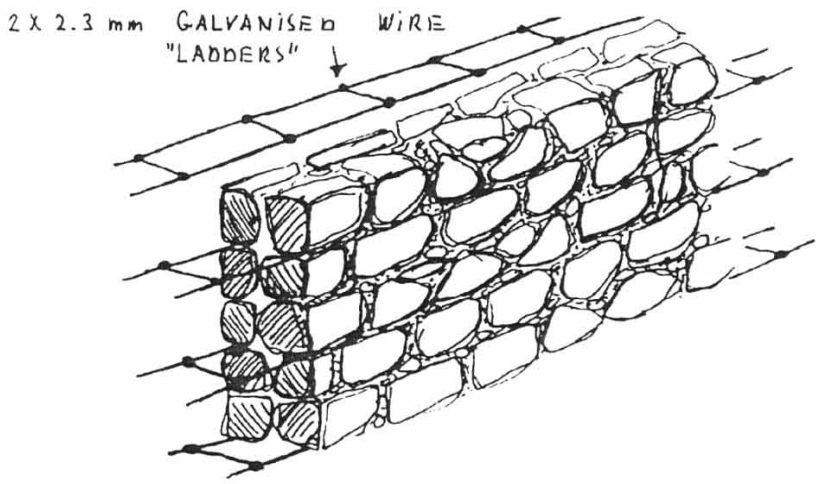

FIGURE 7. STRESS REINFORCEMENT IN THE LENGTH DIRECTION OF STONE MASONRY WALLS

The better the stress reinforcement is adhered to the wall and distributed over the height of the wall, the better the wall will resist shear forces. The hot-dip galvanised wire-mesh reinforcement from BACIP is placed in every other layer (on average 12" per two courses), thus providing a good distribution of the stress resistance inside the wall in two directions. Nine cross-ties are provided per square yard of wall surface.

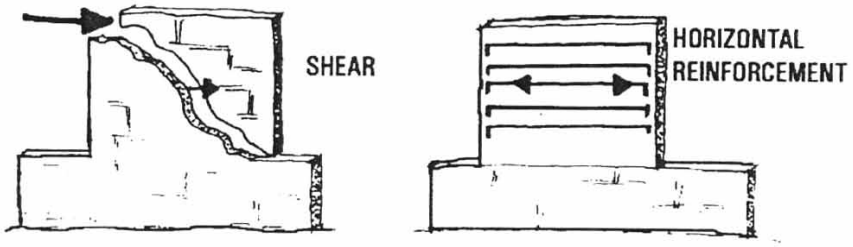

FIGURE 8. FAILURE AND REINFORCEMENT OF SHEAR WALL SECTIONS

Small wall sections (shear walls) that receive strong forces in the length direction of the wall will crack diagonally. To avoid these cracks, horizontal reinforcements crossing the areas where these cracks can occur is the best reinforcement. The horizontal reinforcement in the field of the wall is more than three times as effective as a vertical reinforcement placed across those diagonal cracks. Vertical reinforcement needs to bend first after the wall has been broken, whereas the horizontal reinforcement will be stressed immediately in the length direction of the wires.

Reinforcement in the Height of the Wall in Small Wall Sections

When wall sections become small or slim, such as is the case alongside doors and wall endings, they tend to topple over and cause stress forces alongside their openings. The drawing below demonstrates the effect. To counter these forces, vertical reinforcement needs to be placed alongside these doors and windows.

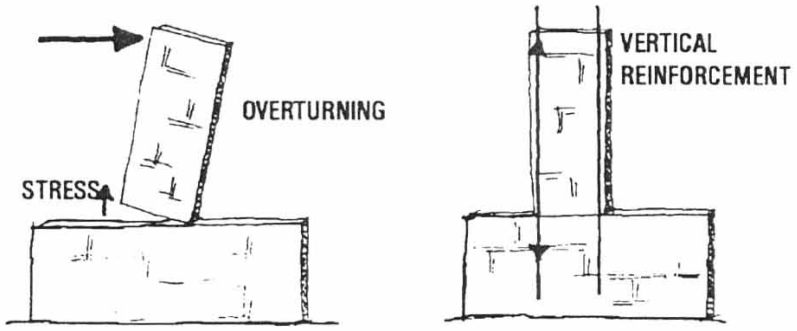

FIGURE 9. TOPPLING OVER OF SMALL WALL SECTIONS AND NEED FOR VERTICAL REINFORCEMENT

The vertical reinforcement is placed inside the C-shaped cement blocks, which also provide for a straight lining of the same door and window frames. As the vertical wall segments become more slender, the steel section of the vertical reinforcements should increase. The best way to obtain a good connection between the horizontal and vertical wall reinforcement is to bend the horizontal reinforcement upwards at the extremes of the wall opening. When there is a 2-ft. overlap between the vertical wires, the reinforcement "ladders" from the various courses together can create the required vertical steel section. The combination of the above principles of wall reinforcement indicates that small shear wall sections need to be fully framed along their four outside borders.

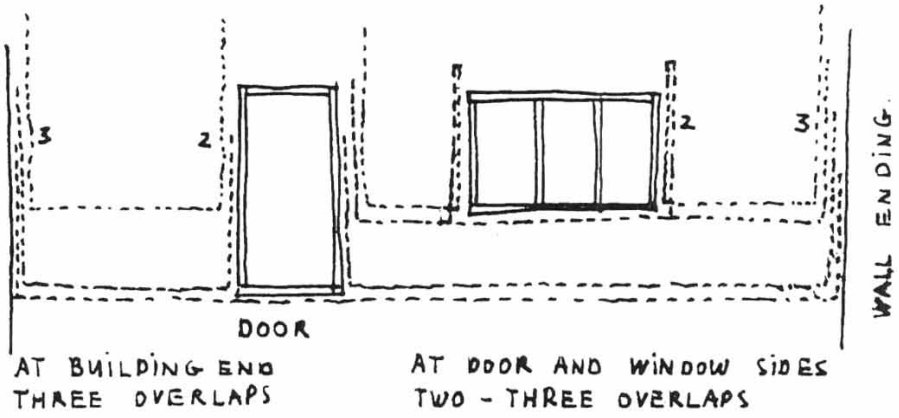

FIGURE 10. RECOMMENDED REINFORCEMENT PATTERN FOR SHEAR WALL SECTIONS

For alongside doors and windows, a minimum of two vertical "ladders" will be required.
For wall-piers that are wider than their height, two "ladders" will be adequate.
For wall-piers smaller than their height, three vertical reinforcement "ladders" are recommended.
At the end walls and cross-sections of walls, three "ladders" will be required vertically.

The shear wall sections need to be reinforced along the vertical sides, whereas the vertical reinforcement needs to be connected to the horizontal reinforcements.

The following four diagrams show the effect of the strengthening of horizontal and vertical reinforcement of the wall sections[5].

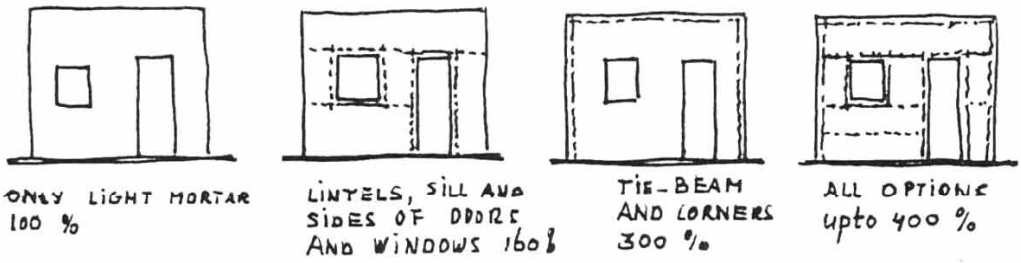

FIGURE 11. INCREMENTAL STRENGTH OF WALL SECTIONS WITH HORIZONTAL AND VERTICAL REINFORCEMENT

In the comparisons, the non-reinforced wall section is taken as 100%.
The four diagrams illustrate that both horizontal and vertical reinforcements have a positive effect (160%). In addition, the wall-plate reinforcements adds considerable overall strength (+100%). The combination of the wall-plate with the vertical reinforcement along the wall ends and sides of doors and windows has the most effect (400%). For this reason it is necessary to build the ends of the walls and along the door and window openings in such a way (using C-blocks) as to allow for the placement of the vertical reinforcement.

Below is a summary list of the above reinforcement patterns for stone masonry walls that are masoned with light cement mortar:

1. Wall section without reinforcement = basis 100%.
2. Wall section with reinforcement of lintel only = 110%.
3. Wall section with reinforcement of windowsill and lintel = 120%.
4. Vertical reinforcement of window sides = 130%.
5. Reinforcement of windowsill, lintel and sides = 160%.
6. Vertical reinforcement of wall ends only = 150% - 200%.
7. Vertical reinforcement of wall ends, corners and wall-plate = 200% - 250%.
8. Vertical reinforcement of wall ends, corners, wall-plate, lintel and windowsill = 250% - 300%.
9. Reinforcement of wall ends, corners, wall-plate, sides of windows and doors = 300% - 350%.
10. Wall ends, corners, wall-plate, lintel, windowsill, sides of doors and windows = 350% - 400%.

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[5] The result of several technical analysis on the behaviour of load bearing masonry constructions:
Strengthening of Brick Buildings Against Earthquake Forces, Jai Krishna and Brijesh Chandra, University of Roorkee, Roorkee U.P., India (1965)
Behaviour of Load Bearing Brick Walls during Earthquakes, Jai Krishna and Brijesh Chandra, S.K. Kanungo, University of Roorkee, Roorkee U.P., India (1968)
Strengthening of Brick Buildings in Seismic Zones, Jai Krishna and Brijesh Chandra, University of Roorkee, Roorkee U.P., India (1969)
Recomendaciones Sobre el Empleo de Mampostería Construcciones para Vivienda en Zonas Sísmicas. R. Meli, O. Hernández, Instituto de Ingeneria, Universidad de México (1976)
The Influence of a Bonding Frame on the Racking Stiffness and Strengths of Brick Walls. R.J. Mainstone, G.A. Weeks, Building Research Station, Watford, England (1972)
Estudio del Comportamiento de Muros de Albañilería Reforzada de Ladrillo de Barro Cocido a Escala Natural, Bajo la Acción de Cargas Verticales, Horizontales y de Impacto. Universidad de San Carlos de Guatemala. Ing. Emilio Beltranena M., Guatemala (1976)
Estudio Experimental Sobre la Resistencia de Muros de Albañilería Sometidos a Cargas Horizontales. Luis Josquera J., Santiago (Julio 1963). Revista IDIEM, Vol. 3, No. 3, 1964.

The above list is an approximation, but the incremental strength due to reinforcing all sides of the wall sections with stress reinforcement will make the houses that have these types of reinforced bearing walls, three to four times stronger than non-reinforced houses.

Although the reinforcement of the lintel and the sides of the windows by themselves do not add too much to the overall strength of the construction, these reinforcements do add to the overall coherence of the building and **avoid progressive failure** in case of long-lasting earthquakes.

The application of the C-blocks at the wall ends, corners and along the sides of windows and doors assists in easy placement of the required wire-mesh reinforcement, achieving additional strength and coherence. In addition they allow for faster construction. Their use in the corners is architecturally appealing.

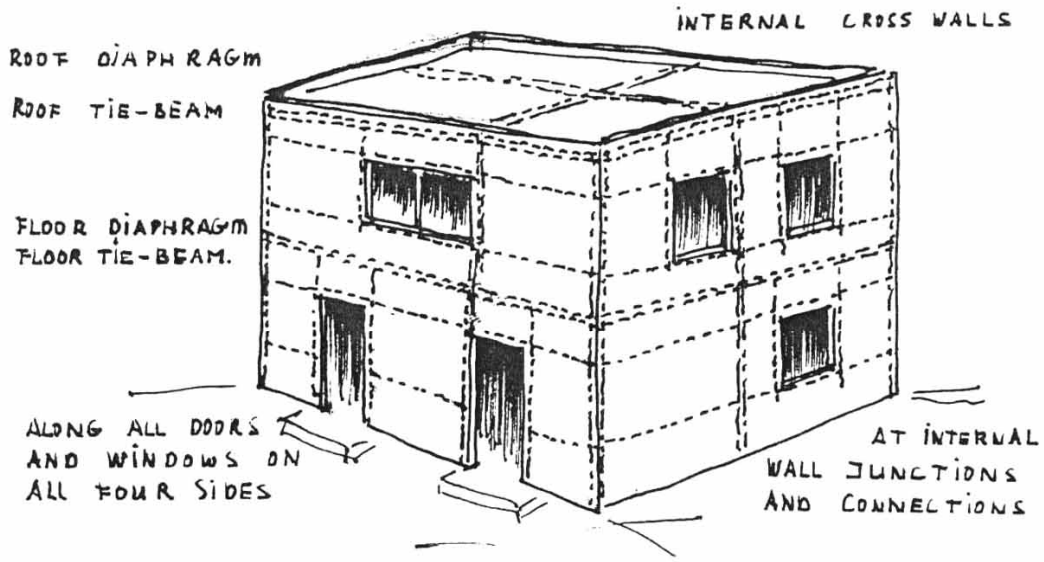

FIGURE 12. OVERALL SCHEMATIC VIEW OF A WELL-REINFORCED HOUSE