Chapter 6

WOODEN BUILDINGS

6.1 INTRODUCTION

Wood has higher strength per unit weight and is, therefore, very suitable for earthquake resistant construction. But heavy cladding walls could impose high lateral load on the frame. Although seismically suitable, use of timber is declining in building construction even where it used to be the prevalent material on account of vanishing forests due to population pressure. The situation in many countries of the world has in-fact become rather alarming on account of the ecological imbalance. Hence use of timber must be restricted in building construction for seismic strengthening of other weaker constructions such as adobe and masonry. Timber buildings may only be used in those areas and countries where it is still abundantly available or in unavoidable situations only.

6.2 TYPICAL DAMAGE AND FAILURE OF WOODEN BUILDINGS

The typical features of earthquake damage to wooden buildings are as follows:

(i) Roof tiles easily slide down during earthquakes, if they are not properly fastened to the roof. Falling roof tiles may hurt people, *Fig* 6.1.

(ii) The failure of the joints connecting columns and girders frequently occurs, accompanying the falling of finishings. As the inclination of the building increases, its restoring force against distortion decreases due to the structural deterioration and roof weight, and finally becomes negative which results in the complete collapse of the building, *Figs* 6.2 and 6.3.

(iii) In the case of two storey buildings, the first storey usually suffers severer damage than the second storey. It is often seen that the first storey falls

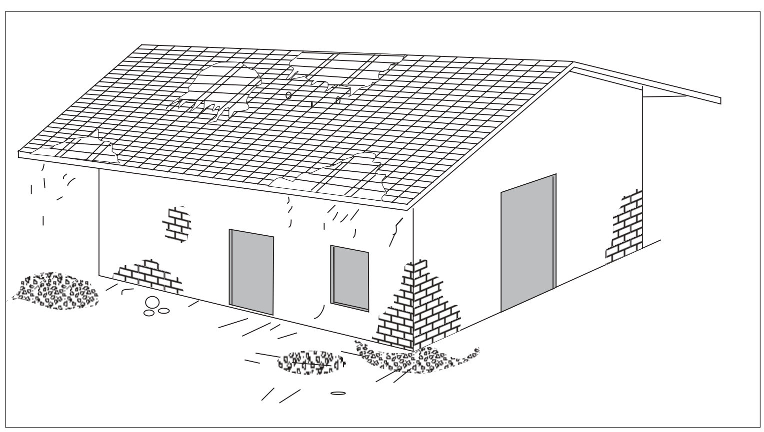

Fig 6.1 Falling of roof tiles

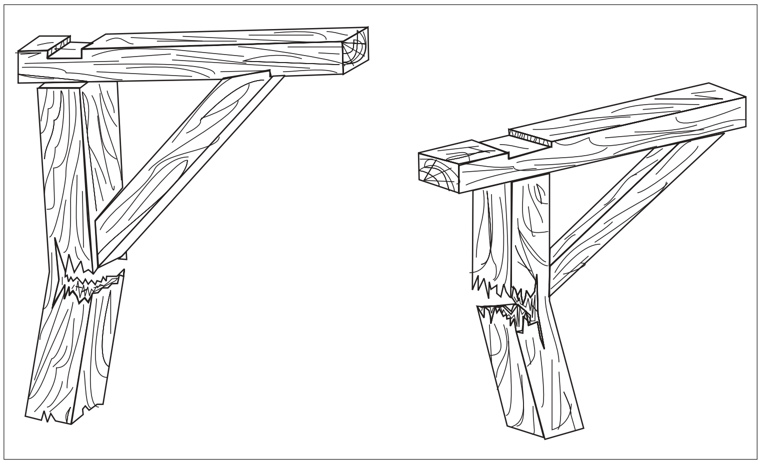

Fig 6.2 Rupture of columns at the connection of knee brace and column

down while the second storey is undamaged, *Fig* 6.4.

(iv) Damage is considerably influenced by the ground condition on which the building stands. In general, the softer the subsoil, the severer the damage to the building.

The damage due to differential settlements of foundations is also observed for buildings on soft ground.

Furthermore, the damage due to the liquefaction of subsoil occurs to buildings on saturated soft sand.

(v) Sliding of the building as a whole is sometimes seen when there are no anchor bolts connecting the sill to the foundation, *Fig* 6.5.

The damage to superstructure is also observed when the foundation cannot resist the lateral force caused by earthquake motion.

(vii) Other types of damage in wooden buildings are failure of wooden gable frames, *Figs* 6.6*(a)* and *(b)*, and failure due to rupture of bottom chords of roof truss, *Figs* 6.7*(a)* and *(b)*.

(viii) The most crucial destruction of wooden buildings has been due to fire resulting from electrical short-circuiting or kitchen fires during the earthquake shaking and spreading into conflagration thereafter. Precautions against fire are most important in case of wooden buildings.

6.3 TYPICAL CHARACTERISTICS OF WOOD

Though wood has higher strength per unit weight than most other construction materials, it has the following peculiarities that are not seen in other materials.

(i) It is a non-homogeneous and anisotropic material showing different characteristics not only in different directions but also in tension and compression.

(ii) Shrinkage of wood on drying is relatively large. Particularly the joints slack easily by the contraction in the direction perpendicular to fibres. Therefore dry wood shall be used,

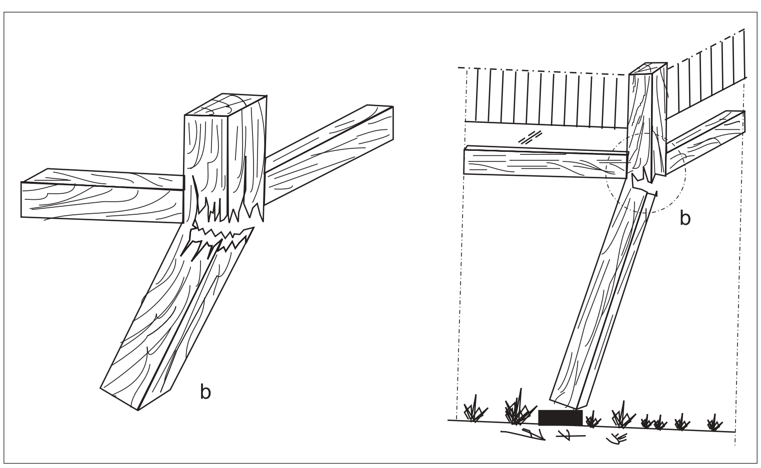

Fig 6.3 Rupture of columns due to large notching at the connection of girder and column

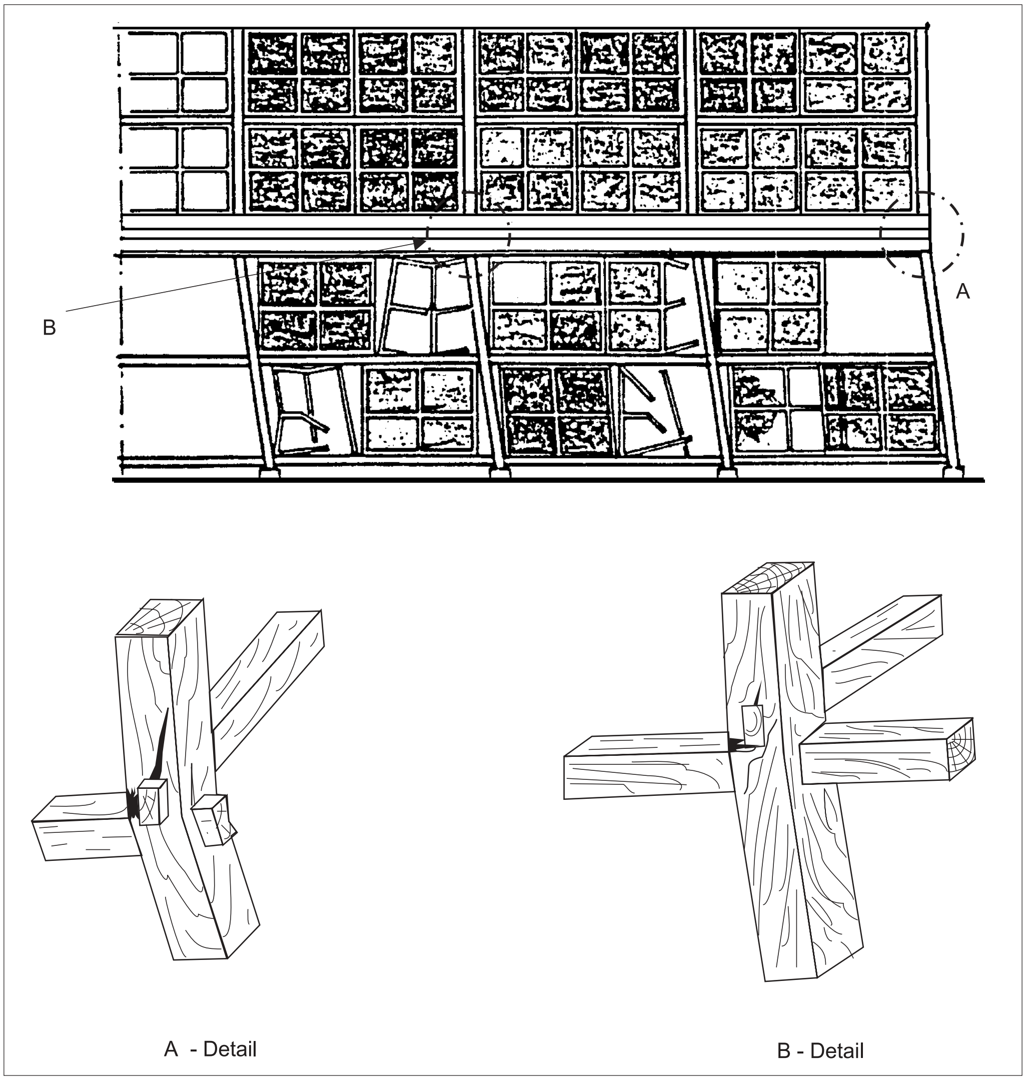

Fig 6.4 Damage of a building having no diagonal bracing

and the moisture content should be less than 20%.

(iii) The elastic modulus is small. Consequently, members are apt to show large deformation.

(iv) A notable creep phenomenon is seen due to permanent vertical loads. This is important especially in snowy area.

(v) Sinking occurs by compressive force in the direction perpendicular to fibers. This has a great influence to the amount of deformation of horizontal members and chord members

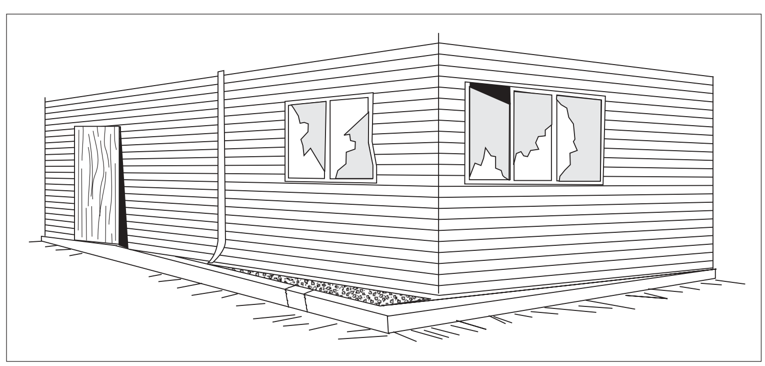

Fig 6.5 Slide due to insufficient connection between sill and footing

of built-up members.

(vi) The defects and notches of wood influence greatly the strength and stiffness. Consequently it is necessary to select and to arrange structural members considering their structural properties.

(vii) Wood is easily decayed by repeated changes of moisture. Therefore seasoned wood should be used in construction.

(viii) Preservative treatment is necessary to avoid rotting and insect attack on timber so as to derive long life.

(ix) Wood is a combustible material. Therefore precautions must be taken to minimize the danger of fire.

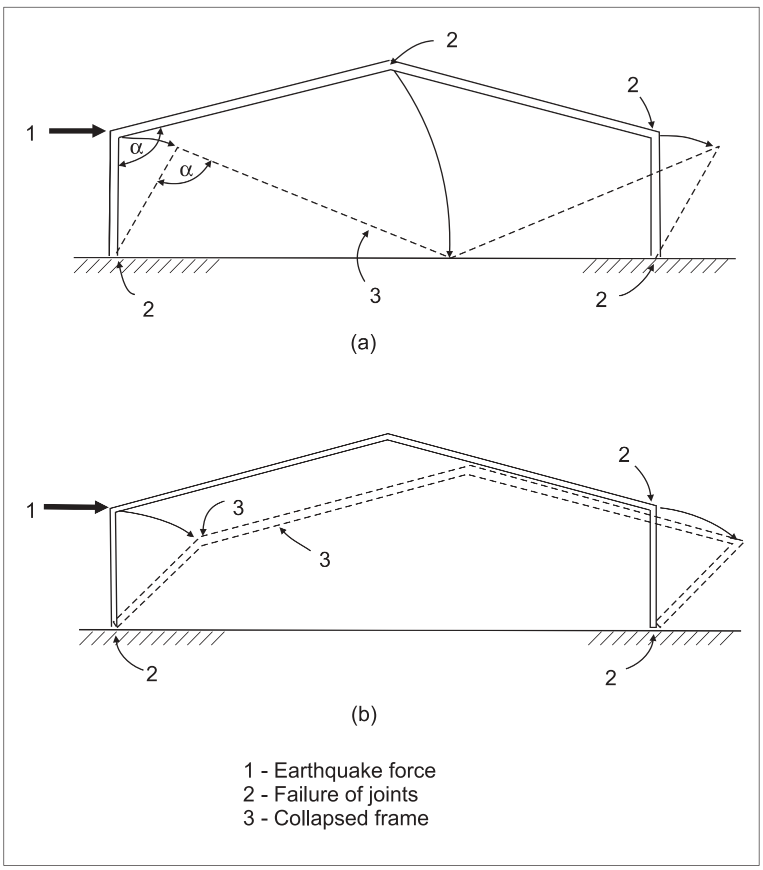

Fig 6.6 Failure modes of gable frame

(x) Long lengths more than 3.5 m and large size timbers are difficult to obtain, hence call for splicing through connectors or gluing.

In view of its lightness, very easy workability like cutting and nailing and safe transportability, timber makes an excellent material for post-earthquake relief and rehabilitation construction.

6.4 TYPICAL STRUCTURAL PROPERTIES

There are large varieties of timbers in use in various countries. It will therefore not be practicable to present their strength properties here. But it will be pertinent to mention that these depend on a number of factors as follows:

(i) Wood specy

(ii) Direction of loading relative to grain of wood

(iii) Defects like knots, checks, cracks, splits, shakes and wanes

(iv) Moisture content or seasoning

(v) Sapwood, pith, wood from dead trees and dried wood conditions

(vi) Location of use, *viz* inside protected, outside, alternate wetting and drying.

The permissible stresses must be determined taking all these factors into account. *Table* 6.1 gives typical basic stresses for timbers placed in three groups A, B and C classified on the basis of their stiffness. It will be reasonable to increase the normal permissible stress by a factor of 1.33 to 1.5 when earthquake stresses are superimposed.

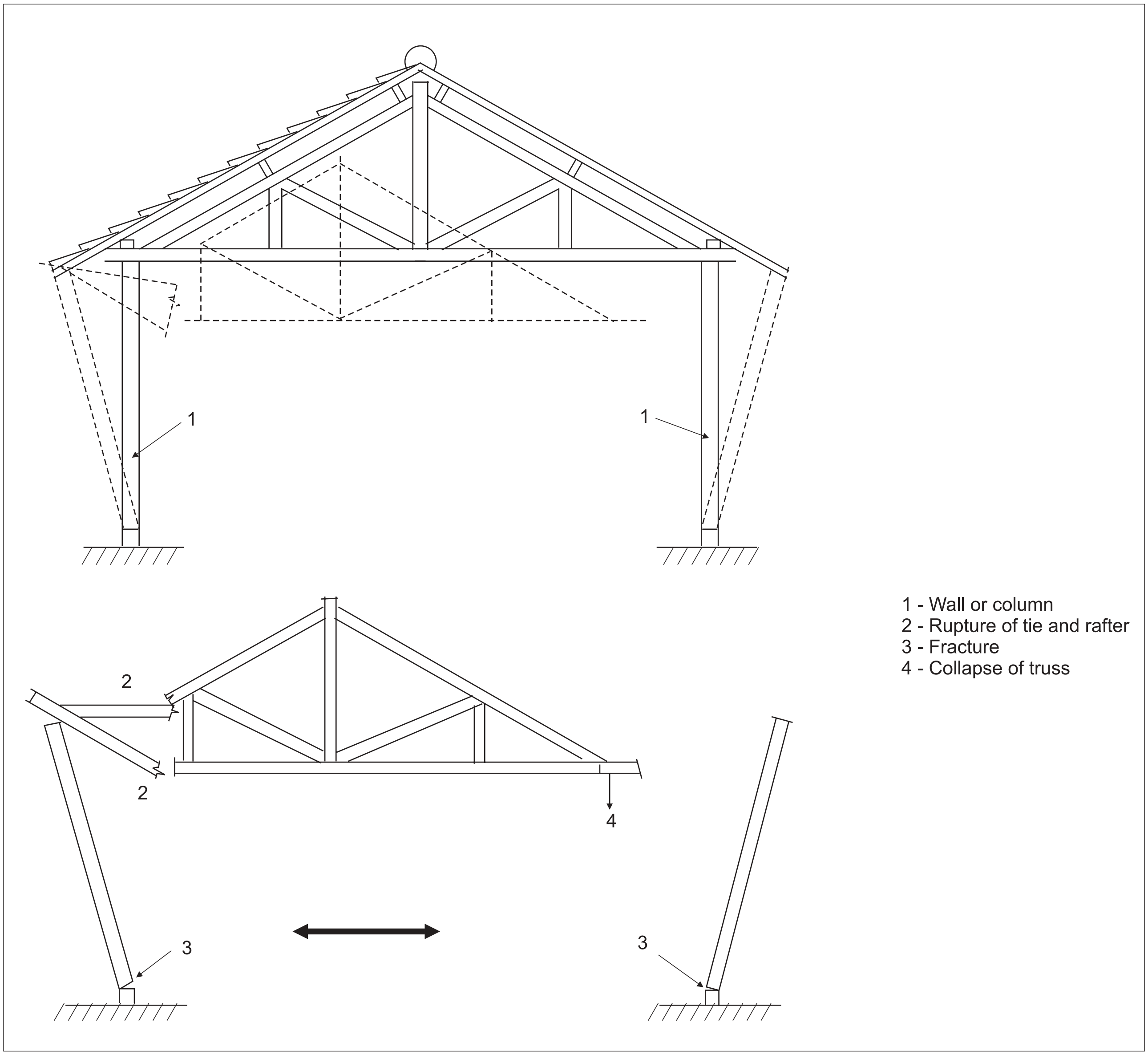

Fig 6.7 Failure due to rupture of bottom chord of roof truss

6.5 THE BUILDING PLAN

The plan of the building should be surrounded and divided by bearing wall lines. The maximum spacing of the bearing wall lines is 8 m. The maximum width of openings in the bearing wall lines is 4 m and the opening is at least 50 cm away from the corner. Adjacent openings should be at least 50 cm apart, *Fig* 6.8.

All bearing wall lines of the lower storey should be supported by continuous foundations, through sills or the columns should rest on pedestals, for details see section 6.9. All bearing wall lines of the upper storey should be supported by the bearing wall lines of the lower storey. The bearing walls may have stud wall type or brick-nogged type construction as detailed in section 6.6 and 6.7 respectively. The height of

Table 6.1 Basic permissible stresses for timber group*

Types of stress	Location	Permissible stress, MPa Group A	Group B	Group C
(i) Bending and tension along grain	inside	18	12	8
	outside	15	10	7
	wet	12	8	6
(ii) Shear in beams	all	1.2	0.9	0.6
shear along grains	all	1.7	1.3	0.9
(iii) Compression parallel to grain	inside	12	7	6
	outside	11	6	6
	wet	9	6	5
(iv) Compression perpendicular to grain	inside	6	2.2	2.2
	outside	5	1.8	1.7
	wet	4	1.5	1.4

* Based on Indian Standard IS:883.

Note: Group A, B and C are classified according to Young's modulus of elasticity as follows:

group A more than 12,600 MPa.

group B more than 9,800 to 12,600 MPa.

group C 5,600 to 9,800 MPa.

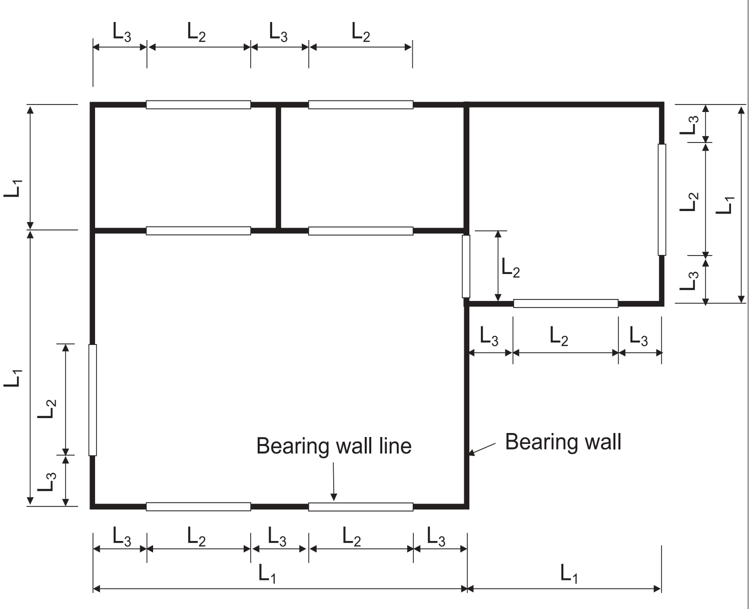

Fig 6.8 Plan divided by bearing wall lines

the building will be limited to two storeys or two storeys plus attic.

6.6 STUD WALL CONSTRUCTION

The stud-wall construction consists of timber studs and corner posts framed into sills, top plates and wall plates. Horizontal struts and diagonal braces are used to stiffen the frame against lateral loads due to earthquake and wind. The wall covering may consist of matting made from bamboo, reeds, and timber boarding or the like. Typical details of stud walls are shown in *Fig* 6.9.

If the sheathing boards are properly nailed to the timber frame, the diagonal bracing may be omitted. The diagonal bracing may be framed into the verticals, or nailed to the surface. Other details are given below:

Sill

The dimension of sill is kept 40 × 90, 90 × 90 (mm units) or larger. The sill is connected to the foundation by anchor bolts whose minimum diameter is 12 mm and length 35 cm. The anchor bolts are installed at both sides of joints of sills and at the maximum spacing is 2 m.

Studs

The minimum dimension of studs is 40 mm × 90 mm. The maximum spacings of these studs are shown in *Table* 6.2. If 90 mm × 90 mm studs are used the spacing may be doubled. Storey height should not be more than 2.70 m.

Top plates

The top of studs is connected to top plates whose dimension is not less than the dimension of the stud.

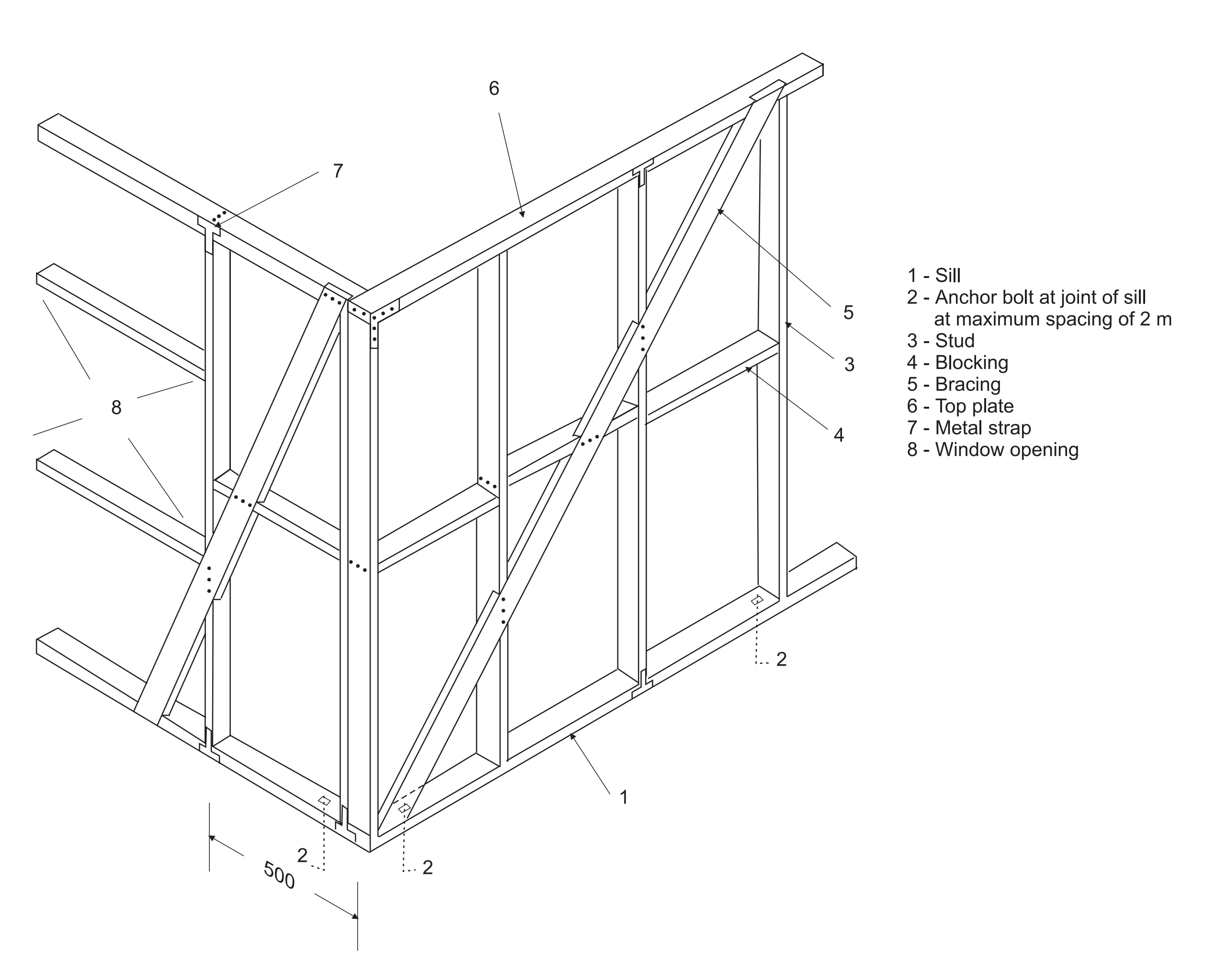

Figure 6.9 Stud-wall construction

Bearing walls

Wall framing consisting of sills, studs and top plates should have diagonal braces, or sheathing boards so that the framings acts as bearing walls. In case no sheathing boards are attached, all studs should be connected to the adjacent studs by horizontal blockings at least every 1.5 m in height, *Fig* 6.9.

The minimum dimension of braces is 20 mm × 60 mm. The brace is fastened at both ends and at middle portion by more than two nails whose minimum length is 50 mm to the framing members. The sheathing board is connected to the framing members by nails whose minimum length is 50 mm and maximum spacing is 150 mm at

Table 6.2 Maximum spacing of 40 mm × 90 mm finished size studs in stud wall construction

Group of timber	*Single storeyed or first floor of double storeyed buildings*		*Ground floor of double storeyed buildings*	
	exterior wall, mm	*interior wall, mm*	*exterior wall, mm*	*interior wall, mm*
A	1000	1000	500	500
B and C	1000	800	500	500

Notes: Group of timber defined in *Table* 6. 1

Table 6.3 Minimum finished size of diagonal braces

*Category**	*Group*** *timber*	*Single storeyed or first floor of double storeyed buildings*		*Ground floor of double storeyed buildings*	
		exterior wall, mm × mm	*interior wall, mm × mm*	*exterior wall, mm × mm*	*interior wall, mm × mm*
I and II	A	20 × 60	20 × 60	20 × 90	20 × 90
	B and C	20 × 60	20 × 60	20 × 90	20 × 90
III and IV	A, B and C	20 × 60	20 × 60	20 × 60	20 × 60

Notes: *Categories of construction defined in *Table* 3.1.

**Group of timber defined in *Table* 6.1.

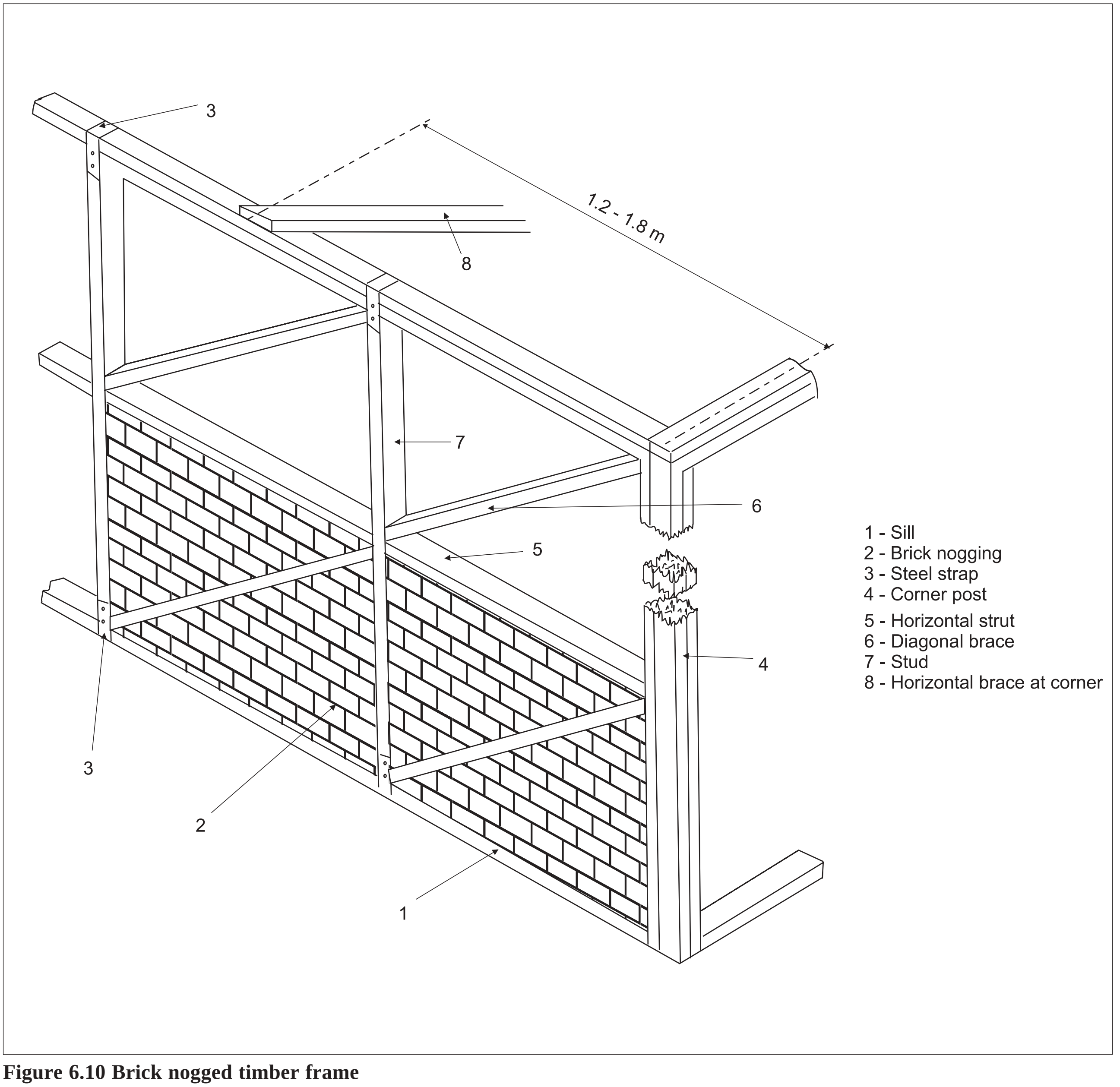

Figure 6.10 Brick nogged timber frame

Fig 6.11 Foundation and foundation reinforcement in concrete

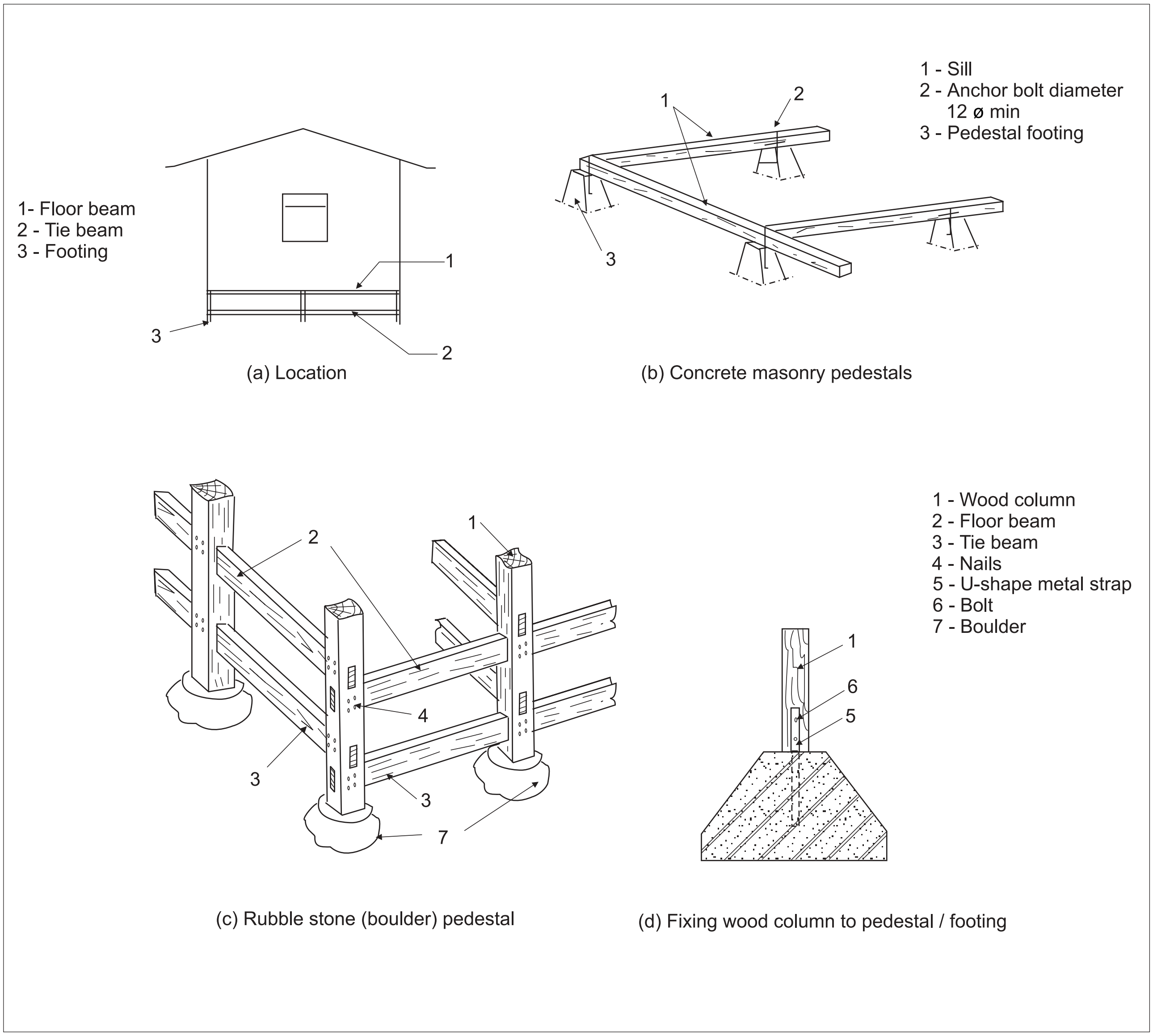

Figure 6.12 Wooden column footings

the fringe of the board and 300 mm at other parts.

6.7 BRICK NOGGED TIMBER FRAME

The brick nogged timber frame consists of intermediate verticals, columns, sills, wall plates, horizontal nogging members framed into each other. Diagonal braces may also be framed with the verticals or nailed or bolted on the faces. The space between framing members is filled with tight fitting brick or dressed stone masonry in stretcher bond.

Typical details of brick nogged timber frame construction are shown in *Fig* 6.10. The vertical framing members in brick nogged bearing walls should have minimum finished sizes as specified in *Table* 6.4. The sizes of diagonal bracing member should be the same as in *Table* 6.3. The hori-

Table 6.4 Minimum finished sizes of verticals in brick nogged timber frame construction

Spacing (m)	*Group of timber*	*Single storeyed or first floor of double storeyed buildings*		*Ground floor of double storeyed buildings*	
		exterior wall, mm × mm	*interior wall, mm × mm*	*exterior wall, mm × mm*	*interior wall, mm × mm*
1.0 m	A	50 × 100	50 × 100	50 × 100	70 × 100
	B and C	50 × 100	50 × 100	70 × 100	90 × 100
1.5 m	A	50 × 100	70 × 100	70 × 100	80 × 100
	B and C	70 × 100	80 × 100	80 × 100	100 × 100

Notes: Groups of timber are defined in *Table* 6. 1

zontal framing members in brick construction should be spaced not more than one meter apart. Their minimum finished sizes are recommended in *Table* 6.5.

Table 6.5: Minimum finished sizes of horizontal nogging members

Spacing of verticals, m	*Size, mm × mm*
1.5	70 x 100
1.0	50 x 100
0.5	25 x 100

6.8 JOINTS IN WOOD FRAMES

The joints of structural members should be firmly connected by nails or bolts. The use of metal straps is strongly recommended at structurally important joints such as those of studs/columns with sill or wall plates and with horizontal nogging members.

6.9 FOUNDATIONS

The superstructure should be supported by concrete or masonry footings as shown in *Fig* 6.11. Openings for ventilation need be provided in continuous foundations, *Figs* 6.11*(a)* and *(b)*. Some reinforcement as shown is also preferable in very soft soil areas and in areas where liquefaction is expected. On firm soil, isolated footings or boulders can also be used under the wood columns as shown in *Fig* 6.12.

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