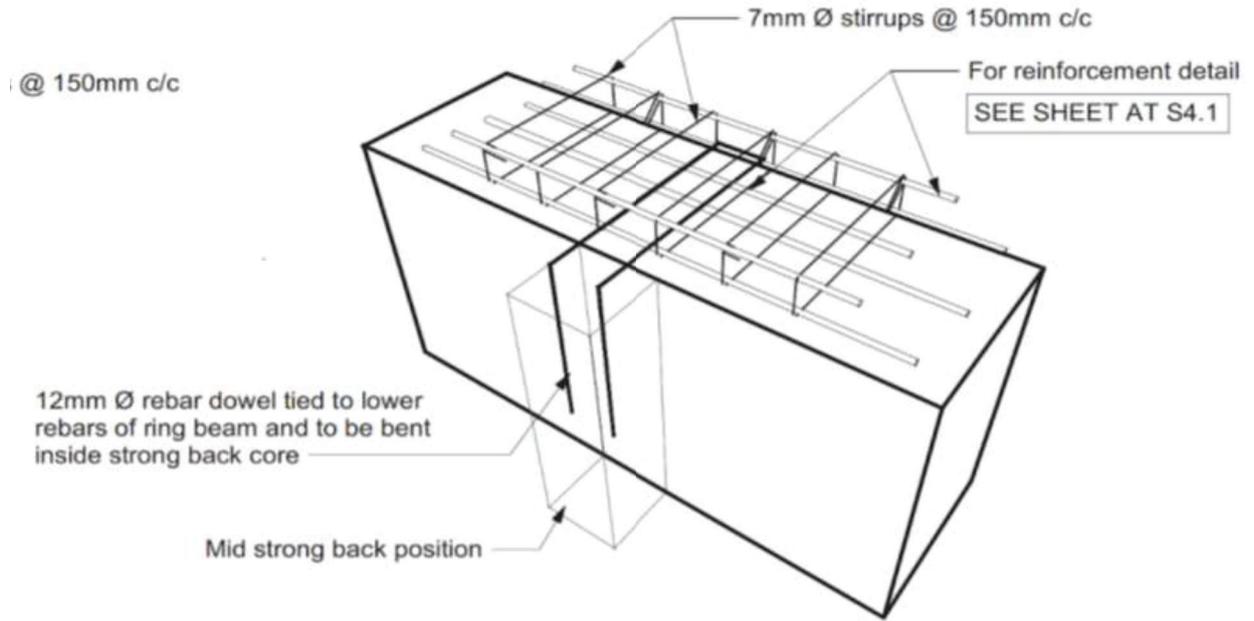


1 RING BEAM REINFORCEMENT PLAN.  
1 : 15



Note: Strong back rebar not shown for clarity

2 CORNER STRONG BACK REBAR DOWEL DETAIL  
1 : 25



Note: Strong back rebar not shown for clarity

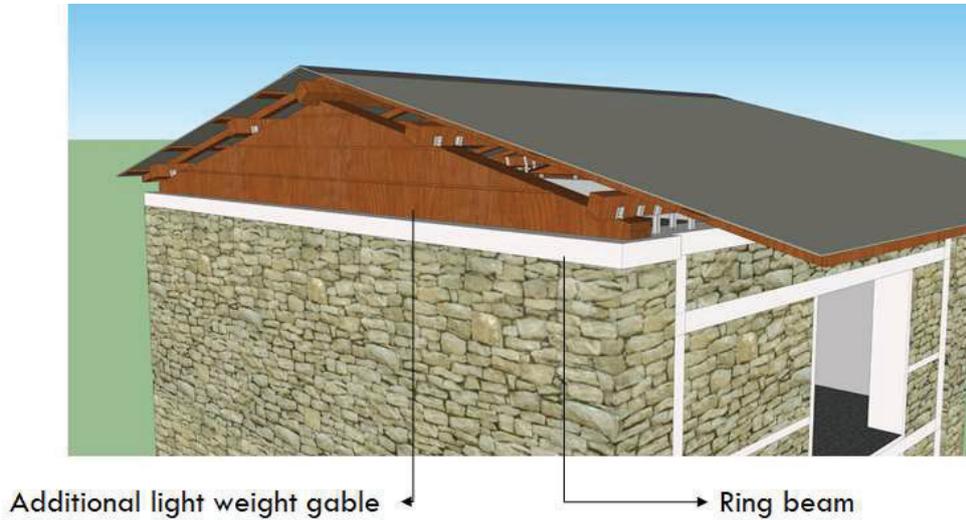
3 MID STRONG BACK REBAR DOWEL DETAIL  
1 : 15



## 5.6 Lightweight gables

### 5.6.1 Description

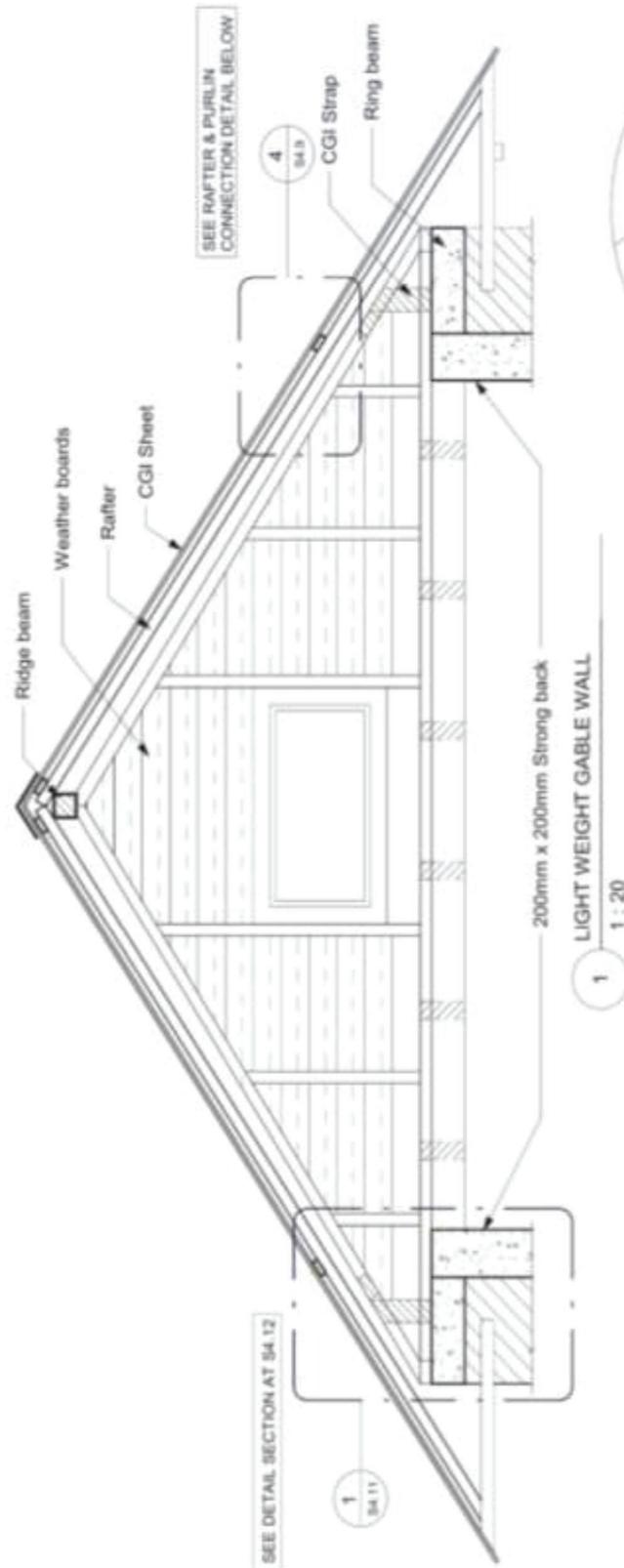
Lightweight gables are wood-framed elements installed above transverse attic walls. They are connected to the ring beam with embedded steel elements and to the roof framing with positive connections.

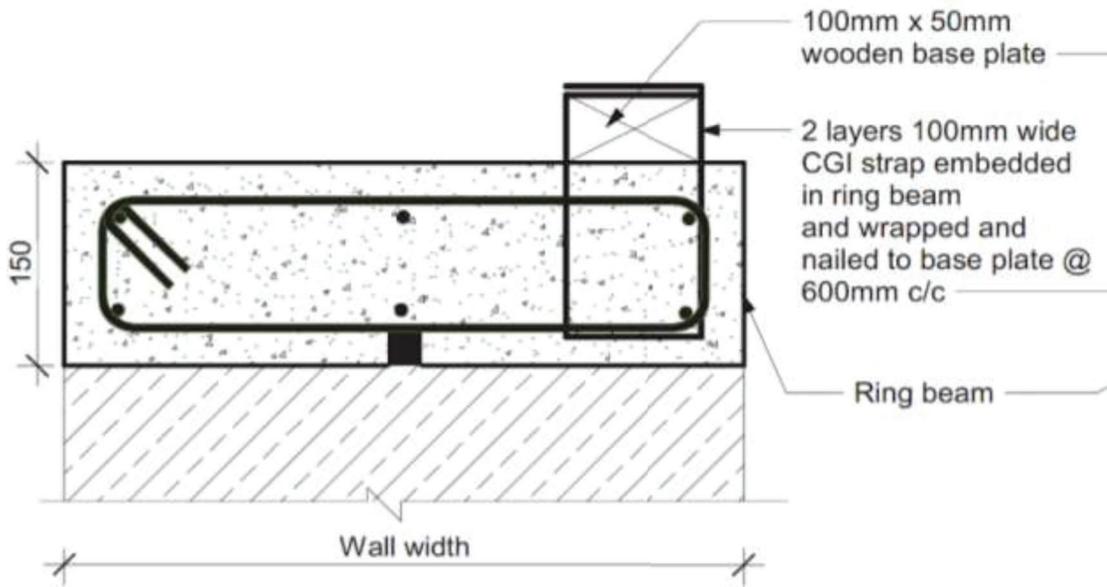


### 5.6.2 Design

Where heavyweight gables exist, remove the gable and install lightweight gable. Install per details in the detailing section.

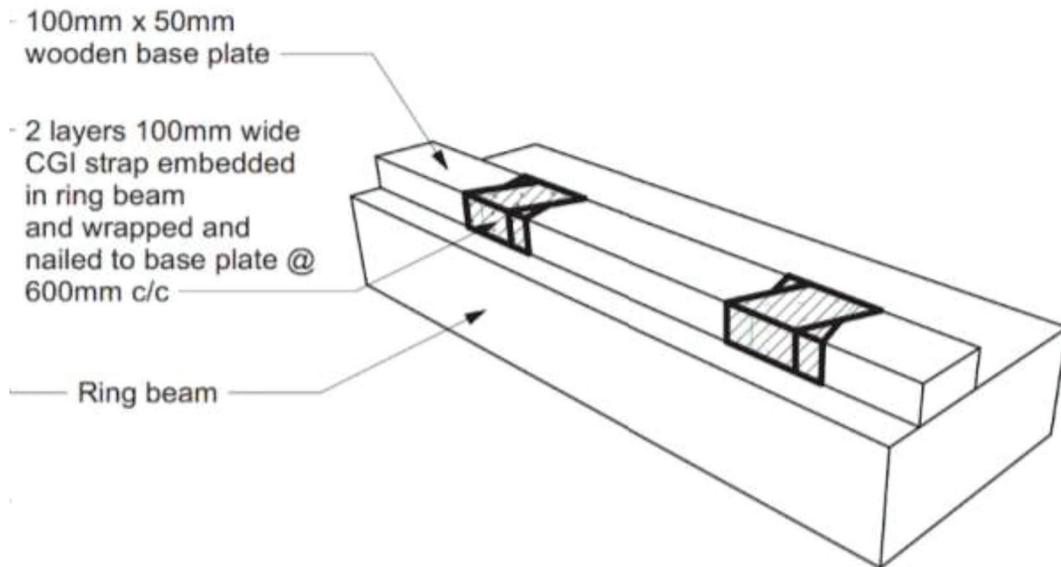
### 5.6.3 Detailing



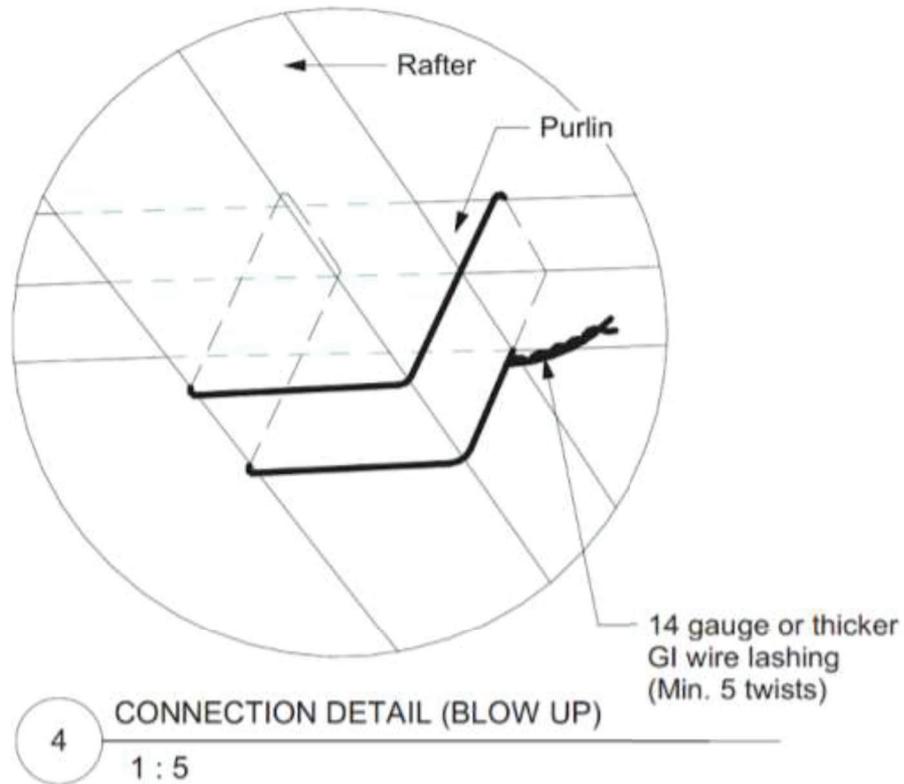


2 GABLE WALL CONNECTION DETAIL  
1 : 5

3 GAB  
1 : 1



3 GABLE WALL CONNECTION DETAIL (3D VIEW)  
1 : 15



## 5.7. Diaphragm Strengthening Design

### 5.7.1 Description

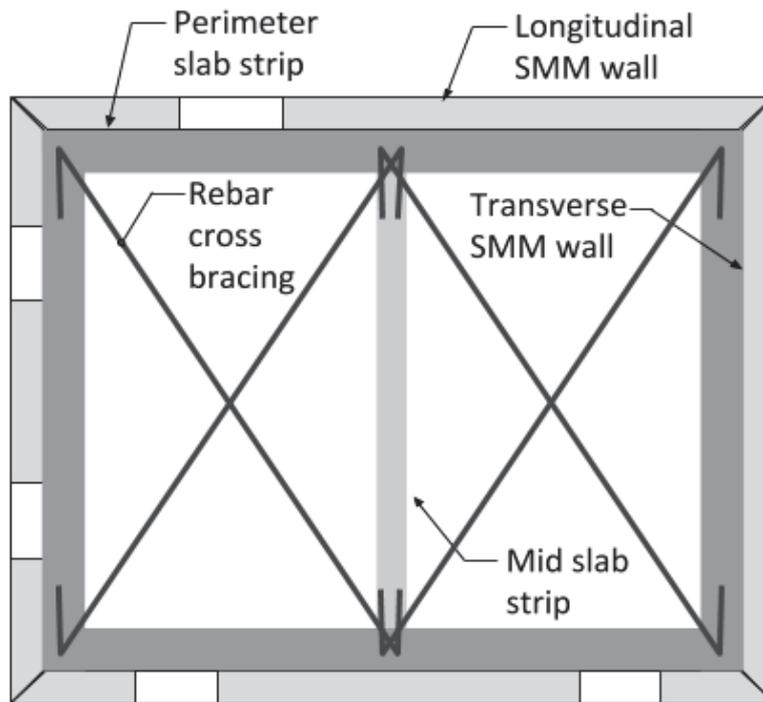
New reinforced concrete slab strips and steel reinforcement tie bracing are installed to increase strength and rigidity of the floor diaphragms. The slab strips are anchored to the walls with ties and connected to the floor framing elements with reinforcement.

### 5.7.2 Design

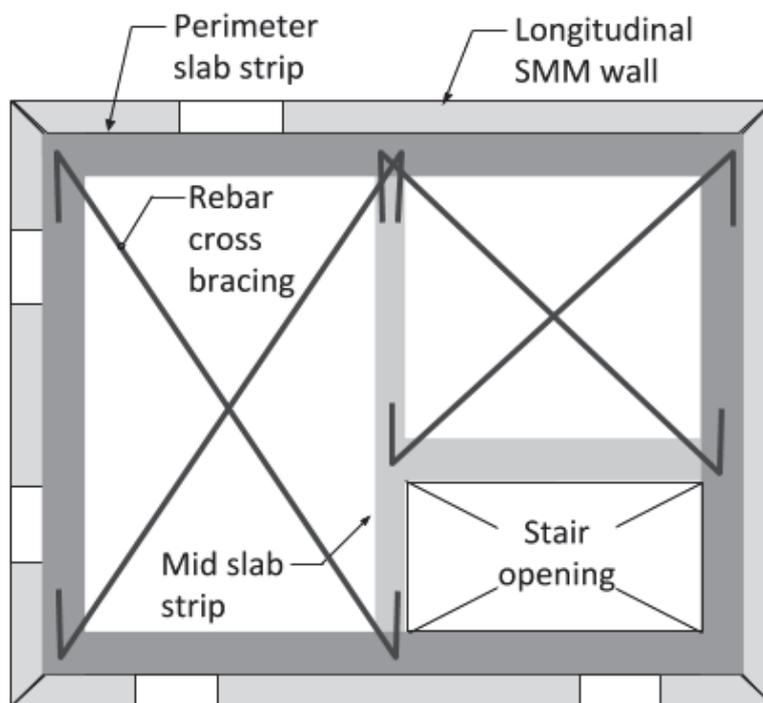
Provide slab strips along the perimeter of each floor diaphragm and at midspan of the floor framing per the table and figure below. Provide ties to walls at 600 mm maximum spacing. Provide steel rebar (12 mm diameter) cross bracing between all intersections of slab strips, except at stair openings.

Install per details in the detailing section.

Slab strip location	Cross section dimensions (width x depth)
Perimeter	300 mm x 100 mm (12" x 4")
Mid slab	200 mm x 100 mm (8" x 4")



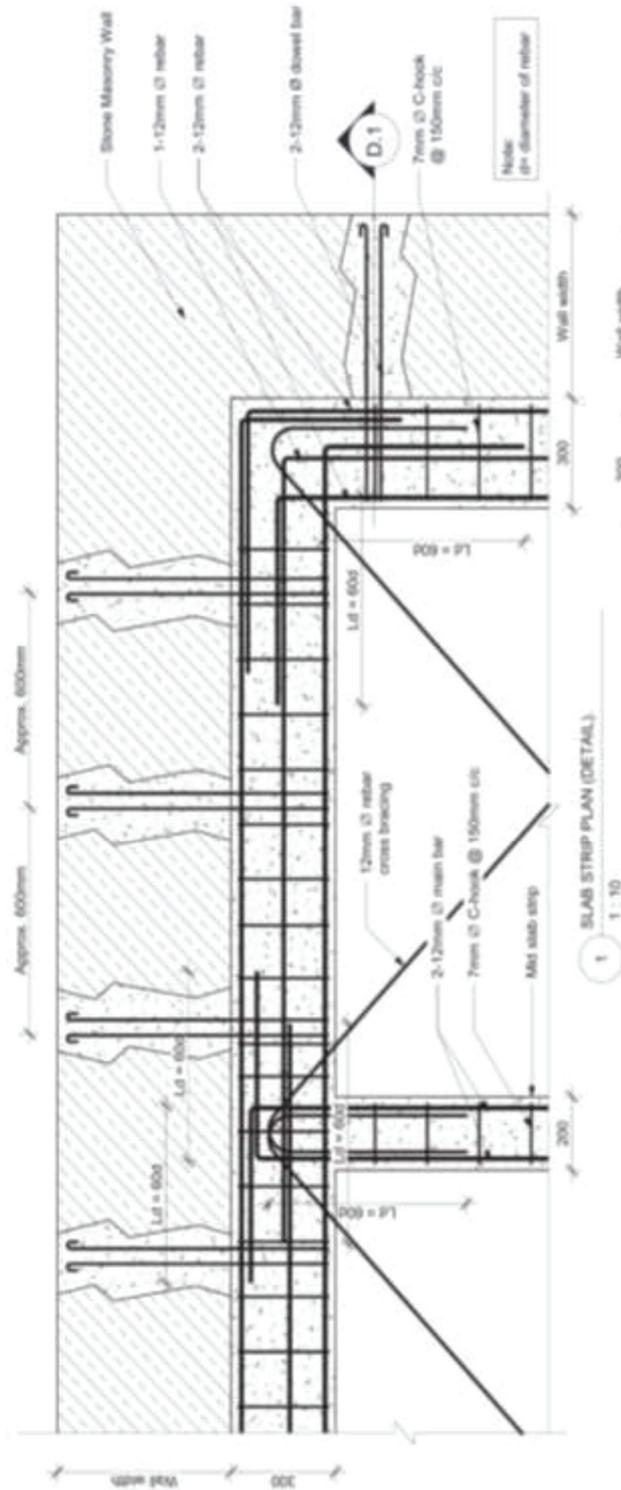
**Plan (No floor opening)**

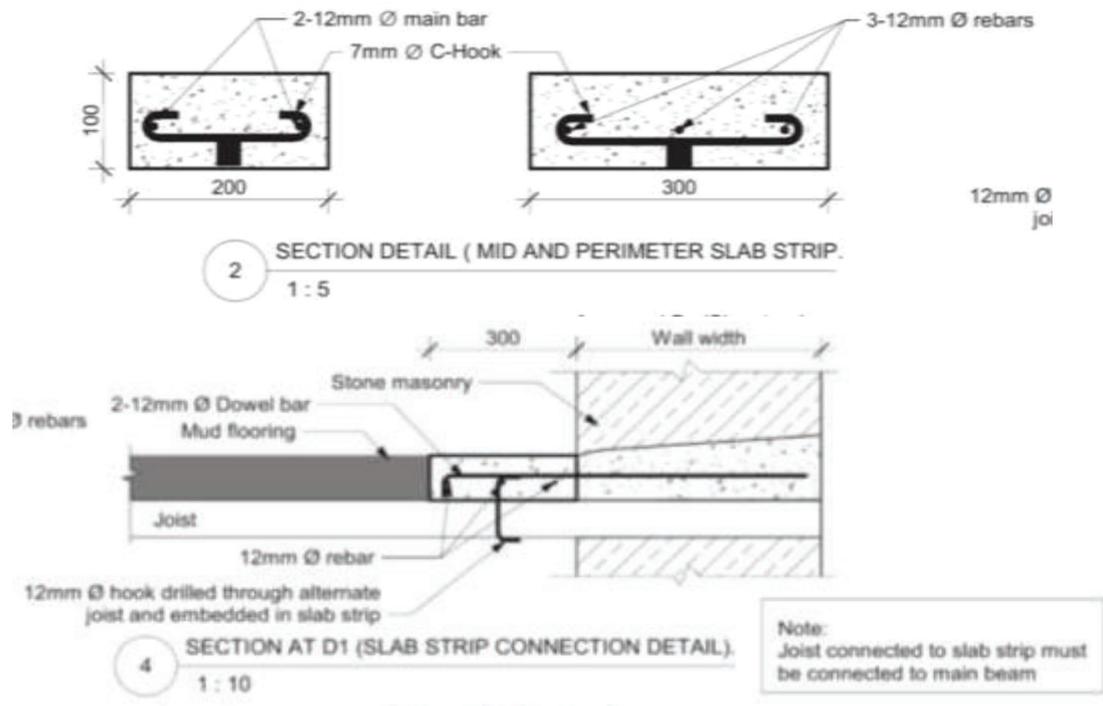


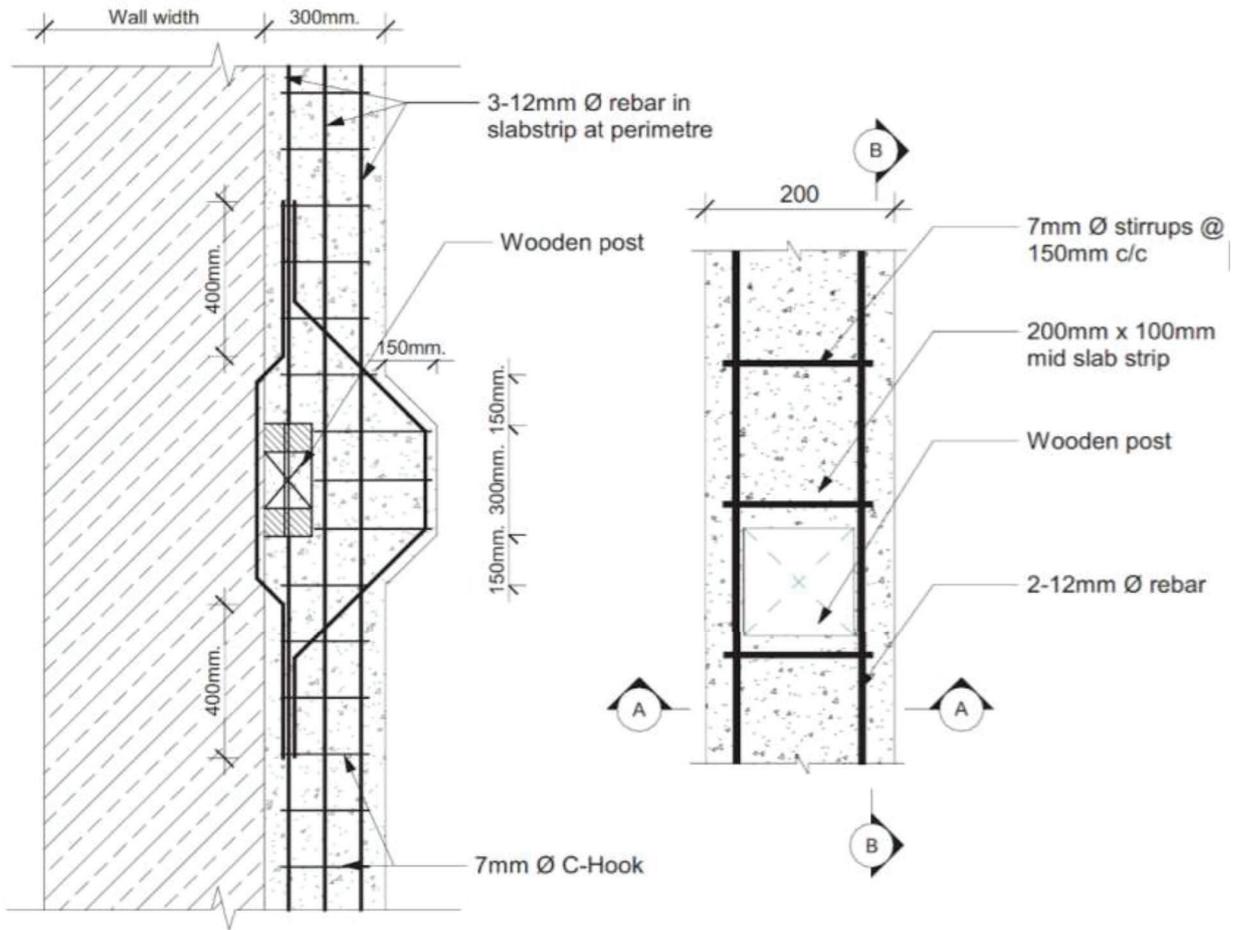
**Plan (Floor opening)**

*Figure 5-5 Plans depicting the locations of slab strips and layout of cross bracing (NTS)*

### 5.7.3 Detailing

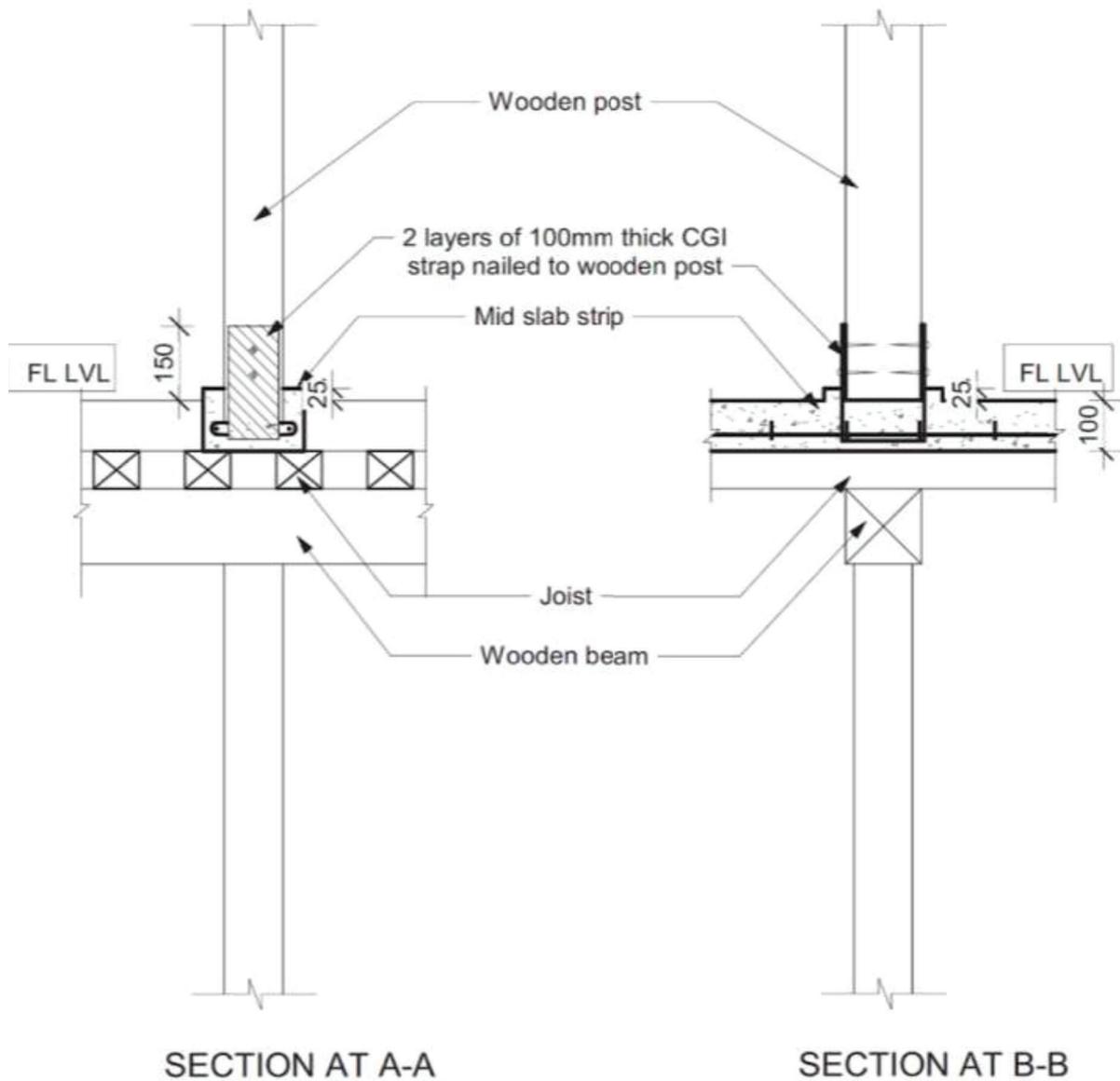






1 Slab Strip Detail at Transverse Wall  
1 : 15

2 Post and Mid Slab Strip Detail  
1 : 6



3 Sectional Details  
1 : 12

## 5.8 In-plane pier strengthening

### 5.8.1 Description

New cement plaster or wire mesh with mortar overlay is required for exterior wall piers. Where piers have inadequate in-plane shear strength, wire mesh overlay is required. Where piers have adequate shear strength, cement plaster overlay (without wire mesh) is required.

### 5.8.2 Design requirements

#### 5.8.2.1 Determining if wire mesh overlay is required

To determine if wire mesh overlay is required, review the pier dimensions on each exterior wall using the following steps.

1. Determine if the piers meet the minimum lengths outlined in the tables that correspond to “without wire mesh”. If they do, proceed with cement plaster overlay only.
2. If the piers do not meet the minimum lengths for “without wire mesh”, confirm they meet the requirements for “with wire mesh”. Provide strengthening

As an alternate to installing wire mesh, openings may be closed or shifted such that the minimum pier sizes for “without wire mesh” are met. In this case, cement plaster is still required.

When reviewing pier dimensions, follow these conventions:

- **Door** is defined as an opening with a height greater than 1.2 meters and not exceeding 1.9 meters.
- **Window** is defined as an opening with a height less than or equal to 1.2 meters.
- Piers between two doors (“door-door”) are **door-governing**,
- Piers between two windows (“window-window”) are **window-governing**.
- Piers between a door and a window (“door-window”) are **window-governing**. (*i.e. any pier beside a window is window-governing*)

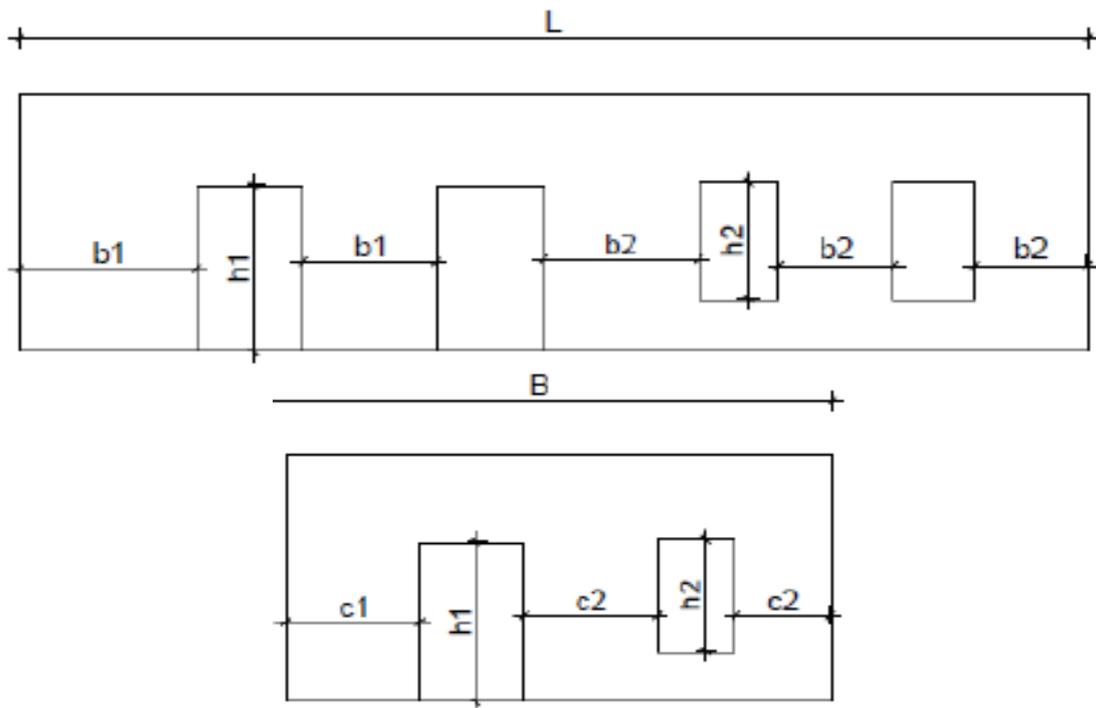


Figure 5-6 Longitudinal wall and transverse walls with pier abbreviations indicated

Abbreviation	Description
L	Length of longitudinal wall
B	Length of transverse wall
$h_1$	Height of door
$h_2$	Height of window
$b_1$	Length of pier from corner edge of building to door (longitudinal wall)
	Length of pier between two doors (longitudinal wall)
$b_2$	Length of pier between door and window (longitudinal wall)
	Length of pier between window and window (longitudinal wall)
$c_1$	Length of pier from corner edge of building to door ( <i>transverse wall</i> )
$c_2$	Length of pier between door and window ( <i>transverse wall</i> )
	Length of pier between window and window ( <i>transverse wall</i> )

Table to determine if wire mesh shear strengthening is required						
	Building Length (m)	Building Width (m)	Minimum size of pier along the longitudinal wall (m)		Minimum size of pier along the transverse wall (m)	
			Door	Window	Door	Window
			(b1)	(b2)	(c1)	(c2)
Without wire mesh (cement plaster only)	L≤9.5	B<4.5	1.5	1	Not applicable	Not applicable
	9.5<L≤10.7					
	L≤9.5	4.5≤B≤5	1.5	1	Not applicable*	2.3
	9.5<L≤10.7					Not applicable*
	L≤9.5	5<B≤6	1.6	1	3.2	2.1
	9.5<L≤10.7				3.4	2.2
With wire mesh	L≤10.7	4.5≤B<5	0.925	0.6	1.6	1
		5≤B≤6			1.35	0.96

\*In these cases, review opening percentage of transverse wall. If opening percentage is 15% or less, used special case table below.

* Table for special case of transverse wall not exceeding 15% opening percentage (longitudinal wall not exceeding 35% opening percentage)						
	Building Length (m)	Building Width (m)	Minimum size of pier along the long wall (m)		Minimum size of pier along the short wall (m)	
			Door	Window	Door	Window
			(b1)	(b2)	(c1)	(c2)
Without wire mesh (cement plaster only)	9.5≤L≤10.7	4.5≤B≤5	1.5	1	Not applicable	2.1

### **5.8.2.2 Cement Plaster (where wire mesh overlay is not required by Section 5.8.2.1)**

Provide cement plaster on both sides of all exterior walls.

### **5.8.2.3 Piers and Wire mesh overlay (where required by Section 5.8.2.1)**

Provide mesh with 1.8mm diameter wires spaced at 20 mm center to center on either side of the wall at the required piers. Fix the wire mesh at the bottom to the plinth beam and at the top to the slab strip.

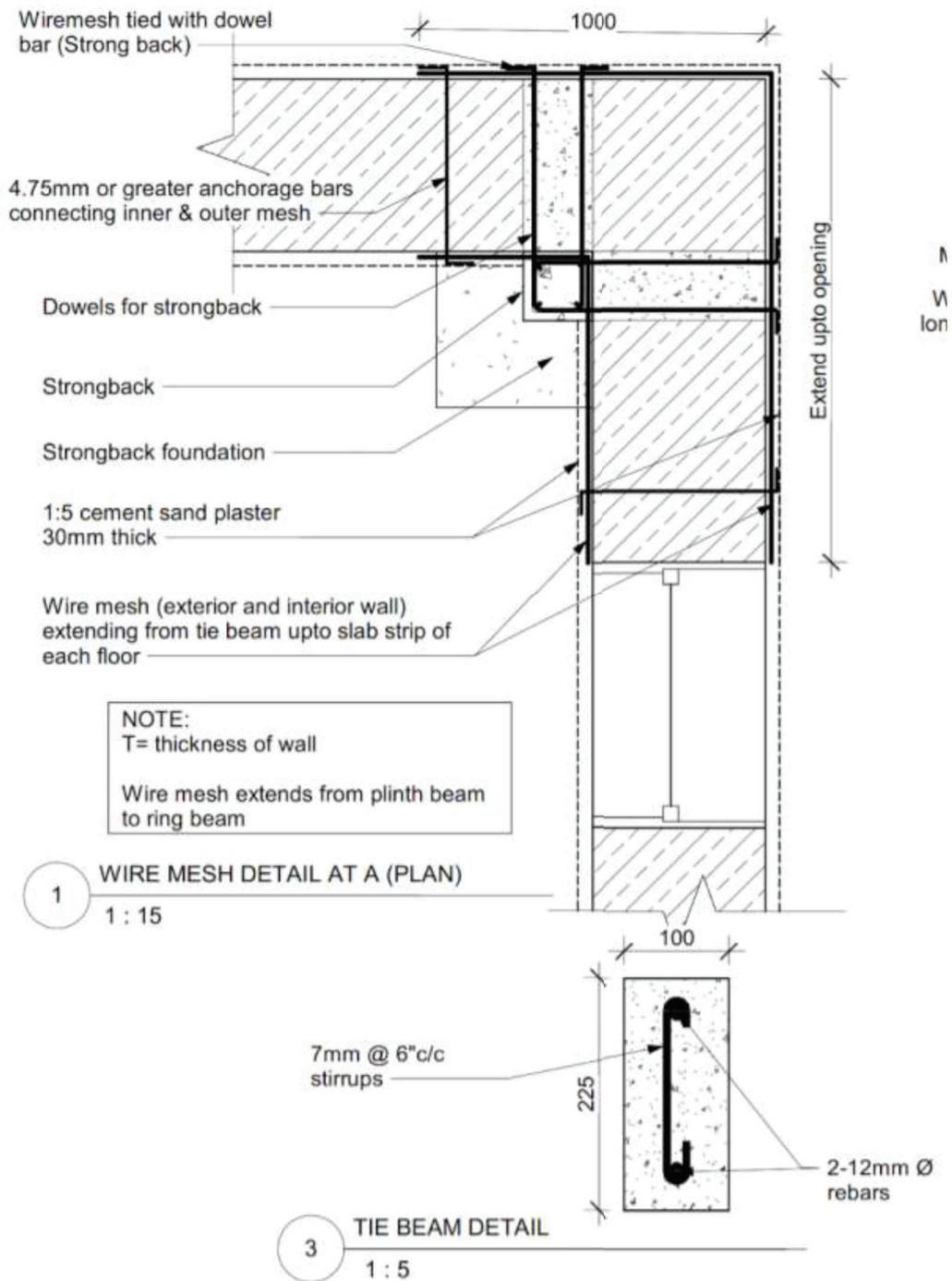
Install per details in Detailing section.

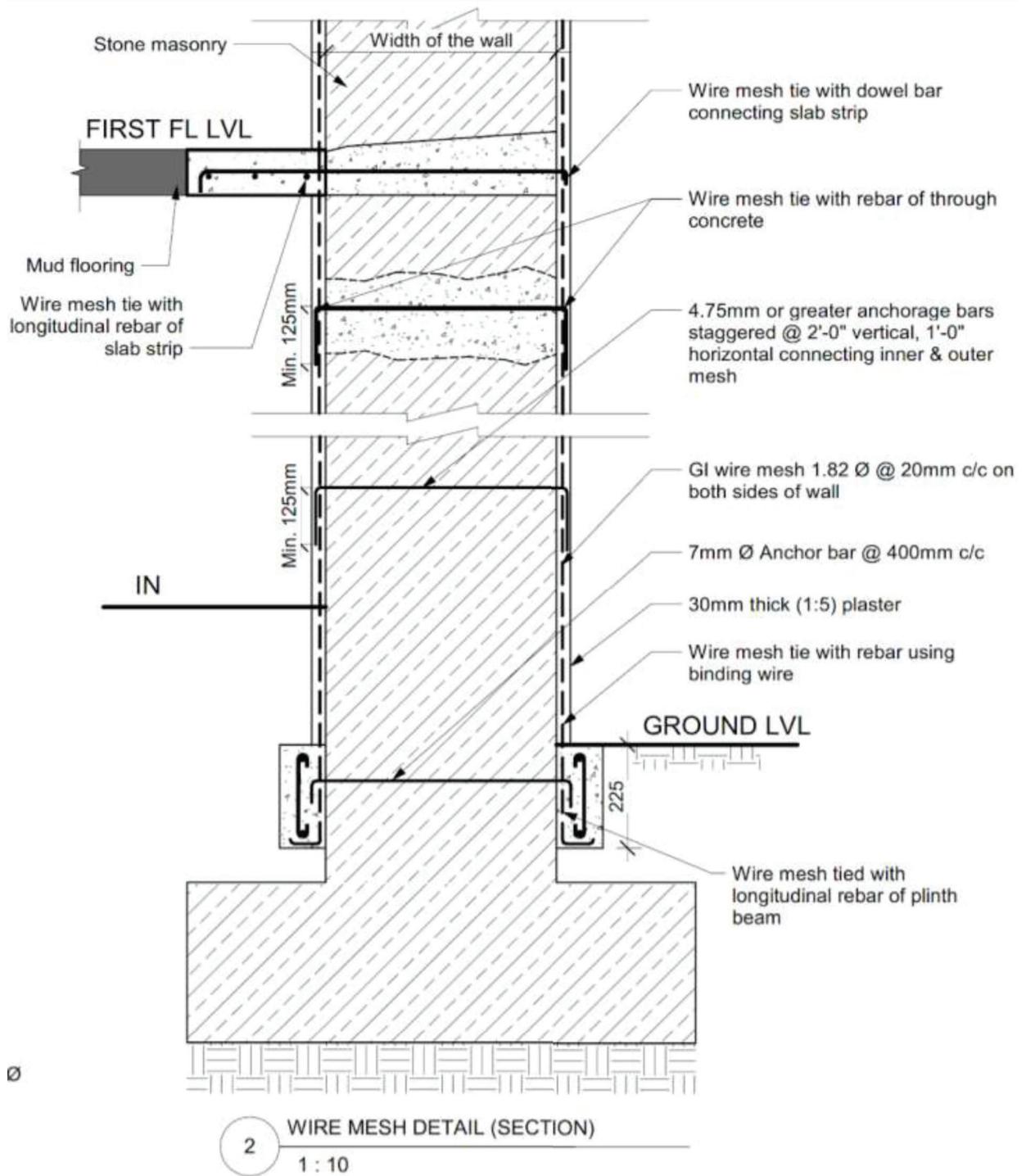
## **5.8.3 Detailing**

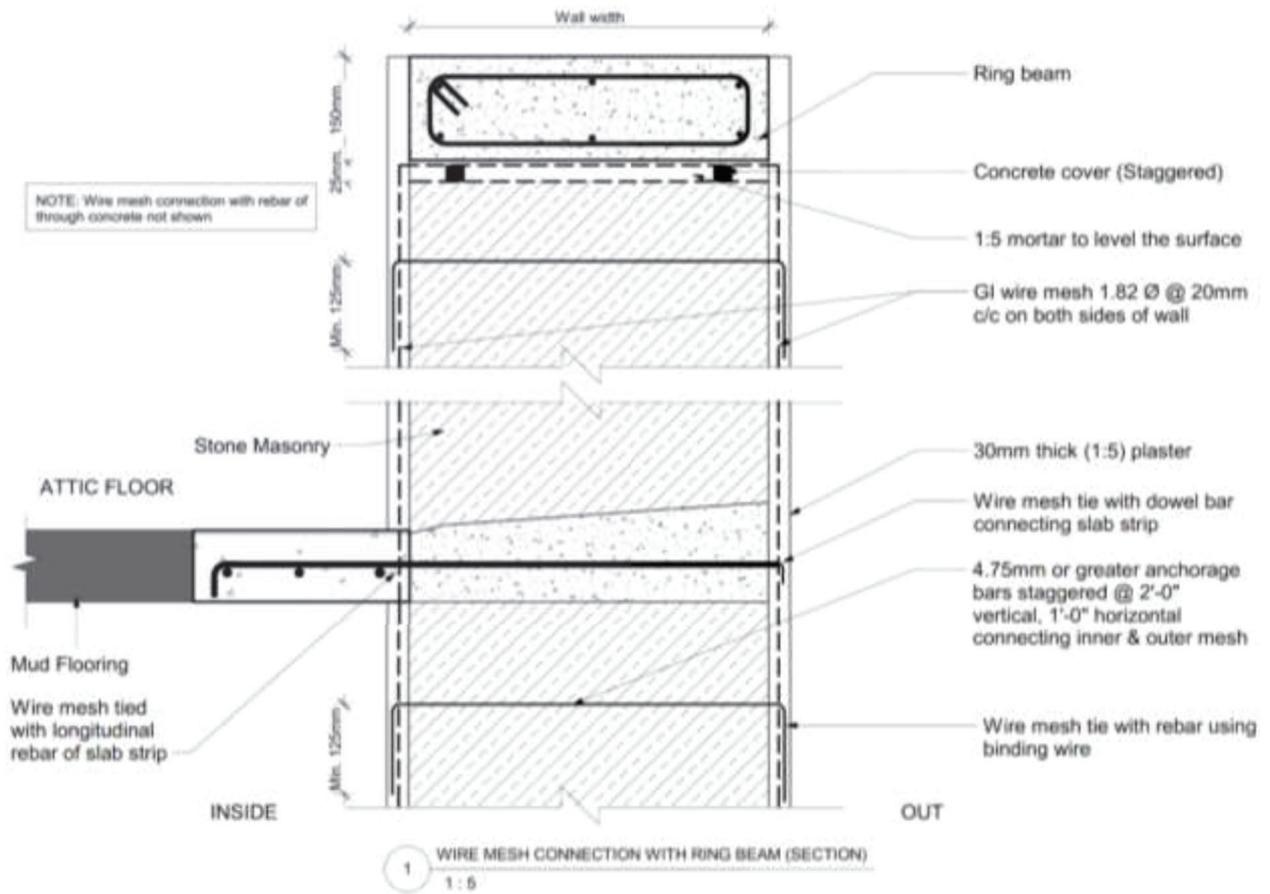
### **5.8.3.1 Cement Plaster**

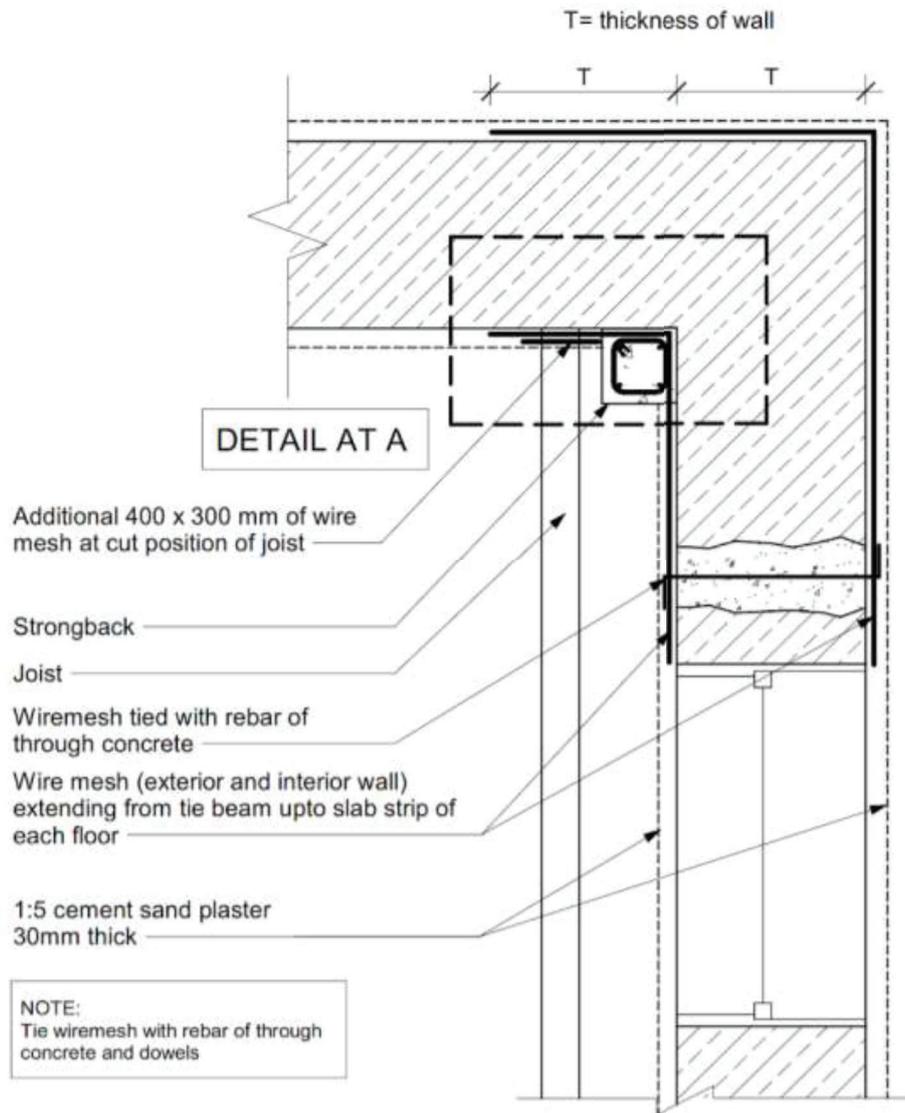
No details.

### 5.8.3.2 Wire mesh overlay

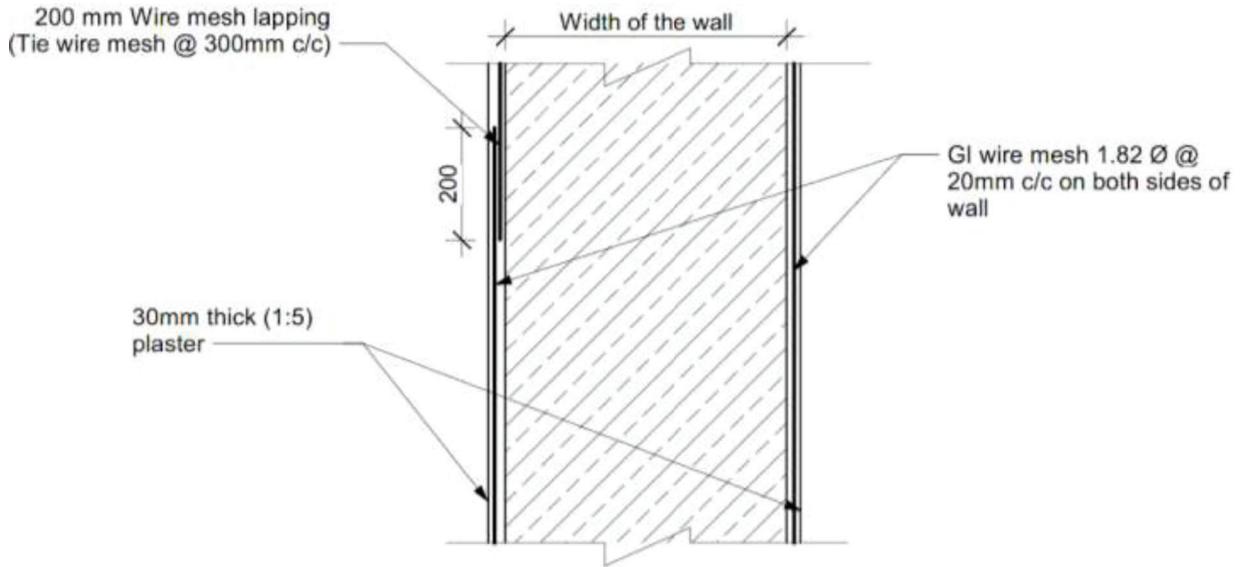




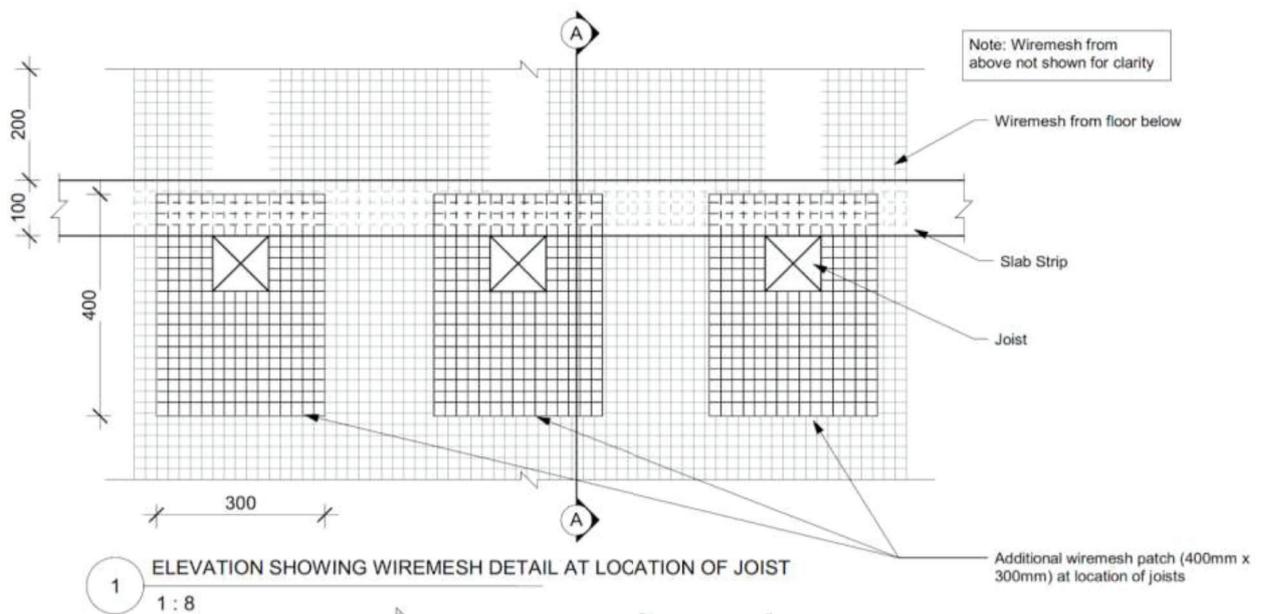


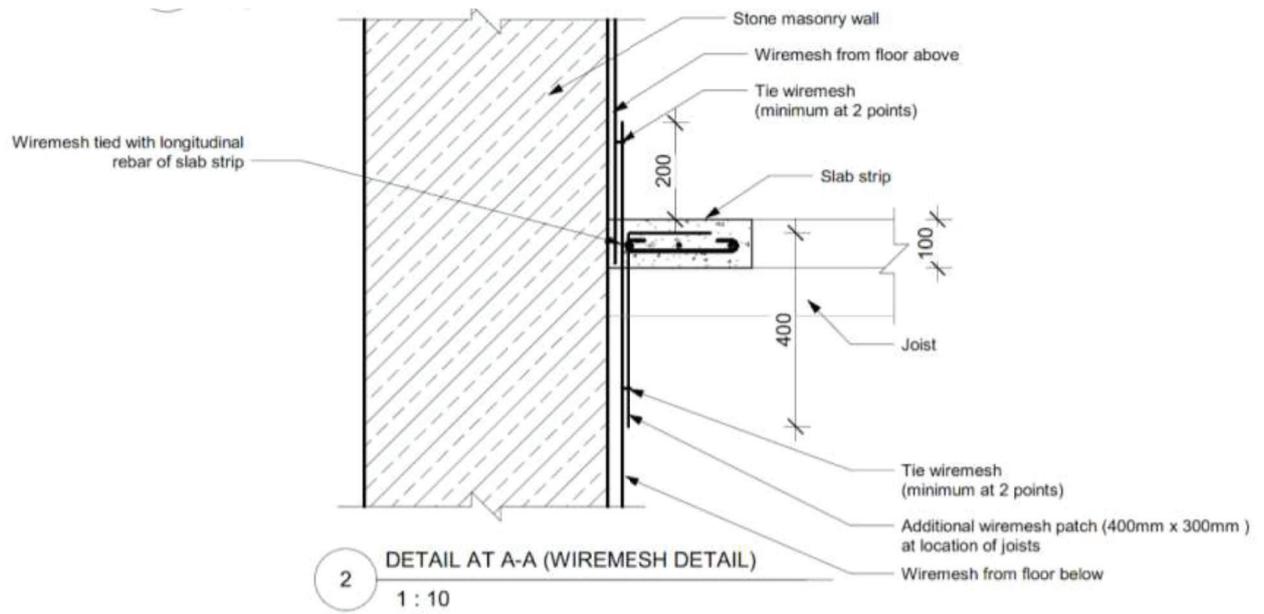


1 JOIST AND WIRE MESH CONNECTION DETAIL (PLAN)  
1 : 15



2 WIRE MESH LAPPING  
1 : 10





## 5.9 Roof framing connection strengthening

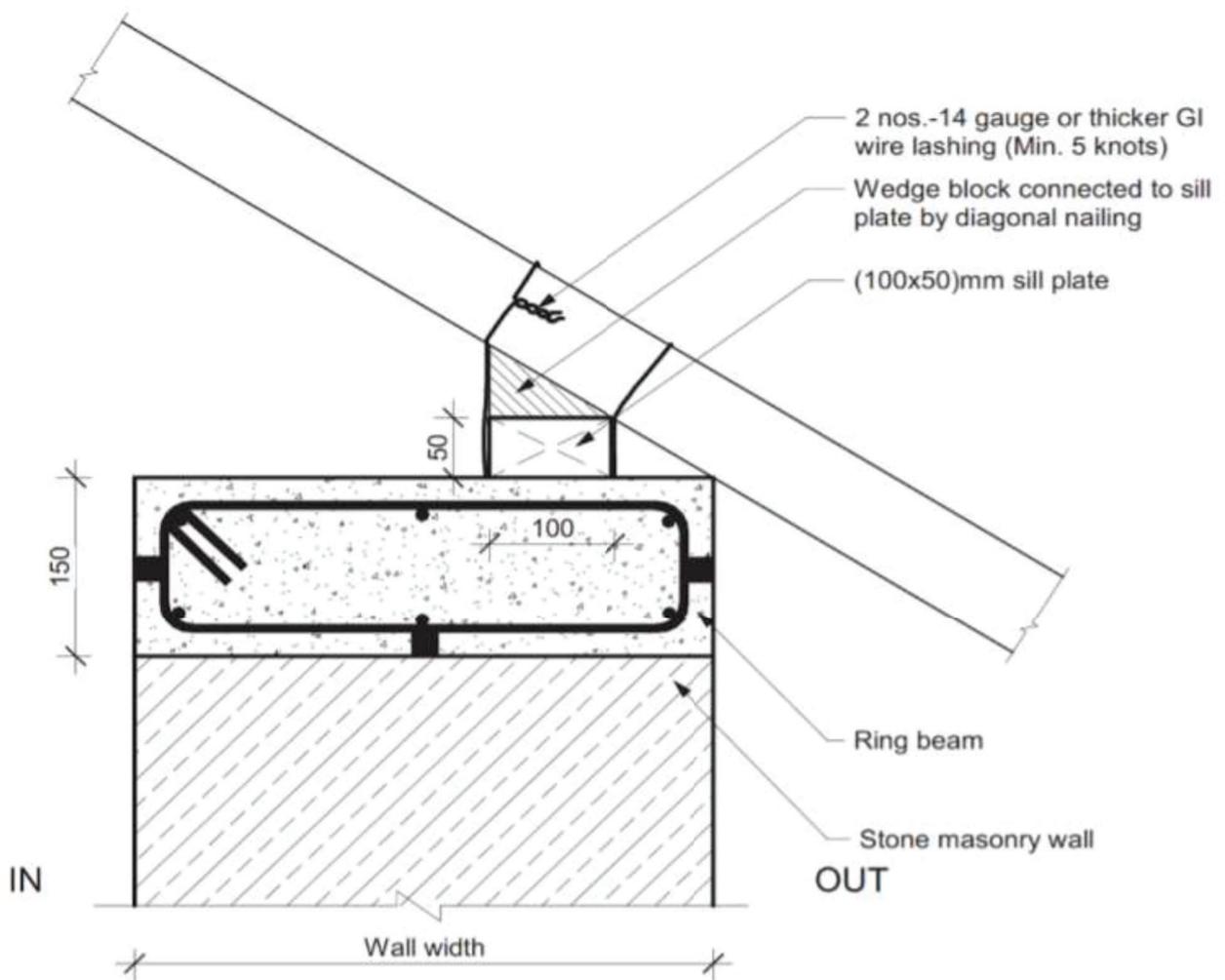
### 5.9.1 Description

Where roof framing is in poor condition or will be replaced, provide connections between framing members as described in this section. .

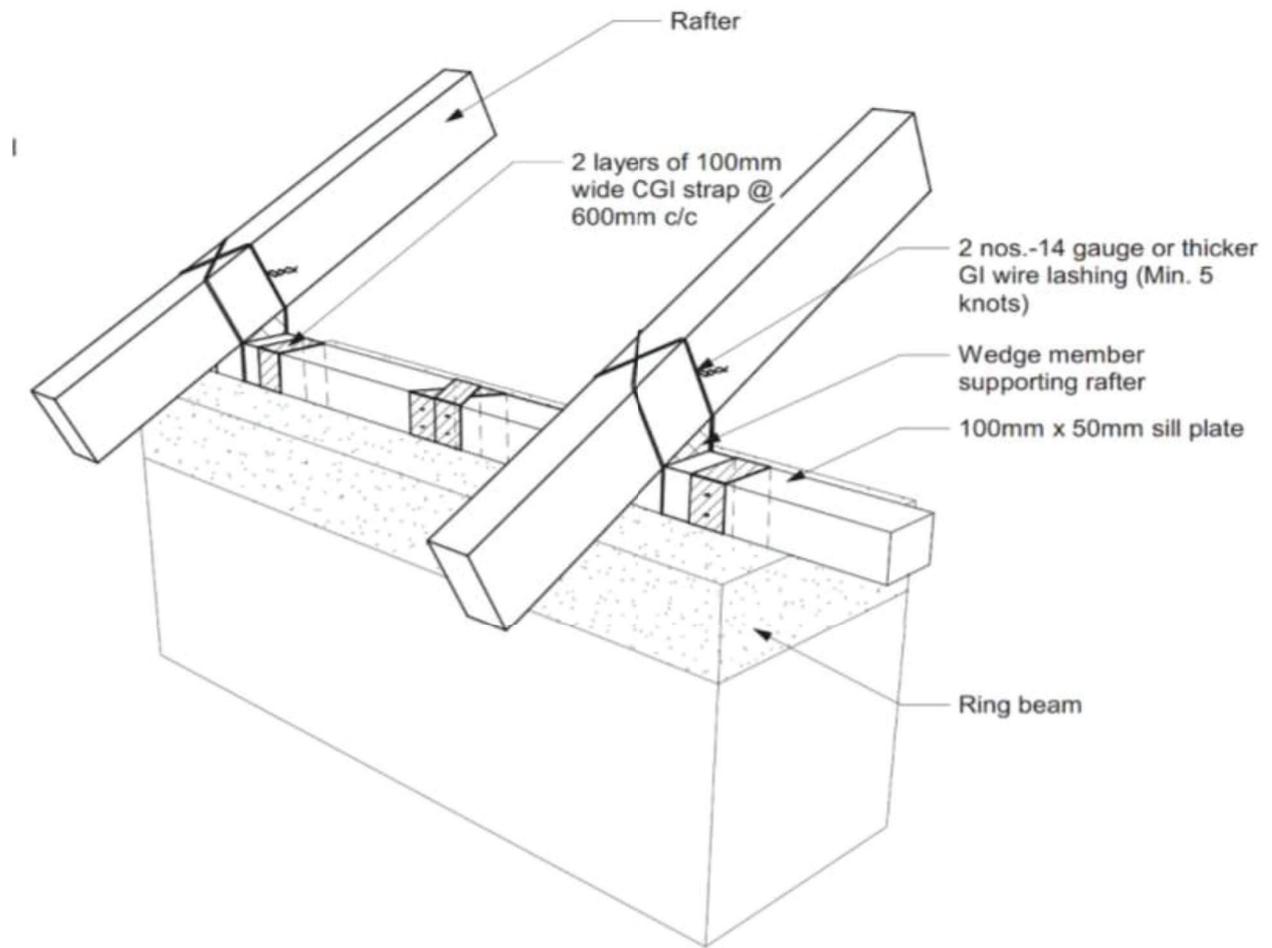
### 5.9.2 Design requirements

Install per the details in the Detailing section.

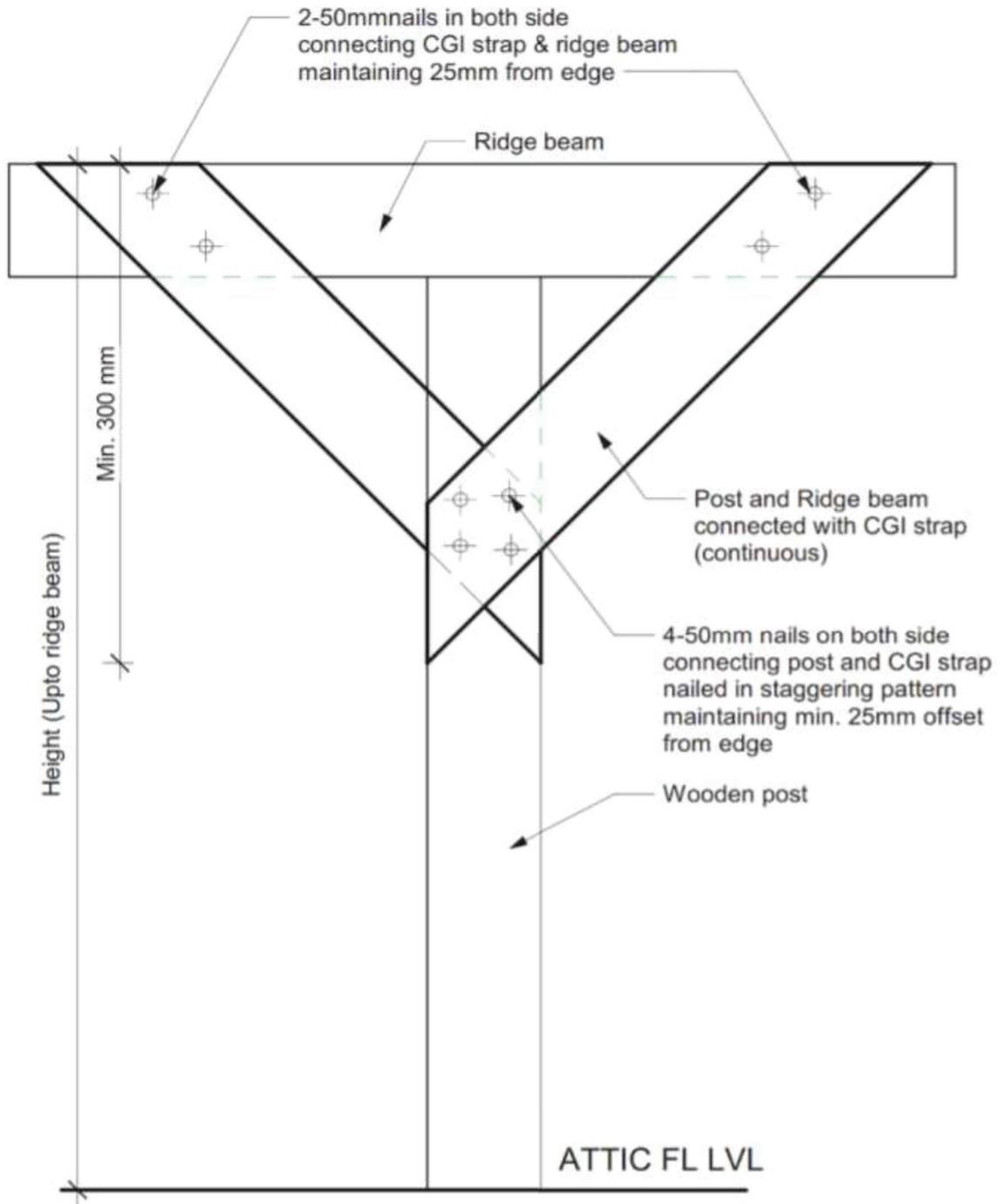
### 5.9.3 Detailing



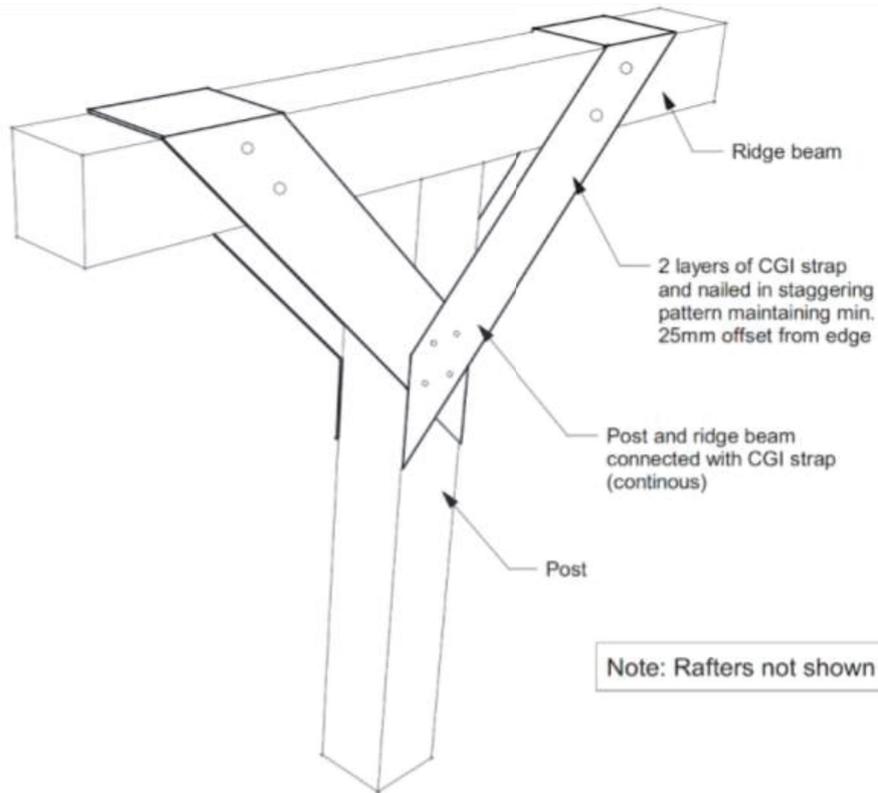
1 RING BEAM & RAFTER CONNECTION DETAIL  
1 : 5



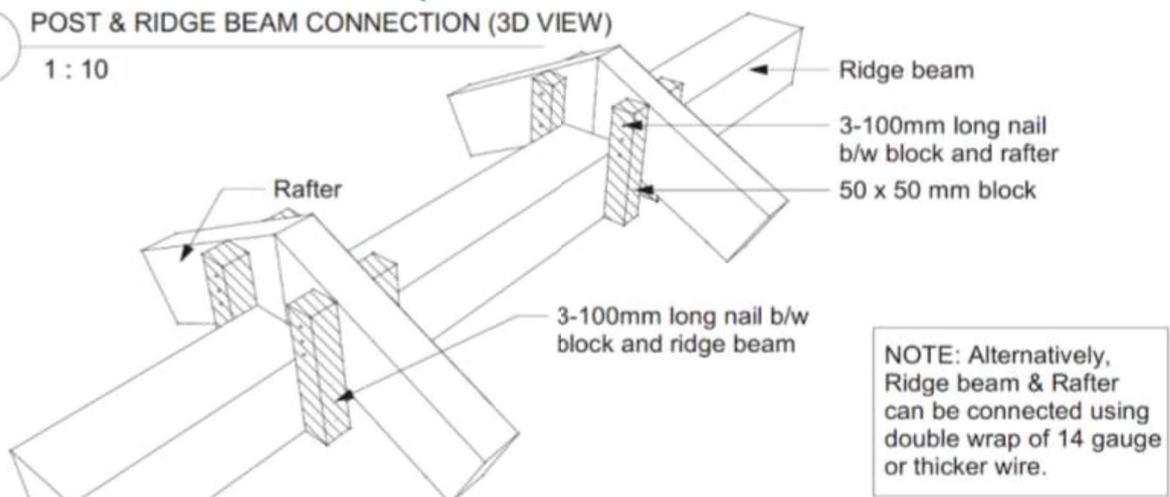
2 3D VIEW RING BEAM & RAFTER CONNECTION DETAIL  
1 : 15



1 POST & RIDGE BEAM CONNECTION ( SIDE VIEW & SECTION)  
1 : 5



3 POST & RIDGE BEAM CONNECTION (3D VIEW)  
1 : 10



2 RAFTER & RIDGE BEAM CONNECTION (EXISTING)  
1 : 20

## **6 MATERIALS**

### **6.1 Introduction**

Provide materials with minimum requirements as described in this section.

### **6.2 Reinforced Concrete**

Rebar HYSD Fe-415

Concrete M20 -- 1:1.5:3

### **6.3 Cement Plaster**

1:5 cement: sand

### **6.4 Wire mesh**

1.8mm dia @20mmc/c

## **7 ADDRESSING COMMON EXISTING CONDITIONS**

### **7.1 How to use**

The details in Section 6 represent the most common conditions for SMM buildings, but they do not address all existing conditions that can be found. This section explores common existing conditions that deviate from the typical details provided in Section 6 and how to address them.

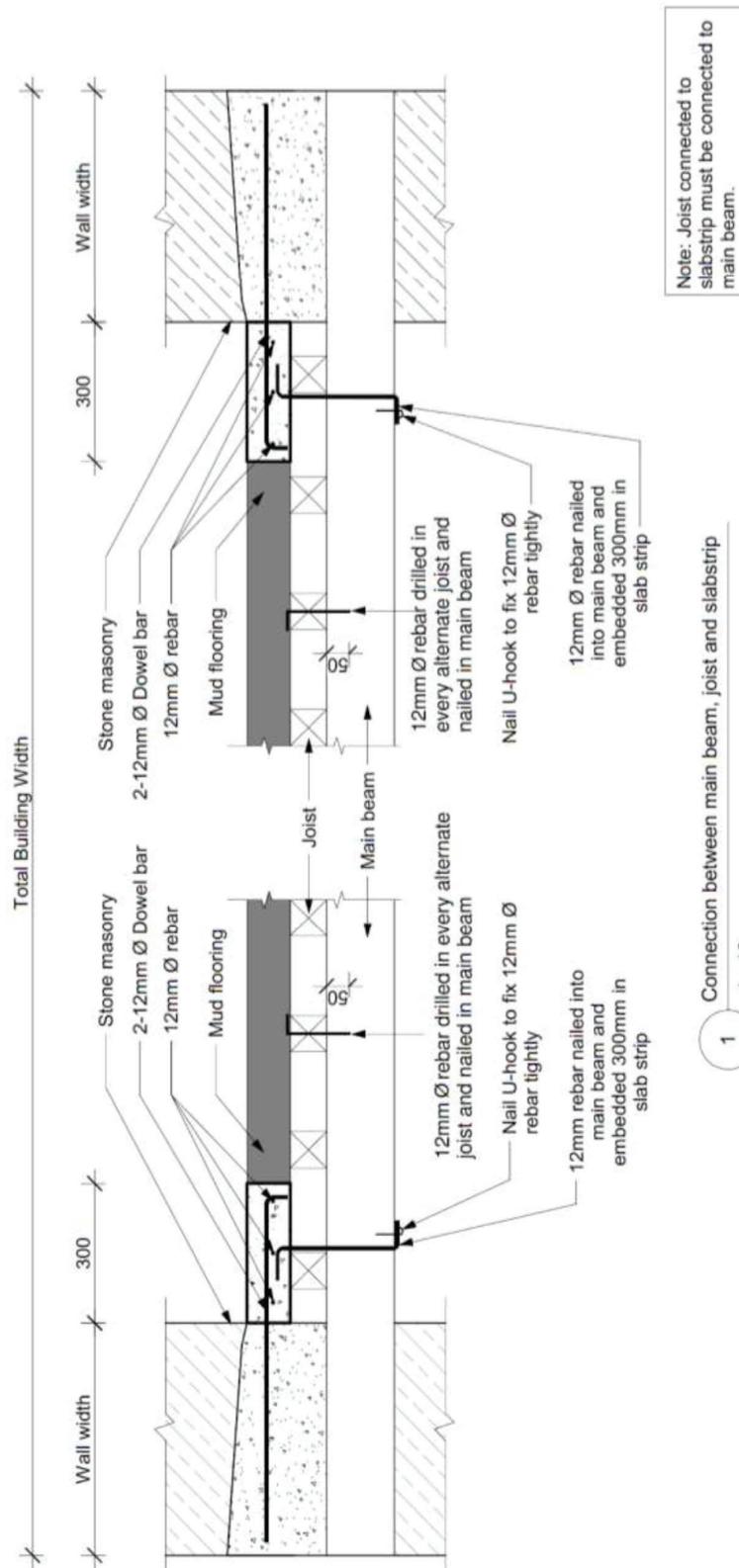
Conditions that are not addressed in this section should be reviewed by an engineer before proceeding with the retrofit.

### **7.2 Wall thickness tapers over elevation of wall**

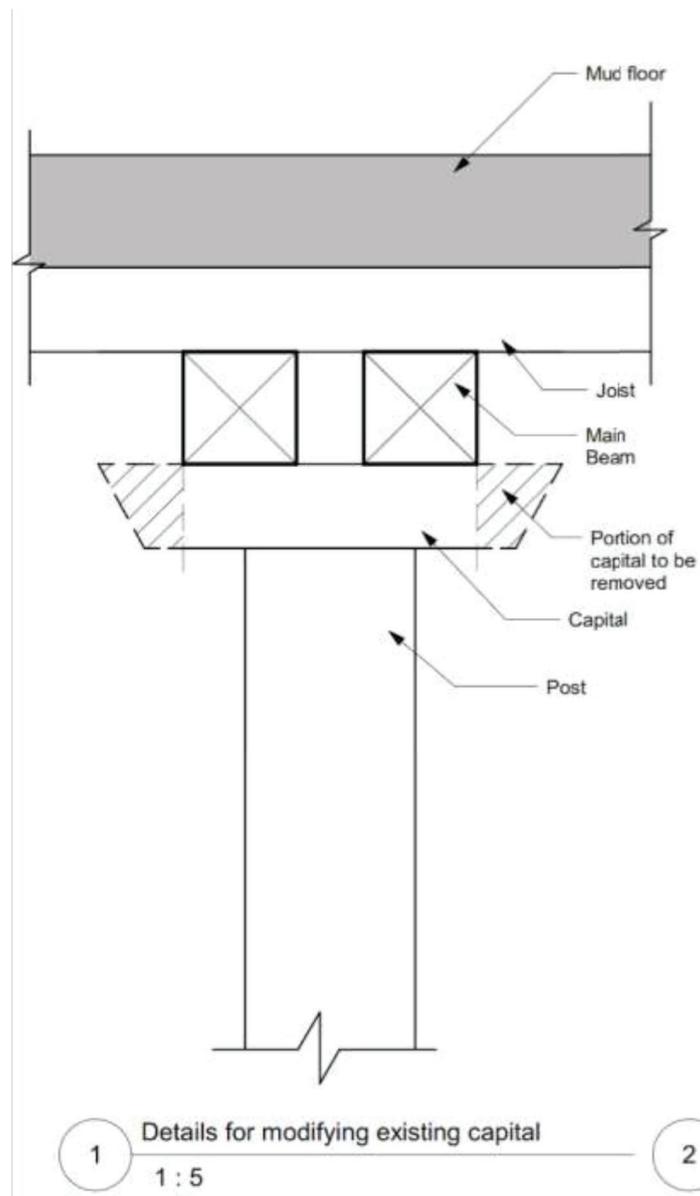
It is not necessary to slope the strongback or provide a thicker strongback where the wall is thinner. Infill gap behind strongback with stabilized mud mortar.

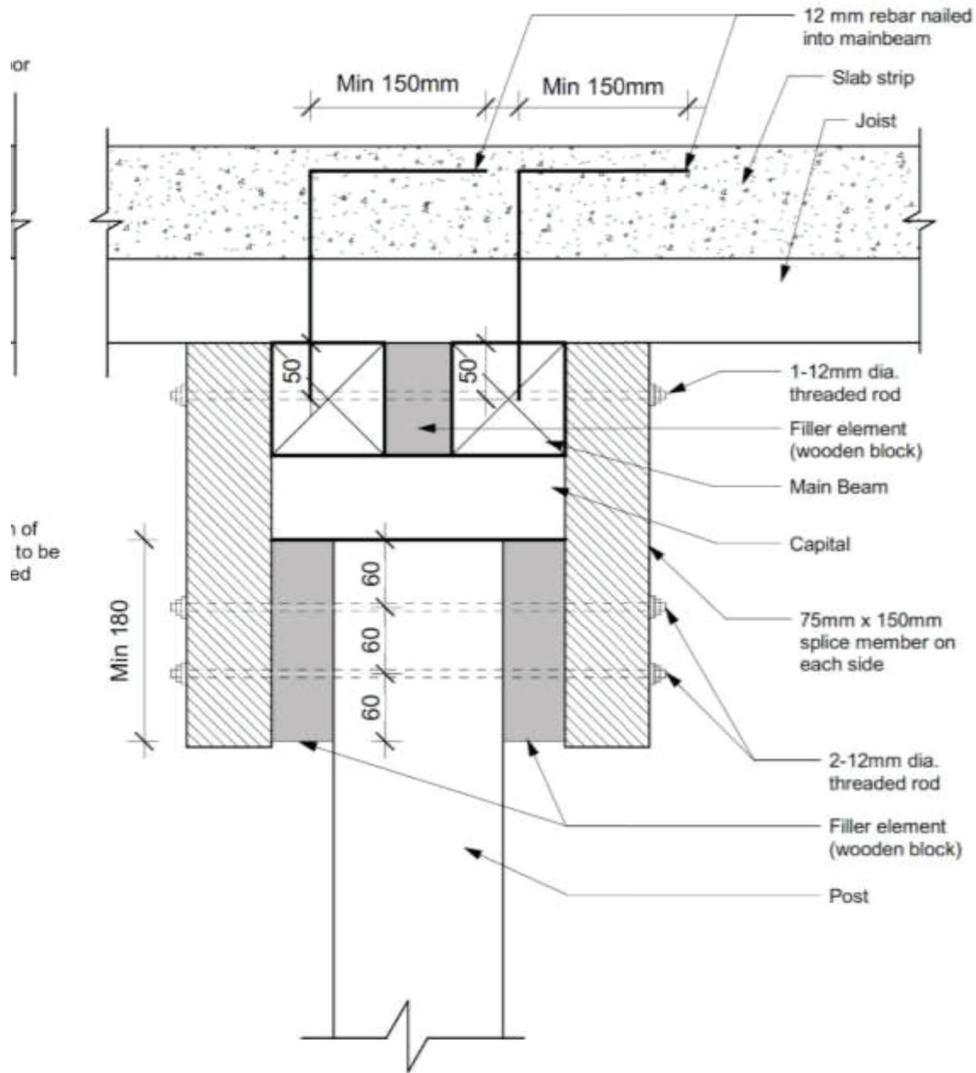
### **7.3 Timber post is not aligned between floors**

### 7.4 Floor framing spans to transverse walls

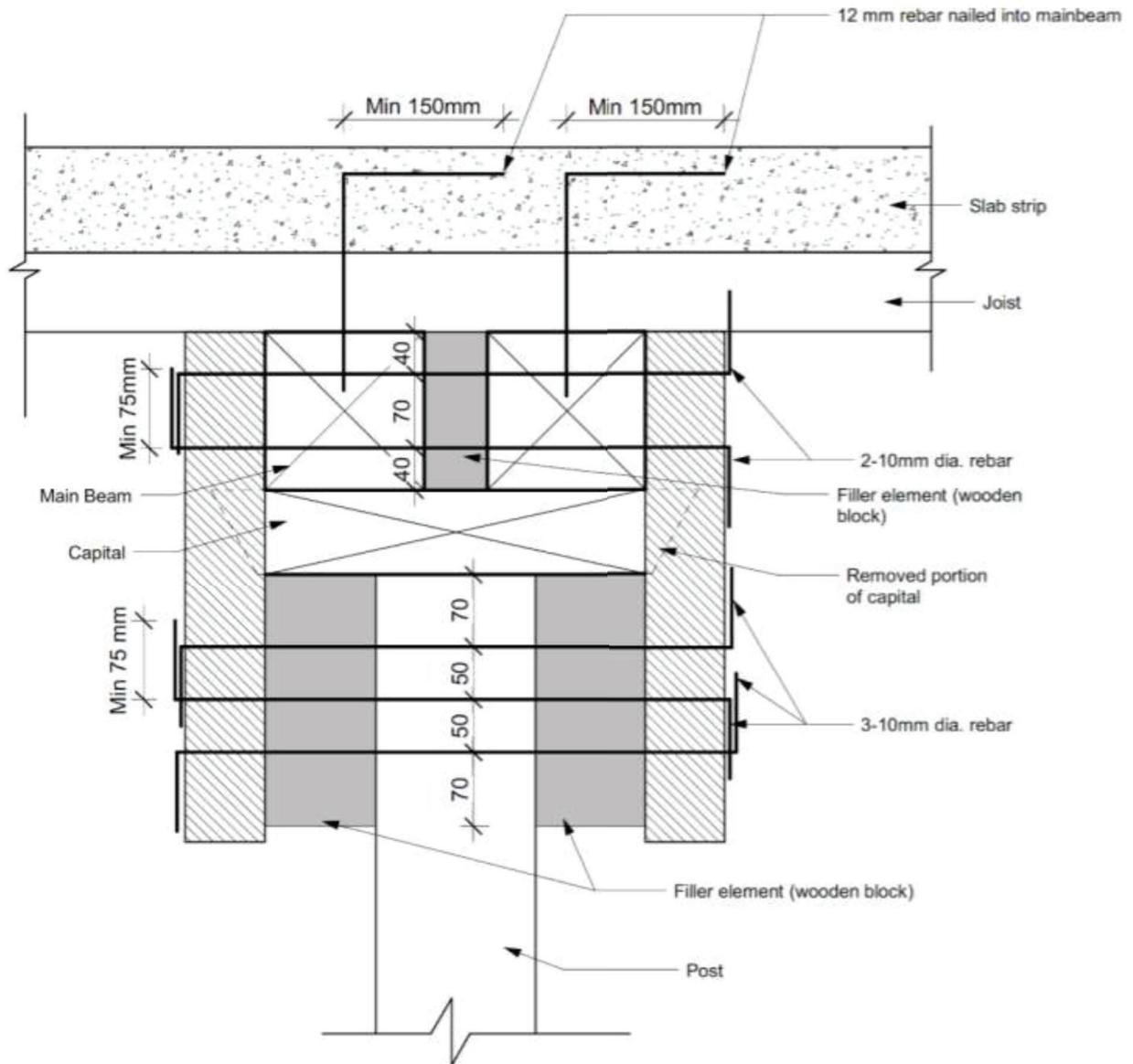


## 7.5 Floor framing has a double beam

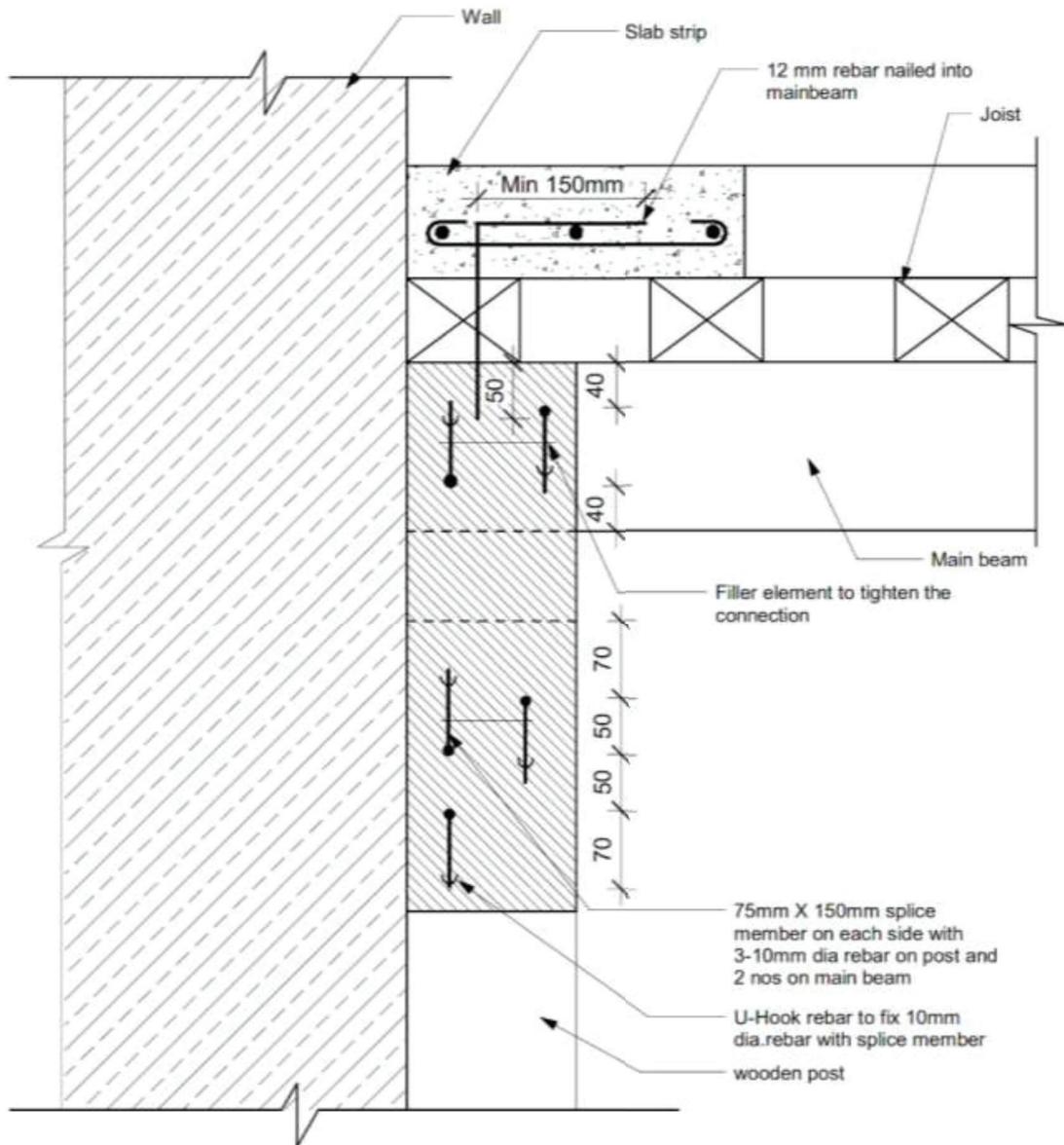




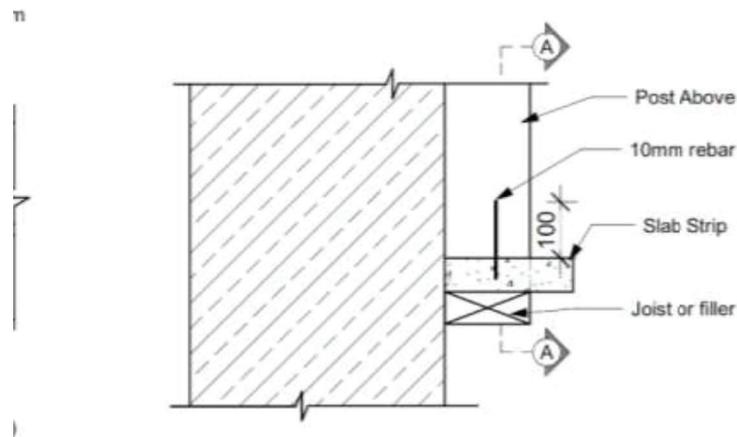
2 Connection between slab strip, main beam, and timber strong back below 3  
1 : 5



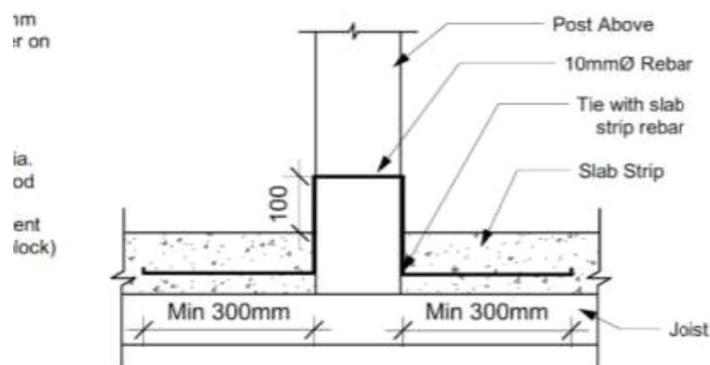
1 Connection between main beam, slab strip and timber strong back below  
1:5



2 Elevation of slab strip, main beam and timber strong back  
1 : 5



Elevation at location of post slab-strip connection



Section at A-A

Note: Slab strip rebar not shown for clarity

3 Connection between slab strip and timber strong back above  
1 : 10

## 7.6 Slope conditions

Install retaining wall per IS-14458 (1)

## 7.7 Partitions

### 7.7.1 Discontinuous

### 7.7.2 Light frame

Wood partitions are considered lightweight and do not have special engineering requirements.

### 7.7.3 Masonry

## 8 SOURCES & REFERENCES

Desai, Rupal, Rajendra Desai. "Field Manual for Restoration and Retrofitting of Masonry Buildings in Nepal". United Nations Development Programme (UNDP), Nepal, Comprehensive Disaster Risk Management Programme. December 2016.

- [\[Google Drive Link\]](#)

"Repair and Retrofitting Manual for Masonry Structure". Government of Nepal National Reconstruction Authority. June 2017.

- [\[Google Drive Link\]](#)

"Seismic Retrofitting Design Guidelines of Buildings in Nepal - Masonry Structures". United Nations Development Programme (UNDP) & Government of Nepal. April 2013

- [\[Google Drive Link\]](#).

Nepal National Building Code (NBC). Department of Urban Development and Building Construction (DUBUC). December 1993.

NBC 105, "Seismic Design of Buildings in Nepal". provides minimum requirements for the seismic design of structures. This standard was used to calculate the seismic demand on the structure.

[\[Google Drive Link\]](#)

NBC 108, "Site Consideration for Seismic Hazards". [\[Google Drive Link\]](#)

NBC 112, "Timber".

NBC 201, "Mandatory Rules of Thumb, Reinforced Concrete Buildings with Masonry Infill" [\[Google Drive Link\]](#)

NBC 202, "Mandatory Rules of Thumb, Load Bearing Masonry".

NBC 203, "Guidelines for Earthquake Resistant Building Construction, Low Strength Masonry".

[\[Google Drive Link\]](#)

A. Guragain, Ramesh, Hima Shrestha, Ram Chandra Kandel. "**Seismic Vulnerability Evaluation Guideline for Private and Public Buildings**". NSET-Nepal. February 2009.

1. Guidance in evaluating earthquake vulnerability (Part I) and damage (Part II) to masonry and reinforced concrete buildings. The guideline is adopted from various standards specifically for application in Nepal. This document includes a description of EMS 98 *Damage Grades*, which are used at BC Nepal.
2. Part 1 (Pre-Disaster Vulnerability Assessment): [\[Google Drive Link\]](#);  
Part 2 (Post-Disaster Damage Assessment): [\[Google Drive Link\]](#)

## 9 APPENDIX A: GO/NO-GO CHECKLIST

The configuration of the various iterations carried out for the SMM type design covers the houses prevalent in the different rural setting in Nepal. Due to the scope of coverage of buildings done to validate the type design, we can apply this design to all the buildings that fulfil a predefined criterion as mentioned below. The criteria are obtained based on the calculations provided in this document and engineering principles wherever applicable.

*If any of the Criteria is found to be non-compliant, the retrofit type design is not applicable to the assessed house.*

### SHAPE:

The building shall be regular in plan and elevation with walls present at least in the perimeter of the building.

### PROPORTION IN PLAN:

Maximum overall length of longitudinal wall shall less than 10.7m.

Maximum overall length of transverse wall shall be less than 6 m.

### STOREY HEIGHT

- The floor to floor height of the building shall be less than or equal to 2.1m at each level.
- Attic height 1.2m. The height of the walls above the attic floor shall not be greater than 1.05 meters, measured from the top of the floor to the top of parapet wall.

### NUMBER OF STORIES

The building shall be no more than two stories plus attic.

### OPENING PERCENTAGE

The maximum percentage of opening allowed along the walls is tabulated below. The length of wall measured must be from the outside end to outside end.

*Table -1 Allowable Percentage Opening*

Building Length (m)	Building Width (m)	Maximum Percentage of Opening allowed along long wall	Maximum Percentage of Opening allowed along short wall
L ≤ 8.3	B ≤ 6	≤ 35%	≤ 25%
8.3 < L ≤ 10.7			≤ 20%

## OPENING

Any openings with height less or equal to 1.2 meters shall be considered as a window.

Any opening between the heights of 1.2m to 1.9m shall be considered as a door.

No openings above a height of 1.9 meters shall be permitted.

## PIER LENGTH

Table -2 Minimum required pier length

Building Length (m)	Building Width (m)	Minimum size of pier along the long wall (m)		Minimum size of pier along the short wall (m)	
		Door	Window	Door	Window
L≤10.7	4.5≤B<5	0.925	0.6	1.6	1
	5≤B≤6			1.35	0.95

## PLUMBLINE

The walls of the building shall be true to plumb line.

## WALL

The walls of the building shall not be retaining soil on any side.

## WALL THICKNESS

The wall thickness shall not be less than 450 mm.

## VERTICAL DISCONTINUITIES

All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.

## GEOLOGICAL CRITERIA

- i. Has the area (ward) been affected by landslides, cracks in the ground, fault line or other types of ground movement?
- ii. Have any adjacent retaining walls or slopes been subjected to movement or damage?
- iii. Is the ward subjected to floods from the nearby watercourses or flash flood?
- iv. Is the building isolated?
- v. Is the foundation intact and stable?
- vi. Is the foundation affected by settlement, consolidation and cracks?
- vii. Is the slope of the ground less than 20 degree?
- viii. Is the soil dense?
- ix. Is the distance between house and nearest water course less than 20m?

## Annex 3: Field Guide for Repair and Retrofitting for up to 2½-Storey Masonry Buildings in Mud Mortar



REPAIR



RESTORATION



SEISMIC RETROFITTING

# FIELD GUIDE

for Repair and  
Retrofitting

FOR UP TO 2 ½ STOREY  
MASONRY BUILDINGS  
IN MUD MORTAR

This **Field Guide for Repair and Retrofitting** is prepared through Government of India supported Nepal Housing Reconstruction Project, Gorkha for UNDP's Comprehensive Disaster Risk Management Programmed by Rupal Desai, Rajendra Desai, CEDAP team with support from ODRC Team.

May 2020

*Disclaimer: All efforts has been made to use the original photographs and illustration or refer to the copyright holders. Likewise, the technical details are based on preliminary recommendations given by the experts and concept based on "Random Rubble Masonry with GI Wire Containment" in DUDBC's Design Catalogue for Reconstruction of Earthquake Resistant Houses. However, any mistakes are unintentional, and will be corrected in subsequent revisions. The retrofitting technique/technology has been implemented in retrofitting of houses in Gorkha, which has been accepted by the district-based government stakeholders for release of the tranches. Approval of the technology from the central level government is in process.*

**PART 1**  
**Repair and  
Restoration  
Field Guide  
for  
Damaged  
Masonry  
Buildings**

**PART 2**  
**Retrofitting  
Field Guide  
for  
2 ½ Storey  
Masonry House  
in  
Mud Mortar**



**Government of India supported  
Nepal Housing Reconstruction Project, Gorkha**



## FOREWORD

UNDP's Comprehensive Disaster Management Programme (CDRMP) was formulated in 2011, aiming to strengthen resilience to natural hazards by building capacity of the key government ministries, its line agencies and local bodies. CDRMP has been a key partner of the Government of Nepal in providing supports in institutional and legislative sectors of Disaster Risk Management in Nepal and strengthening partnership with national, institutional and the private sectors, civil society organization and other development actors for Disaster Risk Management including Climate Change Adaptation.

The partnership between Government of Nepal and UNDP for building seismic resilience dates back to 1990s in preparation of the National Building Code, followed by an extensive program on earthquake risk reduction and recovery that resulted in development of training curricula and manuals for the engineer and masons, which were vital reference material post 2015 earthquake. UNDP/CDRMP has since been providing support to the municipalities within and outside of the Kathmandu Valley in implementation of the National Building Code compliant building permit system through manual and electronic medium.

As an important achievement, the Seismic Retrofitting Guidelines of Buildings in Nepal, prepared by UNDP/CDRMP for the Government of Nepal has been approved by the Ministry of Urban Development. It was developed based on the lessons learnt from UNDP's engagement in school retrofitting project in Illam and Taplejung post 2011 Sikkim earthquake. The guideline encompasses three volumes for the three dominant construction typologies namely Adobe, Masonry and RC construction, targeting the existing housing stock, to strengthen them to cope with the seismic shocks.

In 2015 Gorkha Earthquake, a large number of houses were damaged that did not collapse, and could be repaired, restored and retrofitted for habitation. However, there is a lack of clarity on affordable, contextual and replicable technologies for retrofitting. In addition, as retrofitting is different than constructing a new house, it requires building capacity of the existing masons and engineers, with sensitization of the house owners, to implement retrofitting on any site.

In addition, more than 95% of the housing stock destroyed and damaged by the earthquake were masonry, so the technology of containment reinforcement using GI wire, which has already been approved for new construction, has been further adapted to be used as retrofitting solutions for the stone masonry houses. This Retrofitting Field Guideline has been prepared for the technical human resources in the field, who want to repair, restore and retrofit buildings to reduce their vulnerability against further damage due to earthquakes. It aims to be a hands-on manual to be used in the project area that translates the complexity of retrofitting procedure/guideline for implementation in the field by the engineers.

I would like to extend my sincere acknowledgement to Ms. Rupal Desai and Mr. Rajendra Desai for their technical support in preparation of this manual and Mr. Jitendra Bothara for their expert guidance for finalization of the design and specification. I would also like to acknowledge my colleagues at UNDP/CDRMP, who have helped in this endeavor.

TBD  
UNDP – Nepal

## Preface

The death and destruction witnessed by Nepal in the earthquakes of April and May of 2015 is a wakeup call for reducing the vulnerability of the existing housing stock of the country. Most houses that had suffered damage and destruction have now been rebuilt under the Nepal Housing Reconstruction Program of the Government of Nepal. Yet, there are a large number of masonry houses that were not severely affected by those earthquakes. They are still standing and people have continued to occupy them. Many of them have also been modified without employing technically appropriate methods. Since Nepal is a highly earthquake prone country, earthquake as powerful as the ones of 2015 can occur in foreseeable future. All these houses are vulnerable against future earthquake.

To bring safety to their occupants, the best option is to retrofit these buildings. Government of Nepal also supports repair and retrofitting of such houses as part of their reconstruction program. Many of these pre-earthquake houses are eligible for government assistance under this scheme. Overwhelming majority of these houses have more than a storey plus attic and are constructed with bricks or stone masonry in mud mortar. Unfortunately, there are very few technical options for retrofitting such houses with masonry in mud mortar, if any, that are affordable as well as logistically simple.

This guide is prepared specifically for these masonry houses. The retrofitting approach adopted here is based on the Containment Reinforcement (CR) system that was approved in 2016 by the Nepal government for the reconstruction using stone masonry in mud mortar. It is a simple technique to implement with local artisans in the remote regions and uses local materials that pose minimum logistic hurdles. The guide is developed by NCPDP-CEDAP team that has had an extensive experience of two and a half decades in retrofitting of masonry buildings in different disaster prone regions of India and this effort has been given sound technical basis by Jitendra Bothara, a leading masonry and retrofitting expert from New Zealand. The evolution of this guidebook was in conjunction with the retrofitting of several houses in Gorkha region which made it possible to ensure the practical viability of the approach. This has also made it possible to address the commonly observed vulnerabilities in the vernacular buildings in the region.

The field guide provides the technical specifications adopted in this approach, along with the step by step procedure and the do's and don'ts for the CR System. It also provides construction details specially prepared to address the most common vulnerabilities. CEDAP-NCPDP and the authors humbly acknowledge their gratitude to UNDP Nepal, especially to Shri Ramraj Narsimhan, Shri Vivek Rawal and Ms. Pragya Pradhan for persistent efforts in promoting the vision of disaster free Nepal, and their encouragement in all our efforts in that direction. We are also indebted to the people in the earthquake affected regions of Nepal for welcoming us in their houses to carry out demonstration of retrofitting simultaneously with the training of local artisans.

Rupal Desai and Rajendra Desai - CEDAP-NCPDP

## Background

The 2015 earthquakes in Nepal caused widespread damage and destruction of buildings with different types of construction. Since stone-mud and brick-mud houses are the most common types found in most of quake affected Nepal, the most damage and destruction were observed in them. A large number of damaged houses are still standing and occupied. They are vulnerable to future earthquake. Additionally, there are lakhs of houses that survived the earthquake undamaged but are vulnerable to varying degree to future earthquake. Repairing the damaged houses to restore them to pre-earthquake condition and retrofitting them to strengthen them is one sure way to reduce their vulnerability and increasing safety for those living in them.

Splint and Bandage system as recommended by the NRA Correction Manual is one way to reduce vulnerability of such houses having ground plus half a storey. On the other hand the CR system is suitable for buildings having 2 and ½ stories .

## Scope

The Splint & Bandage system is covered in the “Correction Manual of NRA” and execution details for retrofitting different types of masonry buildings are provided in UNDP’s “Field Manual for Repair & Retrofitting of Masonry Buildings in Nepal”. A large number of stone and brick masonry buildings in mud mortar up to 2 and ½ stories are still vulnerable. This guide book focuses specifically on retrofitting these houses using the CR technique. This technique is suited for Nepal since it is simple, cost effective and uses easily available materials and is simple to implement. Further, most common type of stone masonry observed in the earthquake affected regions allows making 15mm diameter holes necessary in CR system for the insertion of the cross-links for the anchoring different retrofitting elements. It is equally applicable to the houses built with the brick masonry in mud mortar.

Part 1 of this guidebook explains repairing various damages to the buildings and restoring it to its original condition, while part 2 of the guidebook explains retrofitting measures for strengthening the buildings.

## Target Group

It is envisaged that the Guide will be used by the engineers who are going to provide technical assistance to the house owners wanting to reduce vulnerability by retrofitting their houses. This will be useful in the regions of Nepal where stone and brick masonry houses up to 2 and 1/2 storey in mud mortar are built. The Guide could also be used by many of the contractors and masons who are able to understand its content since they possess adequate reading and comprehension abilities.

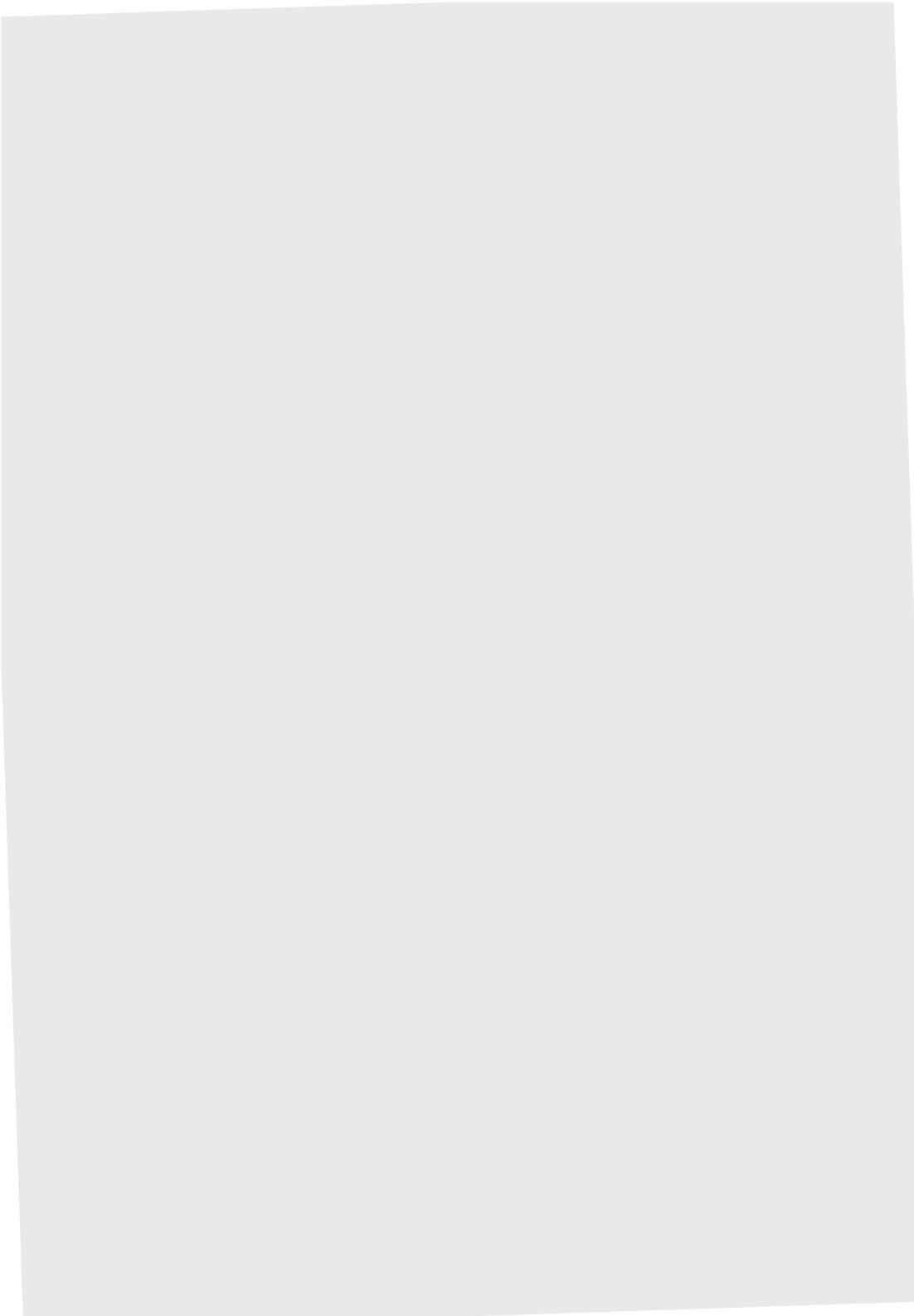
## Ensuring Safety at Site

It is important that the tools, materials and working schedules are so managed that they do not create any safety hazard. Some of the points where caution needs to be exercised during construction are shown below.

- GI wires and welded wire mesh bundles or pieces should not be lying strewn around on floor.
- In the course of inserting the cross-links through the holes made in the walls extreme care must be exercised by the individual standing on the other side of the wall helping with the insertion of it.
- Care also needs to be taken against the injury that the crosslink ends projecting out of the walls or vertical wires not yet tied could cause to those working near the walls.
- Care must be taken while tying the vertical wires, horizontal wires or in-plane bracings. Since in-plane bracings may be close to the eye level, extra care must be taken while tying.
- Twisting the wires for cross-bracings requires extreme care, as over-twisting may lead to sudden snapping of wires already in tension, leading to damage to eye or severe injury.
- During the course of restoration of the severely damaged walls, care needs to be exercised to support the roof, walls, intermediate floor resting on that wall such that removal of the damaged wall does not destabilize them and lead to injury.
- Installation of some of the retrofitting measures on the outer face of the wall will require one to work several feet above the ground, often standing on the sloping roof. It is important that safety harness is worn by the individuals undertaking such tasks.

## Glossary of Important Words - English to Nepal

English	नेपालीमा अनुवाद (Translated in Nepali)
Damaged	क्षतिग्रस्त
Restoration	पुर्नस्थापना
Interlocking	एक अर्कासंग राम्ररी जोडिएको
Seismic belt	भूकम्पीय जोखिमबाट बचाउने पेटिजस्तो संरचना
Lintel	इन्चाल र ढोकामाथीको बन्धन
Anchor	बाधिएको
Encase	घेरिनु
Plumb	घण्टी
Lap joint	ल्याप जोर्नी
Header	हेडर
Ridge	धुरी
Bulging of wall	पेट निस्केझीं देखिने गारो
curing	पानी पटाउने
Delimitation of wall	गरोको एक तह उप्केको वा भत्केको
Diagonal crack	विकर्ण चिरा
Forrocement bandage	फलामको जालीमा रहेको कंक्रीटको पट्टी
Joist	धरन
Purlin	भाटा
Rafter	डाडा
Stone chips	गेग्रान
wythe	दुई सुरको जोडाई
Diagonal guy anchors	कुना बन्धन
Beams	दलिन
Bending of wall	मोडिएको गारो
Two sided roof	दुई पाखायुक्त छाना
Gable wall collapse	चुली गारो भत्केको
Lateral seismic force	पार्श्व भूकम्पीय शक्ति
Stone chips	गेग्रान
Through-stone	वारपार ढुंगा
Thrust	धक्का
Wall going out of blumb	घण्टीबाहिर निस्केको गारो
Wall opening	गारोका खुल्ला भागहरु
Horizontal band	तेर्सी पट्टी
In-plane diagonal ties	प्लेनभित्रको विकर्ण बन्धन
Wall plate	वाल प्लेट
Ground floor	भुइँ तल्ला



# PART 1

## Repair and Restoration Field Guide for Damaged Masonry Buildings



## PART 1 : REPAIRS

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## 1. Introduction

This part focuses on commonly observed damages in the masonry houses.

Restoring the house to its original strength is the first step towards safer living. If a house was damaged in the earthquake, or had already signs of deformation/damage even before the earthquake, this part will help in identifying the extent of damage and whether one should be concerned about it or not.

Before retrofitting any house, it should be repaired to bring it to the level of its original strength. However, it should be noted that repairing the house does not make it stronger to resist future earthquakes, since it still will have all original vulnerability which led to the damage and more. Hence, retrofitting the house is a necessary step after repair and restoration. However, repair, restoration and retrofitting al can be combined together to reduce intervention time and cost.

### **Understanding Damage - Damage Categorization, Description and Restoration**

It is stressed that to understand true extent of the damage, one needs a trained and experienced engineer. However, the information given here would be useful for the engineers in categorizing the damage level based on its description, concerns arising from the damage and measures to be taken for the restoration.

## A. Restoration Procedure for Wall Damage:

### 2. Grade 1 Damage:

**Description:** **Hair-line cracks** in very few walls. Hair-line cracks in plaster or fall of small pieces of plaster from the walls. Fall of loose stones from upper parts of buildings in very few cases.

**Damage measurements:** Only length of the cracks can be measured

**Impact on Strength:** Negligible to slight damage (no structural damage, slight non-structural damage) There is no loss of strength of the buildings from such damage,

**Advice after the earthquake:** There is no need to panic. The building could be continually used. Only cosmetic or architectural repairing is required. If possible the building should be retrofitted after seismic assessment



Wall having Grade 1 cracks

## A. Restoration Procedure for Wall Damage:

### a. Repairs of Grade1 cracks

#### Sealing of cracks - For wall with cement plaster



1. Make 'V' notch along the crack to broaden the mouth of crack. Do this carefully so as not to damage the wall.



2. Clean crack with wire brush to remove all loose materials including dust.



3. If structure has cement mortar and/or cement plaster then seal crack with 1:3 cement mortar after wetting the crack surface and cure it for minimum 7 days.



4. If the structure has mud mortar or mud plaster then seal the crack with mud

5. Leave it to dry for minimum 3 days. Finish the restored parts to match the surrounding wall surface.

**For wall with mud plaster:** The plaster around the crack should be removed and using local technique of plastering the crack and the surrounding wall should be finished in mud plaster.

It is important to note that the Grade 1 cracks are a result not only of earthquakes but also large temperature changes, changes in humidity in air and minor settlements of foundation. From distance these hairline cracks are rarely visible. They can be left alone if one does not mind their appearance.

### 3. Grade 2 Damage:

**Description:** Moderate damage (slight structural damage, moderate non-structural damage); Small cracks **maximum 5mm (1/4")** wide in walls, falling of plaster over large areas, cracking of non-load bearing parts like chimneys, parapets, roof tiles disturbed in small areas.

**Damage measurements:** Cracks are some times across the full thickness of wall. Length and width can be measured.

**Impact on Strength:** Load carrying capacity for the gravity loads of the structure is not reduced substantially.

**Advice after the earthquake:** The building could be continually used. Repair cracks with splicing. If possible the building should be retrofitted after seismic assessment.



Exposed masonry wall having Grade 2 cracks



Grade 2 cracks in Cement plastered wall



Grade 2 cracks in wall with Cement plaster.



Grade 2 cracks in wall with mud plaster

**Caution:** An inexperienced engineer may tend to over estimate the grade of the cracks. Grade 2 crack is commonly interpreted as Grade 3 crack, especially when wall has mud plaster.

For repair methodology see after the damage description for grade 3.

#### 4. Grade 3 Damage:

**Description:** Substantial to heavy damage (moderate structural damage, heavy nonstructural damage) Large and deep cracks **6mm (1/4") to 10mm (1/2") wide** in walls, widespread cracking of walls, tilting or collapse of non-structural elements like chimneys, partition walls, gable walls etc. Roof tiles get detached.

**Damage measurements:** Cracks are generally across full thickness of wall. Length, width and depth, all three can be measured.

**Impact on Strength:** Substantial loss of building strength, especially to withstand horizontal seismic loads.

**Advice after the earthquake:** Until advised otherwise by an expert do not use the building. Such damage can be repaired. Seek engineer's advice regarding the repairs. Retrofitting is a must, after the repairs since this level of damage would not occur unless the structure is vulnerable. Repair and retrofitting work could be combined together.



Grade 3 cracks in plastered wall



Grade 3 cracks in un-plastered wall



Grade 3 cracks between opening

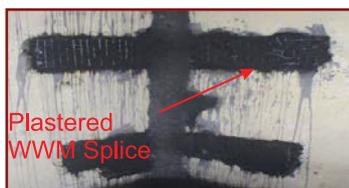
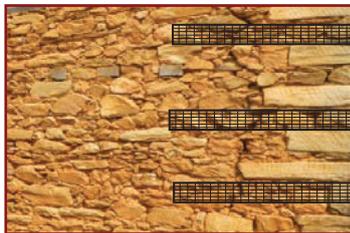
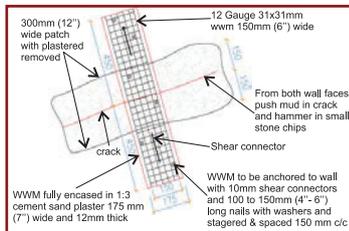


Grade 3 cracks in masonry

### a. Repairs of Grade 2 and Grade 3 cracks

Grade 2 having width up to 5mm (1/4"), and Grade 3 cracks having width more than 5mm (1/4") but less than 10mm (1/2")

#### Splicing Across Cracks



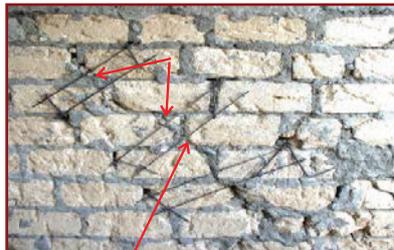
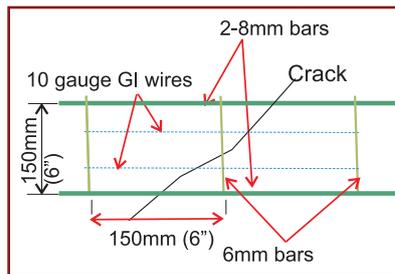
1. In case of cement plaster make 'V' notch along the crack, clean it with wire brush followed by water to remove loose materials and dust.
2. Prepare masonry surface on both faces of the wall for fixing splices extending on both sides of the crack, raking the joints up to 12mm (1/2") depth, and cleaning it with wire brush and water.
3. From both the wall faces push mud having just enough water to permit pushing in the crack as far as possible and as much as possible. Also hammer in small stones in the crack such that they get wedged.
4. In case of cement plaster, seal the crack with 1:3 cement mortar from both faces of the wall.
5. Install the 150mm (6") wide 25x25x2mm Welded Wire Mesh (WWM) splices at maximum spacing of 1,000mm (3' 3") anchored with 10mm diameter bar shear anchors through full thickness of wall, one on each side of the crack, plus 100 (4") to 150mm (6") long thick nails inserted with washer at spacing no greater than 300mm in a staggered manner
6. A gap of 10mm (1/2") must be maintained between the mesh and un-plastered wall.
7. Plaster over the mesh with two 12mm (1/2") coats of 1:3 cement mortar.
8. Cure it with water for 15 days.
9. In case of mud plaster using local technique of plastering finish the crack with mud.

### Repairs of Grade 2 and Grade 3 cracks (cont.)

If WWM is not available, use reinforcing bars as splice or as C Clamp.

#### Splicing Across the Cracks - Alternatives

##### 8mm Deformed Bars Splice



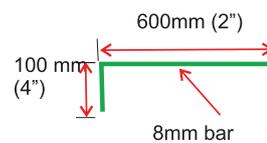
Install 8mm rebar with 100mm nails inserted with washer at staggered spacing no greater than 300mm.



Plaster over the mesh with two 12mm coats of 1:3 cement mortar.

##### 8mm Deformed Bars 'C' Clamp

Appropriate for brick masonry



Hammer in 'C' clamp at maximum distance of 900mm in the mortar joint perpendicular to the crack



Plaster over the clamp and crack with two 12mm coats of 1:3 cement plaster.

**Attention:** (a) Fill the crack with mud and stones as described earlier and seal with cement mortar. (b) Wall must be wet before applying the cement plaster/ mortar particularly if it is built with bricks.

## 5. Grade 4 Damage

### Description:

Heavy structural damage, very heavy non-structural damage

Portions of wall in the state of impending collapse due to tilting or bulging in thick stone or brick walls, one wythe or face collapsed due to delamination, corner collapse. Partial structural failure of roofs and floors. Cracking at wood post and wood beam joint. In over all very heavy damage to the building

### Damage Measurement:

It is possible to measure height, width and depth or length of the damage. This would include parts that are already collapsed or are about to collapse.

### Impact on Strength:

There is a substantial loss of the structural strength and stiffness of the building. Building is unsafe to occupy. It can sustain further damage.

### Advice after an earthquake:

The building has to be vacated. Reconstruction of some parts of the building and repairing of all other damaged parts of the building is necessary, and the whole building should be retrofitting as per engineer's advise for seismic safety.



Typically, this type of damage is most commonly interpreted as total loss or total collapse, and is considered fit for reconstruction. However depending upon the spread of the damage and intensity, building could be restored on the case to case basis. Only those engineers with understanding of structures and damage would be able to advise on repair, restoration and retrofitting of buildings with partial collapse.

**Grade 4 Damage (cont.)Description:**

Grade 4 Damage : Cracks wider than 10mm or a part of wall that has gone out-of-plumb, or has collapsed.



Plaster over the mesh with two 12mm coats of 1:3 cement mortar.



Collapsed corner

Grade 4 Damage: Bulging or Delaminated wall or Partially Collapsed wall.



Bulged wall



Delaminated wall

Grade Grade 4 Damage: Partially Collapsed Gable Wall.

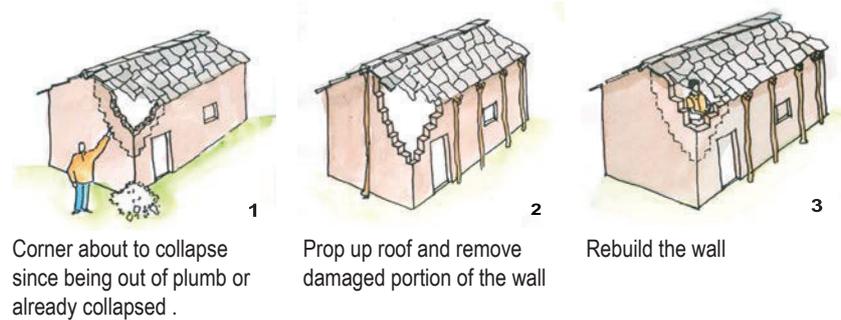


Gable collapse

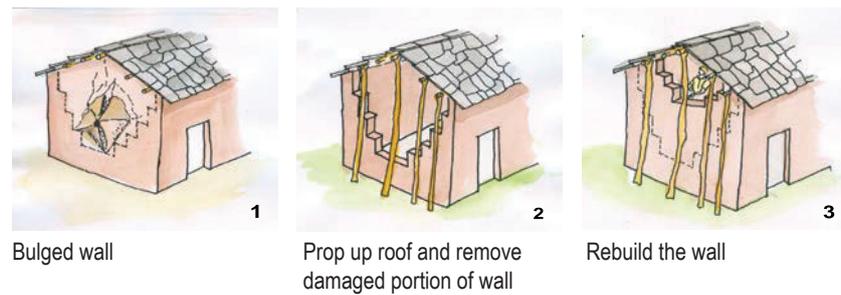
**a. Procedure for Restoration of Damaged Wall Supporting Flexible Roof:**

Follow step by step restoration procedure given in the following pages.

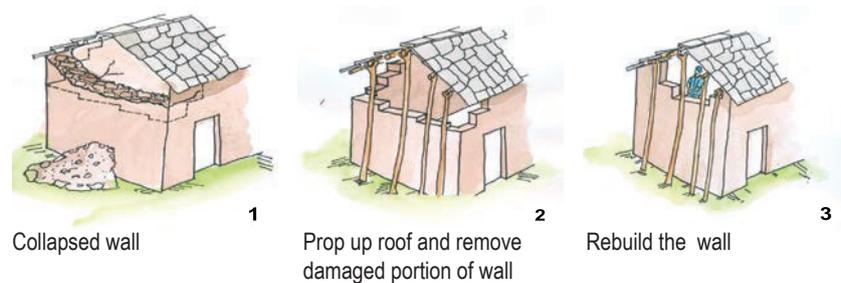
**(a) Out of plumb wall or collapsed corner,**



**(b) Part of wall that has bulged or delaminated.**



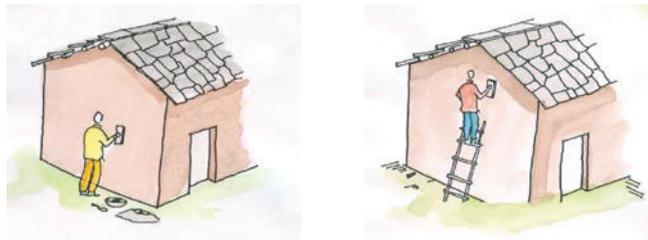
**(C) Part of Gable wall has collapsed**



**Caution:** The damaged walls have to be restored carefully in a systematic manner so that the stability of the whole structure is not undermined.

**Procedure for Restoration of Damaged Wall Supporting Flexible Roof (cont.):**

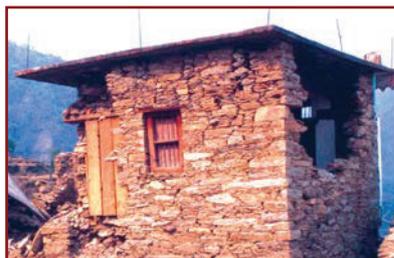
1. Mark the boundary of the damaged portion of the wall.
2. Mark 600mm (2'-0") extra on all sides from the damaged portion for dismantling. If damage extends to a "L" corner then extend marking to next wall. At "T" corner the marking will extend to both the adjacent walls.
3. Support the roof or the floor above the damaged portion of the wall that has to be removed with timber or steel props. Provide additional supports to prevent any accidental collapse.
4. Slowly remove the marked portion of the wall in step like manner so that the new construction connects well with existing wall. In case of damage at corner remove adjacent wall portion in same way
5. Separate and stack reusable material properly. Discard all materials like small round stones unsuitable for construction.
6. Rebuild the dismantled wall using salvaged or new material. Use mortar that is the same as that used in the existing construction. If the existing wall is built with stone in mud mortar, then it is best to use stone in mud mortar in restoring, but not bricks.
7. Adhere to the basic rules of earthquake-resistant masonry construction while rebuilding the wall. If the wall is built in stone, use one Through-Stone in every 0.7 square meter both ways and staggered vertically.
8. If cement is used wet the wall before construction or plastering and cure it for at least fifteen days.
9. Remove props once rebuilt portion has achieved enough strength.
10. Finish the wall to match the adjacent parts of remaining house.



Finishing to match the existing wall

**b. Procedure for Restoration of Damaged Wall Supporting Rigid RC Slab Roof and Timber Floor:**

Restoration of an undamaged RC slab supported on severely damaged supporting walls.



Undamaged RC slab on severely damaged wall

**Caution:** The damaged walls have to be restored carefully in a systematic manner so that the stability of the whole structure is not undermined.

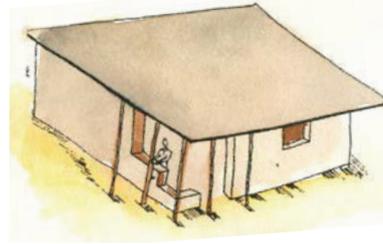
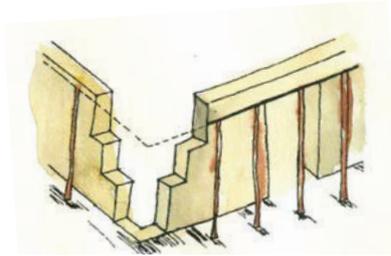


Undamaged RC slab on severely damaged wall



Props placed inside as well as outside the building to support the slab

1. Prop up the slab all along its damaged supporting walls using vertical wooden posts coupled with slant braces, both having horizontal planks on top, on both sides of the walls
2. Supports must be strong and wedged to make sure that the slab is resting well on them. Slant supports will prevent the lateral sway of the slab. Care should be exercised in hammering in the wedges since upward pressure on slab can crack the slab.



3. Mark the portion of the severely damaged wall that has to be removed. Starting from a corner, begin removing the portion of the wall not exceeding more than  $\frac{1}{4}$  of total length of the damaged wall or 3m (10'-0"); whichever is less, in step like manner.
4. Begin removal of the marked portion of wall with extreme caution.
5. Start construction of the new wall from the corner following rules of earthquake resistant construction. Build it in a stepped-like manner to ensure proper bond with the next portion to be constructed.
6. Remove additional 2m (6'-6") length of next portion of the damaged wall.
7. Continue the process till all the damaged walls have been restored.
8. If cement mortar is used for construction, cure it for 15 days.
9. If the slab has developed cracks, follow the instructions given later under "restoration of damaged RC slab" to restore it.
10. When all the walls are restored, remove all the supports once walls have gained strength, and retrofit the entire structure as required. Follow the instructions for retrofitting from the chapter on retrofitting .



**Systematically propping up slab, removing portions of damaged walls, and rebuilding them portion by portion one can save the RC roof. Advise from an engineer is recommended.**

## 6. Grade 5 Damage:

### Description:

A large part of the building severely damaged, or building has fully collapsed.

### Advice after the earthquake:

If the collapse is more than 50% of the building, it is may be advisable to tear down the rest and rebuild. Alternatively, If portions of the buildings are still standing, the collapse parts can be rebuilt in a manner that it is connected well with the portion still standing, and the entire building is seismically retrofitted.



Total collapse of stone masonry houses



Total collapse of stone and brick masonry houses

### a. Restoration of Severely Damaged Buildings that Appear Beyond Repair

#### Grade 4 / Grade 5:

Buildings with visibly major damage including a collapse of one or more walls.

#### Restorable buildings:

Many buildings at first glance seem unsalvageable. The fear-psychosis in most people, and, even in many engineers, makes them opt for demolition. But if planned properly, these buildings can be restored. Damaged portions can be rebuilt but all undamaged walls and roof can be salvaged. There is a good possibility that all the buildings shown here can be restored with systematic planning and action. But a closer and more detailed look is required as first step.



Roof and intermediate floors need to be jacked up, front and rear walls to be dismantled in step like manner, the end wall to be rebuilt all the way to roof such that it is well connected to side walls, and anchored to timber floor and roof



Dismantle the cracked walls further in step like manner all the way from ground level, while propping up the roof and floor. Rebuild walls to connect well with adjacent walls, floor and roof



Out of plumb detached wall to be removed along with adjacent walls in stepped manner, and rebuilt to connect well with other walls, timber floor and roof. Cracks in window corners are to be filled with mud and spliced.

## B. Roof Damage & Restoration Procedure

### 7. Restoration of Damaged Stone / Slate / Concrete Tile Roof:

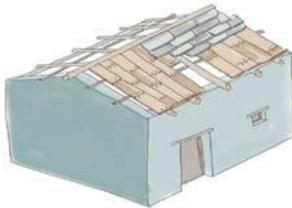


Damaged roof structure and dislodged slate / roof tiles



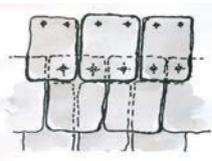
Collapsed roof due to collapsed walls

It has been observed that much of the roof damage has been caused because of breaking of timber roof structure or severe damage to the supporting walls. In such cases, the following steps should be taken:



1. Remove all the stone tiles / concrete tiles roofing carefully, followed by the planks under them, if any.
2. Repair the walls as described earlier in this guidebook and other support systems.
3. Replace damaged timber elements such as rafters, purlins, and planks.

5. Repair the cracked elements by nailing or splicing with the help of metal straps or MS flats. Pre-drill holes in old timber to prevent cracking.



6. Reinstall stone/ concrete tiles. Nail them well to the planks using at least **two nails with washers** near the upper edge on each tile.



7. Install steel hooks at eave level to support the stone tiles along their bottom edge to prevent sliding and uplifting by wind.

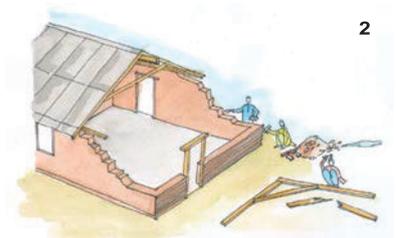
## 8. Restoration of Damaged CGI Sheet Roof:



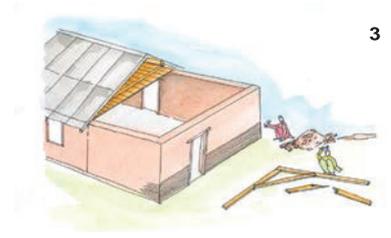
Damaged roof because of severe damage to the support walls and other support systems.



Damaged roof because of severe damage to the support walls and other support systems.



Remove damaged portion of wall

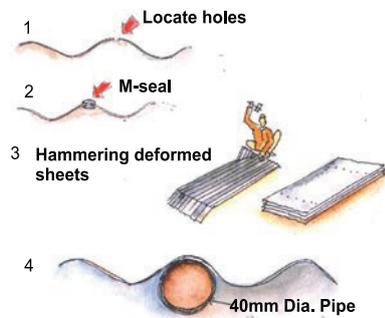


Rebuild the wall

For restoring the roof the following steps should be taken.

1. Remove and store all the sheets carefully.
2. Clear the damaged portion of roof.
3. Clear the severely damaged portions of the walls and reconstruct them while adhering to the principles of good practice.
4. Repair the cracks and minor damages.
5. Replace the severely damaged timber elements including truss top chords, principal rafters, rafters, purlins, and planks.
6. Repair the cracked elements by nailing or splicing with the help of metal straps or MS flats. Pre-drill holes in old timber to prevent cracking.
7. Reinstall CGI sheets, unless they are damaged or deformed, using “J” hooks.

### 9. Repairing deformed CGI Sheet Roof:



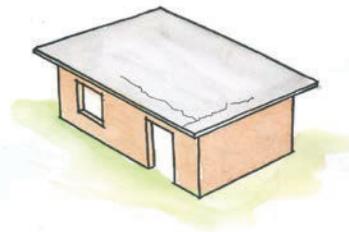
1. Remove any rusted edges around the existing nail/bolt holes with a file or a hammer.
2. If any bent sheets found straighten them using wooden hammer.
3. While hammering, place 40mm pipe under the sheeting to ensure proper corrugation
4. Seal all open holes with M-seal (sealant).

### 10. Restoration of damaged RC slab:

#### a. Crack in RC roof.



Grade1/Grade 2 Crack in RC roof/floor



Grade1/Grad 2 crack

#### i. Sealing of fine (Grade 1) crack.

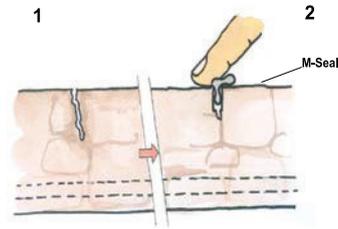


1. Clean the crack with wire brush.



2. Apply 1:3 cement - fine sand mortar over the crack, and cure for 15 days.

### ii. Sealing of Moderate (G2) non-structural crack



1. Rake the crack with chisel and widen the crack.
2. Clean the crack with wire brush.
3. Make sure the crack is absolutely dry.
4. Seal it with M-seal, or with non-shrink flexible crack sealant available in market. Using thumb, apply it with pressure so that no space is left out.
5. Remove excess sealant. Let the applied sealant harden.

### iii. Restoring of Moderate (G2) non-structural concrete spalling

1. Remove all loose chunks of concrete from underside of slab and evaluate the extent of rusting.



2. Dry clean the concrete surface to remove all loose materials.
3. Clean the rusted bars using commercial rust remover or tamarind solution in water to remove the rust. Tap with hammer to dislodge rust.
4. If the bars are severely corroded then new bars with adequate overlap to compensate for the lost steel area will be required.
5. Coat the new and old cleaned bars with Epoxy Zinc Primer to prevent future rusting.
6. Apply locally available bonding agent on old concrete surface for better adherence with the new concrete.
7. Apply micro-concrete to seal the bars ensuring smooth matching with surrounding plaster.
8. Cure for minimum 15 days.

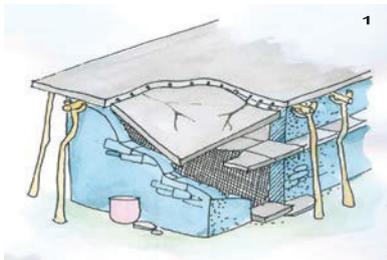
### Restoration of damaged RC slab (cont.).

#### b. Restoration of Partially Collapsed RC Roof :

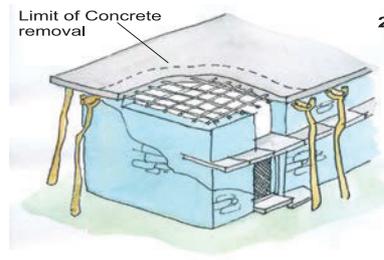


Consisting of wide crack with a portion of the slab bent resulting in bending and exposing of reinforcing bars.

1. Support the undamaged portion of the slab with strong timber posts and wooden planks to prevent further cracking in slab.
2. Mark off a line on the undamaged part of the slab at 600mm (2'-0") from the damaged area periphery.
3. Carefully break off concrete from the collapsed portion to reduce the weight and also from the undamaged portion up to the marked line, and expose the steel bars.



Support undamaged portion of slab with props. Mark area for concrete to be removed



Remove the concrete, expose the bars, and strengthen the bent bars

4. Lift up and straighten out the bars to the correct alignment and prop them up
5. If the walls are damaged or collapsed, restore them as described earlier.

## C. Restoration procedure for Timber Floor Damage:



Sliding out of timber joists sitting on walls



Sliding of timber joists sitting on bearing stones projecting out from walls.



Breaking of floor joists



Falling debris from the upper storey or attic causing damage.

### Restoration Steps:

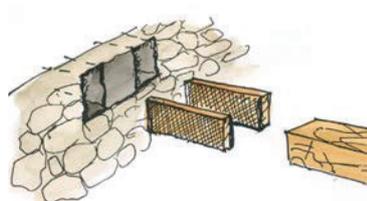
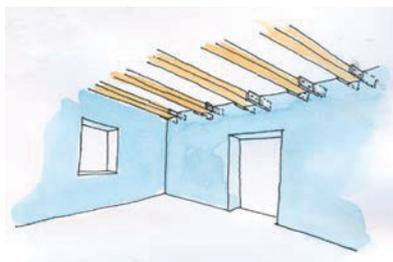


1. Prop up damaged floor, and clear all the debris on it, if any.
2. Open up the floor planks and remove timber joists from the damaged area.
3. Also remove rotten, cracked timber, if any.

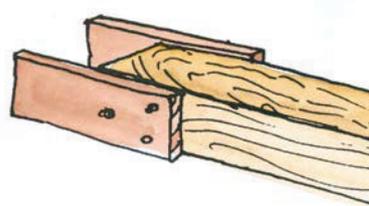
4. Restore the damaged wall on which the floor joists are resting.
5. Restore all the cracked timber elements by nailing or splicing them with the help of metal straps or MS flats. Pre-drill holes in old timber to prevent damage from cracking.

6. Extend floor joists that are not long enough for ensuring adequate bearing on wall. Attach two timber pieces 150mm to 220mm long at the end of the joists with minimum two nails.

7. Where the joists have moved from their place due to rotted end, create a new end portion by attaching timber pieces on both faces of the joist to provide adequate bearing in the original location.



Assembly for safer bearing of joists having inadequate length



Extended joist for safer bearing

8. Fill up cavities beyond the end of floor joists with small stones and mud by pushing them in with a flat headed thing like hammer handle.
9. Reinstall all the timber planks on top of joists with minimum of two nails at each end.
10. Remove all the supports.
11. Once the floor is restored, retrofit it for improved diaphragm action as instructed or advised in the retrofitting field guide.

## D. Examples of Restoration of Walls & Roofs:

Buildings that often look severely damaged and appear to be fit for reconstruction can often be easily restored portion by portion to bring them back to their pre-damage condition. This is then followed by retrofitting to prevent the recurrence of same or other damages.



Cracked arcade being restored stone by stone.



Damaged brick masonry wall being rebuilt to reinstall RC slab on it.



Badly damaged stone masonry wall dismantled and being rebuilt accompanied by a new window.



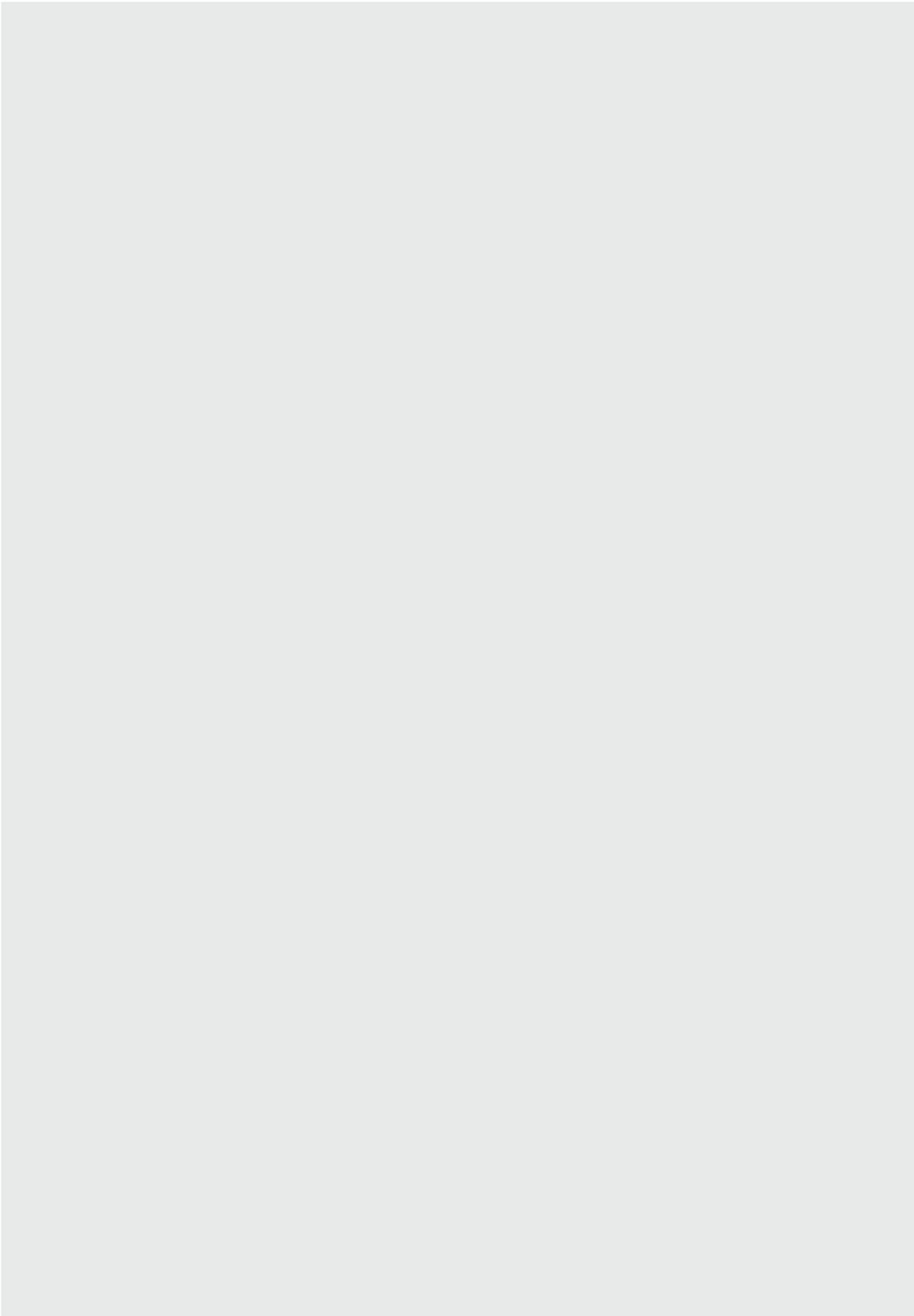
Full height wall to wall separation being rectified with WWM corner splint and additional straps.



Nails being replaced by 'J' hooks to anchor tin sheets to purlins.

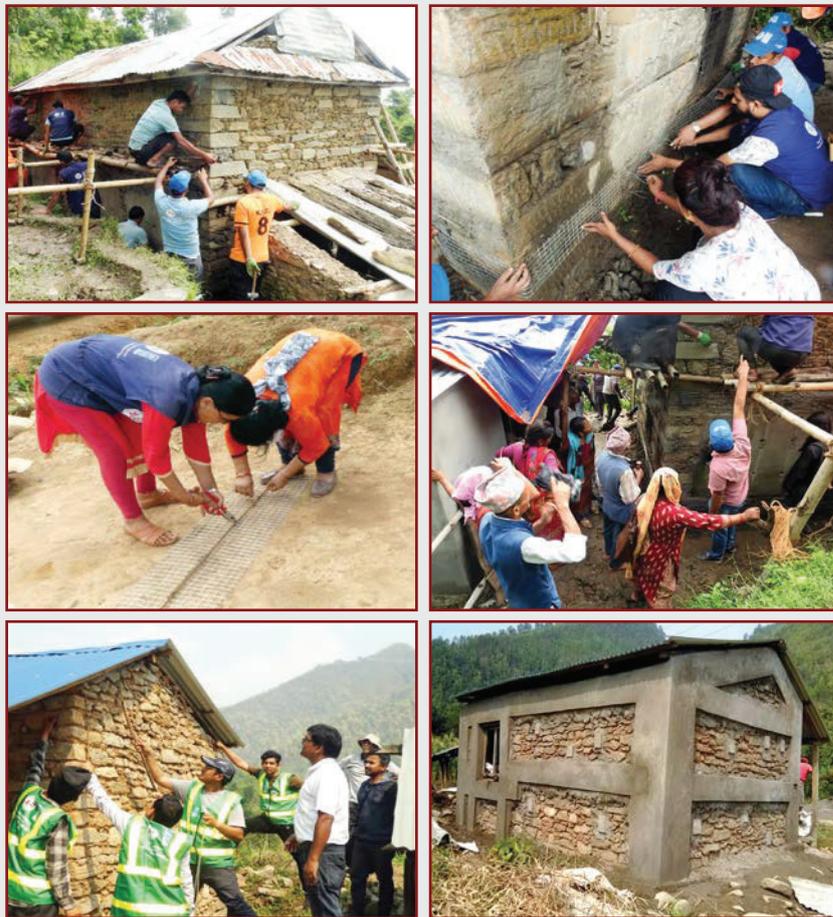


Spalled concrete removed, rusted bars cleaned and coated with anti-rust chemical, bonding agent applied and finished with micro-concrete.



# PART 2

## Retrofitting Field Guide for 2½ Storey Masonry House in Mud Mortar



## PART 2 : RETROFITTING

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## 1. Introduction

**This part of the guidebook focuses on seismic retrofitting of house. Seismic Retrofitting means Increasing the capacity of a building to resist future earthquakes.**

Most existing houses in Nepal do not have seismic resistant features like continuous horizontal bands, corner reinforcement, in-plane roof bracings etc. In addition, a number of fundamental rules of masonry construction are violated which invite weaknesses. A few things to remember...

- If the earthquake hazard was not considered while building your house, then when an earthquake strikes you may not be safe.
- To ensure safety, there is no need to demolish the existing building and reconstruct it, because it will incur huge expense and hardship.
- Instead retrofit it using scientific knowledge, as it is the most economical and fastest way to make a building safer.
- This is equally true for the house that was undamaged or damaged in the past earthquake, and it is advisable to retrofit your house.

Retrofitting requires engineering support and supervision. However, this part explains technical aspects for the benefit of engineers as well as trained masons so that with some basic structural understanding a simple Nepali traditional house up to two storey plus attic using stone or brick masonry can be retrofitted.

## 2. Layout of this section

This part is laid out in a sequence that one would follow if he or she were to undertake retrofitting and install measure in a sequence.

Starting with (a) Understanding vulnerability of a building; (b) Understanding concept of retrofitting; (c) Procedure for marking out each retrofitting measure; (d) Procedure for installation of cross-links; (e) Procedure for installation of belts, splints, opening encasement, vertical CR wires and finally, the horizontal CR wires.

### 3. Understanding Weaknesses in Stone and Brick Masonry in Mud Mortar

- a. **Bulging or separation of wall faces in thick walls.- This weakness is the cause of most of the damage to stone masonry in mud mortar**



Faces of Stone and brick walls separate when Headers are not provided or are not enough



Bulging of outer face of thick stone wall



Separation of a face followed by delamination of part of a stone wall



Delamination of a thick brick wall

**b. Collapse of Gable**



As the gable walls are independently standing at the top of the house their collapse is very common.

**c. Collapse of Walls Supporting Roof and Floor**



Parts of wall or full wall collapsed because of poor wall to wall connection or the walls were too long or too high

**d. Diagonal Cracks at Door Window Corners**



Large diagonal cracks developed at the door and window because of the absence of a band at lintel level.

**e. Vertical Cracks in Corners**



Vertical cracks developed at corners because of poor wall to wall connection.

**f. Roof damage**



Roof damage because of degraded timber and dislodged slate.

**g. Floor collapse**



Floor collapse because of collapse of wall and poor floor to wall bonding.

## 4. Understanding Seismic Retrofitting Concept

### Taking examples from everyday life



When belts are wrapped around an old and over loaded bag, they prevent the bag from tearing. Belt placed around all the walls prevent them from toppling and reduces cracking.



In cotton mattress stitches hold together the fabric on both sides and prevent cotton from sliding. Through-Stones put through stone wall holds together the faces and prevent stones from falling.



Stones in a stack when tied with a string do not fall when shaken. Stones in a wall in the house when tied with wires do not dislodge during an earthquake.



Before packing heavy books in a carton, tape applied on corner prevents it from tearing. In a house a belt around a corner prevents cracking of corner.

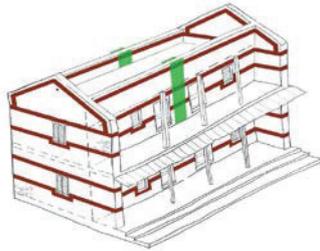
### Seismic Retrofitting

- Eliminates trouble of tearing down the existing house to build new.
- Saves expense of demolition and debris removal
- No need to vacate the house
- Costs of retrofitting is significantly less than the cost of building new house.
- Saves most improvements done in the house such as painting, tiling, decoration, kitchen platform etc.
- It is faster than rebuilding and can be carried out in phases

**Retrofitting is the most economical & fastest way to bring safety against future earthquakes.**

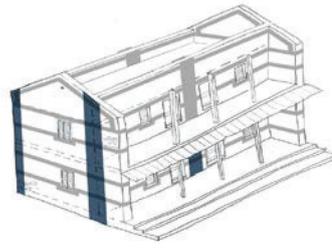
## 5. Retrofitting Measures at a Glance & Specifications

**Note: All Weld Wire Mesh (WMM) has 2mm (14ga) GI wires @ 25mm spacing both ways; All wires are GI wires. 1:3 cement plaster cover on either side of WMM is to be 25mm.**



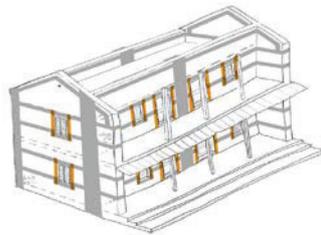
1. Belt at eave, lintel/ floor and sill levels on all walls, inside and outside along with a composite column at mid-length, if length exceeds 5m (16'4")..

**Horizontal Belt:** 250mm (10") wide WMM + 4 - 4mm wire. Finished belt 300mm wide. For length between 5m and 6.5m add 1 - 4mm wire,  
**Composite Column:** 300 mm wide WMM plus 4 - 4mm wires on both faces. Finished width 350mm



2. Corner Splints at 'L' and 'T' wall junctions on outside wall faces using plumb bob for vertical alignment.

**Vertical Splints :** For 450mm wall - L junction: 400mm (16") wide WMM + 2-4 mm wires on each wall; T junction: 400 mm wide WMM + 2 - 4mm wires. For 350mm wall - Both splints: 350mm wide WMM.



3. Opening Encasement Splint around the openings on both faces of the wall ensuring verticality with plumb bob.

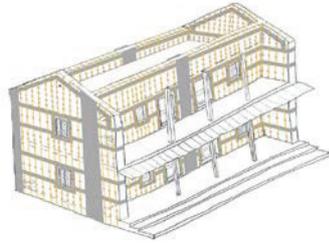
**Opening encasement:** 200 mm (8") wide WMM



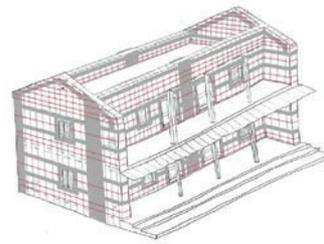
4. GI wire cross-links installed through full thickness of all the walls for anchoring the Vertical Containment Reinforcement wires in the spaces not covered by belts and splints.

**Cross-links:** 2-2mm (14 ga) wires twisted at 400mm (16") spacing horizontally and vertically.

## Retrofitting Measures at a Glance (cont.)

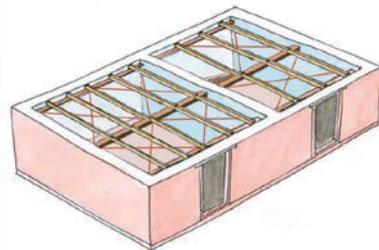


5. Vertical Containment Reinforcement (CR) wires on all the walls on both faces anchored to the walls through cross-links placed between the Corner Splints and Opening Encasement continuous from ground story to the top of attic walls maintaining verticality with plumb bob. **No vertical CR wires are to be placed on splints and opening encasement, and are to continue over the belts.**

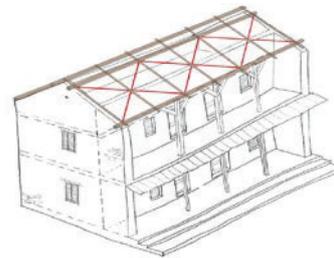


6. Horizontal Containment Reinforcement (CR) wires on all the walls on both the faces anchored to the Vertical CR wires in the vicinity of the cross-links in the clear space between the belts with horizontality maintained with the help of tube-level. **No Horizontal CR wires are to be placed on the belts. Wires to continue over the splints and opening encasement.**

**Containment reinforcement (CR) - Vertical and Horizontal wires to be 4mm (8 ga) or 3.25mm (10 ga) at spacing of 400mm (16") maximum**



7. GI Wire Diagonal Ties just under the floors anchored to walls or wood floor beams depending upon configuration.

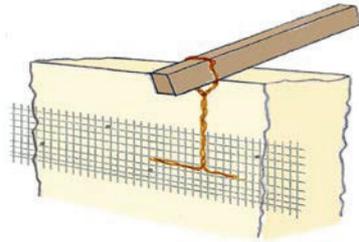


8. GI Wire Diagonal Ties on the underside of roof understructure

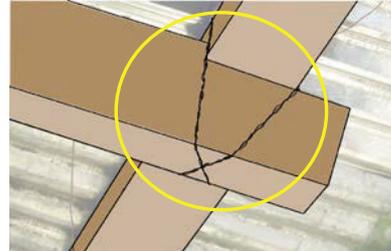
**Floor Diagonal Ties: 4-2mm wires twisted and anchored to wall through the belts**

**Roof Diagonal Ties: 4-2mm wires twisted and anchored at junction of rafters and purlins or beams.**

## Retrofitting Measures at a Glance (cont.)



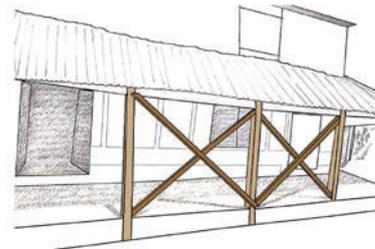
9. Roof understructure tied down with 2- 14 ga GI wires to wall-plate or wires taken out from belts



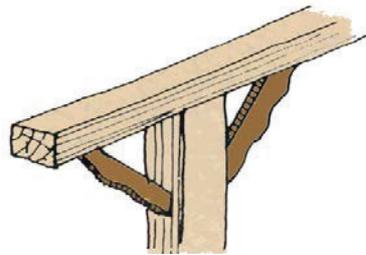
10. Timber connections strengthened with 14 ga GI wire wrapping.



12. Timber diagonal braces between timber posts in "K" configuration. They are placed where they don't obstruct movement.



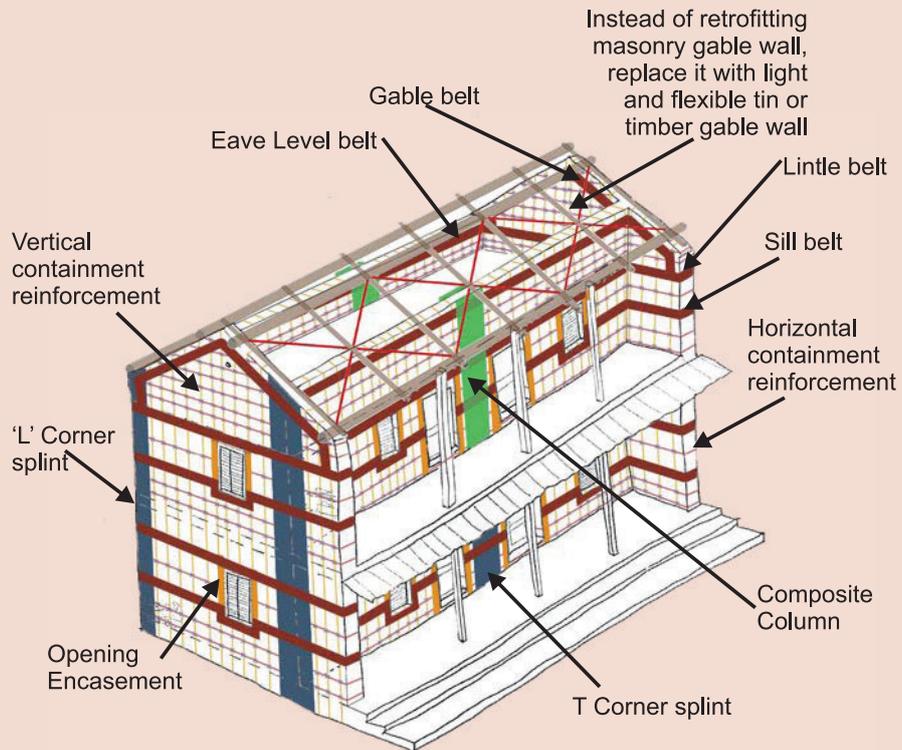
13. Timber diagonal braces between timber posts in "X" configuration. They are placed where they don't obstruct movement.



14. Timber Knee braces. They are not as effective as diagonal braces. But they permit unhindered movement of people.

**Braces are required to resist lateral earthquake forces on top of timber posts. Braces help prevent tilting of the posts and the damage that may occur in roof due to that. Diagonal braces are most effective. But they obstruct movement of people.**

## Retrofitting Measures at a Glance (cont.)



## All Principal Retrofitting Measures at a Glance

## 6. Sequence of Installation of Retrofitting Measures on Walls

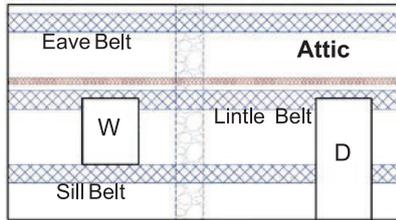
- All horizontal belts-lintle, floor, roof and sill are installed on both faces of wall simultaneously and are fixed to wall with cross links tightly inserted through holes of diameters no greater than 15mm without any grout. Composite Column if wall is longer than 5m. Special Cross-links through the lintle belt and walls for anchoring diagonal bracings under the timber floor. Anchor roof rafters to Attic wall top belt.
- All 'L' and 'T' corner splints are fixed to one face of the wall with "L" shaped shear connectors.
- All opening encasement on both faces of wall, anchored to walls with cross-links. Skip encasement if opening has double frame.
- All vertical wires anchored with cross-links on both wall faces at required vertical spacing simultaneously. While going over the belt alignment they are anchored to the belt WWM with 1mm GI binding wires. In case of masonry gable walls connect the roof to gable wall with the help of the vertical wires going over gable wall.
- All horizontal wires are installed between the belts and any other open spaces, but not on the belts. These wires are securely connected to already fixed vertical wires with 1mm GI binding wires in close vicinity of the cross-links that anchor the vertical wires. No cross-link anchors are needed exclusively for the horizontal wires.
- Cement plaster must be applied on WWM belts and Splints. For vertical and horizontal wires the house owner can choose between plastering the whole wall or covering wires with 2" (50mm) wide strips of cement plaster or stabilized mud plaster or leaving them open.

### Sequence of other Retrofitting Measures

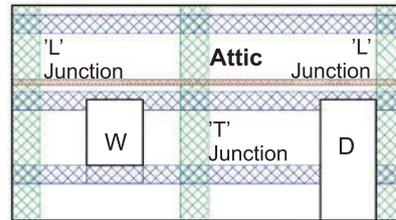
- Diagonal bracings just under the intermediate timber floor, anchored to wall at one end and to the main beam at opposite end.
- Diagonal bracings in roof.
- Strengthening of all timber to timber connections in roof.

**Note: All retrofitting elements are independently anchored to wall with the exception of the horizontal wires. But where these elements cross each other they are interconnected with binding wires at several points. The items are best installed in the sequence listed above and can be incrementally installed as and when the finance and time is available.**

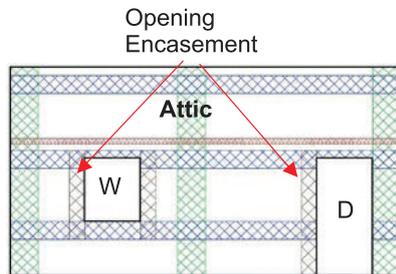
### Installation Sequence of Retrofitting Measures



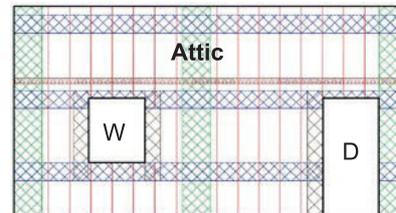
1. Install all the belts including at sill/mid-height, lintle and eave levels, plus composite column, if required.



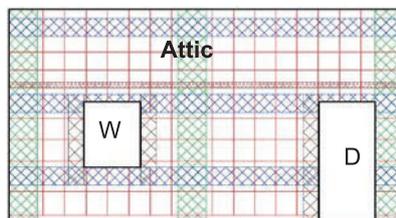
2. Install splints at all 'L' and 'T' wall junctions.



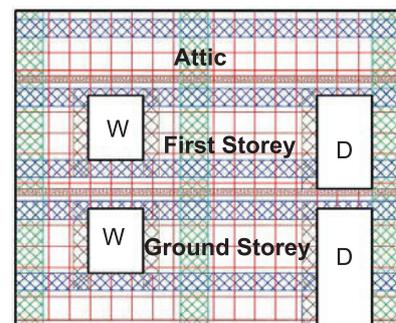
3. Install all opening encasements



4. With all horizontal and vertical measures using WWM and additional wires in place, install vertical CR wires on portions of wall between them.



5. With vertical wires already installed, next install horizontal CR wires in ground storey and attic walls.



6. With vertical wires already installed, next install horizontal wires in ground storey, first storey and attic walls.

## 7. Incremental Retrofitting or Phased Retrofitting

If funds required to install all the retrofitting measures are not available then it can be done in several phases as described here.

### Phase 1:

(a) Install all **belts** (always along with the composite-columns where required) including sill/mid height, lintel/floor, attic wall, eave - in all stories, on both faces of wall simultaneously and anchor to wall with cross-links where required; (b) Install **special cross-links** for under-floor diagonal bracings; (c) Anchor roof rafters and beams to belts in the walls.

If funds are available then (d) install bracings under intermediate floors and roof diagonal bracings, (e) strengthen timber to timber joints in the roof understructure, and (f) knee braces at beam to column joints or diagonal timber bracings. These items can be carried out in any of the phases.

If adequate funds are available then the splints at “T” and “L” wall junctions may be installed at the same time, and finally finish the belts and splints with cement plaster.

### Phase 2:

Install in all stories all the ‘L’ and ‘T’ corner splints fixed to one face of the wall with “L” shaped shear connectors. Install shear connectors at least one day ahead of the installation of splints.

Since this is done while the belts are already on the walls, remove cement plaster from the belts where the splints will overlap the belts, connect them with 1mm galvanized binding wires and then finish with cement plaster.

### Phase 3:

Install all opening encasement in each storey, on both faces of wall and anchor them to walls using cross-links. Skip encasement if opening has double frame. Since this is done while the belts are already on the walls, remove cement plaster from the belts exactly where the encasement overlap them, connect the encasement to the belts using 1mm galvanized binding wires at several points.

## Incremental Retrofitting (cont.)

### Phase 4:

Install uninterrupted vertical containment reinforcement (CR) wires in clear spaces between the splints and the opening encasements on both faces of the walls anchored to walls with cross-links from ground storey to over the top of attic wall simultaneously. Make sure that vertical CR wires are not placed on the splints and encasements. While going over the belts connect the wires to the belt with binding wires at several locations and do not install any additional cross-links for CR wires within the belt alignment. Vertical wires are not to be installed on the Splints.

Since vertical CR wires are being installed when the finished belts are already in place, remove thin strips of plaster from the belts at the overlap and connect the wires with the belts using 1mm galvanized binding wires, and finish it with cement plaster.

### Phase 5:

Install horizontal CR wires in clear spaces not covered by the belts, but not on the belts, on both faces of walls in all stories simultaneously and securely tie to vertical CR wires or the cross-links used for anchoring vertical CR wires maintaining level alignment. No additional cross-links are required.

Since horizontal CR wires are being installed when the finished splints and opening encasements are already in place, remove thin strip of plaster from them at the overlap and tie the CR wires with them with 1mm galvanized binding wires with cement plaster.

**Note: In each phase each retrofitting measure must be installed in all the stories. Every measure with the exception of the horizontal CR wires is anchored independently to the walls. Where a specific measure crosses the other measure they are connected using 1mm galvanized binding wire. Finish the belts, splints and encasement with cement plaster. The CR wires may be encased in 50mm wide strips of cement plaster or cement stabilized mud plaster, or may be left open.**

## 8. Marking Retrofitting Measures on Walls

First of all go around the whole building inside and outside, and understand the building as you document it with following information. 1. number of stories, 2. ceiling levels all around at ground level and intermediate floor, 3. storey heights, 4. materials of walls including mortar, and floor 5. extensions, 6. openings and their top and bottom levels, 7. double or single frame in openings, 8. placing of stones in wall, 9. ground levels adjacent to building any unusual features etc.

Decide the retrofitting scheme for the entire building consisting of belts, splints including opening encasement, vertical and horizontal CR wires, diagonal bracings in timber floor and roof, knee braces etc.

### a. Marking Belt/Bandage



**1. Mark the top line of Lintel belt** just under the floor joists on an inside wall, while ensuring that it clears the bottom of most of the floor joists. Disregard the bottom of the beam that supports the floor joists which is significantly lower.



**2. Consider this level as the datum.** Use the tube level to get the correct level and **mark the top line** of the belt on all four walls with cotton string. The belt alignment can be above or below this datum depending upon the obstructions like beam, window etc.



**3. With top edge of belt marked, next mark the bottom line of the belt** on all four walls to get the desired width 300mm of the belt



**4. With the tube level follow the same level and mark the top and bottom line of the belt on the outside faces of walls.**

## Marking Belt/Bandage (cont.)



5. Mark Sill belt under the window if sill is 600mm (2') or higher. Otherwise at approximately 900mm (3') from the bottom of Lintel Belt or close to mid height mark the belt. If window is close to the floor, discontinue the belt or continue a smaller width belt under the window.

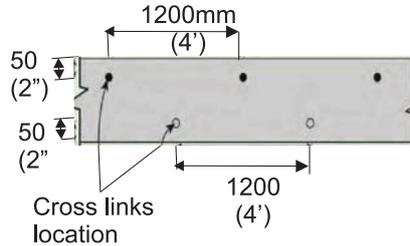


6. Mark the top and bottom line for this belt measuring from the top edge of the Lintel belt. Do not measure from any other point. Use tube level to ensure the right level of the belt along its full alignment.



7. Using the tube level mark the top and bottom line of the belt on the outside walls, ensuring same level as on inside walls.

8. Mark roof/lintel and mid height/sill level belts on all walls on both faces in all stories including the attic wall. Make sure they are properly aligned and leveled with tube level.



9. Mark the cross link locations for anchoring the WWM belt to the wall as shown above. Do not mix up these holes with those for Vertical wires.

## Marking Belt/Bandage (cont.)

### Attic wall

For wall not more than 1,200mm (4'0") high provide belt only near the top, and for higher wall provide also mid-height belt.



10. Mark the top line of Eave belt with string 150mm (6") below top of the wall. Follow the same on all four walls inside and out side using tube level.



11. Measure the width of the Eave belt from top line of the belt and mark bottom line of the belt with the help of the tube level.



12. Finish marking attic wall Eave belt on out side wall also using tube level ensuring the same alignment.



13. Mark Gable belt 150mm (6") below the top edge of the gable wall. while ensuring the proper connection with attic wall Eave belt.



14. Mark Gable belt from outside following the same level as inside



15. For accuracy use tube level to match inside and outside levels

### b. Marking Splint - For Wall to Wall Junctions & Opening Encasement

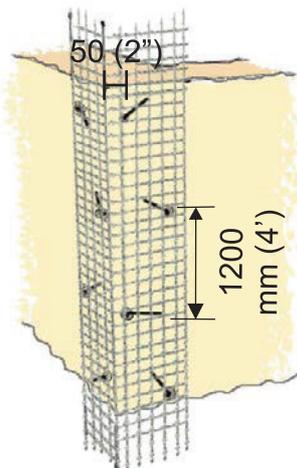


1. Start marking the vertical splints at 'L' and 'T' wall to wall junctions. This is installed only on outer face of walls. Use plumb bob for marking vertical lines. Once lines are marked, mark the location of shear anchors as per the specification.



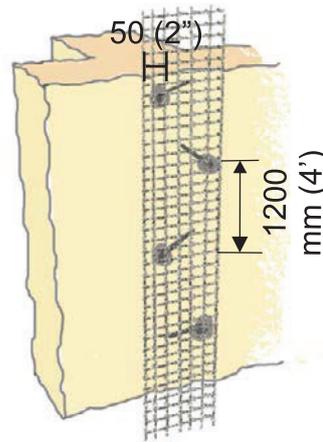
2. Simultaneously start marking the opening encasement on the sides of openings. Use plumb bob and mark vertical lines. Follow the same lines on both faces of the wall. Once lines are marked, mark the location of cross links as per the specification.

**Encasement is not required for openings 750mm x 750mm (2'6" x 2'6") or smaller**



**'L' Corner Junction**

3. When the wall height is not more than 2.1m (7') a total of 6 Shear anchors, 3 on each leg are installed. Use 150mm (6") nails as required to fix the WWM to the wall.



**'T' Junction & Encasement**

4. For 'T' junction Splint install 3 shear anchors. For opening encasement install 3 Cross-links. In addition use 150mm (6") long nails to fix the WWM to the wall.

### c. Marking Vertical CR Wire Alignment

Once the installation of WWM for belts and splints are completed on all walls, make the marking for vertical CR wires on the space between splints and opening encasement. Remember that the cross-link locations for CR vertical wires are independent from all the others cross-link locations marked earlier.



1. Vertical wires are to be marked in the space between a splint and an opening encasement or next splint. Start with the ground story. Moving from one end of wall mark the first and last lines on a wall 100mm (4") from the splints or opening encasement. Measure the gap between these lines and divide it in vertical spaces no wider than 400mm to mark the wire locations. Use string and plumb-bob for marking.

2. Follow the same process and mark vertical lines on all walls between the splints for vertical CR wires on both faces of all walls. **Remember vertical CR wires are not to be located on any WWM splint or encasement.** They can go over horizontal belts.

**Note: For small openings where Splint is not required, start marking for Vertical Wires at 150mm (6") from the opening jamb.**



Marking of vertical CR wires on walls

### Marking Vertical CR Wire Alignment (cont.)

#### Vertical wires alignment in upper stories



3. Mark the exact location of the vertical wires on the underside of ceiling. Drill hole through the floor.



4. Using plumb-bob and cotton string mark the alignment of wires in the upper story. Continue up to attic in the same manner.

#### d. Marking Horizontal CR Wire Alignment



1. Take the level 75mm (3") above the finished ground floor as the datum and mark horizontal line on the out side face of the wall. It indicates the location of the bottom most wire.



2. Divide space between belts, and also between the mid-height/sill belt and floor line in parts not wider than 400mm (16").



- Mark horizontal lines with the help of string and tube level.
- Remember horizontal CR wires are not to be located on WWM belts. But they will go over and across the splints.

**Mark the horizontal lines on inside walls following the same process as outside face using tube level**

## 9. Preparing Wall Surface for Installing Retrofitting Measure

### a. Remove plaster and expose the masonry for all the measures.

If the cement plaster is strong and in good condition it is not necessary to remove it.

- Chip it with hammer every 50mm to 75mm (2" to 3") to create rough surface for good bond between old and new plaster. No need to chip deep to expose the brick/stone.
- Use hard wire brush to remove the existing paint. Wash the surface with water to remove all the dust.
- Apply cement slurry just before applying the new plaster for better bond.



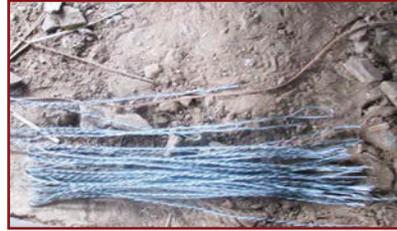
Use electric grinder or chisel and cut the plaster precisely within the area marked for the measure to prevent excessive plaster removal.

### b. Rake all the mortar joints



Rake all the mortar joints to the depth of 12mm (1/2") by hand using chisel. Clean the surface with wire brush and water.

## 10. Making GI Wire Cross-links



Make cross-links by twisting together two 2mm GI wires 150mm (6") longer than the wall thickness. Leave 65 to 75mm (2.5" to 3") long unequal ends straight and untwisted at both ends.

## 11. Install cross-links through the wall at marked points

If stones are encountered at the marked location holes can be made up or down from the marked location following vertical alignments



1. Remove plaster to locate joint in masonry. Make around 15 mm holes in joints with help of a short pointed end 'L' shaped 12mm steel rod through the wall at all locations for cross links.

2. Alternatively, use electric drill to make holes through the mortar joints from one side to the other. Do not make very large holes through the stones by breaking them.



3. The holes shall be just large enough for inserting the cross links through full thickness of the wall.

4. Once the hole is made and cleared of loose materials, insert cross-link across the wall thickness.

### Install cross-links through the wall at marked points (cont.)



5. Insert cross-links in the holes at pre-determined location on walls.



6. Make sure open ends of cross-links protrude out from the wall on both faces.



7. Insert small stones or stone chips below and above the cross links using little mud mortar for closing the hole.



8. Chips must be hammered in strongly to ensure that they lock the stones around them.



9. When pulled, cross-links should not come out without prying out the wedged chips.



10. Follow same procedure for all cross-links in walls

Take extra care in case of cross-links near the edge of the wall or close to opening jambs. Keep minimum spacing of 150mm (6") from jamb.

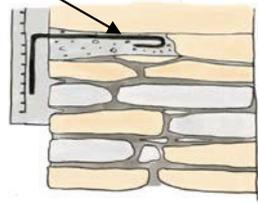
**It will be best to install retrofitting measure immediately after the installation of cross-links that they are meant for. Only after that install the next set of cross-links for another retrofitting measure.**

## 12. Install Shear Connector for Splints

Where it is not possible to make a “through” hole for cross-link, shear connectors could be used to anchor belts as well as splint, but the cross-link in a through hole is preferred.

1. Make shear connector 225mm (9”) long out of ‘L’ shaped 8mm diameter rod having hook at one end and 150mm (6”) long leg at the other end.

Shear connector



2. Make small hole approx. 100mm X100mm (4”x4”) and 250mm (10”) deep by removing stone at desired location. Clean the hole with wire brush and water.



3. Fill bottom half of hole with concrete (1:1.5:3) and place ‘L’ shaped rod over it with the hook end inside the wall.



4. Next fill the entire hole to encase the rod with concrete while continuously compacting it with a rod



5. Finish surface to match with surrounding wall masonry.

**If the hole is too large then make it smaller with small stones in concrete to reduce quantity of concrete required.**

### 13. Installing Seismic Belt (Bandage) on both faces of wall

Seismic belts made from welded wire mesh (WWM) plus additional wires as per specifications are installed at sill, lintel and floor/roof level anchored on both faces of the wall with cross links and nails .



1. Cut WWM of required width and 400mm longer than the required length, while ensuring minimum waste.



2. Insert cross-links in holes. **Be careful of cross-links protruding out and protect eyes from injury.**



3. Install the prepared WWM on the raked and clean wall surface where the cross links are pushed in and anchor it with nails first.



4. Hammer in 100-150mm (4"- 6") long masonry nails in mortar joints in zig-zag manner at 300mm spacing to anchor the belt securely to the wall.



5. Provide 15mm (0.5") thick spacers of any suitable material between the wall surface and the mesh to ensure full encasement in plaster.



6. Pull out the cross-link ends in such a way that they catch at least two wires of WWM and twist them three times max to tightly anchor the mesh.

### Installing Seismic Belts (cont.)



7. Install 4mm wires having 150mm (6") long hook at their ends using 1mm GI binding wires on the WWM belt as required per specifications

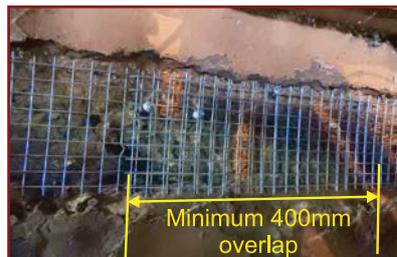


8. When belt length is greater than 5m then install Composite Column as per specifications at the mid-length of belt.

9. Where the belt alignment encounters obstruction, bend the belt to go above or below it. At the change in belt alignment, install a shear reinforcement consisting of zig-zag shaped 4mm GI wire with spacing no greater than 50mm in zig-zag portion.



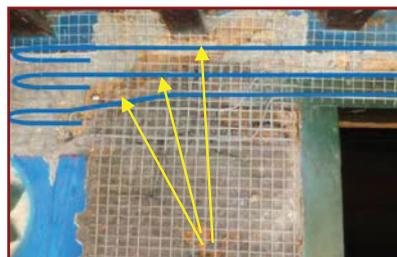
10. Shear Reinforcement installed at a change in alignment of Eave belt.



11. For WWM Belt to Belt connection keep overlap as shown and tie it with binding wires at 6 places. Keep overlap around 1500mm from corner.



12. At the opening jamb install 3-4mm wires connecting belt on both faces of wall with 300mm overlap on faces.



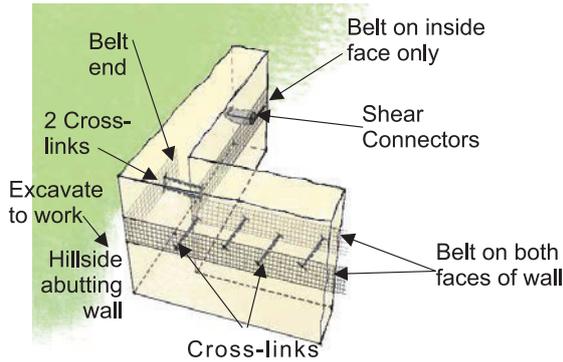
13. If belt width is reduced abruptly then provide additional wires to compensate for reduction in the mesh. See the detailed sketch on the next page.

## Installing Seismic Belts (cont)

### Belt Installation in Special Situations

#### a. One wall against hillside

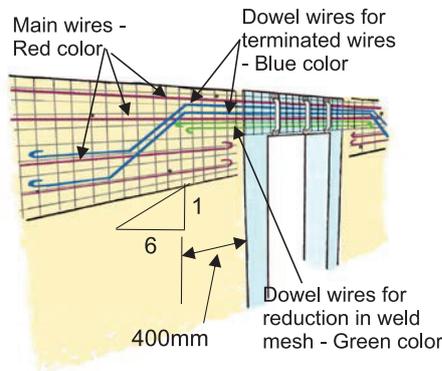
This is a situation where outer face belt cannot be installed. In other words the belt will be only on the inner face of wall.



The belt on the inner face of left wall will continue on to the adjacent wall. But the belt on the outer face of left wall will continue two times wall thickness around the corner. Near its end the belt must be anchored with two cross-links instead of one.

#### b. Belt at Door Opening and Sudden Reduction in Belt Width

When the lintel height and storey height are nearly the same, the belt width get abruptly reduced due the obstruction like a door or a window.



- Install additional wires to compensate for loss of WWM.
- Straighten the wires and anchor to door frame with clips made 25x3 of MS flat.
- Tie the wires with WWM with 1mm GI binding wire.
- All hooks in wires must be minimum 150mm (6") long.

### Installing Seismic Belts (cont.)



15. Splash the exposed wall surface with water to remove all the dust as also to make it moist.



16. While still wet, apply neat cement slurry followed by first coat of cement: coarse sand (1:3) plaster of 12mm (0.5") thickness.



17. After 1 to 2 hours, apply second coat of plaster with same mix and with enough thickness to provide 20mm cover over the GI wires.



18. Finish belts and splints as desired. All vertical and horizontal wires may be covered with 2" (50mm) wide strip of cement plaster or can be left exposed.

### 14. Reduce vulnerability of gable wall



18. Install gable belt with its top edge approximately 100-150 mm below the top edge of gable wall.



19. Alternatively replace masonry gable with GI sheet or timber on timber frame.

**For additional safety of gable wall refer to CR wire section.**

## 15. Installation of Splints at Wall to Wall Junction

Splint is made with WWM and additional wires as per specifications and is installed in 'L' shape on the outside 'L' corner junction, and in flat shape on the outside of the of 'T' junction.



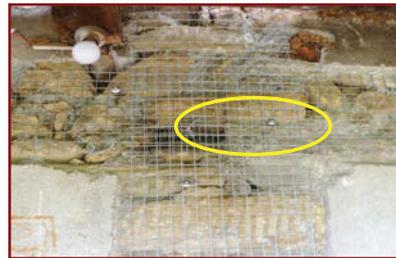
1. Make WWM straps 800mm wide for L and 400mm wide for T junction for full wall height with 450mm extra for starting below plinth level.



2. Install shear connectors a day before the splint installation. Continue to cure until splint is plastered. Exercise care not to exert too much force on shear connector while splint installation.



3. Rake all the mortar joints and Install WWM splint starting from 450 mm below plinth level and continue through to the top of the wall at roof level.



4. Use 100-150mm long nails with washers driven in open joints at 300mm spacing to anchor WWM to wall



5. Using binding wires at minimum of two places secure vertical splints to shear connectors anchored in the wall.



6. Where splint overlaps with belt they are tied together with binding wires at 5 points.

### Installation of Splints at Wall to Wall Junction (cont.)



7. Place 10mm dia steel bar cage with weld mesh end projecting out 150mm at the bottom. All hooks of the cage must be bent away from the wall.



8. Anchor the cage to the wall with 6mm U shaped anchors 150mm long hammered in to the masonry joints to hold down the reinforcement tightly.



9. Install form work not exceeding 150mm in width from the steel cage to prevent wastage of concrete.



10. Pour 1:1.5:3 concrete continuously rodding to prevent cavities in concrete. Cure concrete for 15 days.



11. To ensure continuity of WWM with upper storey, at the top end under the ceiling, install 4-4mm wires on each leg with 600mm overlap plus 150mm long hook, and extend up to storey above



12. Cover splints with 1:3 cement - coarse sand plaster in two coats exactly as is done in the belt and cure for 15 days.

## 16. Installation of Opening Encasement

If opening has double frame or is smaller than 750mm X 750mm then encasement is not required.

The installation process for opening encasement is same as that for belts. Encasement is done on both faces of walls. With lintel and mid-height/sill belts in place the encasement is required on the sides of opening with proper overlap with lintel and sill belts.



1. Make sure that the surface is raked and clean with cross-links in place to anchor the encasement.



2. Install the prepared mesh in right location with right overlap with Lintel & Mid-Height Belts.



3. Plaster encasement using cement mortar in two coats as described earlier.

**Note: In case the horizontal spacing between two openings is less than approximately 500mm, vertical portions of the encasement for both openings should merge in to each other.**

### Belts and Splints at a glance



Horizontal and Vertical CR wires are to be installed in the spaces left uncovered by the belts and splints.

## 17. Vertical Containment Reinforcement Wires

Install Vertical Containment Wires on both faces of wall simultaneously.



1. Install cross links at the junction of vertical and horizontal wires starting from 75mm above the floor



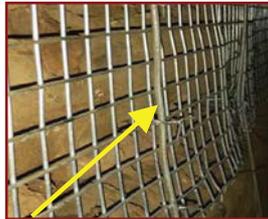
2. Starting from each bottom most cross-link attach 1-4mm GI wire on both faces of the wall.



3. Stretch wires vertically and anchor on both wall faces at same time to each cross-link in row.



4. Use pliers and twist the free ends of cross-link 3 times keeping vertical wires between the ends.



5. When vertical wire crosses a belt it must be tied to it with binding wires at minimum 3 places.



6. Continue vertical wire through a hole in the floor to go over the eave level wall keeping it taut all the time.



7. Pull up wires along both the faces of wall and over the wall plate or portion of the timber floor of the hybrid structure (in which the upper storey is made of tin and timber, and is placed on top of the masonry structure), and anchor it to the wall plate with heavy nails.



8. Pull wires from inside and out side faces over top of attic wall and anchor to cross-link on the opposite face below the belt.

**At the top of attic wall install one extra wire between two vertical CR wires from belt on one face to that on opposite face.**

## 18. Horizontal Containment Reinforcement Wires



1. Install horizontal wires on both faces of walls in the portions not covered by the belts. Stretch each horizontal wire around the walls and corners.



2. Anchor the cross-link with a 10mm diameter 300mm long bar installed against the outer face of the wall.



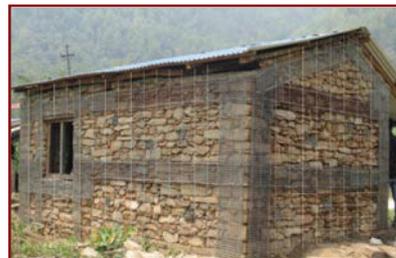
3. Each horizontal wire is anchored to all vertical wires it crosses using 1mm GI binding wire. Keep the wire as level as possible.



4. When a wire goes over and across the Splints it should be tied to Splint at minimum 3 points with 1mm GI binding wires.



5. When a wire is interrupted by a wall opening, wrap it around the jamb to continue on to the other face of wall.



6. Vertical and horizontal CR wires in the open spaces between belts and splints.

**Bottom most horizontal CR wire is important and should not be missed. Vertical CR wires shall go over the belts but not the splints. Horizontal CR wires shall go over the splints but not the belts. Wires going over the WWM must be tied to WWM. Hence, no additional cross links are inserted for wires at the belts.**

## 19. Installing In-plane Diagonal Ties/Bracings Under Floor

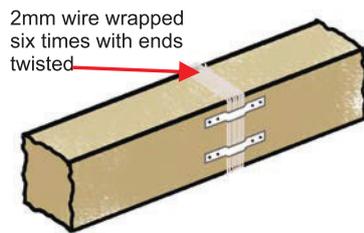
Install In-plane diagonal ties as close as possible to the underside of the floor joists and anchor to walls with special cross-links installed in belt (preferred) or in masonry.



1. Install special cross-link made of 2-2mm wires folded at mid-length to make a loop at one end in four corners of each room through masonry walls .



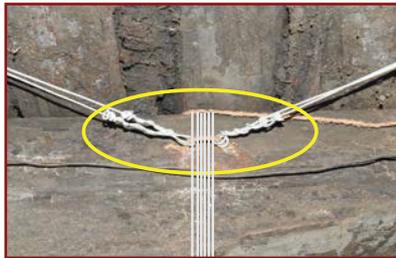
2. Anchor the cross-link with a 10mm diameter 300mm long bar installed against the outer face of the wall.



3. In case of the timber beam in middle of room wrap 2mm wire many time around the beam to tie end of bracings.



4. Install in-plane diagonal tie in 'X' configuration made of 4-2mm GI wires in each tie pulling wires tightly .



5. Ensure continuity of diagonal ties by starting next tie at the point where previous tie ends.



6. Pre-tension each Tie by pulling at the time of installation followed by twisting. Excessive twisting can break the wires.

**Attach the diagonal tie to the underside of the floor joists with 'U' Nails to avoid sagging of the bracing wires**

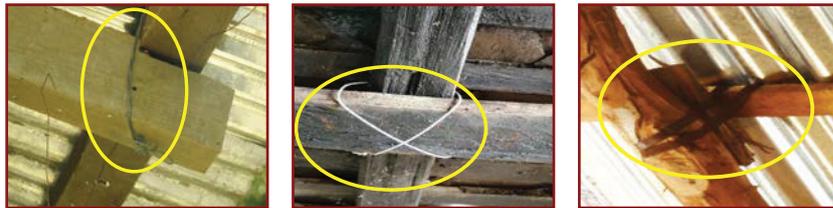
## 20. Installing In-plane Diagonal Ties Under Roof



1. Install GI wire diagonal ties on underside of the roof with tie ends connected to roof timber.
2. Use carpenter's hammer to pull the wire taut while installing the wire. After installing all 4-2mm GI wires twist them together to pretension.

## 21. Strengthen Timber Connections

Strengthen timber to timber connections using 2-2mm GI wire or metal packaging straps, especially in vicinity of diagonal bracing connection.



## 22. Anchor Roof to Wall Joint

Anchor rafters, purlins and beams to the top WWM Bandage on walls they are resting on using 2-2mm GI wire.



## 23. Stiffen Wood Column to Beam Joint

Install knee brace made of MS angle or timber at each beam to column joint.

The post under the central beam of the timber floor is heavily loaded and hence, requires strong knee braces with connections that can withstand the shear and compression that they will be subjected to.

### Steel Knee Braces

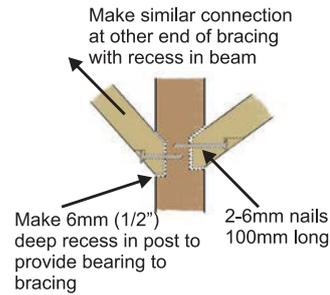
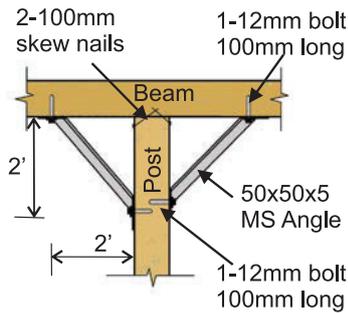


Make the end connections of bracing strong as shown in sketch below. Pre-drill pilot hole to prevent splitting of wood.

### Wooden Braces



Make the end connection of bracing strong as shown in sketch below. Pre-drill pilot hole to prevent splitting of wood. Adopt same design at other end.



In verandah with light loads, simple wooden knee braces are adequate.

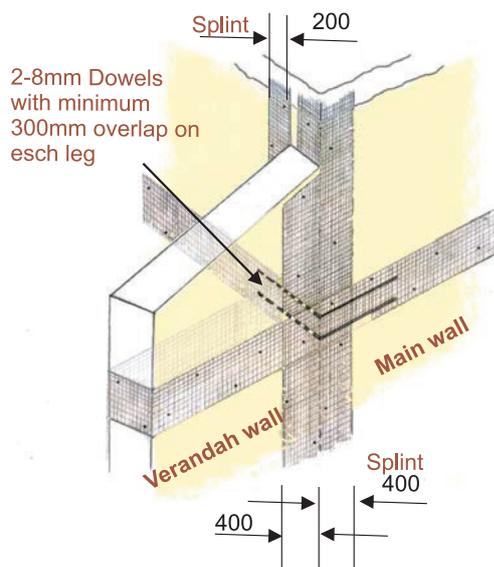
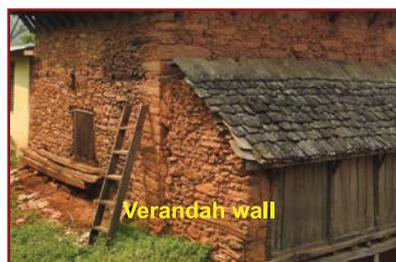


Alternatively, diagonal wooden bracings between column can be installed if space permits.

## 24. Tackling Special Situations

### A. Reducing vulnerability of extension wall

Most houses have verandah in the front and on one or both sides. At the rear end of the side verandah a masonry wall is built, generally of same materials as the main walls of the house, and having no integral connection with the main walls. In other words this wall is not built at the same time as the main walls of the house. It is a free standing wall. Hence, it is vulnerable, especially to the out of plane seismic forces.



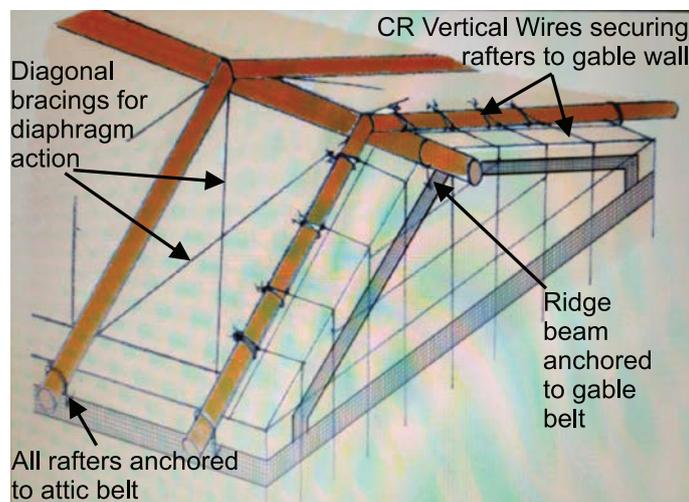
In order to secure the extension wall to main wall...

- Continue the belts from main wall around the verandah wall and then on to the main wall.
- Install 2-8mm L shaped dowels to ensure continuity of belt.
- Install 800mm wide splint at the junction of two walls.
- Install additional 200mm wide splint as shown.

### Tackling Special Situations(cont.)

#### B. Reducing Vulnerability of Free Standing Gable Wall:

- Installing diagonal bracings in roof
- Anchoring roof to walls at eave level
- Strengthening timber to timber connections in roof
- CR Vertical Wires on gable wall extended to tie roof frame together with gable walls
- Installing gable belt integrally connected to eave belt



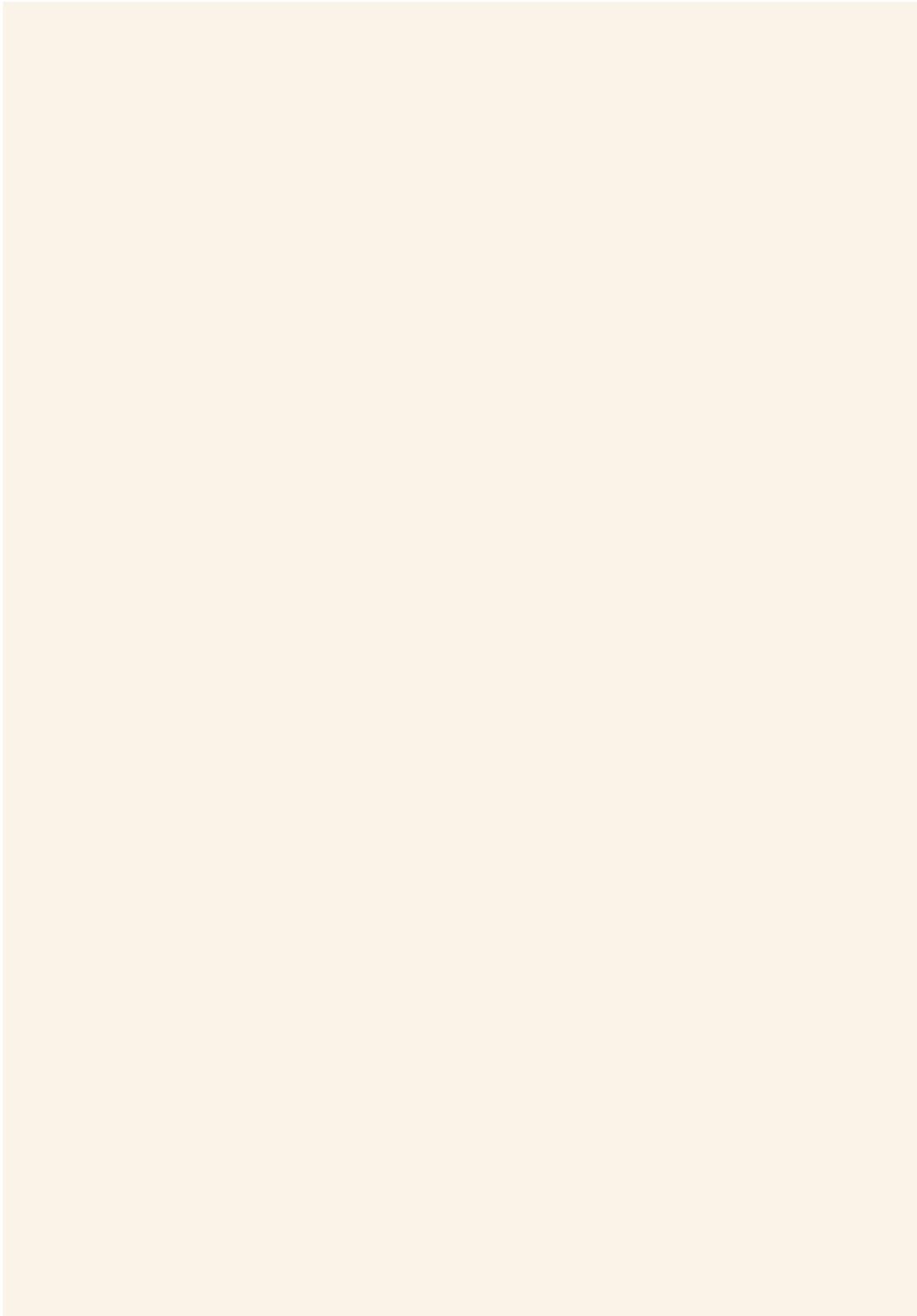
CR vertical wires going over gable



**Note:**  
Gable vulnerability get substantially reduced by not only installing belts and CR wires, but by strengthening the roof and securing it to gable walls.







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