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REGIONAL COCONUT WOOD TRAINING PROGRAMME

DU/RAS/81/110

Technical report: Utilization of coconut palm sawn wood as a light framing structural material*

Prepared for the Governments of the countries participating in the regional project by the United Nations Industrial Development Organization, associated agency of the Food and Agriculture Organization of the United Nations, which acted as executing agency for the United Nations Development Programme

Based on the work of V. K. Sulc, wood technologist

United Nations Industrial Development Organization
Vienna

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Acknowlegement

For all the assistance with structural drawings, I wish to thank James Gross, Architectural Draftsman at Coconut Palm Wood Utilization Division, Philippine Coconut Authority, Zamboanga Research Centre, Zamboanga City, the Philippines.

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1. INTRODUCTION

The possibility of utilising Coconut Palm Wood (CPW) for light framed structures on a large scale has been recognised only in the last decade, although a number of palm species producing large woody stems have been used at the village level from time immemorial, as round or hewn wood for the building of shelters.

Although Nipa Palm does not produce a woody stem, it's mature leafage is one of the best sources of native roof or wall thatching material, lately in short supply in most Pacific tropical regions.

In more recent times (beginning of the 20th Century) Coconut palm wood had been used successfully in large church structures particularly in the Tongan Islands and as reported in Sri Lanka.

In the Tonga Islands can be seen at least two relatively large church buildings with C.P.W. roof construction of an ellipse shape (from inside view it looks like an upside down boat). C.P.W. has been used as round wood combined with axe split or hand sawn roof battens (see Appendix 1).

In the whole roof structure no nails have been used. Round wood is used with scarf joints with a low bevelled angle fastened by wood dowels. and tied by husk fibre strings. Roof battens are 40 - 50 mm wide, 12 to 15 mm thick and are tied only with husk fibre strings.

About 15 - 20 years ago the original thatch roofing was replaced by G.I. sheets without altering or adding any structural members to original roof design. Roof structure has been designed for thatched roof therefore G.I. sheets had not necessary supports for holding roofing nails or screws.

Photograph at Appendix 1 shows the church roof covered by G.I. Sheets, after Hurricane "Isaak" in March 1982 in Ha'apai group of Islands of Tonga, - only part of G.I. sheets have been lifted without any damage to original roof structure.

The above mentioned roof structures of Tongan Churches are 60 to 80 years old and fully protected against weather. Wood is still in good condition although not treated by any wood preservative or paint. Supporting foundations are constructed from large round poles from durable hardwood (most likely species Ai-toa) still available in Western Samoa. The same wood is used for framing and siding load bearing walls.

Nearly all recently built structures were totally or considerably damaged by the hurricane. The most likely reason for this was that, since Tonga no longer has a supply of native grown wood suitable for saw milling, all construction wood must be imported. The price of the imported material is very high in relation to local incomes. Consequently, wood components in local housing tend to be under-sized and too widely spaced (studs, **ceiling ties** and flooring joists) with the weakest point probably being the roof structure, where battens are widely spaced without proper bracing and with poor connections to the side walls. Galvanized iron (GI) roof sheeting is not usually well supported by enough purlins of the correct size and consequently insufficient roofing nails are used with the result that the whole roof structure may be easily up-lifted during high winds.

The diminishing availability of conventional timber species in many coconut palm growing countries means that C.P.W. will increasingly be looked upon as the source of alternate construction material.

In nearly all coconut growing countries existing plantations are approaching over mature (sterile) stage evidenced by reduced production of fruit. In almost all coconut growing regions the proportion of over mature (sterile) palm is increasing, thus effecting the economy of farmers and countries. The solution to this problem is replanting programme by new more productive coconut varieties. Progress in replanting will make available a considerable amount of Coconut palm stems suitable for a number of wood products. Utilisation for construction purposes offers the greatest feasibility.

The designs described in this paper for low and medium cost housing are intended for rural areas, villages or small country towns. Although this paper deals only with light timber frame construction suitable for the tropic regions - there is no reason why selected Coconut Palm sawn wood could not be used for different structural or decorative components in higher quality houses or industrial and commercial buildings. Figure 1 shows terminology used in timber framing.

Basic design is based on the following criteria:

1. Low cost.
2. Reasonable comfort and appearance.
3. Good natural ventilation (important in tropical regions).
4. Easy to maintain.
5. Maximum life expectancy under given environmental conditions.

Finally as many Coconut growing countries are subject to high winds, (cyclone, typhoon, hurricane), brief but destructive floods during rainy seasons, some attention is given to such construction techniques to minimise damage.

Wood in general use for construction purposes in tropics is subject to a faster rate of biological decay, attack by termites - therefore some attention is given to such problems.

Since Coconut Palm Wood is a local indigenous wood, it could considerably assist to produce better and cheaper housing, especially in rural areas for the farmers and labour work force in the plantations, if it's utilisation is properly managed.

One considerable problem is relatively low pay for skilled or semi skilled labourers in rural areas, to be able to purchase a block of their own land where they could construct better quality housing. As now, especially in the Philippines most workers build shelters on land which is owned by somebody else, and the permission is given under condition that shelter must be removed on request of the legal owner - for this reason only very simple shelters are built and transferred when necessary.

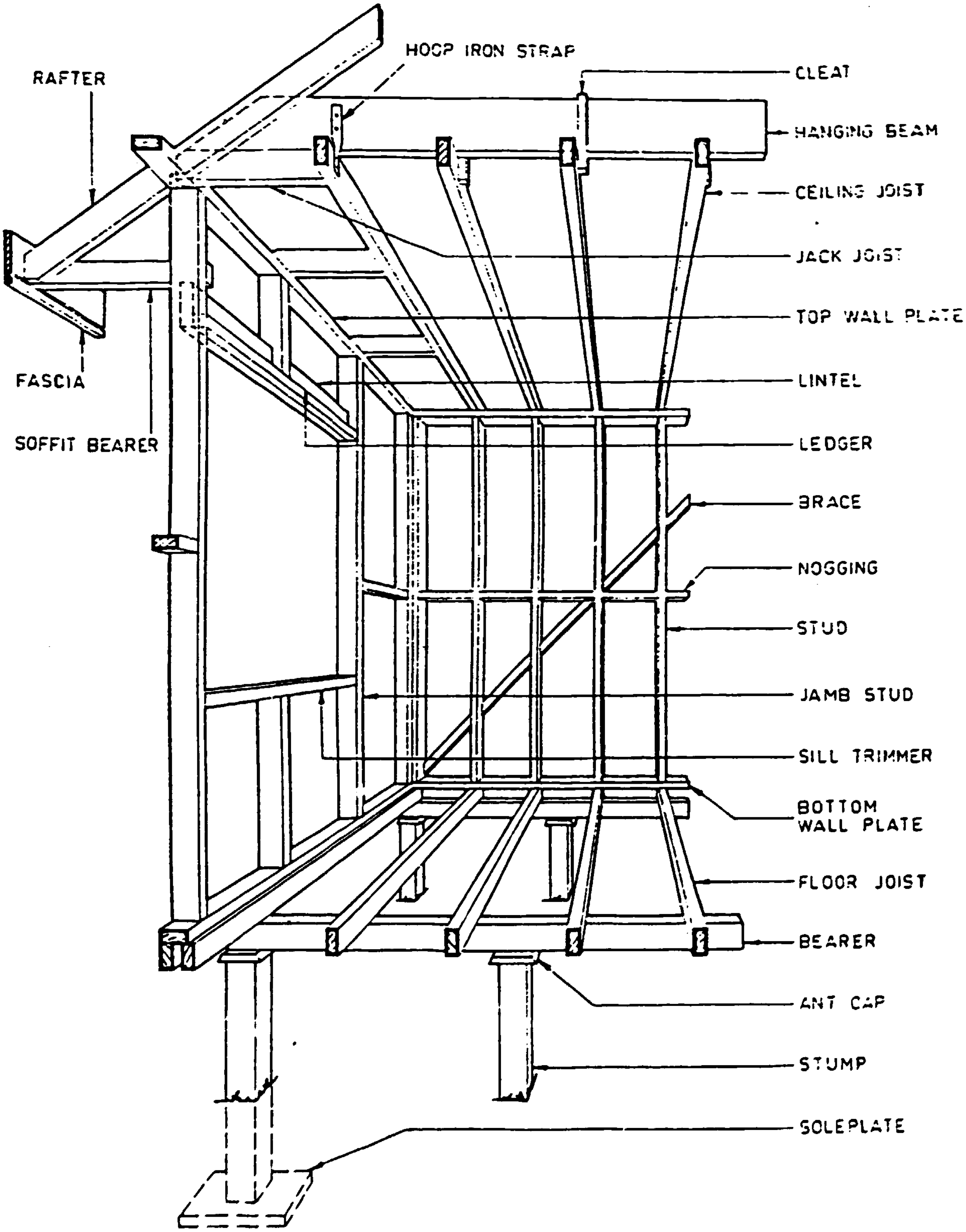


Figure 1. General terms used in framing construction

It is hoped that in future particular Government administrations will assist the rural population to obtain ownership of building sites under reasonable economic conditions and be able to build better types of houses.

2. SELECTION OF A BUILDING SITE AND FOUNDATIONS

Location of a building site in the rural area does not present many problems but nonetheless it is essential for the owner of land to select most suitable place. Low areas should be avoided and it must be free from standing water, have good natural drainage, road access etc.

However, selection of a suitable site is more difficult when only small building lots are available and questions of spacing are involved, so general situations and conditions govern the type of foundation to be used.

Many rural buildings in the tropics are situated under protection of large fruit trees or palms which provide a number of benefits such as:

1. shade against direct sunshine, which protects exposed wood against weathering;
2. protection against high wind (sheltered location);
3. cool and pleasant environment during intensive tropical heat.

The disadvantages, however, are that buildings located in such an environment are subject to biological wood decay (fungi) and termites more often than buildings in open spaces.

2.1 Foundation Material and Types of Supports for Sub-Flooring

Low and medium cost housing especially in the tropics, tends to be light construction without massive load bearing walls, for this reason bearing value of the foundation is more subject to local knowledge and experience.

Types of supports for sub-flooring:

1. Wood stumps (post) - including pole structures. See Fig. 2;
2. Concrete or masonry piers. See Fig. 3 A;
3. Steel pipe.See Fig. 3 B;
4. Combination of concrete elevated footing (Blob footing) and wood stumps. See Fig. 4.

Some care should be taken where building is constructed on soft clay, wet or loose sand. In such foundation material, larger areas of the footings are necessary, and when wood posts are used, sole plates of larger dimensions should be applied. See Figure 2.

Note: Sole plate could be used of the following materials:

1. durable block of wood
2. flat hard stone
3. concrete block embedded to the post.

Building site should be cleared from all types of vegetation, tree stumps etc. (Primary prevention against subterranial termites, there is the tendency to build mostly around old stumps). Organic soil should be removed to level or mineral soil where it is possible.

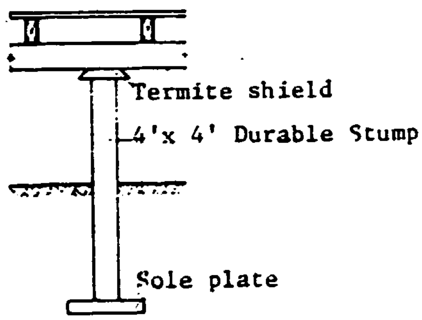
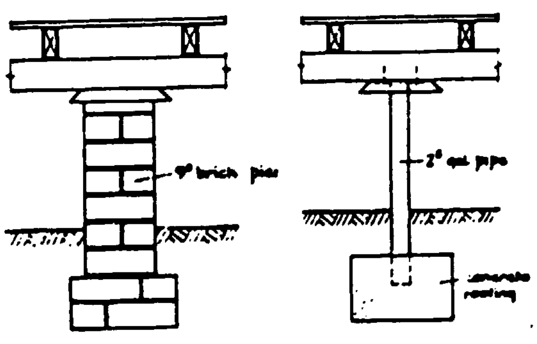


Fig. 2 Wood stump fitted with sole.

Fig. 3

A. Brick pier and footing
B. Steel pipe column welded to steel plate for connection to bearer



A B

Types of footing and sub-flooring:

Note: Sub-flooring is defined as all the parts of the floor structure below the actual decking (i.e. posts, stumps, floor bearers and joists).

When wood flooring is intended to be used in the structural system, the sub-flooring must be elevated from the ground level to a minimum 500 mm. Sub-flooring ventilation is most important.

For tropical regions full enclosure (continuous wall) of the sub-floor should be avoided even if cross ventilation is provided by wire mesh openings.

It is acceptable that only one side of the sub-flooring be enclosed by continuous masonry wall; this will prevent biological decay of sub-flooring wood members and help to safeguard wood members against attack by termites. Figure 4 shows such a design. Figures 6 to 11 show other details for footings and pier to sub-floor connections.

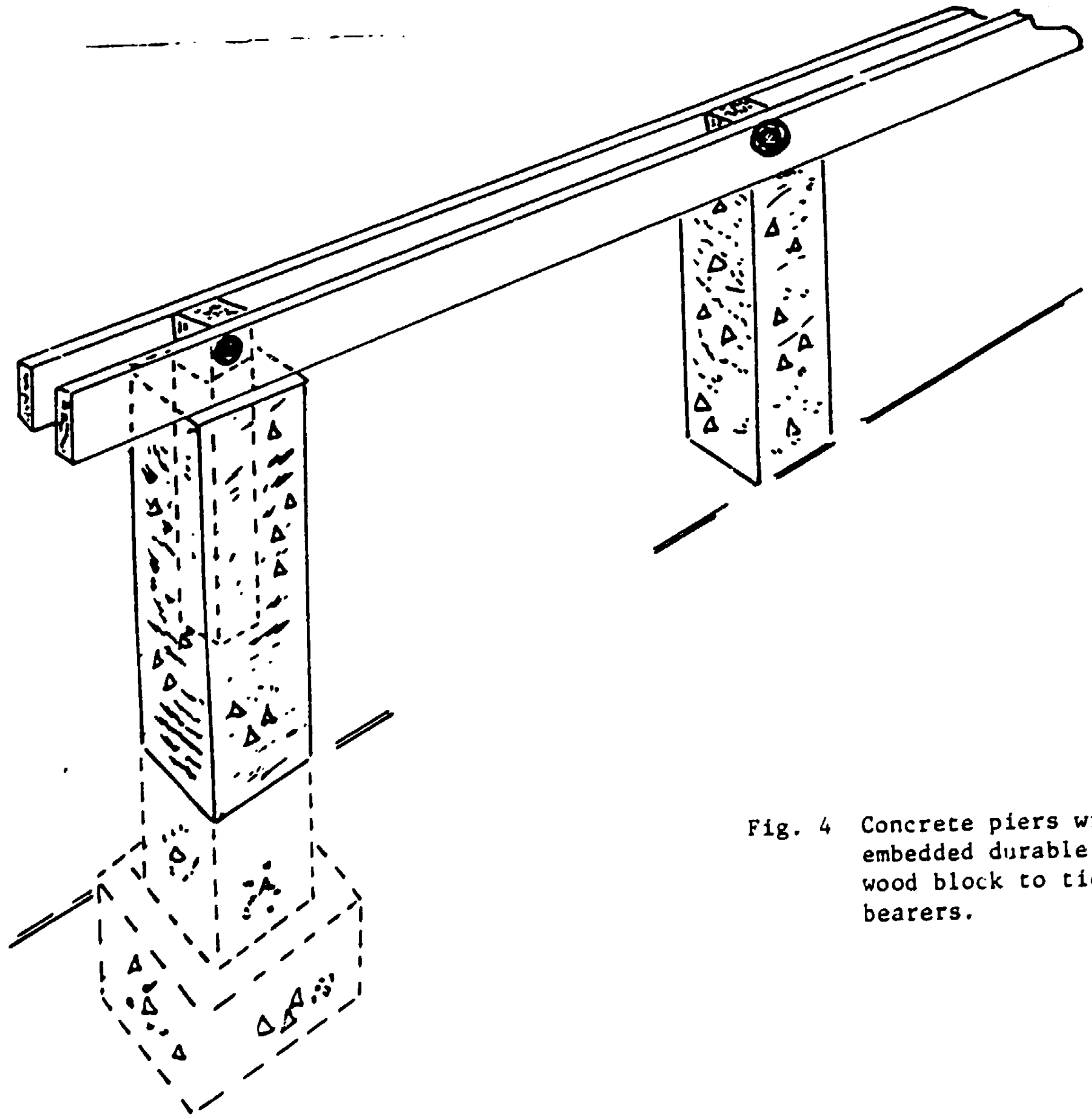
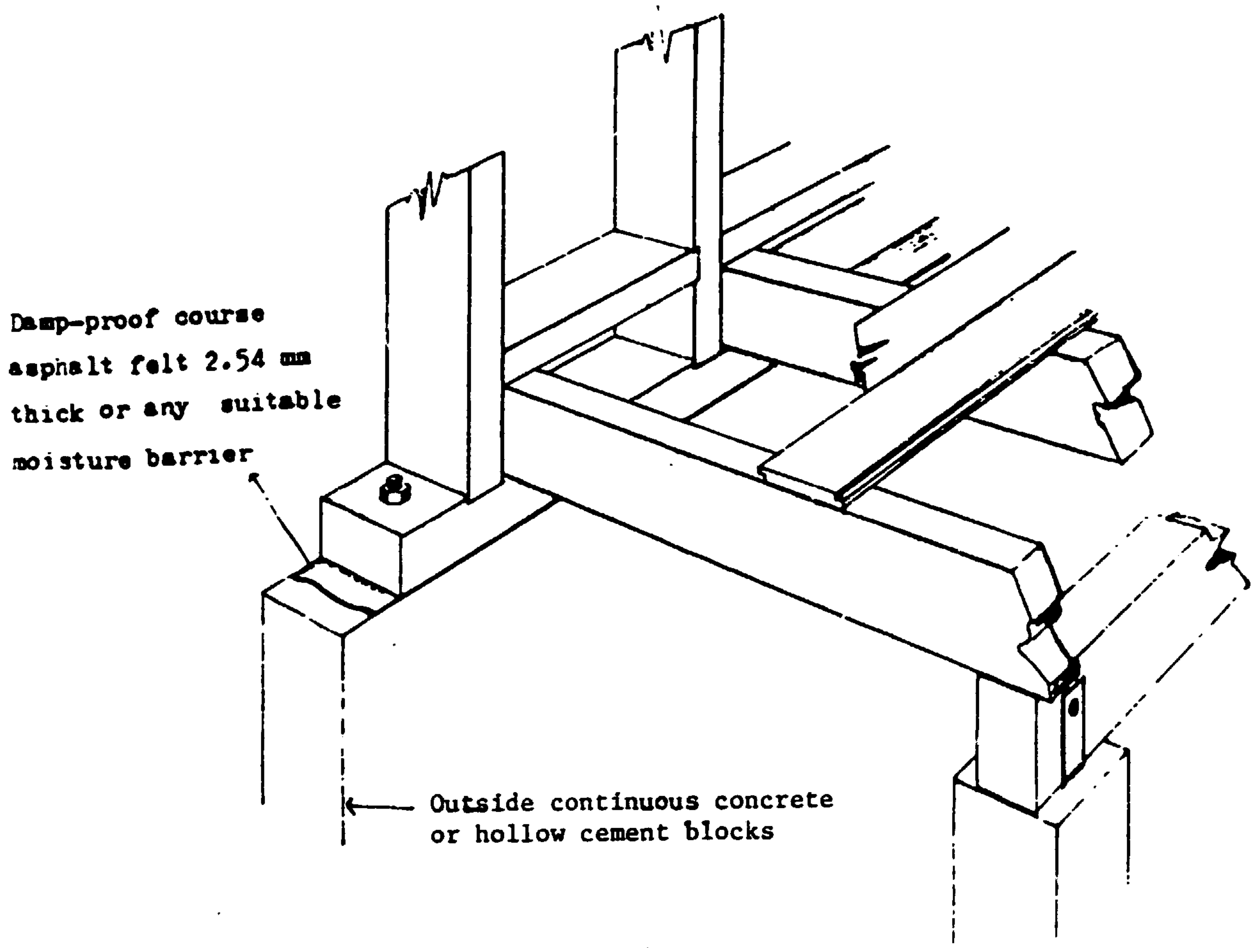


Fig. 4 Concrete piers with embedded durable wood block to tie bearers.

Fig. 5 shows arrangement of subfloor when one side of building used continuous wall.



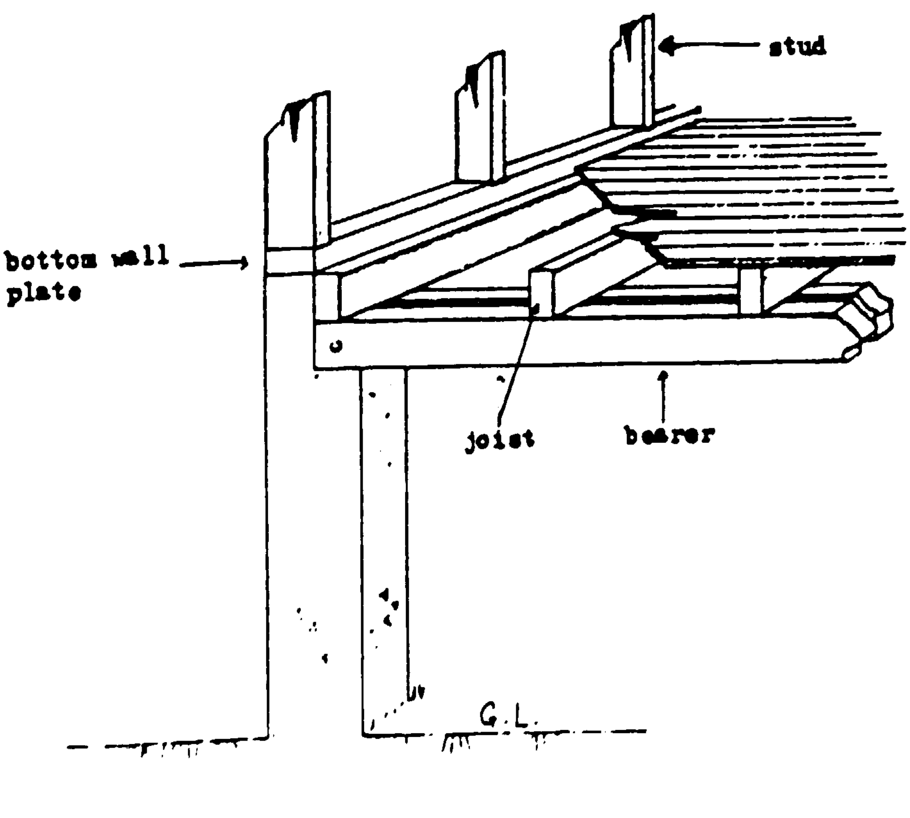


Fig. 6 shows arrangement of the corner concrete pier.

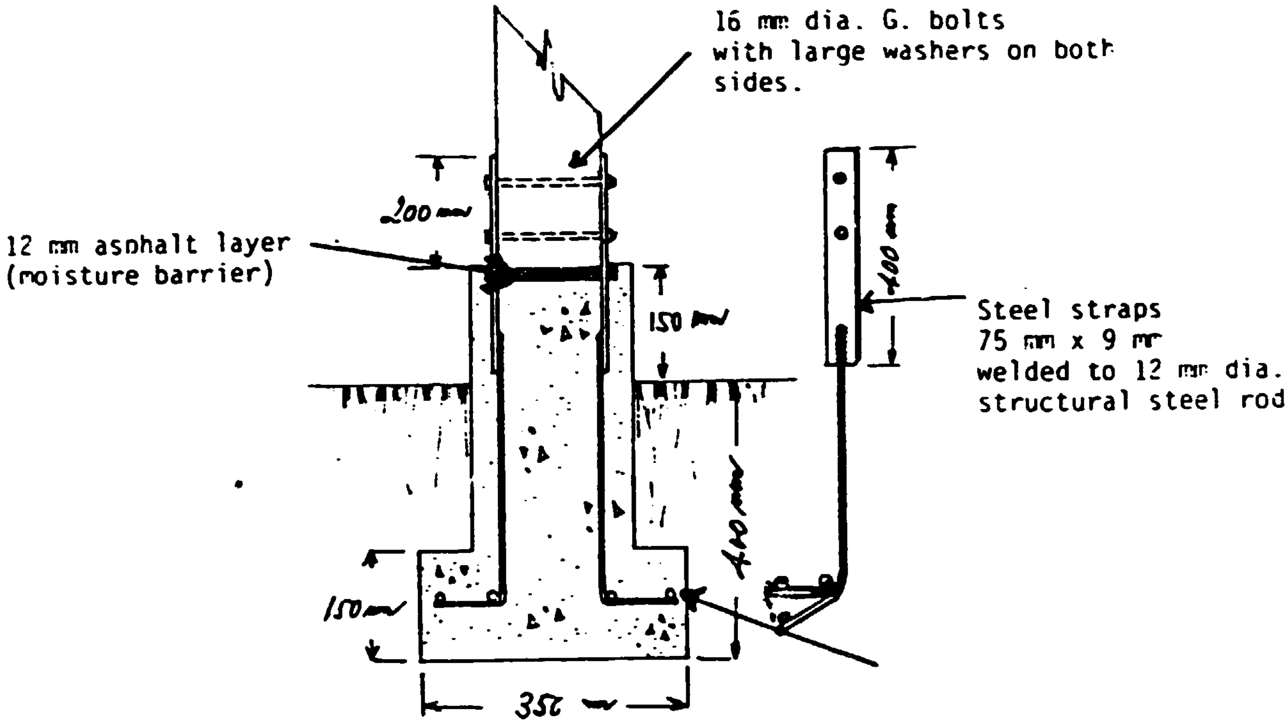


Fig. 7 Shows arrangement of footing and fastening for the pole construction.

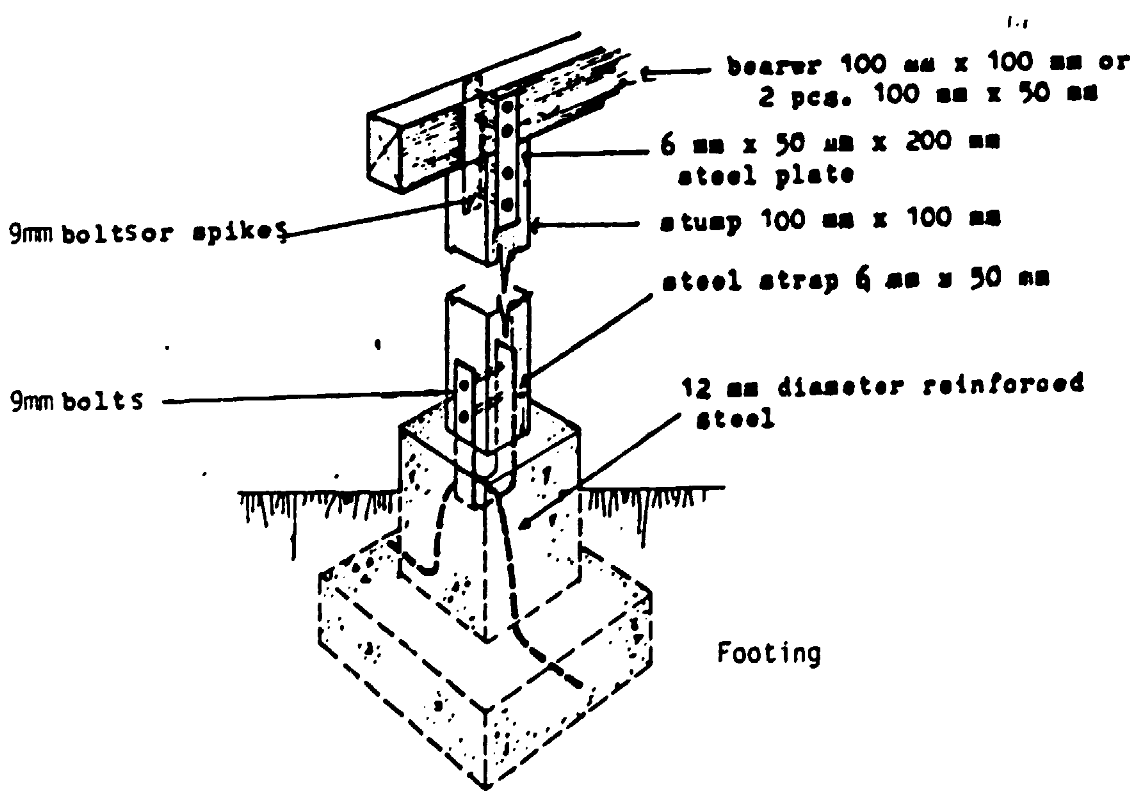
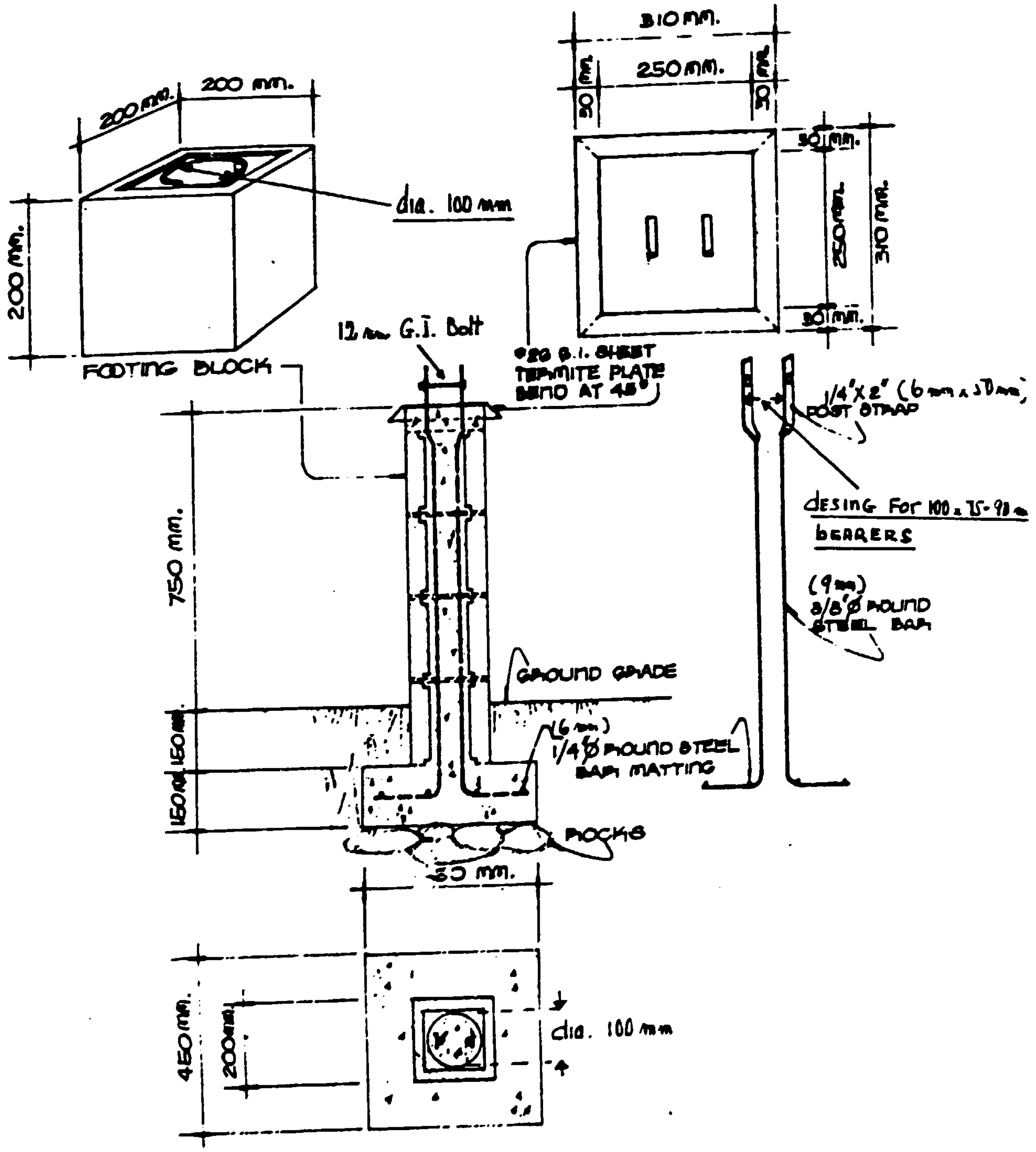


Fig. 8 Shows blob footing arrangement to elevate wood stump above the G.L. (ground level).

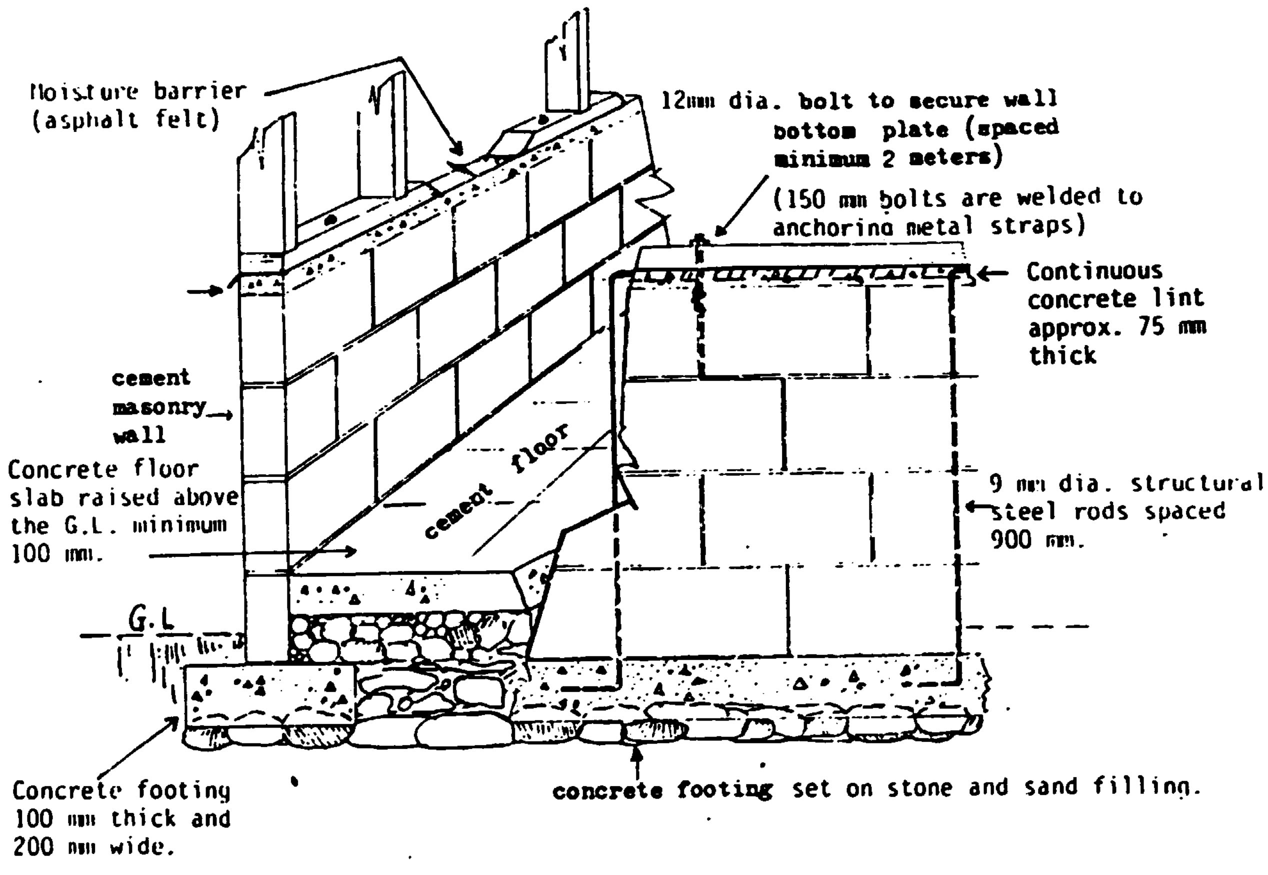
Fig. 9 Footing and masonry posts arrangement with anchored post strap.



Note: Square hollow cement blocks produced with simple collapsable wood form with cylindrical channel - Blocks are joined by mortar and filled with concrete during the assembly.

Note arrangement of Termite Plate.

Fig. 10 Shows arrangement for conrete slab floor with raised single cement hollow blocks wall (2 or 3 layers above floor level).



Whether or not concrete slab construction is used depends considerably on the level or slope of building site ground (See Fig.9).

If the ground slopes upward from the building good drainage on the side (or both sides) of the building is needed.

Floor (the top of the slab) should be elevated minimum 200 mm above the ground level.

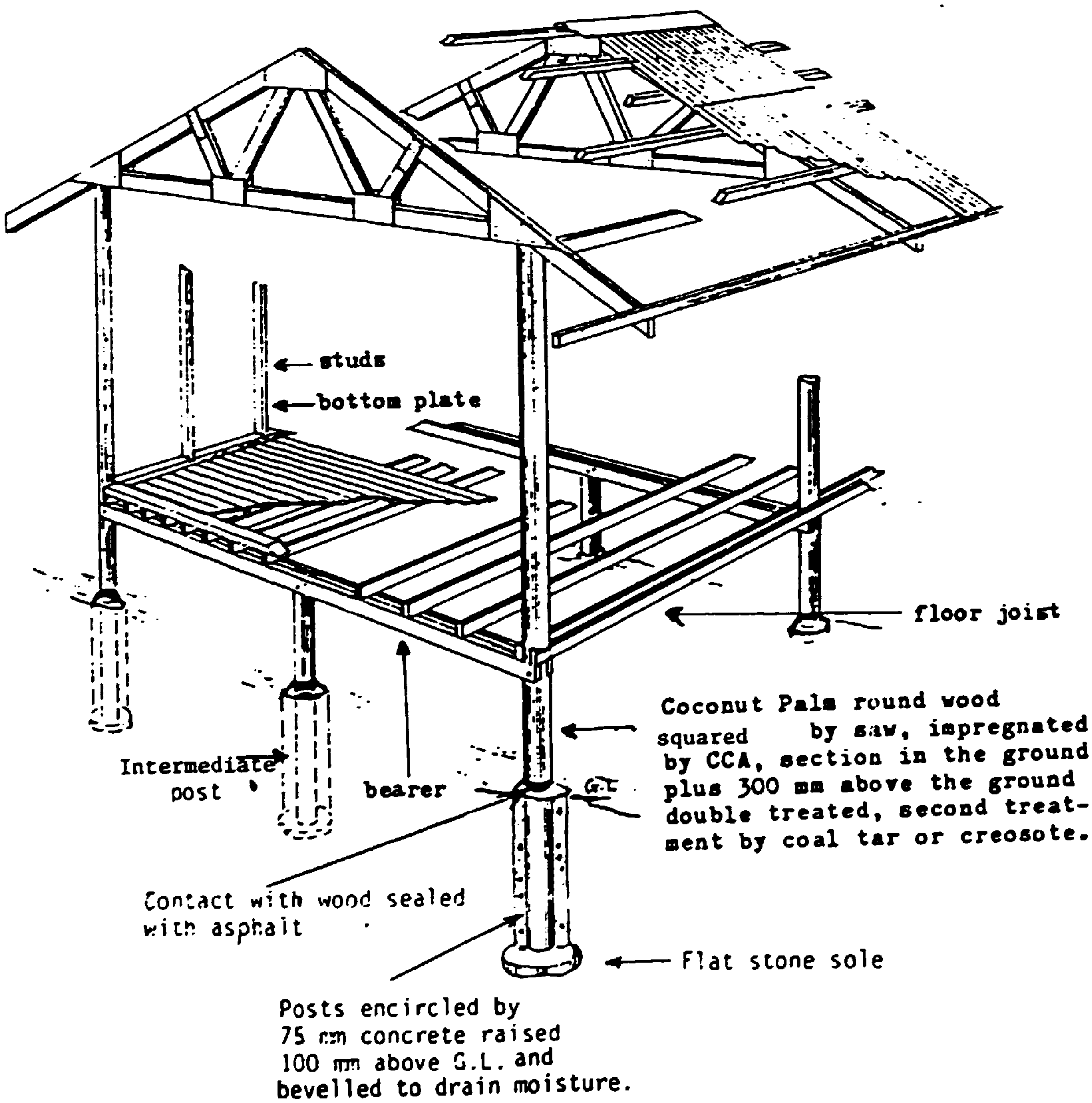
The polyethylene plastic sheet (2/10 mm thick) should be placed on sand levelled stone backfill, over all concrete slab and footing to prevent the rise of moisture to ultimate finish of floor (tiles, wood parquetry or just plain finish).

Note 1: On concrete slab construction the masonry wall (or concrete) should be raised at least 200 mm above floor level to prevent direct contact of wall frame bottom plate with floor fluids (spilled water, cleaning floor etc.) which increase the danger of biological decay (fungi).

Note 2: Concrete slab floors are very attractive to subterranean termites for nests.

Fig.11 - Pole Construction Arrangement Used in Low Cost Housing

Foundation stumps extended to ceiling level in each corner or where internal wall is joined with outside wall.



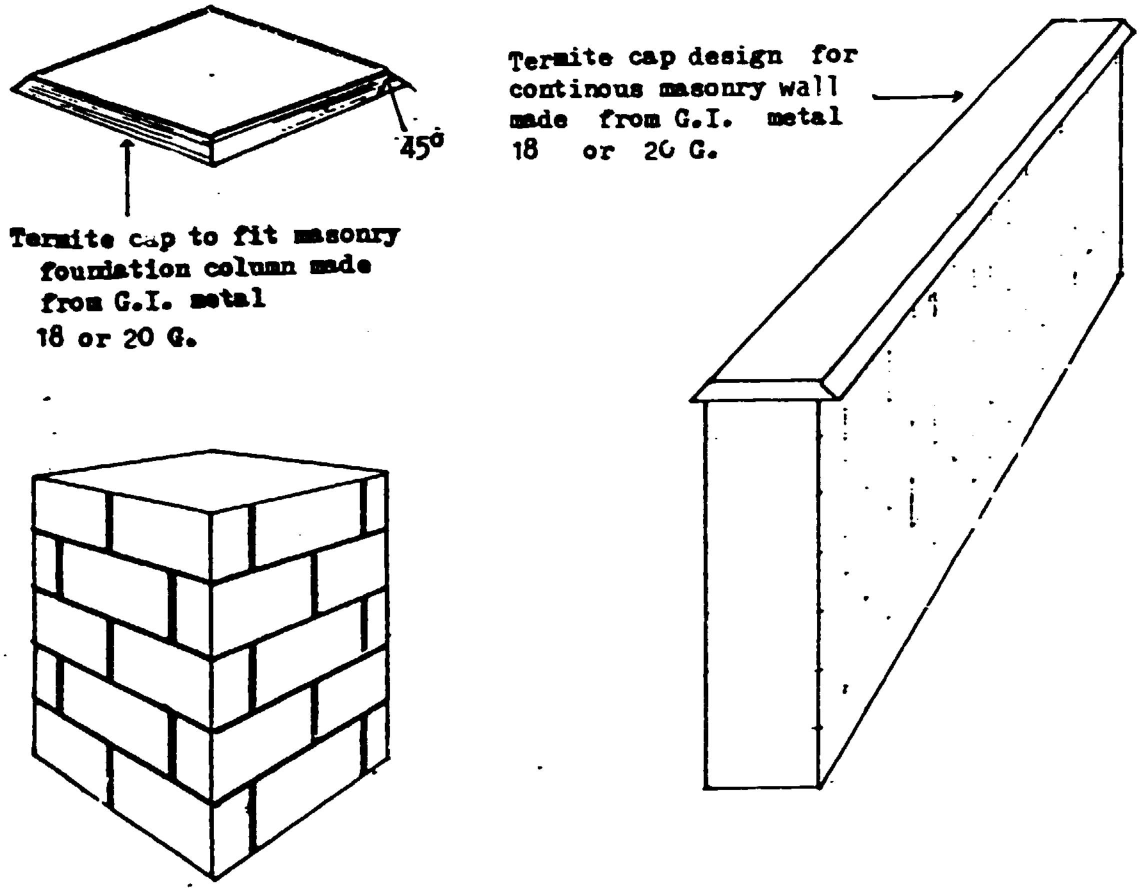


Fig. 12 Termite shields (caps)

2.2 Protection Against Termites

TERMITES are most destructive insects to wood buildings in the warm tropical region. The most common types, the subterranean termites, build nests a considerable distance from actual food sources (construction wood). By underground tunnels they reach foundation walls and enter suitable wood through grey colour tubes easy to see on foundation walls or piers.

Fitting of galvanized steel shields (caps) to all piers and foundation walls just below the wood bearers or in concrete slab construction below wall plate is a good prevention against termite attack.

The edges of the shields (caps) are bent down at an angle of 45^o all around. See Figure. 12. Note: Dry, well ventilated sub-flooor space kept clean assists in the prevention of the termite attack. A tropical region species of dry wood termites (flying type) attacks wood in any location in the structure (including books etc.). Good ventilation, cleanness and normal fanning activity prevent attack and in general these are less destructive than subterranean species.

3. SPACING CONSTRUCTION

The following pages and Tables 1 to 5 describe terms used and give spacing, dimensions and other details for green or partly dry C.P.W.

3.1 General

The following is in fact an abreviated light timber framing code based on the Australian standard 1684-1979:SAA Timber Framing Code and supplement number 4 (June 1975) to it. This is for unseasoned timber of stress grade F8 and shows maximum allowable spans for different components. It also draws on material in supplement number 2 for stress grade F5.

Two stress grades of C.P.W. are used:*/

- grade H75 - basic density 600 kg per m^3 and above - F8
- grade M75 - basic density 400 to 599 kg per m^3.- F5.

These two stress grades are abbreivated in this report to HF8 and MF5, or simply F8 and F5.

Below is a general listing of recommended sizes, materials and spacing which is shown in greater detail in Tables 1 through 5 and discussed in the following text.

Note: Span used in these tables means face to face distance between supports;
Spacing means distances from centre to centre of structural members.

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*Although F11 is attainable, from C.P.W. in the Philippines if special attention is paid to density in sawing F8 is used in this report to increase the safety margin especially since visual stress grading is still very little practised.

1. These apply only to single storey construction;
2. Use "W" roof trusses up to 6.5 m effective roof length (EL) or conventional rafter joist roof up to 4.0 m effective roof length. See Fig. 14;
3. Roofing material
   a) wood shingles
   b) GI sheets 26G
4. Flooring joist and stud spacing 450 mm
5. Wall height (studs) 2.25 to 2.4 m
6. Bearers, joists wall plates, roofing battens (purlins) are considered continuous over two or more supports.
7. If a hanging beam is used, it must be appropriately supported on both ends.
8. The concept of stress grading is explained in "The Grading of Coconut Palm Sawn Wood" (UNIDO document DP/ID/SER.A/649).
9. If wall plates and studs or noggins are not trenched, extra care must be taken in wall bracing. (See Fig. 22 etc.).
10. "Aligned" rafters or floor joist mean these are placed directly above or below the studs. (Not aligned means that rafters or floor joists are not placed directly above or below the studs).

3.2 Stumps

For low cost housing on a protected site (sheltered location), the spacing of the foundation stumps may be increased, but should be not more than a maximum of three meters. For the bearers (50 x 75 or 100 x 75 mm cross section) use grade F8.

The bearers should span not more than 2.0 meters especially when the bearers are running parallel to the load-bearing walls. Slightly larger spacing of stumps could be used between foundation stumps in interior location. Where stumps are high, they may need bracing (See. Fig. 13).

3.3 Bearers

For dimensions of bearers see Tables 1 and 4 Higher density C.P.W. should be used, i.e. F8.

Bearers should be fixed to the sub-floor (piers, etc.) to provide support for the upper structure and be able to transmit the uplifting force (especially in high wind areas) from the upper structure to the foundation.

The methods of the tying down bearers to stumps, piers, etc. are described in preceding drawings. (Fig. 2 - 10).

Note: Simple tie downs for bearers to the foundation can be made from 9 mm diameter reinforced bars enclosed in concrete or masonry pier and bent over bearers, then secured by bending heavy nails or spikes. Wood stumps could be connected to bearers by 2 or 3 mm thick metal straps, bent and nailed to bearers and stumps

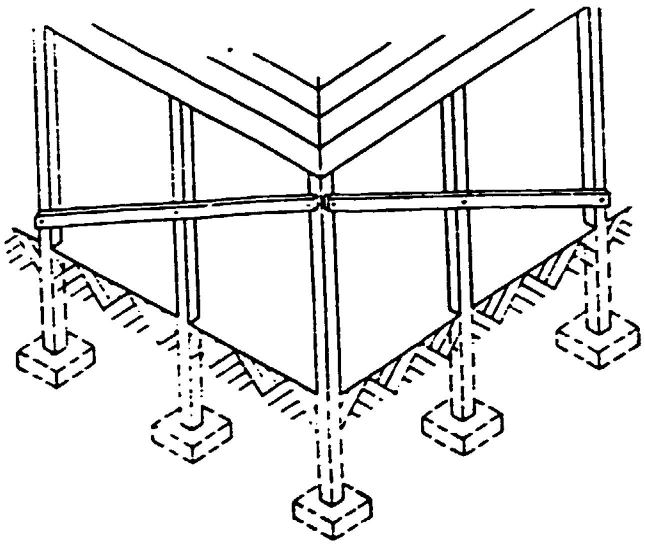


Figure 13. Shows bracing arrangement for the elevated sub-floor where height of wood stumps exceeds ten times minimum width of the stump.

Alternative Coconut Palm Sawn Wood - Cross Section Dimension in Millimeters

Nominal Dimension Unseasoned Wood	Alternative Dimension Seasoned Wood
25	19
38	32
50	44
75	68
100	85
125	115
150	140
175	160

Maximum recoverable cross section dimension from Coconut Palm Wood (butt logs only) of a reasonably uniform basic density from pantropical zone:

Thickness up to a maximum 63 mm
Width up to maximum 175 mm
Length up to maximum 6 metres.

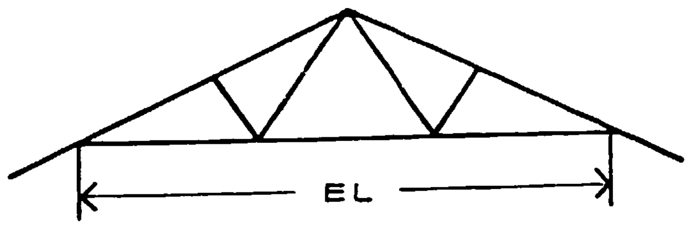
Substitute Coconut Palm Wood - Cross Section Dimension Millimeters

Recommended Construction (framing) sizes	Substitute
75 x 50	100 x 38
100 x 50	125 x 38
125 x 50	150 x 38 or 75 x 75 (laminated)

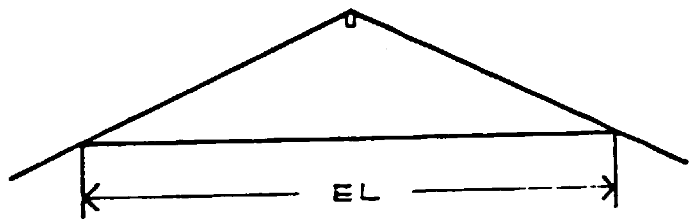
Sub-tropical regions(e.g. marginal coconut palm growing zones or palms growing in poor or unsuitable sites produce smaller diameter and height of stems, bent or crooked shapes. Maximum cross section recoverable from such round wood of an acceptable density range is 100 mm and 50 mm and length 3 to 4 meters.

When it is necessary to use in the construction pieces of wood of required density group of a larger cross section, necessary dimension has to be made by joining (laminating) two or more pieces of smaller dimension together, by nails or glue. Alternatively, timber of other species may be used for these larger dimensions.

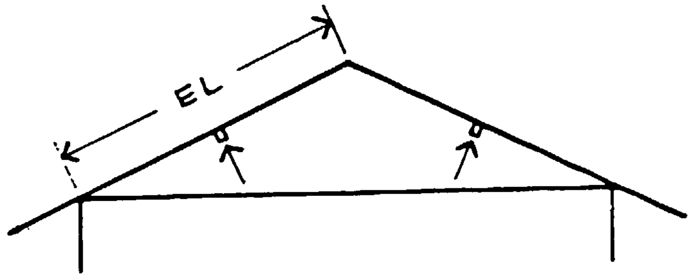
Fig. 14 - Effective Length of Roof



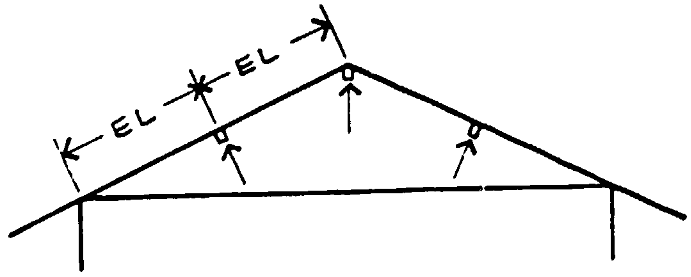
Trussed roof



Coupled roof no underpurlins



Coupled roof with underpurlins



Coupled roof with underpurlins and strutted ridge

Table 1

Framing member	Stress grade	Maximum spacing	Maximum span or length	Minimum wood size (mm)
Stumps (post)	F8	2.75 m	1.8 m in relation to bearers	100 x 100 or 100 x 125 *
Bearers	F8	2.75 m	1.8 m	100 x 75* 2/100 x 50 or 38
Floor or ceiling joist	F8 F5	450 mm 450 mm	2.75 m 2.75 m	100 x 50 or 38 100 x 50
Studs under load	F5	450 mm	2.40 m	100 x 50 or 75 x 50
Internal studs	F5	450 mm	2.40 m	100 x 38 or 75 x 50
Jamb studs	F8	opening: 1 m 2 m 3 m 4 m	2.40 m	100 x 50 100 x 75 or 2/100 x 38* 100 x 75 or 2/100 x 38* 100 x 100 or 2/100 x 50*
Wall plates aligned	F8	-	-	100 x 38 or 75 x 50
Wall plates not aligned Top Bottom	 F8 F8	 - -	 - -	100 x 50 75 x 50 or 100 x 50
Lintels on edge	F8	-	opening: up to 1 m up to 2 m up to 3 m up to 4 m	100 x 50 or 2/100 x 38* 125 x 50* 150 x 50* 150 x 63*

*If Coconut Palm sawn wood is not obtainable in this size, simple fabrication of trussed beam of given size is recommended. Alternatively, another timber species may be used.

Table 2

Framing member	Stress grade	Maximum spacing	Maximum span or length	Minimum wood size (mm)
Under purlins	F8	2.5 m	up to 1.75 m 1.75 to 2.5 m 2.5 to 3.5 m 3.5 to 4 m	100 x 63 125 x 63** 125 x 75** 150 x 75**
Rafters	F5	1.0 m	3.5 m	100 x 50
Gable framing	F5	-	-	75 x 50
Strutting beam	F5	2.5 m	up to 2 m 2 to 3 m 3 to 4 m	175 x 50** 200 x 50** 250 x 50**
Roof struts	F8	-	up to 2 m 2 to 2.5 m	75 x 63 100 x 63
Collar tie	F5	-	up to 4.5 m	100 x 38 or 100 x 50
Flooring	F8	joist spacing 450 mm	-	18 - 20mm thick
Wall bracing	F5	-	-	75 x 18
Ridge board	F8	-	-	125 x 25-30
Roof wind bracing	F8	-	up to 2 m 2 to 4 m	75 x 38 100 x 50 or 38

** If Coconut Palm sawn wood is not obtainable in this size, simple fabrication of trussed beam of given size is recommended.

Table 3

Framing member	Stress grade	Maximum spacing	Maximum span	Minimum wood size (mm)
Hanging beam	F8	2.5 m	up to 2.5 m	125 x 50
			2.5 to 3 m	175 x 50**
			3 to 4 m	200 x 50**
			4 to 5 m	250 x 50**
Battens				
shingles	F8	normal spacing 163 mm	up to 1.75 m	38 x 38***
GI sheets	F5	600 mm	up to 1.75 m	75 x 38***

** As Coconut Palm sawn wood is not obtainable in this size, simple fabrication of trussed beam of the given size is recommended.

*** Gable overhang for batten 38 mm x 38 mm .... 60 mm maximum
Gable overhang for GI sheets 75 mm x 38 mm .... 1200 mm
For wider gable overhang, ladder framing of the fly rafter is necessary.

Table 4

Following tables are recommended for medium class construction.

Bearers supporting single storey load bearing walls - maximum spacing of bearers parallel to wall up to 2.75 meters

Size depth x breath (mm)	Maximum span of bearers (meters)							
	G.I. sheet roof				Shingle roof			
	Trussed rafters or roof truss span in meters							
	5	6	7	8	5	6	7	8
Bearers supported at ends only								
100 x 75	1.6	1.4	1.3	1.2	1.4	1.2	NR*	NR
100 x 100	2.0	1.8	1.6	1.5	1.8	1.6	1.5	1.4
Bearers continuously supported over 2 or more spans								
75 x 75	1.5	1.3	1.2	1.1	1.2	1.1	1.0	NR
100 x 75	1.8	1.6	1.4	1.3	1.6	1.5	1.4	1.3
100 x 100	2.0	1.8	1.6	1.4	2.0	1.8	1.6	1.5

*Not recommended

Table 5 - Roofing Battens:

Spacing (mm) roof rafters or trusses					
Size depth x breath (mm)	G.I. sheet				Shingle roof
	Batten or purlin spacing (mm)				
	450	650	700	750	170
25 x 50	NR*	NR	NR	NR	NR
38 x 38	1000	NR	NR	NR	up to 1250
38 x 50	1250	1000	NR	NR	up to 1750
50 x 50	1250	1250	1000	1000	up to 1750
38 x 75					
50 x 75	See note[1]				
75 x 38					

*Not recommended

Note 1: Roofing purlins (heavy battens) are used for GI sheets where rafters or trusses are spaced more than 1500 mm and purlins are spaced maximum 640 mm.

1. Bearers should be laid level, and directly under the external load bearing walls (e.g. walls supporting roof structure - rafters or trusses).

2. Foundation stumps or piers should have sufficient cross section to provide adequate bearings.

3. Where possible bearers should be of such continuous length that they are laid over the two or more spans. However, shorter bearers may be length-jointed by scarf joint directly over the supporting points (stump, piers) and adequately nailed or spiked avoiding splitting (.e.g pre-drilling).

4. Where it is necessary to join two smaller sizes of a wood to obtain recommended dimension of bearers, spacing blocks of wood should be used. See Fig. 15.

5. When necessary bearers may be levelled by packing at the support points by thin pieces of durable wood.

6. Bearers should be treated by suitable wood preservative before installation - if not possible 2 or 3 brush application of wood preservative after installation is recommended. (Hot coal tar or creosote).

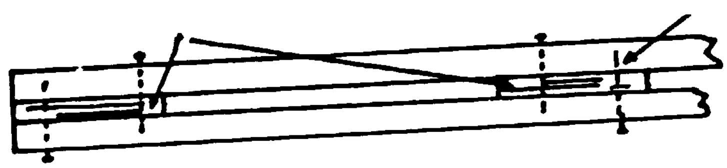


Fig. 15 - Bearer with spring blocks

Fig.15 shows "spacing blocks", used to join by nails two pieces of structural members to obtain necessary cross section or provide adequate bearing for the other structural component (bottom wall plates etc.). Spacing and thickness of spacing blocks depend on thickness of joined members (e.g. spacing blocks should be minimum 400 mm long and not thicker than thickness of joined member. Nails should penetrate all three members from both sides. Depth of spacing blocks should be the same as joined members.

3.4 Floor joists

1. The joists of required grade, size and length (Table 1) are laid at right angle to bearers. Where joists are parallel to external or internal walls bottom plate, two joists should be installed next to each other and nailed together by spacing wood blocks to such width that will provide adequate bearing for the bottom wall plate, plus provide support for the flooring boards (min. 25 mm). Otherwise "ledger strips" of wood have to be nailed along the top of joists to provide support for the flooring boards.
2. It is good practice to lay joists in correct location over bearers (wihtout nailing) to check the level. Oversized joists may be trenched up to 10 mm for 100 mm deep joist and 6 mm for 75 mm. Undersized joists can be packed by suitable pieces of thin wood at the point of the support (bearers).
3. Spacing of joists is recommended 450 mm. However, larger spacing up to maximum 600 mm could be used in low cost housing provided that floor boards are minimum 20 mm thick and selected from higher density sawn wood.
4. Joists should preferably be in full length but where this is not possible could be scarf joined and nailed together (two nails from each side 50 mm long) directly over the support joint.
5. Joists should be Toe (skew) nailed from both sides by two 75 mm long nails (preferably pre-drill to avoid splitting). In high wind regions metal connectors should be used. See Fig. 16.

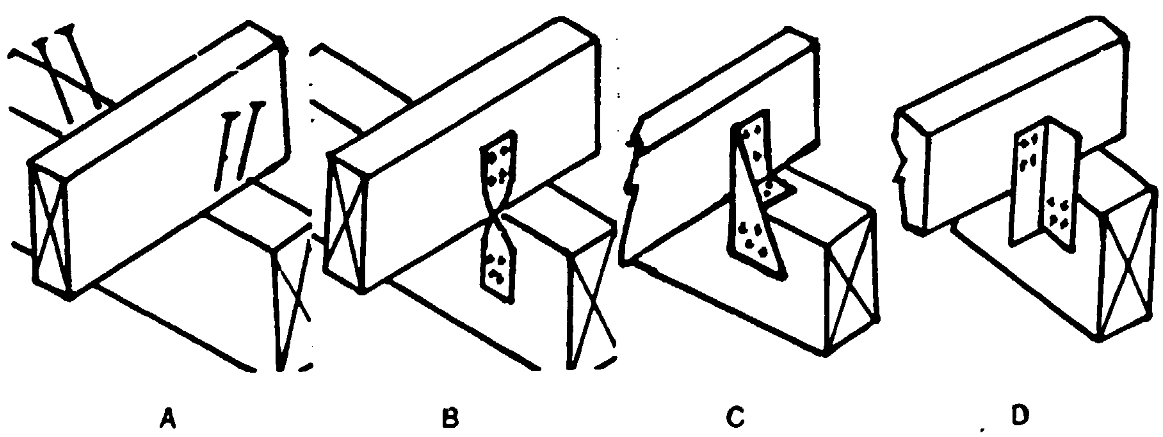


Fig. 16 shows different fastening of floor joists to bearers.

A: Skew nailing; B: Hoop metal strap; C and D: Angle shaped metal connectors

3.5 Construction of Exterior and Interior Wall Frames

The side exterior walls support the roof structure and are thus load bearing walls. Bottom wall plates are located directly above bearers and normal to floor joists thus providing adequate support and fastening.

The end exterior walls where gable roofs are used are constructed the same way as the side walls but are subject to less loading.

Note: For hip or gambrel types of roof - all exterior walls are load bearing

The exterior walls serve as connectors between the roof and foundation systems and should be stiff and strong enough and properly fastened to the floor system by nails or metal connector especially in high wind regions. They also provide the frame for the weather proof outside lining and for the openings for the windows and doors. (The inside lining is arbitrary and is usually omitted for low cost housing in Tropical regions).

Interior walls are simply dividers of the interior space and are usually non-load bearing but this depends on location and orientation.

Structural members of wall frame:

1. Bottom and top wall plates
2. Studs
3. Noggin (horizontal studs)
4. Bracing

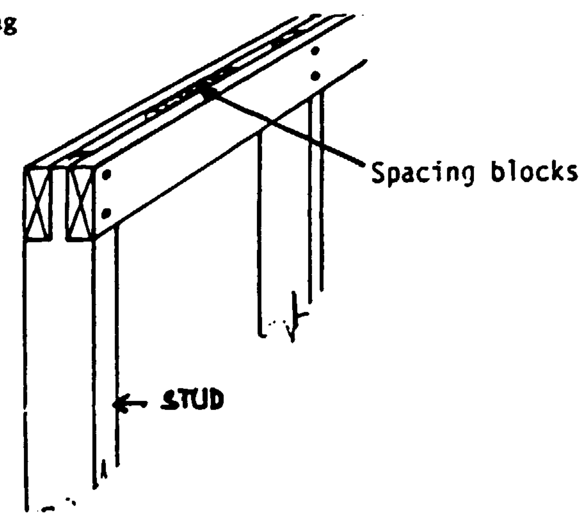


Fig. 17 - Design of wall top plate for wind area. Note horizontal nails

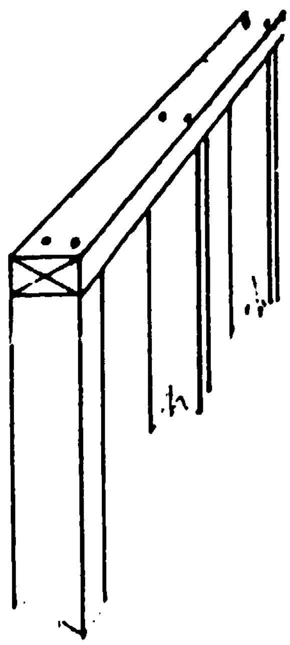


Fig. 18 - Standard top plate vertical nailing

Bottom wall plates

See recommended size and grade table (Table 1).

Where wall studs are aligned with a floor joist, the bottom wall plate may be the same size as the studs.

Wall plates should be as straight as possible and in such lengths as to minimise the number of joints. Joints if necessary should be of the overlap type, see Fig. 21, and directly above supports (floor joists). An alternative arrangement is to use wood splices positioned between studs.

Trenchings (housing) of wall plates is optional, but recommended for high wind regions. When trenching of plates is desired both top and bottom plate is gauged at the same time to secure alignment of studs. Depth of trenching for 50 mm thick plates should be maximum 10 mm.

When bottom wall plates are not continuous such as at door openings, double studs should be installed.

Top wall plates

Where roof rafters or trusses are located directly or close above the wall studs top plates may be the same size as studs.

Note: Top wall plates should be selected from best grade of high density C.P.W. to secure adequate fastening of roof rafters or trusses. For joining of top wall plates, see Fig. 20.

Fig. 17 shows alterantive arrangement for wall top plate for high wind regions.

Studs

See recommended size and grade table (Table 1).

Studs should be straight and truly sawn or dressed with attention paid to width, to ensure straight and even wall faces.

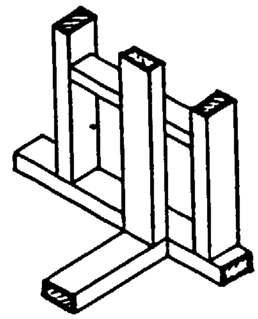
Studs should be cut to exact length to fit tightly between bottom and top wall plates.

Wall studs are skew (toe) nailed to bottom plate - two 75 mm nails for each side and nailed to top wall plate of 100 mm nails as shown in Fig. 18.

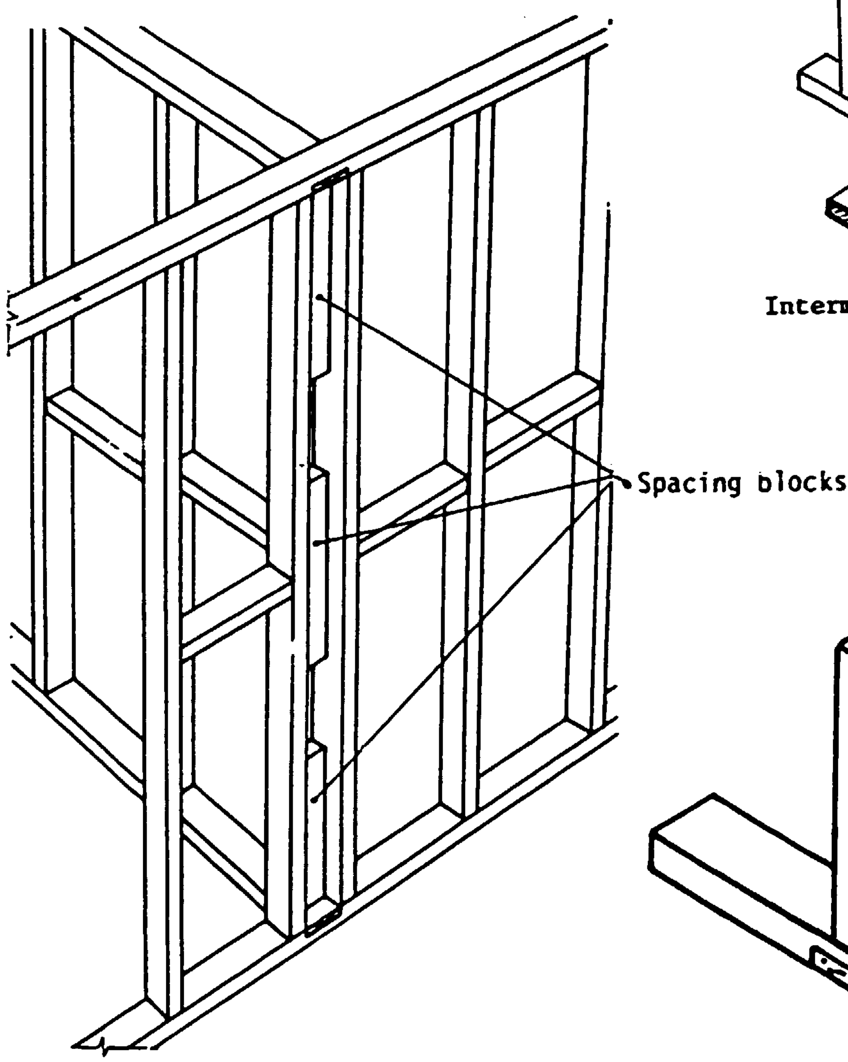
Alternatively, especially in high wind regions, metal connectors could be used or combination with nails.

Note: Walls are framed in horizontal position usually on flooring structure and raised to location when assembly is completed.

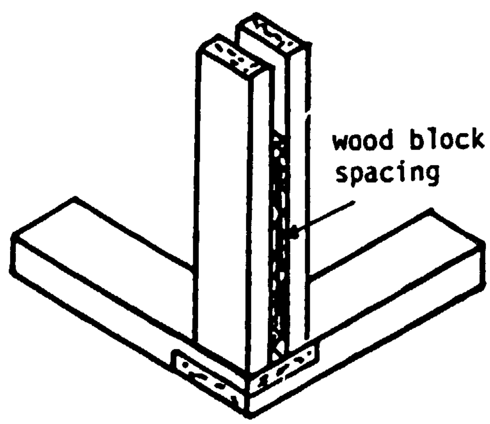
Fig. 19 - Studs at wall junctions.



Intermediate wall junction



Intermediate wall junction



Built-up external wall column

When not intended to install internal siding, studs and noggings should be dressed to avoid wood splinters from rough sawn wood.

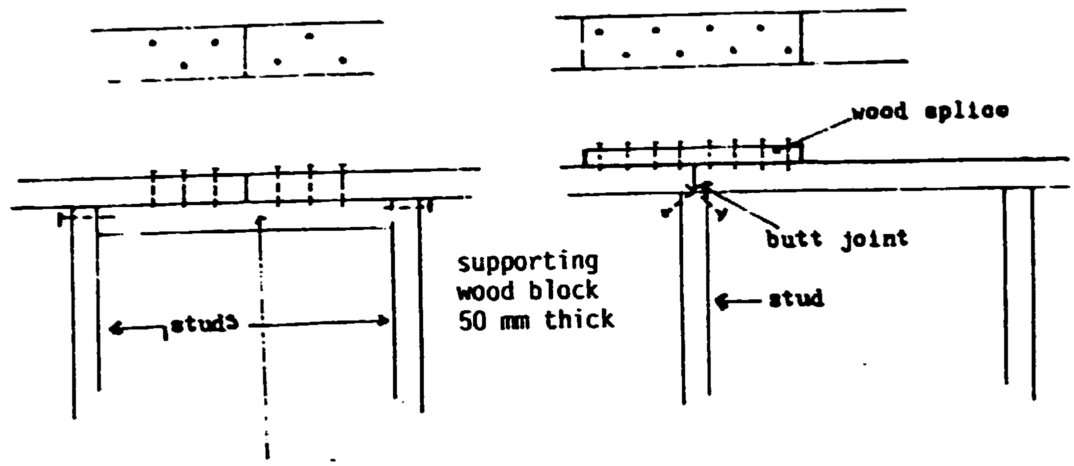


Figure 20: shows type of joints used for top wall plate.

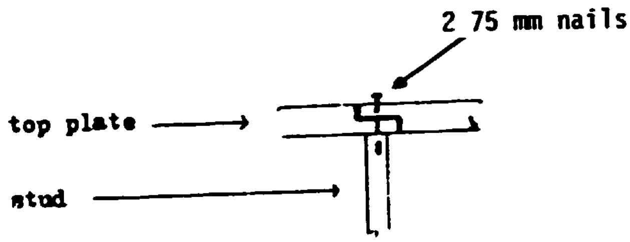
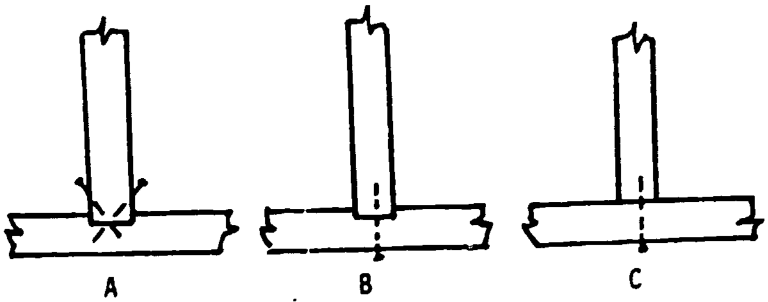


Figure 21: Overlap joints used for top or bottom plate.

Figure 22 shows different type of nailing studs to bottom plate.



A: trenched plate skew nailing
B: trenched plate nailing through plate
C: untrenched plate nail through the plate.

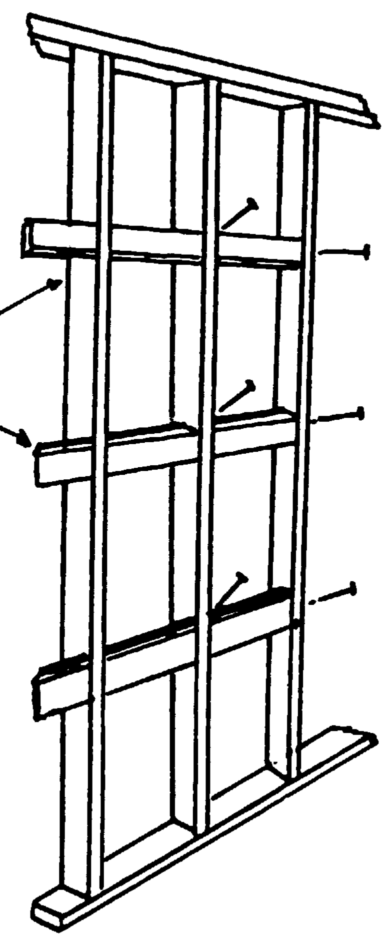


Figure 23 shows arrangement of nailing blocks for vertical board lining.

Note: Used 2/75 mm nails for each stud each side.

Noggings (Sometimes called horizontal studs):

It is recommended that each stud in the wall frame be straightened and stiffened by at least one nogging placed at centre between bottom and top wall plates.

Noggings should be of the same size of wood as the studs, and be flush with the face of wall (outside) to provide support for the exterior lining.

Note: Minimum size of noggings should be the width of studs and minimum 38 mm thick. See fig. 19.

When vertical boards or shingles are used for wall lining, additional support is provided by nailing strips (Battens) or blocking between studs, spaced as necessary to provide adequate nailing support. See Fig. 23.

Noggings are nailed by 75 mm long nails in the following way:

1. When noggings are assembled in straight line one end is skew nailed by two nails, and in the second end, two nails are driven into its end.
2. An alternative method is to offset nogs as shown in Fig. 25.

Noggings or blocks between studs (for vertical siding) should be cut to exact length to fit tightly between studs and to space them correctly.

Trenching noggings is optional but when used, the trench in studs should be no more than 10 mm.

Lintels are pieces of wood placed horizontally above openings such as windows or doors and supporting short stud or studs between lintel and top wall plate. Their dimensions depend on the width of opening. (See Table 1).

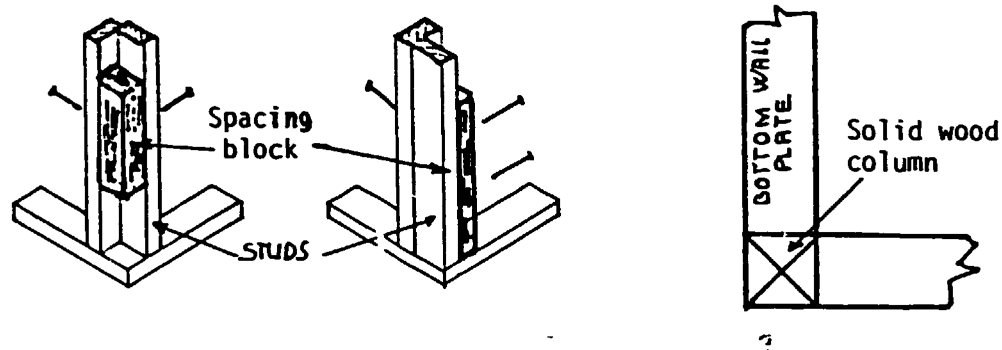
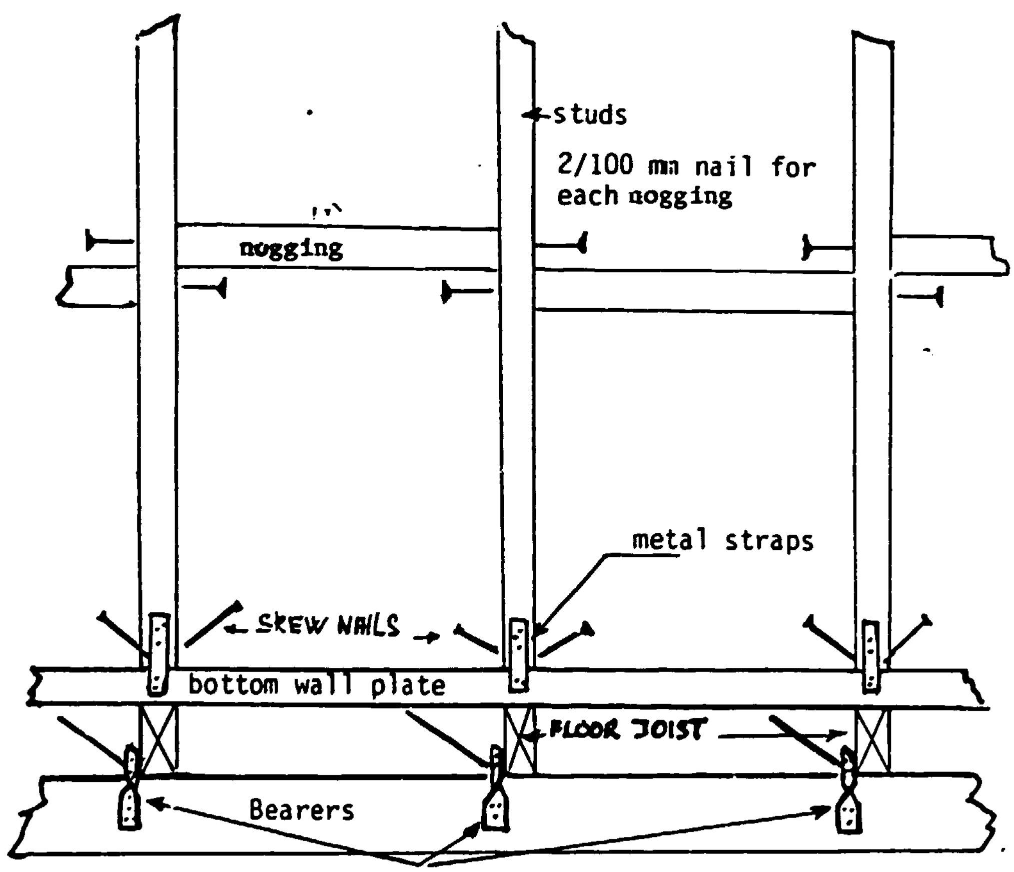


Figure 24 shows studs arrangement at external wall corners.



Loop metal straps from both opposite sides or supplemented with 75 mm nails.

Figure 25 shows alternative position of nogging for horizontal nailing.

Bracing wood framed stud walls

Wood framed load bearing walls should be adequately braced especially in high wind regions to resist horizontal wind forces.

Effective length of bracing wall should be minimum 1.6 m for walls 2.25 up to 2.4 m high. See Fig. 28. Two braces should be provided in opposing direction where the length of wall will permit.

When internal wall linings are intended, the bracing members should be trenched to the studs as shown in Fig. 27 to provide a flush finish. Otherwise they could be nailed directly onto the internal wall side.

Bracing should be diagonal from top wall plate (45^o angle) to bottom plate. When this is not possible smaller or larger angles may be used.

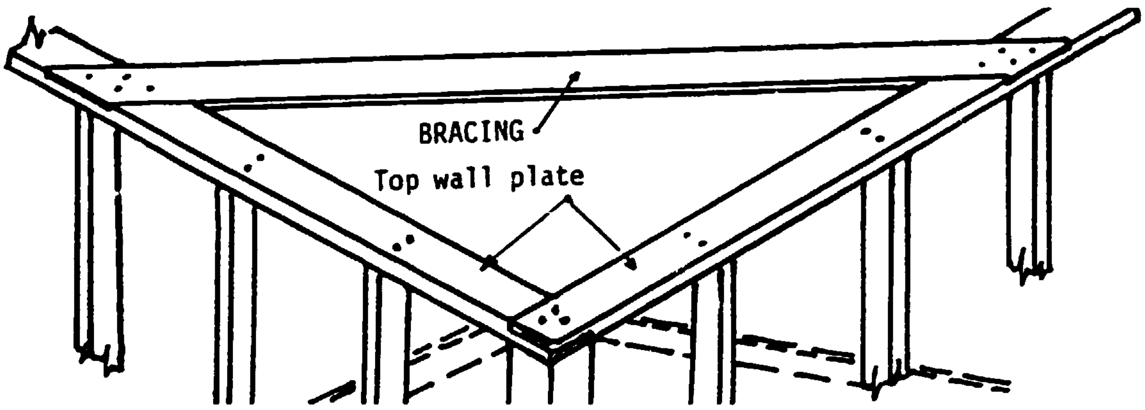


Fig. 26 shows bracing arrangement for corners of external wall junctions (high wind region).

For internal non load bearing wood framed walls, noggings of studs depth and minimum 30 mm thick should be provided at mid wall height. (Or nailing blocks, See Fig. 23). As at least one side of internal walls are lined, nailing blocks are usually placed with wide face at the side intended to be lined. Bracing is optional.

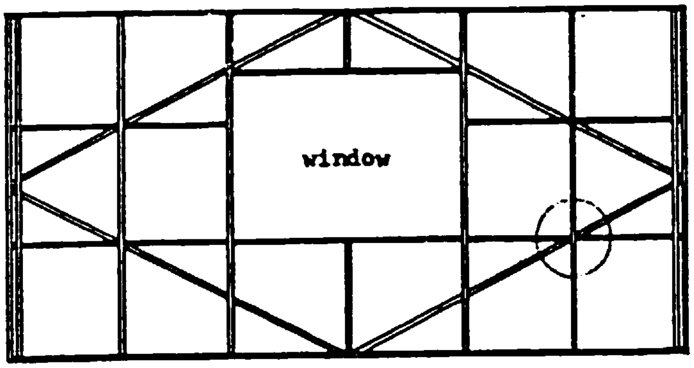
Internal load bearing walls should be braced by similar methods as external walls.

Lintels for internal walls over openings (doors) should be the same size as the studs.

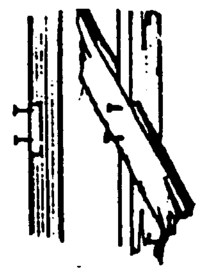
Note: Temporary bracing is used during the assembly of wall frame and erection to correct location.

Permanent bracing is applied when all external walls are in correct location and squared.

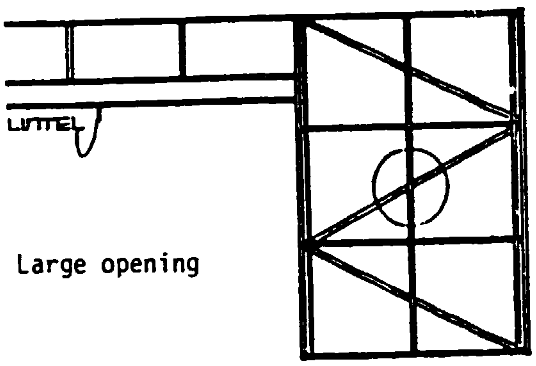
Figure 27 shows bracing types for load supporting walls.



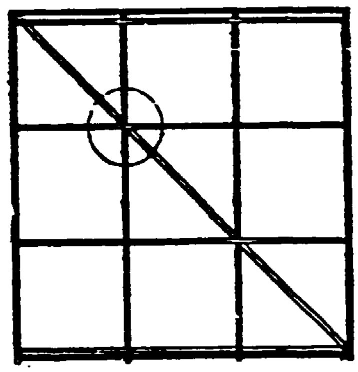
Bracing window opening in **high wind regions.**



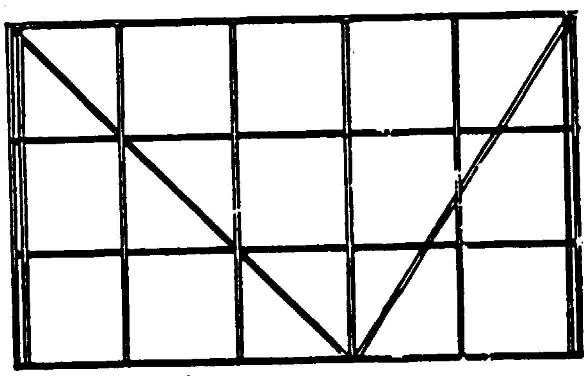
Trenched bracing 2/38 mm nail for each stud and plate or 1/50 mm nail at each stud, 2/50 mm nails in wall plates - apply to trenched or untrenched bracing.



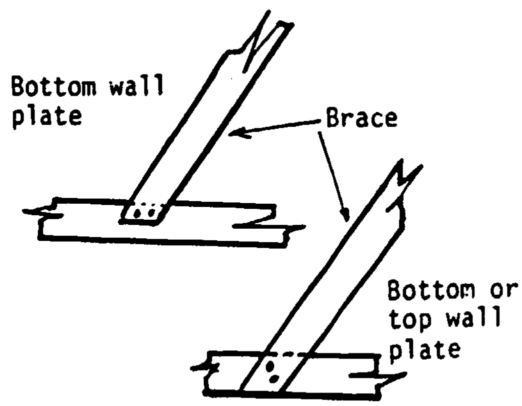
Bracing narrow wall close to large opening.



Single bracing up to 4 m length of wall.



Double bracing for a continuous wall (schools, stores etc.)

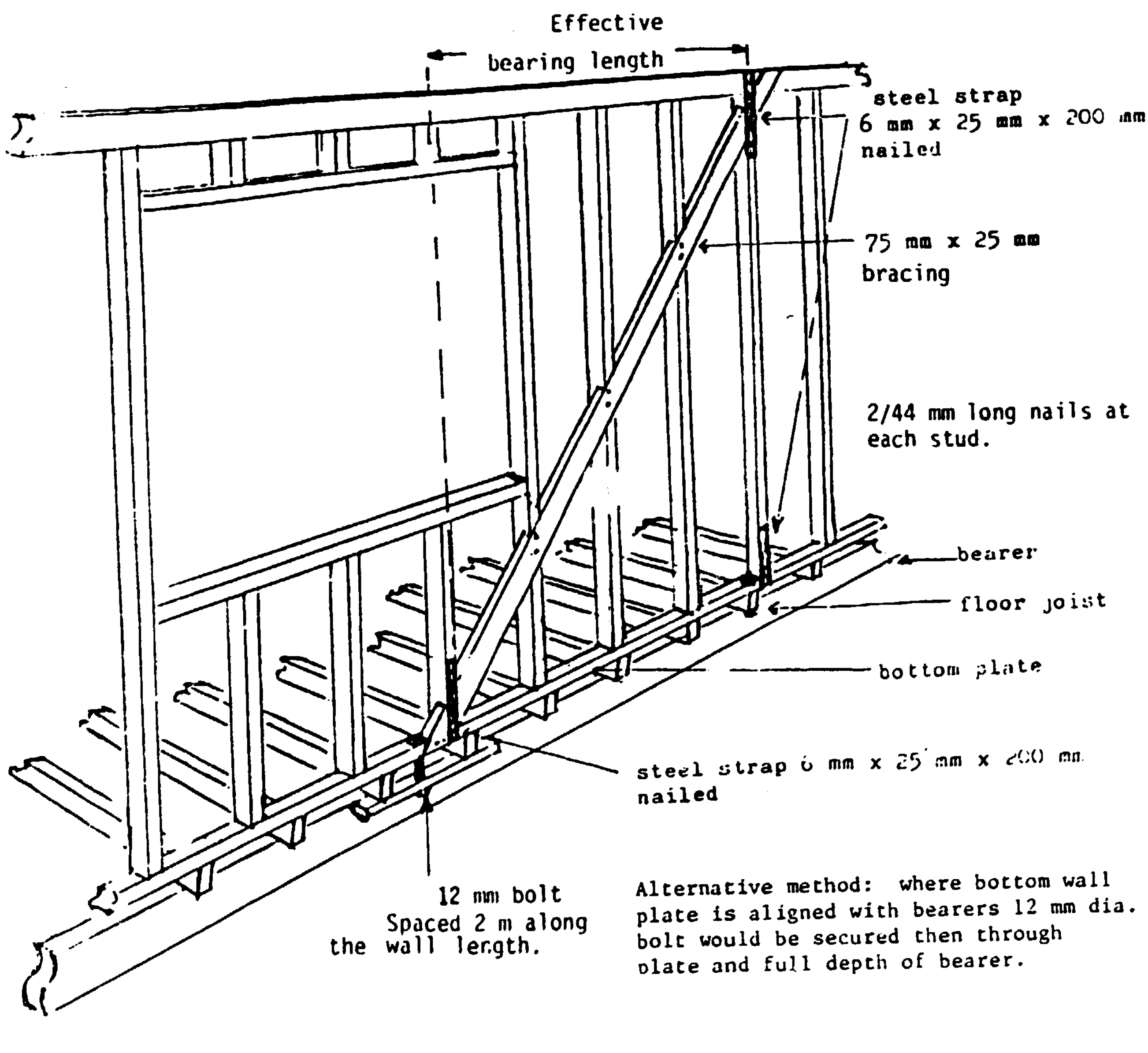


Bracing: (a) untrenched bracing at bottom plate avoiding floor boards.
(b) Connection of bracing to top wall plate and bottom plate when trenched.

Note: Dimension of braces: 25 mm x 50 mm
or 25 mm x 60 mm for high wind region.

C.P.W. grade F8.

Fig. 28 Shows arrangement to secure wall bearing load to bearer in cyclone region especially for buildings in exposed locations.



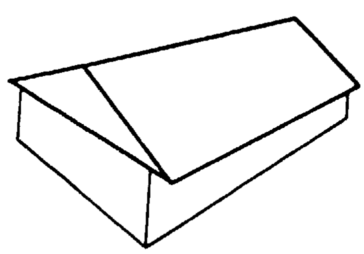
4. ROOF CONSTRUCTION FOR LOW COST HOUSING IN TROPICAL REGIONS

Traditional roof framing in the north west Pacific tropical rural regions has been "gable" type of roof structure with high pitch (25 - 35 degrees), using local indigenous thatching material for roof covering such as leaves from the different species of Palm family (Nipa palm, etc.).

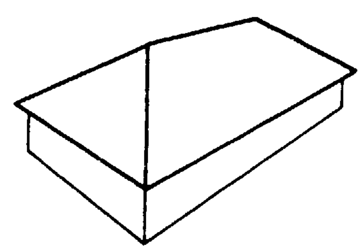
In sub-tropical regions (south Pacific) which is subject to frequent high wind storms (Hurricane) the traditional roof form is of an oval shape with small leaves closer to "Hip" type of roof, which is more resistant to uplifting wind forces.

Figure 29 shows common roof forms.

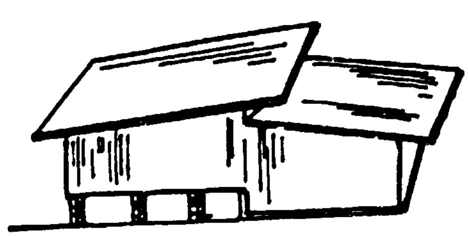
4/12 = ∝ 18°
5/12 = ∝ 22.5°
6/12 = ∝ 26°
7/12 = ∝ 30°



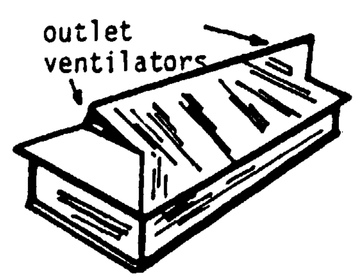
Gable roof



Hip roof



Double skillion roof



Ventilated modified hip roof

In South Pilippines (PCA research centre inZamboanga) three types of roof have been constructed from C.P.W.

1. Gable roofs with pitch from 16^{o} to 35^{o} depending on the type of roof cover.
2. Ventilated modified hip roof.
3. Low pitch roofs - double skillion type.

All roofs constructed used pre-fabricated trusses with the exception of the "skillion" type.

1. A traditional low cost housing in the Tropics omits the ceiling lining (e.g. using whole internal space to provide better air circulation and ventilation). Internal walls dividing available space are built to the same height as external walls with open space up to the ridge of the roof. The low cost C.P.W. housing designs followed the same system.

2. For medium cost housing design with low pitch roof (skillion) using Corrugated Galvanised Iron as roof cover it was necessary to provide the same protection against radiation of heat from the metal roof cover which is a good thermal conductor. The ceiling lining is often of woven bamboo mat called "Amaghn" which is obtainable in flexible sheets 2 x 1 1/4 metres and is fixed parallel to the roof slope. "Amaghn" sheet is nailed directly to roof beams and supported by external narrow battens to avoid sagging.

3. Skilling roofs are constructed from C.P.W. beams 125 x 50 mm spaced 1.25 m and supported by external wood framed walls and internal walls located in the central position of building andproviding support to both roofs running in opposite direction.

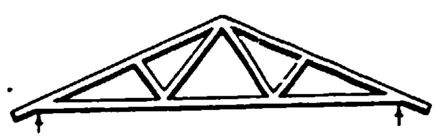
4. Conventional roof structures using rafters, ceiling joists, etc. are stiffened by various structural members. This is not discussed in this paper but for the basic information see Fig. 30 or any house construction technical guide, such as Australian Standard AS 1684-1979.

4.1 Roof Truss Design

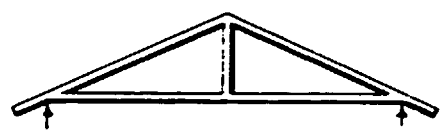
In the past two or three decades there has been increased use of pre-fabricated roof trusses replacing traditional rafter roofs. This trend has been advanced by changing of a traditional structural design forwarded by wood technology research into the pre-fabrication of housing components such as wall frames, roof trusses, etc. used in mass building projects. At the same time, different metal connectors were developed to be used in combination with wood, replacing traditional nailing techniques.

Technological progress in structural design has led to lower house construction costs with less use of wood and utilization of lower grades. It has also been possible to use fewer highly skilled tradesmen and to considerably reduce construction time. Less availability and high cost of prime sawn wood of necessary length and cross section commonly used traditionally in domestic buildings certainly influenced research priorities in this direction.

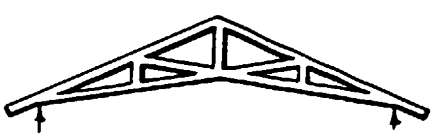
Fig. 30 shows some common types of roof trusses constructed from C.P.W.



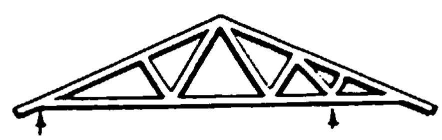
"W" (Fink) Trusses
used for span up to 9 m



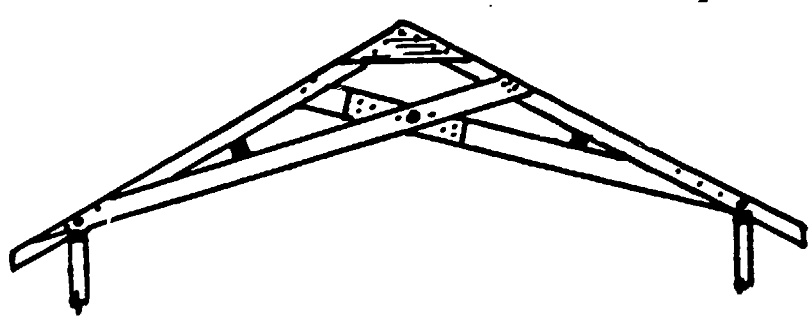
King Post Trusses
Limited span maximum 5 m



Scissor Trusses
used where raking ceiling is desired



Cantilivered Trusses
used over verandahs without additional support post



Scissors rafters
Used for span up to 6 m

Note: Above mentioned "spans" are only approximate as span is governed by cross section of truss members, spacing and type of roof cover.

A trussed roof consists of a number of equally spaced trusses with the span across two points of support (load bearing external walls).

One of the main features of wood roof trusses is that they can carry a roof over considerable spans without intermediate support. This clear span feature makes trusses suitable not only for the domestic buildings with more freedom of location of internal walls (dividing available space), but also for schools, workshops or commercial buildings requiring open space without the necessity for internal supports such as columns.

The computation of member sizes is based on the timbers' mechanical properties or data from a grouping system of different species of commercial wood and with joint detailing, should be done by structural Engineers experienced in wood structural design.

The minimum information necessary for design and fabrication of roof trusses is:

1. Mechanical properties of wood or strength grouping data of given grades to be used as the structural material.
2. Span of trusses.
3. Pitch (slope of roof structure).
4. Spacing at which trusses are to be used.
5. Size of overhang (i.e. length of unsupported top chord measured from outside a supporting wall top plate to the free end.
6. Type of roof covering.
7. Joint connection system.

Note: Roof trusses commercially fabricated from suitable different wood species using multiple punched nail plate are provided by general design technical data from the manufacturer of a particular multi-nail connectors.

Coconut Palm Wood is not yet used in full commercial and structural application, therefore, there is very little information for the design of standard roof trusses.

Pyrde Company, New Zealand, manufacture different types of wood-metal connectors including micro toothed plates - length of punched nail 11 mm, tooth density approximately 1 per 209 mm^2. The Company has designed several light domestic trusses from C.P.W. to be spaced 900 mm maximum. Individual joints have been tested by standard methods in registered laboratory with full report and approved plate sizes for the individual joints. At the time of writing, no deflection test of fabricated trusses with 2.5 times the total design load for a period of 15 minutes without fracture, was conducted.

There was difficulty in pressing connector plates into seasoned C.P.W. of basic density above 600 kg/m^3 due to the strong tendency to split.

A full report is obtainable from Forest Research Institute, Rotorua, New Zealand.

It is important to design joints in trussed rafters carefully to fully utilize the available strength and stiffness of the wood structural members.

There are many methods used to fasten joints in wood roof trusses. These include:

a) Galvanised steel plates with punched nails (gang-nail plates) available in different patented designs, gauge of plate, length and density of nails, manufactured in different sizes, suitable for different truss joints and span. The safe loads are determined by manufacturers for given application. Special press and jig equipment are used to hold truss assembly tight together while the plates are pressed into both sides of each joint at the same time. For this reason trusses are fabricated commercially and transported to the building site.

b) Hand nailed or glue and nailed plywood or tempered structural hardboard gussets from both sides of joints. This type of fastening joints can be made on suitable workshop table with simple tools.

c) Galvanised steel plates 16 G (1.55 mm) cut to necessary sizes from metal sheets and pre-drilled for receiving flat head rust proof nails 33 - 38 mm length depending on the thickness of wood members applied to both sides of joints (see section metal connectors).

d) Hand nailed with wood gussets and splices. This type can be made directly by builder at the site and is sometimes combined with bolts of 10 or 12 mm diameter such as for scissor rafter trusses.

e) Different types of joints connectors such as split rings, shear plates, toothed plates, thick steel plates tightened by bolts are used for heavy and large span trusses.

Although toothed metal connectors are most commonly used for commercial fabrication of roof trusses in developed countries, availability of such a commercial service, at least at the present time, is very restricted in developing countries and non-existant in rural regions.

The cost and difficulties with the supply of the correct sizes of plates makes their use for low cost housing considerably restricted.

P.C.A. Research Centre in Zamboanga, Philippines, own the necessary equipment (press, jig) but eventually discontinued its use for the above mentioned reason.

Following are the basic requirements for the fabrication of a roof truss using different types of joint connectors.

A. C. P. sawn wood has a considerable tendency to split when nailed close to the end or edge. Tendency to split increases with the increase in wood density and lower moisture content of the wood.

To overcome the problem of splitting when using toothed metal connectors, trusses have been fabricated from green or partly dry wood thus minimising the possibility of splitting.

No difficulties associated with wood shrinkage, nail withdrawal, yielding of joints, excessive deflection or lateral deformation of trusses during service have been observed. Nail withdrawal resistance considerably increases as wood members reach average equilibrium moisture content.

Further, the relatively low fibre saturation point for C.P.W. (22 to 24 per cent depending on wood densities) is associated with:

a) low to medium shrinkage values;

b) relatively high average equilibrium moisture content in the tropics (range 15 to 18 per cent);

c) good internal ventilation (no ceiling and internal wall siding permits use of green sawn wood for general construction purposes, and with the exception of plywood or structural tempered hardboard gussets glued and nailed - wood must be seasoned to 16 to maximum 20 per cent moisture content).

B. All wood structural members should be true sawn to required cross section dimensions, still better dressed to uniform sizes.

All structural wood members should be mechanically and/or visually graded.

Selection of wood

Top chord high density wood (e.g. above 600 kg/m^2 stress grade F8, or selected pieces stress grade F11.

Bottom chord and webs - stress frade F5 (it is recommended to select these from the upper level of medium density (e.g. above 500 kg/m^3).

Defects such as: Wane or Want should not be permitted, any defect should be avoided where connectors will be placed or in location of splices. Tolerance of the specified dimension should be for thickness and width "plus 1.00 mm minus 0 mm" where uniform thickness is most critical for the toothed metal plates (uneven thickness of wood member will deform metal plate and will not permit uniform penetration of the plate nails).

Dimensional tolerance when using glue and nails or only nailed plywood or tempered hardboard is "plus .5 mm minus 0 mm" (otherwise a strong glue line or tight contact is not possible).

4.2. Fabrication and Assembly

Where a truss jig is not available, marking on a level concrete floor (outline or truss shape) will serve as a guide to mark the bevelled joints.

Alternatively, a level building site floor could be used for the truss marking, bevelling and fastening using simple types of connectors. Assembly of turss outline starts with the top chords ridge (apex) with the bottom chords and webs following.

A radial arm saw fitted with long supporting tables or rolls on both sides is best where available, to make bevel cuts, as such a saw is designed to turn either side to cut desired angle of bevel.

A hand saw could be used by skilled carpenters. Bevelled or straight cut should make tight fit at all joints.

Application of fasteners:

Before joints fastening begins, the whole truss assembly should be held tightly together in dead horizontal position by jig, improvised clamps or by temporary bracing.

Usually the fastening process starts with the truss apex then truss heels and webs. For location of web members see Figure. 31.

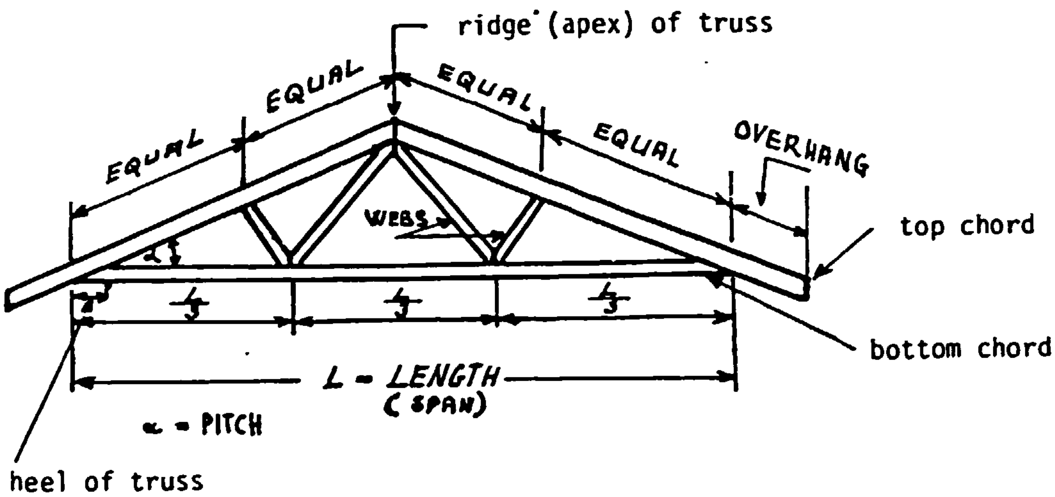


Fig. 31 "W" truss configuration and symmetry

Toothed fasteners using application of the pressure, should be located over the joints on both sides in such a way that the nails are equally distributed over all joint members.[1/] The truss heel plates should be placed

[1/] Except at 1/3-points of ceiling tie where the tension web member has more nails than the compression member.

equally over bottom and top chords. The plates should be selected so they are approximately 10 mm smaller in width than the wood members, and when placed in position should provide 5 mm clearance from each edge, and at least 25 mm from the ends.

This rule is not necessarily applied to metal plates predrilled for hand nailing as splitting can be avoided by locating the nails farther from the edge, or by predrilling with a drill 75 per cent smaller than the diameter of nails. The same rule applies to plywood or hardwood gussets which should be cut flush with the edges of wood members and nails close to edge or end should be predrilled. Nailed truss joints using cleats or splices should be predrilled for all diameter nails.

Note: Metal plates, gusset, wood nailed cleats or splices must be placed on both sides of each joint.

For hand nailed galvanised metal plates and possibly for plywood gussets, flat head rust proof nails should be used. (Plywood gussets could be nailed with nails long enough to penetrate through both gussets and clenched vertically).

Glued and nailed gusset:

Moisture resistant glue should be used, such as cold setting resorcinol-phenol formaldehyde. Any type of hand nailed connector joint must be properly supported by a sold block of wood and the whole truss assembly must be flat.

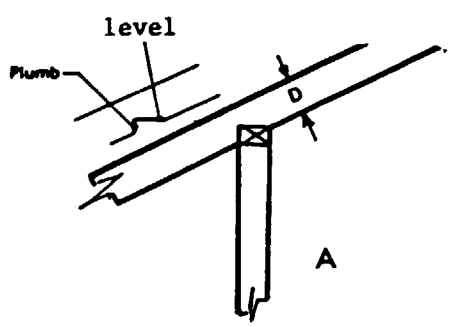
<u>Storage of a fabricated truss</u>

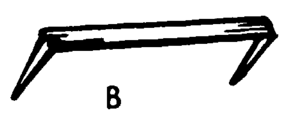
Trusses should be stored under roof or plastic cover in a vertical or horizontal stack, see Appendix 1, Plate 9. On building sites they should not be left without roof cover for long periods of time.

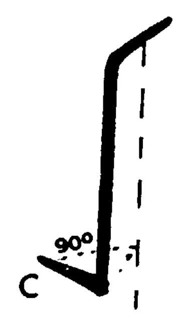
4.3 Roof truss specification

The first "W" form trusses were used in 1976 for the erection of coconut wood work-shop and power house, both pole type of buildings using green (unseasoned) C.P. W. at the PCA Research Centre in Zamboanga, Philippines. All structural sawn wood was hand sawn and edged by the adze (special type of axe where cutting edge is at right angles to the handle),

1. Span 8 metres
2. Pitch 22.5° (5 : 12)
3. Top chords doubled (spaced 50 mm) each 125 mm x 50 mm - designed to accommodate Ridge ventilation system - Jack (roof ridge vent) see Figure 33 with similar ventilation system.
4. Bottom chord <u>doubled</u> spaced 50 mm - 125 x 37 mm each.
5. Webs (ties) 100 mm x 50 mm
6. Spacing of trusses 4 metres
7. Joint fastening:
   a) Each truss heel tied with a 15 mm diameter bolt with large washers - Jack ventilation roof using 100 m x 50 mm members and fastened by 15 mm bolts between top and bottom chords.
   b) Steel connectors of a wide "U" shape made in blacksmith's shop from mild steel with both ends narrowed and pointed - 150 m length, 425 mm wide, 6 mm thick - used from both sides in truss apexes (ridges) in offset location.
8. Roof cover corrugated G.I. sheets 26G (.460 mm)
9. Roof purlins (supported at 2 points) 125 x 50 mm and spaced 700 mm
10. Overhang 1250 mm
11. Trusses were fastened to top wall plate 125 x 70 mm (made from 2 pieces of wood 125 mm x 35 mm) using Birdsmouth notch and aligned with the supporting wall poles by Blacksmith made "Dog spikes" made from 9 mm diameter steel rods and 150 mm overall length.







A - Birdsmouth Notch max 1/3 D.
B - "U" shape spike
C - Dog spike

Comment: Basic design criteria for C.P.W. was at this time taken from the Australian strength grouping system and assigned S6.

These trusses have been observed for the last nine years and no excessive deflections, yielding of joints or deterioration of wood members has been detected. No wood preservative was applied.

With the progressive extension of research activities in the different P.C.A. agriculture divisions, including C.P.W. utilization, a number of auxiliary buildings including housing projects were designed and constructed using C.P.W.

1. Medium cost housing commenced in 1978 to provide accommodation for the technical staff from the different research divisions. See Appendix 1 and design plans Appendix 2.

2. Low cost housing units - split pole type of constructions covered with traditional "NIPA" thatched roof and using "W" type trusses with plywood gussets. See Appendix 1 and design plans Appendix 2.

3. Low to medium cost housing using "W" trusses with plywood gussets, roof cover and wall siding made from shingles. See Appendix 1 and design plans Appendix 2.

All domestic buildings are without ceiling construction to follow general trend in lower cost housing in tropics, with exception medium cost housing where there has been necessary to provide an insulation barrier between metal roof cover and living space.

For this reason it was not necessary to use closely spaced trusses, therefore, trusses were designed medium heavy type and spaced up to 2.4 metres (thatched roof) and 1.8 meters for shingles.(see enclosed plans.)

In the following pages are several designs of C.P.W. trusses for different applications such as: domestic construction, rural primary schools with large overhangs to provide shade (e.g. cantilever trusses), scissor trusses where a raked ceiling line is desired.

Altogether 38 buildings were built from C.P.W. and 2 buildings with C.P.W. as complement material for mainly decorative purposes. Most of the structures use a gable trussed roof form.

All types of buildings were constructed more or less on an experimental basis using relatively unknown wood. However, their presence can aid in the introduction of C.P.W. since interested parties could observe and judge the conditions, wearing of floors, steps, table tops etc under daily use; behaviour of structural wood under stress (deflection - deformation), biological decay etc. With such practical knowledge it will be possible to check technical tables and to standardise dimensional sizes for different application of sawn C.P.W.

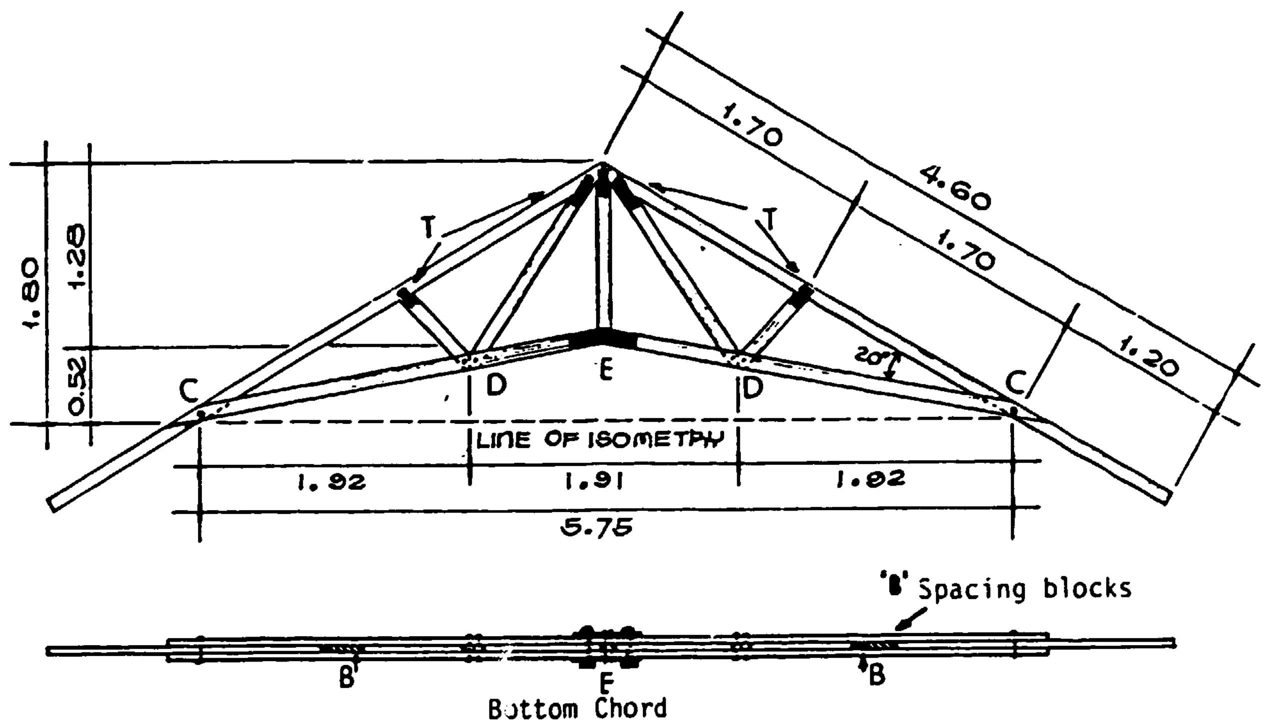


Figure 32 - Scissor truss design and used in the classrooms building for the Regional C.P.W. utilization training programme in P. C. A. Research Centre Zamboanga

See Figure 32.

Basic Specification

Top chords - 90 x 45 mm stress grade F8

Bottom chords (double) - 100 x 30 mm stress grade F8

Webs - 75 x 50 mm stress grade F8

Joints:

"T" toothed metal connector

"E" 6 mm steel plate connected by six 9 mm diameter bolts

"C" 9 mm diameter bolt plus nails

"D" two 9 mm diameter bolts for each mode

"B" spacing blocks.

Overhang stiffed by nailing piece of wood 2 m length, the same cross section as the top chord, using spacing blocks along the end section of top chords.

Roof cover - C.P.W. shingles

Truss spacing 1.5 metres.

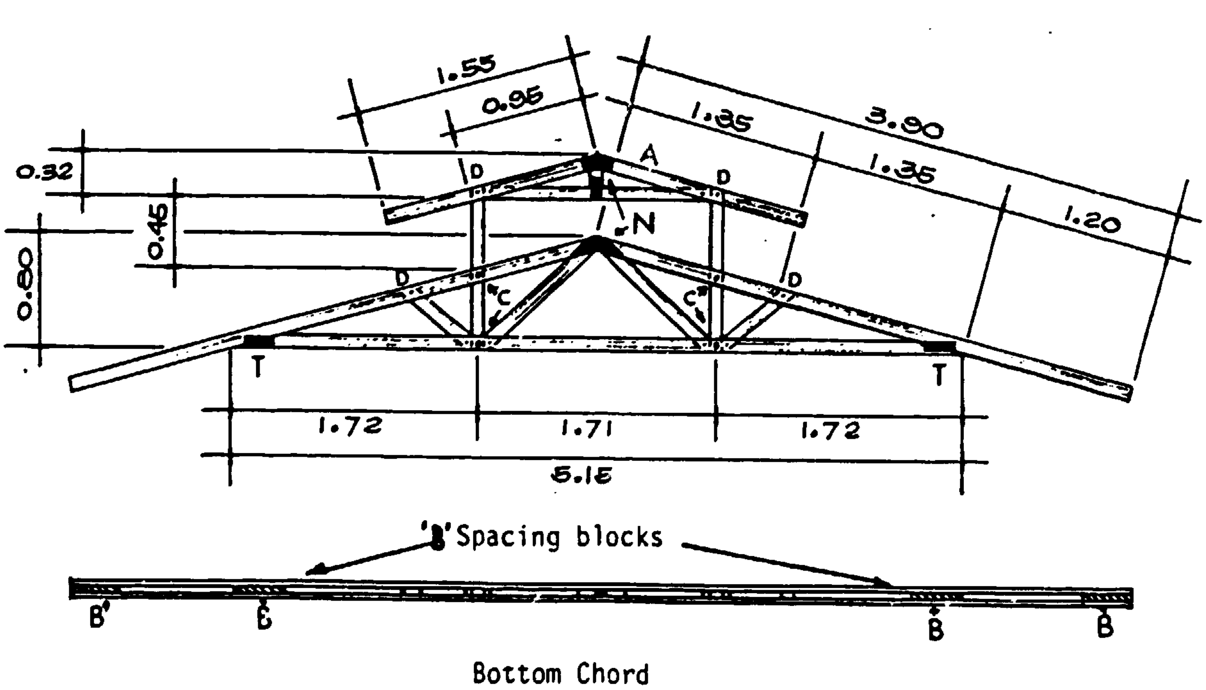


Figure 33 - "W" truss [illegible] he ventilation jack roof, used for the saw doctoring workshop

See Figure 33

Basic Specification

Top Chords (double) 90 x 45 mm stress grade F8

Bottom chords (double) 90 x 30 mm stress grade F5

Webs 75 x 45 mm stress grade F5

"A" jack roof all members 75 x 50 mm stress grade F5

"N" joints predrilled metal plates (16G) 1.59 mm and nailed by flat head nails 38 mm length, 3.7 mm diameter

"T" joints toothed metal connectors

"C" joints 12 mm diameter bolt for each joint and supplimented with common nails

"D" joints nailed

"B" spacing blocks

Truss spacing 2.5 metres

Roof cover: corrugated G.I. sheets.

4.4 Roof battens and purlins

Roofing battens supporting thatched or wood shingle roofs are usually up to max 50 x 50 mm cross section and are subject of span to max. 1800 mm with spacing for shingle roof 150 mm - for thatched roof, battens lie over support of roof purlins and spaced 300 mm with span 1200 mm parallel with rafters or trusses. Larger sizes of roofing "battens" than 50 x 50 mm are called roof purlins.

Wood Shingle battens are described in detail in the section C.P. Wood Roof Shingles.

Thatched roof battens are min. 25 x 25 mm with max. spacing 300 mm depending on the overlap of Palm leaf shingles.

Roofing purlins supporting metal roofing sheets should be in sizes 75 x 37 mm, 75 x 50 mm up to 100 x 50 mm depending on spacing of rafters or trusses which in turn provide roof purlin span.

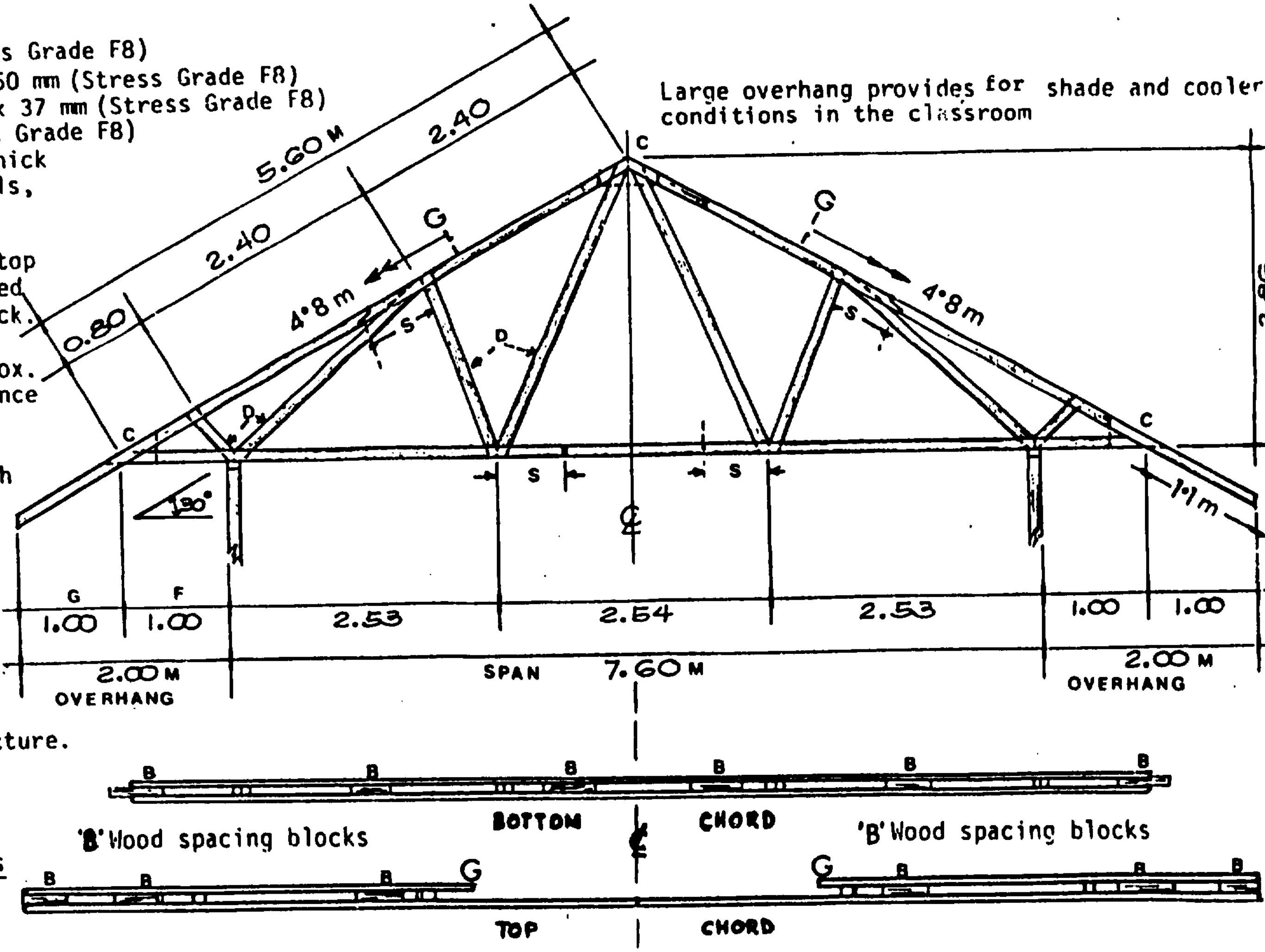
Metal roofing - Corrugated galvanised steel sheet, gauge 26 (.49 mm) is recommended instead of what is usually used in many countries in Pacific region, gauge 30 to 32, (.318 - .258 mm respectively).

Basic specification
Top chord 125 x 50 mm (Stress Grade F8)
Additional top chord 125 x 50 mm (Stress Grade F8)
(Double) bottom chords 100 x 37 mm (Stress Grade F8)
"D" webs 100 x 50 mm (Stress Grade F8)
"C" plywood gussets 12 mm thick used at truss appex and heels, all other joints nailed.

Because of the length both top and bottom chords are spliced and nailed thru spacing block. Letter "S" marks distance of joints from the "node" approx. 1/12 of span or .25 x distance between "nodes".

The double top chord (length indicated by letter G) is necessary to increase strenght for the given overhang especially in high wind regions. Spacing blocks 400 mm length 50 mm thick and depth of given members, considerably increase stiffness and rigidity of the truss structure.

Truss spacing: metal roof 2 metres.
CPW shingles 1.40 metres

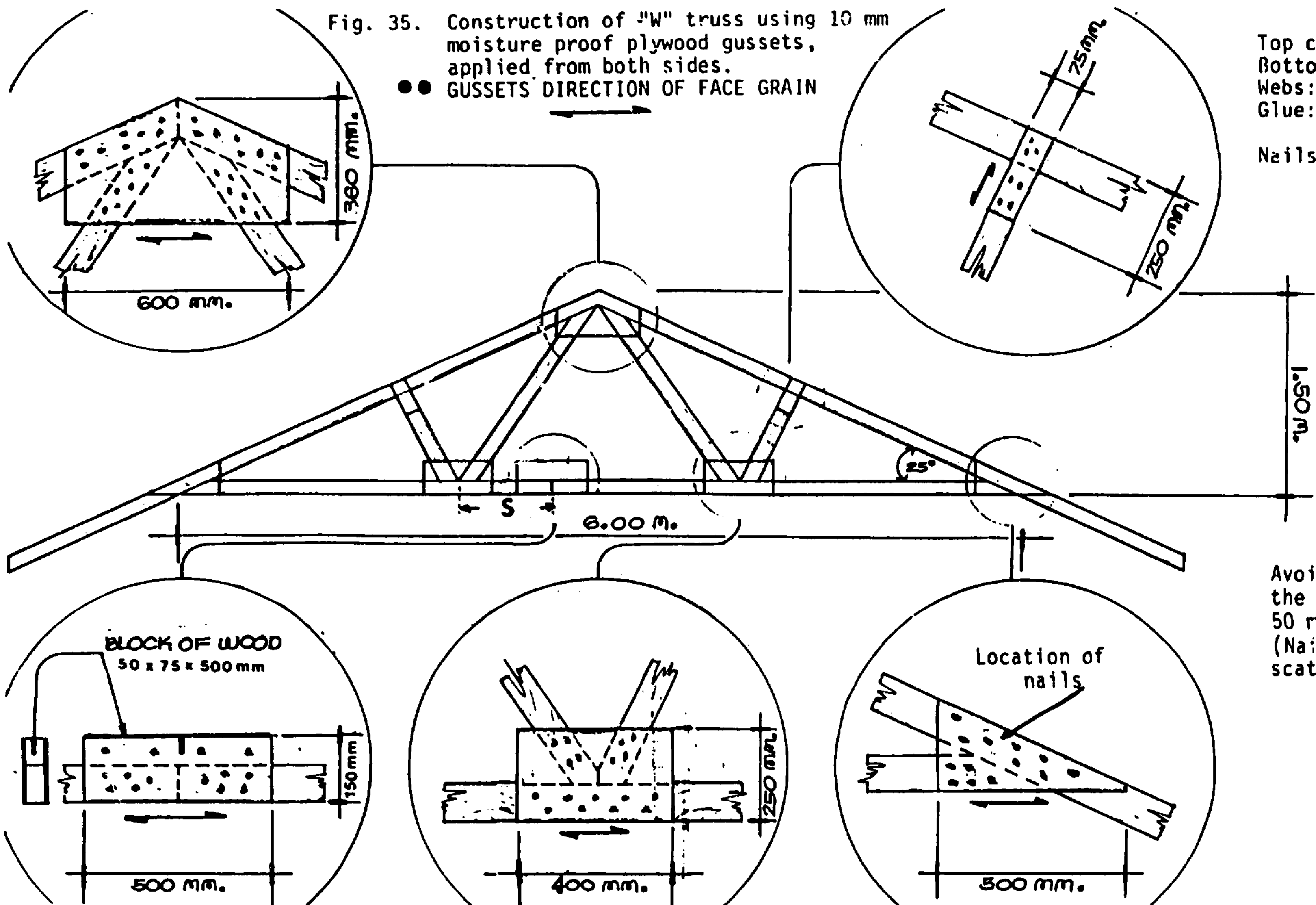


Note: Distance between load bearing wall and truss heel plus free overhang is critical for the given truss span where overhang is a maximum, e.g. distance F plus G.

WHEN PLACING TRUSSES IN POSITION THE BOTTOM CHORD OF THE TRUSS SHOULD BE KEPT CLEAR OF ALL INTERNAL PARTITION WALLS WITH MINIMUM CLEARANCE 12 mm AT THE CENTRE POINT (MAX. DEFLECTION AFTER LOADING). APPLY TO ANY TYPE OF TRUSSES WHEN FASTENED TO SUPPORTING WALLS.

Fig. 34 Cantilevered truss design for rural primary schools in tropical regions

Fig. 35. Construction of "W" truss using 10 mm moisture proof plywood gussets, applied from both sides.
●● GUSSETS DIRECTION OF FACE GRAIN →

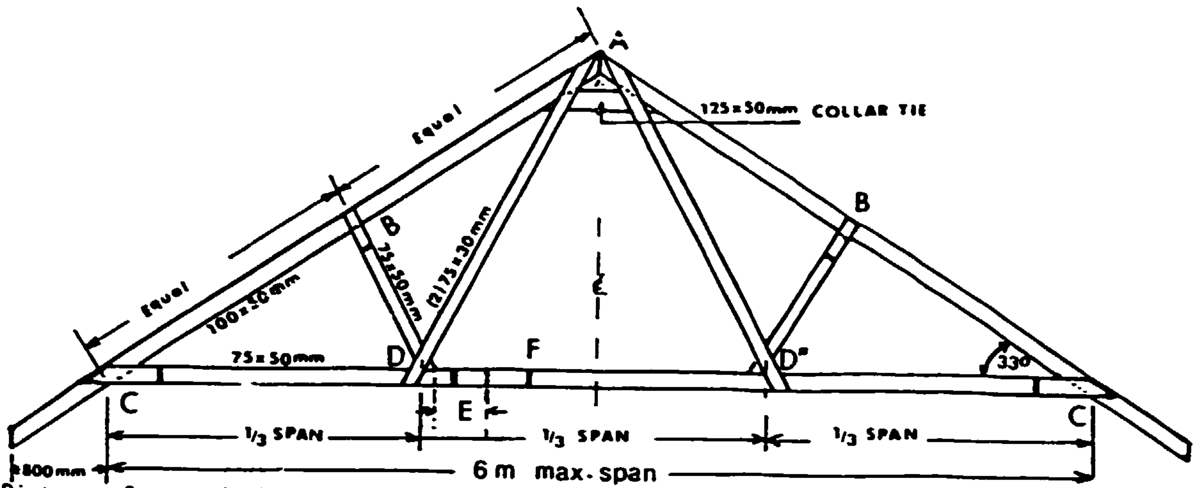


Top chords: 90 mm x 45 mm
Bottom chord: 90mm x 45mm
Webs: 70 mm x 45 mm
Glue: Resorcinol Phenol Formaldehyde
Nails: Galvanised flat head 38 mm length, dia. 3.05 mm (G11)

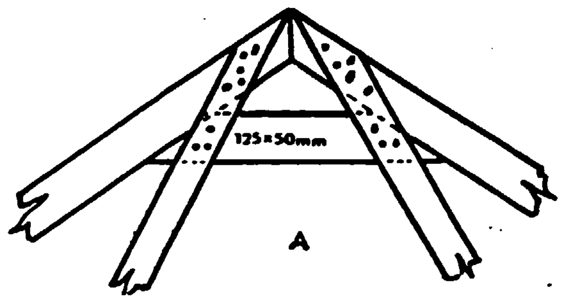
Avoid nailing 15 mm from the members edges and 50 mm from the ends. (Nails should be scattered).

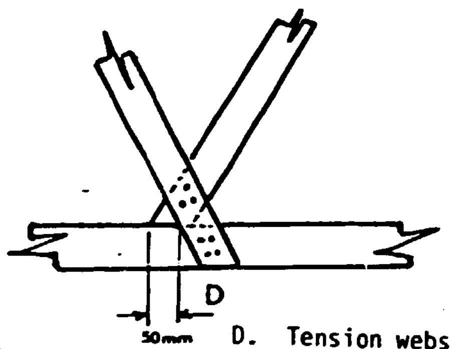
Plywood gusset could be used with glue and nails, e.g. wood must be seasoned, alternatively (Green wood) common nails could be used of such length that will penetrate both gussets of about 10 mm and are vertically clenched. Nailing is done from both sides.

Fig. 36 Nailed CPW truss usable for low cost housing with 33° pitch suitable for thatched roof cover with span 2 meters or corrugated galvanised iron sheets (pitch could be lowered to 25°) span 1.5 meters.



'E' Distance from node D to the bottom chord splice should be 1/12 of the span or .25 distance between Node D and D*.



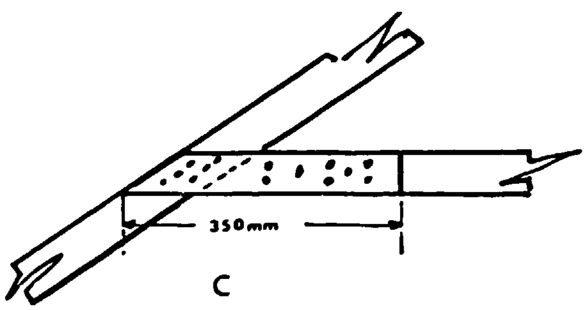


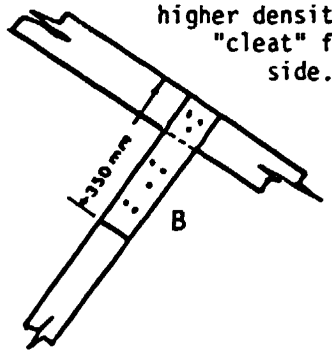
A. Truss appex is stiffened by internal collar tie with well fitted joins to the top chords and nailed from both sides to the tension webs.

D. Tension webs are double e.g. one from each side of truss 75 x 30 mm.

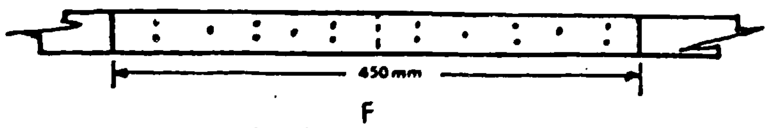
C. 75 x 30 mm x 350 mm higher density wood "cleat" from each side.

B. 75 x 30 mm x 350 mm higher density wood "cleat" from each side.



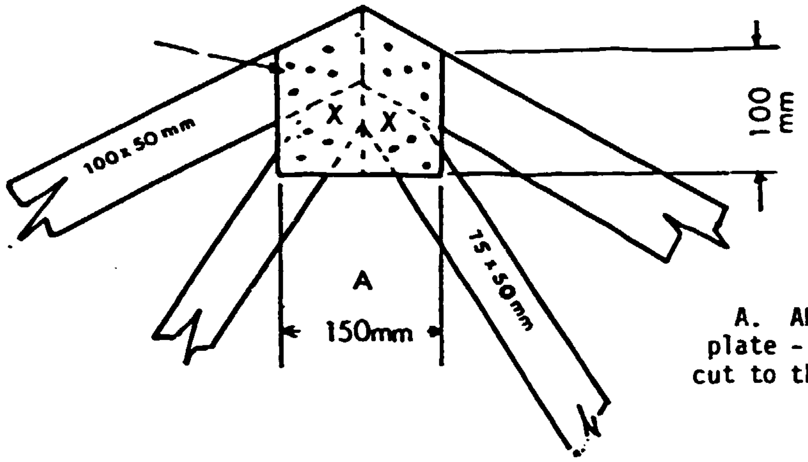


F. Splice, 75 x 30 mm x 450 mm - higher density wood cleat from each side (see E).

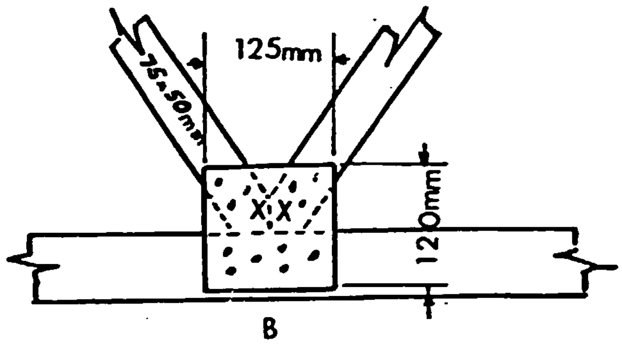


Nails 75 mm length, dia. 3.40 mm (G10), nails holes must be pre-drilled by 2.5 mm drill bit for green wood, 3 mm dia. bit for dry wood.

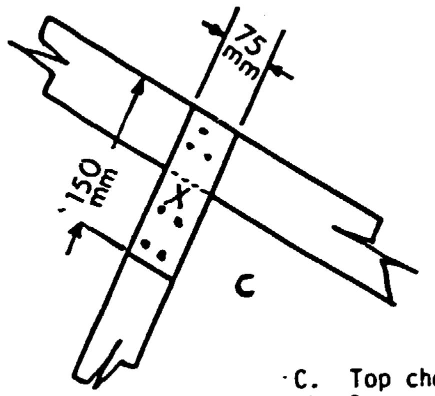
Fig. 37 Construction of "W" truss maximum span 7 m, using 16 gauge galvanised steel plates. (minimum 18 gauge for truss pitch greater than 25°) and predrilled for receiving nails. Metal plates must be applied from both sides.



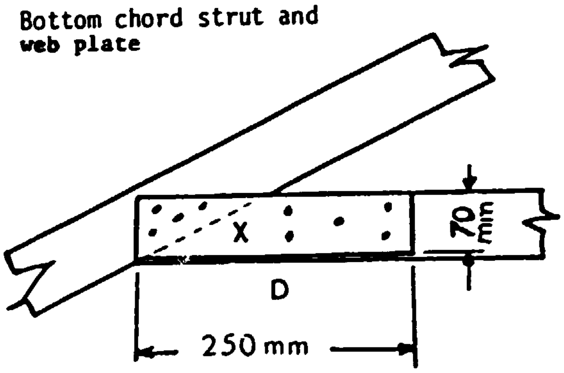
A. APEX (ridge) plate - rectangle or cut to the apex shape.



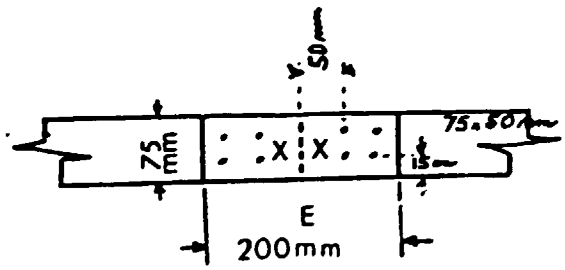
B. Bottom chord strut and **web plate**



C. Top chord and strut web plate.



D. Truss heel plate.



E. Splice at Bottom chord.

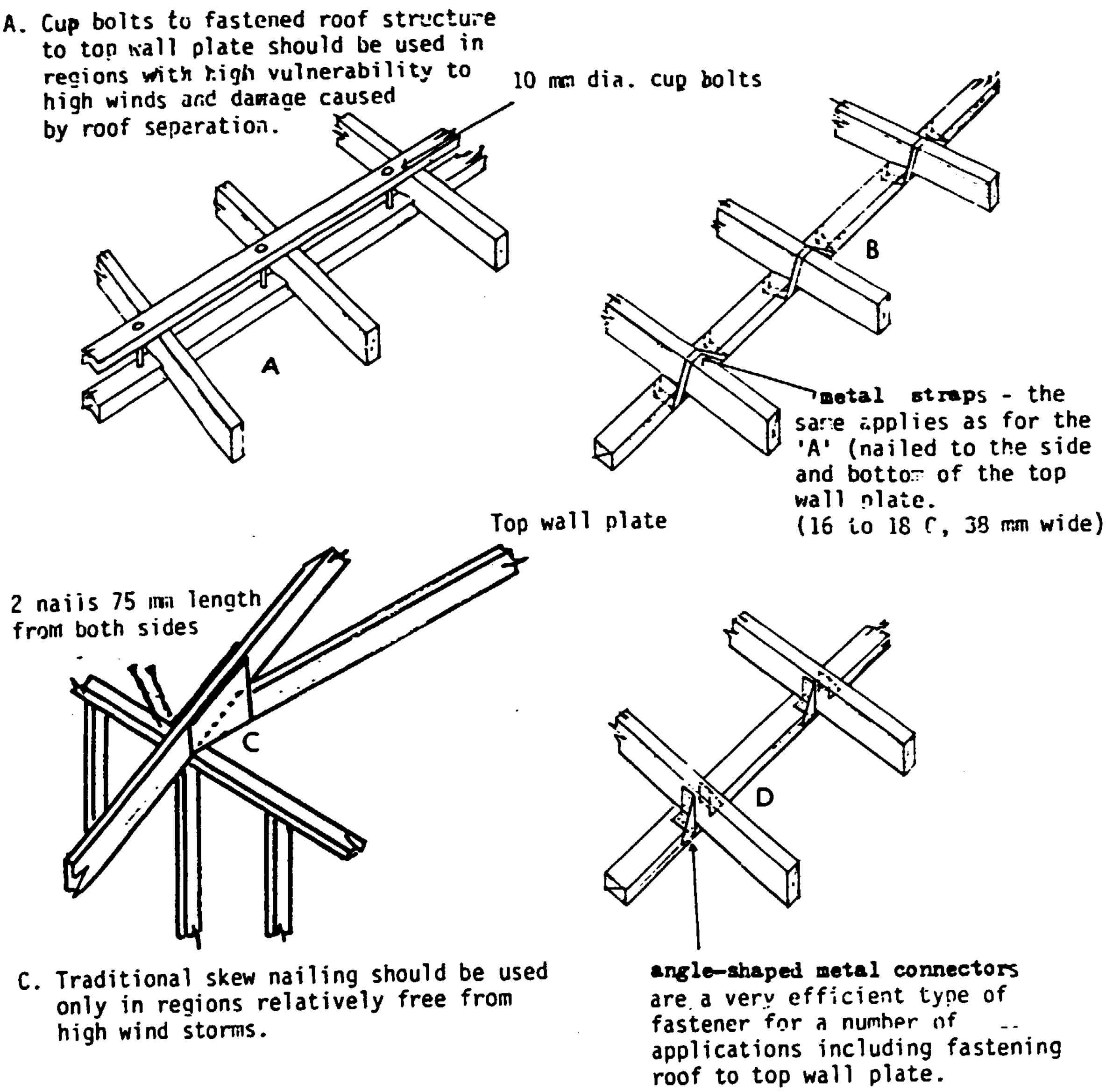
Nails. Rust resistant nails (galvanised) 38 or 44 mm length, dia. 3.05 mm (G 11) scattered - 15 mm off the edge and 50 mm off the ends of wood members.

Wood members should be pre-drilled by a 2.5 mm drill bit.

Letter "X" indicates space in plates where nails should be avoided.

Note: Sizes of the metal plates depend on truss span, sizes of members and pitch (e.g. greater pitch slightly smaller metal plates could be used).

Figure 38 Securing Trusses or Rafters to Wall Top Plate

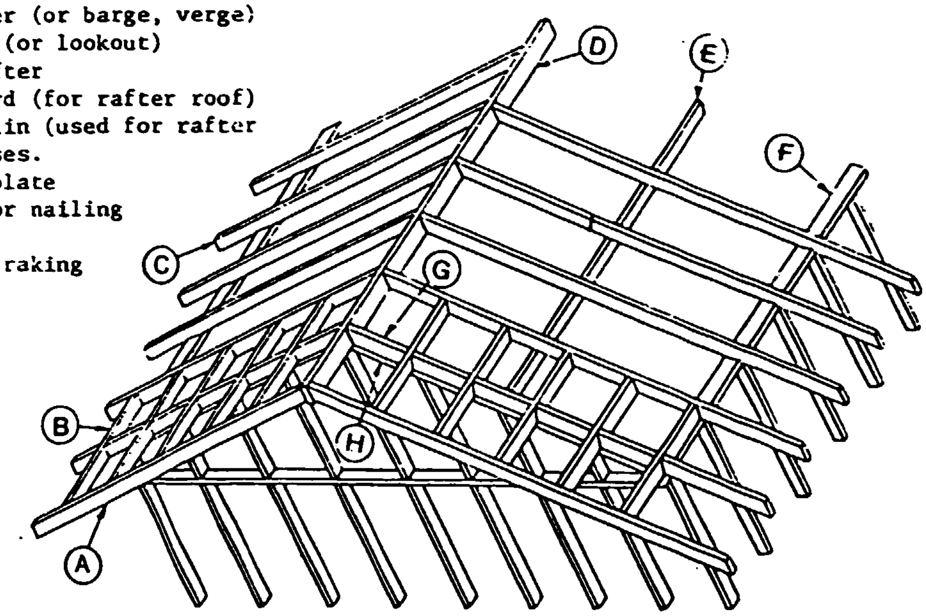


The method of fastening roof to the walls to make whole building structure properly connected together from the foundation to the roof is considerably important to lower vulnerability against climatic disasters. Especially when spacing of roof structural component is larger (e.g. trusses or rafters) more care should be taken to proper tie down roof to supporting walls.

Note: Some types of metal fasteners could be supplemented by skew nailing (e.g. use only one fastener for each member or use more expensive fastener for each alternative truss or rafter and use more simple type for the intermediate (e.g. nails - simple pre-drilled metal plate etc.).

Fig. 39 General terms applying to gable roof framing.

A. Flgy rafter (or barge, verge)
B. Outrigger (or lookout)
C. Common rafter
D. Ridge board (for rafter roof)
E. Under purlin (used for rafter roof trusses.
F. Top wall plate
G. Nogging (or nailing block)
H. Plate (or raking plate)



Gable overhang or extension: Standard gable overhang and its extension beyond the end wall depend on the type of roof cover and sizes of battens or purlins and is usually between 300 to 700 mm.

Larger gable overhangs require rigid framing to resist roof loads and prevent deflection unless truss or rafters are supported by wall or columns (verandah etc.).

Fig. 39 shows arrangement of fly rafter framing for a wide gable extension.

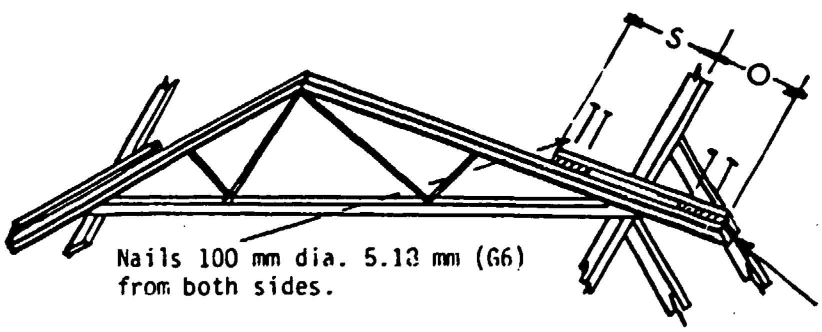
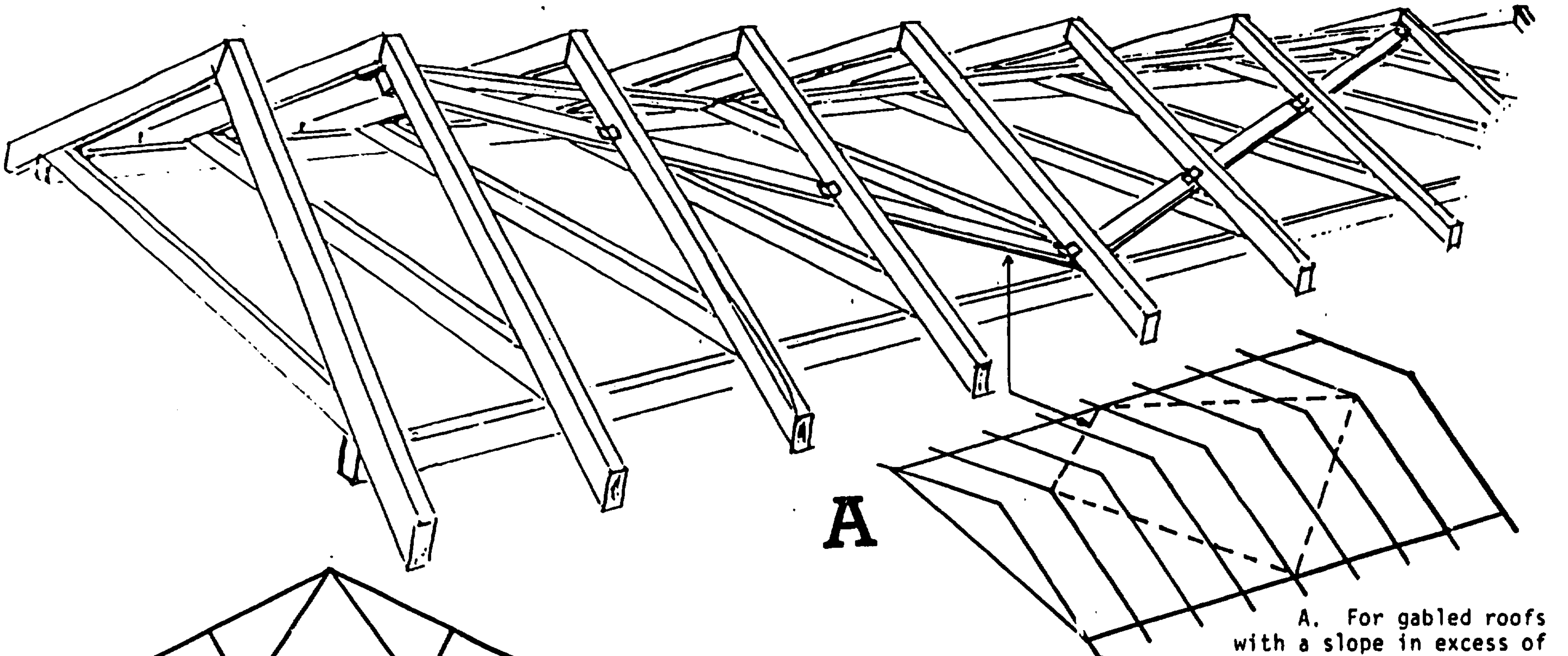


Fig. 40 Eaves overhang:

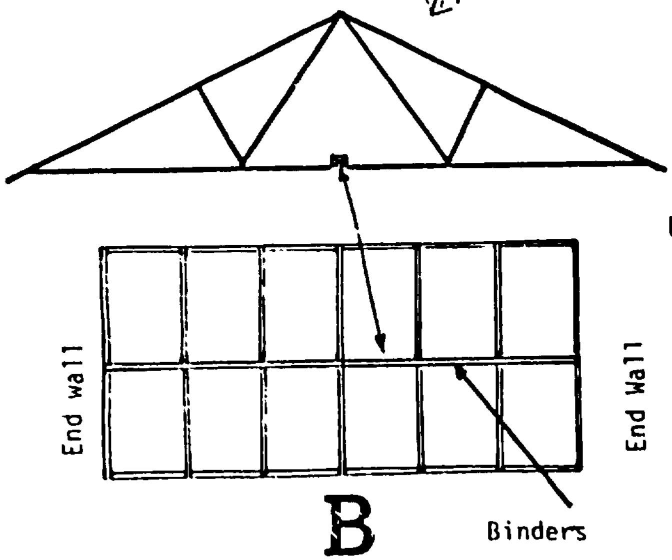
The projection of roof rafters or trusses beyond the supporting wall depend on the rafters or truss cross section, pitch of the roof and the roof cover and could be extended from 700 mm to more than 1,200 mm for standard sizes of rafters or trusses when required by framing see Figure 40.

Larger overhang up to maximum 1500 mm require additional stiffening overhang by double section of a rafter or truss top chord as shown in Fig. 40.

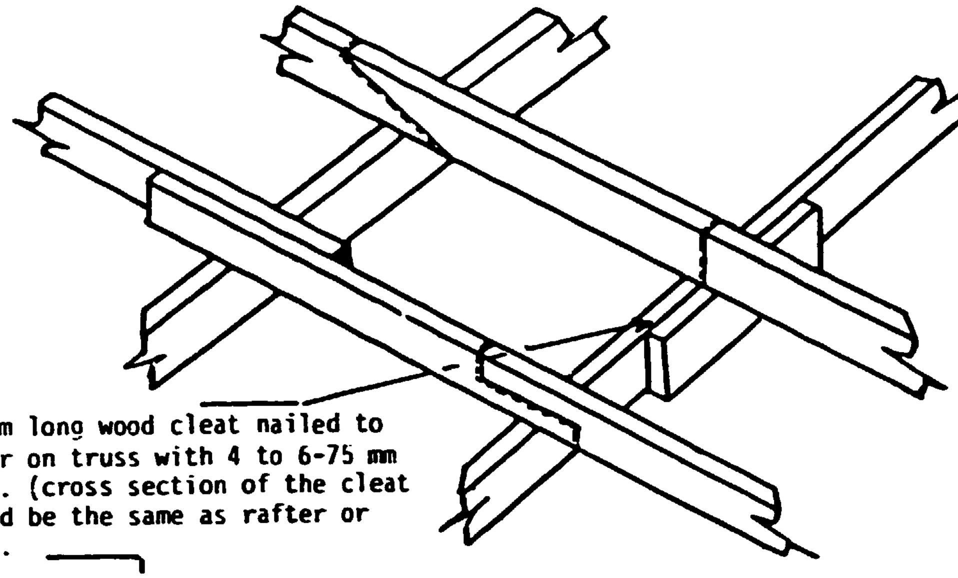
Figure 41 Wind roof bracing - lateral bracing of the end walls and ceiling joists.



A. For gabled roofs with a slope in excess of 10° diagonal bracing should be nailed to the underside of roof members to prevent longitudinal movement especially in high wind regions. Diagonal bracing should run at an angle of about 45° from ridge to load bearing walls and should be double nailed or fixed with the metal brackets to each rafter or top truss chord. Such braces should be minimum 75 mm x 25 mm.

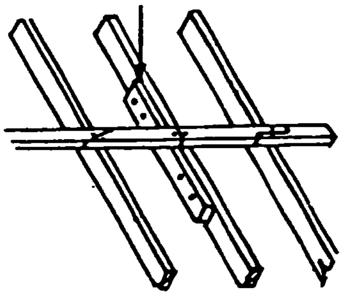


B. End walls which run parallel with ceiling joist should be laterally supported by binders. Binders should be continuous from one end of the building to the other at right angle to ceiling joist and should be nailed to each ceiling member. All joins should be spliced. When roof span is greater than 5 metres 2 binders should be used, equally spaced. Application of such binders is important for high wind regions and when ceiling is open, to provide additional lateral support to ceiling joist.

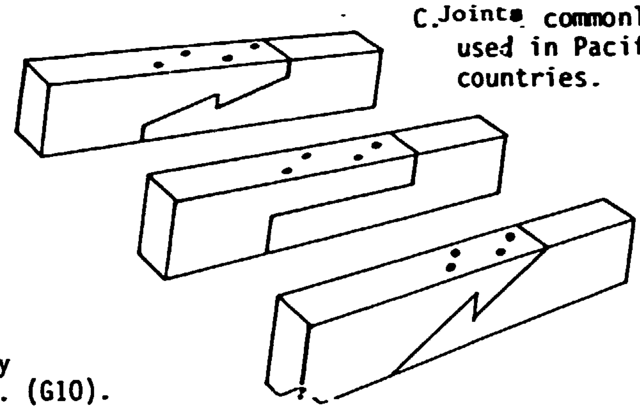


400 mm long wood cleat nailed to rafter on truss with 4 to 6-75 mm nails. (cross section of the cleat should be the same as rafter or truss.

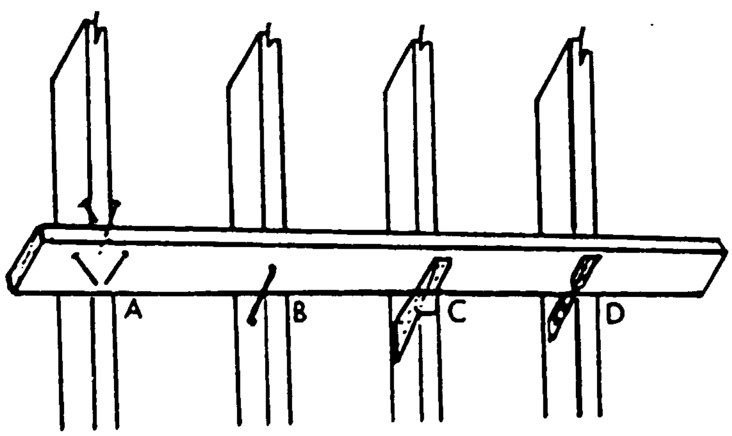
A. Types of joints used for the roof purlins.



B. Roof battens joins - fastened by 2 nails 68 mm length 3.4 mm dia. (G10).



C. Joints commonly used in Pacific countries.



A. Skew nails - four 75 or 88 mm length dia. 4.2 mm.
B. Dog spike from one side and supplemented with two nails from other side.
C. Angle strip connectors from both sides of rafters or truss.
D. Loop plate connectors from both sides of rafters or truss.

The type of connectors to be used depends on the exposure of building to high wind.

Fig. 42 shows different joints for roof battens or purlins and fastening methods to rafters or trusses.

Basic Specification:

A. where rafter or truss length can be covered with a single sheet:
minimum slope 1 : 11 (6^o)
side lap 2 corrugations.

B. where rafter length cannot be covered with a single sheet:
minimum slope 1 : 8 (7.5^o)
side lap 1 1/2 corrugations, minimum end lap 175 mm.

Sheets should be fixed with 45 mm galvanised cup head screws and lead washers to every alternate corrugation at ends and every fourth corrugation intermediately.

The ridge should be covered with 450 mm wide capping, lapped and secured with galvanised screws and lead washers.

Where slope of ceiling follows the slope of the rafters or trusses irrespective of the slope of roof, the vapour/thermal barrier should be fixed to underside of the rafters or trusses.

NOTE: Corrugated G.I. sheets could be used for any slope of the roof and screws are preferred to G.I. nails especially in high wind regions.

Roofing purlins standard size 75 x 38 mm or 75 x 50 mm could be spaced max. 900 mm. However, in high wind regions recommended spacing (especially with the larger truss or rafter spacing) is 650 mm to 700 mm).

For the roofing battens or purlins stress Grade F8 is recommended or selected stress Grade F5 of an upper marginal densities limit.

5. ROOF AND SIDE WALL SHINGLES

In a number of Coconut Palm growing countries, thatched roofs made from indigenous materials such as palm leaves and from suitable tropical grasses such as Imperata cylindirca L. (Cogon) are traditionally used. The most suitable and durable among the palms appear to be the mature leaves of nipa palm. Depending on the quality of leaves and thickness of layers, the serviceable life span of thatched roof is approximately 5 to 8 years. Coconut Palm leaves are one of the poorest materials for roofing of permanent dwelling. They easily become brittle when dry and break into bits during rain and wind.

The above materials provide temporary cover, either as roof or as wide walling. Such built shelters are naturally ventilated and abound in the rural areas.

Owing to the influence of western architectural design, urban housing designs use corrugated G.I. metal and other roofing materials. Depending on economic situations, G. I. sheets used are usually of very light gauge, which may not be suitable to the climatic conditions.

The use of shingles from Coconut Palm wood as a substitute for other roofing material is particularly advantageous in most populated coastal areas, since the seawater moisture can act as preservative in place of protective coats or paints. Coconut Palm wood roof shingles are generally attractive in appearance and provide adequate insulation against heat. However, they may not necessarily be considered as cheap material for low-cost housing projects. It takes experienced labour to set out this type of roof and appropriate nails must be used when the shingles are treated with preservatives.

5.1 Manufacturing Roof and Side Wall Shingles

Considerable technological difficulties and production of substandard products can be expected if the conventional methods of making shingles is used for Coconut Palm wood. The formation of Coconut Palm wood with large density gradient and consequently large variation in wood properties is the basic reason why this is so and such methods cannot be recommended.

Brief comments on the conventional method of making shingles from suitable wood species:

1. Round wood is accurately cross-cut to "blocks" of a convenient length, e.g., depending on the required length of shingles.
2. Blocks are quartered either by saw or mechanical splitter and reduced still further, if necessary, to suitable sizes for the shingle machine.

3. Split blocks then pass through a special saw where bark, sapwood, or defects are removed.

4. Shingles are cut by a special shingle saw from blocks vertically positioned using a small tilting reciprocal carriage so that a tapered shingle is produced by each saw cut along the radial surface exposed by splitting.

5. In the process, the butt end is cut from the top of the block on one stroke, then from the bottom on the second stroke.

6. Then shingles pass through a shingle jointer for edging (to produce parallel edges or, if necessary, to remove defects).

7. Finished shingles are then graded and dried usually in bound bundles (4 bundles should cover one square of roof, 10 x 10 ft. or 9 m^2. Shingles made from less durable species are usually treated by wood preservative.

8. Standard dimensions of shingles:

length:	400 mm (450 mm), or 600 mm
width:	random width 75 to 300 mm, or dimensional shingles supplied in definite width
thickness:	thickness of shingles measured at the butt - a number of butts make up a special dimension such as 4/2, 5/2, e.g. 4/2 means that 4 butts are required to equal 2 inches, etc.

Note: Split shingles are called shakes. The term "shakes" applies to the oldest type of hand-made shingles. Hand split shakes are made, by splitting, from longer roundwood blocks usually 625 mm to 900 mm long, 12 mm up to 30 mm thick and width is random from 125 mm to 450 mm.

Shingle Manufacutring from Coconut Palm Wood

The process and necessary machinery are very simple and consists of rip-sawing the prepared shingle blanks of required dimension by positioning them on endge and sawing from corner to corner, thus producing two shingles with one cut.

Coconut Palm wood shingle blanks are made from dimensionally sawn boards and all three density groups of wood - hard, medium, soft can be used to produce different grades of shingles for specific uses.

Shingles can be produced of random (limited) width but it has been found that dimensional shingles (uniform width) provide better utilization and application.

Process:

1. Dimensionally sized green boards of cross section 100 m x 25 mm ± 2 mm tolerance are accurately cross-cut to the desired length of shingle blanks.

Note: Shingle products make possible the use of partly defective or short boards but the blanks must be defect-free.

2. Shingle blanks are stacked close to shingle saw and processed as soon as possible. (Sawing or machining green Coconut Palm wood is much easier).

Figure 43 illustrates a simple bench rip saw fitted with 450 mm strobsaw[1/] (Fig. 44) powered by 10 HP (kW. 7.5) electric motor. The bench table is fixed with two permanent guides, one on each side of the saw to provide a channel where the jig holding the shingle blank passes through the circular saw.

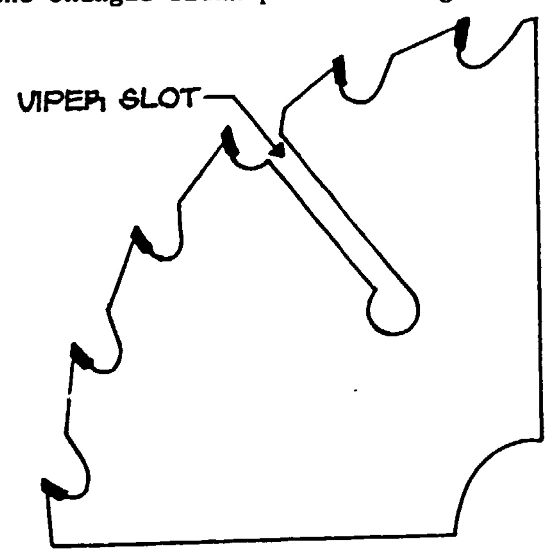


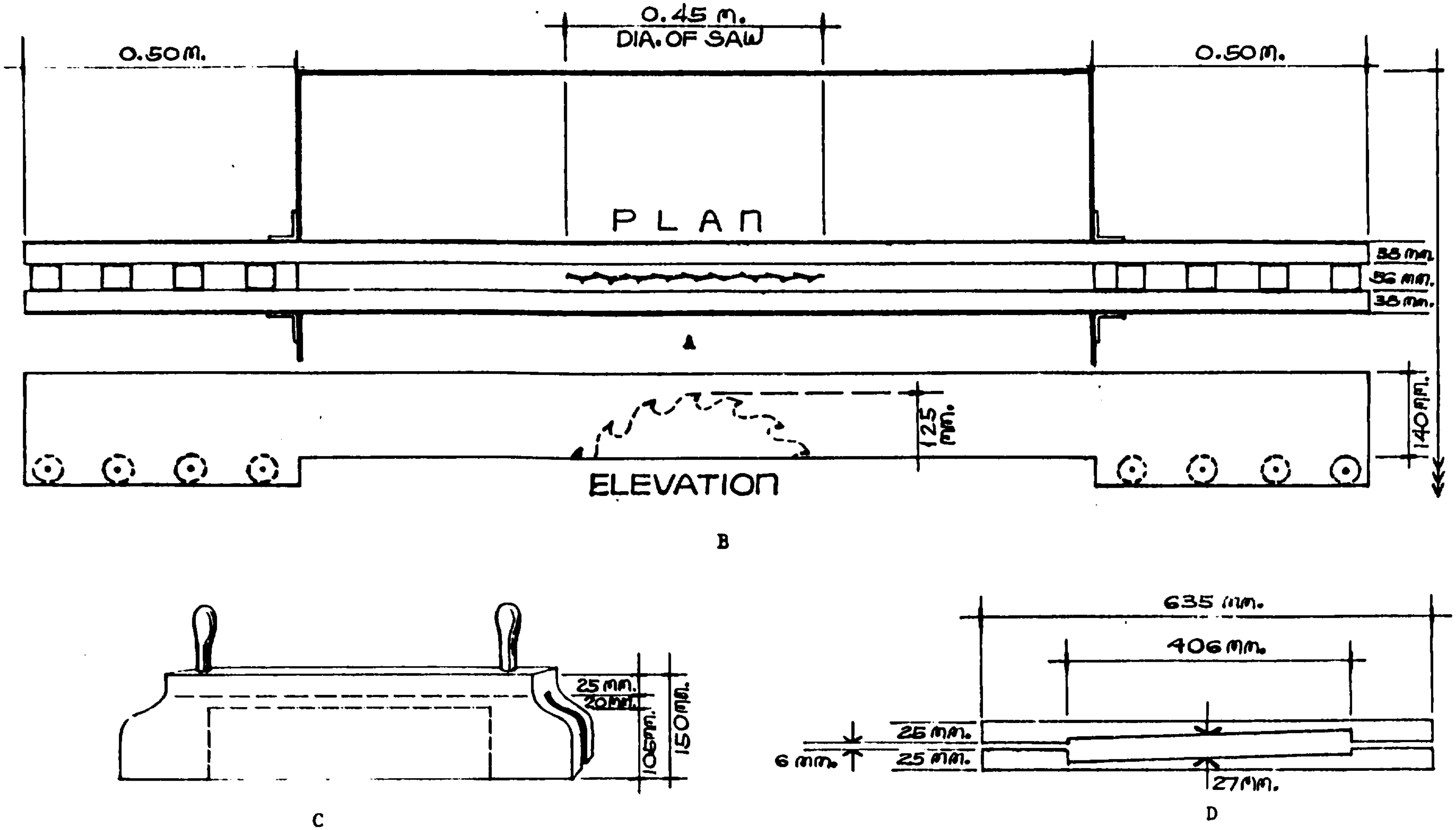
Fig. 44 - Carbide-tipped strobsaw fitted with two viper slots

1/ Strobsaw is manufactured by "Sandvik" and is obtainable in limited different diameters. At PCA-Zamboanga Research Centre, a strobsaw is used for cutting shingles. Specifications: 400 mm diameter, G 11 (3.05 mm), 22 tungsten carbide-tipped teeth producing 5 mm kerf, hook (rake angle) is 20°, blade is fitted with viper slot on each side of plate and which secures a clear kerf free of slivers and irregularities and reduces the risk of binding. Peripheral speed of saw is 40 m/sec. which is approximately 2,500 m/min. RPM 1780.

Fig. 43 Bench saw fitted to produce shingles

- A Arrangement of shingle saw bench with extended guides and fitted with stationary transfer rollers.
- B Illustration of elevation of fixed saw guides.
- C Simple jig made from wood containing slot with size of shingle blank.
- D Direction of shingle blank slot in offset position such that saw cuts the blank into 2 tapered shingles.

Length of bench approximately 1.40 m.



5.2 General Comments on Quality and Service of Coconut Palm Wood Shingles

Durability of Coconut Palm wood shingles should be increased by preservation treatment, where possible pressure treatment is preferred. Dipping or brushing the whole shingles by suitable wood preservative before they are laid is less effective. Repeated brush application in 2 or 3 years time on the exposed surface is recommended.

Splitting

a) by driven nails. When shingles are laid, they should be pre-drilled by a drill bit 2 gauges smaller than the diameter of nails.

b) by exposure to weather and effect of shrinkage or warping. Shingles should be laid on the roof or sidewalls as close as possible to equilibrium moisture content (16 %) with expansion joint between shingles 5 to 6 mm wide. Green shingles especially those made from high density wood, may develop drying stress between nails, when nailed in position and later dried.

Dimensional stability

Coconut Palm wood has low to moderate shrinkage, in general, and has very low ratio (close to unity) of tangential to radial shrinkage. Therefore, if laid in dry condition, the shingles can be considered dimensionally stable.

The weight of shingles depends on the wood density group from which shingles are made.

a) Roofing shingles should have approximate average basic density of 600 kg/m^3 (density range between 500 to 700 kg/m^3).

One thousand shingle blanks, 25 mm x 400 mm, equal one cubic meter. When shingle blanks pass through a shingle saw, 2,000 pieces of shingles are produced with the following dimension:

length	400 mm
thickness (at butt)	12.0 mm
width	100 mm

i) When laid on the roof with 160 mm weather exposure, it takes 60 shingles to cover 1 m^2.

The weight of 60 shingles (1 m^2 laid on the roof) in different moisture contents (mc) and recommended basic density range is:

At 16 % MC - weigh approximately 16 kg
At 25 % MC - weigh approximately 17.5 kg
Fully saturated (green) or affected by prolonged rain it can reach up to 25 kg, if not treated by waterproof preservative.

ii) When laid on the roof with 125 mm weather exposure (recommended weather exposure), it takes 80 shingles to cover 1 m^2.
As above, the weight of 80 shingles (1 m^2 laid on the roof) is:

At 16 % MC - weigh 21.6 kg
At 25 % MC - weigh 23.0 kg
Fully saturated (green) or affected by prolonged rai[illegible] can reach up to 34 kg, if not treated by waterproof preservative.

b) <u>Sidewall shingles</u>

i) external application

Shingles should have average basic density of 500 kg/m^3 (density range is 400 kg/m3 and above).

Standard dimension:

length	400 mm or 600 mm
thickness (at butt)	12.5 mm
width	100 mm

Sixty shingles, 400 mm long, exposed 165 mm to weather, are needed to cover 1 m^2 of wall siding.

If 600 mm long shingles with 275 mm exposure to weather are used, 37 pieces are needed to cover 1 m^2 of wall siding.

ii) internal wall shingles
Internal wall shingles are made from wood with average basic density 300 kg/m^3 and above.

Standard dimension:

length	400 mm or 600 mm
thickness (at butt)	12.5 mm
width	100 mm

400 mm-long shingles

Shingles can be laid in single or double course.
Single course installation is the same as for roof covering, only weather exposure could be slightly larger. See Fig. 45

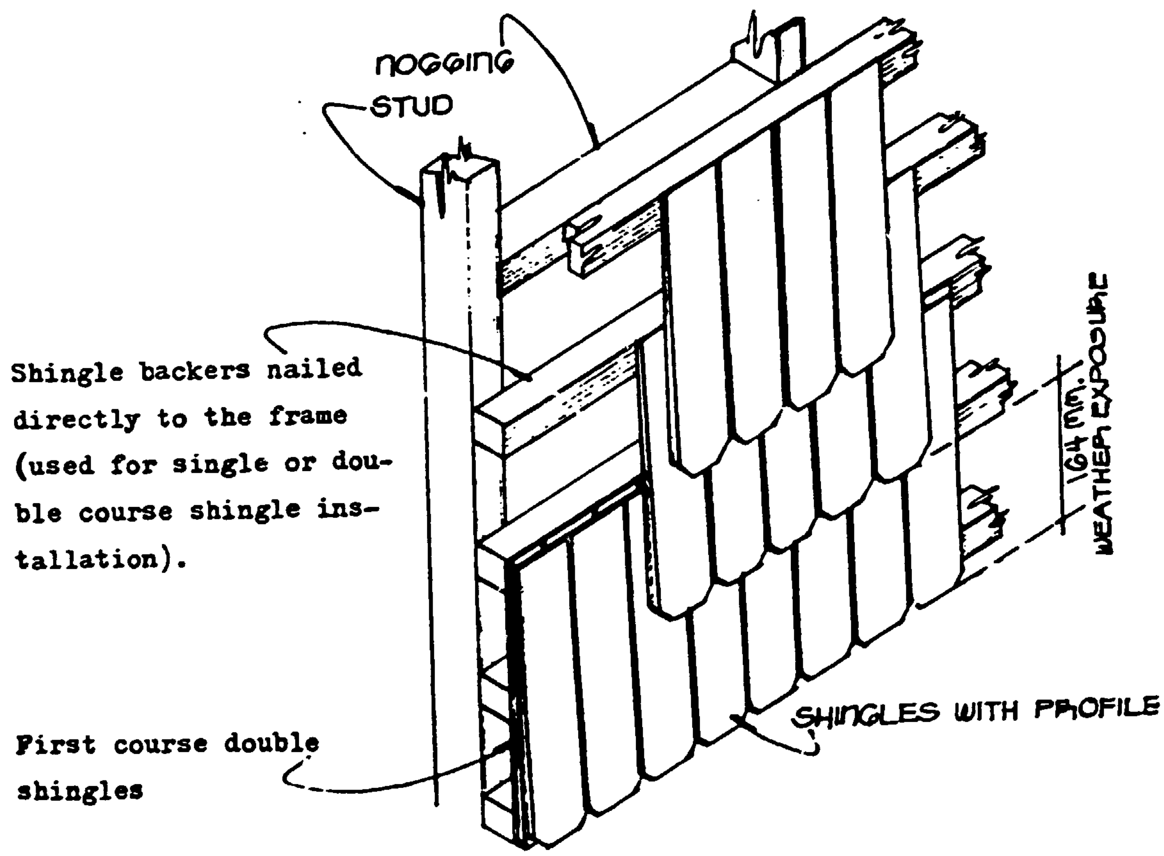


Fig. 45 Single course shingles for sidewalls

Double course consists of 30 shingles for the undercourse (lower grade) and another 30 shingles for the second "face course" with weather exposure of approximately 360 mm, so that most of the shingle surfaces are exposed. (See Fig. 46). To cover 1 m^2 of wall siding, approximately 60 shingles are used.

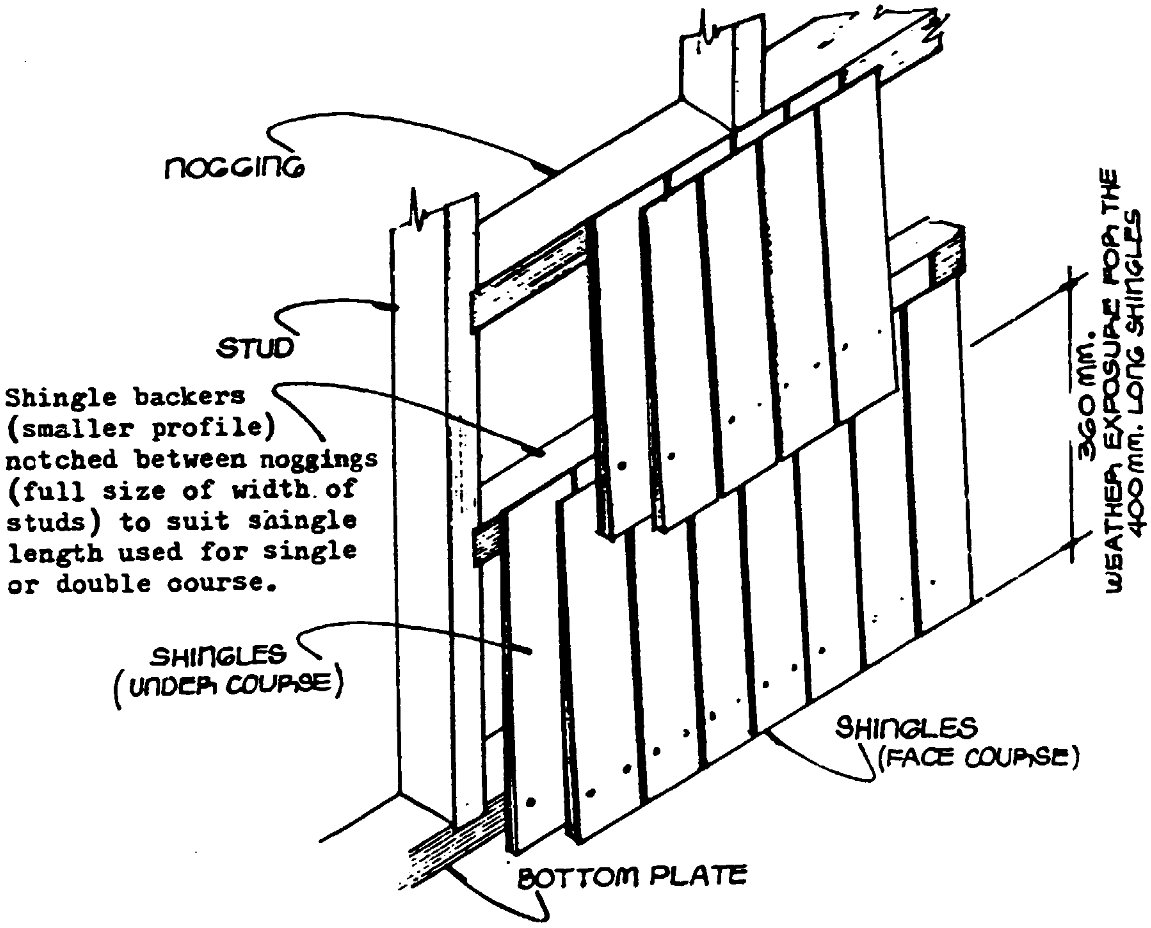


Fig. 46 Double course shingles for sidewalls

600 mm-long shingles

If laid in single course with 275 mm exposure, 40 pieces are necessary to cover 1 m^2 of wall siding.

If laid in double with 500 mm exposure, 40 pieces are necessary to cover 1 m^2 of wall siding.

Strength and weathering

Coconut Palm wood shingles made from higher density wood have sufficient strength for roofing or exterior wall siding.

Weathering by the combined effect of sunlight and rain tends to raise the grain (vascular elements). At the same time, erosion of ground parenchyma tissues takes place especially for the lower density wood.

The decomposition of softer tissues by sunlight ultra-violet rays can be controlled by wood preservatives containing copper and chromium to minimize the absorption of ultra-violet rays.

Internal wall shingles made from low density wood and fully protected from weather extremes give good service.

Coconut Palm wood has ability to take wood preservative by pressure, dipping, brushing, etc.

Coconut Palm wood shingles produce an exceptionally good appearance when used as roofing or wall siding.

Economics

Making shingles from Coconut Palm wood does not require expensive machinery and gives the possibility to utilize short pieces of wood. This applies to all Coconut Palm growing countries, especially some Pacific islands where palm stems are relatively short and twisted, and so makes it possible to produce a product of considerable commercial and aesthetic value.

Shingle covered roofs have exceptionally good insulation properties and good appearance from outside and inside. Therefore, ceilings are not necessarily required. When metal roofing material is used, some insulation is necessary against heat radiation.

Whether locally made Coconut Palm wood shingles can replace imported roofing and wall siding building materials (sometimes of a low quality) for the lowcost housing, brings up a number of considerations such as local employment, new skill acquisition, savings or relocating import quota, more comfortable housing, etc.

Note: A shingle saw as illustrated in Fig. 43 can produce from available shingle blanks, with relatively unskilled operators, between 3,500 to 4,000 shingles per working day. This is based on the study that operators work 6 hours in 8 hour shifts with normal effort which can be repeated day after day.

5.3 Recovery from Coconut Palm Round Wood Converted to Shingles

A study was carried out at the Zamboanga Research Center of the Philippine Coconut Authority to convert palm stems to shingles. The combined total volume of the palm stems was 3.7 m^3 and the average height 17.8 meters (from butt to first leaf). The palm stems were converted to boards with cross section dimension of 100 x 25 mm which were cross cut to shingle blanks, 25 x 100 x 40 mm, then sawn to shingles.

The following recovery was obtained by visual grading after air drying to 16 % moisture (equilibrium moisture content).

Average BD[1/] 450 kg/m^3 and above	994 pieces
Average BD below 450 kg/m^3	806 pieces
"Reject shingles" usable as undercourse for the double course shingles application or secondary type of buildings	202 pieces
Total:	2,002 pieces

Note: Rejects mostly came from shingles made from very low density wood.

Shingle recovery from 3.7 m^3 volume of round wood:

1 m^3 shingle blanks (1,000) is equivalent to 2,000 shingles.

Therefore, percentage of recovery obtained is approximately 27 per cent.

Note: 3.7 m^3 volume of round wood was based on the total volume of stems, e.g., from butt to first leaf. This explains the larger proportion of the recovery of low density shingles. Selected palm stems were slightly below average in reference to the general quality of local mature Coconut Palm.

[1/] BD = Basic Density

5.4 Grading Shingles

Shingle blanks must be free of defects when cross cut from boards to required length. For this reason, when the blanks are processed to shingles, very few are defective as all defects are docked out during the cross cutting of shingle blanks.

Coconut Palm wood shingles can be made from blanks of a mixed density, then air dried before visual grading by density groups and defects or imperfections.

Shingles should always be visually graded after drying to equilibrium moisture content (approximately 16 %) to include defects developed during the drying process.

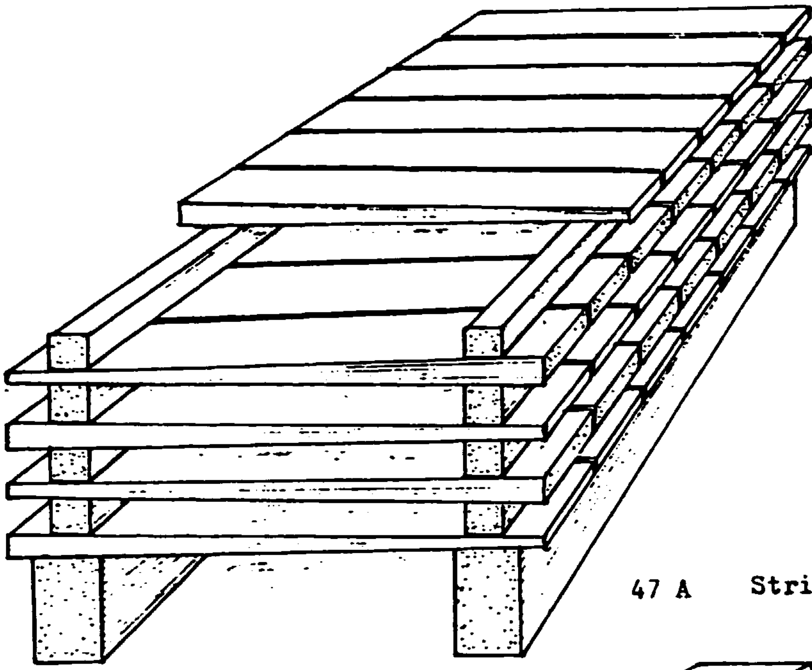
Fig. 47 shows methods of drying shingles in a drying shed with open sides. Air drying green shingles during dry weather could be completed in about 4 weeks time to equilibrium moisture content.

An experienced grader with basic knowledge of Coconut Palm wood can visually grade air dried shingles to appropriate density groups and for possible defects, then sort them, at the same time, for the final end-use without much difficulties. This is done by utilizing the knowledge of the visual appearance of surface such as colour of wood, size of texture or grain (vascular elements) and judgment of the weight.

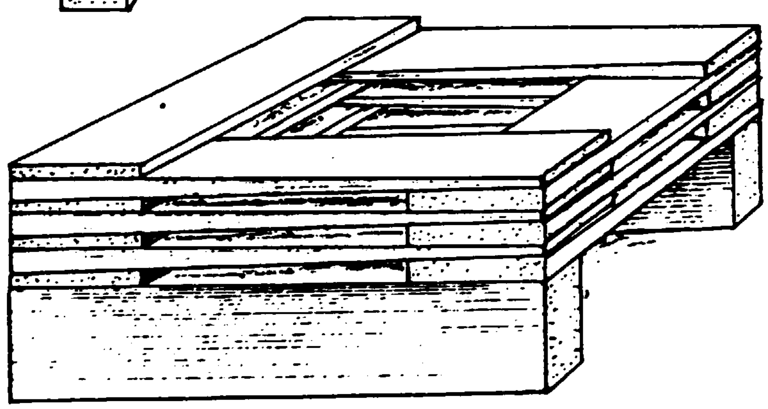
5.4.1. Roofing shingles should be made from wood with average basic density range 500 to maximum 700 kg/m^3.

Shingles made from very high density wood should be excluded from roof installation as they have tendency to split when exposed to weather conditions.

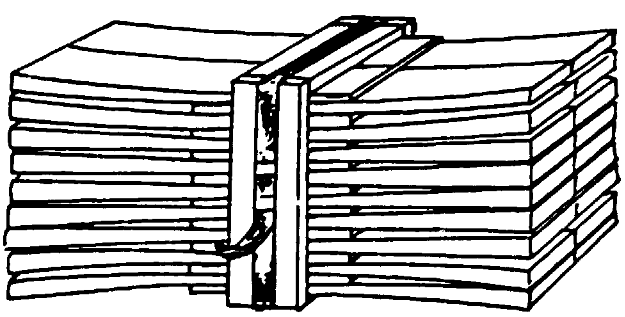
Fig. 47 Arrangement for drying roof or sidewall shingles.



47 A Strip stacking



47 B Self-crossing



47 C Commercial type of shingle bundle suitable for dipping preservation (as single shingles float).

Standard size of bundles is produced from green shingles and can be dried and eventually treated by wood preservative in such bundles. Note that 1/2 of the butts are at one end of the bundle and the other half at the other end with tapered ends overlapping in the center.

Recommended dimensions of roofing shingles:

length	400 mm	400 mm
width	100 mm ± 5 mm tolerance (when cut to definite width)	
thickness	4 shingle butts should be equal to 50 mm unless different thickness of butts is required.	

General rules:

a) No bark should be included.

b) Edges should be parallel.

c) Ten per cent of shingles can be 25 mm longer or shorter.

d) No warping is allowed. Shingles should lay flat.

e) Wane on one side should not exceed 1/10 of wiedth or thickness or both.

f) Splits or severe checks are not allowed on the butt side. (Small splits are allowed on the tapered side not exceeding 1/4 of length).

g) Reject roofing shingles can be used for secondary buildings, wall sidings, or undercourse layer for double course shingle application.

5.4.2 Wall siding shingles

Dimension:

length	400 mm or 600 mm
width	100 mm ± 5 mm tolerance
thickness	4 shingle butt ends should be equal to 50 mm unless different thickness of butts is required.

a) Exterior wall siding shingles - average basic density range 400 kg/m^3 and above. (No limit for shingles made from high density wood).

Note: Side wall shingles can be made from Coconut Palm wood of random width from 75 mm to 125 mm, if desired.

Because exterior sidewall shingles are partly protected, they usually last longer than roof shingles.

In general, rules which apply to roof shingles apply to exterior wall siding shingles.

Exterior wall siding shingles are sometimes surfaced and can be machined to desired profile (see Fig. 48), then treated by suitable wood preservative. After installation, coloured wood stain can be applied by brushing.

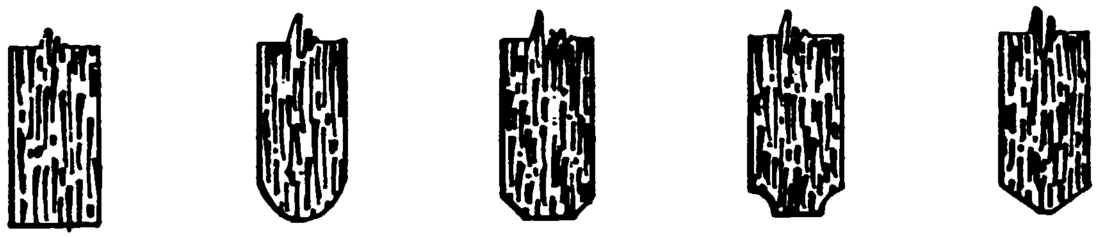


Fig. 48 Different profiles of sidewall shingles

Any butt shingle profile can be used for sidewalls application. Exception: roof shingles should always have plain (square) profile of butt end.

Weather exposure for the exterior wall siding shingles can be slightly increased.

b) Internal wall siding shingles - average basic density range 250 kg/m^3 and above. (No limit for shingles made from high density wood).

It is recommende' that internal shingles should be treated by Boron type of chemicals as a protection against Anobium species wood borers.

Shingles used for internal wall sidings are usually surfaced and sanded. They can be machined to desired profile butts as shown in Fig. 48 and then finished by natural clear finish or by suitable coloured wood stain.

For internal wall sidings, shingles made from a large density range can be used. Mixing different densities during installation depends on choice, and using sorted density for each different wall probably produces a better visual effect.

5.5 General Comments on Installation of Shingles

Instllation of shingles is a subject of practical skill and experience, but it is not difficult to obtain the necessary skill when recommended rules are observed:

1. First course must be double laid for single course sidewall and roof shingles. See Figs. 45 and 49. (Exception: internal double course wall sidings).

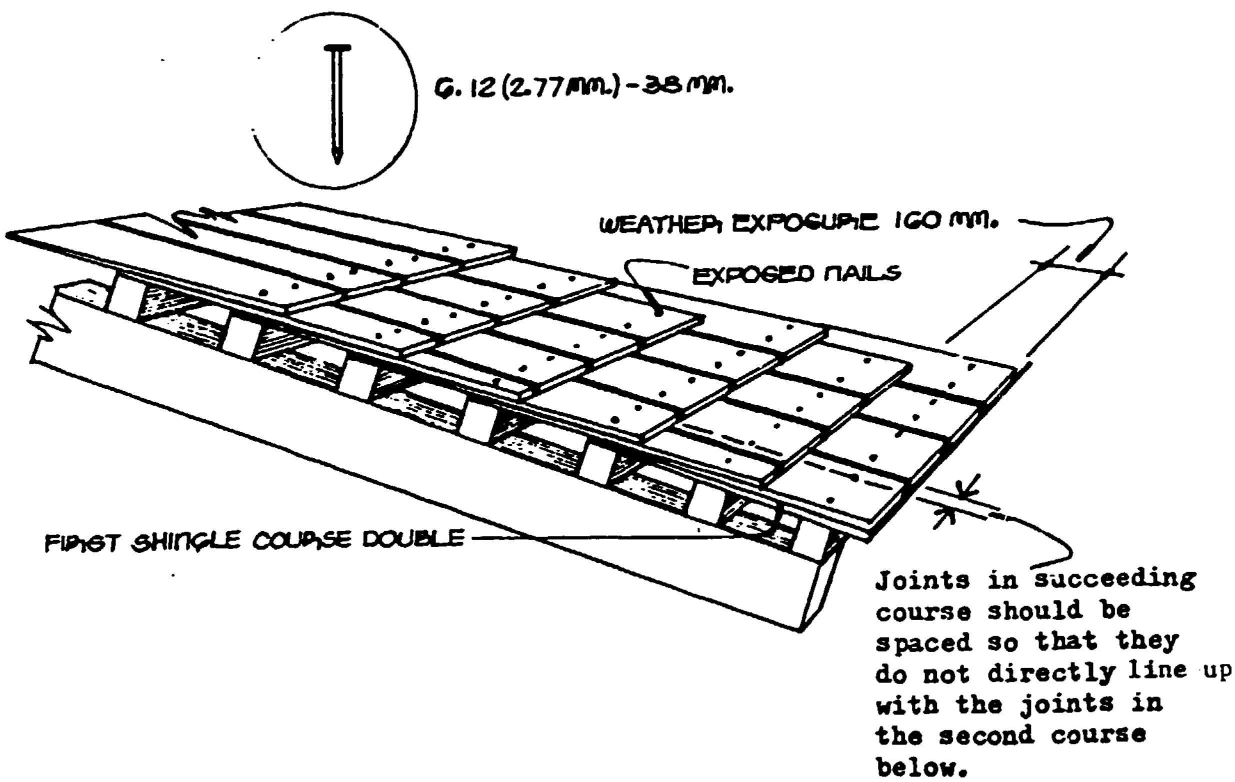


Fig. 49 Roof shingles with 164 mm weather exposure, therefore, 4 nails are used for each shingle (2 nails exposed).

2. <u>Nails</u>

G 12 (2.77 mm diameter), 38 mm long, rustproof nails such as galvanised, stainless steel, or cadmium coated if obtainable, preferably with ring shank (threaded nail).

Internal shingles are laid with common finishing nails and are usually punched and sealed by wood putty.

If weather exposure is large, as 164 mm, 4 nails are necessary to hold the shingles flat, with 2 nails exposed to weather. See Fig. 49.

When roofing shingles are weather exposed 125 mm, only two nails per shingle should be used and nails should always be covered by the succeeding course. See Fig. 50.

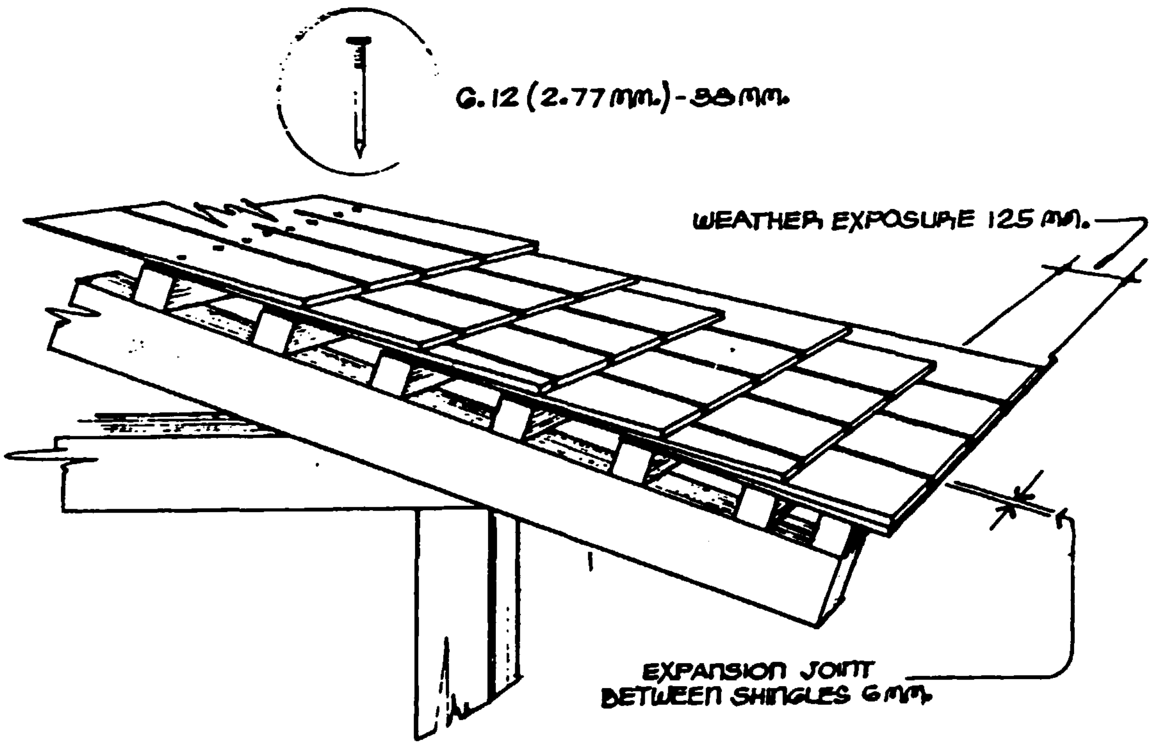


Fig. 50 Roof shingles with 125 mm weather expousre. Only 2 nails are used for each shingle, e.g., no nails are exposed.

Installation of the roof shingles with 125 mm weather exposure and using only 2 nails per shingle is preferred taking into account that up to 25 per cent more shingles are necessary to cover the given areas.

Coconut Palm wood shingles must be pre-drilled to avoid splitting. The nails should be driven at minimum 44 mm from the butt and 25 mm from the side edge.

3. Expansion joints between shingles (space between shingles) should be 5 to 6 mm. See Fig. 50. The joints between shingles should be offset minimum 38 mm from the joints between shingles in the course below. See Fig. 51. The joints in the succeeding course should be spaced so that they do not directly line with the joints in the second course below. See Fig. 49.

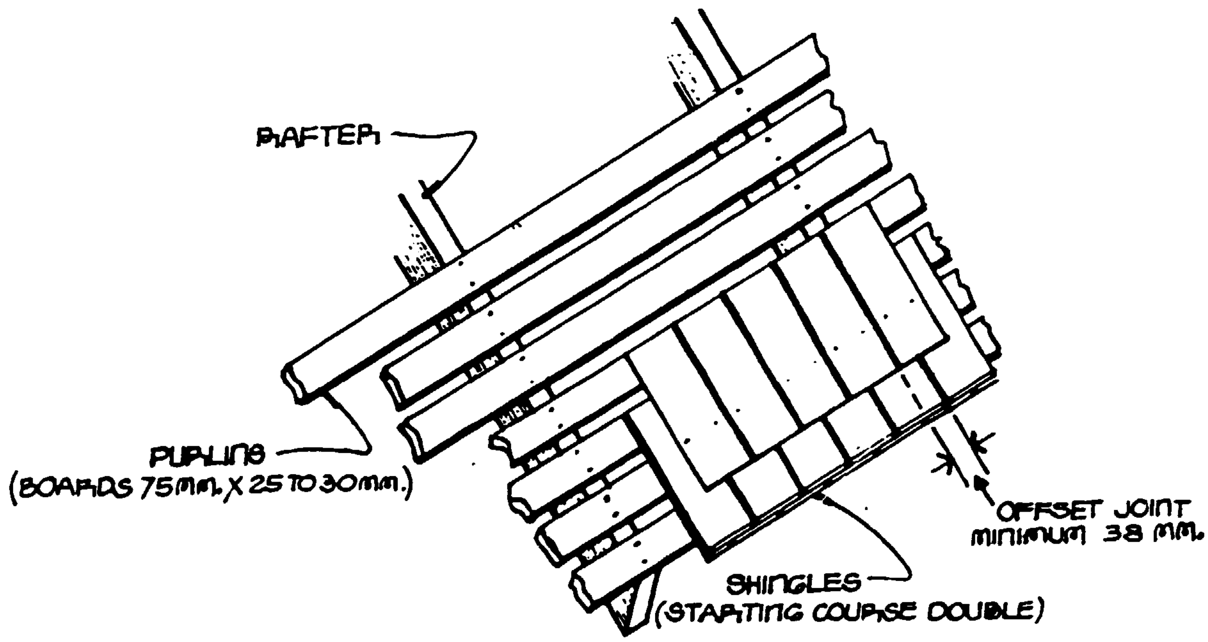


Fig. 51 Spaced-type (purlins) board roof. Note the offset (overlap) joints between succeeding shingle courses.

4. Wall siding shingles can be nailed directly to the framing members, or to battens connected to frame. See Figs. 45 and 46.

Roof shingles can be nailed to boards approximately 75 x 32 mm. See Fig. 51. Such an arrangement provides an acceptable internal ceiling finish and provides ventilation for the inside surface of shingles.

Roof shingles can also be nailed to standard type of purlins with cross section depending on spacing of trusses or rafters. See Fig. 52.

Note: In humid climatic conditions, shingle underlying materials such as plywood or closed wood decking should not be used as it is necessary to provide good ventilation to keep the internal surfaces of shingles dry.

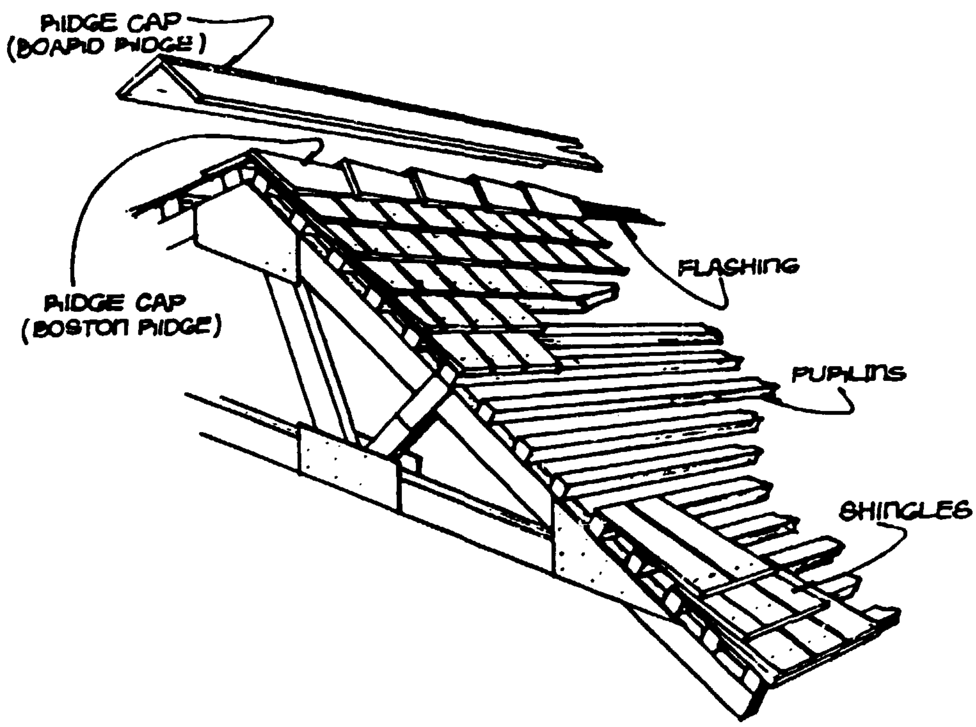


Fig. 52 Standard type of purlins cross section 38 x 44 mm used for 1.75 m spaced trusses. Permitted maximum overhang on gable side is 600 mm without framing overhang (flying rafter).

5. Shingles should overhang on the eaves side about 32 mm and on the gable side minimum 18 mm.

6. Slope of roof.
The weather exposure of shingles depends on the slope of the roof. If the slope of roof is less than 25 degrees, the weather exposure must be reduced. The recommended slope is minimum 25 up to 35 degrees.

7. Flashing of roof (See Fig. 52).
Flashing of the roof ridge is necessary and flashing of overhang by strip of flashing material at least 3 to 4 shingles wide on the gable side is recommended.

8. Shingles should not be wet or soaked in water prior to installation. Splitting due to shrinkage stress between nails will occur if shingles are laid wet.

5.6 General Comments on Preservation Treatment of Shingles

Coconut Palm wood roofing or external wall siding shingles should be treated by wood preservative before installation. Where it is possible, pressure treatment is preferred, otherwise dipping or brushing can be employed although such methods are less effective.

5.6.1 Pressure treatment Waterborne preservatives such as Tanalith C (a proprietary brand of copper chrome arsenic applied by pressurized tank (Bethell method) has been used for roof shingles at the Zamboanga Research Center of the Philippine Coconut Authority.

Roof shingles air dried to approximately 16 to 18 per cent moisture content and pressure treated by 2 per cent Tanalith C solution obtained preservative retention of 12 to 14 kg/m^3 (4.2 to 4.9 kg of active elements). There were 2,564 pieces of shingles treated, 400 mm long, 100 mm wide and 12.5 mm average butt thickness.

As for penetration achieved for shingles treated by pressure Bethell method by Tanalith C was:

High density wood	- Irregular penetration, minimum 2 mm from all faces.
Medium density wood	- 70 to 90 % penetration, minimum 4 mm from all faces.
Low density wood	- Complete penetration

5.6.2 Hot and cold bath Air dry (equilibrium moisture content) shingles were dipped in water at about 70°C and brought to boiling point in approximately 60 minutes. Then the shingles were dipped into a cold solution of 5 - 10 % concentration of Tanalith C for about 60 minutes. At ZRC the obtained retention from 6.6 % concentration was 7 kg/m^3 (2.45 kg of active elements)/m^3 of shingles (2,564 pieces).

Penetration achieved for shingles treated by hot and cold bath was:

Air dry:	High density wood	- 1 to 1.5 mm penetration from all faces.
	Medium density wood	- 1.5 to 2 mm penetration from all faces.
	Low density wood	- Irregular penetration through whole thickness and all sides.
Green:	High density wood	- Irregular penetration approx. 1 mm from all sides.
	Medium density wood	- Irregular penetration of 1.5 mm from all sides.
	Low density wood	- Irregular penetration, minimum 2 mm from all sides.

Note: Shingles made from low density wood are not usually treated by wood preservative as they are used only for interior wall sidings. However, by diffusion method by Boron compounds is recommended where necessary.

5.6.3 Double diffusion treatment

Another method used at the Zamboanga Research Center is the modified double diffusion treatment. (See Fig. 53). In this case, a 5 % solution of copper sulphate ($CuSO_4$) was heated to 70° to 80° C (not more) in a stainless steel tank.[1/]

Bundles of shingles were submerged in the solution and the temperature was maintained for 5 hours. Then the shingles were transferred to the cold bath tank containing 5 % solution of sodium dichromate ($Na_2Cr_2O_7$) and 5 % arsenic pentoxide ($As_2O_2 2H_2O$) and were kept there for 48 hours.

[1/] Ordinary steel cannot be used for $CuSO_4$ solutions since at higher temperatures it will rapidly attack steel. When the temperature exceeds 80°C, the solution may attack the welded joints.

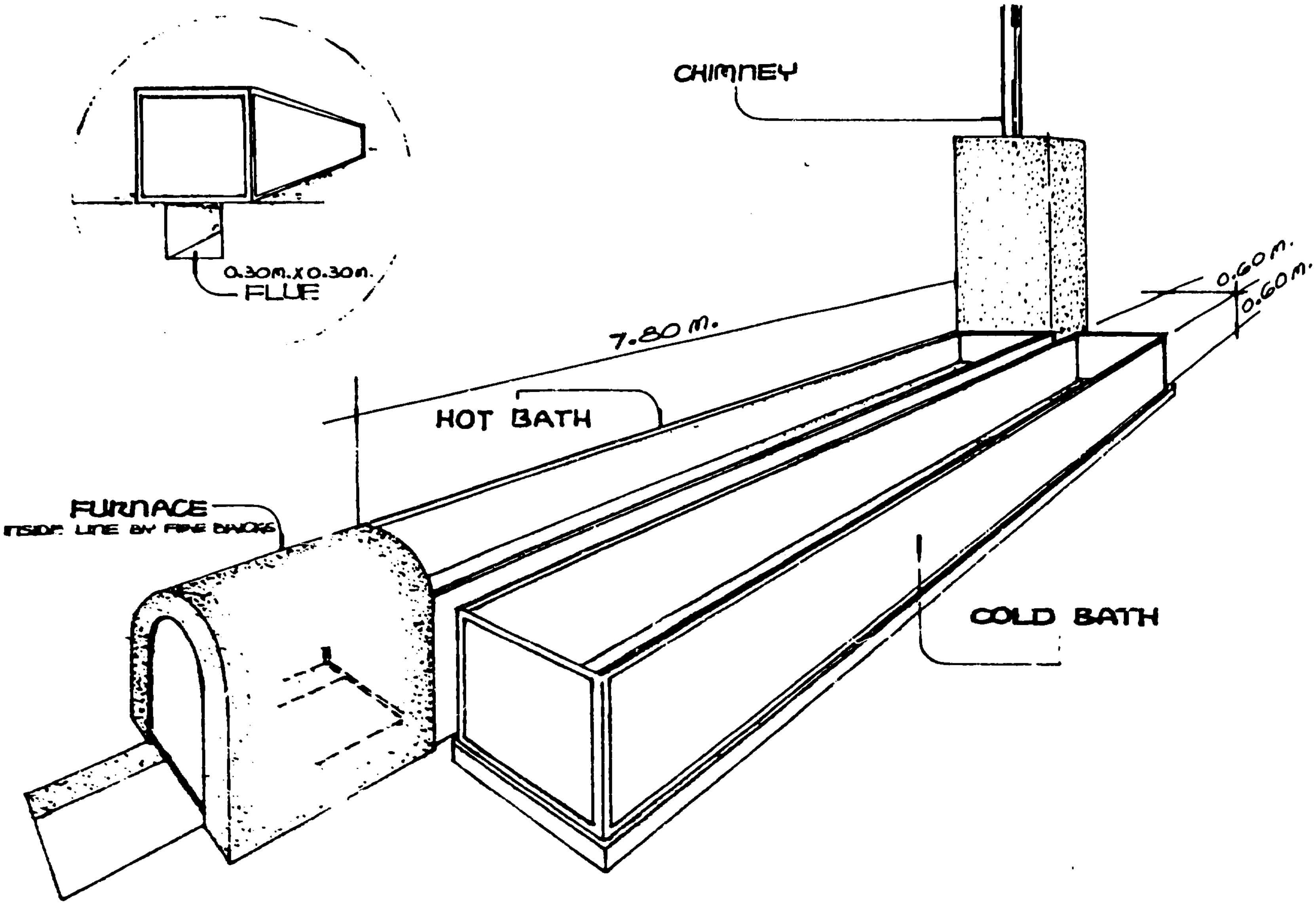


Fig. 53 - Sketch of hot and cold open tanks used for impregnation of transmission poles and shingles.

The results were as follows:

Moisture condition/ density of shingles		Retention	Penetration
Air dry:	high density	15.84 kg/m^3 (5.56 kg of active elements)	Irregular, at least 2 mm from all sides
	basic density 500 to 700 kg/m^3 [1/]	18.70 kg/m^3 (6.56 kg of active elements)	Complete
Green:	High density	7.98 kg/m^3 (2.80 kg of active elements)	Irregular, at least 1 mm from all sides
	basic density 500 to 700 kg/m^3 [1/]	12.03 kg/m^3 (4.22 kg of active elements)	Irregular, 1 to 2 mm penetration from all sides.

Note: No low density wood shingles were treated.

Retention values for roof shingles were unnecessarily high. The treatment described here should be the subject of further experimental work with concentrations reduced to approximately 3 % in the hot and cold bath.

The recommended dry salt retention is between 10 and 14 kg/m^3 (3.5 to 4.9 kg of active elements), e.g., for 2,564 shingles of standard size. The level of retention depends on the service condition, e.g., high humidity in tropical climate adds to the risk of possible biological decay.

5.6.4 Soaking in ammoniacal copper borate

In general, because of low toxicity of ammoniacal copper borate, it has the potential to be used for roofing and sidewall shingles, especially in places where domestic supply of water is collected from the roof. It is reported to be effective as an insecticide or fungicide.

No data on retention and penetration for Coconut Palm wood are available.

Coconut palm wood shingles can be treated by less effective methods such as cold dipping or brushing using the following wood preservatives:

1. Cuprinol direct as supplied.
2. Creoste direct as supplied (more suitable for agricultural auxilliary buildings as it has a tendency to bleed especially in hot climates).

1/ Recommended density for roofing shingles.

3. 6 % tanalith solution.
4. Other suitable commercial brands of wood preservatives.

Note: All these wood preservatives can be applied by brush or by dipping and can be used for regular re-coating of installed roofs or sidewall shingles.

5.6.5 Water repellent wood preservatives

Water repellent wood preservatives can be applied at 2 or 3 years interval by brush over roof shingles. A number of brands are commercially available, or a solution can be prepared as follows.

For approximately 15 liters of waterproof preservative:

1.20 kg Pentachlorophenol (dry powder) dissolved in 2 liters of paint thinner (10 % concentration, purity of commercial Pentachlorophenol is approximately 85 %).

1 3/4 liters boiled linseed oil

200 grams Parafin wax (melted in moderate heat)

9 liters diesel fuel oil

4 - 5 liters turpentine or mineral spirit

Mix together (add liquified Parafin wax to solution before adding boiled linseed oil).

Colour pigment can be added when applied to exterior side-wall shingles (approximately 100 grams of colour pigment is added for each 4 liters of waterproof preservative).

Note: When standard 5 % Pentachlorophenol is used (in liquid form), use:

5 liters of 5 % Pentachlorophenol

3 1/4 liters boiled linseed oil

200 grams Parafin wax

5 liters diesel fuel oil

Add mineral spirit or turpentine to make a total of 15 liters. When applied by brush on the shingle roof especially in humid and hot climates, butts and joints should be treated thoroughly.

Such waterproof coatings can be applied to shingles already treated by wood preservative before installation, or to untreated installed shingles. They should be applied immediately after installation and re-coated after 12 months. Re-coating should be done every 2 to 3 years. Spreading rate is approximately 4 liters per 12 to 15 sqaure meters of laid shingles.

The results of a brief test of the efficiency of such a waterproof preservative for shingles is described below:

Absorption of moisture is expressed as a percentage of the weight of shingles before dipping or brushing.

1. Treatment was applied by dipping the shingles in waterproof preservative for 30 seconds. After brief surface drying, the shingles were submerged in water for 30 minutes.

	Absorption of moisture in percent			
	Untreated shingles	Control	Treated shingles[1]	Control
High density	1.97	5.6	1.15	3.6
Medium density	4.16	12.62	1.75	5.9
Low density	7.43	up to 24	2.3	18.6

2. Treatment was applied by dipping the shingles in waterproof preservative for 15 minutes. After brief surface drying, the shingles were submerged in water for 30 minutes.

	Absorption of moisture in percent			
	Untreated shingles	Control	Treated shingles[1]	Control
High density	1.15	1.5	0.8	2.53
Medium density	4.40	9.0	1.2	3.77
Low density	5.70	10.0	2.3	6.53

3. For hard density shingles only, treatment was applied by brush. After 30 minutes, the shingles were submerged in water. Absorption of moisture was 1.4%.

4. Square blocks, 50 mm cube, absorption of moisture was 0.7%.

[1] Treated by CCA.

Conclusion:

Application of waterproof preservative to wood cross section area considerably reduces the absorption of moisture.

All wood preservatives are, more or less, toxic. Waterborne preservatives containing arsenic (CCA types) are highly toxic. The danger of leaching of arsenic to drinking water, especially in regions where domestic water is collected from the roof, is considerably limited if shingle roof is coated regularly by waterproof preservative.

5.7 Advantages of wood shingles

1. Excellent insulation properties suitable for all climatic conditions.
2. Resistance to high wind damage.
3. Attractive appearance on roofs or sidewalls.
4. Life of Coconut Palm wood shingles:
   It is difficult, at this stage of Coconut Palm wood shingles application, to forecast the service life, especially as a roofing material. But it can be safely assumed that if roofing shingles are correctly selected, installed and treated by wood preservative, the serviceable life can match that of roof shingles made from a number of commercial wood species.
5. Shingle roofs can be over-roofed without necessarily removing the old shingles. A number of different roofing materials or new shingles can be laid over.
6. The higher cost of a shingle roof can be offset by omitting the construction of ceiling for decorative or insulation reasons.
7. Internal finish of shingles is quite acceptable.
8. Metal roofs, without some kind of insulation, radiate excessive heat.

5.8 Summary

1. For roof and external siding walls, shingles should be selected by density as described. Shingles made from low density wood should be avoided for roofing application. Defective shingles (split, warped, or those affected by biological decay) should be avoided for any applciation, especially for prime building roofings.

2. Narrow shingles with less warp, 100 mm wide and 400 mm long have been found most suitable for roofing.
3. Only dry shingles should be installed.
4. Weather exposure, for 400 mm-long shingles, should be approximately 1/3 (125 - 130 mm).
5. Spacing between shingles should not be less than 5 or 6 mm. Shingle joints should be overlapped by the next shingle course by at least 38 mm.
6. Rust resistant nails should be used. The recommended size is G 12 (2.77 mm diameter), 38 mm long and ringed or threaded if possible.
7. Shingles should be pre-drilled before driving nails and if the dimension of nails used is as recommended, the drill bit should not be larger than 2.1 mm diameter (5/64").
8. Roofing shingles should be treated by a suitable wood preservative before installation and maintained by applying coats of waterproof wood preservative in 3 to 4 year intervals by brush.
9. Shingle roofs in tropical countries should have good drying ventilation on the internal side of roof. Therefore, close decking or underlayer of plywood is not recommended.

6. DETAILING OF GABLE ENDS, EAVES, GABLE OVERHANG AND FASCIA BOARDS

The gable ends may be completed by vertical cladding which should overlap the end wall cladding (which ends at ceiling level) to allow rain water from the gable ends to drip directly to the ground.

However, in tropical regions the gable ends often provide for important ventilation, such as framed by vertical studs, by fixed wood blade louvres sloping at 45^{o} downwards. (See Fig. 54).

700 mm to 1,000 mm long
100 mm wide, and
20 mm to 25 mm thick, depending on length.

Louvres should be made from selected C.P. sawn wood in the basic density range of 500 to 650 kg/m^3, seasoned to 30 per cent M.C., dressed and rounded edged. Dipping or coating by wood preservative is recommended.

Louver blades may be fixed directly to trenched (10 mm deep) gable end studs or framed before installation, inserted in the opening between the gable end studs and anchored on to the frame by nails (See section 10).

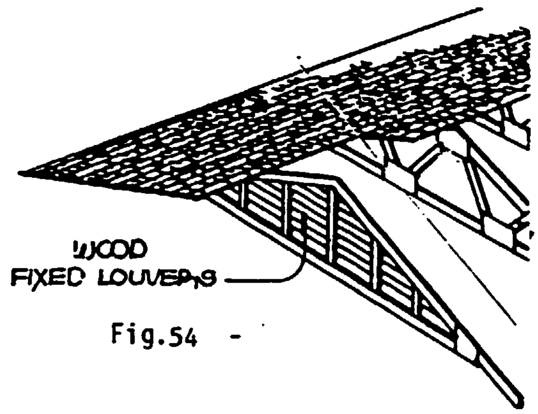


Fig.54 -

6.2 Soffits

The overhang of the eave (soffit) must be closed against the entry of birds etc. if the battens are nailed directly to the rafters or trusses overhang (see Fig. 55).

Soffit battens:

Length - as long as possible (but end joints)
Width - 50 mm
Thickness - 20 to 25 mm depending on rafter or truss spacing.
Nailed at each support by 2 nails 44 mm length, dia. 3.05 mm (G11). Soffit battens should be spaced 8 to 10 mm.

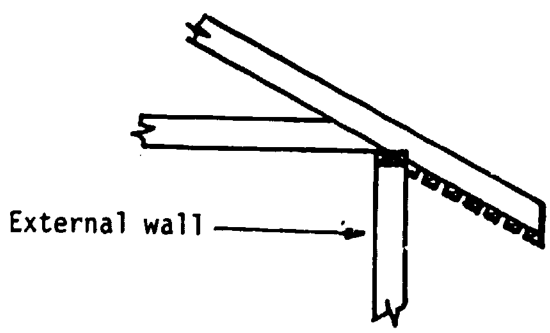


Fig. 55 -

6.3 Fascia boards

Fascia boards are used to trim the ends of overhang at the eave sides and gable roof ends. Since it is difficult to recover wide boards of uniform density from C.P. round wood narrow boards, splayed on the thicknesser using moulding pattern may be used (See Fig. 56) and nailed in place as with horizontal wall cladding.

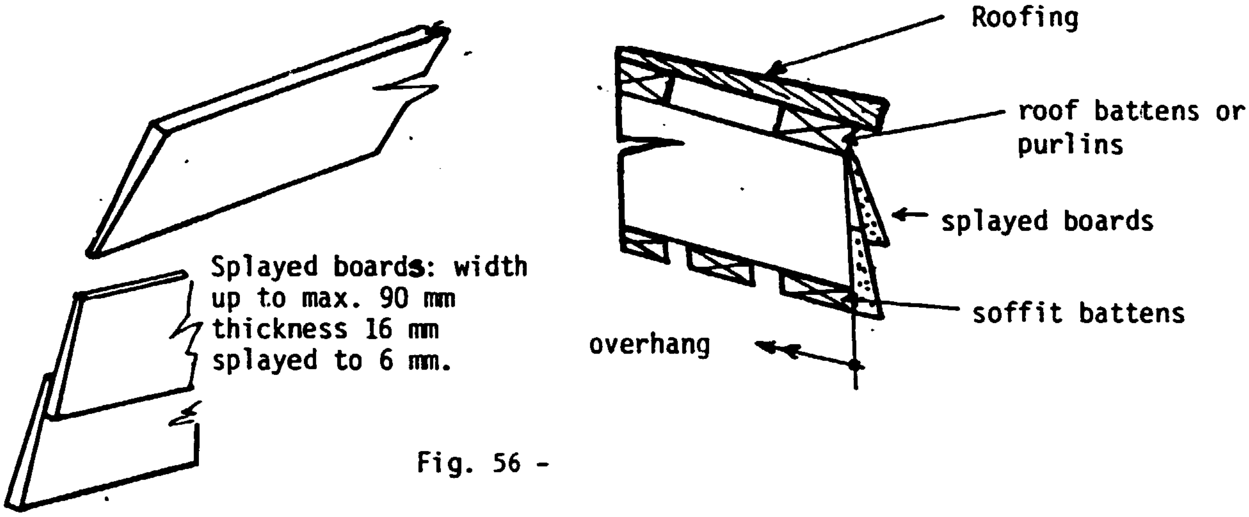


Fig. 56 -

6.4 Wall covering (wood)

Wall covering for wood frame construction is called cladding, if exterior and siding, if interior.

Wood wall coverings may be machined to many different patterns and used either horizontally or vertically.

Machining sawn boards to different profiles is not always possible in many regions of developing countries and if available is costly. Therefore in all experimental buildings from C.P.W. described in this paper only simple vertical cladding types needing minimum machining have been used or side wall shingles, as described in Section 5.

Another good reason for using vertical cladding or siding is that only relatively short lengths are used since wall heights are between 2.25 to 2.4 metres.

At ZRC cladding or siding boards were cut from selected cants or flitches on the re-saw bench with tungsten carbide or stellite tipped saw blades 700 mm diameter, gauge 10 or 11 to uniform thickness:

Cladding boards	- 18 mm, tolerance plus or minus 1 mm
Siding boards	- 12 - 16 mm, tolerance plus or minus 1 mm
Battens	- 12 - 16 mm, tolerance plus or minus 1 mm

Width:

Cladding or siding boards should be correctly edged to uniform width or random width between 70 mm to maximum 100 mm. Wider boards should be used only for internal siding as when exposed to the weather they have a tendency to twist or split unless they are very closely nailed.

Cladding boards may be used without any further machining. Boards and battens will have been visually graded to be defect-free on one face and the edges. Minor defects may be permitted for edges, if on the building site the carpenters will place boards with slightly defective edges under covering boards in such types of vertical siding as shown in Fig. 57.

It is recommended that selected cladding boards and battens are strip stacked under cover and dried to at least 25 per cent moisture content then treated by water-borne preservatives (C.C.A.) Copper-Chromium-Arsenic, by pressure when available with retention 8 to 19 kg dry salts per 1 m^3.

When pressure treatment is not available wood could be dipped in a suitable tank using 6 % solution Tenalith C, for a minimum of 24 hours. The retention depends on moisture content of wood. The lower the moisture content, the greater will be the retention.

A dipping tank could be made from diesel oil or grease barrels by cutting them in half and removing intermediate bottoms/tops and welding them together. (See Fig. 58).

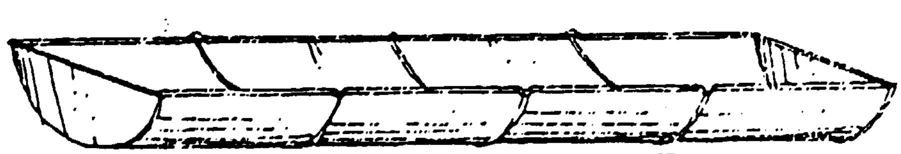
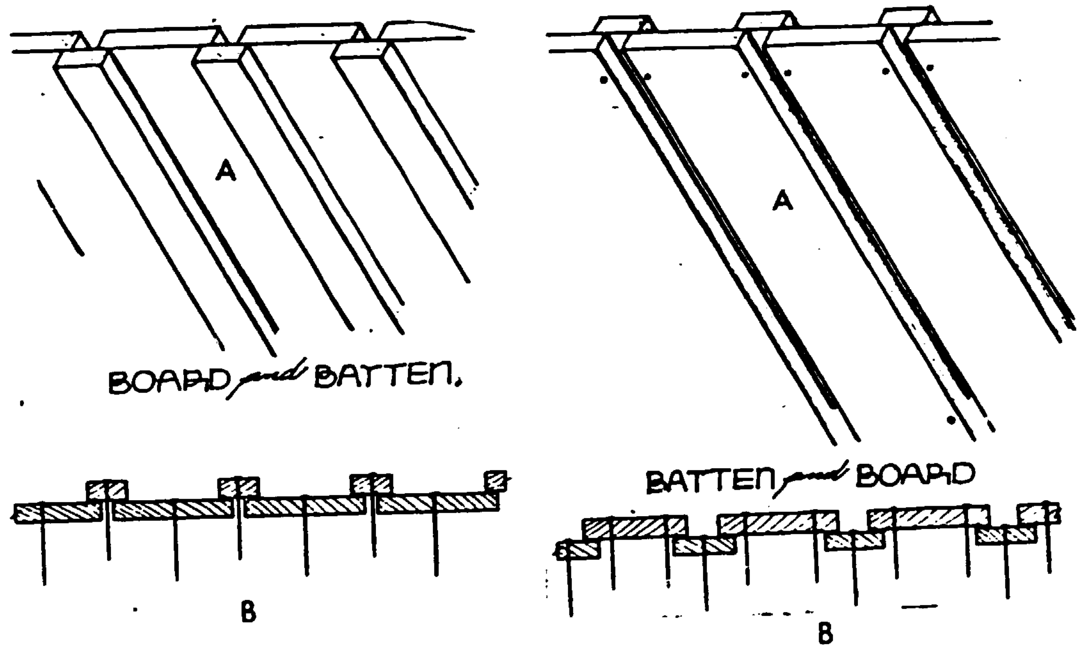
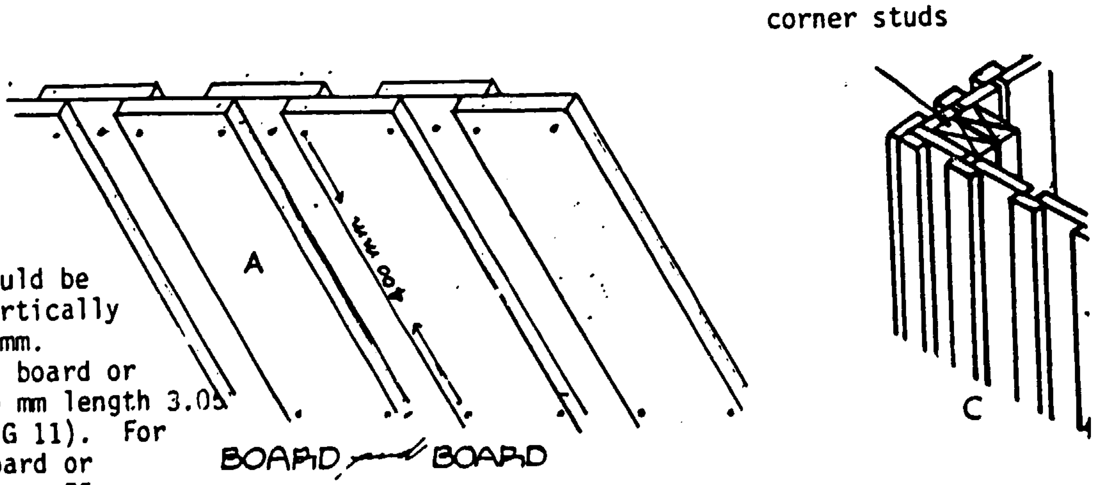


Fig. 58 - Dipping tank made from diesel barrels and welded to desired length.

Figure 57 - A. Vertical cladding or siding
B. Nailing pattern
C. Arrangement of external corner





Nails:
Nails should be spaced vertically max. 400 mm.
For first board or batten 50 mm length 3.05 mm dia. (G 11). For second board or batten 68 or 75 mm length dia. 3.4 mm (G10) - pre-drilling by drill bit 80% of the nail diameter is strongly recommended.

Nails are punched below wood surface and filled by wood putty.

A dipping vessel could also be made by digging a ditch in the ground with inclined sides of a necessary length, 500 mm or slightly more deep, one metre wide at ground level and 500 mm at the bottom, and lined with heavy plastic sheeting, secured on top of ground with stones or heavy wood.

Note: Dipping tank must be covered or secured from easy access as preservation chemicals are toxic. Dipped wood must be handled with gloves.

When dipping is not possible, application of 6 % solution of Tanalith C or similar formulation by brush before installation of siding and second coat after installation is better than nothing.

When water-borne wood preservatives are not available a number of wood stain preservatives are available such as Cuprinol, pigmented creosote oil, stain type finishes containing fungicide, etc. Two coats should be applied by brush when cladding is installed and single coats repeated at two-three years internals (no surface preparation is necessary).

In tropical climatic conditions opaque types of paint arenot advisable as coatings exposed to extensive direct sunshine will deteriorate in a short time.

From all the above-described possible cladding finishes CCA formulation is most recommended for the following reasons. (Reference D.S. Belford of Inst. Wood Science 1970 - 25:44-50).

a) It is relatively cheap, easy to apply and provides an acceptable natural finish of greenish brown appearance.
b) It provides protection against biological decay and termites.
c) It slows down the weathering process of wood. See note. 1.
d) Preservative applied by pressure penetrates through boards and is permanent.
e) Dipping treatment is also possible but every 3 - 4 years an additional brush coat is needed. Brush applications should be repeated every 2 - 3 years.

Note: Location of dipping tank and disposal of the remaining solution must be a safe way from well or water pond. To dispose of remaining chemicals dig a hole in the ground and let the solution seep away - then fill the hole with soil.

A disadvantage of the chromium treatment is the toxicity of the chemical which is a potential hazard when handling the chemicals and from treated wood especially when chromic acid (CRO_3) is used.

A 3-year test of C.P. sawn wood showed a definite decreasing effect of weathering and a nice brown-greenish appearance was retained.

If using a 5 per cent molar solution of Copper Sulphate ($CuSO_4$) and Chromium Trioxide (CRO_3), it is possible to make 20 L of 5 per cent solution:

20 litres of water
2 kg Copper Sulphate
1.25 kg Chromic acid

Dissolved in about 30°C water.

This solution should be applied by brush - 2 coats at an interval of 2 days in dry weather, and repeated in 2-3 years, or by dipping dry wood (max. 25 % MC) for 12 hrs (wet wood must be handled in rubber gloves).

6.4.2 Internal siding

Internal siding is installed the same way as exterior cladding and its function is more or less decorative or to obtain privacy in interior divisions. Therefore, joints need not be weatherproof.

Lining boards could be fixed vertically or horizontally. Similar patterns as are shown in Figure 57.

Internal linings may be finished by a suitable stain or a clear finish or left in a natural condition.

Varnishes or any finish which contains vegetable oils should be avoided as they are subject to attack by moulds in high humidity regions, unless they contain a large percentage of fungicide such as pentachlorophenol or sodium pentachlorophenate.

For exterior cladding stress grade 5 or medium density wood should be used. For interior siding any density group may be used from 300 kg/m3 basic density and above. However, low density below 400 kg/m3 is preferable.

Interior siding boards or battens are sawn as described for exterior cladding and used, fine sawn or dressed, and should be dried to minimum 20 per cent moisture content before installation.

Application of wood preservatives is omitted and immunisation by Boron compounds against wood borers is optional.

Internal wall siding by shingles is descriped in Section 5.

7. FLOORING

Flooring should be laid after roof cover and internal wall siding is completed.

7.1 Ins allation on joists

Strip flooring is laid crosswise to floor joists with the best face showing. End matched joints should be scattered over the joist supports. A space about 12 mm must be allowed for floor expansion at the ends and sides along the walls.

To prevent splitting of the flooring boards all nail holes should be pre-drilled and special care should be taken at the end (butt) joints.

Each board should be laid tight to the next by clamps or chisell supported by the flooring joist.

Nails should be 38 mm in length, 2.77 in diameter (Gauge 12), two nails for each board where they cross the floor joists. They are normally nailed through the face for the tongue and groove and square edged. However, ship-lap flooring boards are usually nailed with a single nail through the under lap (secret nailing).

Face nails should be punched below the surface and the holes filled by wood putty and sanded.

The floor area is finished with suitable battens or skirting boards around the parameter of each room.

A simple finish for domestic floors may be no more than regular polishing by split coconut, leaving endosperm in the shell.

Flooring boards should be selected from the highest density C.P. sawn wood, e.g. lumber recovered from the perhiphal zone of a butt log. Such coconut palm flooring satisfies the basic requirements such as:

a. a good degree of hardness to resist face identation,

b. good, even wearing properties and resistance to abrasion,

c. close dense grain with minimum tendency to develop splinters.

If it is inteded to cover the flooring by bamboo mats, a lower density grade could be used.

Green flooring boards should be well sawn to 30 mm thickness and edged to 75 mm to 100 mm widths then graded by density and defects, strip stacked under cover to dry to minimum 20 per cent moisture content before final machining.

As high density CP sawn wood is very abrasive to cutting knives, complicated profiles such as tongue and groove and shiplap were avoided in prototype houses in preference to square edged flooring board which, when properly dried and tightly nailed, produce satisfactory flooring without excessive open joints. (See Figure 59).

There should be a minimum space of 6 mm between adjacent boards.

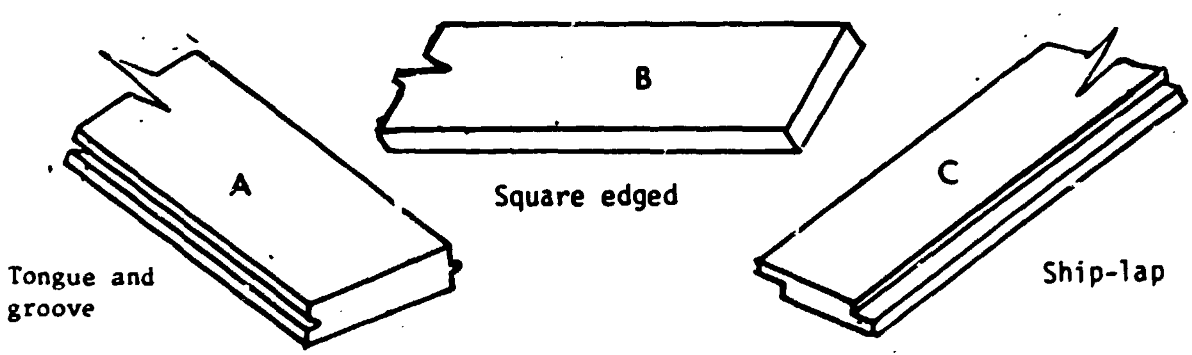


Fig. 59 - Standard flooring profiles.

Note: Ship lap flooring boards when "secretly" nailed through under lap should have maximum effective cover 70 mm and be seasoned before machining to 16 per cent moisture content to minimise any deformation in service. Otherwise additional nails are necessary through face. (Ship lap machined boards could alternatively be used as Internal wall siding).

Basic description of the dressed flooring boards (stress grade 8 or 11):

1. Length:

   lengths may be between 1 m to 5 metres but the number of short pieces in the bundle should be reasonably proportional to longer length to avoid too many joints.

2. Width:

   effective cover: 70 mm to max. 90 mm since wider boards could bow, warp or develop uneven surfaces.

   Widths may be either uniform or random within the limits above.

3. Thickness:

   Standard 20 mm, tolerance plus 1 mm minus 0.

   Dressed flooring boards are finally visually graded:

a. Face - Machining defects:
   1. Torn grain exceeding 1 m in depth or covering area larger than 50 mm square should not be permitted.
   2. Hit and miss not permitted.
   3. Kick-out (i.e.) decrease in the thickness not permitted.

b. General defects: excessive spring, bow or twist not permitted.

c. Back: Imperfections permitted provided that they do not excessively reduce the strength of the flooring board.

   Flooring boards required for open locations such as verandahs, porches etc. where weathering is a factor should be:

   stress grade F8 or 11 (selected high density wood)

   square edged:

   Full length without end joints, if possible.

   70 mm to 90 mm wide

   25 mm thick.

Visually graded (clear face and edges).

7.2. Installation of wood strip flooring over concrete slabs

a. Over existing concrete slab with or without moisture movement barrier.

b. Over concrete slab to be poured during the foundation construction.

In the situation where a moisture barrier was placed over gravel filling and levelled with a layer of sand before placing the concrete slab, the concrete surface could be directly framed by wood nailing blocks well treated by preservative and of the cross section 75 mm x 50 mm spaced 450 mm flatwise and anchored to concrete by special hard steel nails randomly spaced. One method is to pre-drill nailing blocks about half of its thickness with drill bit of the same diameter as nails, then using a narrow nail punch to drive 50 mm length concrete anchor nails to the bottom of the pre-drilled hole. The flooring boards are then installed as already described.

When an existing concrete slab has no moisture barrier then it is necessary to cover the slab by a suitable moisture barrier before anchoring nailing blocks or flooring frame.

It is preferable, however to put a moisture barrier under the slab if wood strip flooring is foreseen.

Nailing blocks, well treated by wood preservative, may also be anchored directly to wet concrete, flush or slightly above the concrete slab surface.

Simple types of moisture barrier:

- heavy (thick) plastic sheet in one piece (no joining) such as polyethylene or similar is most suitable when placed under slab and turned in all sides upward, along the walls or formwork.
- roofing felt, well coated with hot asphalt under and over with attention to necessary overlapping joints is more suitable for the moisture isolation on top of the slab.

8. Doors and windows

8.1 Doors

Hollow core flush panel doors - exterior or interior - may be made from C.P.W. using lower density wood for the frame and paneled with thin (10 mm) narrow boards (width 70 mm) glued and nailed vertically or at a 45° angle. However, a number of difficulties arise with the thin C.P.W. panelling and when thickness is increased, the weight of doors becomes a new problem.

Therefore exterior or interior doors have been hollow framed from lower density C.P.W. and paneled by 6 mm standard plywood (water proof for exterior doors) or 4 mm hardboard and finished with clear or opaque paint.

Standard dimensions for the exterior and interior doors:

height:	whether exterior or interior - 2000 mm	
width:	interior	750 mm
	exterior	800 mm
thickness		42 mm

Basic installation

During wall construction, door openings may be framed by jambs pre-assembled or cut to length at the building site, starting with head jamb and followed with side jambs of the correct length. As door jamb framing should accommodate door dimensions, any difference between door wall opening and jamb framing should be packed with suitable strips of wood and nailed to the frame.

Door jambs may be machined with stops or may be plain with door stop strips nailed on separately.

No door sill is necessary for interior doors. Plain door sill with or without stop is optionally used for the exterior doors.

Dimension of door jambs - stress gradeF8

Width: the same as width of wall plus siding

Thickness: 300 mm plus door stops 30 mm x 20 mm

Exterior door sill - selected hard density wood: thickness 30 mm.

The door frame should be trimmed by battens from both sides. The width of battens depends on the area which should be covered plus overlap of wall cladding or siding.

Standard placement of door hinges is:

175 mm from top of door

275 mm from bottom of door

(For heavier doors, 3 hinges should be installed, with the third hinge centred between top and bottom hinge. A lock should be installed 900 mm from the door bottom).

Exterior door frame trimming battens should be coated by wood preservative.

8.2 Windows

There are many types and designs of windows. In the pacific tropical regions louvre types are very common, not necessarily only for low cost housing but also for many well-built houses, schools, hospitals etc.

In hot and humid conditions louvre windows have a number of advantages. They:

- provide good ventilation
- restrict sunlight
- are not subject to expensive large glass breakage
- may be provided with horizontal security steel bars which are easily installed
- are relatively cheap and make use of curtains optional

Louvre fittings are obtainable for different heights of windows, width and thickness of blades and are usually made from aluminium or galvanized steel. Standard clip channels will take 6 mm thick blades. Special louvre fittings are commercially available for wood slates with channels 9 mm wide.

Blades (slats) may be clear or tinted glass, aluminium or wood (most common in tropics).

Standard glass or aluminium blades are:

Length:	750 mm
Thickness:	aluminium 3 - 4mm, glass 4 - 6 mm
Width:	100 or 125 or 150 mm.

Louvre slats made from selected C.P.W. of basic density approx. 500 to 600 kg/m3, seasoned to 12 per cent M.C. before final machining provide good serviceability without cupping or any deformation in spite of being only 6 mm thick,* however, 9 mm slats are recommended when louvres with such width of channels are available.

Recommended dimensions of C.P.W. louvre slats:

3 thickness 6 mm - width 100 mm - length 600 mm
3 thickness 9 mm - width 100 mm - length 650 mm
3 thickness 12 mm - width 100 mm - length 700 mm to maximum 750 mm

---

* 6 mm thick slats need considerable care during the seasoning process to avoid any degrade. Stock 12 mm thick has to be closely strip stacked under cover (strip spacing not less than 150 mm and stack top levels to be weighed).

Note: Longer slats might bend under their own weight during service. (12 mm thick slats are used with an ingenious louvre operating mechanism as explained under Fig. 60 D).

For the installation of louvre windows it is necessary to decide on the length of louvre blades (slats) and the number of window divisions - usually 2 or 3 before the wall frame is constructed, see Fig. 60.

For window openings 900 mm above floor level and height of window 2000 mm, top trim is at the same level as doors. Height of window 1100 mm will take 11 louvre slats 100 mm wide. Rough opening is framed by plain window jambs, sill and dividing jambs see Fig. 60 A.

Head and side jambs

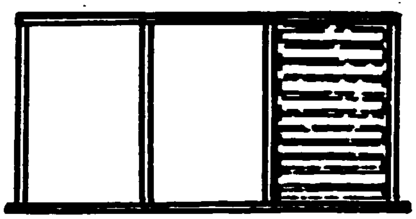
- Width: stud width plus the thickness of cladding and (if applied) internal siding.
- Thickness: 25 mm
- Sill: width of side jamb plus minimum 25 mm to bring "drip groove" outside the wall cladding, see Figure 60 C. Sill and jambs are made from selected wood. Stress grade F8 - seasoned to minimum 18 per cent M.C. Sills are made from 50 mm thick wood and machined to shape and dimension. See Fig. 60 B and C.
- Dividing jambs: Should be minimum of 50 mm thick and 100 mm wide (the same as the width of louvre slats).

Ingenious method to assemble wood slats (12 mm thick) to louvre type of windows with simple mechanism. See Figure 60 D . Framing battens 25 x 35 mm x length (window height) are attached to slats on each end by 4 mm diameter steel pins in the following way:

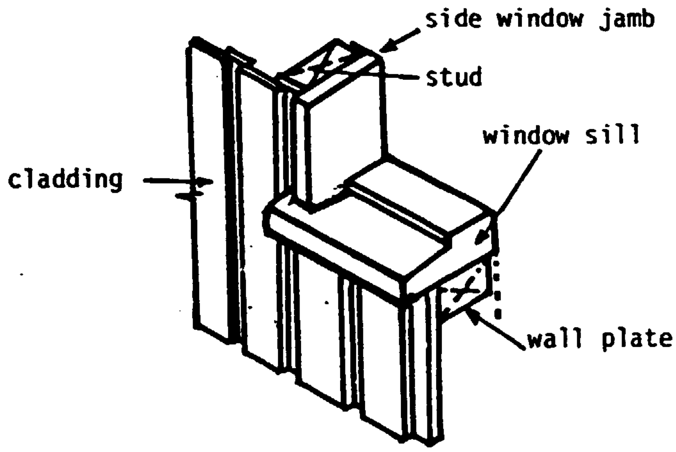
Steel pins are attached tightly in correct location to framing battens permitting minimum 10 mm overlap of the slats when in vertical (closed) location.

Then the protruding pins (30 mm) are attached to pre-bored holes at the ends of slat (25 mm from edge) to permit free rotation. The whole assembly is then inserted into the window opening and battens are nailed to window side jambs.

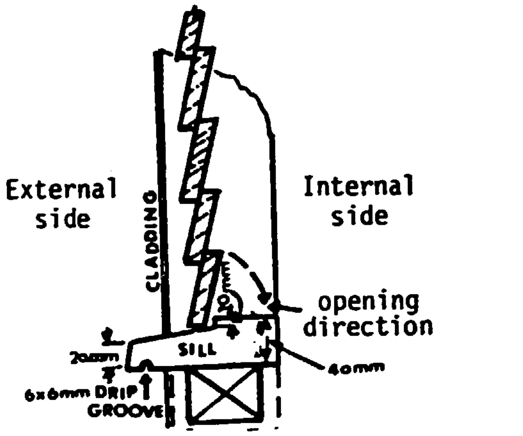
To permit opening or closing all slats at once, a connection rod is attached to one end of slats by flat head common nails in such a way that the end of the nails are firmly driven to end of slats but part of nail shank contained in connecting rod is free to rotate (pre bore nails holes to avoid splitting).



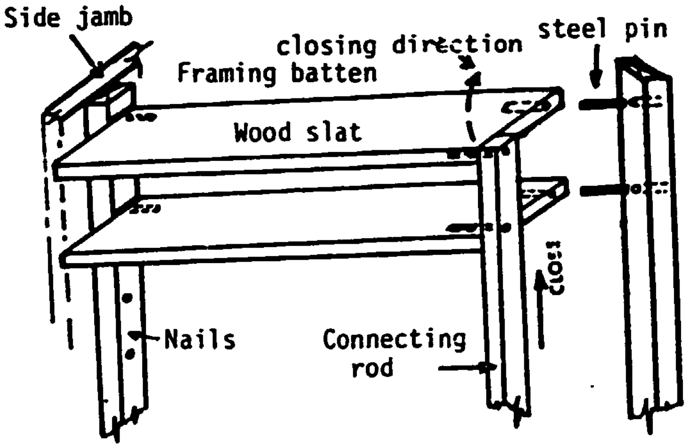
A Window opening divided into three sections



B Window framing



C. Arrangement of louvres slats and location of window sill to permit water to drip outside wall cladding



D. Simple mechanism for the louvre window - fitted with wood slat.

Fig. 60 - Installation of louvred windows.

Flashing:

Should be provided under all window sills either 1 mm lead or bitumen coated aluminium or 32G galvanised steel and turned minimum 25 mm at back and 50 mm at each end of wood sill, fastened to side jambs. The flashing should be bent down minimum 25 mm over external wall cladding (face).

Flashing by roofing asphalt paper is recommended under shingles along the gable roof sloping overhang and along the eave overhang with a strip of flashing 200 mm wide.

9. FASTENING WOOD JOINTS

The selection of the appropriate fastening method depends on the type of joint and the requirements of particular locations' weather: relatively safe or subject to frequent high winds.

There are a number of methods available such as nails, adhesives, metal plate anchors, screws, bolts and special wood connectors such as split ring, shear plate, rivets.

Many methods are not suitable for low cost housing or light wood structures - therefore only use of nails and metal plate connectors will be briefly described.

Rust-proof nails (galvanised) should be used where corrosion is an important factor such as for roofs with plywood or metal gussets, metal plate connectors, or for structures exposed to weather.

9.1 Nails

Nails are the most common mechanical fasteners for wood in construction, and are manufactured in many types, sizes and forms. Table 6 describes standard wire nails with diamond head suitable for hardwoods. (Flat head nails are used for softwoods).

Table 6: Standard Common Wire Nails

Length		Usual Gauge	Diameter in mm	Approximate number per kilogram
inches	mm			
1	25	15	1.82	1930
1 1/4	32	14	2.10	1250
1 1/2	38	12	2.77	695
2	50	11	3.05	395
2 1/2	63	10	3.40	235
3	76	9	3.76	155
3 1/2	88	8	4.19	110
4	100	6	5.18	68

C.P.W. splits readily during nailing especially close to edges of ends. This characteristic increases with density and decreases with moisture content increase. Split wood reduces the strength and stiffness of the joint and decreases nail withdrawal resistance. Therefore, it is recommended that C.P.W. in green or dry condition should be pre-drilled by drill bit of 80 per cent diameter of nail shank. Such pre-drilling will increase withdrawal load for the nails and also if pre-drilled to the full nail length, permits driving nails closer to the structural member's edge or end. Blunted nails reduce splitting tendency.

When green wood is used in construction, nail withdrawal resistance increases as moisture content decreases.

The greatest resistence to withdrawal is when nails are driven perpendicular to the grain of wood. Driving nails into the end of wood should be avoided where possible. Simple pre-drilled metal plate connectors can eliminate the necessity for such nailing especially in high wind regions - for example top and bottom wall plate conventionally nailed to the ends of studs are subject to a withdrawing force during a wind storm due to the tendency to uplift the roof. (Metal connectors permit lateral nailing).

Skew (toe) nailing only increases withdrawal load resistance slightly. Skew nails should be driven between 30^{o} to 40^{o} to horizontal and about 30 mm above the surface contact of a member to which it is to be joined.

Resistance to lateral displacement is increased when nails are evenly placed over the joint area.

Length and diameter of nails

Length of nails should be such that penetration into the structural member receiving the nail point is at least one half of its thickness.

On multiple joints, wherever possible, nails should be in double shear resisting the load laterally if loads on the joint do not permit nail withdrawal. See Fig. 61.

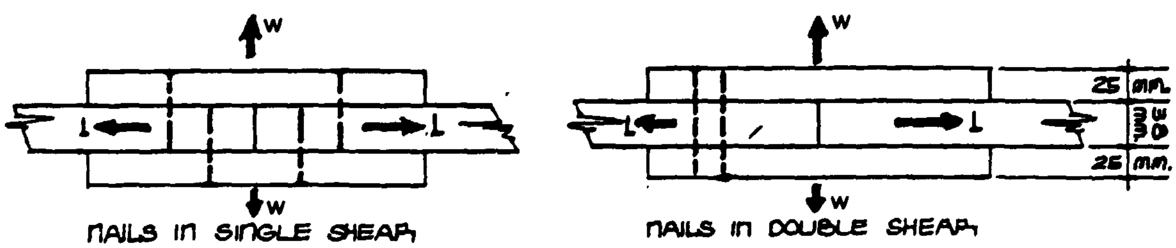


Fig. 61 - L - Lateral load
W - Withdrawal load

Clenched nails increase withdrawal resistance (i.e. the bending of the protruding end of the nail (about 10 mm) across the wood grain).

For common wire type nails, length and diameter are related, and a simple rule is to use the largest diameter nail in construction joints without splitting or damaging wood members.

For metal side plates (connectors) or glued and nailed plywood gussets flat head galvanised nails are used, length 38 mm to 50 mm depending on the thickness of structural member. Pre-drilled nail holes in metal connectors should be the same diameter as nails.

Spikes are nails with square shanks and chisel points and are suitable for anchoring foundation bearers to steel pier brackets or wood stumps. (Spike leading hole should be pre-drilled by drill bit of 80 per cent of a side dimension of spike).

Screws have greater resistance to withdrawal than nails. Pre-drilled leading holes shouldbe 90 per cent of the roof diameter of the screw (e.g. roof of threads) to full length of screw shank. Screws are recommended for corrugated metal roofing in high wind regions instead of roofing nails.

9.2 Bolts

Selected diameter of the bolt or bolts up to 18 mm diameter should be minimum 25 mm longer than nominal overall thickness of the wood members. Washers should be used on both sides and as large as possible, minimum thickness 2 mm. When using bolts to join green wood, the nuts should be progressively tightened as wood dries to lower moisture content.

Minimum spacing of bolts:

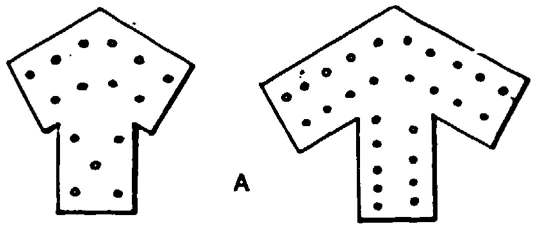
from the edge - 2 bolt diameters
end - 6 bolt diameters
spacing - 5 bolt diameters.

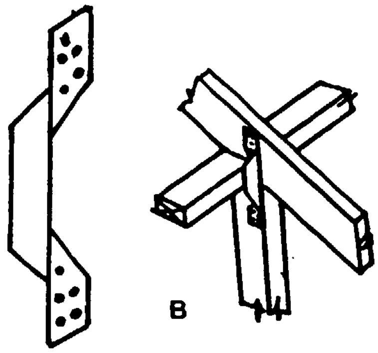
9.3 Metal plates

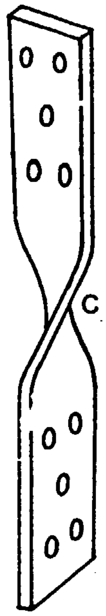
Metal wood connectors (fasteners) are recommended for general use. In high wind regions they should not be ommitted from the construction framing. Metal connectors of different types and sizes are commercially available. Many types of connectors could be made locally from flat galvanized metal sheets or strips (14 to 18 gauge). Pre-drilled nail holes should be the same as the nail diameters. Nails should be galvanised, flat head 38 mm to 50 mm length 2.77 to 3.05 mm (Gauge 12 to 11 respectively).

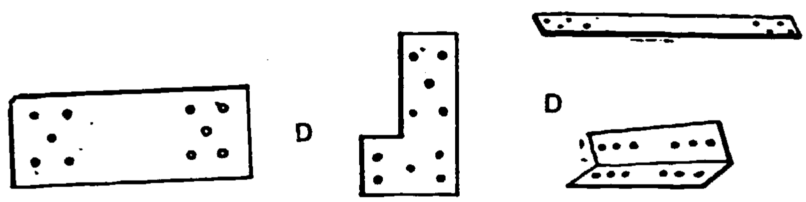
Fig. 62 - Metal wood connectors.

3.05 mm (Gauge 12 to 11 respectively)



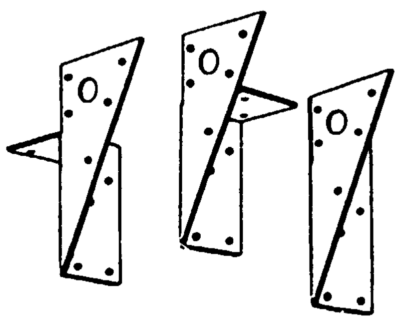


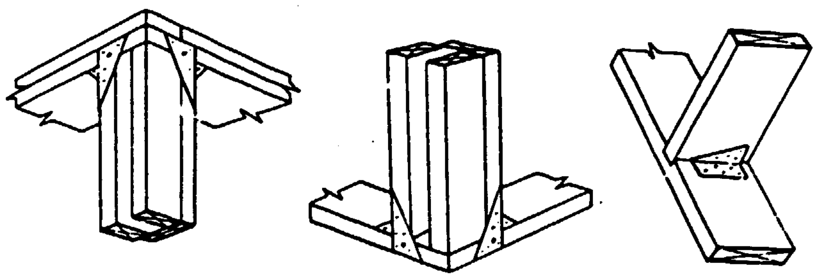




A. Roof truss ridge anchoring plates.
B. Anchor suitable for the fastening trusses or rafters to top wall plate.
C. Hoop steel strap suitable for many framing applications such as floor joist to bearers - wall frame to joist or truss to wall plate etc.
D. General metal plates - suitable for fastening studs to wall plates etc. angle type could be used to fasten roof purlins to top chord or trusses or rafters.

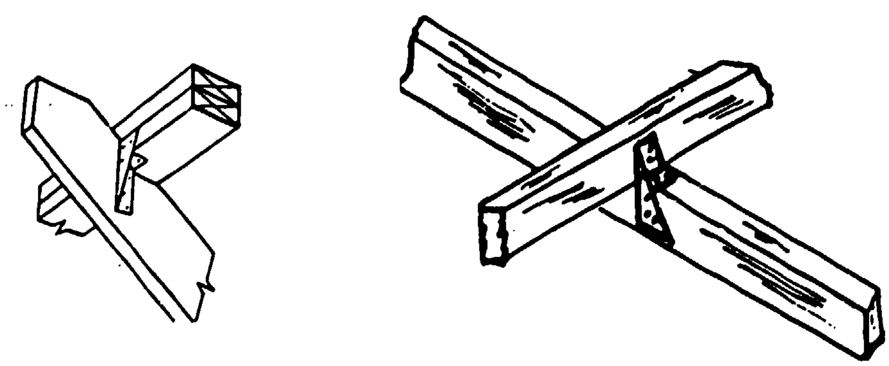
Fig. 62 a - shows other types and applications





Angle shaped plate connectors (Trip-L-Grip framing anchors) have many wood framing applications.

Suitable for the fastening wall studs to plates - corner studs to plates. etc.



Fastening trusses or rafters to wall plate and roof purlins to top chords.

10. VENTILATION

10.1 Houses

In hot and humid tropical weather, ventilation under the roof space is an effective means of removing hot air from the internal house space.

Air movement through stationary wood louvres at both ends of the gable roof provide such ventilation and is most effective where no ceiling is installed, improving personal comfort during the night. Metal roofing cover without insulation increases the necessity for such ventilation. The ventilated area of bable roof ends could be the entire or part of the triangular section.

Traditional gable roof designs have extended roof ridges with the gable overhang tapered along the gable roof slope. Such a design limits the entry of rain and sunlight through stationary wood louvres. (See Figures 63 and 64).

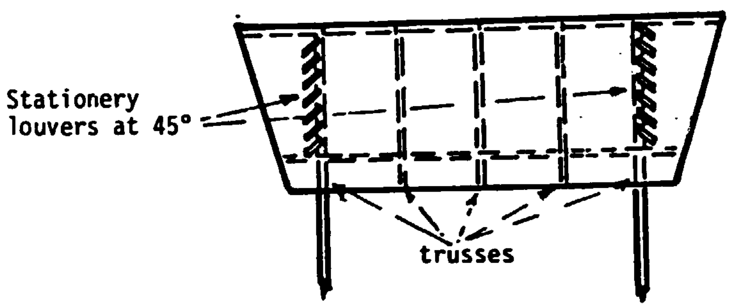


Fig. 63 Traditional shape of thatched gable roof

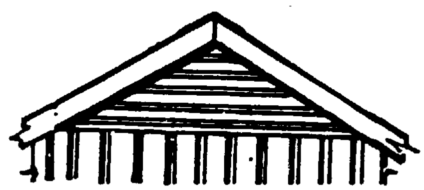
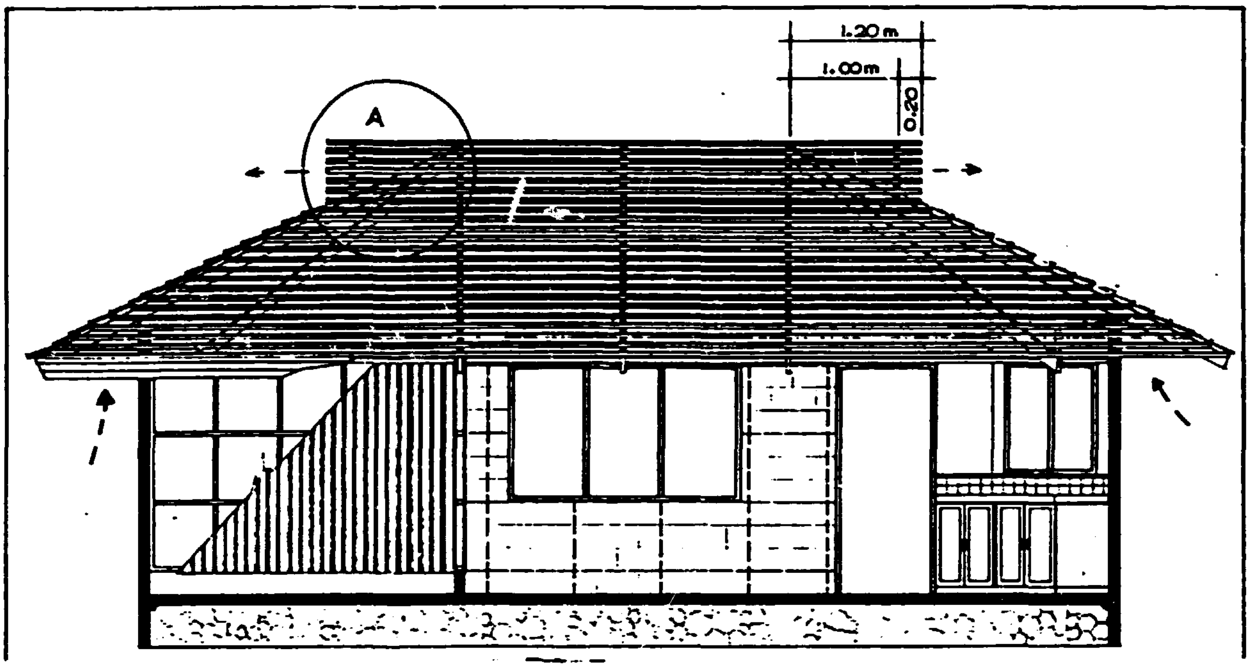


Fig. 64 Arrangement of ventilation for gable type roof in the sub-tropical region.

Triangular ventilation from both sides of gable ends. Ventilator openings located close to ridge could cover only desired section of the gable ends.

In the South Pacific region, subject to frequent hurricane storms, traditional oval shaped roofs are similar to hip roofs in form and both are more resistant to wind forces than gable roof. Figure 65 shows the attic type of stationary outlet louvre ventilators with additional inlet vent openings in the soffit area. This smaller area of ventilation is suitable for the subtropical South Pacific regions.



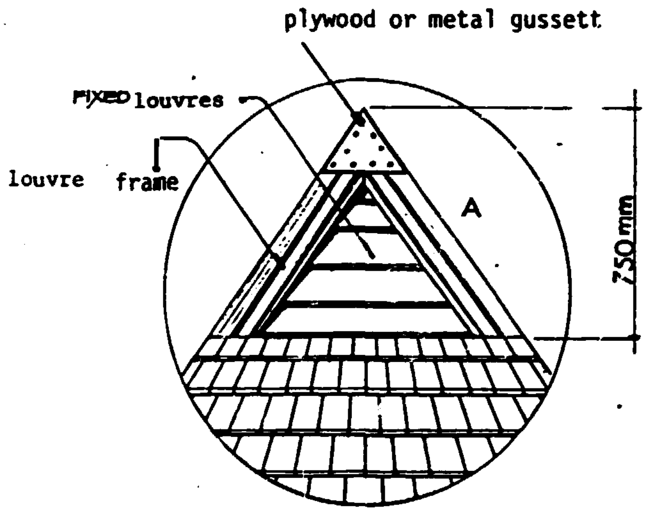


Fig. 65 shows arrangement of ventilation for the modified Hip roof (gambrel) - stationery (fixed) wood louvres are protected by small overhang - approx. 200 mm length.

Inlet vents are provided beneath the eaves by spaced battens at soffit area(see Fig. 55,) or provide air inlet along the external walls, between head of the windows and top wall plates using small closed spaced balusters between studs and trimmed exposed edges of studs and top wall plates by suitable wood molded cover strips. This method is very common in the tropics. A common susbstitute for balusters is a type of lattice framework formed by wood strips crossing each other diagonally.

An efficient natural ventilation of low pitched double skillion roof is shown in Fig. 66 Corrugated metal roofing is used and the floor plan is designed in two levels, see Appendix 2. Note the ventilation of the living space by louvre openings, and the roof above the ceiling lining through the soffit and the sloping sides of roof (See Fig.67 Insert A). Internal louvre ventilation (tinted glass blades) can be opened or closed from level by a connecting metal rod.

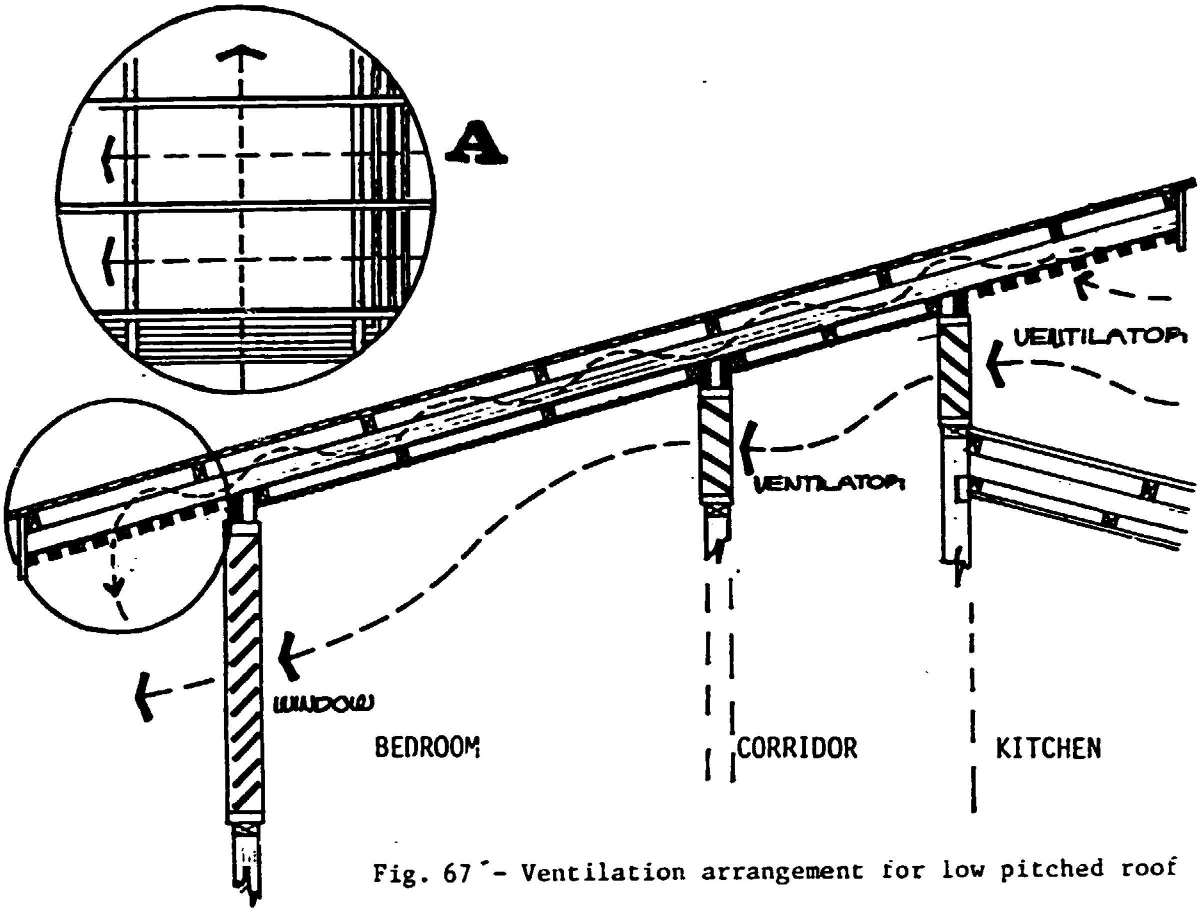


Fig. 67 - Ventilation arrangement for low pitched roof

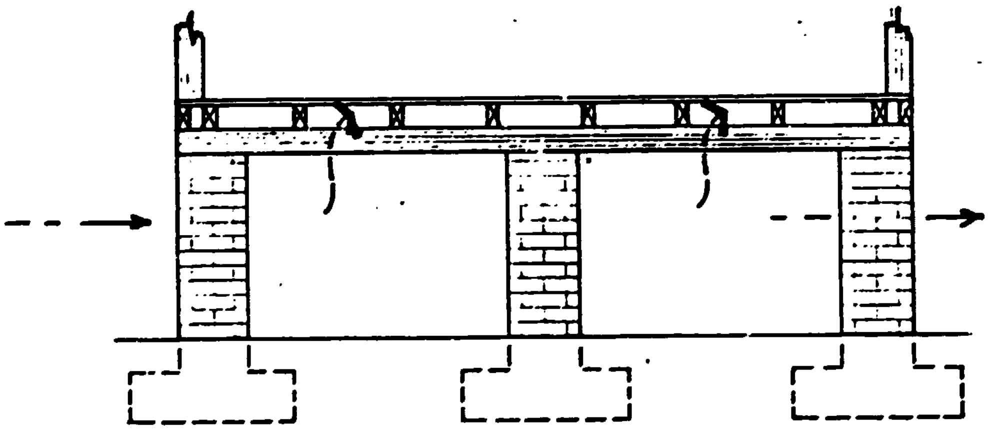


Fig. 68 - Sub-floor ventilation for wood floor.
An adequately cross ventilated subfloor is very important for any geographical location. In tropical regions with high relative humidity it is not recommended to enclose the sub-floor area by built-up masonry-to-wood walls. A maximum of 2 sides may be enclosed when necessary, and such enclosing walls should be provided by suitable wire mesh ventilation openings to secure cross ventilation. Poor cross-ventilation of the sub-floor space maximises the effect of increased moisture content of the sub-floor wood framing members thus producing ideal conditions for fungal decay of wood and attack by termites.

10.2 Industrial Buildings

Natural ventilation of industrial buidlings such as workshops, store rooms etc., may be atained by erecting a jack roof above trusses or rafters to provide an out let for hot air especially when the roof is covered by metal sheeting. Such an arrangement improves working conditions of the labourers and helps cool the operating machienry in intensive tropical heat. See Appendix 1 - Plate 8 ventilated sawmill roof design.

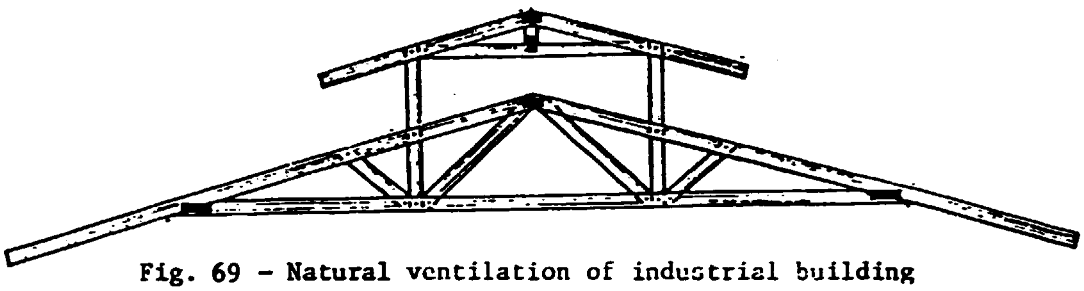


Fig. 69 - Natural ventilation of industrial building

11. POLE TYPE BUILDINGS

Pole type structures are one of the oldest building types, and round wood has been used by many human sttlements in many climates. At the present time their acceptance has expanded especially in rural regions for a wide range of applications in primary industry but also including houses.

Pole construction has a number of advantages:

1. The foundations and in general the whole structure is relatively simple when compared with conventional types.
2. Less skilled tradesmen may be employed.
3. Less sawn wood is used.
4. Buildings offer high resistance to lateral wind and earthquake forces as poles are firmly anchored in the ground. When the roof is securely attached to a rigid pole frame, resistance to uplifting force is considerably increased.

Disadvantages

Embedded pole butts in the ground are exposed to biological decay (fungi) or/and attack by termites. It is necessary to select poles from a more durable wood and increase their resistance to such attack by impregnating the poles with wood preservative. The embeded sections of poles should be double treated unless the wood is naturalydurable and free from sapwood.

Selection of a suitable size pole from conventional wood species is usually a simple process, but this is not so with Coconut Palms, where density, strength and durability of wood varies greatly with height of the Palm stem. The most suitable section of the stem for poles is the lower portion (butt section). The diameter of such poles is suitable for large pole constructions such as sawmill buildings, workshops, stores etc., but they are too large for housing construction.

Therefore, the solution lies in splitting the larger poles into quarters or halves depending on the selected round wood diameter. (See Fig. 70').

Selection and splitting process:

1. Select straight as possible, reasonably tapered palm stem (selection of pole is best done on the standing palms).
2. After felling the palm, avoid the first .75 to 1 metre section of the stem base as it is usually butt-swelled or too tapered.

A. When the pole is intended to be used for larger constructions it should be, as soon as possible, debarked to a smooth finish, then stacked preferably under cover for drying process which could take three or more months. Pole stacks should be separated from the ground by at least 300 mm by suitable bearers, and should be cross-piled. To prevent mould or fungal attack during drying, it is recommended to brush or spray green poles with a 6 per cent solution of a "Tanalith" or 5 per solution of Pentachlorophenol or 1 per cent solution of Sodium pentachlorophenate and repeated 2 or 3 times during the drying process. Special attention should be given to the pole ends as these are most likely to be subject to fungal attack.

It is very difficult to dry round wood to a low average MC, therefore, it is sufficient to season poles to approximately half the green MC and then preservative treat by pressure or dipping (steeping). When poles are intended to be imbedded in soil, additional treatment of hot coal tar or hot creosote coating on butt end to 200 mm above the ground line is recommended just before imbedding in ground.

B. Poles intended to be split in halves or quarters:
Splitting should be done as soon as possible after felling, by one of the following methods:

1. at sawmill "Head Rig"
2. chainsaw
3. splitting by axe and wedges
4. combination of '2' and '3'

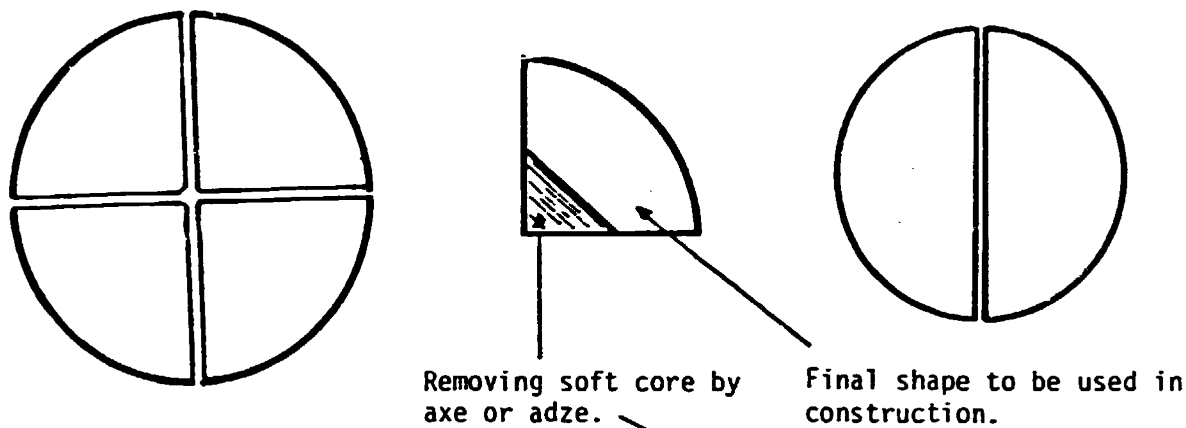
3. Sawn or axe-split poles may be re-sawn or hewn by axe or adze to final shape, debarked to a smooth finish and cross piled for drying before the preservation treatment, see Fig.71.

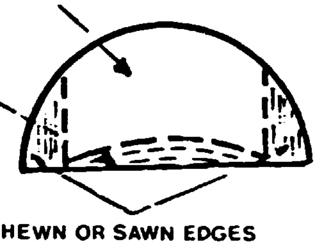
When splitting of the pole is done by chainsaw, a guideline should be marked with colour or chalk line from both sides of the splitting plane. Using chainsaw bar end a groove is made about 30 mm deep along the splitting line on both sides. Best results are obtained by progressively splitting the pole outlining from both sides to secure strength and smooth faces.

The same process applies to axe and wedge splitting. "V" shape grooves are made by axe on both sides of the splitting plane (face) to serve as a guideline. Then the pole is split alternatively from both sides. Cross grain (vascular bundles must be frequently severed by axe to achieve smooth straight split face).

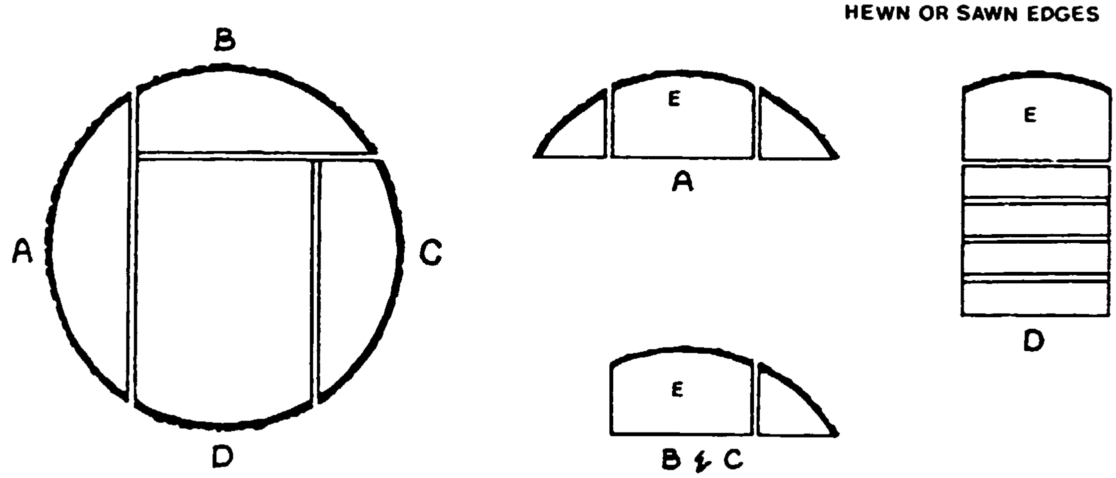
A few simple preservation methods are shown in Figure 72 and the debarking process in Figure 73.

Figure 70 - Splitting or sawing C.P. round wood to halves or quarters to be used for "pole" type housing construction.

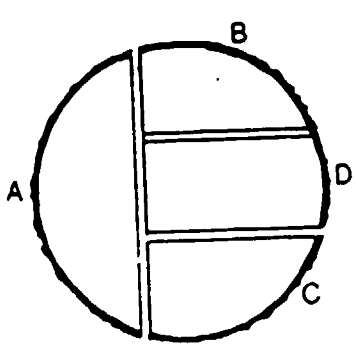


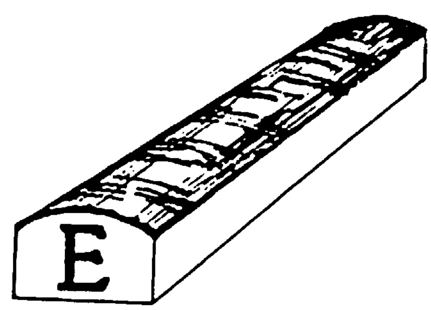


Breakdown and re-saw patterns for small diameter logs, utilizing slab section. (see Drawing E).

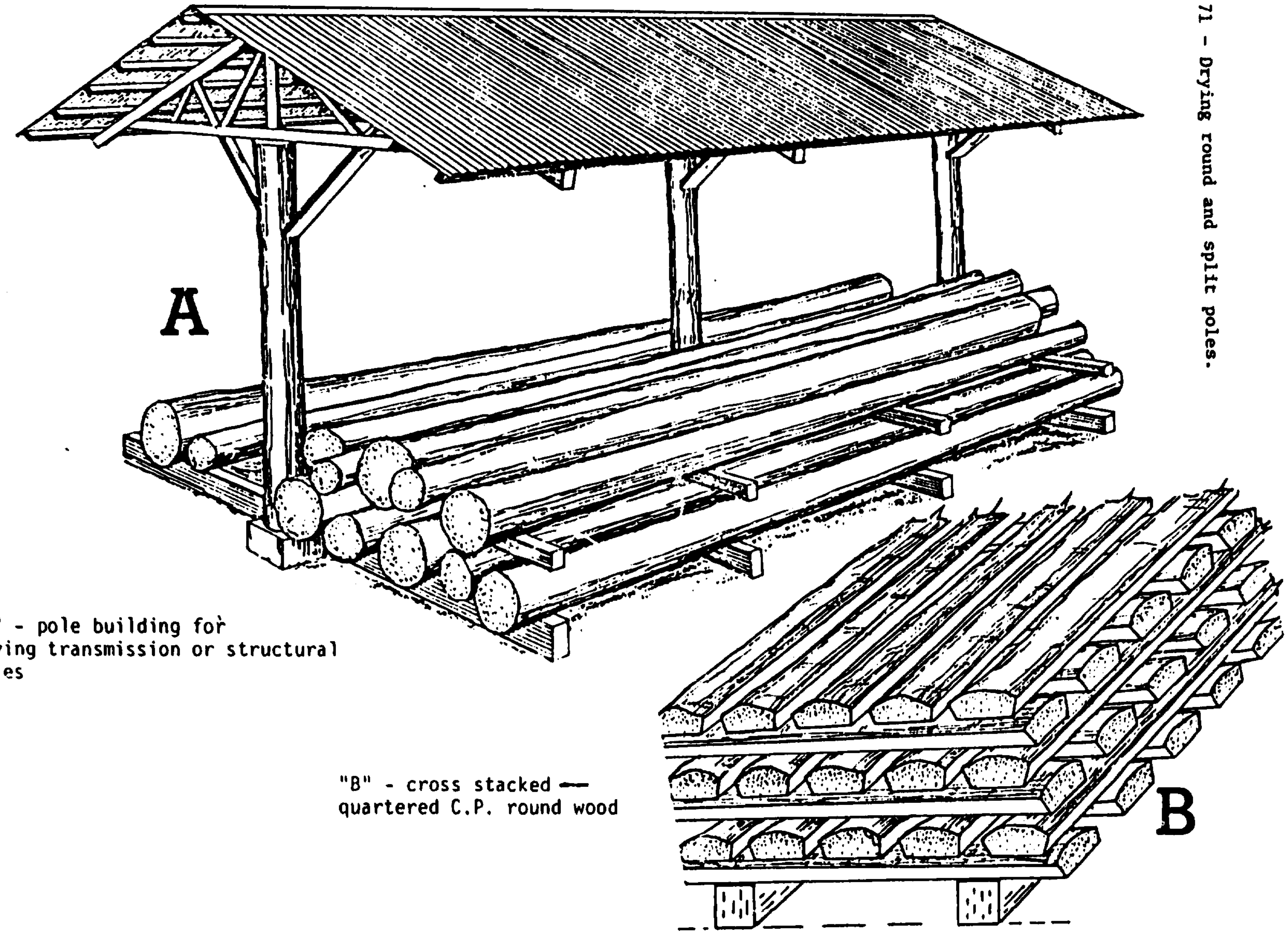


Log 1 - diameter 250 mm or less





Log 2 - diameter 200 mm or less

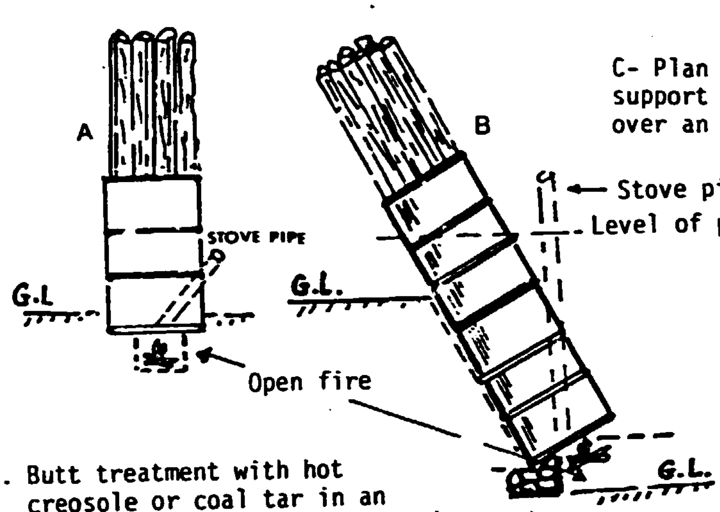


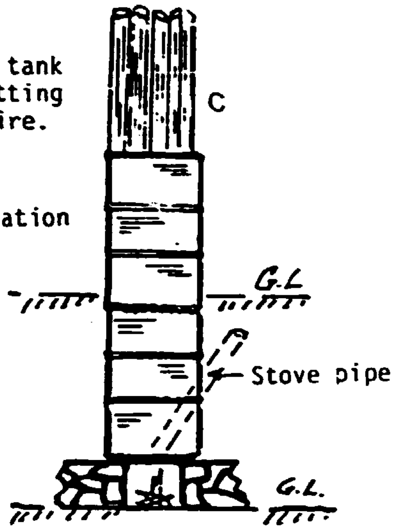
"A" - pole building for drying transmission or structural poles

"B" - cross stacked — quartered C.P. round wood

Fig. 71 - Drying round and split poles.

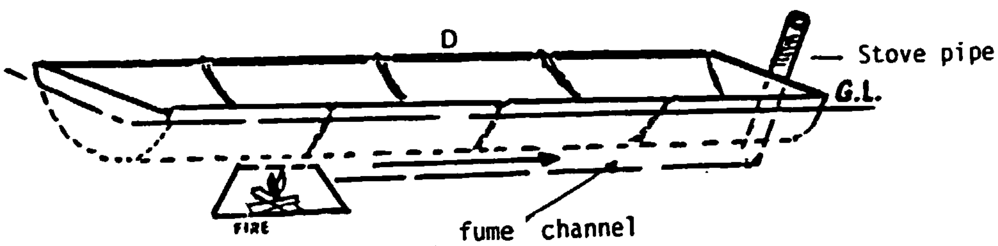
Fig. 72 - Simple preservation methods where pressure impregnation is not available.





A. Butt treatment with hot creosole or coal tar in an oil drum. (Suitable for fencing post and short/intermedium poles or foundation stumps.

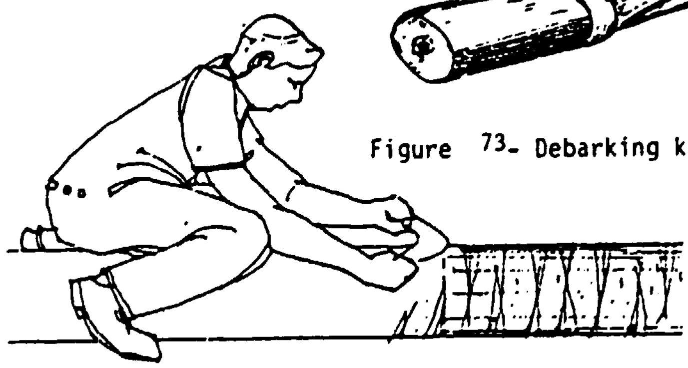
B - Shows two butt-welded drums and for a convenience laid in the inclined position (installation of a tank is simplified where a suitable embankement is available).



D - Horizontal tank made from welded half sections of oil drums - heating arrangement is shown in sketch.

Note - fire has to be controlled to keep the temperature of creosote or coal tar from boiling or splashing out of tank and igniting. This danger is increased if oil contains water. Alternatively a "bain marie" may be used so that the tank holding the creosote is enveloped in a larger tank of heated water.

Figure 73- Debarking knife (suitable for the Coconut Palms).



Debarking process.

General notes - pole structures

House foundation area should be cleared from vegetation and the site reasonably level - removing of organic layer of soil is optional but is recommended.

The straightest and strongest (largest cross section) poles should be used in the building corners.

A. Depth of embedment for framed buildings using halved or quartered Coconut Palm poles:

Total pole height up to a maximum 5 metres and up to 2.4 metres for an unsupported height (e.g. length of portion of pole between support by the framing members).
Given depth of embedment is based on well compacted soil such as dry clay, shale (hard clay mixed with small stones), compacted fine sand etc. avoiding wet low ground. Slope of the building site should be maximum 1 in 10.

In this case the depth of pole holes above concrete, or large flat stone* footing is 0.8 to 1 metre. Similarly, the embedment depth for short intermediate pole stumps is .6 to .75 metre.

B. Aligning the poles

Standard building site layout procedures are used (staking out the building and pole locations) and the foundation footings are constructed) in the dug pole holes. All poles should be inserted butt first into the holes and the poles turned or moved for the best horizontal and vertical alignment. The straightest pole sides should face outwards. The aligned poles are temporarily braced them embedded. (Concrete embedding must be left for a few days to cure, before further construction activities commence). Figures 74 to 80 show various construction details.

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*Concrete footings should be approximately 250 x 250 mm x 125 mm thick or a similar sized flat stone.

Fig. 74 - "A" - Pole construction design for the low cost housing.

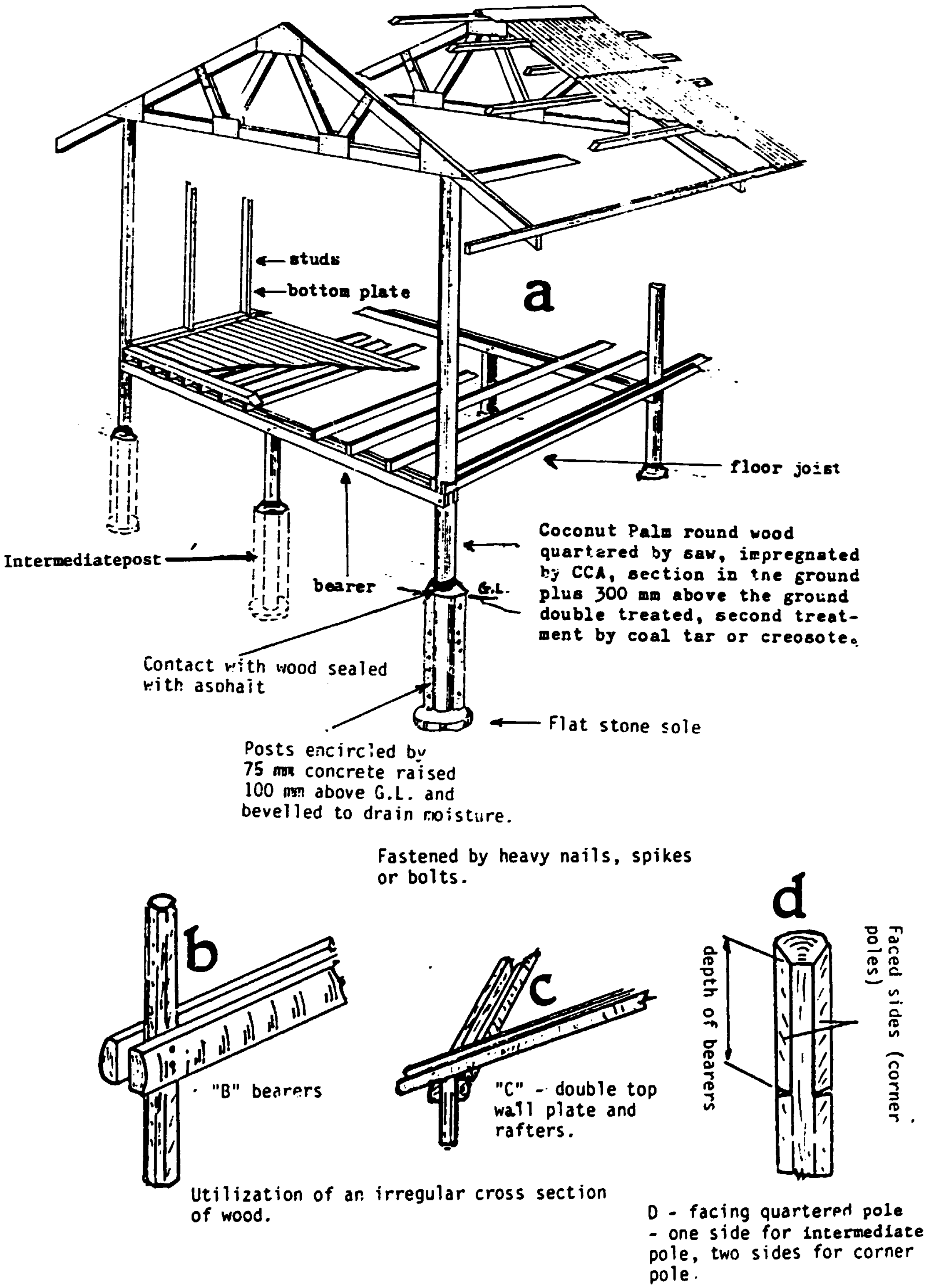
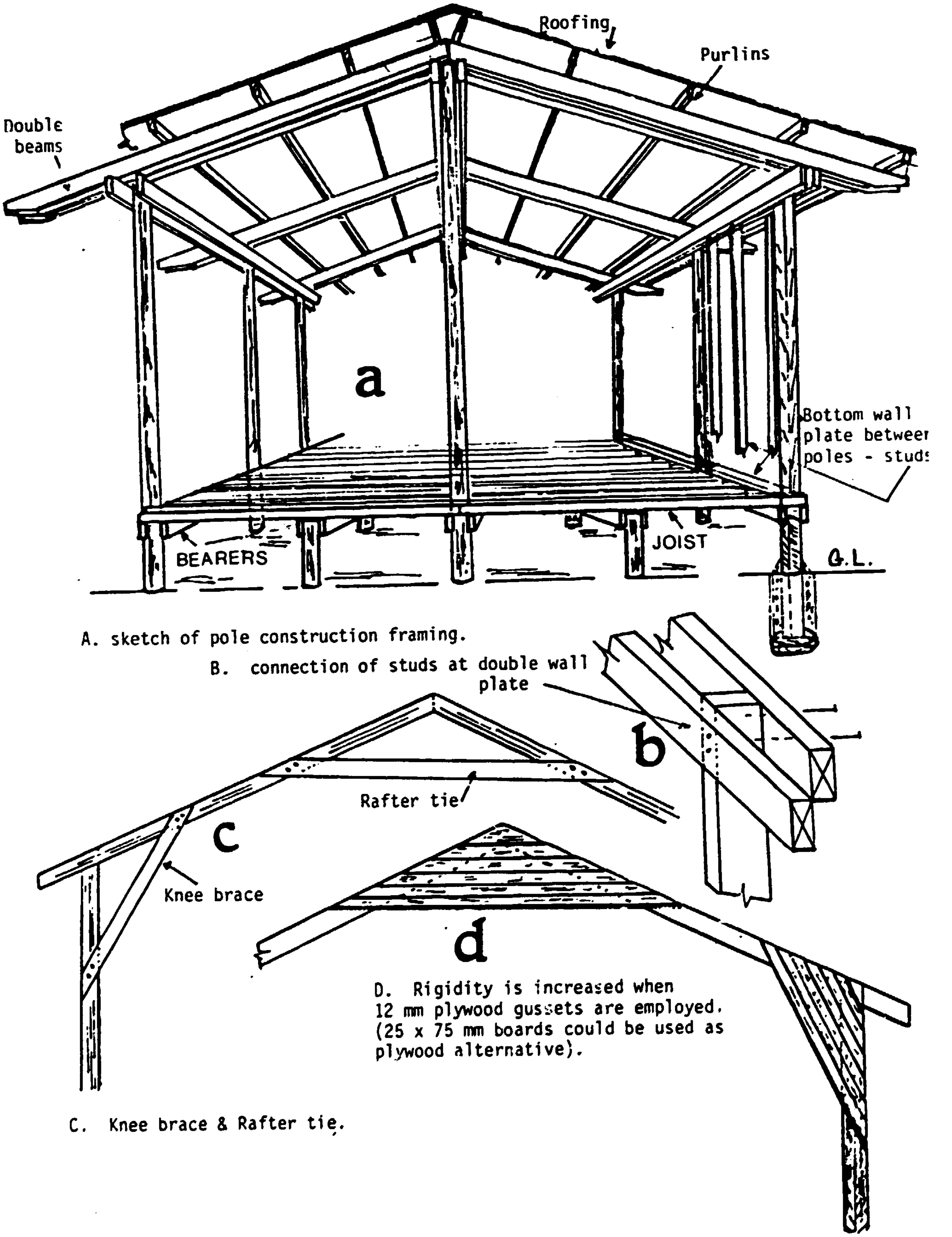


Fig. 75 - Pole building construction.



A. sketch of pole construction framing.

B. connection of studs at double wall plate

D. Rigidity is increased when 12 mm plywood gussets are employed. (25 x 75 mm boards could be used as plywood alternative).

C. Knee brace & Rafter tie.

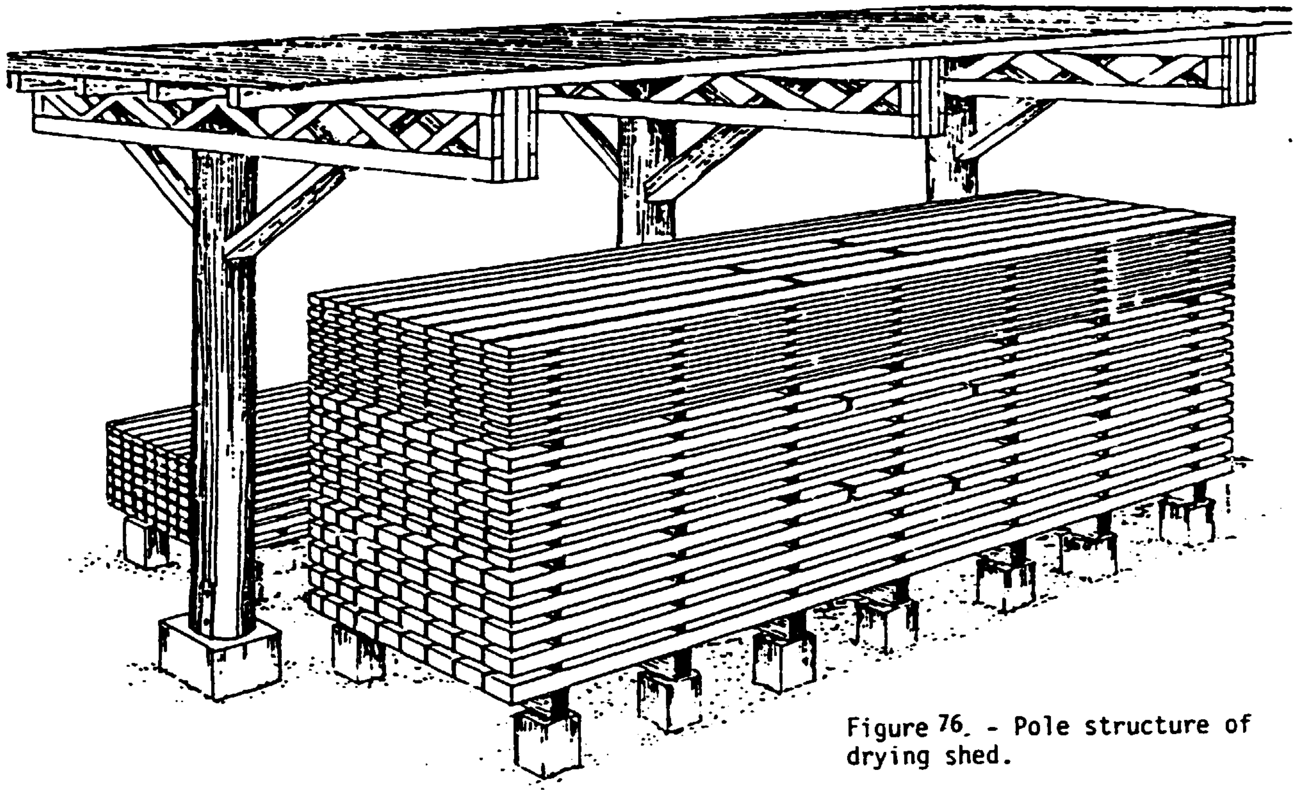
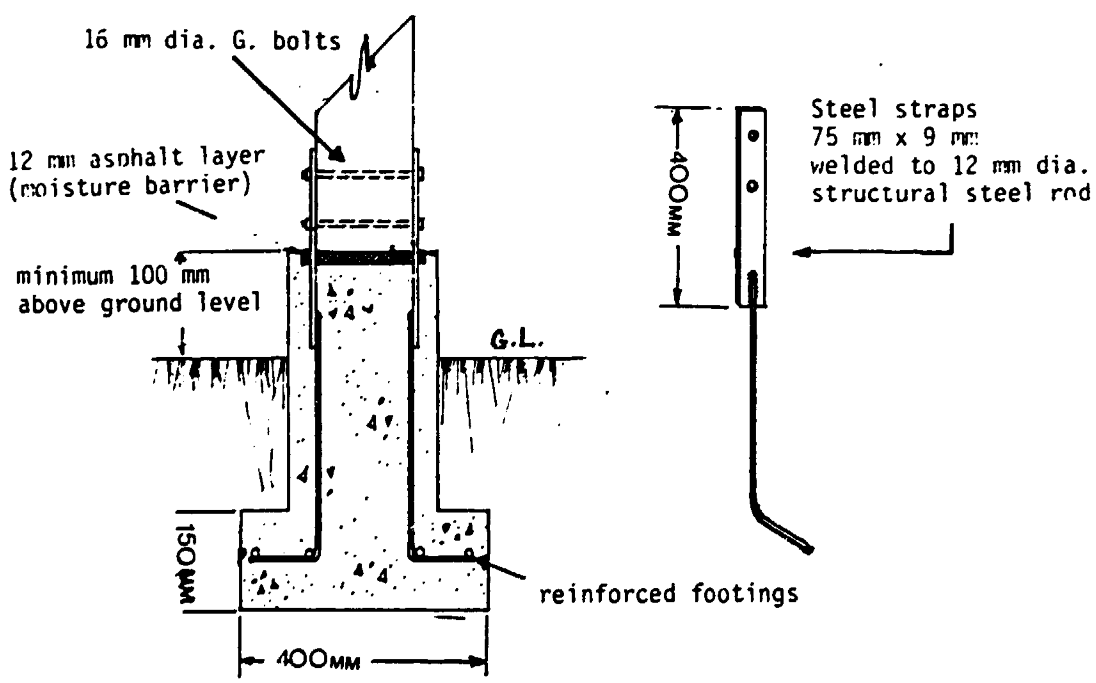


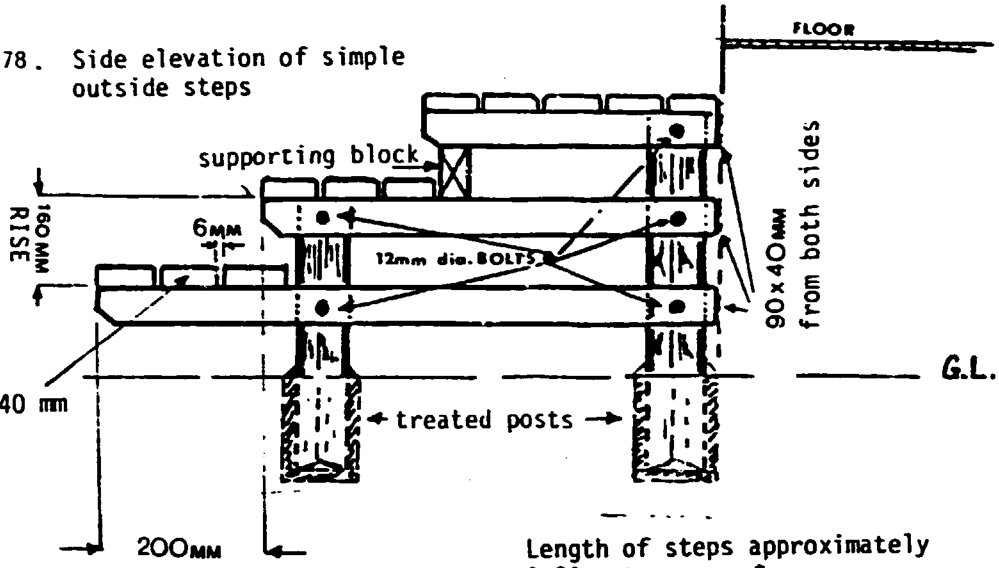
Figure 76. - Pole structure of drying shed.

Figure 77 - Footing and fastening of a pole in industrial construction to avoid wood contact with soil.



Note: Depth of footing depends on the type of soil. Hard clay or compound soil 400 to 500 mm deep - loose sand or wet clay depth should be above 500 mm.

Figure 78. Side elevation of simple outside steps



Core:
2 pieces 100 x 50 mm

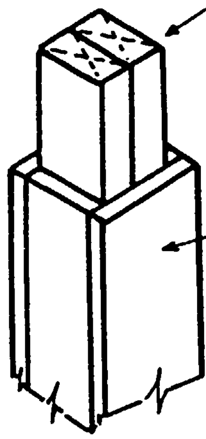
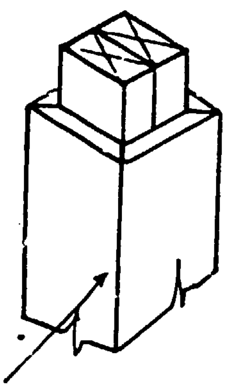


Fig. 79. Cased post - (built up columns)

Case:
2 pieces 100 x 25 mm
2 pieces 150 x 25 mm
or 4 pieces 125 x 25 mm



Beveled corners are not recommended for C.P.W. as will easily open, unless they are well glued.

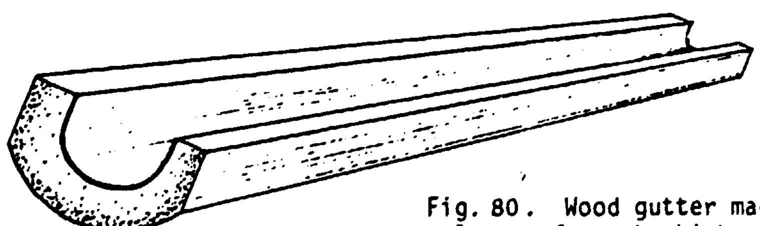


Fig. 80. Wood gutter made from the C.P.W. - selected from the higher section of the stem (soft core is removed by axe or adze) - suitable for above front door (can be directly through spacing blocks to fascia or ends of rafters).

12. BUILT-UP BEAMS

Larger cross sections of structural members not obtainable from C.P. sawn wood may be built up if required.

The following notes apply to relatively small fabricated beams to be used in light frame construction not exceeding beam depth 400 mm, length 6 metres and width 150 mm. The quality and peformance of such built- up beams depends on the experience and skill of the builder, using his judgement based on criteria of solid wood dimensions. Built up beam strength and stiffness can equal that of solid beams of the same cross section, possibly better depending on the defects in solid wood. For safety it is recommended to build up beams considered as 85 per cent strength value when compared to solid wood beams.

Large beams or those subject to public safety criteria should be designed and computed by structural engineers.

A number of methods can be used to build up larger structural beams.

Simple lamination by nails or metal connectors, is a common practice. Glue laminations is more efficient but costly.

Note: Boards laminated by nails or metal connectors should be air dried since moisture in the joined faces attracts moulds or fungal attack.

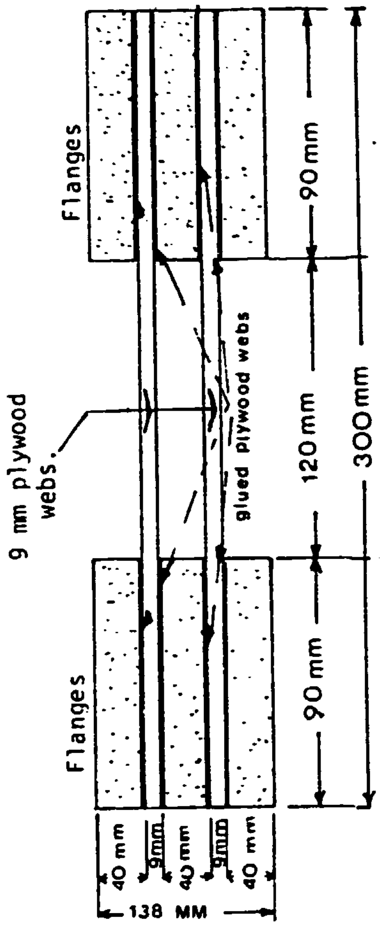
Fig. 81 shows some of the more simply designed, straight built-up beams. The choice of beam design depends on the application requirement such as:

1. attractive appearance
2. fabrication simplicity and economy
3. performance.

Figure 81 - drawings "A", "B", "E", "F", - illustrate single and double "I" beams with plywood webs and wood flanges. This type of fabricated beam depends in performance on the quality and strength of glue line.

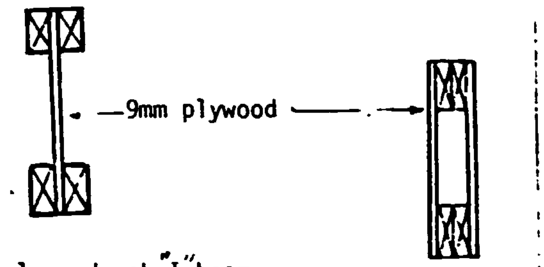
Flanges (seasoned to 16-18 per cent MC) and plywood webs must be glued under pressure of clamps (nails are not used) - glue and plywood must be moisture resistant when beams are in service partly exposed to weather.

Fig. 81 - Various built-up beams.
The difficulty to obtain larger sizes of solid wood from C.P.W. can be overcome by fabrication of different types of beams with glued plywood webs or trussed beams using nails.



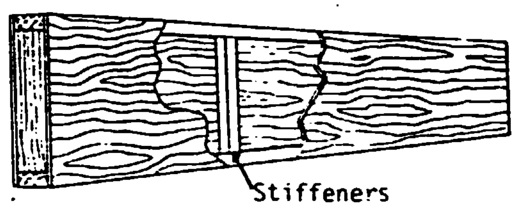
A. Double plywood webs(I beam)
The flanges or parallel chords in trussed beams could be joined with long scarf joint (joints must be scattered).

Stiffeners should be spaced approx. 1 metre along the length of box or I beams.

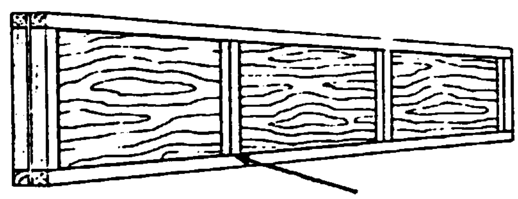


B. Single plywood web "I" beam

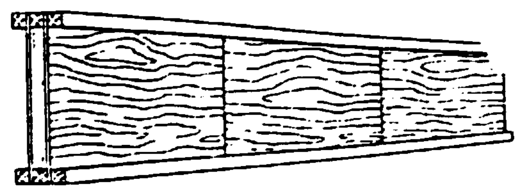
C. Box beam



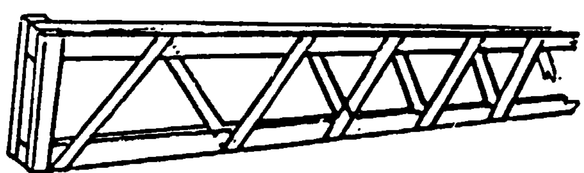
D. Box beam with flanges covered - note internal stiffeners.



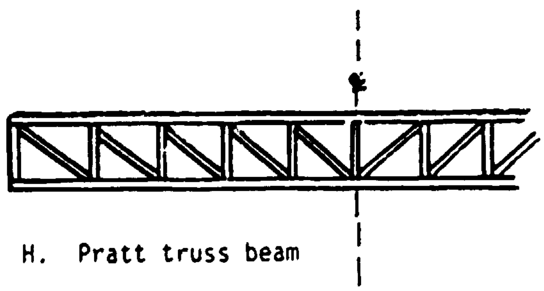
E. "I" beam with exposed stiffeners



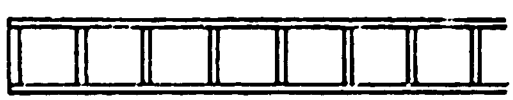
F. Double "I" box beam
Stiffeners must be located at the centre of plywood butt joints.



G. Truss beam with webs at 45°



H. Pratt truss beam



J. Simple truss beam with vertical webs (strength and stiffness is improved when webs are trenched in)

Basic design requirements:

1. The beam depth to span ratio should be 1 :12 to max 1 : 16 (using selected defect-free wood. (Stress Grade 8 or 11 for C.P.W.)

2. Plywood webs (selected industrial grade) 9 mm thick, are butt joined and supported externally or internally by glued stiffeners.

3. Flanges: dressed to required sizes.
   Thickness minimum 4 x thickness of plywood webs.
   Face depth minimum 1/4 of beam depth (height).

Flanges can be joined longitudally by flat scarf joint of a slope 1 : 10 or 1 : 12.

Flange joints must be scattered and avoided in or close to the centre of beam span, since the maximum bending movement is at the centre of the span.

Camber (a longitudinal concave curvature of the bottom edge of the beam) should be provided in built-up beams in the bottom chord or both bottom and top chords. Roof trusses camber is usually povided only in the bottom chord. A splice provides the most simple way of introducing camber. Minimum camber measured in mid span of beam or truss should be for green wood 1 : 180 of the span and for seasoned wood 1 : 240 of the span. Such camber should compensate for most of the designed deflection.

As a general guide, the stiffness and rigidity of beams are increased by flanges or chords if possible without joints. Stiffners should be extended to flange edges.

Box beams (Fig. 81 - drawings "C", "D") are more simplified beam fabrications and could be only nailed or glued and nailed. Design requirements are similar to those for "I" beams.

Trussed beams (Fig. 81 - "G", "H", "J") are fabricated entirely from wood and are fastened by nails or metal connectors - type "J" could be improved in stiffness and strength by lining sides with 6 mm nailed plywood or tempered hardboard.

Lateral stability of beams is improved by larger bearing area (i.e. beam width and area of the supporting member).

13. WIND FACTORS

Most Coconut Palm growing countries are situated in geographical regions subject to frequent high wind storms. For this reason particular attention has been given in this paper to fastening methods for light wood framed domestic buildings to minimize their damage by high wind.

Some basic precautionary methods follow, which when applied to light frame construction will prevent or reduce damage unless buildings are subject to exceptional wind forces.

On a flat surface exposed at right angles to the wind direction, the value of wind pressure is proportional to the wind speed (velocity).

Therefore, wind speeds of:

10 m/s (36 km/hour) apply pressure 6 kgf/m^2 or .06 KPA*
20 m/s (76 km/hour) apply pressure 24 kgf/m^2 or .24 KPA
30 m/s (108 km/hour) apply pressure 49 kgf/m^2 or .49 KPA
40 m/s (144 km/hour) apply pressure 96 kgf/m^2 or .96 KPA

Walls of a building exposed to direction of wind (windward) are subjected to the above tabulated positive pressure and walls on the opposite side (leeward) to negative pressure called suction. These combined forces act on the whole building and could, as recorded by various building research centres, increase forces to up to 20 per cent greater than the direct pressure on the windward side.

The magnitude of wind pressure decreases as pitch of roof decreases as pressure of wind is considered normal (at right angle) to the roof surface, but negative pressure, e.g. suction, increases as roof slope decreases.

Therefore, flat or low sloped roofs are subject to considerable suction on the leeward side and are dependant on the adequacy of roof fastenings to battens or purlins, purlins to trusses or rafters - rafters to top wall plates which in turn should be well fastened to the studs and this process of secured fastening continues down to foundation footings.

---

*5 miles approximately equals 8 kilometres
Wind speed 1 m/s equals 3.6 km/hour One Pascal (Pa) = $\frac{\text{Newton (N)}}{\text{metre}^2}$
for practical purposes 10 N equals approx. 1 kg force.
therefore $\frac{10N}{m^2}$ = 10 Pa = approximately $\frac{1\ kgf}{m^2}$
therefore .06 KPa = .06 x 100 Pa (K is a symbol for 1000)
= 60 Pa = $\frac{60\ \text{Newtons}}{m^2}$ = $\frac{6\ kgf}{m^2}$

For regions subject to frequent cyclonic or hurricane storms, the following points should be borne in mind:

A. Hip type of roof is more resistant to high wind storm.

B. Roof overhang should be kept to a minimum.

C. Roof over open verandah should be well secured by metal fasteners to adequately anchored verandah columns.

D. Roof cover such as corrugated metal sheets should be well fastened by screws rather than nailed especially at the sheet ends and sides.

E. Structural members of the whole building should be securely fastened from the foundation footings up to the roofing cover by different means of anchorage, wall and roof bracing, as described in this paper.

F. Good anchorage and adequate size of footings are most important to prevent over-turning of the building by high wind force.

G. Louvre windows fitted with wooden slats should prevent window damage and consequently wind entry to the inside of the building which would increase internal pressure.

H. Shortly after the disastrous Hurricane Isaac in the Kingdom of Tonga, the author had the opportunity to see the effect of damage to buildings in nearly all the Tonga Islands.
It looked as if the main reason for such large damage to domestic hosues was due to poor construction methods:

1. Houses built by standard building code for wood framed houses (e.g. correct sizes of wood members, with acceptable span and spacing,adequately nailed employing hip type roof, covered with corrugated metal sheets properly fastened to more closely spaced purlins were not damaged at all or only marginally.

2. Houses built with less care, mainly with the minimum use of structural members with minimum cross sections, members widely spaced with poor fastening of roof cover had been considerably damaged or totally destroyed.

Note: The recommendations and designs described in this paper may not agree with the local "Building Code" which could be more appropriate for the different geographical location. In this case, it is recommended to alter designs to suit such requirements.

14. WEIGHT OF COCONUT PALM WOOD

The following Tables (Nos . 7 and 8) provide useful values of green and dry coconut wood of different dimensions and basic densities, and/or different areas of flooringor walling. Figures 82 and 83 show the relationship in graph form.

Fig.82 Green density (weight) for different basic densities of C.P.W.

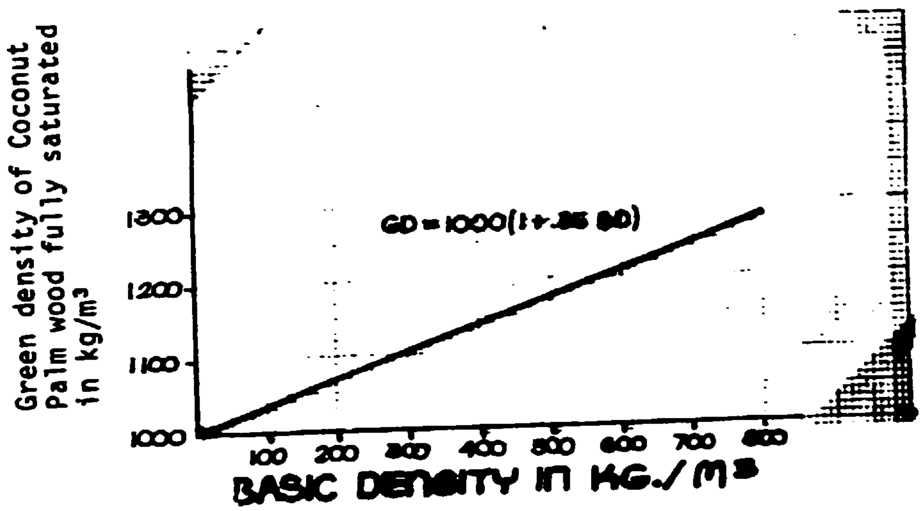


Fig.83 Nominal densities for C.P.W. at 12, 16 and 25 per cent M.C.

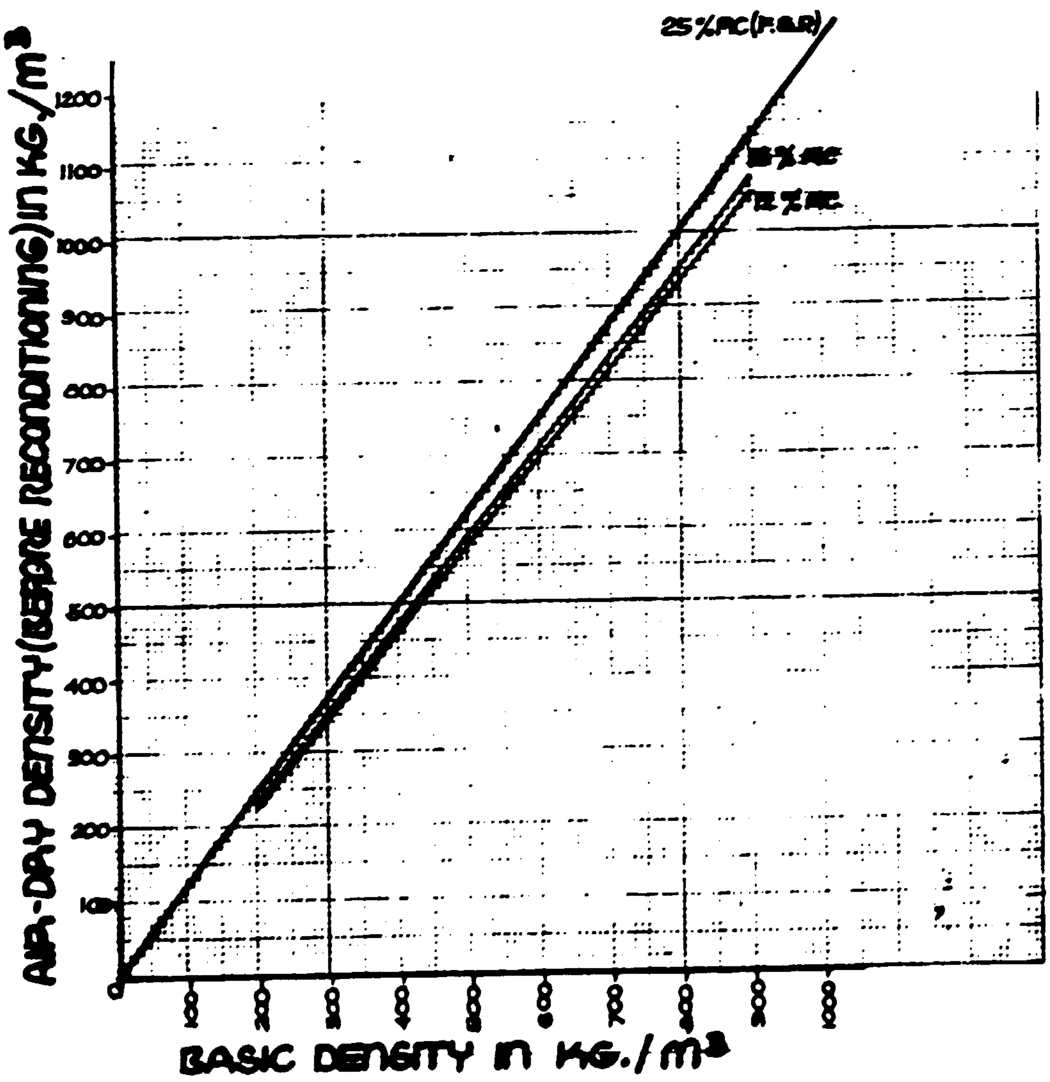


Table 7.

Green and air dry (in brackets) weight of C.P.W. of different basic densities and cross section per one metre length.

Density	25 x 75 (mm)	38 x 75 (mm)	50 x 75 (mm)	25 x 100 (mm)	38 x 100 (mm)	50 x 100 (mm)	50 x 125 (mm)
800 kg/m^3	2.40 kg (1.50 kg)	3.65 kg (2.28 kg)	4.80 kg (3.00 kg)	3.20 kg (2.00 kg)	44.86 kg (3.04 kg)	6.40 kg (4.00 kg)	8.00 kg (5.00 kg)
700 kg/m^3	2.32 kg (1.31 kg)	3.53 kg (2.00 kg)	4.65 kg (2.60 kg)	3.10 kg (1.75 kg)	4.71 kg (2.66 kg)	6.2 kg (3.50 kg)	7.74 kg (4.40 kg)
600 kg/m^3	2.26 kg (1.13 kg)	3.44 kg (1.71 kg)	4.52 kg (2.25 kg)	3.02 kg (1.50 kg)	4.58 kg (2.28 kg)	6.03 kg (3.00 kg)	7.54 kg (3.75 kg)
500 kg/m^3	2.19 kg (0.94 kg)	3.33 kg (1.43 kg)	4.39 kg (1.88 kg)	2.93 kg (1.25 kg)	4.45 kg (1.90 kg)	5.85 kg (2.50 kg)	7.31 kg (3.13 kg)
400 kg/m^3	2.14 kg (0.75 kg)	3.25 kg (1.14 kg)	4.28 kg (1.50 kg)	2.85 kg (1.00 kg)	4.33 kg (1.52 kg)	5.70 kg (2.00 kg)	7.12 kg (2.50 kg)

C.P.W. below basic density 400 kg/m^3 and wood from immature palms should not be used for construction purposes, unless building is only temporary. Exception when wood is used for internal lining.

Table 8

Green and air dry (in bracket) weight per square metre of a C.P.W. in different basic densities and thicknesses.

Density	25 mm.	20 mm.	18 mm.	12.5 mm.
800 kg/m^3	32.00 kg (20.00 kg)	25.60 kg (16.00 kg)	23.04 kg (14.40 kg)	16.00 kg (10.00 kg)
700 kg/m^3	30.99 kg (17.50 kg)	24.78 kg (14.00 kg)	22.30 kg (12.60 kg)	15.49 kg (8.75 kg)
600 kg/m^3	30.15 kg (15.00 kg)	24.12 kg (12.00 kg)	21.71 kg (10.80 kg)	15.08 kg (7.50 kg)
500 kg/m^3	29.25 kg (12.50 kg)	23.40 kg (10.00 kg)	21.06 kg (9.00 kg)	14.62 kg (6.25 kg)
400 kg/m^3	28.50 kg (10.00 kg)	22.80 kg (8.00 kg)	20.52 kg (7.20 kg)	14.25 kg (5.00 kg)
300 kg/m^3	27.60 kg (7.50 kg)	22.08 kg (6.00 kg)	19.87 kg (5.40 kg)	13.80 kg (3.75 kg)
200 kg/m^3	26.75 kg (5.00 kg)	21.40 kg (4.00 kg)	19.26 kg (3.60 kg)	13.38 kg (2.50 kg)

Recommended width, tnickness and average densities of C.P.W. thin boards for different application:

Strip flooring boards: 18 to 20 mm thickness
75 to 90 mm width
Basic density 600 kg/m^3 and above.

External wall lining: 16 to 18 mm thickness
71 to 110 mm width
Basic density 400 kg/m^3 to 700 kg/m^3

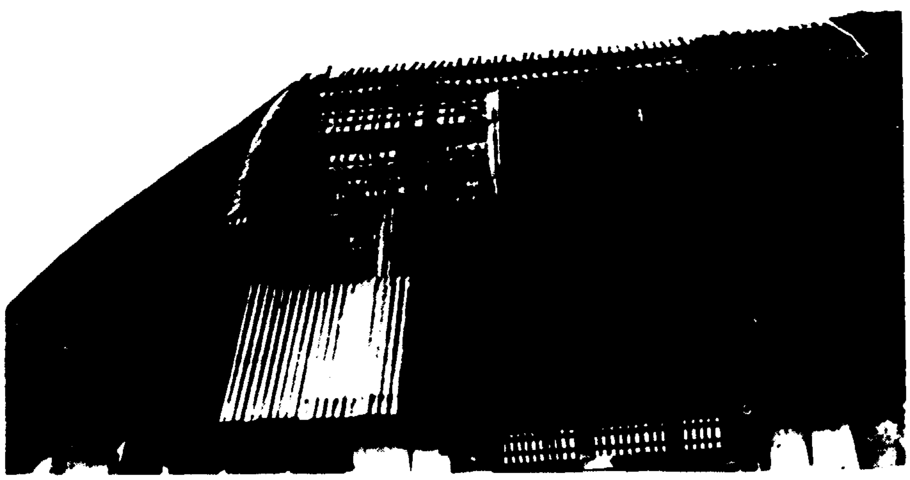
Internal wall lining: 12.5 to 16 mm thickness
75 to 110 mm width
Basic density 300 kg/m^3 to 800 kg/m^3

NOTE: C.P.W. of a high density exposed to weather has tendency to split or warp due to relatively large shrinkage. This defect is minimised when exposed boards are narrow as possible.

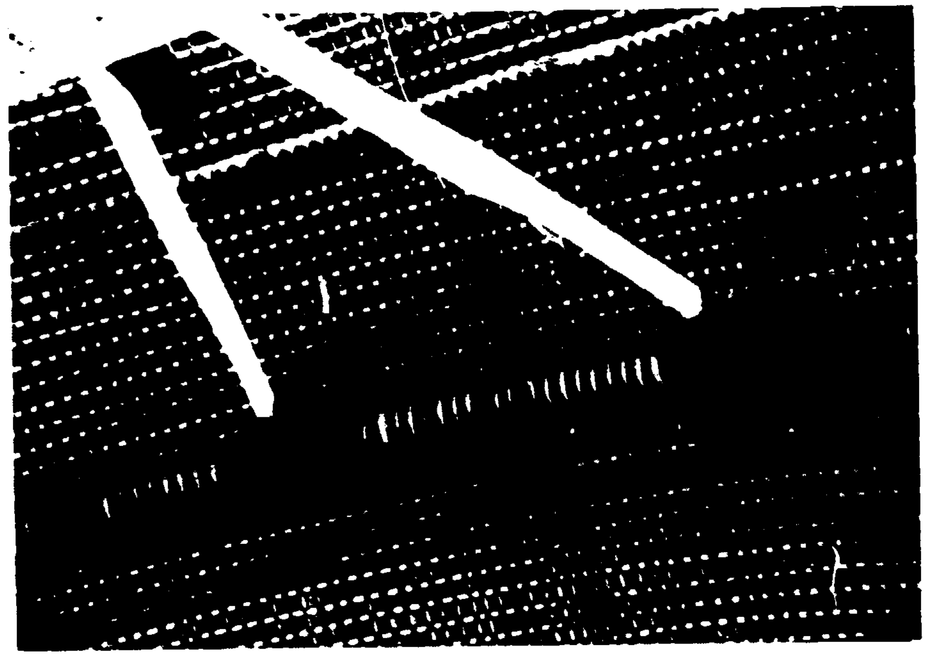
APPENDIX I

Contains some photographs to indicate the possibilities for use of Coconut Palm Wood as structural material for the light and medium frame construction of houses or for similar applications.

Church building at Tongatapu Island - constructed at the beginning of this century. Whole roof is constructed from C.P.W. - originally with thatched roof cover - later covered with corrugated metal sheets - undamaged by Hurricane "Issac" in March, 1982.

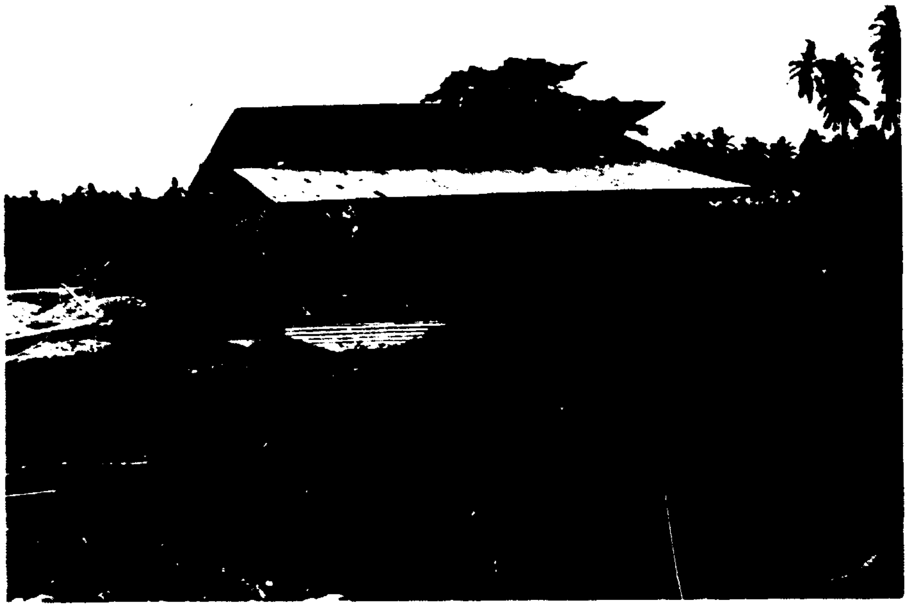


Similar church building at the FOA island (Ha'apai group of Tonga Islands) partly damaged by Hurricane "Issac" (blow out roofing sheets) - roof structural C.P.W. slightly damaged. Age of church approximately 60-80 years. See horizontal nailing battens added to roof when thatching was replaced by metal sheet cover.



Internal view of the C.P.W. roof framing, suitable for thatched roof cover - no steel nails have been used, joints are fastened by wood dowels and coconut husk fibre ropes.

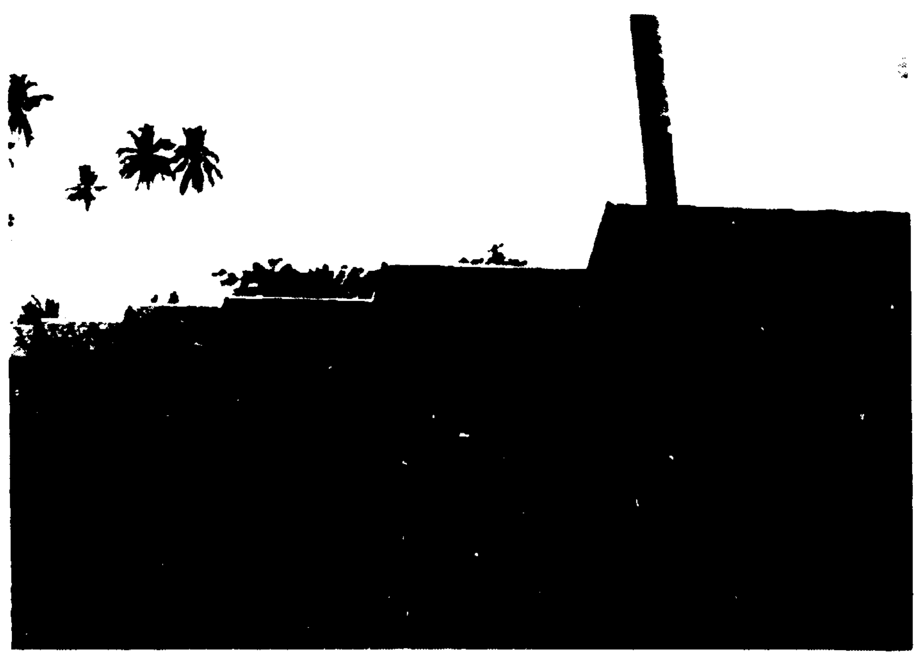
Internal view of the C.P.W. roof framing - (structural framing wood in good condition).



Medium cost housing - location of louvre ventilators between skillion roofs.

Medium cost housing project with double skillion roof and two floor levels.

Low cost house - main frame constructed from quartered round wood. Quartered poles providing supporting frame from foundation footing to ceiling level - combined with intermediate short stumps.



Low cost housing project.

Quartered C.P.W. "pole type of structure" of a low cost house with Nipa Palm thatched roof. (See included design plan)

The same as above - front view - note gable end stationary louvre ventilation.

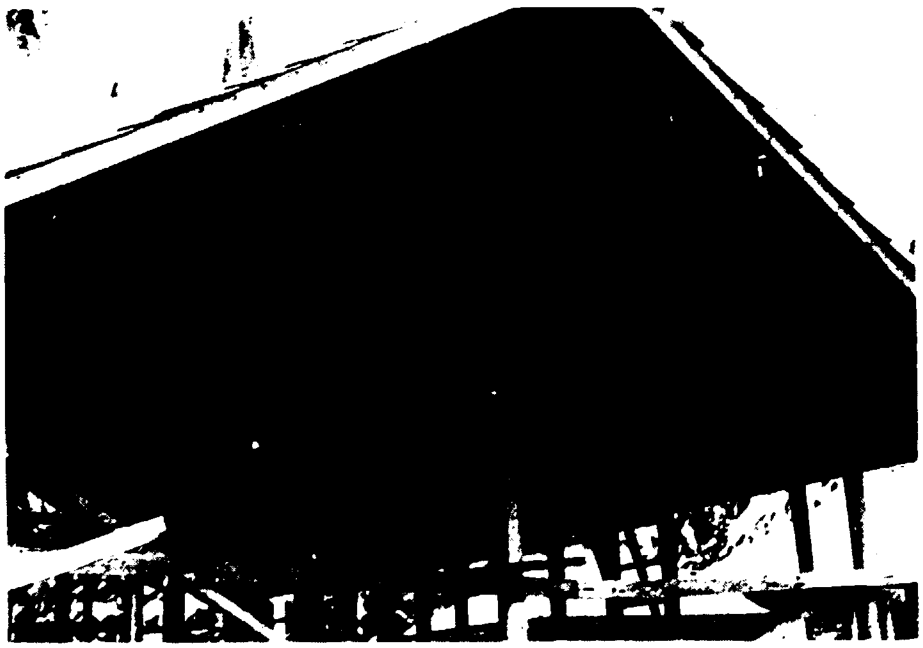
Detail of wall shingle application.

Housing project with application of roof and side wall shingles with masonry foundation piers.

Low cost housing project - application of roof and side wall shingles.

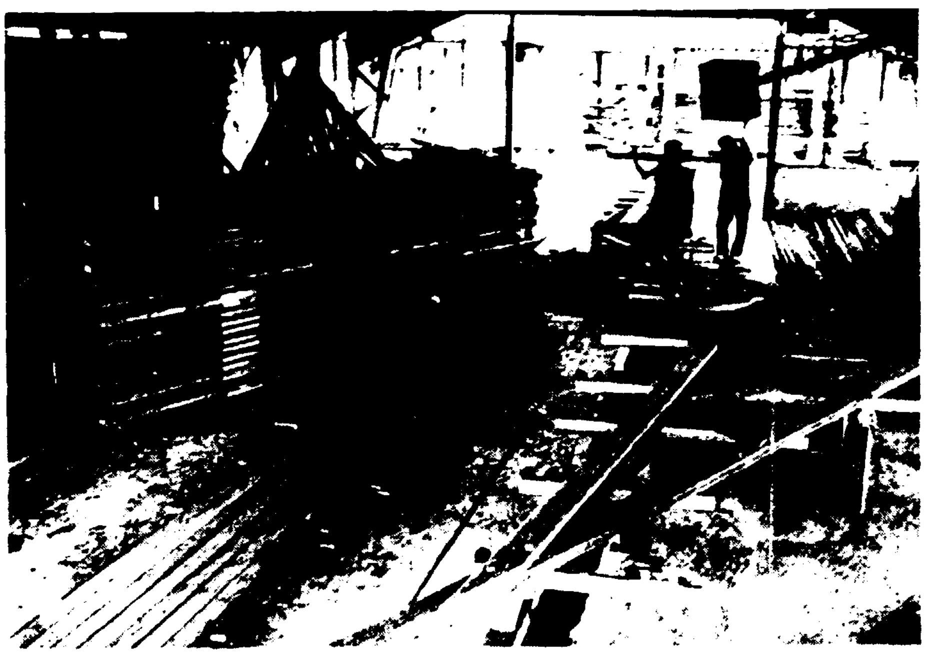
"Tongian" design with modified hip type of roof - concrete slab flooring and masonry walls up to 1.75 metres from floor level.

Pole type of sawmill structure with ventilated roof arrangement.



Roof truss with plywood gussets - note metal plate connectors used for fastening roof purlins to trusses top chords.

Jig table for assembling trusses - application of pressure to toothed metal plates at the joints.



Jig table could be used for most types of truss design - note stacking of finished trusses with the support at the trusses apex.

APPENDIX II

Selection of low and medium cost housing drawings, built at Philippine Coconut Authority - research centre in Zamboanga - Philippines, during the years 1978 to 1984.

Appendix II: List of designs for low cost Coconut Palm Wood frame houses.

A. Standard design - wood framed house, using C.P.W. shingles for the roof and side walls cover, wood strip floor with separate open fire kitchen and shower-bath and W.C.

A1 The same floor areas as 'A' - using concrete slab flooring and external masonry walls made from cement hollow blocks* up to the top level of the windows.

A2 The same as above - height of the external masonry walls only to lower level of the windows.

A3 Standard design as 'A' with the possibility to build one bedroom extension later on. Note floor plan with the different location of porch and entry.

A4 Details of roof trusses using plywood gussets and schedule of doors and windows - detail of external stairs.

B. Tonga design - with shingle covered 'oval' roof, concrete slab flooring - masonry external walls up to top height of windows (the same design could be used for wood framed walls).

B1 Modified 'Tonga design' with ventilated roof, open fire kitchen and shower-bath and W.C. as separate building. See Appendix I, Plate 7.

C. Low cost - quartered poles design house with thatched roof (See Appendix I, Plates 4 and 5).

D. Medium cost wood framed house design - with different type of ventilation. For reference see Appendix I, Plate 3 and ventilation section, Fig. 67).
Note: A number of this type of house has been built with 2 or 3 bedrooms and different types of roofs (e.g. low pitch gable roof and skillion type of roof all covered by corrugated metal sheets).

E. Close to 100 low cost houses have been built by the labourers employed by P.C.A. Research Centre in Zamboanga from free but somewhat defective Coconut Palm sawn wood using their own design - typical for the low income people in South Philippines if the structural wood is available. Roofs are covered by corrugated metal sheets or indigenous thatching material, or veneer rejects from conventional woods in several years.

F. Simple design of a domestic septic tank with single sludge tank.

Fl. Septic tank with sludge and secondary filtration tank. (Note the larger subirrigation drainage trench (as number of houses have been connected to the common subirrigation trench distribution).

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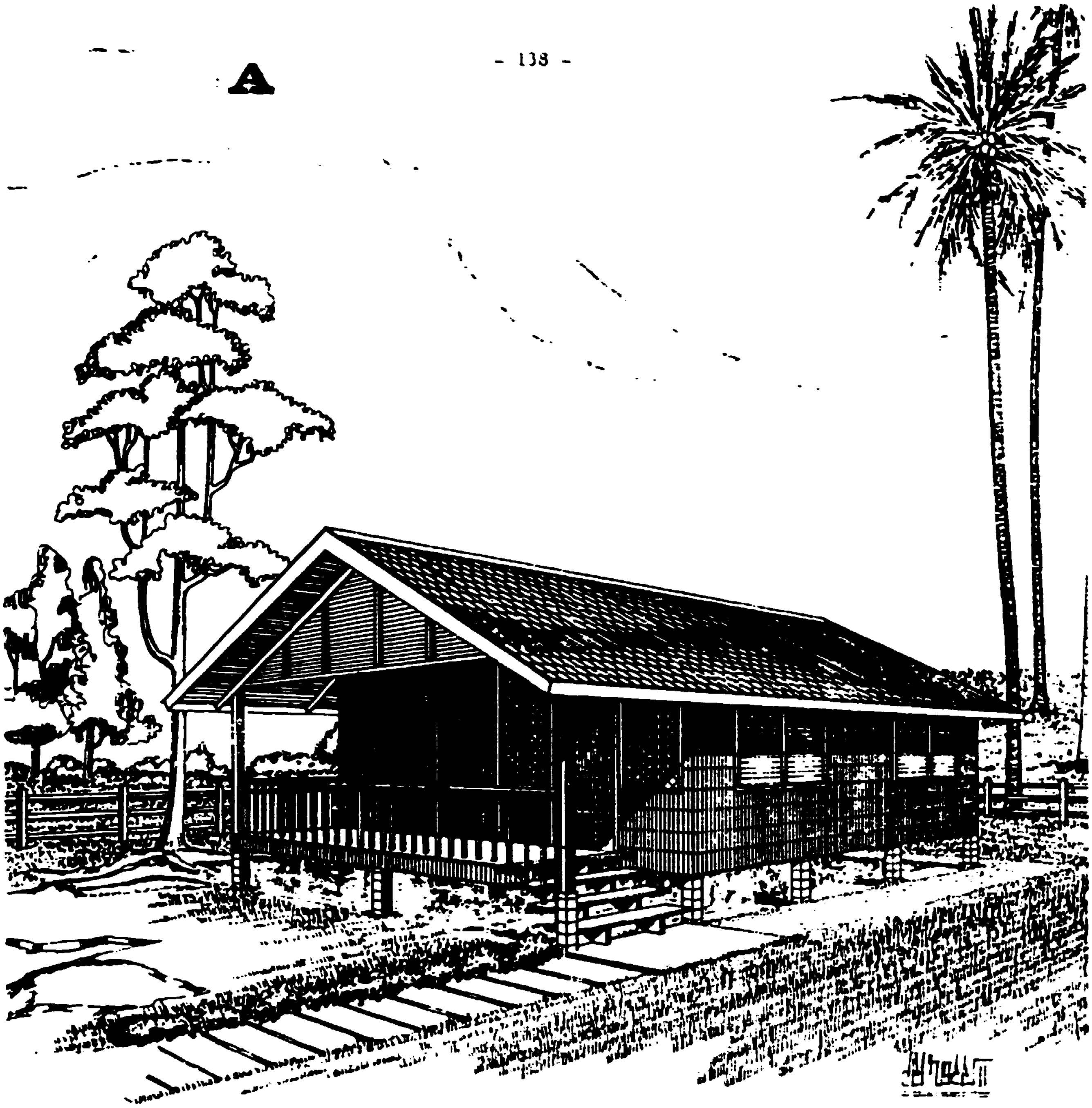
*Cement hollow blocks (made manually on the building site with a simple metal form).

Standard dimension:

Length	290 mm
Width	100 mm
Height	190 mm

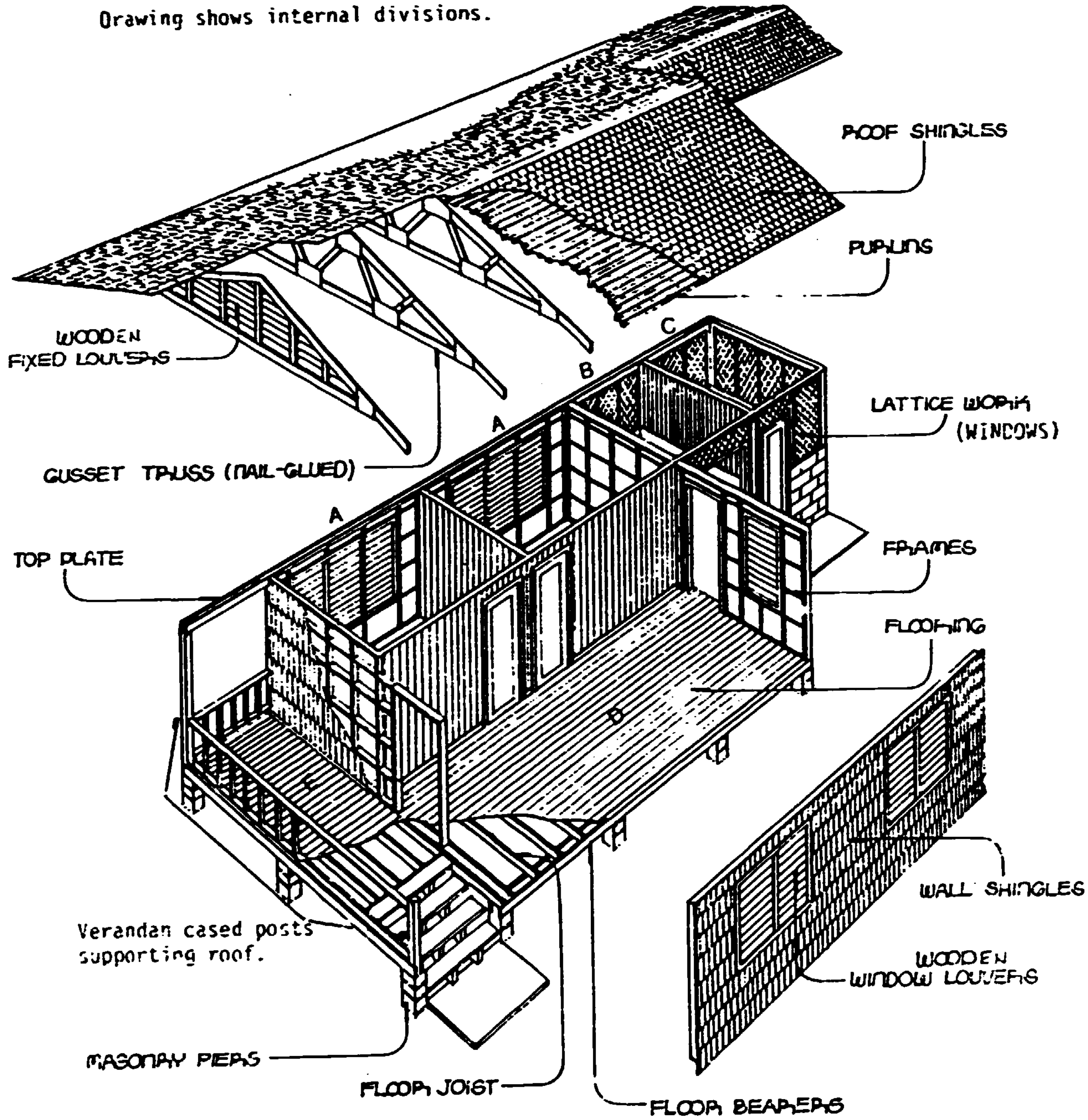
plus suplementary dimension: half and three quarters of a standard length to permit scattered vertical joints.

A

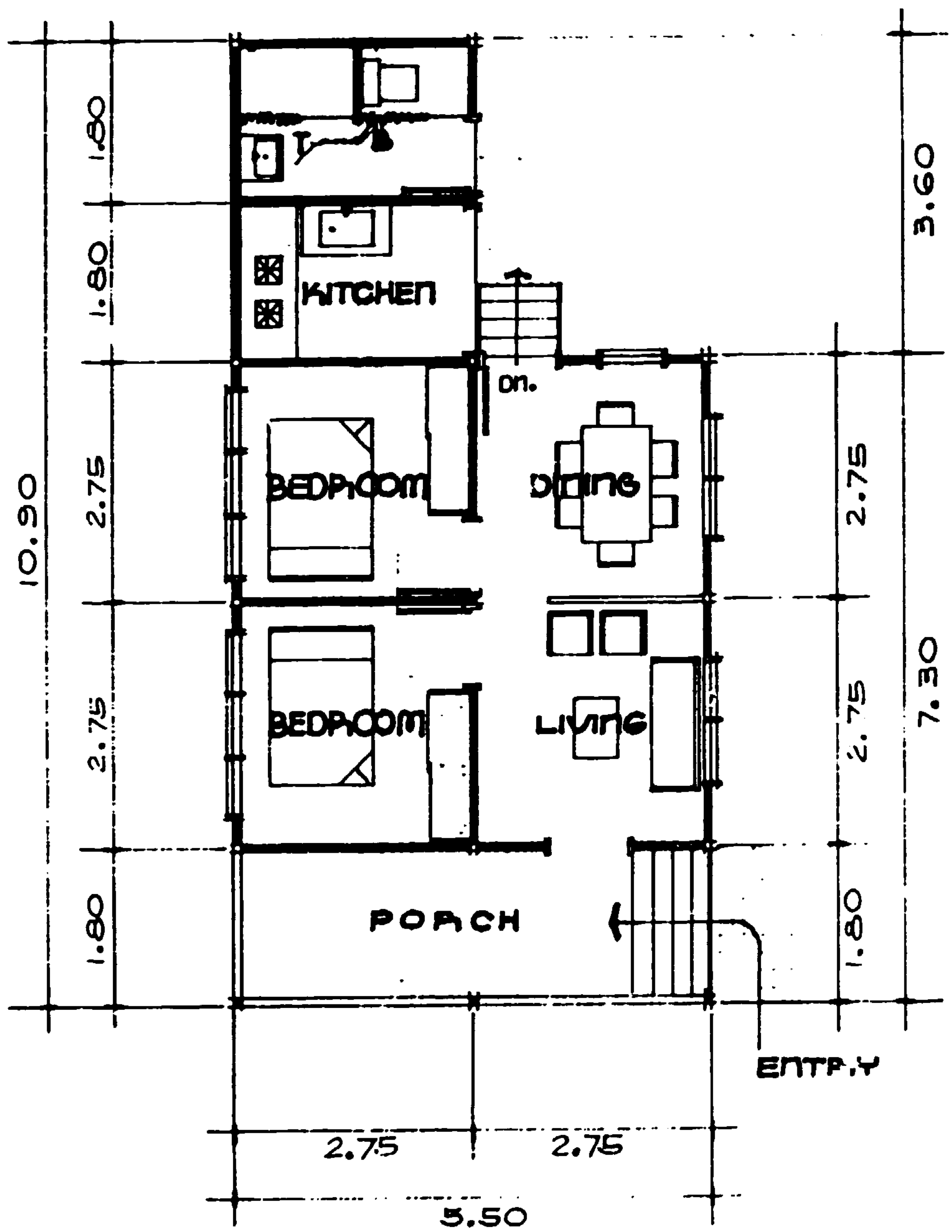


PERSPECTIVE VIEW

Exploded view of a Coconut Palm Wood framed house.
Utilization of roof and side wall shingles.
Drawing shows internal divisions.

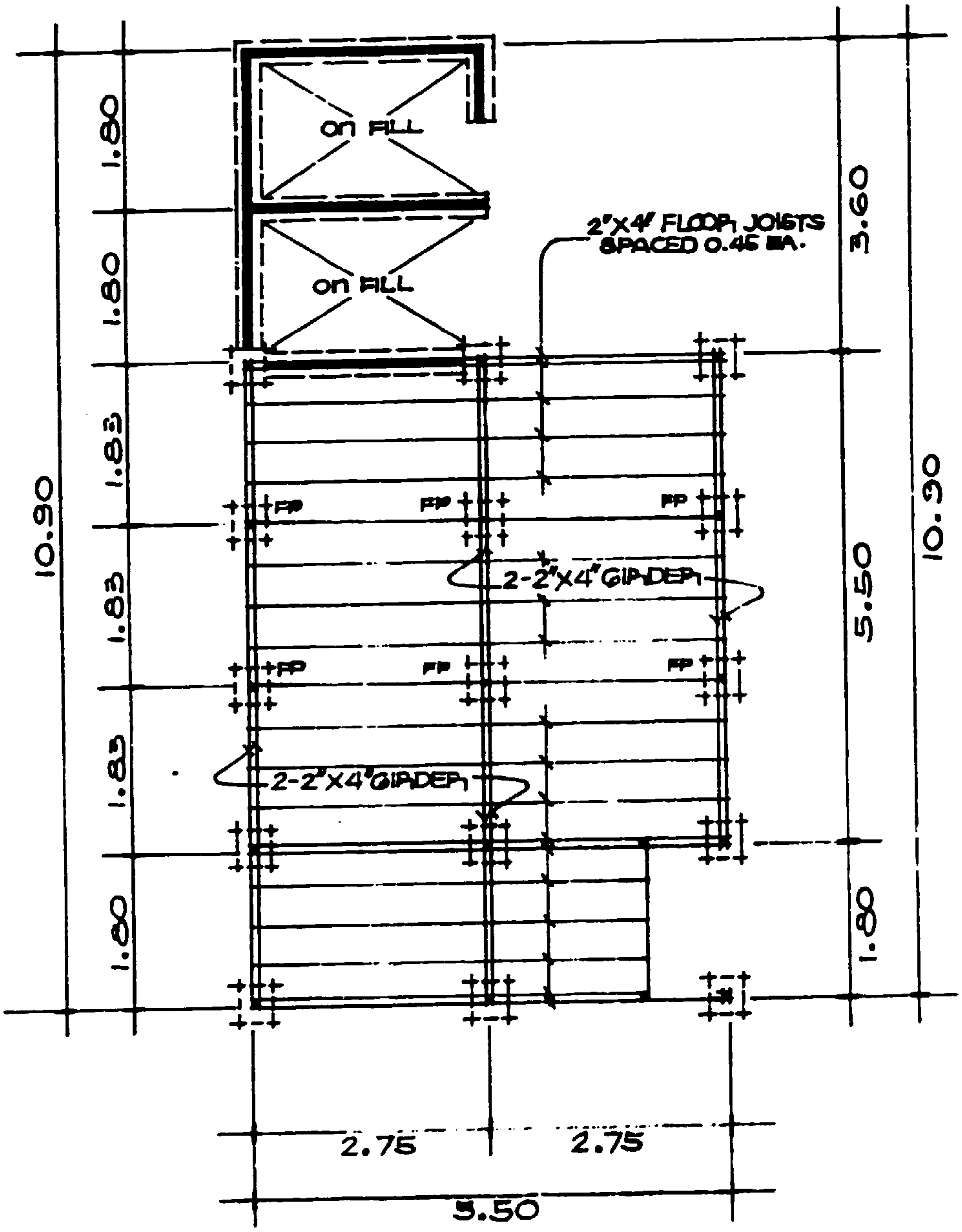


A. Bedrooms
B. Kitchen } built at ground level(concrete slab floor.)
C. Shower and W.C. }
D. Living and dining room
E. Verandah



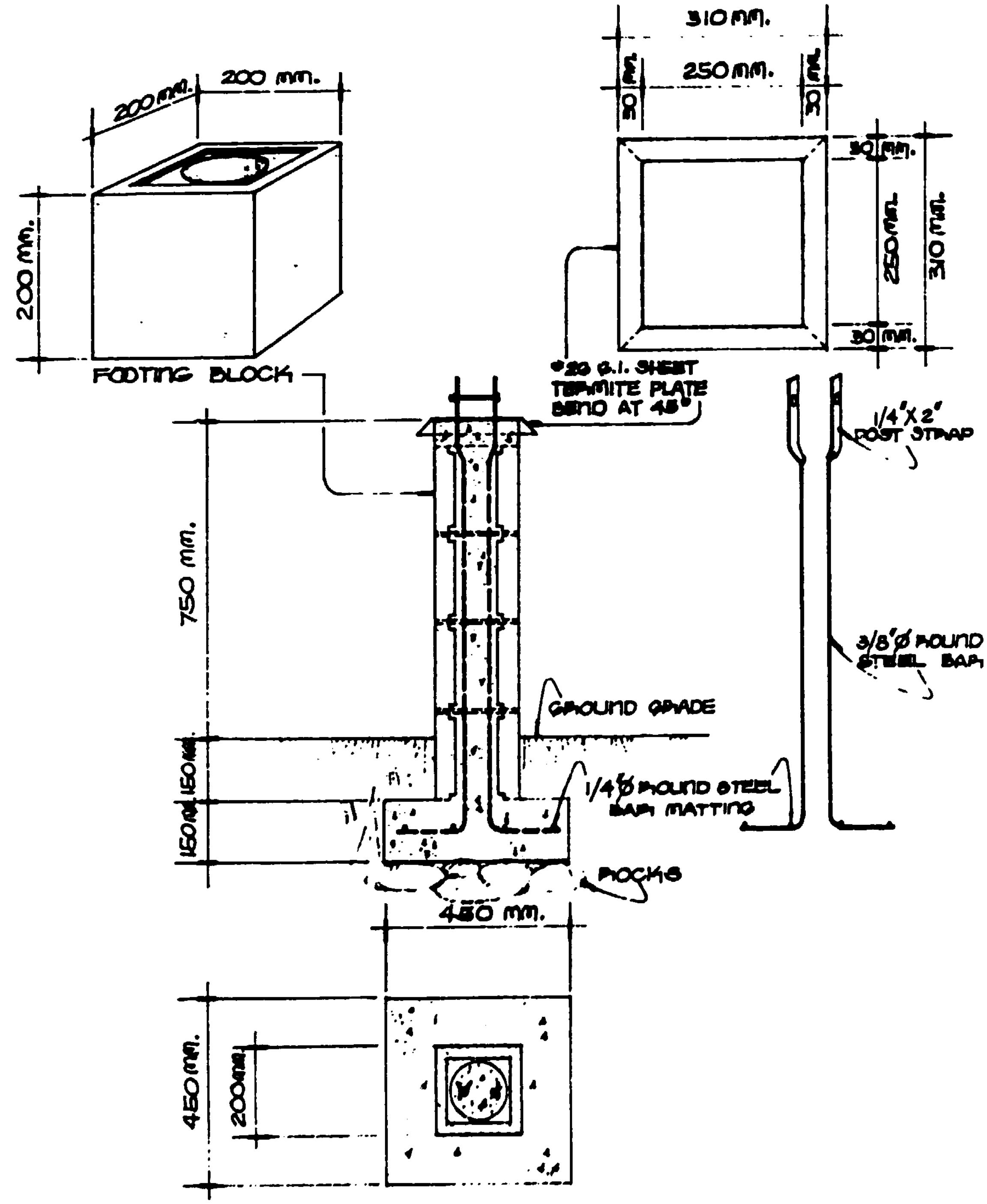
FLOOR PLAN

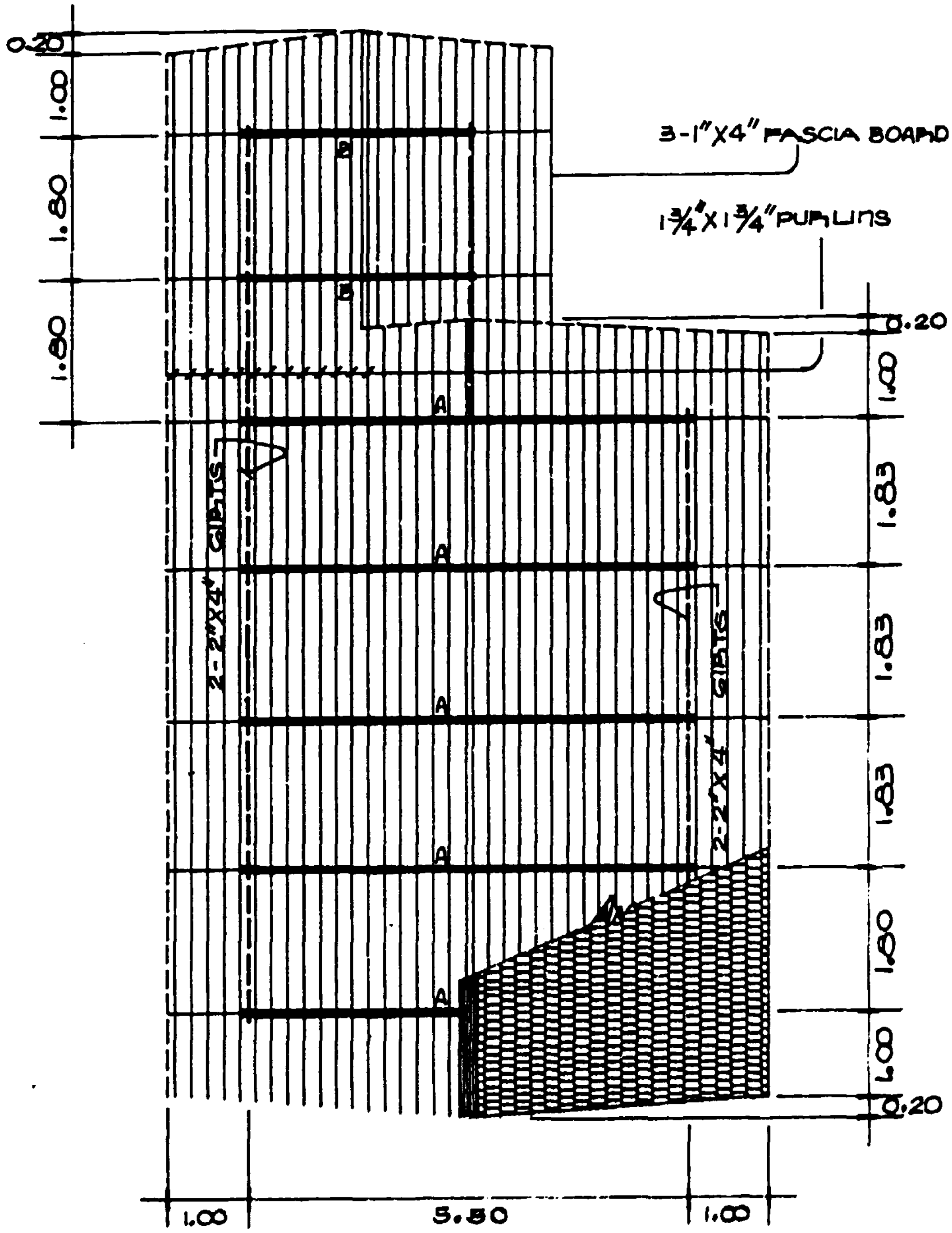
SCALE 1:80 METER



FOUNDATION • FLOOR FRAMING PLAN

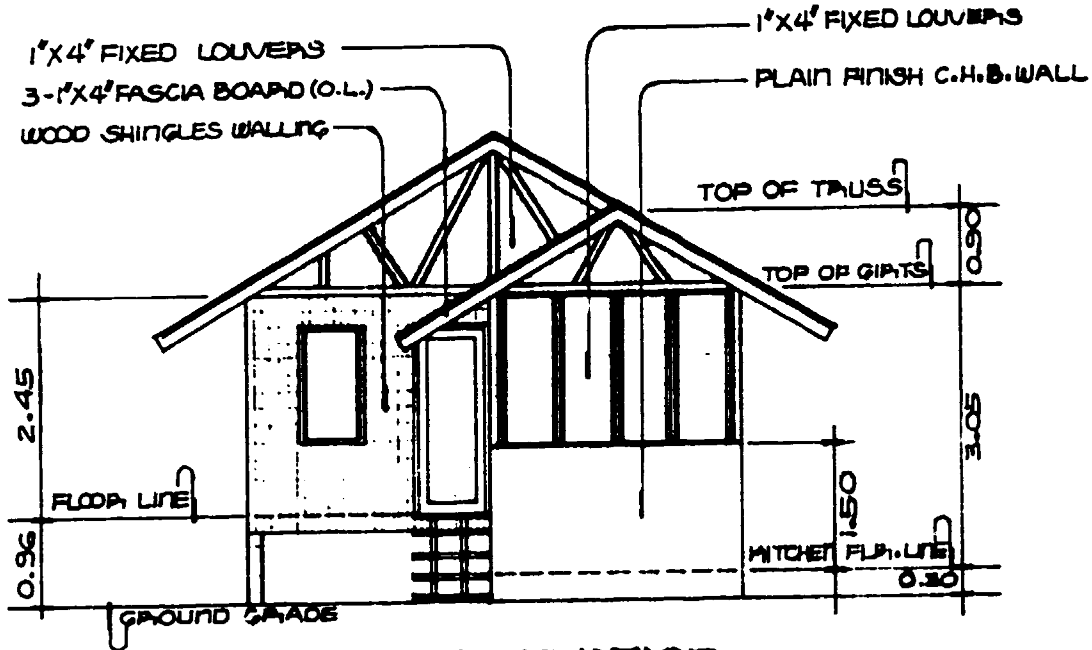
SCALE 1 : 80 METER


200 mm.
200 mm.
200 mm.
FOOTING BLOCK
310 mm.
250 mm.
30 mm.
30 mm.
30 mm.
250 mm.
310 mm.
30 mm.
#26 G.I. SHEET
TERMITE PLATE
BEND AT 45°
1/4"X 2"
POST STRAP
750 mm.
3/8"Ø ROUND
STEEL BAR
GROUND GRADE
150 mm.
150 mm.
150 mm.
1/4"Ø ROUND STEEL
BAR MATTING
ROCKS
450 mm.
450 mm.
200 mm.



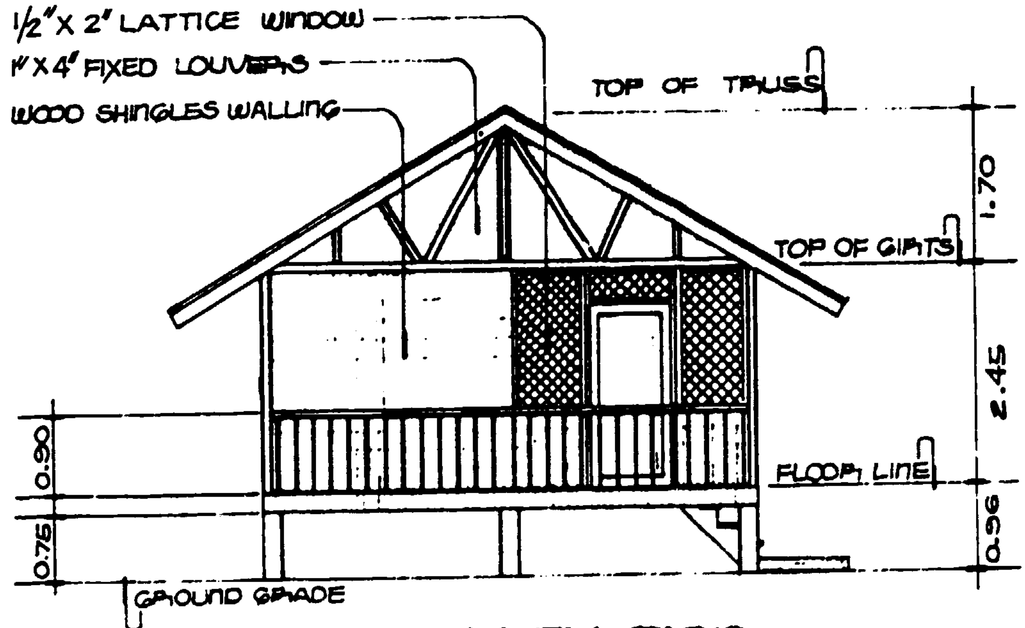
ROOF FRAMING PLAN

SCALE 1:80 METER



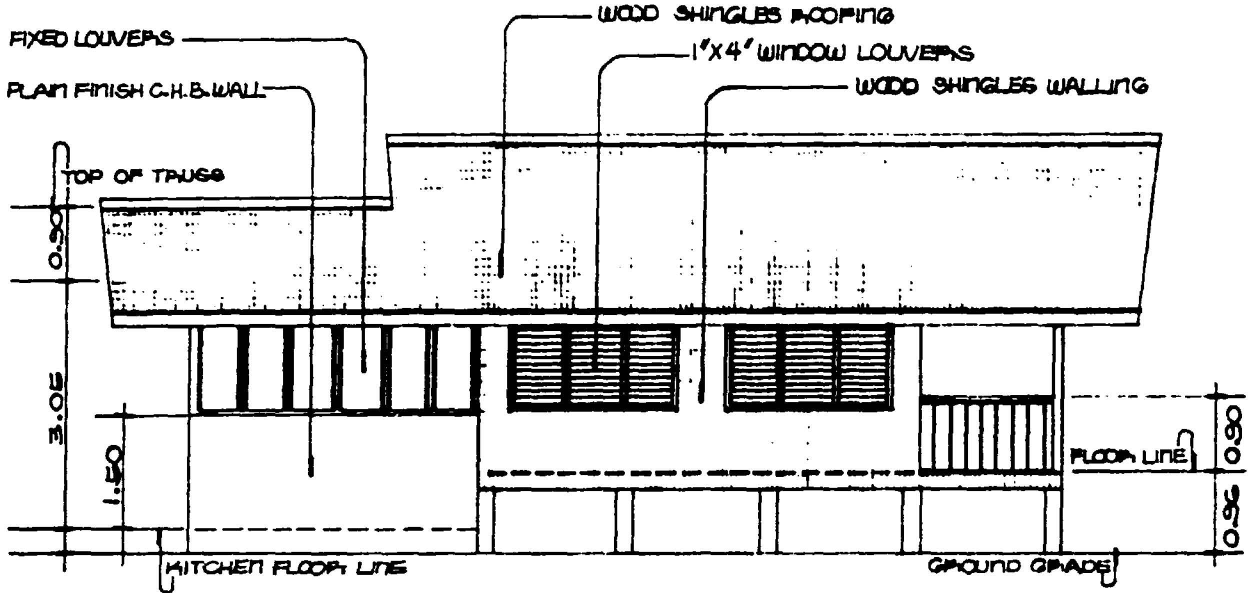
REAR ELEVATION

SCALE 1:80 METER

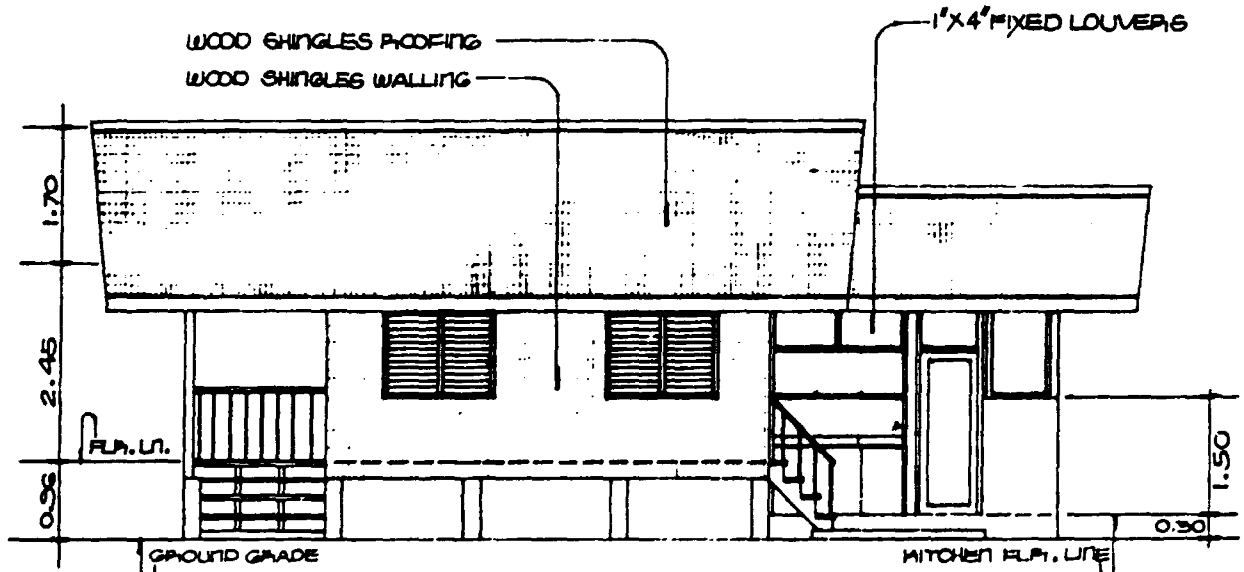


FRONT ELEVATION

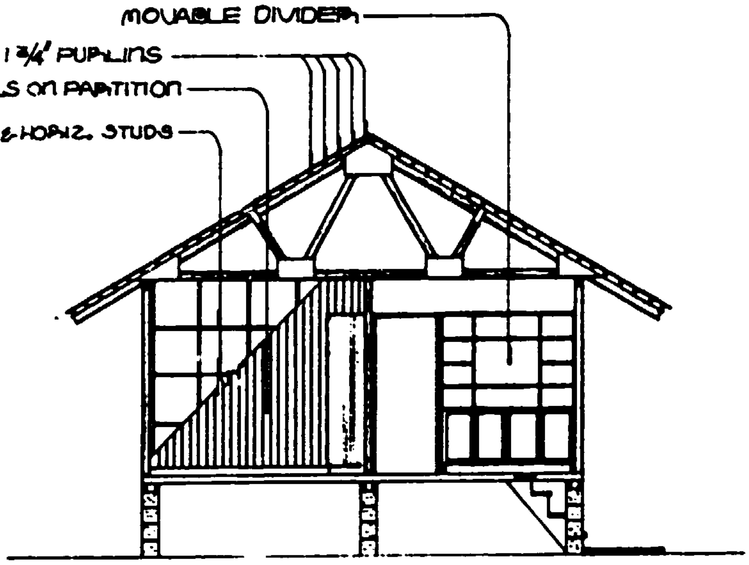
SCALE 1:80 METER



LEFT SIDE ELEVATION
SCALE 1:80 METER

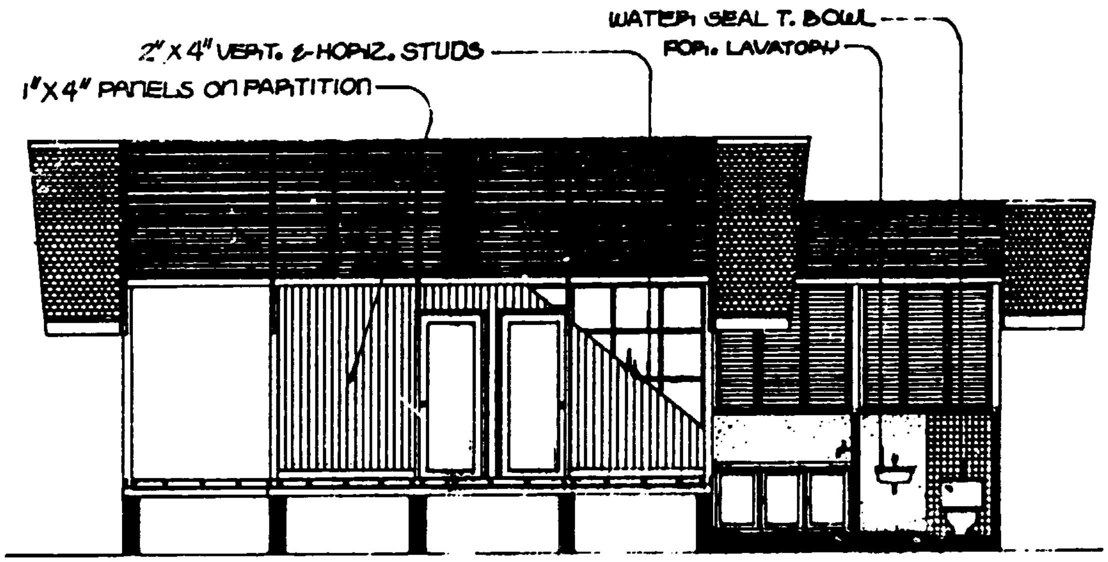


RIGHT SIDE ELEVATION
SCALE 1:80 METER



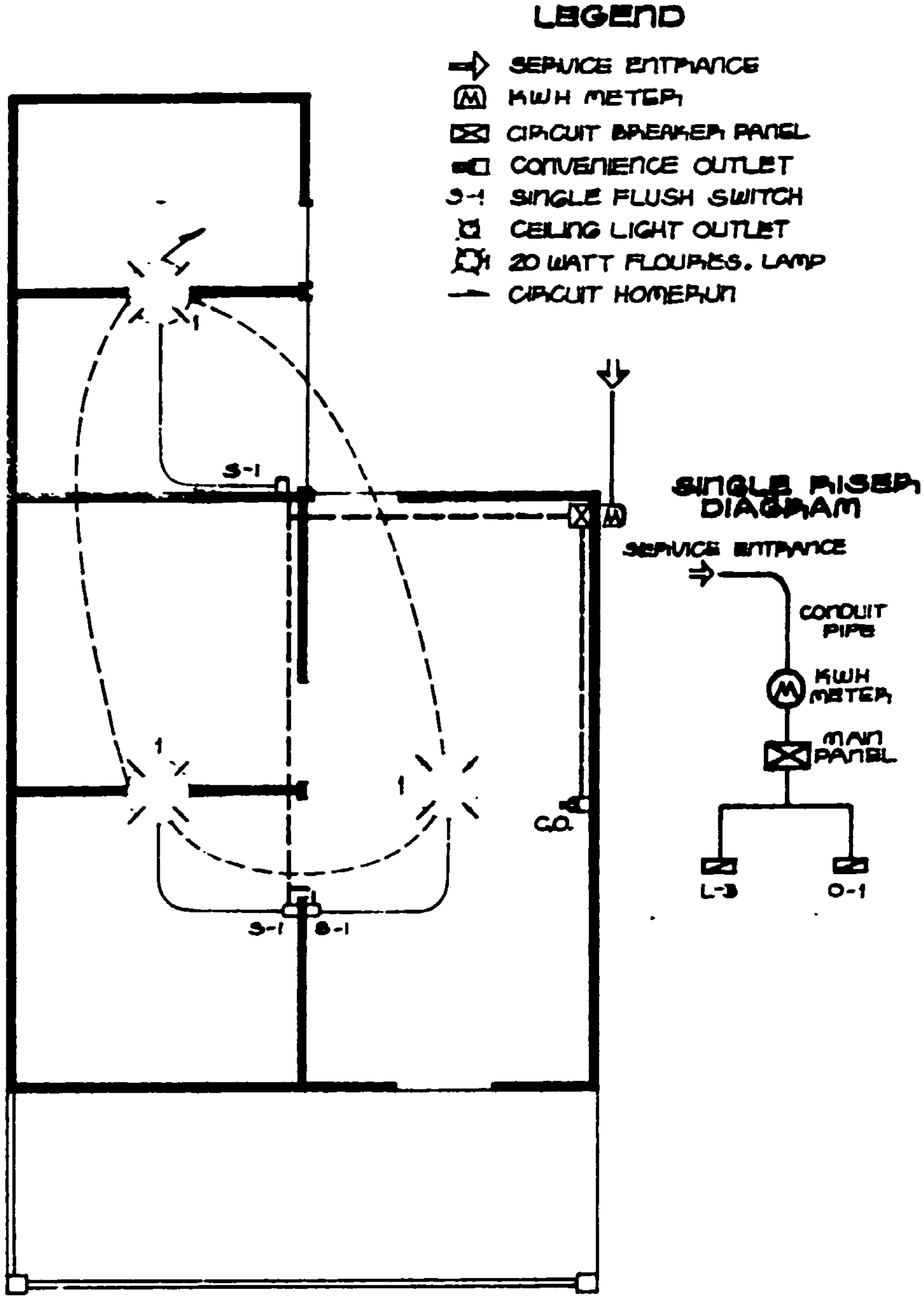
CROSS SECTION thru B' · B'

SCALE 1:80 METER



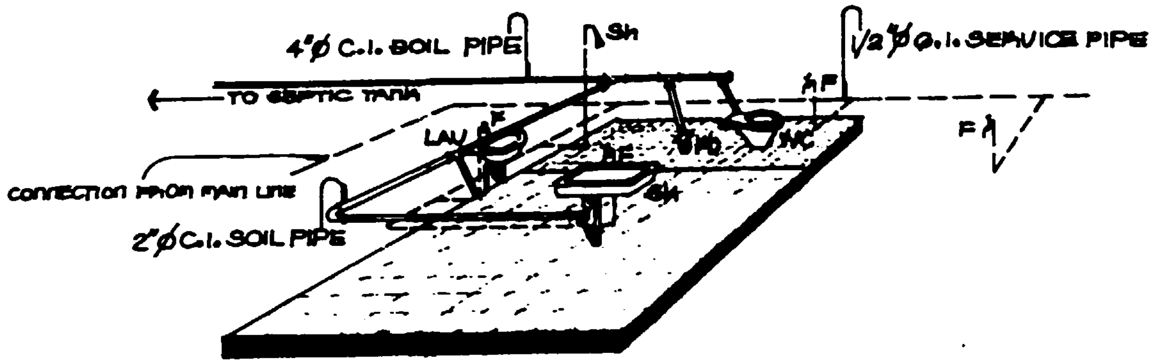
CROSS SECTION thru A' · A'

SCALE 1:80 METER



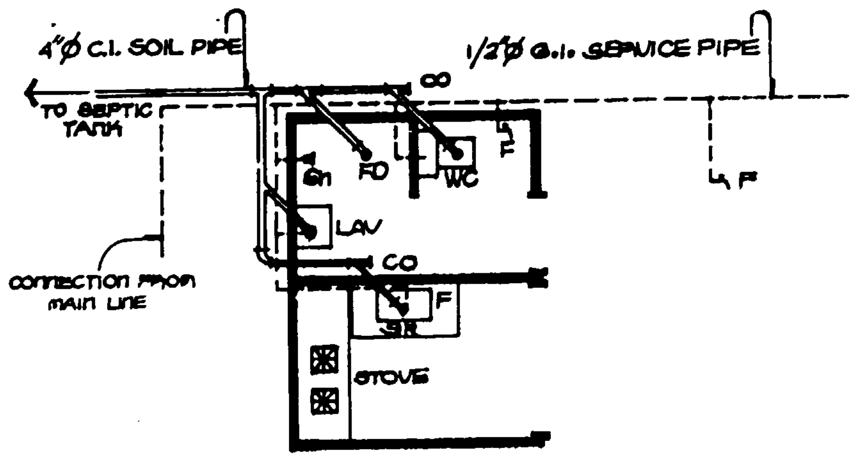
ELECTRICAL LAYOUT PLAN

SCALE 1:60 METER



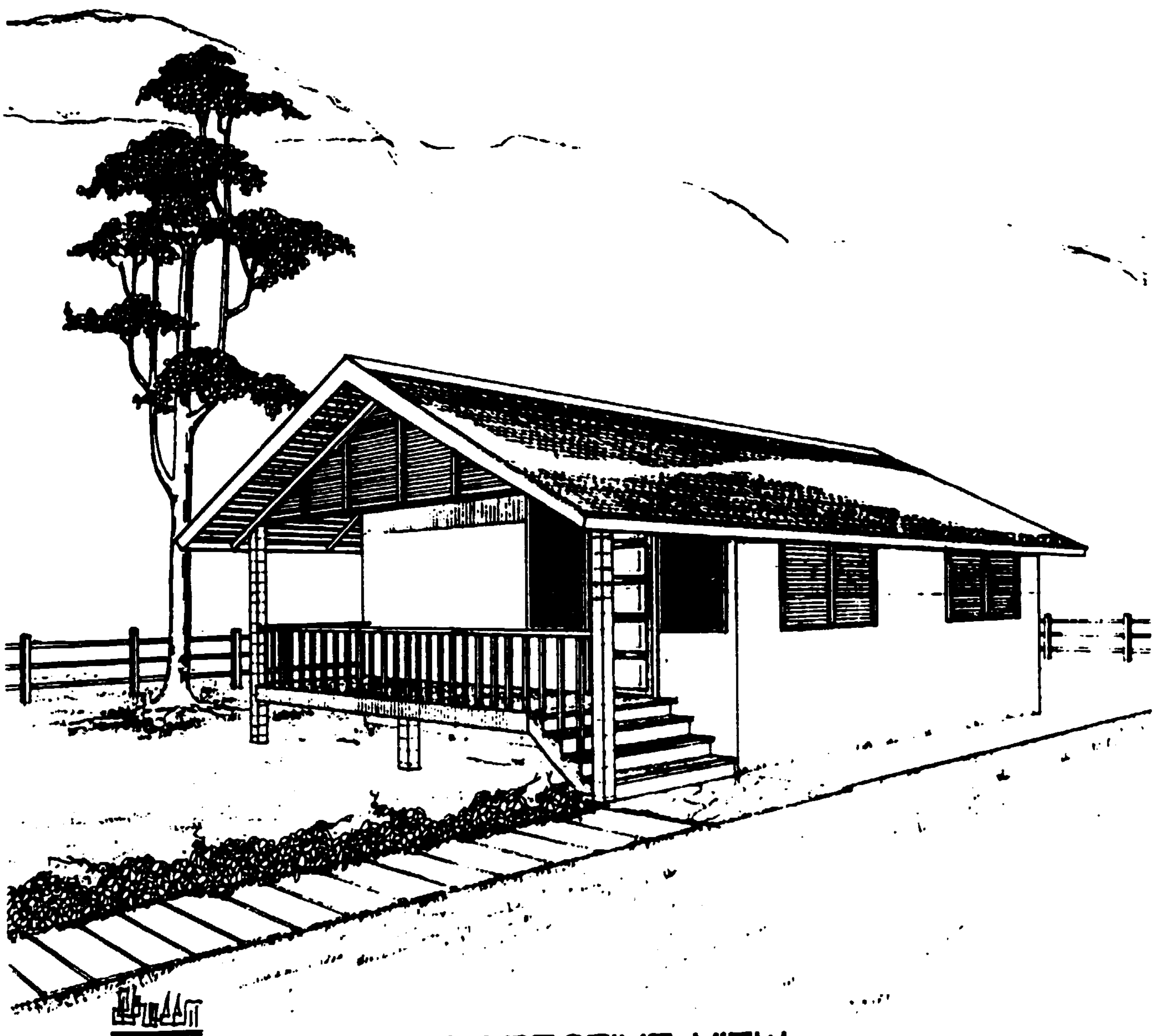
ISOMETRIC PLUMBING LAYOUT PLAN

SCALE 1 : 80 METER

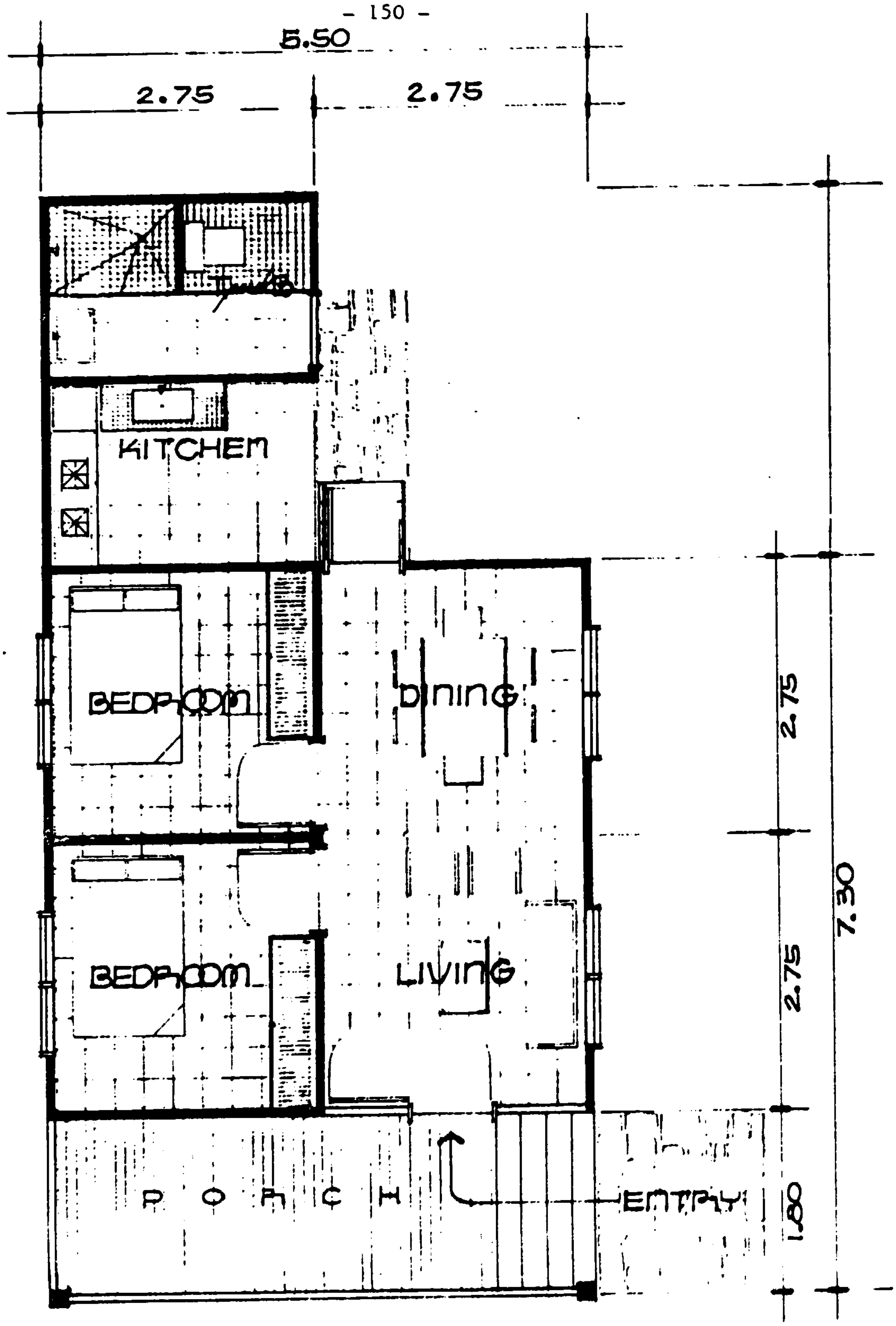


PLUMBING LAYOUT PLAN

SCALE 1 : 80 METER

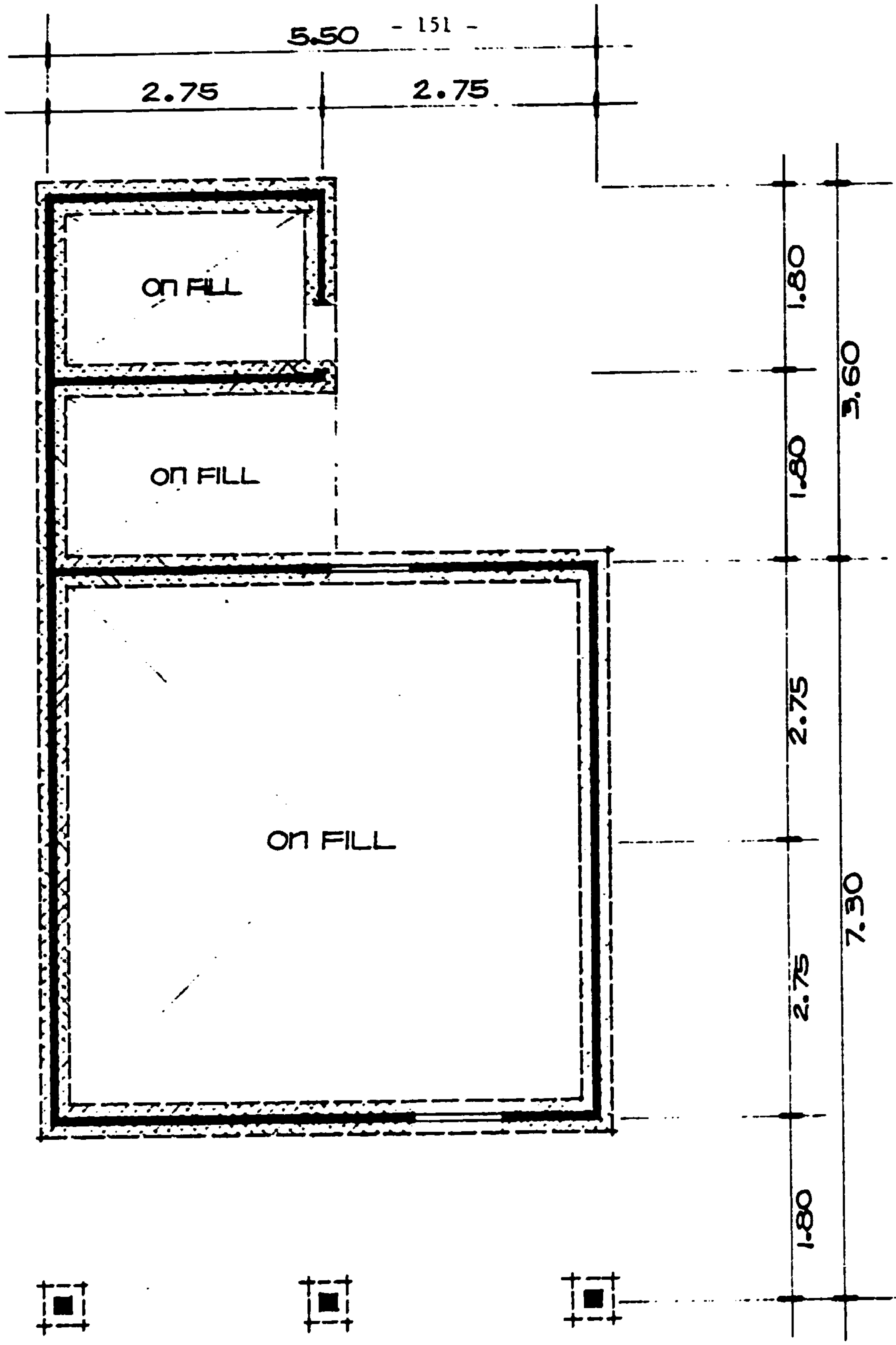


PERSPECTIVE VIEW



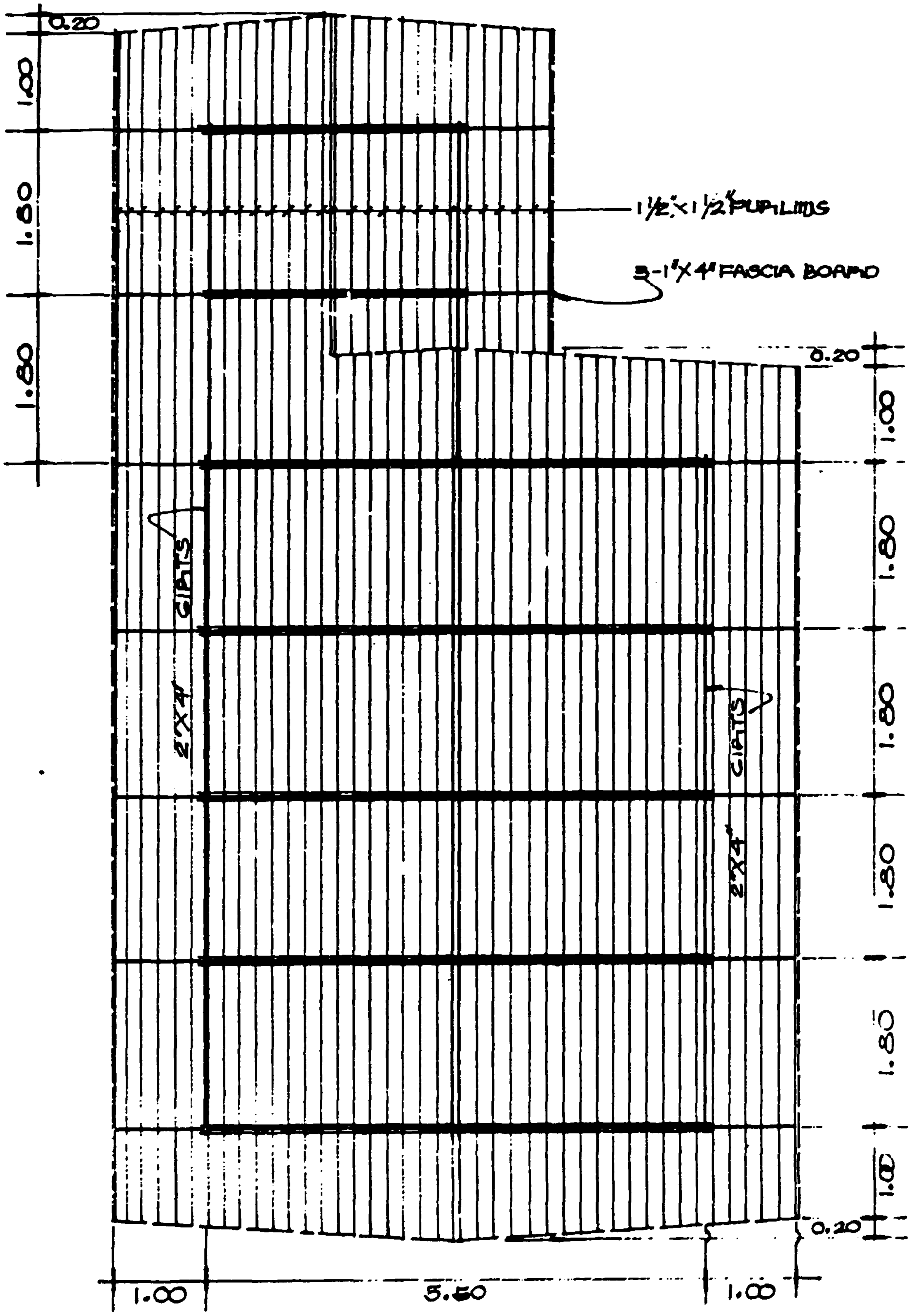
FLOOR PLAN

SCALE 1:80 METER



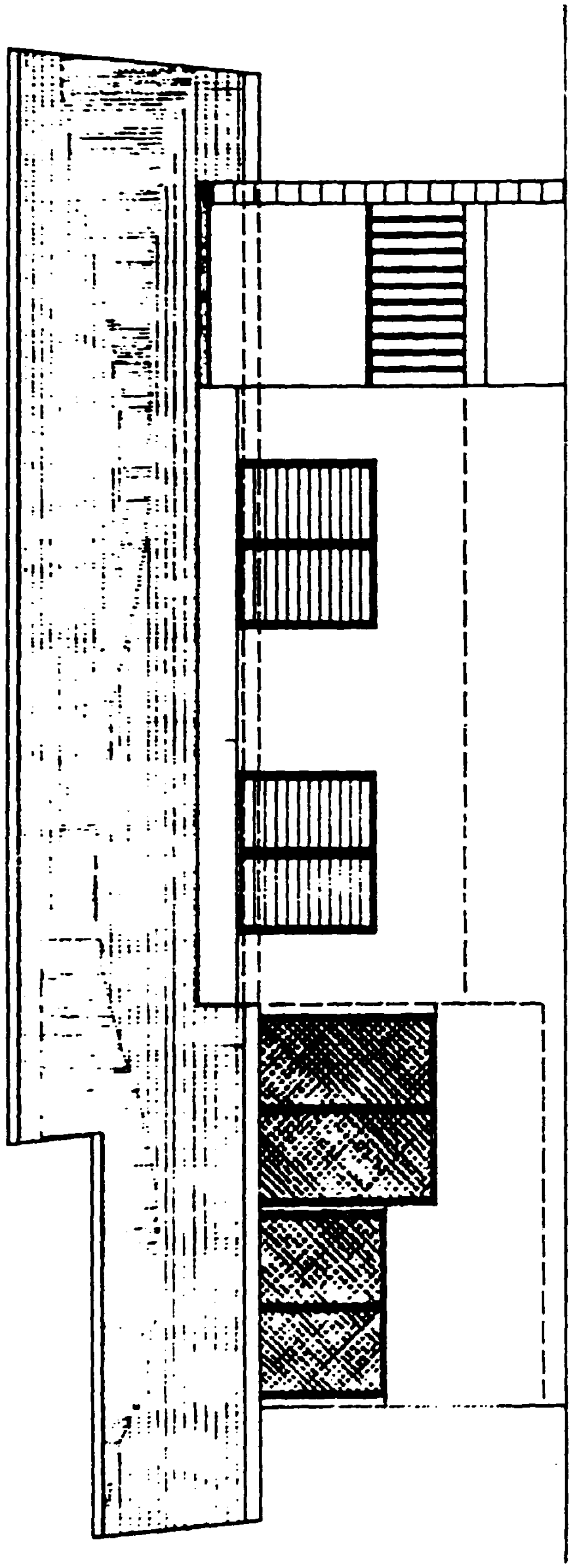
FOUNDATION PLAN

SCALE 1:60 METER



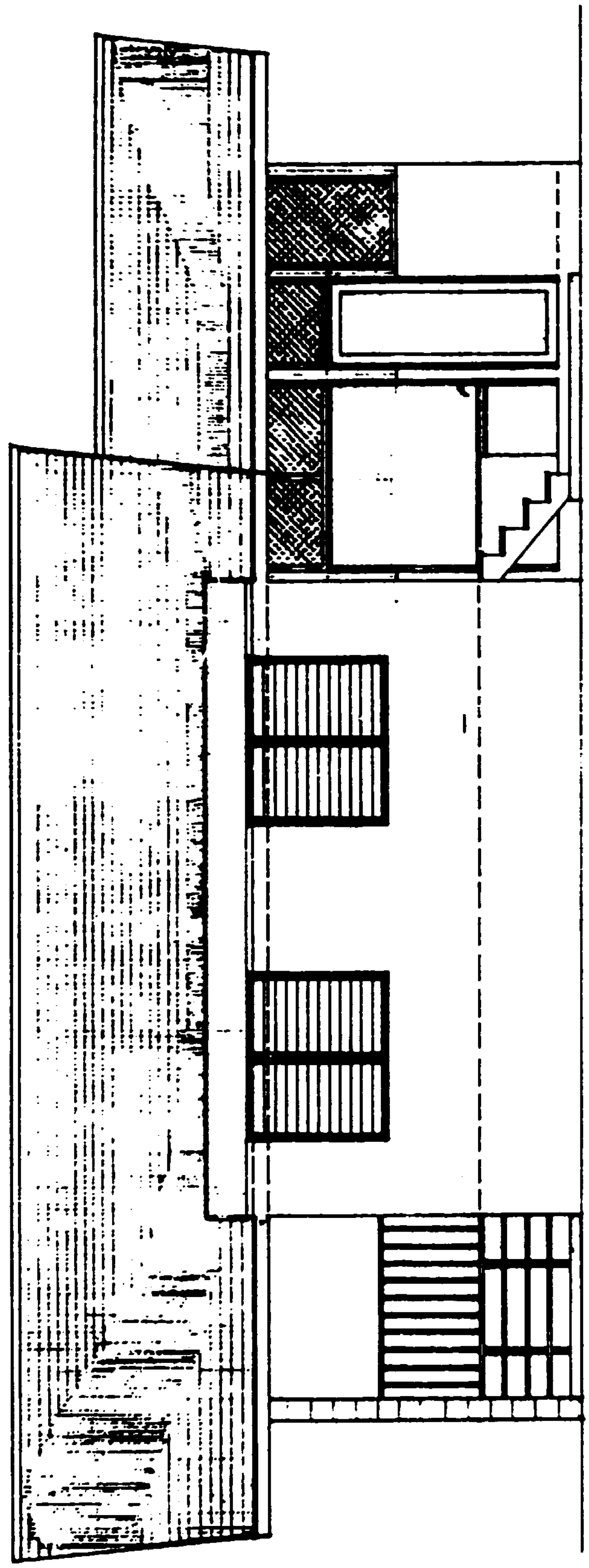
ROOF FRAMING PLAN

SCALE 1:60 METER



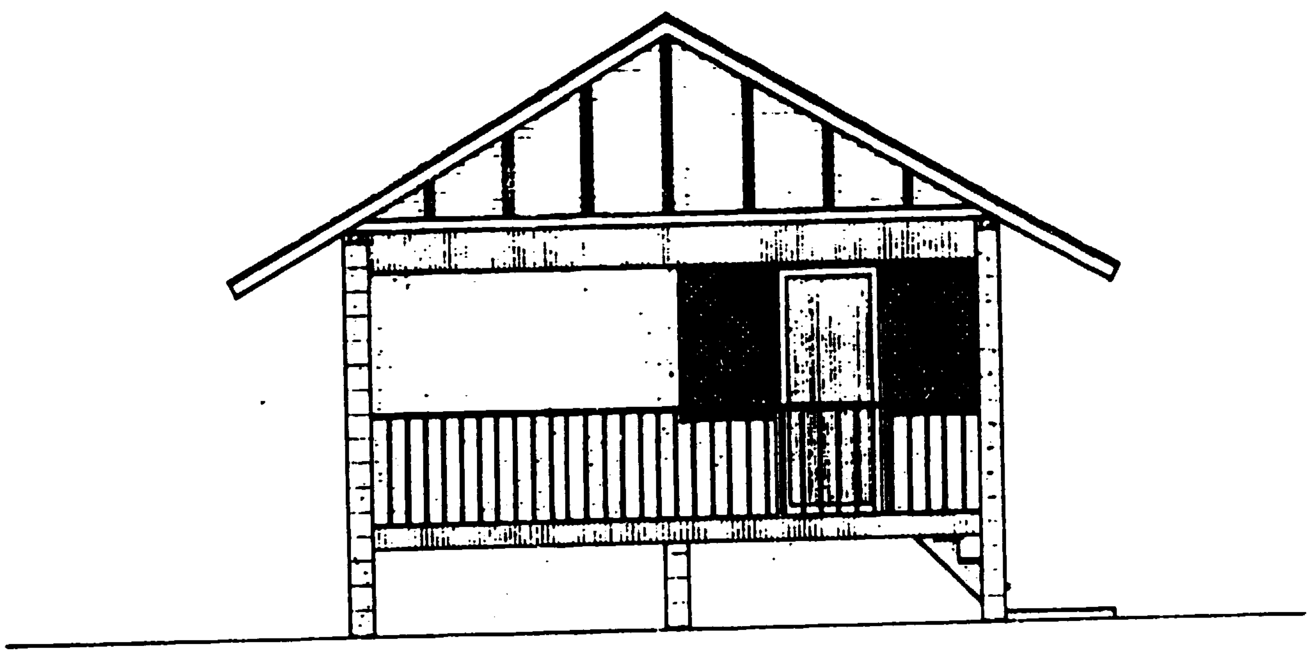
LEFT SIDE ELEVATION

SCALE 1:60 METER



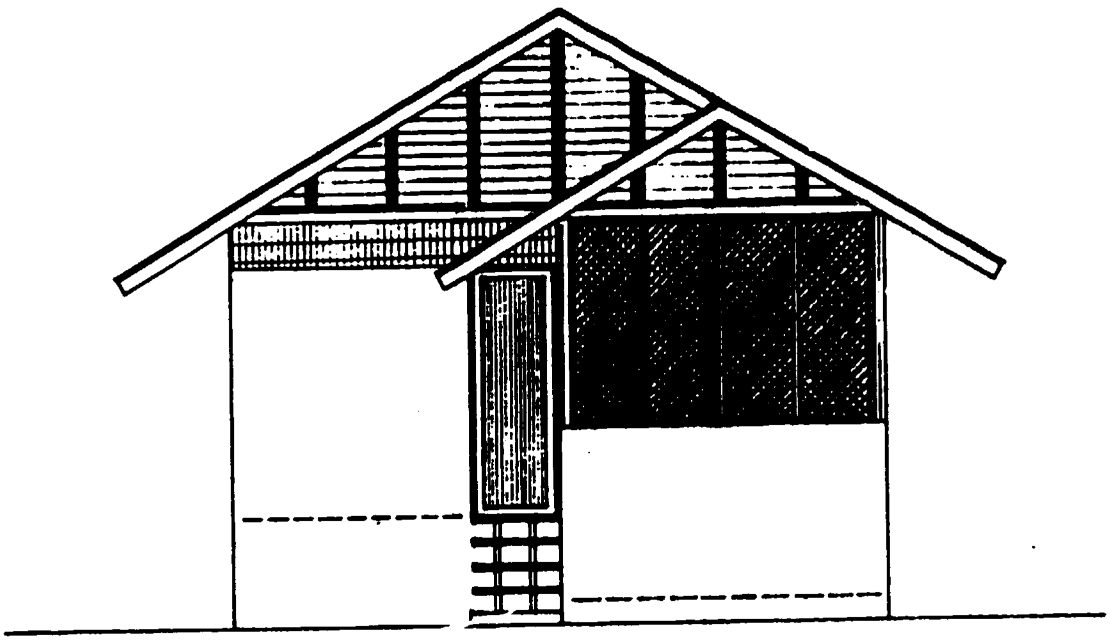
RIGHT SIDE ELEVATION

SCALE 1:60 METER

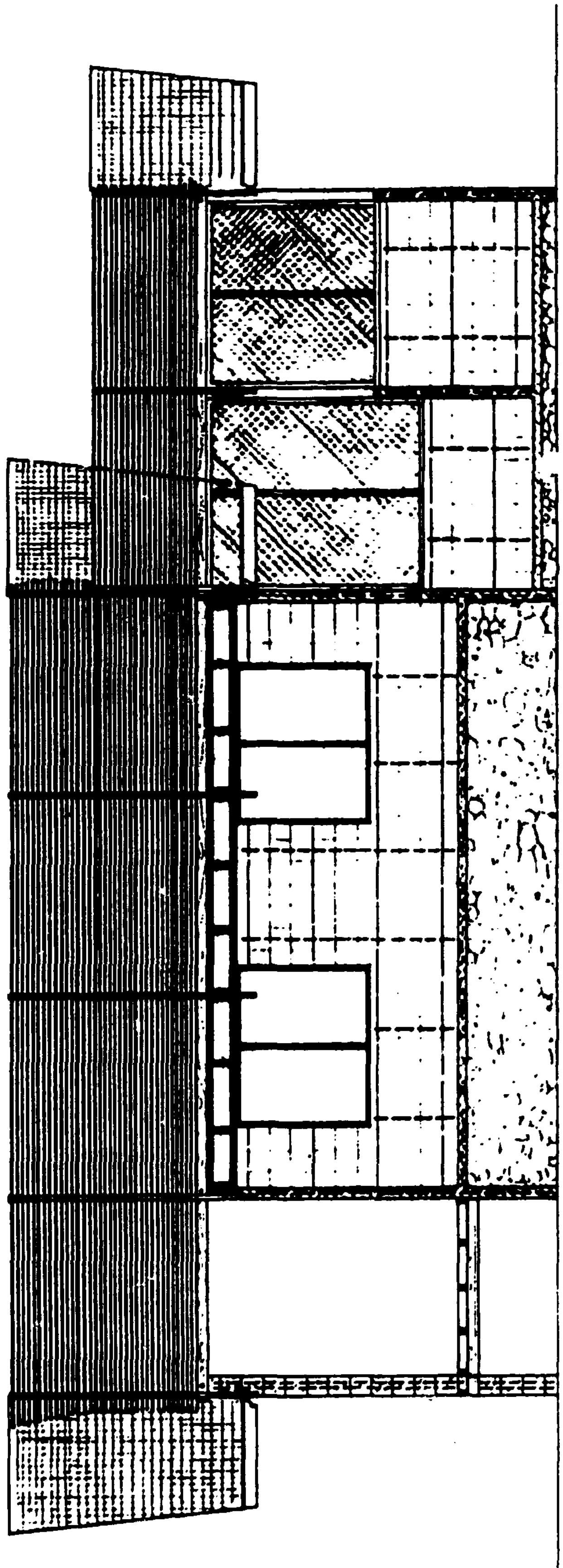


FRONT ELEVATION

SCALE 1:60 METER

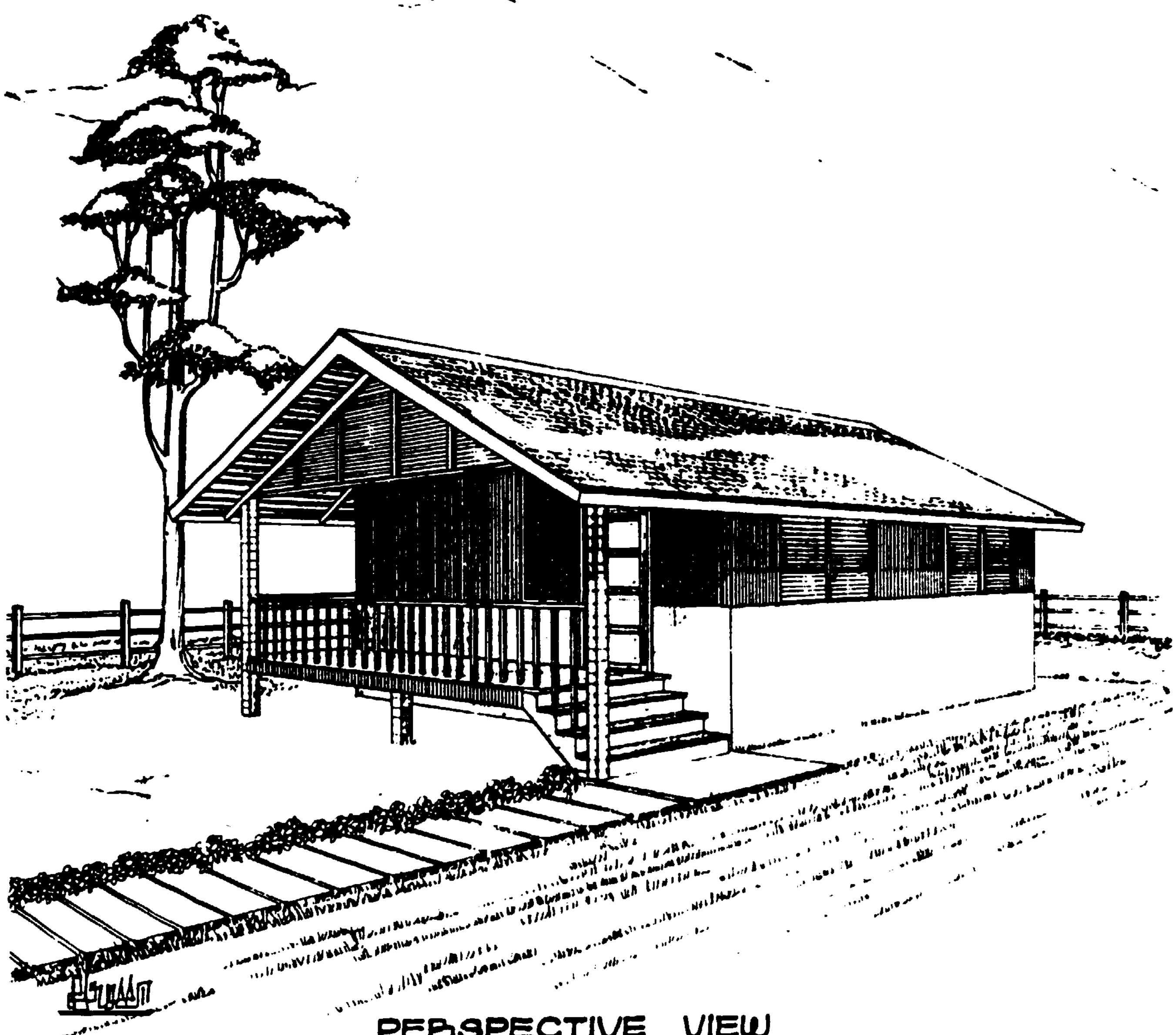


REAR ELEVATION
SCALE 1:80 METER

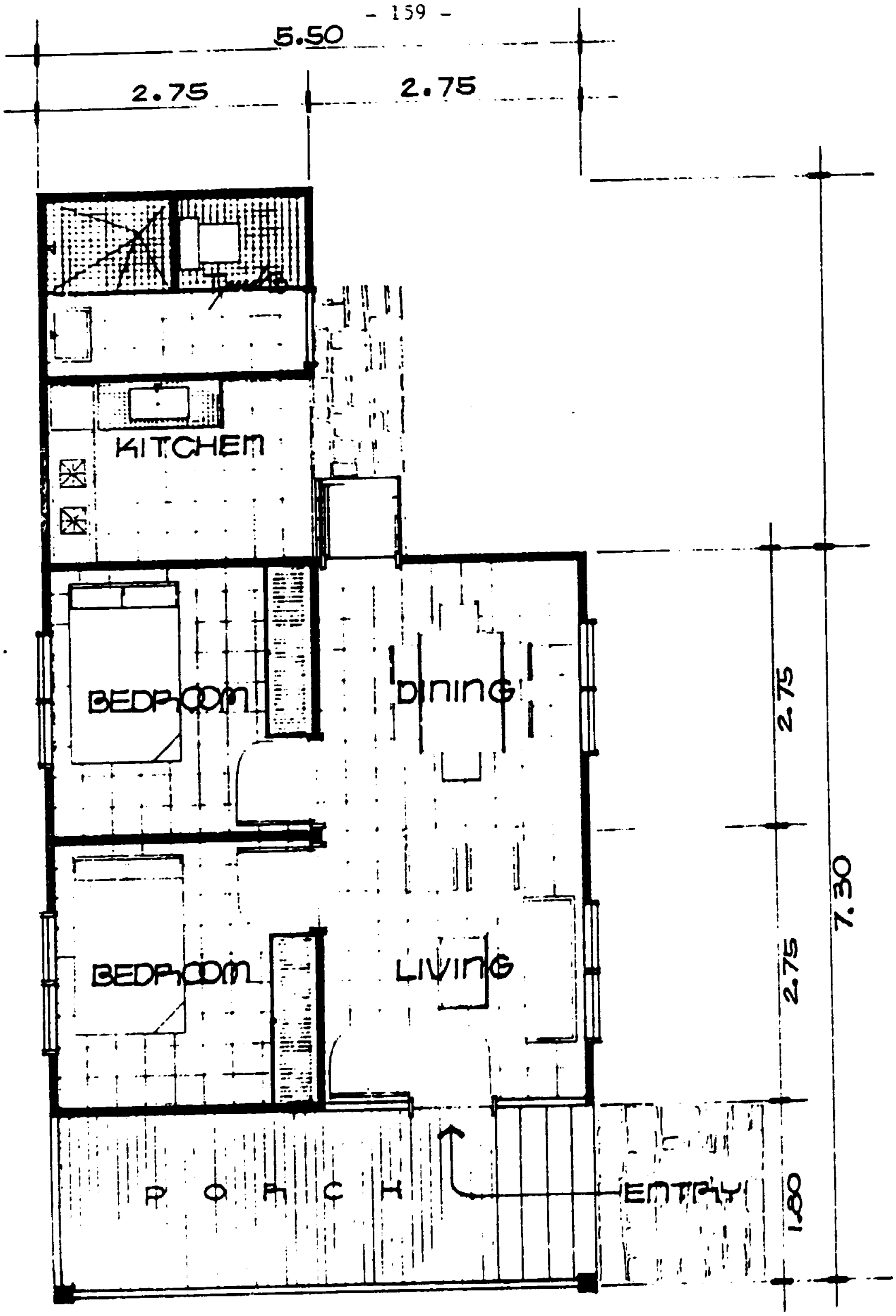


LONGITUDINAL CROSS SECTION

SCALE 1:60 METER

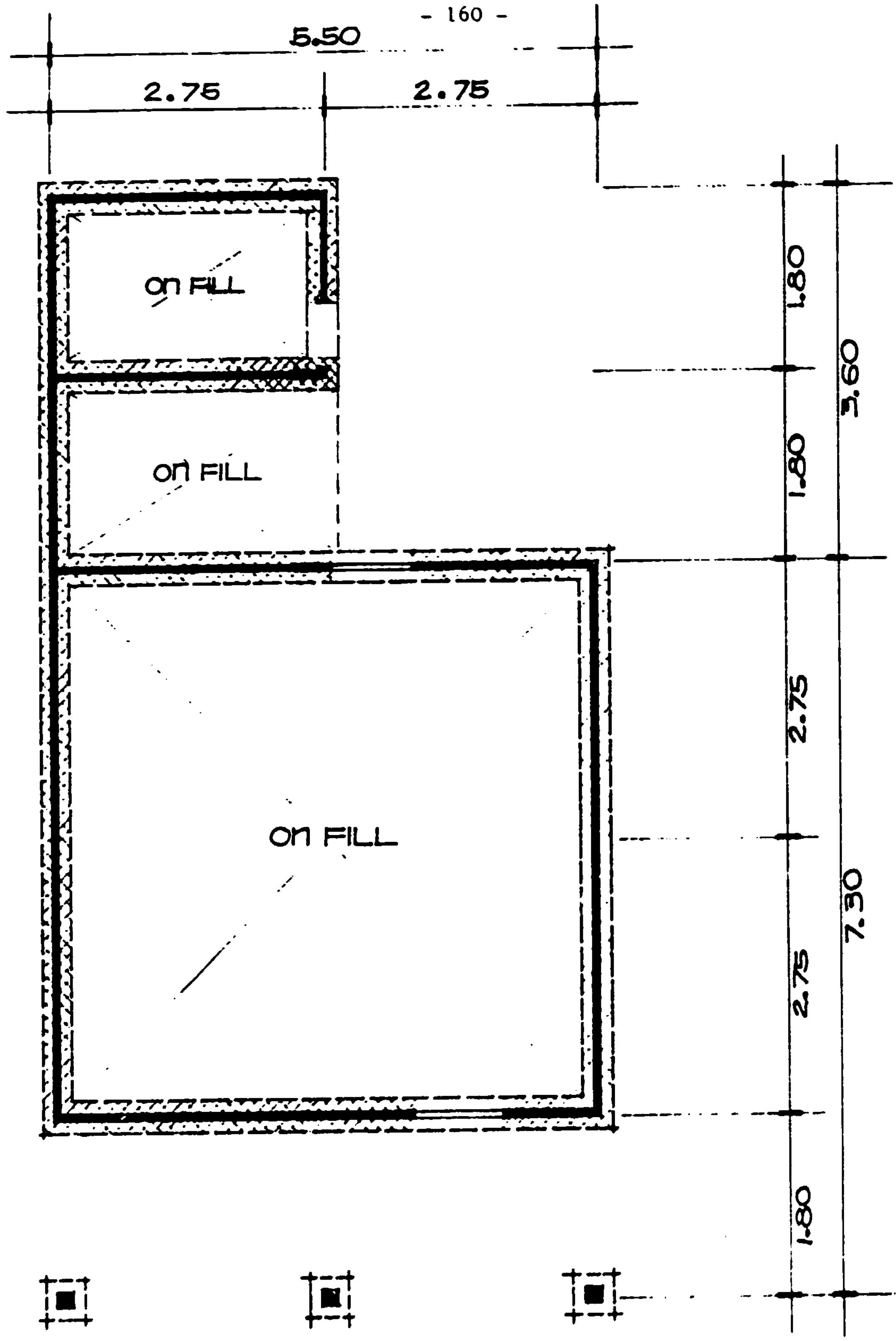


PERSPECTIVE VIEW



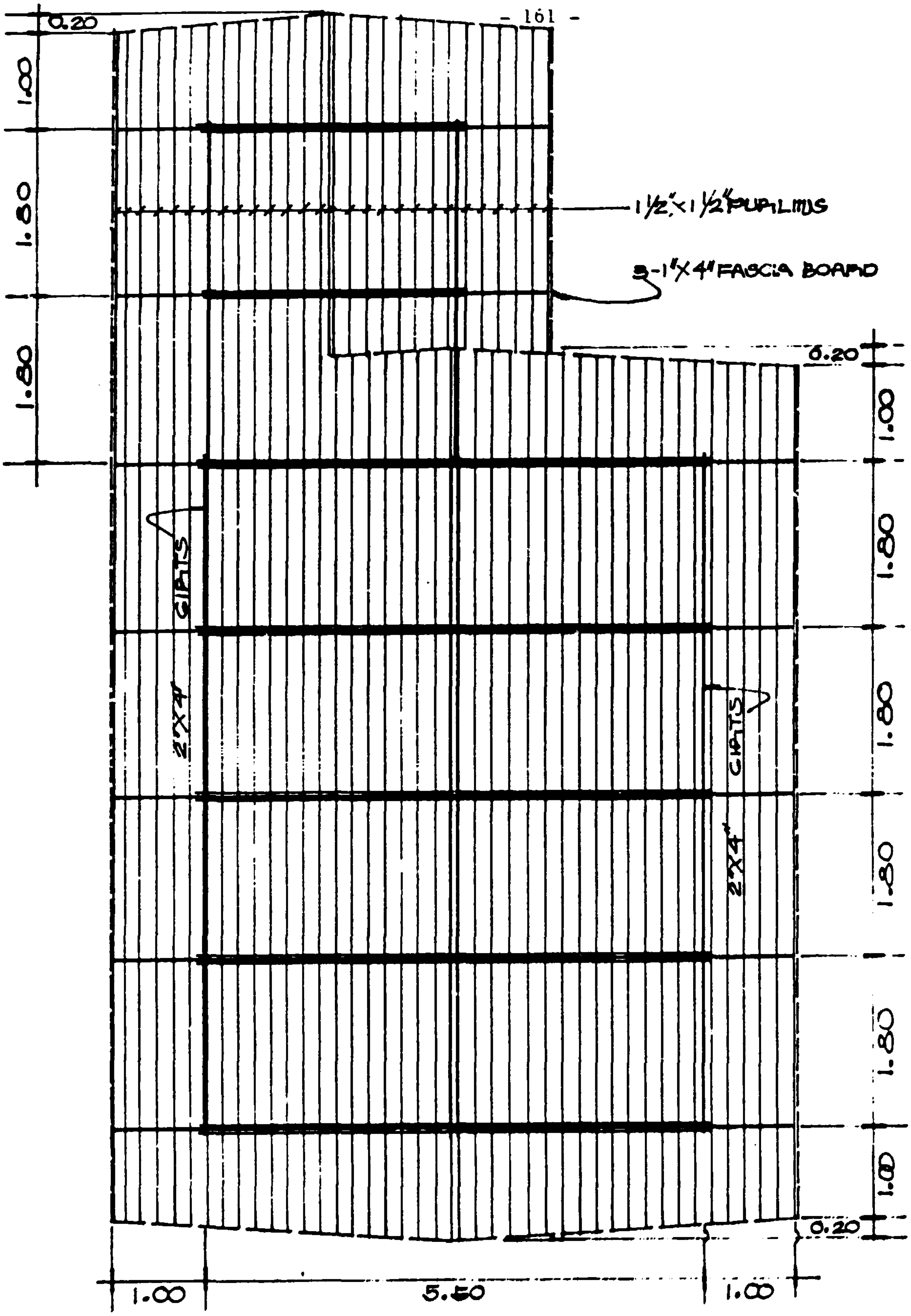
FLOOR PLAN

SCALE 1:100 METER



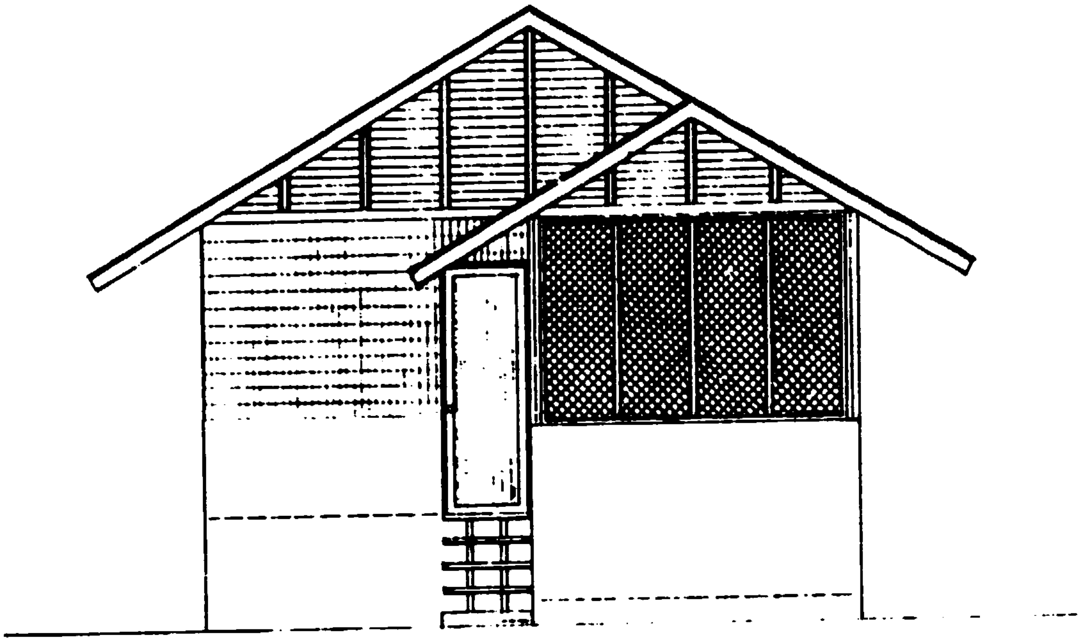
FOUNDATION PLAN

SCALE 1:60 METER



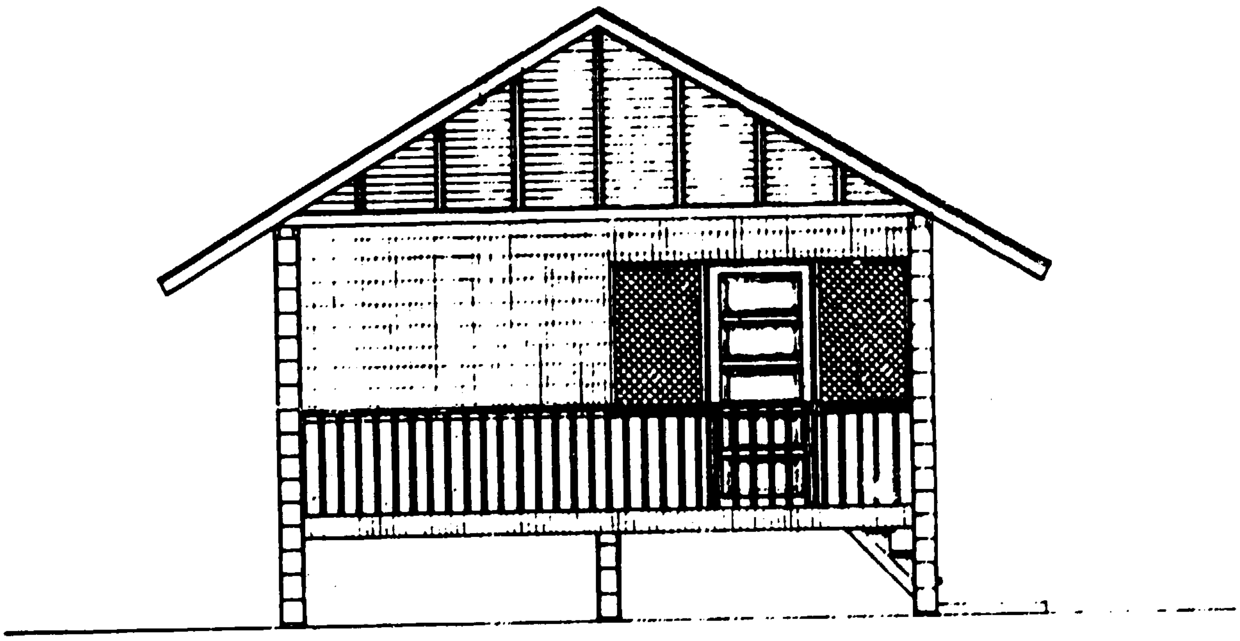
ROOF FRAMING PLAN

SCALE 1:60 METER



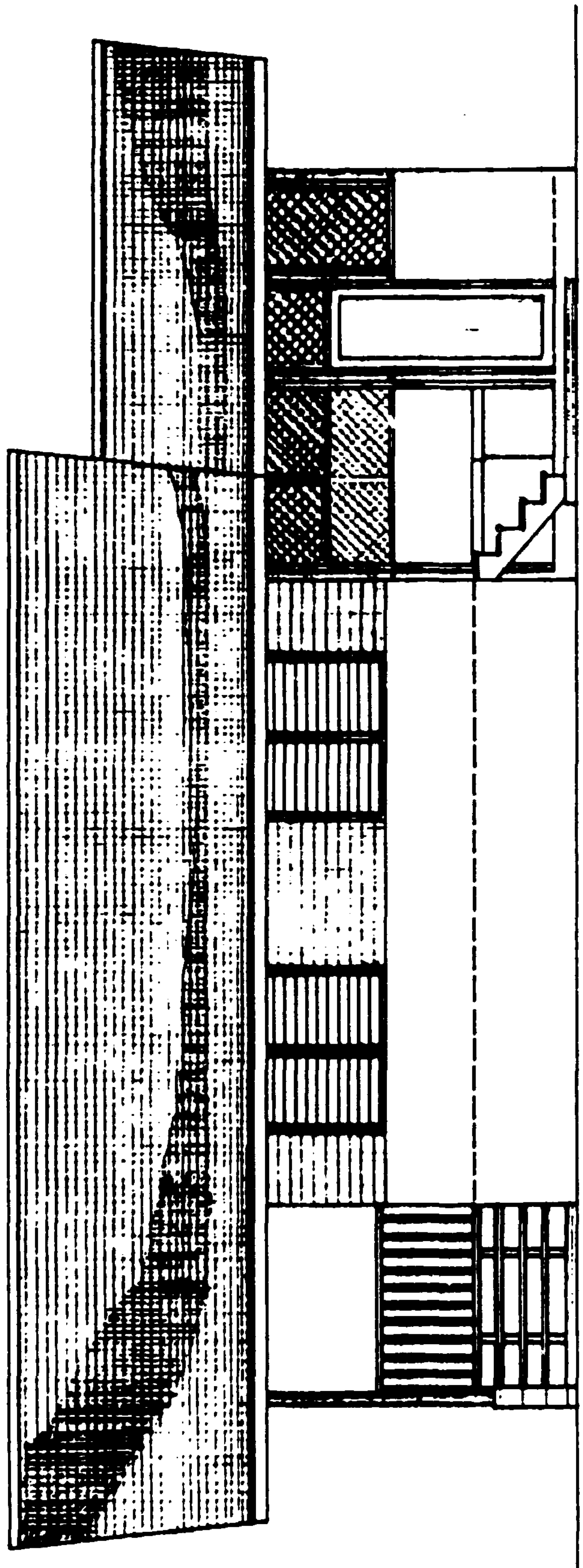
REAR ELEVATION

SCALE 1:60 METER



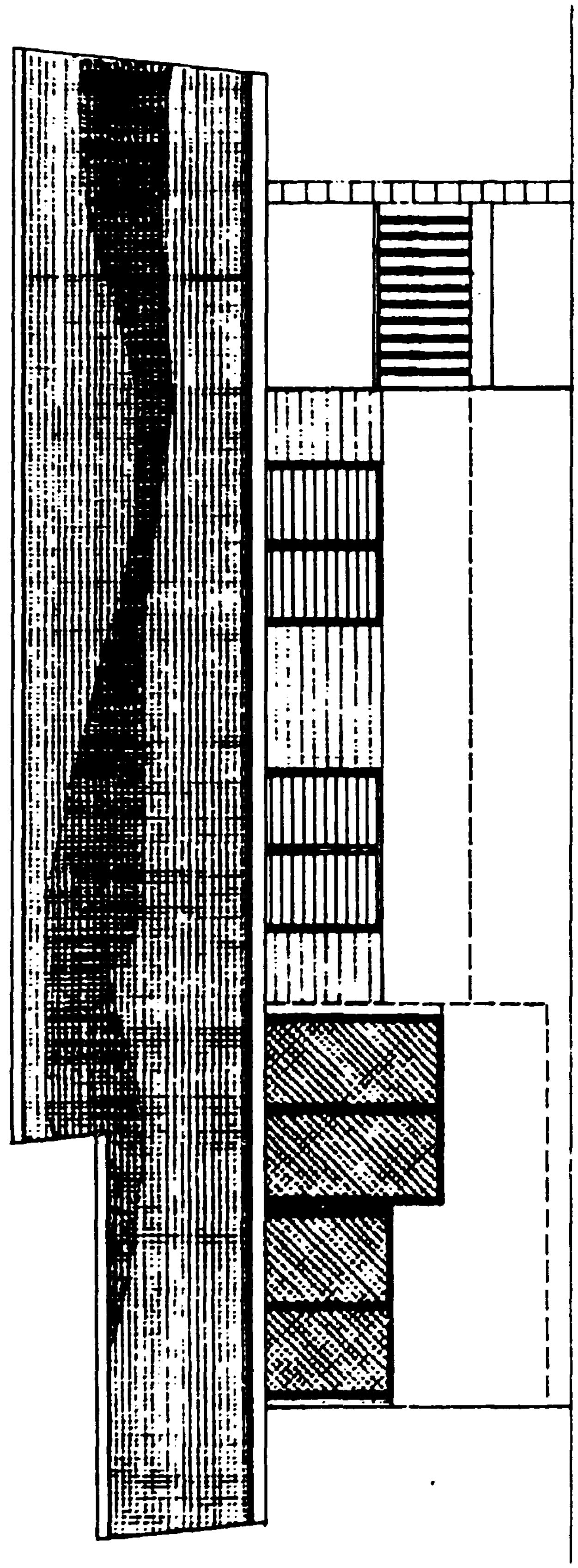
FRONT ELEVATION

SCALE 1:60 METER



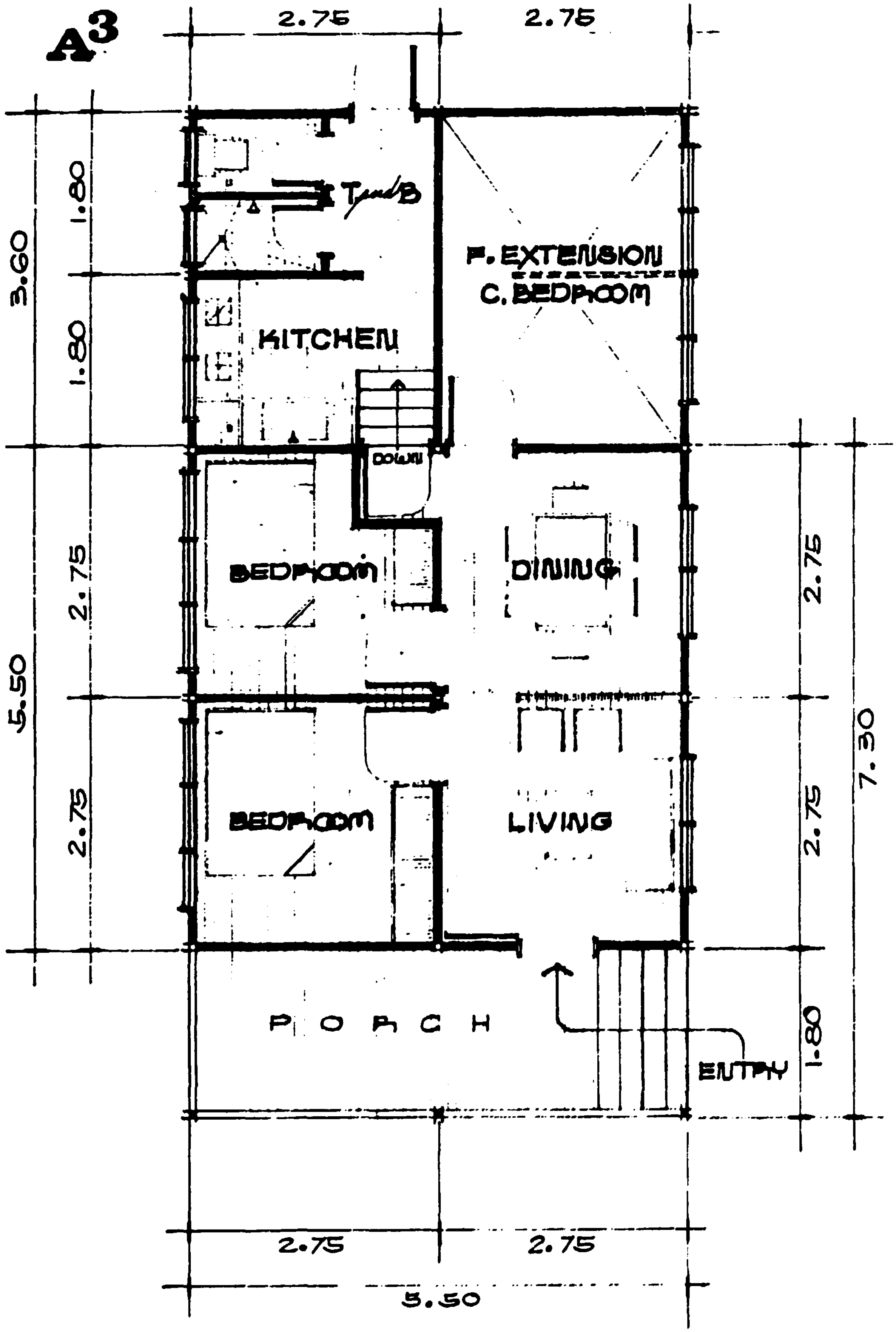
RIGHT SIDE ELEVATION

SCALE 1:60 METER



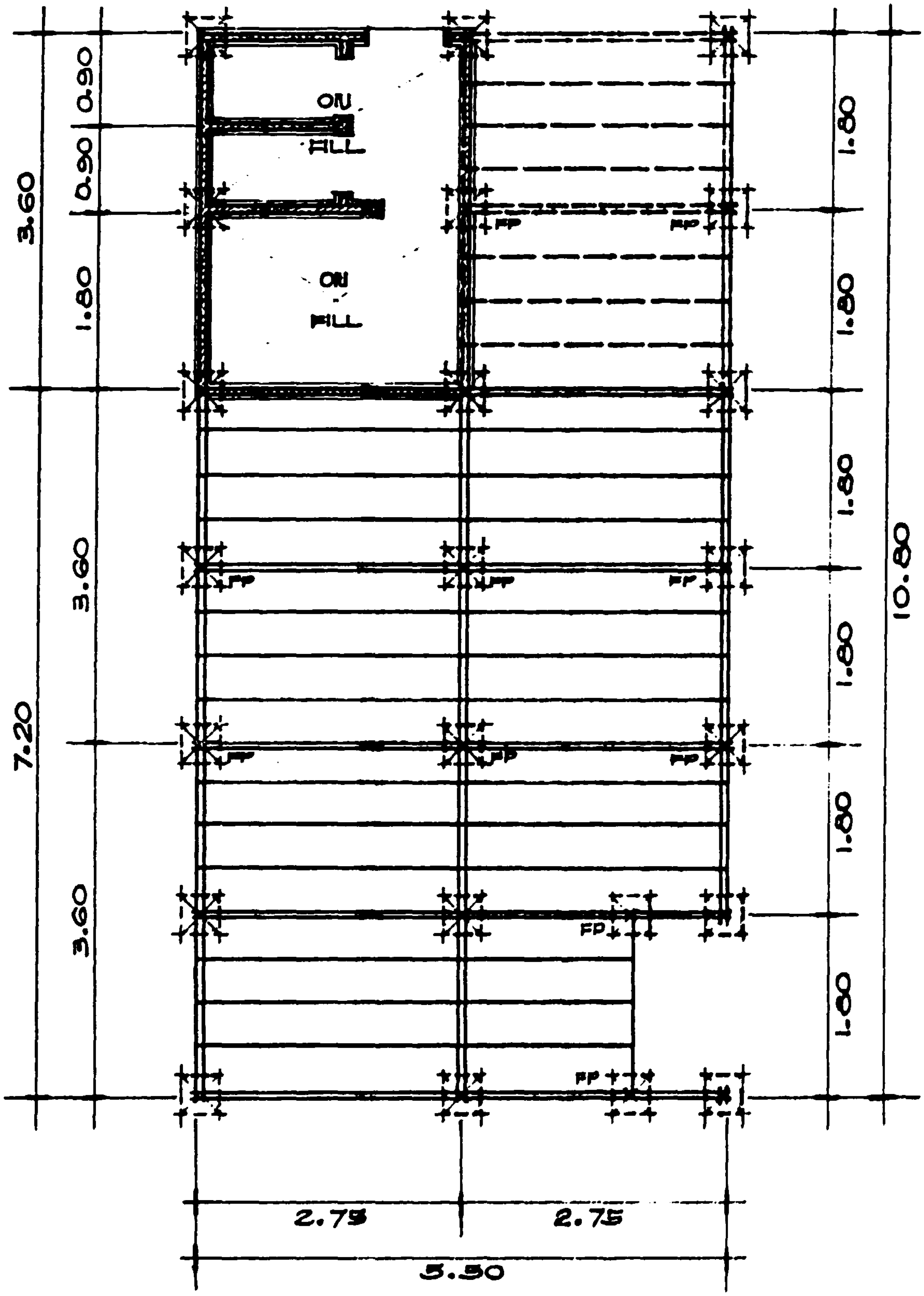
LEFT SIDE ELEVATION

SCALE 1 : 60 METER



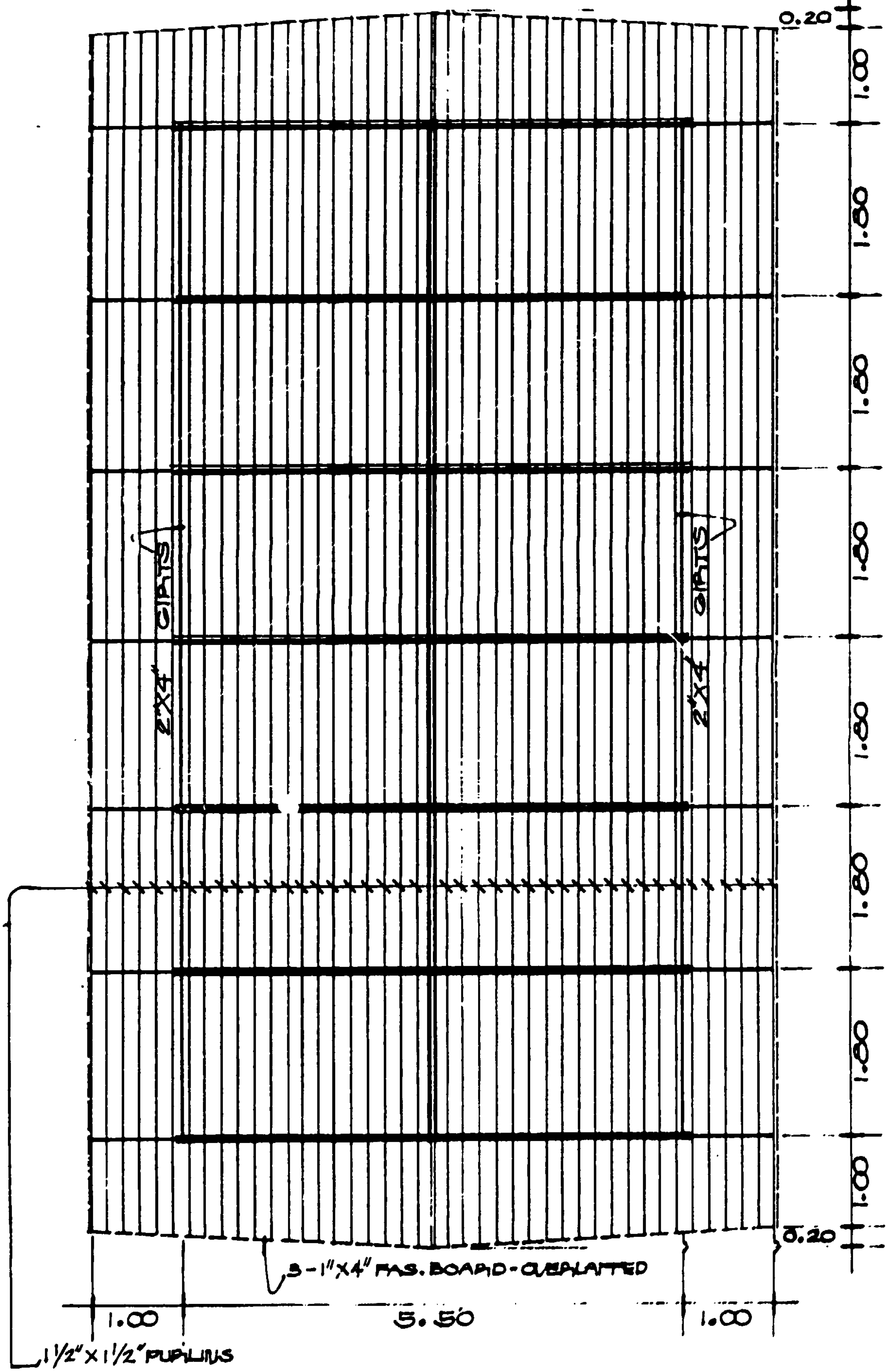
FLOOR PLAN

SCALE 1:60 METER



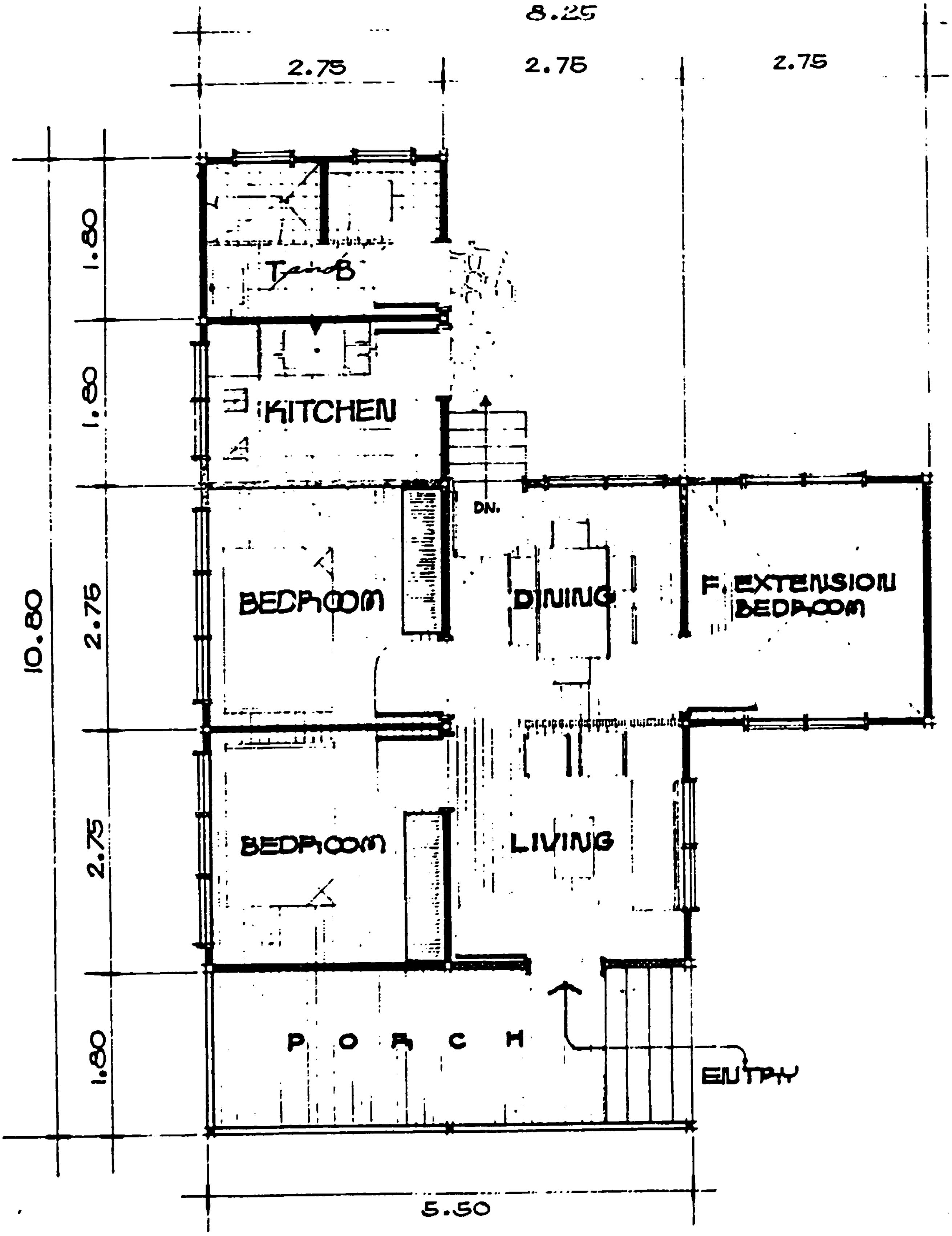
FOUNDATION and FLOOR FRAMING PLAN

SCALE 1:60 METER

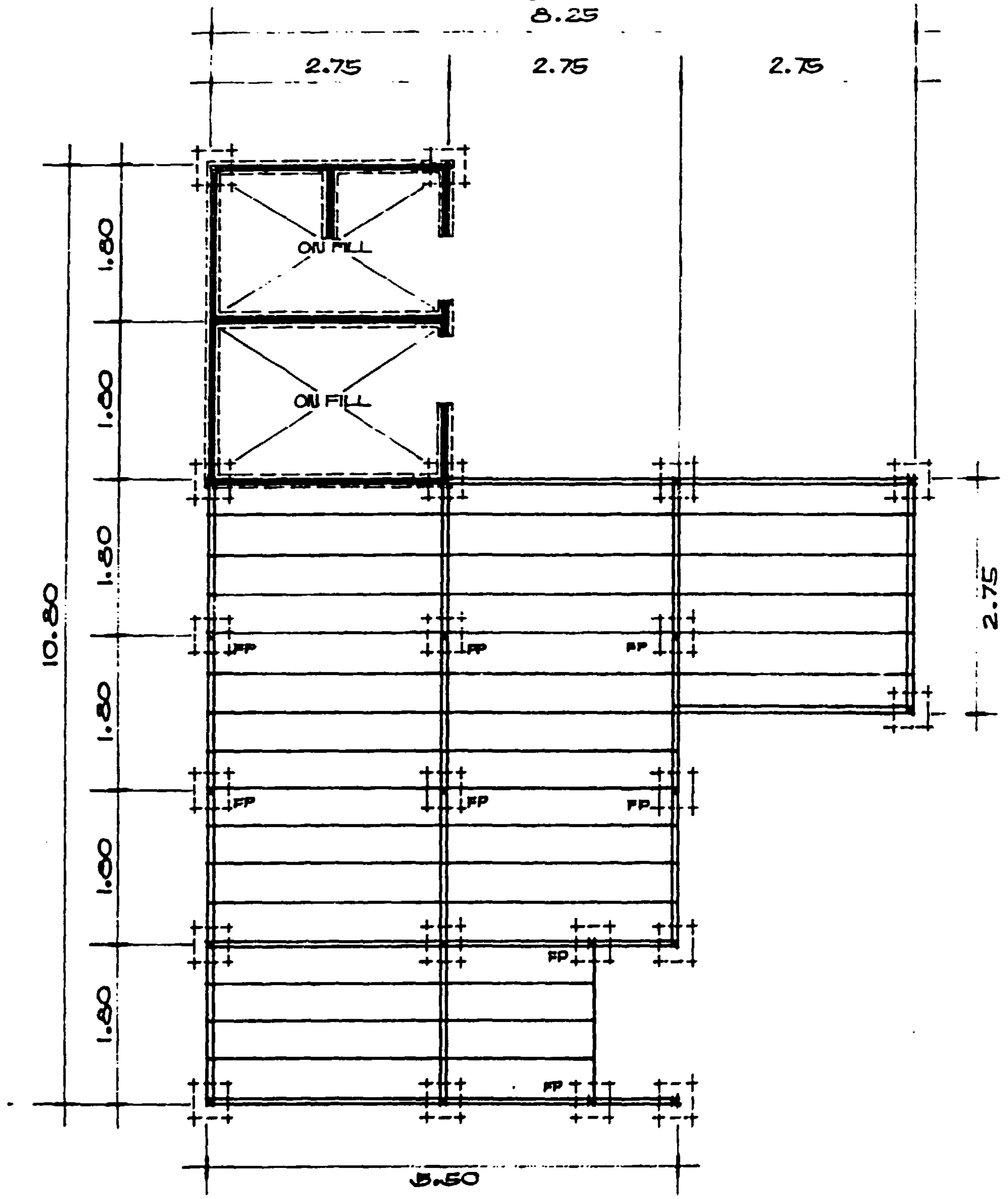


ROOF FRAMING PLAN

SCALE 1:20 METER

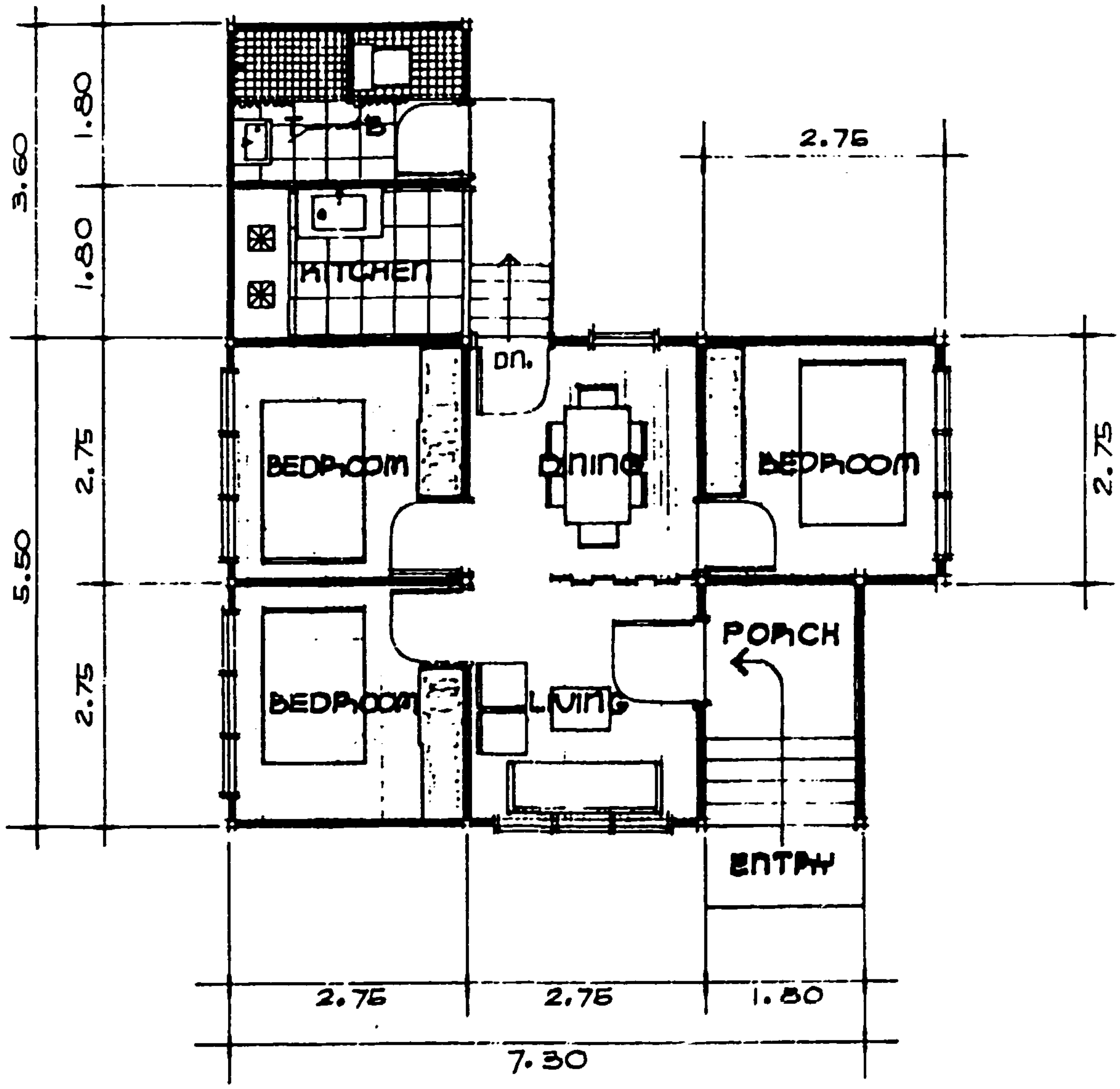


FLOOR PLAN
SCALE 1:60 METER



FOUNDATION and FLOOR FRAMING PLAN

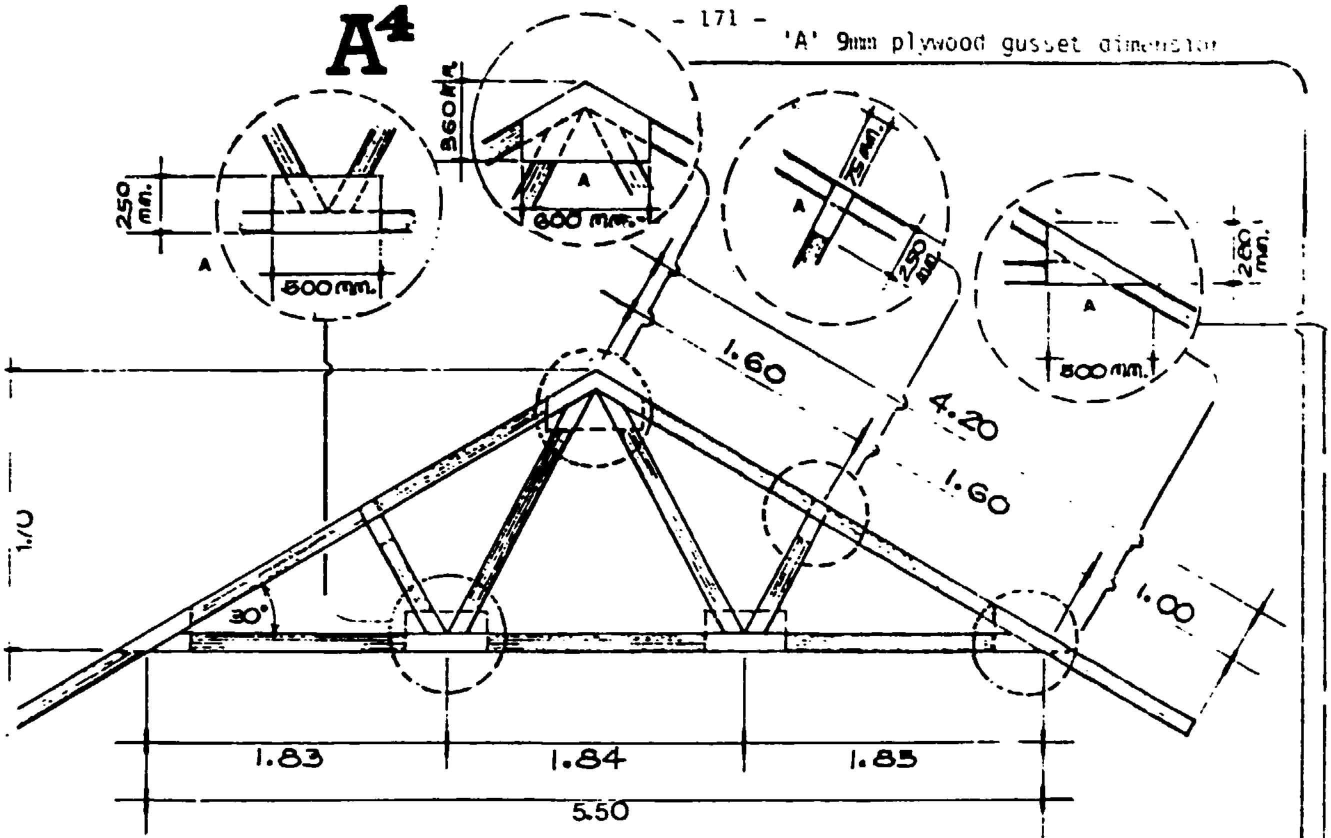
SCALE 1:80 METER



FLOOR PLAN

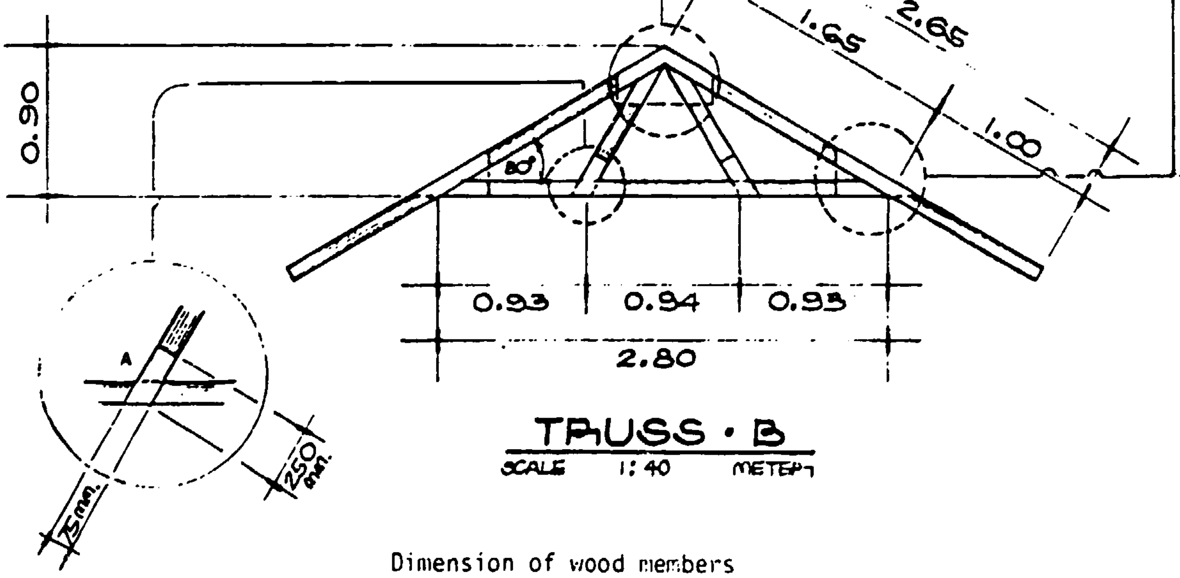
SCALE 1 : 80 METER

A4



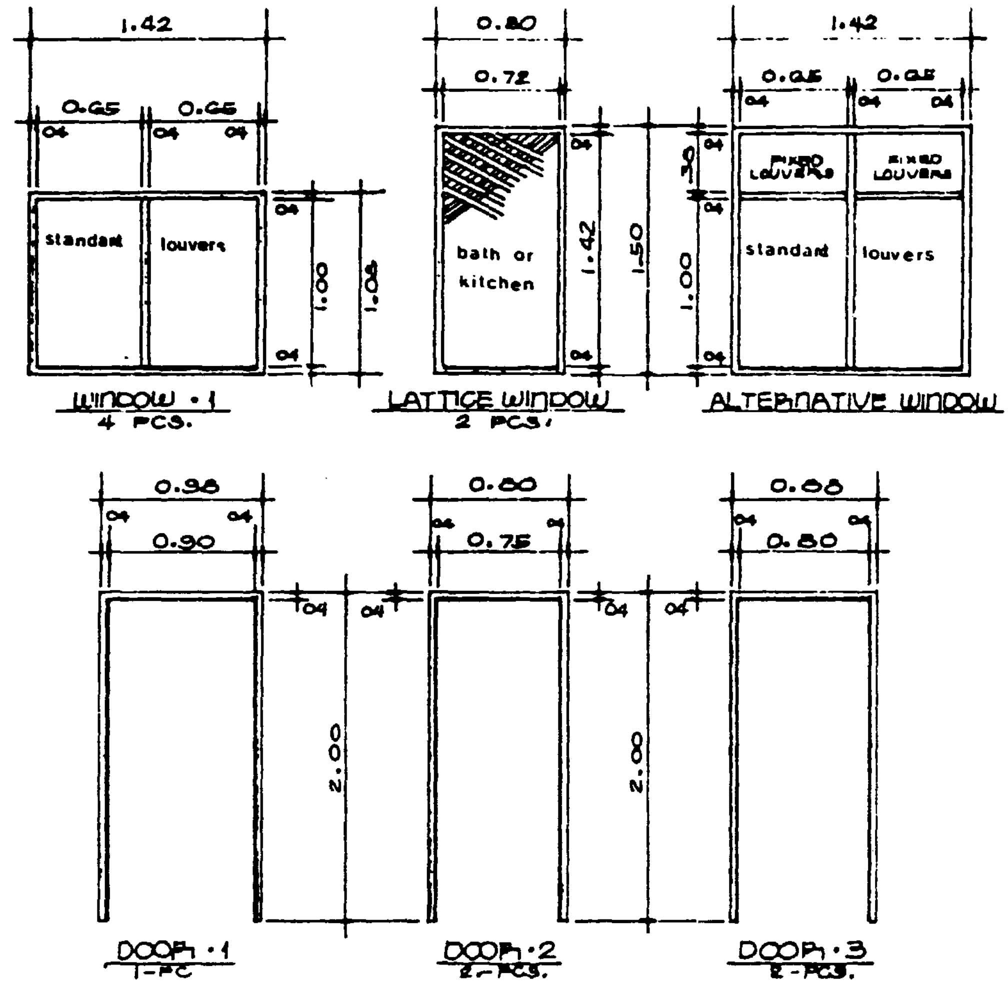
TRUSS • A
SCALE 1:40 METER

Dimension of wood members:
Top and bottom chords - 90 x 40 mm
Webs - 70 x 40 mm

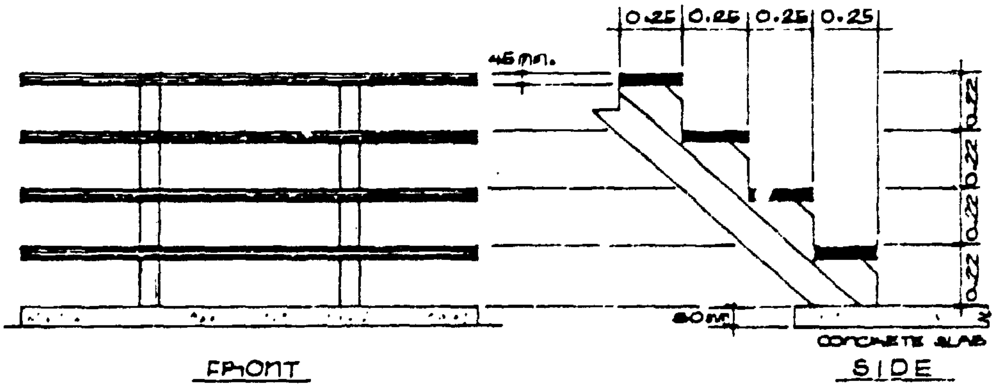


TRUSS • B
SCALE 1:40 METER

Dimension of wood members
Top and bottom chords & webs 70 x 40 mm

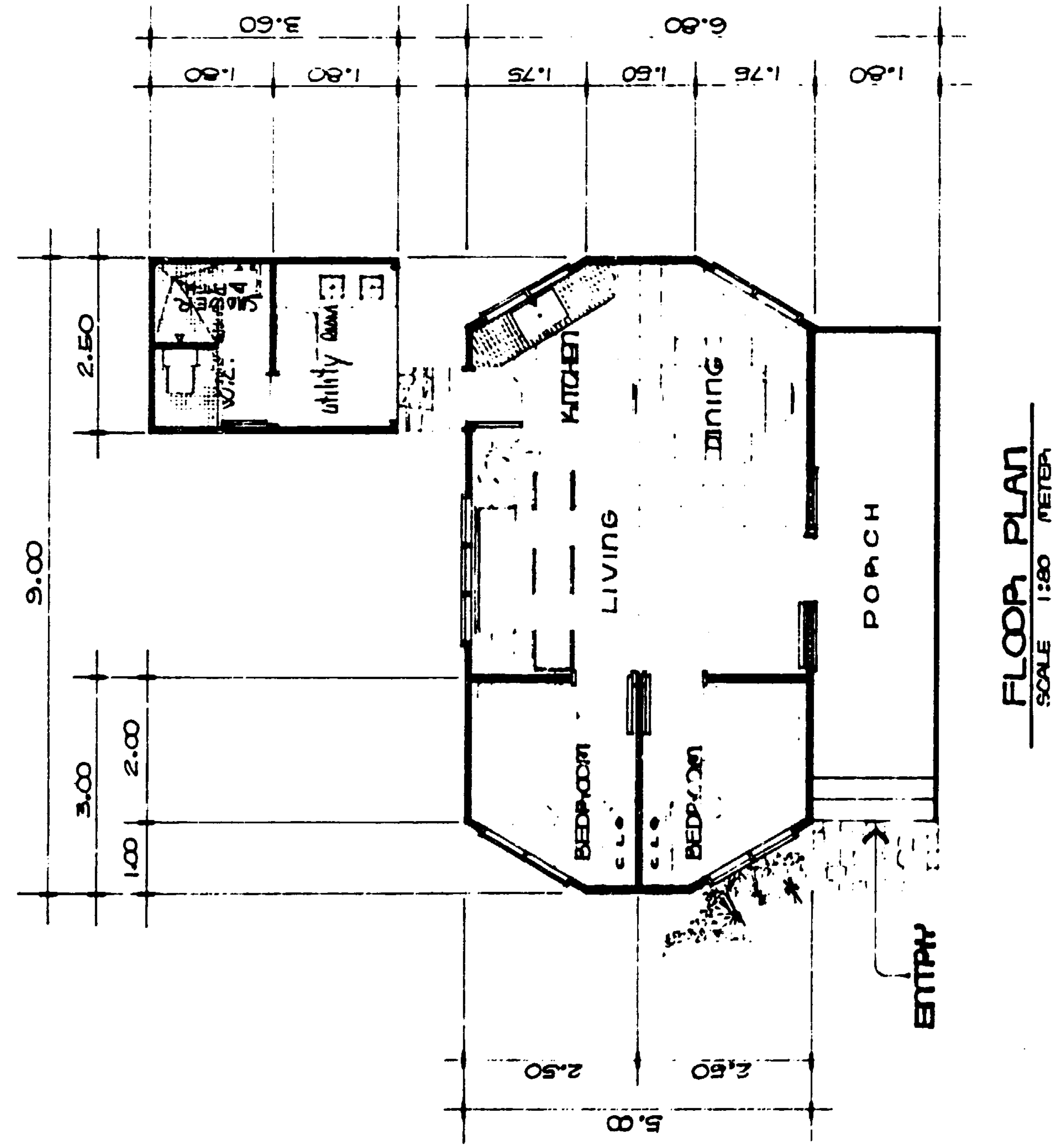


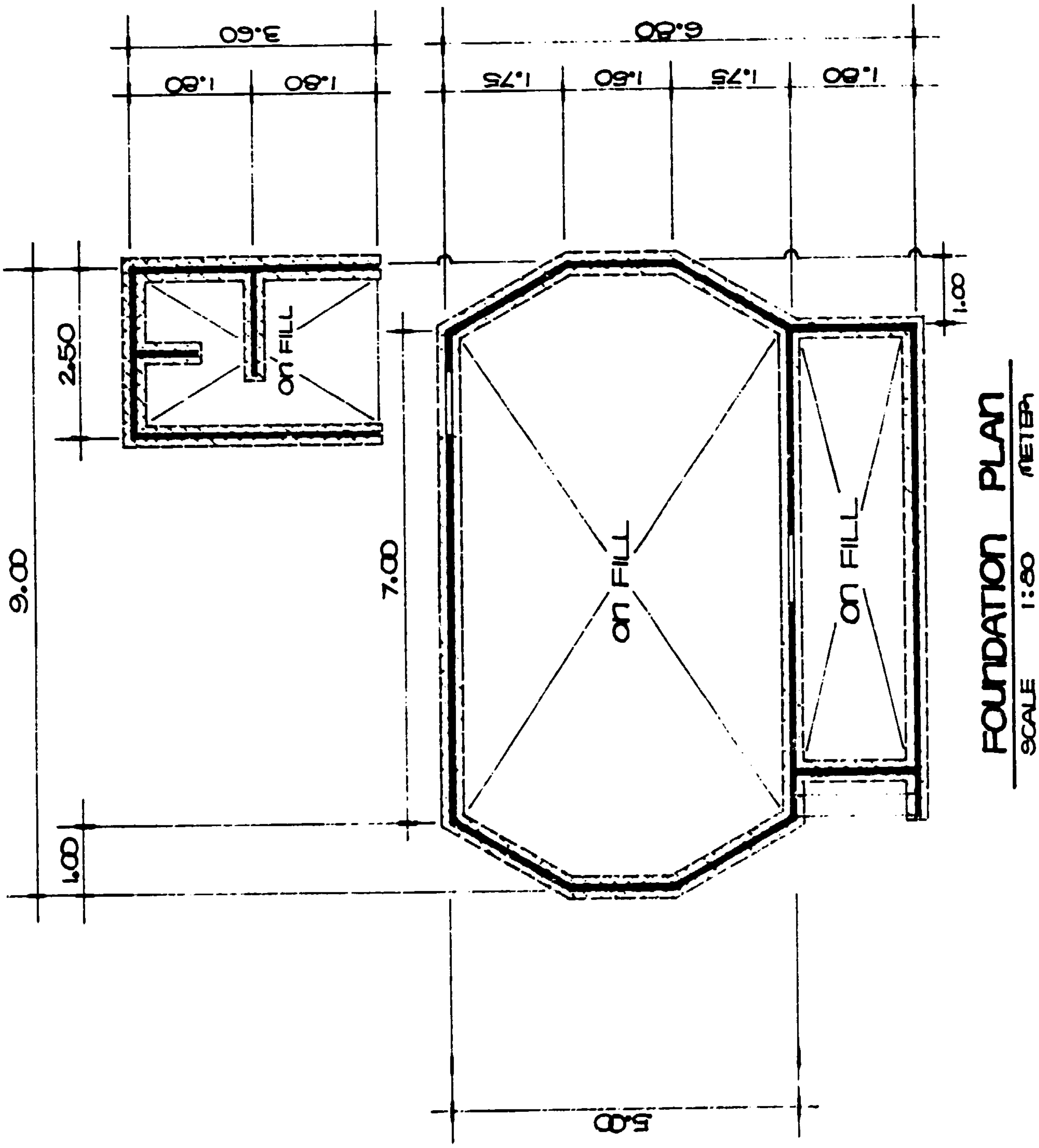
SCHEDULE OF DOORS/WINDOWS

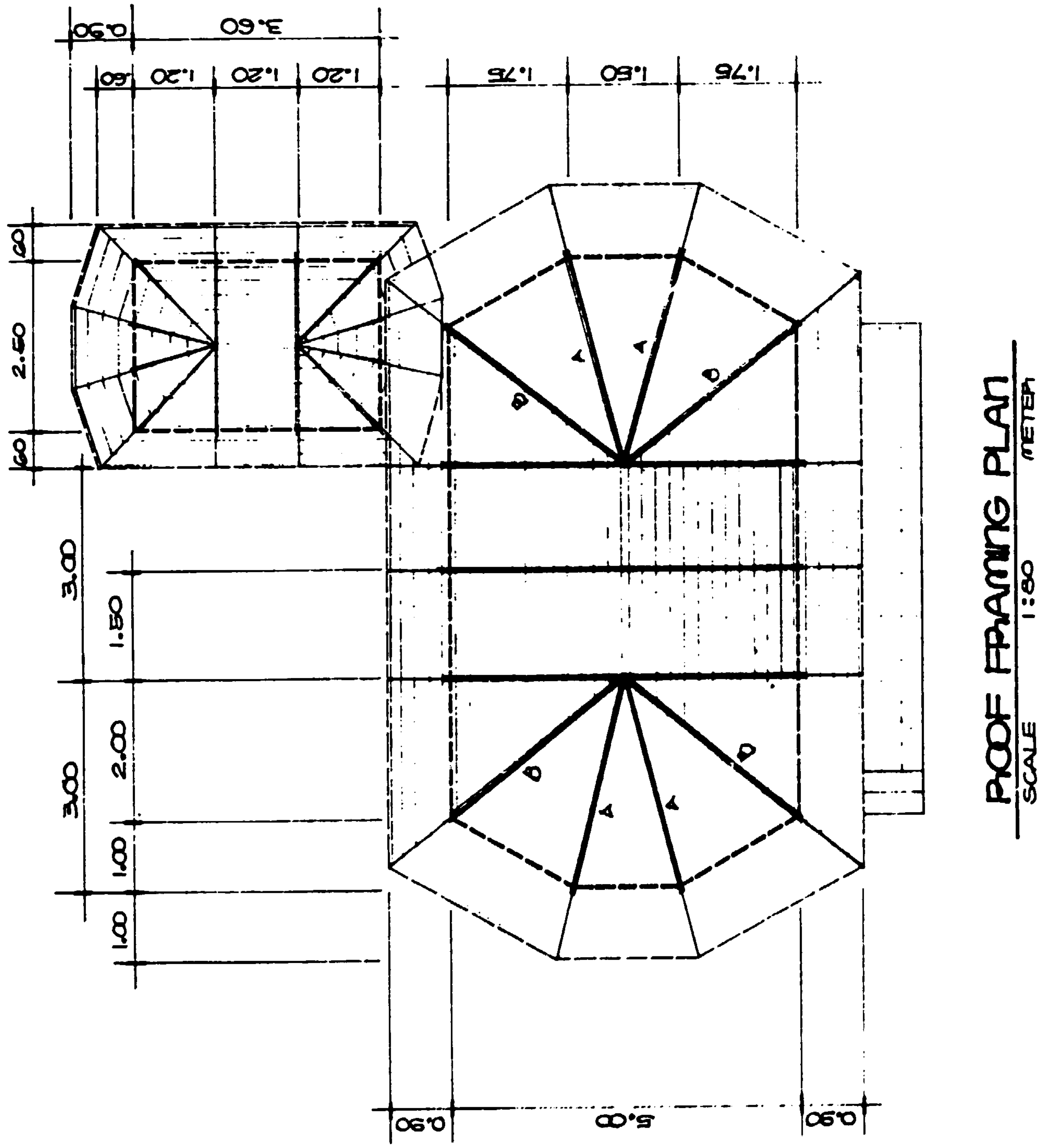


DETAILS ON STAIRS

B


FLOOR PLAN
SCALE 1:80 METER
PORCH
LIVING
KITCHEN
DINING
BEDROOM
BEDROOM
utility
ENTRY
9.00
2.50
3.00
2.00
1.00
3.60
1.80
1.80
6.80
1.75
1.50
1.75
1.80
5.00
2.50
2.50


FOUNDATION PLAN
SCALE 1:80
METER
on FILL
on FILL
on FILL
3.60
1.80
1.80
6.80
1.75
1.60
1.75
1.80
1.00
2.50
9.00
7.00
1.00
5.00


ROOF FRAMING PLAN
SCALE 1:80
METER
0.90
3.60
.60
1.20
1.20
1.20
1.75
1.60
1.75
.60
2.50
.60
3.00
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3.00
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1.00
1.00
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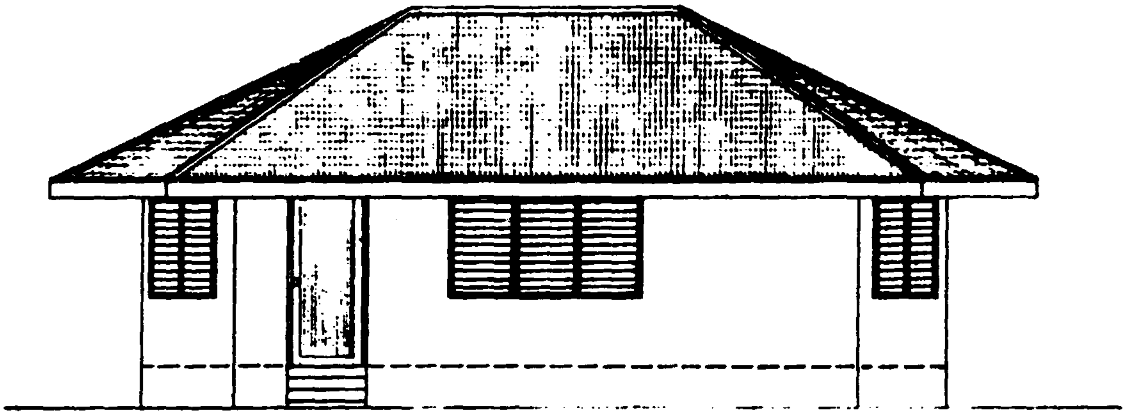
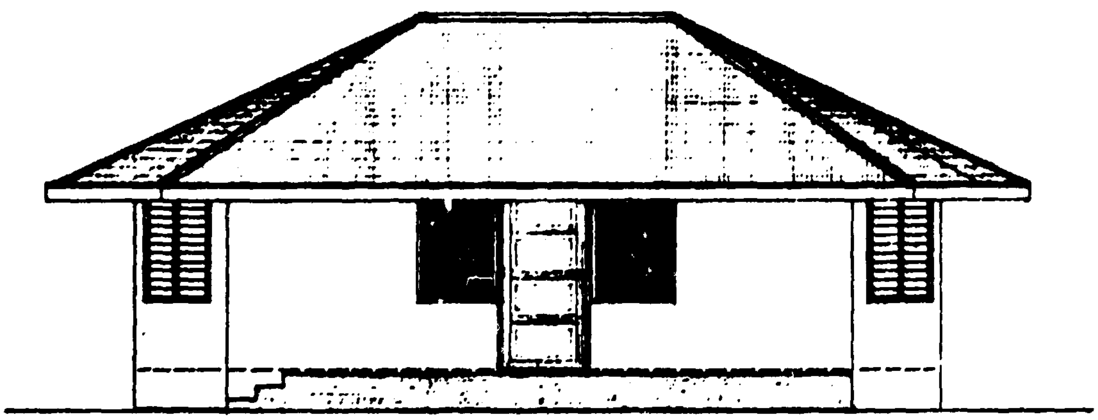
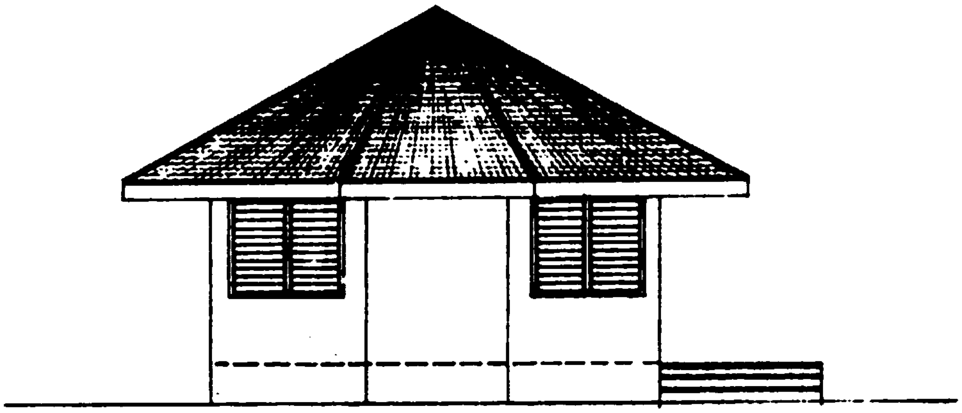
5.00
0.90
A
A
B
B



REAR ELEVATION
SCALE 1:80 METER

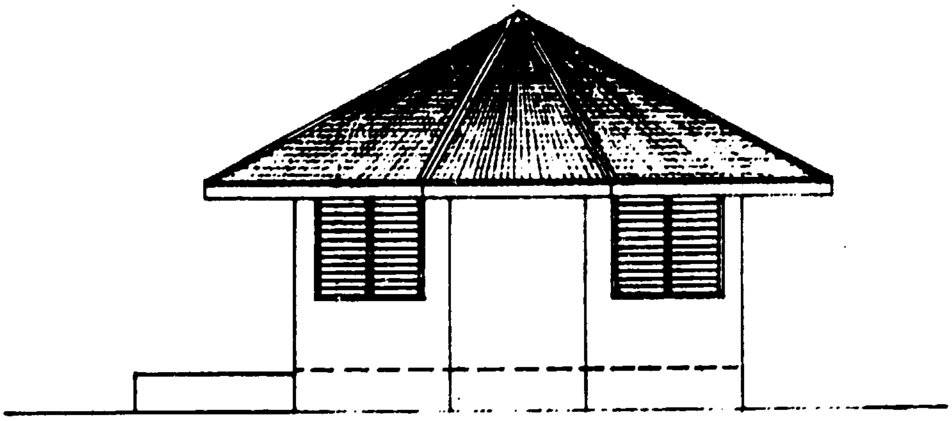


FRONT ELEVATION
SCALE 1:80 METER



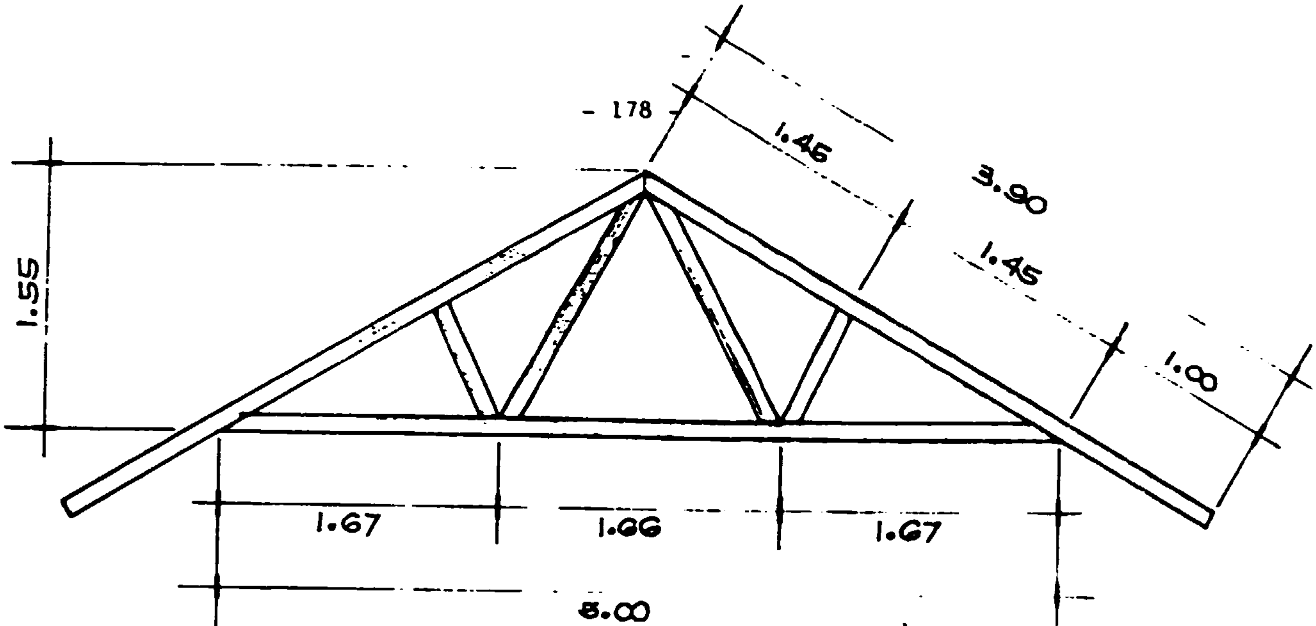
LEFT SIDE ELEVATION

SCALE 1:50 METER

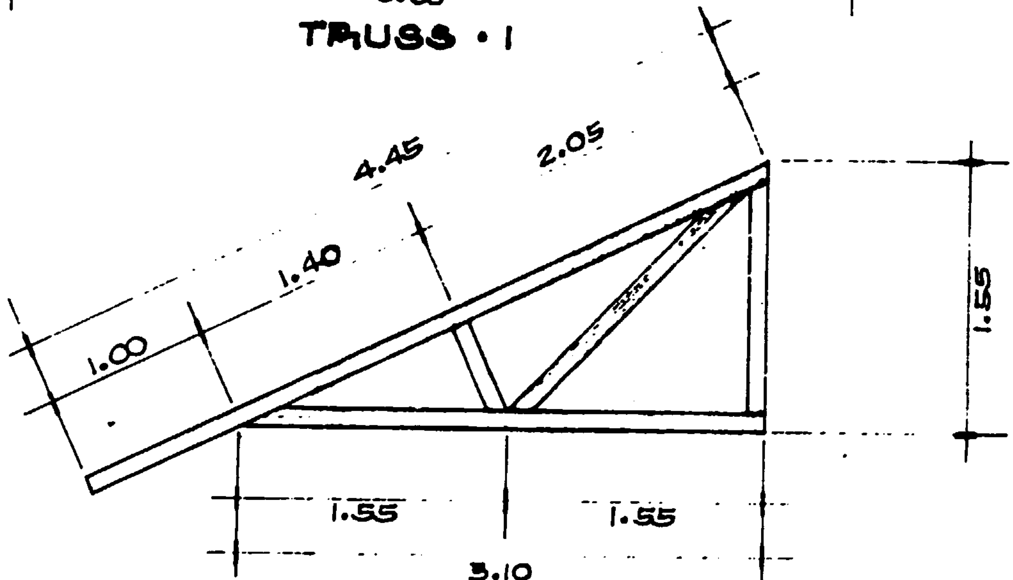


RIGHT SIDE ELEVATION

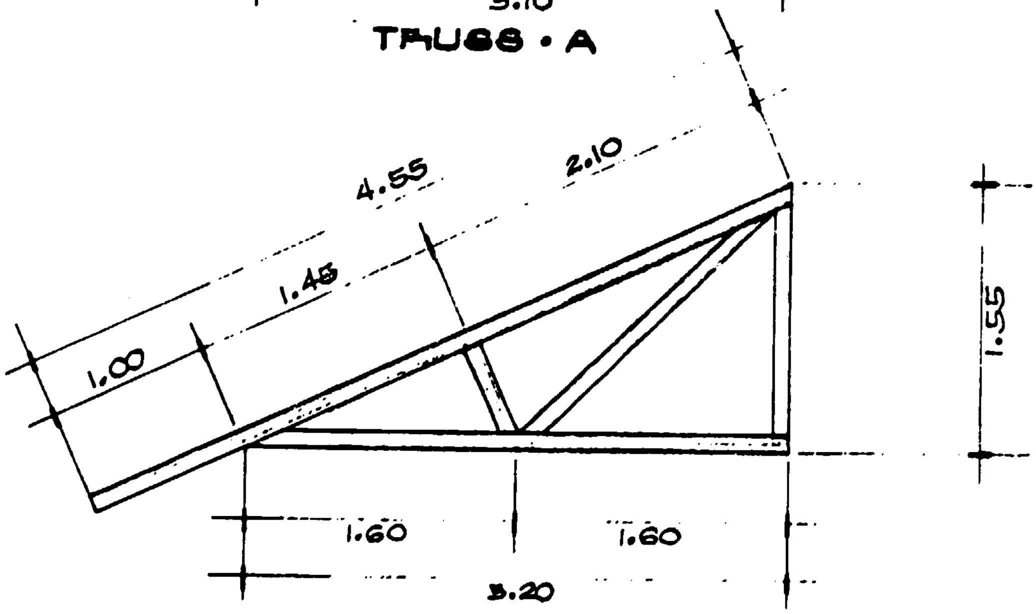
SCALE 1:50 METER



TRUSS • 1

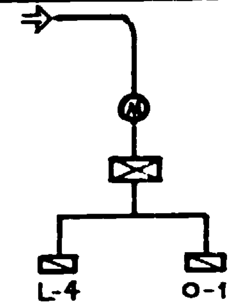


TRUSS • A



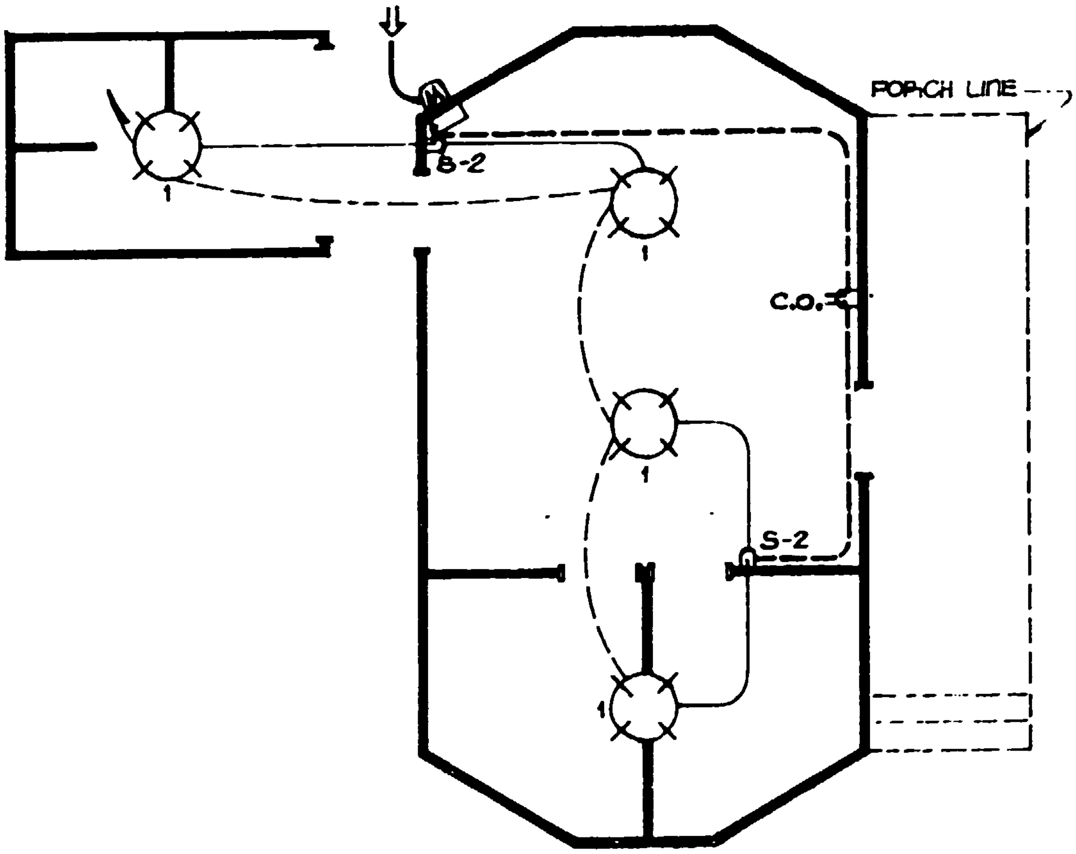
TRUSS • B

SINGLE RISER DIAGRAM



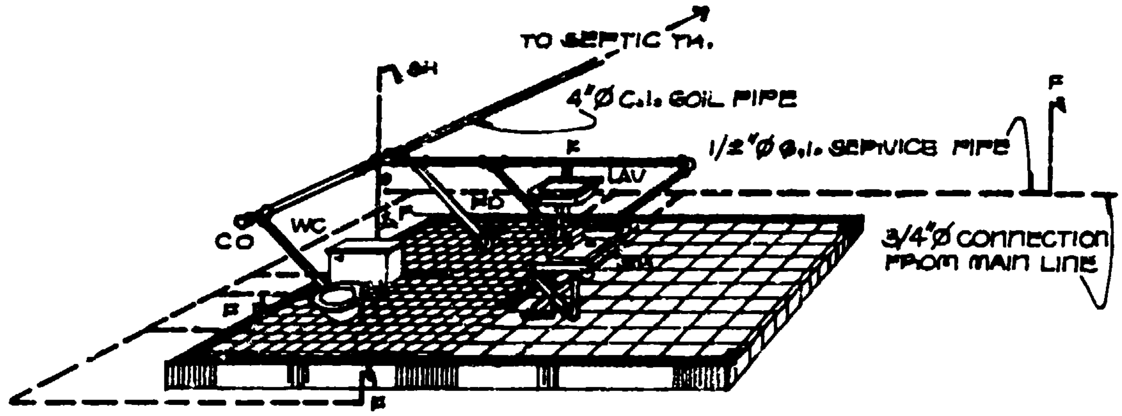
LEGEND

- SERVICE ENTRANCE
- KWH ELECTRIC METER
- CIR. BREAKER PANELBOARD
- CONVENIENCE OUTLET
- S-2 2-GANG FLUSH SWITCH
- CEILING LIGHT OUTLET
- 20 WATT FLOURES. LAMP
- CIRCUIT HOMERUN



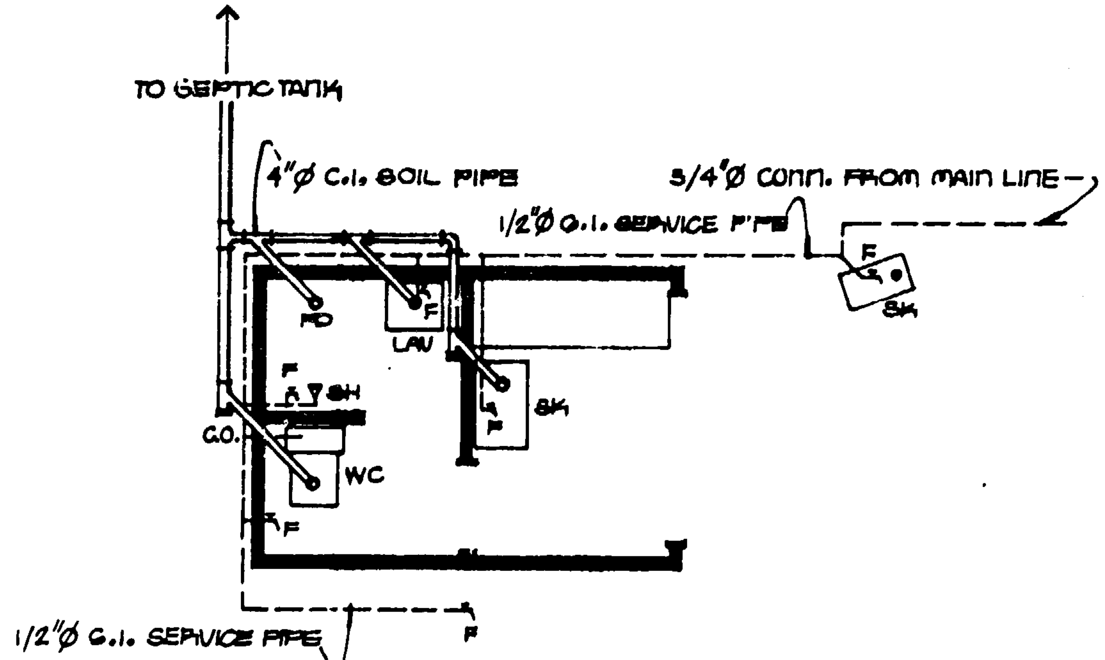
ELECTRICAL LAYOUT PLAN

SCALE 1 : 80 METER



ISOMETRIC PLUMBING LAYOUT

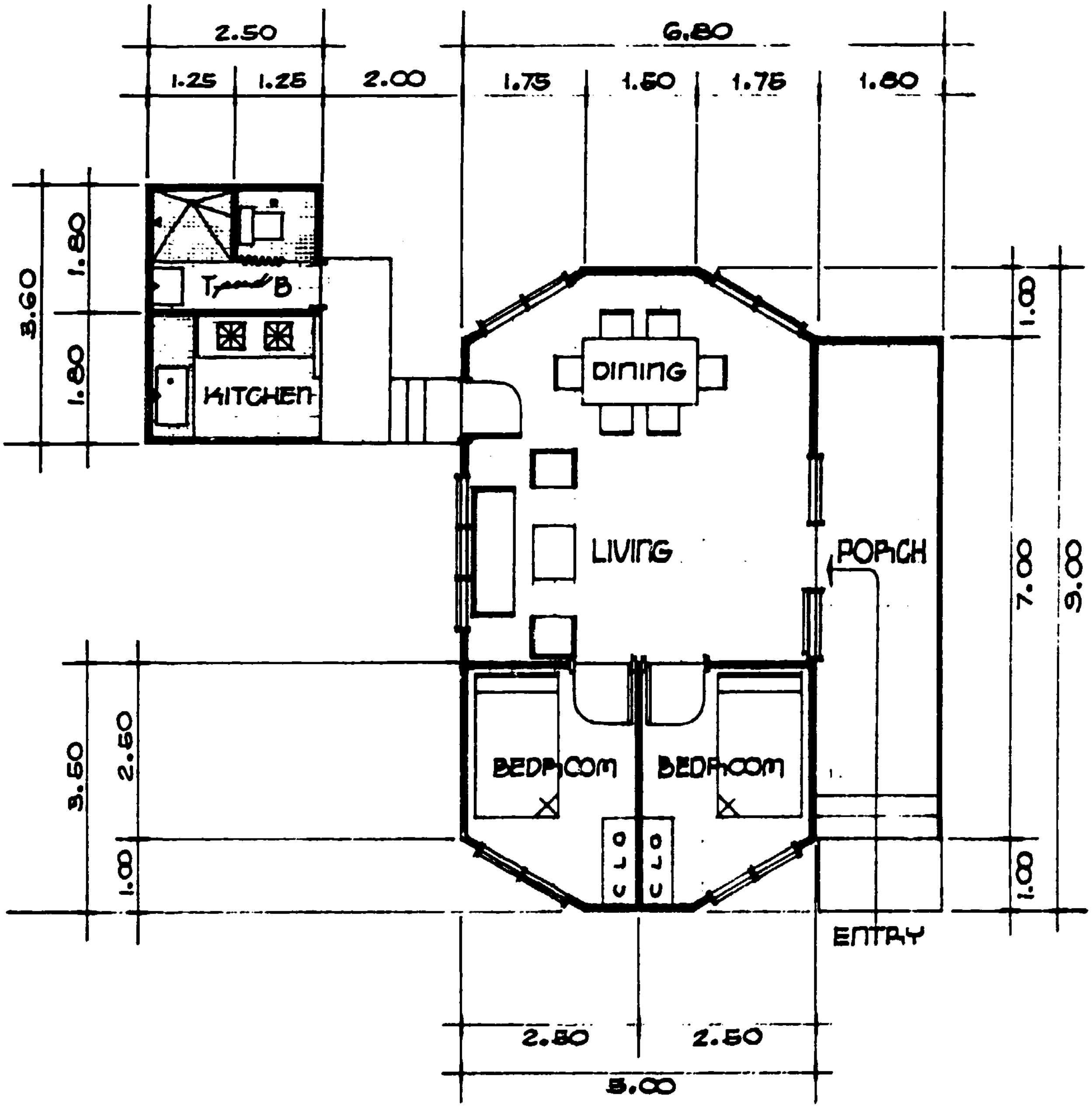
SCALE 1:80 METER



PLUMBING LAYOUT PLAN

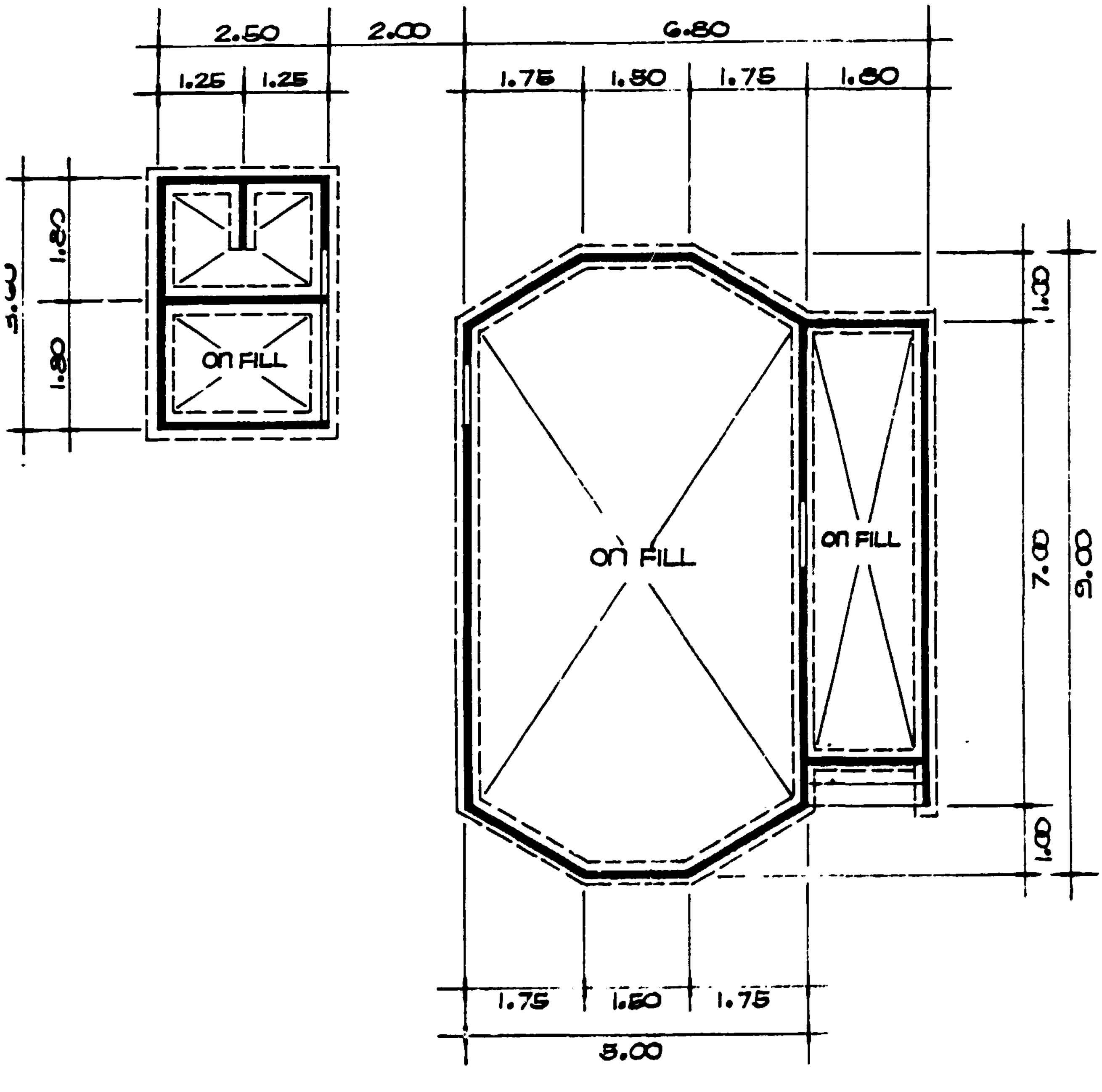
SCALE 1:80 METER

B[1]



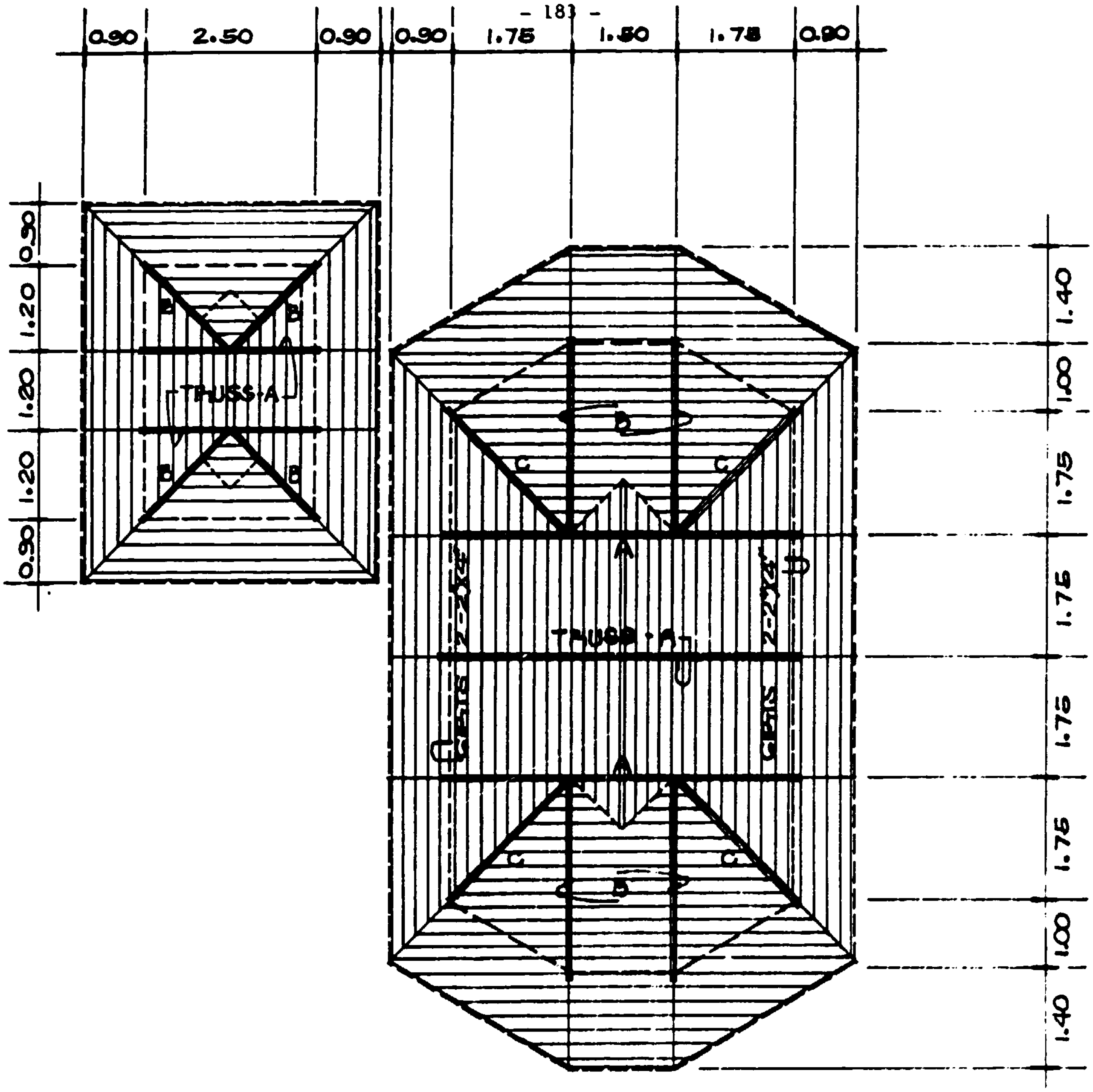
FLOOR PLAN

SCALE 1:80 METER



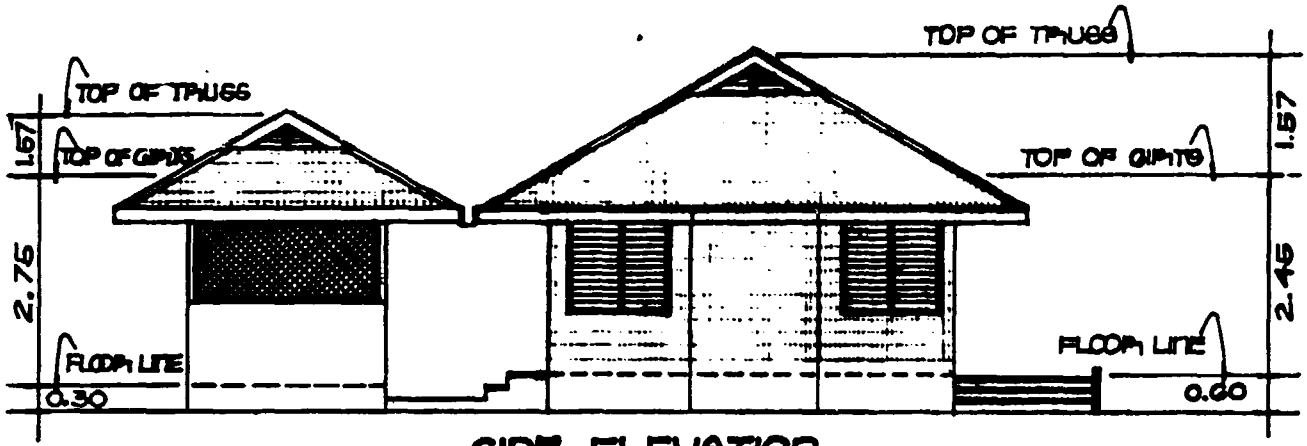
FOUNDATION PLAN

SCALE 1:50 (METER)

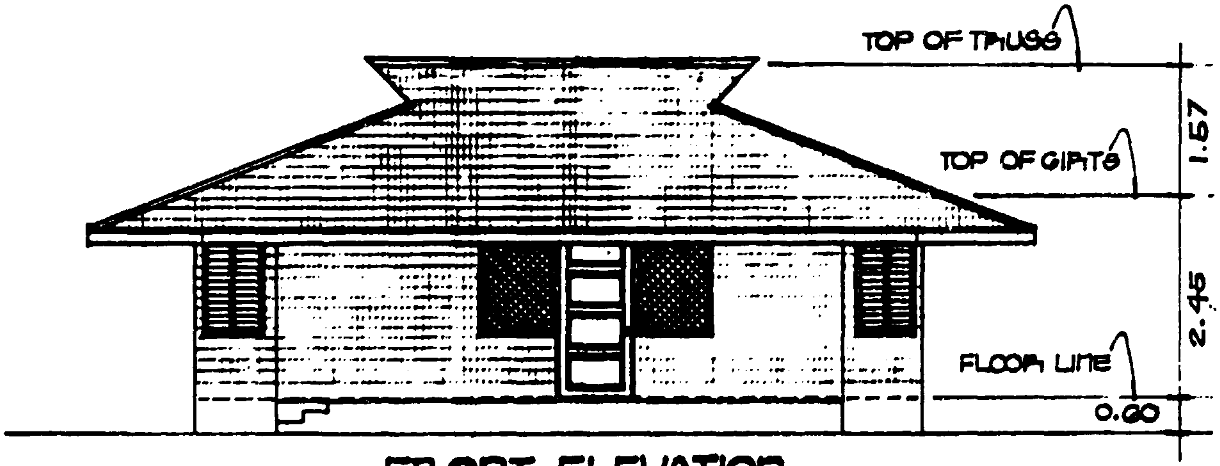


ROOF FRAMING PLAN

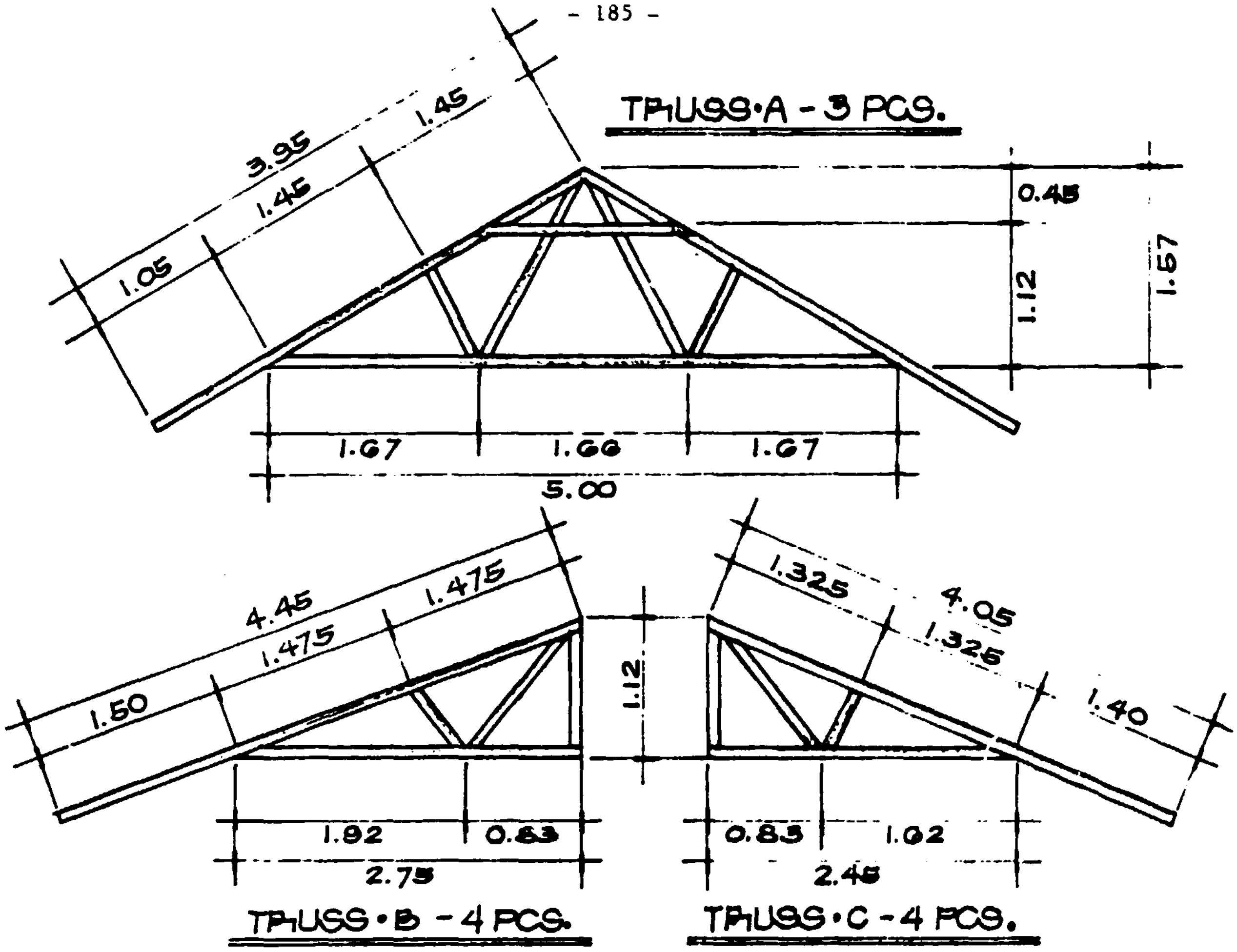
SCALE 1:80 METER



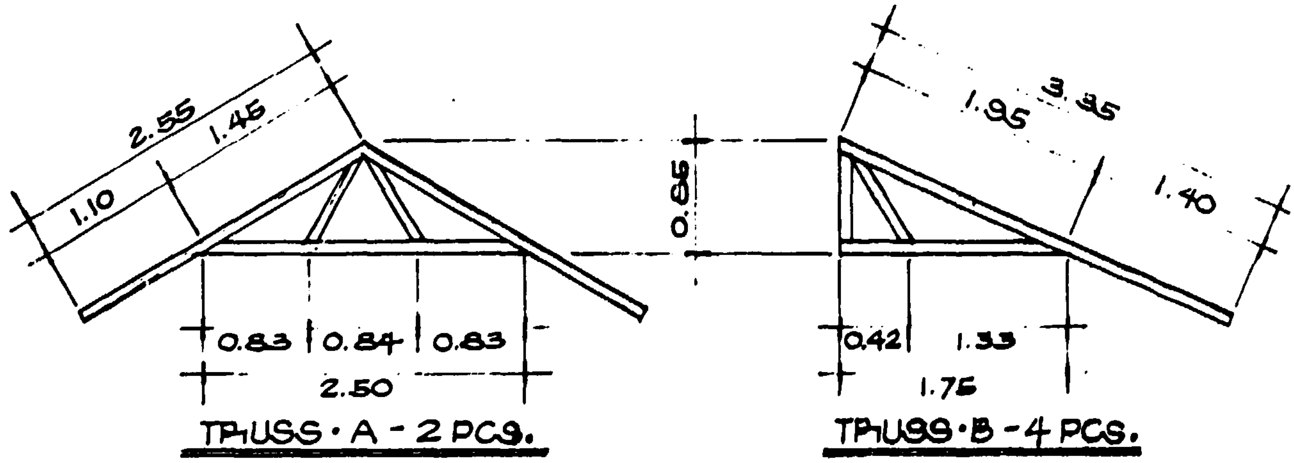
SIDE ELEVATION
SCALE 1:80 METER



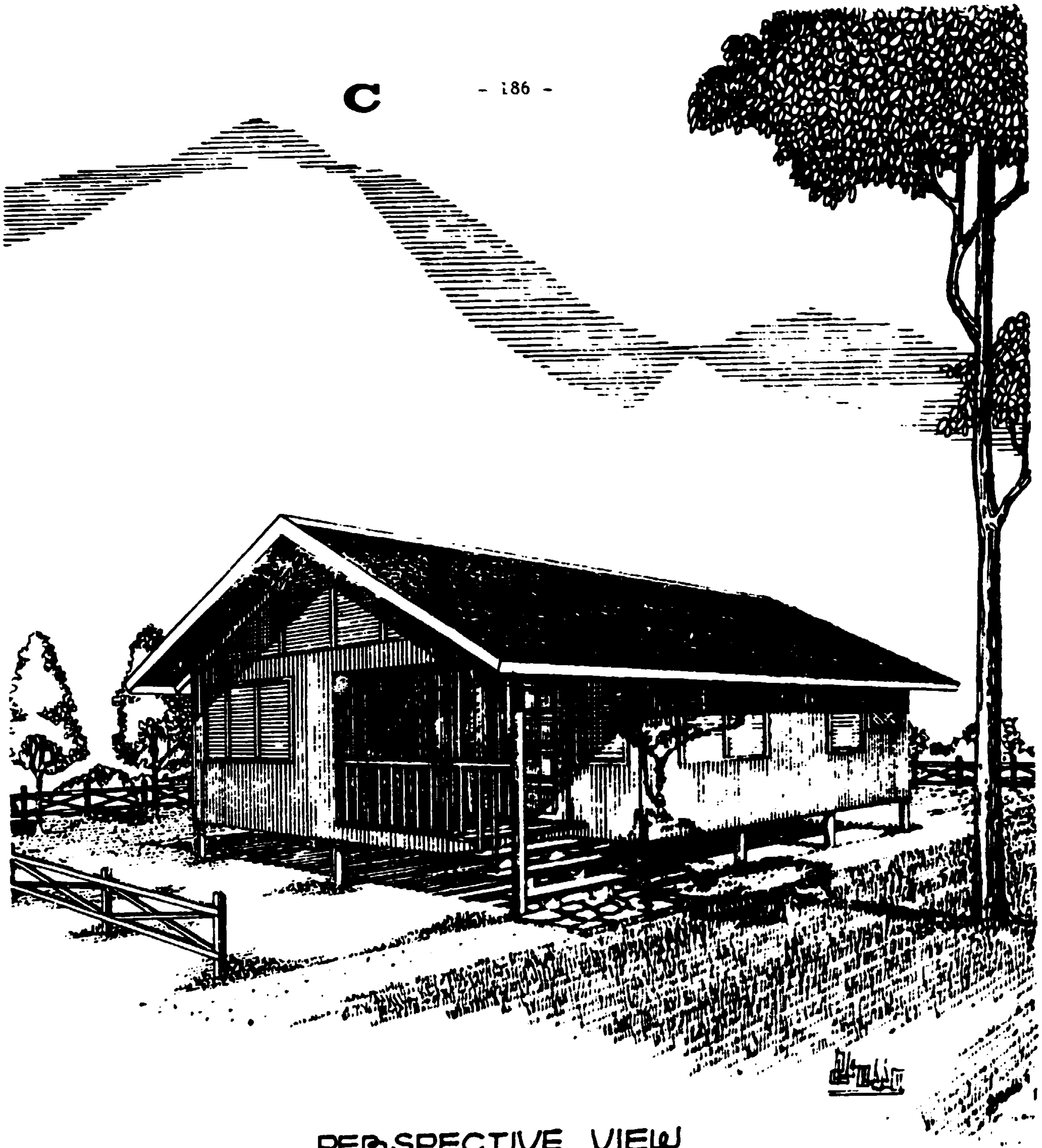
FRONT ELEVATION
SCALE 1:80 METER



SCHEDULE OF TRUSS - MODIFIED TONGA HOUSE



SCHEDULE OF TRUSS - KITCHEN



PERSPECTIVE VIEW

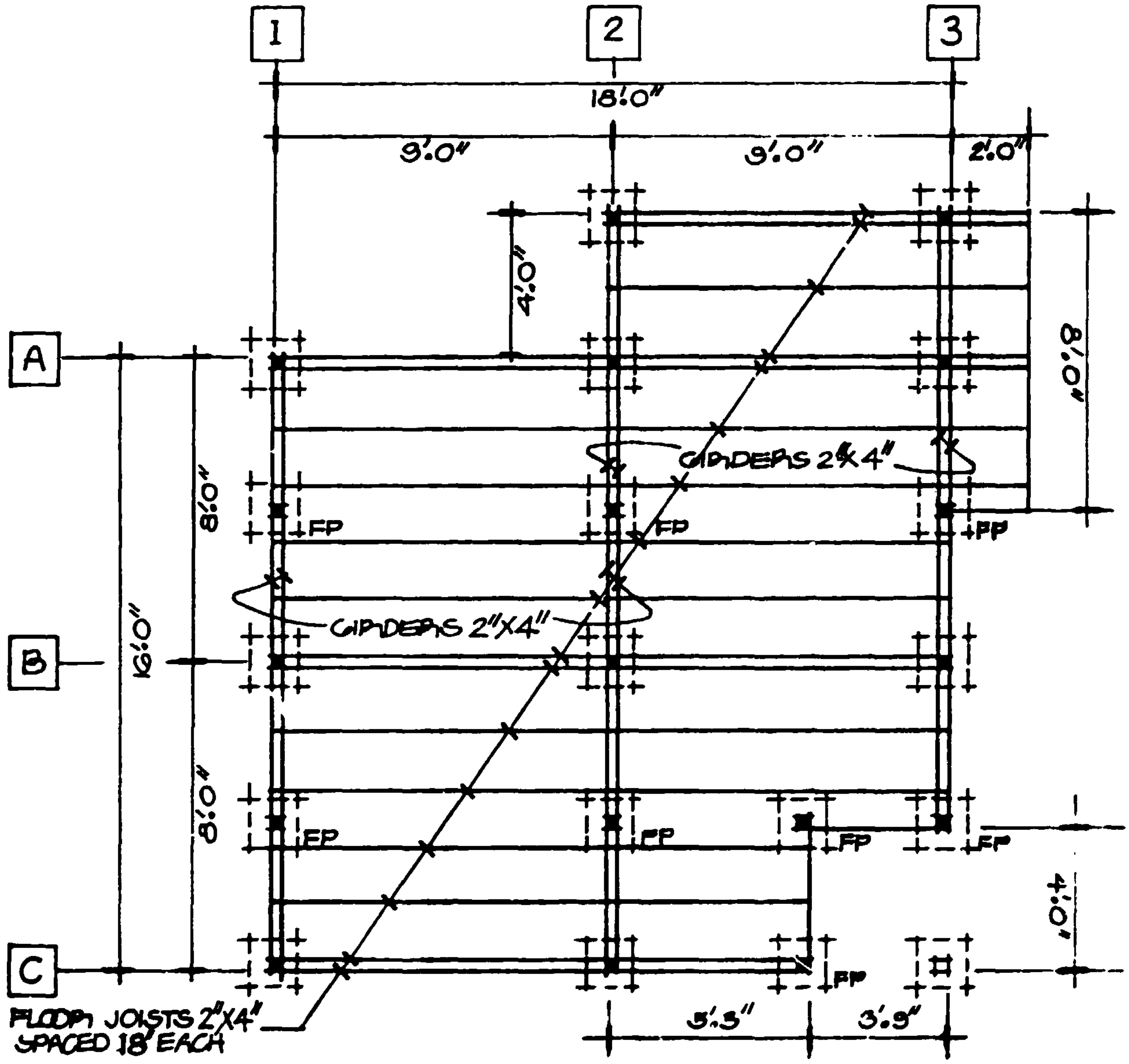


FIG. 1 FLOOR FRAMING • FOUNDATION PLAN

SCALE 1:60 FEET

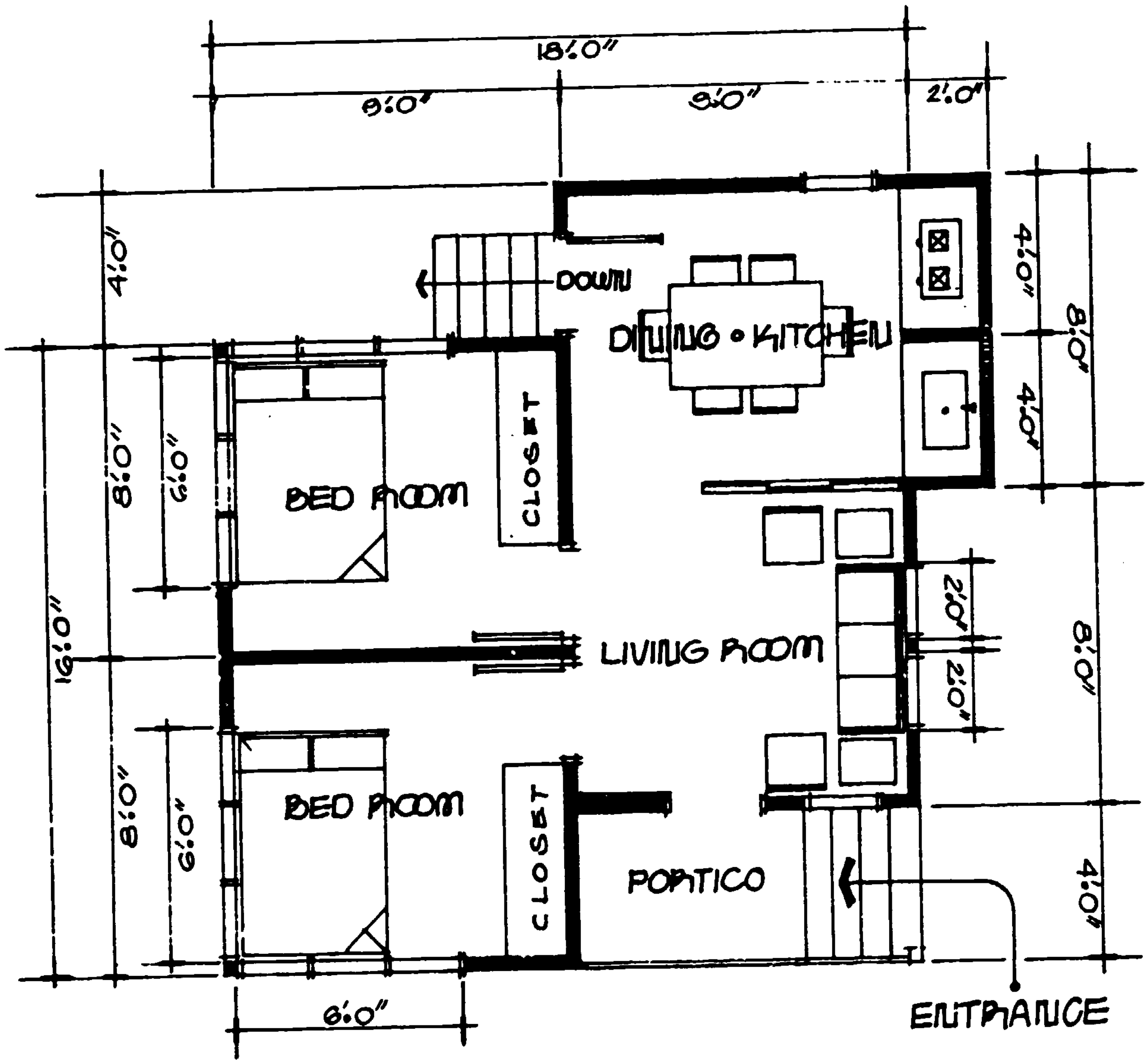


FIG. 2 FLOOR PLAN
SCALE 1:50 FEET

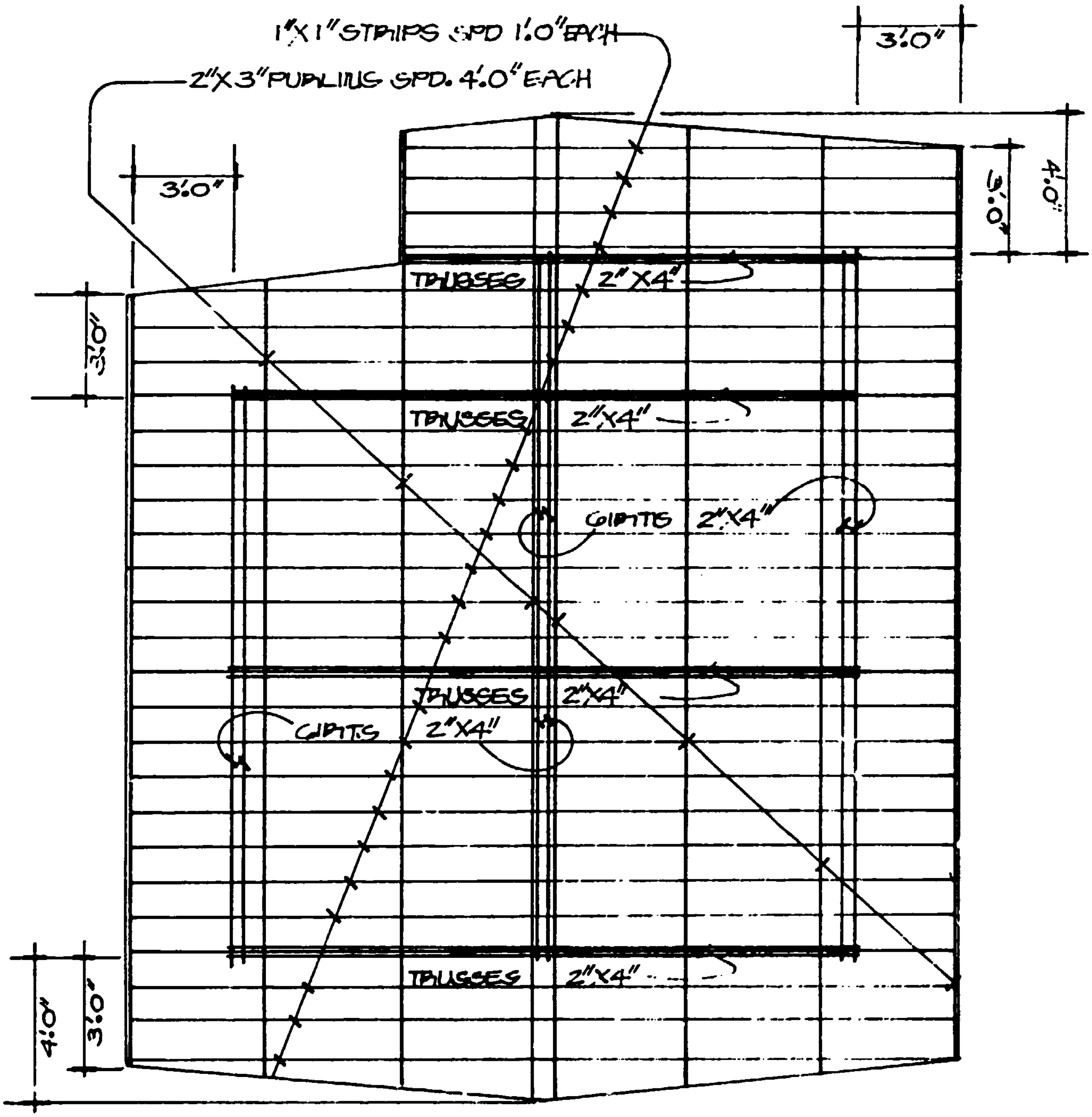


FIG. 3 ROOF FRAMING PLAN

SCALE 1:50 FEET

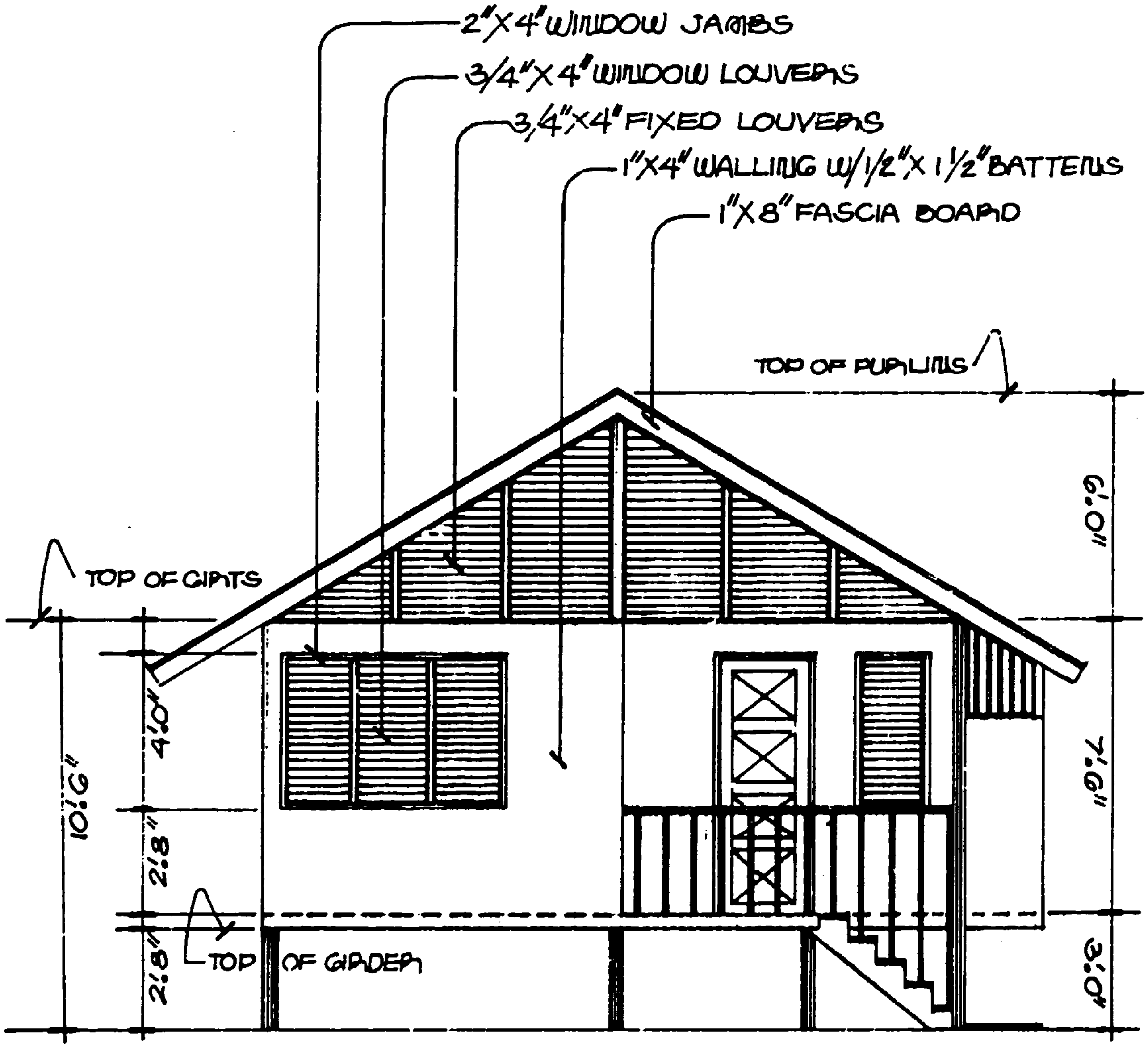


FIG.4 FRONT ELEVATION
SCALE 1:80 FEET

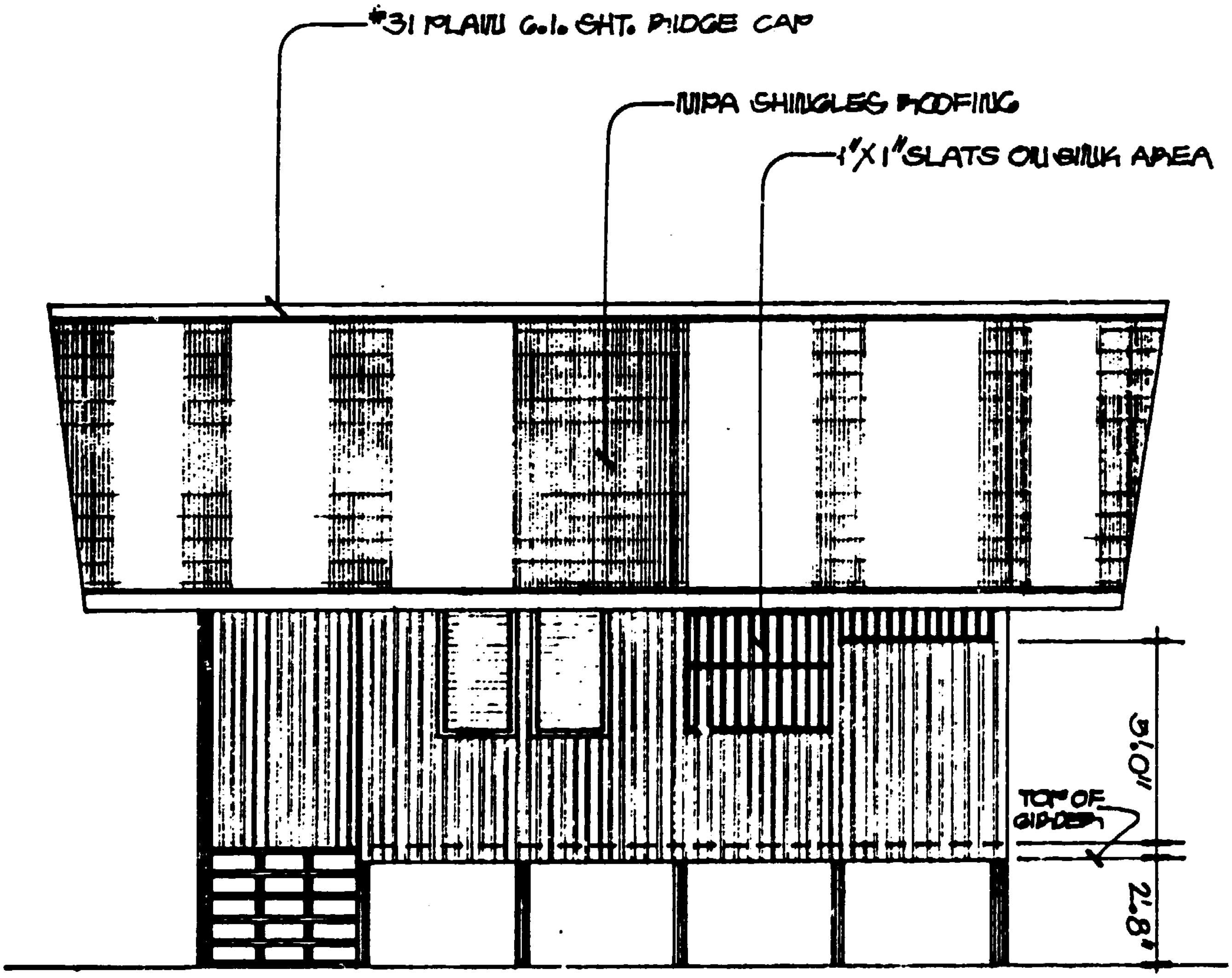


FIG.5 RIGHT SIDE ELEVATION
SCALE 1:50 FEET

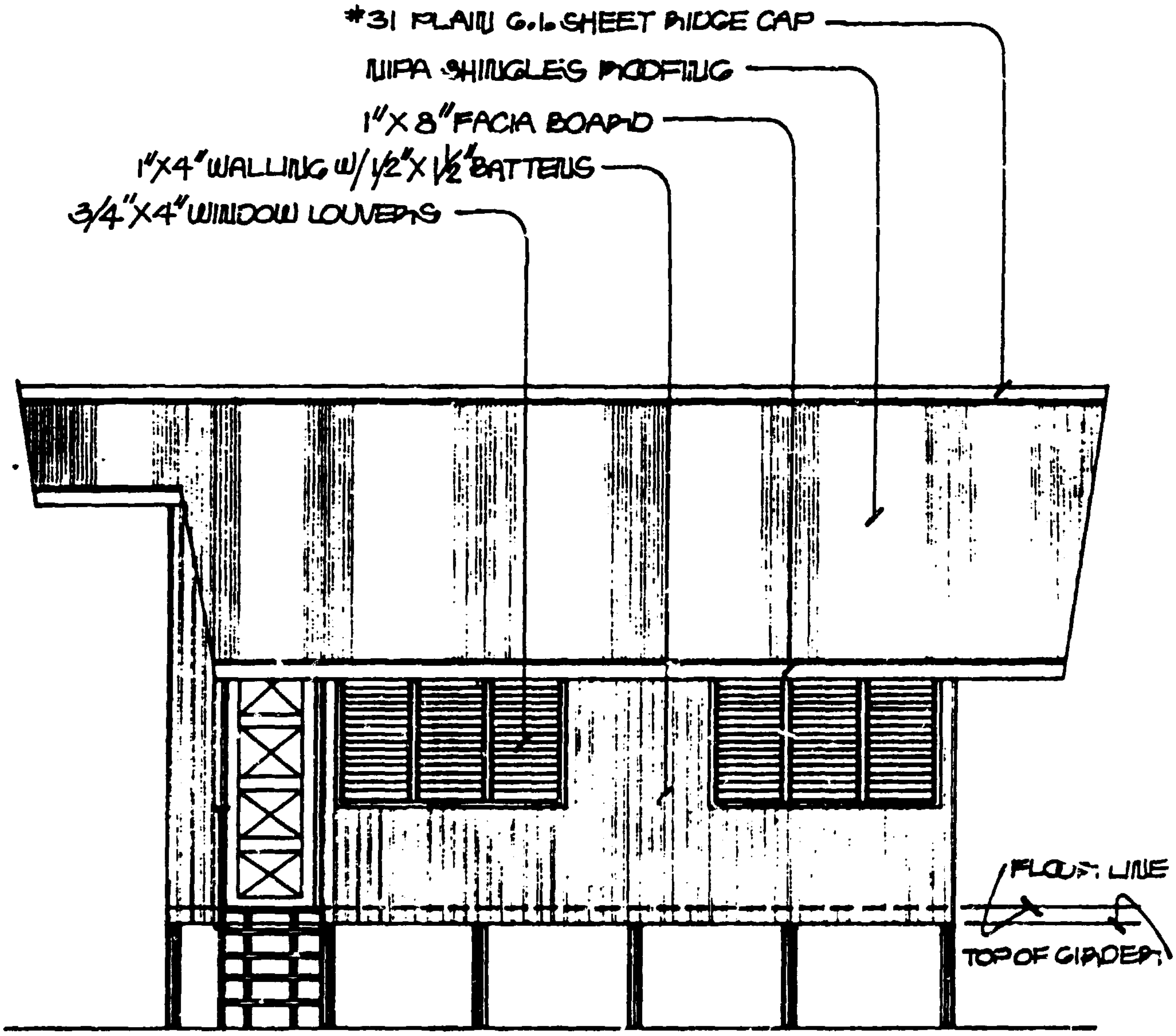


FIG. 6 LEFT SIDE ELEVATION
SCALE 1:50 FEET

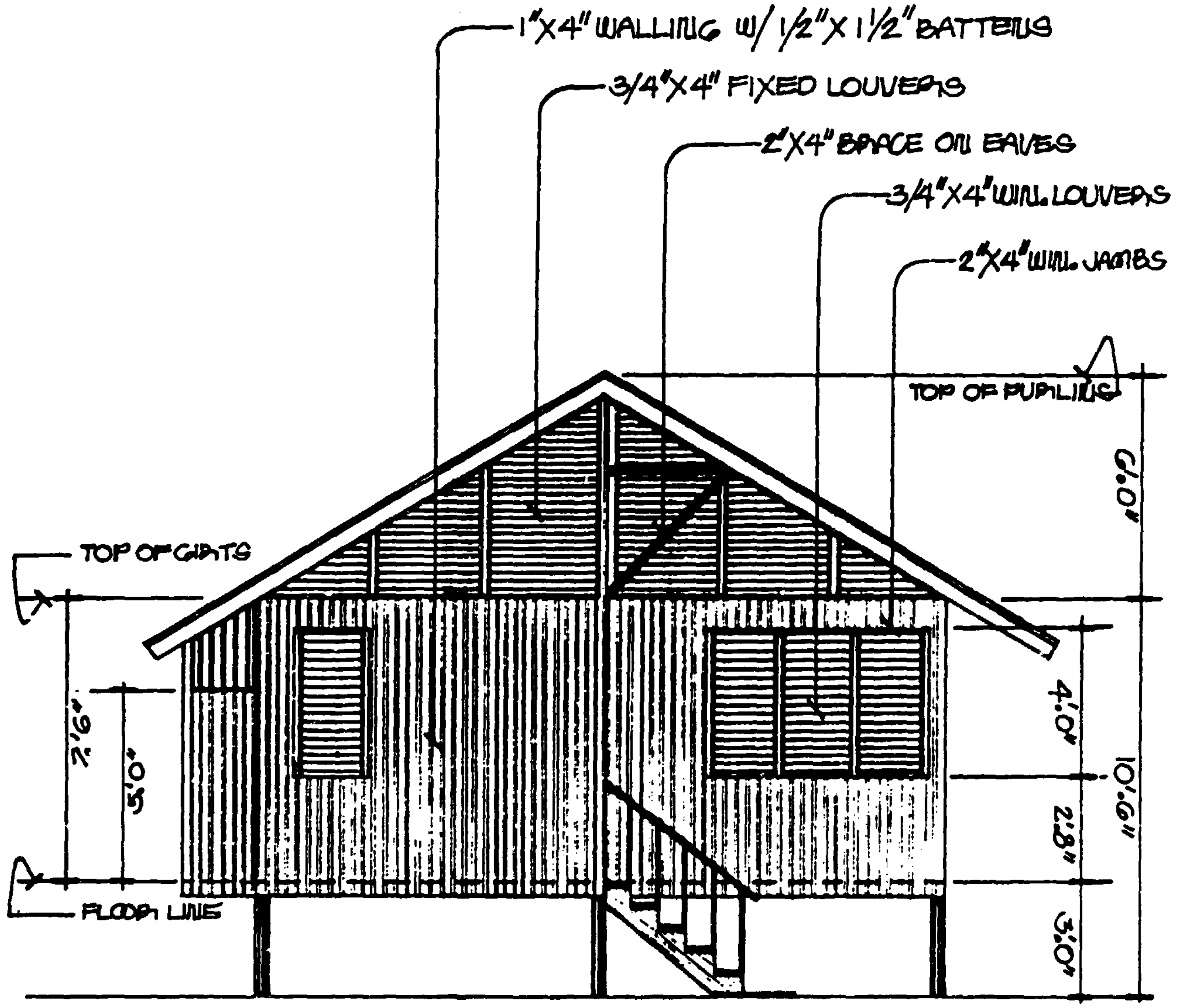


FIG. 7 REAR ELEVATION
SCALE 1:50 FEET

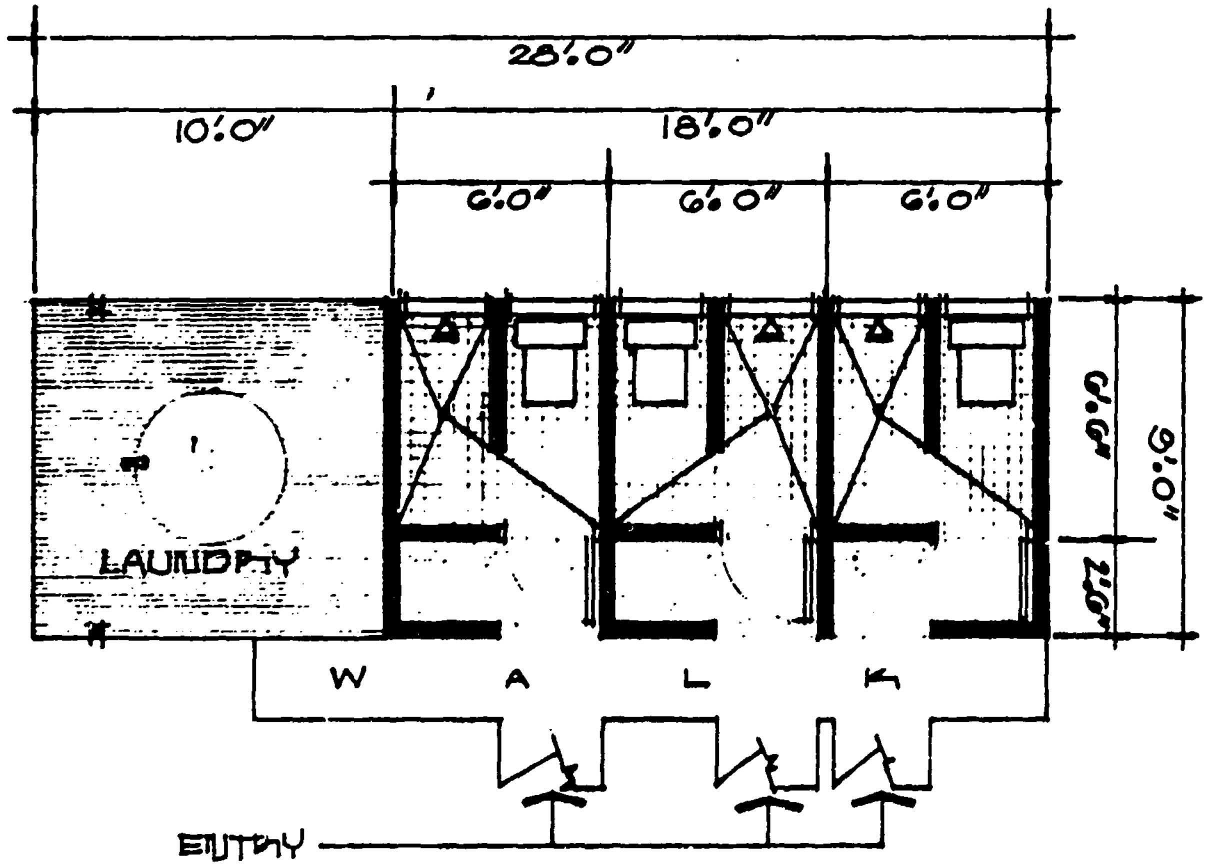
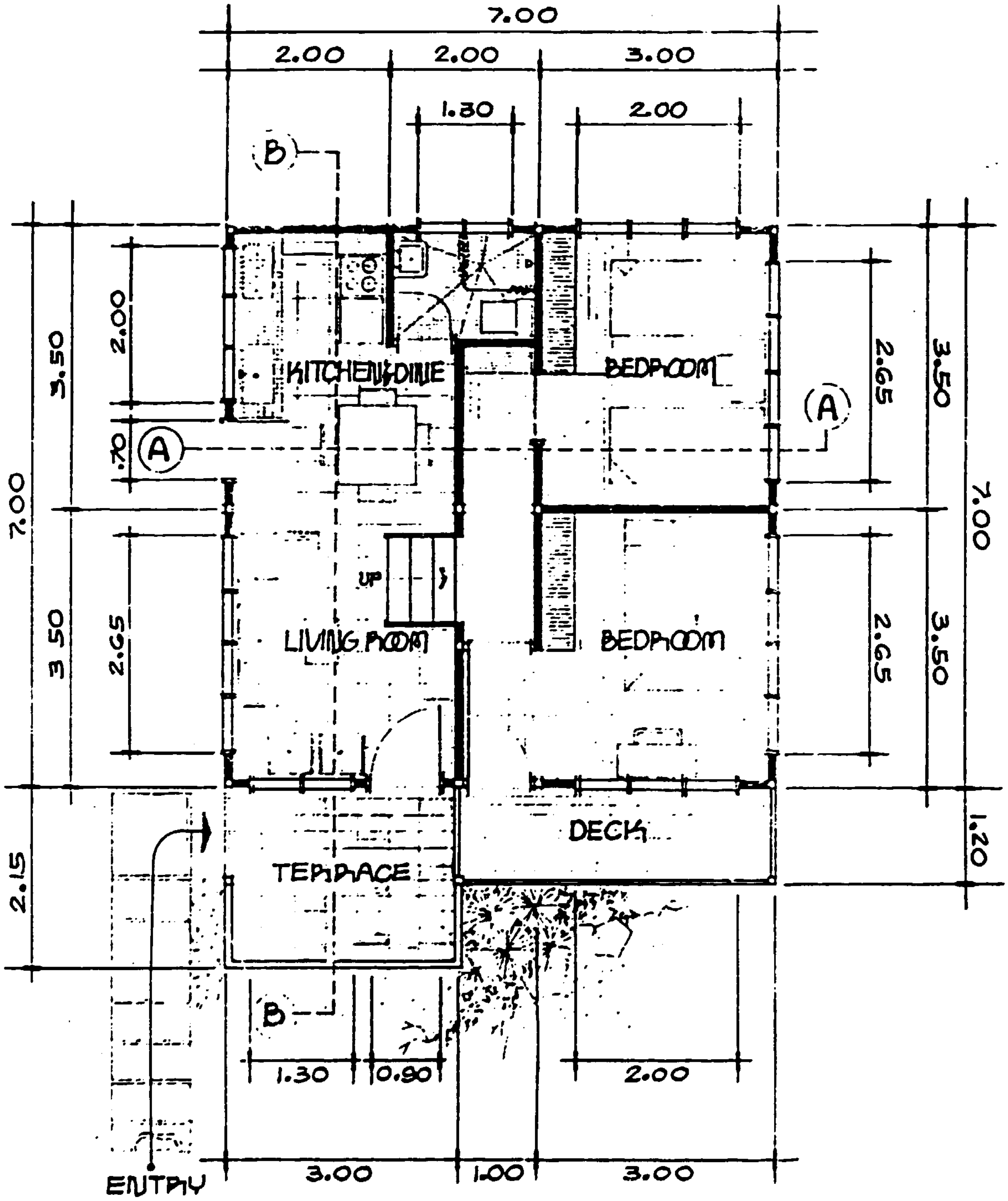


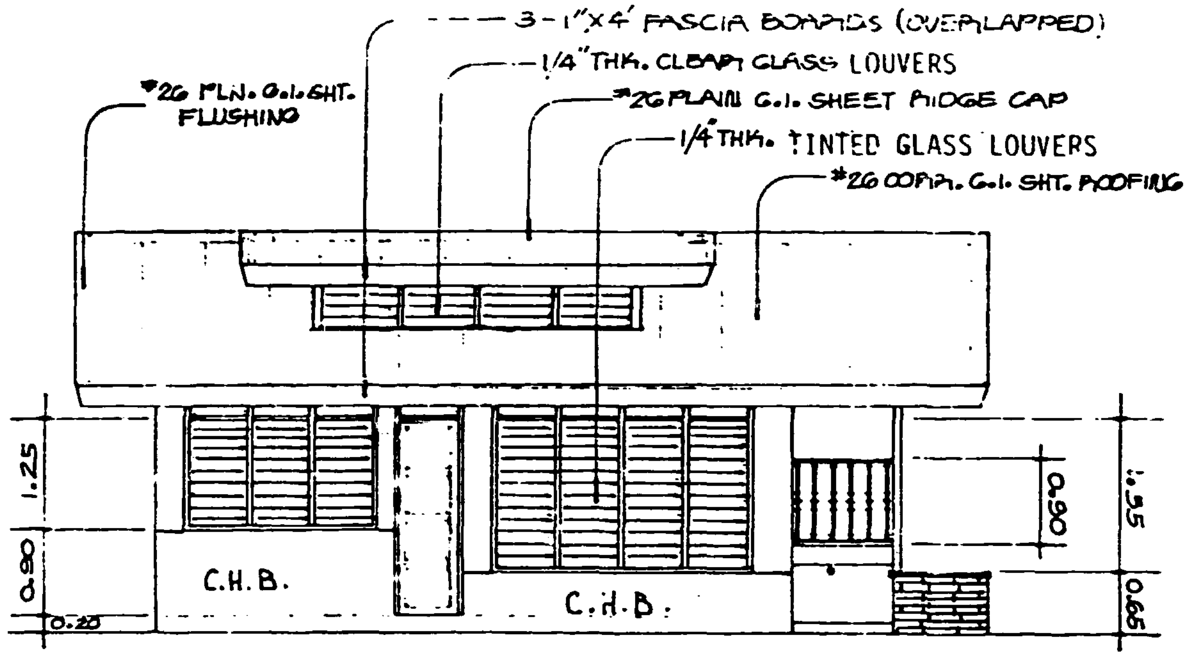
FIG. 8 FLOOR PLAN OF TOILETS & BATHS FOR 3 UNITS LOW-COST HOUSE

SCALE 1:200 FEET

D

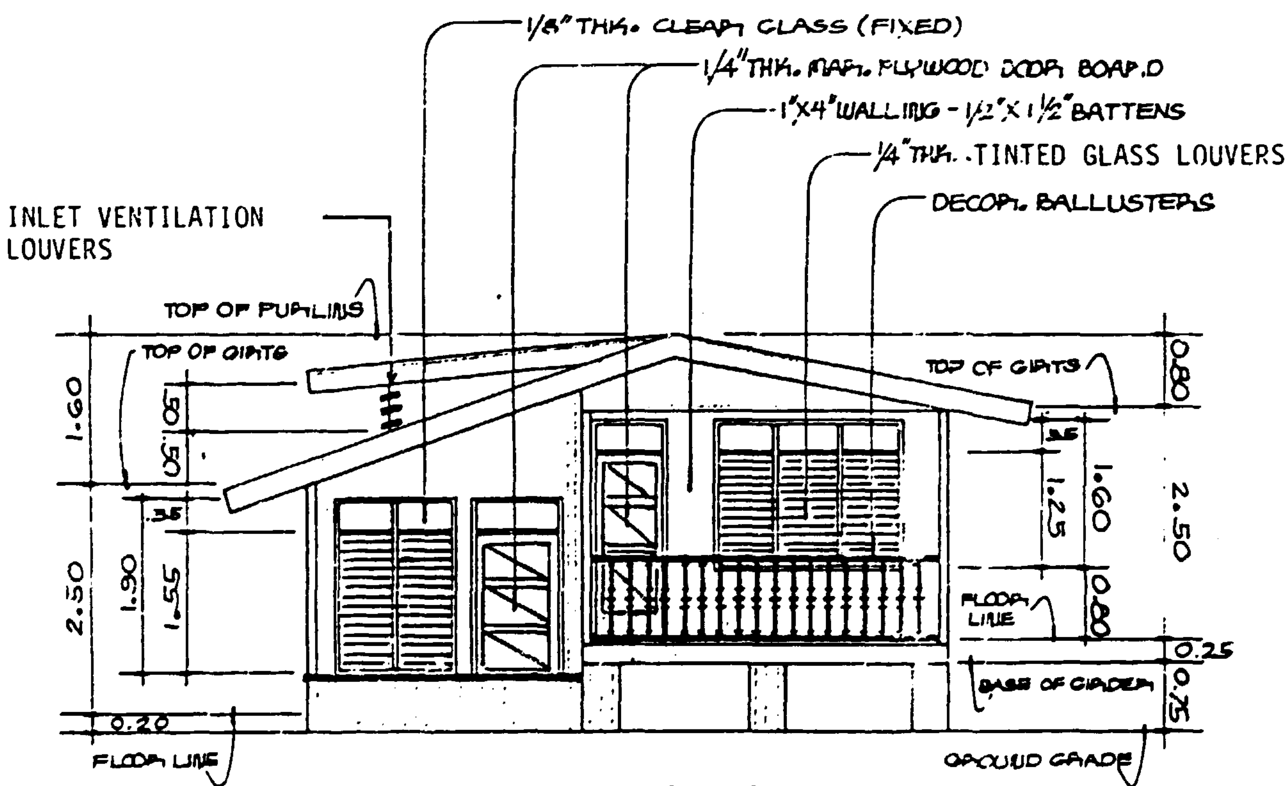


FLOOR PLAN
SCALE 1:80 METER



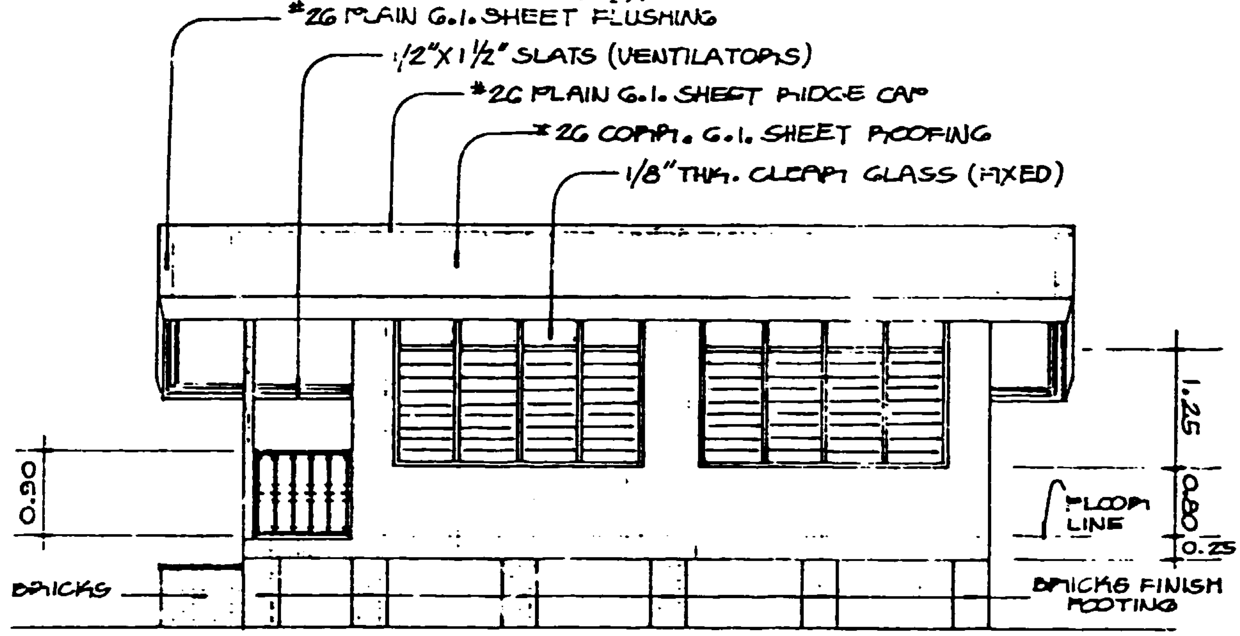
LEFT SIDE ELEVATION

SCALE 1:80 METER



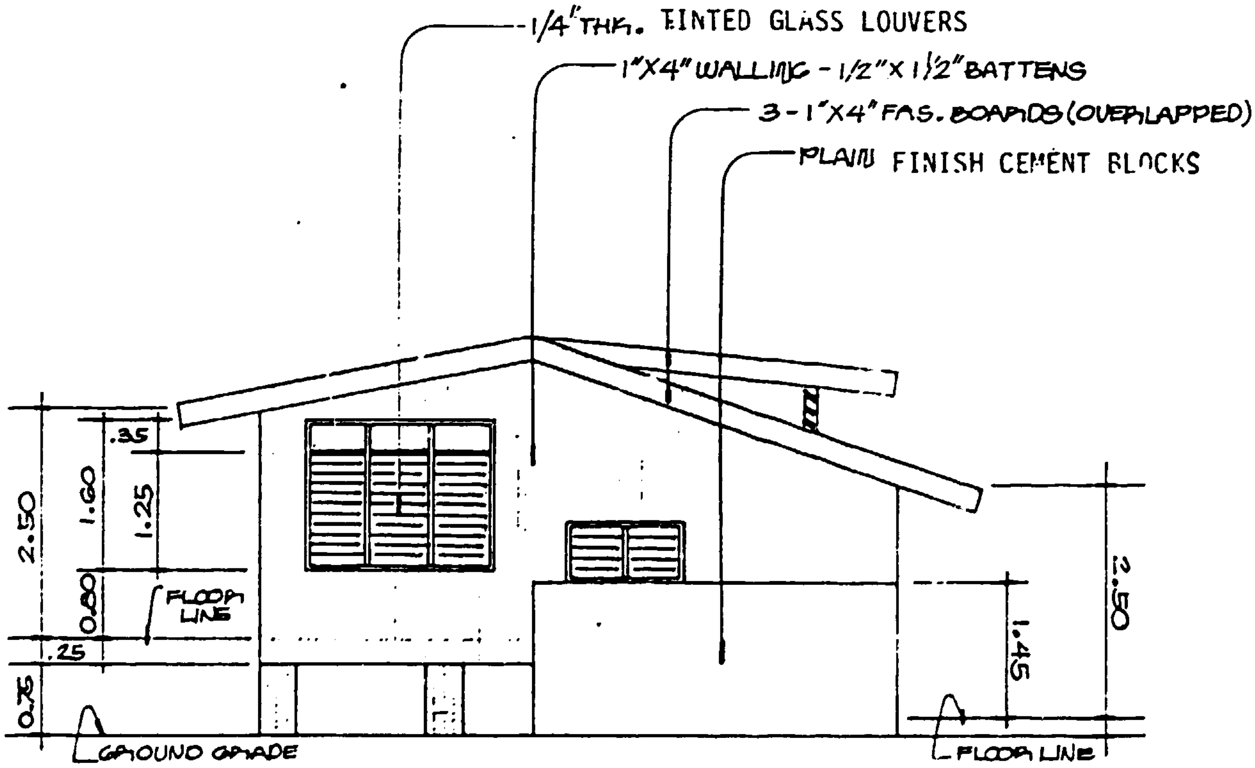
FRONT ELEVATION

SCALE 1:80 METER



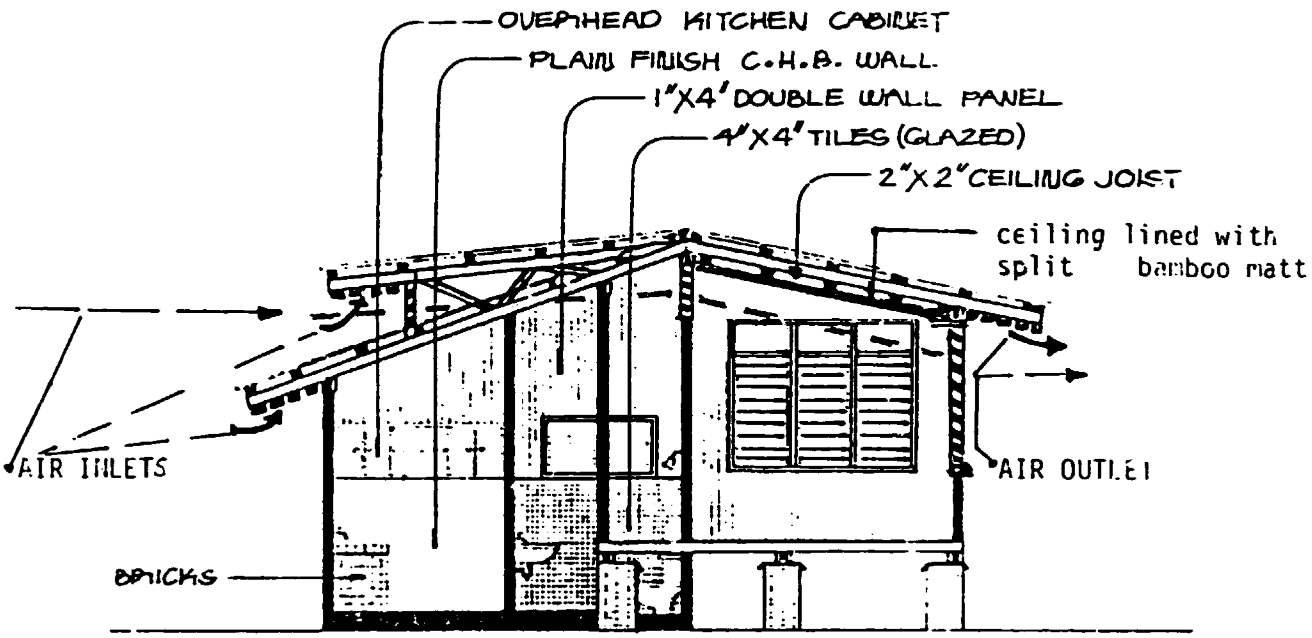
RIGHT SIDE ELEVATION

SCALE 1:80 METER

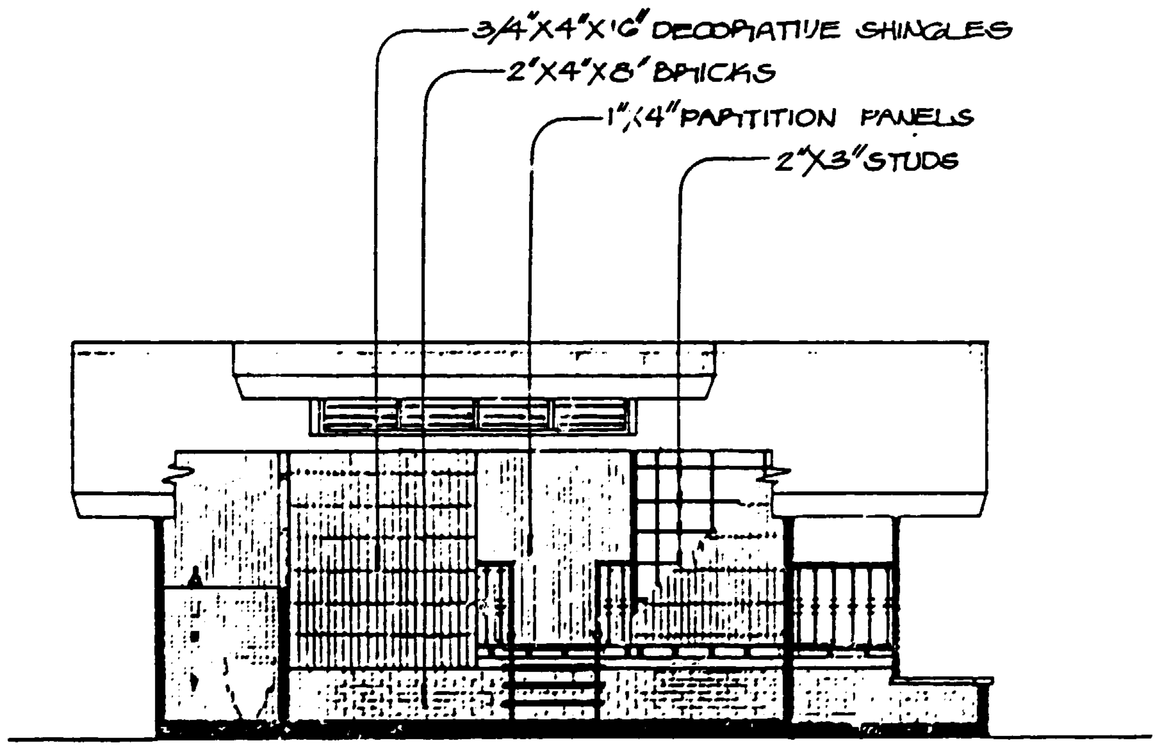


REAR SIDE ELEVATION

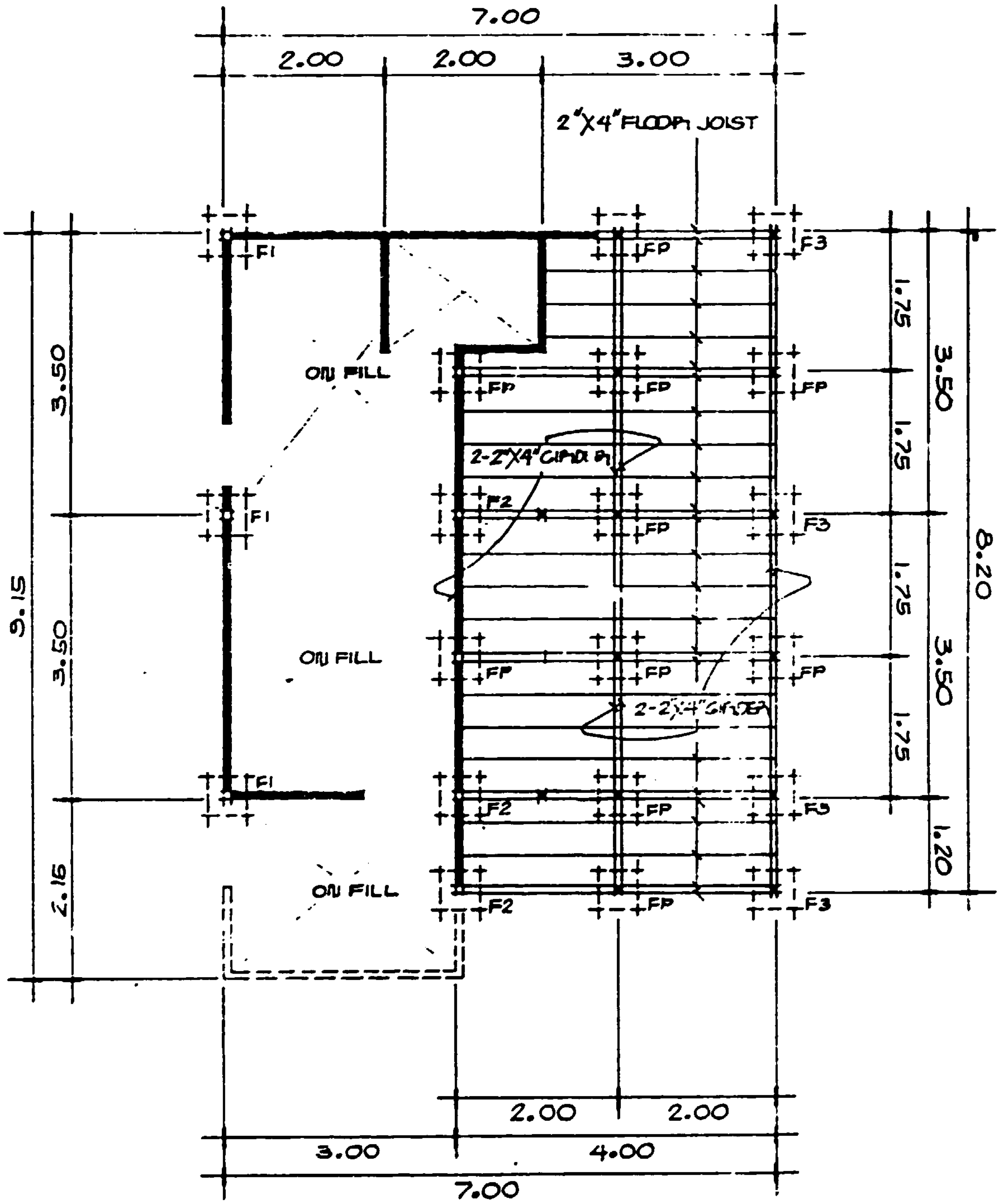
SCALE 1:80 METER



CROSS SECTION thru A'-A'
SCALE 1:80 METER

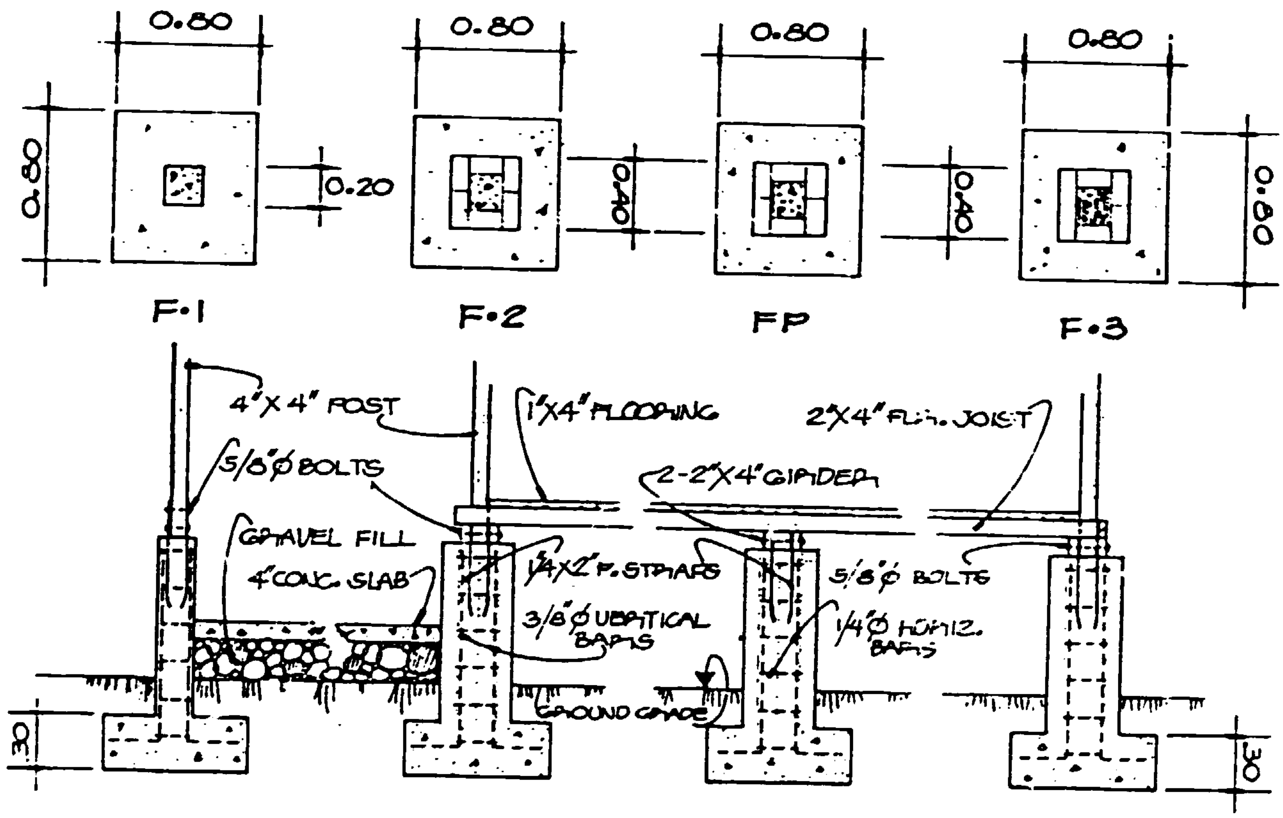


CROSS SECTION thru B'-B'
SCALE 1:80 METER



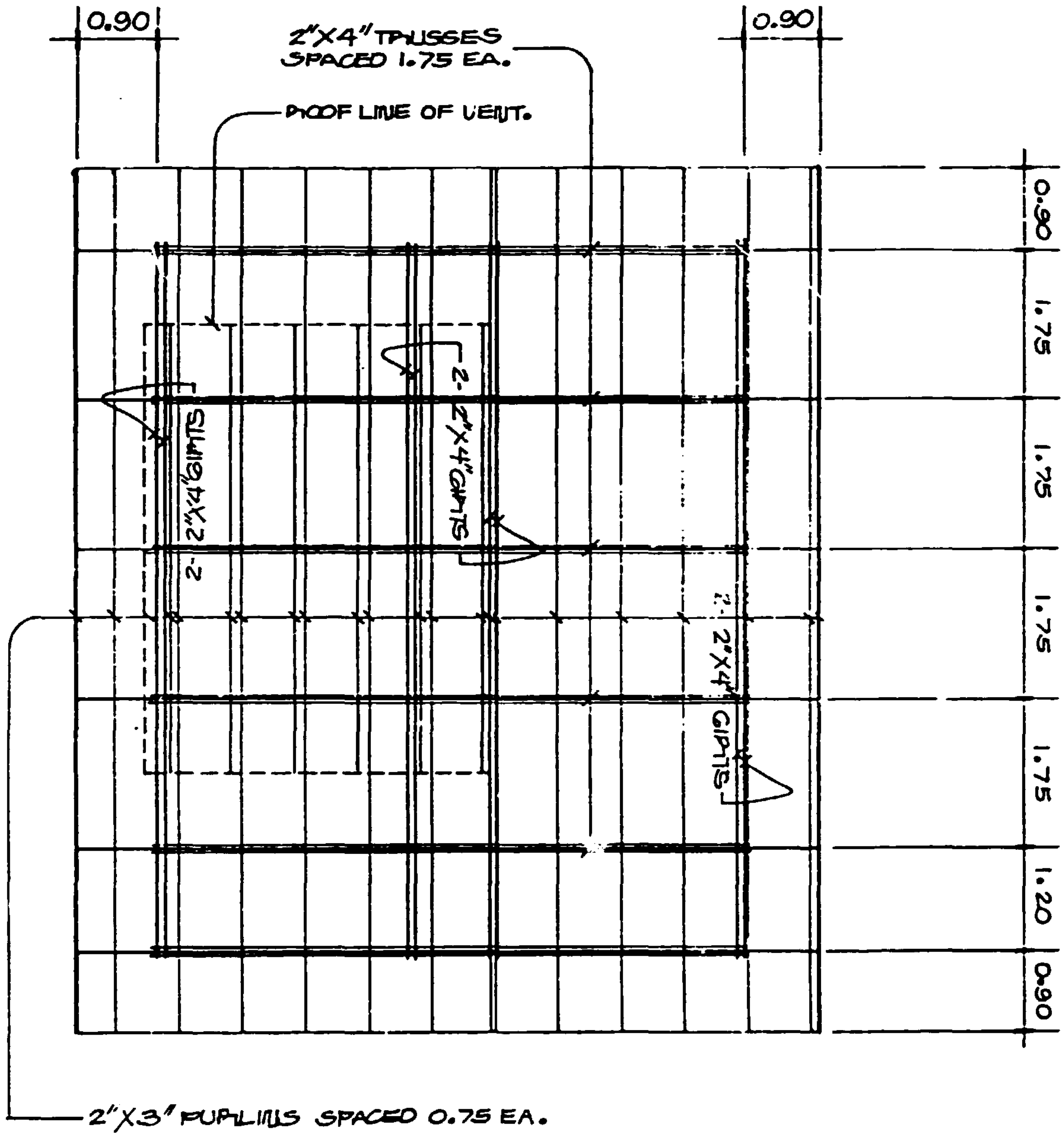
FOUNDATION-FLOOR FRMNG. PLAN

SCALE 1:80 METER



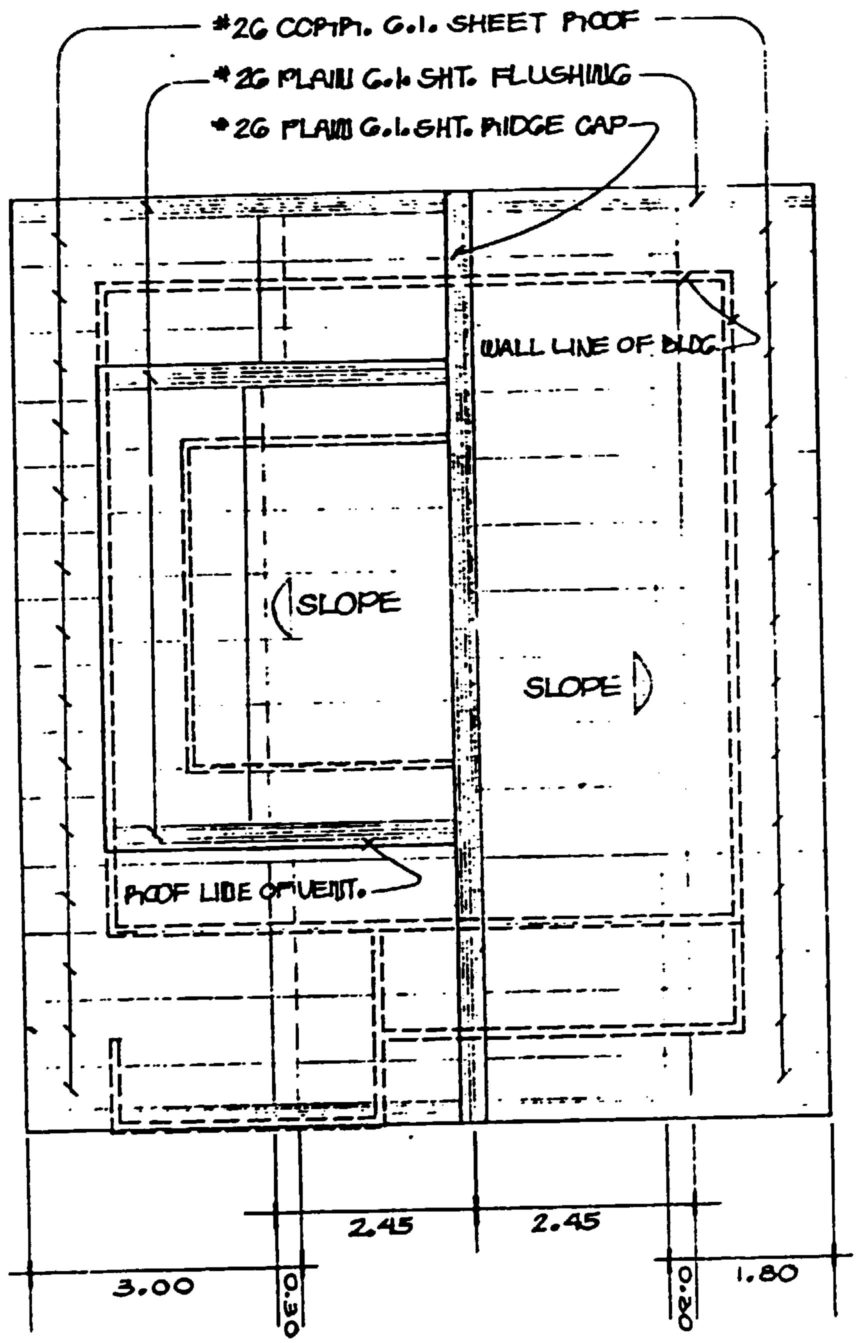
DETAILS ON FOOTING, REINS., GIRDER, CONNECTIONS, ETC.

SCALE 1 : 40 METER



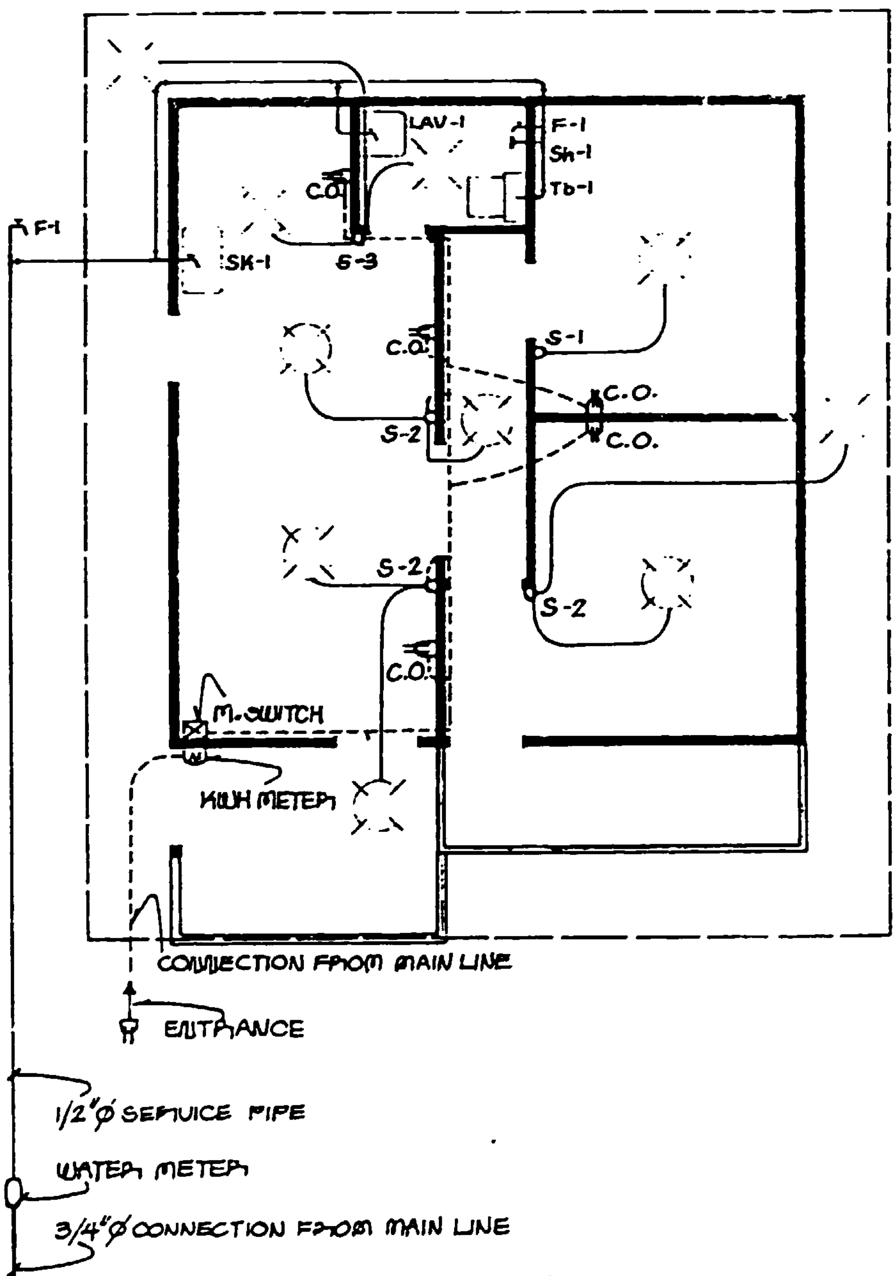
ROOF FRAMING PLAN

SCALE 1:80 METER



ROOFING PLAN

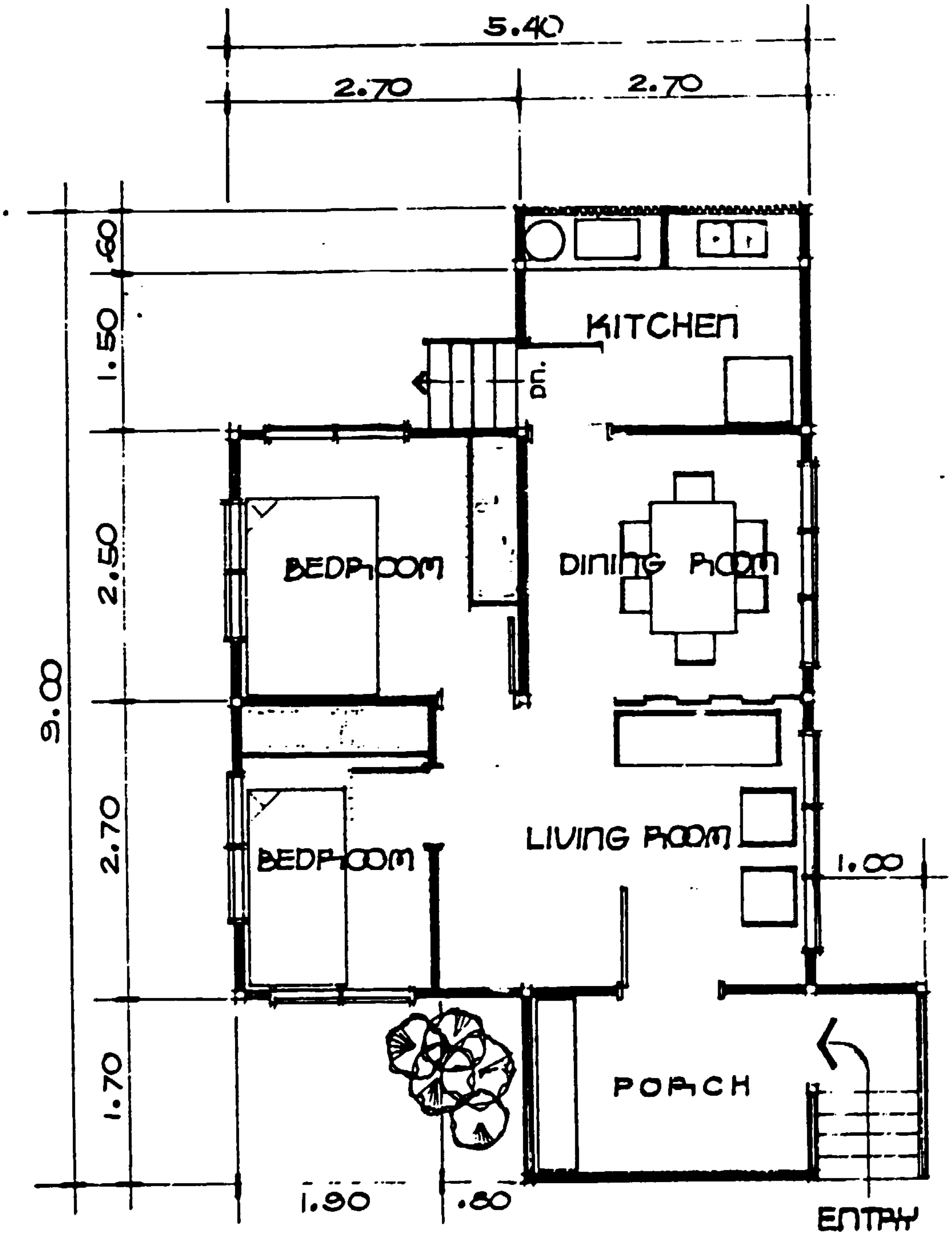
SCALE 1:80 METER



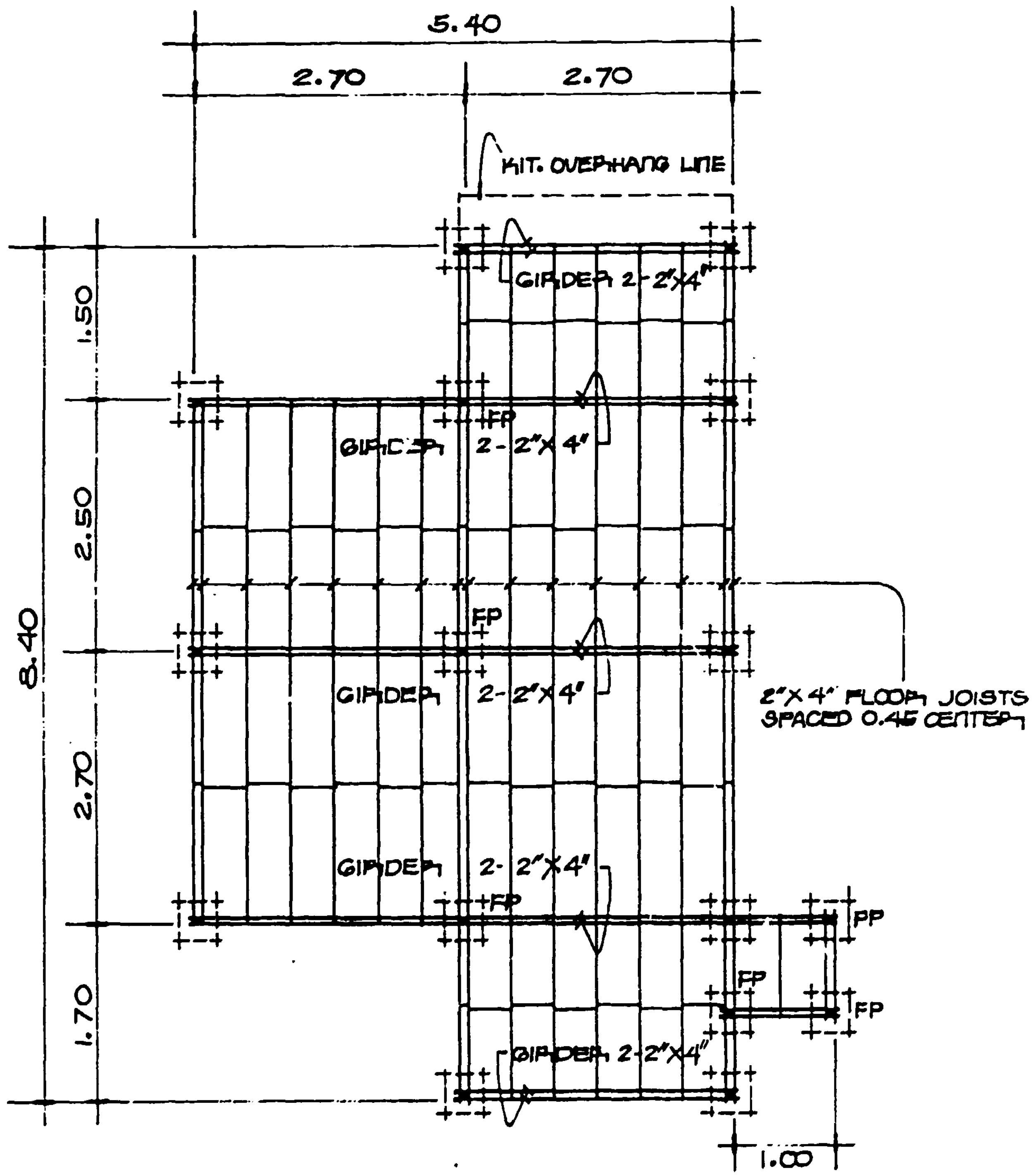
ELECTRICAL LAYOUT and PLUMBING AUGMENT

SCALE . 1:80 METER

E

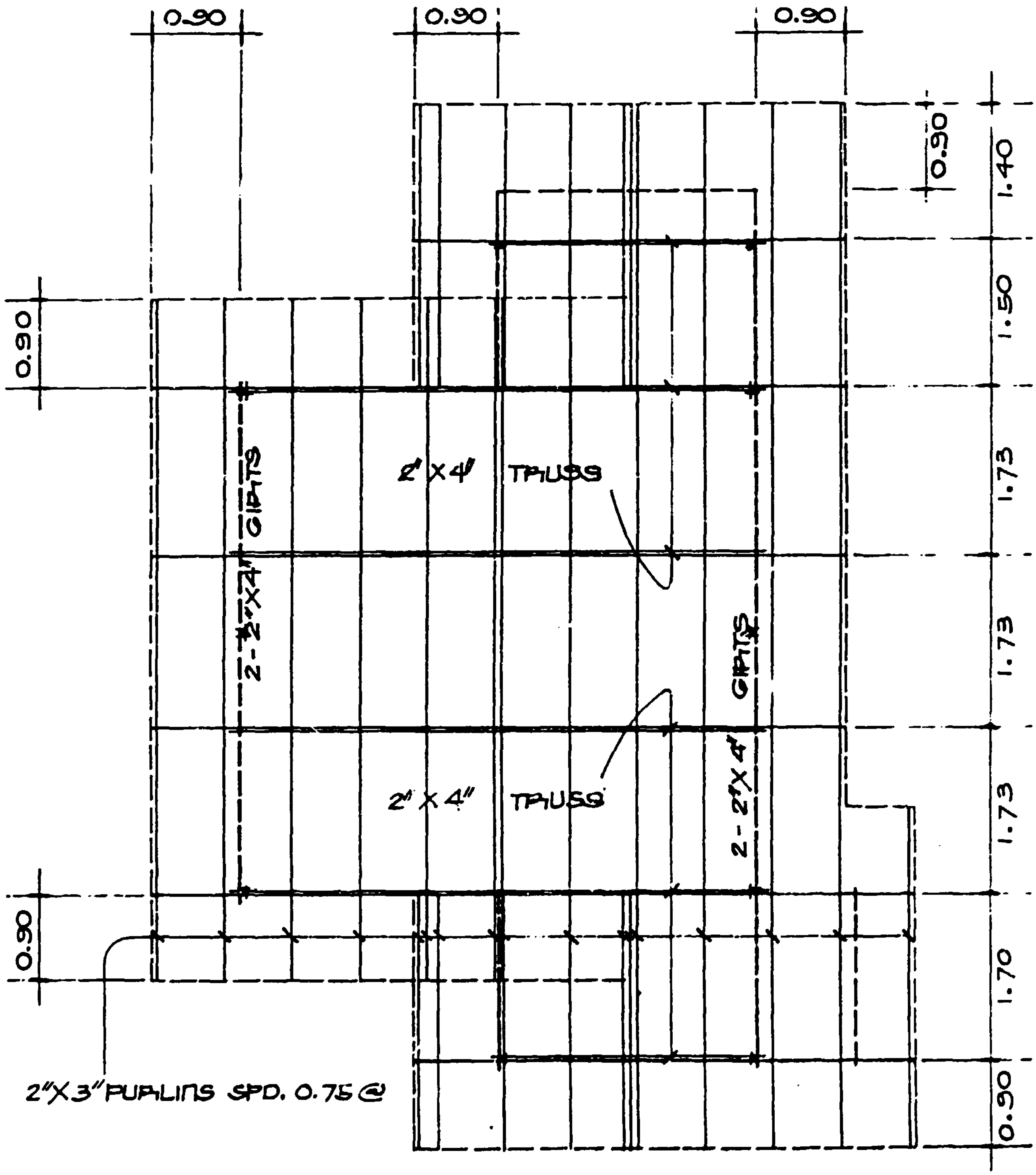


FLOOR PLAN
SCALE 1:60 METER



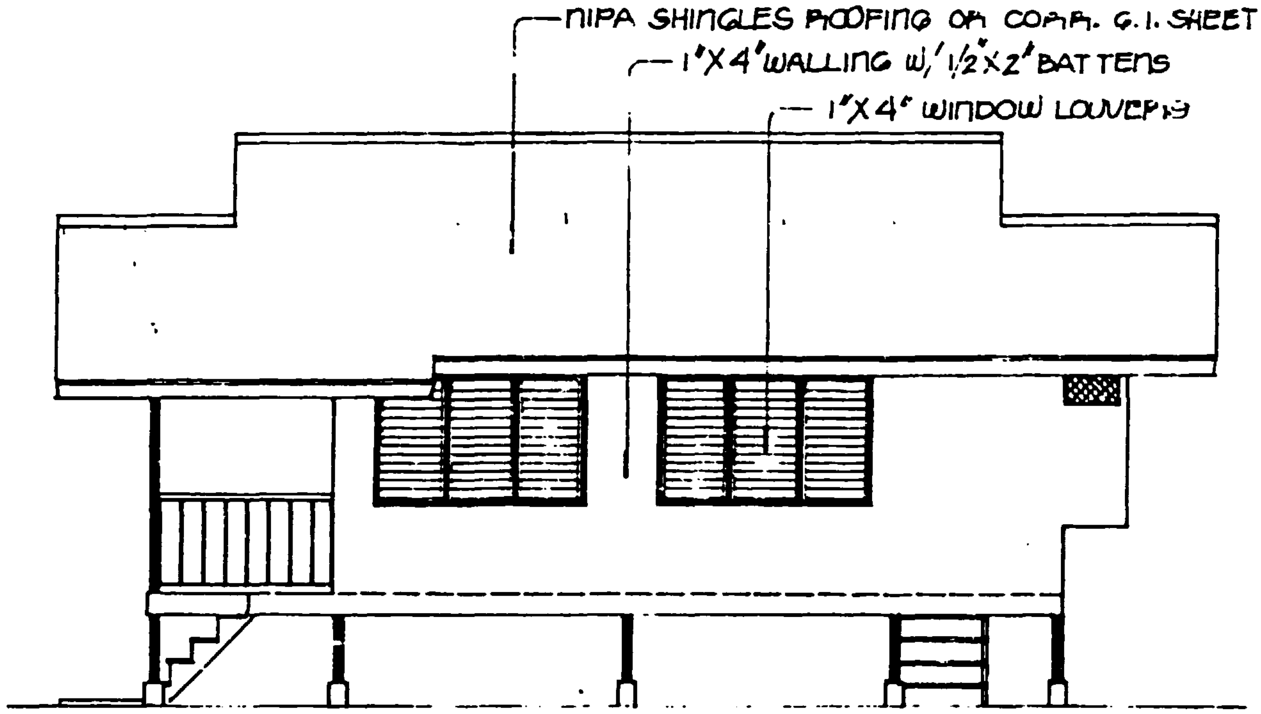
FOUNDATION • FLOOR FRAMING PLAN

SCALE 1:60 METER



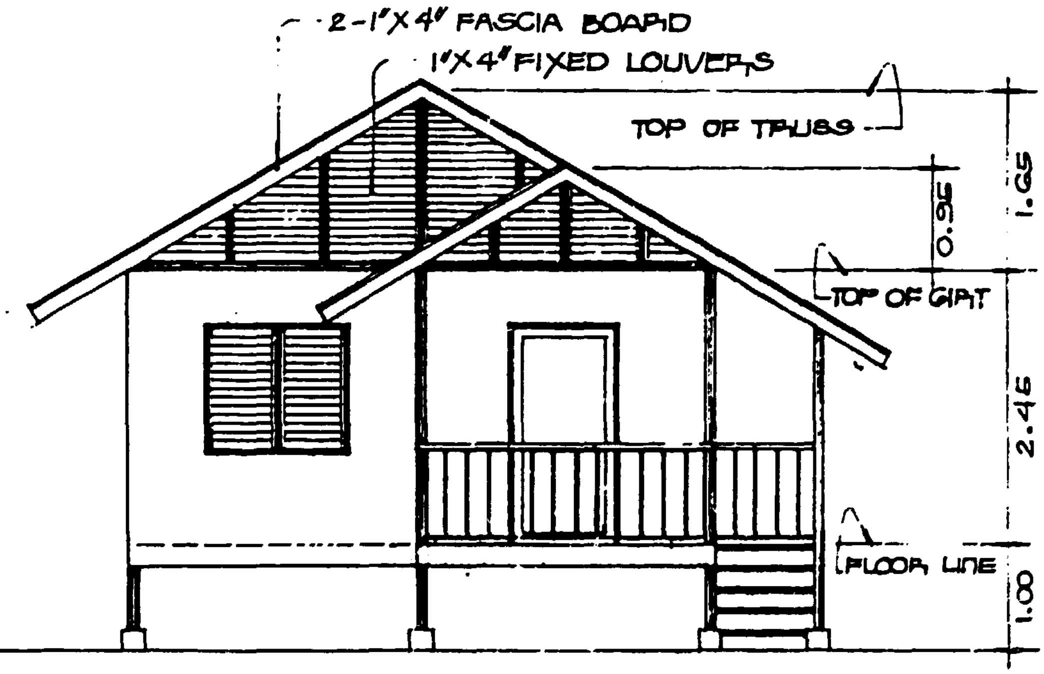
ROOF FRAMING PLAN

SCALE 1:60 METER



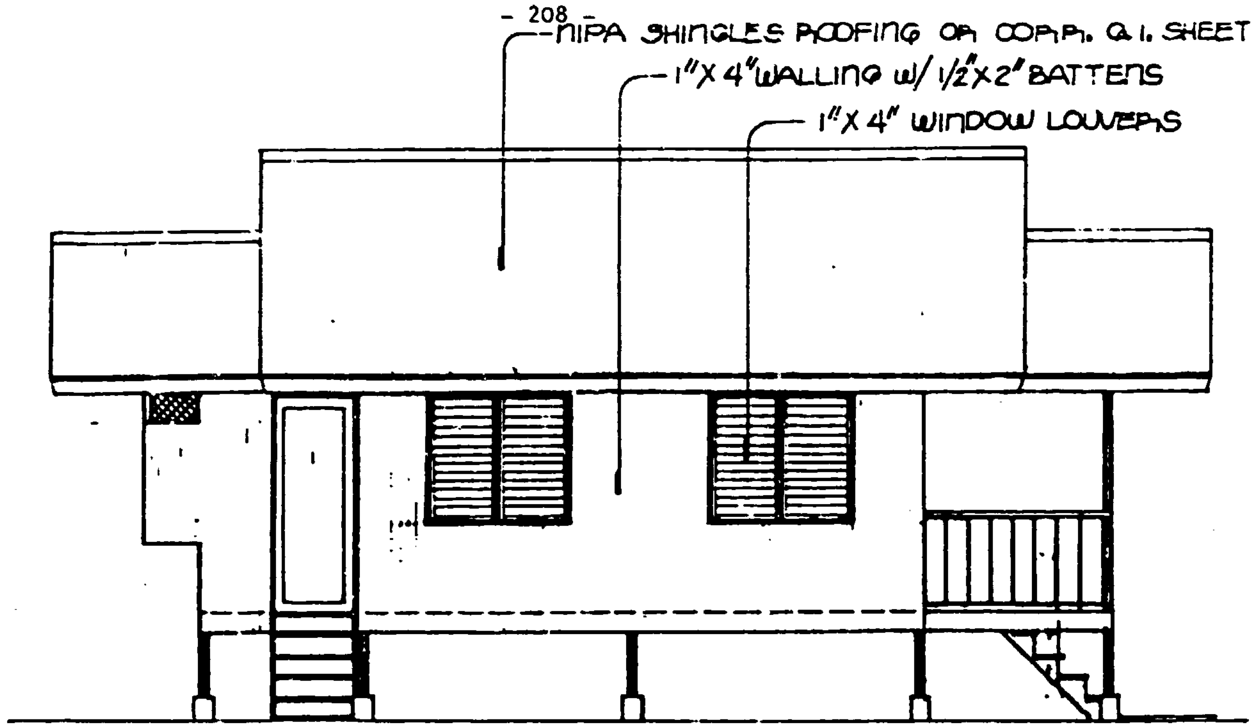
RIGHT SIDE ELEVATION

SCALE 1:60 METER



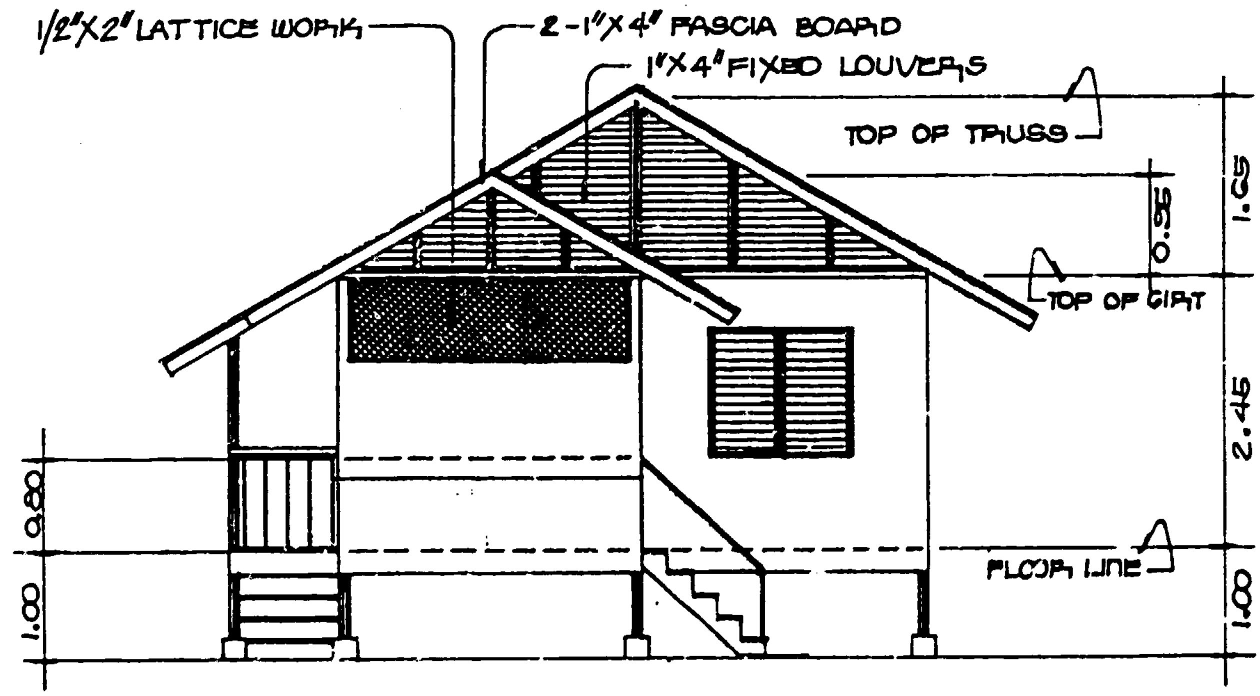
FRONT ELEVATION

SCALE 1:60 METER



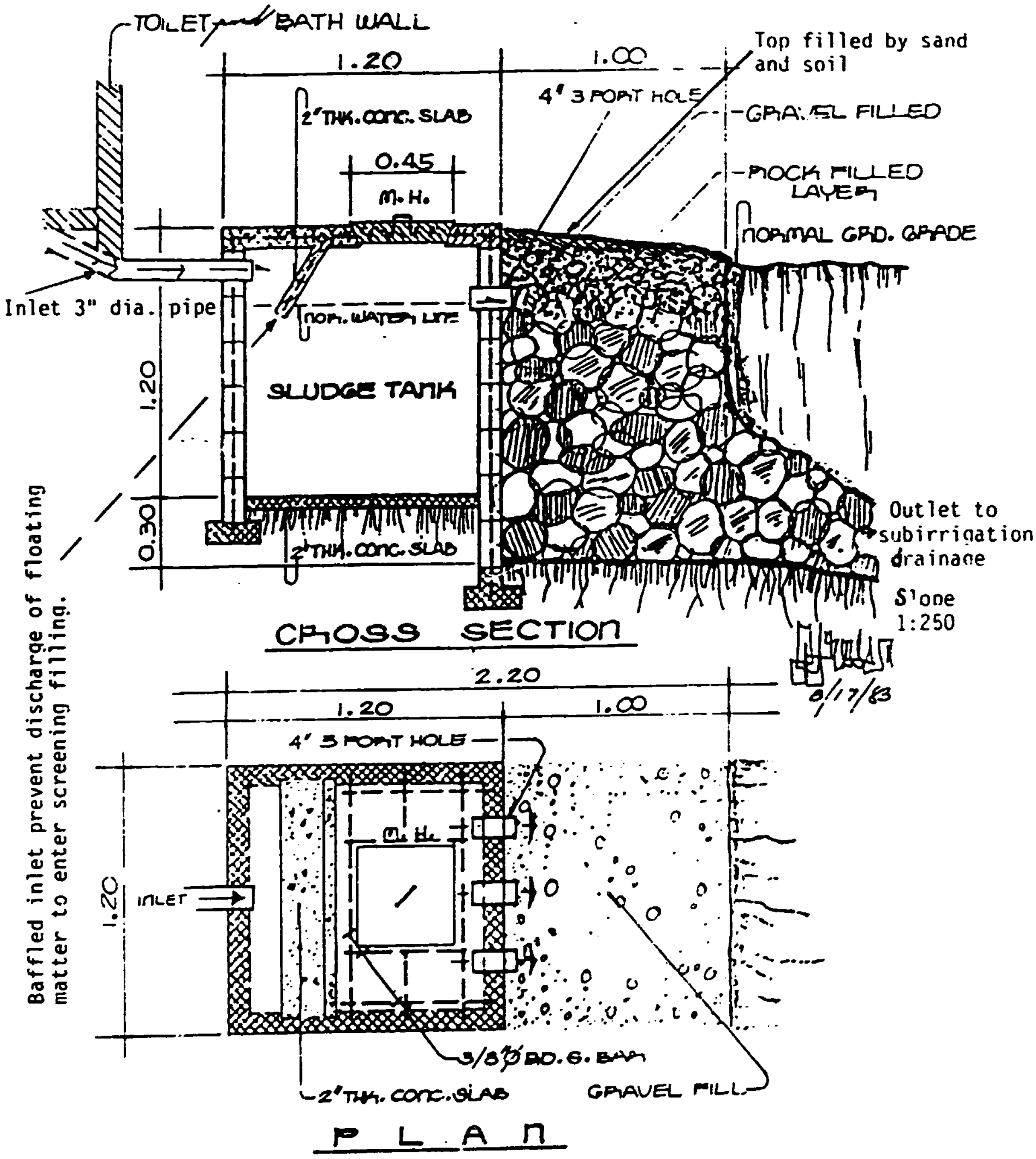
LEFT SIDE ELEVATION

SCALE 1:60 METER



REAR ELEVATION

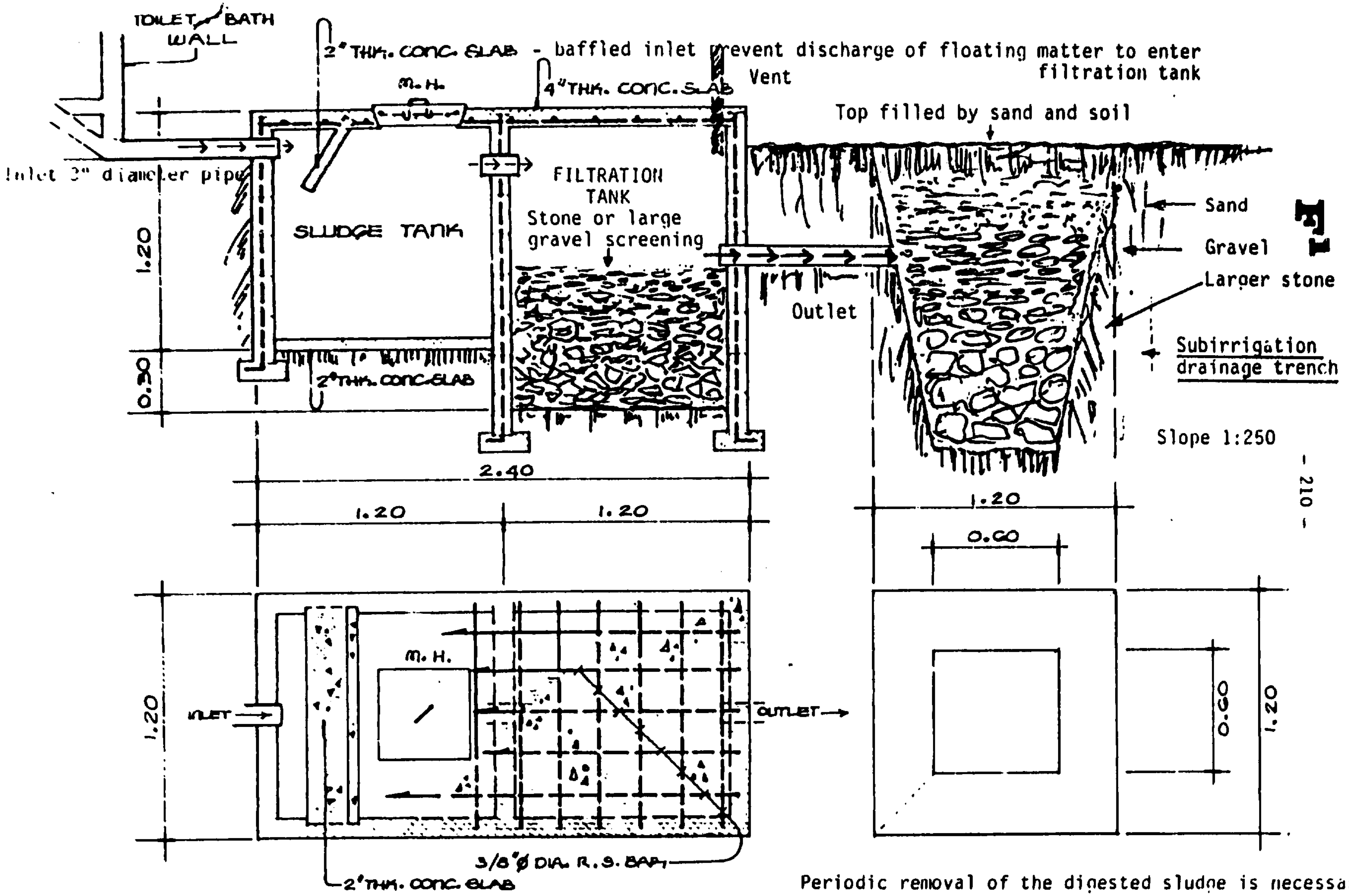
SCALE 1:60 METER



SIMPLE DOMESTIC SEPTIC TANK WITHOUT FILTRATION CONCRETED TANK SCREENING FILLINGS ATTACHED TO SUBIRRIGATION DRAINAGE

Periodic removal of the digested sludge is necessary.

Dimensions in metres unless otherwise stated.



Periodic removal of the digested sludge is necessary.

DOMESTIC SEPTIC TANK

Dimensions in metres unless otherwise stated.