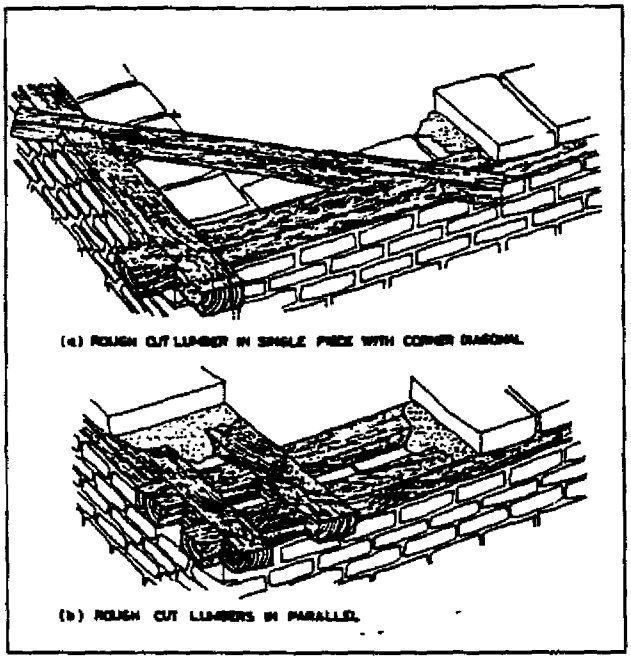


Figure 16.1-3 Collar Band in Walls at Lintel Level [1].

integral action of walls and facilitate the connection of collar beams with each other (Figure 16.1-4)

1.2 Special Measures

Reinforcing can take many shapes, depending on the financial means of the user and the local conditions:

- Timber in the walls.

  Some codes suggest the use of horizontal timber bond beams at four levels: at the base, under and above openings, and at the roof-level. These bond beams can be double, that is one timber section of 10x10 cm at each side of the wall, connected by 5x10 cm ties every 50 cm. They can also be in the form of a single bond beam, which is then braced at the corners.

  Wooden reinforcement in adobe masonry in the form of hori zontal timber beams at roof and basement level, with verti cal timber columns at corners and intersections, and braces make these frames more rigid. Such wooden frames need good connection with the masonry, through anchor bolts, nails or mesh.

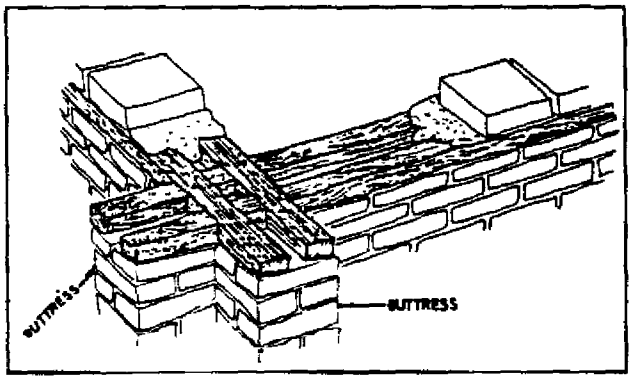


Figure 16.1-4 Use of Buttresses [1].

- Concrete columns and beams, probably the most expensive solution.

- Various steel products can be used as reinforcement. Steel bars can be used horizontally and vertically, for instance inserted in hollow masonry, to tie walls together and fix them to the foundations. For those who cannot afford these bars, the use of barbed wire in both vertical and horizontal ways is suggested, and eventually in combination with a wooden frame (Figure 16.1-6).

  Wire-mesh, in the joints or in the plaster, can be used to reinforce high stress areas The problem of steel products in adobe is the high risk of corrosion

- The same effect as with the wire-mesh can be reached with some vegetable materials that have a high tensile strength, such as sisal. Sisal fibers can be laid in the horizontal joints, with their ends hanging on both sides of the wall, as reinforcement in the plaster This con siderably increases the earthquake resistance of adobe walls. The durability of sisal in such constructions is yet, however, unknown.

- Instead of wood, various vegetable materials can be used as reinforcement, particularly bamboo and reeds Some codes allow the replacement of the wooden bond beams by canes at 5 cm distance, tied every 50 cm

Tests are being performed on both vertical and horizontal reinforcement with reed and bamboo. A common solution is to use asphalt-stabilized adobes, that have a single small hole, through which a halved bamboo painted with asphalt is fitted. The horizontal reinforcement then consists of small bamboos or quartered bamboo laths (Figure 16.1-7) A split bamboo mesh, dipped in bitumen, may be used as reinforcement in wall plaster

- Apart from continuous reinforcement, which may be expensive and not necessary in all places, one could put reinforcement in areas with high stress, particularly corners and inter sections.

1.3 Roofs

1 The roof should preferably be of light material, such as sheeting of any type

2. If thatch is used for the roof covering, it should preferably be made waterproof and fire-resistant by applying mud plaster mixed with bitumen cut-back on both surfaces of the thatch or other plaster such as lime plaster Cut-back is prepared by mixing bitumen 80/100 grade, kerosene oil and paraffin wax in the ratio 100:20·1

For 1.8 kg cut-back, 1 5 kg bitumen is melted with 15 grams of wax and this mixture is poured in a container having 300 millimeter Kerosene oil with constant stirring until all ingredients are mixed This mixture can then be mixed with 0.03 m^3 of mud mortar to make it both water repellent as

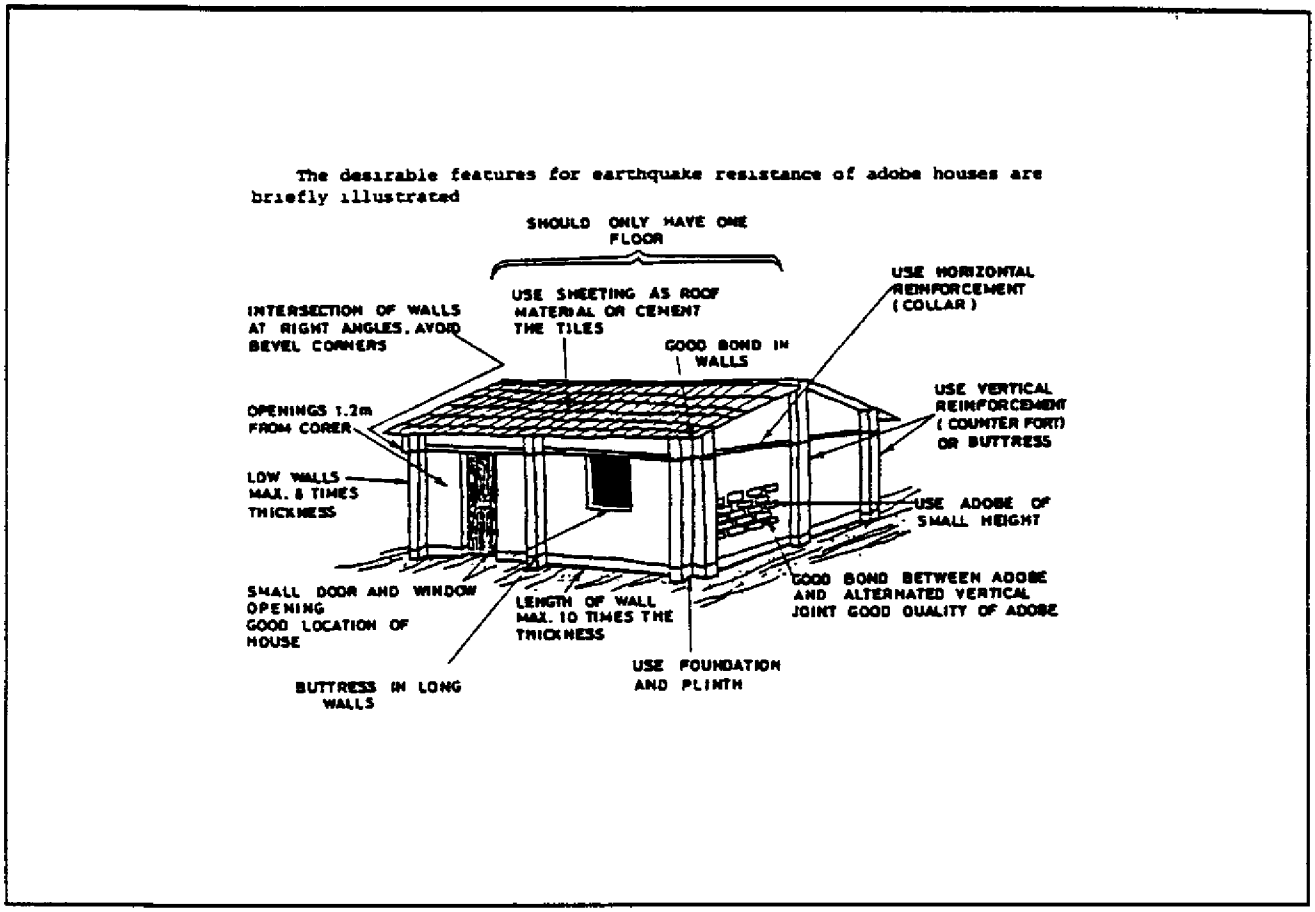


Figure 16.1-5 Overall Arrangement of Reinforcing Adobe Buildings [1].

well as offering fire protection for thatch.

3. The roof beams or rafters should preferably be rested on longitudinal wooden elements to distribute the load on adobe (Figure 16 1-8 Preferably two top courses of burnt bricks may be laid instead of adobe for accepting the longitudinal wooden elements.

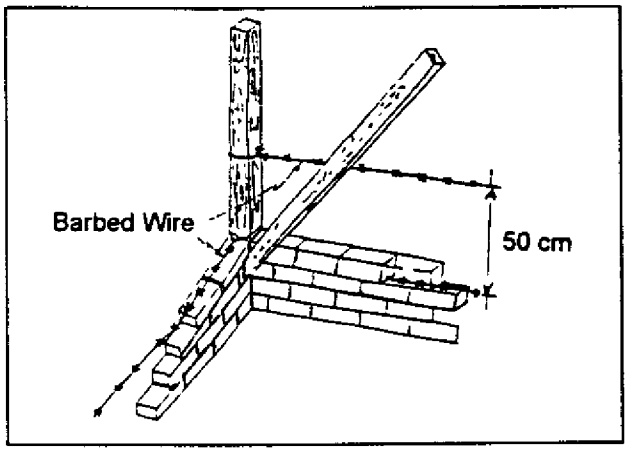


Figure 16.1-6 Barbed Wire Reinforcement [9].

4. The roof beams or rafters should be located to avoid their position above door or window lintels. Otherwise, the lintel should be reinforced by additional lumber (Figure 16.1-9)

2. *Quality of the material*

In adobe masonry two materials are important. The blocks and the mortar. The latter ensures the bond between the blocks and makes masonry act as a single unit. The mortar should therefore have at least the same, and preferably even a better quality, than the blocks.

The adobe can be improved by:

Careful selection of the soil, with enough clay (15-30%) to have a good bond but not too much to avoid shrinkage, and enough sand to provide strength (for clay contents higher than 30% generally vegetable material has to be added to the mix to avoid shrinkage cracking).

Careful manufacture, avoiding an excess of water, with proper braking and mixing of the soil, and gradual drying under cover.

The inclusion of certain vegetable or animal materials, such as straw, grass, bagasse or hair helps to prevent drying cracks and generally increases the strength of the

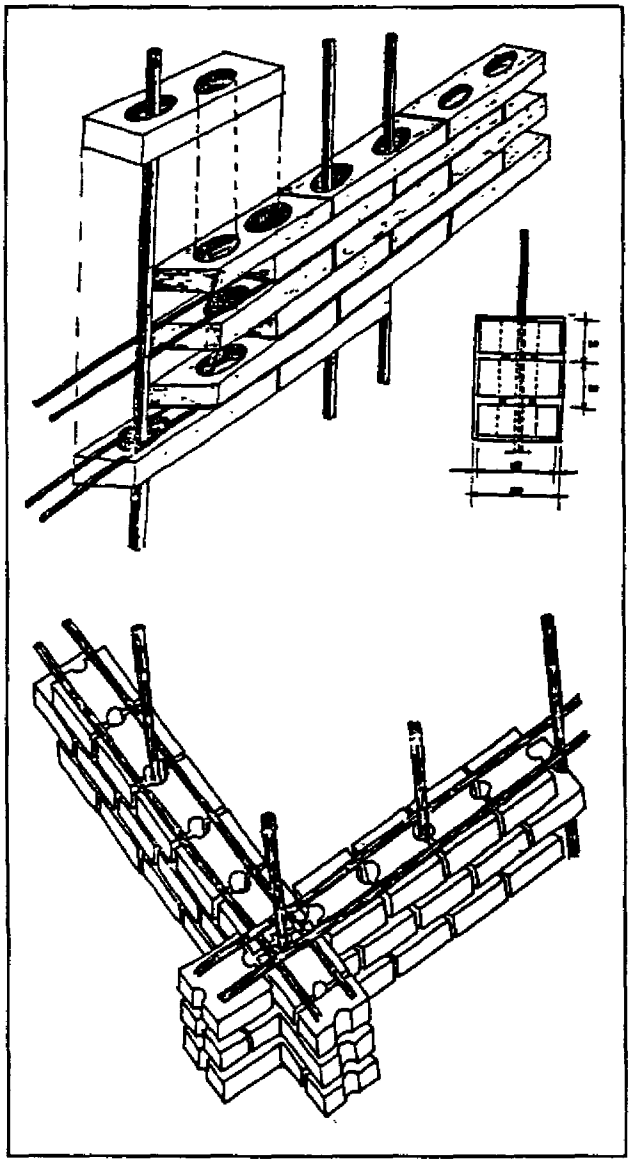


Figure 16.1-7 Examples of Cane Reinforcement in Hollow Block Masonry [9].

adobe.

Stabilization of blocks can increase their strength enormously, and also improve their resistance to humidity. To keep this an economical solution, not more than 4-10% of stabilizer is used, the actual percentage depending on various factors, such as the intended use of the blocks. Common stabilizers are:

- cement, particularly for sandy soils
- lime, particularly for clay soils.
- or a mixture of the two.

The economic use of stabilizers is promoted if compression is applied in molding the blocks (Figure 16.1-10).

For good bonds in the walls, the shape of the block is also important. Adobes should preferably be rather flat, not more than 10 cm thick.

The mortar can be improved by measures similar to a, b, c and d above.

3. *Quality of construction*

Care should be taken with the design of adobe walls, their actual construction and in protecting them sufficiently, particularly against water.

- During construction, no fresh adobes should be used because these could still shrink. Masonry should not go up too fast, certainly not more than 1 meter per day, to give it time to settle and strengthen. It is crucial to have a good masonry pattern, with sufficient overlaps and no continuous vertical joints, especially in corners and at intersections. The practice of mixing adobe with a different facing material in the same wall is better avoided, because it generally leads to insufficient bonding.

- When adobes are not stabilized they should be protected against water. Plastering of walls with a water-resistant plaster can help, though it is difficult to obtain a good bond between the adobes and different plasters (The use of an interlayer between adobe and plaster (for instance chicken-wire nailed on the adobe wall) is a effective but expensive means to ensure a good bond)

- A very crucial area is the base of the walls, that is usually less protected by roof overhangs, and besides is often eroded by splashing water. It would be preferable to have a base in a different material, for instance stone or brick masonry, and to provide a damp-proof course, such as asphalt paper, between the base and the adobe masonry.

The Improvement of Rammed Earth Walls

1. *Reinforcing*

Between the different layers of rammed earth, horizontal reinforcing can be applied using timber, other vegetable materials, concrete or steel products. As vertical reinforcement, wooden or concrete posts are handy, because they can also be used to fix and guide the shuttering. But other reinforcements could be incorporated as well, often similar to those for adobe.

A recently developed construction is that of poured, and not rammed adobe. To gain sufficient strength, poured adobe is usually stabilized, for instance with asphalt or lime. It has also been used with a wire mesh as reinforcement and tests are underway with the use of bamboo. The problem of steel products in earth walls is the high risk of corrosion.

2. *Quality of material*

Many of the improvements mentioned for adobe are also applicable to rammed earth, notably: the careful selection of soils, the careful manufacture, better compression through improved ramming, stabilization

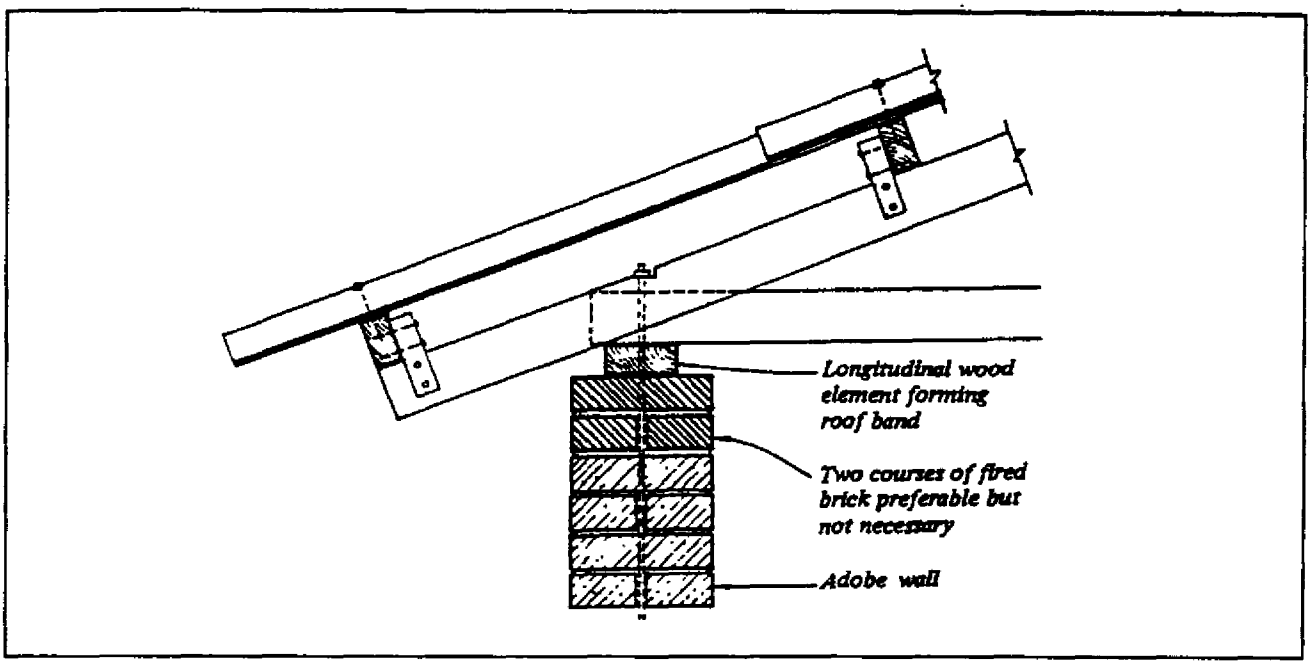


Figure 16.1-8 Use of Longitudinal Wood under Roof Rafters [2].

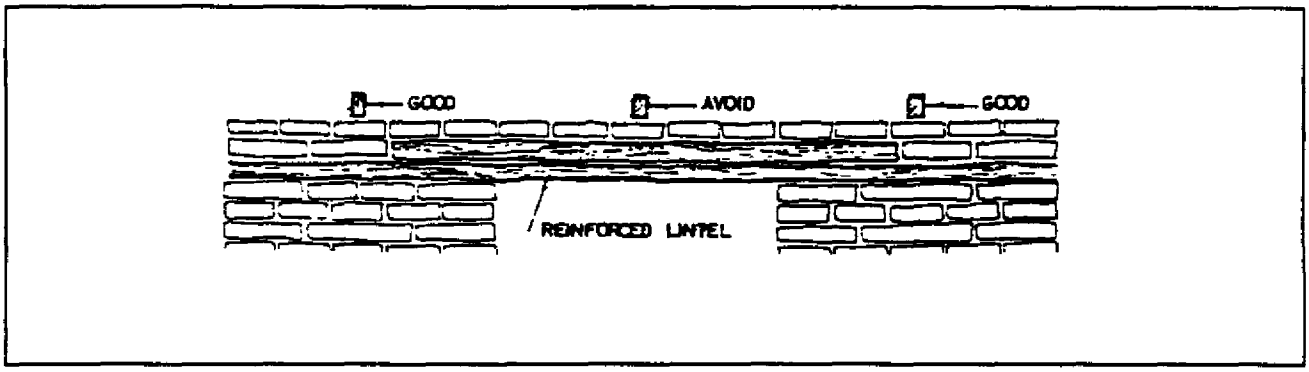


Figure 16.1-9 Reinforcing Lintel under Floor Beam [1].

3 *Quality of construction*
- The same rules with regard to adobe construction also apply for earth walls, with the exception that the wall thickness may have to be slightly increased.
- Not more than one layer of rammed earth should be built per day
- Although rammed earth is a typical construction for hot and arid areas, care should still be taken to protect it from excessive humidity, particularly at the basement.

The Improvement of Low Cost Brick Masonry Walls

Reinforcing

1. The importance of vertical reinforcement, was found to have considerably more effect than horizontal But in other countries, the contrary has been found As long as this contradiction is not fully explained it is better to combine vertical and horizontal reinforcement. Because the properties of bricks are different from soil, there is advantage in using steel in mortar or concrete as reinforcement. The mortar will bond well with the bricks, which is not the case with soil.

Timber is a good alternative if properly anchored to the masonry, via bolts or long nails, wires or steel strips or with attached wire-mesh in horizontal joints (Figure 16.1-11). The detailing is fairly similar to the one shown for adobe masonry. Vegetable materials, such as bamboo or reeds, can be used but seem to provide the lesser solutions.

2. *Quality of material*
- As with soil constructions, the earth for fired bricks should be properly selected.
- Mixing, molding and curing need sufficient care and are certainly not an unskilled job.
- The traditional firing of bricks in field kilns often does not reach sufficiently high temperatures and may produce low-quality products. A fixed kiln, with permanent walls, generally produces a better product and saves energy.
- Bricks should not be too big, to avoid excessive cracking during drying and firing, and insufficient firing; the length should certainly not exceed 30 cm.

- It is possible to produce studded bricks that fit into each other, and thus produce a much better bonded wall.
- The improvement of the mortar can considerably improve the performance of brick walls; if possible, mud mortar should be replaced by stronger mortars on the basis of cement, lime, pozzolanas or even gypsum.

3. *Quality of construction*

- One mistake sometimes made with brick masonry, in comparison with e.g. adobe, is that walls are made too slender.
- Construction of walls should not go too fast and should be regular, that is not building up the corners or certain segments first, but with gradual, progress. The masonry pattern should include sufficient overlaps, avoid continuous vertical joints, especially at corners and intersections These recommendations apply to all types of masonry construction. Care should be taken to fill the joints well with mortar. Bricks should be wet when laid.
- When mud mortar is used, this should preferably be replaced by a cement mortar for foundations and basement. If not, the joints should at least be pointed with such a mortar.

reinforcement, strengthening, low cost construction, adobe, stone, timber, bamboo, wire, roof, material quality, soil stabilization, construction quality, rammed earth.

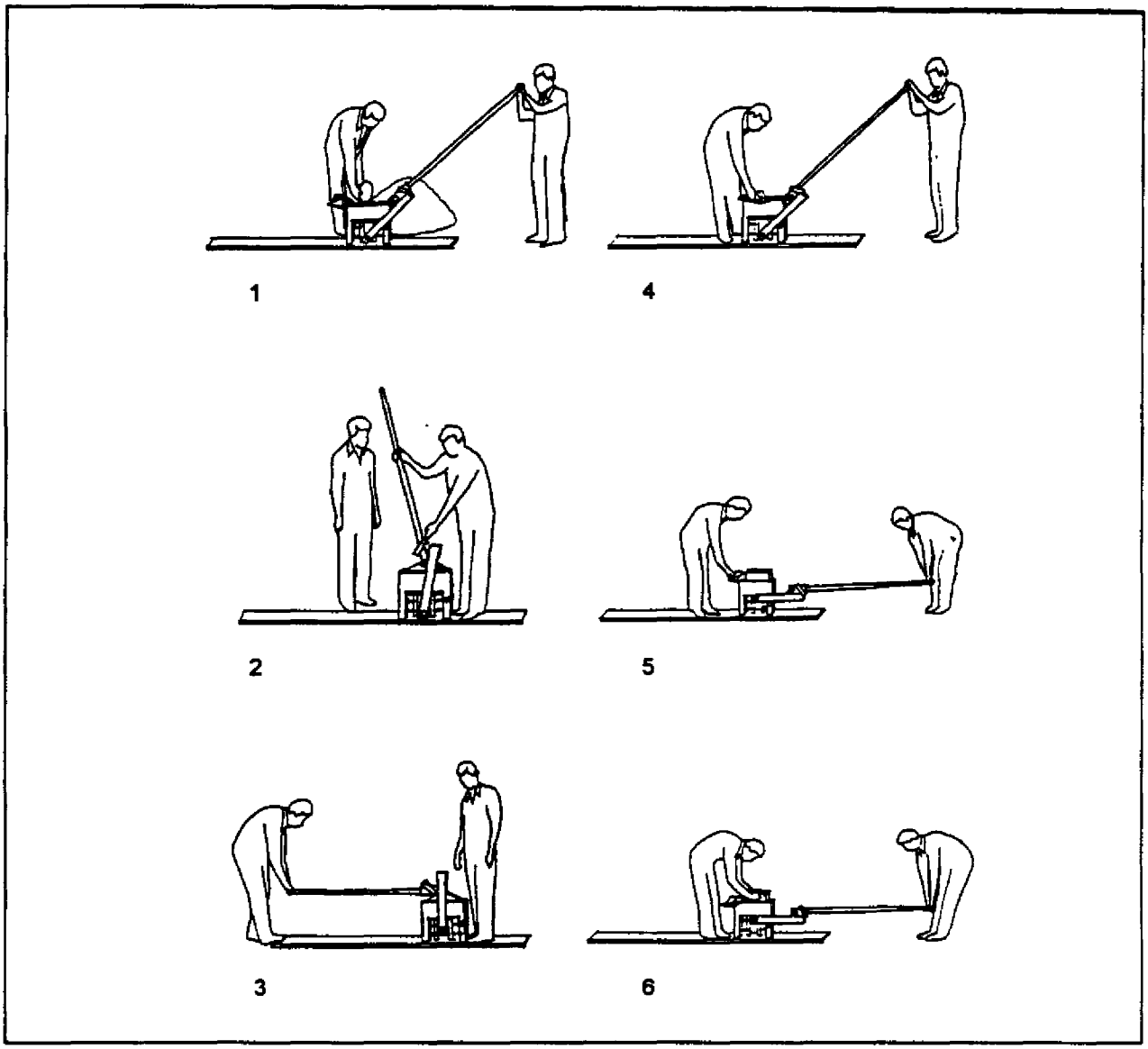


Figure 16.1-10 Molding of Stabilized Soil blocks with a Cinva Ram Press [12].

Topic 16.2: Light Wall Constructions

The seismic behavior of light wall construction differs substantially from that of heavy wall constructions. Light walls are appropriate in hot wet climates because of their low thermal capacity. The main principles and methods for the improvement of light walls are described here.

Light wall constructions have shown the best performance during earthquakes, as long as they support light roofs, and were properly built and maintained. They usually consist of a frame with cladding material; the cladding in itself can help to make the frame quite rigid and much stronger. For frames, material which can be used are steel, concrete, wood, bamboo and other like materials. Steel and concrete frames are not very common in low income housing and will not be considered here. As sheeting, vegetable mats or leaves, wood planks, plywood, various fiber boards, ferrocement, fiber cement, plasters and various plastics.

Planks and vegetable materials are the most common cladding but other materials are receiving increasing interest. (Figure 16.2-1(b))

The improvement of wood frames

1. Keep wood above ground level, to prevent damage by termites and rot. That means that a different foundation is needed, preferably a continuous one; or otherwise piers. The wood frame has to be well connected to this foundation, preferably via a wooden beam, that is well anchored with for example bolts. Not connecting the frame to the foundation may be good during a light earthquake as it allows for a slight shift of the house on its footings, but it can be disastrous during heavy earthquakes.

2. If possible, treat the wood against insects and rot, or arrange for supply of treated timber. (Figure 16 2-1(a)).

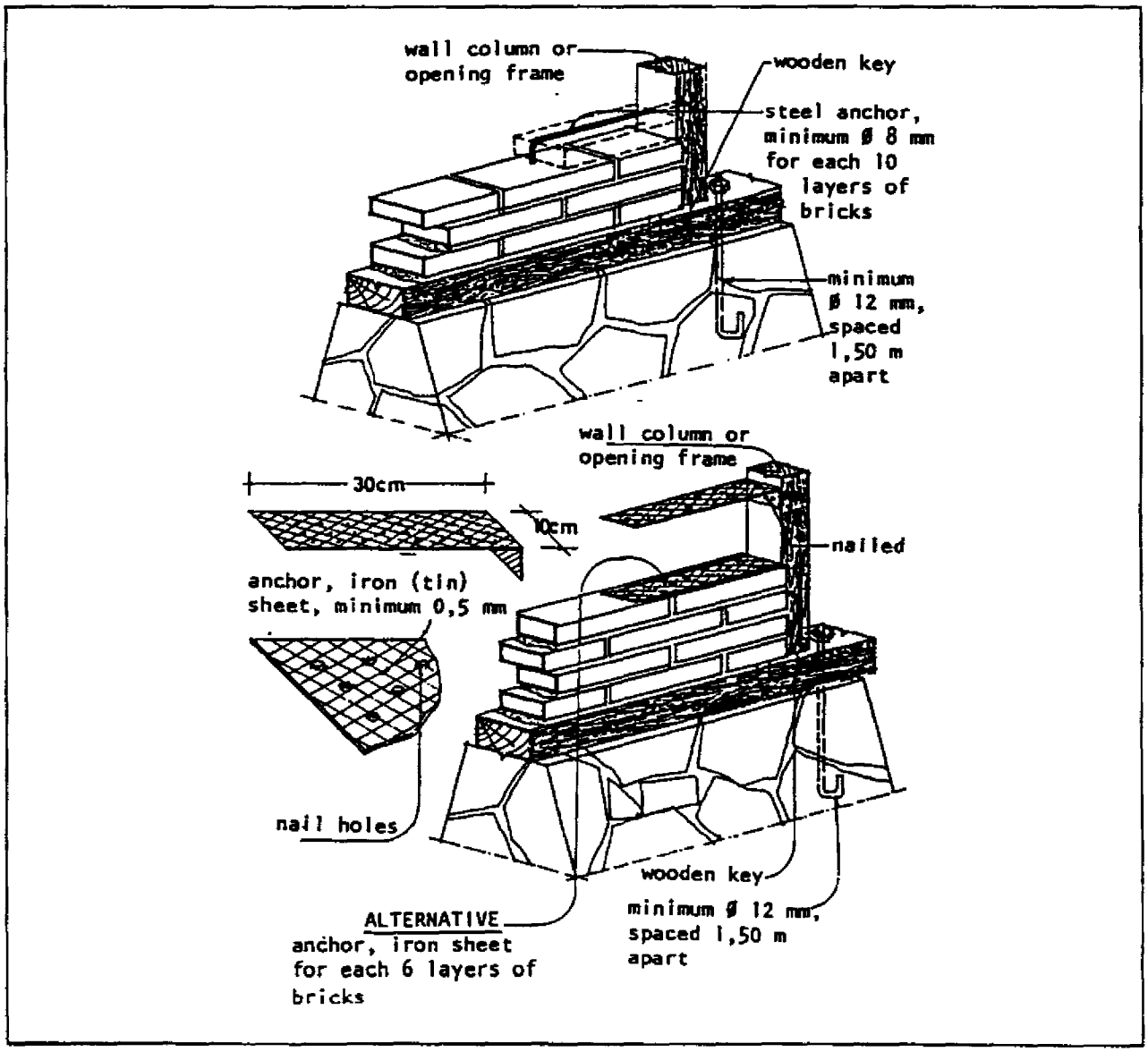


Figure 16.1-11 Connection of Wooden Frames with Brick Masonry [4].

Protection of wood

- Seasoned timber should be used for building construction so as to maintain the joints in tight condition.
- Preservative treatment of the timber used in building construction will be desirable to achieve long, trouble-free life.
- Mechanical barriers against termite action should be incorporated and soil poisoning of the building site should also be carried out wherever possible

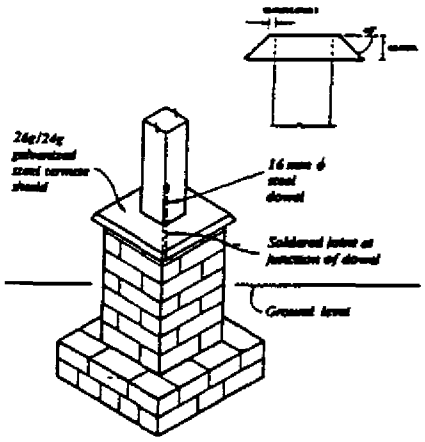


Figure 16.2-1a Protection of Wood [2].

3. Provide proper bracing in the walls vertically and horizontally and especially at corners (Figure 16.2-1(c)). The insertion of horizontal nogging pieces, at two or three intervals in the wall is also very useful.

4. Nailed connections can be quite weak, since nails sometimes get pulled out. Especially where heavy beams are anchored to each other, the use of various possible steal anchors (flat sheet, grip anchor, storm anchor, anole-iron etc) is to be preferred.
5. Connections in a frame can be made more rigid by

   - inserting wooden triangular corner pieces between the elements of the frame, that are bolted to the two elements (Figure 16.2-2a),
   - nailing a triangular sheet over two connected pieces (Figure 16 2-2b),
   - if roundwood frames are used, connections should be made with metal strips or wires (Figure 16.2-2c).

The improvement of bamboo frames (Figure 16.2-3) All the above apply equally to bamboo frames, with the difference that anchoring of bamboo frames can also be achieved with wooden or bamboo anchors. Since bamboo

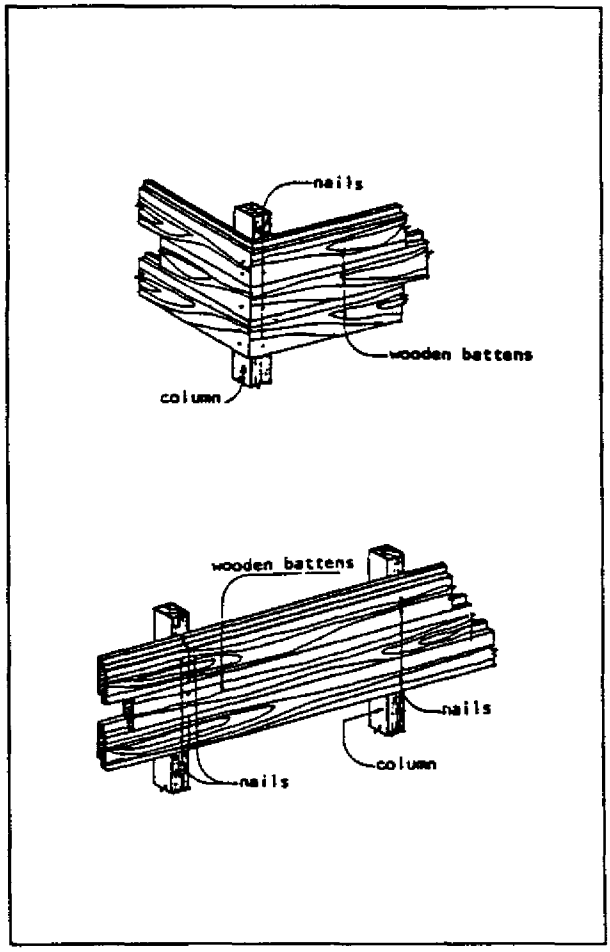


Figure 16.2-1b Light Wall Cladding Material [4].

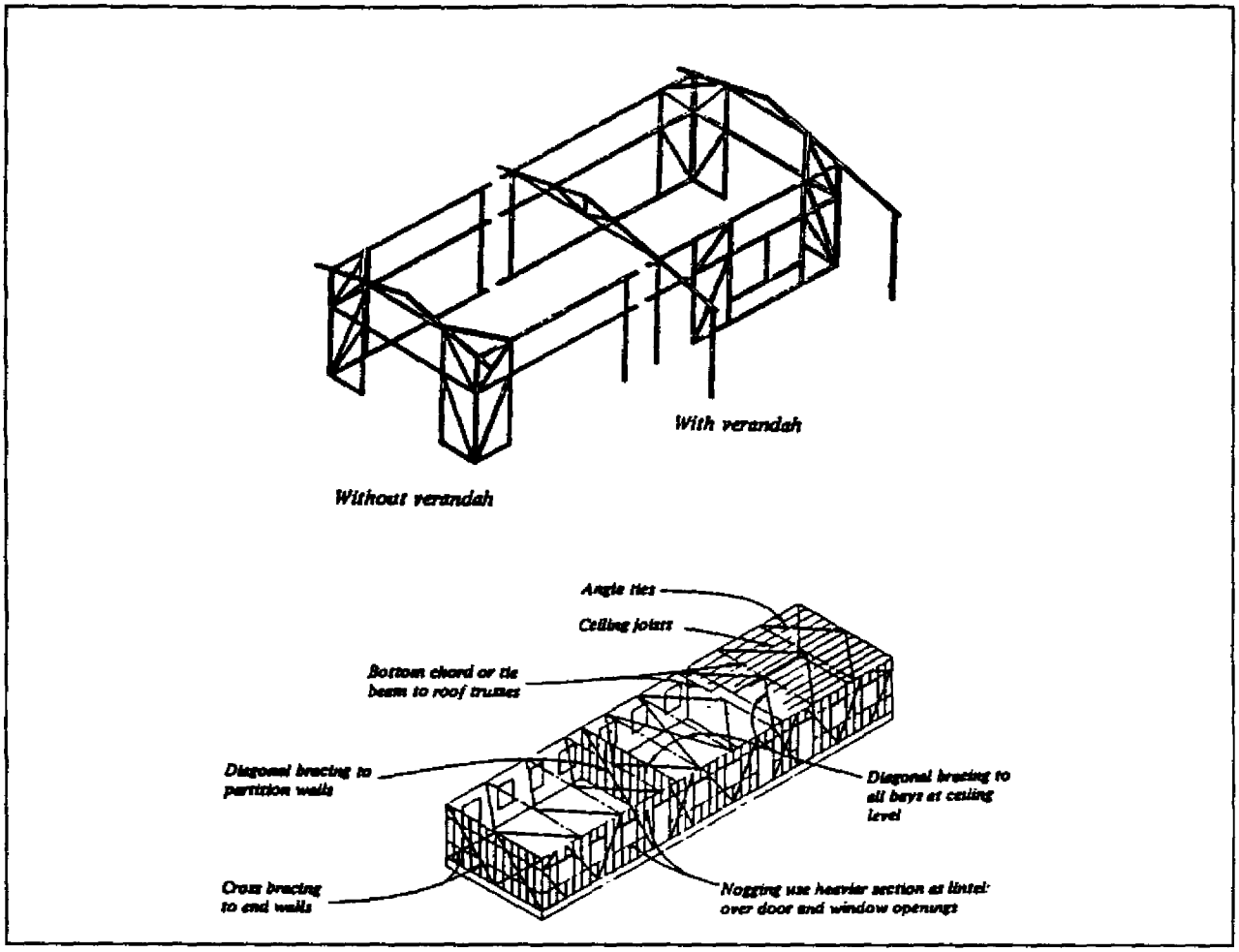


Figure 16.2-1c Examples of Bracing of Wood Construction [2].

connections are usually tied with rope, and these ropes may become dry and loose, such connections can be kept in place by inserting the bamboo pieces into each other and using wooden pins or dowels.

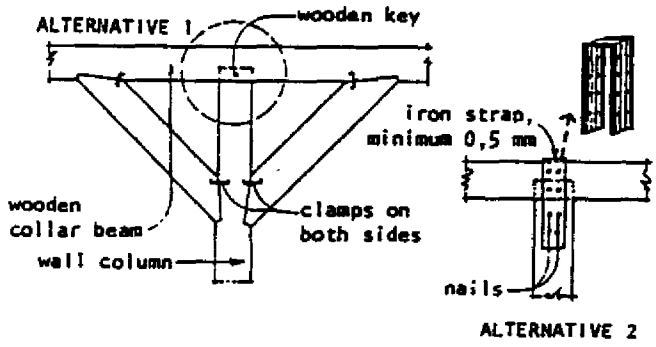
The cladding material

The frame can be covered by various materials to make the walls .Some of these materials have no structural function at all, but others can add substantial qualities to the frame, notably strength and rigidity. It is found that sheet materials such as plywood, can make a fairly rigid box for a wood frame house, with a good resistance against earthquakes. Wood planks can do the same, but to a lesser extent than sheets.

All these materials to make a frame rigid should be well connected to the frame. Further, if they are on a wood or vegetable foundation, they have to be protected against insects and humidity by treatment and coating with a water-resistant substance. The traditional vegetable sheathing of leaves or bamboo mats does not have a structural function. But could serve as a base for plaster, and even as reinforcement for a fiber cement cladding material

lightweight wall, frame, timber, bamboo, bracing, corner connection, reinforcement, wire, foundation, bamboo connection.

The collar beam should be connected firmly to the wall columns.



The connection of collar beam parts at wall corner should be made firmly by using a horizontal brace.

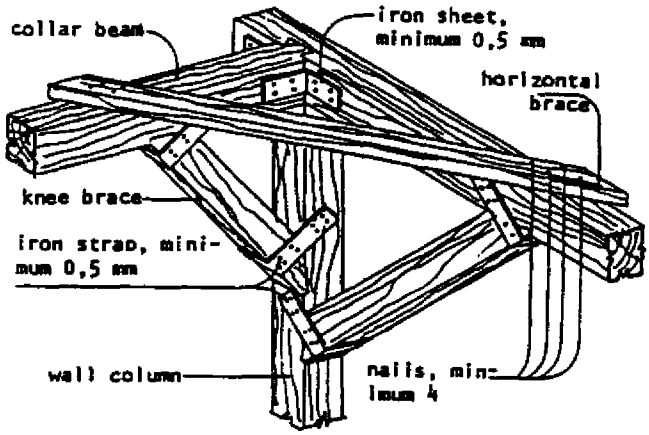


Figure 16.2-2a Inserting Wooden Triangular Corner Pieces [4].

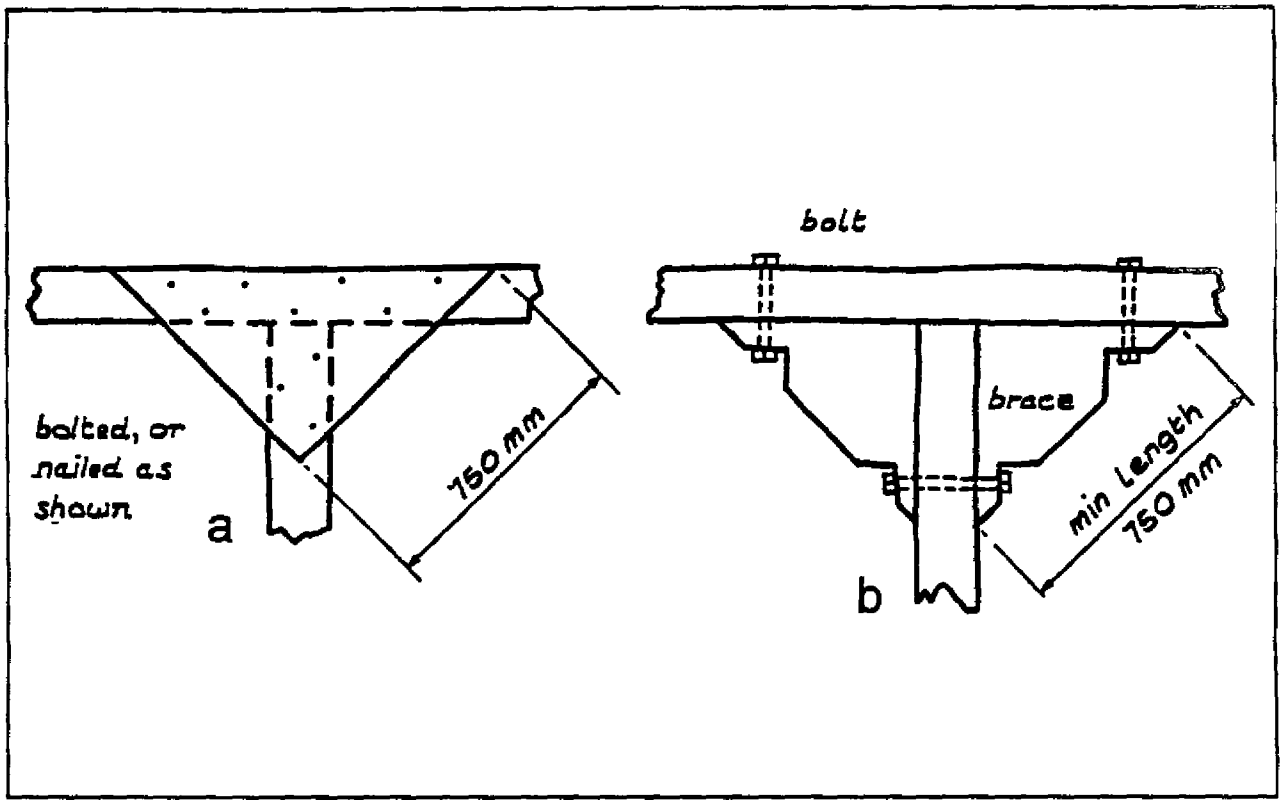


Figure 16.2-2b Stiffening of Corner by Nailing Triangular Sheet (a) and Bracing (b) [7].

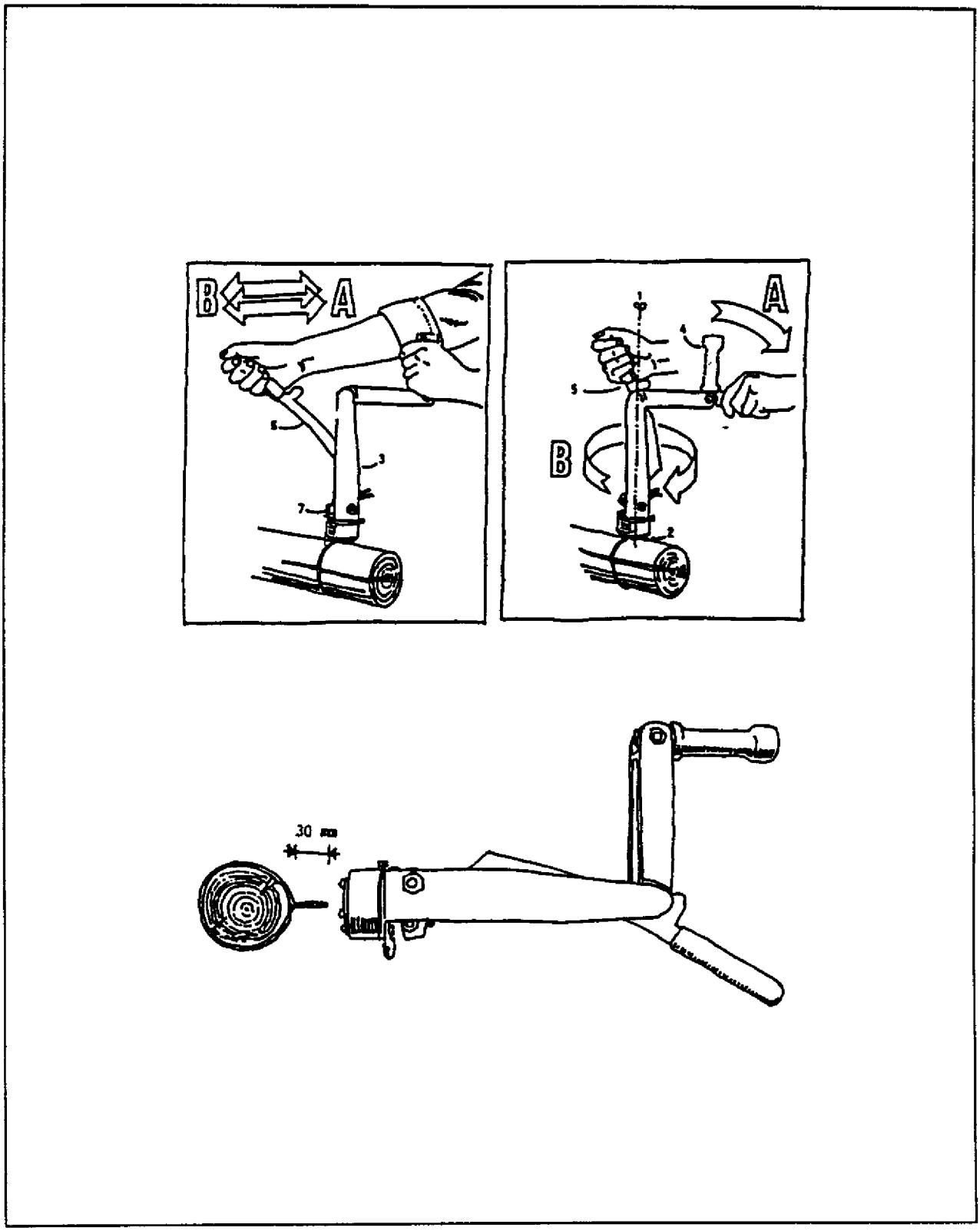


Figure 16.2-2c Connections with Wires [13].

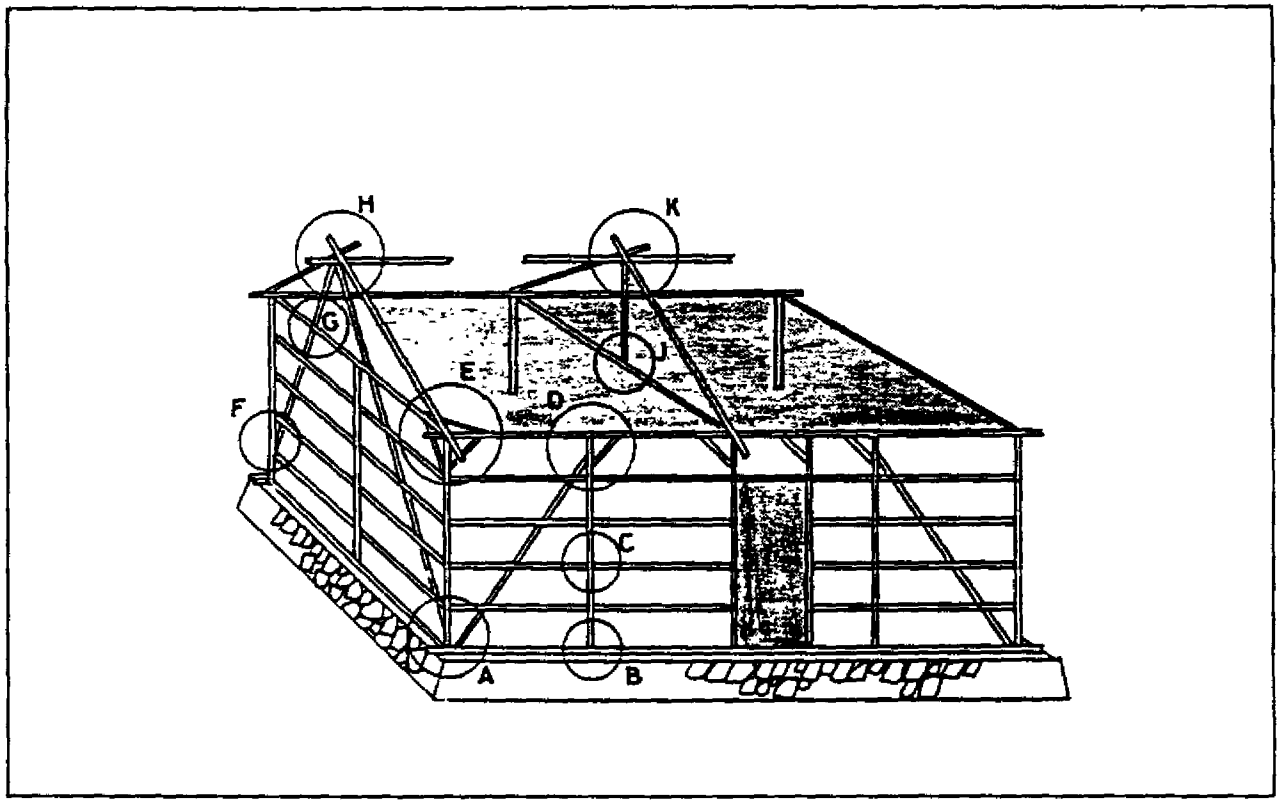


Figure 16.2-3a Bamboo Frame Structure with Wall Covering of Woven Bamboo [4]

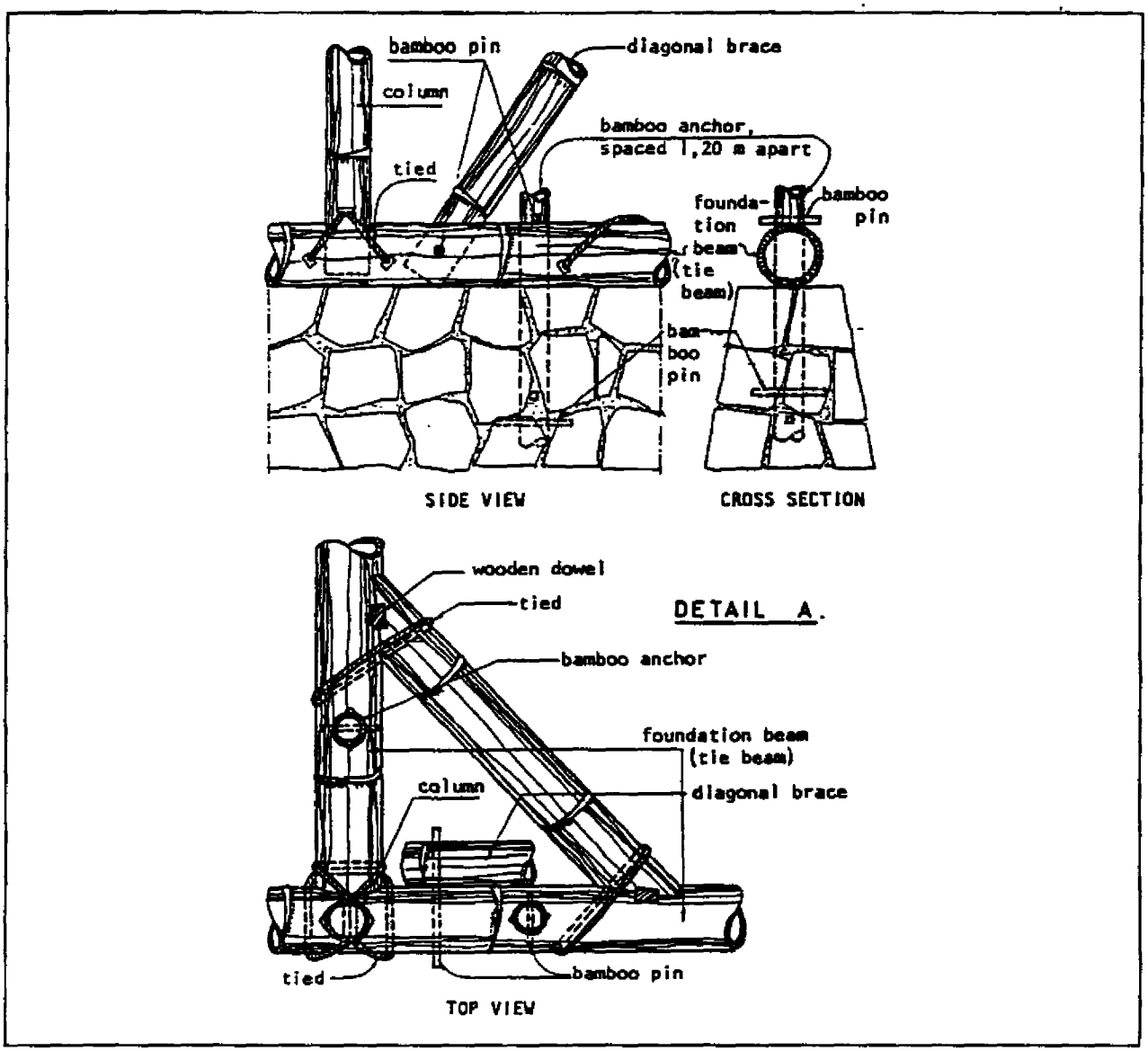


Figure 16.2-3b Detail Bamboo Construction (Foundation) [4].

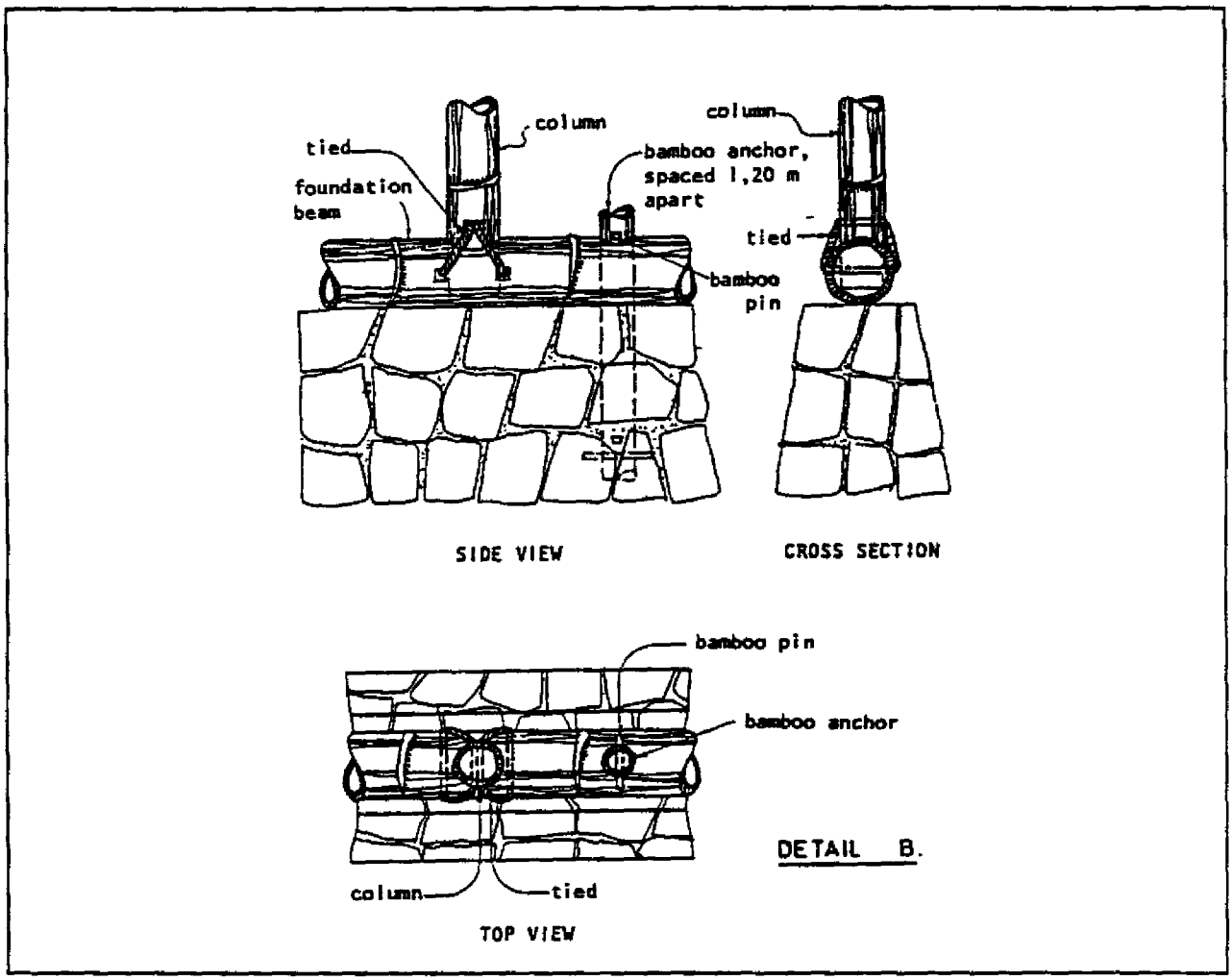


Figure 16.2-3c Connections of Wall Frame Components [4].

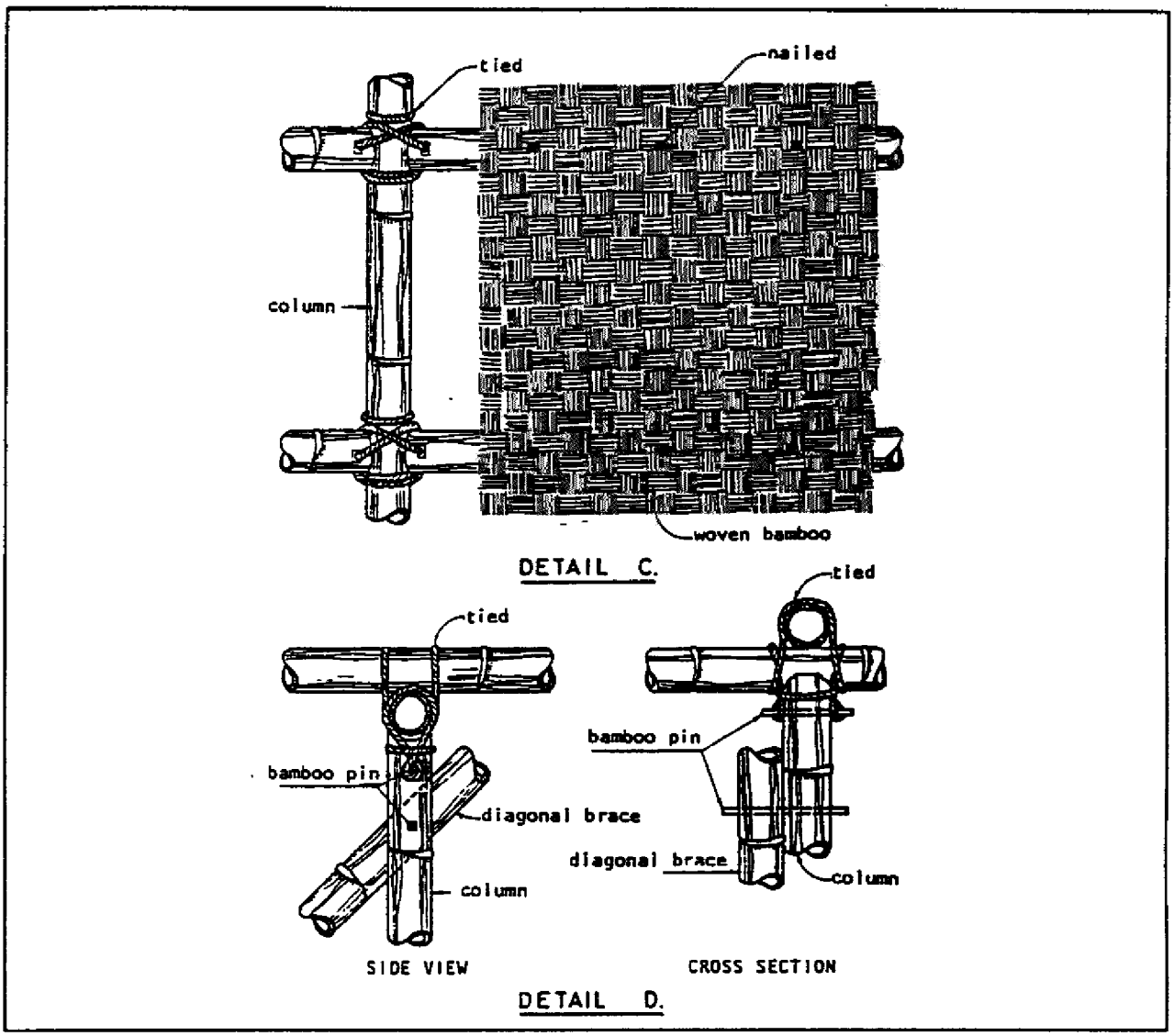


Figure 16.2-3d Detail Bamboo Construction with Woven Bamboo [4].

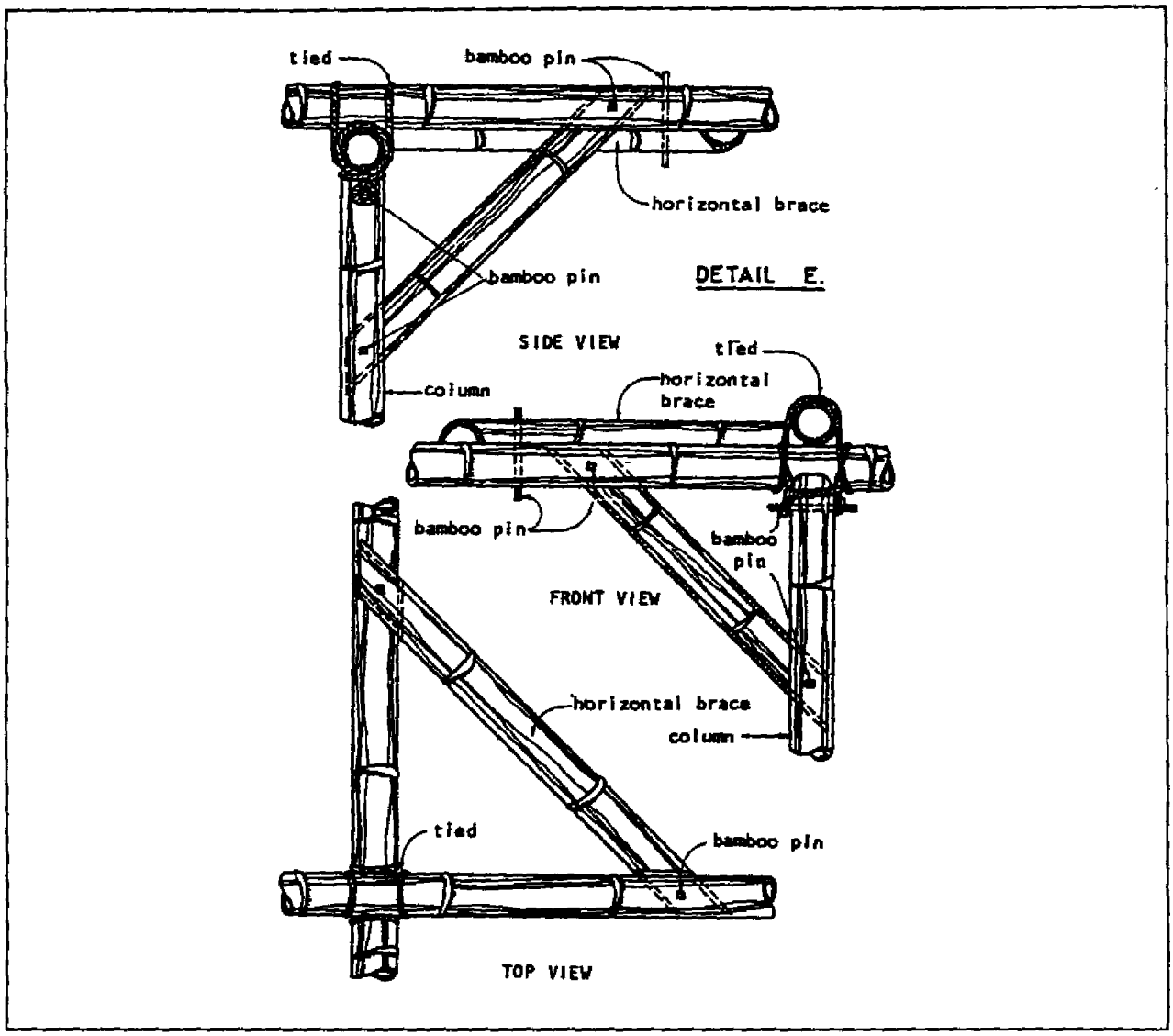


Figure 16.2-3e Detail Bamboo Construction [4].

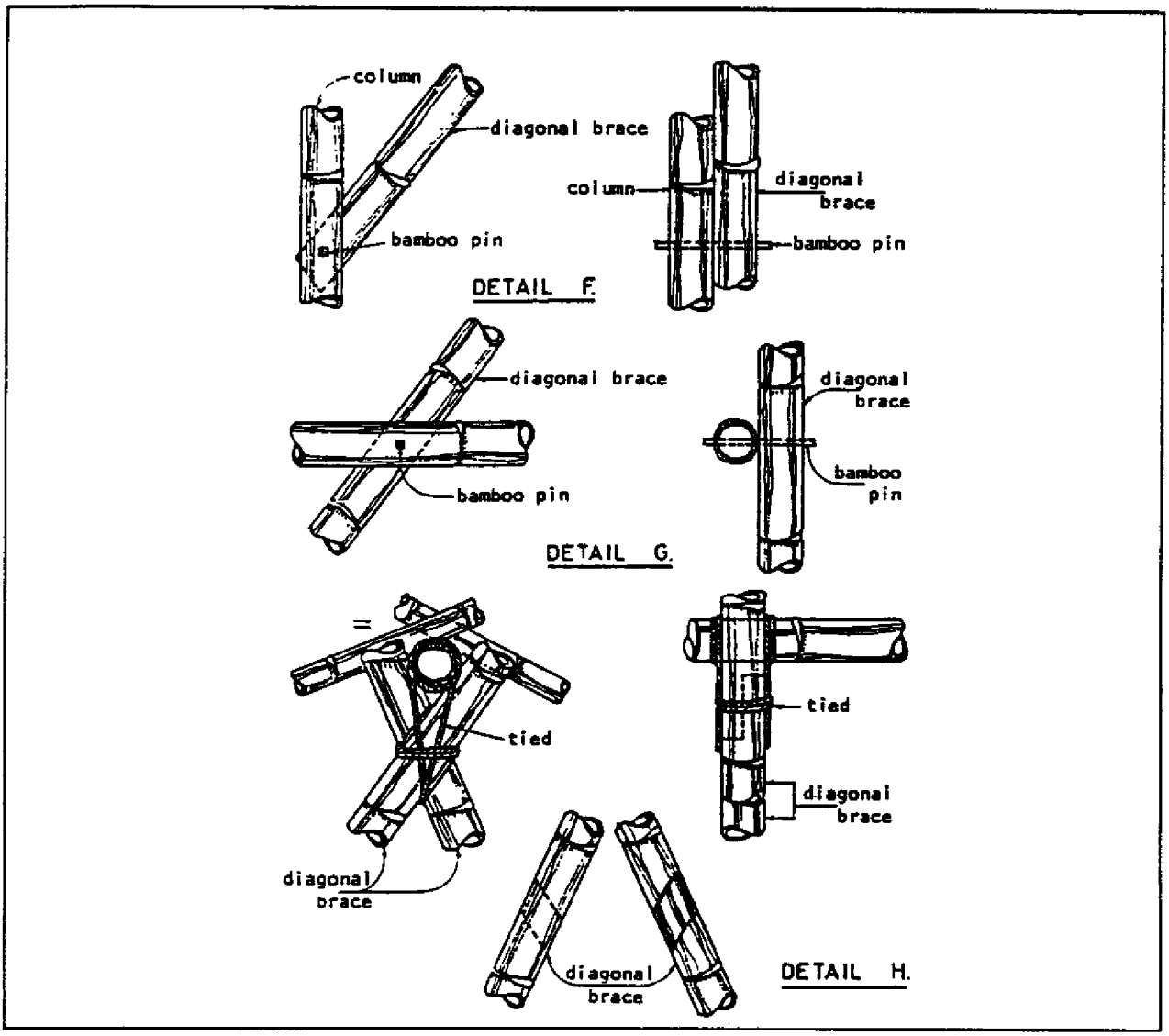


Figure 16.2-3f Detail Bamboo Construction [4].

Topic 16.3: Intermediate wall constructions

Walls of intermediate thickness are made of durable and non-durable materials They are used in all types of climates Reinforcement, at least partial, is required to meet safety requirements during earthquakes. The main principles and methods for the improvement of intermediate walls are described here.

Some walls with an intermediate weight could be light masonry; these follow the general guidelines mentioned before for adobe and bricks. An interesting development here are cavity walls of light interlocking concrete blocks developed in the USA that have proved their value under earthquake circumstances. Due to the locking effect, there is an excellent bond in these walls.

Most of the intermediate wall types, however, are frames with infills such as

- roundwood frames with mud infill;
- sawn timber frames with infills of mud, adobe, stone or brick,
- concrete frames with hollow block infills

When the infills are properly connected to the frames and are vertically and horizontally distributed, they contribute to the strength and rigidity of a house. Otherwise, infills may reduce the resistant properties of a building.

Frames should also be filled over their whole height. Leaving an open strip under the top tiebeam, for instance for windows, leads to unequal lateral loading during earthquakes and in most cases failure of the frame.

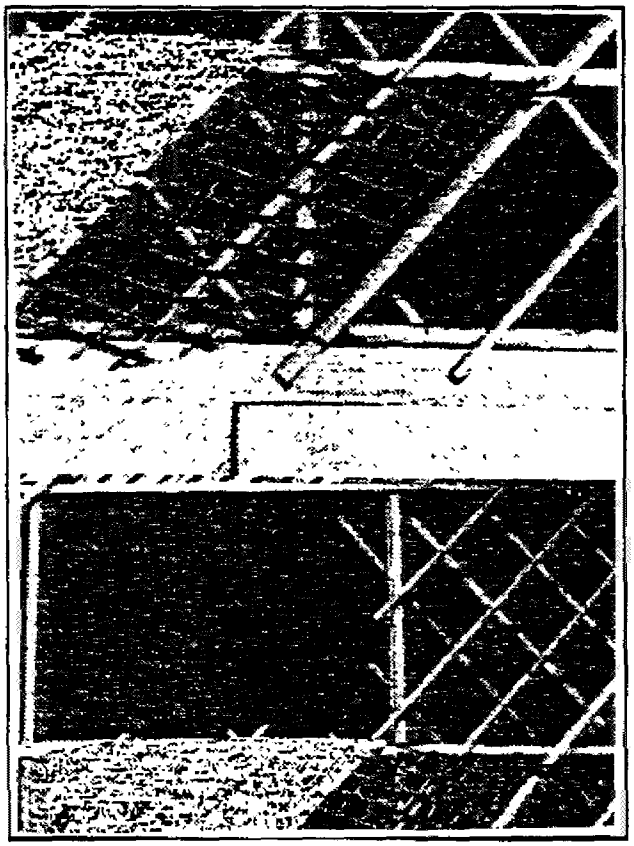


Figure 16.3-1 Braced Quincha Wall [14]

Improvement of mud and pole frames

1. A first important improvement is to include braces in the planes of the walls, (Figure 16.3-1).

2 A wall plate must be introduced on top of the walls, which should be braced at the corners or intersections

3 A big improvement would be to introduce a foundation in, f.i stone or brick masonry, so that termites no longer could enter the wood easily, an excess of humidity would be avoided in the wood and the walls would receive a stronger base The poles could be connected to the foundation via a horizontal sawn timber beam, to which they could be fixed with steel anchors.

4 If such a foundation is not feasible, one should try to treat all vegetable materials used against insects, and pour an insecticide solution all around the foundations.

5 Interior walls should be pulled up to the roof level and well connected to the roof, to form a kind of cage

6. The use of vegetable ties to connect the horizontal branches or reed to the vertical frame is often unsatisfactory, since they loosen and brittle over time, particularly leading to disintegration of corners and intersections. The use of steel wires (not nails) can lead to better connections, provided the wood used is not too wet and does not shrink much

7. Corners and intersections could be reinforced by wire mesh fixed to the horizontal laths, or by sisal fibers in the wall and plaster, as done for the adobe walls. Steel or barbed wire can also be used to tie all the walls together, in a band above the doors.

The improvement of filled sawn timber frames

1. The same recommendations as those for light cladded frames with respect to anchoring, bracing, connections and timber treatment, apply. (Figure 16.2-1(b))

2 To improve the quality of the infills, one can follow the guidelines for adobe, stone and brick walls

3. The infills should be well connected to the wood frame, f.i through anchor bolts, protruding long nails, incorporated steel or barbed wire, wire mesh in the joints or the plaster (Figure 16 1-11)

The improvement of concrete block constructions

A wall made of concrete blocks with vertical reinforcing can be made in 3 ways:

- cast reinforced columns first and a masonry filling in between.
- first build the wall but leave vertical gaps in which columns are cast later.

- put vertical reinforcement at regular distances, in the voids of the blocks and so make columns by infill.

The first method is expensive, because it needs more shuttering and labor but it may produce better columns. However, the bond between masonry and columns is lower, and it will be difficult to attach horizontal reinforcement in the masonry joints and the column, unless the latter is cast in stages which affects its quality.

The second method is faster and cheaper, and provides a good bond between masonry and column.

The last method is the cheapest, but the quality and strength of the columns is lower; the steel is more centrally placed, and the risk of out of plane bending is high. Therefore, such infill columns are usually spaced closer in the wall, that is not only at corners or intersections.

More than any other construction concrete and concrete blocks needs proper quality control. Aggregates should have the right grading and be clean; mortars should have the right mix; blocks are better when vibrated and need curing in the shade, whilst wetted regularly The placement of reinforcement and stirrups needs attention and knowledge. Concrete should be vibrated after casting, not left in the full sun, and properly cured.

Apart from vertical reinforcement, horizontal reinforcing should at least be used as a tiebeam at roof level, and preferably also as lintel and at basement level. To save on shuttering, U-shaped concrete blocks can be produced in which the beams can be cast. The application of horizontal reinforcement is facilitated via slightly U-shaped blocks (Figure 16.3-2).

Continuous reinforcement is expensive and may not be required in all cases therefore, one could place reinforcement in areas of high stress such as corners, intersections

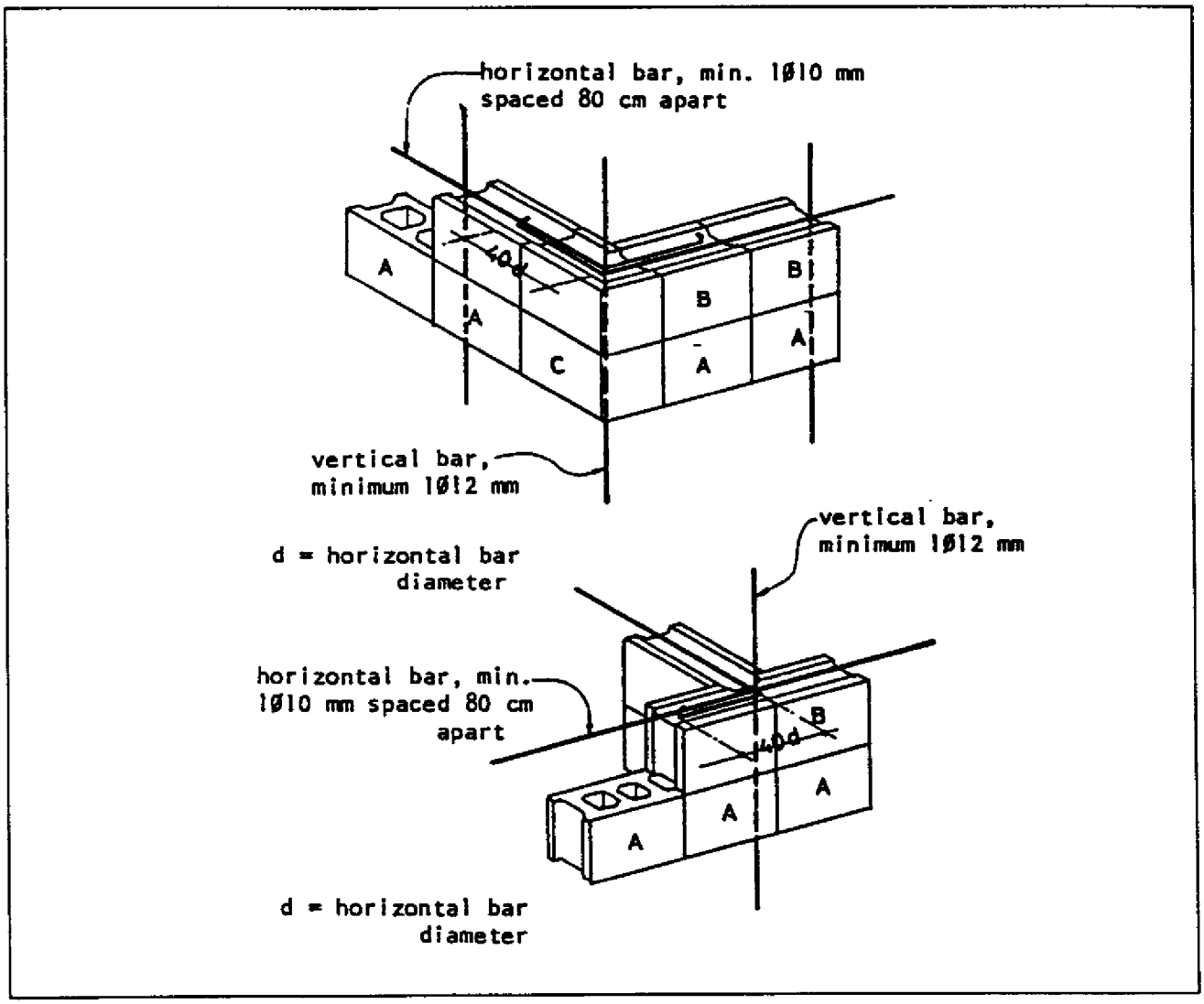


Figure 16.3-2 Horizontal Reinforcement in Slightly U-Shaped Blocks [4].

Bamboo or cane has also been used, for both vertical and horizontal reinforcement through the vertical voids and via U-shaped blocks (Figure 16.3-3).

medium weight wall, frame, timber, wattle and daub, quincha, hollow block.

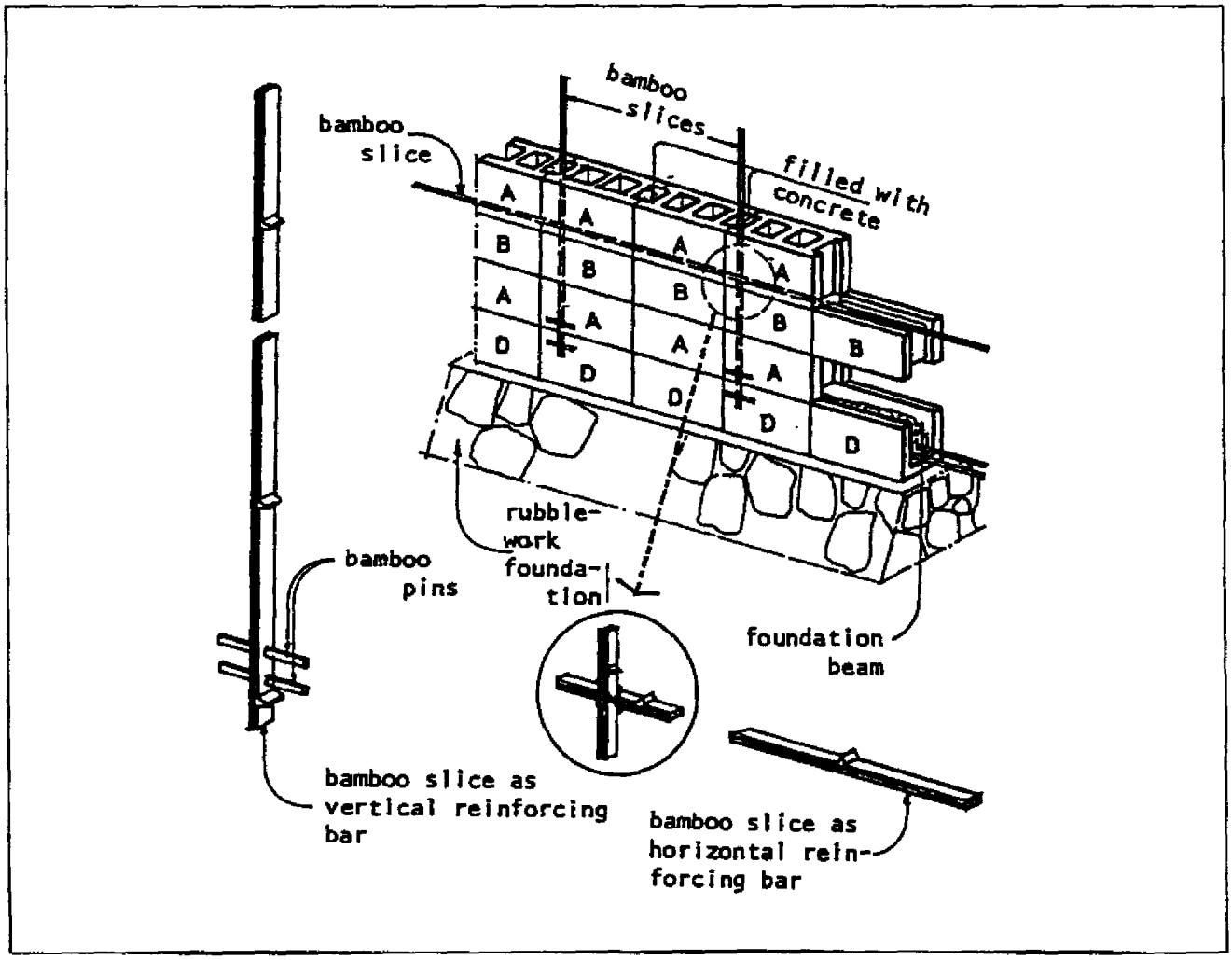


Figure 16.3-3 Sliced Bamboo Reinforcement of Hollow Block masonry [4].

Topic 16.4: Connections

A construction may be strong enough in itself, but it may fail due to poor connections, for instance:

- frames can fail due to improper connections or insufficient bracing of the various elements.
- masonry can fail due to bad bonds and joints, and particularly the disintegration of corners and intersections.
- the different elements of a house can separate due to poor connections, particularly of roofs to walls and walls to foundations.

We can distinguish three kinds of connections (Figure 16.4-1).

Laid up, or Gravity Connections

Examples are for instance the traditional connections of heavy earth roofs to walls, as well as the loose placement of timber or bamboo frames on footings, or as floor beams.

Due to lateral forces, the laid-up element can slip and fall, leading to collapse This kind of connection is extremely dangerous and should be avoided. This is common in multi-storey buildings and known as pancaking.

Tied or Hinge Connections

Examples are for instance nailed or tied connections in frames or the anchoring of wall plates to walls. These connections do not resist moments, because they are not stiff, but they are meant to keep the various elements in place.

Rigid Connections

Examples are mainly in the form of concrete and steel frames, though wood frames with bracing and sheathing can also attain in high level of rigidity These connections are moment-resisting.

connection

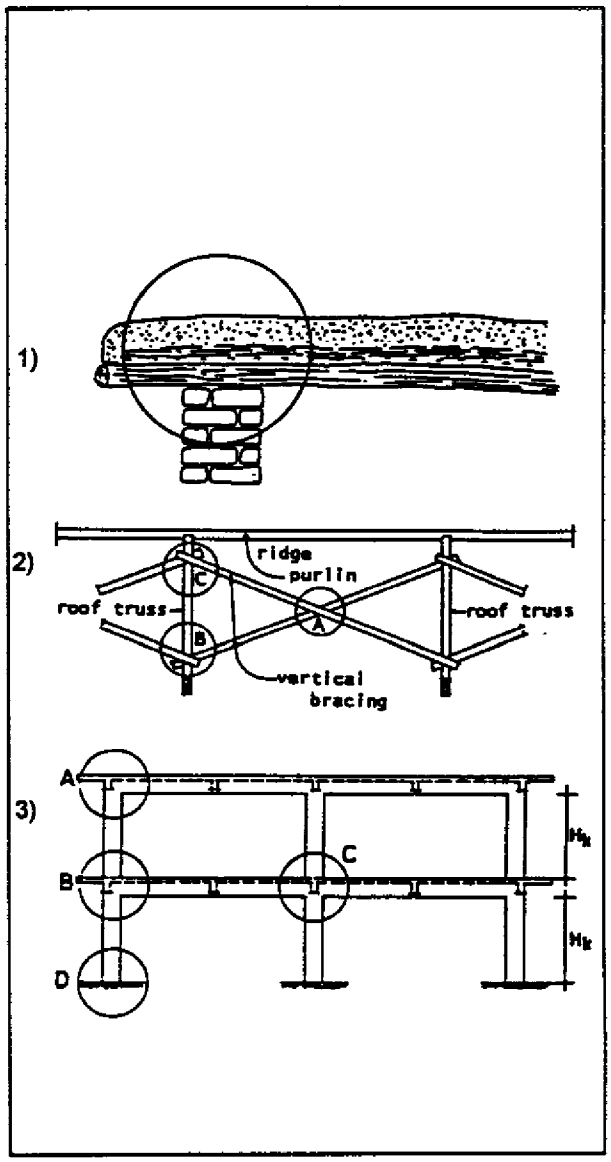


Figure 16.4-1 Connections:
1) Laid up, or Gravity Connection
2) Hinge Connections
3) Rigid Connections [4,14].

Topic 16.5: Strengthening of heavy roofs in low cost constructions

Heavy roofs suffer great damage during earthquakes and their collapse has often caused the death of many people. Light and intermediate roofs behave much better as an earthquake force exerted on these kinds of roofs is much smaller. In general, the roof must be strong, rigid and well connected to the walls in order to create a box-like building that is very strong under earthquakes. This data sheet describes methods and principles for the improvement of different types of roofs.

As it has been seen in many earthquakes, a heavy roof is a potential risk. If possible, it should therefore be avoided, but sometimes there are no alternatives. (Figure 16.5-1).

The improvement of flat roofs

1. The flat roof should act as a strong and rigid diaphragm that keeps the walls together The roof beams should therefore be tied together in a perpendicular direction to them by tie beams or wall plates. These connections should be made strong, preferably using angle irons, steel rods, bolts, or steel strips rather than nails. The roof should also be braced in its plane, to achieve rigidity by wood, steel or other members.

2. The weight of the roof should be equally distributed over the walls via a wall plate, and preferably by using many small roof beams instead of fewer big ones that lead to heavy concentrations of loads on the walls. Heavy concentration of loads should not occur above

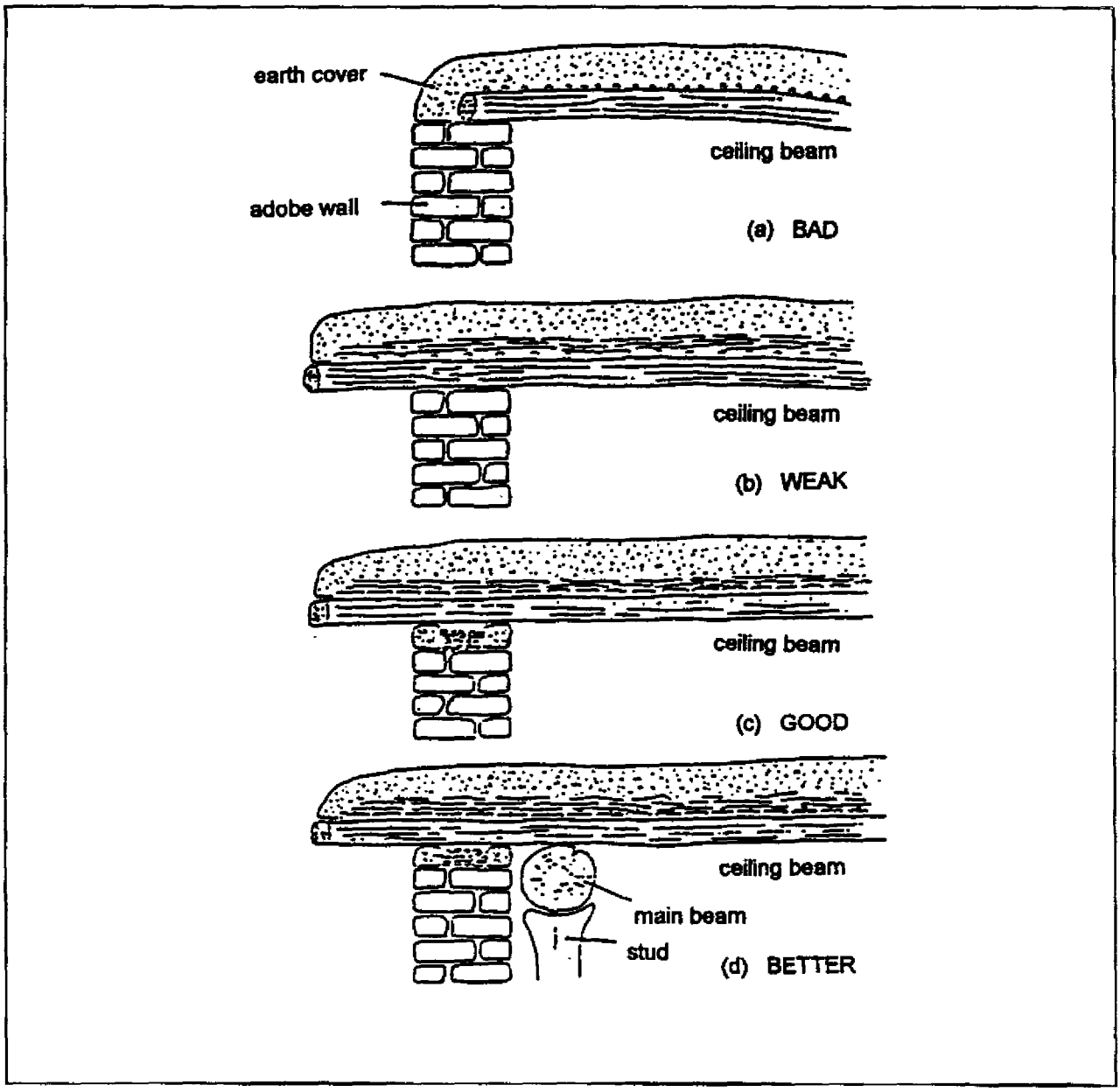


Figure 16.5-1 Constructing an Earth Roof [14].

wall openings

3. The durability of timber roof beams can be increased by treating them against insect and rot.

4 During maintenance, care should be taken not to increase the weight of the roof unnecessarily, f.i. by adding new layers of earth. Instead, the old and cracked earth should be removed and replaced by new earth.

5 To avoid continuous maintenance, it helps to waterproof the roof, by adding lime or another stabilizer to the earth or by coating it.

The improvement of barrel vaults

1 Do not make them unnecessarily thick since earthquake force is proportional to the vertical weight.

2. The quality of the vault can be improved by using well-fired bricks, and by replacing the mud mortar with better mortars on the basis of cement, lime or gypsum. The same mortar should preferably be used for a plaster.

3 Unless the lateral thrust of the vaulted roof is resisted by neighboring vaults, it should be taken either by buttresses at regular distances perpendicular to the supporting walls, or by tie beams over the walls connected by horizontal ties (Figure 16.5-2).

The improvement of domes

Principles (1) and (2) mentioned above for the improvement of vaults equally apply for domes.

Unless the domes are supported by adjacent domes or walls, strong tie beams should be placed on top of the supporting walls to keep those together, and balance the horizontal thrust.

Improvement of wall to roof connections

Traditionally these connections are usually of the laid up type (Figure 16 4-1, 16.5-1) One of the most common mistakes is the insufficient bearing length of roof beams on the walls Therefore

1. Roof beams should get sufficient bearing length on the wall, even as far as protruding through wall, (Figure 16.5-1)

2 A wall plate in timber or concrete should be provided to improve the distribution of weight of the roof, to tie the roof together, and for proper anchoring of roof to wall. Particularly in the case of roundwood, nails are not a good connecting element between beams and wall plate. The use of steel rods, strips or bolts is much preferable (Figure 16.5-3).

3. The wall plate should be anchored properly to the wall, preferably over several layers of masonry or at least one layer of rammed earth.

Connection can be made by steel strips, anchor bolts, or even wire-mesh folded around several layers of masonry and the wall plate and fixed with nails.

roof, strengthening, connection, low cost construction, barrel vault, dome, roundwood.

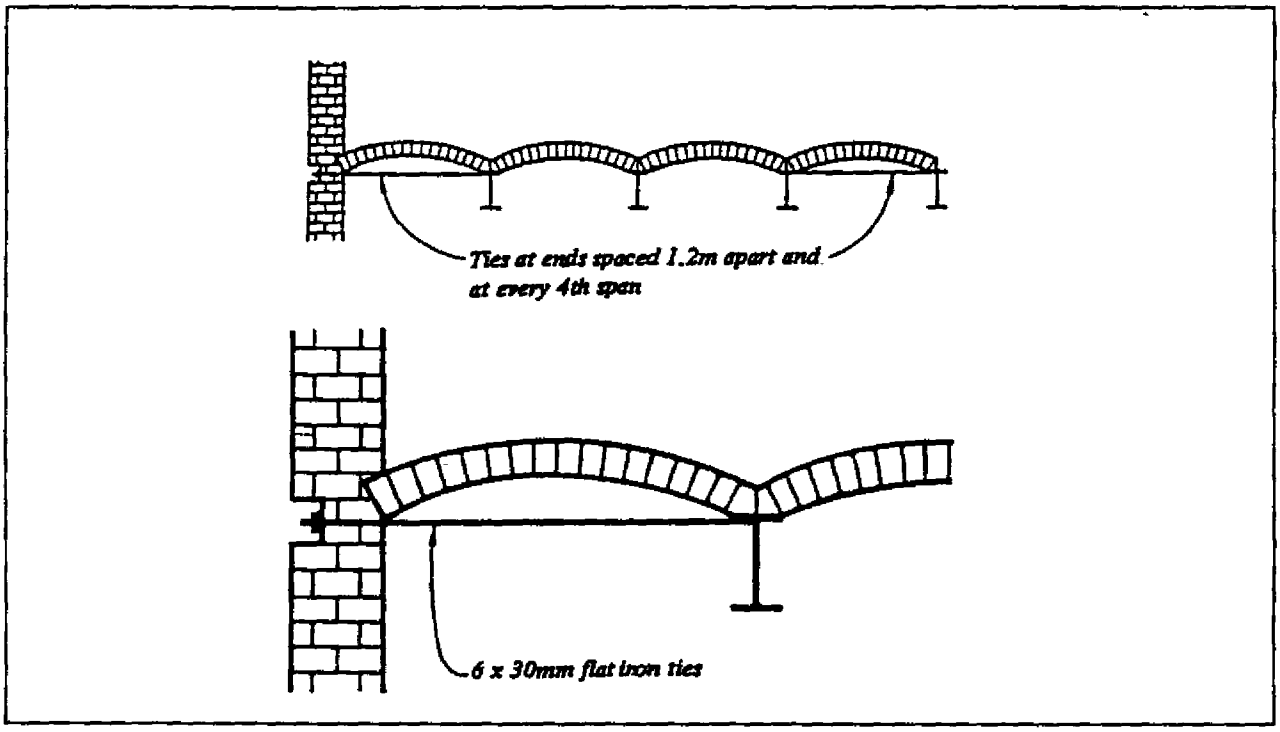


Figure 16.5-2 Ties in Jack Arch Floors and Roofs [2].

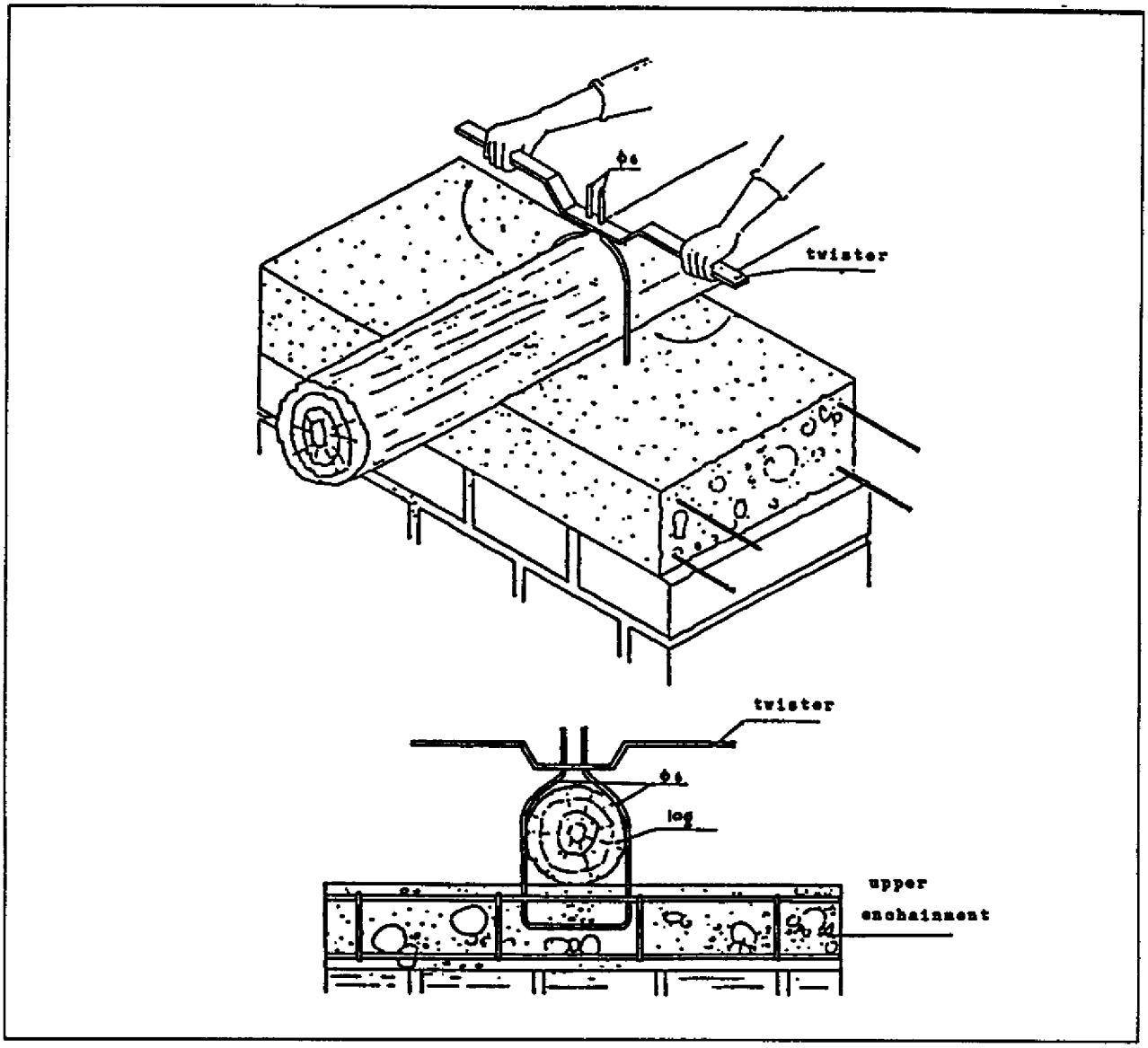


Figure 16.5-3 Anchoring of Roundwood to Concrete Wall Plate [14].

Topic 16.6: Light and Intermediate Roofs

The lighter the roof the better, since lateral forces will be reduced and it will be less risk to residents if ever it collapses. In this category we can place:

- sloping roofs, usually having a wood frame and a covering of grass, thatch, leaves or tiles.
- curved roofs, usually on a cement basis.
- flat roofs with voids, such as concrete roofs with hollow bricks inside.

The latter two are expensive solutions in many third world countries.

The improvement of wood framed roofs

1. The roof should be made to act as a unit. Therefore, the roof beams should be properly connected to each other via ties and braces, and to the walls, preferably via wall plate. If sawn timber is used, the best connections are obtained with steel strips, angle irons, or grip anchors Connections of roundwood are always more difficult to make. Direct nailing is usually not very good, it is preferable to use steel strips nailed to the beams or to tie them together with steel wire. In the latter case the wood has to be dry, otherwise the wires will loosen. The University of Delft, Holland, has developed a special spanner for these wire connections (Figure 16.2-2c)

2 When tiles are used, it is preferable to select the rather flat machine-molded tiles instead of the half-circular traditional models, because of the lower weight.

3 When maintaining thatch or grass roofs, care should be taken not to add too many new layers; it is better to remove the old material and place a new one.

Curved roofs

Earth or brick vaults and domes, that are heavy, have been treated earlier But a lighter alternative exists in the form of thin concrete vaults or domes, and even thinner and much cheaper ones in ferrocement. In future, when its durability has been proved, similar constructions may be possible using vegetable fibers as reinforcement.

Flat roofs

Flat roofs out of hollow brick or concrete elements, with reinforcement rods in between, covered with concrete, are not too heavy and are rigid and strong. They are expensive, however, and their construction needs much care.

Alternatively, a flat wooden roof may be used, consisting of sawn timber beams, covered by wood planks or flat sheets of plywood or particle board, and provided with a waterproof coating, f.i. in the form of asphalt paper. This is not a very common type of roof in the third world, because the covering material often creates problems. Through bracing and good connections to the walls, it can be a quite strong solution.

Summary of factors preventing roof collapse

The following factors are important to prevent roof collapse:

1. The roof should be strong enough in itself; that is it should be able to behave as a unit and have sufficient in-plane rigidity. Therefore, the various elements of the roof should be well connected to each other. A wall plate or a tie beam can serve to bind the various roof beams together. For rigidity, diagonal bracing in the plane of the roof may be required.

2 The roof should be properly connected to the supporting structure Walls should not be allowed to move apart, causing the roof to slip from its support. Connections of roofs to frames should also be sufficiently strong. In general, the roof can act as a diaphragm that helps to make a house a strong box-like structure, if it is properly connected to the walls and is sufficiently strong and rigid.

connection, roof, lightweight roof, roundwood, medium weight roof.

SESSION 17: SELF-HELP HOUSING

Topic 17.1: Self-help Housing

Non-engineered construction is the most suitable type of construction for self-help housing projects, but it must be stressed that the worker's knowledge and skill together with the quality of materials and workmanship, considerably affect the quality and strength of the final product.

There are two common approaches to self-help housing around the world:

- Maximum contribution.
- Partial contribution of labor and effort by the family to produce the building materials and to construct the house.

Maximum contribution

The simplest and most familiar form of construction in the world, of course, is the traditional one-family approach, best exemplified by the Eskimo's igloo, the nomad's tent, the African's, Asian's and Latin American's mud-pole-thatch hut. Stone walls and soil roofs are also used. The family gathers the materials, shapes and fits them, and build its house. Skilled labor is not required. These are mainly the traditional houses, and the building techniques, often quite complicated, are passed down from father to son.

The next most common form is the group building approach, which is usually associated with villages or other settlements. Neighbors and friends help to build houses in return for reciprocal aid when they build their own. Sometimes these houses have components that are too big or too heavy to be handled by one man even when assisted by his family and sometimes the materials must be found far away from the village.

Partial contribution

For a number of reasons which are usually based on political or technical decisions, maximum family contribution is not always possible. In this case, a combination of paid skilled and self-help labor is used.

The following are some cases of partial contribution:

1. In-slum clearance and resettlement project; the building of a one-room, "core structure", by skilled labor and of the other rooms latter by self-help.

2. The building of part of the house such as the foundation and walls by self-help, and of the roof by skilled workers.

3. The self-help production of materials and buildings elements such as sand, blocks, bricks, timber, which are supplied to skilled workers who build the houses.

It should also be added that the actual nature of the partial or maximum contribution may depend on arbitrary factors and circumstances.

General Rules

For any type of self-help housing project simple and understandable drawings of different size of single and two-storey seismic-resistant houses, should be prepared by the government or other organization. These houses should be simple and regular in their form and construction in order to offer good resistance to earthquakes without considerable increase in cost. Guidelines and specifications for the proper methods of construction and materials to be used should also be given.

Supervisory groups must always take care to clarify the aims of the earthquake resistance provisions in the drawings and the guidelines, and make sure that they are followed. Adequate materials of good quality should also be made available to self-help builders at reasonable prices.

Technical assistance, supervision, training and different forms of information and communication are some measures that contribute to the improvement of the quality of construction and the resistance to earthquakes. Demonstration houses are essential for training and transfer of knowledge and skills.

Whatever type of house is to be used for self-help projects, be it a complete house, a shell or simply a core house etc., it should be stressed that symmetry in geometry and structural form, in plan and elevation, should exist at all stages of construction. This may be difficult to accomplish in the case of expandable core houses but always keep in mind that large irregularities lead to failures during earthquakes.

? a. One of the problems in self-help construction is quality control. How can this be achieved in this case ?

b Is there an institution that could render advisory services in this area ?

self-help housing

SESSION 18: COST OF EARTHQUAKE RESISTANCE

Topic 18.1: Cost of Earthquake Resistance

Throughout the centuries natural disasters have caused great human and property losses all over the world. In the past two decades, natural disasters have caused damage of over 25 billion dollars and claimed three million lives.

The cost of providing earthquake resistance, though it may not be accurately estimated, is by no means comparable with the potential losses.

The cost of design and construction of a seismic-resistant building will depend mainly on the following parameters and factors:

- Type of building
- Soil conditions
- Seismicity of the area
- Importance of building
- Form, simplicity and regularity of the building
- Height of building.

Unfortunately it is not possible to give simple guidelines on costs, although it will not be misleading to say that most engineering projects designed to the new fairly rigorous codes, would spend a maximum of 10 percent of the total cost on earthquake provisions, with 4 percent as an average figure.

Good building form; geometry; simplicity; symmetry; regularity in mass, stiffness and strength, together with fairly good site conditions, lead to a strong and economical structure. It must be stressed that minor changes in the framing system or in design details, may have an overwhelming influence on the seismic performance, and merely adding more materials, though it will directly increase cost, will not guarantee satisfactory performance

Figure 18.1-1 shows some comparative costs carried out in Boston for the increase in construction costs for seismic design provision. Obviously the costs will also vary according to the baseline design provision for wind If high wind forces are experienced then the percentage increase due to seismic design would be lower

Other estimates (Leslie and Biggs 1972, Whitman, Biggs, Brennan, Cornel, de Neufville and Vanmarcke, 1975; Fernto,

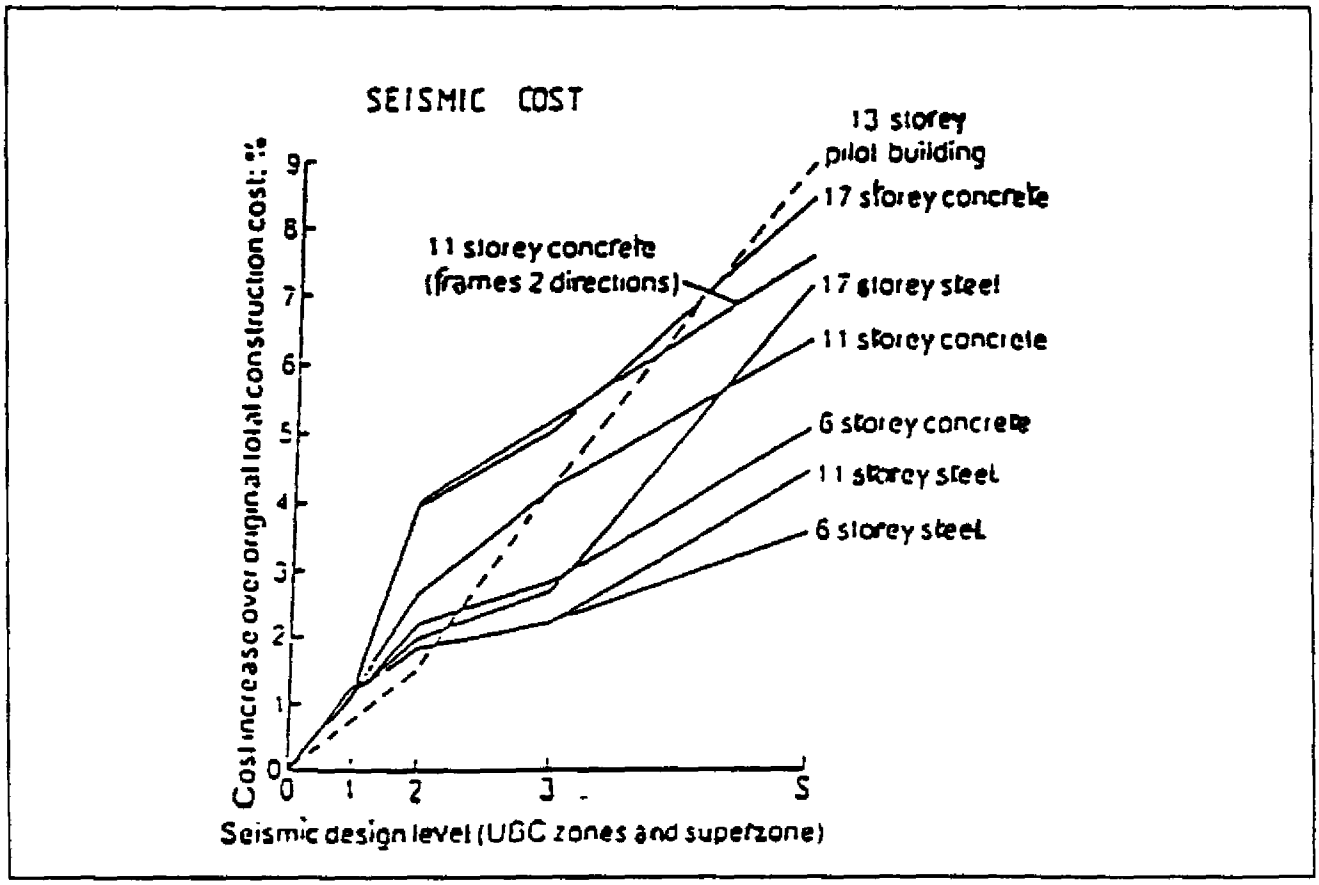


Figure 18.1-1 Seismic Cost

1985) generally lie within the upper and lower bounds of Figure 18.1-1 and agree that the proportional increase is less for structural steel than for reinforced concrete. In the United States of America steel is thus a more economical material than reinforced concrete for buildings for six or higher stories. This may not be the case in other, especially developing countries.

One must bear in mind that the calculated values shown in Figure 18.1-1 are for typical apartment buildings. It must be also stressed that for low rise buildings the increase in cost for earthquake resistance may be in the order of 2 to 5 percent only.

Low income people work a lifetime to build their own house but an earthquake can destroy it completely within a few seconds.
It is the duty of all of us, architects, engineers, contractors and advisors to help people, especially those on low incomes, by providing simple, durable, strong and inexpensive houses


seismic cost

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