



NEPAL NATIONAL BUILDING CODE

NBC 202: 2015



GUIDELINES ON: LOAD BEARING MASONRY

Government of Nepal
Ministry of Urban Development
Department of Urban Development and Building Construction

Babar Mahal, Kathmandu, NEPAL

2072

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

Preface

This Nepal Standard was prepared during 1993 as part of a project to prepare a National Building Code for Nepal.

In 1988 the Ministry of Housing and Physical Planning (MHPP), conscious of the growing needs of Nepal's urban and shelter sectors, requested technical assistance from the United Nations Development Programme and their executing agency, United Nations Centre for Human Settlements (UNCHS).

A programme of Policy and Technical Support was set up within the Ministry (UNDP Project NEP/88/054) and a number of activities have been undertaken within this framework.

The 1988 earthquake in Nepal, and the resulting deaths and damage to both housing and schools, again drew attention to the need for changes and improvement in current building construction and design methods.

Until now, Nepal has not had any regulations or documents of its own setting out either requirements or good practice for achieving satisfactory strength in buildings.

In late 1991 the MHPP and UNCHS requested proposals for the development of such regulations and documents from international organisations in response to terms of reference prepared by a panel of experts.

This document has been prepared by the subcontractor's team working within the Department of Building, the team including members of the Department and the MHPP. As part of the proposed management and implementation strategy, it has been prepared so as to conform with the general presentation requirements of the Nepal Bureau of Standards and Metrology.

The subproject has been undertaken under the aegis of an Advisory Panel to the MHPP.

The Advisory Panel consisted of :

Mr. UB Malla, Joint Secretary, MHPP Chairman

Director General, Department of Building

(Mr. LR Upadhyay) Member

Mr. AR Pant, Under Secretary, MHPP Member

Director General, Department of Mines & Geology

(Mr. PL Shrestha) Member

Director General, Nepal Bureau of Standards & Metrology

(Mr. PB Manandhar) Member

Dean, Institute of Engineering, Tribhuvan University

(Dr. SB Mathe) Member

Project Chief, Earthquake Areas Rehabilitation &

Reconstruction Project Member

President, Nepal Engineers Association Member

Law Officer, MHPP (Mr. RB Dange) Member

Representative, Society of Consulting Architectural &
Engineering Firms (SCAEF) Member

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

Representative, Society of Nepalese Architects (SONA) Member
 Deputy Director General, Department of Building,
 (Mr. JP Pradhan) Member-Secretary
 The Subcontractor was BECA WORLEY INTERNATIONAL CONSULTANTS LTD. of New Zealand in conjunction with subconsultants who included :
 Golder Associates Ltd., Canada
 SILT Consultants P. Ltd., Nepal
 TAEC Consult (P.) Ltd., Nepal
 Urban Regional Research, USA
 Principal inputs to this standard came from :
 Mr. AM Tuladhar, DoB, HMGN
 Dr. AS Arya, Professor Emeritus, University of Roorkee
 Mr. YK Parajuli, TAEC
 Mr. JR Pokharel, TAEC
 Mr. JK Bothara, TAEC
 Dr. RD Sharpe, BECA (Team Leader)
 Revisions and Updated to this code came from:
 Mr. Purna P. Kadariya, DG, DUDBC
 Mr. Kishore Thapa, DDG, DUDBC
 Mr. Mani Ratna Tuladhar, Sr. Div. Engineer, DUDBC
 Mr. Jyoti Prasad Pradhan, Ex. DG, DOB
 Mr. Bhubaneswor Lal Shrestha, Ex. DDG, DOB
 Mr. Uttam Shrestha, Architect, Architects' Module Pvt. Ltd.
 Mr. Manohar Lal Rajbhandrai, Sr. Structural Engineer, MR Associates
 Mr. Amrit Man Tuladhar, Civil Engineer, DUDBC

.....
 Ganesh Karmacharya
 Engineer

.....
 Parikshit Kadariya
 SDE

.....
 Mani R. Gelal
 DDG

.....
 Ramesh Pd. Singh
 DG

.....
 Arjun K. Karki
 Secretary

Preface for revised NBC202:2015 will be written

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

Table of Contents

0.	Foreword	1
0.1	Design Aspect	1
0.2	Objective	1
0.3	Intended Users	1
0.4	Alternative Materials and Construction	1
0.5	What are Non-Engineered Buildings	1
0.6	Related References	2
1.	Scope	3
1.1	Applicability	3
1.2	Limitations	3
2.	Interpretation	7
2.1	General	7
2.2	Terminology	7
3.	Materials	8
3.1	Concrete	8
3.2	Brick Masonry	8
4.	Selection and Investigation of the Site	10
4.1	General	10
4.2	Use of Local Knowledge	10
4.3	Site Investigation Requirements	10
4.4	Allowable Bearing Pressure	10
5.	General Construction Aspects	12
5.1	Plan of Building	12
5.2	Footing	13
5.3	Openings in Walls	14

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

5.4	Masonry Bond	14
5.5	Mortars and Concrete	15
5.6	Vertical Joints between Orthogonal Walls	16
6.	Horizontal Reinforcement in Walls	18
6.1	Horizontal Bands or Ring Beams	18
6.2	Section of Bands	20
7.	Dowels at Corners and Junctions	23
8.	Vertical Reinforcement in Walls	25
9.	Floors and Roofs	27
9.1	Pitched Roof:	27
9.2	Trussed Roof:	27
9.3	Lean to Roof:	27
9.4	Timber Flooring/Roofing	29
9.5	RCC Roofs and Floors	34
10.	Reinforcement Details for Hollow Block Masonry	37
10.1	Horizontal Band:	37
10.2	Vertical Reinforcement	37
11.	General consideration for Stone Masonry Buildings	39
11.1	Overall Dimensions	39
11.2	Foundation for Stone Masonry	39
11.3	Openings in Walls	39
11.4	Masonry Bond	40
11.5	Mortars and Concrete	41
11.6	Horizontal Reinforcement in the Walls	41
11.7	Vertical Reinforcement in Walls	42

List of Figures

Figure 1-1: Wall Section and Stone/Brick Wall Footing Details	5
Figure 5-1: Plan of building blocks	12
Figure 5-2: Recommendations Regarding Openings in Bearing Walls	14
Figure 5-3: Strengthening of Masonry around Openings	15
Figure 5-4: Joints between orthogonal walls	16
Figure 5-5: Corner walls to be built first	17
Figure 6-1: Different Bands in Building	19
Figure 7-1: Junction and Corner-Strengthening by Dowel	23
Figure 7-2: Detail of T-Junction and Corner Strengthening by Dowel Reinforcement	24
Figure 8-1: Vertical Reinforcement in Walls	26
Figure 9-1: Details for Fixing Roofs to Gables and Walls	28
Figure 9-2: Details of Fixing Keys on Timber Beams	29
Figure 9-3: Fixing of Joists	30
Figure 9-4: Fixing of Rafters	31
Figure 9-6: Details of Improved Mud Roofing	32
Figure 9-7: Details for Fixing Slates	33
Figure 9-8: Details for Fixing Clay Tiles	33
Figure 9-9: Details for Fixing MCR Tiles	34
Figure 9-10: Details for Fixing CGI Sheets	34
Figure 9-11: RCC Slab Detail	36
Figure 10-1: U-Blocks for Horizontal Bands	37
Figure 10-2: Vertical Reinforcement locations in Cavities	38
Figure 10-3: Vertical Reinforcement in Cavities	38
Figure 11-1: Recommended Openings in Load-Bearing Rubble Masonry	40
Figure 11-2: Random Rubble Masonry with Through-Stones or other bonding elements	41
Figure 11-3: 'Through Stones' or Bond Elements	42
Figure 11-4: Vertical Steel in Random Rubble Masonry	44
Figure 11-5: Vertical Reinforcement in Rubble Stone Masonry	44

0. Foreword

0.1 Design Aspect

Most of the loss of life in past earthquakes in Nepal has occurred due to the collapse of buildings constructed in traditional materials such as brick, stone, wood, mud and adobe and which were not engineered (not designed for structural safety) to be earthquake-resistant. Thus, it is very necessary to introduce earthquake-resistant features in to non-engineered buildings during their construction.

0.2 Objective

The objective of this Guideline is to achieve an appropriate level of earthquake-resistance in non-Engineered load bearing masonry buildings constructed in Nepal.

Following this Guideline does not render masonry buildings able to totally withstand any earthquake without any appreciable damage. However it is intended to limit the damage to a level which does not threaten human lives and which can be repaired quickly. This document includes suitable illustrations to explain the important points, sketches and sufficient data to proportion the critical strength elements correctly. The requirements are based on design calculations of typical structures.

0.3 Intended Users

This document is intended to provide necessary guidelines to owners, builders and masons when a masonry building is to be constructed without engaging professional engineers. However, professional designers could also use this guideline for an effective utilisation of their time.

0.4 Alternative Materials and Construction

The provisions of this Guideline are not intended to prevent the use of alternative materials and methods of construction if such materials and methods are specifically prescribed by competent professional designers or other competent authorities equivalent to, or better than, those specified here.

0.5 What are Non-Engineered Buildings

The term *non-engineered* buildings may be defined as describing those buildings which are informally constructed in the traditional manner without any input from qualified Engineers in their design. However, they may follow a set of recommendations derived from the observed behaviour of such buildings. Unless strengthened (as per this guideline), such buildings are prone to severe damage in earthquakes inducing ground shaking of intensity VIII or more on the Modified Mercalli Scale.

0.6 Related References

"Guidelines for Earthquake-Resistant Non-Engineered Construction", International Association for Earthquake Engineering (IAEE), United Nations Educational, Scientific and Cultural Organization (UNESCO) & International Institute of Seismology and Earthquake Engineering (IISEE), June 2013.

"NBC 109:1994 Masonry: Unreinforced", Department of Urban Planning and Building Construction, Kathmandu Nepal, May, 1994.

"IS1905:1987 Code of Practice for Structural Use of Unreinforced Masonry", Bureau of Indian Standards, New Delhi, India, 1989.

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

1. Scope

1.1 Applicability

This Guideline covers load-bearing masonry buildings meeting the criteria specified in clause 1.2. They do not cover wooden buildings, mud buildings (low-strength buildings), or those constructed in adobe. No attempt should be made to apply these rules to these latter categories of buildings.

The requirements set forth in this Guideline are applicable only for buildings complying with the specified limitations. The Guideline only intends to achieve minimum acceptable structural safety, and it is always preferable to undertake specific calculation based design. Owners and builders are also encouraged to use the services of competent professional designers for better economy and tailor-made detailing. In such cases, the requirements stated here should be construed as advisory.

The provisions of this Guideline should be construed as advisory when undertaking repairs, alterations and additions necessary for conservation, preservation, restoration, rehabilitation, reconstruction or continued use of structures of archaeological significance.

1.2 Limitations

This Guideline is valid (with certain limitations as to span, floor height, etc., as prescribed in Table 1-1) for:

- i) Up to two-storied load-bearing brick plus attic (and other rectangular building units) masonry buildings constructed in cement mortars.
- ii) Up to two-storeyed load-bearing stone masonry buildings plus attic constructed in cement mortar.
- iii) Ordinary buildings (eg. residential, ordinary offices, etc.) with maximum clearlong span not exceeding 4.5 metres and area of individual floor panel not exceeding 13.5 square metres (area of floor panel is the clearshort span times the clearlong span of any room/space).

This code is not valid for important buildings which either houses facilities essential before and after a disaster (eg., hospitals, fire and police stations, communication centres, etc.), or which by its very purpose has to house large numbers of people at one time (eg., cinema halls, schools, convention centres, etc.), or which has special national and international importance (eg., palaces, museums, monuments, temples, etc.), or which houses hazardous facilities (eg., toxic or explosive facilities, etc.).

However, these limitations shall not bar anyone wishing to employ qualified professionals to produce an appropriate design. Structures falling outside these limitations will require the appropriate specific design as required by the territorial authority in which they are to be located.

Table 1-1: Buildings Size limitations

	Floor	Min. Wall Thickness (mm)	Max. Height (m)	Max. short-span of Floor (m)
Two storied construction				
Load-Bearing Brick Masonry in Cement Mortar	Attic	230	3.2	3.5
	First	230	3.2	3.5
	Ground	350	3.2	3.5
Load-Bearing Stone Masonry in Cement Mortar	Attic	350	3.0	3.2
	First	350	3.0	3.2
	Ground	350	3.0	3.2
One storied construction				
Load-Bearing Brick Masonry in Cement Mortar	Ground	230	3.2	3.5
Load-Bearing Stone Masonry in Cement Mortar	Ground	350	3.0	3.2

NOTE: In two storied constructions, the walls in the firststorey shall be exactly above the walls in the groundstorey and the thickness of wall in the firststorey shall not be greater than that in the groundstorey.

The cantilever-projection of roof/floor, where provided, shall not exceed 1m. No load-bearing wall shall be constructed over such cantilever projections.

See Figure 1-1also.

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

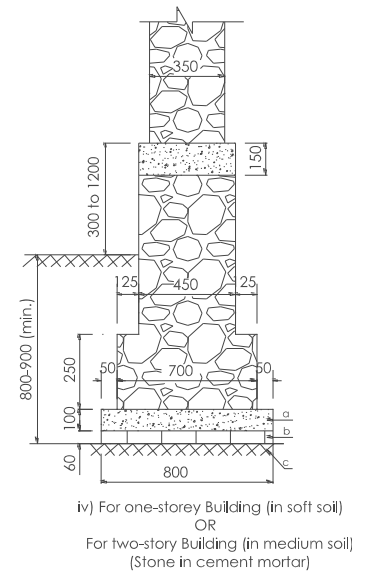
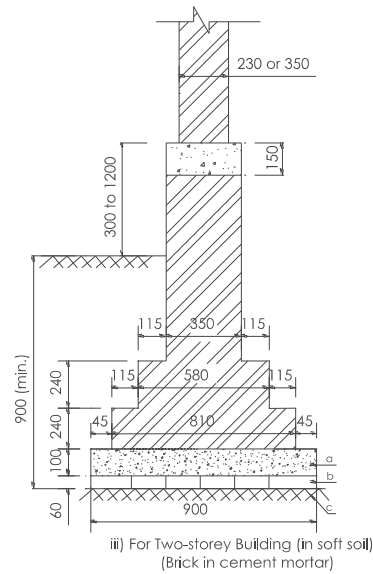
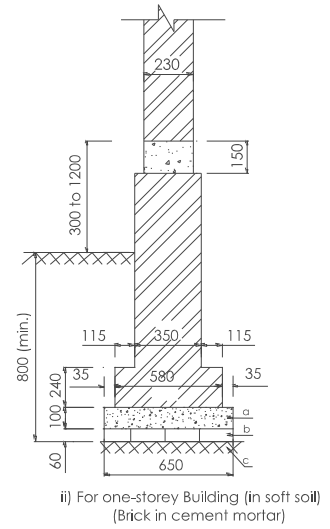
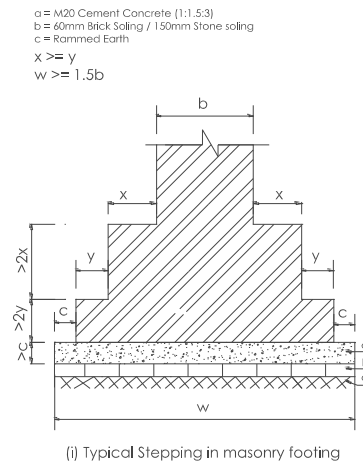
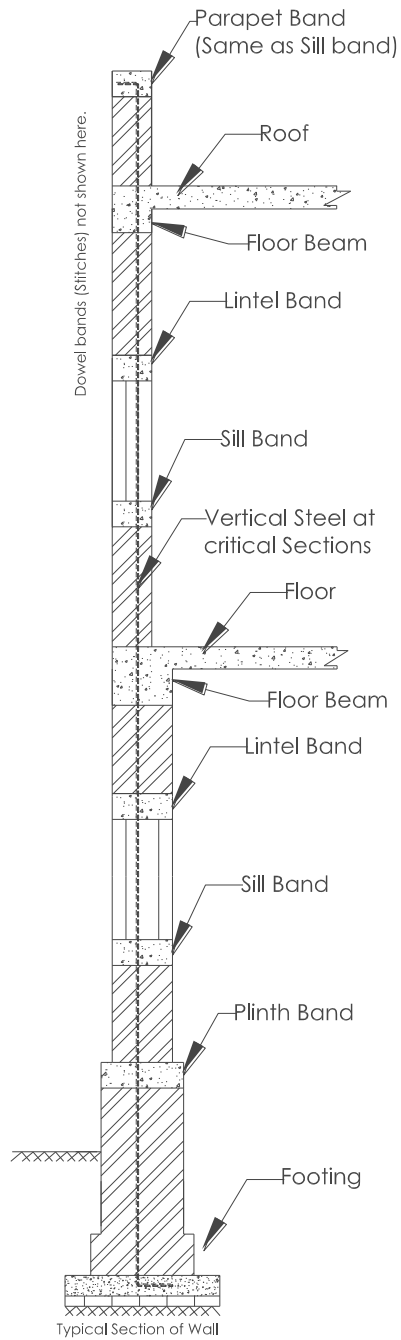


Figure 1-1: Wall Section and Stone/Brick Wall Footing Details

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

2. Interpretation

2.1 General

- 2.1.1** In this Guideline, the word 'shall' indicates a requirement that is to be adopted in order to comply with the provisions of this document, while the word 'should' indicates recommended practice.
- 2.1.2** Words implying the singular only also include the plural and vice versa wherever the context requires this.

2.2 Terminology

In this Guideline, unless inconsistent with the context, the following definition shall apply:

REINFORCEMENT:

- (i) High Strength Deformed Bars – Fe500: High strength deformed bars with $f_y = 500 \text{ N/mm}^2$ and minimum elongation not less than 14% (Fe500 Grade).
- (ii) High Strength Deformed Bars – Fe415: High strength deformed bars with $f_y = 415 \text{ N/mm}^2$ and minimum elongation not less than 14% (Fe415 Grade).
- (iii) Mild Steel Bars: Mild steel bars with $f_y = 250 \text{ N/mm}^2$ and minimum elongation not less than 20%.

Note: *NS191-2046 and NS84-2042 can be referenced for the reinforcement specifications.*

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

3. Materials

3.1 Concrete

The concrete to be used in footings, columns, beams, slabs and other horizontal and vertical reinforcements in wall (bands, dowels, etc.) shall be of at least M20 Grade; i.e. have a minimum crushing strength of 20 N/mm² (or 20 mpa) when a 150 mm cube is tested in 28 days.

Note: Where adequate care has been taken in the following: the selection of materials; mixing; correct proportioning; proper placing; compacting and curing of the concrete, a nominal mix of 1:1.5:3 (cement : coarse sand : coarse stone aggregate) is expected to produce M20 grade concrete. However water-cement ratio shall not exceed 0.6 (i.e. not more than 30 litres of water per 50kg of cement shall be used).

3.2 Brick Masonry

All brick masonry shall be built in a tradesman-like manner using the best practices and workmanship that include:

- Pre-soaking of bricks in water
- Level bedding planes fully covered with mortar
- Vertical joints broken from course to course and filled fully with mortar

Bricks: The bricks shall be of a standard rectangular shape, burnt red, hand-formed or machine-made and shall conform to the Nepal Standard NS: 1/2035. Bricks used as masonry units shall be of class A1 or class B1 as per NS: 1/2035 with compressive strength as specified in clause 5.5.

Wall Thickness: Minimum wall thickness has been specified in clause 1.2 (Table 1-1). A minimum thickness of one half-brick (or 110 mm) and a maximum thickness of one brick (or 230 mm) shall be used for the walls constructed as non-load bearing walls in these buildings.

Mortar: Mortar used in load-bearing walls of masonry buildings shall be as specified in clause 5.5. The addition of small quantities of freshly hydrated lime to the mortar in a lime-cement ratio of 1/4:1 to 1/2:1 will increase its plasticity greatly without reducing its strength.

Plaster: All plasters shall have a cement-sand mix not leaner than 1:6 on outside or inside faces. It shall have a minimum 28 days cube crushing strength of 3 N/mm².

Thick plaster is not desirable but a minimum plaster thickness of 10 mm shall be adopted.

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

4. Selection and Investigation of the Site

4.1 General

This section sets out some of the requirements to be considered during site selection for the construction of buildings in order to minimise the risks to the buildings from primary geological as well as secondary seismic hazards such as fault rupture, landslides and liquefaction. A building shall not be constructed if the proposed site is:

- Water-logged
- A rock-falling area
- A landslide-prone area
- A subsidence and/or fill area
- A river bed or swamp area

4.2 Use of Local Knowledge

It is a good practice during the construction of a building to examine the existing local knowledge and the history of the performance of existing buildings. This will assist in identifying whether there is any danger from inherent natural susceptibilities of the land to the processes of sliding, erosion, land subsidence and liquefaction during the past earthquakes or any other natural/geological processes likely to threaten the integrity of the building. The local practice of managing such hazards, if any, should be judged against the required level of acceptable risk.

4.3 Site Investigation Requirements

Site exploration shall be carried out by digging test pits, two as a minimum, and more if the subsurface soil condition shows a significant variation in soil type.

Generally, the minimum depth of exploration for a building covered by this Guideline shall be 2 m. In hilly areas, exploration up to the depth of sound bed-rock, if it lies shallower than 2 m, should suffice.

No exploration shall be required if the site is located on rock or on fluvial terraces (Tar) with boulder beds. The soils encountered in the test pits should be classified as per Table 4-1.

4.4 Allowable Bearing Pressure

The allowable bearing pressure that can be used is given in Table 4-1 in conjunction with the visual classification of the subsurface soil type.

Table 4-1: Classification of Foundation Soil and Safe Bearing Capacity

	Type of Foundation Materials	Foundation Soil Classification	Presumed Safe Bearing Capacity, KN/m ²
1.	Rocks in different state of weathering, boulder bed, gravel, sandy gravel and sand-gravel mixture, dense or loose coarse to medium sand offering high resistance to penetration when excavated by tools; stiff to medium clay which is readily indented with a thumb nail.	Hard	≥ 200
2.	Fine sand and silt (dry lumps easily pulverised by the fingers); moist clay and sand-clay mixture which can be indented with strong thumb pressure.	Medium	< 200 and ≥ 150
3.	Fine sand, loose and dry; soft clay indented with moderate thumb pressure.	Soft	< 150 and ≥ 100
4.	Very soft clay which can be penetrated several centimetres with the thumb, wet clays.	Weak	< 100

Buildings can be constructed on hard, medium and soft soils, but it is not recommended to construct buildings on weak soils. Hence, appropriate soil investigations should be carried out to establish the allowable bearing capacity and nature of soil and if required, various measures can be adopted for improvement of bearing-capacity of soils.

5. General Construction Aspects

5.1 Plan of Building

a) Symmetry: The building, as a whole or its individual blocks, shall be planned to be as close to symmetrical as possible.

b) Regularity: Buildings of simple rectangular shapes behave better in earthquakes than irregular buildings with projections. To avoid torsional effects which are pronounced in long narrow rectangular blocks, length of a block shall not be greater than three times its width. If longer lengths are required, it should be divided into two (or more if the length desires so) separate blocks with sufficient separation.

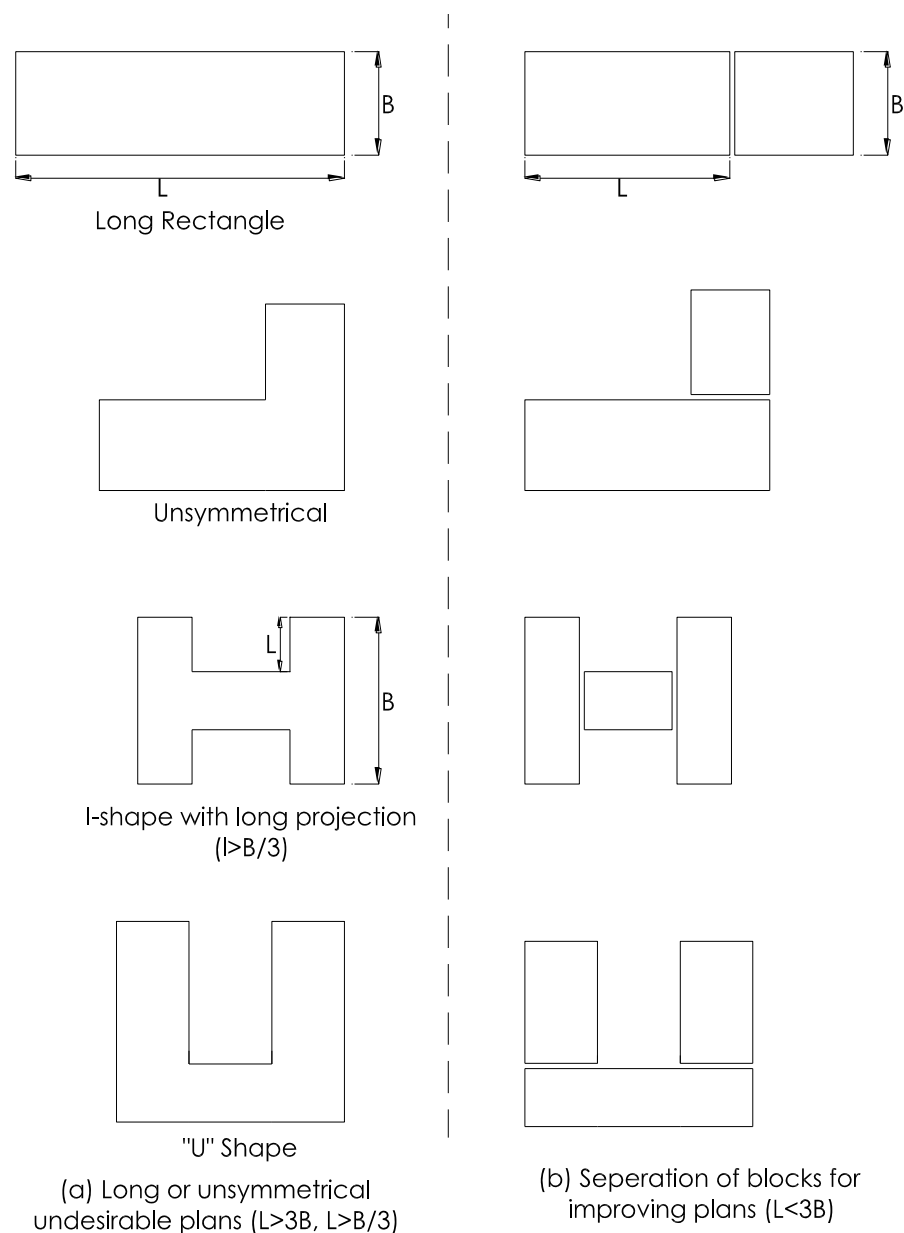


Figure 5-1: Plan of building blocks

c) Separation of Blocks: Separation of a large building into several blocks may be required so as to obtain symmetry and regularity of each block. For preventing hammering or pounding damage between blocks a physical separation of 40 to 50mm shall be provided through out the height of the building above the plinth level.

The separation can be treated just like an expansion joint or it may be filled or covered with a weak material which would easily crush and crumble during earthquake shaking.

d) Simplicity: Ornamentation involving large cornices, vertical or horizontal cantilever projections, facia stones, etc. where used must be reinforced with steel, which shall be properly embedded or tied into the main structure of the building.

5.2 Footing

The building must be well connected to the foundation and the earth. While selecting a proper site or evaluating the suitability of a given site, clause 4 shall be followed.

The footing should be provided at a depth below the zone of deep freezing in cold regions and below the level of shrinkage cracks in clayey soils but not less than 800 mm for one storey building and not less than 900mm for two storey building.

The minimum dimensions for footing in soft soil shall be as per Figure 1-1. For other soil types, the footing dimension shall be taken as per Table 5-1.

Table 5-1: Base width of footings

Masonry Type	No of Storey	Minimum base width (mm) of wall footing for soil type:		
		Soft	Medium	Hard
Brick	Two	900	650	550
	One	650	550	450
Stone	Two	*	800	600
	One	800	600	600

*: Two-storied buildings with load-bearing stone masonry of random rubble or half-dressed stone are not recommended in soft soil.

5.3 Openings in Walls

Any opening in the wall should be small in size and centrally located. The following are the guidelines for the size and position of openings.

- Openings are to be located away from inside corners by a clear distance equal to at least $1/4$ of the height of the opening, but not less than 600 mm.
- The total length of openings in a wall is not to exceed 50 % of the length of the wall between consecutive cross-walls in single-storey construction, 42 % in two-storey construction.
- The horizontal distance (pier width) between two openings is to be not less than one half of the height of the shorter opening (see Figure 5-2), but not less than 600 mm.
- The vertical distance from one opening to another opening directly above it shall not be less than 600 mm, nor less than one half the width of the smaller opening see Figure 5-2
- When an opening does not comply with requirements (i) to (iv), it shall be boxed in reinforced jambs through the masonry (Figure 5-3).
- If the vertical opening of the wall is more than 50 % of the wall height, vertical bars shall be compulsorily provided in the jambs.

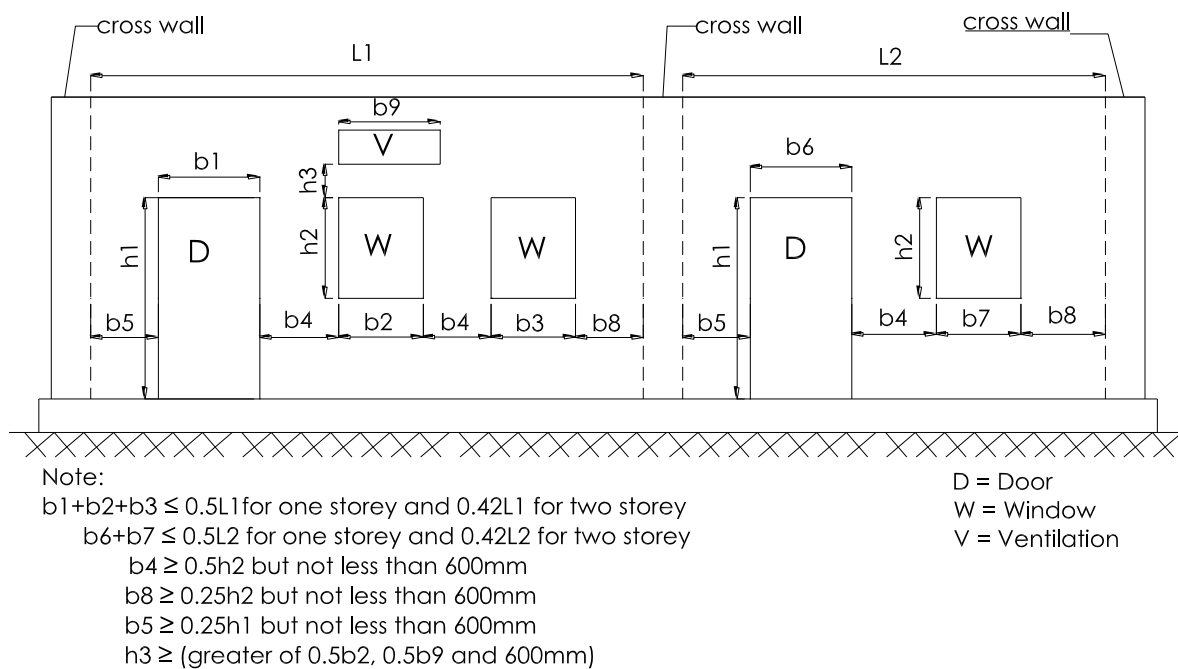


Figure 5-2: Recommendations Regarding Openings in Bearing Walls

5.4 Masonry Bond

In order to achieve the full strength of masonry, the usual bonds specified for masonry shall be followed so that the vertical joints are broken properly from course to course.

5.5 Mortars and Concrete

Where steel reinforcing bars are provided in walls, the bars shall be embedded in a cement concrete mix of at least M20 grade (refer clause 3.1). The mortar for brick-masonry shall not be leaner than 1:6 in any case.

Table 5-2: Brick and Mortar specification for different building

No of Storey	Floor	Proportion of ingredients for mortar (cement: sand)	Min. crushing strength of bricks (N/mm ²)	Minimum brick wall thickness (mm)
2	First	1:6	3.5	230
	Ground	1:6	7.5	230
			5	350
1	Ground	1:6	3.5	230

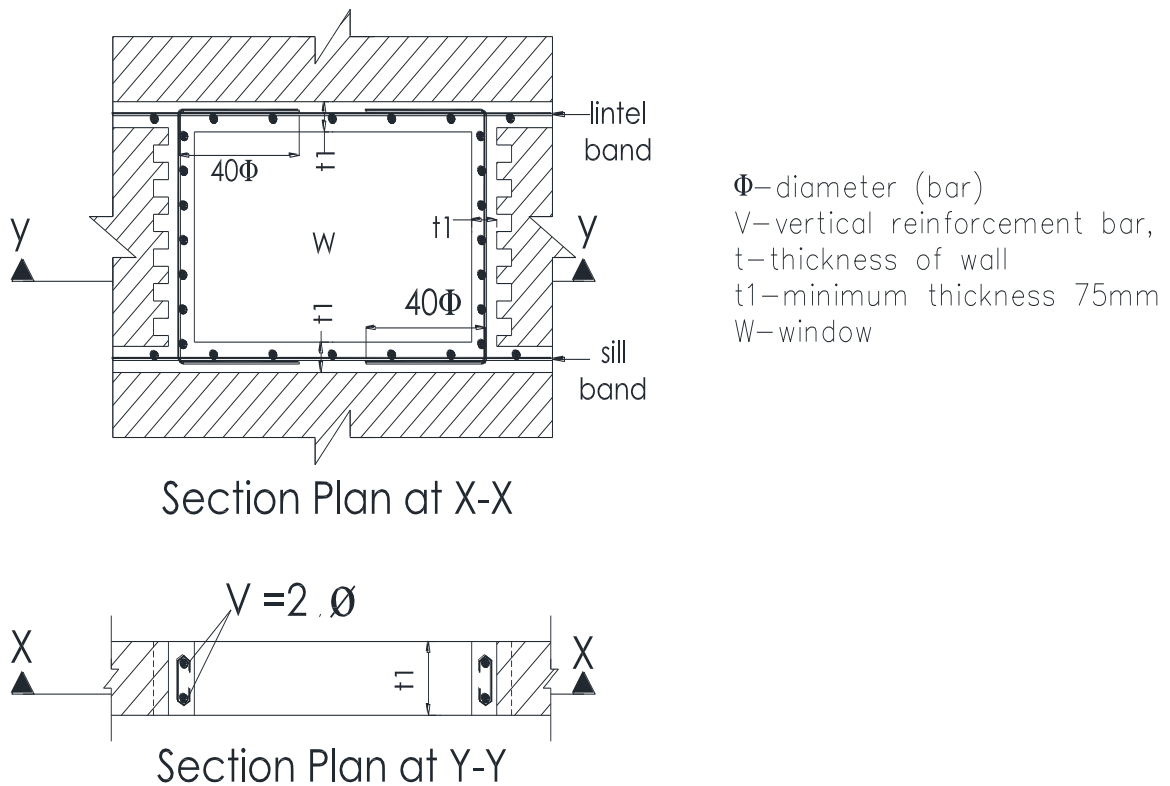


Figure 5-3: Strengthening of Masonry around Openings

5.6 Vertical Joints between Orthogonal Walls

For convenience of construction, builders prefer to make a toothed joint which is later often left hollow and weak. If the joint (connection) between orthogonal walls is not lost during lateral forces such as those induced by earthquakes, the building will tend to act as a box and its resistance to lateral forces will be much larger than the resistance offered by individual walls with lost connection (or broken joint).

To obtain full bond, it is necessary to make a sloped or stepped joint. It should be constructed so as to obtain full bond by making the corners first to a height of 600 mm, and then building the wall in between them. Alternatively, the toothed joint shall be made in both the walls alternately in lifts of about 450 mm, as shown in Figure 5-4 and Figure 5-5.

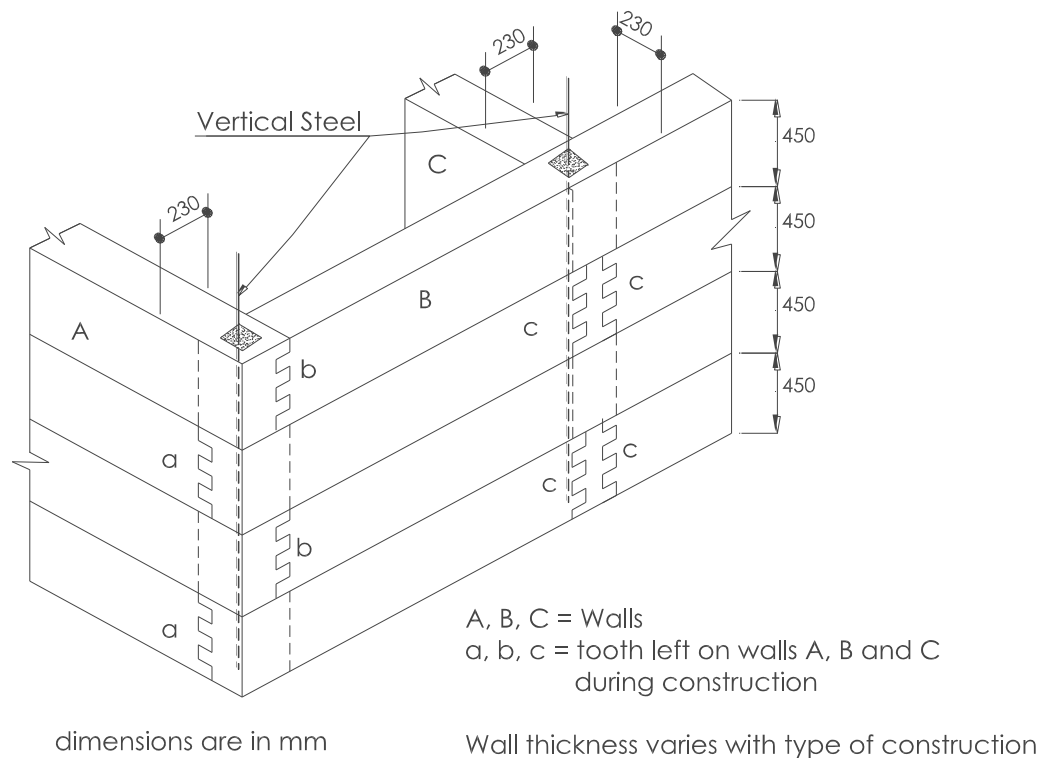


Figure 5-4: Joints between orthogonal walls

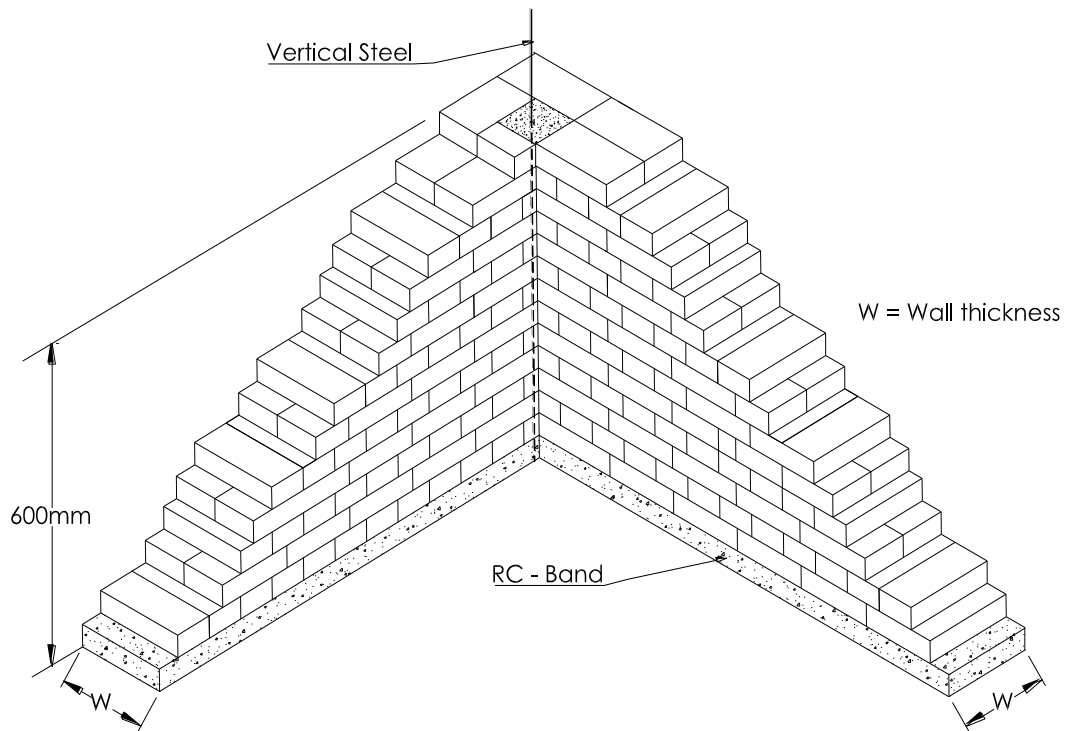


Figure 5-5: Corner walls to be built first

.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

.....
Arjun K. Karki
Secretary

6. Horizontal Reinforcement in Walls

Horizontal reinforcing of walls is required in order to tie orthogonal walls together, to confine the masonry units against spalling during earthquakes and to avoid greater reduction in load-carrying capacity of walls.

6.1 Horizontal Bands or Ring Beams

The most important horizontal reinforcing is by means of reinforced concrete bands provided continuously through all load-bearing longitudinal and transverse walls at plinth, lintel and roof eave levels, and also at the top of gables according to the requirements stated below.

6.1.1 Plinth Band

This should be provided in all masonry buildings. It may also serve as a damp-proof course. Plinth bands are more important in soft or uneven soils. Reinforcement as given in Table 6-1 shall be provided in a plinth band.

6.1.2 Sill Band

A continuous sill band shall be provided through all walls below openings (especially, just below windows). It should be provided in all storeys in all buildings.

6.1.3 Lintel Band

A continuous lintel band shall be provided through all walls just above openings. Thus the top-level of all the openings (doors and windows) shall be at the same line as far as practicable. Lintel bands must be provided in all storeys in all buildings as per Table 6-1. Additional reinforcement may be required to be provided over openings to distribute loads to the walls on the sides of the openings.

6.1.4 Dowel Band (Stitches)

This band shall be provided where dowel-bars are required as specified in section 7.

6.1.5 Roof Band / Floor Beam

Roof band shall be provided at the eave-level of trussed roofs (Figure 8-1) and also just below the joists on all such floors which consist of joists and covering elements (flexible floors), so as to integrate them properly at their ends and fix them into the walls.

Floor beam shall be constructed monolithically with RCC slab over all bearing walls when RCC slab is provided. Reinforcement as given in Table 6-1 shall be provided in this band.

6.1.6 Parapet Band

This band shall be provided at the top of parapet walls, where parapet walls are constructed. Similar to sill band, it shall be continuous over all parapet walls and reinforced as per Table 6-1.

6.1.7 Gable Band

Masonry gable ends must have the triangular portion of masonry enclosed in a band, the horizontal part of which will be continuous with the eave-level band on the adjacent longitudinal walls (Figure 8-1). It is advantageous to replace gable masonry wall with a truss covered with light-weight materials.

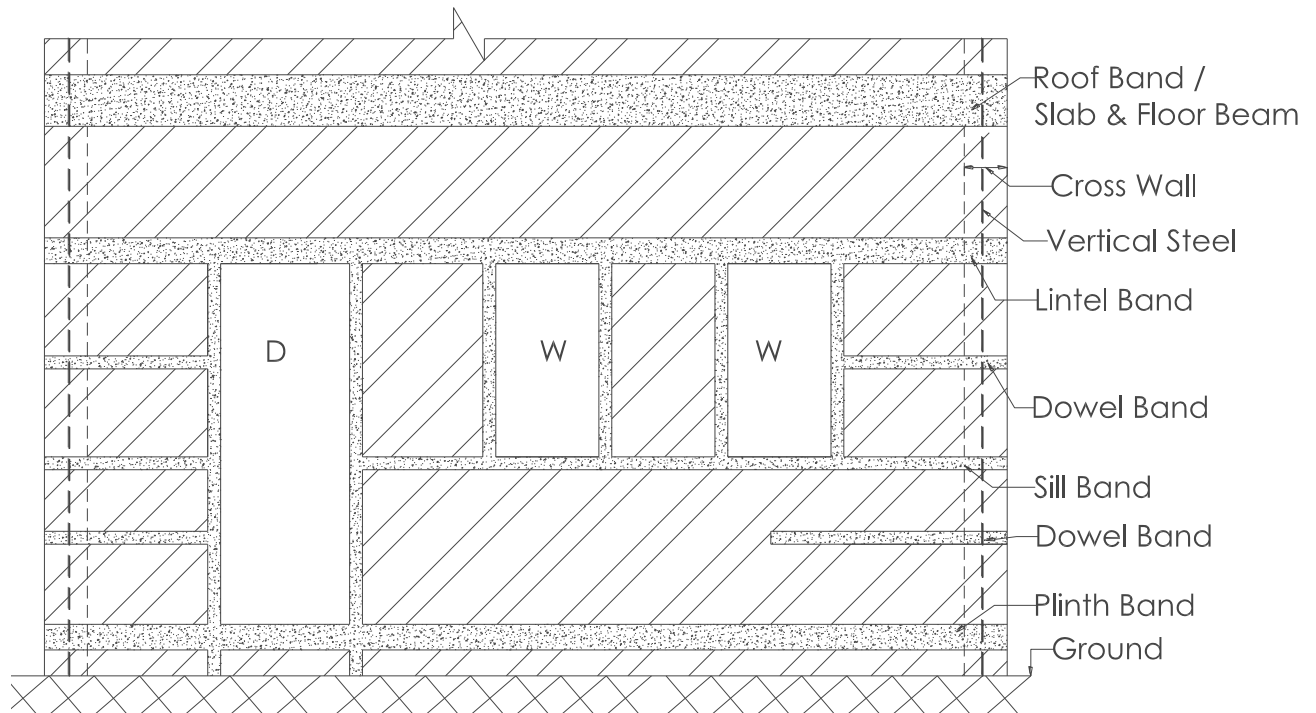
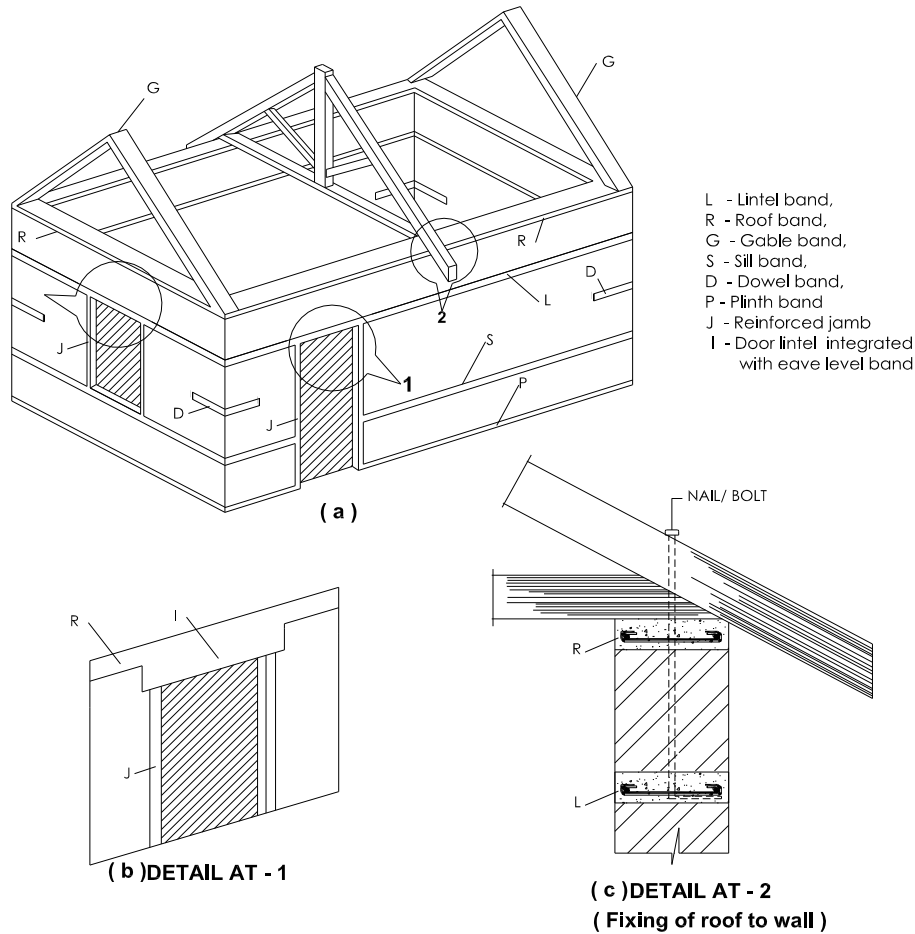


Figure 6-1: Different Bands in Building

**Note:**

- i) As an alternative to the gable masonry, a truss or open gable may be used and the openings covered with a light material such as sheeting, matting etc.
- ii) If the wall-height up to eave-level is less than or equal to 2.5 m, the lintel band may be omitted and the lintel integrated with the eave-level band (Roof-band) as shown in Detail 1.

Figure 8-1: Overall Arrangement of Reinforcing Masonry Buildings

6.2 Section of Bands

The width of the RC band shall be the same as the thickness of the wall. The vertical thickness of the RC band may be kept to a minimum of 75 mm where two longitudinal bars are required and at least 150 mm where four longitudinal bars are required. The thickness of the band shall be made closely equal to, or a multiple of, the thickness of masonry unit.

The minimum steel requirements for various buildings for these bands or ring beams are shown in Table 6-1. Additional bars may be required where the band is carrying any other additional loads such as masonry loads above openings. A cover of 25 mm from the face of wall shall be maintained for all steel reinforcements. Full continuity of steel shall be provided around corners and through junctions.

The longitudinal bars shall be held in position by steel stirrups or links of at least 6 mm in diameter spaced 150 mm apart. Stirrups or links shall be made of high strength deformed bars-Fe415 or Mild steel bars. The concrete mix shall be of at least M20 Grade.

Table 6-1: Requirement for steel in RC BAND

Band /Beam	RC band minimum thickness	Min. No. Of bars	Min. Diameter of Bars (mm)
Plinth	150mm*1	4	12
Sill	75mm	2	10
Lintel	75mm*2	2	12
	150mm*2	2 2	10(top) 12(bottom)
Roof	75mm *3	2	12
	300mm *3	4	12
Dowel (Stitch)	75mm	2	8

Note: *1: Plinth band thickness can be reduced to 75mm reinforced with 2-12mm dia bars in case of hard soil.

*2: Where opening width does not exceed 1.25m and masonry height above opening does not exceed 0.9m, 75mm thick lintel is sufficient. In such lintels, longitudinal reinforcement shall be placed maintaining 25mm cover from bottom. For opening width up to 2m and masonry height above opening upto 1.2m, 150mm thick lintel band is necessary.

*3: Roof band of at least 75mm thickness shall be provided where flexible floor/roof (eg. timber floor) rests. For RCC roof/floor, 300mm deep RCC beam (including slab) cast monolithically with slab, shall be provided.

The specified bar number and diameter are for High Strength Deformed Bars-Fe415. For bars of other grades specified in clause 2.2, reinforcing bars should be provided to form the same steel area as in the Table.

Additional 8mm dia. longitudinal bars shall be provided at the middle of each layer if the width of the wall exceeds 250 mm such that spacing of these bars do not exceed 250mm.

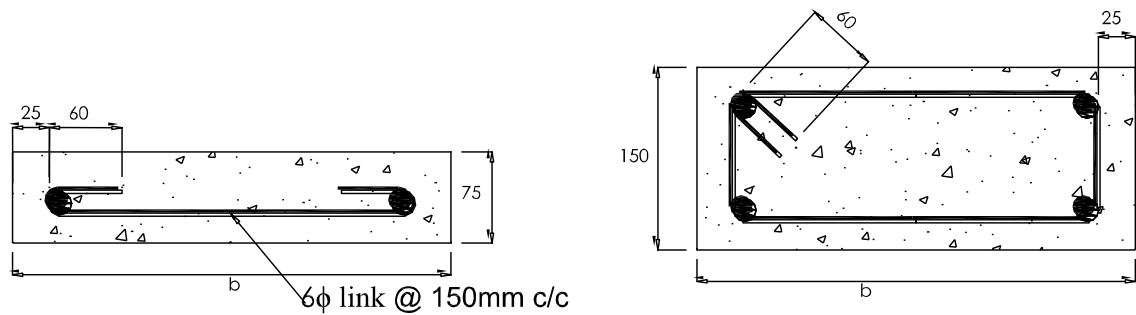
.....
Ganesh Karmacharya
Engineer

.....
Parikshit Kadariya
SDE

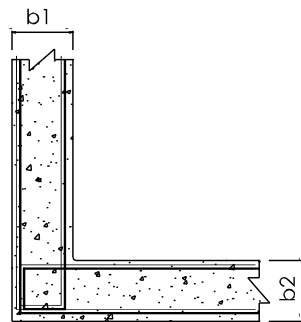
.....
Mani R. Gelal
DDG

.....
Ramesh Pd. Singh
DG

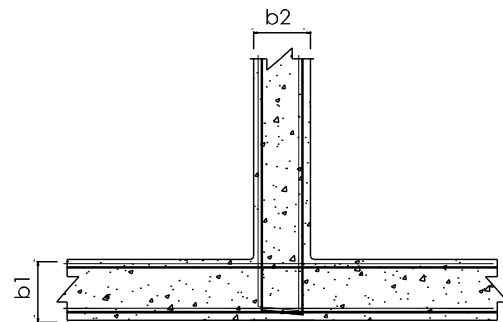
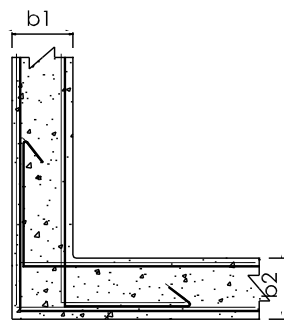
.....
Arjun K. Karki
Secretary



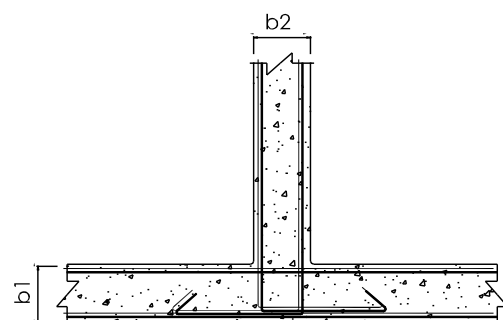
(a) Cross section of R.C.C band for two bars and four bars



or



or

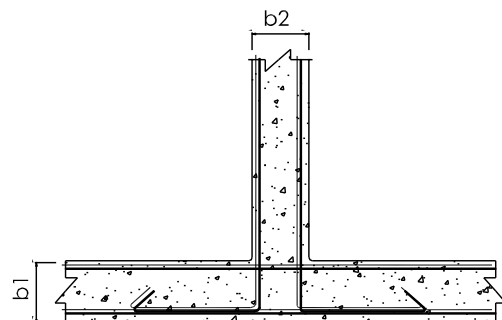


or

b, b_1, b_2 = Wall thickness

Note:

Provide overlaps for splicing bars outside the corner, length of overlap to develop full bond say $50d$.



(b) R.C. band reinforcement details at corner and junction (links not shown)

Figure 8-2: Reinforcement in RC Bands

7. Dowels at Corners and Junctions

Steel dowel bars shall be used at corners and T-junction to integrate the box action of walls. Dowels are to be taken into the walls to a sufficient length so as to provide their full bond strength.

Dowels shall be provided in 75 mm thick concrete (M20 Grade) bands at a vertical spacing of 500 -700 mm. The size and layout of the bars in dowel band are shown in Figure 7-1 and Figure 7-2.

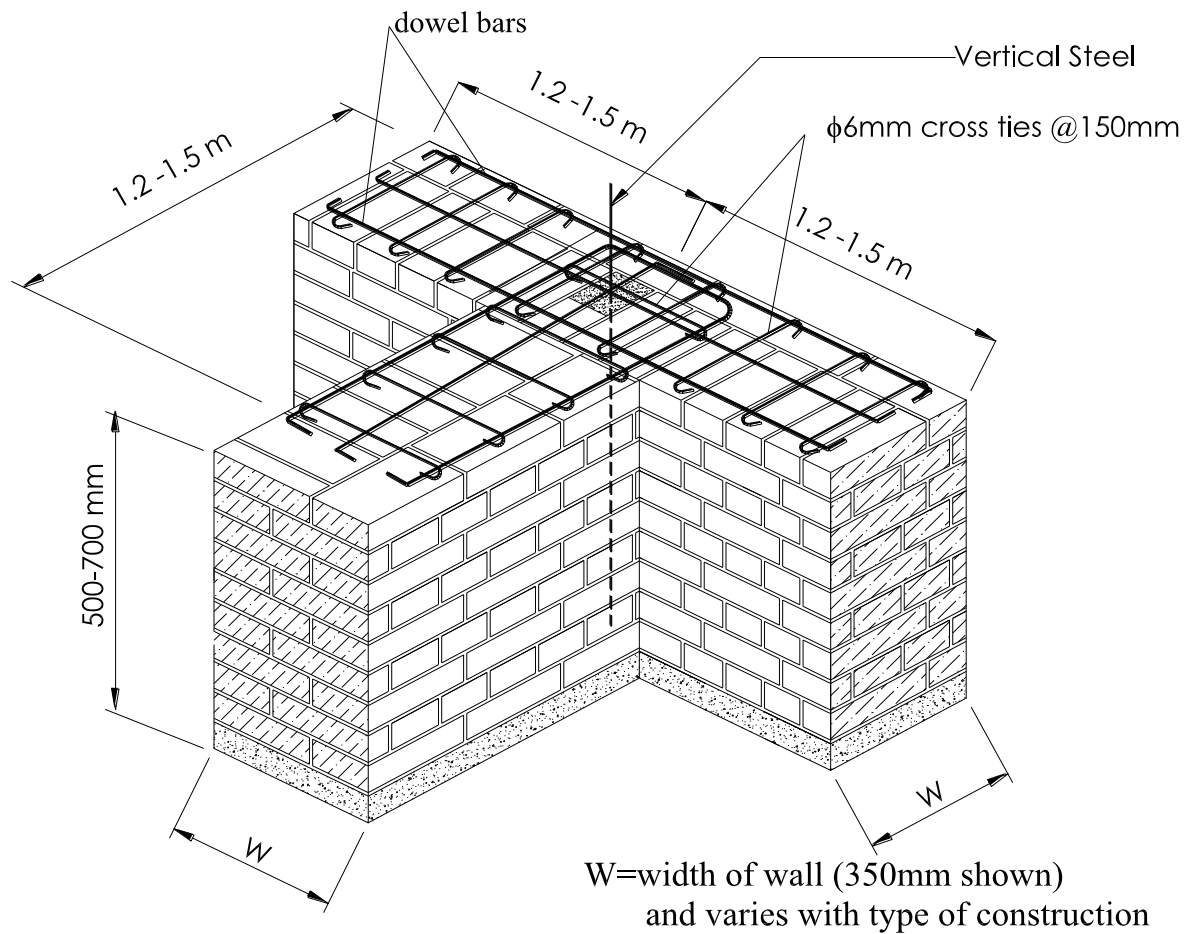


Figure 7-1: Junction and Corner-Strengthening by Dowel

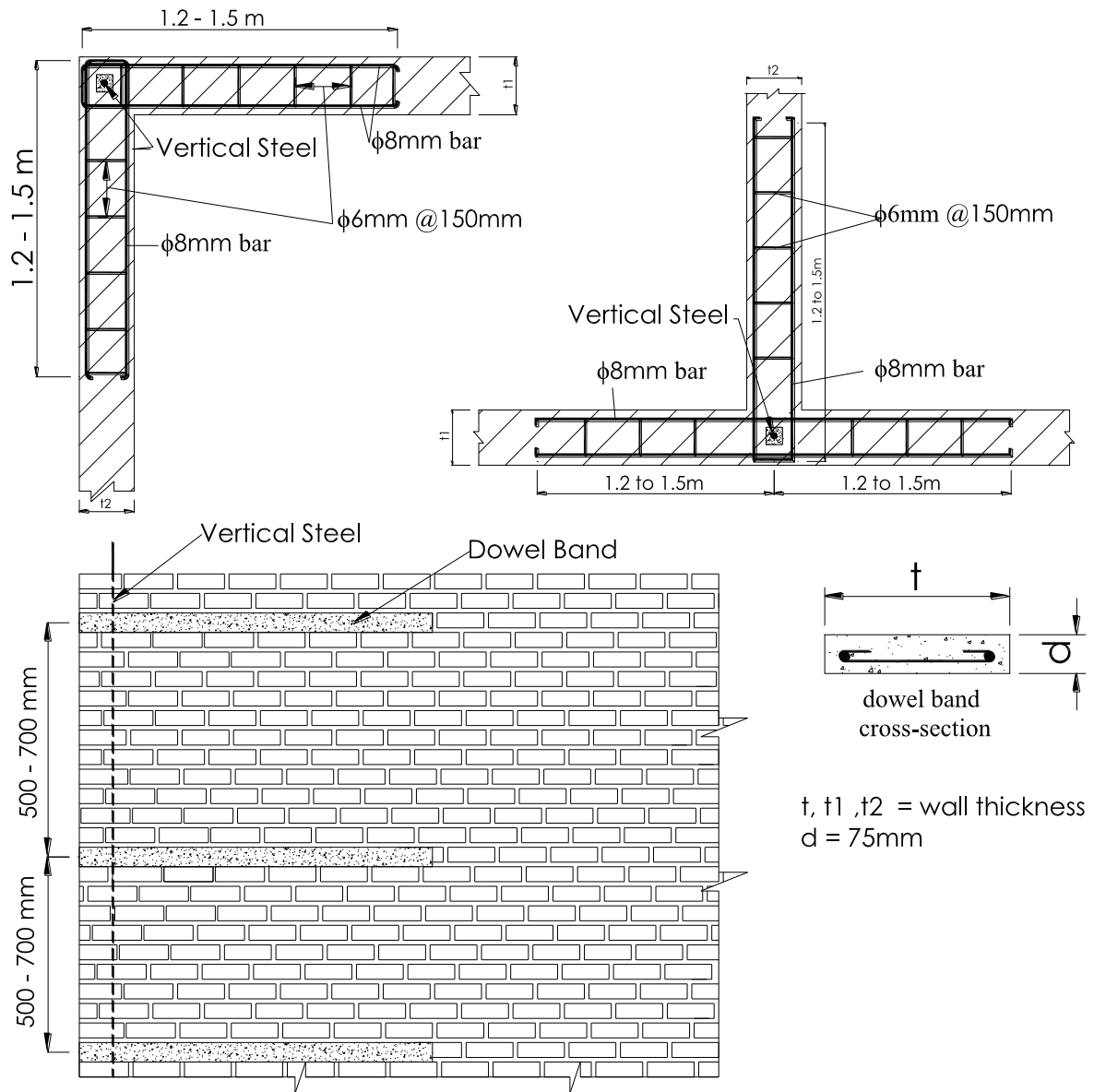


Figure 7-2: Detail of T-Junction and Corner Strengthening by Dowel Reinforcement

8. Vertical Reinforcement in Walls

Vertical steel bars shall be installed at the critical sections like corners of walls and junctions of walls right from the foundation concrete. They shall be covered with cement concrete in cavities made around them during the masonry construction (see Figure 8-1). This concrete mix should be kept to M20 Grade or richer (refer clause 3.1).

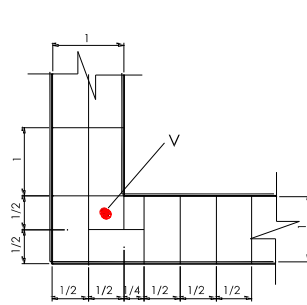
The vertical steel may also be required at jambs of the openings (refer clause 5.3), which shall start from the foundation and may be terminated by embedding it into the lintel band (or roof band/beam), but the vertical steel at the corners and junctions of walls must be taken into either the floor and roof slabs or the roof band.

The recommended amount of vertical reinforcing steel for brick masonry is given in Table 8-1.

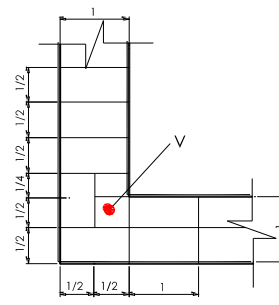
Table 8-1: Vertical Steel Requirement at Critical Sections for Brick Masonry

No. of Storeys	Floor	Diameter of high strength deformed bars-Fe 415 single bar in mm for :	
		at each critical section	at jambs of opening (where required)
One	Ground	12	12
Two	First	12	12
	Ground	16	12

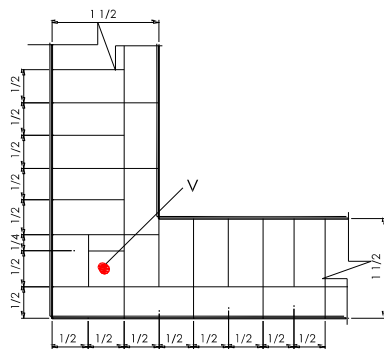
Note: Equivalent diameter reinforcement can be used for reinforcement grades other than Fe415 specified in clause 2.



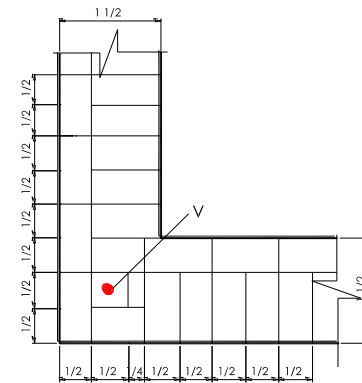
FIRST LAYER



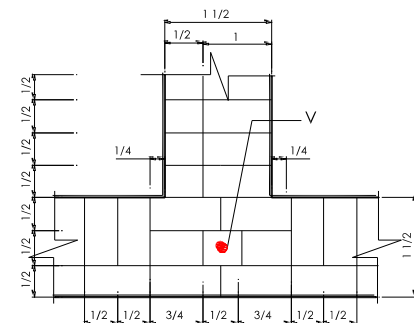
SECOND LAYER

CORNER JUNCTION DETAILS FOR ONE BRICK WALL FOR PROVIDING VERTICAL STEEL.

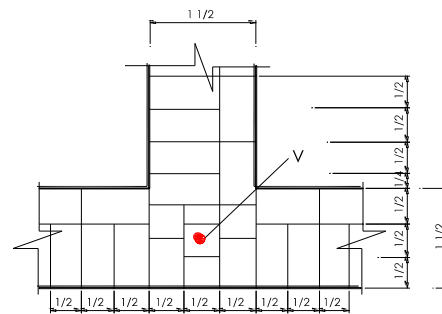
FIRST LAYER



SECOND LAYER

CORNER JUNCTION DETAILS FOR ONE AND HALF BRICK WALL FOR PROVIDING VERTICAL STEEL.

FIRST LAYER



SECOND LAYER

T- JUNCTION DETAILS FOR ONE AND HALF BRICK WALL FOR PROVIDING VERTICAL STEEL.

$\frac{1}{4}$, $\frac{1}{2}$, 1 and $1\frac{1}{2}$ indicates: $\frac{1}{4}$ Brick wide, $\frac{1}{2}$ Brick wide, 1 Brick wide, 1.5 Brick wide etc.,
V - Vertical Bar

Figure 8-1: Vertical Reinforcement in Walls

9. Floors and Roofs

As a general rule, heavy floors and roofs are source of seismic hazard. Hence, roofs as well as floors should be made as light as possible structurally and functionally.

9.1 Pitched Roof:

Pitched roofs may be trussed, with the top of the walls generally at one level - except for the masonry gables at the ends of the building. Alternatively, the longitudinal and cross-walls may be raised to varying heights up to the roof slope and the rooms spanned by rafters and purlins. From a seismic design point of view, the trussed arrangement is preferable, particularly for school buildings.

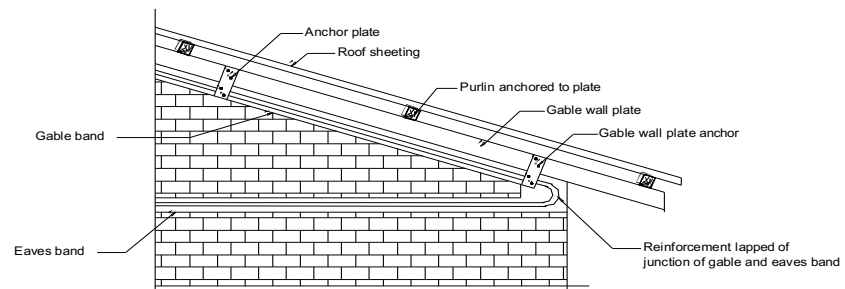
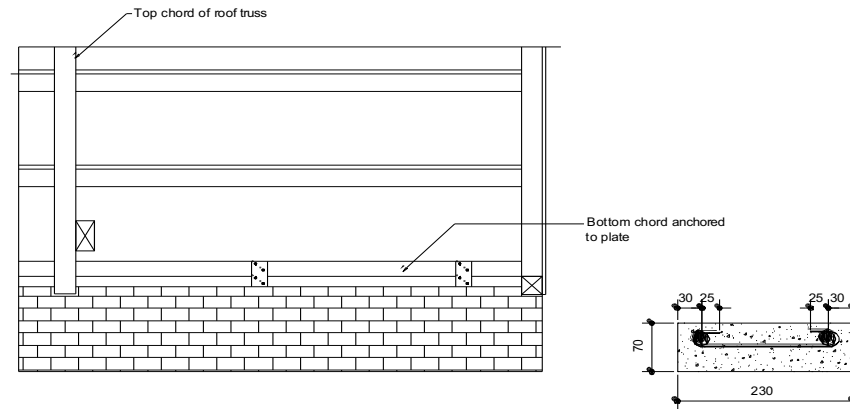
9.2 Trussed Roof:

In trussed roofs, all trusses shall be supported on the eave or roof-band. Where a trussed roof adjoins a masonry gable, the ends of the purlins shall be carried on and secured to a plate securely bolted to the band at the top of gable-end masonry (Figure 9-1).

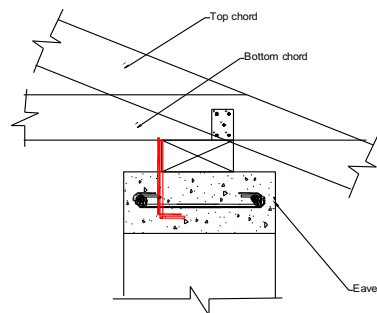
Gable triangles are very weak when loaded perpendicular to their plane and may fail even in small earthquakes. Hence, all trusses shall be sufficiently braced to transmit the lateral forces from the roof to the appropriate cross walls. Also, where possible, gable walls should be made of light weight materials.

9.3 Lean to Roof:

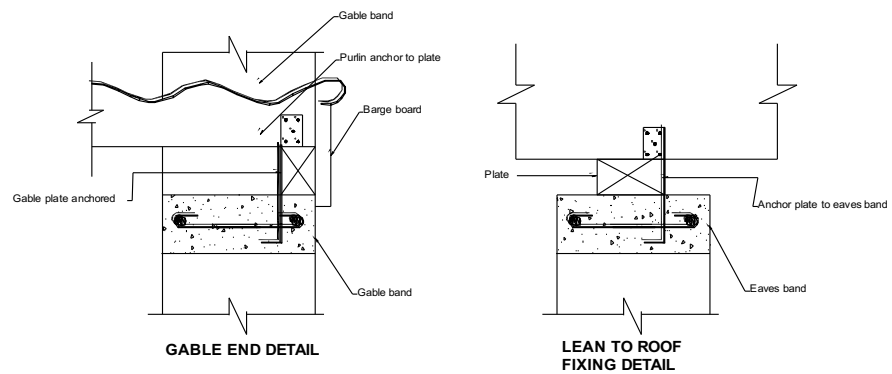
All masonry walls shall be topped by a reinforced concrete roof-band securely held by means of bolts. Alternatively, wall plates may be used which are bolted to the band and to which the rafters and purlins are fixed (Figure 9-1).



(a) Roof Fixing Details at Gables



INTERMEDIATE TRUSS FIXING



(b) Roof Fixing Details at Walls

Figure 9-1: Details for Fixing Roofs to Gables and Walls

.....

Ganesh Karmacharya
Engineer

.....

Parikshit Kadariya
SDE

.....

Mani R. Gelal
DDG

.....

Ramesh Pd. Singh
DG

.....

Arjun K. Karki
Secretary

9.4 Timber Flooring/Roofing

Where timber flooring or roofing is provided, following provisions shall be followed.

9.4.1 Structure

The following points shall be duly considered when selecting the materials for flooring structures:

- Locally available hardwood species, preferred to soft wood species, shall be used for the structural elements of flooring.
- Using a whole tree trunk as a structural element not only increases the weight, but also makes the wood more susceptible to termite attack. This results in a shorter life for such elements. Hence, only sawn timbers shall be used.
- Seasoned and treated timber or bamboo shall be used. Simple methods of treating and seasoning timber and bamboo are given in Appendix 1. These shall be carried out prior to the placement of these structural elements.

9.4.2 Beams and Bearings

Beams shall never rest directly on a wall and shall rest on roof band.

The beam shall be long enough to extend beyond both the supporting walls. Timber keys shall be provided on both the external and internal walls as shown in Figure 9-2.

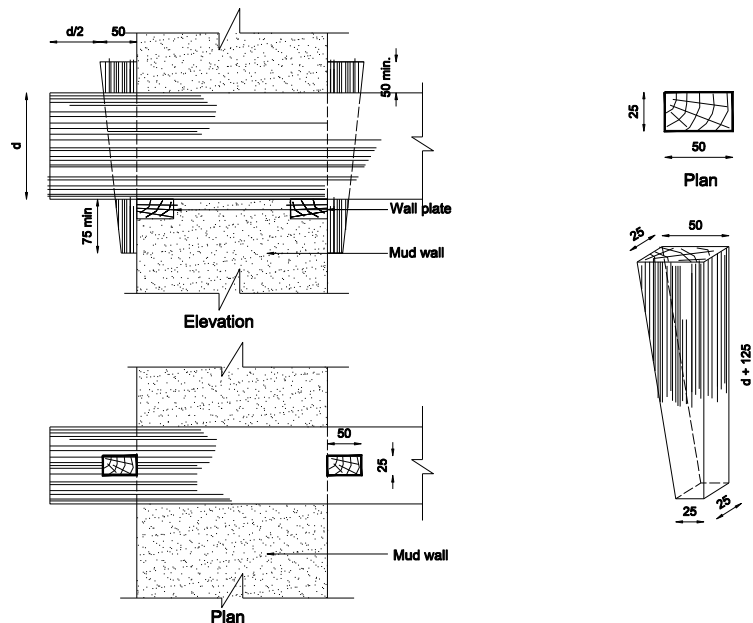


Figure 9-2: Details of Fixing Keys on Timber Beams

The beams shall be rectangular in section and shall never be laid wider surface horizontal. The minimum dimensions of the beams for different spans shall be as tabulated in Table 9-1.

Table 9-1: Size of Beams (mm) for Various Spans

SPECIES	Size (DxB) for SPAN of			
	2 m	2 to 2.5 m	2.5 to 3 m	3 to 3.5 m
Hardwood	190x100	220x100	240x120	270x140
Softwood	230x120	270x140	310x150	340x160
Spacing (mm)	≤450	≤450	≤450	≤450

9.4.3 Joists and Rafters

Joists/rafters shall be long enough to extend beyond supporting members such as walls and/or beams. The extended joists/rafters shall have timber keys on both external and internal sides of the supporting elements as shown in Figure 9-3 and Figure 9-4.

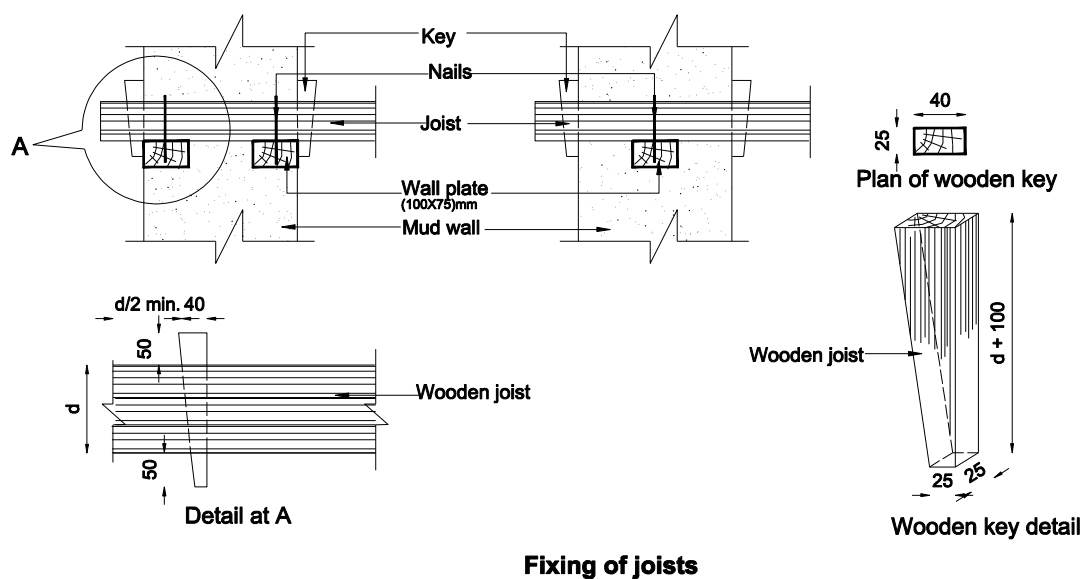


Figure 9-3: Fixing of Joists

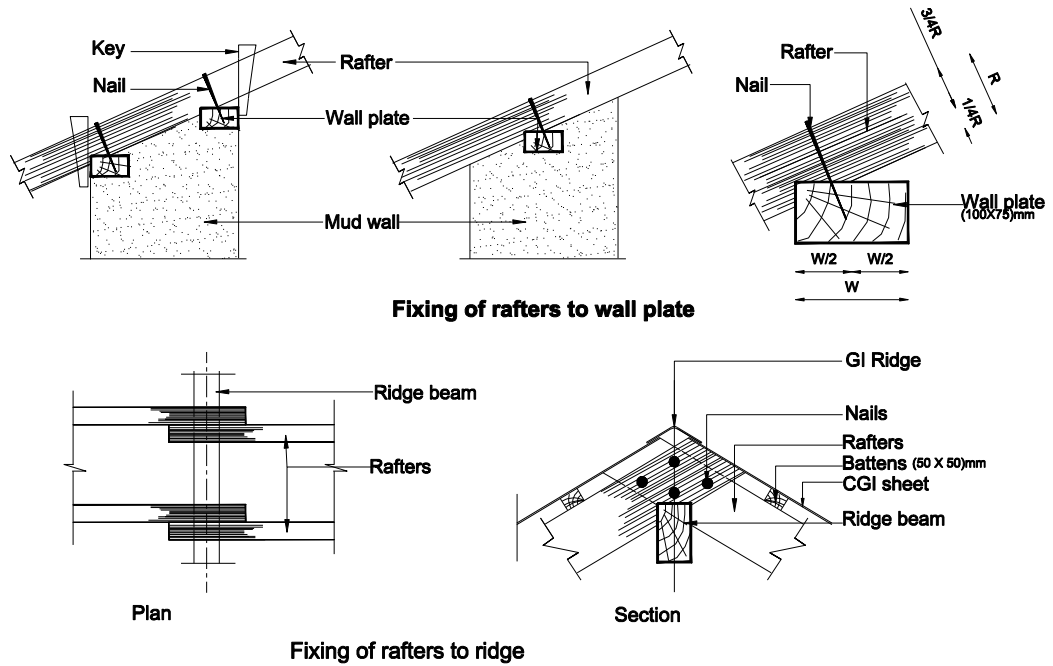


Figure 9-4: Fixing of Rafters

The joists/rafters shall be rectangular in section and shall never be laid with their wider surface horizontal. The minimum sizes of joists/rafters for various spans considering 1" plank shall be as tabulated in Table 9-2.

Table 9-2: Minimum Size (mm) of Joists and Rafters

SPECIES	Dimension (DxB) FOR SPAN UPTO				
	1 m	1.5 m	2 m	2.5 m	3 m
Hardwood	100*65	100*65	100*65	120*65	130*75
Softwood	140*75	140*75	140*75	170*90	180*90
Spacing (c/c)	≤0.5m	≤0.5m	≤0.5m	≤0.5m	≤0.5m

9.4.4 Floor Finishing

It is preferable to use better bridging materials between the joists to achieve stiffer flooring. Timber planks and half-cut bamboo are examples of these. The fixing shall be carried out as illustrated in Figure 9-5. The mud layers used for the floor base and the finish shall not be more than 75 mm thick in total.

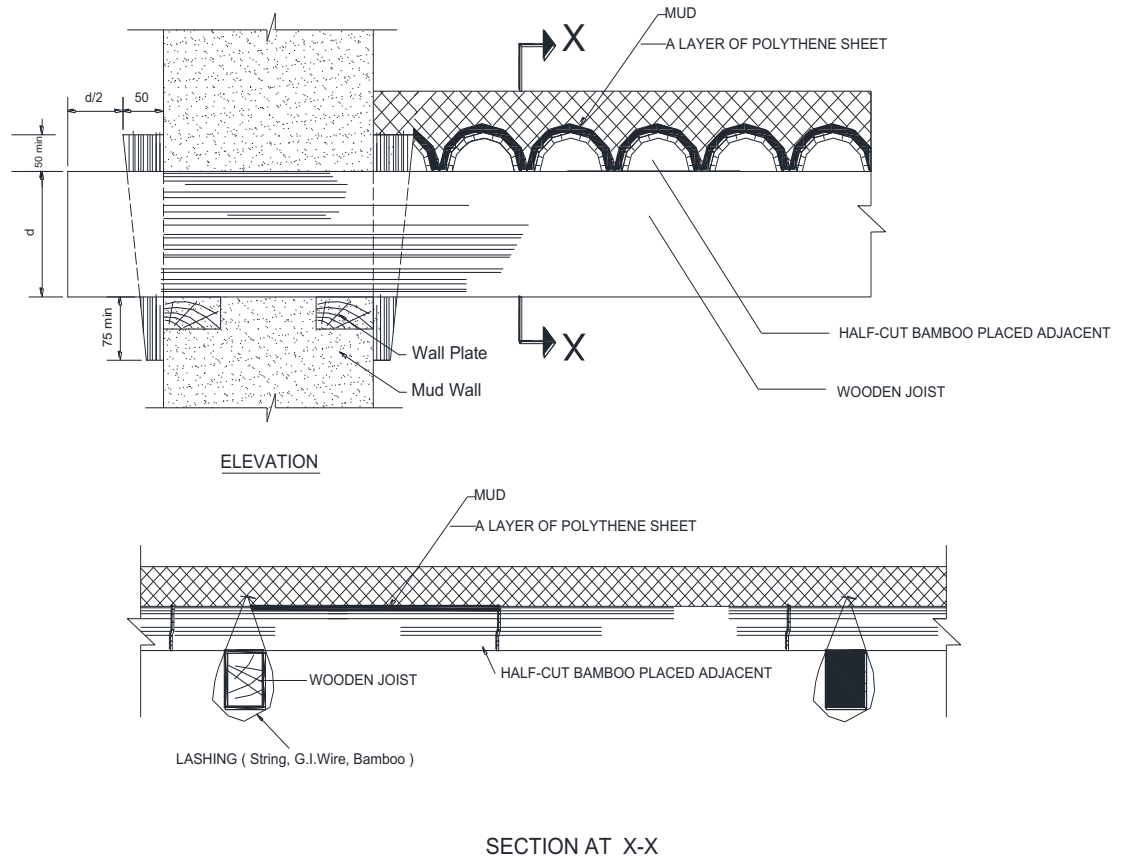


Figure 9-5: Details of Fixing Bridging Materials to Joists

9.4.5 Roof Coverings

9.4.5.1 Mud

Mud is widely used in the north-western parts of Nepal. The general techniques practised for making mud roofs consume high quantities of mud, resulting in heavy buildings. Mud roofs shall be constructed as illustrated in Figure 9-6.

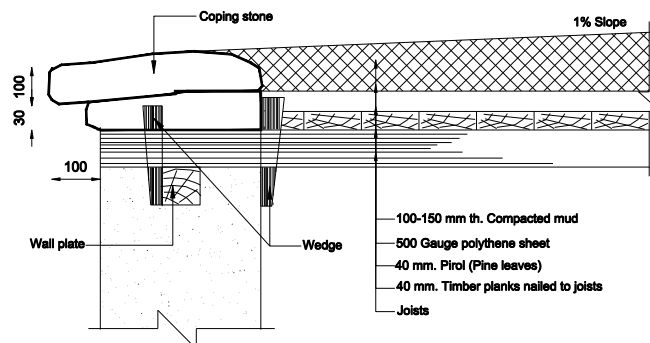


Figure 9-6: Details of Improved Mud Roofing

9.4.5.2 Slates

Thin slates shall be preferable to thicker ones. Slates shall be of uniform size. They shall be nailed to purlins and laid with a minimum overlapping of 75 mm to prevent leaking. The details illustrated in Figure 9-7 shall be adopted for slate roofing.

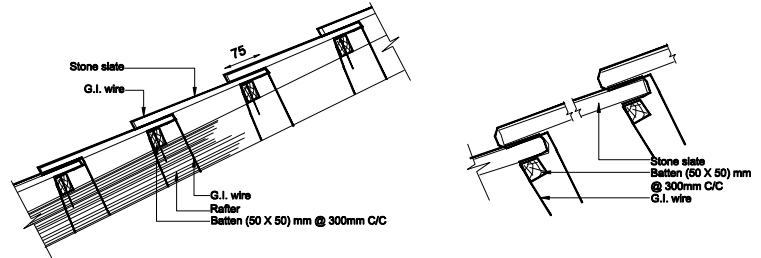


Figure 9-7: Details for Fixing Slates

9.4.5.3 Clay Tiles

Well-burnt, good-quality clay roofing tiles shall be used for roofing. All the tiles shall be well-anchored on the battens. The details given in Figure 9-8 shall be adopted for fixing clay tiles.

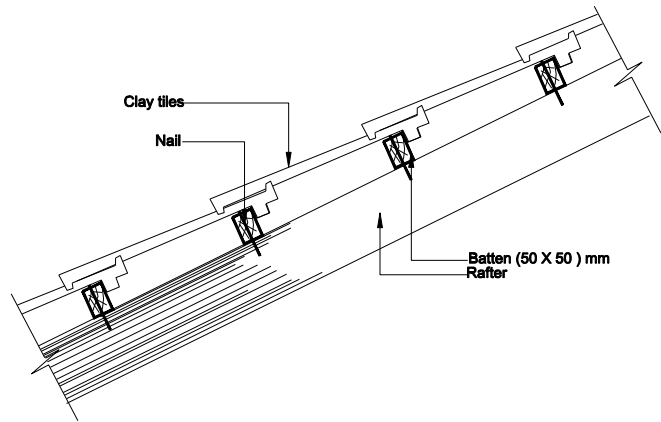


Figure 9-8: Details for Fixing Clay Tiles

9.4.5.4 MCR Tiles

Micro concrete roofing (MCR) tiles are becoming popular in many parts of the country. These tiles have projected binding wires embedded into the tiles for anchoring. All the tiles shall be properly tied with these protruding wires to the battens and purlins, as shown in Figure 9-9.

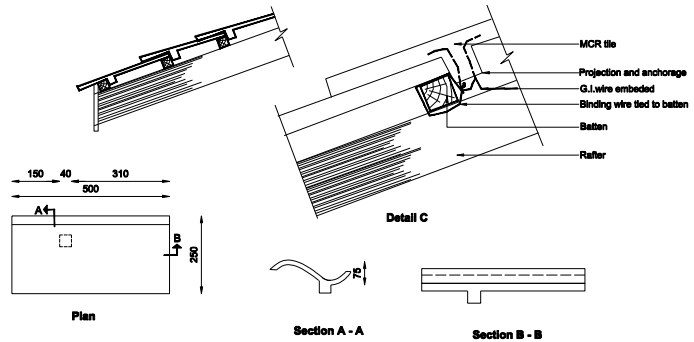


Figure 9-9: Details for Fixing MCR Tiles

9.4.5.5 CGI Sheets

Corrugated galvanised iron (CGI) sheets are very popular in all parts of the country, except in the high mountains. These sheets shall be properly anchored to each purlin/batten that supports them. The details are illustrated in Figure 9-10.

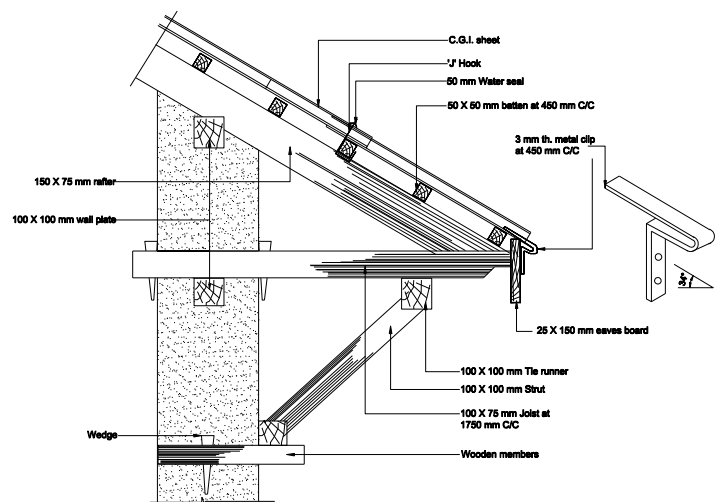


Figure 9-10: Details for Fixing CGI Sheets

9.5 RCC Roofs and Floors

Since RCC slabs are rigid for in-plane deformation, they are preferred for floors and roofs. RCC slab and beam shall be cast directly over the walls. Hence, all walls shall be raised to the required height before casting the RCC Slabs. The concrete used for RCC slab or slab and beam shall be at least M20 Grade as defined in clause 3.1.

Following provisions are specified for the reinforcement in RCC slabs with at least two edges continuous and maximum short span not exceeding 3.5m:

- i) The thickness of slab shall be at least 115mm. However the thickness shall not exceed 125mm.
- ii) The reinforcement shall be provided with high strength deformed bars (with minimum yield strength of 415N/mm²) of at least 8mm diameter.
- iii) The spacing between bottom reinforcing bars shall not exceed 150mm in both directions.
- iv) At a discontinuous edge, at least 50% of the bottom bars (i.e. every alternate bars) shall be extended to the supports and remaining bars can be curtailed at a distance of 0.15 times the span in that direction from the support.
- v) At a continuous edge, at least 50% of the bottom bars shall be continued to the next panel and remaining bars can be curtailed (or bent-up to form top bars) at distance of 0.25 times the span in that direction from the support.
- vi) The spacing between the top bars shall also not exceed 150mm.
- vii) At a discontinuous edge, additional top bars equal to at least 50% of the bottom bars shall be provided (or 50% of the bottom bars can be U-hooked to act as top bars) up-to a distance of 0.1 times the span in that direction.
- viii) At a continuous edge, at least 50% of top bars shall extend up to a distance of 0.25 times the span in that direction from the support. Remaining bars can be extended only up to a distance of 0.15 times the span in that direction (or it may be a continuity of bent-up bottom bars).
- ix) At edges, top bars running parallel to edges might be kept at spacing of 200 mm up to width of 0.2 of span in the direction perpendicular to the bar.

Above stated reinforcement detailing guidelines are only for general cases. Where larger span is required or a special case exists, it shall be designed by competent professionals.

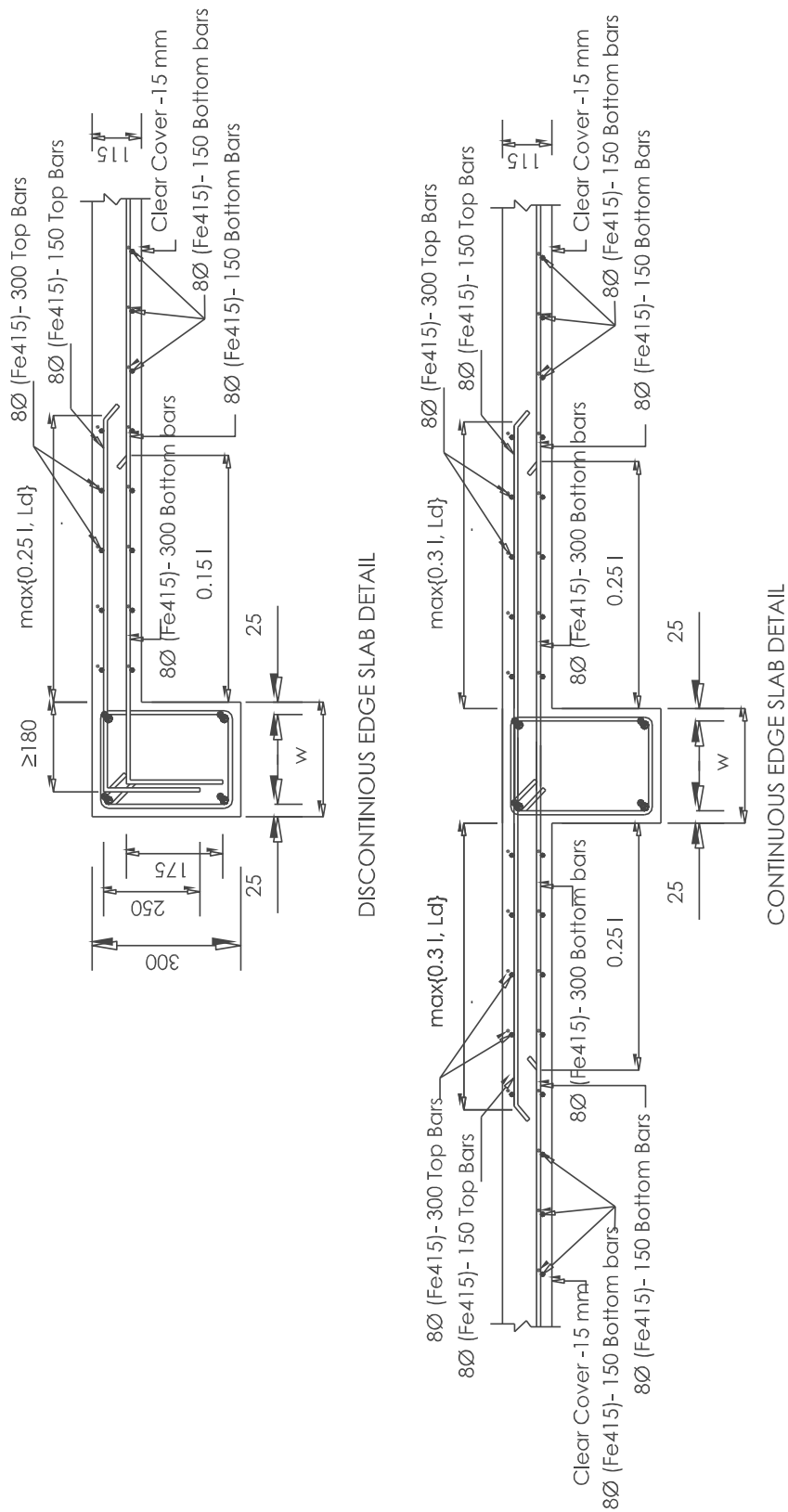


Figure 9-11: RCC Slab Detail

10. Reinforcement Details for Hollow Block Masonry

The following details shall be followed in placing the horizontal and vertical steel in hollow block masonry using cement concrete blocks.

10.1 Horizontal Band:

Reinforcement bands as explained in clause 6.2 can be provided to block masonry also. U-shaped blocks as shown in Figure 10-1 can be used for easier construction of the horizontal bands at various levels of the storey.

The amount of horizontal reinforcement shall be taken same as that given in Table 6-1. If U-blocks are used in sill/lintel bands, then the reinforcements shall be taken 25% more than that given in Table 6-1 and may be provided by using four longitudinal bars and 6 mm diameter stirrups. But the reinforcement in these bands need not be more than four number of 12 mm bars.

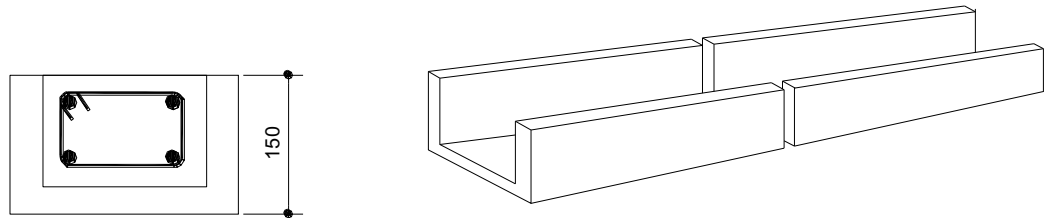


Figure 10-1: U-Blocks for Horizontal Bands

10.2 Vertical Reinforcement

The vertical bars specified in Table 8-1 shall be located conveniently inside the cavities of the hollow blocks, one bar to each cavity. Where more than one bar is planned, these can be located in two or three consecutive cavities, as shown in Figure 10-2. The cavities containing bars are to be filled by using a concrete mix of at least M20 Grade, and are to be properly rodded for compaction.

To avoid the need to lift blocks too high, the bars are made shorter and lapped with upper bars. This is wasteful of steel and has a second disadvantage that the capacity to develop sufficient bond strength in small cavities remains doubtful. To solve this problem, the two alternatives shown in Figure 10-3 may be used:

the use of three sided or U-blocks or slotted blocks bent interlocked bars

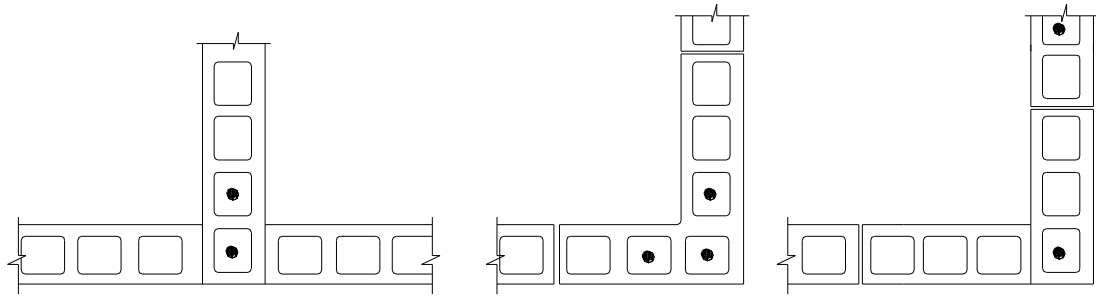


Figure 10-2: Vertical Reinforcement locations in Cavities

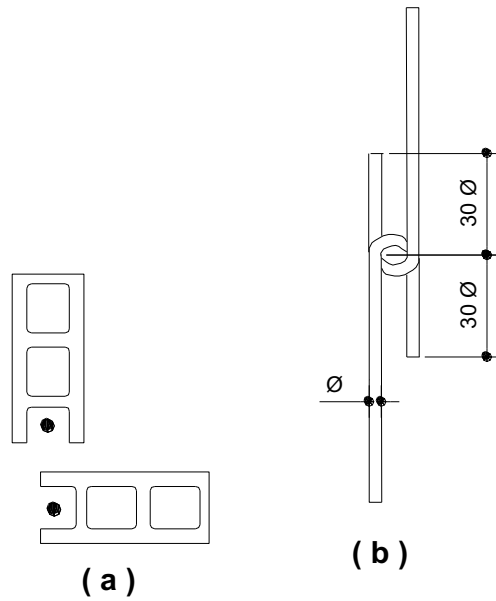


Figure 10-3: Vertical Reinforcement in Cavities

11. General consideration for Stone Masonry Buildings

11.1 Overall Dimensions

The height of stone buildings constructed to this Guideline is restricted to two storeys only. Nevertheless, two-storied buildings with load-bearing stone masonry of random rubble or half-dressed stone are not recommended in soft soil. However, an attic floor may also be used within the building.

The inter-storey height may be kept as low as 2.5 metres, but not more than that specified in Table 1-1. The maximum unsupported length of a wall (long wall) between cross-walls shall be limited 4.5 metres. For longer walls, buttresses shall be used at intermediate points not further apart than three metres. Each buttress shall have a minimum thickness equal to the thickness of wall it supports, base width not less than one-sixth of the wall height and top width not less than the thickness of the wall it supports.

11.2 Foundation for Stone Masonry

The foundation for stone masonry walls shall follow clause 4, clause 5.2 and Figure 1-1.

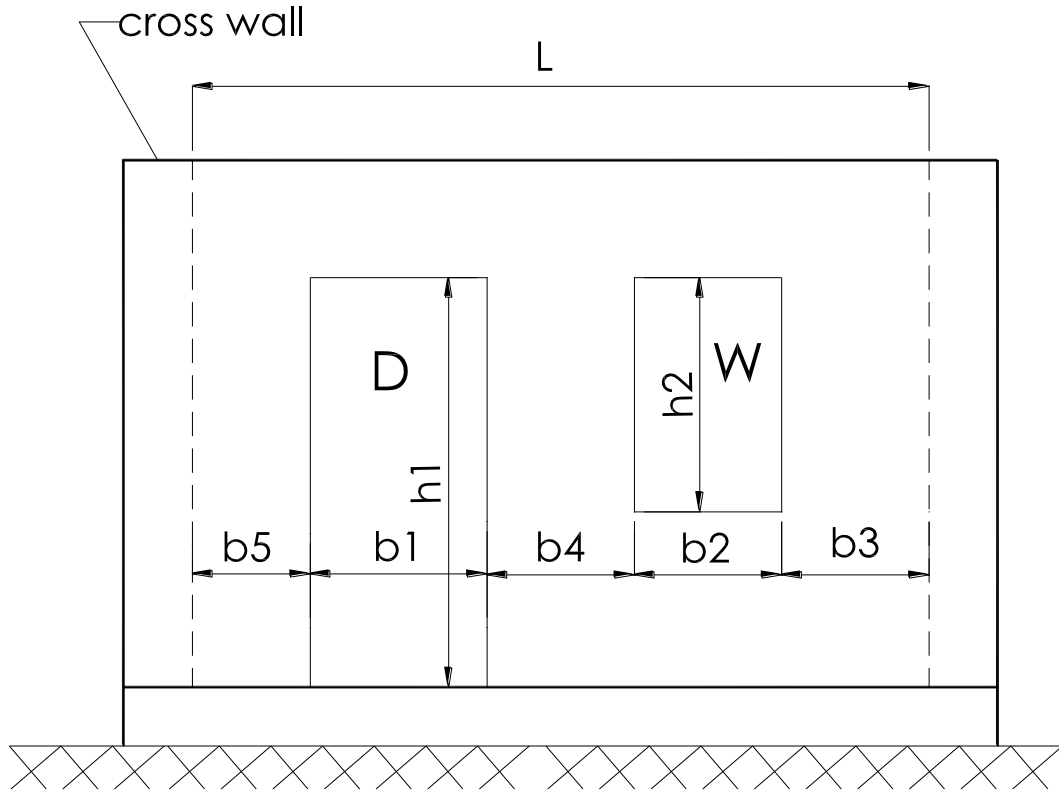
11.3 Openings in Walls

Openings should be as small and as centrally located as practicable. The required limits on opening size are shown in Figure 11-1. Ventilators, where used, shall be 450 x 450 mm or smaller.

Tops of openings in a storey should preferably be at the same level, so that a continuous horizontal band can be provided over them that includes the lintels throughout the building.

The horizontal distance between two openings shall not be less than one-half of the height of the shorter opening.

The vertical distance between openings one above the other shall not be less than 600 mm.



Note:

$$b_1 + b_2 \leq 0.3L$$

$$b_4 \geq 0.5h_2 \text{ but not less than } 600\text{mm}$$

$$b_5 \geq 0.25h_1 \text{ but not less than } 600\text{mm}$$

$$b_3 \geq 0.25h_2 \text{ but not less than } 600\text{mm}$$

D = Door

W = Window

Figure 11-1: Recommended Openings in Load-Bearing Rubble Masonry

11.4 Masonry Bond

Random rubble masonry construction should be constructed in lifts of not more than 600 mm.

Through-Stones of a length equal to the full wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally. If full-length stones are not available, pairs of stones, each not less than three-quarters of the wall thickness long shall be used in place of one full-length stone so as to provide an overlap between them (see Figure 11-2 and Figure 11-3).

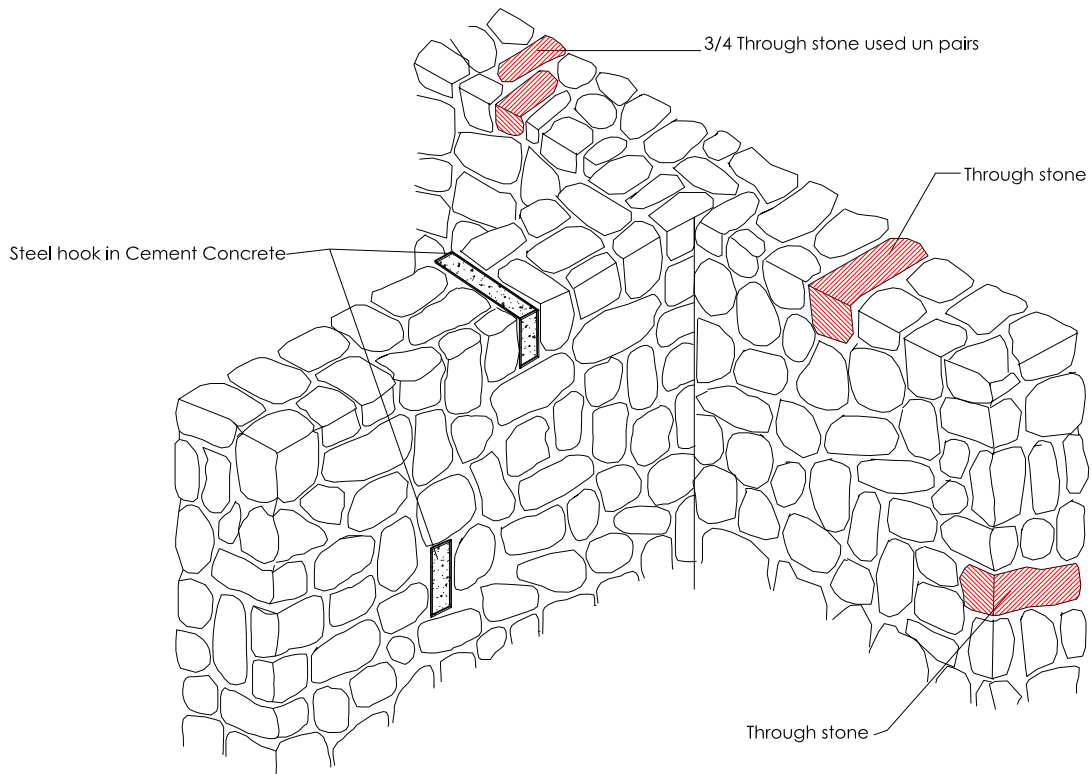


Figure 11-2: Random Rubble Masonry with Through-Stones or other bonding elements

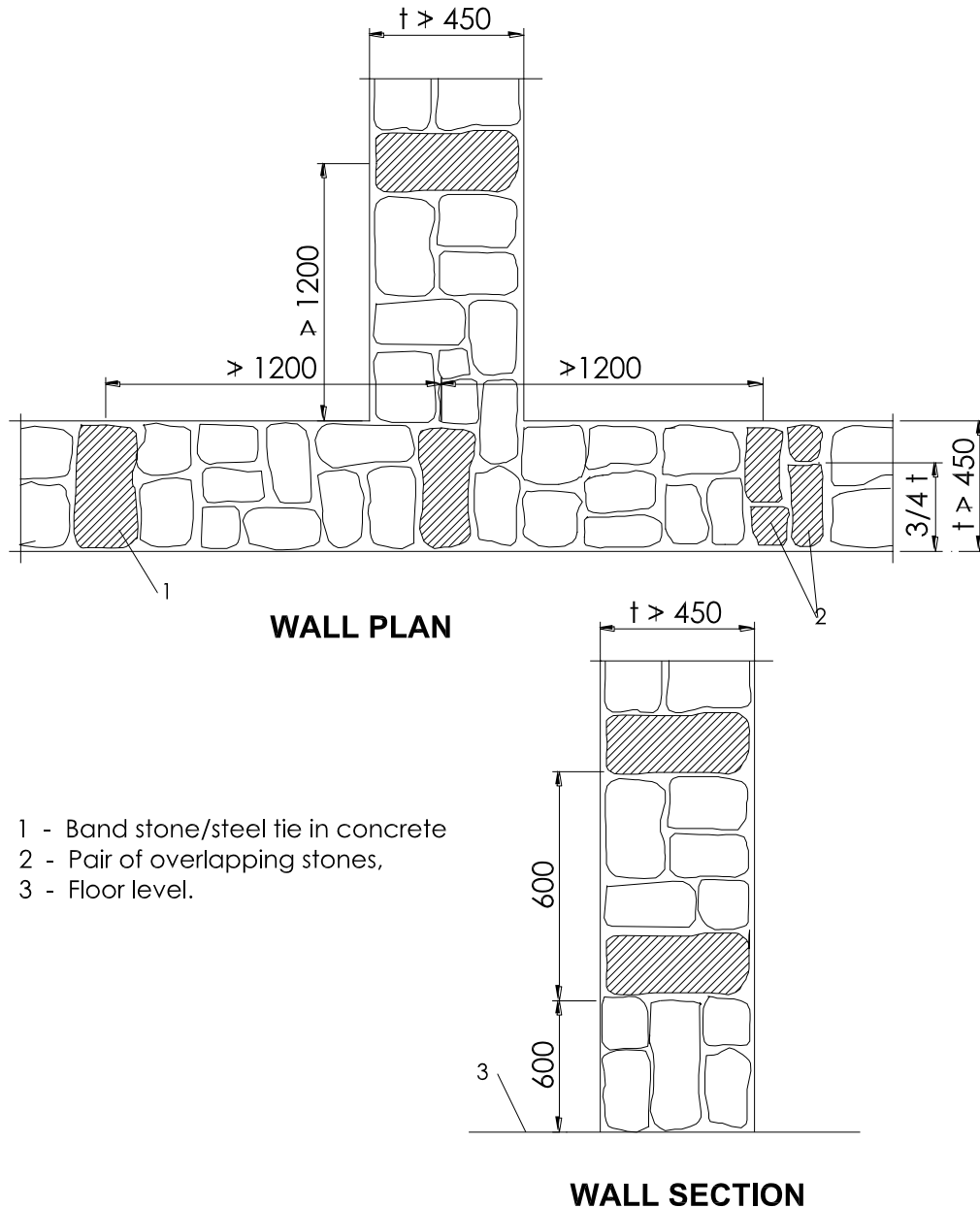
Alternatively, steel hooked link or S-shaped tie can be used by embedding it in cement-concrete mix of at least M20 Grade with minimum thickness of 75 mm. Long stones shall also be used at corners and junctions of walls to break the vertical joint pattern and to provide bonding between adjacent walls.

11.5 Mortars and Concrete

Where steel reinforcing bars are provided, the bars shall be embedded in cement-concrete mix not leaner than M20 Grade. Mortars used for stone masonry shall not be leaner than 1:6.

11.6 Horizontal Reinforcement in the Walls

All the horizontal reinforcing recommended in clause 6 (recommended for brick masonry) shall be used for random rubble construction as well.

**NOTE:**

If bond stone is not available then steel bar 8 mm diameter embedded in M20-grade concrete in the stone wall can be provided.

Figure 11-3: 'Through Stones' or Bond Elements

11.7 Vertical Reinforcement in Walls

The amount of vertical reinforcement required to be provided in masonry walls at the corners and T-junctions and at jambs of openings is shown in

Table 11-1

.....
Ganesh Karmacharya Engineer	Parikshit Kadariya SDE	Mani R. Gelal DDG	Ramesh Pd. Singh DG	Arjun K. Karki Secretary

Table 11-1: Required Vertical Steel at Critical Sections for Stone Masonry

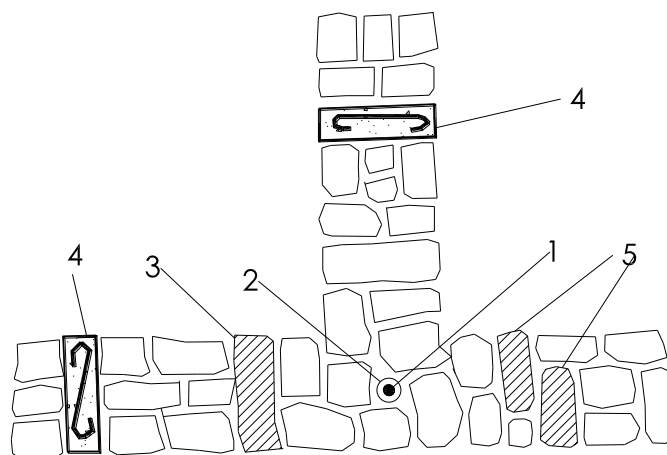
No of Storey	Floor	Dia. of single Fe-415 bars at each at:	
		Critical section	Jamb of opening
One	Ground	12	12
Two	First	16	12
	Ground	16	12

Notes: High strength deformed bars-Fe500 or High strength deformed bars-Fe415 as per section 2.2 shall be used as vertical reinforcement

Two-storied buildings with load-bearing stone masonry of random rubble or half-dressed stone are not recommended in soft soil.

The installation of a vertical bar in stone masonry can easily be executed by using about 750mm long and 75 mm diameter pipe casing around which the masonry is built to a height of 600 mm. The pipe is kept loose by rotating it during masonry construction. Then the casing is raised up and the cavity filled around the bar with concrete of M20 grade as shown in figures 17.1 and 17.2. The concrete will not only provide a bond between the steel and the masonry, but it will also protect the bar from corrosion.

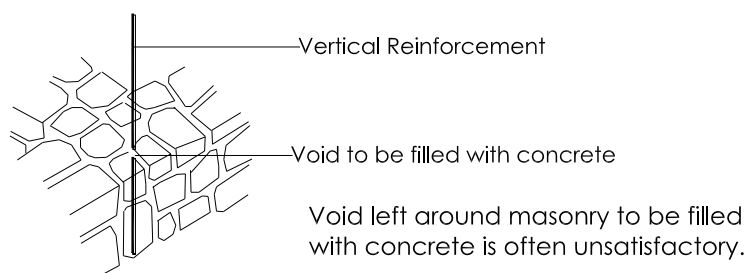
The jamb steel shall be taken from the footing up to the lintel band (or roof band) and anchored into it.



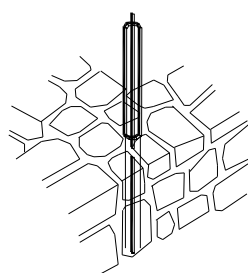
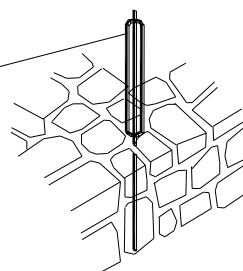
WALL PLAN

- Vertical steel bar, 2 - Casing pipe, 3 - through stone,
4 - steel hook/tie in M20 grade cement concrete,
5 - Over lapping pair of stones.

Figure 11-4: Vertical Steel in Random Rubble Masonry



75 mm. Ø Int.dia. and
about 75 cm. long pipe sleeve



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

1. Place pipe sleeve around reinforcement.
2. Build masonry around the pipe sleeve.
3. Lift the pipe sleeve leaving hollow in masonry.
4. Fill the void with mixed concrete made with coarse aggregate of 10 mm.
5. Repeat process.

Figure 11-5: Vertical Reinforcement in Rubble Stone Masonry