Chapter 5

STONE BUILDINGS

5.1 INTRODUCTION

Stone buildings using fully dressed rectangularized stone units, or cast solid blocks consisting of large stone pieces in cement concrete mix 1:3.6 may be built according to the details given in Chapter 4. Those also generally apply to the random-rubble and half -dressed stone buildings except such details as are dealt with in this Chapter.

5.2 TYPICAL DAMAGE AND FAILURE OF STONE

Buildings Random rubble and half -dressed stone buildings, *Fig* 5.l, have suffered extensive damage and complete collapse during past earthquakes having intensifies of MSK VII and more.

The following are the main ways in which such buildings are seen to be damaged :

- Separation of walls at corners and T-junctions takes place even more easily than in brick buildings due to poorer connection between the walls.
- Delamination and bulging of walls, that is, vertical separation of internal wythe and external wythe through the middle of wall thickness, *Fig* 5.2. This occurs due mainly to the absence of "through" or bond stones and weak mortar filling between the wythes. In half-dressed stone masonry, the surface stones are pyramidal in shape having more or less an edge contact one over the other, thus the stones have an unstable equilib-

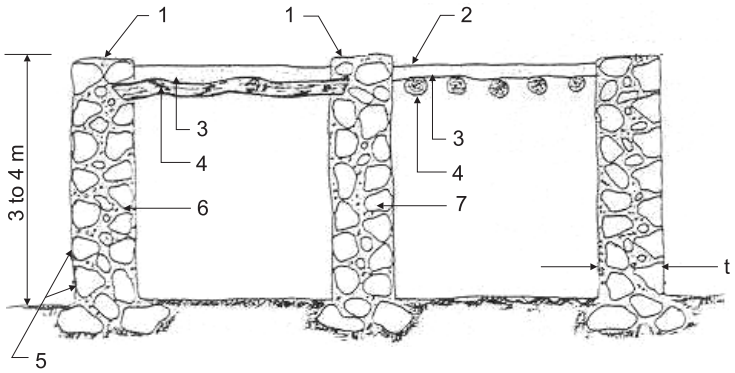

Fig 5.1 Schematic cross-section through a traditional stone house

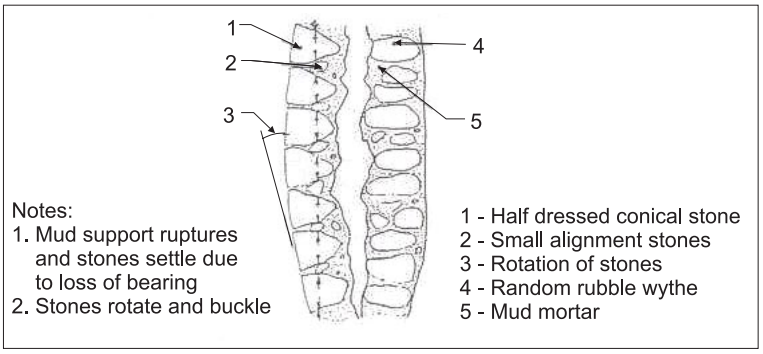

Fig 5.2 Wall delaminated with buckled wythes

rium and easily disturbed under shaking condition.

- Crumbling and collapsing of bulged wythes after delamination under heavy weight of roofs/ floors, leading to collapse of roof along with walls or causing large gaps in walls.
- Outward overturning of stone walls after separation at corners due to inertia of roofs and floors and their own inertia when the roofs were incapable of acting as horizontal diaphragms. This particularly happened when the roof consisted of round poles, reed matting and clay covering.

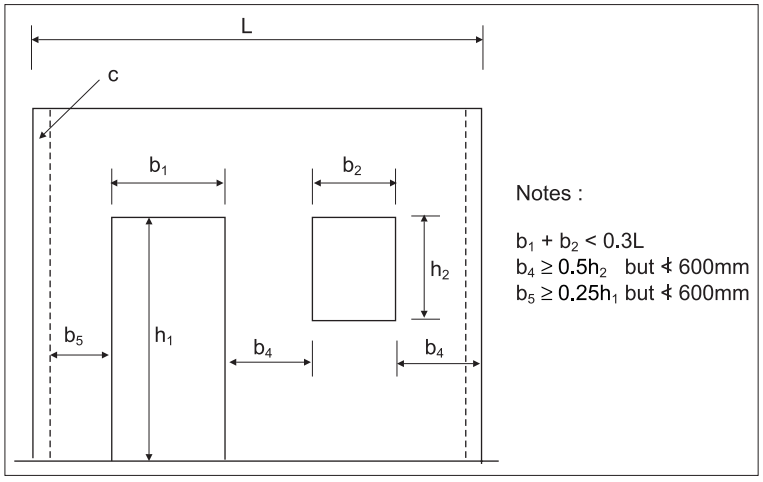

Fig 5.3 Recommended openings in bearing walls in rubble masonry

Frequently, such stone houses, under MSK VII or higher intensifies, are completely shattered and razed to the ground, the walls reduced to only heaps of rubble. People get buried and more often killed. Thus such buildings, without the seismic improvements as suggested here below, can be considered as dangerous particularly in seismic zones defined by Zones A and B in Chapter 3.

5.3 TYPICAL STRUCTURAL PROPERTIES

Test data on the strength characteristics of random rubble and half-dressed stone masonry is not available. It is, however, qualitatively known that the compressive strength even while using clay mud as mortar will be enough to support three storeys but the tensile strength could only be near about zero. Sliding shear strength will only be due to frictional resistance.

5.4 GENERAL CONSTRUCTION ASPECTS

5.4.1 Overall dimensions

- The height of the construction may be restricted to one storey of category I and II buildings and two storeys of categories III and IV buildings. Where light sheeted roof is used, an attic floor may also be used.
- The height of a storey may be kept as low as 2.5 m but not more than 3.5 m.
- The wall thickness should be used as small as feasible, say 300 to 450 mm.
- The unsupported length of a wall between cross walls may be limited to 7 m.

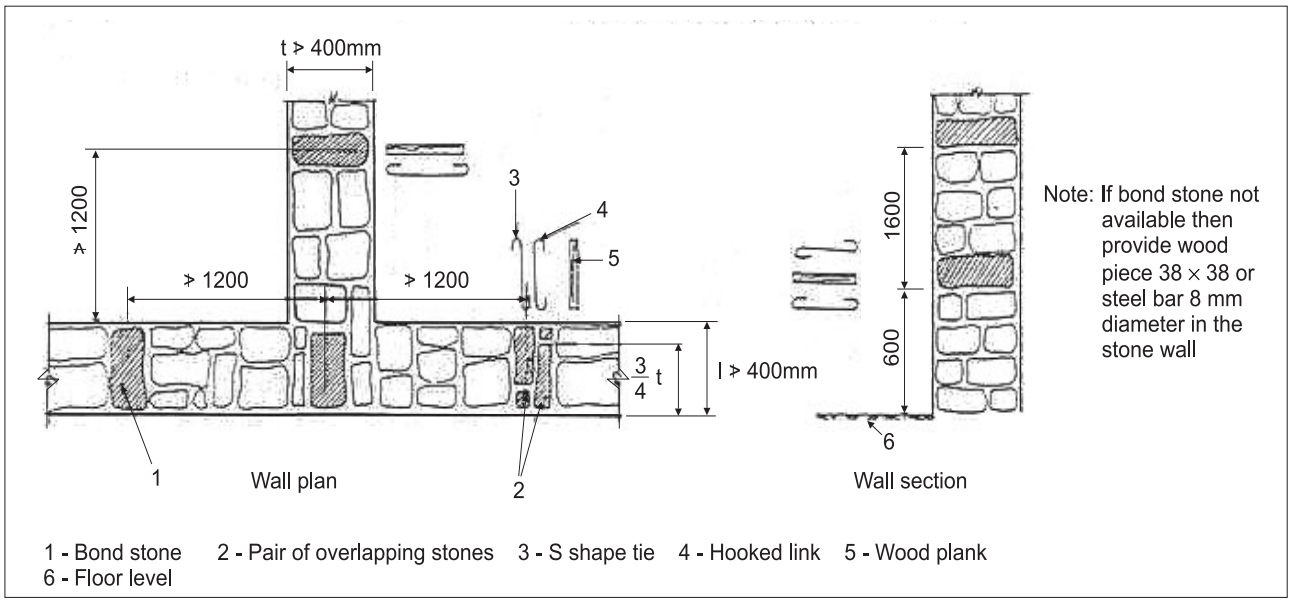

Fig 5.4 "Through" stones or "Bond" elements.

- For longer walls, buttresses may be used at intermediate points not farther apart than 3 m. The size of buttress may be kept as: thickness = top width = t and base width = $h/6$ where, t = thickness of wall and h = actual wall height.

5.4.2 Mortar

- Clay mud mortar should be avoided as far as possible.

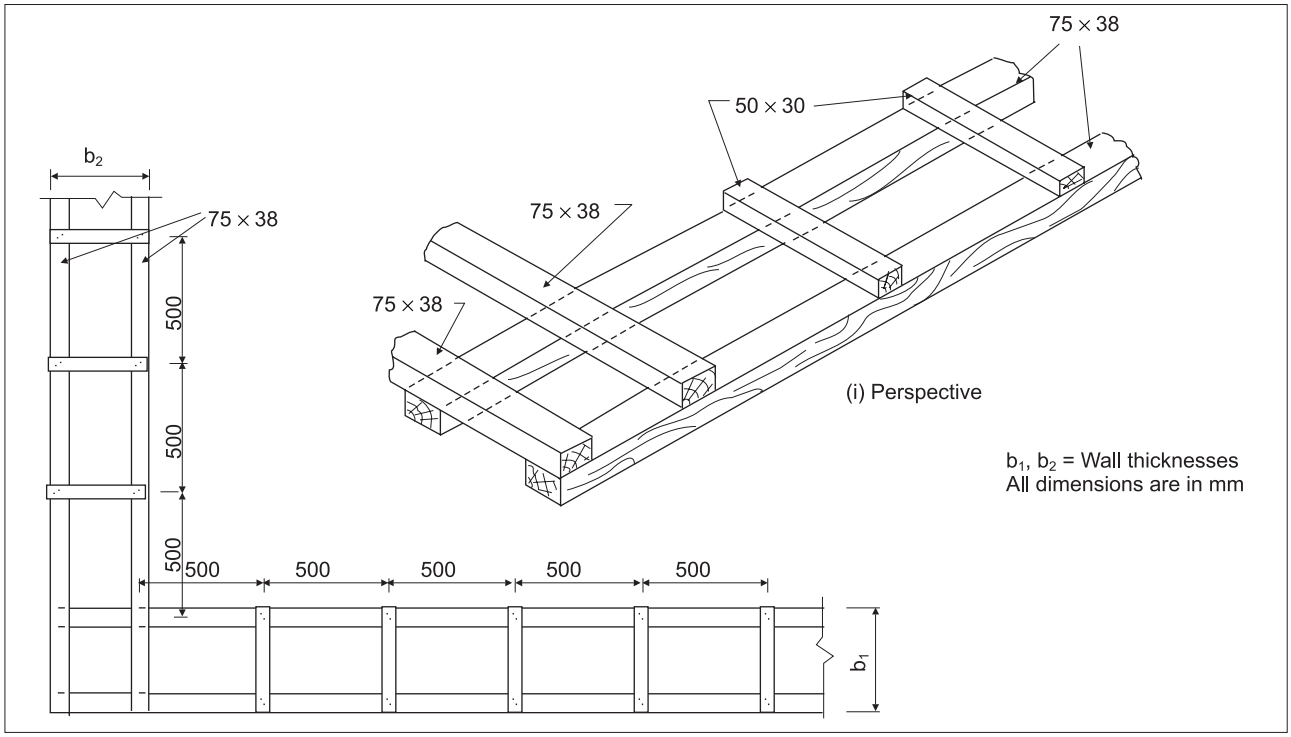

Fig 5.5 Lintel level wooden band on all load bearing walls

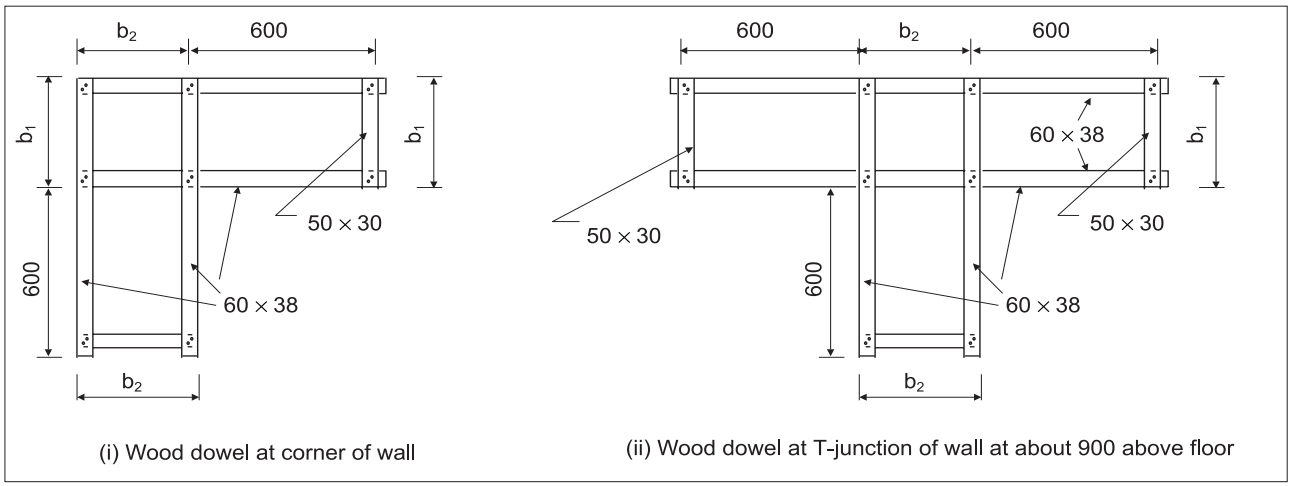

Fig 5.6 Details of wood reinforcing at corners and T-junctions

- Mortars as specified in *Table* 4.4 may be used for stone walls.

5.4.3 Openings in walls

- Openings should be as small and as centrally located as practicable.
- The recommended opening limitations are shown in *Fig* 5.3.

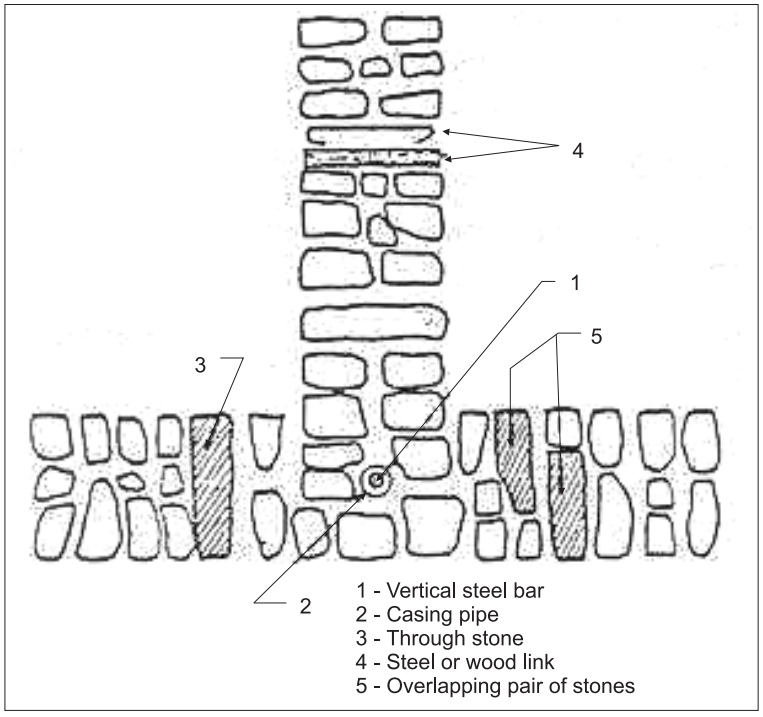

Fig 5.7 Vertical steel in random rubble masonry

- Ventilator, where used, may be made 450 x 450 mm or smaller.

5.4.4 Masonry bond

- Random rubble masonry construction should be brought to courses at not more than 600 mm lift.
- "Through" stones of full length equal to 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, stones in pairs, each of about 3/4 of the wall thickness may be used in place of one full length stone so as to provide an overlap between them, *Fig* 5.4.
- In place of "through" stones, bonding elements of steel bars 8 to 10 mm ϕ in S-shape or as a hooked link may be used with a cover of 25 mm from each face of the wall, *Fig* 5.4.
- Alternatively, wood bars of 38 mm x 38 mm cross-section or equivalent may be used for the "through" stones. Wood should be well preserved through seasoning and

chemical treatment so as to be durable against weathering action and insect attack, *Fig* 5.4.

- Use of long stones should also be made at corners and junction of walls to break the vertical joint and provide bonding between perpendicular walls.

5.4.5 Horizontal reinforcing of walls

All the horizontal reinforcing recommended for brick buildings in Section 4.5.1, 4.5.2 and 4.5.3 may be use for random rubble constructions as well.

As an alternative to steel reinforcing bars, wooden planks of rectangular section, effectively spliced longitudinally and held by lateral members in lattice form may be used where timber is available and also more economical. Recommended sections are shown in *Fig* 5.5 and *Fig* 5.6

5.4.6 Vertical reinforcing of walls

The amount of vertical steel in masonry walls required to be provided at the corners and T-junctions of walls and at jambs of openings is shown in *Table* 5.1.

Table 5.1 Recommended vertical steel at critical sections

No. of storeys	*Diameter of mild steel single bar in mm at each critical section category**		
	category I	*category II*	*category III*
One	20	16	14
Two	**	**	16

Notes: * Category of construction is defined in *Table* 3.1. Equivalent area of twisted grip bars or a number of mild steel bars could be used alternatively, but the diameter should not be less than 12 mm

** Two-storeyed buildings with load bearing stone masonry of random rubble or half-dressed stone type are not recommended in categories I and II.

Buildings of Category IV need not have the vertical steel at all. For providing vertical bar in stone masonry a casing pipe is recommended around which the masonry is built to heights of 600 mm, *Fig* 5.7. The pipe is kept loose by rotating it during masonry construction. Then the casing pipe is raised and the cavity below is filled with 1:2:4 concrete mix and rodded to compact it. The concrete will not only provide the bond between the bar and the masonry but will also protect the bar from corrosion.

The jamb steel may be taken from the footing upto the lintel band and anchored into it. The corner steel must be taken from the footing upto the roof slab or roof band and anchored into it.

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