PN-AAR-150

ISN 36630

FINAL REPORT

Temporary Systems for Community Space During Disaster Relief and Rehabilitation

This report has been prepared by the Cooperative Housing Foundation for the Agency for International Development under Contract AID/otr-C-1738.

000393

May, 1982

002960

ACKNOWLEDGEMENTS

The production of this document required the combined efforts of many persons. Primary responsibility for the preparation of the document was that of Mr. Barry Frazier of CHF, and Mr. L.E. Birch, Consultant. The contributions of the following are due special thanks:

Agency for International Development

Office of Housing

Mr. Fredrik A. Hansen, Deputy Director
Mr. David Olinger, Senior Technical Specialist
Mr. Peter Feiden, Housing Intern (IDI)

Office of Foreign Disaster Assistance

Mr. George McCloskey, Assistant Director of Operations Support Division
Mr. Harry Wilkinson, Assistant Director for Latin American Caribbean Division
Mr. George Beauchamp, Disaster Operations Officer
Ms. Gudrun Huden, Operations Officer
Mr. Weston Emery, Operations Officer

Table of Contents

1.0 BACKGROUND AND PROJECT OBJECTIVES

2.0 DESIGN SPECIFICATIONS AND PRE-DESIGN DATA

2.1 Plastic Sheeting
2.11 Sheeting Properties/Characteristics
2.12 Plastic Materials Matrix
2.13 Analysis and Recommendations

2.2 Lightweight Framing Systems
2.21 Indigenous
2.22 Military
2.23 Recreational
2.24 Prefabricated

2.3 Buillding Construction Materials
2.31 Compression
2.32 Tension
2.33 Linear, Torque Resistant
2.34 Sheeting

3.0 COMMUNITY SPACE SYSTEM DESIGN

3.1 Design Methodology
3.11 Design Approach
3.12 Use of the Design Manual

3.2 Design Information
3.21 Siting and Orientation
3.22 Climatic Considerations and Guidelines
3.23 Structural Considerations and Guidelines
3.24 Cultural Considerations and Guidelines
3.25 Space Planning and Layout
3.26 Security Considerations
3.27 Properties of Plastic Sheeting

3.3 Framing Systems
3.31 BRE Braced Frame
3.32 Bamboo Lattice Cylinder
3.33 Pole Tent
3.34 Wrap-around Frame
3.35 Hanging Tent Shed
3.36 Dug Out
3.37 Circular Frame
3.38 Rubble Wall Shed
3.39 Wood Truss-Bent

Table of Contents

3.4 Use of Plastic Sheeting with Existing Damaged Structures
- 3.41 Partially Blown Off Roof
- 3.42 Wall Reconstruction
- 3.43 New Roof
- 3.44 New Doors and Windows

3.5 Structural Connections
- 3.51 Masonry
- 3.52 Dimensional Lumber
- 3.53 Bamboo
- 3.54 Poles
- 3.55 Rope

3.6 Plastic Sheeting Connections
- 3.61 Connector Spacing Information
- 3.62 Sheeting to Sheeting
- 3.63 Sheeting to Masonry
- 3.64 Sheeting to Dimensional Lumber
- 3.65 Sheeting to Bamboo
- 3.66 Sheeting to Pipe
- 3.67 Sheeting to Rope

3.7 Ground Interface Connections
- 3.71 Plastic Sheeting
- 3.72 Foundations
- 3.73 Anchors

3.8 Doors, Windows, and Openings
- 3.81 Doors
- 3.82 Windows
- 3.83 Vents
- 3.84 Chimney Openings
- 3.85 Electrical Service Entry

3.9 Maintenance, and Repair
- 3.91 Maintenance of Plastic Sheeting Covered Structures
- 3.92 Repair of Plastic Sheeting Covered Structures

4.0 APPENDICES

4.1 Disaster Prone Developing Countries

4.2 Bibliography

4.3 Sample of Plastic Sheeting Material

1.0 Background and Project Objectives

1.0 BACKGROUND AND PROJECT OBJECTIVES

Following many major disasters, it is difficult to obtain adequate enclosed space in order to provide such essential public services as health stations, classrooms, nutrition and food distribution centers, warehouses, and public meeting places. These needs are sometimes met partially with contributions of hospital-type tents, military medium and large general purpose tents, and pre-fabricated buildings of various sizes and materials. Although these shelters are available for immediate shipment from most of the major international disaster relief donors, they are often expensive, difficult to erect, and rarely offer flexibility in the amount of floor space they might provide. The temporary nature of these needs does not justify permanent or even semi-permanent structures.

Dependence on imported tents and pre-fabricated buildings can be reduced by using plastic sheeting material in combination with a frame made of indigenous new or salvaged materials. Erecting an adequate community services structure may be difficult because the space to be housed is usually large and the which is wind- and rain-resistant, capable of sustaining a snow-load, and usable in hot and cold weather, yet made of indigenous materials, may be beyond the capabilities of local expertise, especially when the population is recovering from a major disaster and lacks the time to experiment.

Although the need for multi-family dwellings is not frequent following disasters, when the need does occur there is no standard international response. Existing buildings such as schools are sometimes modified with temporary partitions, but are then unavailable for their intended purpose. This type of shelter system should provide a temporary alternative.

The two primary objectives of this project are to design systems for the following:

1. Temporary Multiple-purpose Community Structures: for use as enclosed space for essential public services following a disaster in a foreign country. These services could include a health station, a school classroom, a nutrition and food distribution center, a warehouse, or a public meeting place.

2. Temporary Multi-family Shelters: for use as a multi-family dwelling space for at least four families of two adults and four children each (24 people) separated sufficiently to retain family integrity and privacy and to provide protection from the elements. The activities would be those associated with family life in a disaster relief situation, but would not include significant bathing and food preparation.

These designs must incorporate indigenous materials normally found in disaster-prone developing countries (See Appendix 4.1) and lighweight reinforced plastic sheeting material (or an A.I.D. approved substitute with similar characteristics) which is currently available commercially from several sources.

2.0 Design Specifications and Pre-Design Data

2.0 DESIGN SPECIFICATIONS AND PRE-DESIGN DATA

A) The framing systems will be made from wood (including bamboo) or other building materials or combinations thereof that are usually available for use at a disaster site.

B) The framing systems should be modular and connectable in order to be able to provide larger areas of contiguous enclosed space.

C) The systems should be simple in design so that they can be erected by semi-skilled workers with a minimum of professional or skillled direction. Supervision should be by local building authorities.

D) In all cases the outer covering to be used shall be the reinforced plastic sheeting (or AID approved substitute with similar characteristics). Samples of the plastic sheeting currently stored by AID and data on its characteristics will be provided. No approval will be given under this contract to any construction design which does not utilize plastic sheeting (or AID approved substitute with similar characteristics) as a major component.

E) Methods for attaching or fastening plastic sheeting to the frames will utilize locally available materials wherever possible and not rely on imported materials..

F) Fabrication and erection of the framing and fastening of the plastic sheeting will not require any tools that are not locally available under ordinary circumstances. No power tools will be required.

G) The design of the buildings should be culturally acceptable to the disaster victims.

H) As this contract covers temporary shelters only, the shelter should be designed to last only one year with normal use. However, it should

sustain no more than 20% loss of function during the first six months, given normal maintenance.

I) The design should permit repairs of minor damage incurred to framing or roofing by falling branches, children's play, vandalism, and fire.

J) Measurements (when included) will be given in metric terms.

2.11 SHEETING PROPERTIES/CHARACTERISTICS

As discussed in the Project Objectives and Design Specifications, the intended application of the plastic (polymer) sheeting is either in conjunction with existing damaged structures - to repair and bring them back into service - or in the erection of new, temporary spaces in which public service and residential activities can take place. The repair or construction of these structures would be done primarily by unskilled and low-skilled labor. Because of this fact, and their very nature, the structures will be short lived and expected to endure only reasonable evnironmental forces - wind, rain, heat, cold, etc. - in providing shelter. They are not intended to withstand secondary disaster events - earthquakes, hurricanes - without being damaged.

Given this series of design requirements and parameters, a set of desirable characteristics for the material was identified and are shown below.

1. Capable of providing a serviceable life for approximately one year given normal use.
2. Compatible with use of local materials, unskilled labor, and few tools.
3. Provided in a sheet size sufficiently large to accommodate the creation of spaces for community/public scale functions and repair of existing damaged structures.
4. Capable of repairs to minor damage.
5. Relatively inexpensive on a per square foot basis.

6. Produced by and available from several manufacturers.

7. Available in colors which are compatible with climate and social/cultural variations.

8. Flame resistant/retardant.

9. Capable of bending/stretching in two directions simultaneously.

10. Capable of limited stretch/elongation with a "memory" (i.e. the ability to return to original shape and size after deformation forces are removed).

11. Puncture and rip resistant.

The spectrum of commercially available plastic materials from which to select one material having the greatest number of characteristics shown above is extremely broad. These sheeting materials range from the most commonly known thin polyethylene films used in consumer packaging to very high technology Teflon-coated woven glass fiber fabrics used in architectural applications. In this investigation, no attempt was made to design or engineer a new material to meet the specific needs of the project. Rather, a conscious effort was made to restrict the scope of products to materials which are produced by a number of manufacturers and that would likely be available in quantity, if the need arose.

As might be expected, each plastic sheeting material has its own set of characteristics or properties. For this project, it was determined that the set of characteristics listed above would act as the criteria against which the various sheeting materials would be assessed. Those materials identified as most closely meeting the requirements

of the characteristics would be recommended for fuller evaluation under Phase II of the project.

One difficulty encountered in carrying out this analysis was acquiring measurement data for one specific property of all materials which had been obtained using a uniform testing procedure or standard. Because of the nature of different materials, one particular quality in two materials is often measured by different standards and procedures. Consequently, the test results from one material to another must be closely analysed and interpreted. A brief description of the standards against which materials have been measured is found in the Notes for Plastic Materials Matrix. Manufacturers tend to perform tests and publish information which present the best properties of a given material. In addition, materials distributors often do not have access to or a thorough understanding of technical information. For these reasons, information which does not appear in the accompanying Plastic Materials Matrix for a specific property of a given material is not available at this time.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
2.12 PLASTIC MATERIALS MATRIX	CONST. warps/inx wefts/in	COATING mils	TOTAL THICK. inches	FINISHED WEIGHT oz/sq yd	GRAB TENSILE STREN. lbs	TONGUE TEAR STREN. lbs	MULLEN BURST STREN. PSI	HYDRO STATIC RESIST. PSI	FLAME RESIST. Meets regs. listed	ELONGA-TION	ROLL SIZE w-ft l-ft	COLORS	APPRX. COST $/1000 SF
1 OFDA MATERIAL	PE-HD 12x12	PE-LD 1.0	.012	6.5	165x165	60*	350	144	none	-	20S 100S	T,G,O,B W	82.50
2 SCRIMWEVE S-1010	PE-HD 10x10	PE-LD 1.25	.007	4.35	113.76x 101.08	40.8x 45.32	260*	-	none	>1%	40 500	B,G,R,W BK,GR,O,T	81.60
3 SCRIMWEVE T-120	PE 12x10	PE 1.25	.010	4.6	160.33x 144.47	69.93x 61.13	357.5*	-	none	-	40 1000	B,G,R,BK, GR,O,T,W	93.20
4 LORETEX 1212	PE 12x12	PE 1.5	.012	6.5	214x219	60x60	415	144	UL, NFPA, CPAI 84.6	<1.5%	150 1500	B,G,O W,	250.00
5 BRUN-TUFF VRN 200	Nylon -	PVC -		10.0	-	-	-	-	CFMA	-	5.0 300	B,G,W, Y,BK,R	134.07
6 DURA-TUFF #4802	Nylon 22x22	PVC	.010	6.0	105x90*	34x32+	-	175	CFMA	1-2%	6.0 300	G,W,Y	110.00
7 DURA-TUFF #4932	Nylon -	PVC -	.014	10.0	125x120*	45x45+	-	210	CFMA	-	4.5 300	B,G,W,Y F	172.60
8 DURA-PRO #6010	Polyester 10x10	PVC	.016	10.0	250x220*	50x70+	-	300	CFMA	-	5.16 300	B,G,W,Y	127.50
9 SHELTER-RITE #8218	Polyester -	PVC -	-	18.0	230x200*	100x100+	-	200	UL,NFPA CFMA	-	4.67 300	B,G,W,Y	321.20
10 NYLON REINFOR. PE FILM	Nylon 3.5x3.5	PE -	.004	-	-	-	85	-	-	-	20 100	-	47.50
11 LD PE FILM MONSANTO	-	No Coating	.004	2.88	-	-	-	-	-	495%M 550%T	40 100	BK	10.41N 11.04BK
12 LD PE FILM ALMAC	-	No Coating	.010	1.71	-	-	-	-	-	495%M 550%T	4.0 1000S	BK	13.78
13 LD PE FILM ALMAC	-	No Coating	.015	2.88	-	-	-	-	-	-	4.0 1000S	BK	20.66
14 RUFCO 400 CROSS LAMIN. FILM	PE-HD	No Coating	.004	2.30	89.5*	12.95	-	55	none	-	4.0 100S	W,BK	42.50
15 TUTUF 4 CROSS LAMIN. FILM	PE-HD	No Coating	.004	2.74	-	-	202.5+	-	ASTM D1433	356%M 428%T	30 100S	B,G,O,W BK	50.00
16 SUPER-POLY FILM ASTRUP	PE	No Coating	.015	3.8	174	14	118	63	CPAI 84.7	-	6.0S 750S	B,G,B/BK W,Y	58.33

NOTES FOR PLASTIC MATERIALS MATRIX

COLUMN
NUMBER

1. NAME OF MATERIAL

2. CONSTRUCTION
   This column lists on the first line the type of polymer used in the material. If the material is woven, the warps and wefts per inch are shown on the second line.
   PVC = Polyvinyl chloride
   PE = Polyethylene
   HD = High Density
   LD = Low Density

3. COATING
   For those materials which have a coating applied to both sides of a scrim fabric, the type of polymer is shown on the first line and the thickness of the coating on each side is shown below it.

4. TOTAL THICKNESS
   The measurement of the sheeting (including coatings where applicable) is shown.

5. FINISHED WEIGHT
   The total weight per square yard of the material is shown.

   ASTM #D1910-75 Procedures Summary
   The length and width are measured and then weighed on a calibrated balance to the nearest 0.01% of its weight.

6. GRAB TENSILE STRENGTH
   The first figure given is the value at which the material fails in the direction of the warp; the second number represents the value at which the material fails in the weft direction.

   ASTM # D1682-64 Procedures Summary
   The grab method is applicable whenever it is desired to determine the"effective strength" of the fabric in use, that is, the strength of the yarns in a specific width together with the additional strength contributed by adjacent yarns. The breaking load determined by the grab method is not a reflection of the strength of the yarns actually gripped between clamps and cannot be used for direct comparison with yarn strength determinations. Grab tests are as precise as ravelled strip tests and the speimens require much less time to prepare though they require more fabric per specimen. There is no simple relationship between grab tests and strip tests since the amount of fabric assistance depends on the type of weave, fabric count, mobility of yarns, etc.

COLUMN
NUMBER

A continually increasing load is applied longitudinally to the specimen, and the test is carried to rupture in a specific time. Values for the breaking load and elongation of the test specimen are obtained from machine scales or dials or autographic recording charts.

* FTMS # 191/5100 Procedures Summary
(Not available at time of printing)

7. TONGUE TEAR STRENGTH
The first figure given is the value at which the material fails in the direction of the warp; the second number represents the value at which the material fails in the weft direction.
* Only one value given

ASTM # D2261-71 Procedures Summary
A rectangular specimen, cut in the center of the shorter edge to form two "tongues" (or "tails"), is gripped in the clamps of a recording tensile testing machine and pulled to simulate a rip. The force to continue the tear is calculated from integrator readings as the average force to tear, or from the autographic chart as the median-peak load or the average of the five highest peaks.

+FTMS 191/5134 Procedures Summary
(Not available at time of printing)

8. MULLEN BURST STRENGTH
* These figures are an average of the two values

ASTM #D751-73 Procedures Summary
Lay the specimen smoothly on the face of the lower ring of the clamp, and lower and fasten the upper plate in place. This shall form a watertight compartment. When the specimen is coated on only one side, place the coated side next to the water column, unless otherwise specified. With the leveler at the zero postion, turn the water on and keep it running at such a rate as to overflow continuously. Raise the column at a rate of 10 mm/s until the first drop of water appears through the coated fabric. Read on the scale the height of the water column above the level of the specimen.

ASTM# D1822-79 Procedures Summary
The energy utilized in this method is delivered by a single swing of a calibrated pendulum of a standardized tension-impact machine. The energy to fracture by shock in tension is determined by the kinetic energy extracted from the pendulum of an impact machine in the process of breaking the specimen. One end of the specimen is mounted in the pendulum. The other end of the specimen is gripped by a crosshead which travels with the pendulum until the instant of impact and instant of maximum pendulum kinetic energy, when the crosshead is arrested.

COLUMN
NUMBER

9. HYDROSTATIC RESISTANCE FTMS 191/5512
(Not available at time of printing)

10. FLAME RESISTANCE
The standards/regulations referenced in this column are cited by the manufacturers as those which their product meets. Following in this section is a brief synopsis of each standard cited. These synopses are included only to give the reader a general idea of the scope, procedures, and requirements of the standards. Each of the standards is much too lengthy and detailed for incorporation in this report and necessarily, some information has been omitted. Consequently, the summaries presented should be used for general informational purposes only and are not intended to fully represent detailed aspects of the standards.

UL
Underwriters Laboratories
Standard for Tests for Flame-Propagation of Fabrics and Films - UL214

General Scope

These requirements apply to the performance in flame-exposure tests of flame-resistant fabrics of natural, synthetic, or combinations of natural and synthetic fibers; or films intended for such use as as tents, awnings, draperies, or decorations. The flame resistance of the fabric or film may be inherent in the material used or may be the result of chemical treatment to retard ignition and spread of flame. The flammability tests provide a means of determining the flame-propagation, if any, of fabrics or films under light fire exposure.

The Small-Flame Test is intended to determine the burning characteristics of fabrics and films in single sheets when exposed to a luminous flame 1-1/2 inches (38.1 mm) high. Fabrics and films that show acceptable performance in the Large-Flame Test may not retard flaming or smolding combustion in the Large-Flame Test.

The Large-Flame Test is intended to determine the burning characteristics of fabrics and films in single sheets and folds when exposed to an oxidizing flame 11 inches (279 mm) high. Fabrics and films that show acceptable performance in the Large-Flame Test may not retard flaming or smolding combustion under more severe fire exposure.

Fabrics and films shall be in accordance with the Conditions of Acceptance of both the Small-Flame Test and the Large-Flame Test.

Conditions of Acceptance
Small-Flame Test

A test specimen shall have the following properties:

A. The specimen shall not continue to flame more than 2 seconds after withdrawal of the test flame.

B. Portions or residues which break or drip from a test specimen shall not continue to flame after falling.

C. The vertical spread of flame and afterglow (smoldering combustion) on the specimen, as indicated by the length of char, shall not exceed the values indicated below.

Length of Char

Weight of Fabric or Film	Maximum Average Length of Char of Destroyed Material (10 Specimens)		Maximum Length of Char or Destroyed Material for any Specimen	
Ounces per square yard (kg/m^2)	inches	mm	inches	mm
Over 10 (0.34)	3-1/2	88.9	4-1/2	114
Over 6 (0.20) and not exceeding 10 (0.34)	4-1/2	114	5-1/2	140
Not exceeding 6 (0.20)	5-1/2	140	6-1/2	165

Large Flame Test

A test specimen shall have the following properties:

A. The specimen shall not continue to flame for more than 2 seconds after withdrawal of the test flame.

B. Portions or residues which break or drip from a test specimen shall not continue to flame after falling.

C. The vertical spread of flame and afterglow (smoldering combustion) in a single sheet specimen, as indicated by the length of char above the tip of the test flame, shall not exceed 10 inches (254 mm).

D. The surface spread of flame in a folded specimen shall not exceed 35 inches (889 mm) above the tip of the test flame, but the afterglow may spread in the folds.

NFPA
National Fire Protection Association Standard Methods of Fire Tests for Flame-Resistant Textiles and Films
NFPA-701 Large Scale

General Scope

It is the intent of these requirements to provide tests to determine whether the flame-resistant textiles and films are comparatively difficult to ignite and whether it is comparatively difficult to propagate flame beyond the area exposed to the source of ignition.

These performance tests do not necessarily indicate whether the material tested will resist the propagation of flame under severe fire exposure or when used in a manner which differs substantially from the test requirements.

General Description

Two methods of assessing flame resistance are described. Both methods will provide a comparison among textiles and films, but do not necessarily indicate the behavior of a material in a large building fire or other conflagration.

The small scale test employs a relatively small sample and small igniting flame. It is simple and convenient for general use. The small scale test is commonly used to indicate susceptibility to flame spread from small ignition sources; but may also be used as a screening test prior to large scale testing.

The large scale test requires a much larger sample and applies a more severe fire exposure which will more nearly approach severe fire conditions. Initial screening may be done with the small scale test. This method is also useful for investigating the flammability of fabrics when hung in folds.

Test Selection

All flame-resistant textiles and films shall be capable of complying with the performance requirements of either the small or the large scale tests or both. The authority having jurisdiction shall determine whether both the small and the large scale tests are required and this will generally depend on the purpose to be served or the nature of the materials tested.

Conducting the Test

The gas burner shall be ignited and the gas pressure regulated at 4-1/4 inches (108mm) of water.

The burner shall be adjusted to produce an 11-inch oxidizing flame having an indistinct inner cone.

The flame shall be applied vertically near the middle of the width of the lower end of the specimen in a single sheet, or to the middle of the width of

the lower end of the middle fold of the specimen in folds. The position of the specimen relative to the test flame shall be maintained by guide wires attached to the outer edges of the specimen. The test flame shall be applied to the specimen for two minutes, then withdrawn.

The duration of flaming combustion on the specimen shall be recorded after withdrawal of the burner.

Flame Resistance Requirements
Large Scale Test

When subjected to the large scale test, no specimen, in single sheets or in folds, shall continue flaming for more than two seconds after the test flame is removed from contact with the specimen.

The vertical spread of burning on the material in single sheets shall not exceed 10 inches above the tip of the test flame. This vertical spread shall be measured as the distance from the tip of the test flame to a horizontal line above which all material is sound and in original condition, except for possible smoke deposits.

The vertical spread of burning on the folded specimens shall not exceed 35 inches above the tip of the test flame, but the afterglow may spread in the folds.

At no time during or after the application of the test flame shall any portions or residues of textiles or films which break or drip from the test specimen continue to flame after they reach the floor of the tester.

CPAI
Industrial Fabrics Association International (Formerly Canvas Products Association International - CPAI)
A Specification for Flame Resistant Materials Used in Camping Tentage CPAI-89

General Scope

This standard provides performance requirements and test methods for evaluating the flame resistance of fabric and other pliable materials used in camping tentage. It also provides for certification of materials by suppliers and for labeling programs to caution the user against actions detrimental to flame retardant finishes, as well as to facilitate the identification of tentage as being constructed of flame resistant materials and to identify the manufacturer.

Material Classification
All materials covered in this standard fall under one of the following definitions:

Flooring Material: Any pliable material used for flooring in camping tentage but excluding such things as rugs or carpets placed in the tent which are not

Wall and Top Material: Any pliable material used in camping tentage for other than flooring including walls, roofs, tops, doors, windows, screens, awnings, flies and canopies.

Performance Requirements

Flooring Material. When subjected to the test described in Section 6, no specimen from a sample unit of flooring material shall be damaged within 1.0 inch of the edge of the hole in the flattening frame.

Wall and Top Material. When subjected to the test described in Section 7, no specimen from a sample unit of wall and top material shall have an after-flame time (length of time a specimen continues to flame after removal of the test flame source) of more than 4.0 seconds; the average after-flame time for all specimens in a sample unit shall not exceed 2.0 seconds. The damaged length (distance from the bottom of the specimens shall not exceed the values shown in the following table. Portions or residues which break or drip from the test specimens shall not continue to flame after they reach the floor of the test cabinet.

Damaged Length. The maximum permissible damaged lengths for wall and top material shall be as follows:

Untreated Weight of Material being Tested Ounces Per Square Yard	Maximum Average Damaged Length for Sample Unit Inches	Maximum Damaged Length for an Individual Specimen - Inches
Over 10	4.5	10.0
Over 8 but not over 10	5.5	10.0
Over 6 but not over 8	6.5	10.0
Over 4 but not over 6	7.5	10.0
Over 1.5 but not over 4	8.5	10.0
Not over 1.5	9.0	10.0

Section 6 Test Method Procedure
Flooring Material

Place the test chamber in the draft-protected environment with its bottom in place and the supporting frame centered in the bottom of the chamber, shimmed side down.

Punch a 1/4 inch diameter hole in the center of the specimen of flooring material to be tested.

Place the specimen on the supporting frame in the position in which it will be used, exercising care that the specimen is horizontal and flat. Place the flattening frame on the specimen and position a methenamine tablet on one of its flat sides with its edge within 1/8 inch of the hole in the center of the specimen.

Ignite the tablet by touching a lighted match or an equivalent igniting source carefully to its top.

Continue each test unil the last vestige of flame or glow disappears or the flaming or smoldering has approached within 1.0 inch of the edge of the hole in the flattening frame at any point.

Section 7 Test Method Procedure
Wall and Top Material

The specimen in its holder shall be suspended vertically in the cabinet in such a manner that the entire length of the specimen is exposed and the lower end is 3/4 inch above the top of the gas burner. The apparatus shall be set up in a draft free area.

Prior to inserting the specimen, the pilot flame shall be adjusted to approximately 1/8 inch in height measured from its lowest point to the tip. The burner flame shall be adjusted by means of the needle valve in the base of the burner to give a flame height of 1-1/2 inches (± 1/16 inch). It is an important aspect of the evaluation that the flame height be adjusted with the tip of the flame level with the tip of the metal prong. After inserting the specimen, the stopcock shall be fully opened, and the burner flame applied vertically at the middle of the lower edge of the specimen for 12 seconds (± .2 second) and the burner turned off. The cabinet door shall remain shut during testing.

After both flaming and glowing have ceased, the damaged length shall be measured.

A tearing force shall be applied gently to the specimen by grasping the corner of the cloth at the opposite edge of the char from the load and raising the specimen and weight clear of the supporting surface. The end of the tear shall be marked off on the edge and the damaged length measurement made along the undamaged edge.

Loads for Determining Damaged Length. The specific load applicable to the weight of the test material shall be as follows:

Untreated Weight of Material Being Tested Ounces per Square Yard	Total Tear Weight for Determining the Damaged Length - Pounds
Not exceeding 3.0	0.125
Over 3.0 and not exceeding 6.0	0.25
Over 6.0 and not exceeding 10.0	0.50
Over 10.0	0.75

ASTM
American Society for Testing and Materials Rate of Burning and/or Extent and Time of Burning of Flexible Thin Plastic Sheeting Supported on a 45 Degree Incline
ASTM #D 1433-77

This standard should be used to measure and describe the properties of materials, products, or systems in response to heat and flame under controlled laboratory conditions and should not be used for the description or appraisal of the fire hazard of materials, products, or systems under actual fire conditions.

This method is not intended to be a criterion for fire hazard. It is intended to provide data for comparing the relative burning rates of thin plastic sheeting under the conditions of this test. The rate of burning will vary with thickness. Test data should be compared with data for a control material of known performance and of comparable thickness. Correlation with burning characteristics under actual use conditions is not necessarily implied.

Even though the test reproducibility within a laboratory will generally be within 5 to 10%, the reproducibility between various laboratories has been found to vary by as much as 40 to 50%. This must be recognized when making interlaboratory comparisons of data. The test is therefore not suitable as a precise general specification test. However, it is suitable for control testing or for making relative evaluations within a laboratory.

General Test Procedure

Prior to inserting the specimen and holder into the track in the cabinet, wet the automatic timer to zero and regulate the butane flame.

With the hood fan off, the clock set at zero, the flame adjusted, and the cabinet window closed, insert the specimen holder on the specimen holder rack in the cabinet. Slide the holder into place at a constant rate, covering the entire distance in approximately 1/2 s. If there is any sticking or abnormal hesitation in this action make a retest.

If the flame goes out before reaching the upper thread, record the Time of Burning at which this occurs. Measure the length from the upper thread to the highest point burned and record it as the Unburned Length in millimetres. The Extent of Burning is defined as 152 mm minus the Unburned Length.

Reporting
The report shall include the following:

The average burning rate in millimetres per second.
If none of the ten specimens or no more than one of 20 burns to the upper thread: Report the Average Time of Burning rounded after averaging to the nearest multiple of 5 s; if burning or glowing continued for less than 3 s after burning the lower thread, it shall be reported as "less than 5 s."

Report the Average Extent of Burning beyond the lower thread, rounded after averaging to the nearest 5 mm from the data recorded in accordance with 7.6; for Average Extent of burning less than 3 mm, report as "less than 5 mm."

CFMA
California State Fire Marshall
Regulations From the California Administrative Code - Public Safety
Title 19 - Subchapter 8. Regulations Relating to Flame-Retardant Chemicals, Fabrics, Application Concerns

Test Requirements for Interior Flame Retardant Chemicals (When Aplied to Standard Synthetic Test Fabrics)

Fire Resistance.
The treated fabric shall not continue to flame for more than one second after the burner is removed. The average length of char (for the standard test fabric) shall not exceed six inches (6").

Specimens shall be tested for fire resistance in accordance with the method outlined under the Test Method below.

Test Method
Small Scale Test. Six specimens each not less than two and one-half inches (2 1/2") x twelve and one/half inches (12 1/2") shall be subjected to the fire resistance test. One half of each set of specimens shall be cut with the long dimension in the direction of the warp, and the other half with the long dimension in the direction of the filling.

The specimens shall be suspended vertically in a rack which covers the upper one-half inch (1/2") of the length and holds the sides firmly to prevent curling, leaving a strip two inches (2") x twelve inches (12") exposed.

The specimens shall be suspended with their lower end three-quarters inch (3/4") above the top of a three-eighths inch (3/8") I.D. Bunsen or Tirril gas burner, with the air supply completely shut off, and adjusted to give a luminous flame one and one/half inches (1 1/2") long. The flame shall be applied vertically at the center of the width of the lower end of the specimens for twelve (12) seconds, then withdrawn, and the duration of flaming in the specimens after withdrawal of the burner noted. After complete extinction of all flame and glow in the specimen, the length of char shall be measured, as specified in Federal Specifications CCC-T-191a Supplement October 1945.

COLUMN
NUMBER

11. ELONGATION
The figures shown represent an increase in length as a percentage of the original length of the material. Beyond the values shown, failure of the material would occur.
> greater than
< less than
M = Machine direction
T = Transverse direction

12. ROLL SIZE
The first value shown for each material is the width, in feet, of a roll of material. The second value is the length, in feet, of a roll of material. These are the maximum sizes possible unless an "S" follows the number. The "S" signifies the standard roll size available from the manufacturer.

13. COLORS
The colors indicated are those commonly available from stock. In some instances, specific shades may be special ordered at an increased cost. the colors other than natural-N are listed in the following manner: B-blue; G-green; R-red; Bk-black; A-aluminum; O-orange; T-tan; GR-gray; W-white; Y-yellow; F-flourescent.

14. APPROXIMATE COST
The figures shown were quoted per 1000 square feet in March 1982 and are based on orders of large quantity. These figures may vary with the cost of raw materials, quantities, and other factors.

2.13 Analysis and Recommendations

At the time of the first in progress review meeting in late March, four plastic sheeting materials which warranted further study were identified. This determination was made on the basis of preliminary data available at that time. The four materials were, as shown in the Plastic Materials Matrix:

#10 Nylon Reinforced Polyethylene Film

#14 Rufco 400 Cross Laminated Film

#15 Tu Tuf 4 Cross Laminated Film

#16 Super-poly Film

The findings of investigations into each of these materials since that time are presented below.

#10 - Nylon Reinforced Polyethylene Film

Upon receipt of a sample of the film and other technical information, it became clear that the nylon reinforcing is too widely spaced to provide sufficient strength qualities to the polyethylene film. Additionally, the film is only available in natural (clear) color. As such, the film would degrade extremely quickly when exposed to ultraviolet sun rays making it unserviceable. These two factors alone would virtually eliminate the film from consideration, but when given the fact that the maximum roll width is 20 feet, any futher review of the film would not be fruitful.

#14 - Rufco 400 Cross Laminated Film
#15 - Tu Tuf 4 Cross Laminated Film

These two films have quite similar characteristics and so may be considered together. One of the most interesting aspects of this type of material is that the mullen burst strength is relatively high whereas the tongue tear valve is quite low. In other words, the material resists puncturing

well, but once a tear is initiated, it will propagate very easily. The material is capable of significant elongation, but does not have "memory", i.e. it does not return to its previous unstressed shape once the force is removed. One other quality, which is not apparent from the technical data, is that under movement and dynamic loading, such as that which would be caused by wind, the material generates a high amplitude "crackling" sound. Although this aspect of the material is not necessarily quantifiable, it would unquestionably be a significant environmental factor when employed in the manner illustrated by the designs developed during this project.

#16 Super-poly Film

Upon comparing the results of the three "strength" tests with those of the OFDA material, it became apparent that the Super-poly values are sufficiently low to disqualify the material from further consideration. The values for the mullen burst and tongue tear tests indicated that, in a manner similar to the cross laminated films, the resistance to an initial tear is many times greater than to the continuation of the tear.

Based on an analysis of the additional information which was gathered on the four sheeting materials and a comparison to the material presently procured by OFDA, it is apparent that, as a generic polymer type and sheeting construction (i.e. woven, 12x12) it has superior values in all of the established strength categories. This material also exhibits some degree of ability to conform to complex shapes and return to its original form without an unreasonable noise factor.

There are three specific modifications to the sheeting which would be recommended for future additional procurements.

Size - The material is presently acquired in 20'x100' rolls. As discussed in Section 3.27, a wider sheet size would allow larger spaces, facilitate construction, and reduce the number of seams and connections. Based on the size of spaces required for the various types of community facilities presented in Section 3.2, a sheet width of 7.9 meters (26 feet) would be recommended. The 30.5 meter (100 feet) sheet length should be retained.

Flame Resistance - The present material as specified, requires no flame resistance qualities. In the preliminary review meeting, AID expressed a desire to investigate the possiblility of incorporating this type of quality into the material. This question was discussed with a number of manufacturers including the present supplier of the material. As illustrated in the discussion under the Materials Matrix Flame Resistance, there are several standards and regulations by which films and fabrics may be specified and each is slightly different.

One particular standard would need to be selected, and testing for it performed. This procedure would of course require some time, but there was no question among the manufacturers that the material could be made to conform to any of the standards noted in the Plastic Materials Matrix. Although this issue may require additional investigation, perhaps during phase two of this project, for reasons of national distribution and availability it would be recommended that either the Underwriters Laboratories or the National Fire Protection Association Standards be considered as the basis for the material specification.

Using these types of standards, it was the general opinion of the manufacturers with whom the question was discussed that a basic minimal level of flame resistance could be achieved for an estimated additional cost of approximately 15% of the present cost of the material. However, it must be emphasized, that this price is only an estimate and not based on any detailed technical investigation and is stated only to give a rough approximation of probable cost.

Color - As illustrated in the Plastic Materials Matrix, sheeting materials are available in a wide range of colors. Most of these colors are compatible with admixtures which inhibit the deleterious effects of ultraviolet radiation on polyethylene. This type of UV inhibitor should be specified for the color applied to both sides of the sheeting.

The material currently supplied to OFDA is furnished with UV inhibitors and is green on both sides. Although the shade is not especially deep or dark, there have been reports from sites where it has been used that it absorbs solar radiation to the extent that, the spaces which it has been used to create are often considered overheated. As regards the interior of spaces, it has been noted that light - whether from artificial or natural sources - tends to be absorbed by the material, thus making inside spaces darker than desired and difficult to light adequately at night. One additional factor relates to the qualilty and color of light reflected from the green interior surfaces. Although no actual full scale testing was conducted on this matter, it is likely the reflected light would tend to cast a green tinted hue, creating an environment which may be stressful or objectionable to some -- especailly those who are already under adverse conditions.

For these reasons and others discussed below, it is recommended that future acquisitions be specified to have white on one side and light tan on the other. This would allow local populations some choice in using the material within their given set of environmental (and perhaps cultural/social) conditions. The white color, if used on the exterior, would reflect solar radiation and tend to keep interiors cooler. If used on the interior, it would absorb only a small amount of ambient light thus making the spaces brighter and easier to light.

If sun conditions are so extreme that a white exterior would create stark visually offensive, or an excessively glary environment, the light tan could be used on the exterior exclusively, or it could be used in wall and other horizontal applications. The light tan may also be more appropriate in high dust or wind areas or where white may become soiled quickly. If the shade of the light tan were chosen carefully, it could allow a reasonably high degree of reflectivity so that interiors could still be lighted with minimum difficulty.

When compared to the 15 polymer sheeting materials identified during this study, the basic polyethylene-coated, 12x12 woven polyethylene material presently acquired by OFDA was found to have qualities and characteristics most appropriate to the contemplated use of the material to provide temporary community facilities spaces. In essence, three technical modifications to the material's configuration are suggested:

1. The sheet size of the material should be 7.9x30.5 meters (26'x100').
2. The material should be specified to be in conformance with one several fire retardant codes.
3. The material should be colored white on one side and light tan on the other.

2.2 LIGHTWEIGHT FRAMING SYSTEMS

2.21 Indigenous
2.22 Military
2.23 Recreational
2.24 Prefabricated Temporary Utility Structures

2.2 LIGHTWEIGHT FRAMING SYSTEMS

2.21 Indigenous

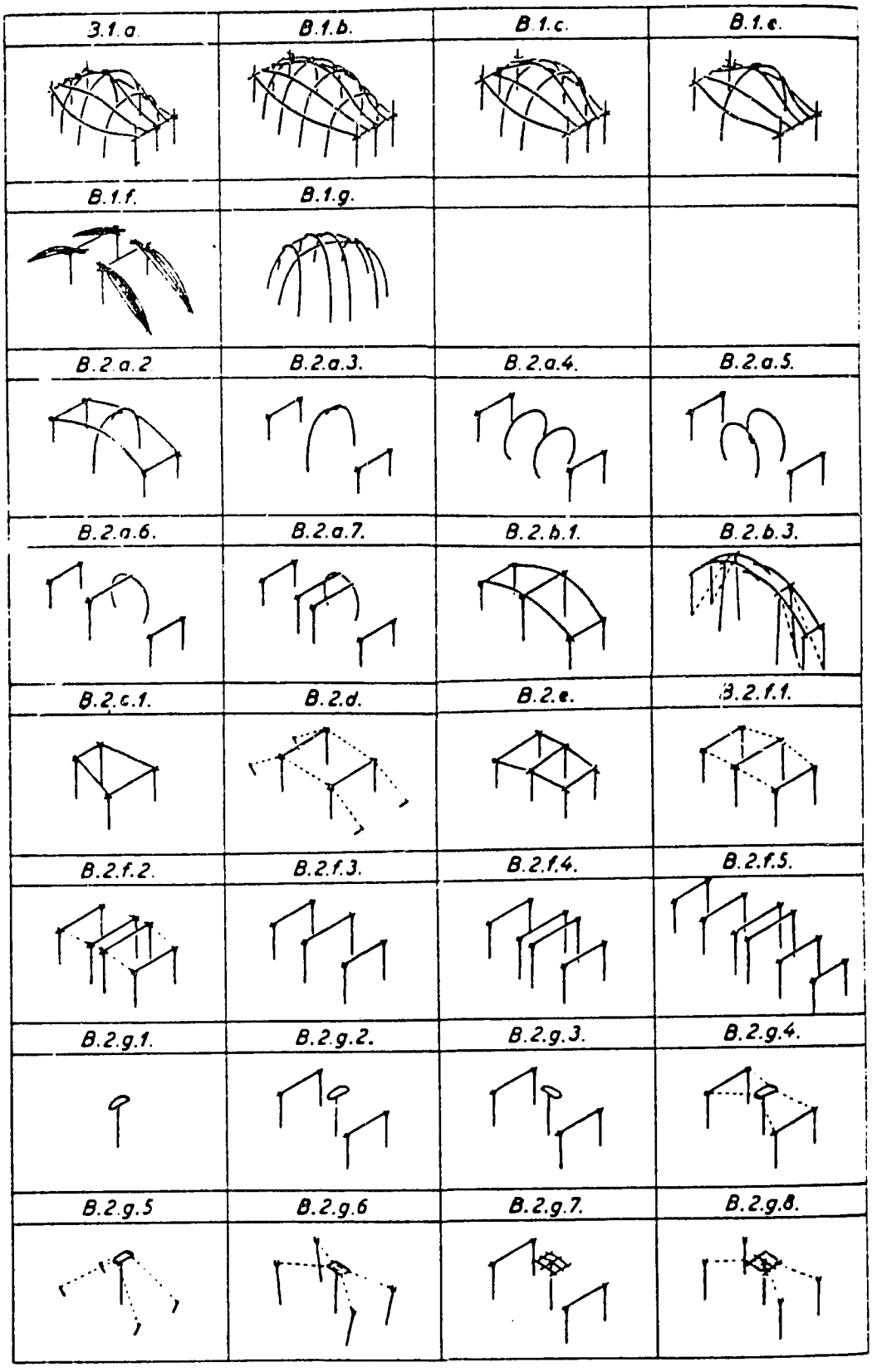
Presented in the following pages are examples of indigenous and historic means, materials, and forms by which various societies and cultures have assembled supporting systems for large and small structures. Included are examples from Africa, the Middle-East, and North America.

The supporting systems or frames are usually of wood in some form; saplings, twigs, branches, and in a few cases, dimensional lumber. As the different types of materials would indicate, the frames cover a wide spectrum of shapes and forms. They range from quite small, easily disassembled and transported to more permanent structures which, thought perhaps not large, are not intended, for social or religious reasons, to be moved.

These framing systems served as the base upon which covering materials are laid. For instance, the Taureg use light skins and woven mats -- easily transportable; whereas Pomo Indian structures are covered with a mud roof laid on top of grass mats -- much more permanent. In tropical climates, bamboo often serves as both the frame and covering material -- most often as walls. The joining and attachment of frame members is accomplished almost exclusively by lashing and tying. For major connections, pins may be inserted through members for added strength, and then lashed.

The varied uses and shapes of these indigenous types of framing systems are united by their simplicity and efficiency of design and use of materials.

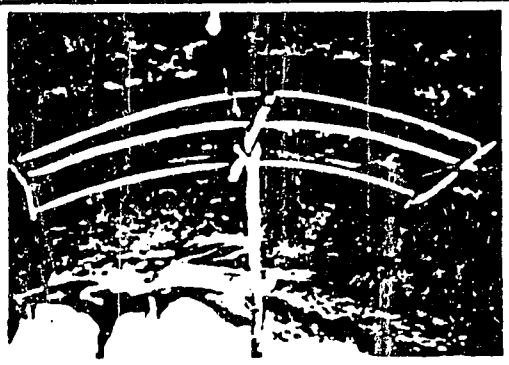
The main types of Tuareg mat tents (top 2 rows) and skin tents (bottom 6 rows).



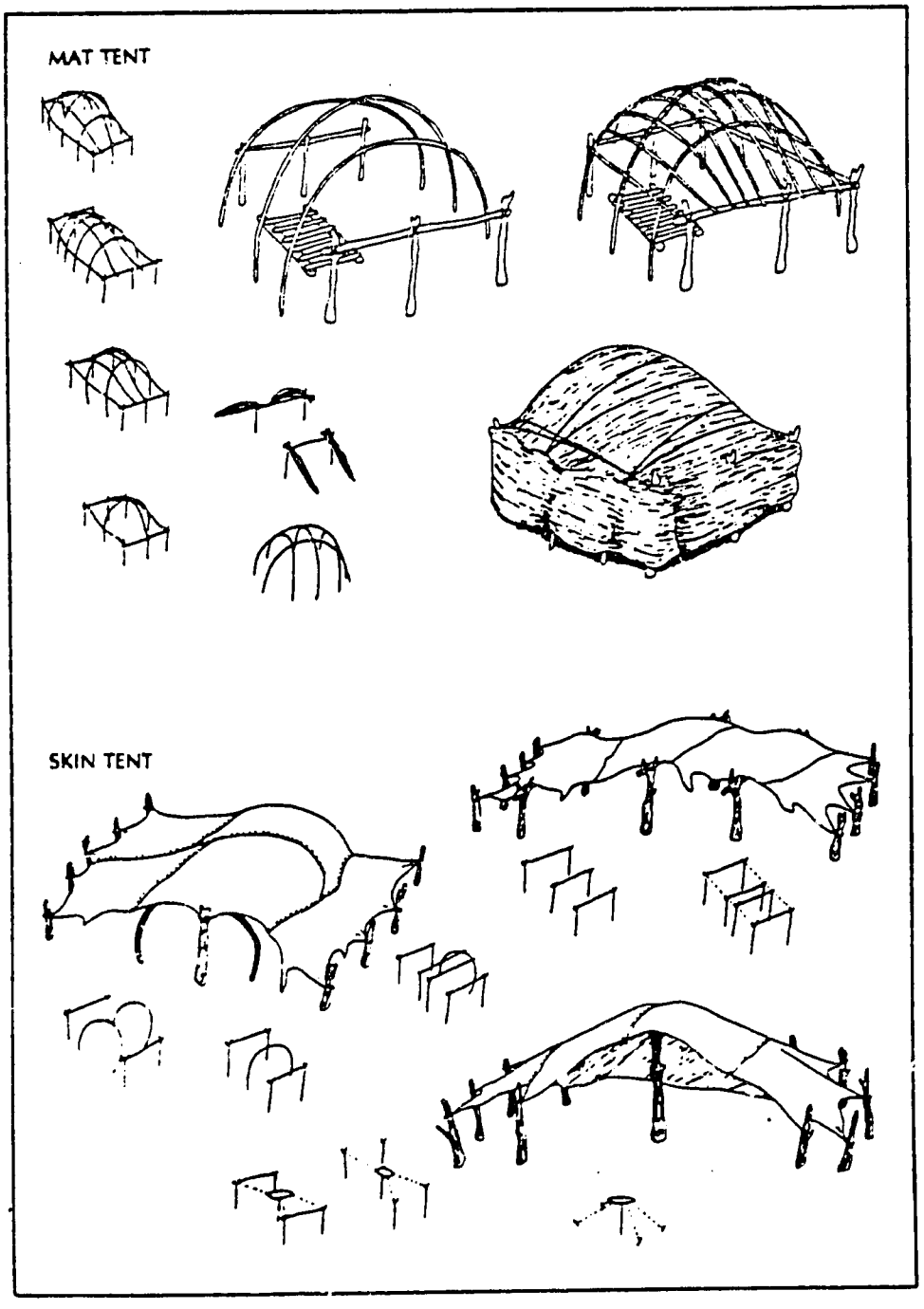
LIGHTWEIGHT FRAMING SYSTEMS

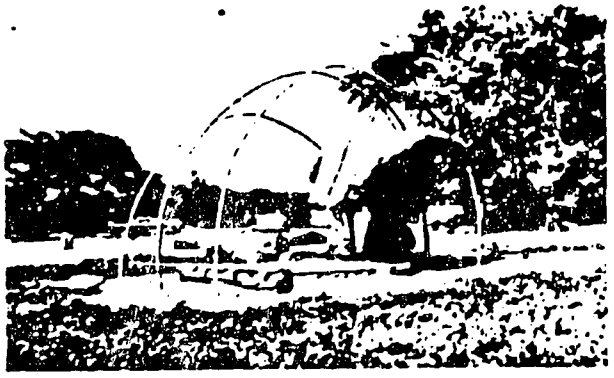
No. 2.21-3

INDIGENOUS



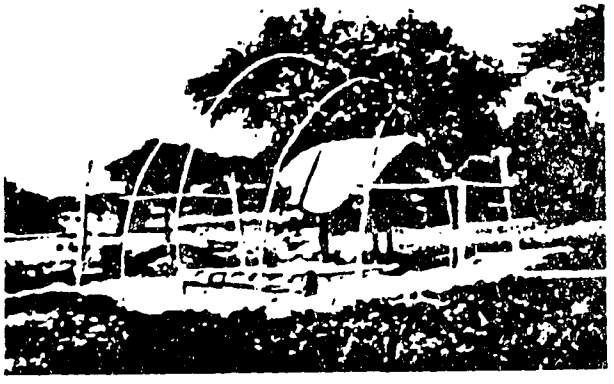
Cross bar of the B.2.g.7 tent. Ahaggar Tuareg of Tamesna, the Iregenaten tribe.



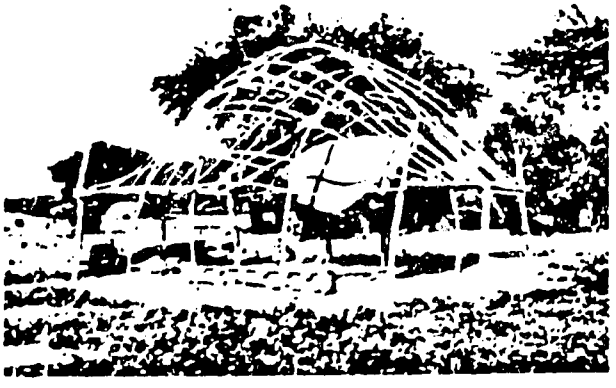


Erection of mat tent in Ayr:

The wooden bed (tedabut) is placed upon the cleared ground. The pronged posts carrying riding cushions, skin bags, etc., and the curved wooden pieces constituting the three arches known as tekkekkewat *and* t'illisawin *are buried in the ground. The cushions and decorated skin bags resting in the heavy wooden prongs are temporarily covered with tent mats so that their colours may not be damaged by sunshine.*



*The arch pieces are lashed together and the two horizontal crossbars (*isgar*) are fixed to vertical sticks (*tigettewin*) buried in the ground at the narrow ends of the tent. A little discus-like thickening carved at the middle of each cross-bar is seen on this photograph.*



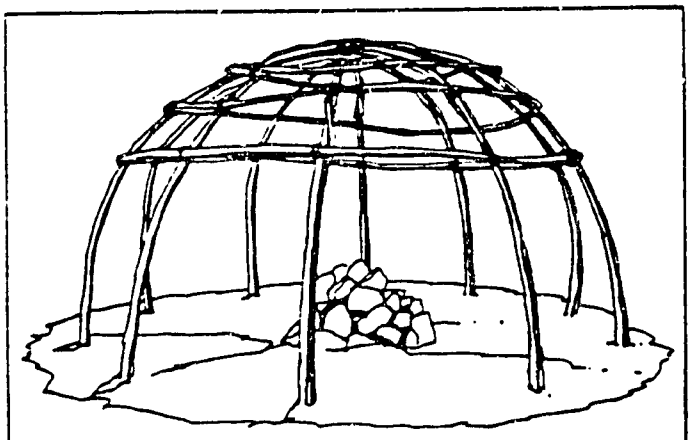
A long cord is wound around the high middle arch to form loops for the insertion of the slender rods forming semi-arches in the longitudinal direction. The thick ends of these rods are fastened to the crossbars but are not yet lashed together at their upper, narrow ends.

The narrow ends of the pieces of longitudinal semi-arches are lashed together. The tent structure is now ready to be covered with mats. The interior cover consisting of two rectangular mats made from plant stems and known as iwerweren (sing. ewerwer) *is seen in this photograph.*

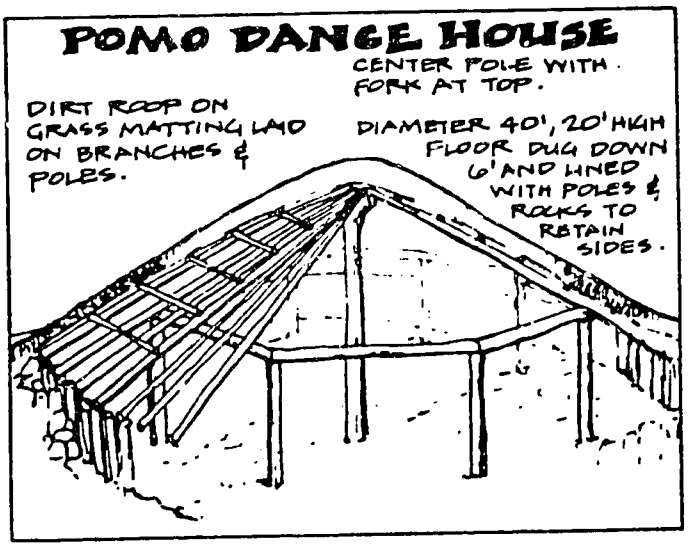
The dum palm mats of oval shape (isfal) *and the long narrow dum palm mats* (asalemamas) *are placed over the* iwerweren *mats and are tied to the dome-shaped structure with cords. The narrow dum palm mat* (ereli) *surrounding the lower part of the tent is fixed to the structure.*

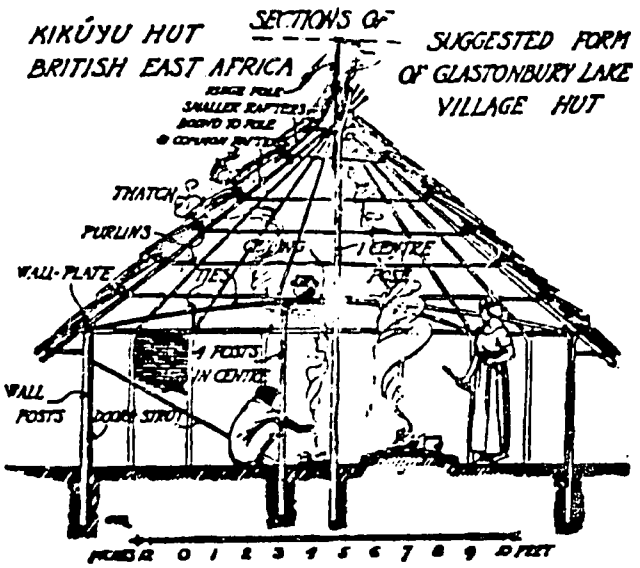
The mat tent is taken down for erection in a new place. The woman standing within the structure is loosening the looped cord which attaches the semi-arches to the high middle arch.

It is not the same tent as that depicted above, but the two tents belong to the same camp of the Imezzureg *tribe near Agadez in Southern Ayr.*



Frame of Peyote Sweat Lodge

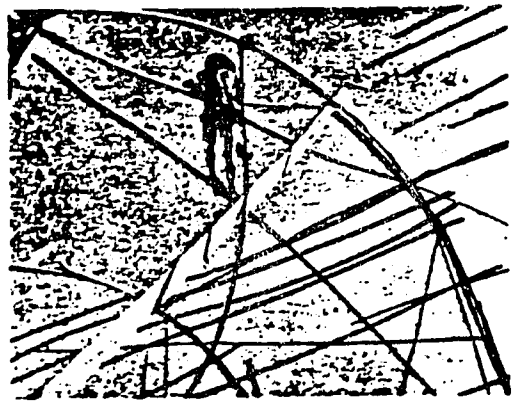




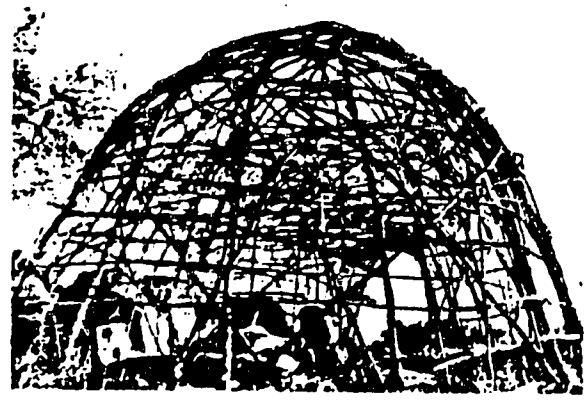
LIGHTWEIGHT FRAMING SYSTEMS	No. 2.21-7
INDIGENOUS	

Made of mud, straw and clay mixture. Patted on by hand between lodge pole frame. Roof is bamboo thatch. All materials local Los Angeles county! The people who live in the apartments below complain that the hut is an eyesore.

Carey Smoot

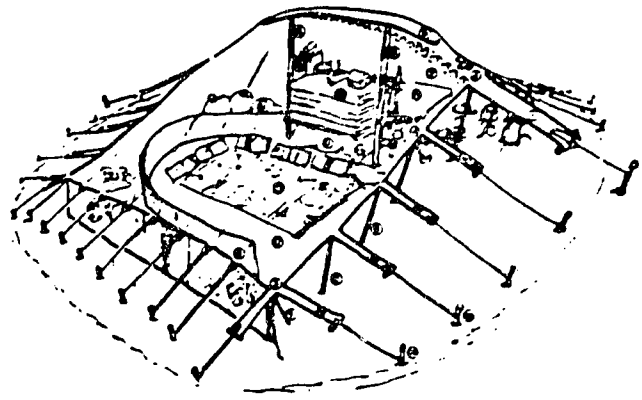


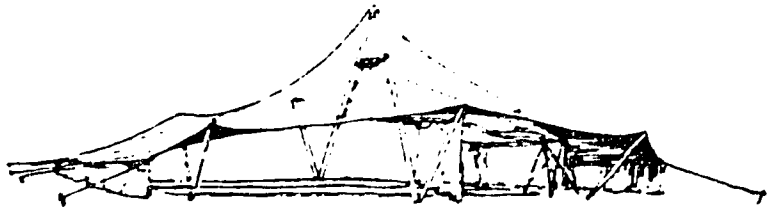
RONYOON, BURMA. BUILDING A TEMPORARY THEATER.



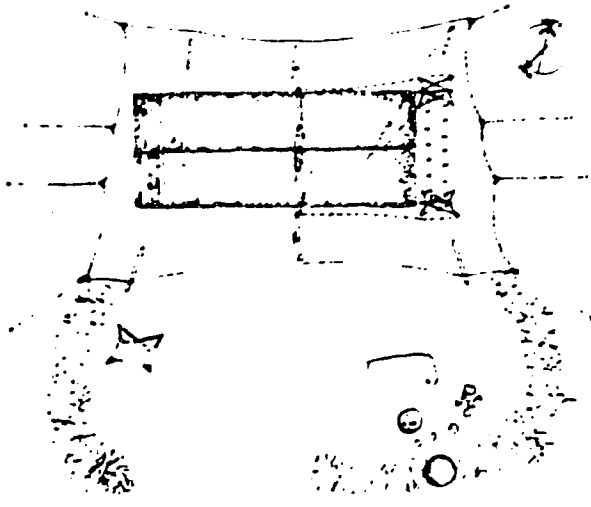
Court Johnson saw this twig framework in a dream and built it on a Santa Barbara mountain side. He wired together bent green eucalyptus branches set in a circular concrete and rock footing. Since this photo the frame has been plastered with adobe mud. Court's dream revealed to him an archetypal structure as used by various primitive cultures — thin saplings tied to achieve the strength of compound curves. The same frameworks are found in Ethiopia.

Moroccan tents.

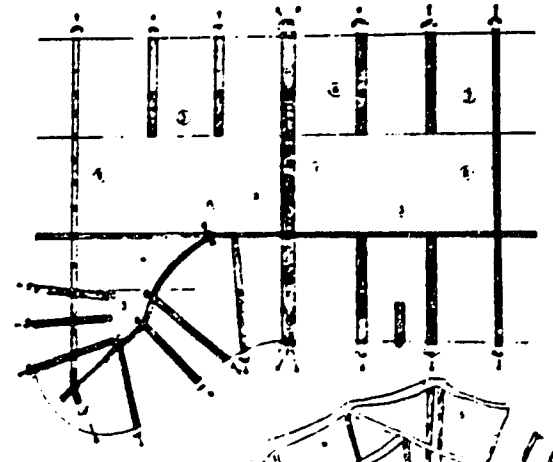




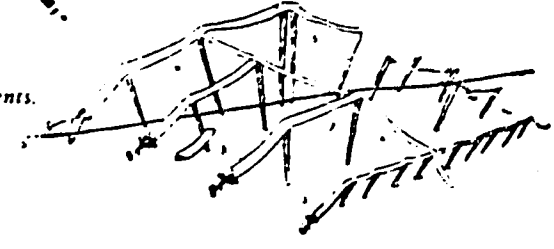
Front view of tent open for day use.



Plan of tent. Two floor mats are shades, with the womens' side on the right. The fireplace and oven pit are in the forecourt to the right, on the left is a water skin on its trestle. Brushwood surrounds the forecourt.



Plan.

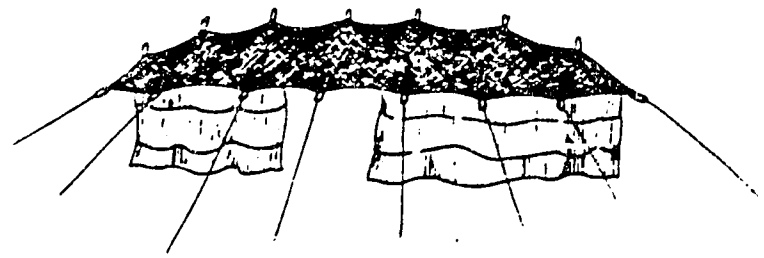


Berber tents.

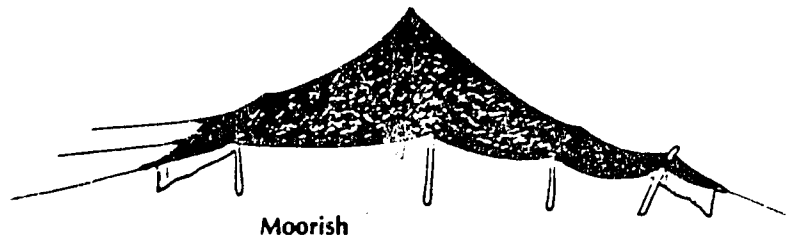
LIGHTWEIGHT FRAMING SYSTEMS

INDIGENOUS

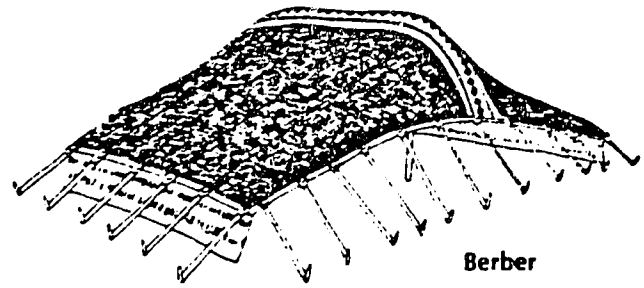
No. 2.21-9



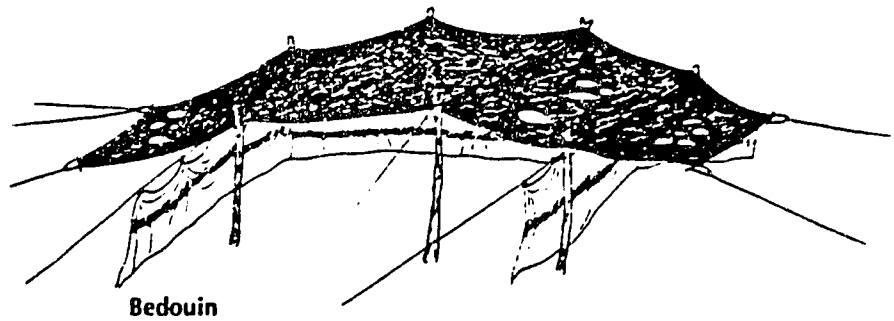
Kurdish



Moorish

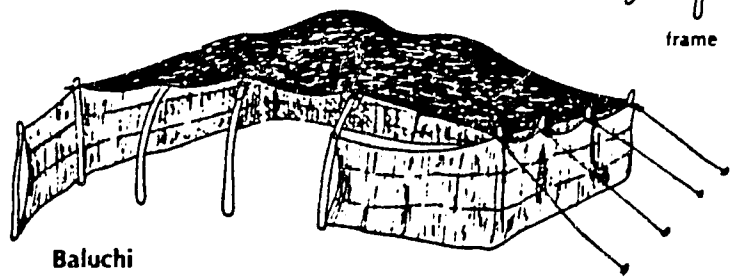


Berber



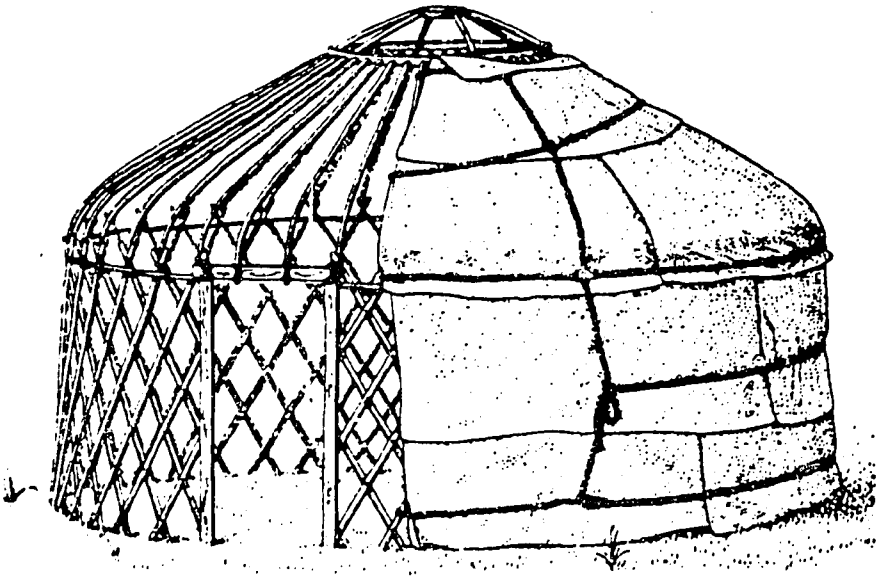
Bedouin

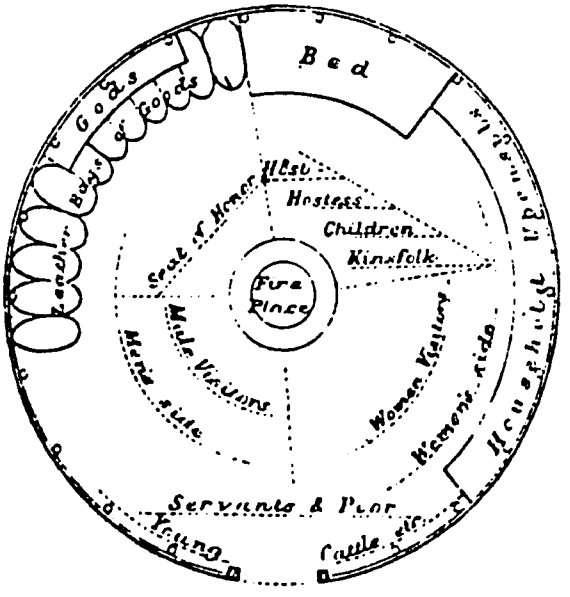
frame



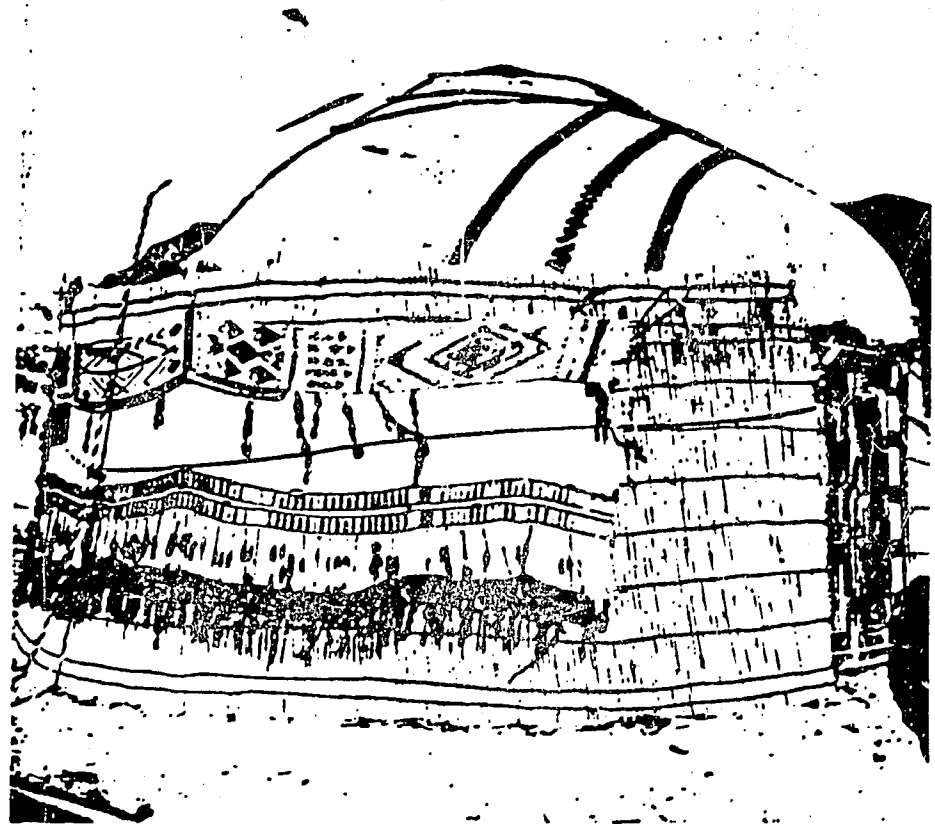
Baluchi

YURTS

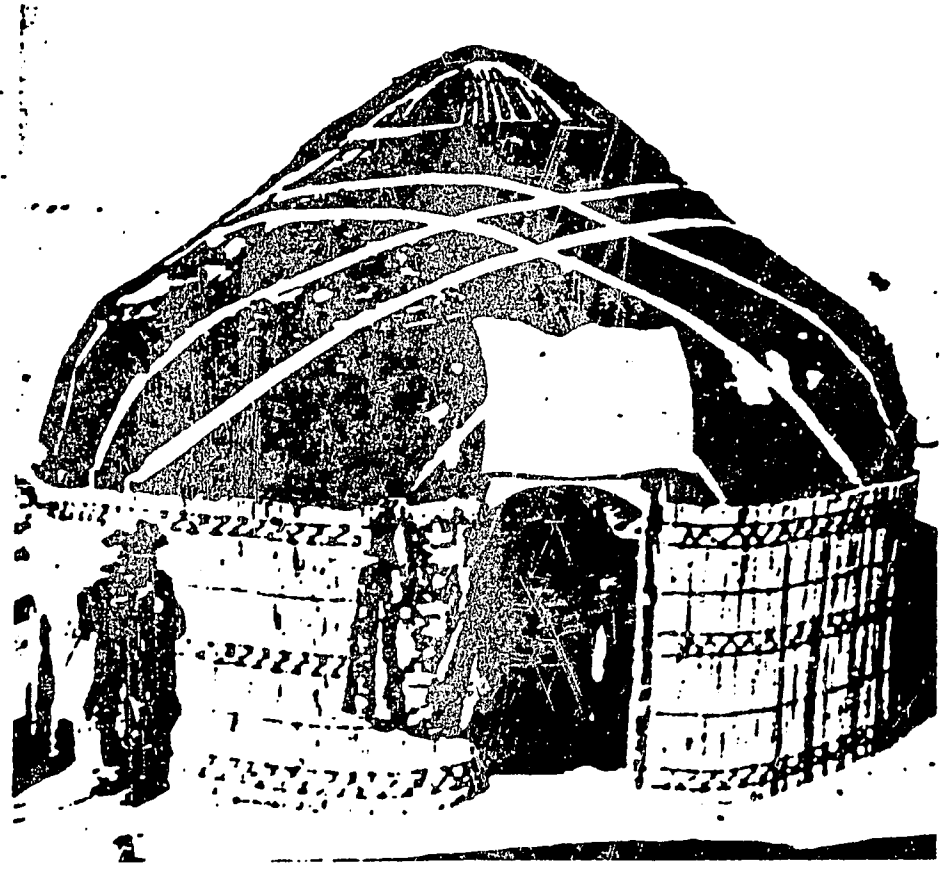




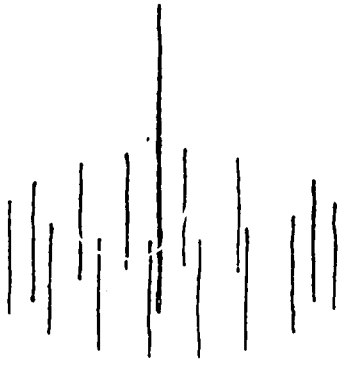
Another Turkish yurt, on this one a highly ornate band of cloth is wrapped around two thirds of the circumference and the decorated doors at right identify this tent as the dwelling of a high-ranking personage. The cord draped over the left side is used to pull the felt cover over the smoke hole. (Musée de l'Homme, Phototèque, Paris)



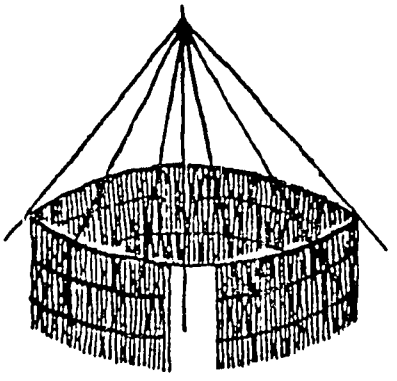
This yurt of the Akcha of Northern Afghanistan has a higher and more conical dome. The shape and coverings of the yurt may vary according to the tribe and region. (Musée de l'Homme, Phototèque, Paris)



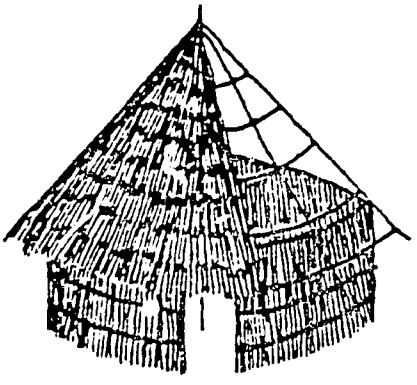
The tukul or sarbet (grass house) of the Ethiopian high plateau is a structure which utilizes simple building techniques and excellent use of natural resources.



1.
First a circle with a diameter of 9 to 20 ft. is drawn at the building site. Eucalyptus poles are placed in the ground at one yard or so intervals along the circumference. The poles should be long enough so that at least 7 or 8 feet of the pole is above the ground. Next the center pole is set. It should be tall enough to give the roof an angle of at least 50°.

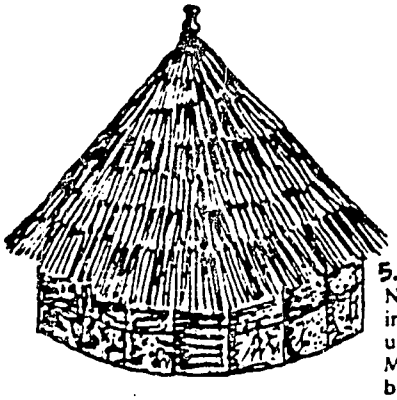


2.
Now the walls are filled with upright poles set close together and stuck in the ground. Rope is used to tie supports to the side of the wall. Green wood is used for ease in bending. Now the roof supports are attached 1 foot from the top of the center pole and extend about two feet past the top of the wall. This helps shed rain away from the wall. The supports can be extended even farther and used as a type of veranda.



3.
More supports are added to the roof. These again are of green wood and tied with rope. Now it is time to put on the roofing material. Sumbalit, a straw type grass is used. It is thatched or tied. This work is done from the top down, working carefully to insure a good roof. A pottery jar is added over the top of the center pole both as a decoration and to help shed water from the center of the roof.

4.
Now an adobe plaster of straw and mud is put on the wall. After the plastering is finished, a door is built and installed and two small holes are put in the wall to allow sunlight to come in.



5.
Now with the outside finished it is time to work the inside. This is done according to the use. It can be used as living quarters, kitchen, stable, or storage. Many times it is used for all four and therefore must be partitioned accordingly.

Winter camp of a detachment of the 50th NYV Engineers, U.S. Civil War, November 1864. These tent houses, complete with chimneys, have been insulated with pine branches. Gaps were left in the design for light entry. (Library of Congress)

Winter officers' quarters of Captain J. R. Coxe and wife at Headquarters, Army of the Potomac at Brandy Station U.S. Civil War, April 1864. This tent cabin has two layers of canvas — one securely fastened to the structure and the other draped over it. At right the overhang and a vertical piece form a shed. The army took the time to construct these more permanent structures to withstand winter weather. (Library of Congress)

A tent house at the New York state sanitarium at Ray Brook in the Adirondack Mountains. The tent house has enjoyed great popularity in this country, especially at resorts and religious communities. At the turn of the century camping was not considered the exciting return to nature it is today. It was still strongly associated with pioneering and the rough lifestyle of the frontier and was, therefore, not genteel. Camping was also difficult for women wearing the Victorian fashions that were in style. Children, however, were encouraged to camp out, and did. And vacationing in a tent house served as the equivalent of camping out for the adults.

2.22 Military

The framing systems presented in this section represent a compilation of recent U.S. Military efforts to date in the development and deployment of revelent temporary, frame supported tent structures. These designs range in size from a 5 person 113.2 SF tent to a 936 SF general purpose shelter. Accompanying each photo is brief descriptive information on materials, physical characteristics, use, etc.

Each of these structures is designed to meet very specific requirements; personnel and equipment capacity, square footage, weight, use erection and striking characteristics, etc. Framing members are wooden poles in all but the largest structures. In these, metal structural sections -- usually extruded aluminum or aluminum-alloy -- are used. The frame members often fit into a grommet and/or specially sewn pockets in the covering material. The framing systems are tension supported and held in place by rope tension members attached to stakes driven into the ground.

The covering material itself is most commonly a cotton duck fabric weighing between 8.5 and 9.85 ounces per square yard. The fabric is cut and sewn to exactly tailored dimensions, allowing for doors, ventilation, windows, bug screening, etc.

1. Name of Shelter: Tent, Hexagonal, Lightweight, M-1950

2. Type of Shelter:

Non-Rigid
Pole-Supported

3. Current Status:

Standard

4. Responsible Engineering Activity:

U. S. Army Natick Laboratories

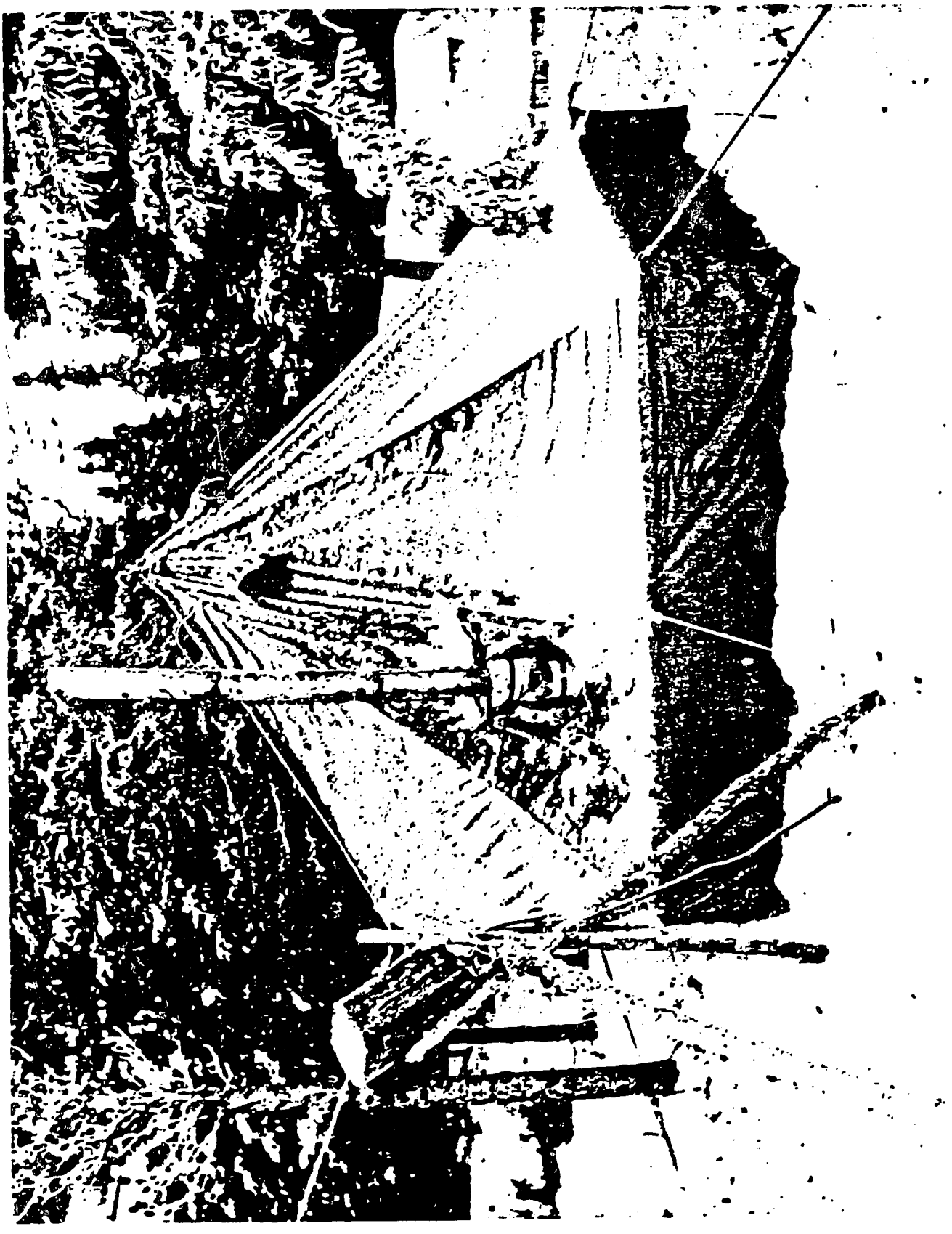
5. Physical Characteristics:

This is a six-sided, pyramidal tent fabricated of 8.5 oz. wind-resistant sateen and supported by a telescopic pole at the center of the tent. A stovepipe opening is located in one of the sides near the eave. A fire-resistant liner is provided to insulate the tent and prevent frost from falling on the occupants. Each side of the tent measures 6'7". It is 8'6" high at the peak with a wall height of 2'. The floor area is 113.2 sq.ft. and the complete tent weighs 56 pounds. The tent can be pitched by 5 men in 15 minutes and struck by 5 men in 10 minutes.

6. Concept of Use:

This is a special purpose tent intended to provide shelter for troops (5 men) operating in extremely cold or cold-wet areas.

LIGHTWEIGHT FRAMING SYSTEMS	No.
MILITARY	2.22-3



1. Name of Shelter: Tent, Command Post, M-1945

2. Type of Shelter:

Non-Rigid
Pole-Supported

3. Current Status:

Standard

4. Responsible Engineering Activity:

U. S. Army Natick Laboratories

5. Physical Characteristics:

This is a pole-supported tent made of 9.85 oz. cotton duck. The central part of the tent is A-shaped and the ends are hip-roofed, with converging sidewalls. The tent has a blackout vestibule long enough to accommodate a litter and bearers. The tent is equipped with a liner, detachable sidewall screens and a cover. The tent is 10' wide, 20'7" long (6'10" of which is vestibule), 9' high with a sidewall height of 6'. The floor area is 172 sq.ft. and the complete tent weighs 257 pounds. The tent can be pitched by 5 men in 20 minutes and struck by 5 men in 15 minutes.

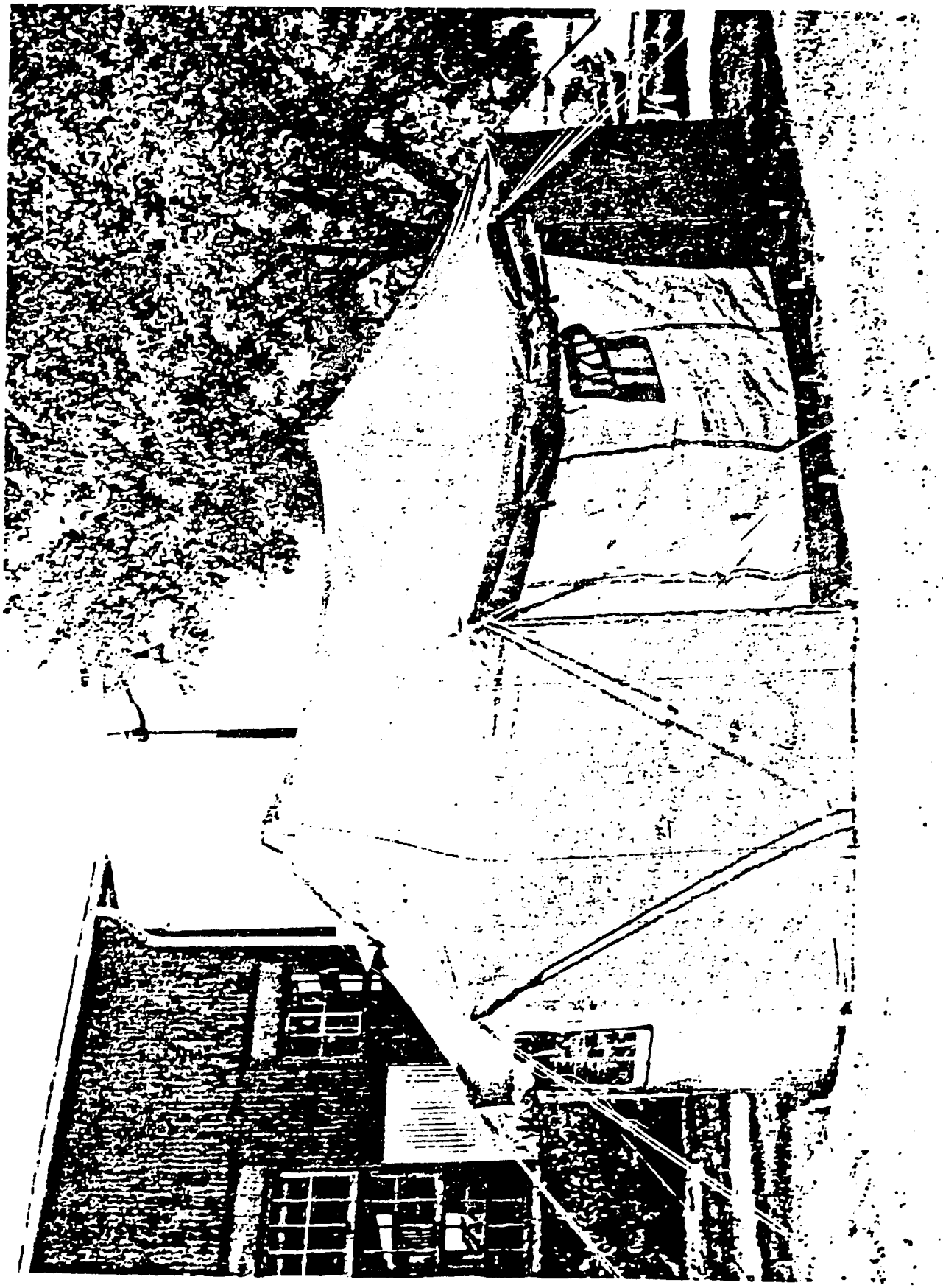
6. Concept of Use:

Designed to provide a portable tent suitable for housing a battalion command post, small staff sections of higher echelons and/or battalion aid stations.

LIGHTWEIGHT FRAMING SYSTEMS

MILITARY

No. 2.22-5



1. Name of Shelter: Tent, Kitchen, Flyproof, M-1948

2. Type of Shelter:
Non-Rigid
Pole-Supported

3. Current Status:
Standard

4. Responsible Engineering Activity:
U. S. Army Natick Laboratories

5. Physical Characteristics:
This is a pole-supported tent made of 9.85 oz. cotton duck. The tent is an "A" type, with square end, and rectangular in shape. The back portion of the tent forms a stack higher than the rest of the tent. The side and front walls may be guyed out to form awnings. A wall screen which snaps to the tent provides an insect-proof closure on the sides and front when the walls are raised. The tent is 12' wide, 18' long and 9' high. The wall height is 9' on the stack section and 6' on the deck section. The floor area is 216 sq.ft. and the complete tent weighs 420 pounds. The tent can be pitched by 5 men in 1 hour and struck by 5 men in 40 minutes.

6. Concept of Use:
Designed to provide shelter for the preparation, cooking and serving of food with a minimum danger of contamination from flyborne diseases.

LIGHTWEIGHT FRAMING SYSTEMS	No.
MILITARY	2.22-7

1. Name of Shelter: Tent, General Purpose, Large

2. Type of Shelter:
Non-Rigid
Pole-Supported

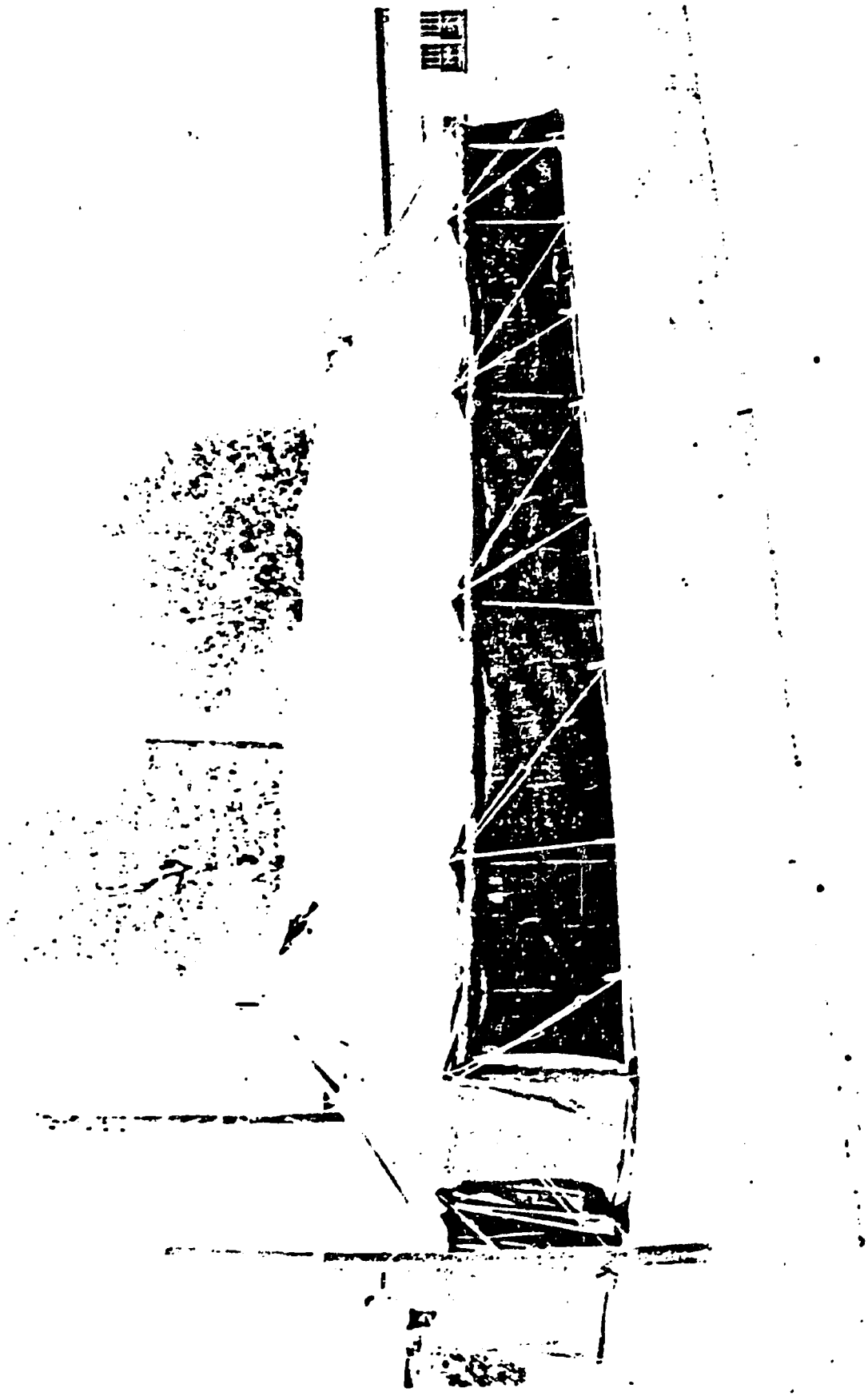
3. Current Status:
Standard

4. Responsible Engineering Activity:
U. S. Army Natick Laboratories

5. Physical Characteristics:
This is a rectangular, hip-roofed, pole-supported, off-center ridge, large size, general purpose tent, made of 9.85 oz. cotton duck. The tent is provided with screened windows, roll-up sidewalls, and a sliding double door entrance at each end. Screen ventilators with flaps are located at the upper part of each end roof and three stovepipe openings are provided in the roof section. A liner which contains screens along the entire length of the sidewalls is available as a separate item of issue. The tent is 18' wide, 52' long, 12' high at the ridge and 5'6" at the sidewalls. The floor area is 936 sq.ft. and the complete tent (including liner) weighs 761 pounds. The tent can be pitched by 6 men in 1-1/4 hours and struck by 6 men in 50 minutes.

6. Concept of Use:
Designed to provide a large shelter primarily for use as a hospital ward. Also for use as a small bakery, for storage, quartering of troops, etc.

LIGHTWEIGHT FRAMING SYSTEMS	No.
MILITARY	2.22-9



1. Name of Shelter: Tent, Frame-Type, Insulated, Sectional, 16' x 16'

2. Type of Shelter:

Non-Rigid
Frame-Type

3. Current Status:

Standard

4. Responsible Engineering Activity:

U. S. Army Natick Laboratories

5. Physical Characteristics:

The shelter is a sectional, frame-supported tent composed of an insulated skin, wooden supporting frame, insulated plywood floor boxes, and insulated vestibules. The insulated skin consists of 1" thick fiberglas batting captured between two layers of vinyl-coated cotton duck. The shelter is 16' wide, 16' long and 8' high and can be expanded in multiples of 4'. The complete shelter weighs 2,252 pounds. Six men can erect the shelter in 45 minutes and strike the shelter in 30 minutes.

6. Concept of Use:

To be used as a general purpose tent in extreme cold climates. The shelter can be transported by vehicle or aircraft.

LIGHTWEIGHT FRAMING SYSTEMS

No. 2.22-11

MILITARY

1. Name of Shelter: Tent, Frame-Type, Maintenance, Medium, Light Metal

2. Type of Shelter:
Non-Rigid
Frame-Supported

3. Current Status:
Standard

4. Responsible Engineering Activity:
U. S. Army Natick Laboratories

5. Physical Characteristics:
This is a sectional, frame-supported tent consisting of an outer fabric, inner liner and supporting frame. The outer fabric is 9.85 oz. cotton duck. An insulated liner made of fiberglas batting captured between two layers of cloth, cotton, sateen, carded, 8.5 oz. and natural in color, is available for use in cold climates. The frame is made of magnesium and consists of two end arches, intermediate arches, connecting purlins, and cantilever-type door assemblies. The basic tent measures 20' wide, 32' long and 14' high. However, it can be lengthened in increments of 8' to any desirable length. The floor area of the basic tent is 640 sq.ft. and the complete tent weighs 3,276 pounds. Four men can erect the tent in 5 hours and strike the tent in 4 hours.

6. Concept of Use:
Designed as a medium-sized maintenance shelter for use in the repair of tracked and wheeled vehicles.

LIGHTWEIGHT FRAMING SYSTEMS

MILITARY

No. 2.22-13

1. Name of Shelter: Tent, Accordion Type

2. Type of Shelter:

Non-Rigid
Frame-Supported

3. Current Status:

Commercial item with military potential

4. Responsible Engineering Activity:

U. S. Army Natick Laboratories

5. Physical Characteristics:

The tent is supported by an accordion type frame made of 1" square aluminum tubing colored olive drab. The fabric is 16.5 oz., neoprene coated nylon, olive drab outside and white inside. The tent is provided with four screened windows equipped with blackout flaps. The ends of the tent are provided with two vertical slide fasteners. When the slide fasteners are opened, a door 6' wide by 6'6" high is provided. An inner partition, which includes a personnel door, is snapped in place 4' from the end wall making a built-in vestibule. Two tents can be joined together to form a larger shelter. The tent measures 10' wide, 20' long and 8' high. The floor area is 200 sq.ft. and the tent weighs 225 pounds. Four men can erect a shelter in 15 minutes and strike the shelter in 10 minutes.

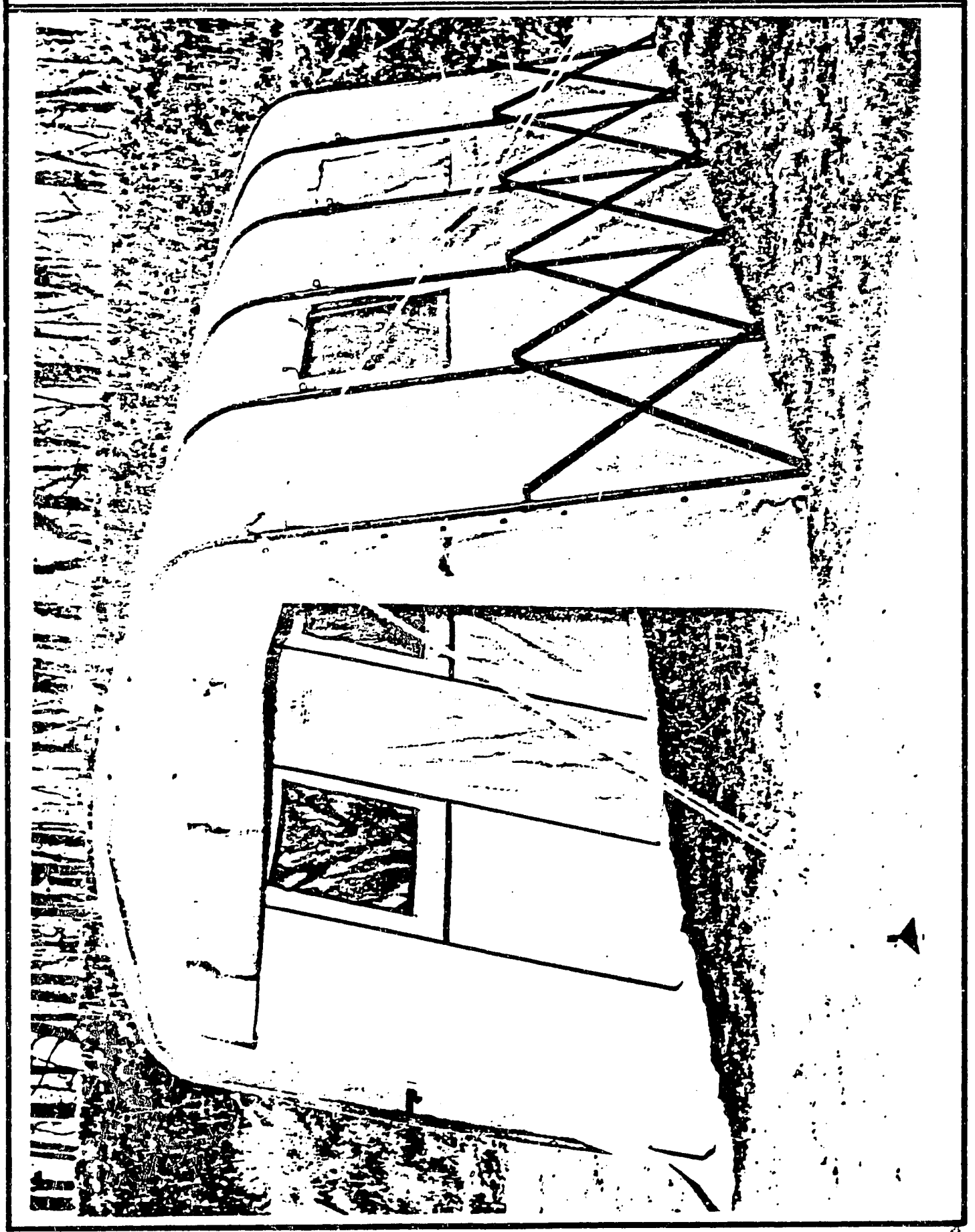
6. Concept of Use:

Provides a quickly erected shelter for general purpose use.

LIGHTWEIGHT FRAMING SYSTEMS

MILITARY

No. 2.22-15



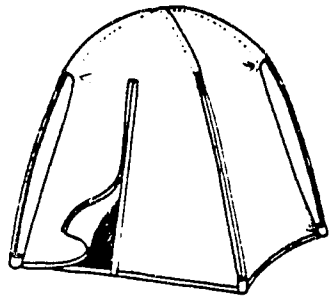
2.23 Recreational

The framing systems employed in traditional recreational shelters and tents are made of wooden or metal, usually aluminum, poles. These may be telescoping, hinge-jointed, or sectional. The frame is either erected inside the stucture to hold the tent out, or it surrounds the fabric material which is suspended from it.

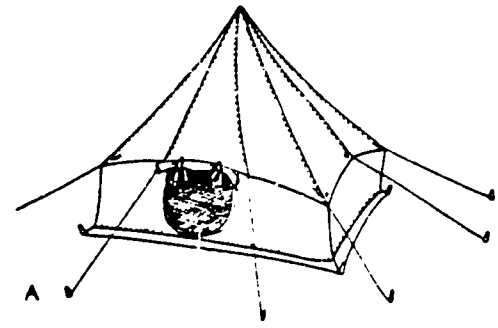
The frames for most recreational tents being manufactured today are made of solid or hollow fiber glass rods, aluminum alloy, or a "shock corded" rigid tube. Each of these systems has a very simple, however, finely designed and engineered precision jointing system. They often depend on the use of a fabric such as nylon or polyester which is able to accommodate complex bends (i.e. in three planes simultaneously). This stretchy type of material used in conjunction with the flexible frames establishes a static tension and adds rigidity and resiliency to the entire structure. In this type of configuration, the frame and fabric become interdependent and act as one integrated unit.

Most recreational tents are designed for 1-2 up to 8-10 people. As they are normally intented for intermittent, short-term use, their floor area requirements on a per person basis can be lower than for long term use shelters. This fact also allows the interior heights to be lowered and more restricted. The clear, open spans necessary are also less than would be required for community facility spaces. Since both spans and heights are less, the size of frame members may be correspondingly reduced.

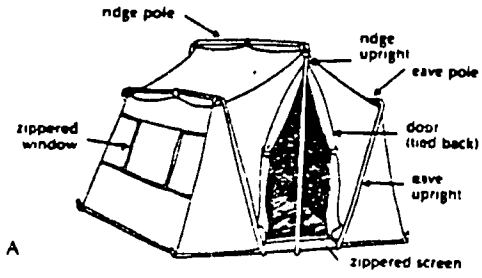
Although there are hundreds of recreational tents available on the market, those illustrated on the following pages represent the basic generic shapes and framing system-tentage configurations.

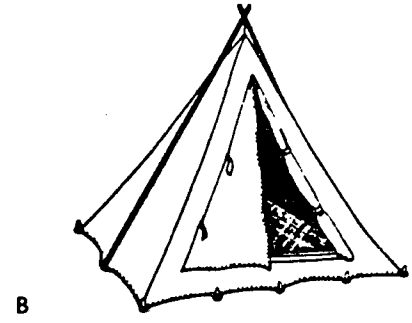


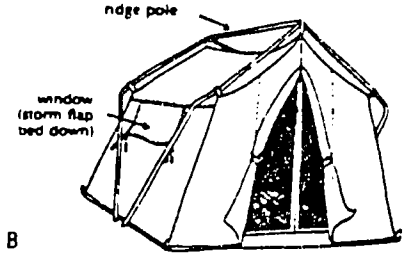
Ice-fishing tent



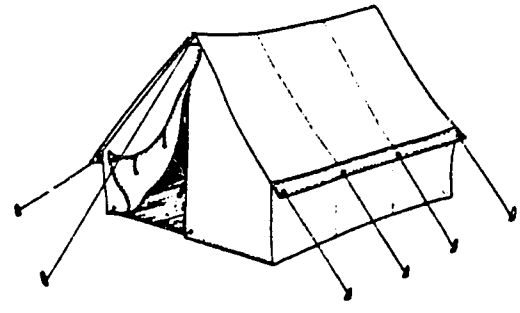
Pyramid tents: A. with wall; B. without wall



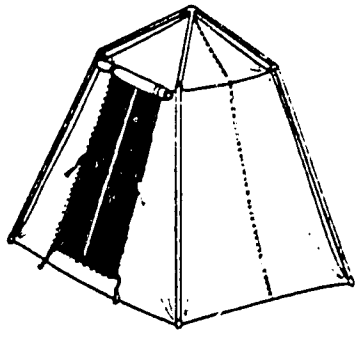




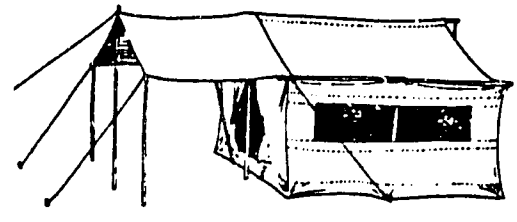
Cabin tents: A. roof-truss cabin tent; B. yoke-type cabin tent



Wall tent

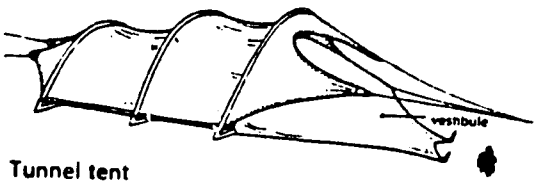


Umbrella tent

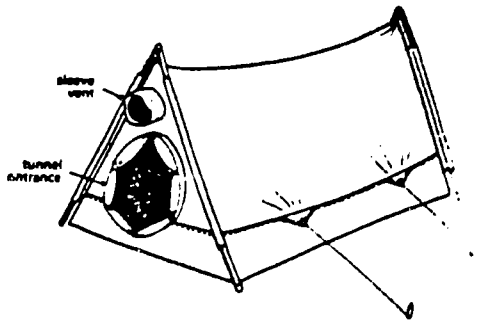


Cottage tent

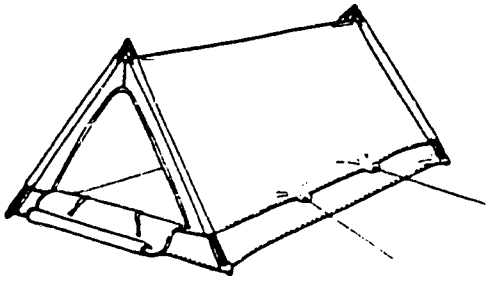
LIGHTWEIGHT FRAMING SYSTEMS	No.
RECREATIONAL	2.23-3



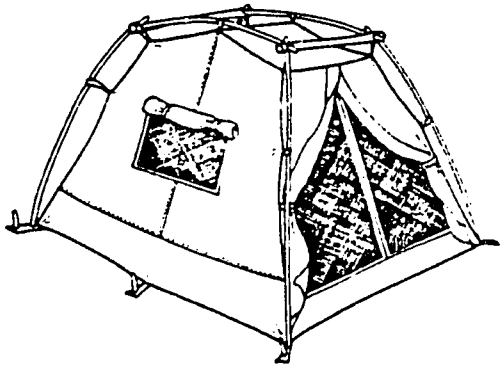
Tunnel tent



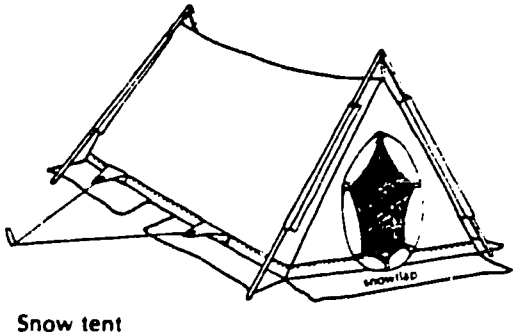
Expedition tent



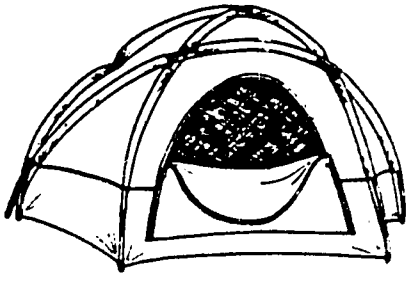
Lineless or A-frame tent



Exoskeleton tent



Snow tent



Dome tent

2.24 Prefabricated Temporary Utility Structures

The type of structures presented in this section have been developed and marketed for a number of different uses. The broadest application has been in the agricultural and construction fields where storage facilities are required on a short-term or intermittent basis in relatively remote or undeveloped areas. The military has also used this type of structure under similar conditions. In terms of numbers, the greatest quantity of this sort of shelter at its smallest sizes is purchased by homeowners for use as storage for tools, equipment, and other household items.

Although the size and shape of these structures may vary, they are typically composed of a frame of extruded metal structural sections which attaches to pre-cut and drilled metal sheets. These sheets then form the skin of the structure. In plan, the structures are rectilinear with few exceptions, and most structures have a simple gable or mansard roof.

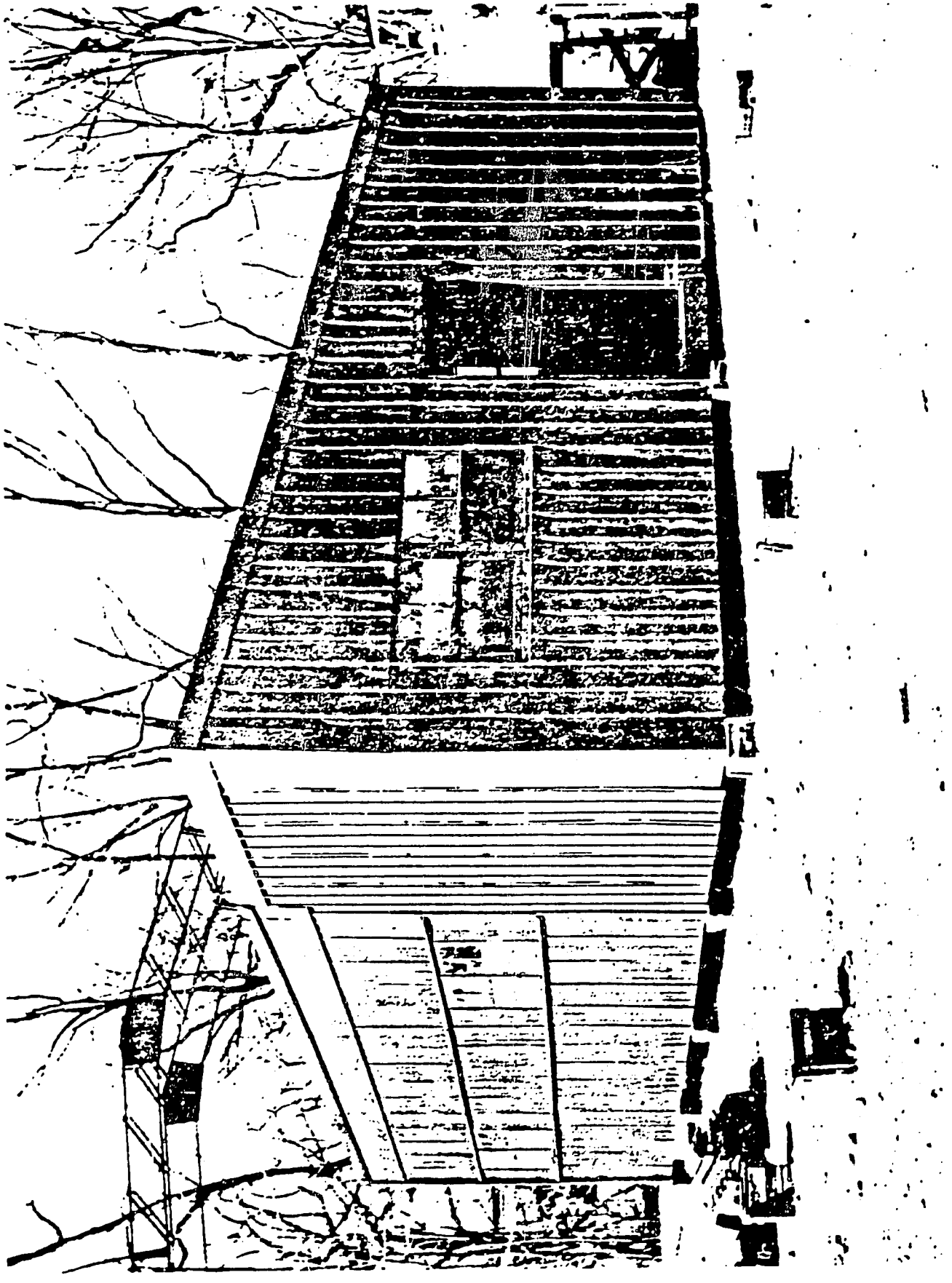
In contrast to the rectilinear shape there is a group of structures which are arch-shaped in section. These are usually made from the same type of extruded and corrugated metal pieces as the rectilinear structures -- only the shapes are different. The supporting members may be an extruded solid structural section or an open web truss, bent to the desired curve. In either case, the members are joined together at the ridge and attached to a concrete slab or footing at the base. Prefabricated metal sheets-usually aluminum or aluminum-alloy with pre-cut and pre-drilled fittings are then attached to the frame. In some instances, where required by special conditions, cross-bracing is added to the frame for extra strength and stability.

As illustrated on the last page of this section, there is a type of structure which replaces the corrugated metal sheets with prefabricated plastic fabric panels. Each panel spans between the structual frame members and openings can be placed as required in the panel.

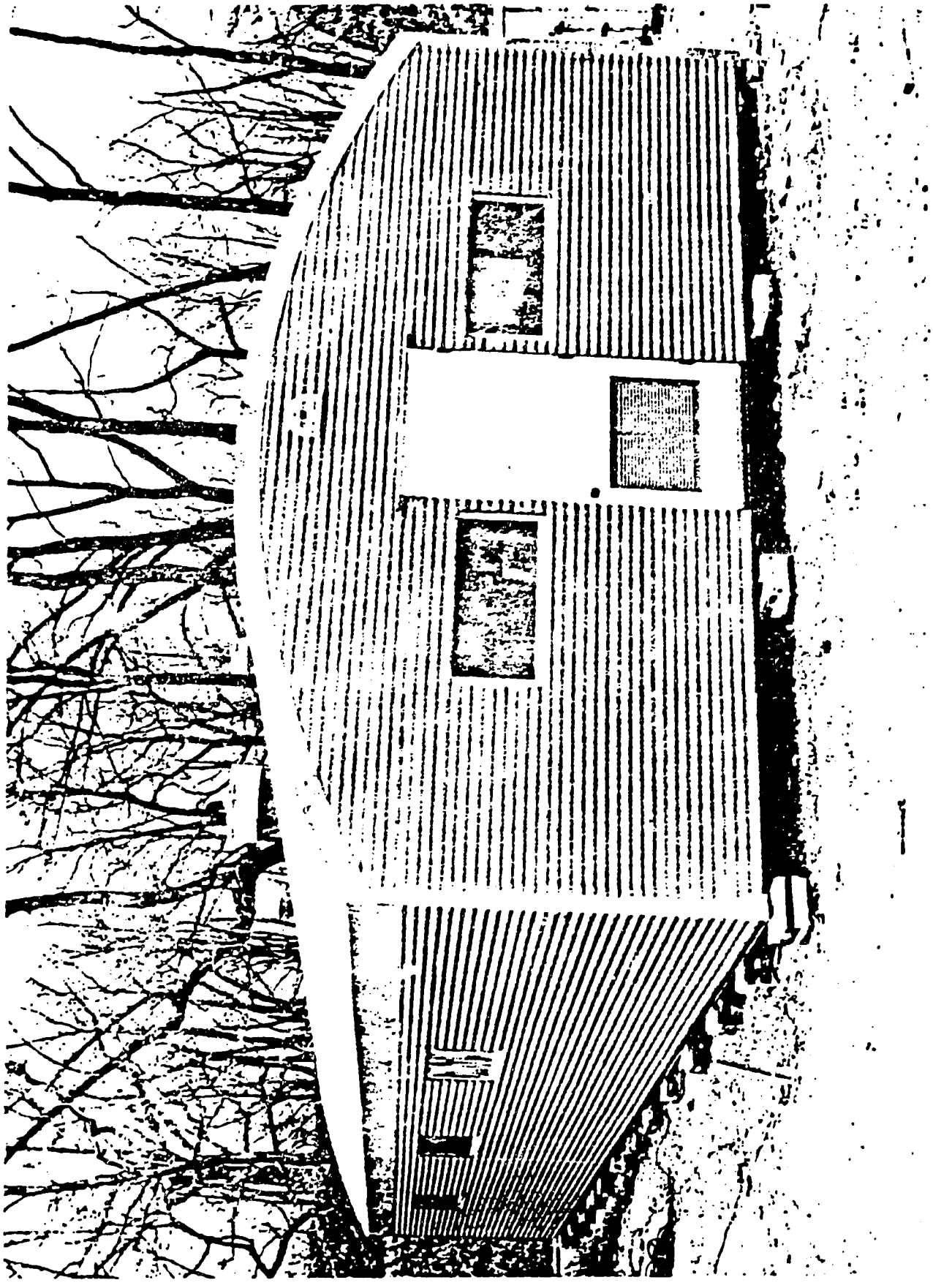
LIGHTWEIGHT FRAMING SYSTEMS

No. 2.24-2

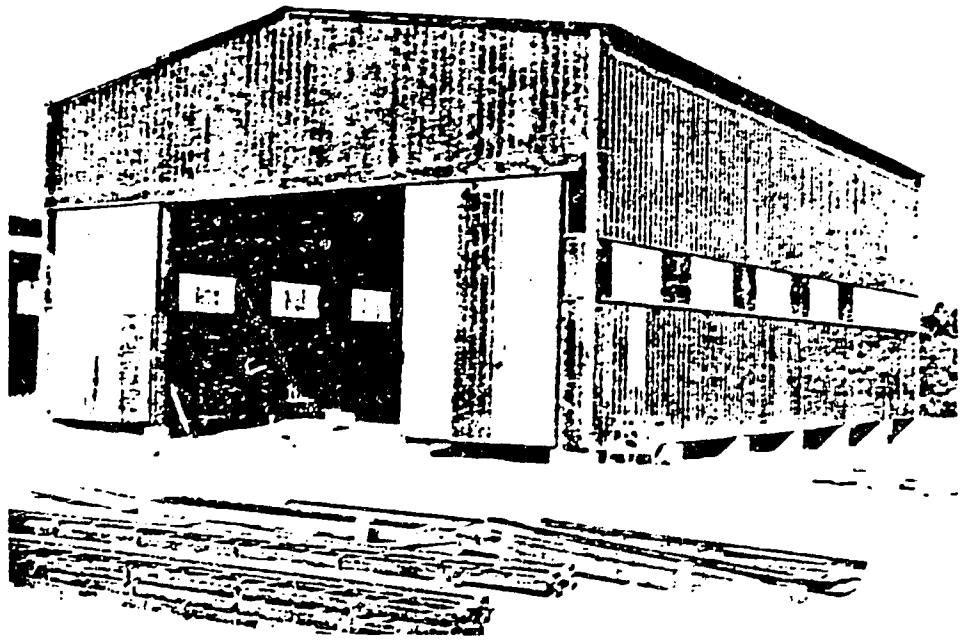
PREFABRICATED TEMPORARY UTILITY STRUCTURES

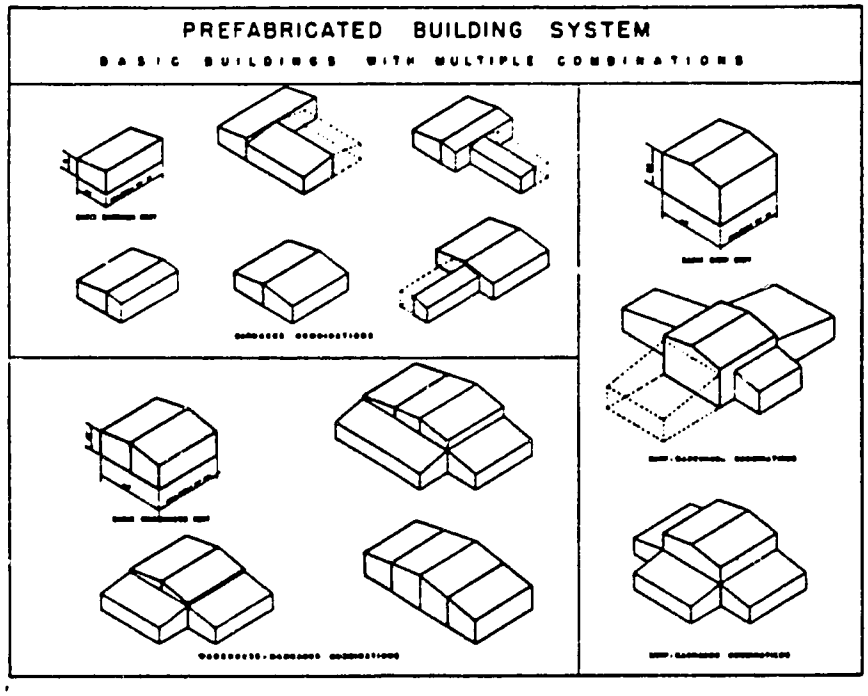


LIGHTWEIGHT FRAMING SYSTEMS	No.
PREFABRICATED TEMPORARY UTILITY STRUCTURES	2.24-3

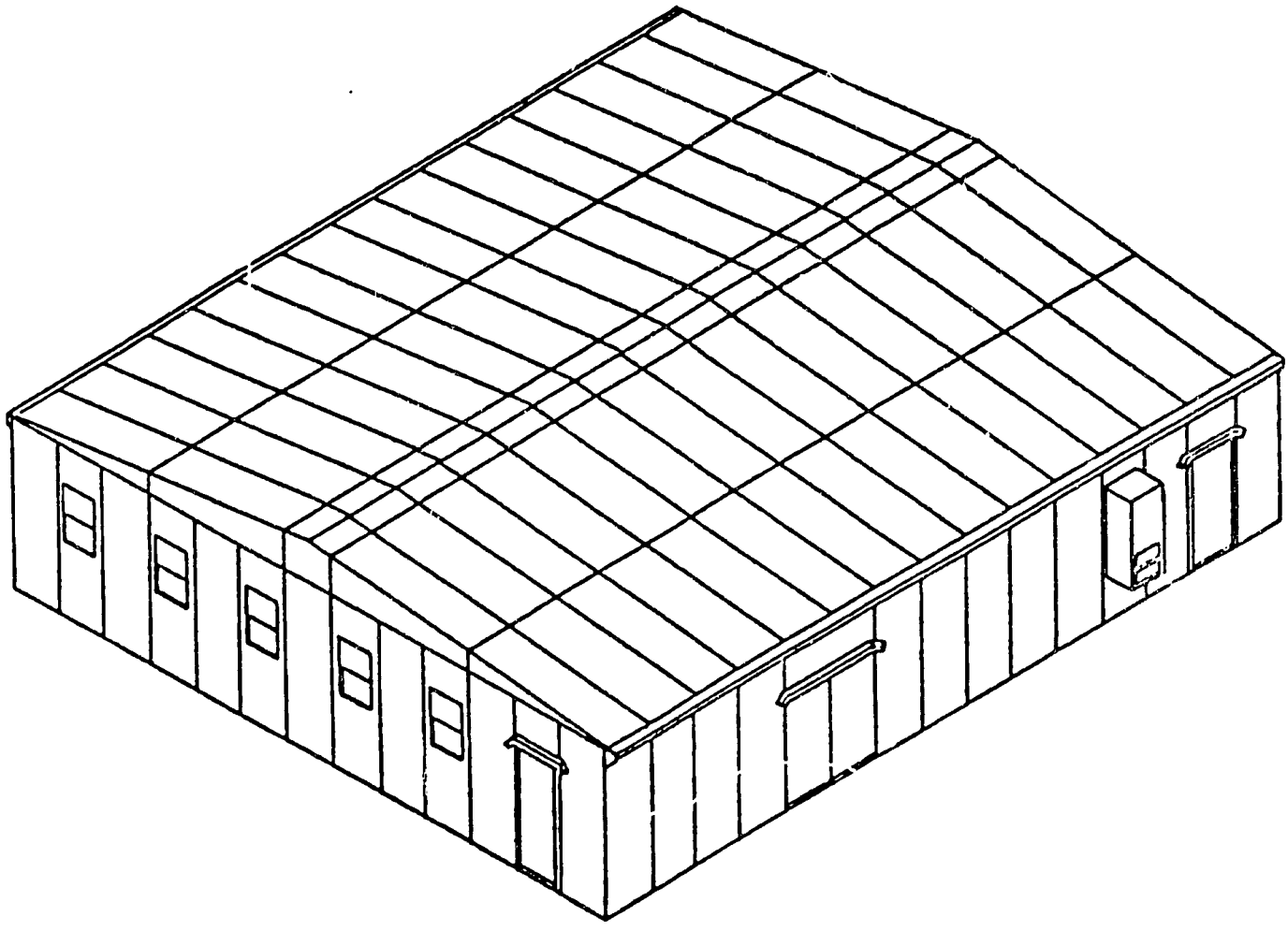


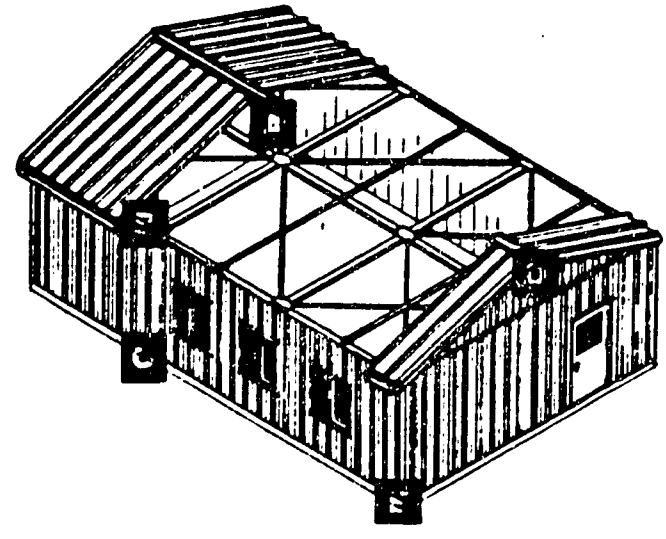
LIGHTWEIGHT FRAMING SYSTEMS	No.
PREFABRICATED TEMPORARY UTILITY STRUCTURES	2.24-4





LIGHTWEIGHT FRAMING SYSTEMS	No.
PREFABRICATED TEMPORARY UTILITY STRUCTURES	2.24-5

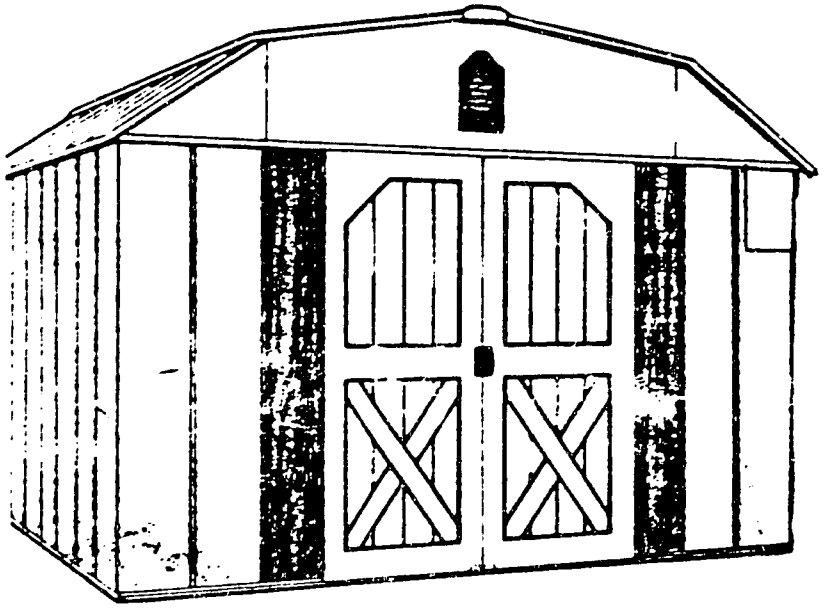


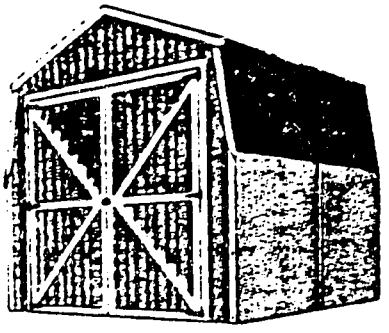


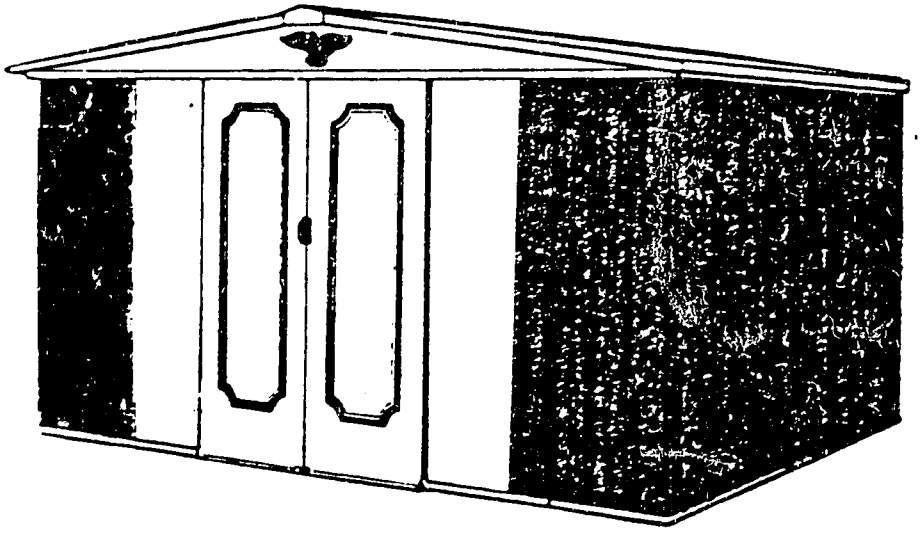
LIGHTWEIGHT FRAMING SYSTEMS

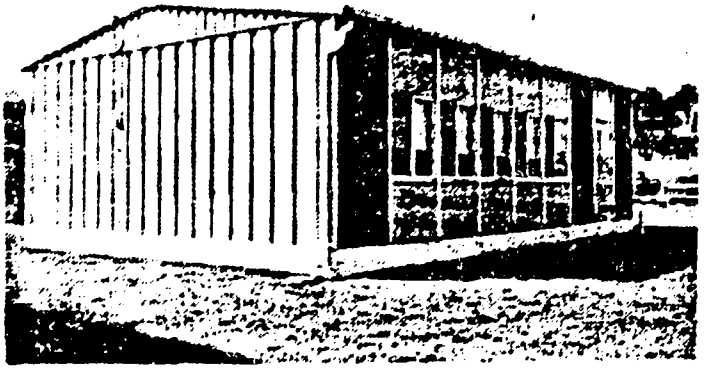
No. 2.24-6

PREFABRICATED TEMPORARY UTILITY STRUCTURES





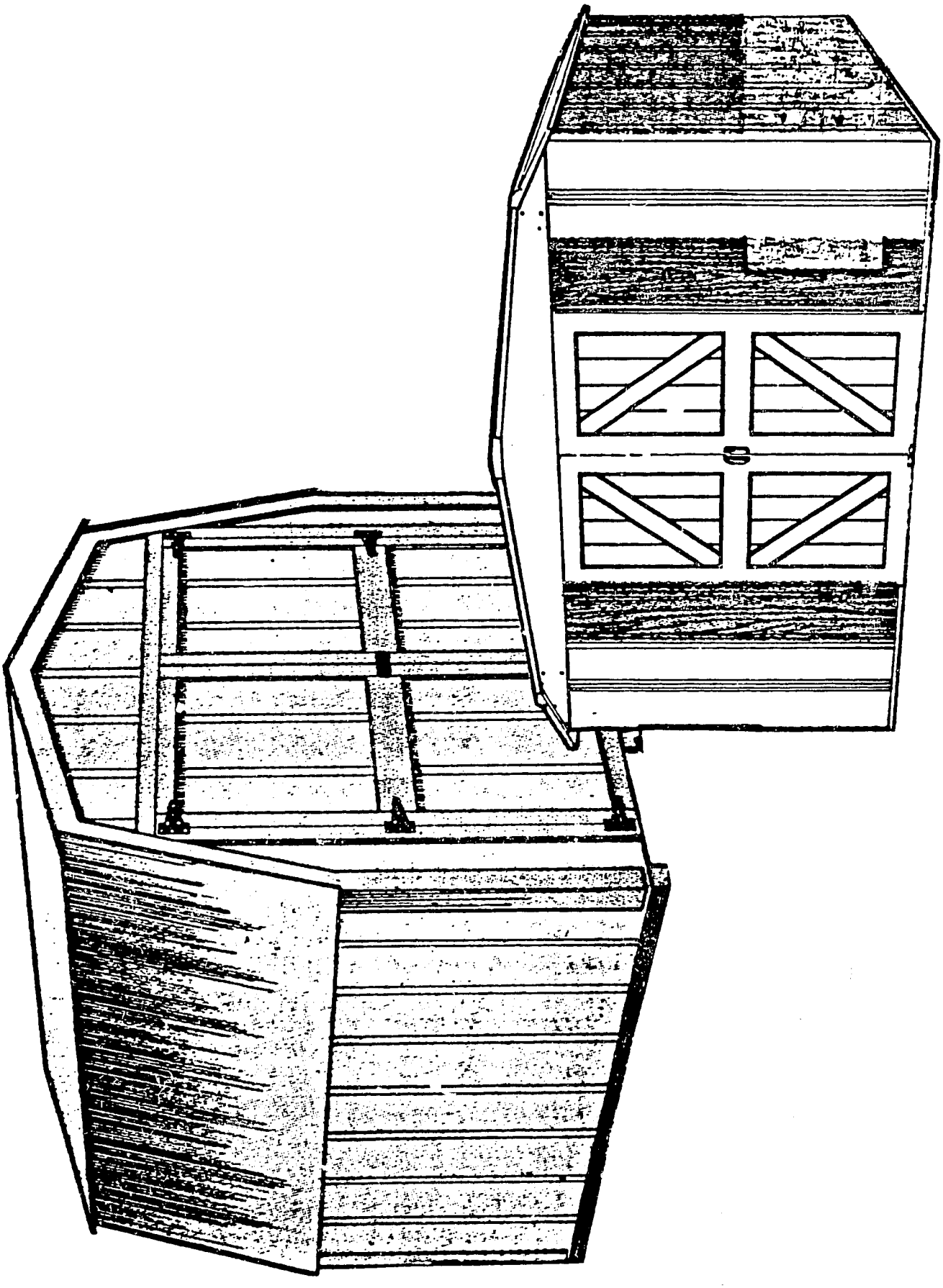




LIGHTWEIGHT FRAMING SYSTEMS

No. 2.24-7

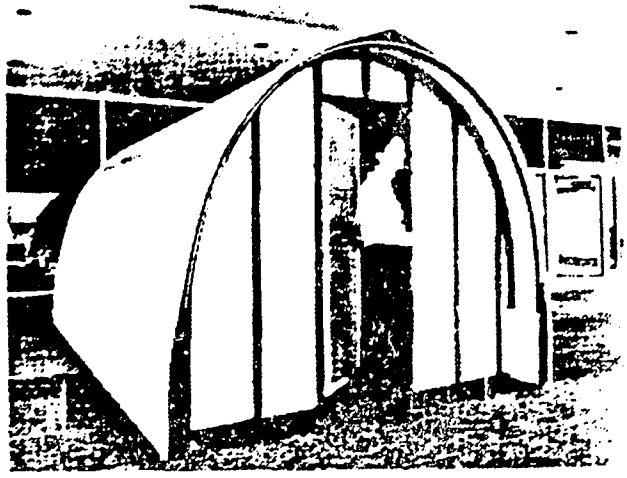
PREFABRICATED TEMPORARY UTILITY STRUCTURES

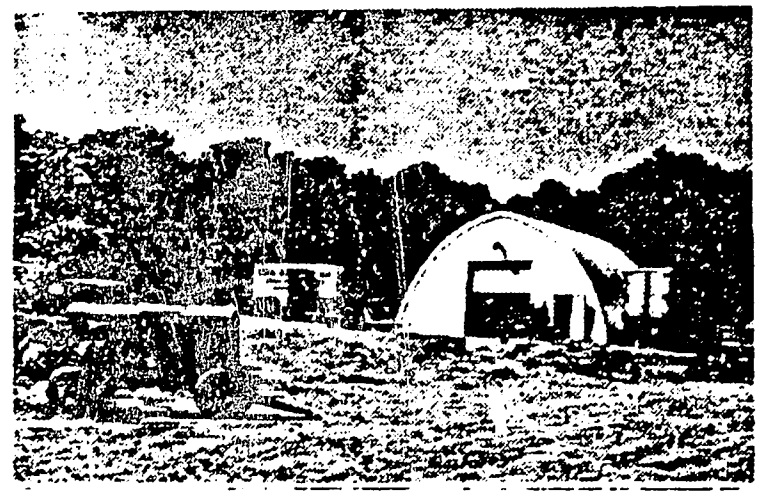


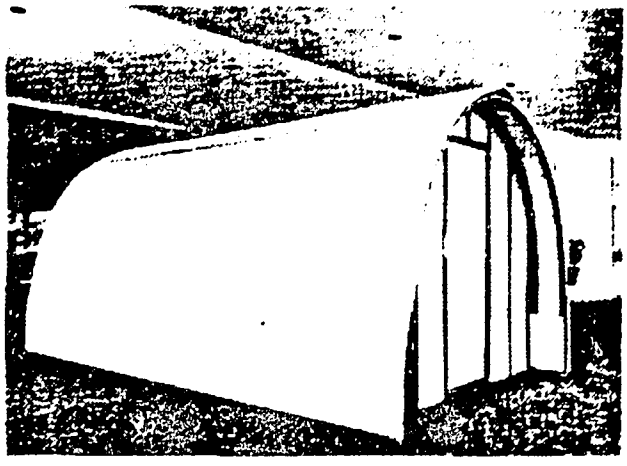
LIGHTWEIGHT FRAMING SYSTEMS

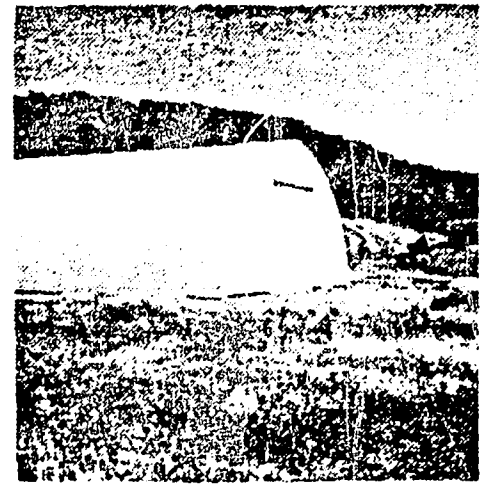
No. 2.24-8

PREFABRICATED TEMPORARY UTILITY STRUCTURES





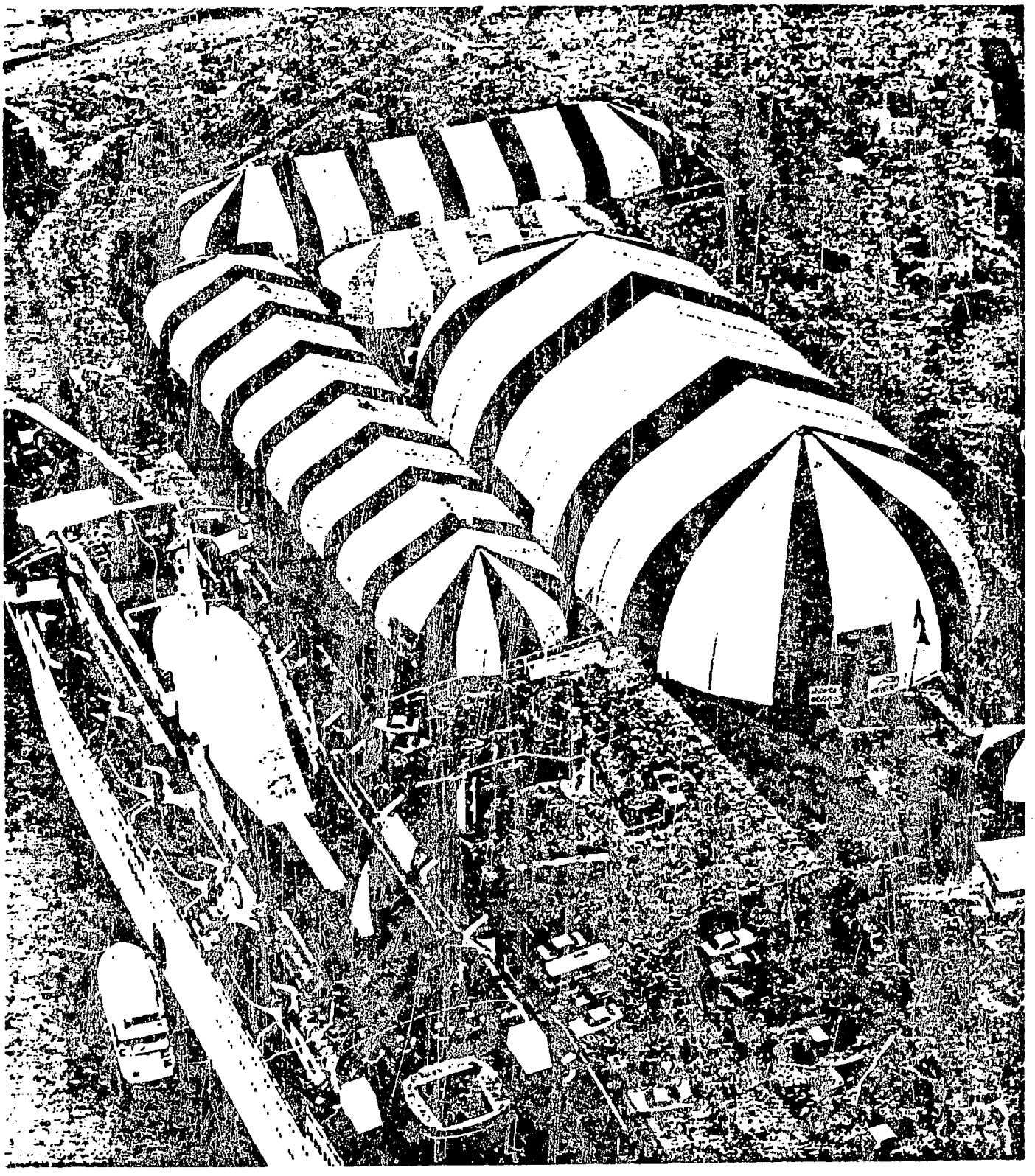




LIGHTWEIGHT FRAMING SYSTEMS

No. 2.24-9

PREFABRICATED TEMPORARY UTILITY STRUCTURES



2.3 BUILDING CONSTRUCTION MATERIALS

2.31 Compression
2.32 Tension
2.33 Linear, Torque Resistant
2.34 Sheeting

2.3 BUILDING CONSTRUCTION MATERIALS

The construction materials which could be used immediately following a disaster would be: available from stockpiles of new materials which have not been damaged by the disaster; scavenged from damaged buildings; produced/gathered from local indigenous sources. An effort to list all building materials possibly available in all localities worldwide, after all types of disasters, would be a research task of enormous proportions and is clearly beyond the scope of this project.

The approach adopted in this investigation as shown on the following pages, has been to identify generic categories of uses and strength characteristics of construction materials commonly used in disaster-prone developing countries which may be used in conjunction with plastic sheeting material and the community space system designed and developed during this project. Under each of these categories is grouped a number of materials which are available across a wide-range of geographic locations and climatic conditions.

As there are many types and combinations of items which could be adapted in unusual ways to meet exceptional circumstances, the materials presented here are intended only as representative examples of the type of items which could be directly employed by persons engaged in disaster relief activities. Clearly, the resourcefulness and ingenuity of the disaster victims and on-site relief agency personnel would be the most effective mechanisms in adapting whatever resources are available to meet the specific needs and conditions presented by a particular disaster.

Specific examples of the use of these materials and methods for joining and connecting them are illustrated in Sections 3.5 and 3.6.

BUILDING CONSTRUCTION MATERIALS	No.
COMPRESSION	2.31

Earth-solid and built-up wall, dug-out and bermed enclosure

Sand

Rock, Stone

Building Block - adobe, stablized adobe, fired clay, concrete

Bamboo

Palm Stalks

Wood - saplings, trunks, branches, dimensional lumber, "telephone poles"

Piping - steel, aluminum, copper, rigid metal conduit, rigid PVC plastic

BUILDING CONSTRUCTION MATERIALS	No. 2.32
TENSION	

Grasses and Vines - wound, woven

Rope

Bamboo - split and full diameter stalk

Wood - saplings, dimensional lumber

Palm Stalks

Electrical Wiring

Steel Reinforcing Bar

Flexible Conduit - plastic, metal

Wire Mesh - welded wire mesh, expanded lath, "chicken wire", "cyclone" fencing

BUILDING CONSTRUCTION MATERIALS	No. 2.33
LINEAR, TORQUE RESISTANT	

Bamboo

Palm Stalks

Wood - trunk, branches, dimensional lumber, "telephone poles"

Piping - steel, aluminum, copper, rigid metal conduit, rigid P/C plastic

Steel Reinforcing Bar

16

BUILDING CONSTRUCTION MATERIALS	No.
SHEETING	2.34

Woven Mats - grasses, saplings, split bamboo

Palm Leaves

Plywood

Woven Fabrics - blankets, carpets

Other available plastic sheeting

Sheet Roofing Material - metal, asbestos, glass fiber

Wire Mesh - welded wire mesh, expanded lath, "chicken wire", "cyclone" fencing

3.0 Community Space System Design

3.1 DESIGN METHODOLOGY

3.11 Design Approach
3.12 Use of the Design Manual

3.11 DESIGN APPROACH

The specifications contained in Section 1.0 of the scope of work for this project call for a framing system which is:

*Constructed from materials usually available at a disaster site

*Capable of being constructed by semi-skilled workers under local supervision

*Constructed using locally available tools

*Culturally acceptable

These constraints make it difficult to conceive of a single building system or type which would be universally acceptable for widespread application in the many regions around the world with vastly differernt cultural preferences, climatic conditions, material availability, and disaster types.

The solution presented here is a matrix of techniques in manual form which allows the local disaster official to respond to the problems of his particular situation with the use of plastic sheeting supplied by the United States Agency for International Development, Office of Foreign Disaster Assistance. This approach allows the local official on the scene to access information concerning the use of the plastic material at any stage from the siting and selection of a frame type to merely patching a hole in the roof.

By use of this manual, proper and proven attachments, details, and techniques can be applied as necessary to enable the people on site to adapt the plastic sheeting to their needs rather than adjusting their needs to the characteristics of the plastic. Using this manual, local craftsmen can build the type of structure to which they are accustomed, paying attention to important guidelines dictated by the particular characteristics and dimensional constraints

of the plastic sheeting. In cases where indigenous solutions are not possible, the manual fully details the assembly and erection sequence of several framing types and gives guidelines for selection of the one most appropriate for the situation at hand.

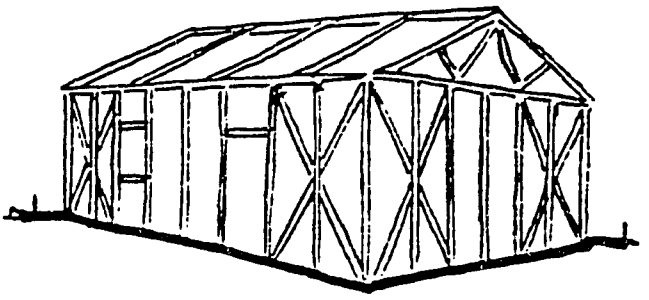
The flexibility of this approach has several very distinct advantages over a more specific universal design solution:

1. It is adaptive rather than imposed, active rather than passive.
2. It will involve local leaders and systems, reinforcing their authority in the post-disaster situation, strengthening their ability to lead the way to reconstruction.
3. It mitigates a dependent psychological response which puts inordinate faith in international relief agencies.
4. It offers program as well as material support.
5. It encourages continuity of local building forms and techniques.
6. It offers a vehicle for introduction of disaster mitigation techniques into the vernacular building technology.

While conforming to the overall concepts and the legislative mandate of the Office of Foreign Disaster Assistance, the adaptation of the plastic sheeting to indigenous forms could allow for a progressive transition to more permanent structures. Referring to the following illustration (Figure 3.11-1), it can be seen that the efforts of the local workers using their indigenous materials in the period directly following a disaster need not be for short term benefit alone. Careful attention to design guidelines contained in the manual will allow the sensible use of the plastic material on traditional building forms, thus allowing for their later adaptation to more permanent structures.

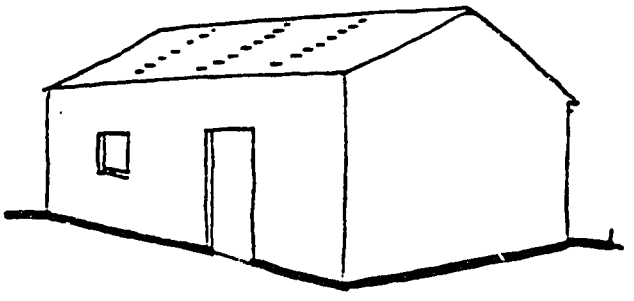
1. INDIGENOUS FRAME

Any available building materials can be used for a frame.



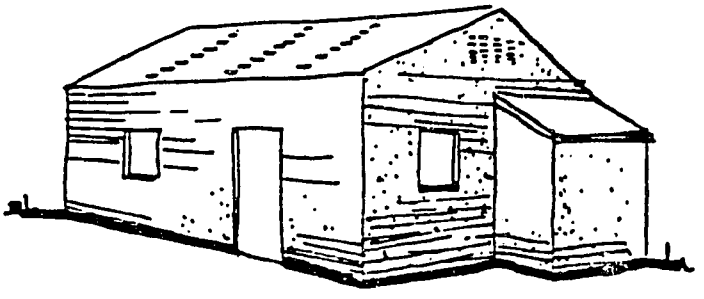
2. PLASTIC FABRIC

The fabric provides a usable space after the frame is covered, but has some short term problems (noise, heat, humidity, etc.).



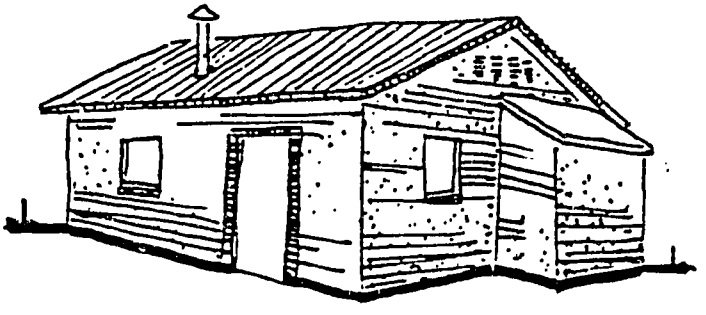
3. PERMANENT INFILL

As funds and materials become available (1-2 yrs after the disaster) the interior & exterior walls can be upgraded to a permanent material.



4. PERMANENT ROOF

As additional funds and materials become available (2-3 yrs) the roof structure & covering can be upgraded.



3.12 USE OF THE DESIGN MANUAL

Dissemination

The use of the design document (following its conversion into a simple and self-explanatory field manual), will be determined largely by the methods through which it is disseminated. Although it is intended that the manual be understandable to a disaster victim in the chaos of an emergency situation, it would be most ideal if local disaster preparedness officials were familiar with it prior to the event. It is recommended that copies of the manual and samples of the plastic sheeting be sent to disaster officials in countries which are likely to receive the plastic material in the event of a disaster. The manual will be produced in a loose-leaf or other adaptable format; it is therefore possible for local officials, perhaps with the assistance of USAID technical advisors, to modify or annotate the manual to make it more specific to the region.

In addition to its prior distribution, it is assumed that copies of the document would accompany the plastic sheeting to the disaster site. The methods used to achieve this should be carefully coordinated with the Office of Foreign Disaster Assistance and the countries involved to insure that the sheeting and manuals arrive simultaneously on site.

Manual Organization

The manual is organized so as to allow logical access to imformation by three categories of users:

1. Those who need to repair a damaged structure
2. Those who desire and are able to build a structure of indigenous materials using locally established form and techniques
3. Those who do not know what to build and need full instructions

For the first group, reference to Section 3.4 will provide graphic descriptions of methods for repairing damage such as partially blown off roofs. Specific damage, such as how to attach plastic to galvanized roofing, are contained in other sections to which the user is referred.

The second group can use the manual in several ways:

1. To employ mitigation details, such as windbracing, in the new construction
2. To dimension the structure so as to make it adaptable to the plastic material
3. To find proven details of attachment methods for securing the plastic material to the structure
4. To find information on siting, layout of functional spaces, and other design decisions

The third group will depend on the manual to assist them in the entire building process, from selection of an appropriate frame type to utilization of the correct plastic attachment methods.

By dividing the manual into sections on design, frame types, and details, the utility of the information is increased and its application made more universal and acceptable.

Frame Selection System

To assist the user in the selection of an appropriate frame for a particular climate and geographic region, a simple matrix system will link site-specific conditions to the frame types compatible with those conditions. For example,

use of the matrix will prevent selection of a frame using loosely strung sheeting in an area that can expect high winds.

Each frame type is described in three basic ways:

1. The General Description drawings, including plans, sections, and a sketch perspective.
2. The Erection Sequence, providing a step-by-step method for erection.
3. Specific Details and Notes, including the partitioning method and other details specific to the frame type.

All general details common to several of the frames are referenced in the General Description drawings.

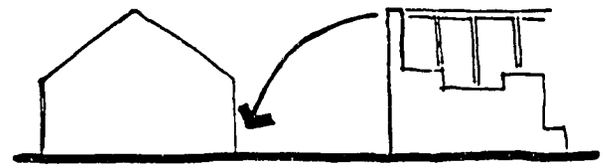
3.2 DESIGN INFORMATION

3.21 Siting and Orientation
3.22 Climatic Considerations and Guidelines
3.23 Structural Considerations and Guidelines
3.24 Cultural Considerations and Guidelines
3.25 Space Planning and Layout
3.26 Security Considerations
3.27 Properties of Plastic Sheeting

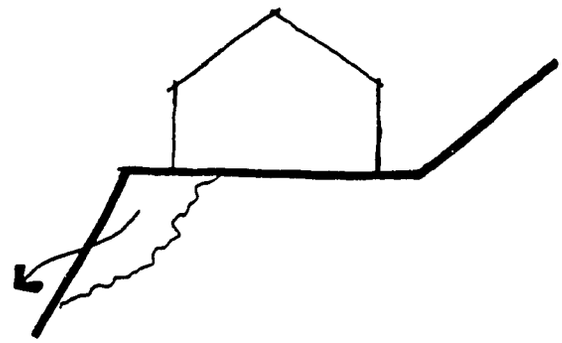
SEISMIC

Following an earthquake, there is a period of time during which aftershocks are likely to occur. To avoid the potential for further damage or injury from these aftershocks, consider the following guidelines when siting the post-disaster construction.

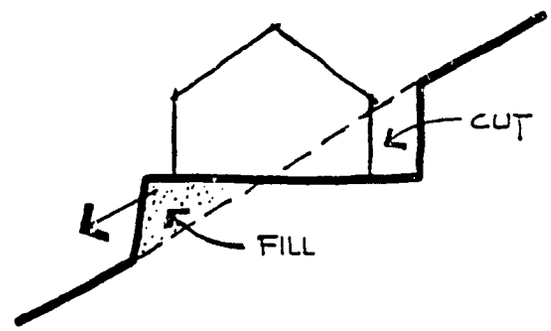
1. Avoid construction near buildings which are damaged and may collapse.



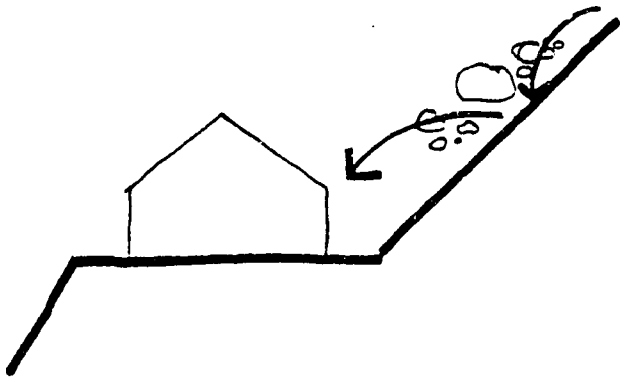
2. Do not build on steep slopes which may slip away.



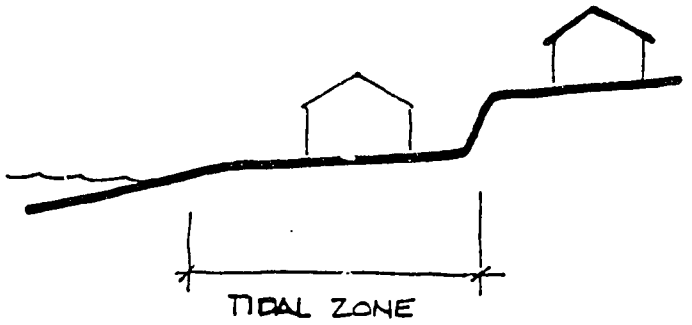
3. If a hillside is the only available site, avoid building on fill or close to a cut-out hillside.



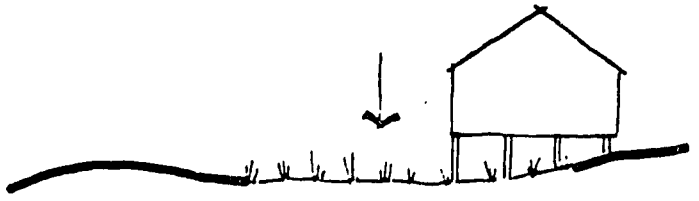
4. Do not build in areas which are likely to have rockslides.



5. If near a coastline, avoid siting near the shore where tidal waves would be a danger.

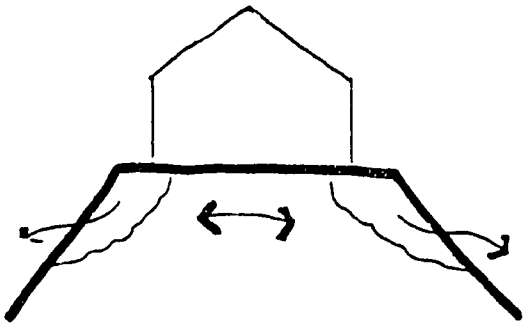


6. Avoid building in areas with loose soil or near marshy areas as they may settle.

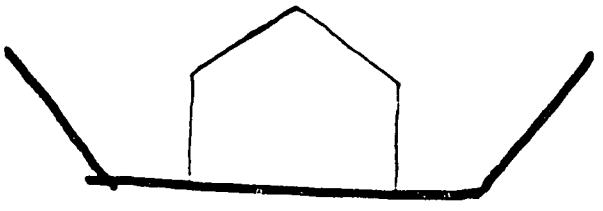


7. Avoid construction in an area below a dam.

8. Avoid building on or near the top of narrow ridges, where ground shaking is amplified.



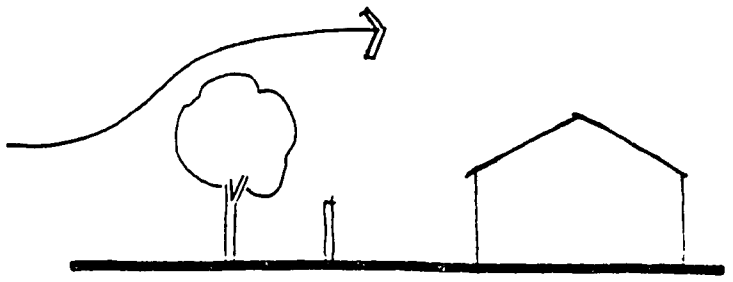
9. Avoid building in the bottom of narrow valleys.



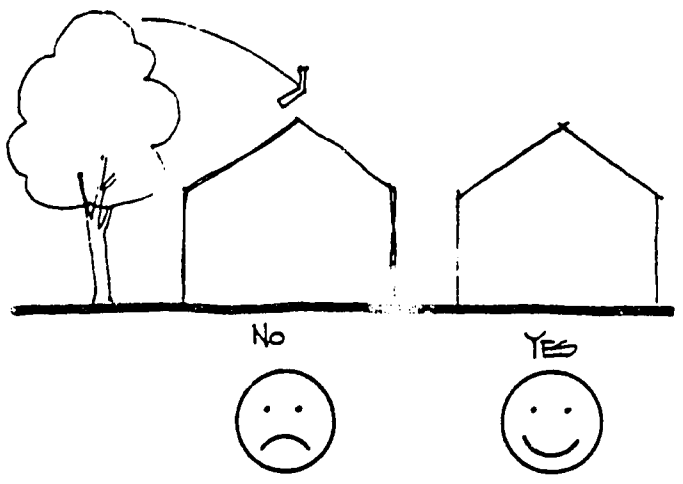
HIGH WINDS

In areas which are susceptible to winds in excesss of 17 meters/second, or about 40 miles per hour, site design guidelines for high wind should be considered. This is particularly important because of the susceptibility of the plastic sheeting to wind damage. In such cases, the plastic acts as a sail and can concentrate significant dynamic pressures leading to self-destruction or damage to the structure.

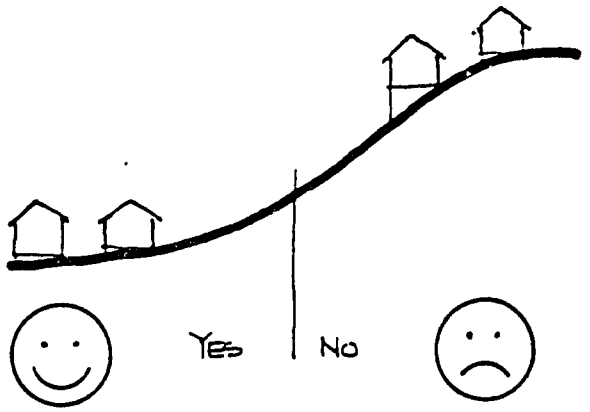
1. Take advantage of natural windbreaks such as trees or small hills.



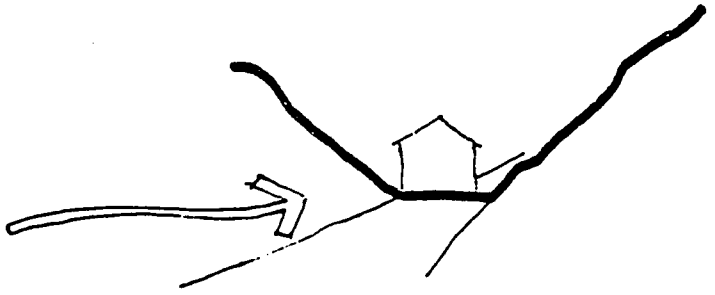
2. Avoid locations adjacent to trees or structures which may be blown down.



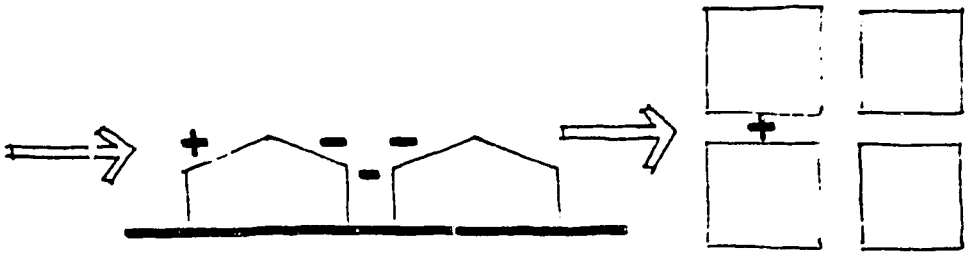
3. Avoid sites on or near the tops of tall hills.



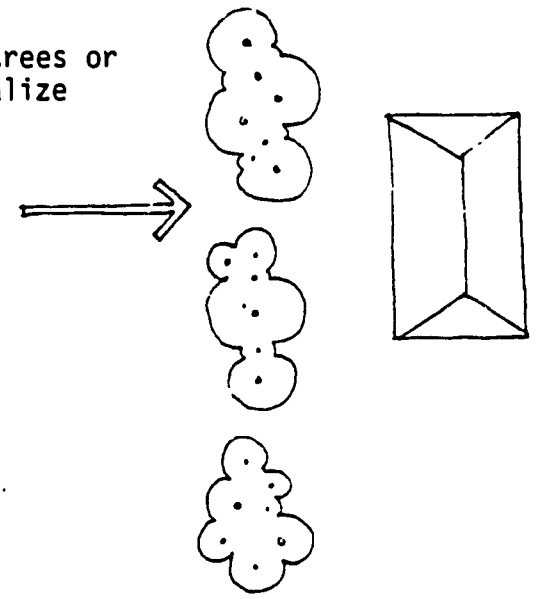
4. Avoid locations in narrow valleys or passes.



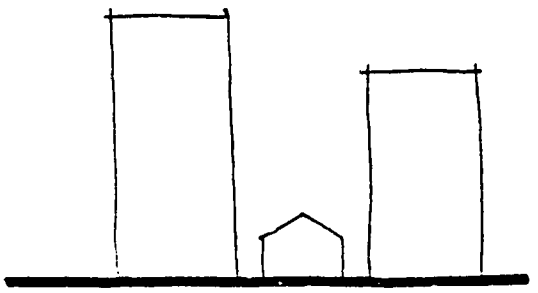
5. Do not place buildings very close to each other because this can cause higher velocities, turbulence, and exaggerated pressures.



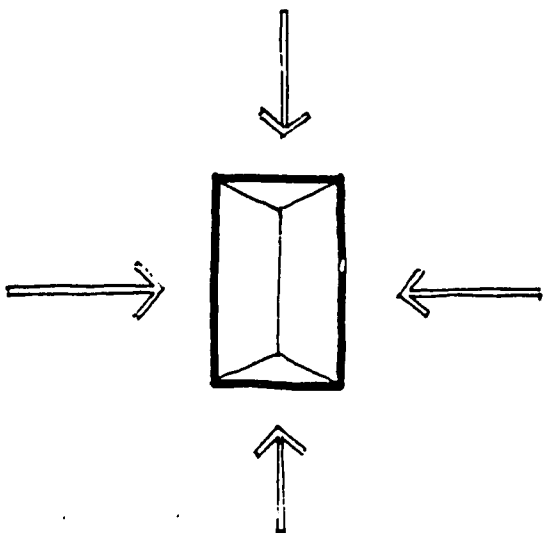
6. When forming a windbreak with trees or walls, allow small gaps to equalize pressure.



7. In cities the space between tall buildings will have higher winds.



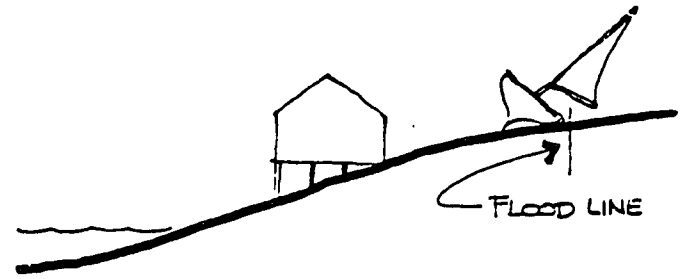
8. In a cyclone, the wind will blow from all directions during the storm.



FLOODING

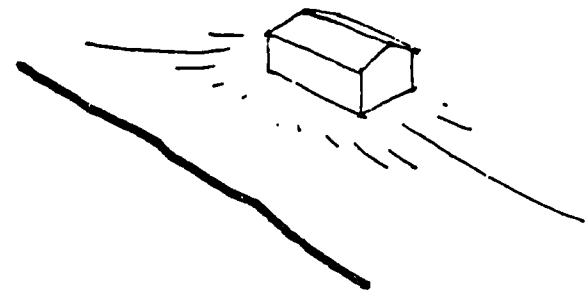
Since many types of disaster (cyclones, earthquakes, tsunamis) can cause flooding, it is important that emergency structures be sited where the effect and aftereffects of the disaster will not cause a secondary risk.

1. Avoid building in areas that show evidence of recent or historical flooding.

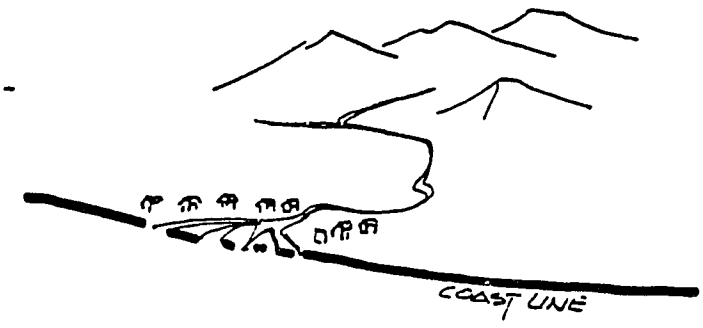


2. If it is necessary to build near the coastline, attempt to find a location behind a continuous embankment.

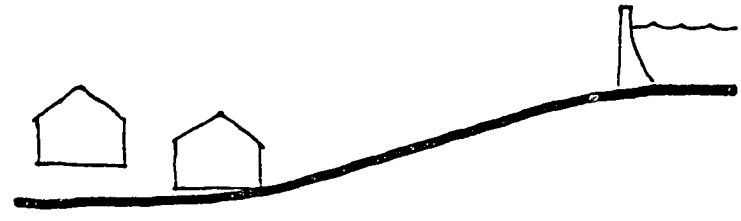
3. If a continuous embankment is impossible, build on or behind the highest land possible.



4. Avoid building directly adjacent to rivers, streams, and major water courses. In coastal areas, initial flooding may come from the storm surge of the ocean; however, secondary flooding may occur as runoff from inland regions.



5. Avoid building downstream from dams (particularly earthen dams).



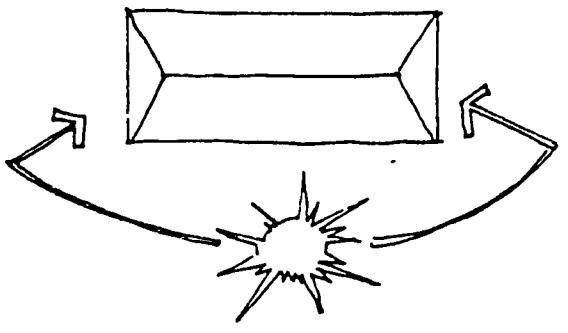
HOT DRY CLIMATES

The use of plastic, particularly in the roofs of structures in hot dry climates, poses three categories of problems:

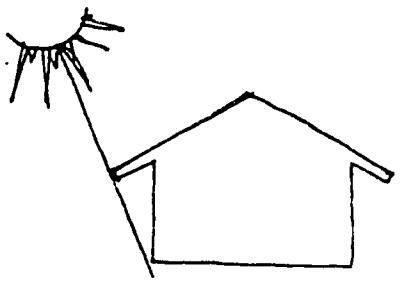
1. Intense heat buildup within the structure.
2. Damage to the plastic sheeting in the short term due to softening and in the long term due to degradation.
3. Damage to the supporting structure due to the cooking out of wood resins caused by the trapping of heat by the plastic.

The following paragraphs give general guidelines for the control of environmental problems in hot dry climates.

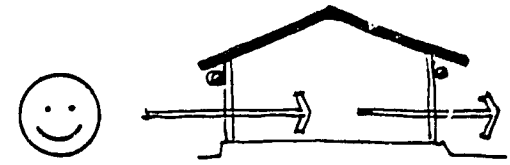
1. Orient the structure so that the sun falls on the short side during the morning and afternoon.

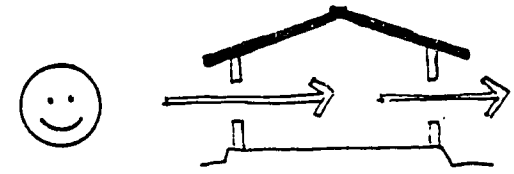


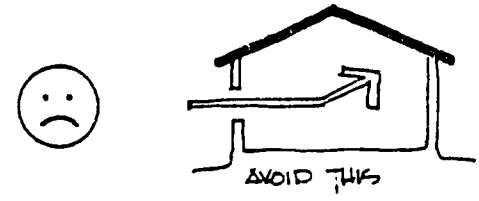
2. Protect the south side with an overhang. (CAUTION - In areas with high winds, the overhang should be minimized to prebent the roof from blowing off. See Section 3.23 - High Winds.)



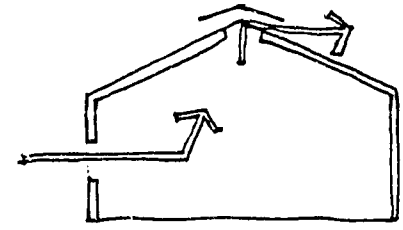
3. Use a maximum of natural ventilation. However, provide for total closure of the structure during cold nights. (CAUTION - In areas with high winds, opening on the windward side can cause dangerously high pressures if not properly vented. See Section 3.23.)

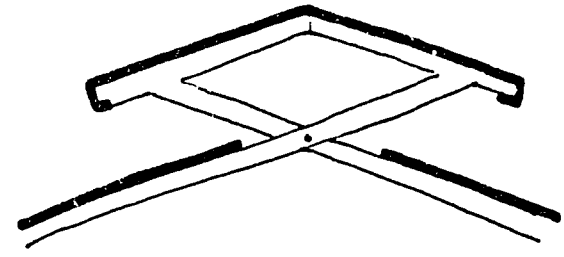




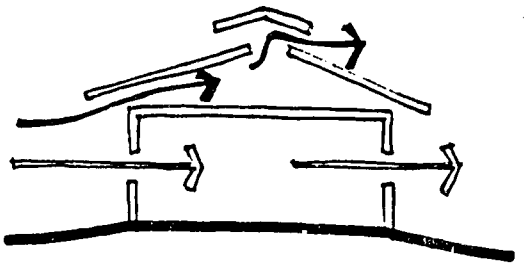


4. To prevent heat buildup, ventilate the roof.

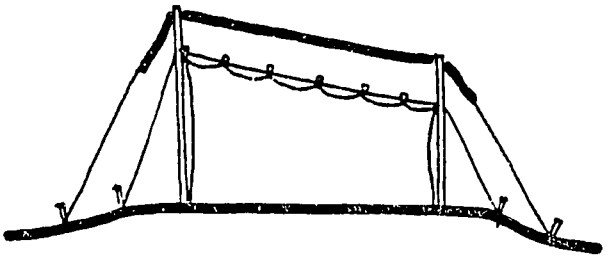




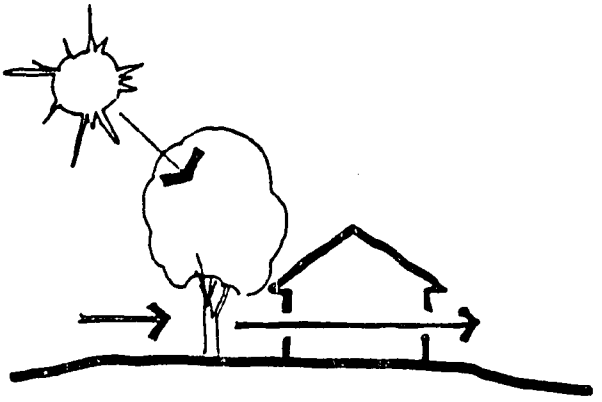
5. Isolate a ventilated space above the occupied space with a ceiling.



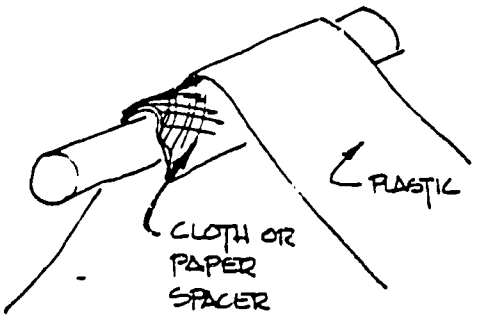
6. Shade the structure with an awning.



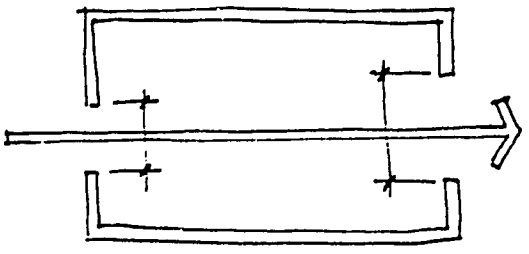
7. Locate the building in the shade of trees. (CAUTION - In areas with high winds, falling treees or branches may be dangerous.)



8. In places where the plastic material is in contact with supporting structure, high temperatures may damage the plastic. Use a double sheet of plastic or place a piece of cloth or cardboard between the plastic and the support.



9. If the wind usually blows from one direction, make the windows on the windward side smaller than those on the leeward side.



HOT WET CLIMATE

The use of plastic sheeting in hot wet climates has three basic problems which require careful attention:

1. The chance of frequent and often severe rainstorms which can cause severe structural problems with the sheeting due to flapping and ponding.

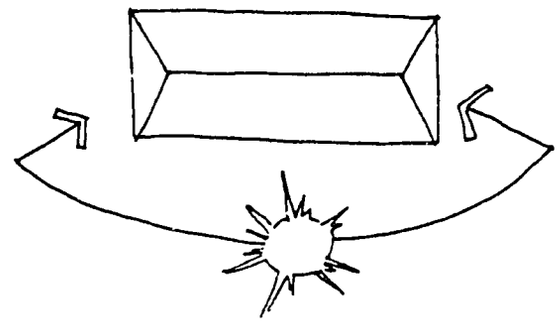
2. High humidity, which is aggravated by the fact that the plastic does not breathe.

3. Intense heat which causes discomfort in the structure and damage due to the softening and eventual degradation of the plastic. The heat also cooks resins out of wood supporting structure.

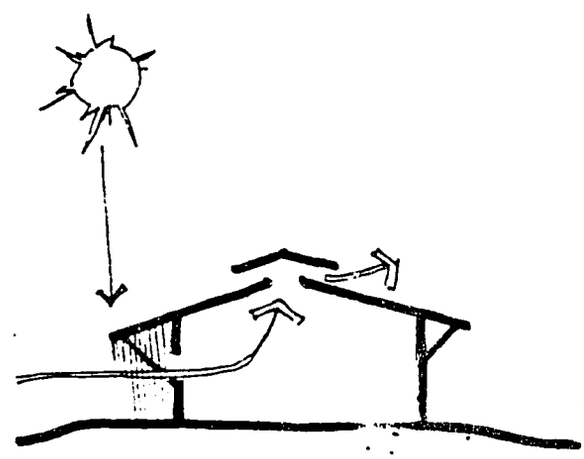
The combination of these problems makes the achievement of comfortable living and working environments in structures made of plastic sheeting very difficult.

One mitigating consideration is that the temperature differential between day and night or between seasons is not very great in contrast to hot dry climates where days can be very hot and nights cool. This allows for less careful control of natural ventilation.

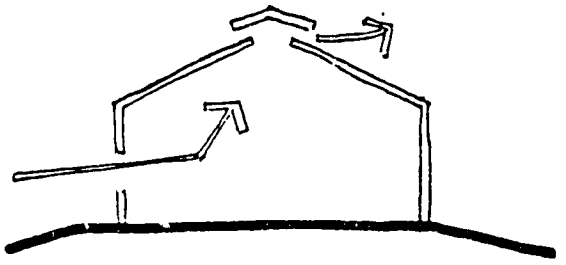
1. Orient the structure so that the sun falls on the short sides during the morning and afternoon.

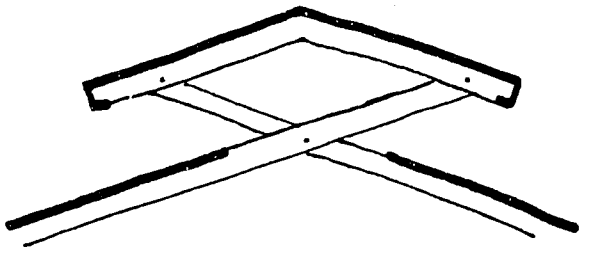


2. Construct wide overhangs all around the structure. Support the overhangs and allow a vent where the overhang meets the wall so that wind does not blow the roof off.

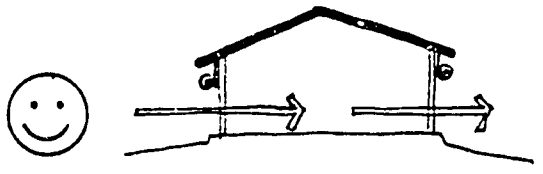


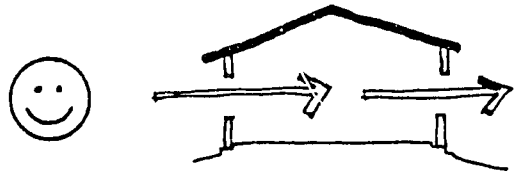
3. Ventilate the roof at the ridge.

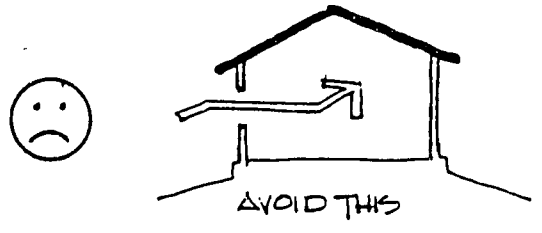




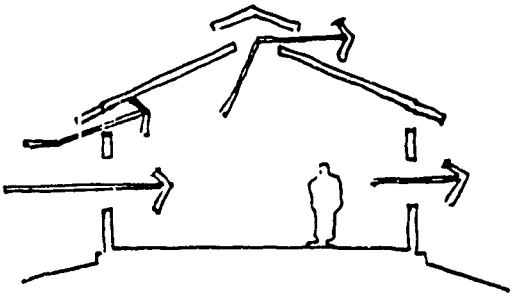
4. Use a maximum of natural ventilation. (CAUTION - In areas with high winds, openings on the windward side can cause dangerouly high pressure if not properly vented. See Section 3.23)



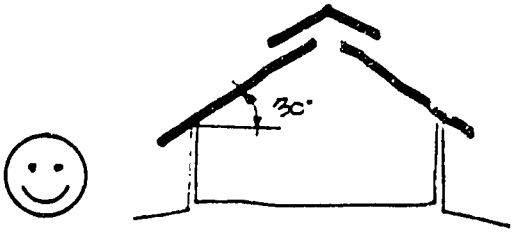


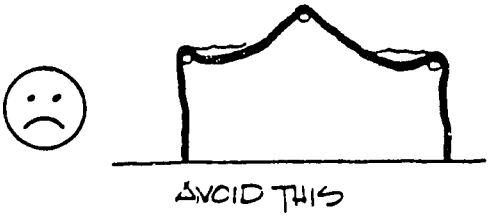


5. Make ceilings high and well-ventilated.

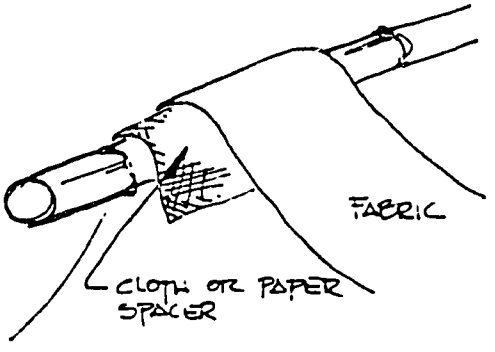


6. Use roof slopes of 30% or greater to avoid ponding and support the plastic often. See Section 3.23.

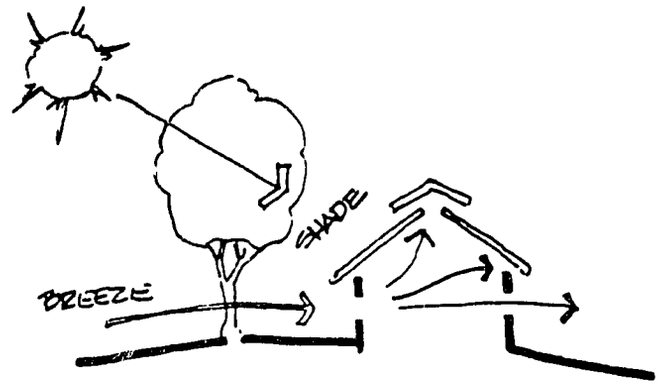


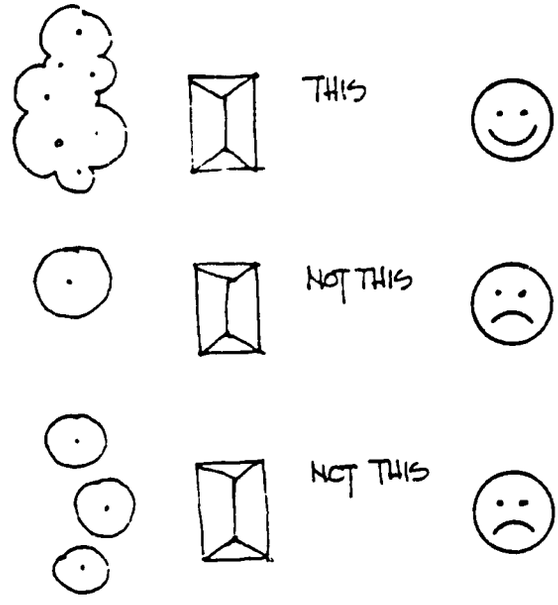


7. In places where the plastic material is in contact with supporting structure, high temperatures may damage the plastic. Use a double layer of plastic or place a piece of cloth or cardboard between the plastic and the support.

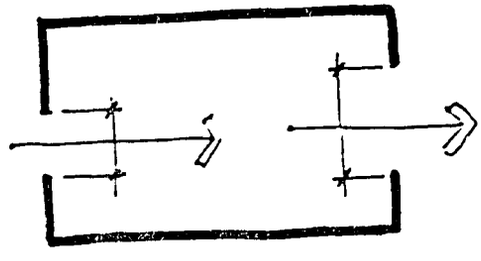


8. Locate the building in the shade of trees. Avoid places with dense underbrush which would block the breeze. (CAUTION - In areas with high winds, falling trees or branches may be dangerous. Avoid single treees or rows. See Section 3.23.)

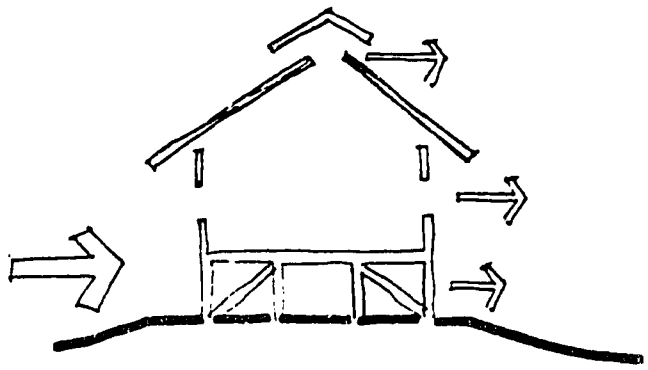




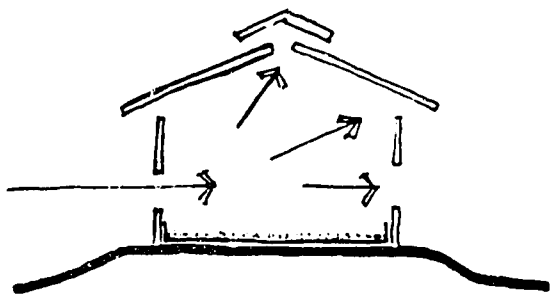
9. If the wind blows from one direction, make the windows on the windward side smaller than those on the leeward side.



10. Raise the building off the ground to catch the breeze and avoid ground moisture.



11. If the structure is on the ground, put plastic on the ground and cover it with sand or packed earth to avoid extra humidity from ground moisture.



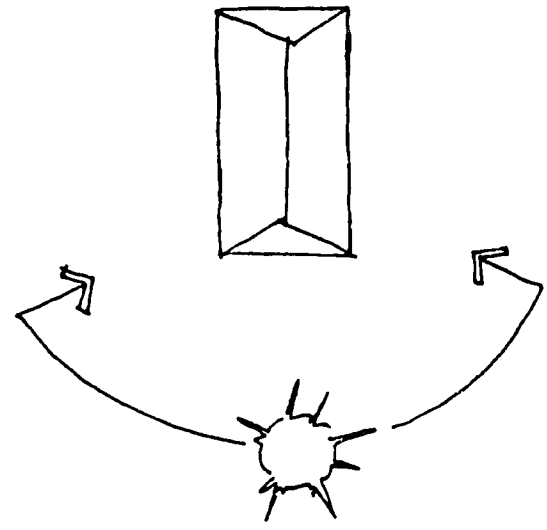
COLD CLIMATE

Structures constructed from plastic sheeting are difficult to adapt to cold climates. Buildings in cold climates must be tightly sealed, causing the following problems:

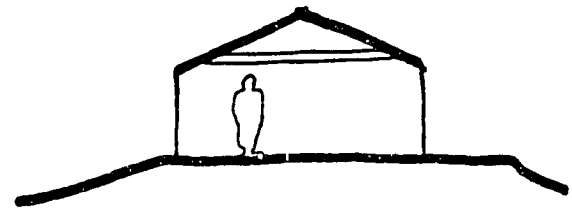
1. Plastic does not breathe, so water vapor is trapped in the space.
2. Plastic sheeting is very thin, so the water vapor tends to condense on the cooled sheet.
3. Plastic is very flammable, so great care must be taken with heating sources.

Additionally, it is difficult to insulate plastic and to control the infiltration of cold air.

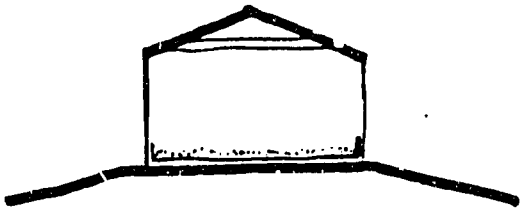
1. The structure should be oriented so that the morning and afternoon sun strikes the long side of the building.



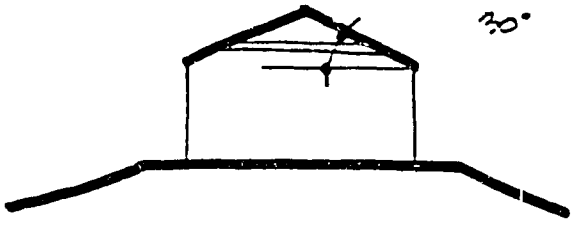
2. The ceiling should be low to minimize the volume to be heated.



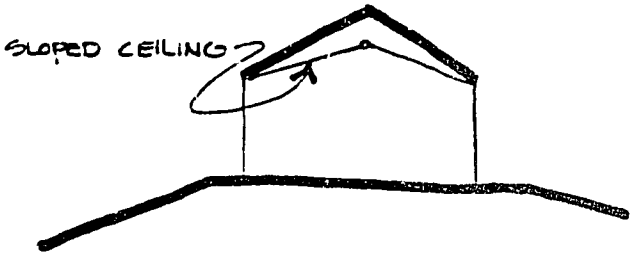
3. If the structure is on the ground, put plastic on the ground and cover it with sand or packed earth to prevent moisture from entering into the space.



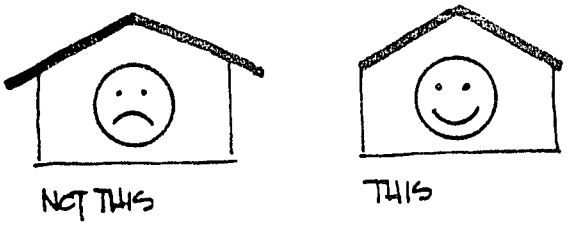
4. Roof slopes should be at least 30° and closely supported if snow is likely.



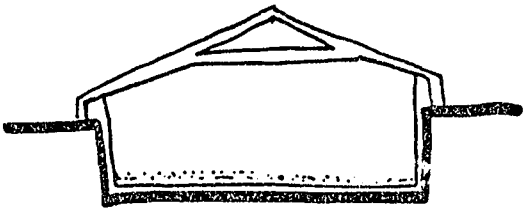
5. Care should be taken to allow water which will condense on the plastic to have a place to go.

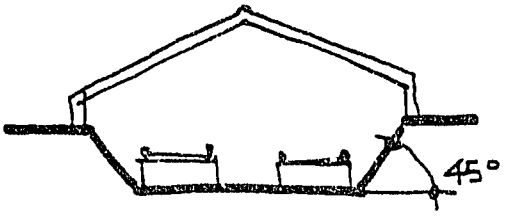


6. Avoid roof overhangs.

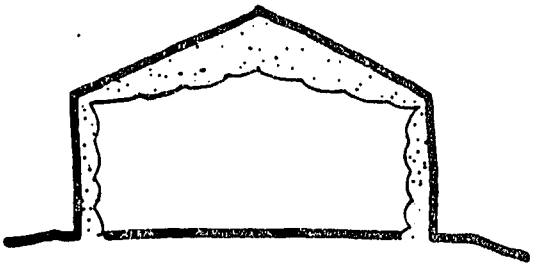


7. Where it is possible and where flooding is not a concern, bury part of the structure in the ground. Be sure to line the exposed earth with plastic. (CAUTION - If the area is in an earthquake zone, make sure the sides are sloped at 45°.)

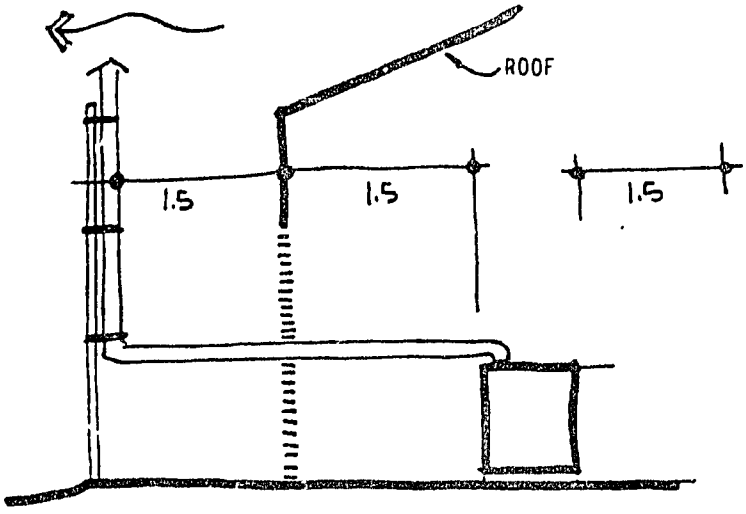




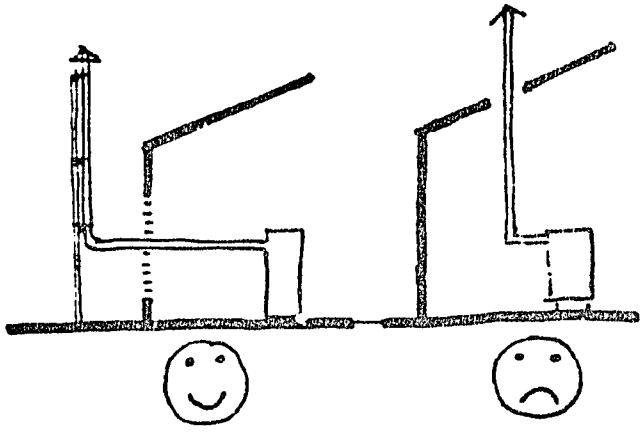
8. Insulate the structure by attaching a double skin of plastic. If possible, place dry leaves, straw, or similar materials between the plastic layers. (CAUTION - Do not leave the insulated skin on the structure during the summer as a fire hazard may be caused by overheating of the fill.)



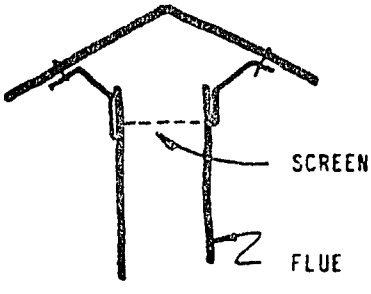
9. If a heater is used, extreme care must be taken.



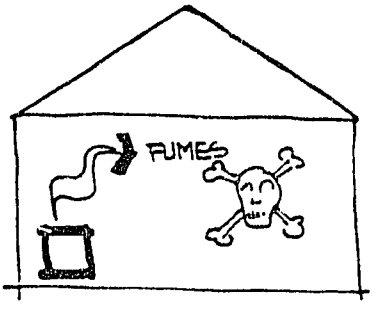
10. If a heater is used, make sure the flue is never within 1.5 m of any plastic. Vent the flue through the wall rather than through the roof.



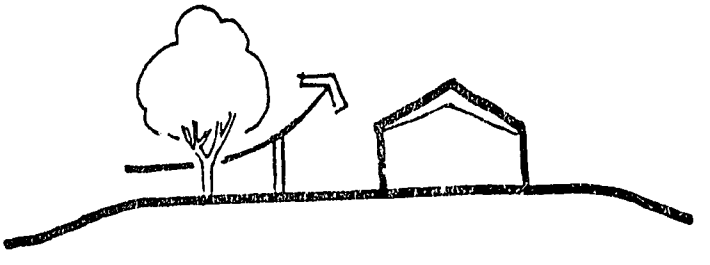
11. Make sure the flue is screened so that no sparks can escape and ignite the plastic.



12. Make sure that adequate ventilation is maintained within the space. The plastic skin will not allow air to enter, so other avenues of ventilation must be ensured.



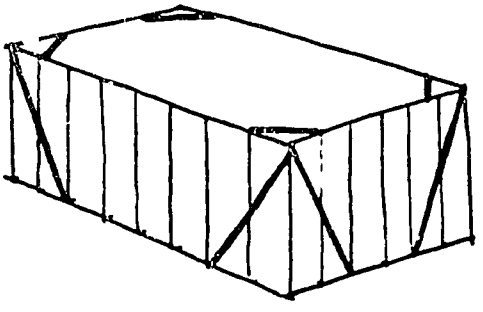
13. Cold winds should be deflected from the structure by windbreaks or vegetation.

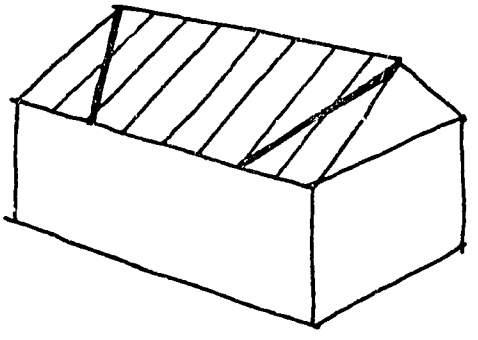


GENERAL

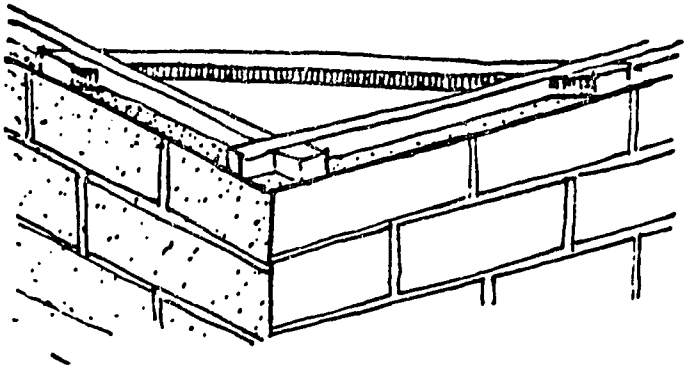
In any disaster type, it is important that construction of post-disaster structures be strong enough to survive aftershocks, continued high winds, or floods.

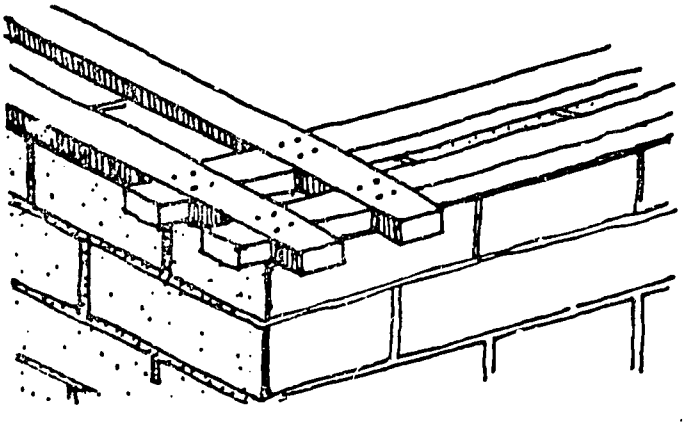
1. Wood frame structures should be thoroughly braced with diagonal members.



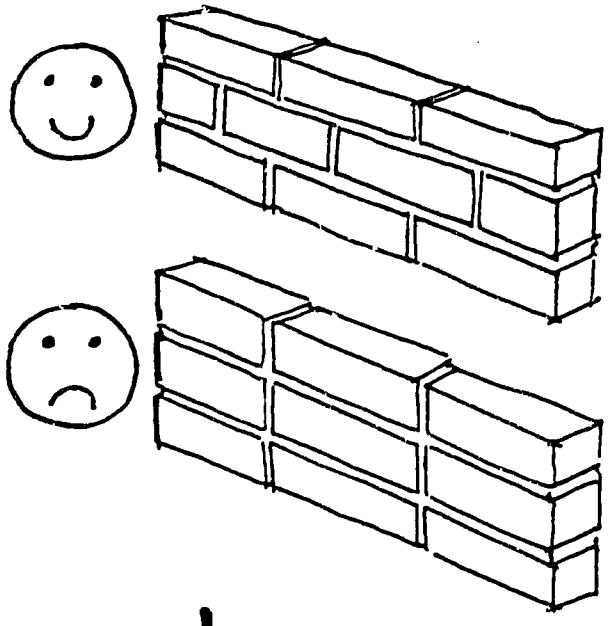


2. Masonry rubble or adobe structures should be braced at the top of the wall.

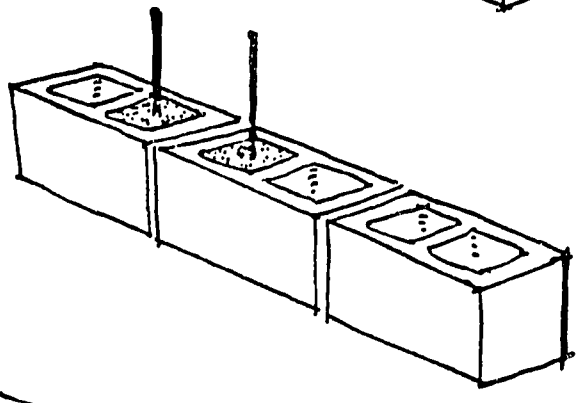




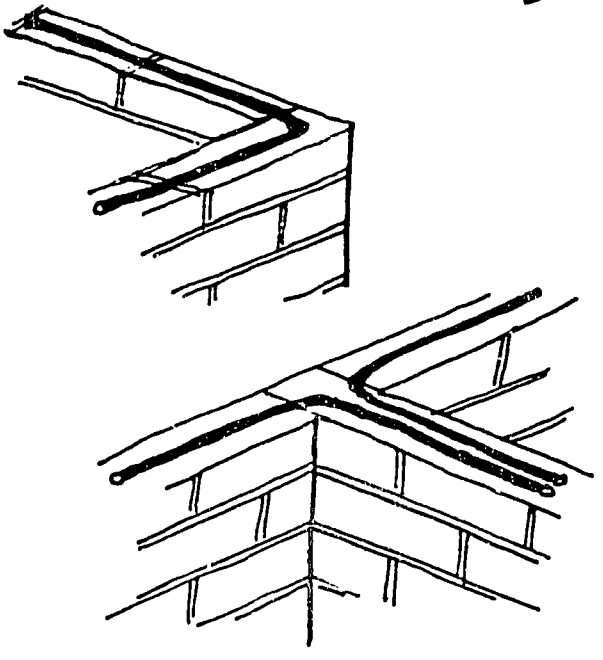
3. Masonry construction should use running bond rather than stack bond.



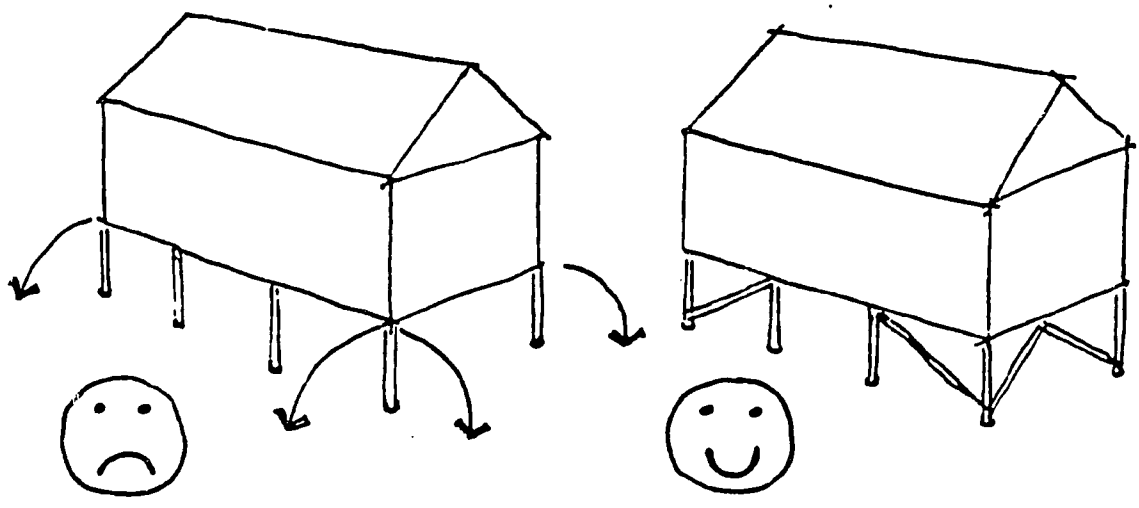
4. Masonry should be reinforced <u>vertically</u>.



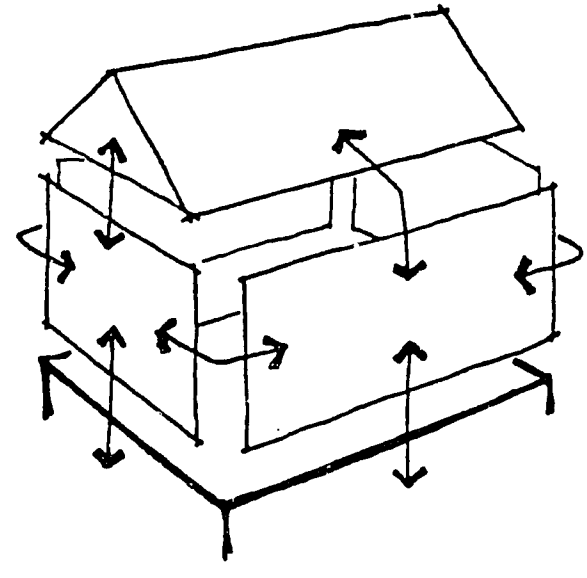
5. Masonry should be reinforced <u>horizontally</u> at corners or <u>intersections</u> of walls.



6. Foundation walls or piers should be braced to avoid collapse.



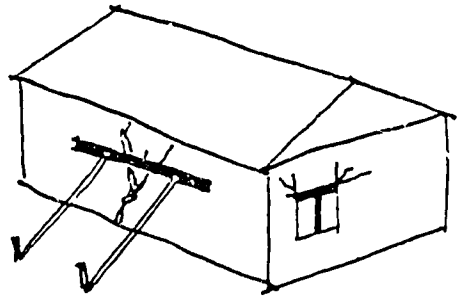
7. Make certain that every part of the structure is securely tied together. The roof components must be thoroughly nailed and strapped together and in turn securely attached to the walls. Similarly, the walls must be anchored to the foundation and the foundation firmly in the ground. (Specific illustrations of connection methods may be found in Section 3.5.)



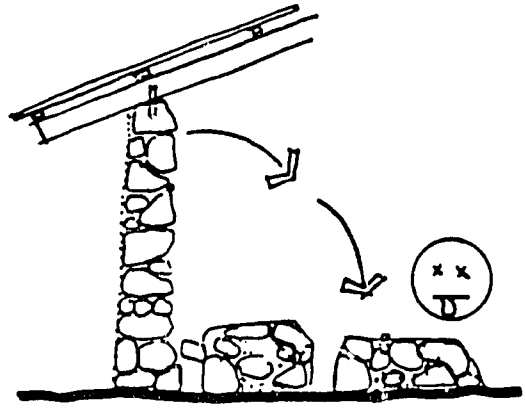
SEISMIC

Following an earthquake, there is a period of time during which aftershocks are likely to occur. To avoid the potential for further damage or injury from these aftershocks, consider the following guidelines when constructing new structures or when repairing damaged ones. (For information on siting considerations following an earthquake, see Section 3.21.)

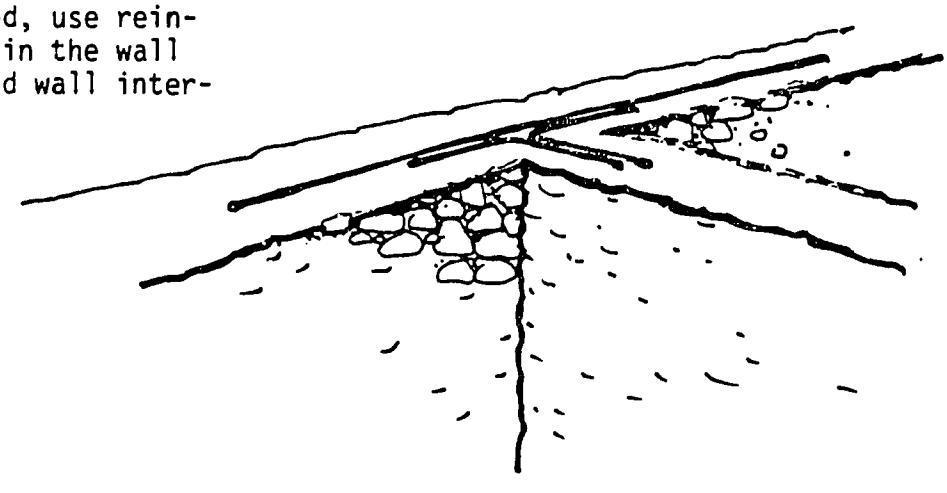
1. Use extreme caution when using or repairing damaged structures. If alternative safer structures or materials exist, use them. If the damaged structures must be used, brace and reinforce any obvious failures.



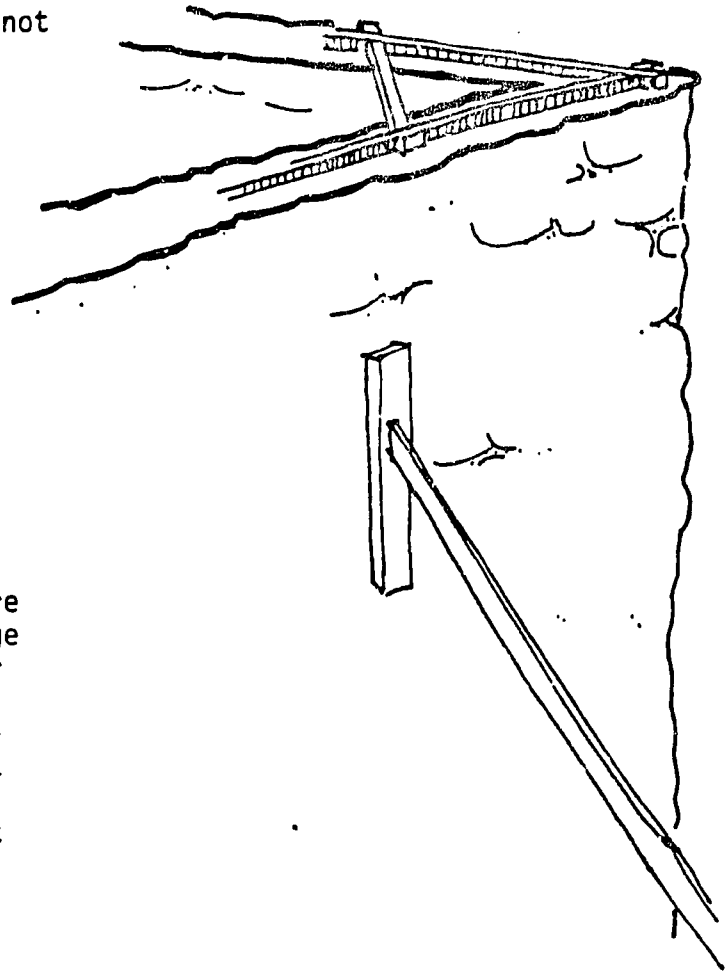
2. If possible, avoid the use of unreinforced rubble or masonry; it is the most dangerous type of construction.



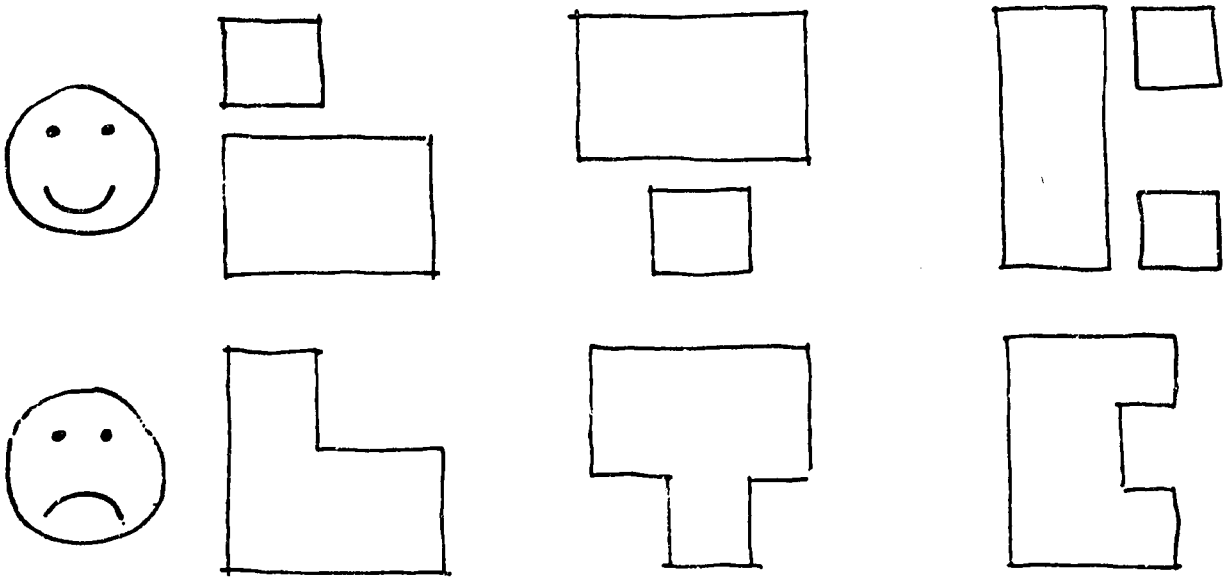
3. If rubble must be used, use reinforcing horizontally in the wall and at all corners and wall intersections.



4. If horizontal reinforcing is not used, rubble walls should be braced and buttressed.



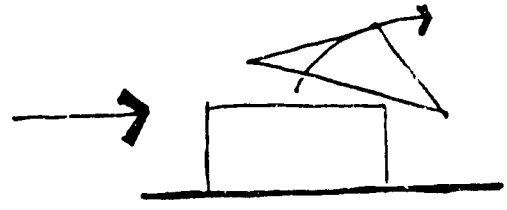
5. Simple building forms are more resistant to earthquake damage than are complex or irregular forms. Where "L" or "C" or other complexly shaped structures are required, construct them so that the parts are structurally separate so that one part could fall or shift without damaging the other.

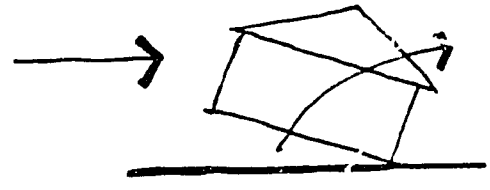


HIGH WINDS

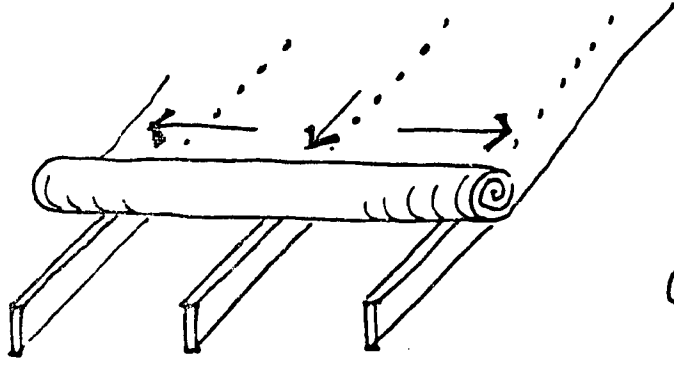
Following cyclones or in areas where high winds are common, the use of plastic sheeting, particularly as a roof membrane, requires particular attention to the structural integrity of the construction.

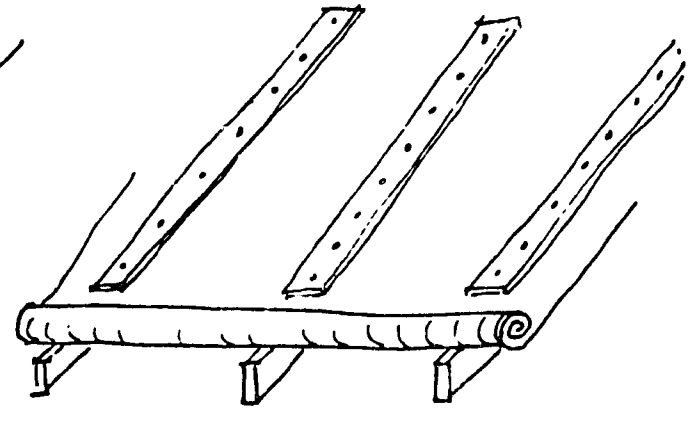
1. In high winds, the plastic acts like a sail and will lift the roof off the structure or the structure off its foundation if it is not securely attached. (Specific illustrations of connection methods may be found in Section 3.5.)



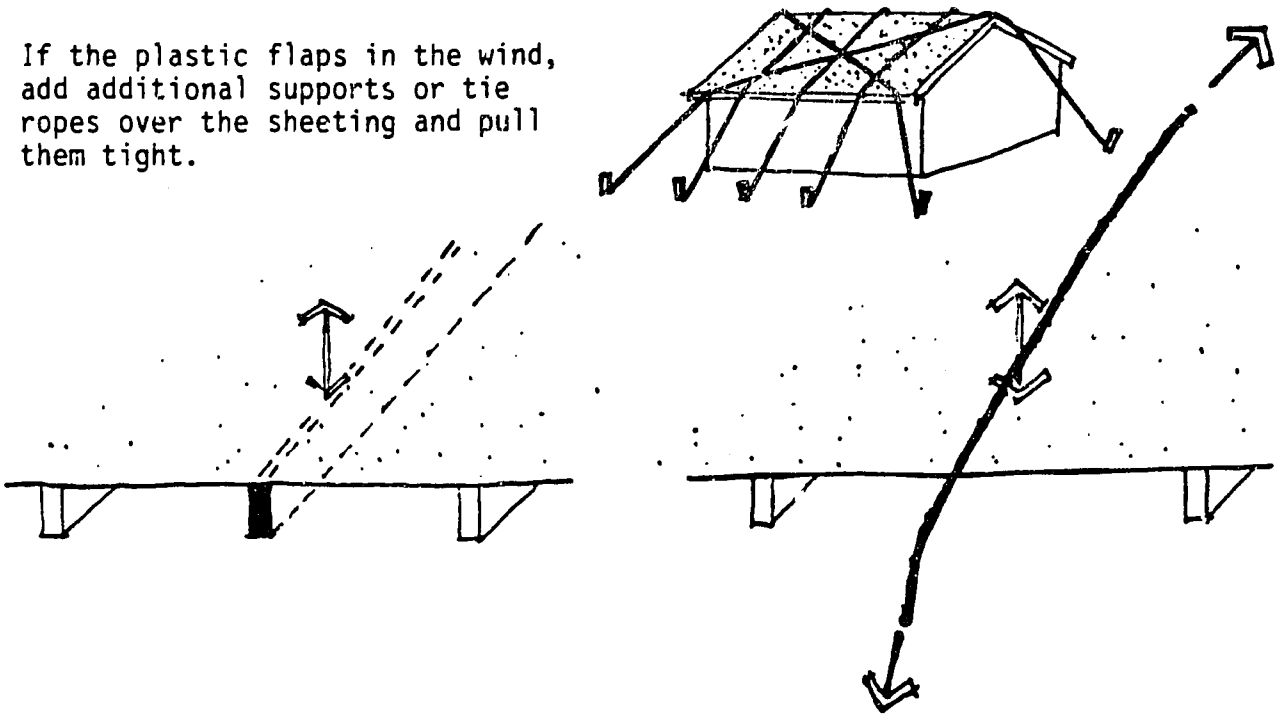


2. In high winds, the plastic must be securely attached to the roof structure and stretched tight.

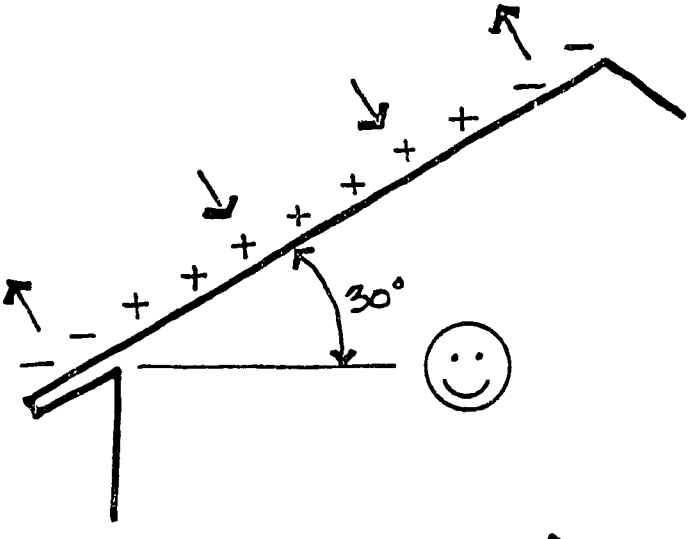




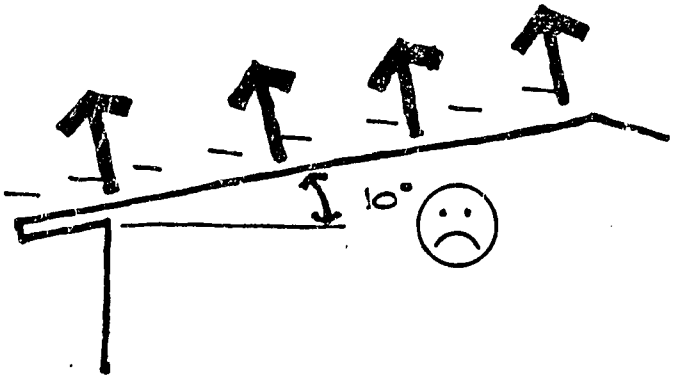
3. If the plastic flaps in the wind, add additional supports or tie ropes over the sheeting and pull them tight.



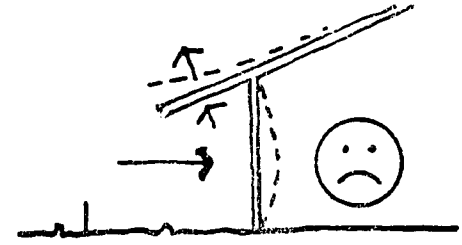
4. Roof pitch should be approximately 30° to reduce aerodynamic lifting pressures on the roof.

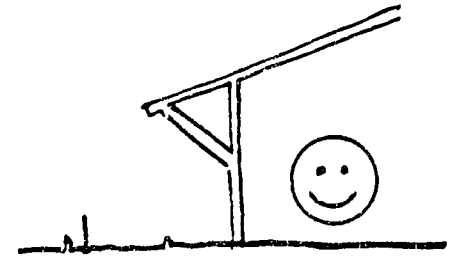


Roof pitches of 5° - 10° cause the greatest lifting effect.

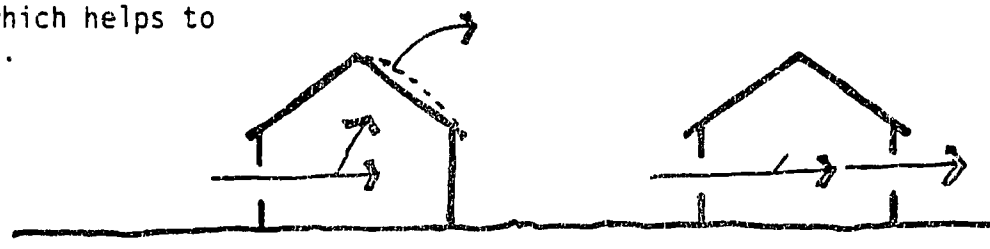


5. Avoid large unsupported overhangs. This is particularly important since the lifting effect of wind blowing over a structure is concentrated at the eaves of the roof, reinforcing the lifting forces from below caused by the overhang.

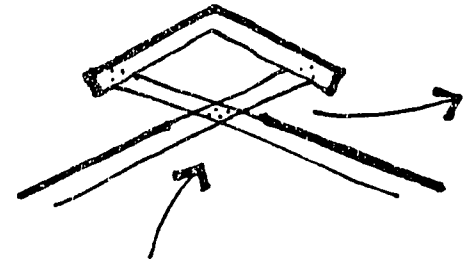




6. Openings on the windward side of a building which are not balanced by openings on the leeward side can cause pressure inside the structure which can help to blow the roof off. If the building cannot be sealed in high winds, openings should be provided on the leeward side. These will create suction which helps to hold on the roof.



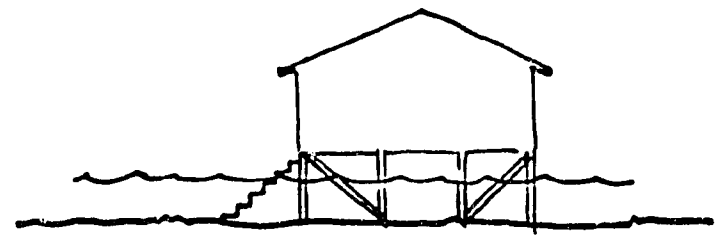
7. Where possible, plastic roofs should be vented to reduce pressure buildups.



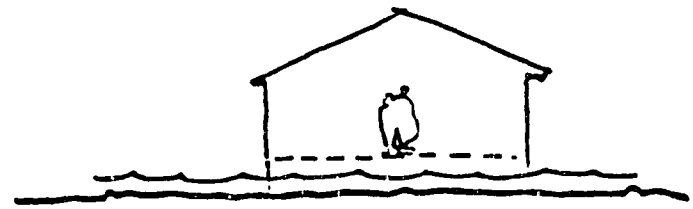
FLOODING

Obviously, the best protection from flooding is to avoid areas where flooding is possible. However, in areas subject to minor flooding, the following guidelines should be followed.

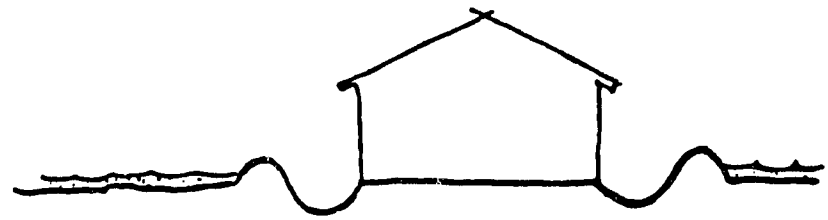
1. In areas where materials and soils permit, build on stilts.



2. Where minor flooding is likely, raise the floor of the structure.



3. Alternatively, construct a trench and dike around the structure. This is particularly useful in flat areas with heavy rainstorms which run off quickly.



DESIGN INFORMATION

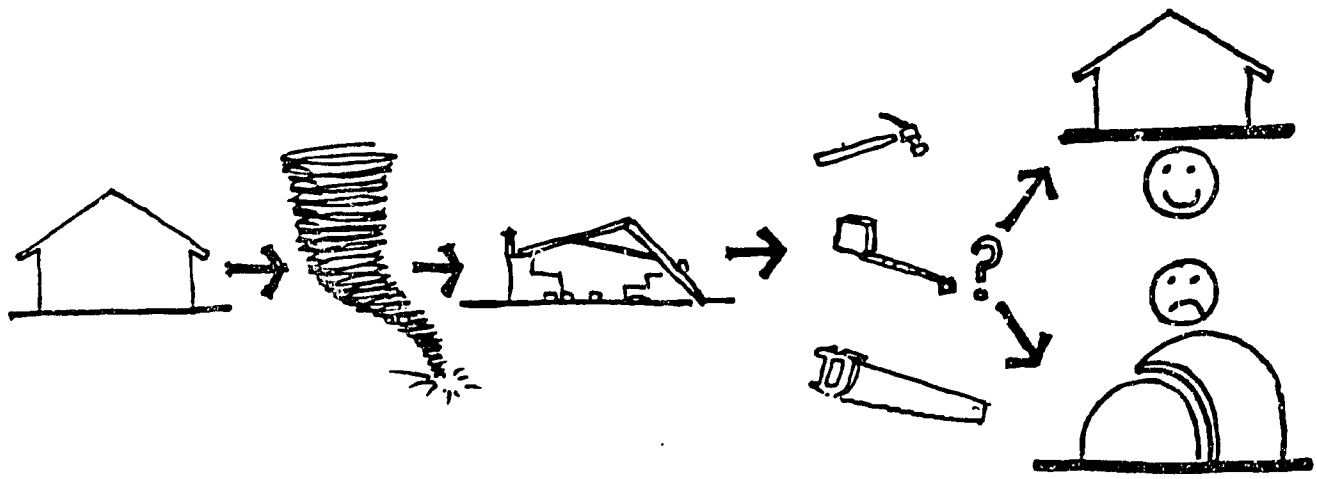
No. 3.24 - 1

CULTURAL CONSIDERATIONS AND GUIDELINES

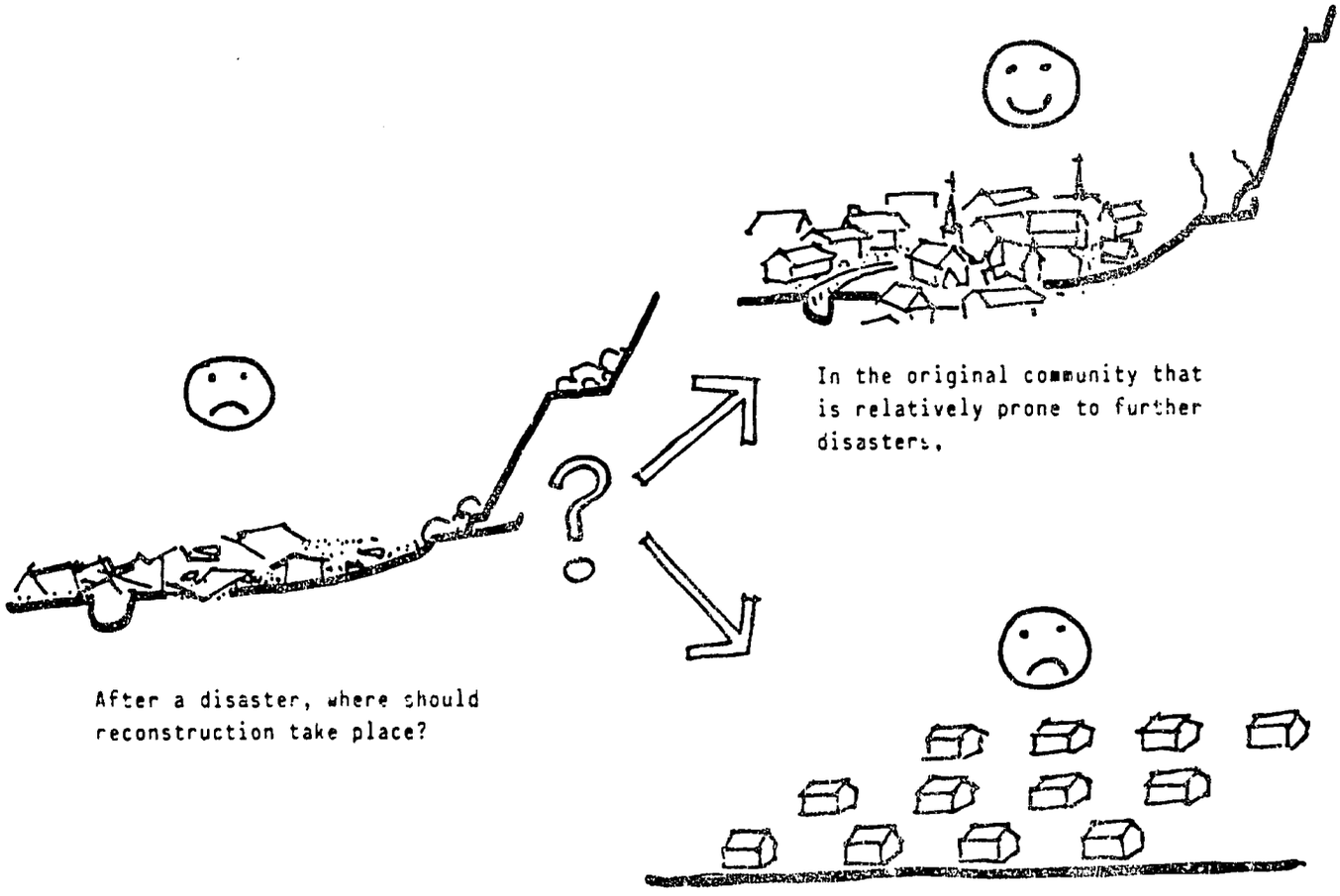
In the post-disaster period, physical needs for food, shelter, medical care, etc. are compelling. However, cultural and psychological needs should not be overlooked.

1. The most fundamental cultural consideration is that the community experiencing the disaster should be assisted in returning to as normal a state as is possible in the shortest possible amount of time. The plastic sheeting is ideally suited for the task of allowing the community to quickly restore essential functions.

2. The character and appearance of structures constructed using the plastic sheeting should resemble the traditional building forms of the area as closely as is possible. The use of this manual is intended to allow the community to build quickly with the plastic sheeting, using indigenous skills, materials, and forms.



3. Cultural preferences and dictates should be included in the consideration of a community's desire to rebuild in areas relatively prone to further disaster damage, even though a safer site may exist.



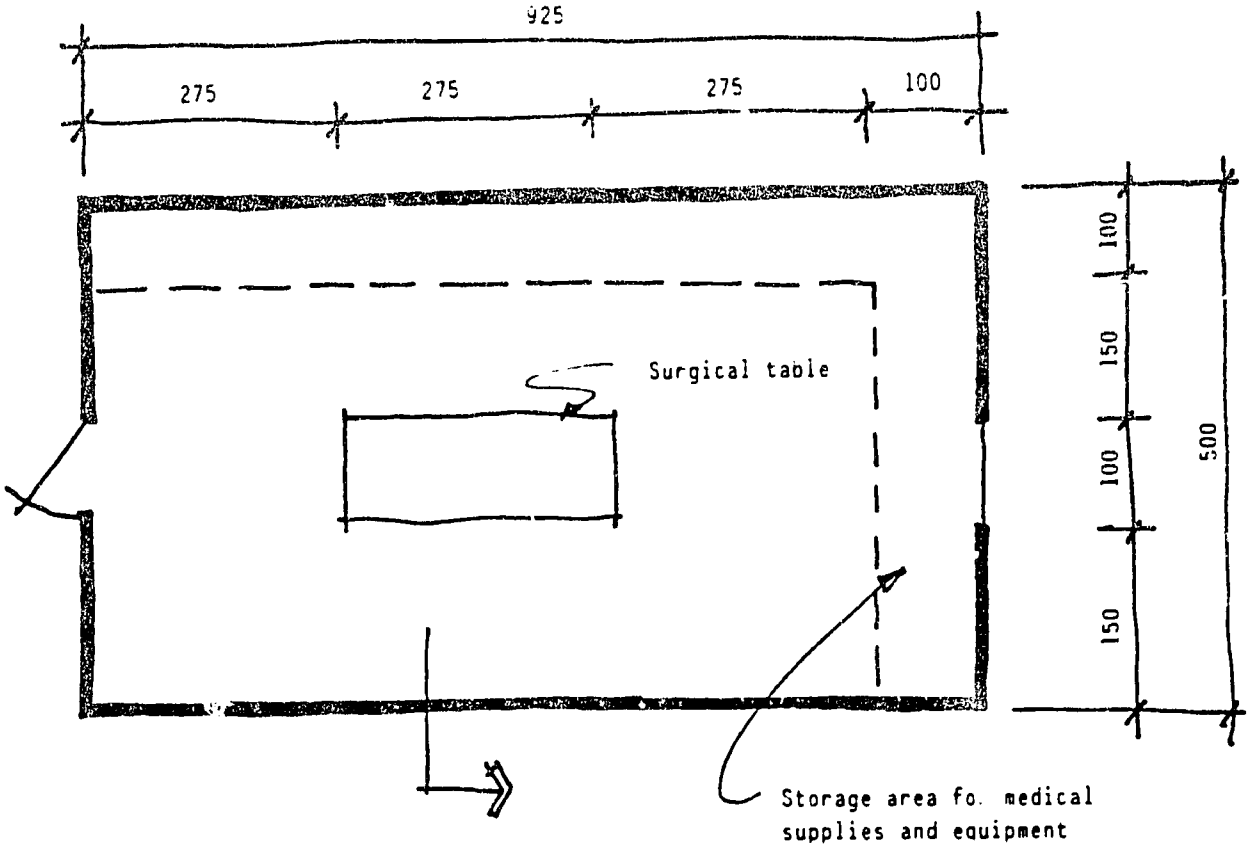
SPACE PLANNING AND LAYOUT - Introduction

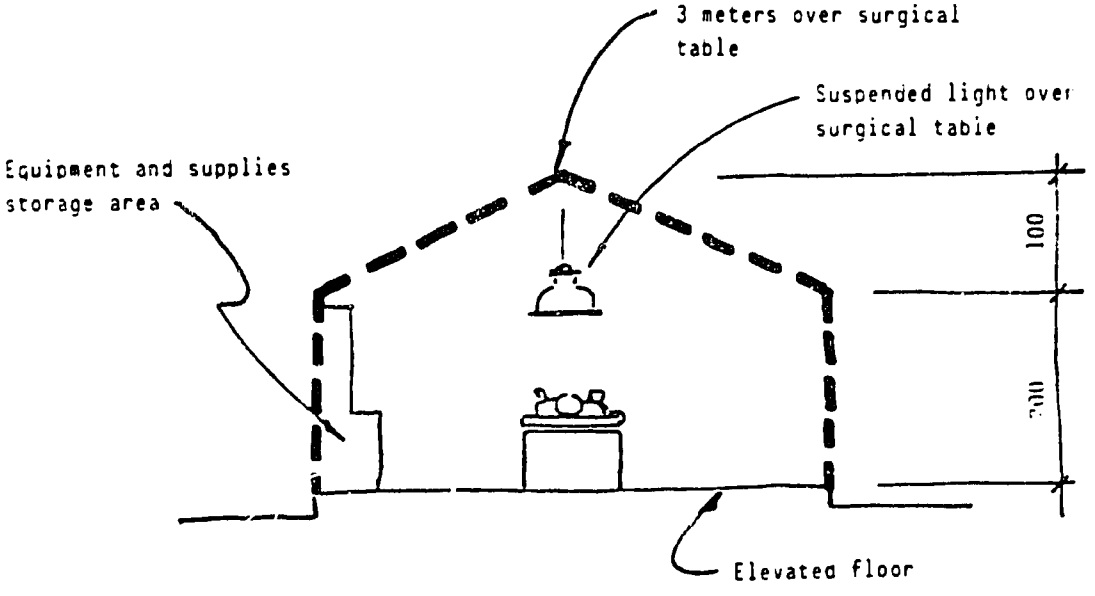
This section is intended to provide dimensional and layout information for accommodating selected community activities within the constraints of the framing systems presented in this manual. These suggestions are by no means the only way to enclose these functions; however, the 5 meter dimension is to a great extent fixed by the constraints of the plastic sheeting.

Structures to house the following functions are shown in this section:

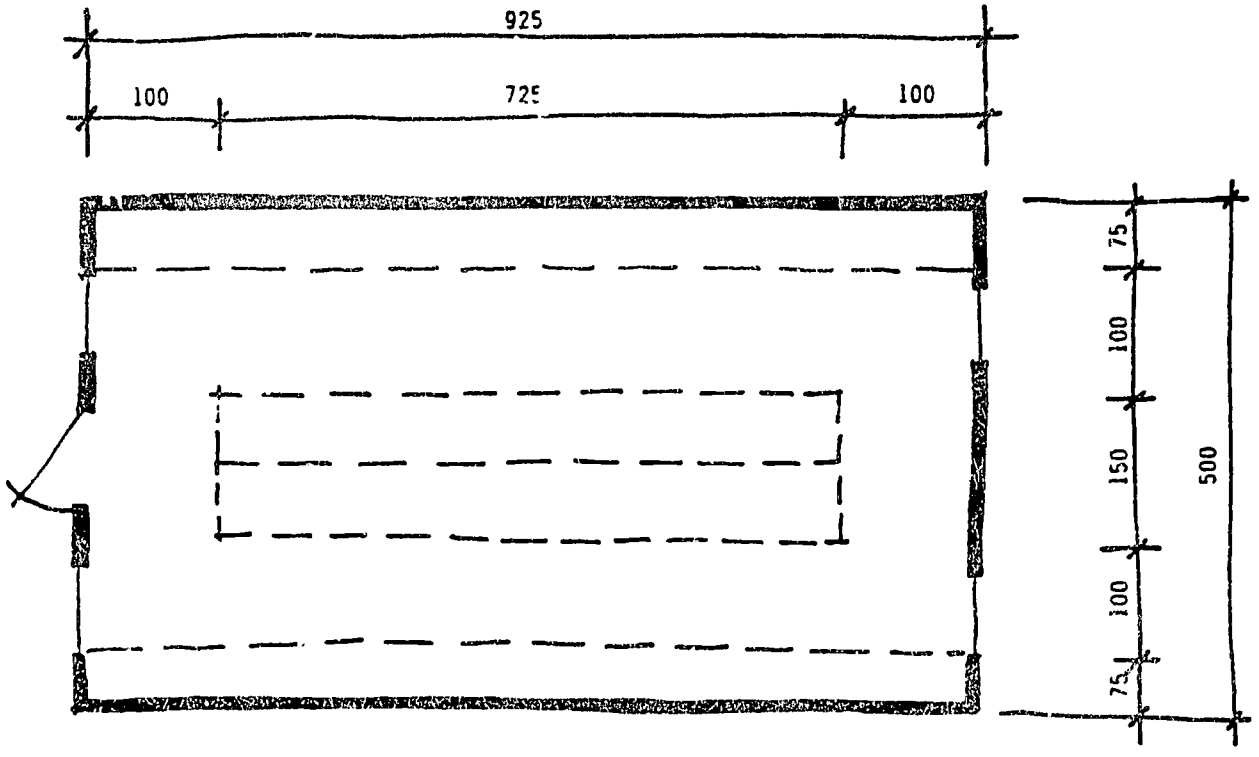
- Health Station - Surgical
- Medical Storage
- Health Station - Ward
- Health Station - Clinic
- Food Service Station
- Food Distribution Station
- Office/Administrative
- Communal Sanitation
- Multi-family Housing
- School
- Community Activity Facility

DESIGN INFORMATION	No. 3.25 - 1
SPACE PLANNING AND LAYOUT - Health Station - Surgical	

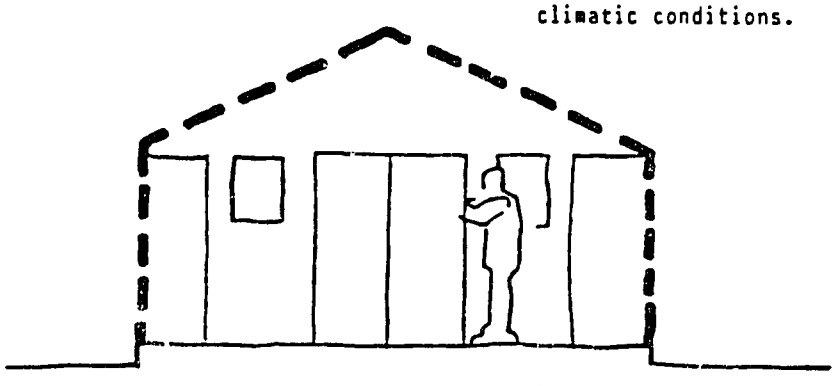




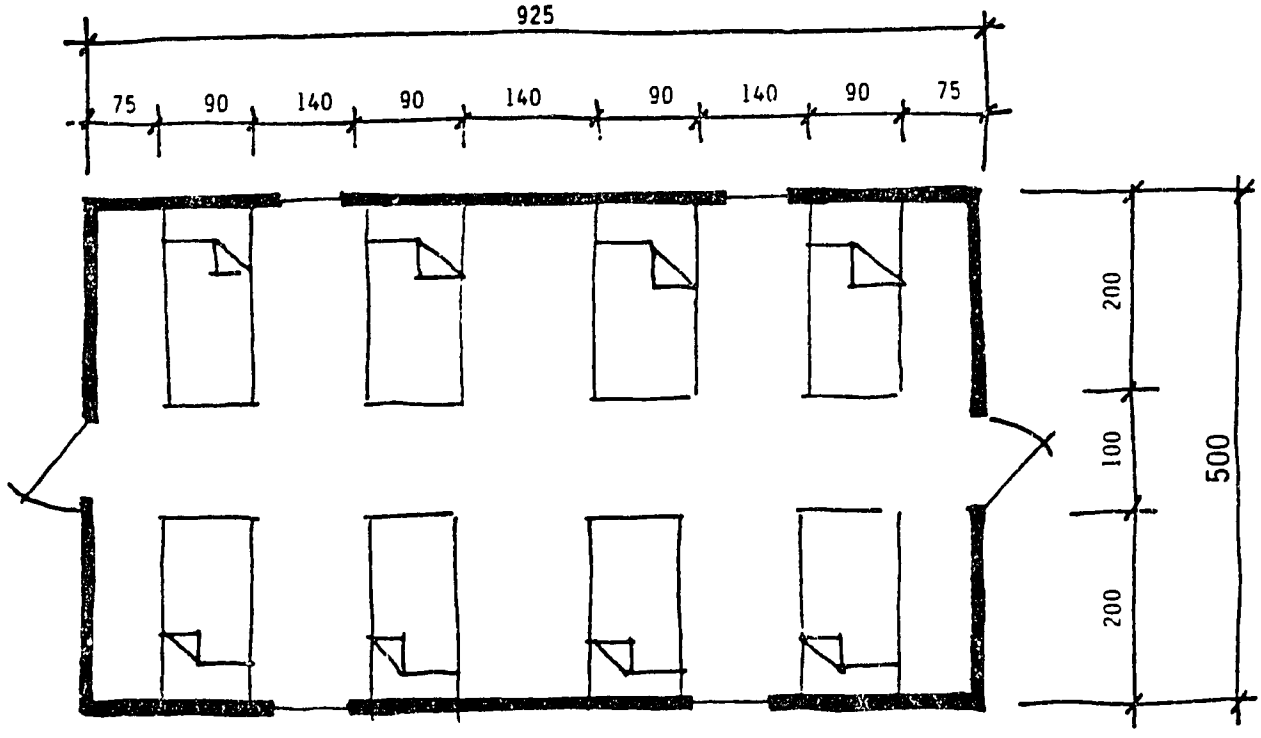
DESIGN INFORMATION	No.
SPACE PLANNING AND LAYOUT - Medical Storage	3.25 - 2

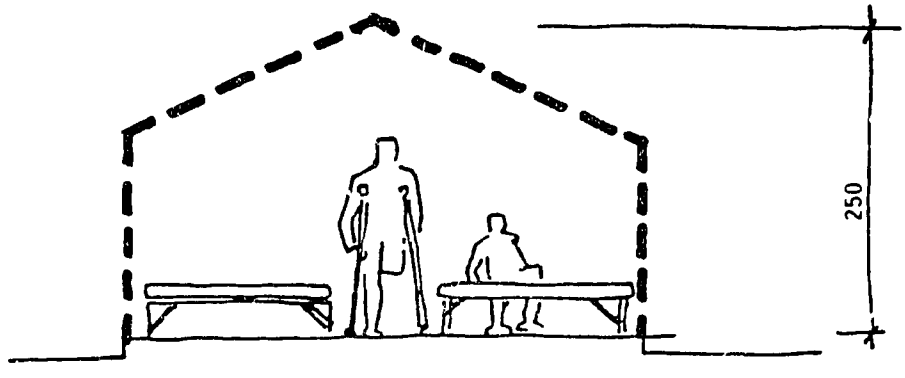


Roof slope is dependent on local climatic conditions.

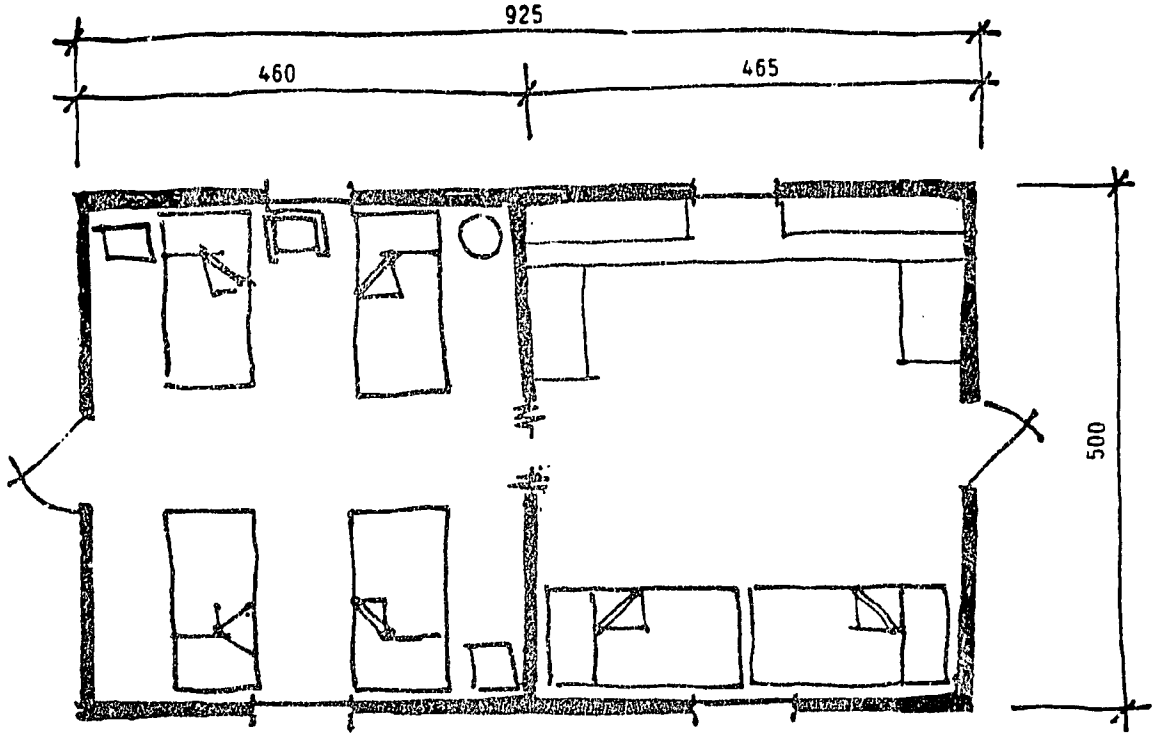


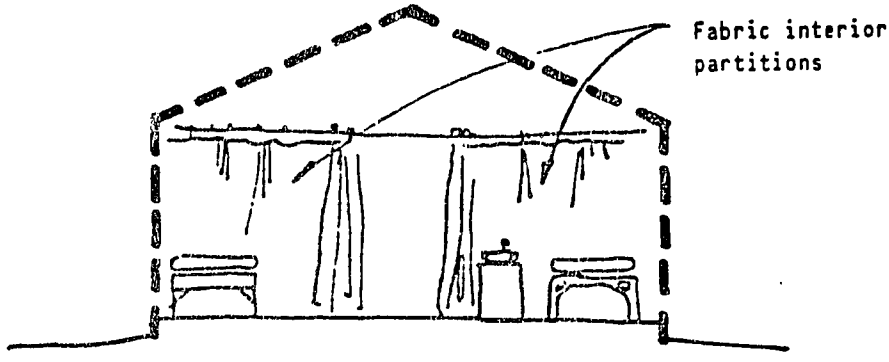
DESIGN INFORMATION	No. 3.25 - 3
SPACE PLANNING AND LAYOUT - Health Station - Ward	



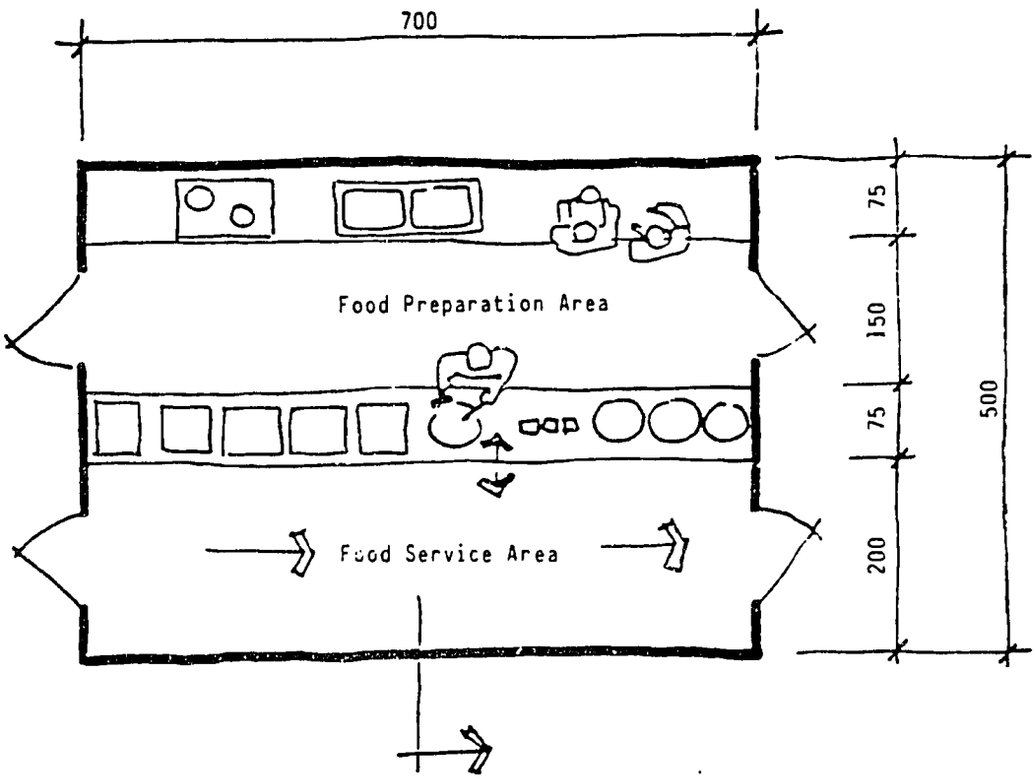


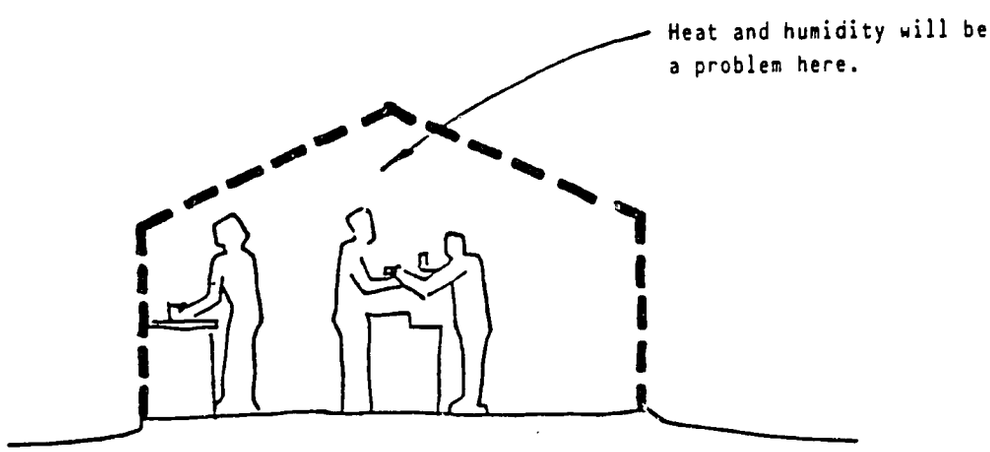
DESIGN INFORMATION	No. 3.25 - 4
SPACE PLANNING AND LAYOUT - Health Station - Clinic	



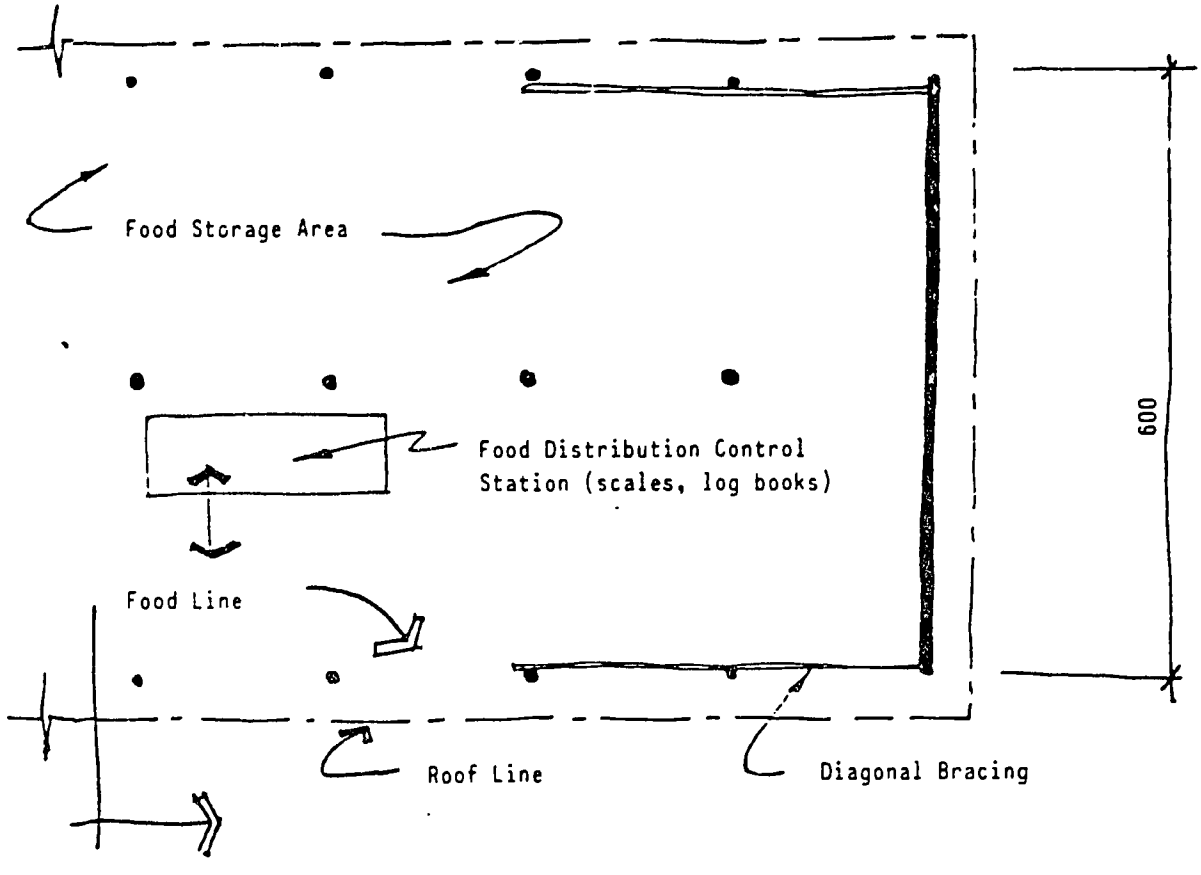


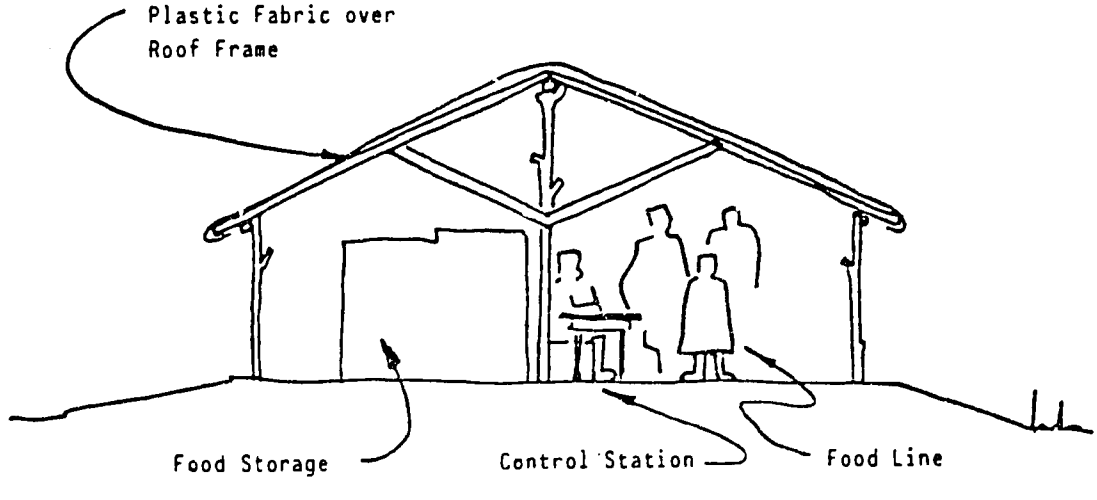
DESIGN INFORMATION	No. 3.25 - 5
SPACE PLANNING AND LAYOUT - Food Service Station	



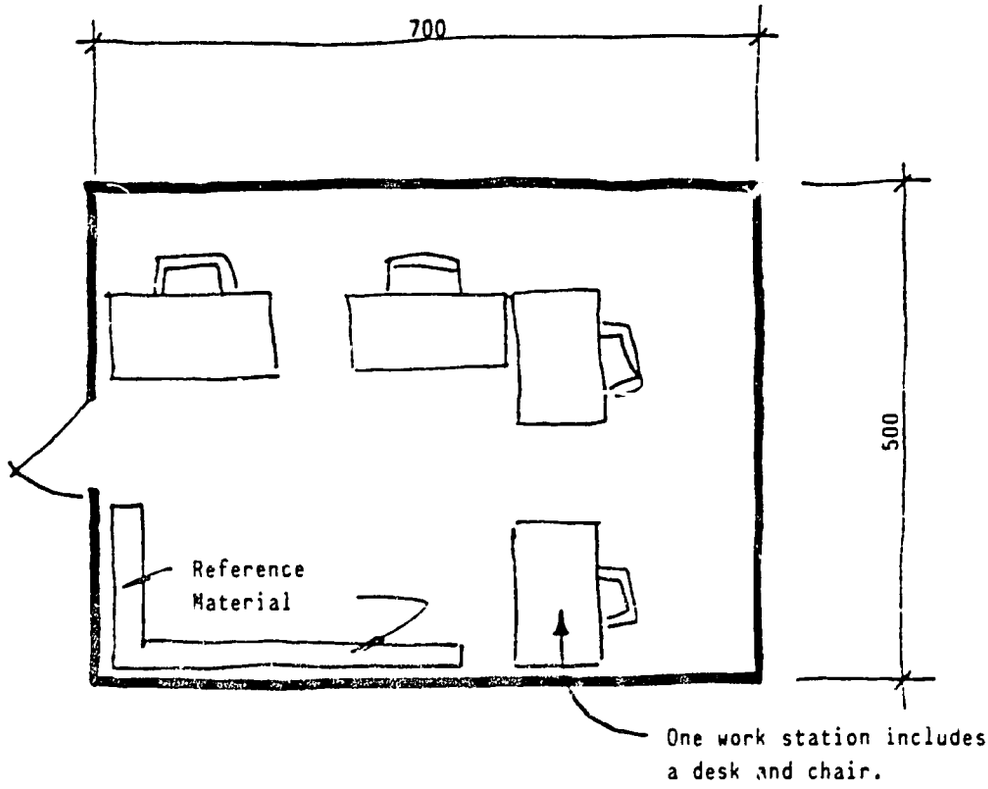


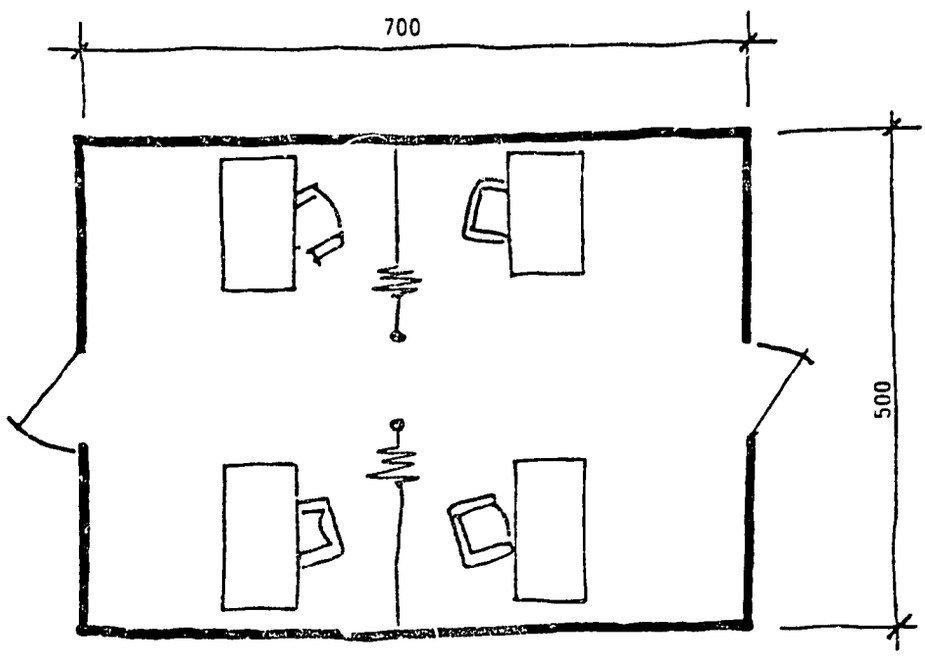
DESIGN INFORMATION	No. 3.25 - 6
SPACE PLANNING AND LAYOUT - Food Distribution Station	



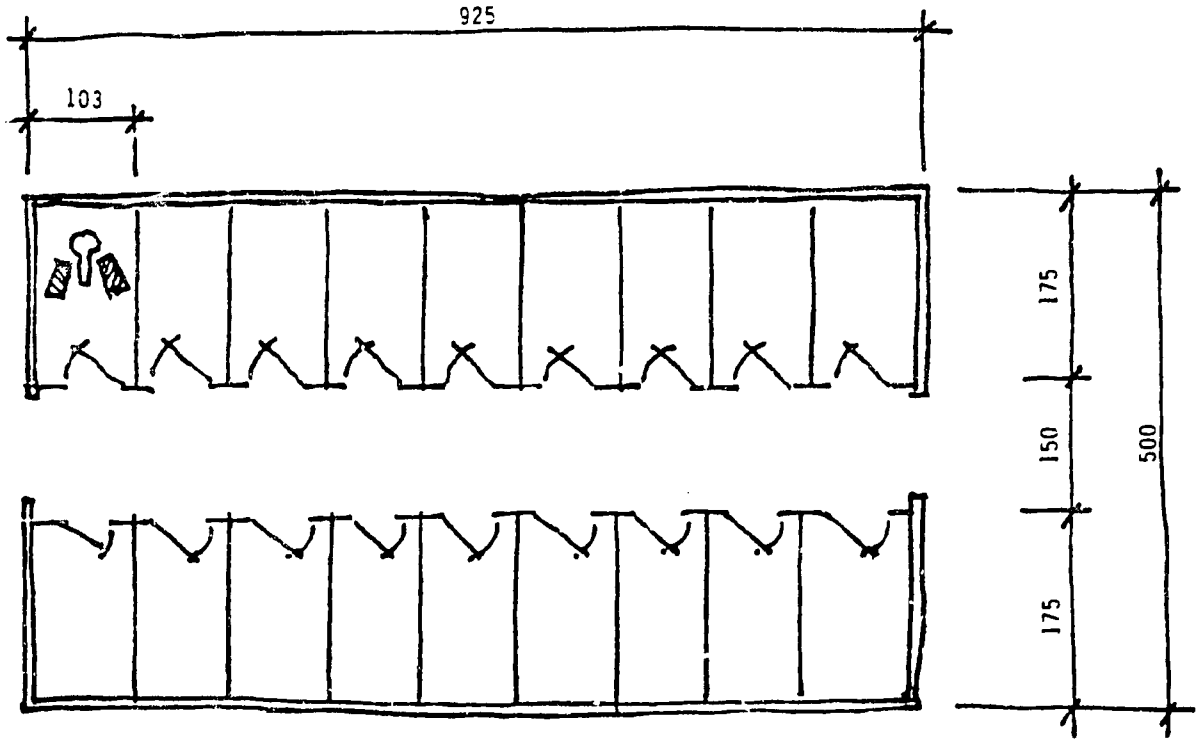


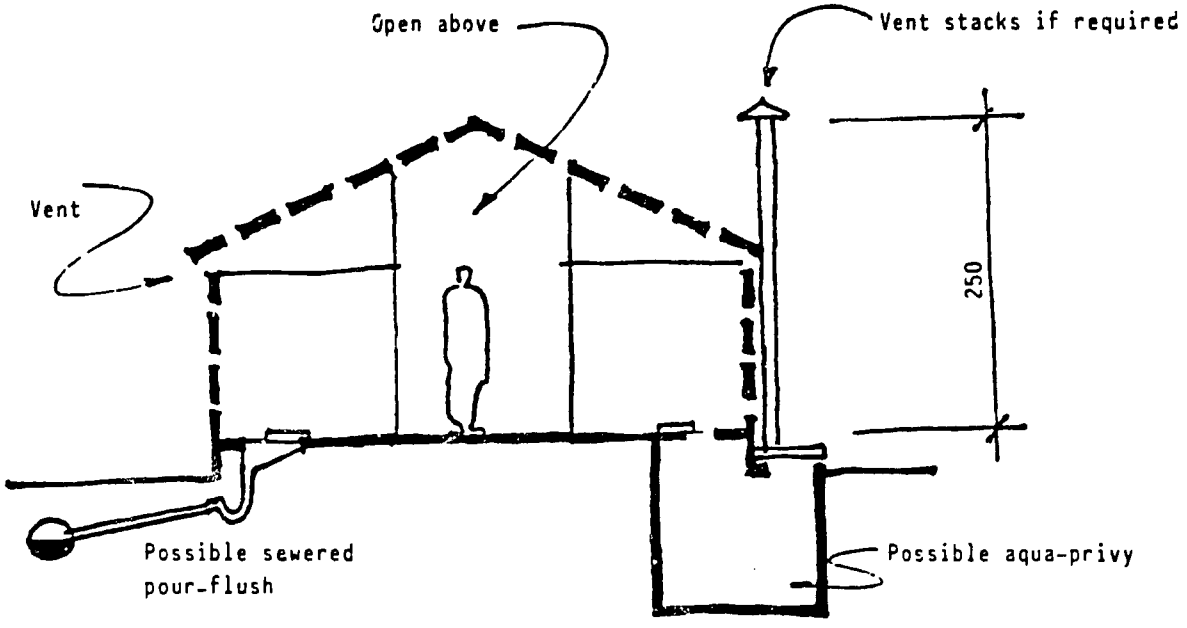
DESIGN INFORMATION	No.
SPACE PLANNING AND LAYOUT - Office / Administrative	3.25 - 7



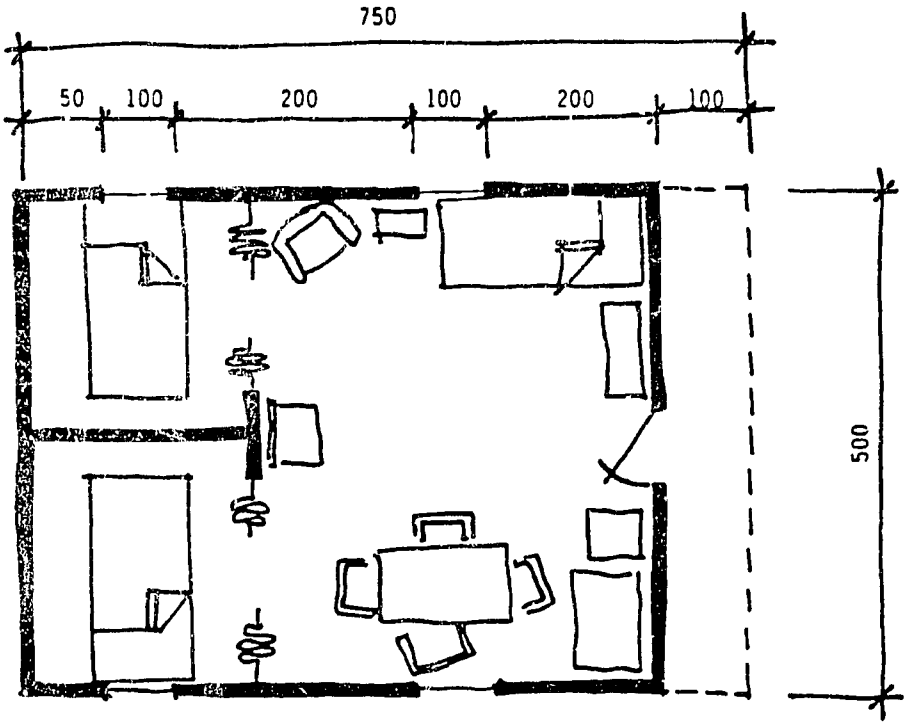


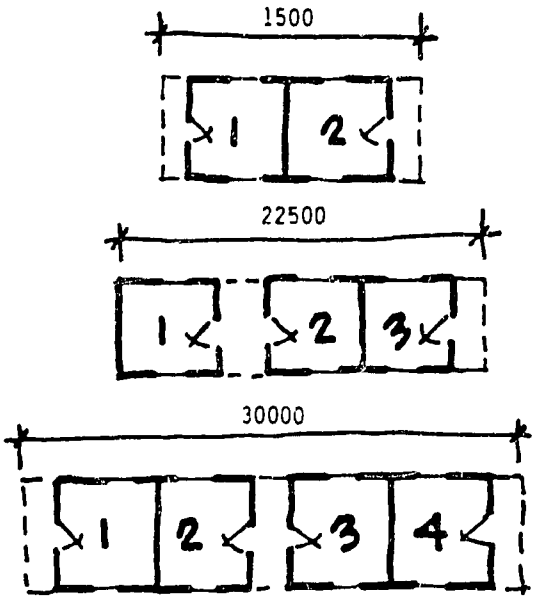
DESIGN INFORMATION	No.
SPACE PLANNING AND LAYOUT - Communal Sanitation	3.25 - 8



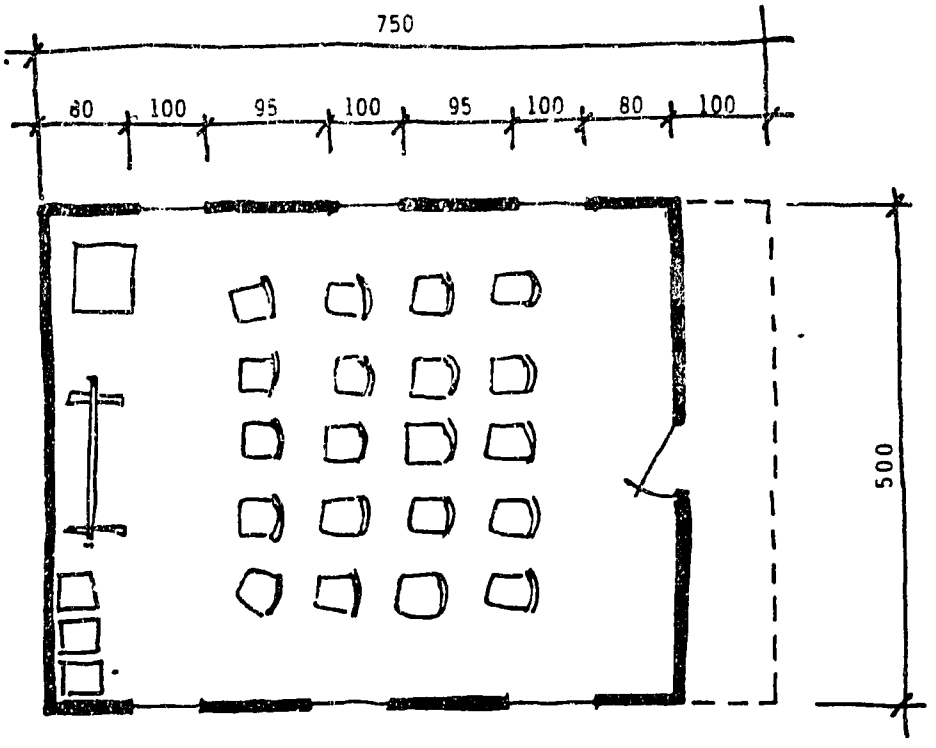


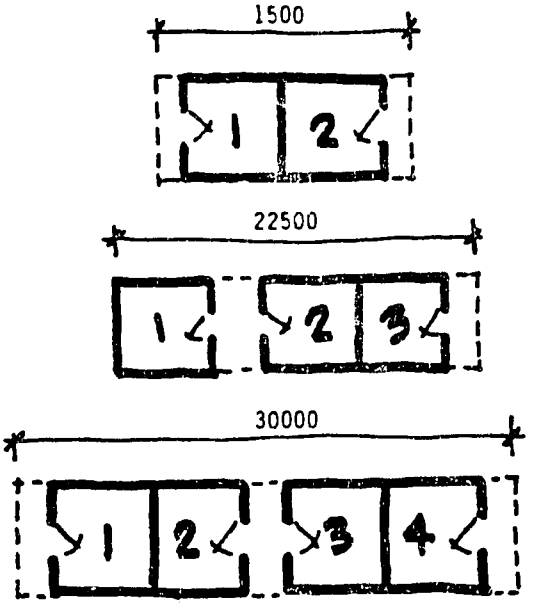
SPACE PLANNING AND LAYOUT - Multi-family Housing



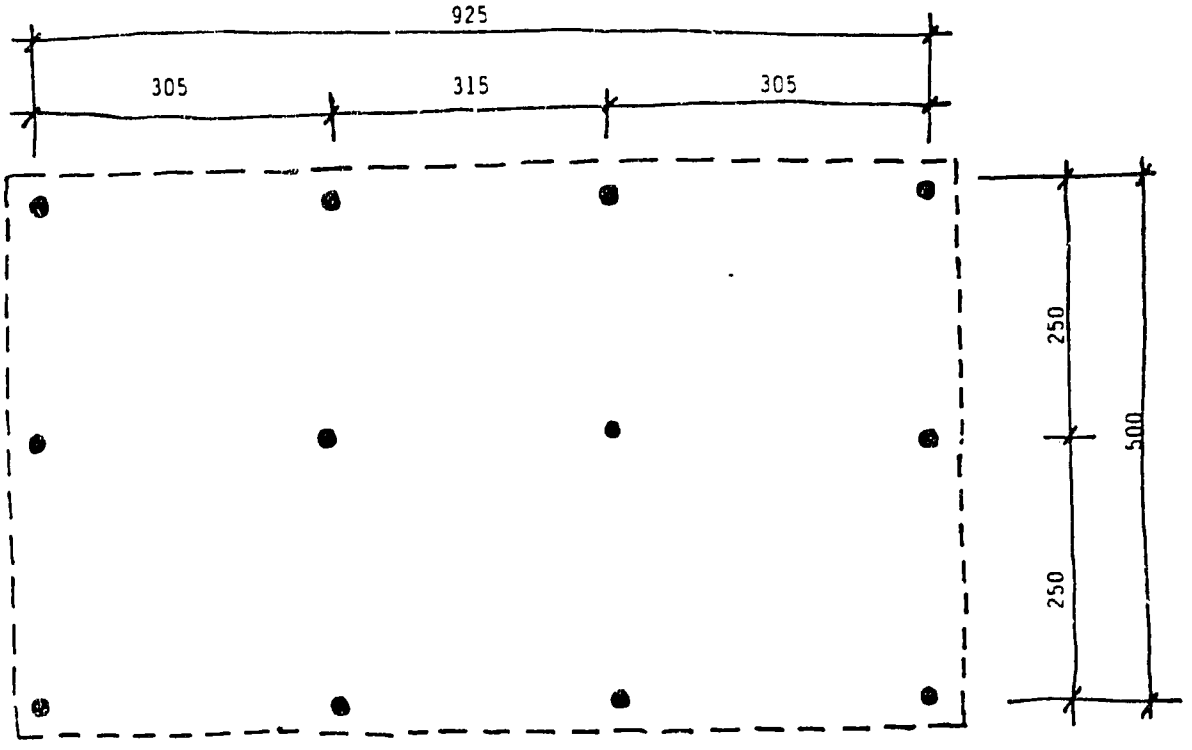


DESIGN INFORMATION	No.
SPACE PLANNING AND LAYOUT - School	3.25 - 10

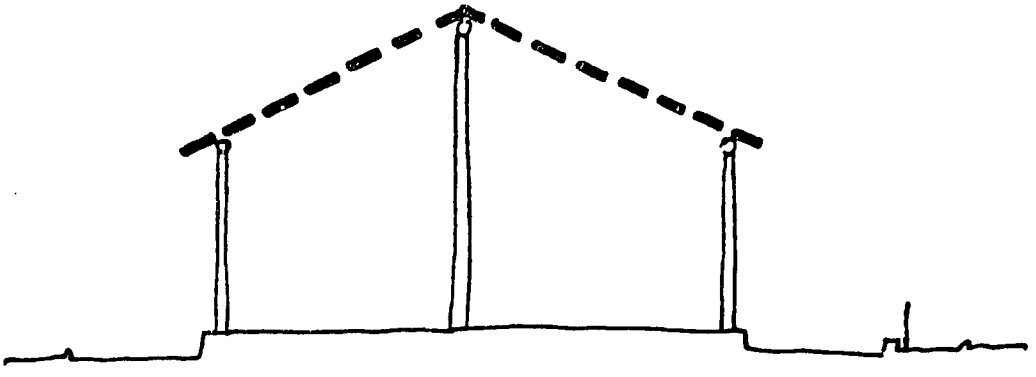




DESIGN INFORMATION	No.
SPACE PLANNING AND LAYOUT - Community Activity Facility	3.25 - 11



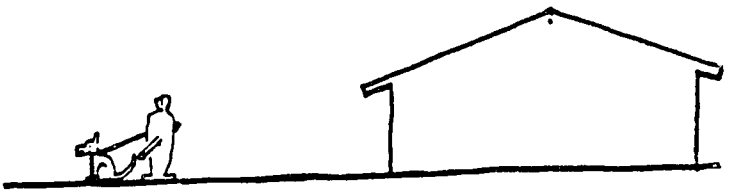
This is a simple open facility set in the village for the purpose of allowing the villagers or people from a neighborhood to meet and organize their activities. It also serves as a field office for medical and health care activities until structures for those functions are in place.



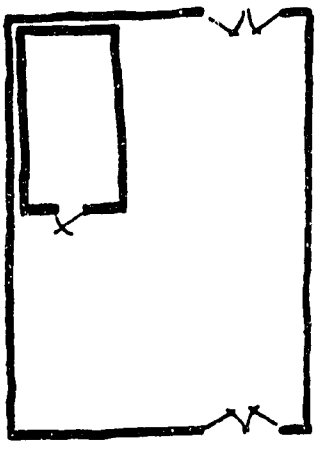
DESIGN INFORMATION	No.
SECURITY CONSIDERATIONS	3.26 - 1

The plastic sheeting is not capable of securing a structure against vandals or burglers. The plastic, if used in the walls, can be easily sliced with a knife or piece of broken glass. The following suggestions should be considered if valuable or dangerous materials must be stored.

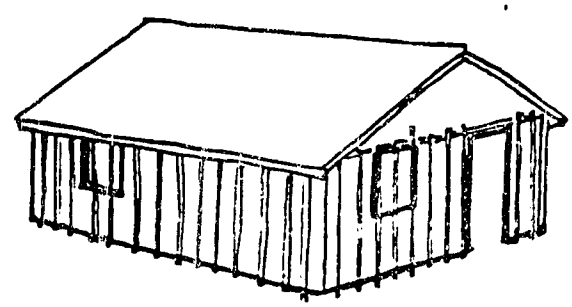
1. Hire a guard. In many instances, this may be the least expensive and most secure way of protecting the structure.



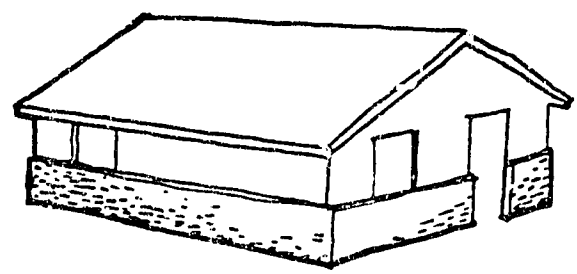
2. Secure an area within the structure to store the materials which need protection. A storage cage can be made with masonry, wire mesh, lumber, etc.



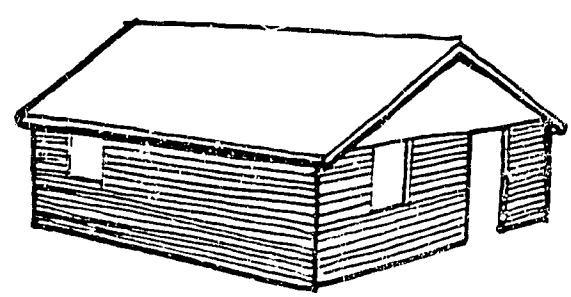
3. Place bamboo or wattle bars at 15 cm intervals and lash or nail them to the structure. Before undertaking such an expensive task, be sure the doors and windows do not provide an easy access.



4. To deter a potential intruder, a low wall can be built around the structure. This method obviously will not deter the determined thief.



5. Construct the walls from a material which is not easily penetrated. This solution is the most expensive but may be sensible if the materials are readily available or if it is indicated for thermal, privacy or other reasons.

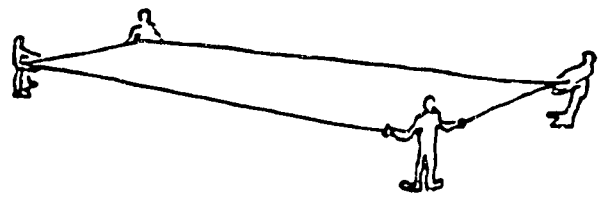


DESIGN INFORMATION	No.
PROPERTIES OF PLASTIC SHEETING	3.27 - 1

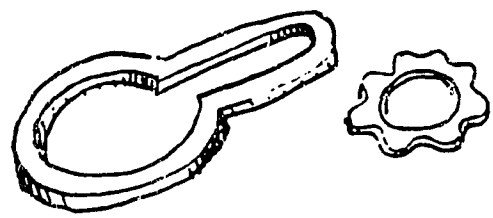
This section is intended to inform the potential user of USAID-supplied plastic sheeting about important characteristics of the material which relate to its use as membrane roofing or siding. Specific illustrations of methods for connecting the plastic sheeting to various structures is contained in Section 3.6 - Plastic Sheeting Connections.

1. The plastic sheeting package provided by USAID Office of Foreign Disaster Assistance contains:

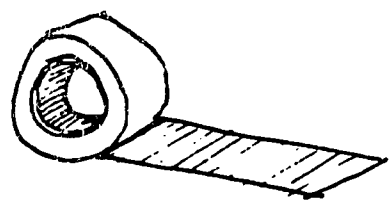
   (1) A 7.9 m x 30.5 m (26 ft. x 100 ft.) piece of woven plastic fabric



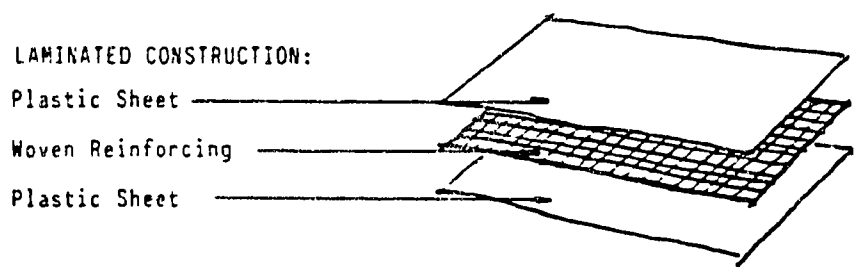
   (2) Specially designed connectors



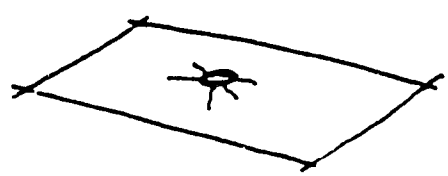
   (3) One 55 m (180 ft.) roll of plastic joining tape



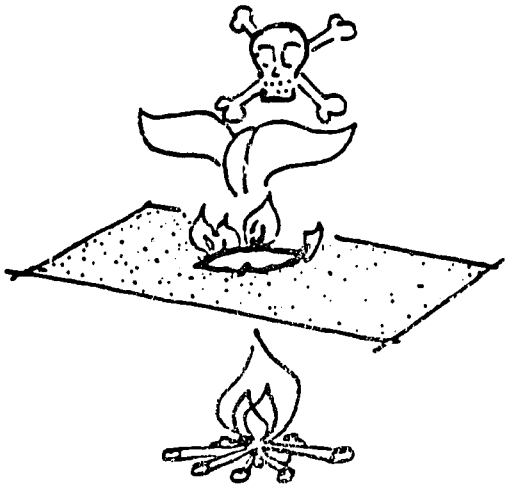
2. The plastic sheeting is strong and resists ripping because of plastic reinforcing embedded in it.



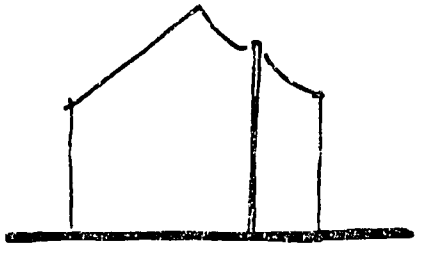
The reinforcing of the plastic sheeting prevents minor punctures or holes in the fabric from becoming major rips.



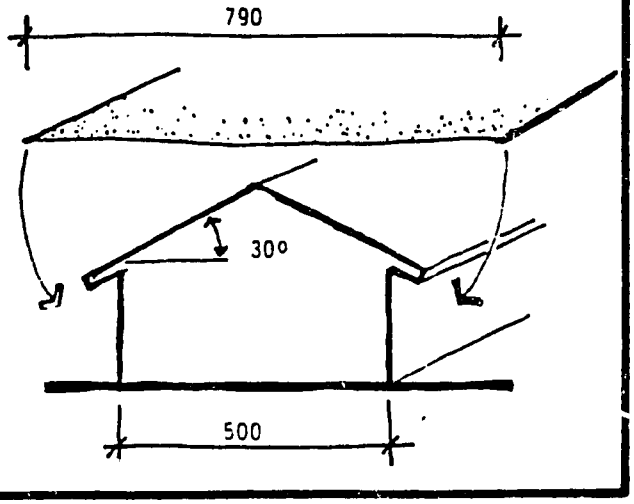
3. The plastic sheeting will burn and produces dangerous fumes. Extreme caution should be taken to keep cooking or lighting flames away from the plastic.



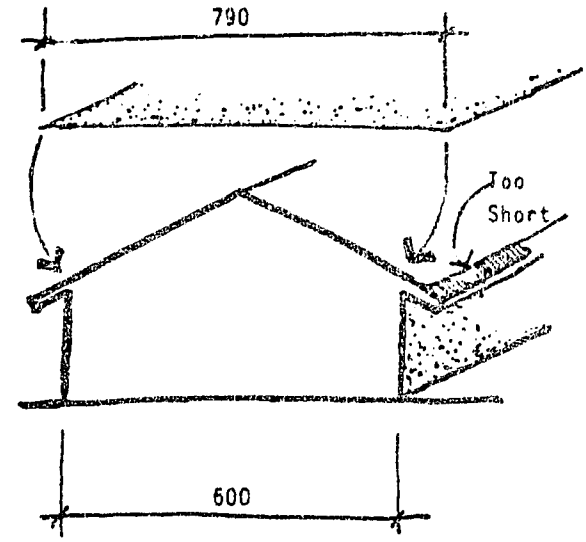
4. The plastic sheeting can be punctured quite easily. Avoid contact with sharp objects, particularly when the wind causes the plastic to flap. (For methods of repairing damaged sheeting, see Section 3.10 - Use, Maintenance, and Repair.)



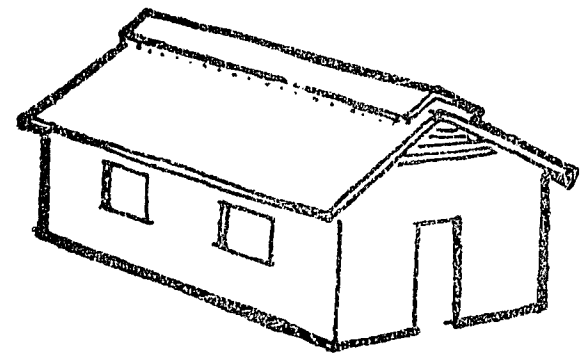
5. The 7.9 m width of the plastic allows it to cover a 5 m wide building with a 30° roof pitch, which is optimal to reduce the lifting effects of wind. This allows for a 0.5 m overhang and sufficient material to securely attach the plastic at the eave.



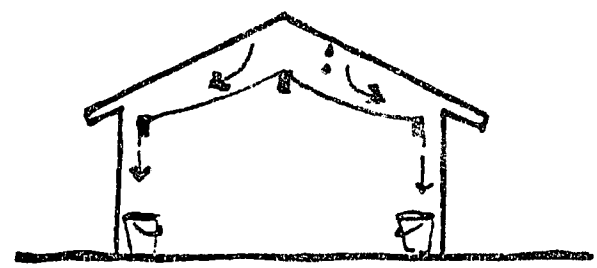
6. It is important to carefully consider the width of the plastic when choosing a size for a structure. If spans greater than 5 m are used, the plastic will not be able to cover in one piece and joints will be necessary. (For methods of joining sheeting, see Section 3.6 - Plastic Sheeting Connections.) Avoid wasting plastic by cutting odd sizes.



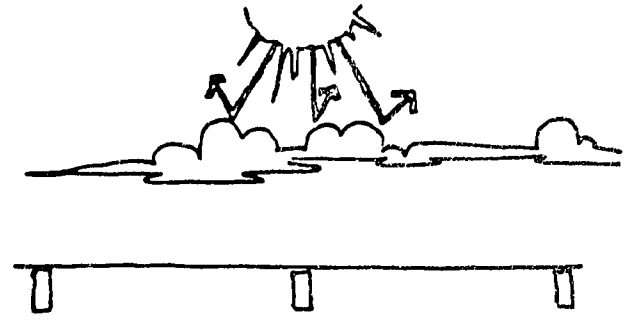
7. Plastic sheeting does not breathe and traps humidity which quickly condenses on the surface at night or on cold days. Ventilate the structure with vents and windows. (See Section 3.8 - Doors, Windows, and Openings.)

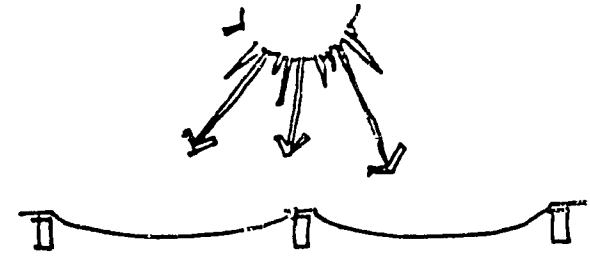


8. In hospitals or other critical areas where dripping water would be a problem, it may be necessary to provide a ceiling to catch the condensation. The ceiling must slope so that the condensation does not pond.



9. Plastic expands significantly when hot. Where the plastic sheeting should be stretched tight, be sure it is exposed to the sun before securing.



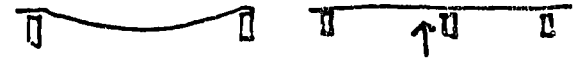


10. Rainwater which is allowed to pond on a plastic roof will quickly damage the plastic. Ponding can be controlled by:

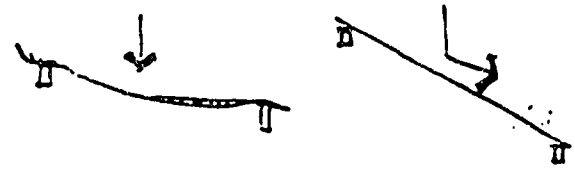
Problem Solution

(a) Stretching the plastic tightly

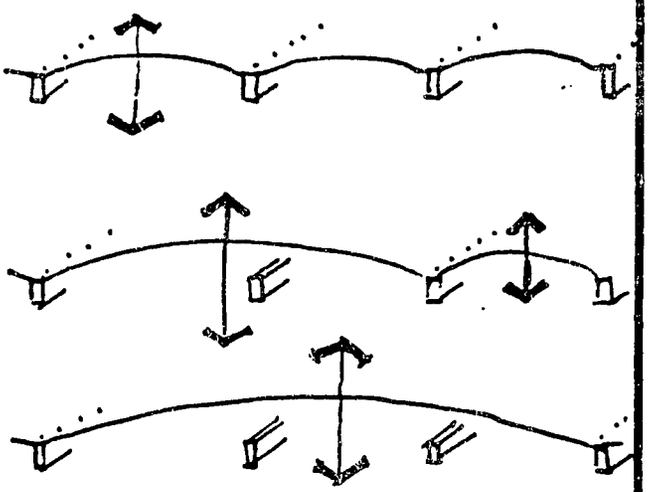
(b) Closely spacing supports



(c) Increasing the roof pitch



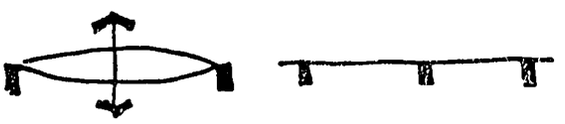
11. Loosely secured plastic will flap dangerously in high winds. Continuous flapping can lead to failure of attachment and ultimately the roof.



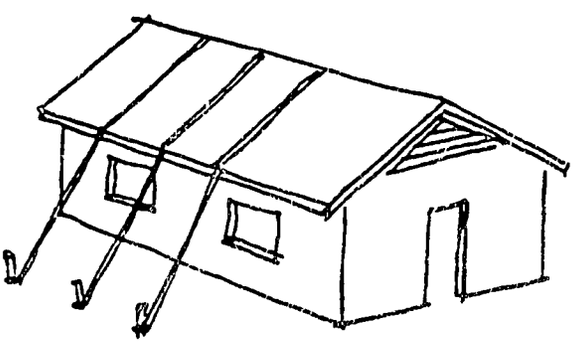
To avoid flapping:

(a) Stretch the plastic tightly.

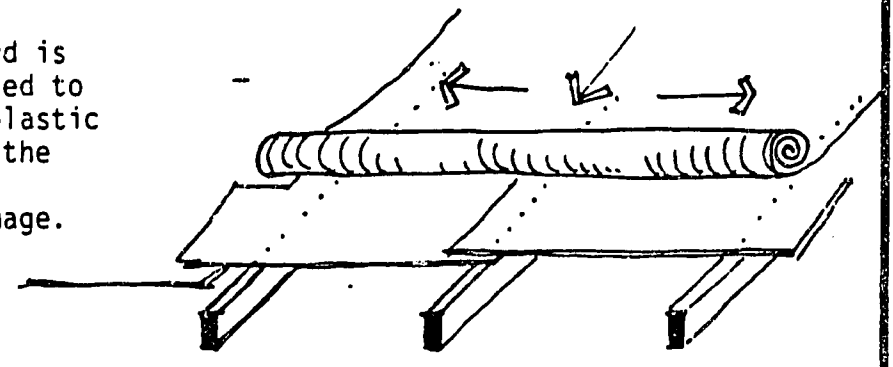
(b) Closely space supports.



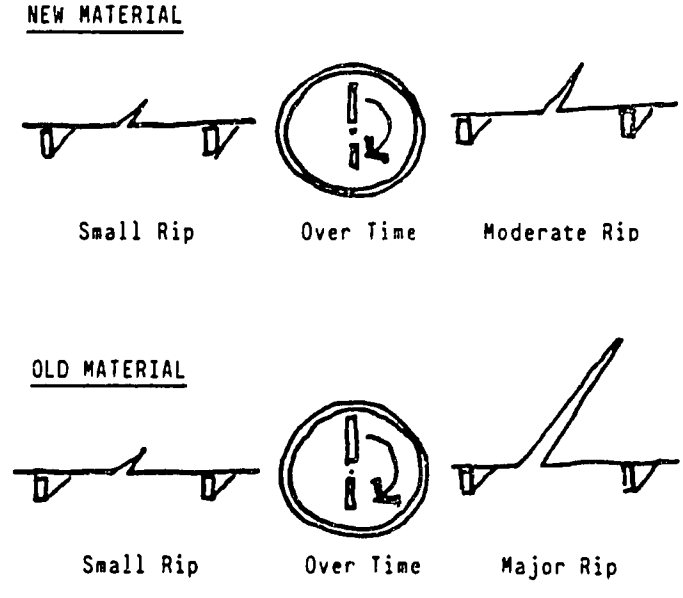
12. If flapping continues to occur or appears to be dangerously affecting the structure, tie ropes tightly over the structure and securely anchor them into the ground.



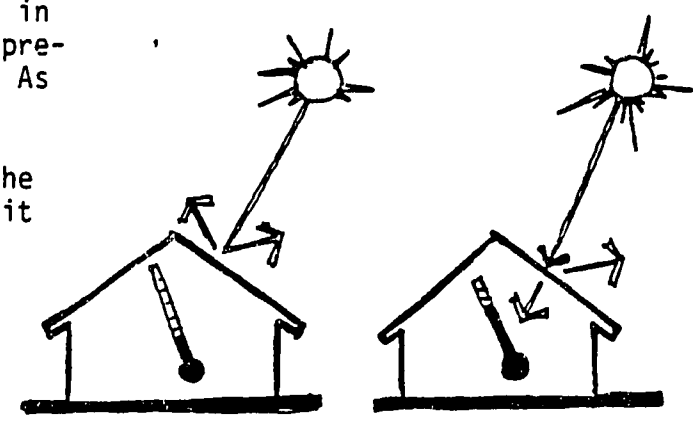
13. Where corrugated cardboard is available, it may be nailed to the structure under the plastic to significantly improve the resistance of the plastic sheeting to high wind damage.



14. Plastic sheeting is degraded by sunlight and will become more brittle with age. The plastic sheeting should not last more than one year. As it gets older, greater care must be taken to protect it and quickly mend rips or other damage. (See Section 3.10 - Use, Maintenance, and Repair.)



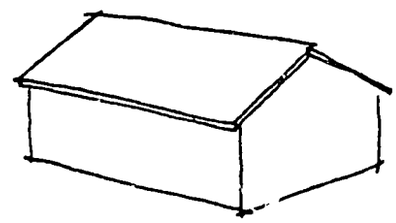
15. The plastic sheeting is light in color to reflect the sun and prevent excessive heat buildup. As it gets dirty, its ability to reflect sunlight is lessened. If water is plentiful, wash the surface periodically to keep it as light as possible.



16. For buildings with the following shapes, general guidelines for attaching the plastic sheeting have been developed and are discussed on the following pages. (For more specific illustrations of methods for attaching the plastic to the structure, see Section 3.6 - Plastic Sheeting Connections.)

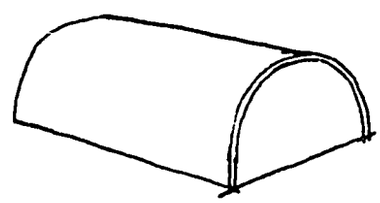
(a) Rectangular with pitched roof

(See also Sections 3.31 and 3.34.)

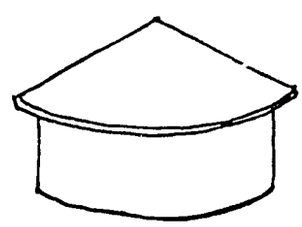


(b) Cylindrical

(See also Section 3.32.)



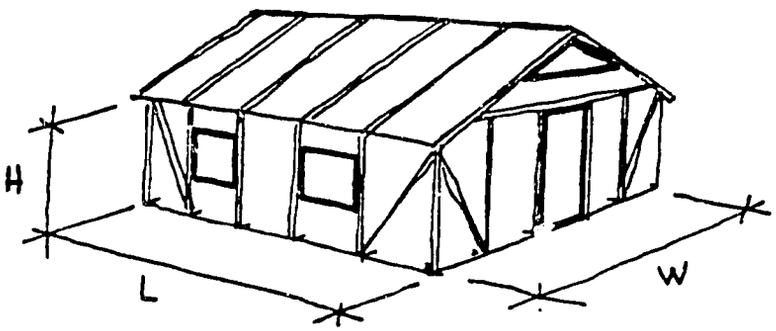
(c) Conical



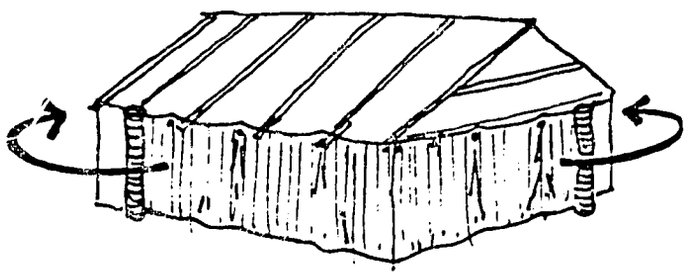
(d) Dome-shaped

ATTACHMENT TO RECTANGULAR-WITH-PITCHED ROOF FRAME

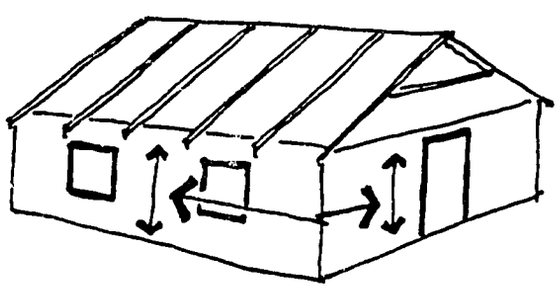
1. Cut the plastic to the proper length and height so that it can be wrapped around the frame. If possible, use a single piece to cover the walls, up to the roof line.



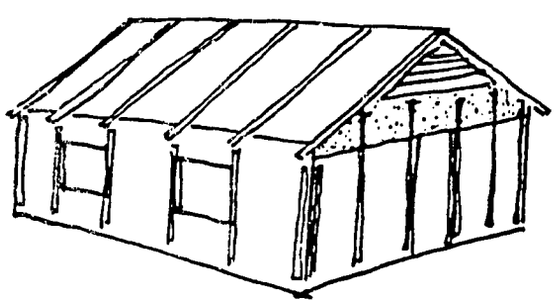
2. For best results, let the sheet lie in the sun unrolled so that it can expand. Then roll up the plastic from both ends and, starting at one corner, temporarily tack the plastic in place.



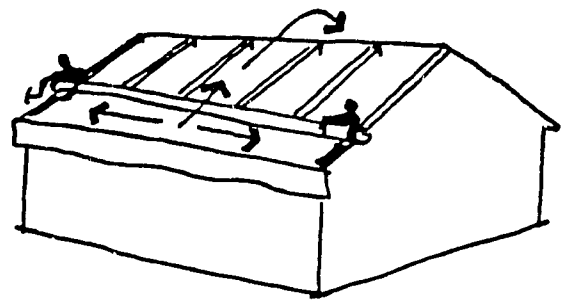
3. After the plastic is in place, return to the starting corner and stretch the sheeting tight before nailing it permanently. Cut and secure door and window openings.



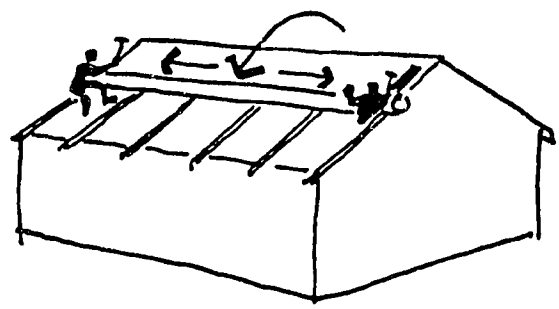
4. Cut and attach plastic sheeting to both gable ends. After the walls and gable ends are in place, battens can be applied if required.



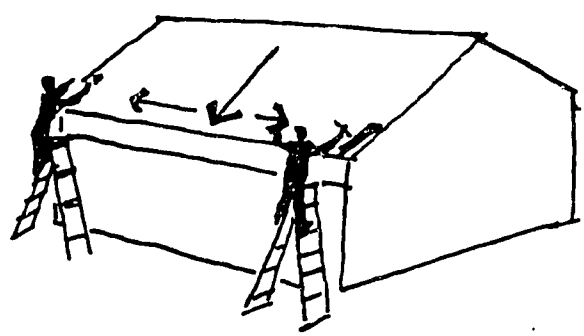
5. Cut the plastic to the proper length and width to cover the roof. If possible, use a single piece to cover the entire roof. (See Section 3.64 - 3 for details.) Roll the plastic sheeting as shown and work from the inside of the roof, leaning over the rolled plastic.



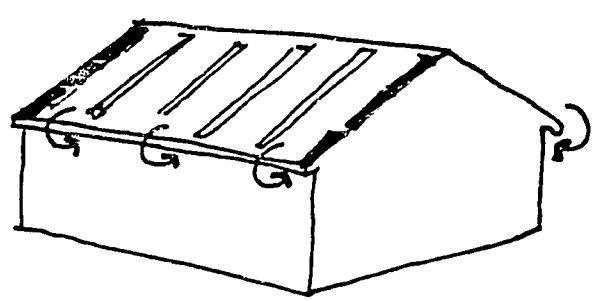
6. Continue up to the roof ridge and move down the other side of the roof.



7. Secure the last batten by working from a ladder.

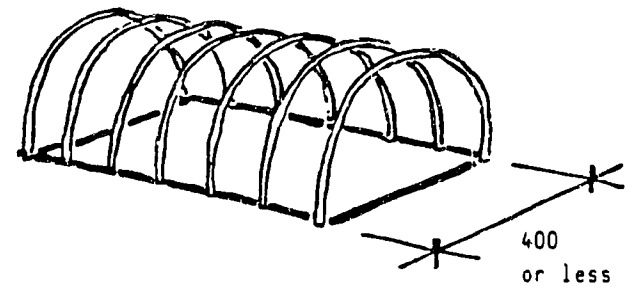


8. Attach the plastic sheeting under the eaves.

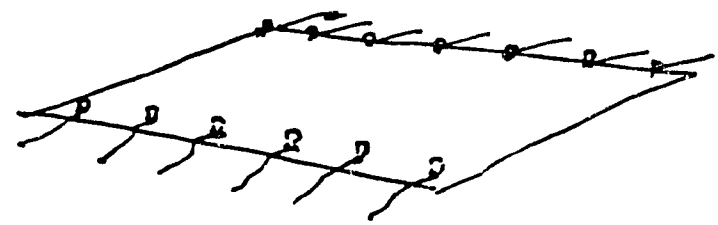


ATTACHMENT TO CYLINDRICAL FRAME (Span less than 4 meters)

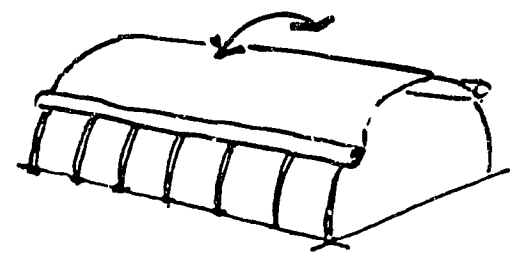
1. For a simple vaulted span of four meters or less, one piece of plastic sheeting will cover the structure.



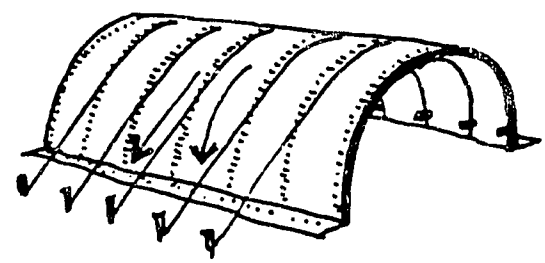
2. Attach ropes to either side of the plastic sheeting, about 30 cm from the edge of the material. These will be used to tie the sheeting to the frame. Roll the sheeting up from both sides.



3. Place the rolled plastic sheeting on top of the vault and unroll it slowly down the face of the vault. (See Section 3.64 for additional information on connections.)

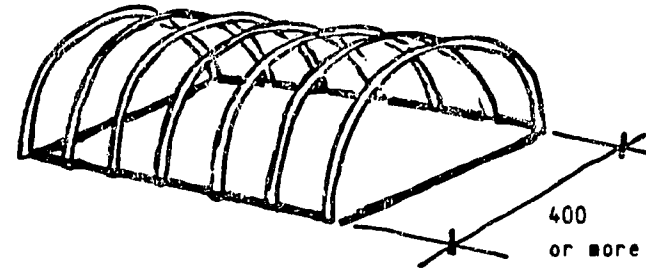


4. Pull the sheeting down to the ground and tie the ropes off to the base of the structure. The remaining 30 cm of fabric should be turned out and covered with soil. To prevent the sheeting from blowing off, use the tie-down ropes as required.

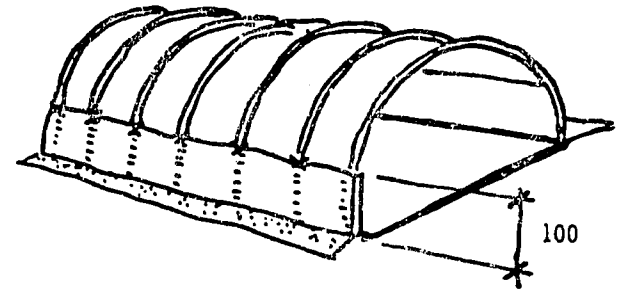


ATTACHMENT TO CYLINDRICAL FRAME (Span greater than 4 meters)

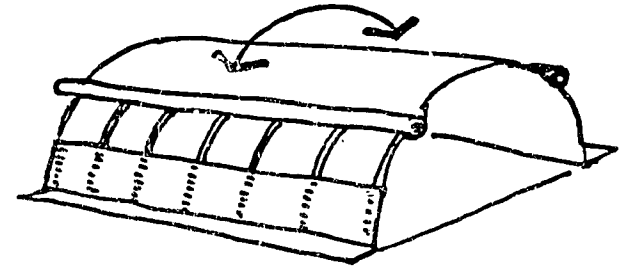
1. For a simple vaulted span greater than four meters, one piece of plastic sheeting will not adequately cover the structure.



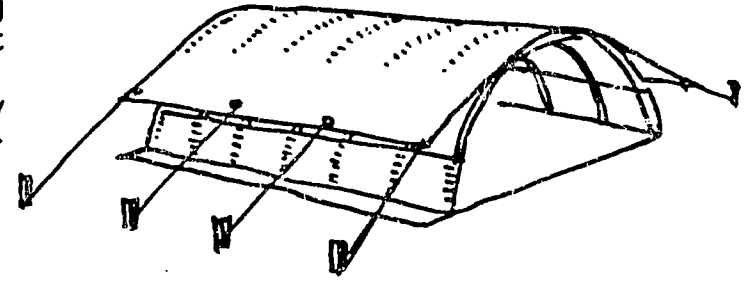
2. Fasten a strip of sheeting on both sides of the structure so that one meter of the structure is covered and 30 cm of sheeting is turned out flat on the ground and covered with soil.



3. Roll up the sheeting and, starting from the top center of the structure, unroll and secure the sheeting to the structure.

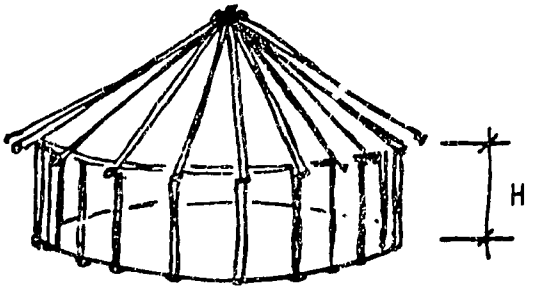


4. The two sides of the sheeting can either be tied down tight over the lower pieces of fabric or pulled out and away from the structure for lighting and ventilation purposes.

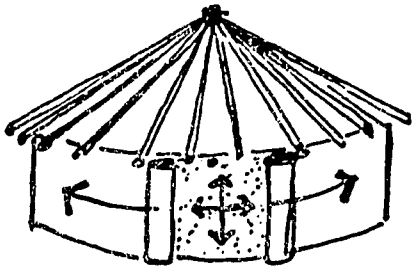


ATTACHMENT TO CONICAL FRAME

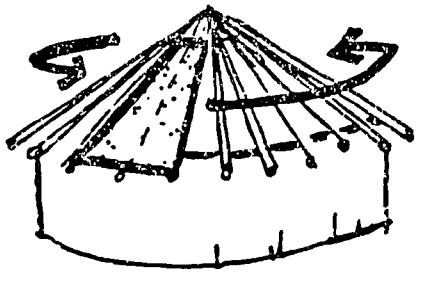
1. Measure the height and circumference of the walls and cut a piece of sheeting to fit. Roll up the piece of sheeting from both ends.



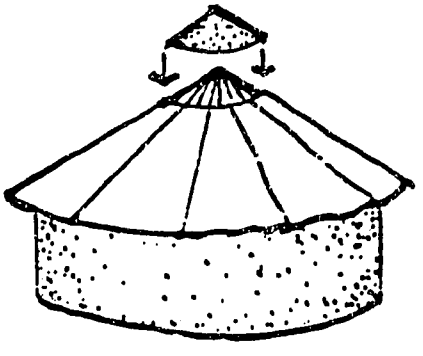
2. Tack the sheeting in place as it is unrolled around the frame, keeping it as tightly and evenly stretched as possible. After the sheeting is up, it can be permanently attached. (See Section 3.4.)



3. Cut the sheeting so that the roof can be covered as illustrated at right.

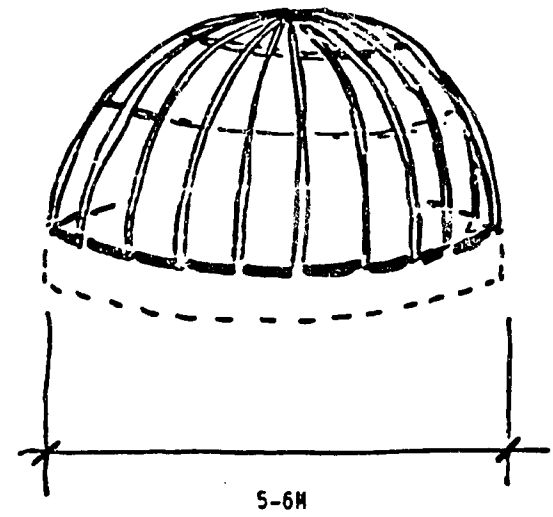


4. Wrap and secure a cap to cover the peak of the structure.

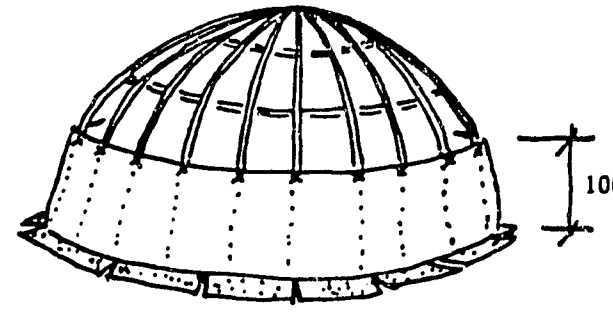


ATTACHMENT TO DOME-SHAPED FRAME

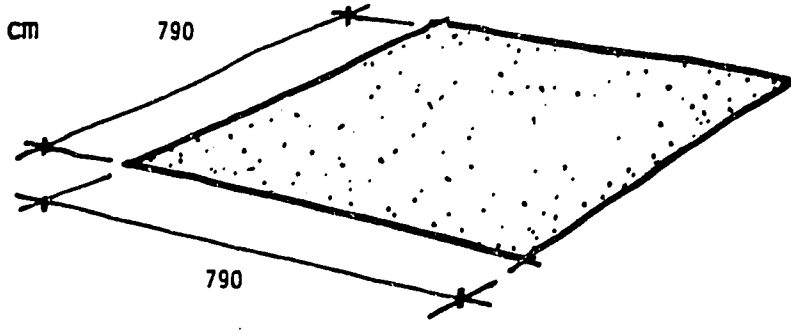
1. This configuration is usually limited to small, one-room structures (4-5 meters in diameter) and associated with residential functions.



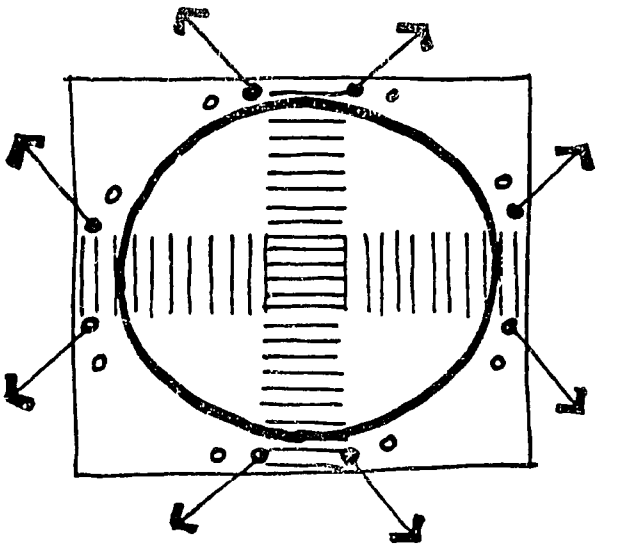
2. Cut a strip of sheeting 150 cm wide and long enough to wrap around the structure. Fasten it in place so that one meter of wall is covered and the remaining 50 cm is turned out flat on the ground and covered with soil.



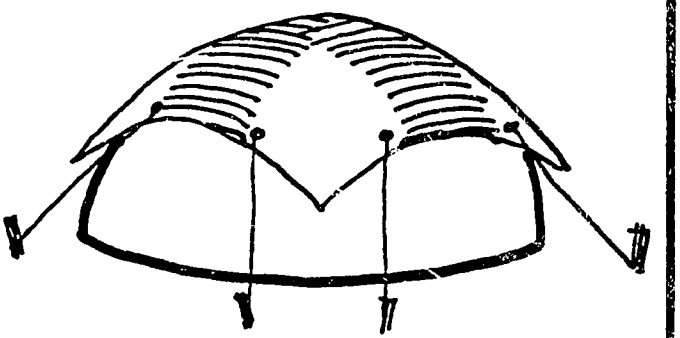
3. Cut a piece of sheeting 790 cm square and place over the structure.



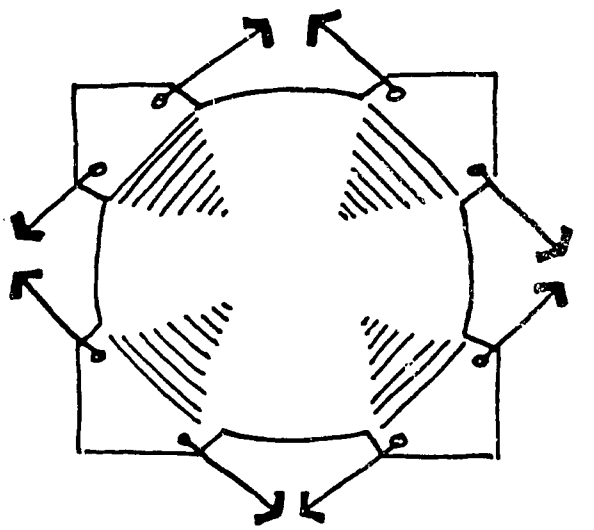
4. Tie off the sheeting at the eight points indicated at right.



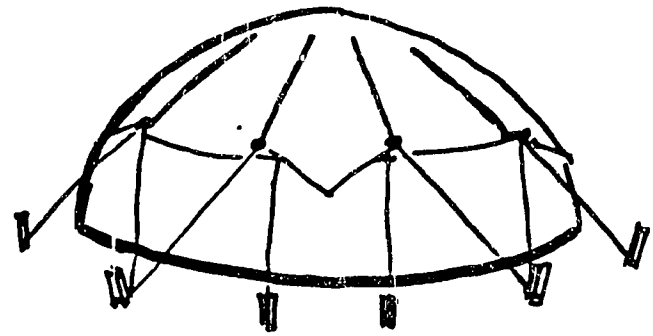
This will pull the sheeting tight over most of the structure, but will leave the corners loose.



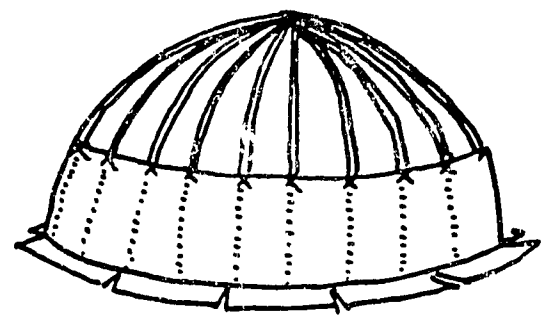
5. To secure the corners, tie the sheeting at the eight points indicated at right.



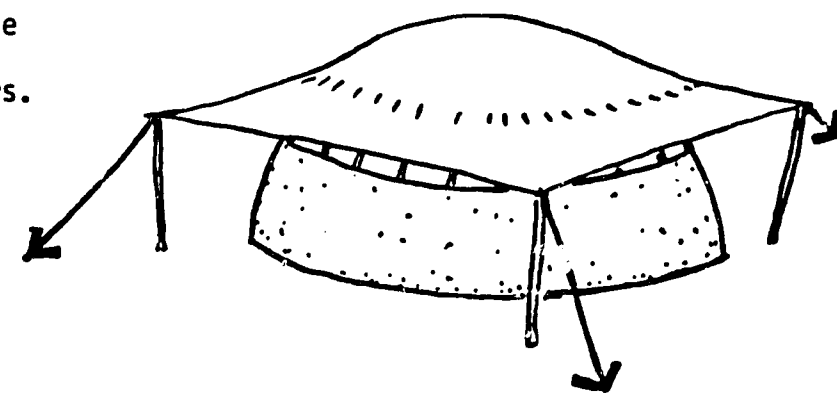
6. The result is a one-piece cover for a dome-shaped structure.



7. If the sheeting doesn't need to fit over the structure as tightly as indicated above, the procure is more simple. First, cover the base as described in Step #2.



Then, stretch a single piece of sheeting over the frame and secure it at the corners.



3.3 FRAMING SYSTEMS

3.31 BRE Braced Frame
3.32 Bamboo Lattice Cylinder
3.33 Pole Tent
3.34 Wrap-around Frame
3.35 Hanging Tent Shed
3.36 Dugout
3.37 Circular Frame
3.38 Rubble Wall Shed
3.39 Wood Truss Bent

FRAMING SYSTEMS

MATRIX

No. 3.3

LEGEND

● – ☺

◑ – 😐

○ – ☹

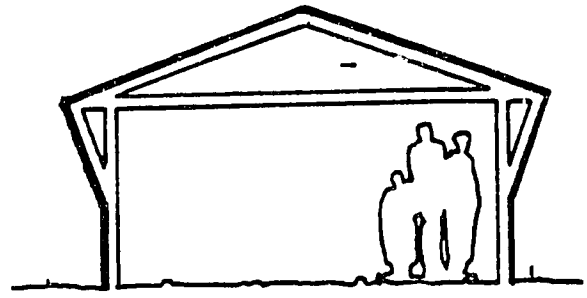
		BRE BRACED FRAME	BAMBOO LATTICE CYLINDER	POLE TENT	WRAP AROUND FRAME	HANGING TENT SHED	DUG OUT	CIRCULAR FRAME	RUBBLE WALL SHED	WOOD TRUSS BENT
DISASTER TYPES	SEISMIC	●	●	●	●	●	◑	●	○	●
	HIGH WINDS	●	○	○	●	○	●	●	◑	●
	FLOODING	●	◑	◑	●	◑	○	◑	◑	◑
AVAILABLE MATERIALS	MASONRY	Can be used for walls and partitions								
	DIMENSIONAL LUMBER	●	○	●	●	●	●	◑	●	●
	BAMBOO	●	●	●	●	●	●	●	●	○
	POLES	◑	○	●	◑	●	◑	◑	●	○
	RUBBLE	○	○	○	○	○	◑	○	●	○
CLIMATE	HOT DRY	●	●	●	○	●	●	●	●	●
	HOT WET	●	○	◑	◑	○	◑	●	●	●
	COLD	●	◑	◑	●	○	●	◑	◑	●

FRAME TYPE: BRE BRACED FRAME	No. 3.31 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	●
HIGH WIND	●
FLOOD	●

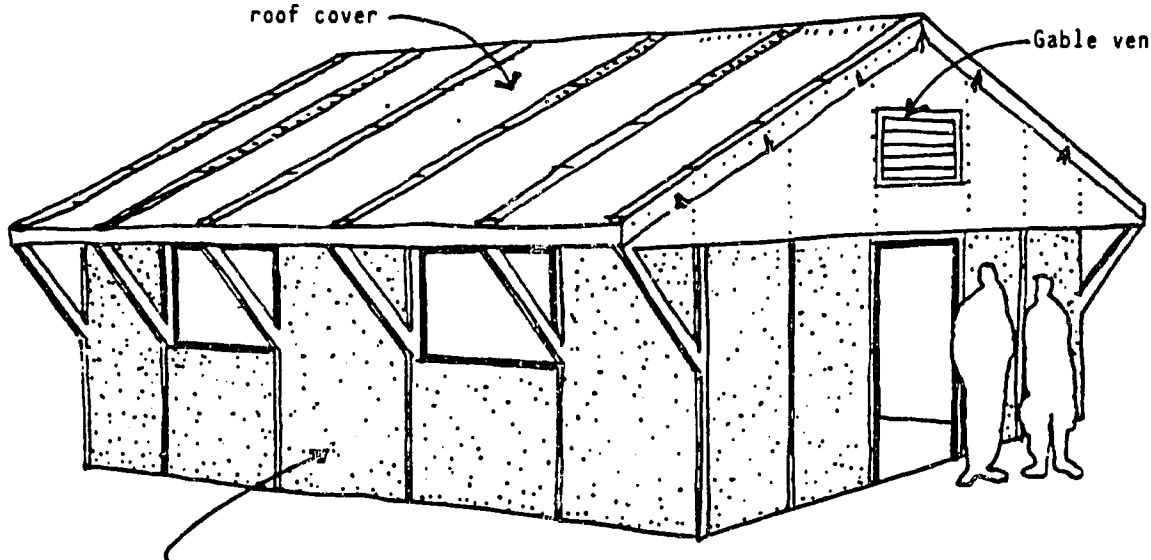
FRAME MATERIALS

Dimensional Lumber
Bamboo



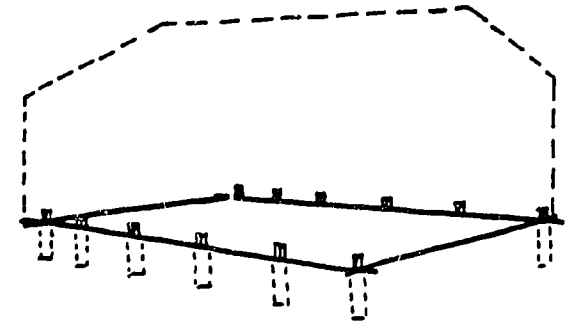
REFERENCE DETAILS

3.52
3.53
3.61
3.62
3.64
3.65
3.71
3.72
3.8

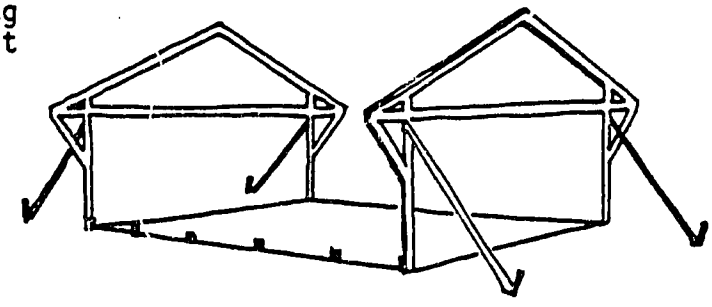


BRE BRACED FRAME	No.
ERECTION SEQUENCE	3.31 - 2

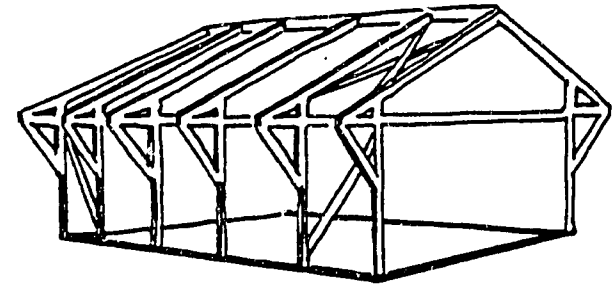
1. Layout building according to site conditions. Set foundation posts in place.



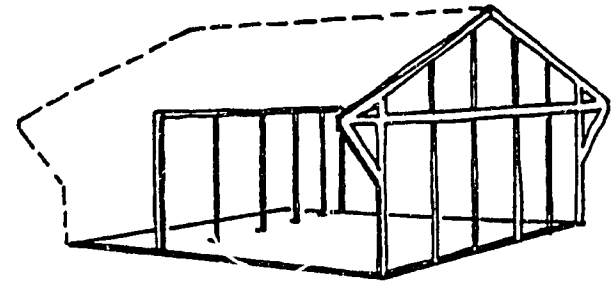
2. Fabricate trusses near the building site. Tip the end trusses up first and secure with temporary braces.



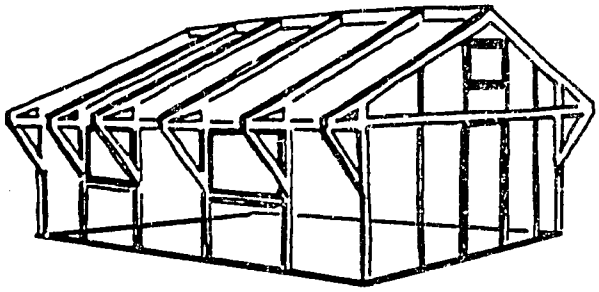
3. Set the remaining trusses in place, temporarily bracing them as you go. After all trusses are up, permanent diagonal bracing (walls & roof) and the ridge beam are set in place and the temporary bracing is removed.



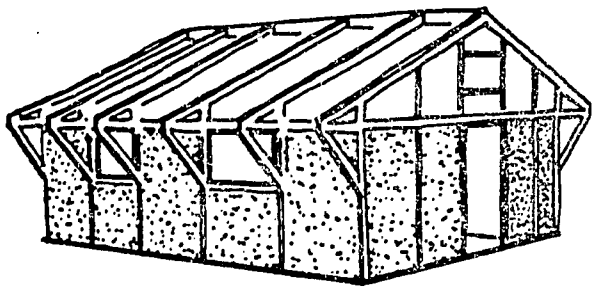
4. Frame-in the end walls (and gable) and which ever internal partitions that are required.



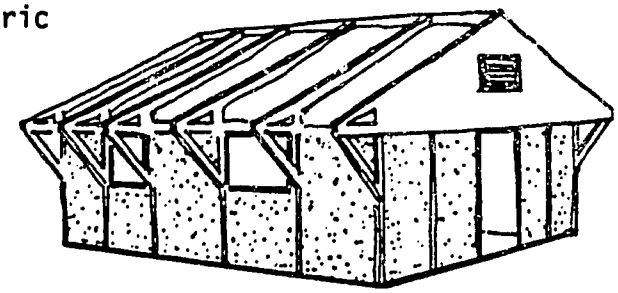
5. Determine where door, window & vent openings are required and frame them in.



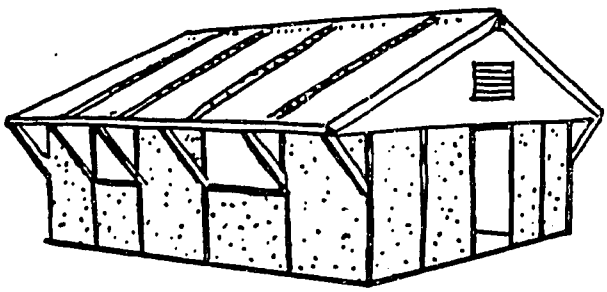
6. The walls can be constructed out of what ever materials are available.



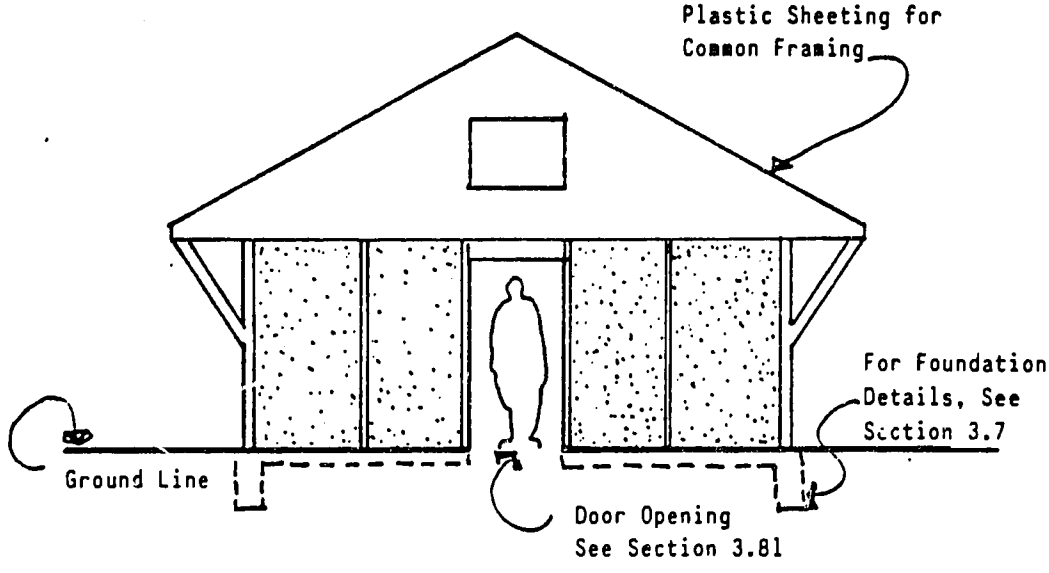
7. Cover both gable ends with plastic fabric and install gable vents.

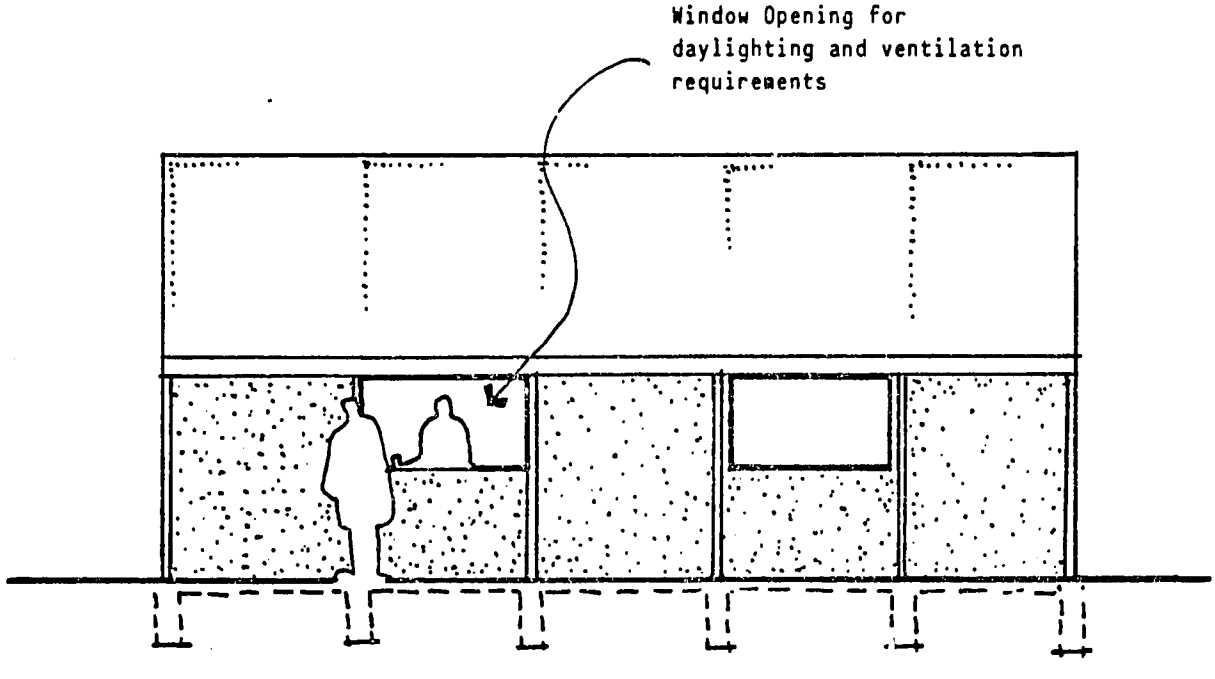


8. Cover the roof with plastic fabric.



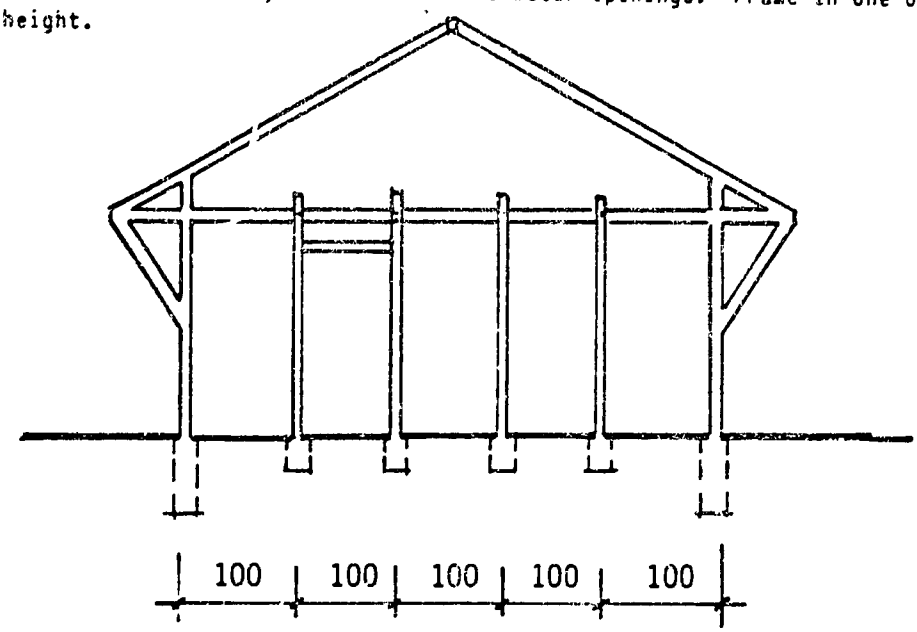
BRE BRACING FRAME	No.
ELEVATIONS	3.31 - 4



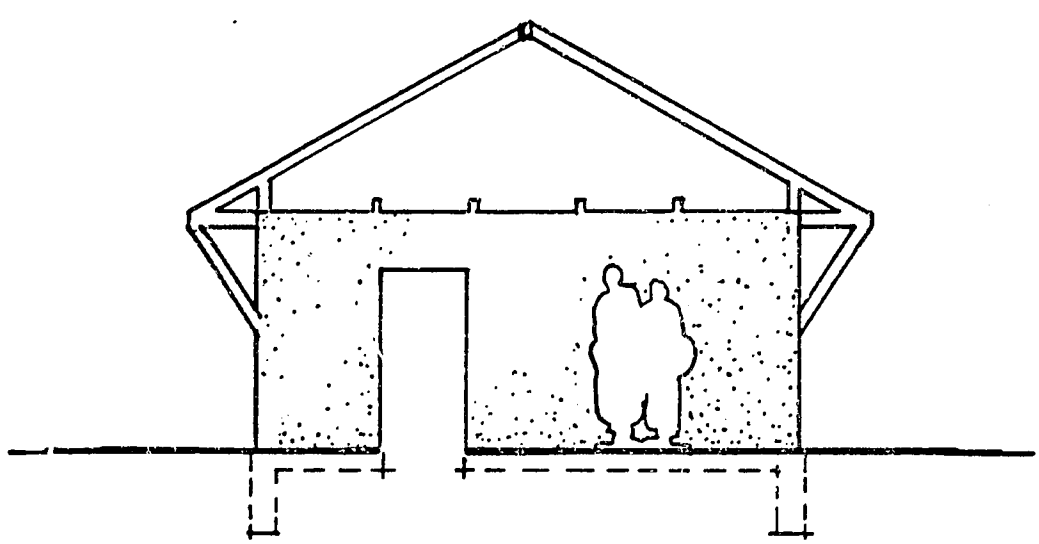


BRE BRACING FRAME	No.
PARTITION FRAME	3.31 - 5

1. Determine where interior partitions are required. If at all possible, line up the internal partitions with the structural elements of the frame. Set poles 20cm into the ground and connect the top of each pole to the bottom chord of the roof truss above. The door (if required) can be located in any of the three one meter openings. Frame in one opening to the desired height.



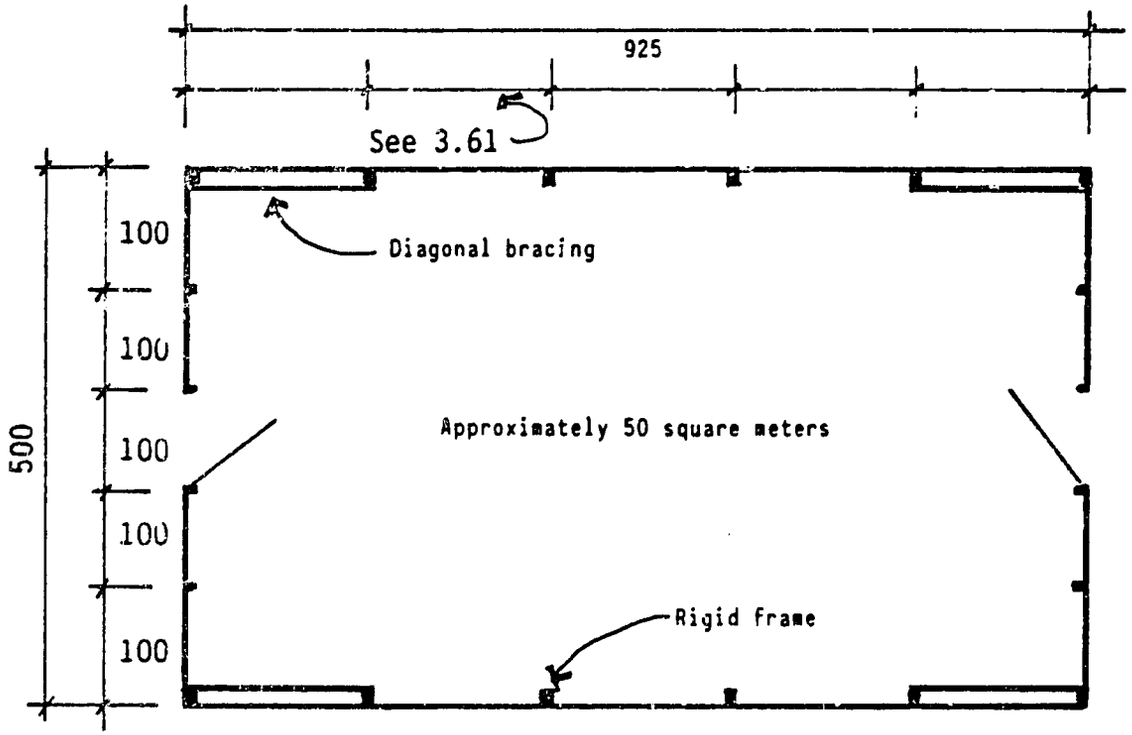
2. Starting at the top and working down, nail plastic fabric to the poles, keeping the fabric as tight as possible. Let the fabric extend down 15-20 cm below the floor level. Cut the fabric at the door opening.



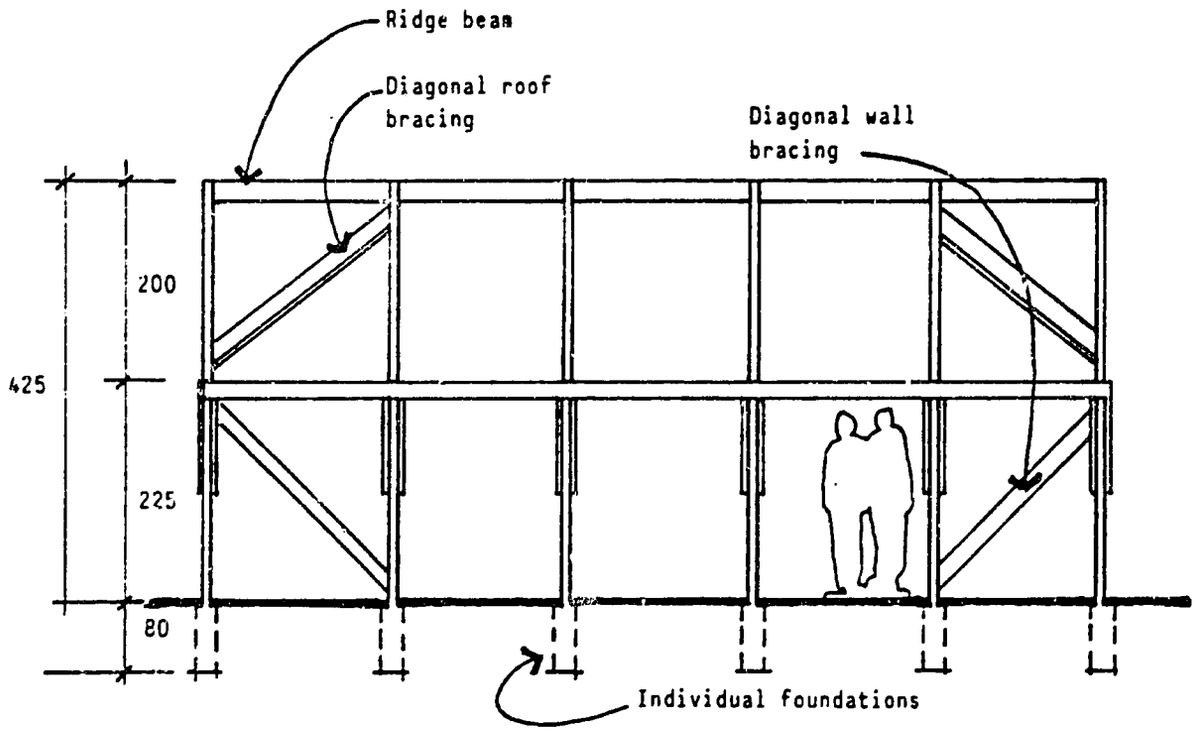
BRE BRACING FRAME

FRAMING PLAN AND ELEVATION

No. 3.31 - 6



FRAMING PLAN



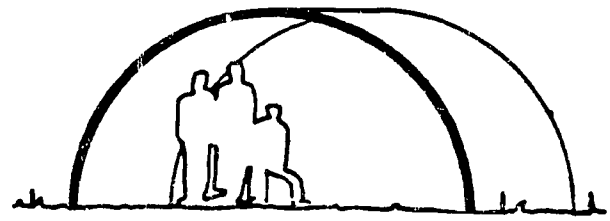
FRAMING ELEVATION

FRAME TYPE: BAMBOO LATTICE CYLINDER	No. 3.32-1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	●
HIGH WIND	○
FLOOD	◑

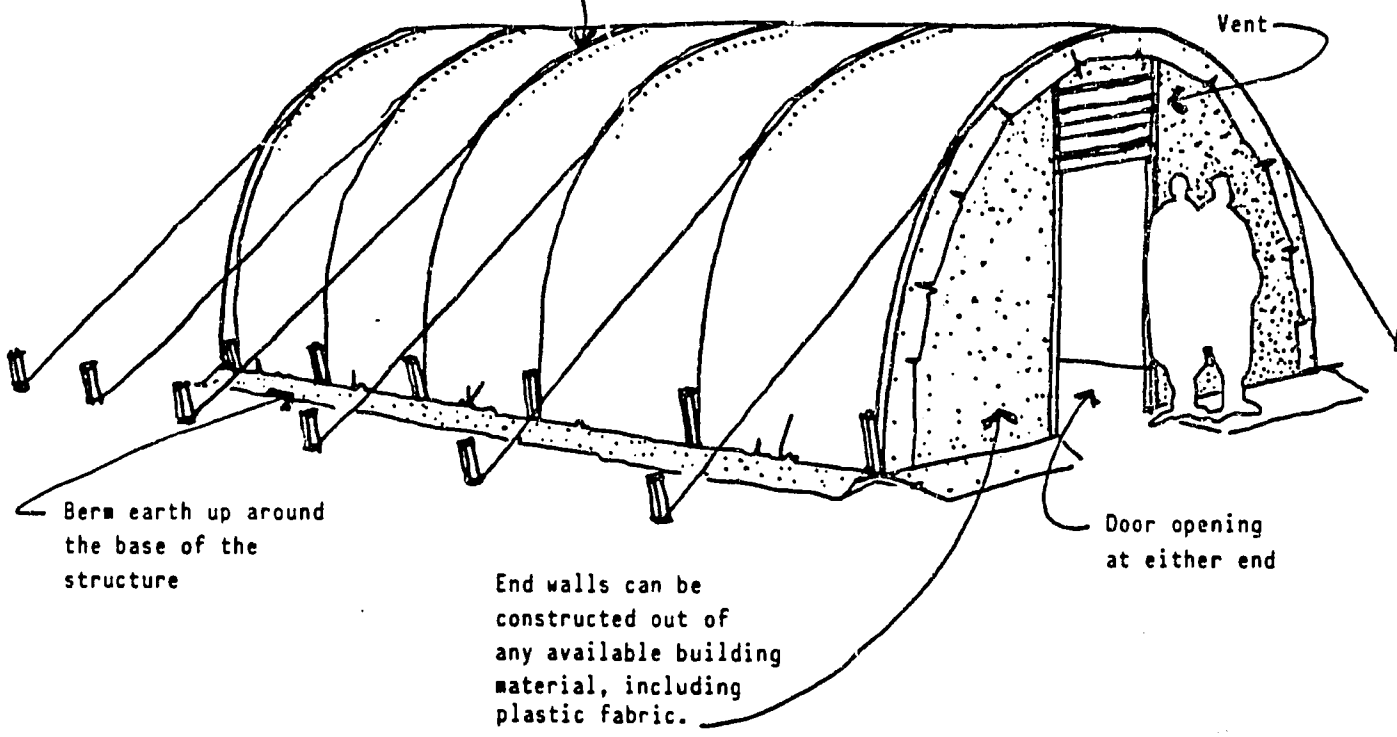
FRAME MATERIALS

Bamboo



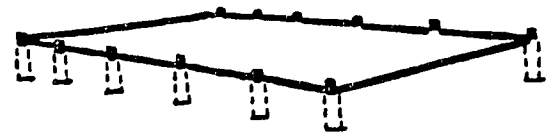
REFERENCE DETAILS

3.53
3.55
3.61
3.62
3.65
3.71
3.73
3.8

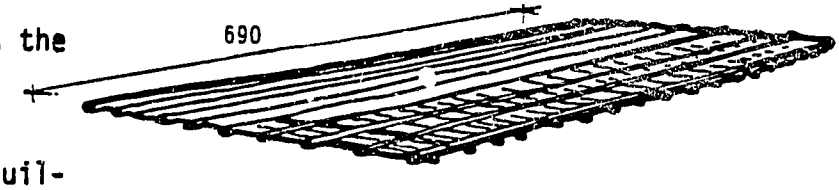


BAMBOO LATTICE CYLINDER	No.
ERECTION SEQUENCE	3.32-2

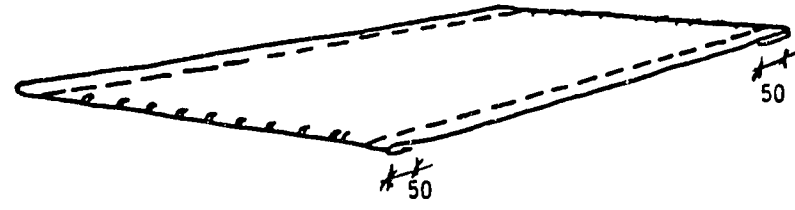
1. Layout the plan on the ground and build a foundation along the long sides. The foundation can be continuous or individual short posts as shown at right.



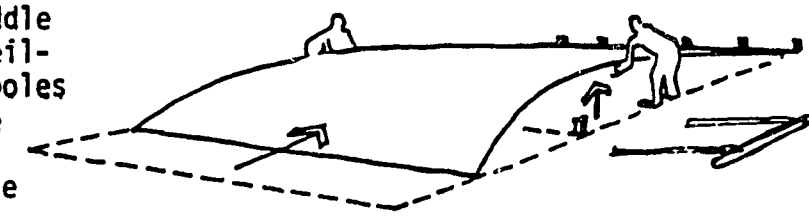
2. Build a bamboo lattice on the ground of green or flexible dry bamboo. The lattice should be 690 cm wide and as long as the building need be.

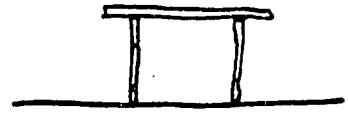


3. Stretch the plastic sheeting over the lattice with 50 cm overhanging each end.



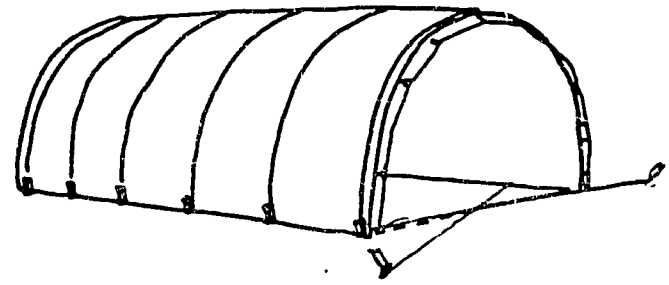
4. Lift the lattice from the middle and prop it at the desired ceiling height with poles. The poles should be prepared in advance as shown so they can hold the frame and not puncture the plastic sheeting.



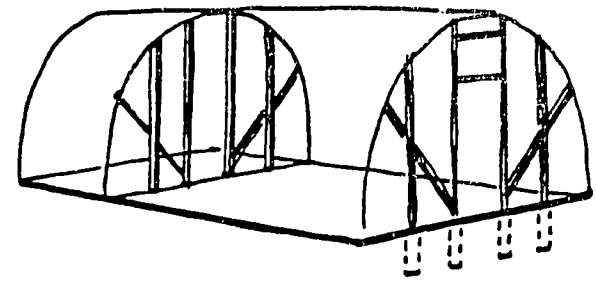


BAMBOO LATTICE CYLINDER	No.
ERECTION SEQUENCE	3.32-3

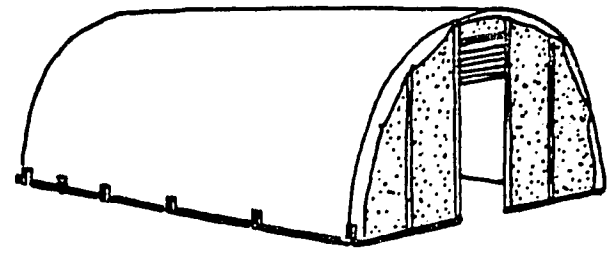
5. With ropes pull the ends of the ends of lattice together until the edges are over the foundation connections.



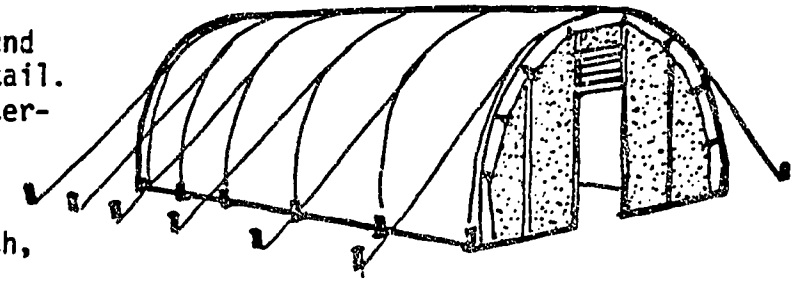
6. Erect end frames and partition frames.



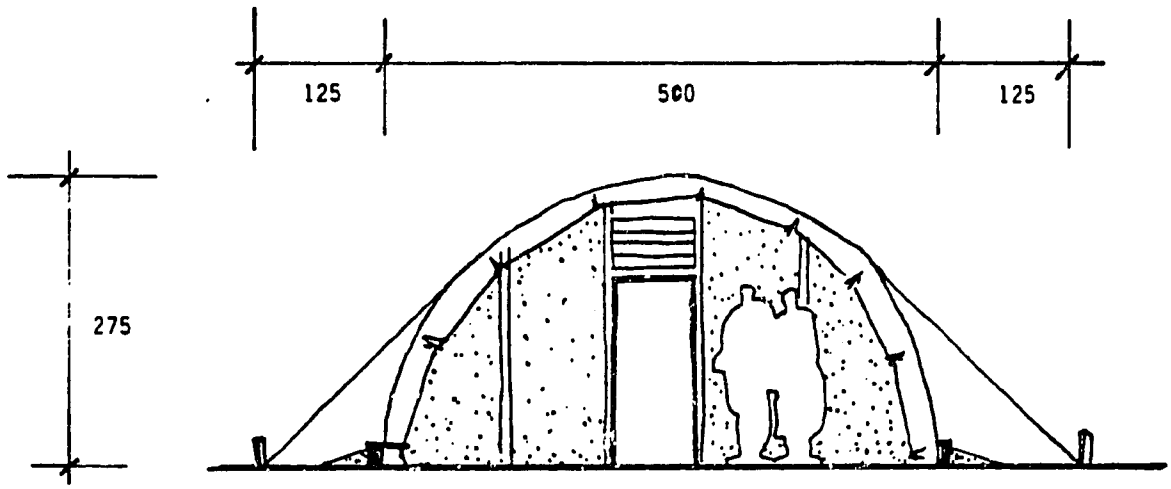
7. Cover the end frames with any material. If plastic is used, see Section 3.6 - Plastic Sheeting Connections.

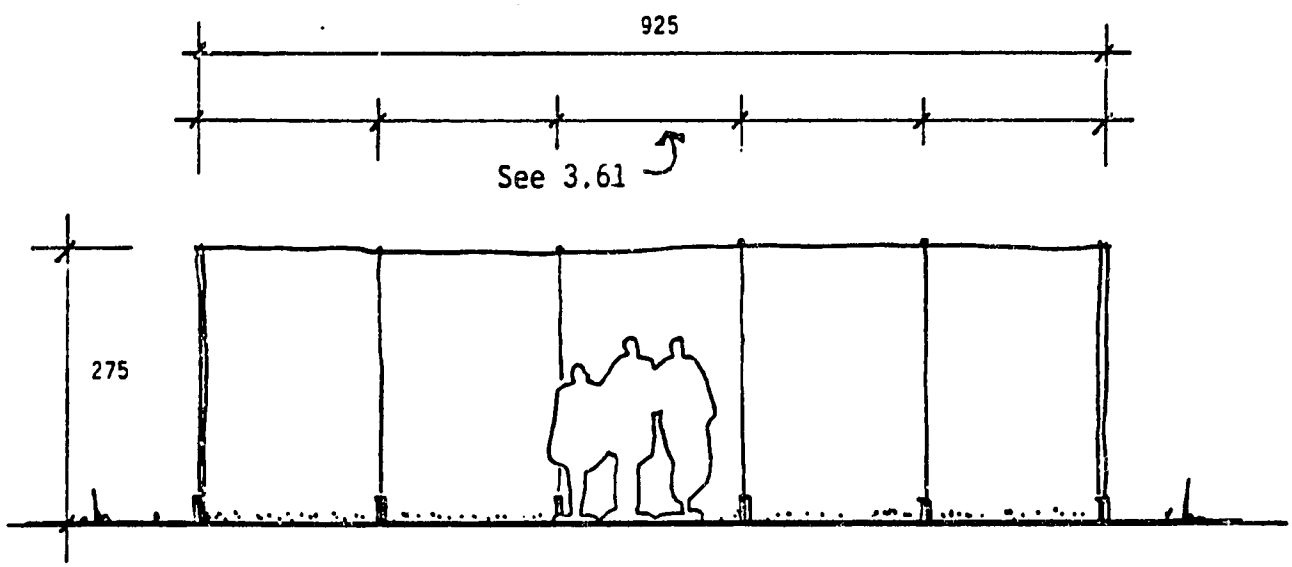


8. Secure the plastic at the ground with the continuous trench detail. (See Section 3.71 - Ground Interface Connections.) Ropes should be placed over the top of the structure and anchored. For spacing and anchor strength, see Section 3.61 - Plastic Sheeting Connections.

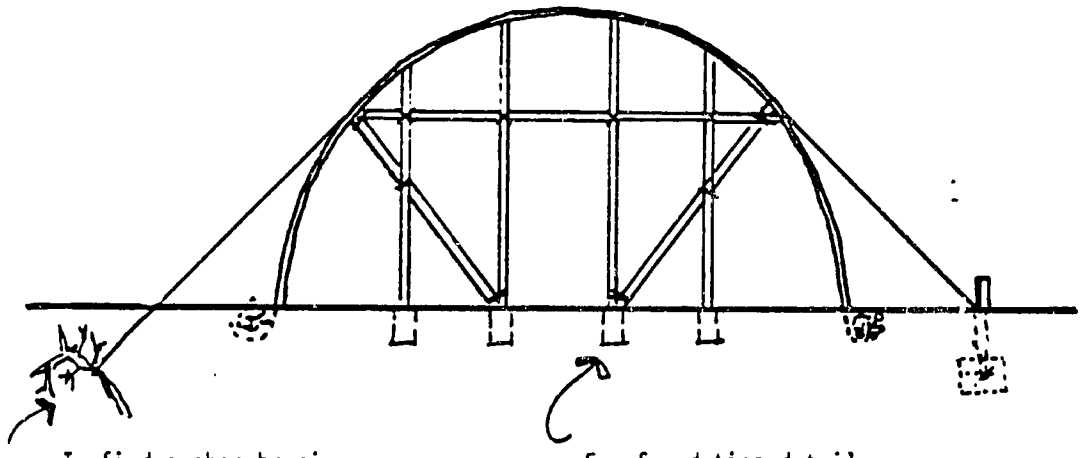


BAMBOO LATTICE CYLINDER	No.
ELEVATIONS	3.32-4





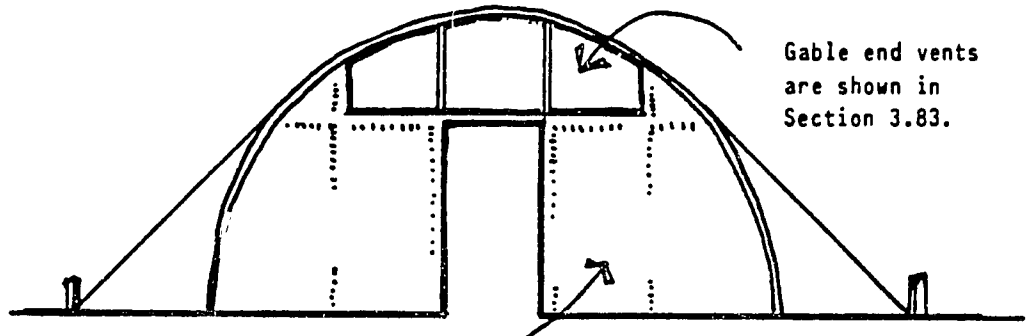
BAMBOO LATTICE CYLINDER	No.
PARTITION FRAME	3.32-5



To find anchor bracing,
See Section 3.61.

For anchor types,
See Section 3.73.

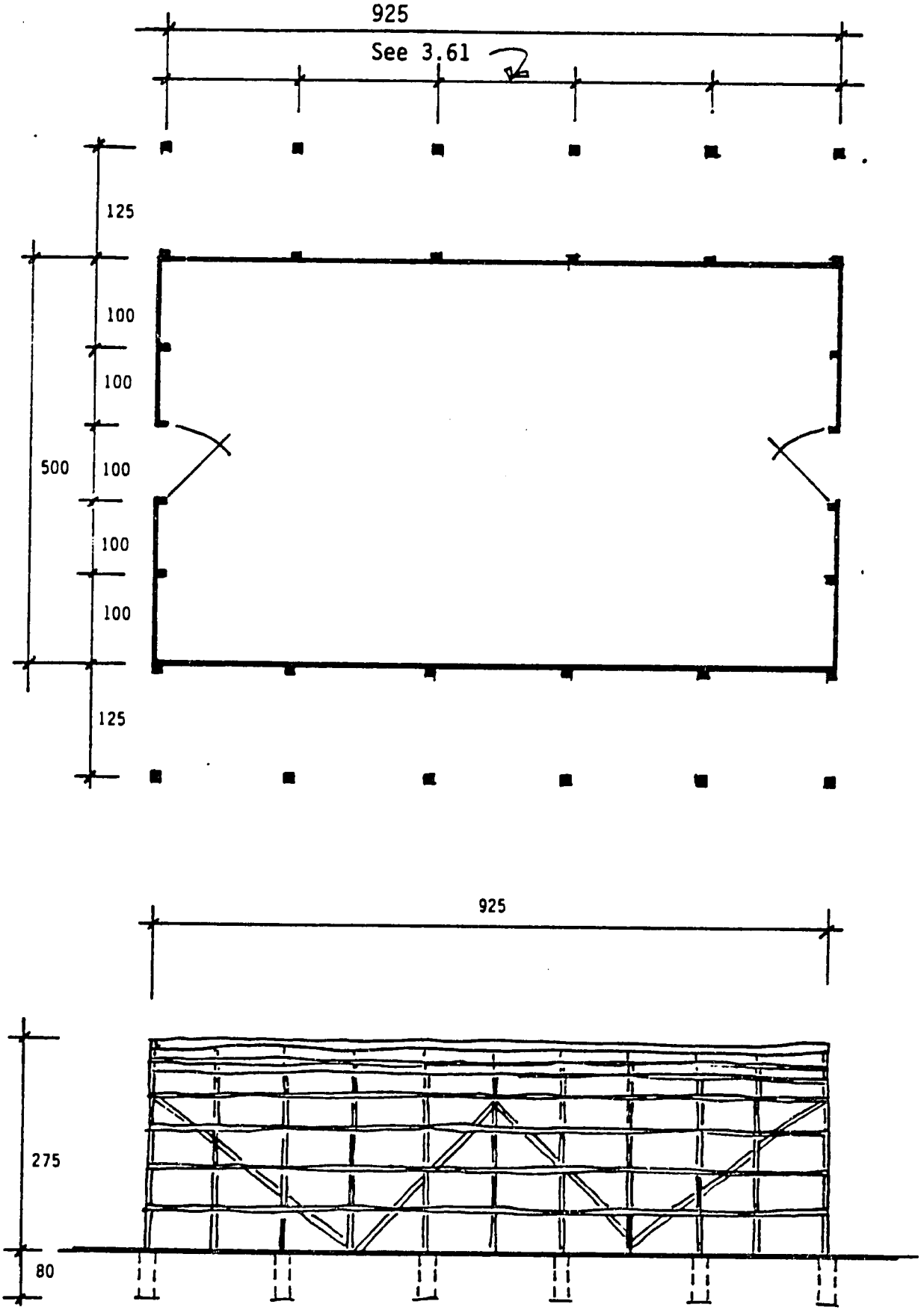
For foundation detail,
See Section 3.71.



Gable end vents
are shown in
Section 3.83.

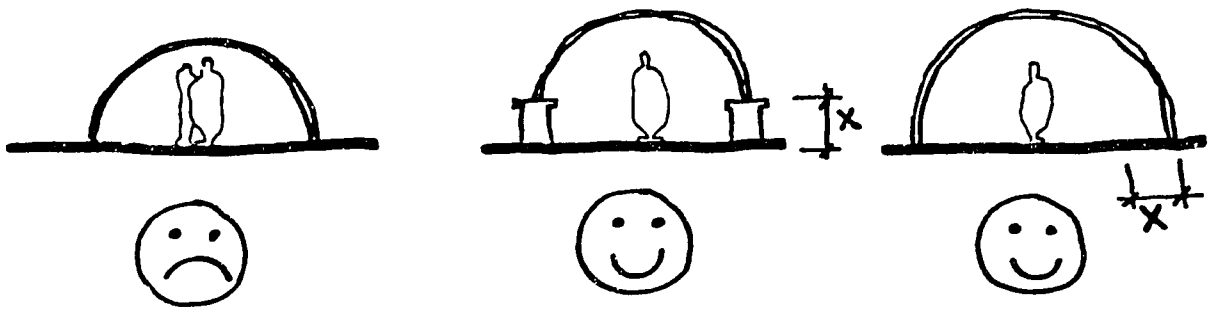
The end wall may be made from
any available materials. If plastic
sheeting is used, see Section 3.6.

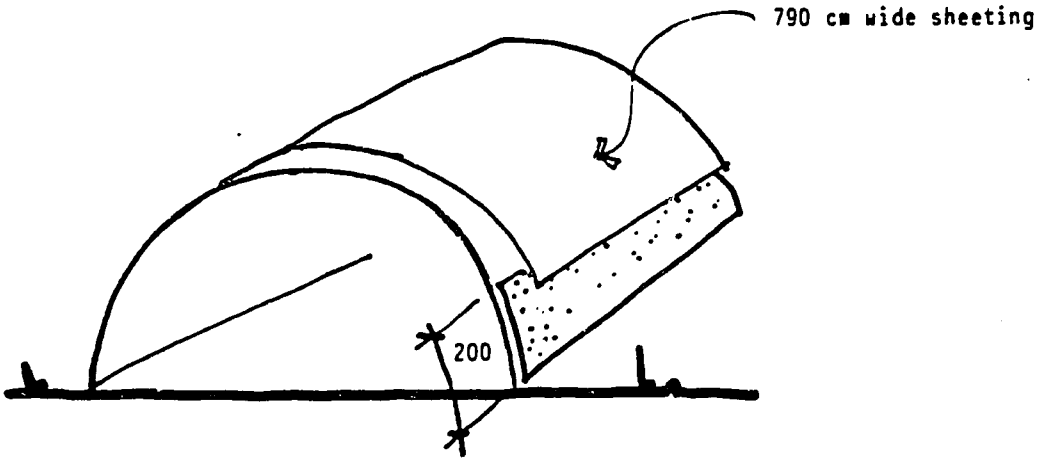
BAMBOO LATTICE CYLINDER	No.
FRAMING PLAN AND ELEVATION	3.32-6



BAMBOO LATTICE CYLINDER	No. 3.32 - 7
NOTES	

For increased usable headroom or floor space, the frame may be increased in width. This will require that more than one plastic sheet be used to cover. (See Section 3.27 - 11 - Design Information.)

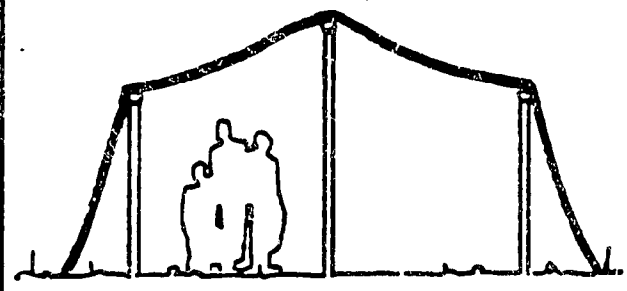




FRAME TYPE: POLE TENT	No. 3.33-1
DRAWING: PERSPECTIVE SKETCH	

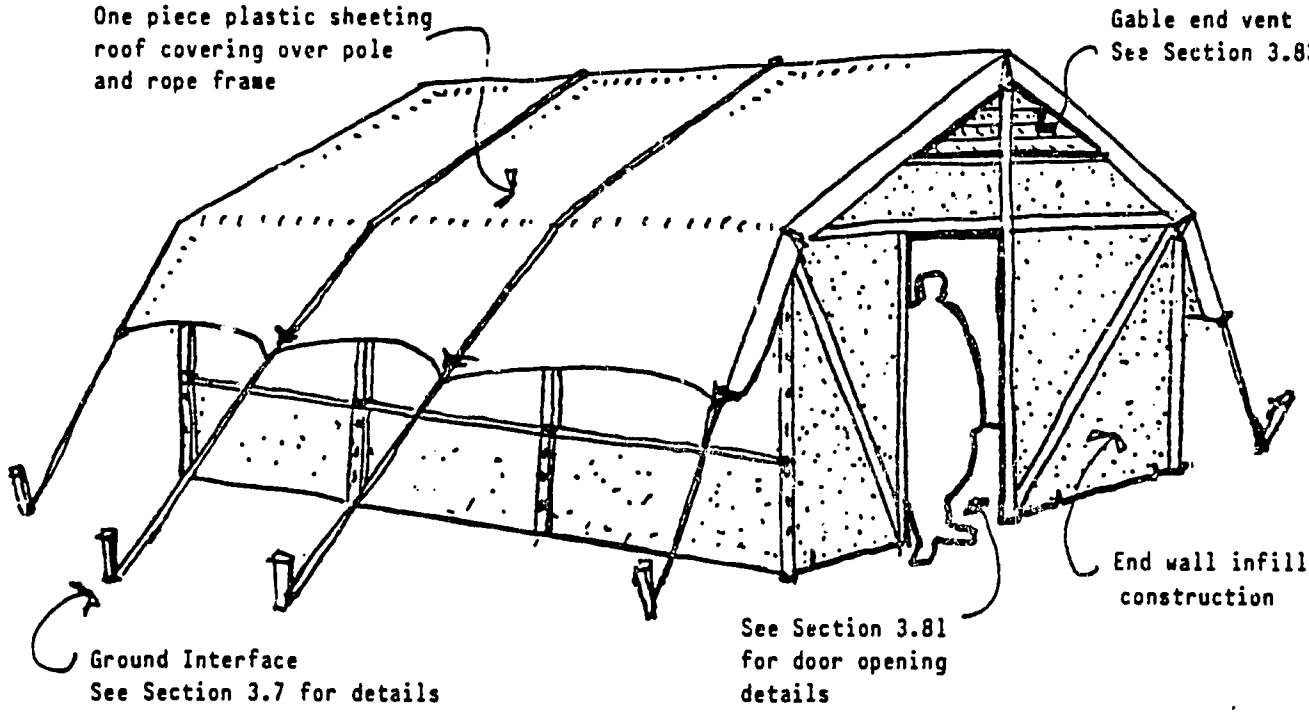
SEISMIC	●
HIGH WIND	○
FLOOD	◐

FRAME MATERIALS
Dimensional Lumber
Bamboo
Poles
Pipes
Rope



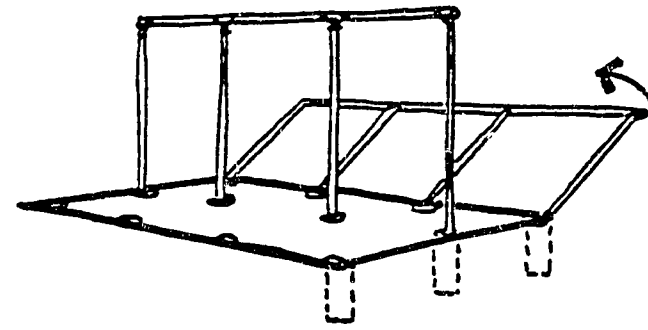
REFERENCE DETAILS

3.52	3.66
3.53	3.67
3.54	3.7
3.55	3.8
3.61	
3.62	
3.64	
3.65	

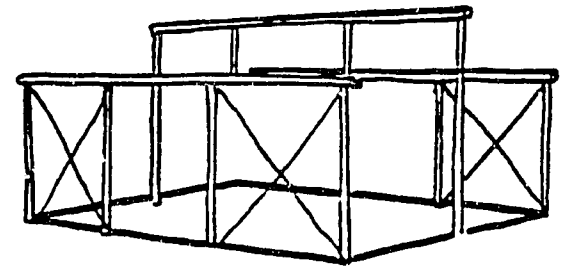


POLE TENT	No. 3.33-2
ERECTION SEQUENCE	

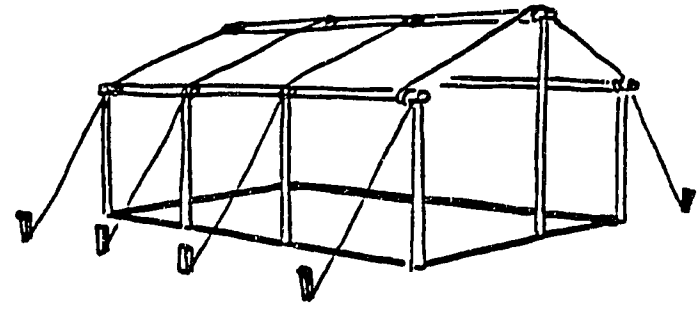
1. Layout the building site and dig foundations according to guidelines in Section 3.7 - Ground Interface Connections. Fabricate the frames on the ground and tip into place.



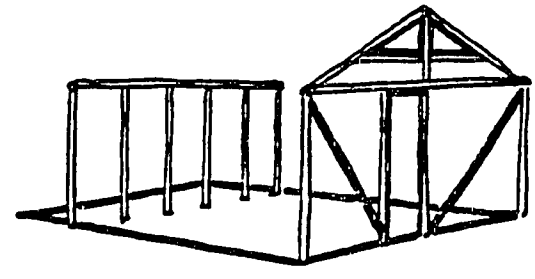
2. Diagonally brace the frames with rope to resist movement down the length of the structure.



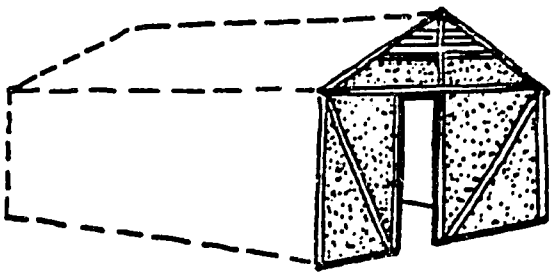
3. With heavy ropes, tie the three frames together. Start at the center ridge and then tie off to the outer poles.



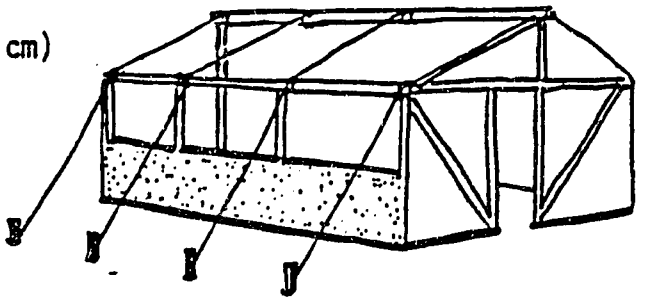
4. Layout interior partitions and frame in end walls and partitions. Include diagonal bracing in the end walls.



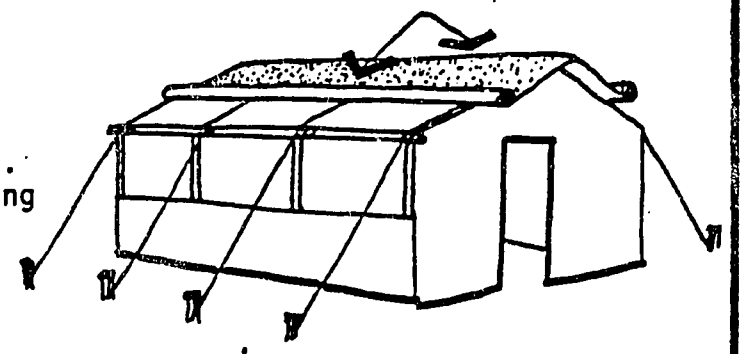
5. The end walls below the roof line can be infilled with any available construction material. The gable ends are common framing covered with plastic sheeting.



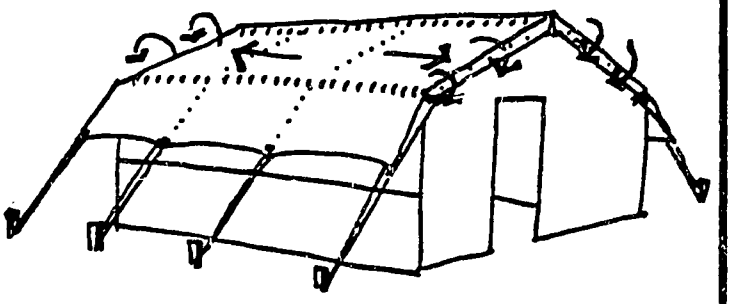
6. Partial walls on the long sides come up to window sill height (100 cm) and can be constructed out of any available material.



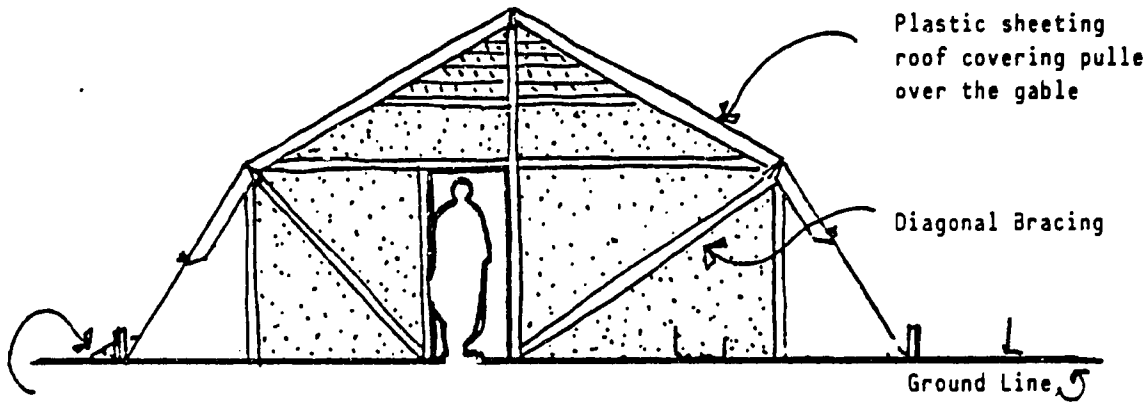
7. Layout and cut a single piece of plastic sheeting for the roof covering. Start at the ridge and unroll the sheeting over the ropes. Tack in place at both ends and along the eave lines.



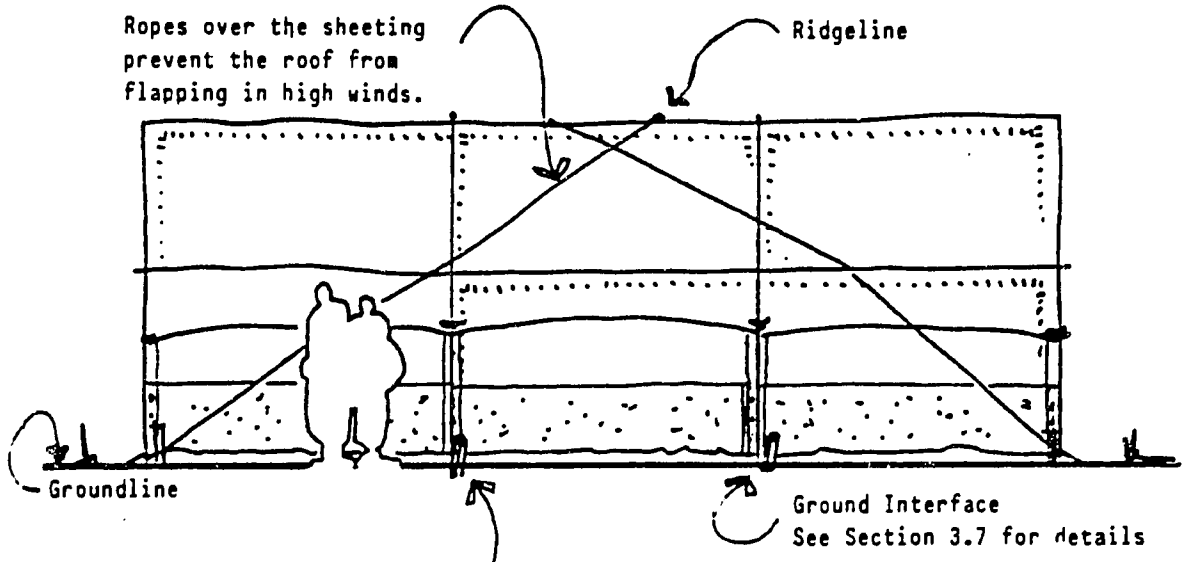
8. Cable the ends of the sheeting according to the guidelines in Section 3.6 - Plastic Sheeting Connections. Pull the sheeting tight and secure on both gable ends. (See Section 3.27 - 8 & 9 - Design Information for batten details.)



POLE TENT	No.
ELEVATIONS	3.33-4

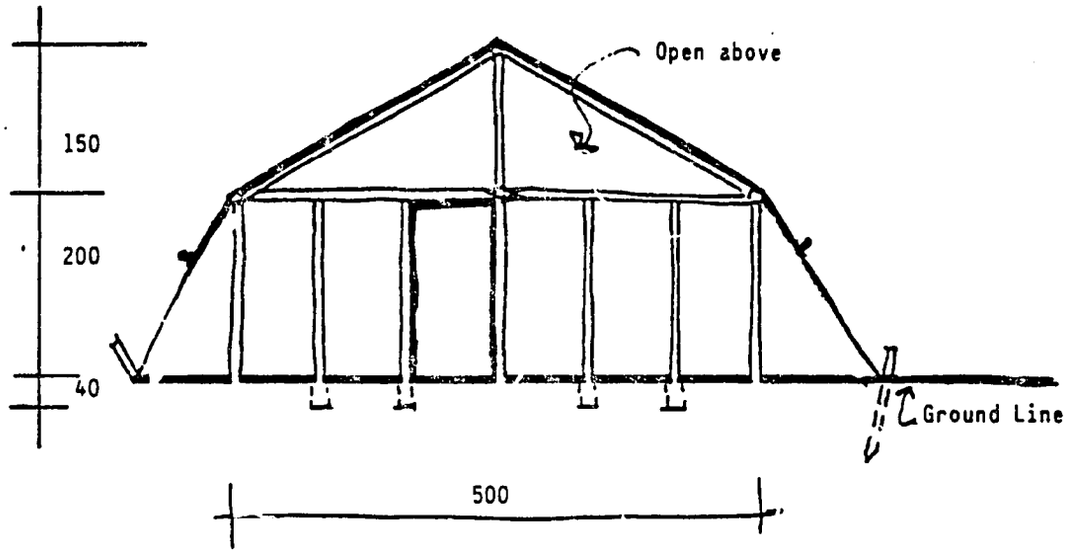


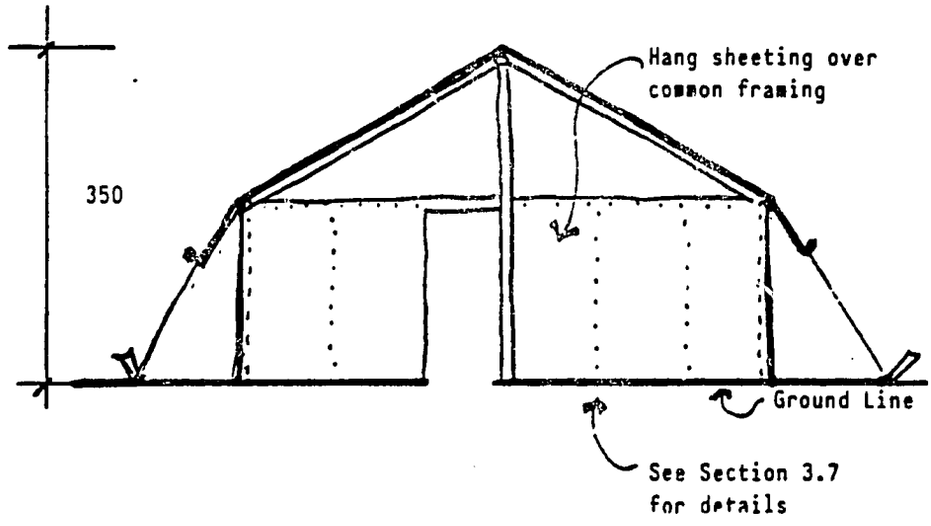
Berm up soil at the base of
the structure. See SEction 3.7



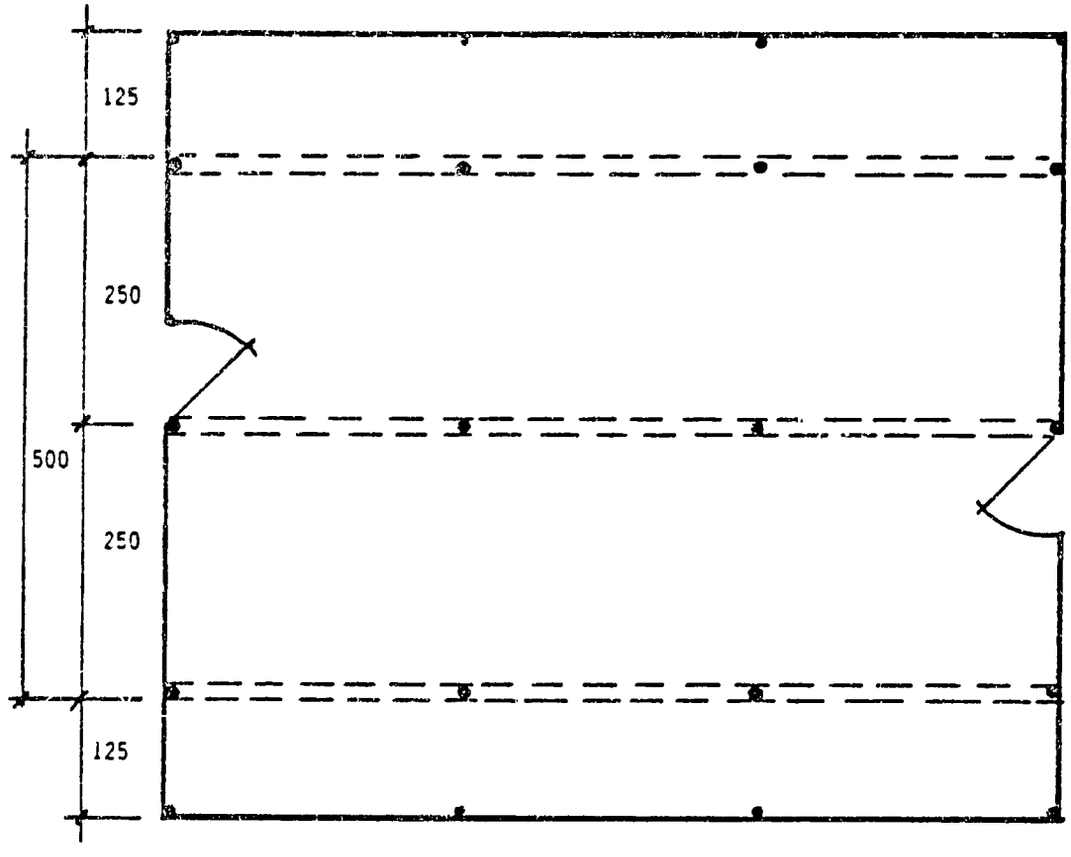
Rope over supports as
required. See 3.61

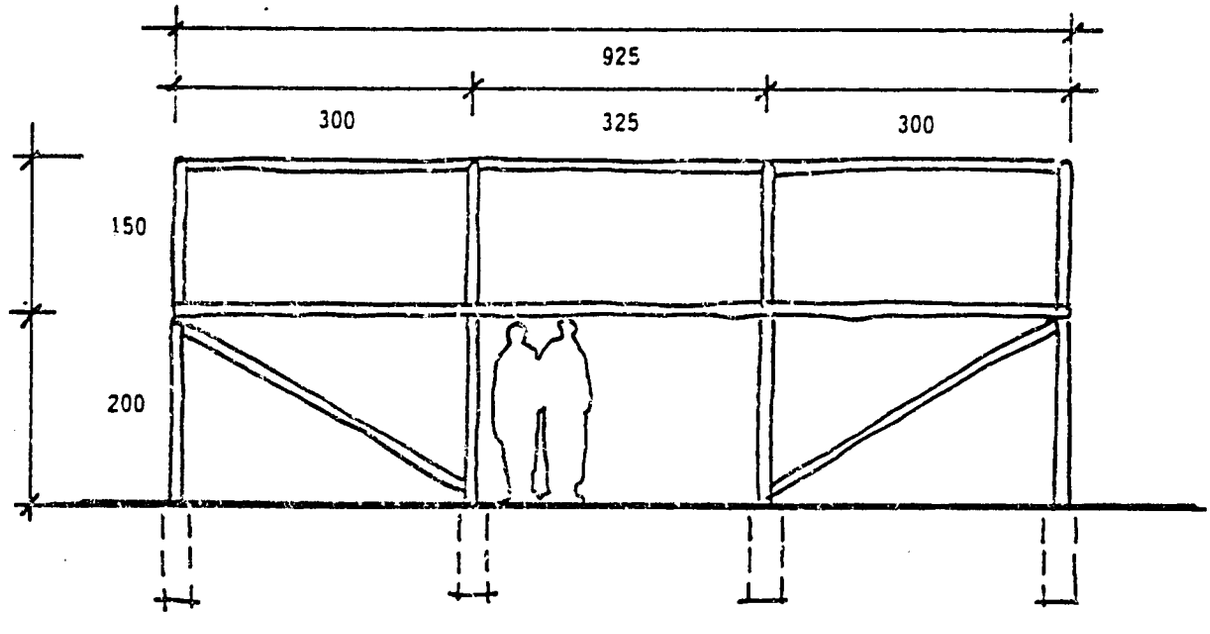
POLE TENT	No.
PARTITION FRAME	3.33-5





POLE TENT	No.
FRAMING PLAN AND ELEVATION	3.33-6



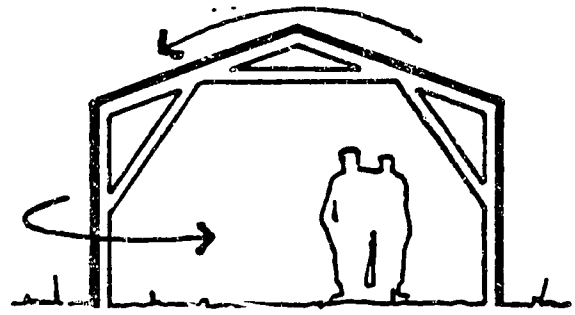


FRAME TYPE: WRAP AROUND FRAME	No. 3.34 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	●
HIGH WIND	●
FLOOD	●

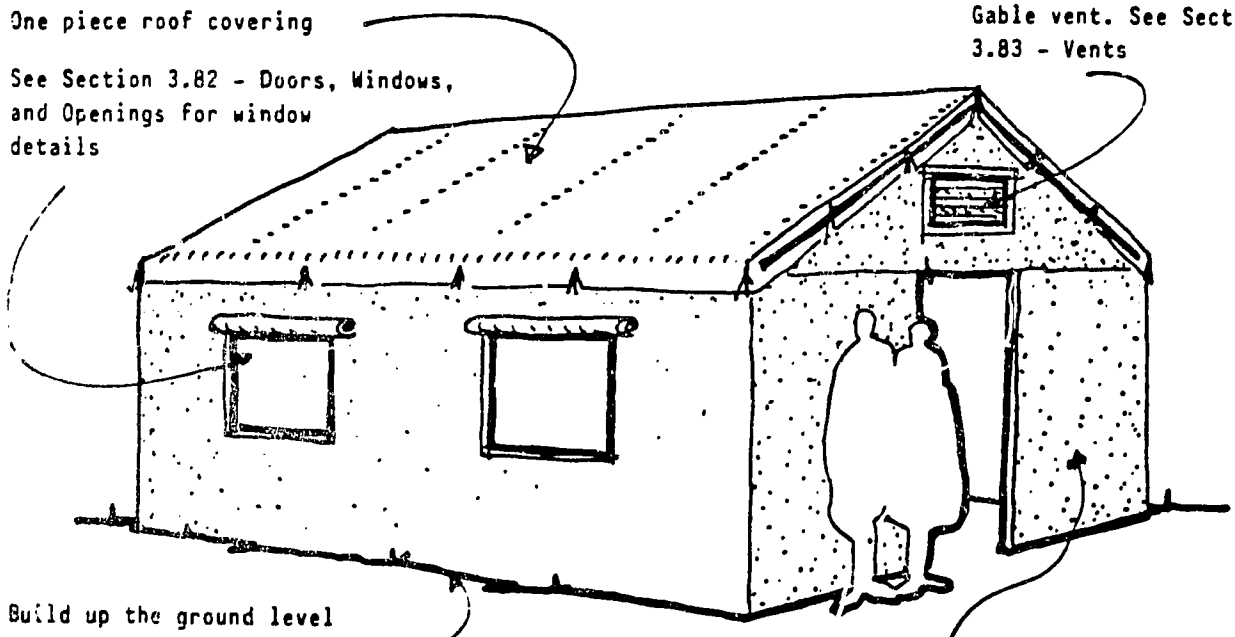
FRAME MATERIALS

Dimensional Lumber
Bamboo



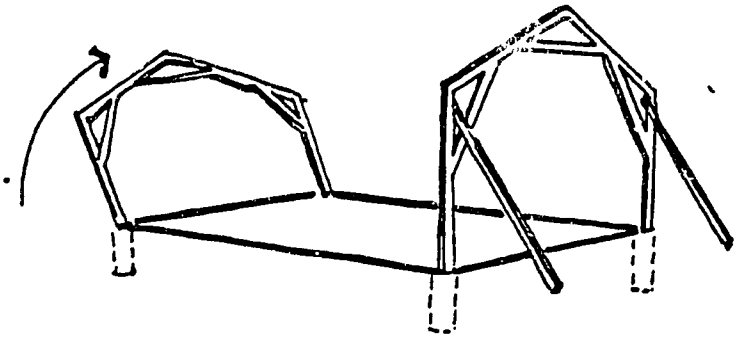
REFERENCE DETAILS

3.52
3.53
3.61
3.62
3.64
3.65
3.71
3.72
3.8

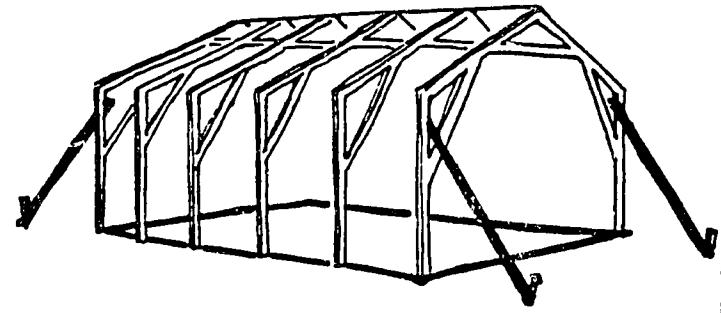


WRAP AROUND FRAME	No.
ERECTION SEQUENCE	3.34 - 2

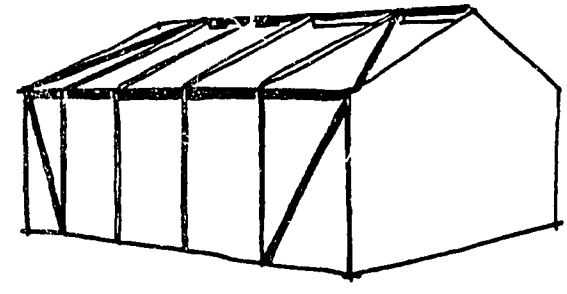
1. Layout the building site and prepare for each frame according to the guidelines listed in Section 3.7 - Ground Interface Connection. Set the two end frames first and brace securely.



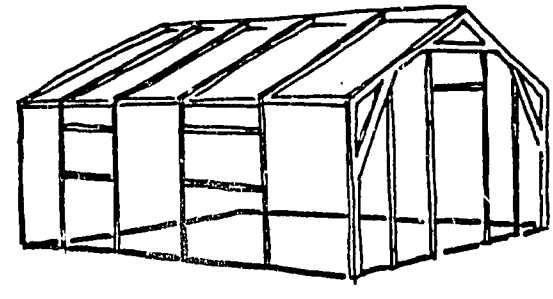
2. Stretch a string between the two end frames and set the remaining frames to that line.



3. After all the frames are in place and adjusted for level permanent bracing at the ridge and eaves are attached. Diagonal bracing, to resist lateral forces, are fabricated and nailed in place (roof and walls).

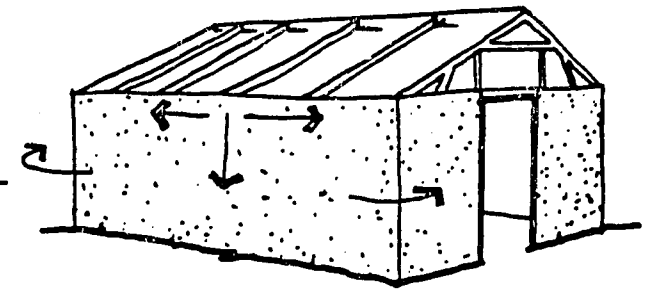


4. Determine where door, window and vent openings are needed. Frame in these openings according to the guidelines in Section 3.8 - Doors, Windows, and Openings.

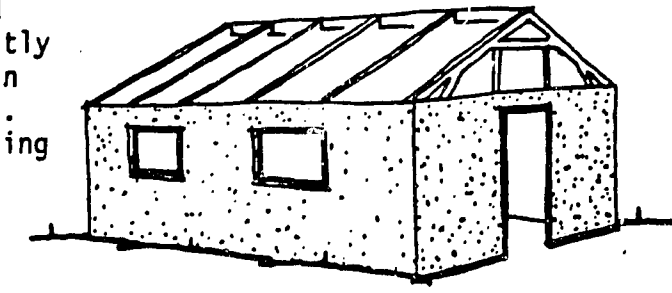


WRAP AROUND FRAME	No. 3.34 - 3
ERECTION SEQUENCE	

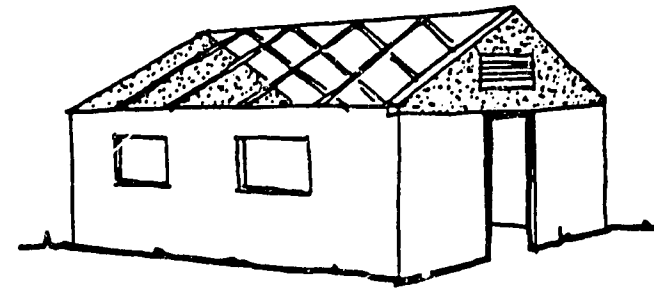
5. To use plastic sheeting, cut a piece to fit around the building (approximately 2 meters x 30 meters). Roll the sheeting up from both ends and temporarily nail in place, wrapping the sheeting evenly around the structure.



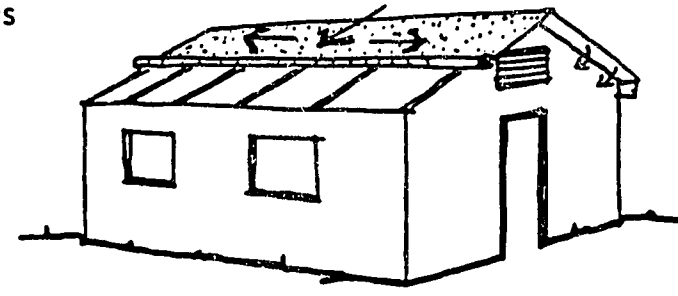
6. After the sheeting is up and checked for proper coverage, attach permanently according to the guidelines listed in Section 3.5 - Structural Connections. Trim window and door openings according to Section 3.8 - Doors, Windows, and Openings.



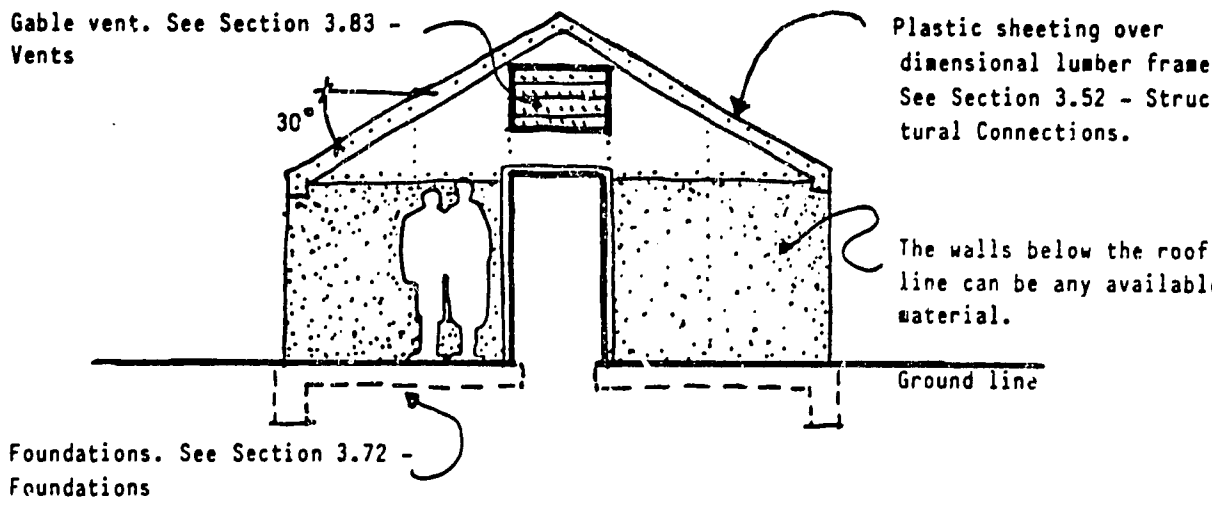
7. Cover both gable ends making provisions for vents if required.

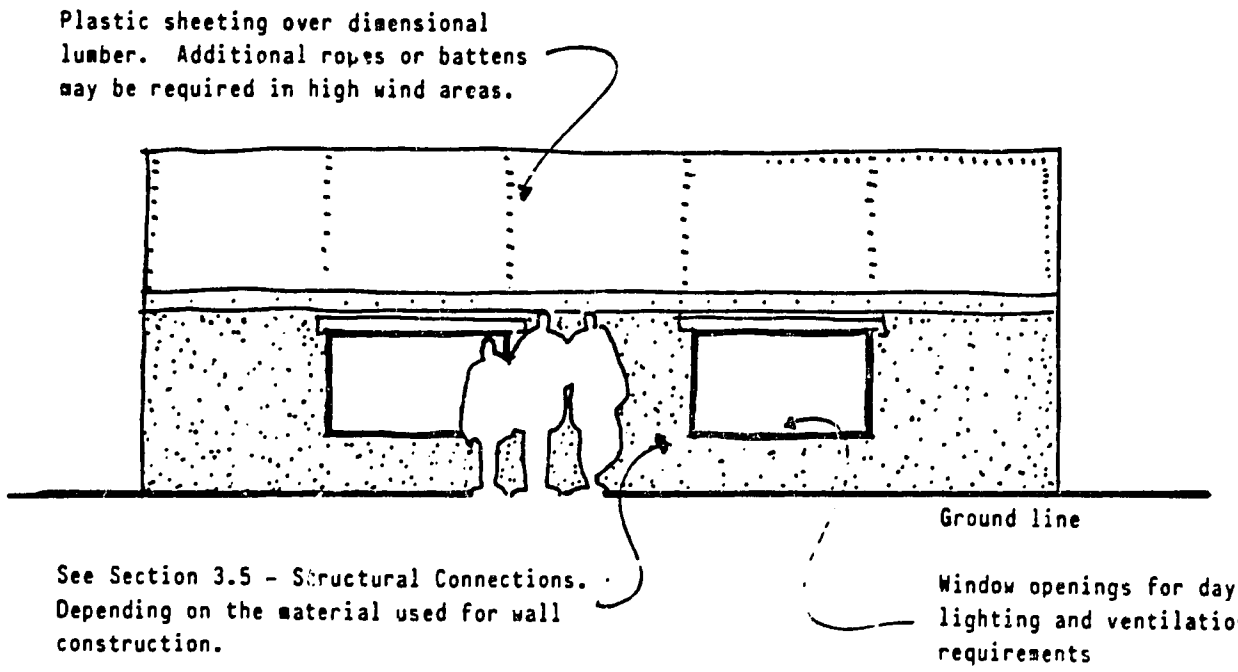


8. A single piece of sheeting (7.9 meters x 10 meters) should cover the roof. Roll the sheeting up and start at the ridge line working down to the eave line. Use battens at the edge of the roof to secure the sheeting.

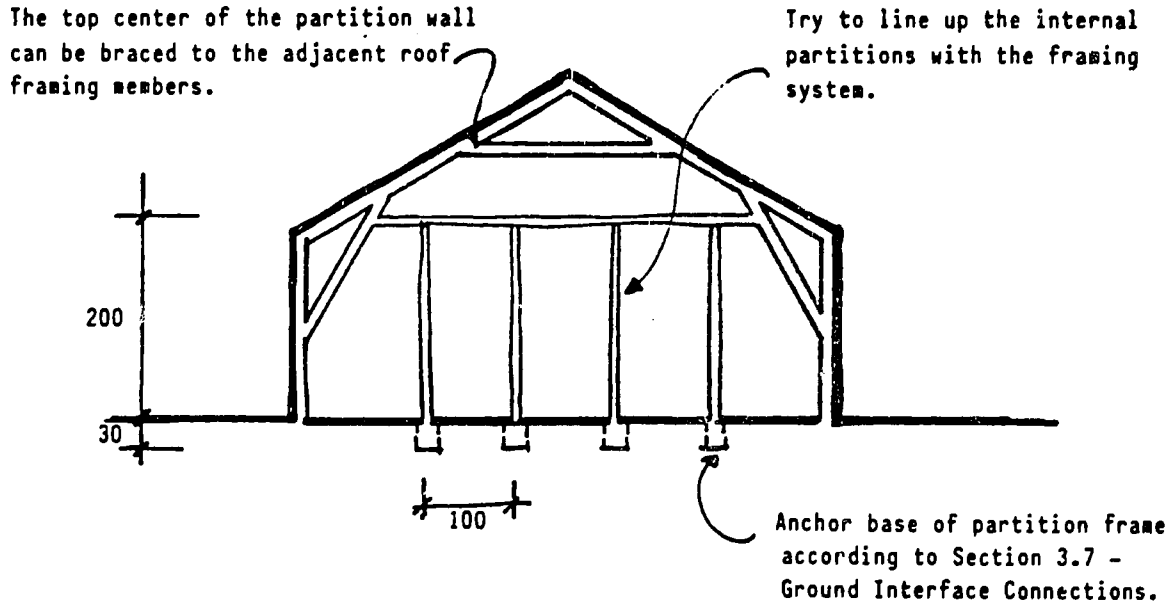


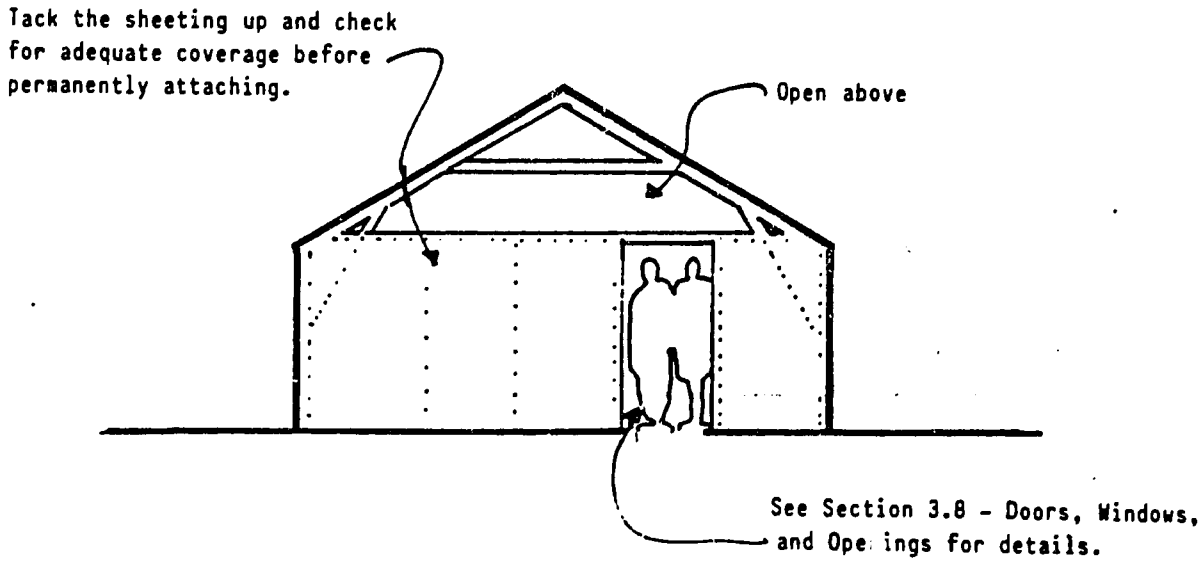
WRAP AROUND FRAME	No.
ELECTIVES	3.34 - 4



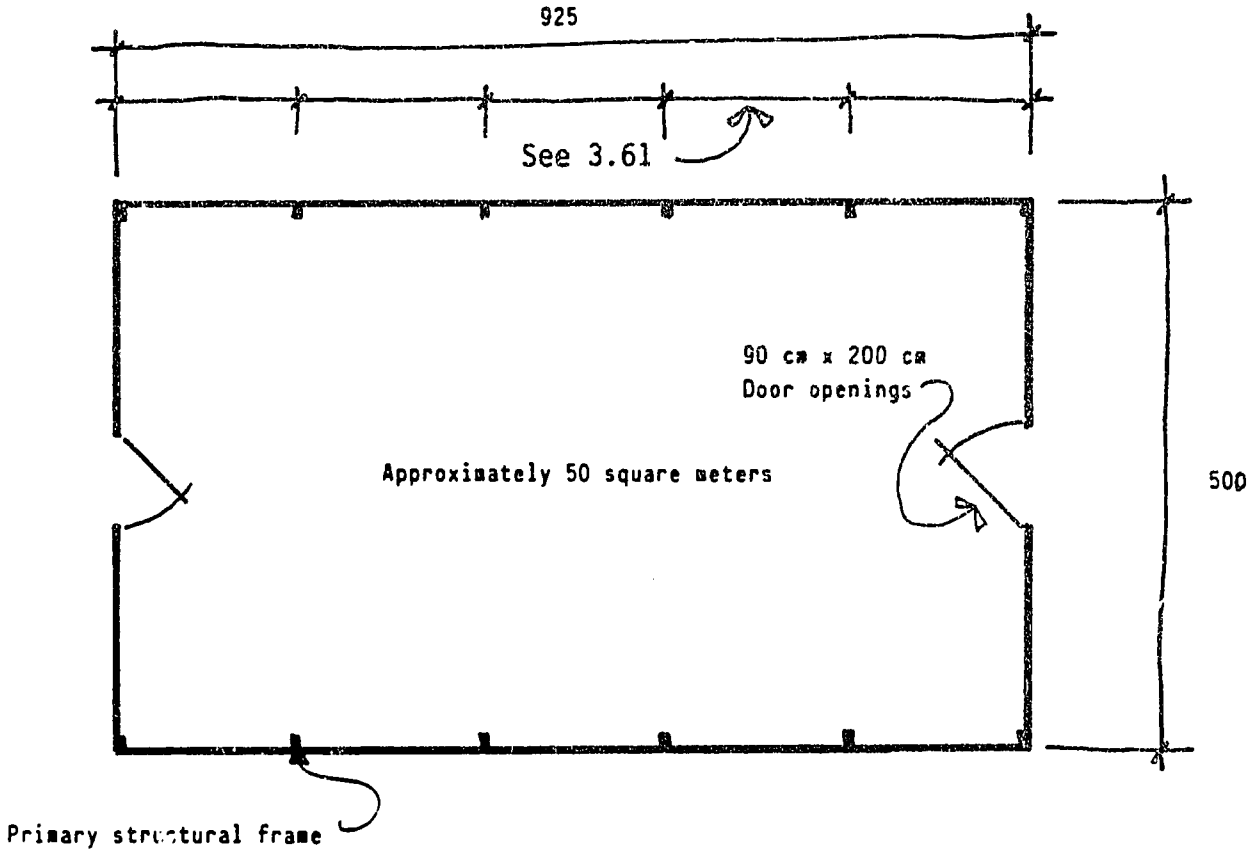


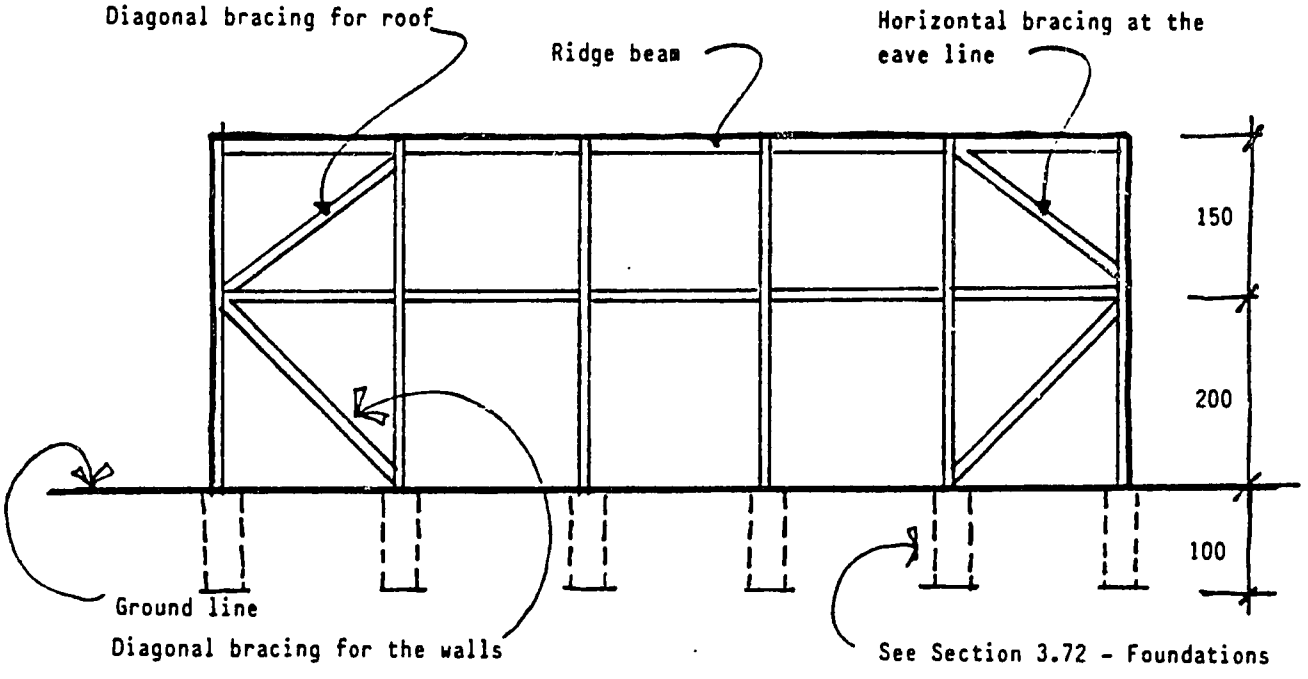
WRAP AROUND FRAME	No.
PARTITION FRAME	3.34 - 5





WRAP AROUND FRAME	No.
FRAMING PLAN AND ELEVATIONS	3.34 - 6

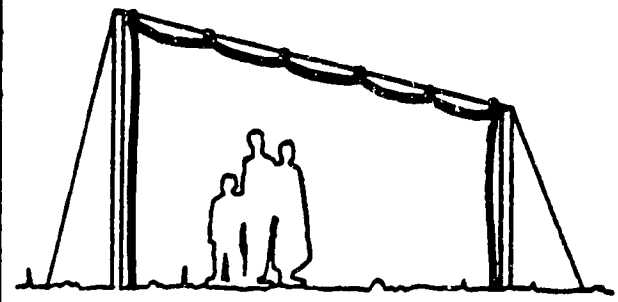




FRAME TYPE: HANGING TENT SHED	No. 3.35 - 1
DRAWING: PERSPECTIVE SKETCH	

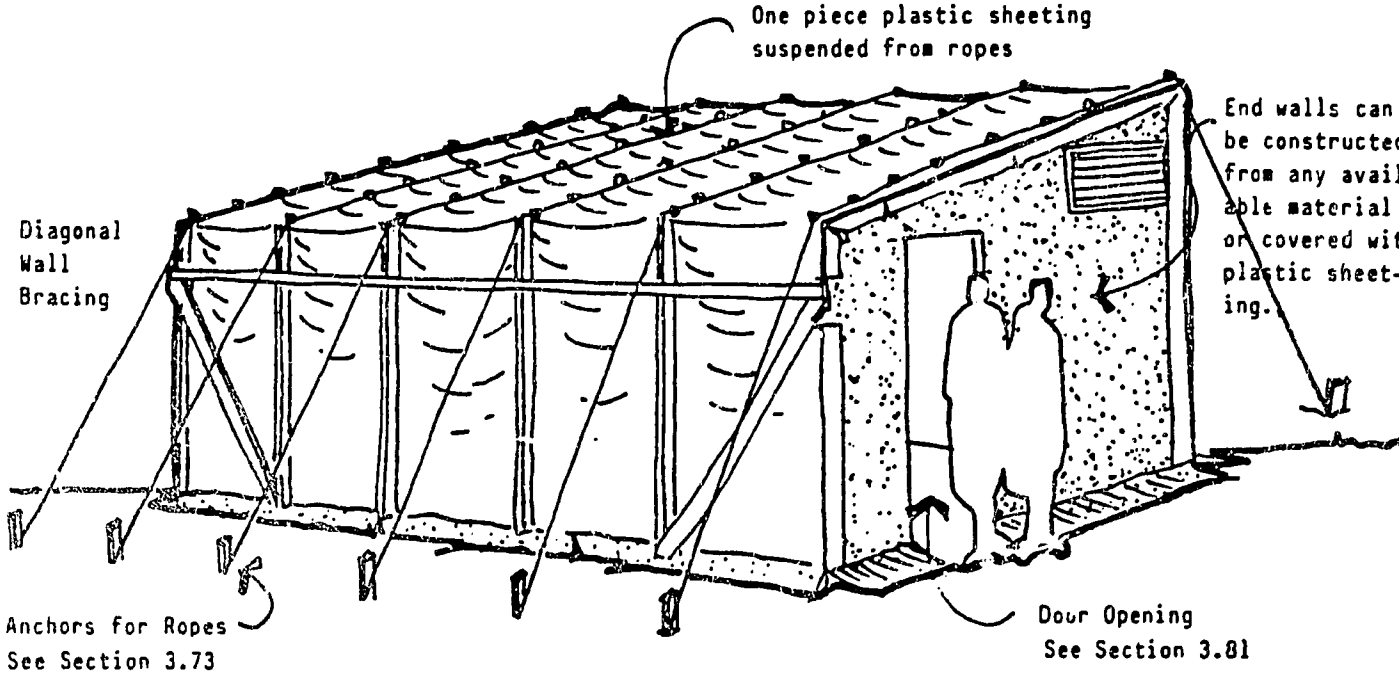
SEISMIC	●
HIGH WIND	○
FLOOD	◑

FRAME MATERIALS
Dimensional Lumber
Bamboo
Poles
Pipe
Rope



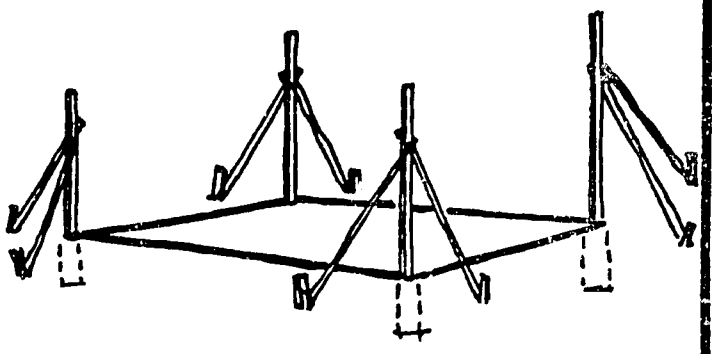
REFERENCE DETAILS

3.52	3.67
3.53	3.7
3.54	3.8
3.55	
3.61	
3.62	
3.64	
3.65	
3.66	

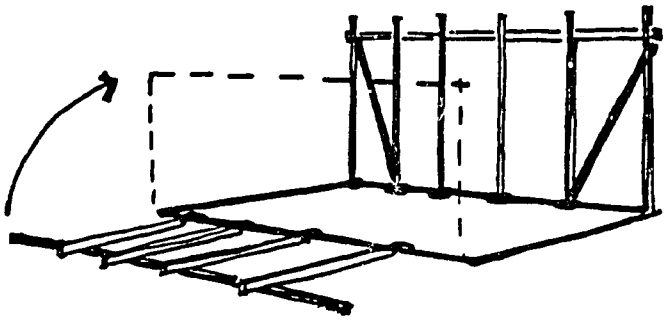


HANGING TENT SHED	No.
ERECTION SEQUENCE	3.35 - 2

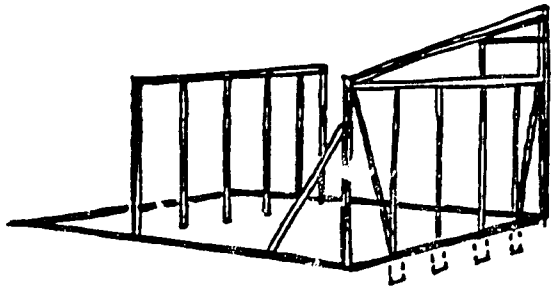
1. Lay out the building site and prepare foundations for each frame according to the guidelines listed in Section 3.7. Set the four corner posts first, bracing in both directions.



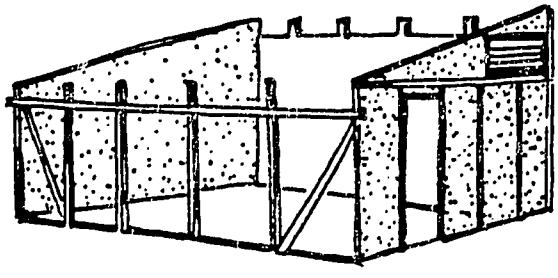
2. Fabricate the remaining posts on the ground and tip them into place. After the walls are up and have been checked for levelness, add diagonal bracing.



3. Lay out the internal partitions and construct the end walls and partitions. If plastic sheeting is used for the end walls and partitions, common framing techniques can be followed.

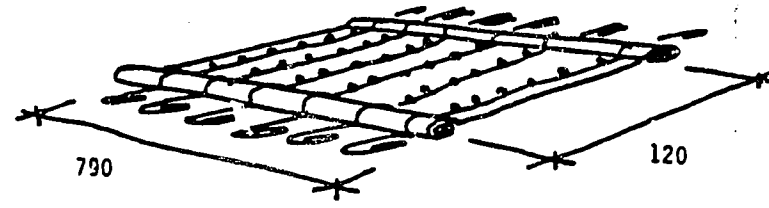


4. Locate door, window, and vent openings before covering the end wall frame. Tack the sheeting in place and check for coverage before fastening it permanently.

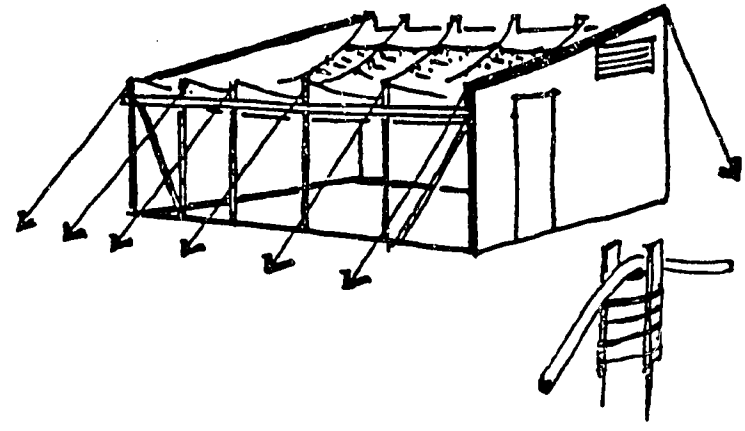


HANGING TENT SHED	No.
ERECTION SEQUENCE	3.35 - 3

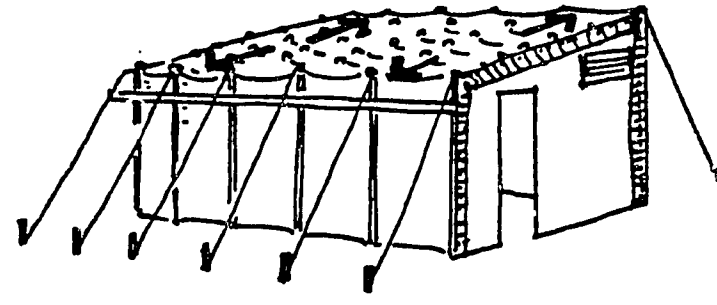
5. Lay out a piece of sheeting 7.9 meters x 12 meters. Fasteners to connect the sheeting to the ropes must be constructed. (See Section 3.67.) After the connectors are in place, cut and attach 15 meter ropes to the fabric.



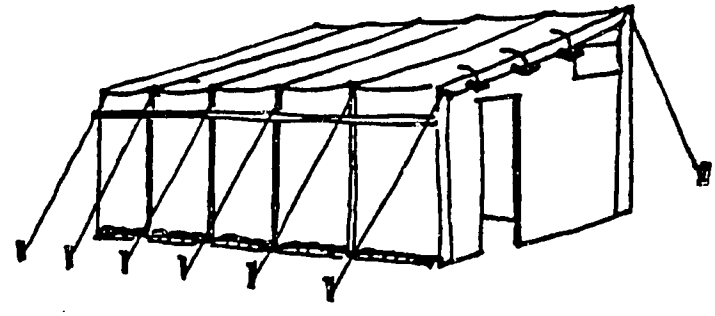
6. Place the sheeting and ropes inside the structure and loop the ropes over the top of each post. Then, pulling the ropes from both sides, evenly raise the sheeting and secure the ends of the ropes.



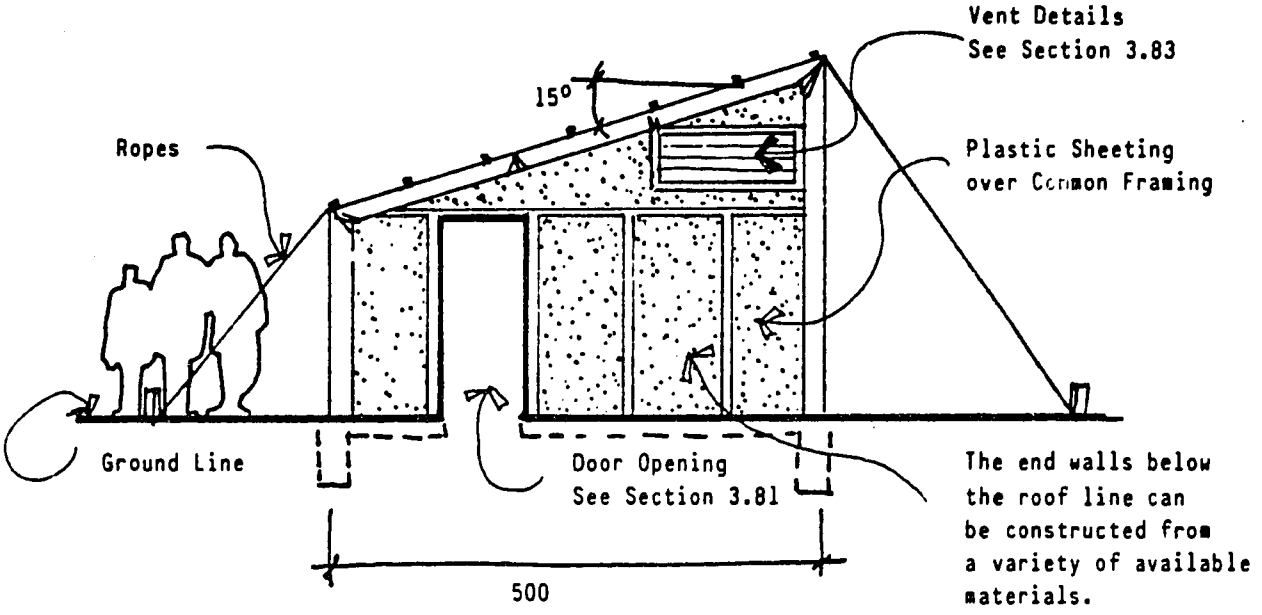
7. With a short length of rope tied to the top of each post, pull the fabric as tight as possible. The fabric for the side walls will be hanging straight down and will need to be attached to the post with battens.

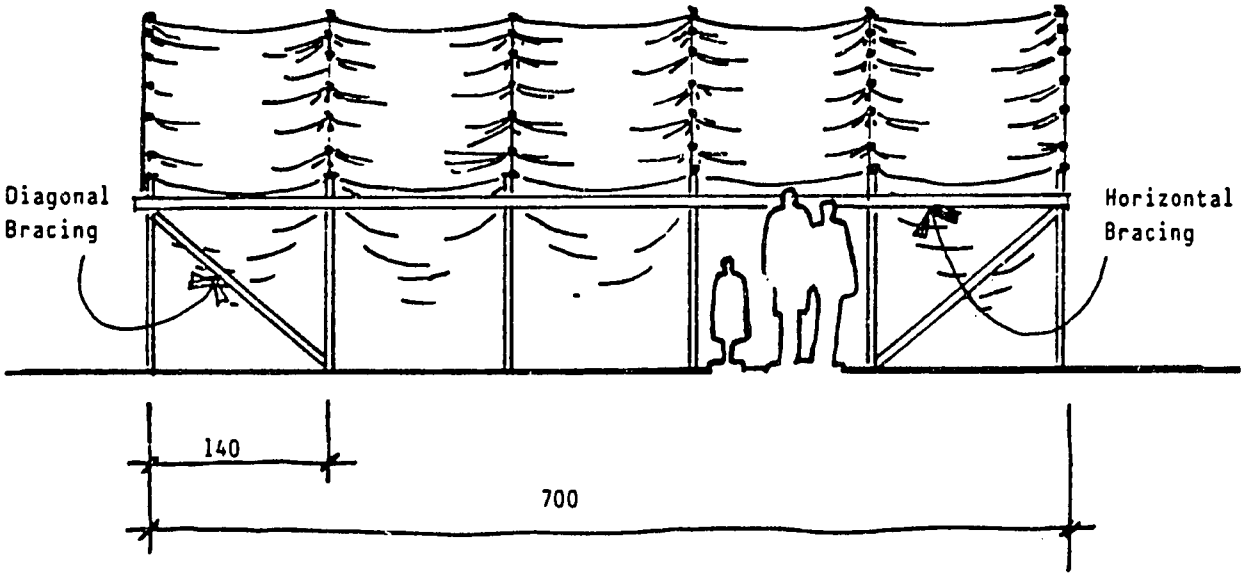


8. Pull 20 - 30 cm of sheeting over the top of the end walls and secure it with battens. Use soil to build up a berm around the base of the structure so as to secure the bottom of the sheeting.

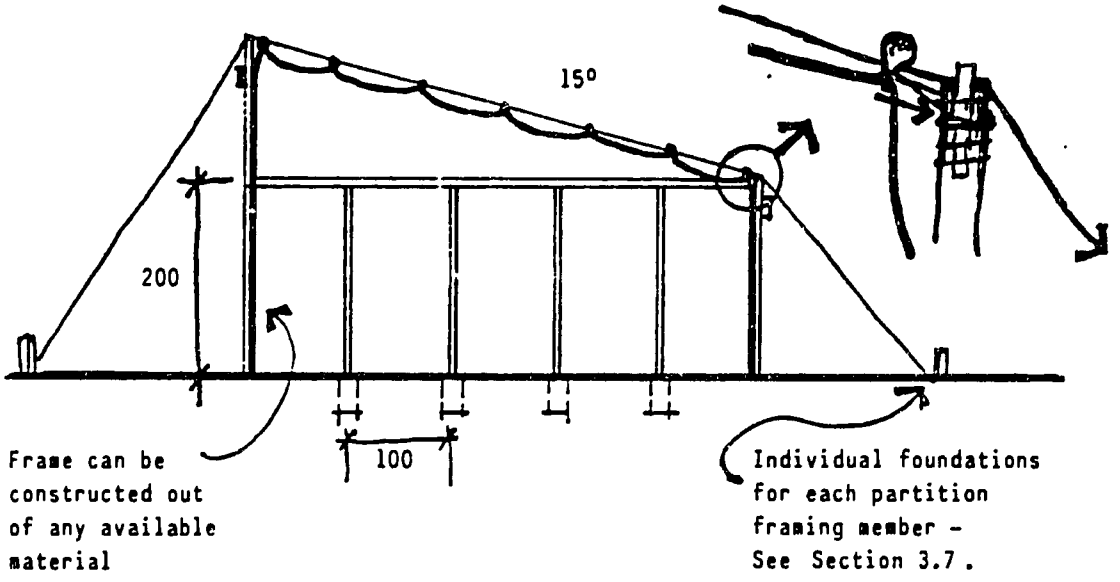


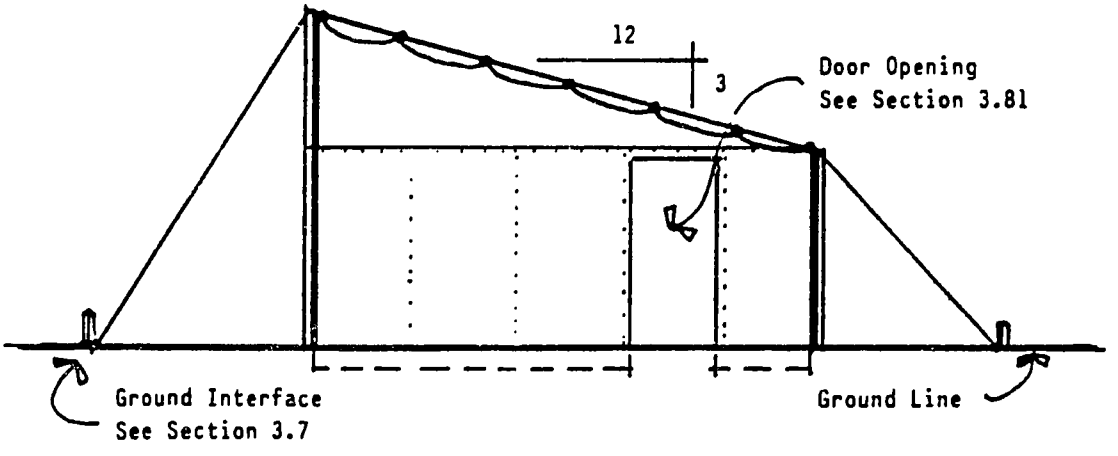
HANGING TENT SHED	No.
ELEVATIONS	3.35 - 4



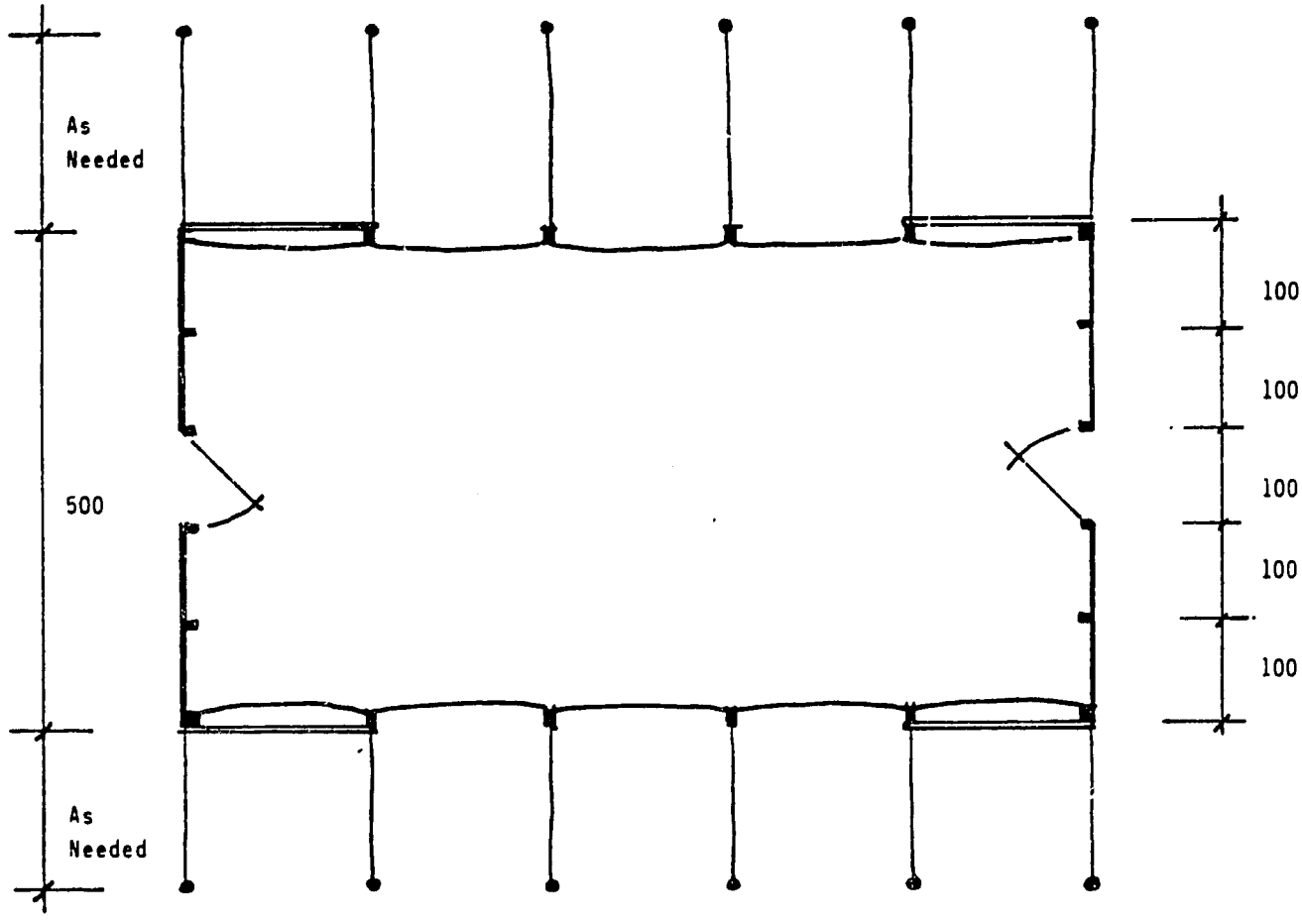


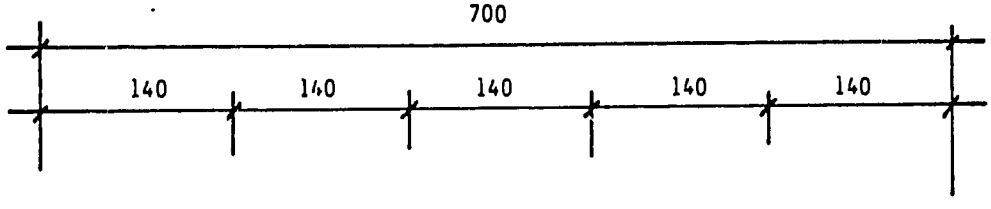
HANGING TENT SHED	No.
PARTITION FRAME	3.35 - 5

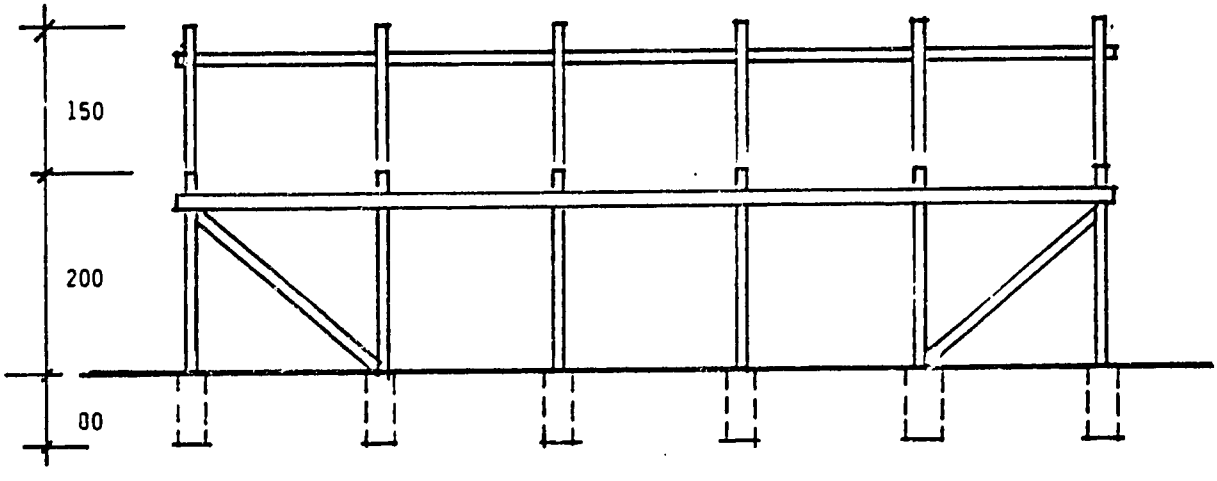




HANGING TENT SHED	No.
FRAMING PLAN AND ELEVATION	3.35 - 6





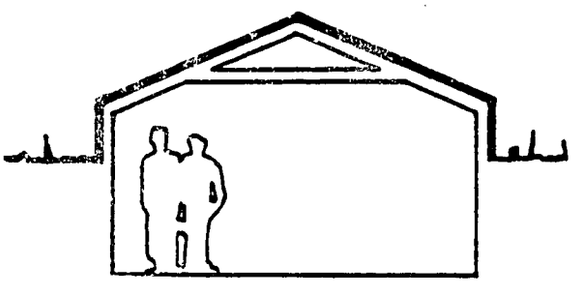


FRAME TYPE: DUGOUT	No. 3.36 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	◐
HIGH WIND	●
FLOOD	○

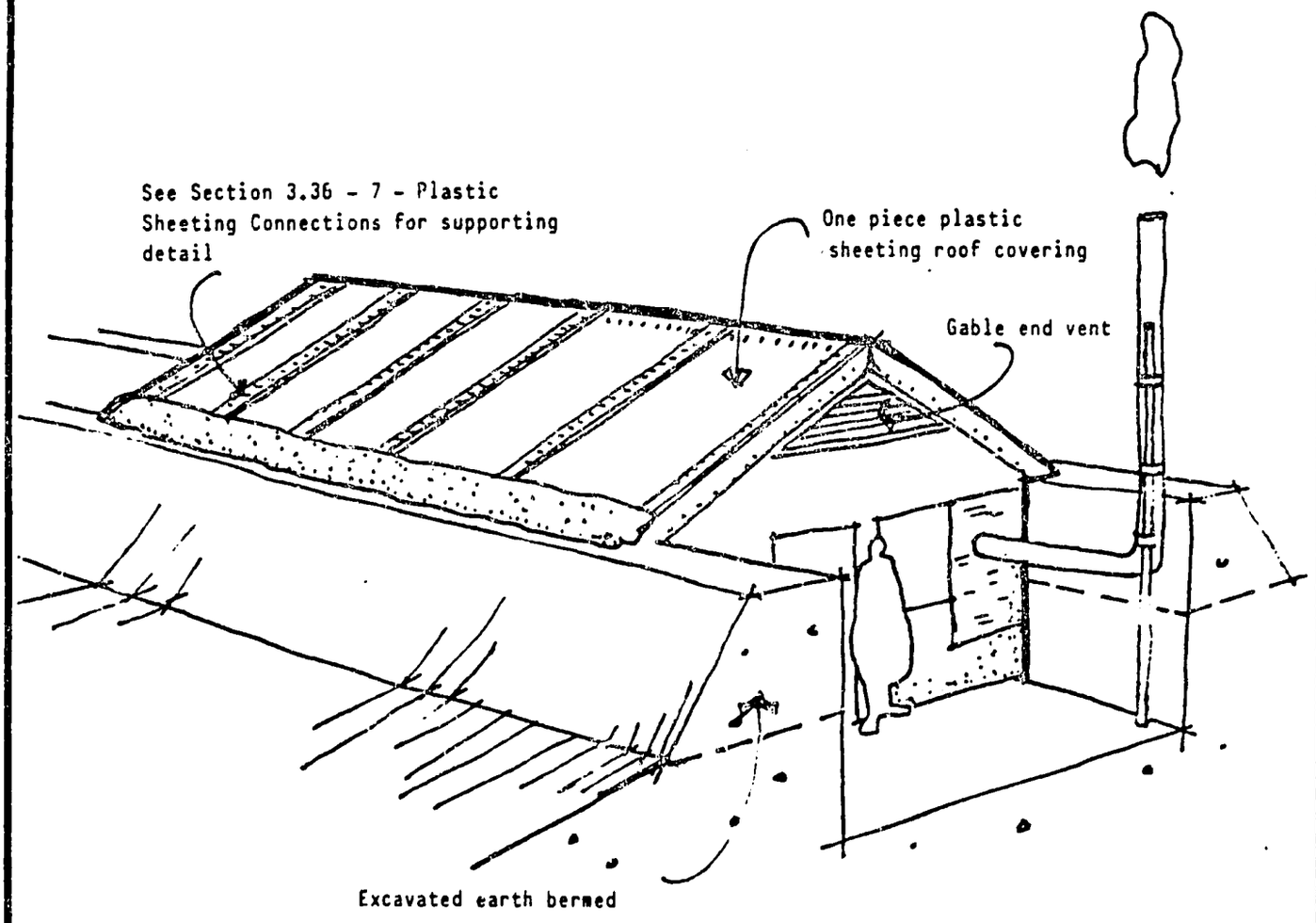
FRAME MATERIALS

Dimensional Lumber
Bamboo



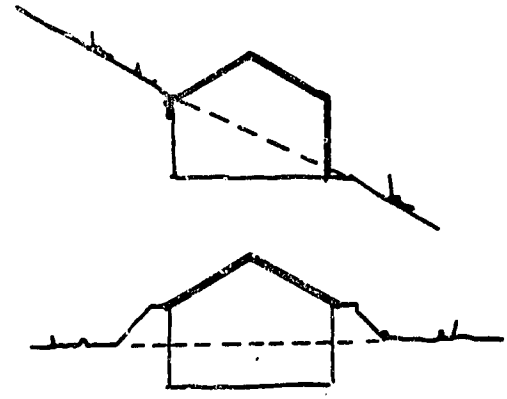
REFERENCE DETAILS

3.52	3.71
3.53	3.8
3.54	
3.61	
3.62	
3.64	
3.65	
3.66	

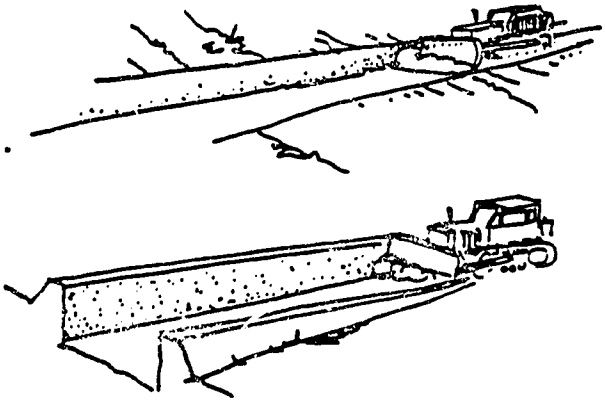


DUGOUT	No.
ERECTION SEQUENCE	3.36 - 2

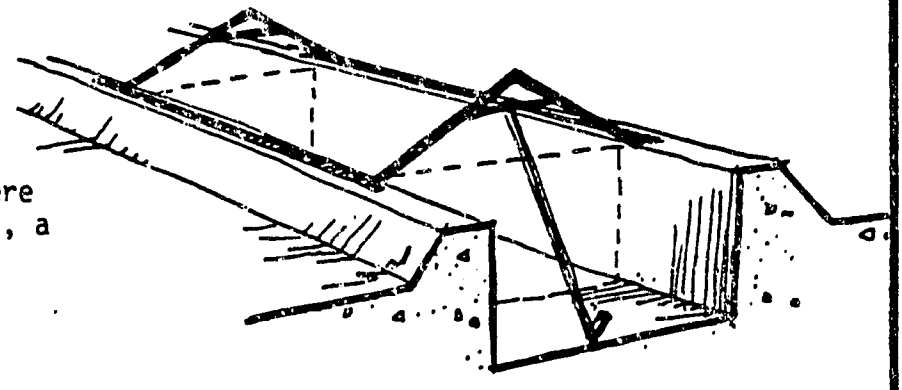
1. The Dugout may be cut into the side of a hill if there is no seismic, landslide, avalanche or other danger associated with the slope. Level ground is preferable in areas with danger.



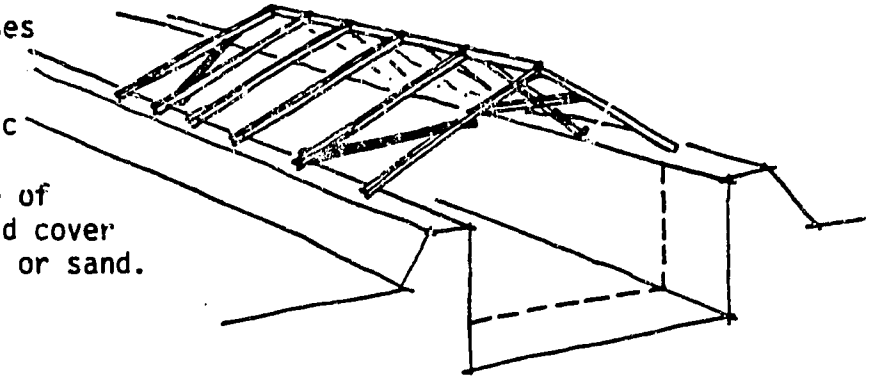
2. If a bulldozer is available, the trench can be quickly formed. Digging with shovels would be also possible. CAUTION: The inside walls must be angled or braced to prevent cave-ins. In sandy or wet soil 45° may be necessary. Clays allow a steeper angle. If there is any concern, make the walls 45°. In earthquake areas, use 45° in any soil.



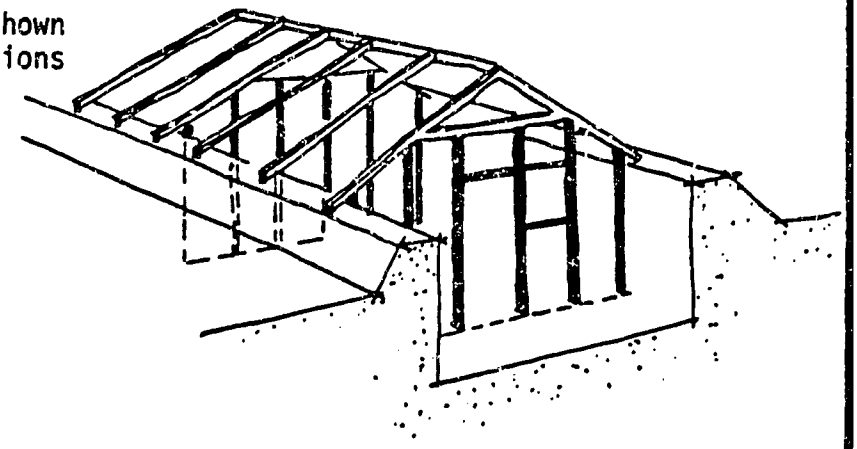
3. Erect and brace the end as shown at right. (See 3.36 - 7 - Plastic Sheeting Connections for supporting details.) Where the spans exceed 5 meters, a center pole is necessary.



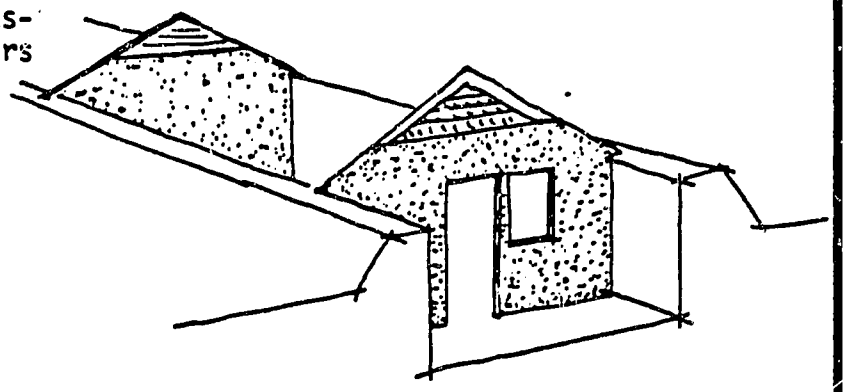
4. Fill in the interior trusses and secure permanent bracing as shown at right. (See Section 3.61 - Plastic Sheeting Connections for spacing.) Line the inside of the trench with plastic and cover the floor with packed soil or sand.



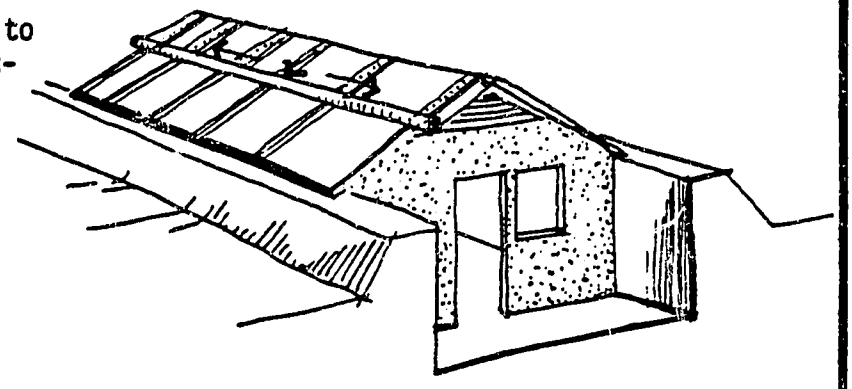
5. Frame in the end walls as shown at right. Erect any partitions required making sure they line up with a roof truss.



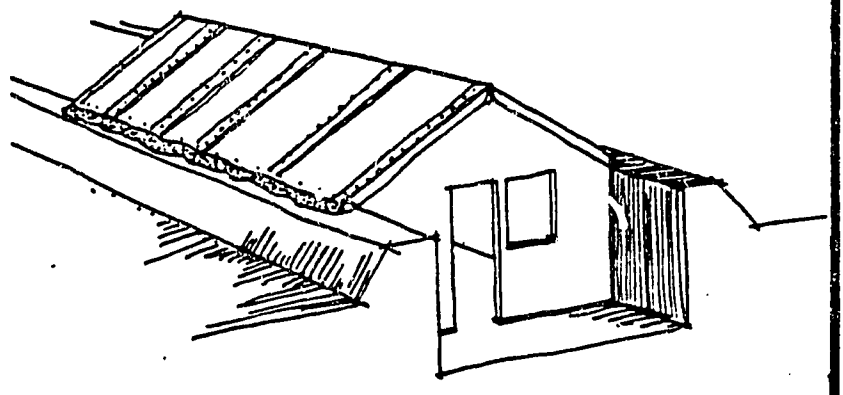
6. Cover the end walls with plastic sheeting and cut out doors and windows. (See Section 3.8 - Windows, Doors, and Openings.)



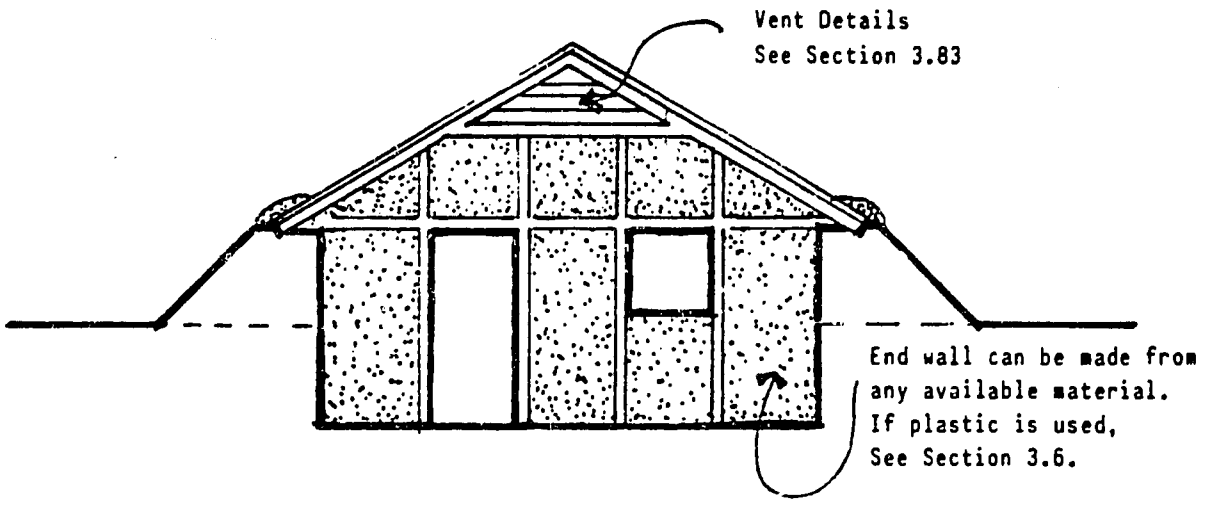
7. Secure the plastic sheeting to the roof using batten connections. (See Section 3.27 - 8 & 9 - Design Information.)

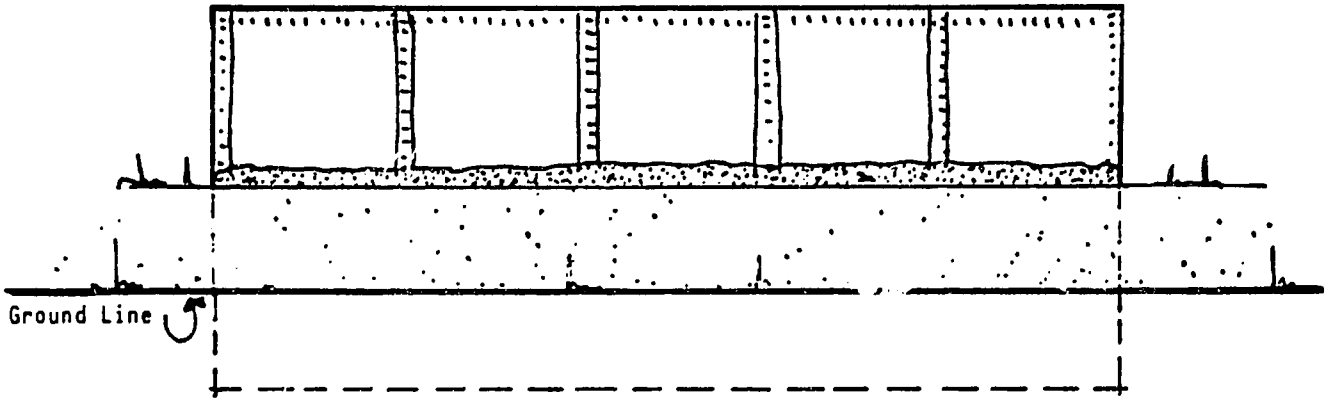


8. Secure the plastic of the eaves using the continuous interface shown in Section 3.71 - Ground Interface Connections.

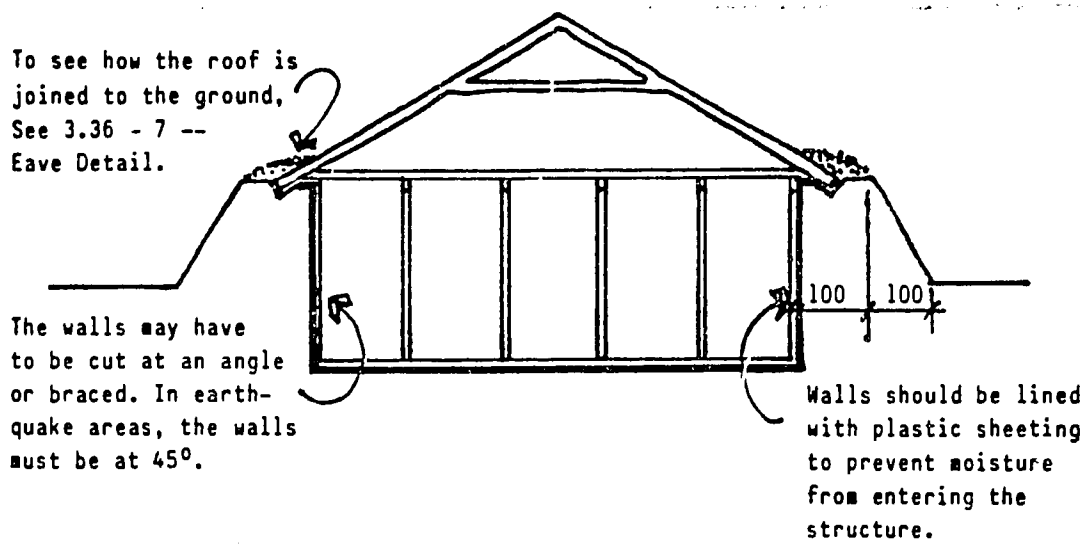


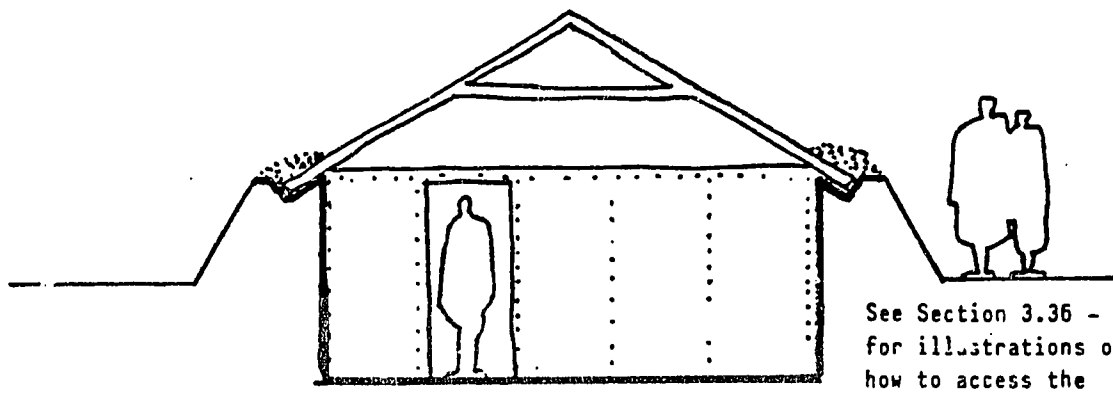
DUGOUT	No.
ELEVATIONS	3.36 - 4





DUGOUT	No.
PARTITION FRAME	3.36 - 5

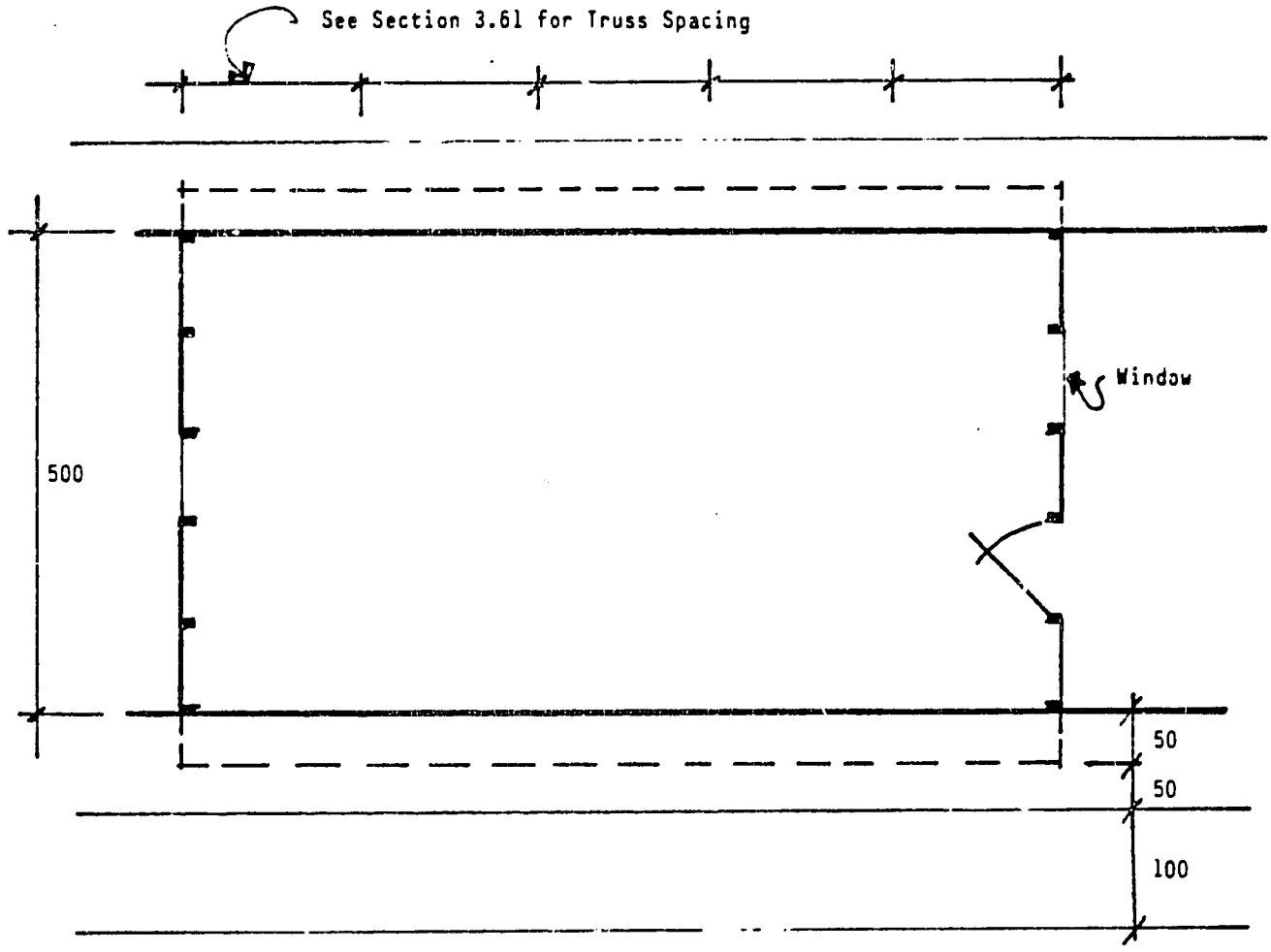


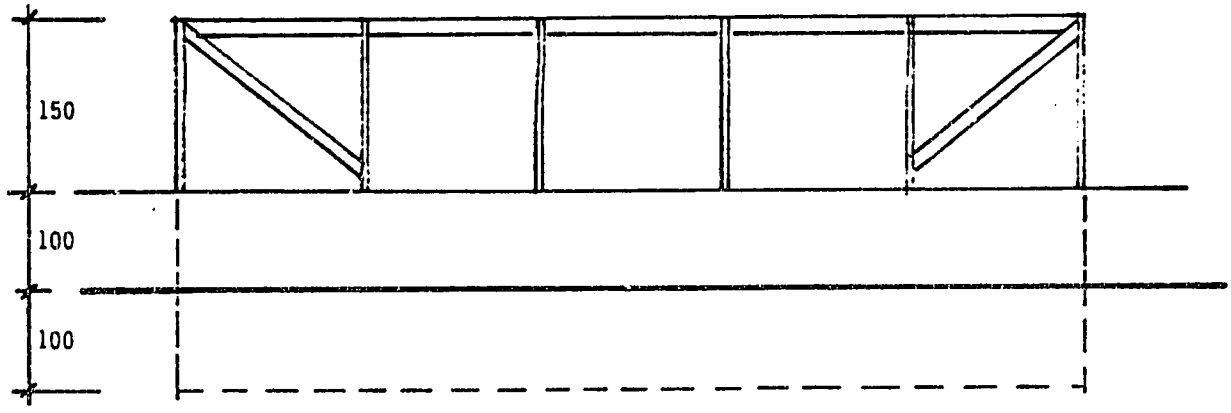


See Section 3.36 - 8 for illustrations on how to access the building.

156

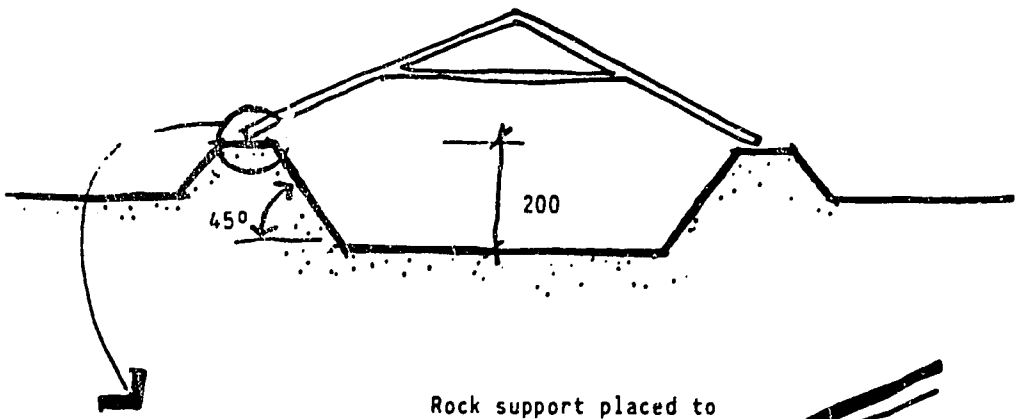
DUGOUT	No.
FRAMING PLAN AND ELEVATION	3.36 - 6



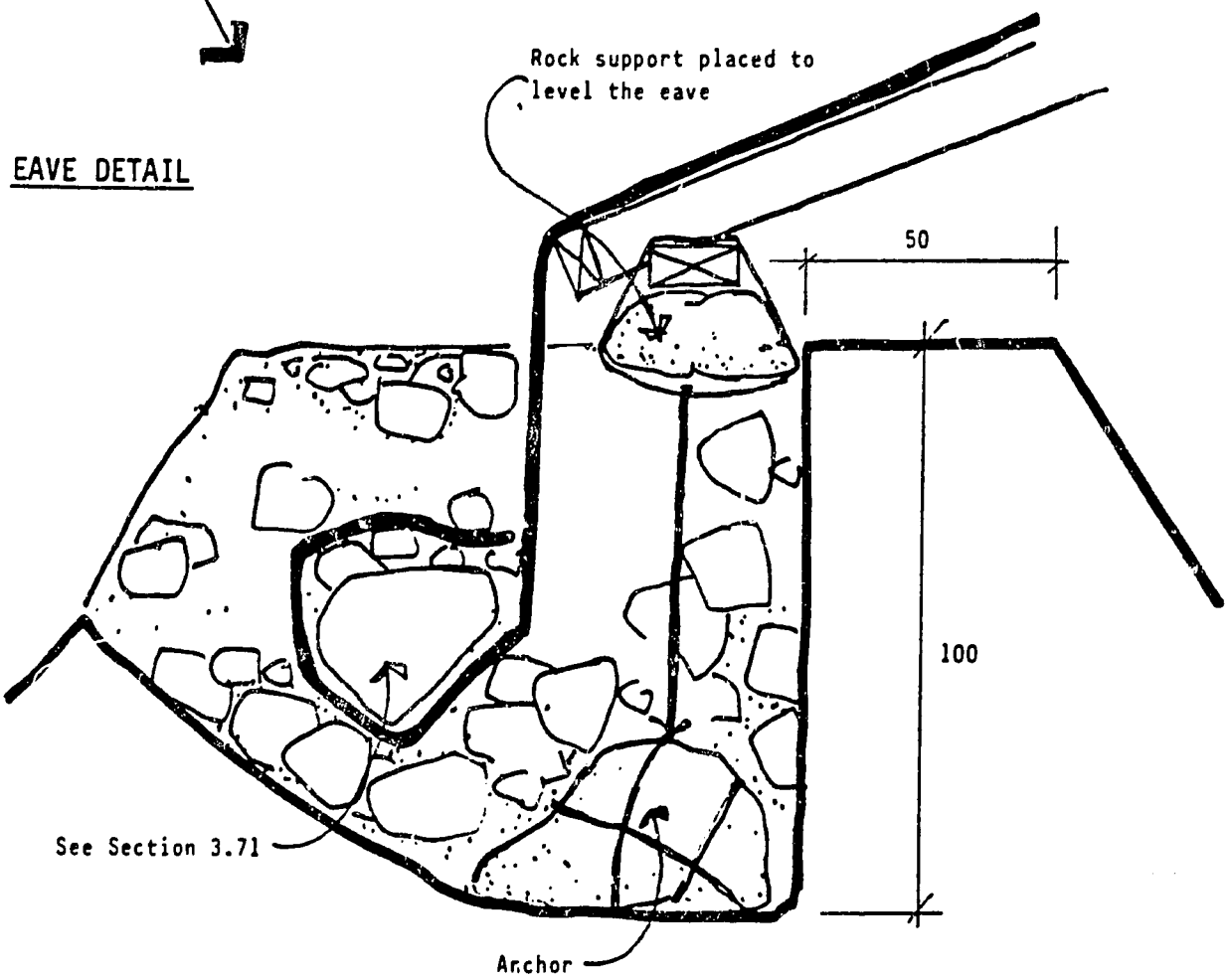


DUGOUT	No.
NOTES	3.36 - 7

CAUTION: In areas with seismic risk, the walls of the Dugout must be sloped at a 45° angle.

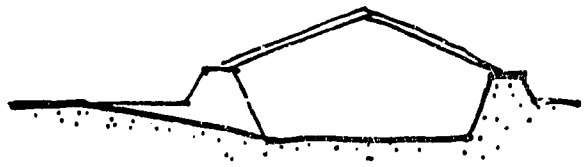


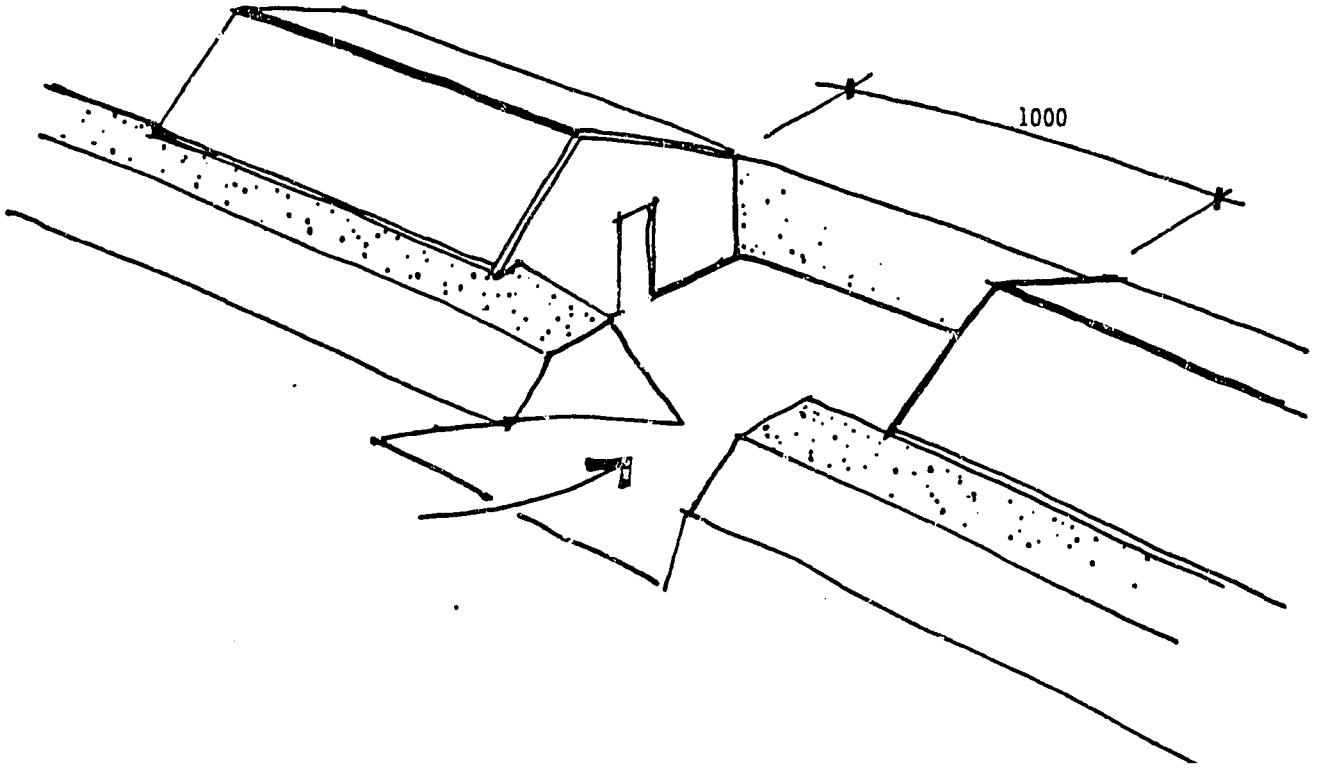
EAVE DETAIL



DUGOUT	No.
NOTES	3.36 - 8

If more than one structure is placed in a trench, access between the structures is required. Ramp down through one side of the trench.

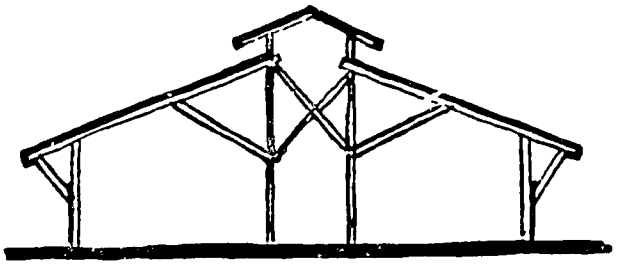




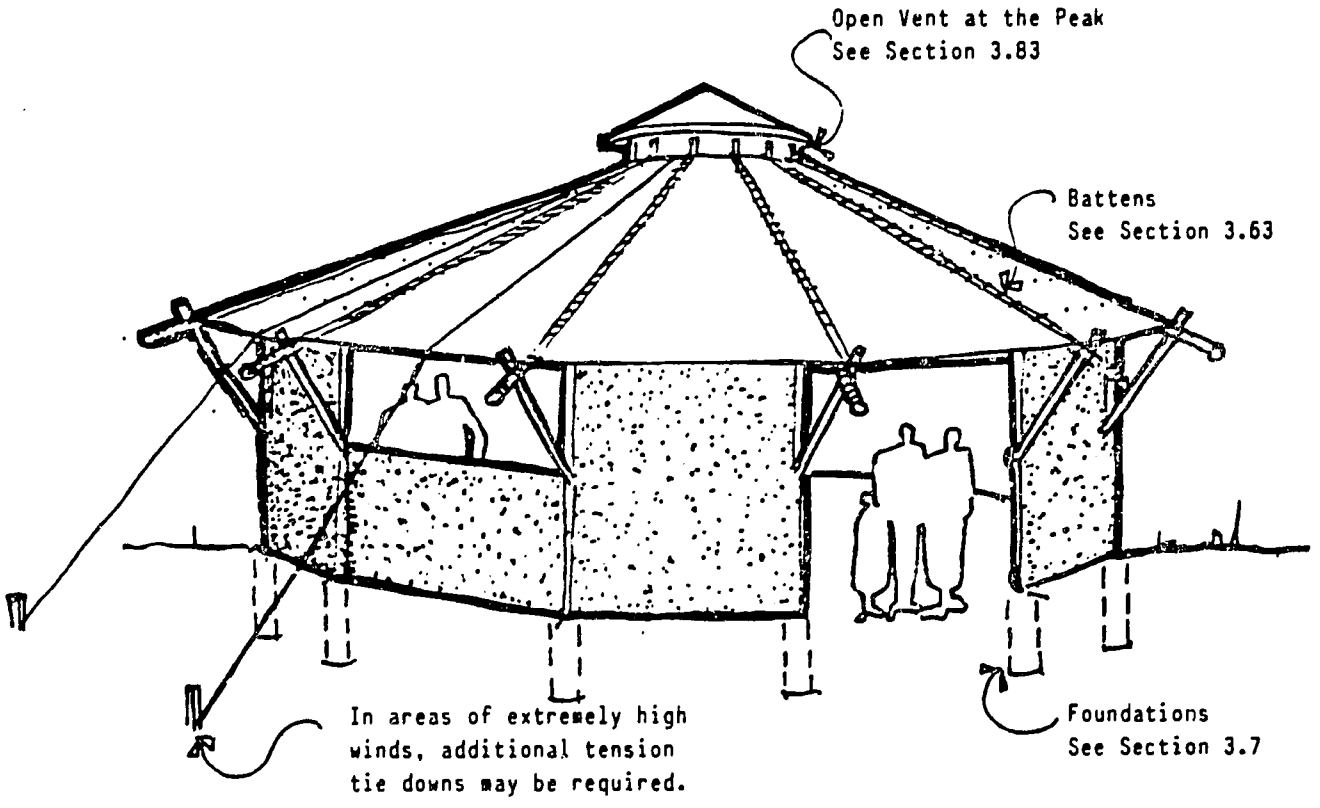
FRAME TYPE: CIRCULAR FRAME	No. 3.37 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	●
HIGH WIND	●
FLOOD	◑

FRAME MATERIALS
Dimensional Lumber
Bamboo
Poles



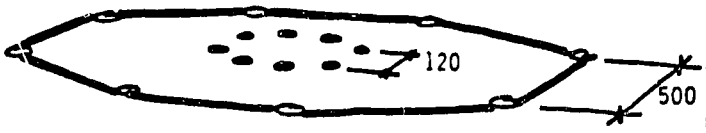
REFERENCE DETAILS
3.52
3.53
3.54
3.61
3.62
3.64
3.65
3.66
3.7
3.8



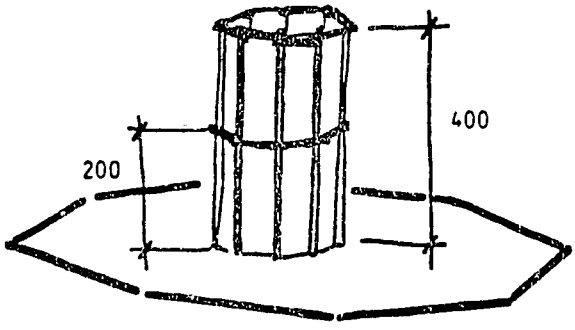
In some cases, because of cultural necessity or to resist high winds, a circular framing system can be used.

CIRCULAR FRAME	No.
ERECTION SEQUENCE	3.37 - 2

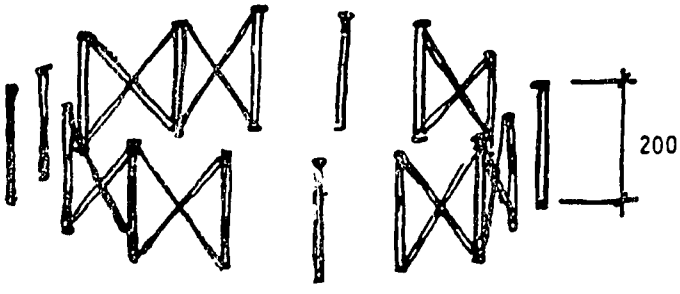
1. Lay out the building site and dig foundation holes according to the plan on 3.37 - 6.



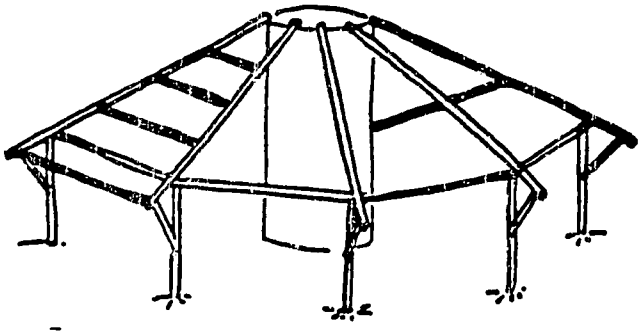
2. Set the center ring of poles first. Brace them temporarily and then tie them all together at the top and at a point two meters from the ground.



3. Set the outside ring of poles. (See Section 3.72 for details on post foundations.) To resist racking in the frame, diagonal wall bracing is needed. (See 3.37 - 6 for exact location.)

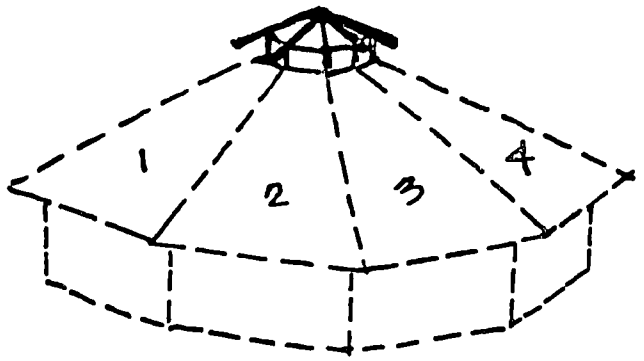


4. After the inner and outer posts are in place and braced, six meter poles are set up to span between them. The six meter timbers are braced at mid-span. (see Section 3.37 - 4 for details.)

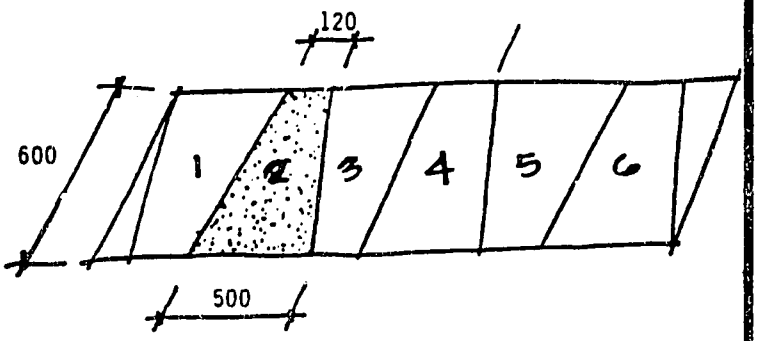


CIRCULAR FRAME	No. 3.37 - 3
ERECTION SEQUENCE	

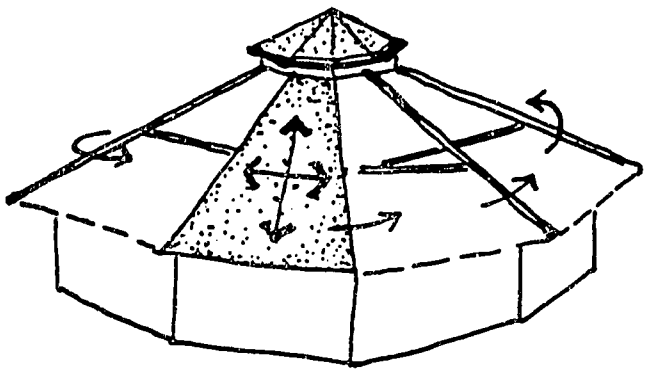
5. Frame in the vent at the peak.



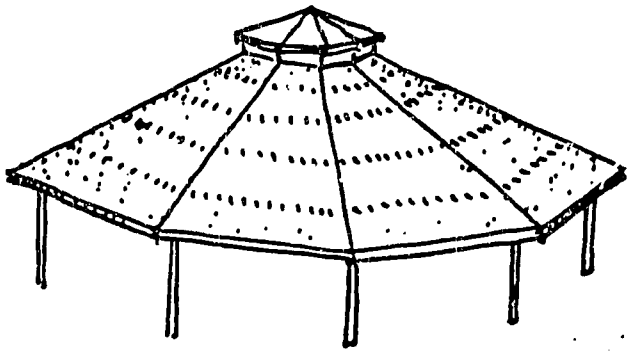
6. Lay out and cut sheeting to fit over each of the eight roofing areas according to the sketch at right.



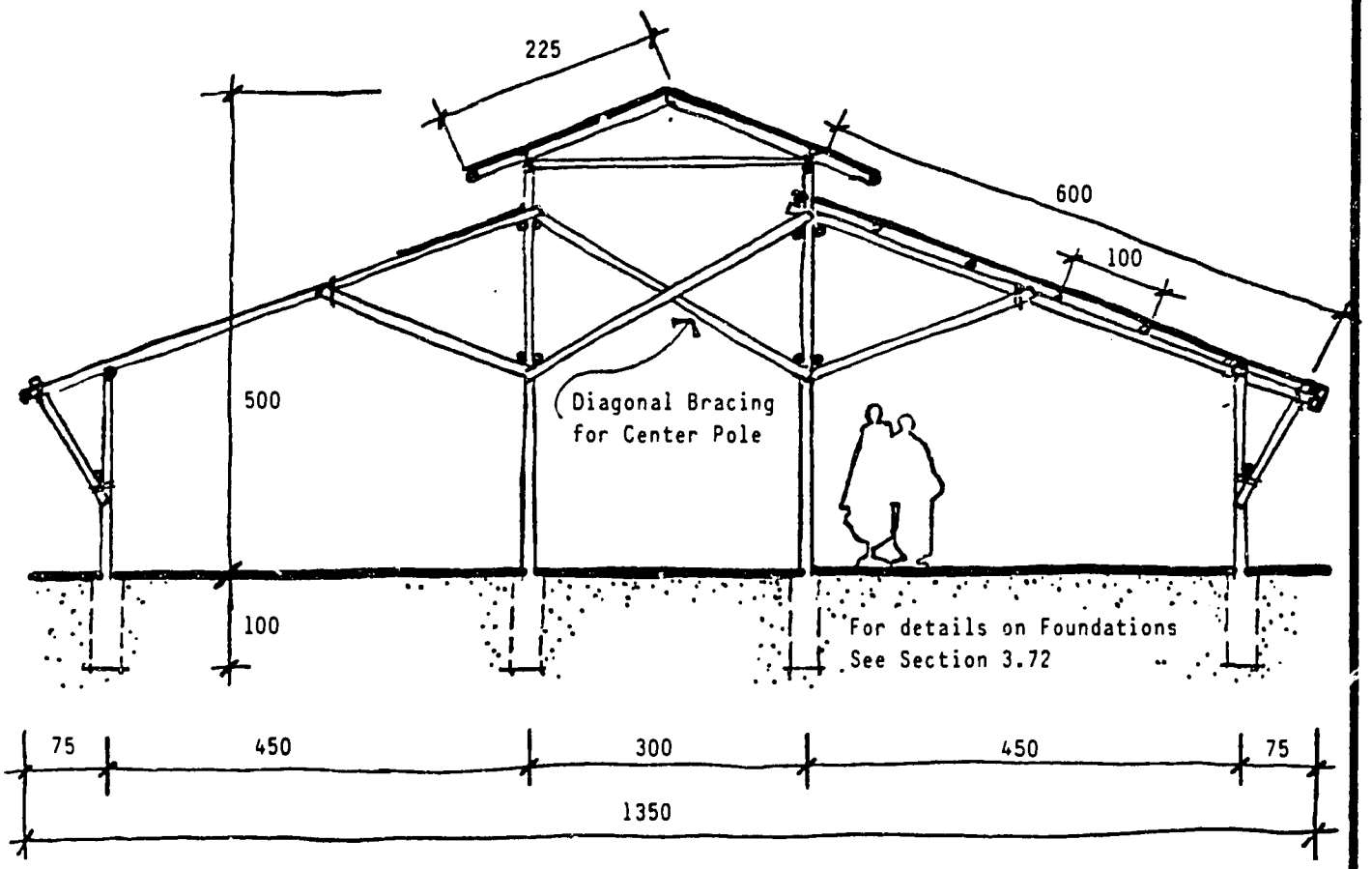
7. First cover the peak vent and then start with the lower roof. Tack the sheeting in place before nailing it permanently. Stretch the sheeting tightly

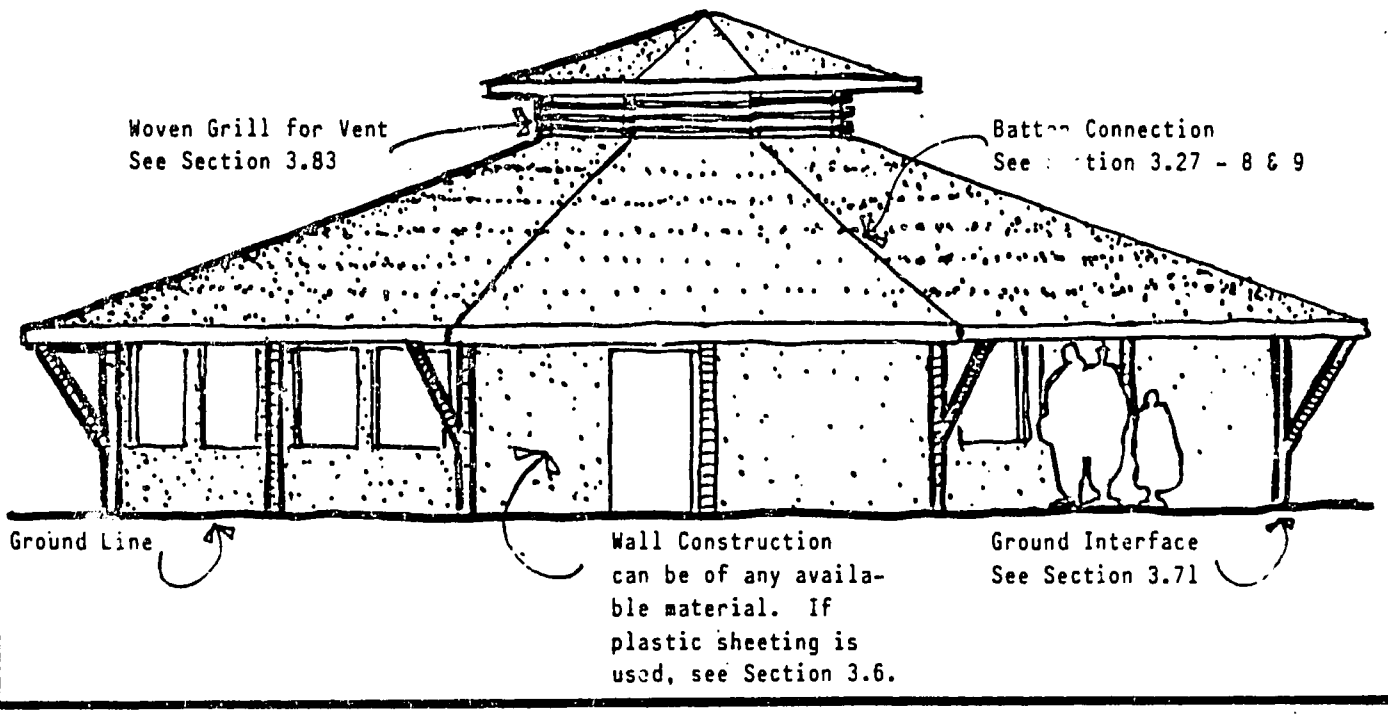


8. After the first segment is tacked in place, move around the roof and tack the remaining seven segments in place. Cover all seams with sealant and battens.

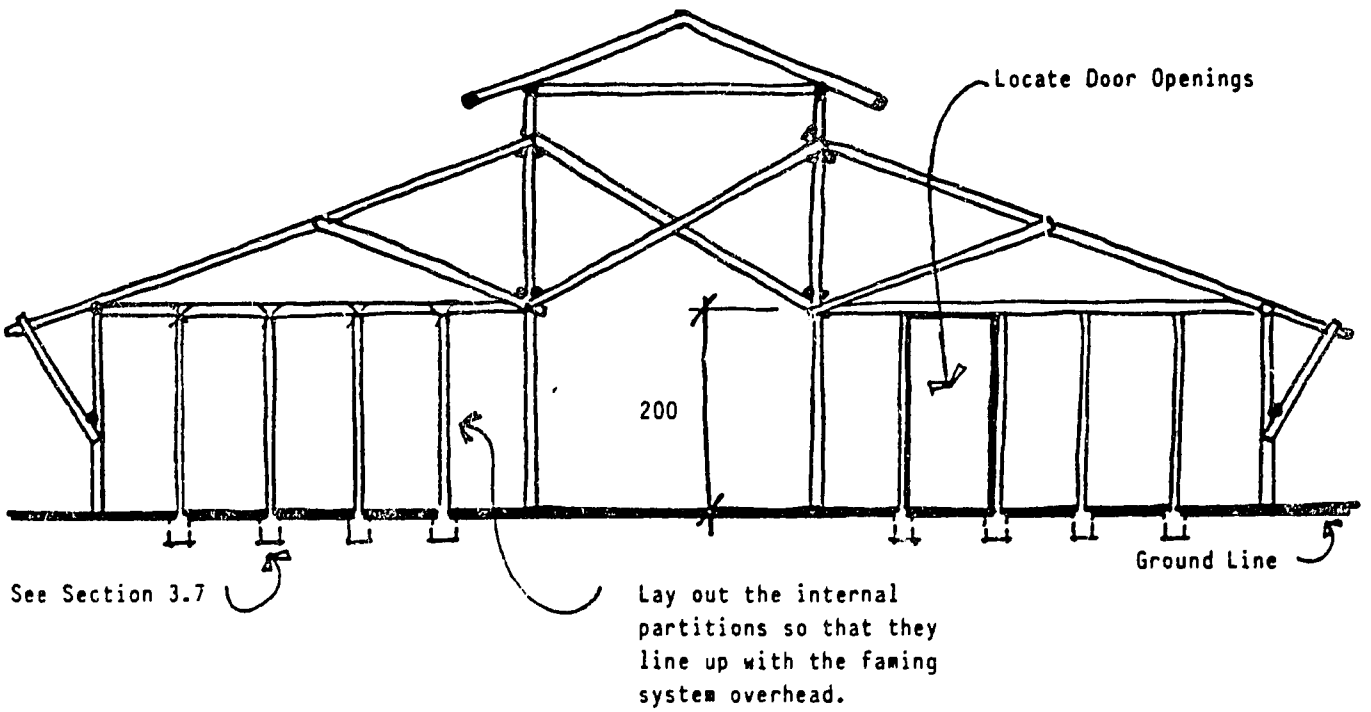


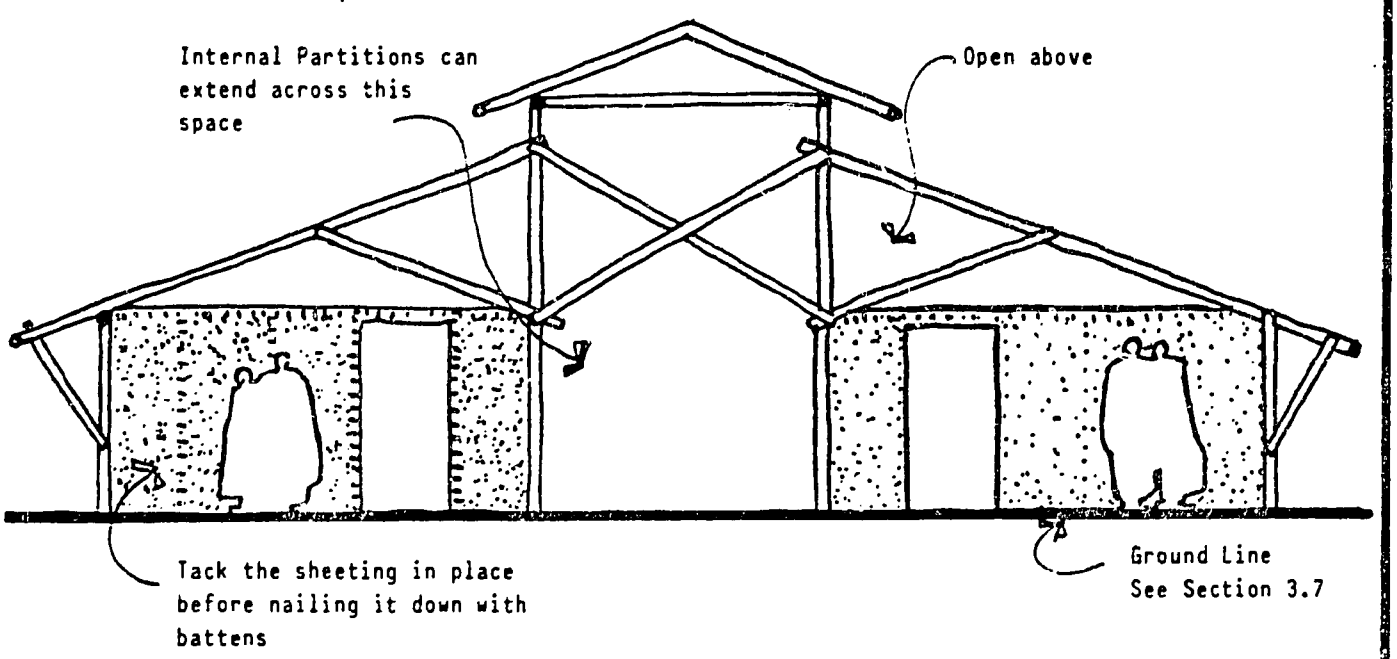
CIRCULAR FRAME	No.
SECTION AND ELEVATION	3.37 - 4



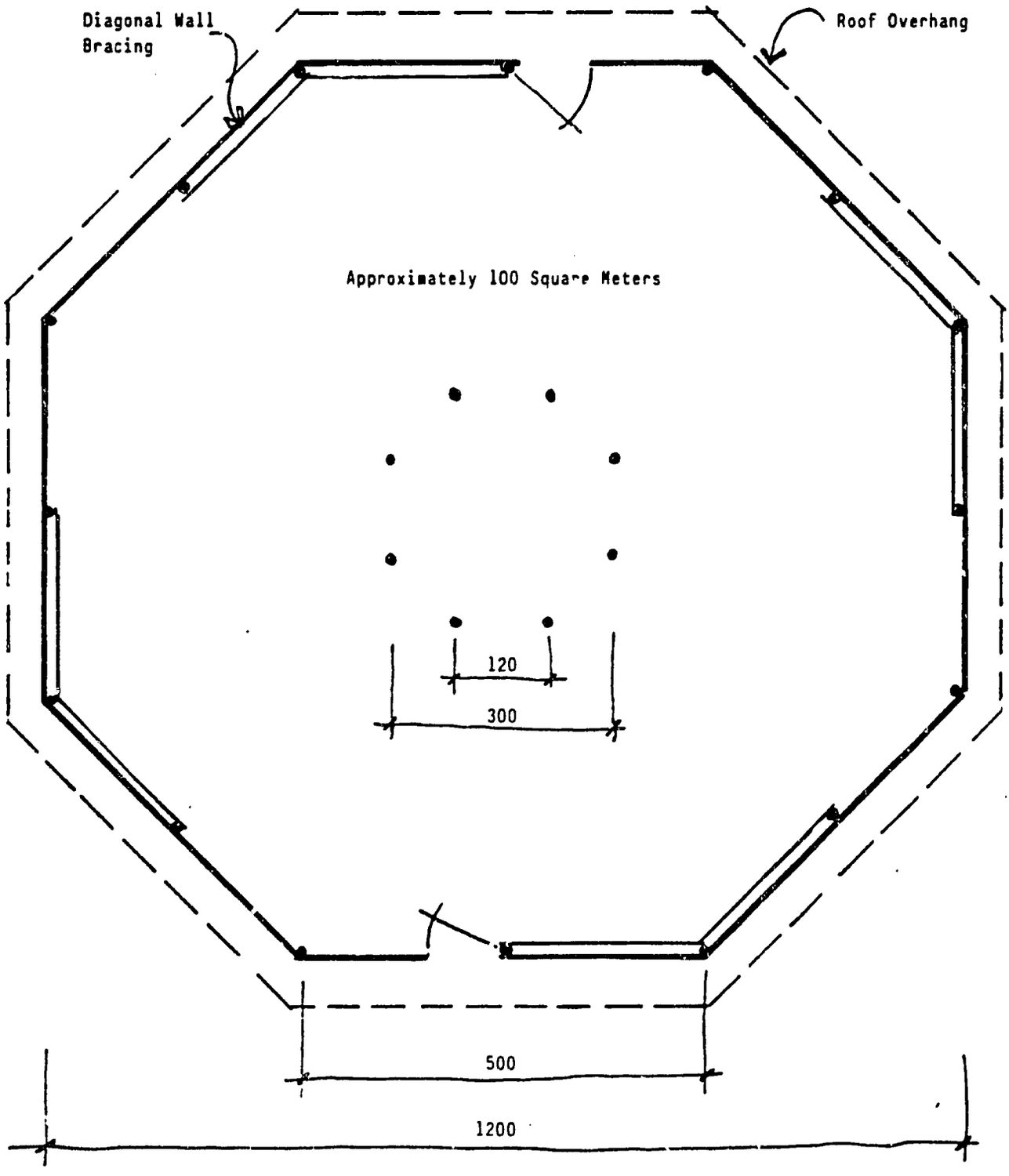


CIRCULAR FRAME	No.
PARTITION FRAME	3.37 - 5





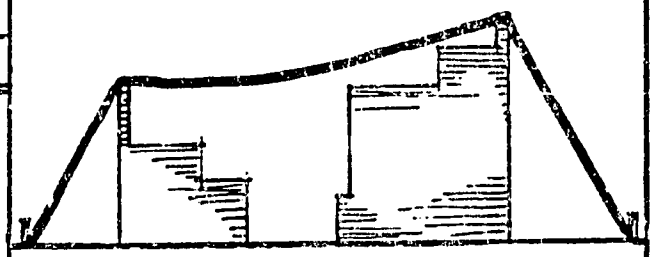
CIRCULAR FRAME	No.
PLAN	3.37 - 6



FRAME TYPE: RUBBLE WALL SHED	No. 3.38 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	○
HIGH WIND	◑
FLOOD	◑

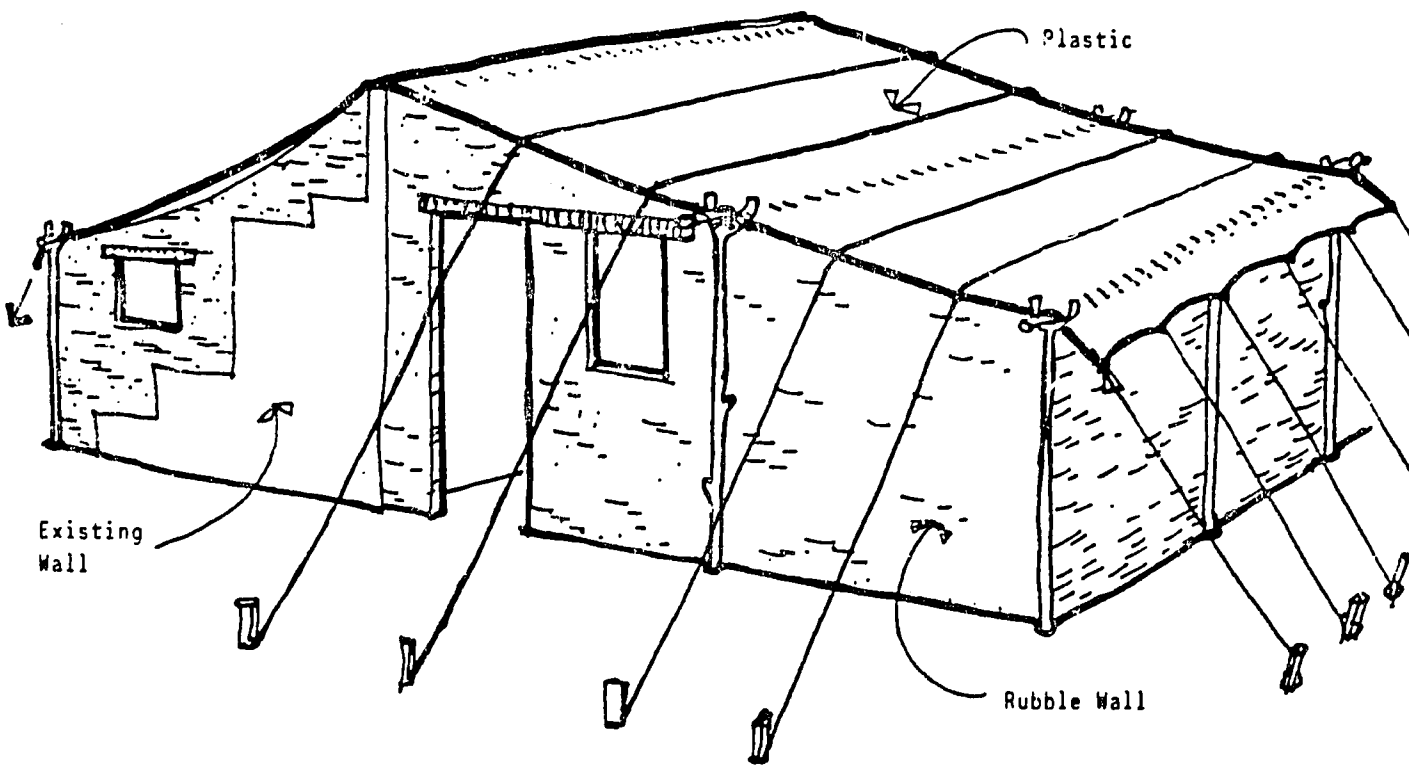
FRAME MATERIALS
Dimensional Lumber
Bamboo
Poles
Rope



REFERENCE DETAILS

3.52	3.72
3.53	3.73
3.54	3.8
3.55	
3.61	
3.62	
3.64	
3.65	
3.66	
3.67	

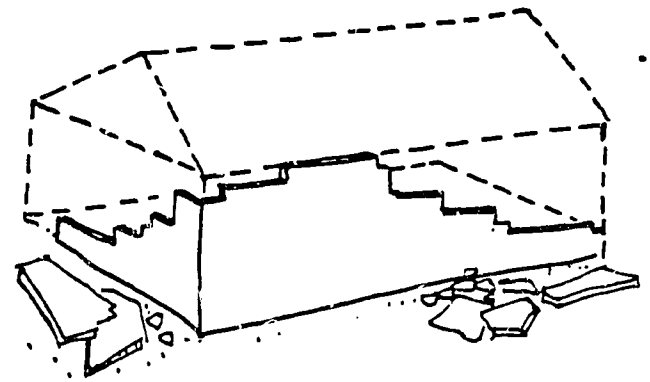
In some instances a significant portion of the building is destroyed, leaving only a few standing walls. These walls can be shored up structurally and used to support a light weight roofing system.



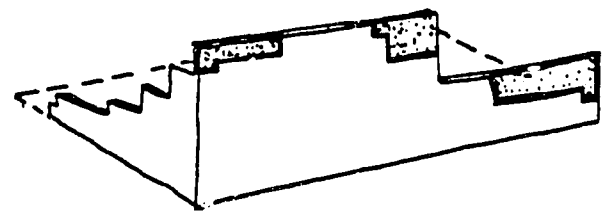
The solution could utilize an entire 790 x 3000 cm sheet of plastic, depending on the size of the damaged building.

RUBBLE WALL SHED	No. 3.38 - 2
ERECTION SEQUENCE	

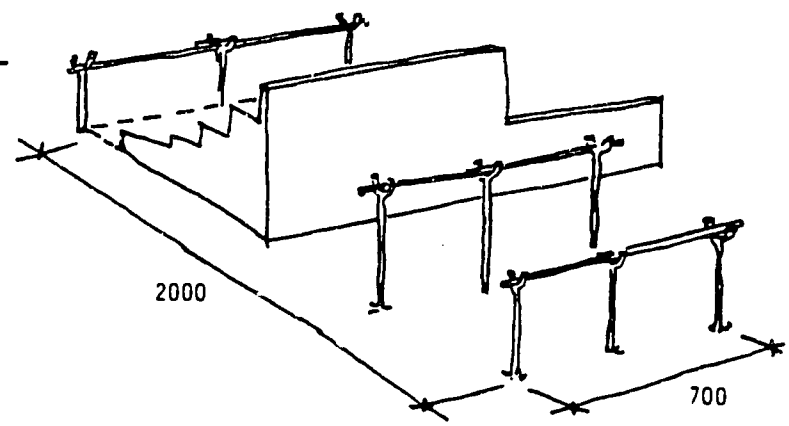
1. Clear the debris from the building site and inspect the remainding walls for structural problems.



2. Reconstruct the remaining wall, building up the wall to a uniform roof line. Reinforce and buttress the wall if necessary.

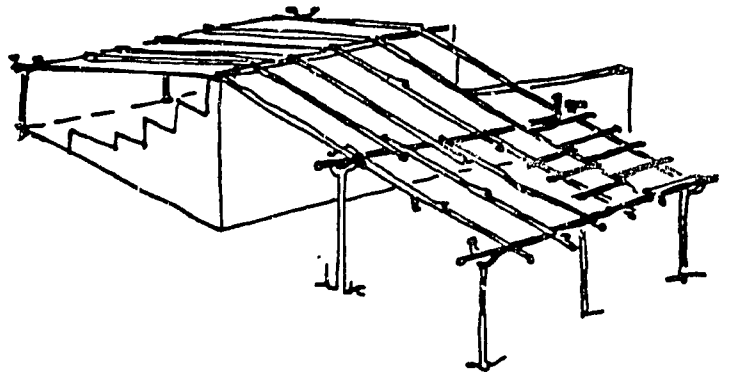


3. Using salvaged or found materials, construct a simple roof framing system. Be sure to provide sufficient roof slope (20° or more) to prevent water ponding and uplift forces from high winds.

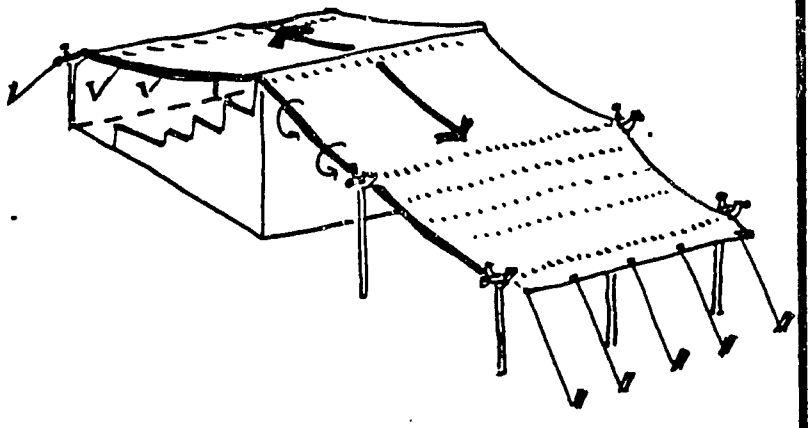


RUBBLE WALL SHED	No. 3.38 - 3
ERECTION SEQUENCE	

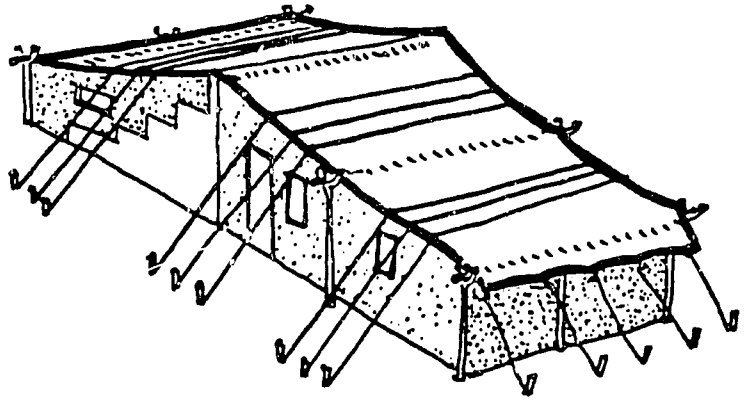
4. Depending on the availability of building materials, use progressively smaller framing members to infill between the primary structural members.



5. Starting at the roof ridge, unroll the plastic sheeting, stretching the sheeting over the frame. Secure it at both ends with the appropriate anchoring system. Wrap the sheeting around the outside structural members and nail in place.



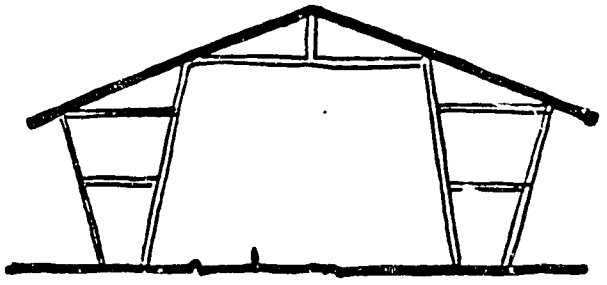
6. After the roof is in place, the rubble walls can be constructed from locally available materials and according to local methods. The final step is to secure ropes over the plastic sheeting to prevent high winds from blowing the roof off.



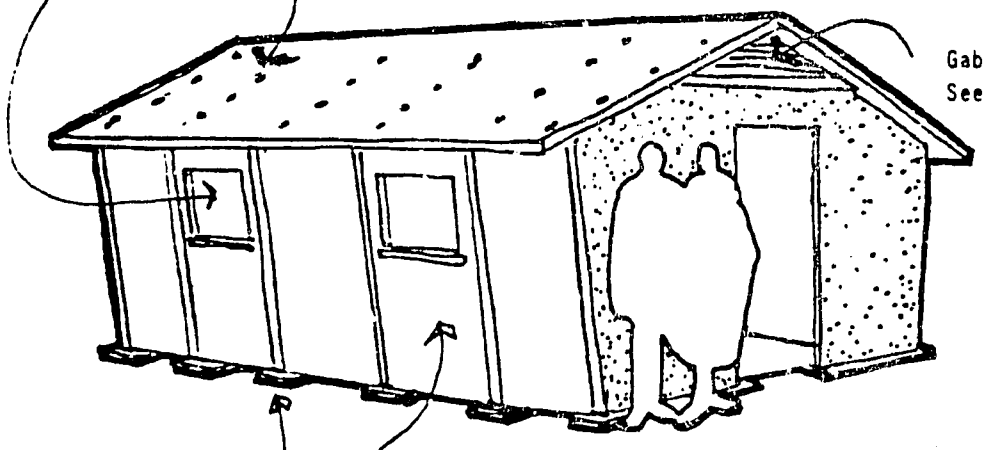
FRAME TYPE: WOOD TRUSS BENT	No. 3.39 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	●
HIGH WIND	●
FLOOD	◔

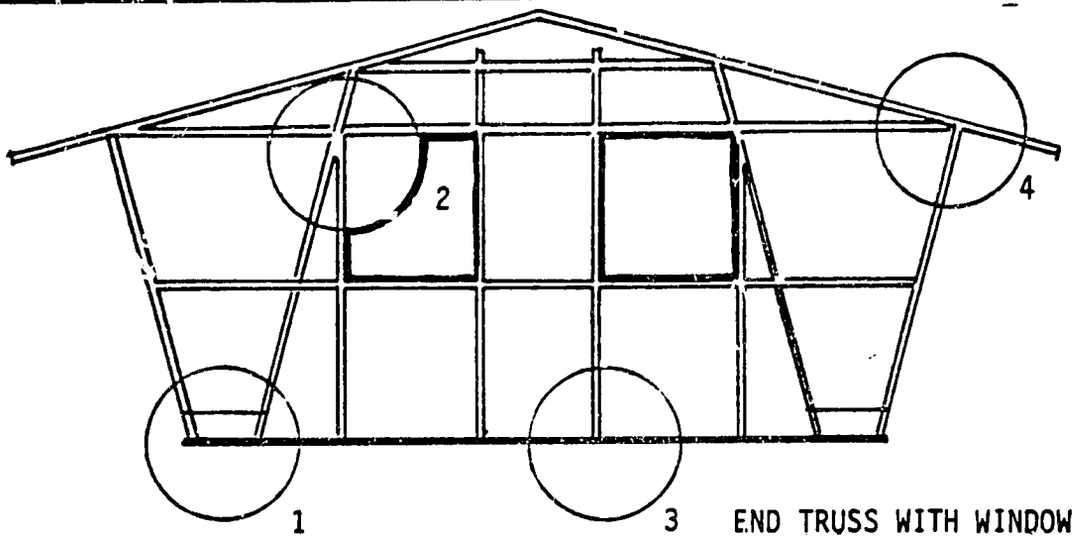
FRAME MATERIALS
Dimensional Lumber



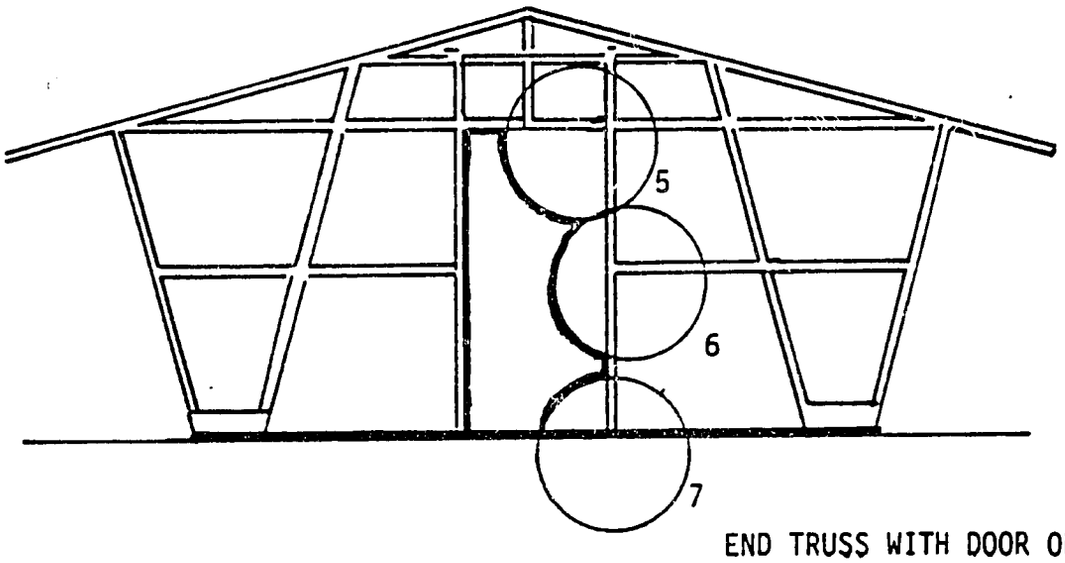
REFERENCE DETAILS
3.52
3.61
3.62
3.64
3.71
3.72
3.8



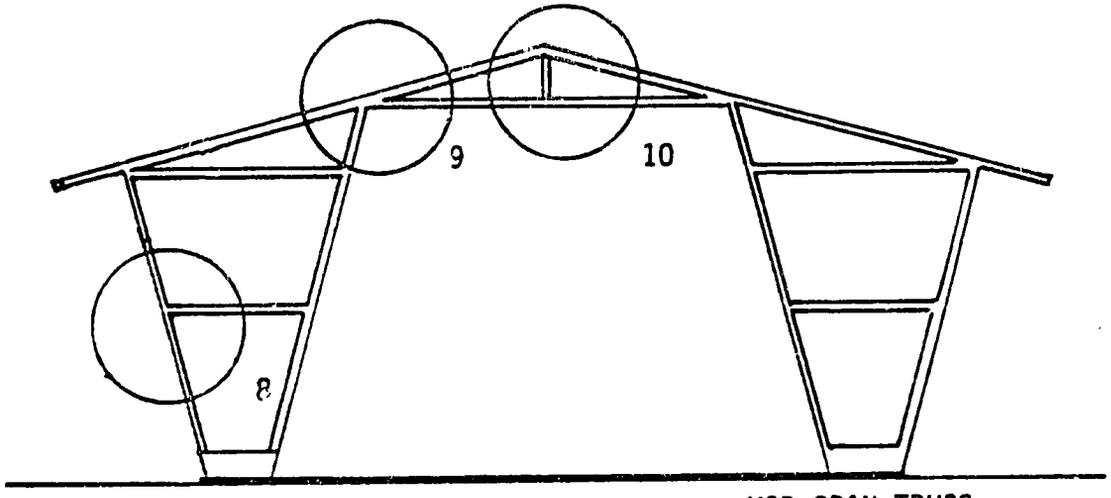
WOOD TRUSS BENT	No.
FRAMING ELEVATION	3.39 - 2



END TRUSS WITH WINDOW OPENINGS

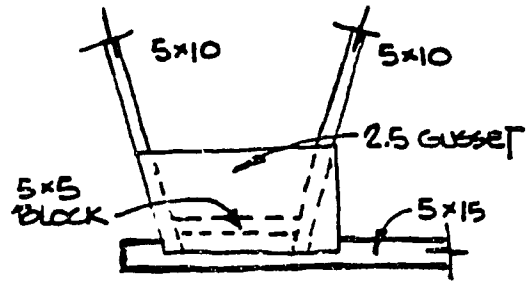


END TRUSS WITH DOOR OPENING

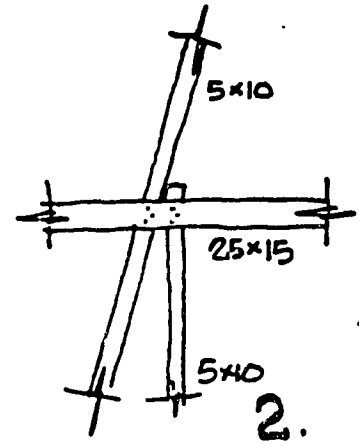


MID-SPAN TRUSS

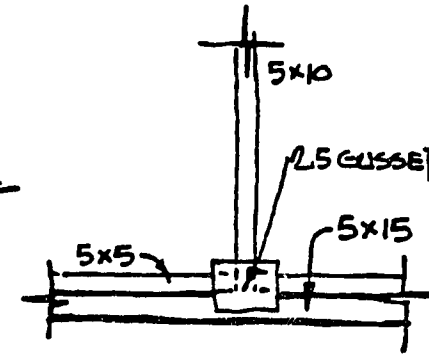
WOOD TRUSS BENT	No.
FRAMING DETAILS	3.39 - 3



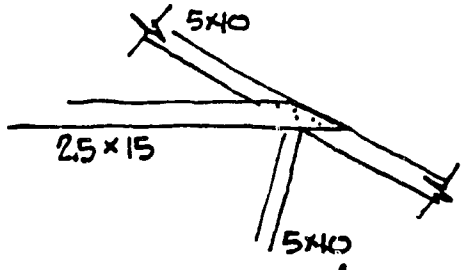
CONNECTION 1.



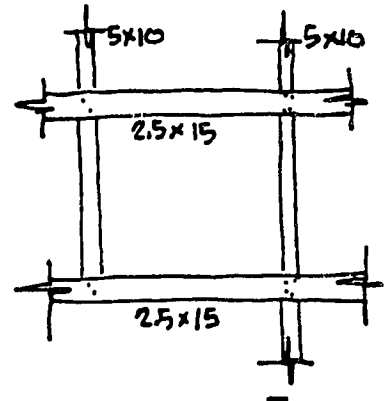
2.



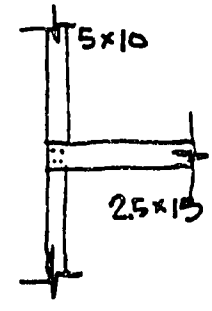
3.



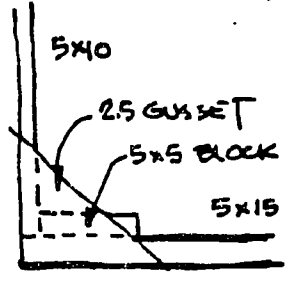
4.



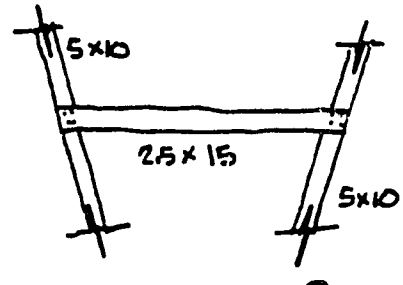
5.



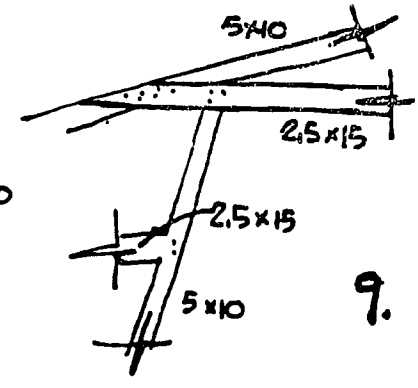
6.



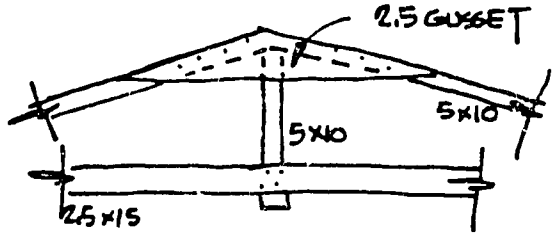
7.



8.

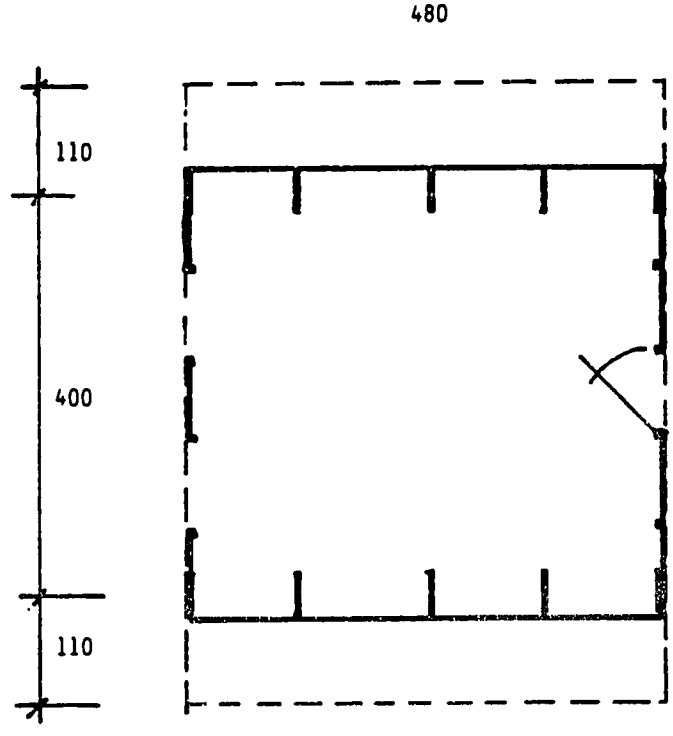


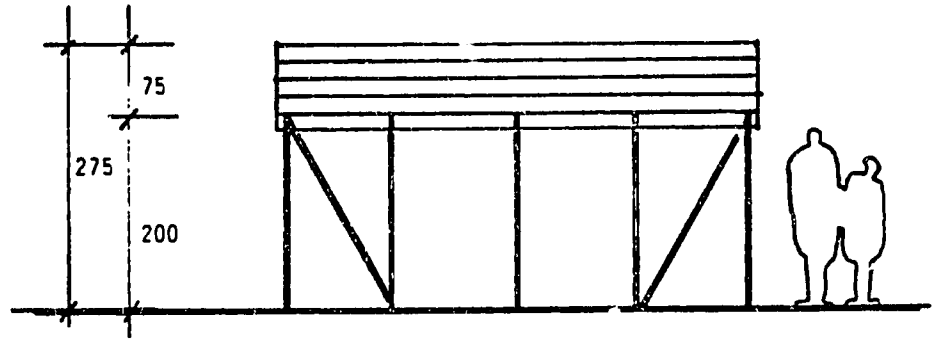
9.



10.

WOOD TRUSS BENT	No.
PLAN AND ELEVATION	3.39 - 4





WOOD TRUSS BENT	No. 3.39 - 5
ELEVATION	

POSITIVE ASPECTS

- Ventilation is controlable
- Rainwater would fall well away from the base of the building
- There is good shade provision on long side; may not be sufficient on short side

DETRIMENTAL ASPECTS

- Material is nailed (polyester fabric will probably continue to rip)
- Sheeting attached across hip at ends of building would likely rip unless facia board was added
- Many tools are required, especially nails and glue
- Dimensional lumber is required
- Truss construction would require significantly skilled labor
- Gussets are required and must be cut
- Accurate angles must be cut for joints and connections
- The overhang on the long side, the lightness of structure, and the ground attachment may be problems in high wind areas

OBSERVATIONS

- There seems to be air space where the wall plane meets the roof and ground planes
- The attachment of the plastic to the wall structural members spanning the trusses is not clearly described
- The foundation/ground attachments is not explained
- Truss construction/nailing procedure requires wooden guard blocks to be nailed to a platform to form an outline of the truss. In addition, a full scale drawing of the truss must be made on the platform. A concrete slab or the ground would not be sufficient for these purposes. The availability of this type of platform, space or materials to build it is questionable.
- Openings - window & door - would have less tendency to rip if they were made with rounded - not 90° - corners. This is especially true if opening edges are nailed to frames.

- It is not clear how gusset and foundation work at door opening

CONCLUSIONS

- Three different sizes of structural grade lumber are required, as is plywood. If these materials in sufficient quantity are not available, the frame of the structure cannot be built. The availability of sufficient quantities of this material in many countries is questionable.

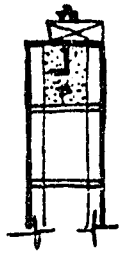
- Little detail is given regarding the type or installation of the "polyester fabric." The selected attachment system is nailing (stapling optional), which immediately introduces holes and the possibility of continued ripping of the material. The attachment system and jointing between walls and roof and walls and ground seem to leave air gaps. These gaps would allow air (possibly undesired cold) to enter. Perhaps more importantly, the gaps create significant potential for wind damage - especially given the long eave overhang on two sides and the unexplained system attaching building to the ground.

- Reasonably skilled labor would be required to layout, cut, and assemble the trusses and to connect the trusses and attach the sheeting material. These types of skills may be available, however not in sufficient quantity. The fact that the wooden joints do require a relatively high degree of accuracy introduces the following possibilities. First, there will be increased waste of likely limited lumber resources. Second, the trusses and resulting buildings may be weakened to represent an additional risk to occupants, in the event of a secondary disaster occurance -- e.g. aftershock, additional flooding, high winds.

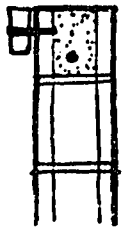
- Because of the findings of this review, it is concluded that the Wood Truss-Bent Temporary Emergency Shelter in its current state of development is not appropriate to the objectives of this project. Further, that the efforts required to modify the Shelter design to meet those objectives are beyond the resources and constraints of this project.

PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO MASONRY	3.63 - 1

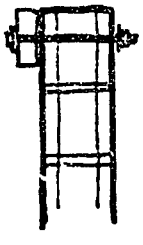
Plastic sheeting cannot be reliably attached directly to masonry. For secure connection, a piece of wood must be anchored to the masonry and the plastic attached to the wood using a battened, stapled, or nailed connection. (See Section 3.64 - Sheeting to Dimensional Lumber.)



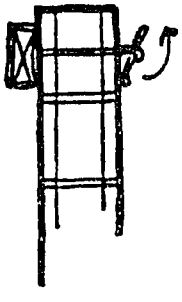
Anchor bolts and filled cores



Masonry nails



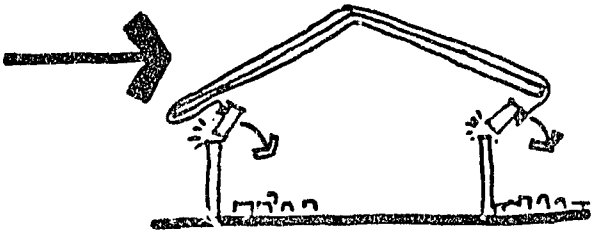
Drilled and bolted through



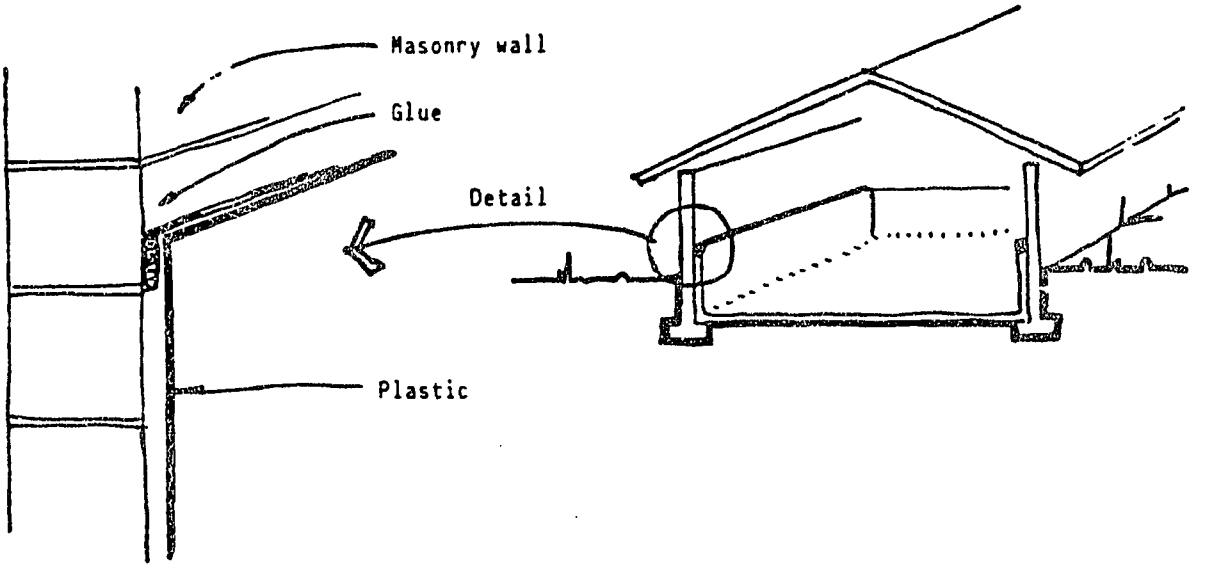
Tied through mortar joint with wire

PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO MASONRY	3.63 - 2

1. Consideration should be given to the effects of the lifting force of the plastic on masonry construction. Because the plastic is light and acts like a sail, extreme upward lift can be created which may damage masonry - particularly where the plastic is attached near the top of the wall.



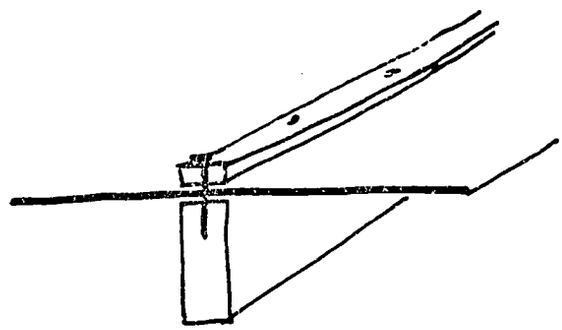
2. Plastic sheeting can also be attached to masonry by gluing with contact cement or other adhesive. This should not be considered a structural joint but may be useful if using the plastic to line a floor in wet areas.

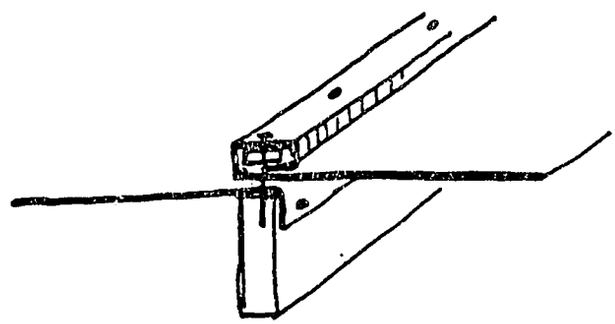


PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO DIMENSIONAL LUMBER	3.64 - 1

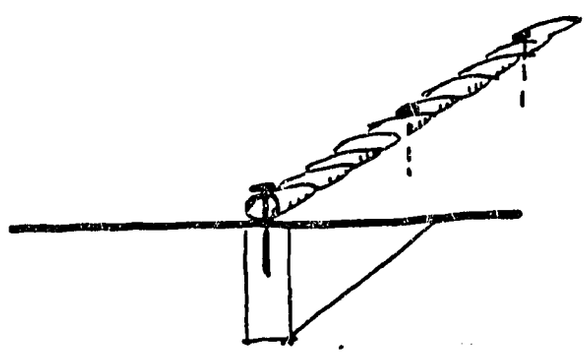
Dimensional lumber provides a very good support for plastic sheeting as it does for most materials. If dimensional lumber is available, particularly if the structure is only temporarily to be covered in plastic and will later be roofed with permanent materials, its use is highly recommended. If it is to be covered eventually with another material, consider the dimensions of that material. (See also Section 3.27 - Properties of Plastic Sheeting.)

WOOD BATTEN





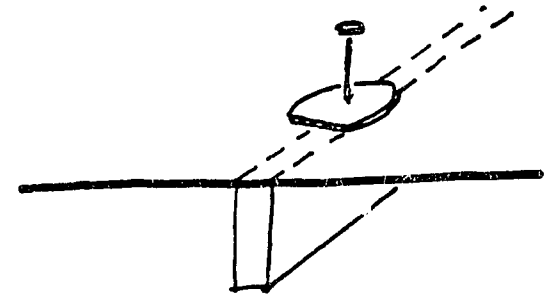
ROPE BATTEN



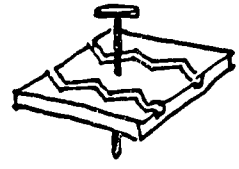
PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO DIMENSIONAL LUMBER	3.64 - 2

ROOF WASHERS

Bottle cap

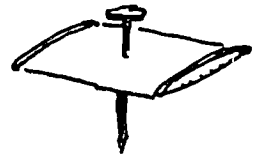


Tire Tread

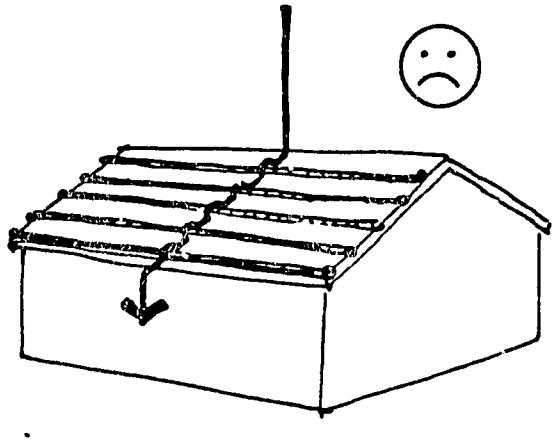


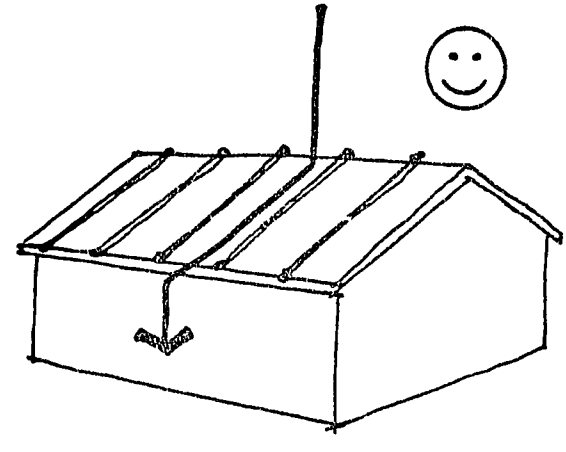
Wood

Tin can



Battens should be attached to the roof over structure running up and down. This is to prevent water from ponding.



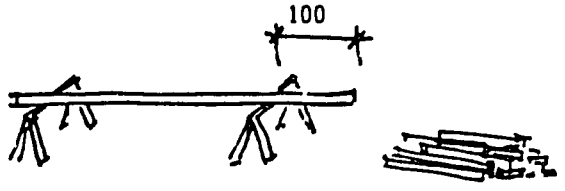


208

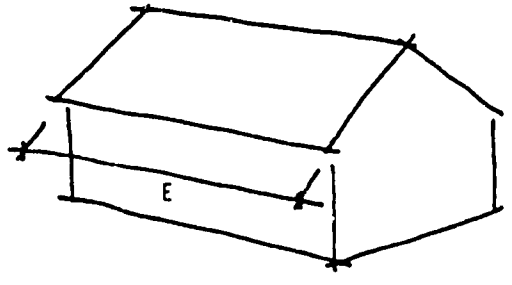
Procedure

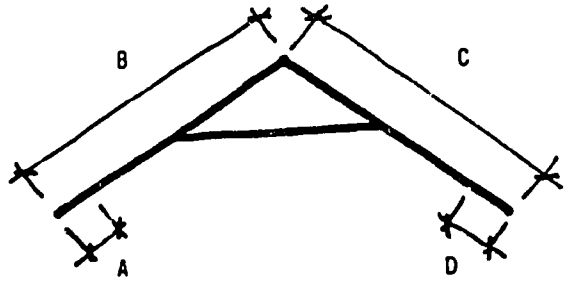
To cover a roof with battens or roof washer attachments, observe the following guidelines:

1. Cut the batten material (2.5 cm x 5 cm) into 1 meter strips.

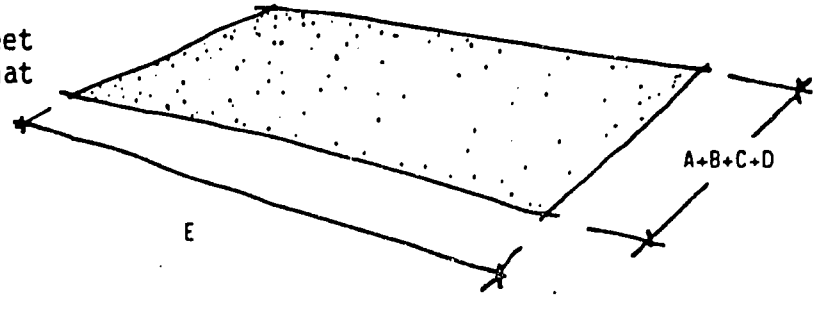


2. Cut the plastic to the proper length and width to cover the roof. If possible, use a single piece to cover the entire roof.

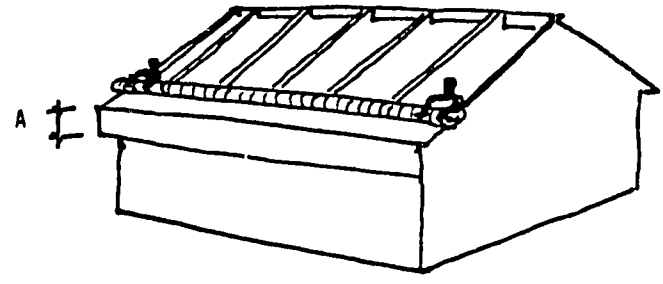




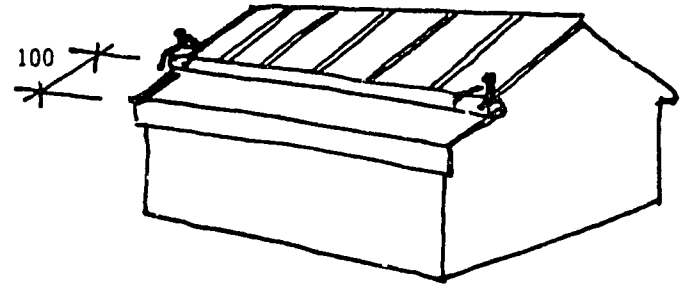
For best results, let the sheet lie in the sun unrolled so that it can expand. (See Section 3.27 - Properties of Plastic Sheeting.)



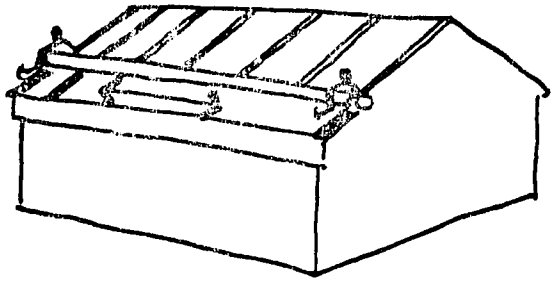
3. Roll the plastic sheeting as shown.

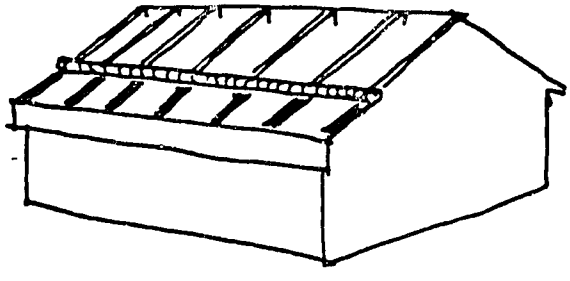


4. Starting at one end, nail in place the first batten at the eave. Work from inside the roof, leaning over the rolled plastic.

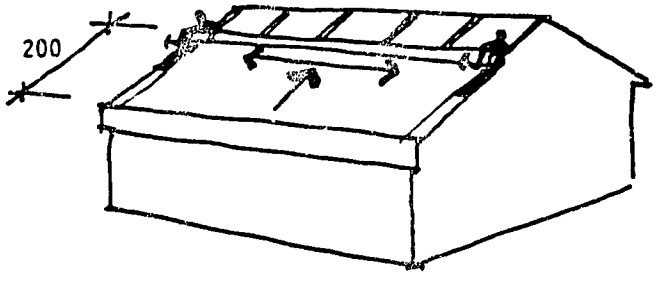


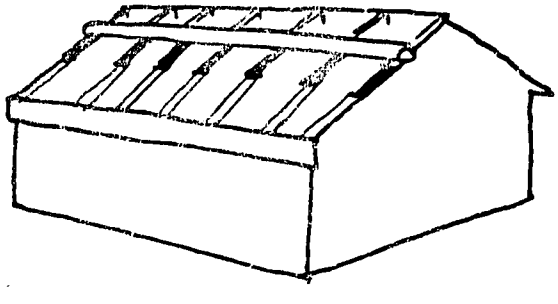
5. Proceed along the eave, nailing battens. Pull the plastic tight between battens.



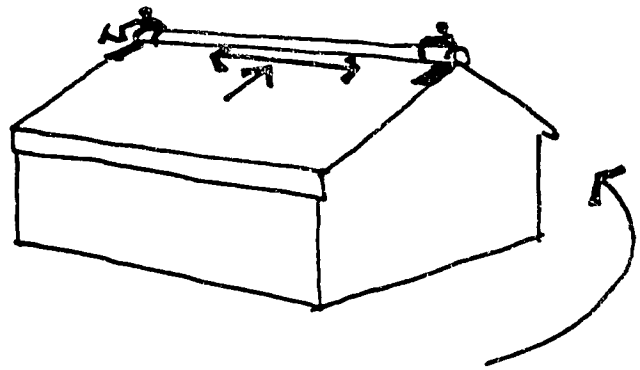


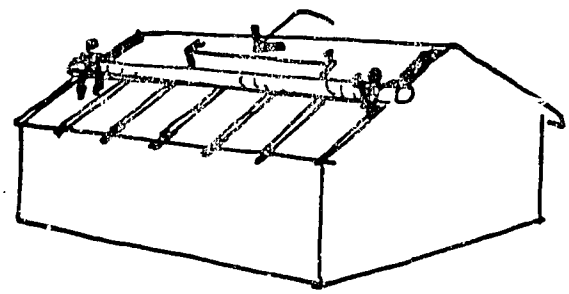
6. When the first row of battens is in place, start at the end and install successive rows, unrolling the plastic one meter at a time.

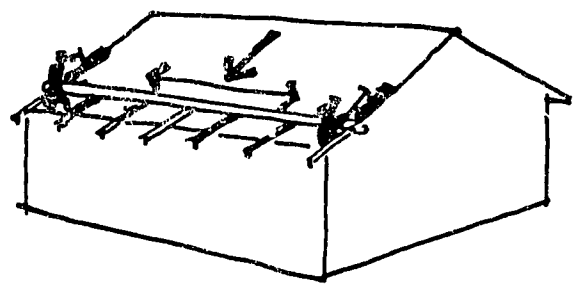




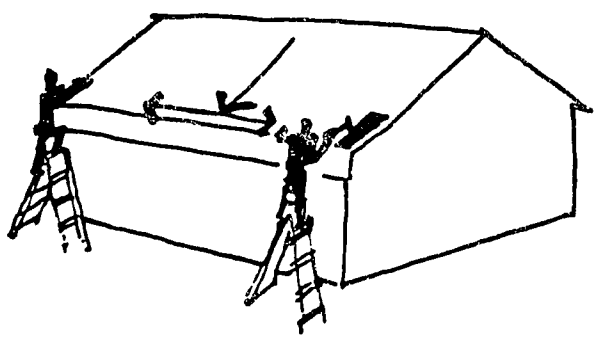
7. Work over the peak of the roof, cutting the battens to meet at the ridge.



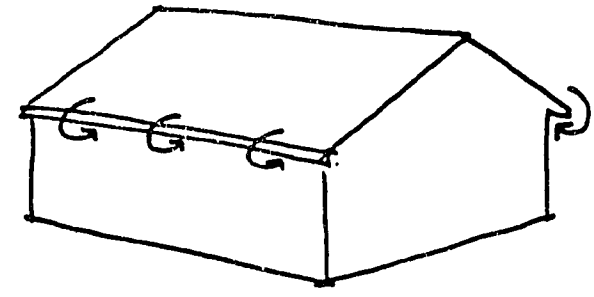




8. Secure the last batten by working from a ladder.

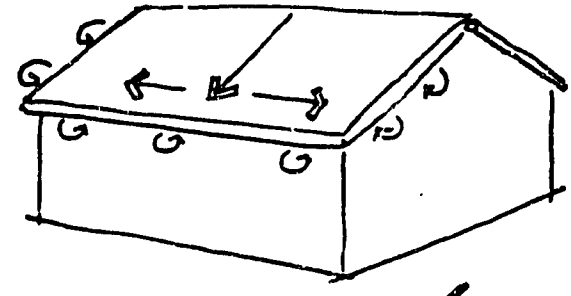


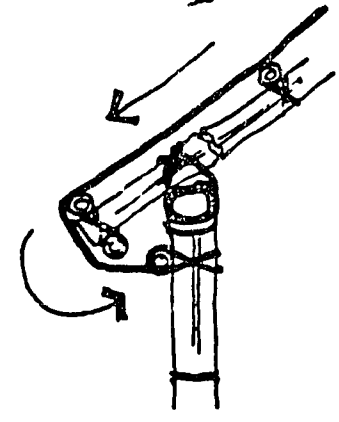
9. Attach the plastic sheeting under the eaves.



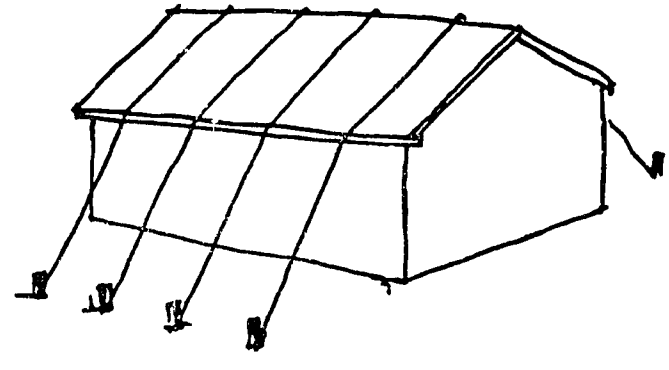
PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO BAMBOO	3.65 - 1

The best way to use a bamboo structure is to stretch the plastic sheeting over it and anchor the sheeting at its edges.





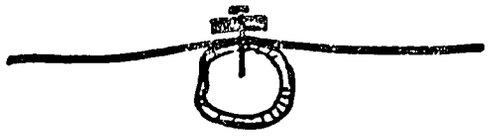
If extra strength is needed to prevent lifting, ropes or rolled pieces of the plastic sheeting can be stretched over or under the plastic roof.

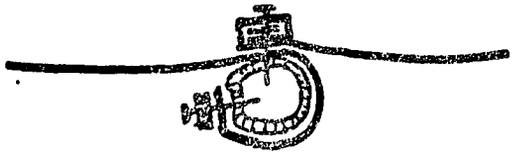


If the plastic must be connected directly to the bamboo, the following methods are suggested.

BATTEN METHOD

Light dimensional lumber can be nailed, wired, or lashed to the bamboo and a batten connection constructed. (See Section 3.64 - Sheeting to Dimensional Lumber.)

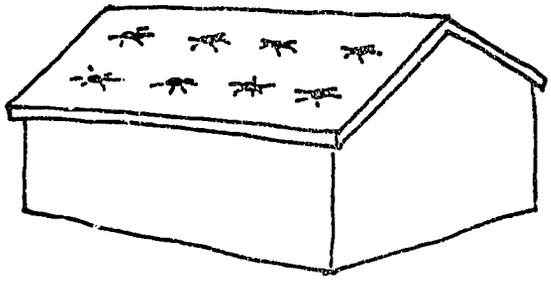




ROCK TIE METHOD

Tie rocks into the plastic sheeting at the points where attachments need to be made, as shown in Section 3.67. Then tie the rope end to the bamboo.

This method causes the plastic to distort and it cannot be stretched smooth. Another disadvantage is that rainwater may catch in the pockets formed by the rock and eventually may leak into the structure.



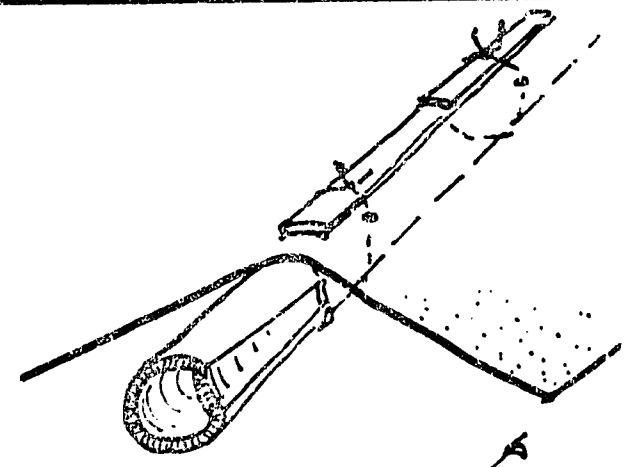
PLASTIC SHEETING CONNECTIONS

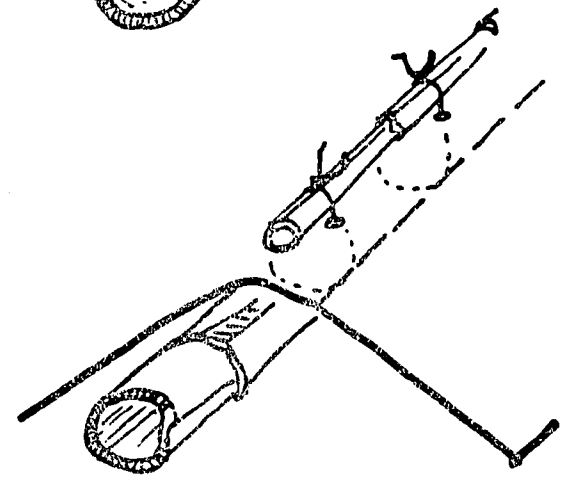
SHEETING TO BAMBOO

No. 3.65 - 3

LASHING METHOD

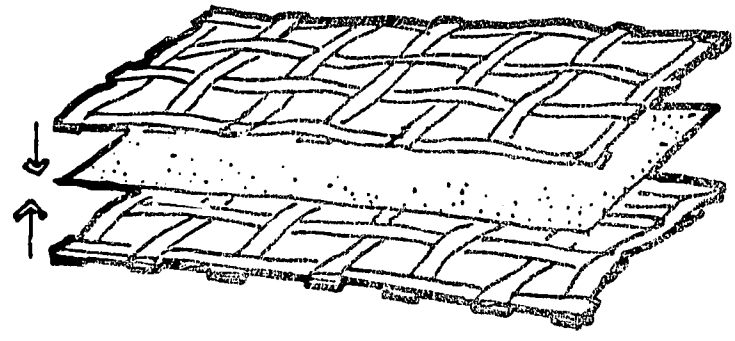
This method is a simple and inexpensive way of securing plastic sheeting to bamboo. However, since it requires punching holes in the sheeting, it is likely to cause leaks and may lead to ripping of the sheeting. The outside piece of bamboo should be smaller than the piece to which the sheeting is being attached.





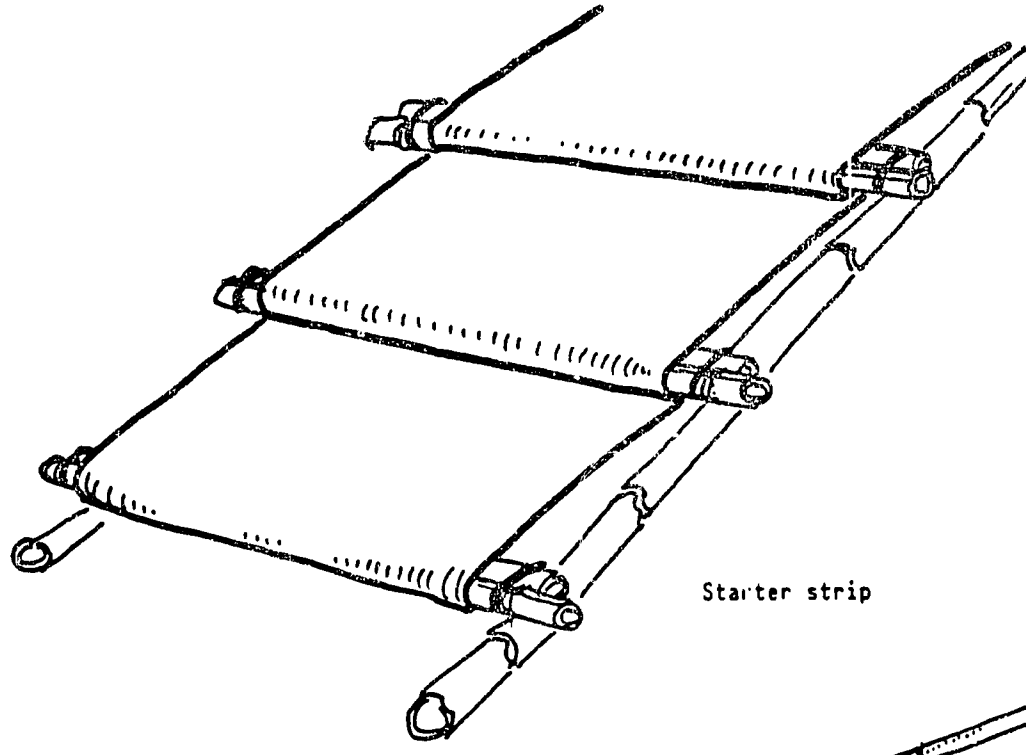
BAMBOO SANDWICH MAT

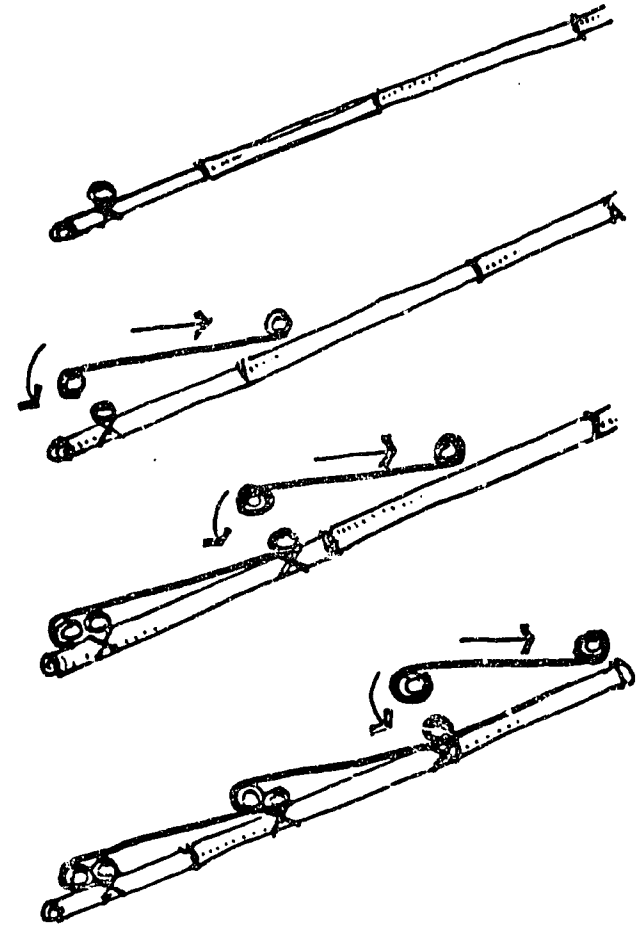
Plastic sheeting may be sandwiched between two woven bamboo mats or frames and then used as a large shingle or panel.



PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO BAMBOO	3.65 - 4

TENSION FRAME





PLASTIC SHEETING CONNECTIONS

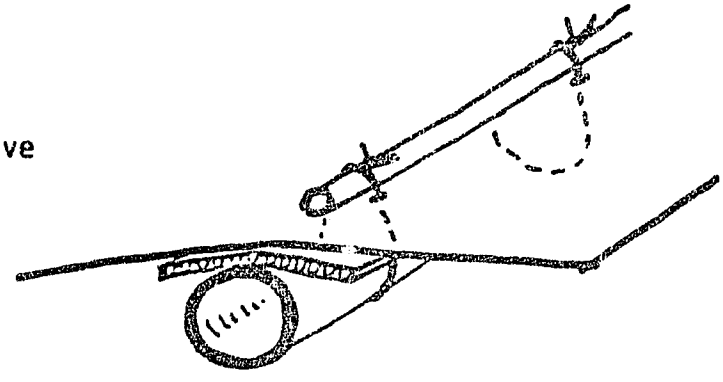
SHEETING TO PIPE

No. 3.66 - 1

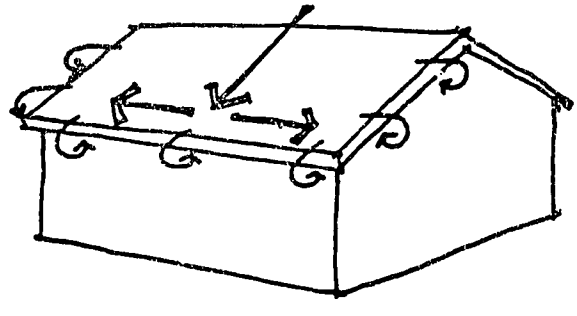
Where metal or plastic pipe is used as a structural material, the Batten, Rock Tie, and Lashing methods are suggested. Because metal pipe will get very hot under the plastic sheeting, it is suggested that an insulator (e.g., paper, cloth, cardboard, or leaves) be placed between the pipe and plastic wherever they meet.

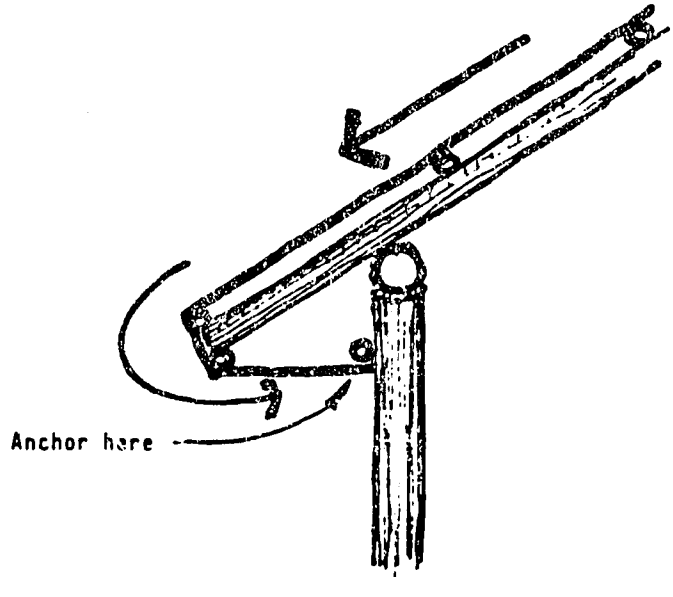
LASHING METHOD

This method is a simple and inexpensive way of securing plastic sheeting to a metal pipe frame. However, since it requires punching holes in the sheeting, it is likely to cause leaks and may lead to ripping of the sheeting.

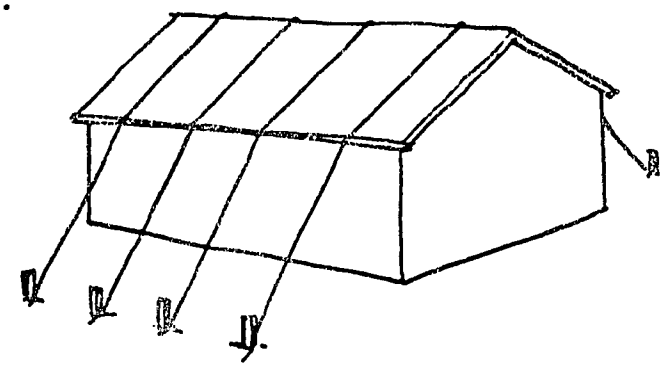


The best way to cover a pipe structure is to stretch the plastic sheeting over it and anchor the sheeting at its edges.



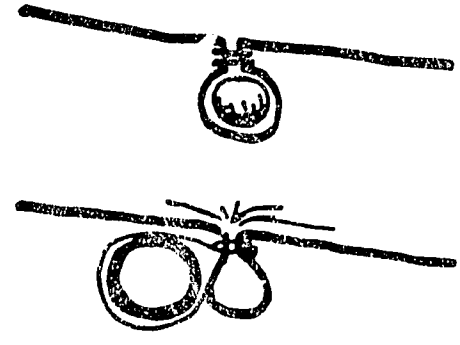


If extra strength is needed to prevent uplifting of the plastic sheeting, ropes can be stretched over the plastic roof.

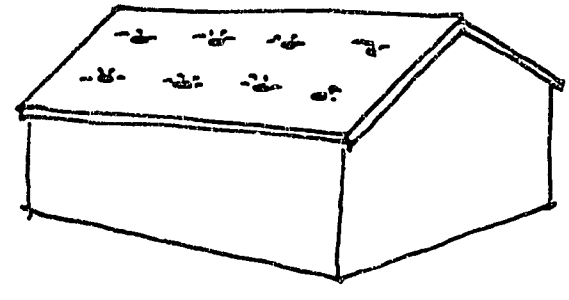


ROCK TIE METHOD

Tie rocks into the plastic sheeting at the points where attachments need to be made, as shown in Section 3.67. Then, tie the rope end to the metal pipe.

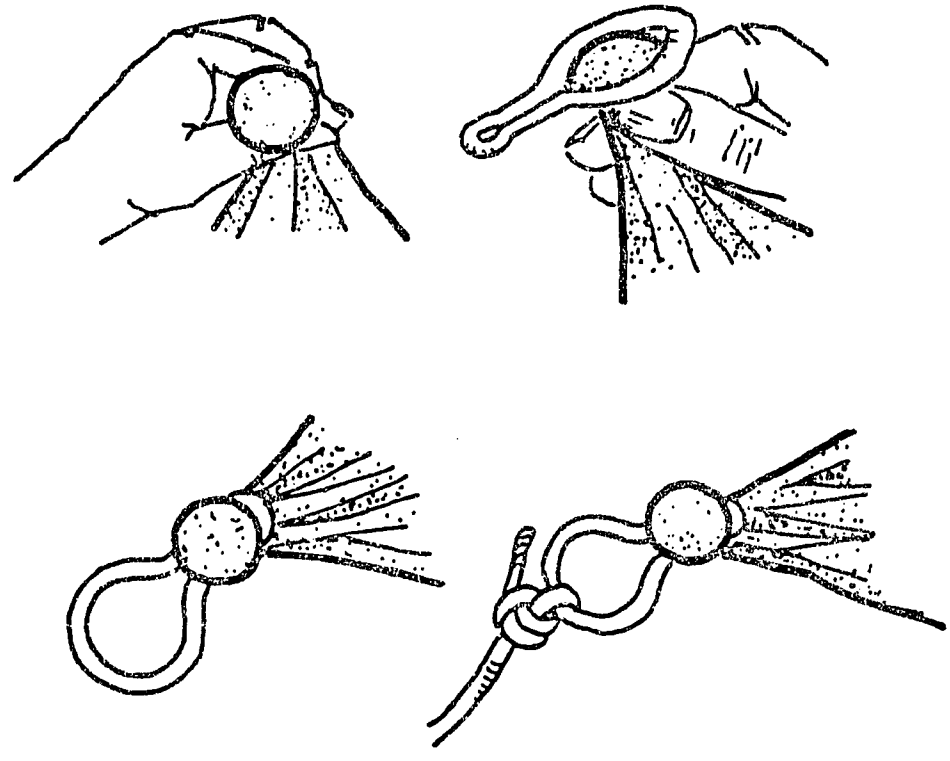


This method causes the plastic to distort and it cannot be stretched smooth. Another disadvantage is that rainwater may catch in the pockets formed by the rocks and eventually may leak into the structure.



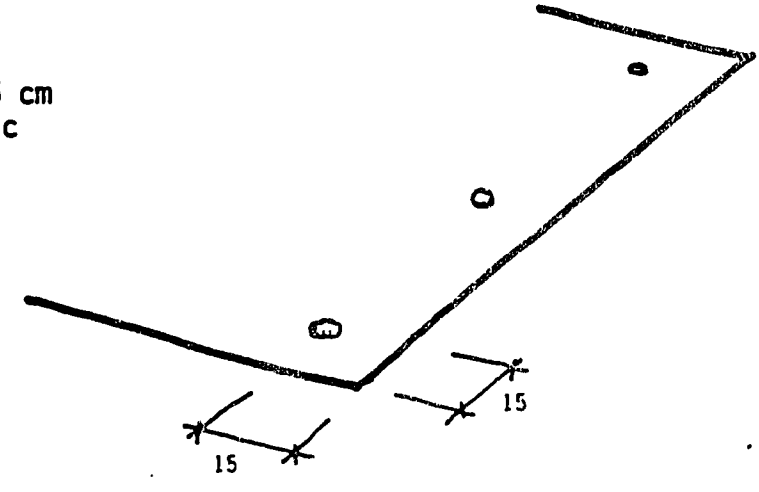
PLASTIC CONNECTOR METHOD

The plastic connectors enclosed in the package are the simplest method of connecting plastic sheeting to rope.

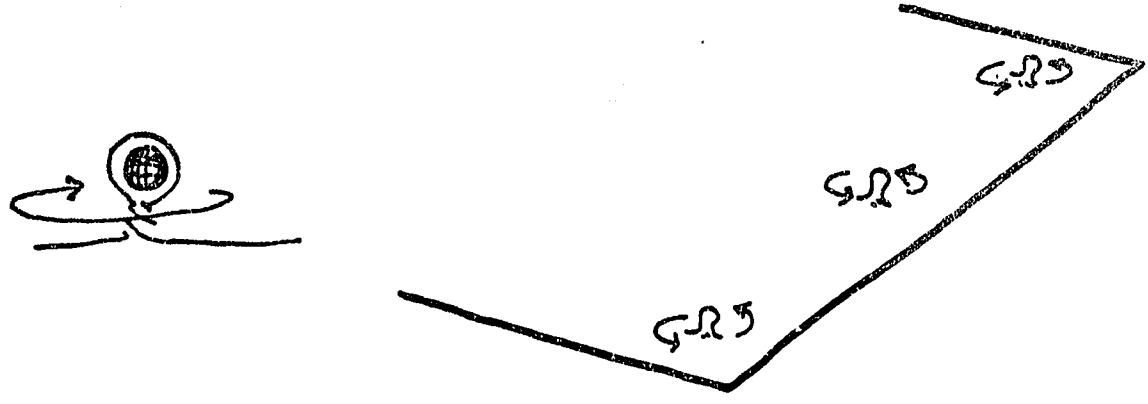


ROCK TIE METHOD

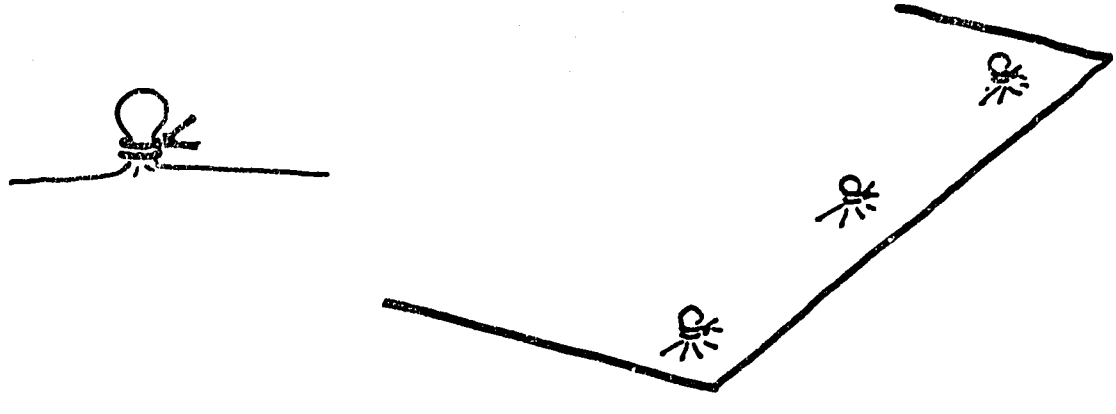
1. Place a 3 - 5 cm rock about 15 cm in from the edge of the plastic sheeting.



2. Twist the sheeting around the rock.



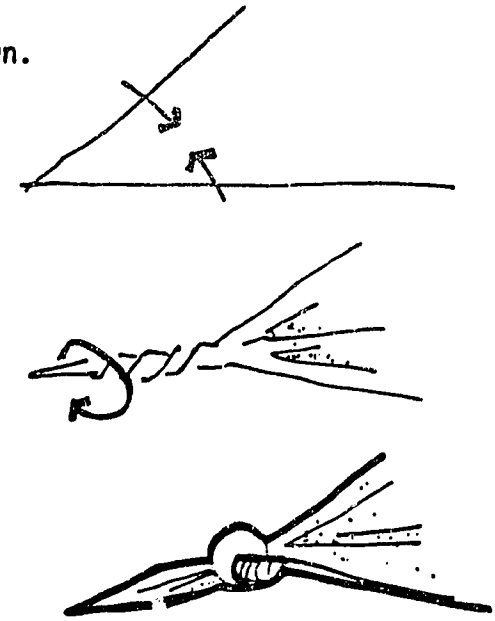
3. Tie a piece of rope around the neck of the embedded rock.



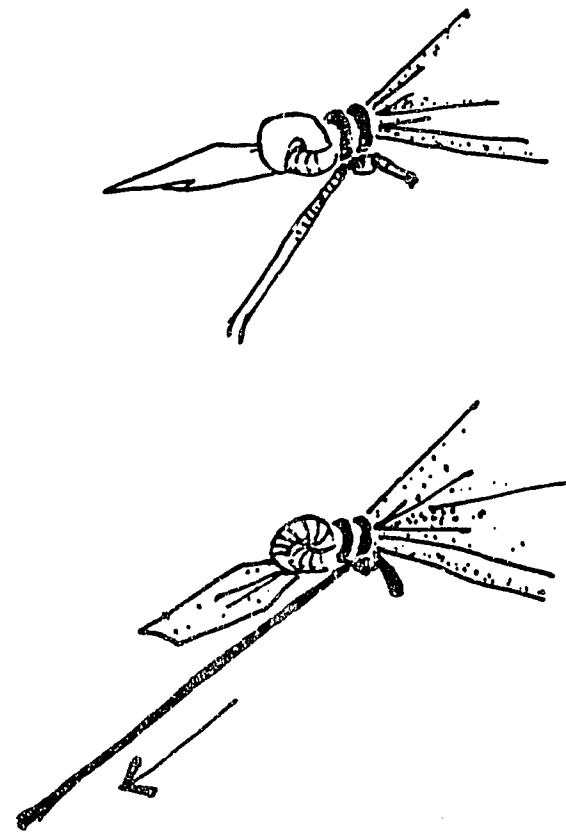
PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO ROPE	3.67 - 3

KNOT METHOD

1. At corners of the plastic, tie a knot as shown.



2. Tie a rope around the knot.



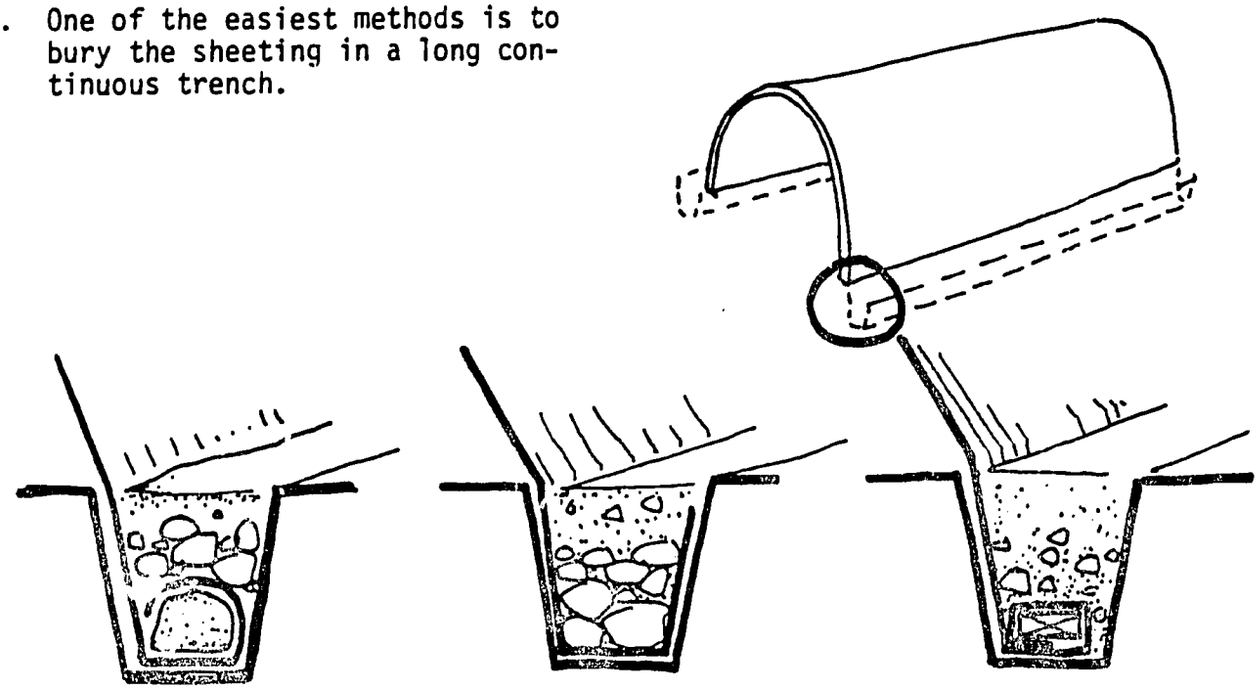
3.7 GROUND INTERFACE CONNECTIONS

3.71 Plastic Sheeting
3.72 Foundations
3.73 Anchors

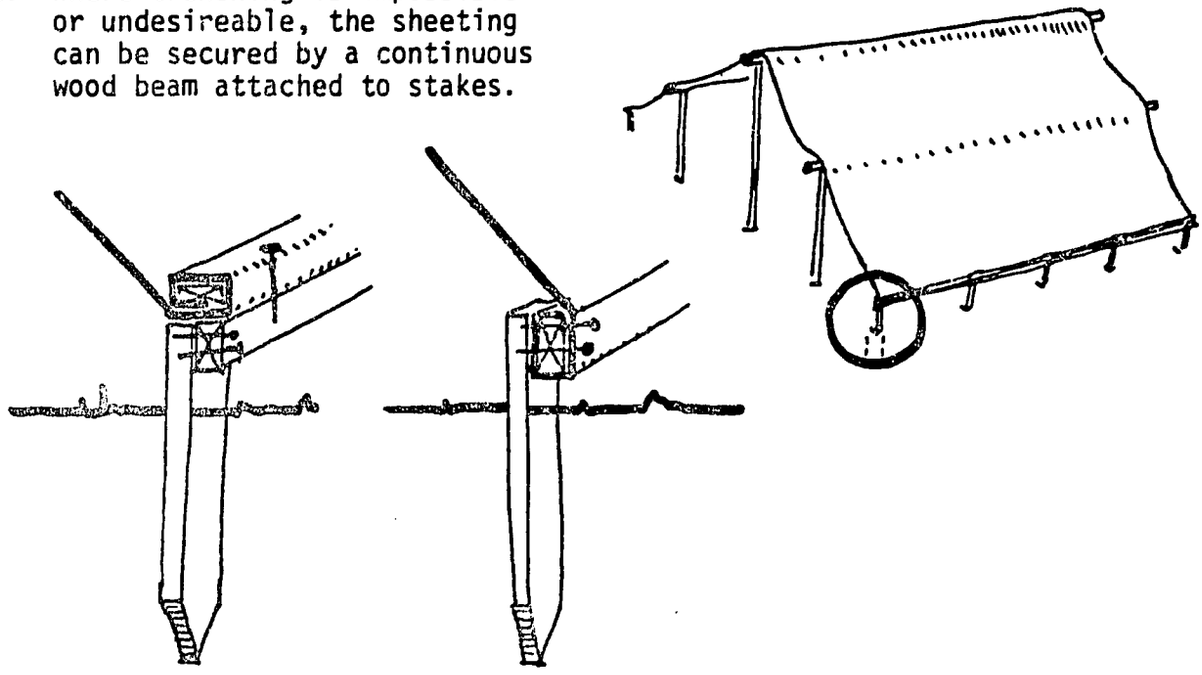
GROUND INTERFACE CONNECTIONS	No.
PLASTIC SHEETING	3.71 - 1

Where the plastic sheeting is used as a wall covering or where the roof covering comes to the ground, as in in Bamboo Lattice Cylinder in Section 3.32, the sheeting should be secured at the ground to prevent flapping. The following illustrations show several ways to secure the sheeting.

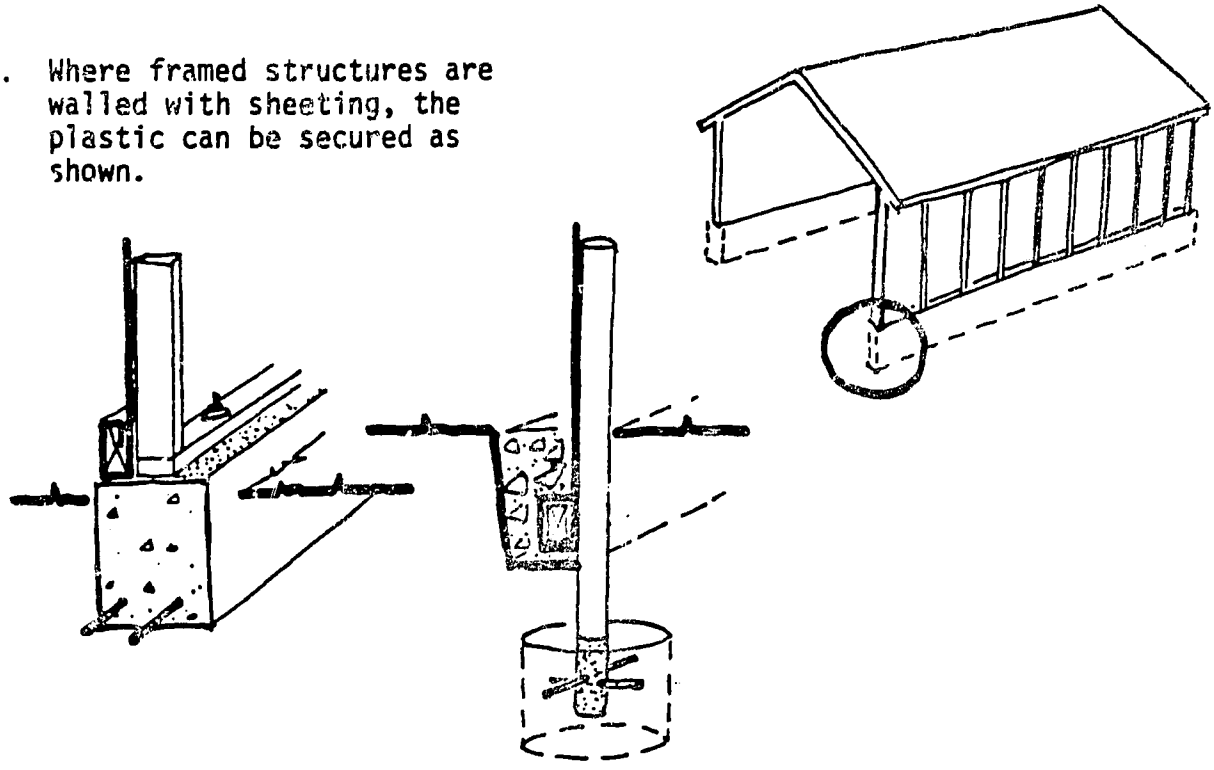
1. One of the easiest methods is to bury the sheeting in a long continuous trench.



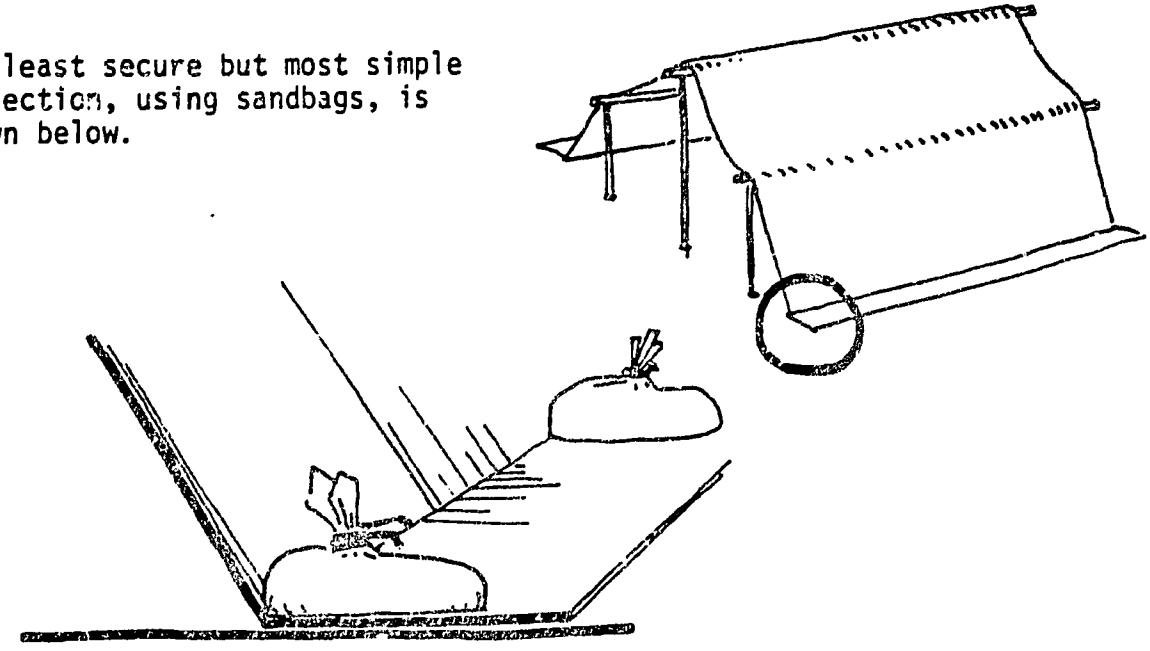
2. Where trenching is impossible or undesireable, the sheeting can be secured by a continuous wood beam attached to stakes.



3. Where framed structures are walled with sheeting, the plastic can be secured as shown.

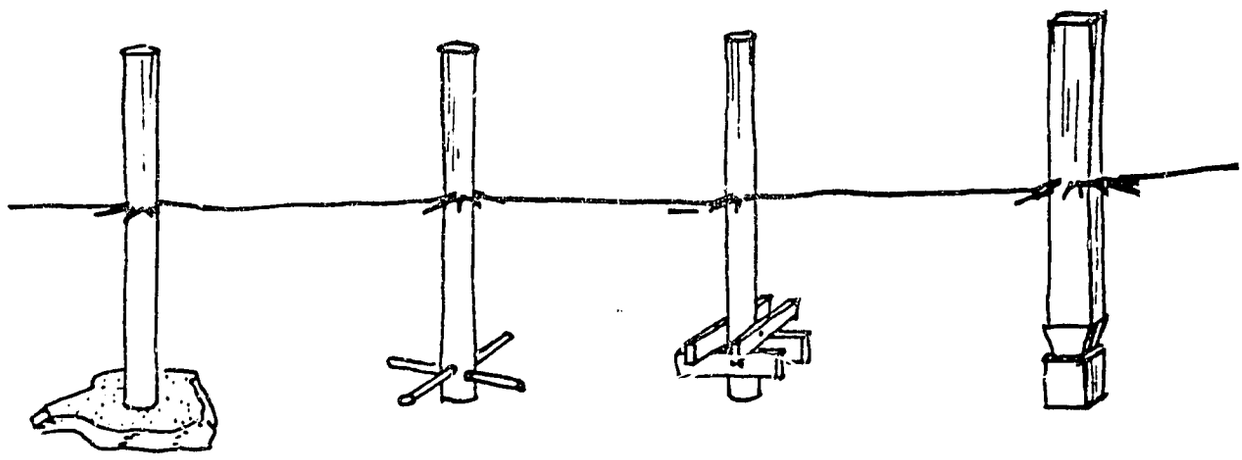


4. The least secure but most simple connection, using sandbags, is shown below.

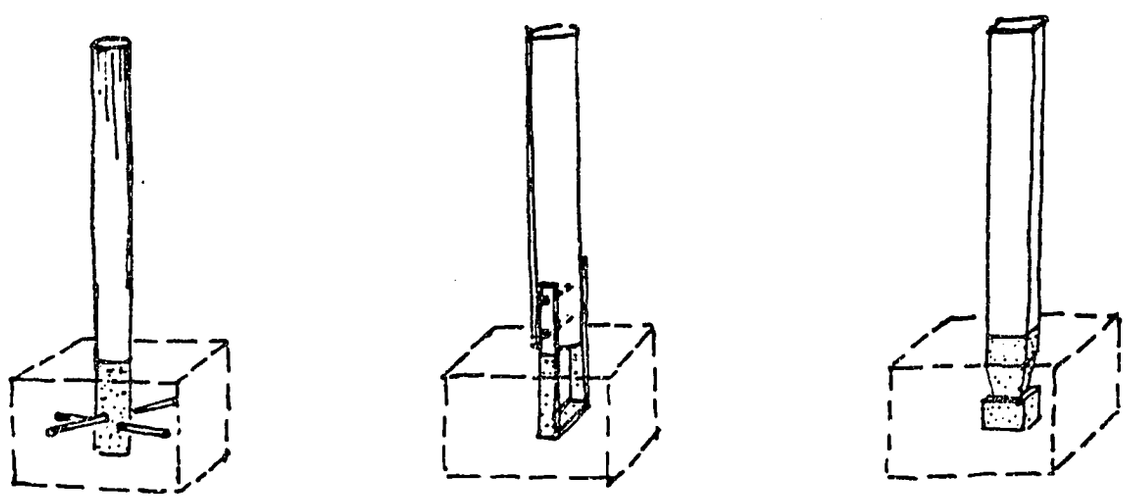


This section is not intended to offer an exhaustive listing of foundation types, but rather to illustrate a selected few which are adaptable to quick erection and lateral force resistance. It is good practice to observe successful foundation types in the disaster area and use the one which best adapts to the problem at hand.

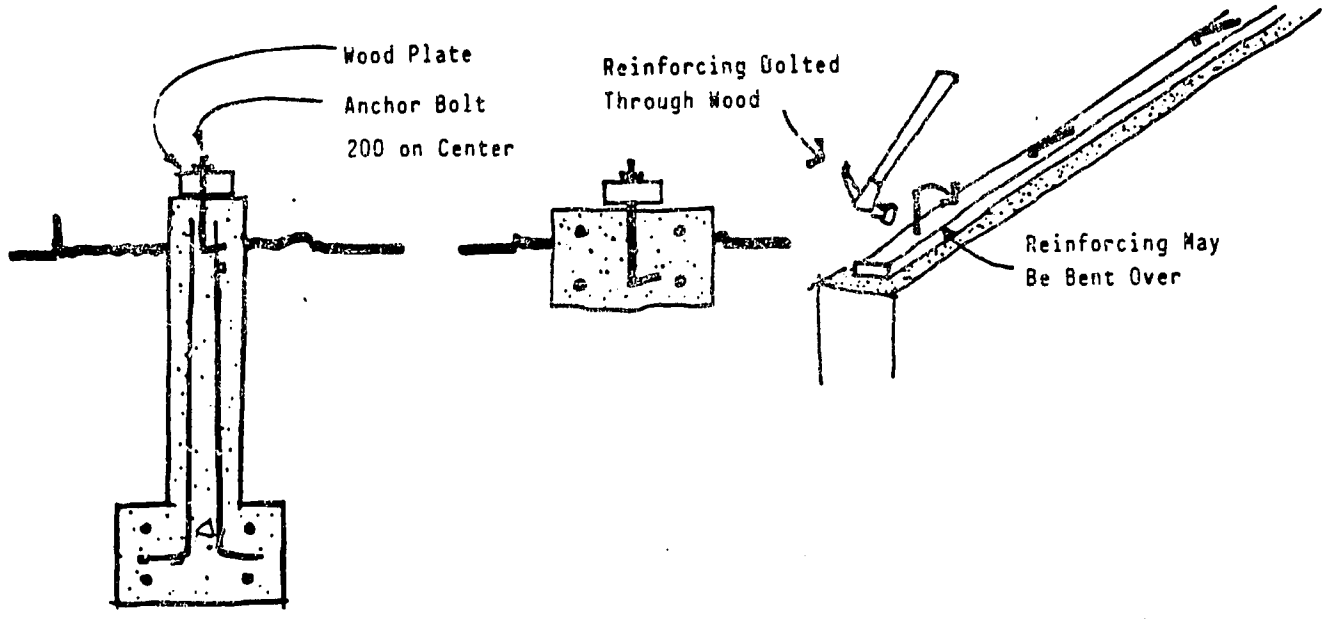
POSTS IN SOIL



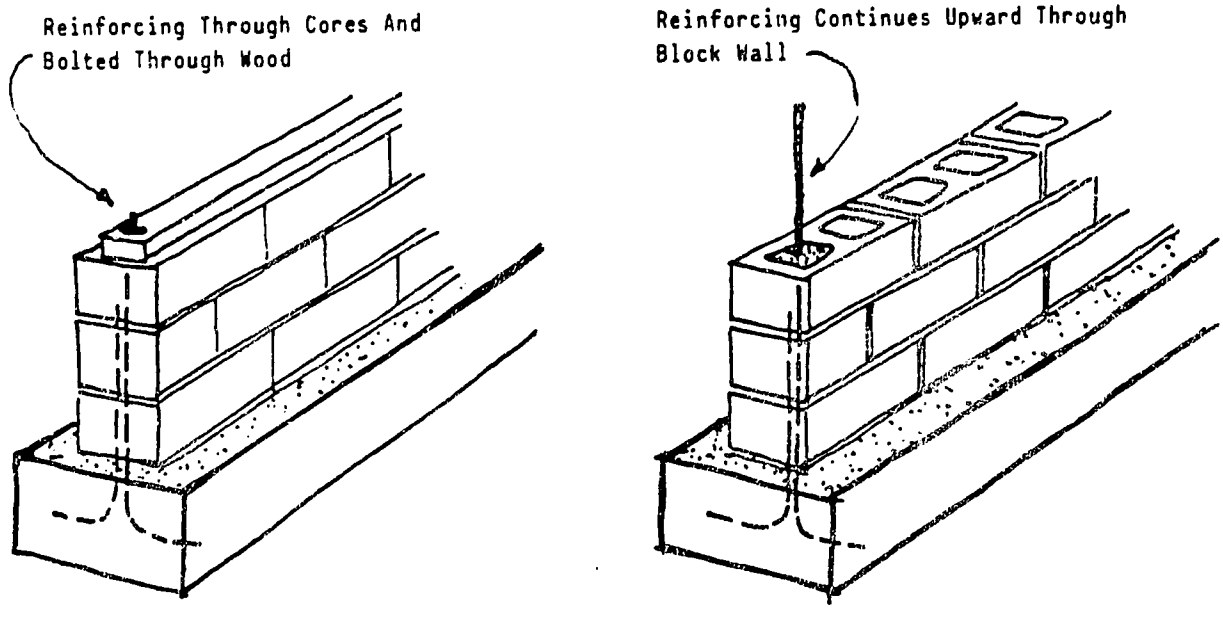
POSTS IN CONCRETE



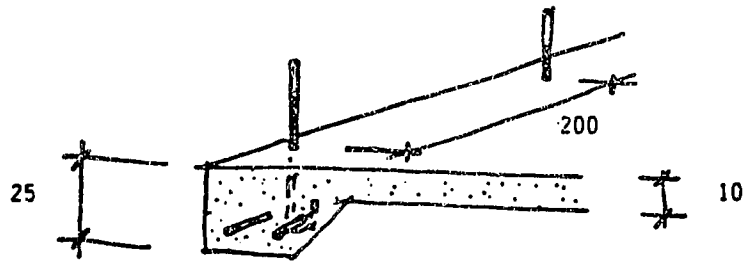
CONCRETE FOUNDATION



BLOCK FOUNDATION

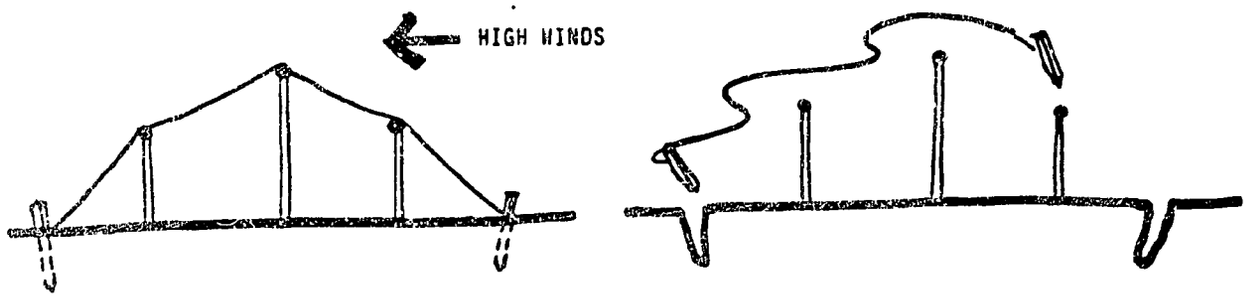


SLAB FOUNDATION



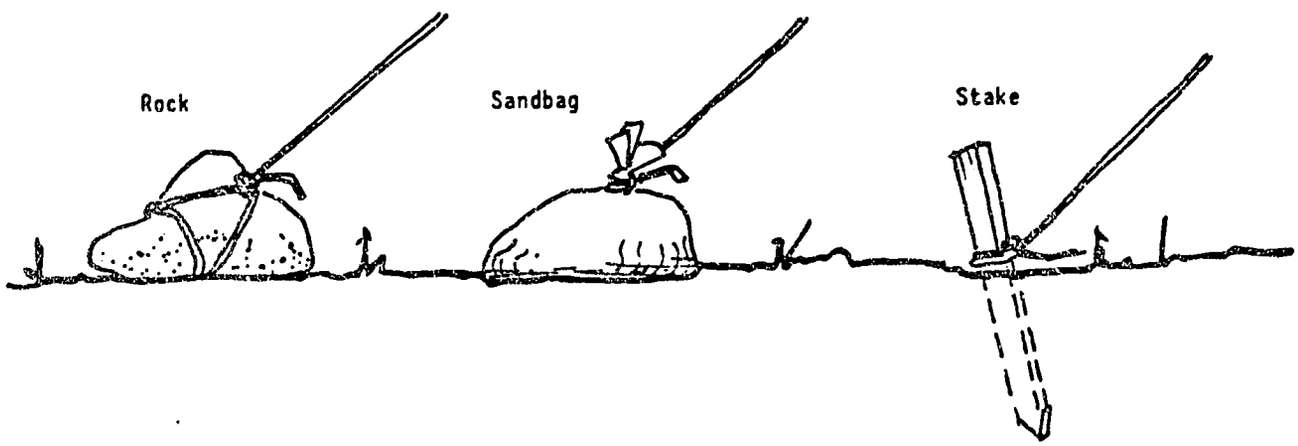
GROUND INTERFACE CONNECTIONS	No.
ANCHORS	3.73 - 1

For the framing systems which require ropes to fasten or restrain them, the weakest structural part of the system is likely to be the anchorage of the rope.



In high wind areas, simple stakes are not likely to hold - particularly in wet ground. The following drawings illustrate a variety of anchor types.

LOW STRENGTH

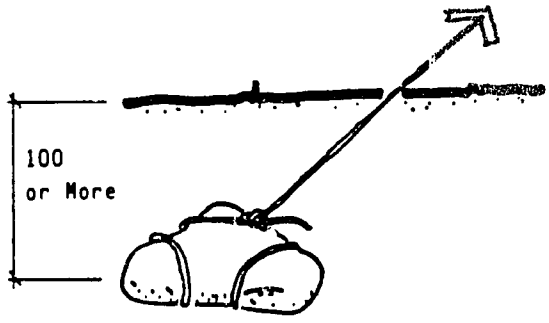


GROUND INTERFACE CONNECTIONS

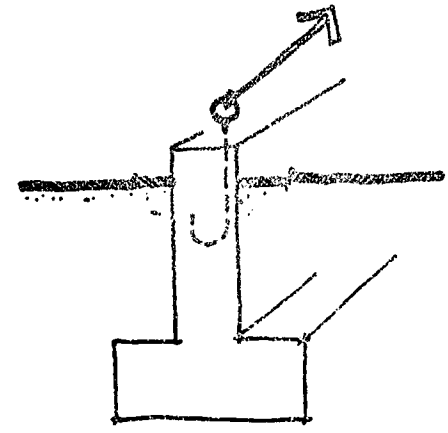
ANCHORS

No. 3.73 - 2

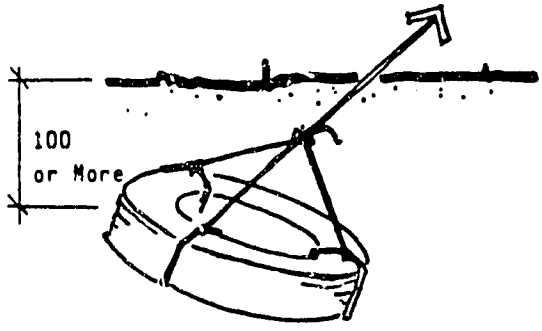
HIGH STRENGTH



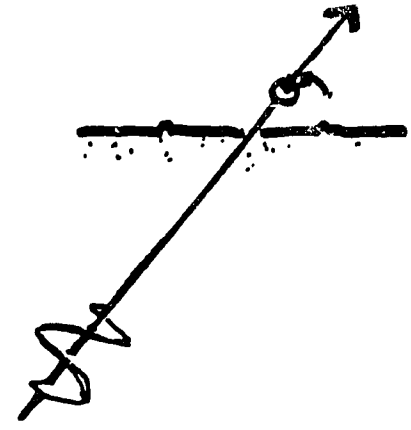
Buried Rock



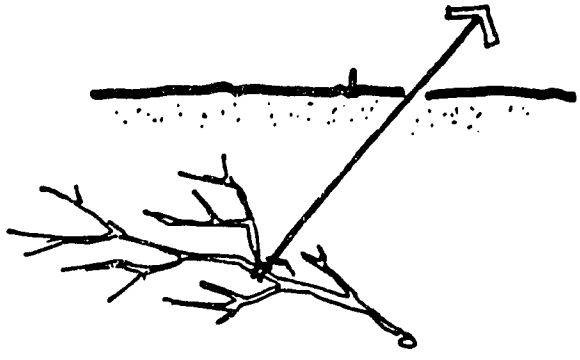
Concrete Footing



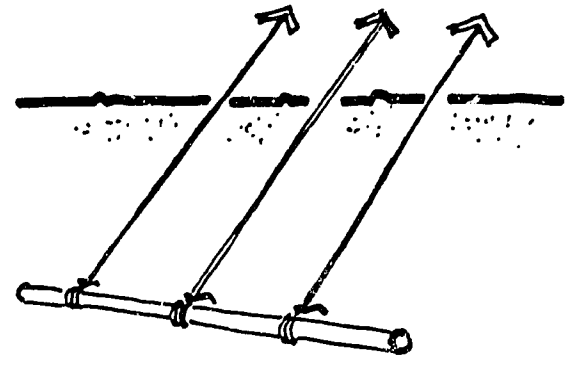
Buried old tire



Auger



Green tree branch



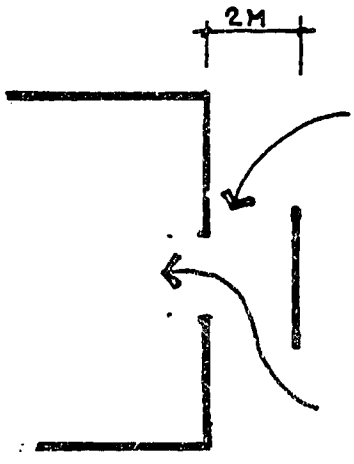
Buried log or pipe

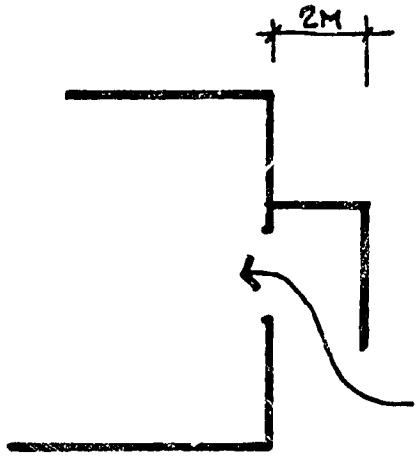
3.8 DOORS, WINDOWS, AND OPENINGS

3.81 Doors
3.82 Windows
3.83 Vents
3.84 Chimney Openings
3.85 Electrical Service Entry

The primary function of doors and door openings is to control the movement of people into and out of an enclosed space. Door openings can also function as a means of ventilation and a source for daylighting. Typically, doors are rated and specified according to their frequency of use. Doors which are used 100 times per day must be significantly stronger than doors which are used 5 per day if they are to hold up and function adequately. If the interior room layout or design will permit, doors should swing inwards where they can be secured and protected from being buffeted and damaged in strong winds. Two external door openings for an enclosed area of 50 square meters is sufficient, unless special conditions prevail.

DOOR OPENINGS WITHOUT DOORS





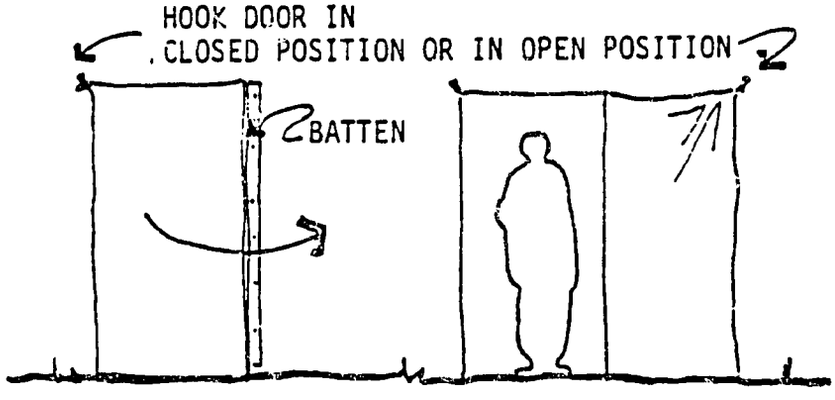
For this type, the door opening itself must be framed in and the plastic sheeting attached to the frame. The following factors should be considered:

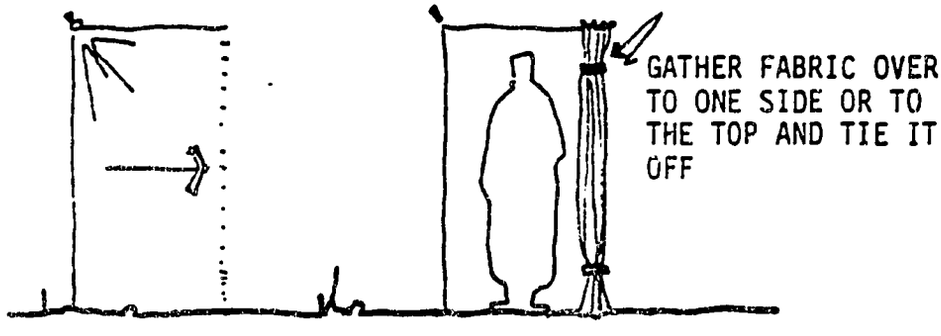
- This system provides visual privacy only.
- This system can be used in conjunction with other door configurations to reduce wind penetration into the structure.
- Some degree of daylighting and ventilation of the enclosed space is accommodated by this system.
- Where climate and security conditions will allow, this is a good system for very high use areas where even a sturdy door and frame may fail.

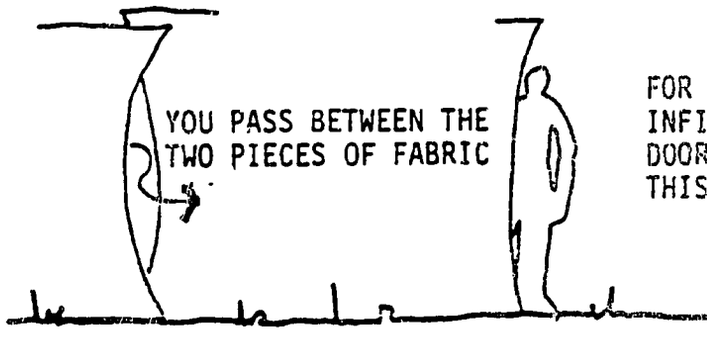
DOORS WITHOUT RIGID FRAMES

In this sytem, the door opening must be framed in and the fabric securely attached to the frame. Consider the following:

- Where security conditions will allow, this system is good for doors which are used infrequently.
- When the doors are open, interior lighting and ventilation are achieved.



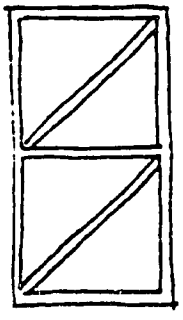




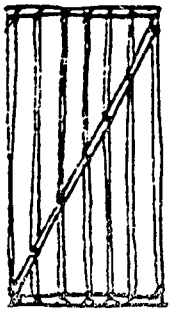
FOR COLD CLIMATES, WHERE NO INFILTRATION THROUGH THE DOOR OPENING IS DESIRABLE, THIS SYSTEM WORKS WELL

RIGID DOOR FRAMES

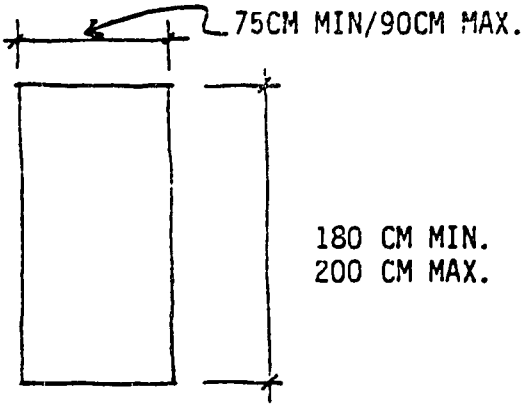
A variety of materials can be used to construct rigid door frames. Diagonal bracing is required to prevent the weight of the door from causing it to sag and become difficult to operate. After the door frame is complete, cover the frame with plastic sheeting or other available covering.



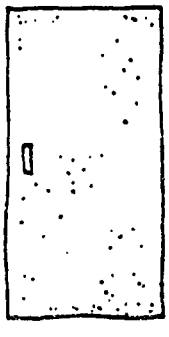
DIMENSIONED LUMBER RIGID DOOR FRAMES



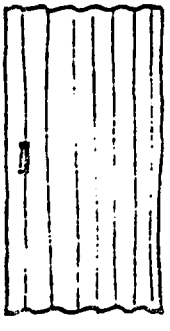
BAMBOO



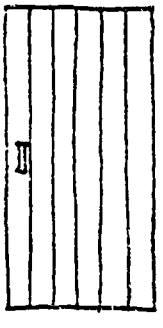
PLYWOOD DOOR DIMENSIONS



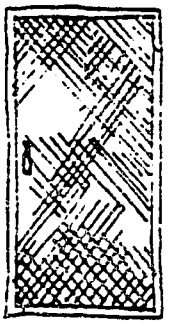
PLASTIC FABRIC DOOR COVERINGS



CORRUGATED METAL

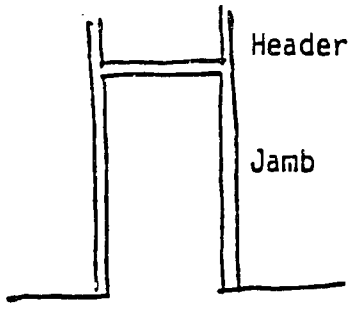


WOOD PLANKS

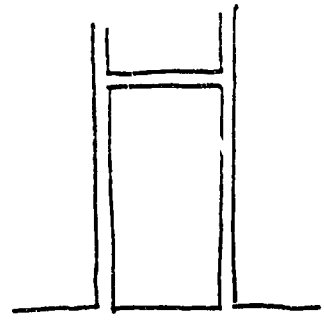


MATS

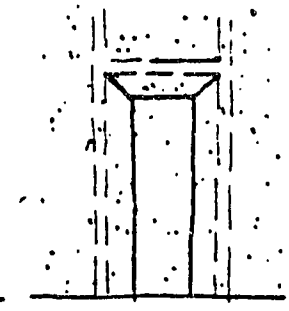
DOORS



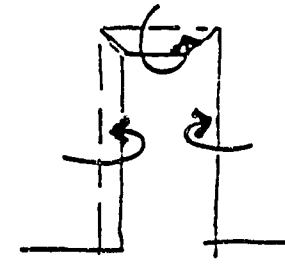
DOOR OPENING



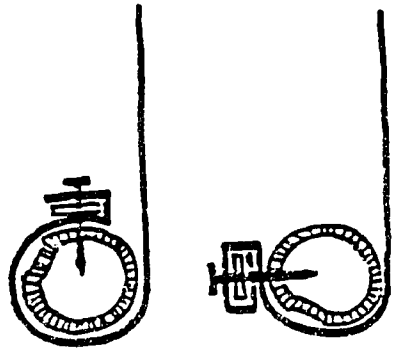
Frame Opening



Cover With Sheeting

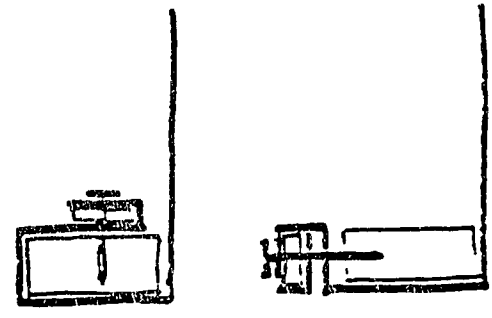


Trim and wrap the sheeting around the frame

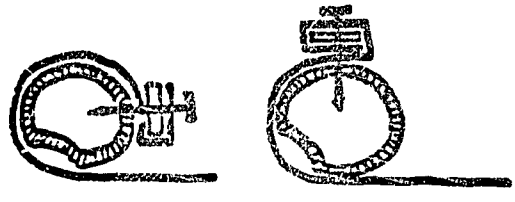


DOOR HEADERS

Bamboo

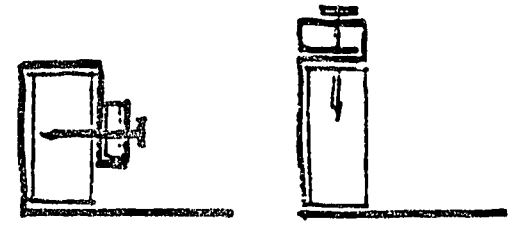


Dimensional Lumber



DOOR JAMBS

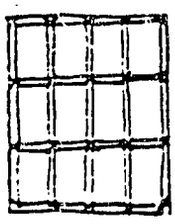
Bamboo



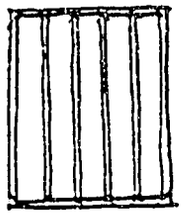
Dimensional Lumber

DOORS, WINDOWS, AND OPENINGS	No.
WINDOWS	3.82 - 1

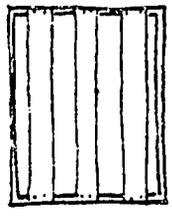
The primary function of windows and window openings is to allow natural daylighting into an enclosed space, and to ventilate the space. The placement or location of the window openings is dependent upon the interior layout. Four external window openings, of approximately one square each, are sufficient for an enclosed area of 50 square meters unless special conditions prevail.



BAMBOO

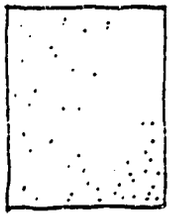


STICKS

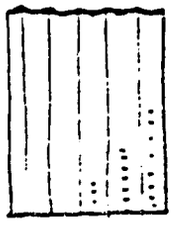


WOOD PLANKS

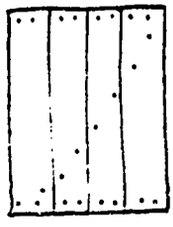
WINDOWS WITH FRAMED OPENINGS (NO COVERING)



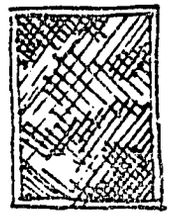
PLASTIC FABRIC



CORRUGATED METAL

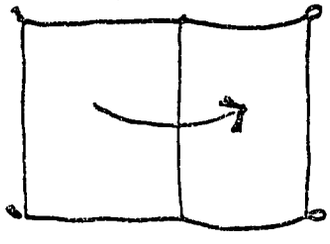


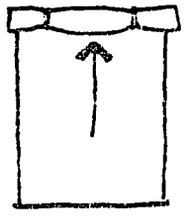
WOOD PLANKS



MATS

WINDOW COVERINGS OVER RIGID FRAMES





PLASTIC FABRIC OR WOVEN MATS ONLY (NO FRAME)

WINDOW COVERINGS WITHOUT FRAMES

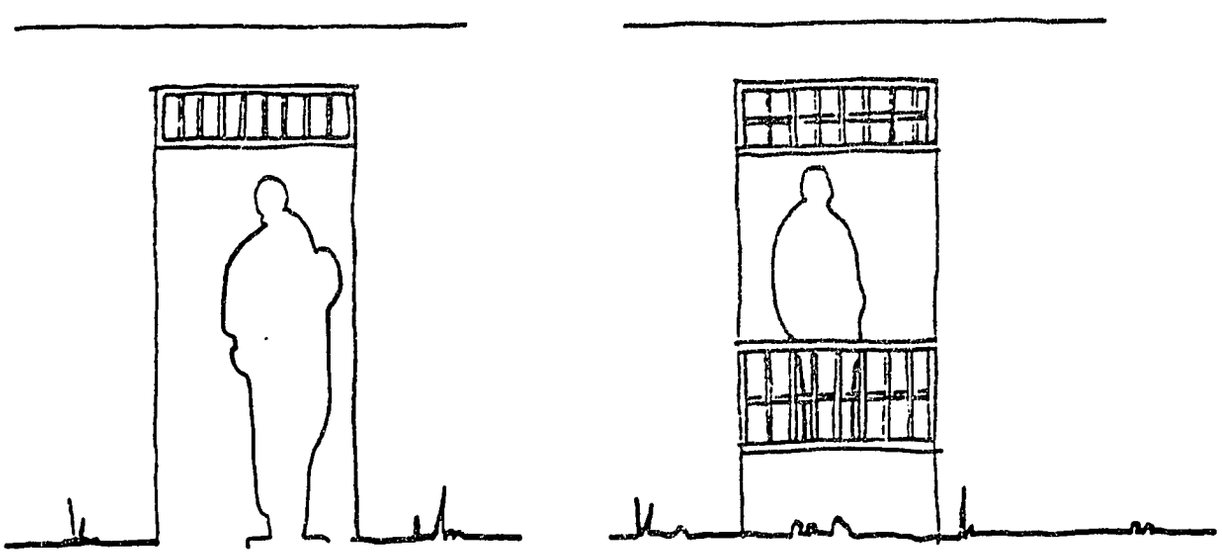
236

VENTS

The primary purpose of vents is to improve the level of human comfort inside the structure. This is achieved by:

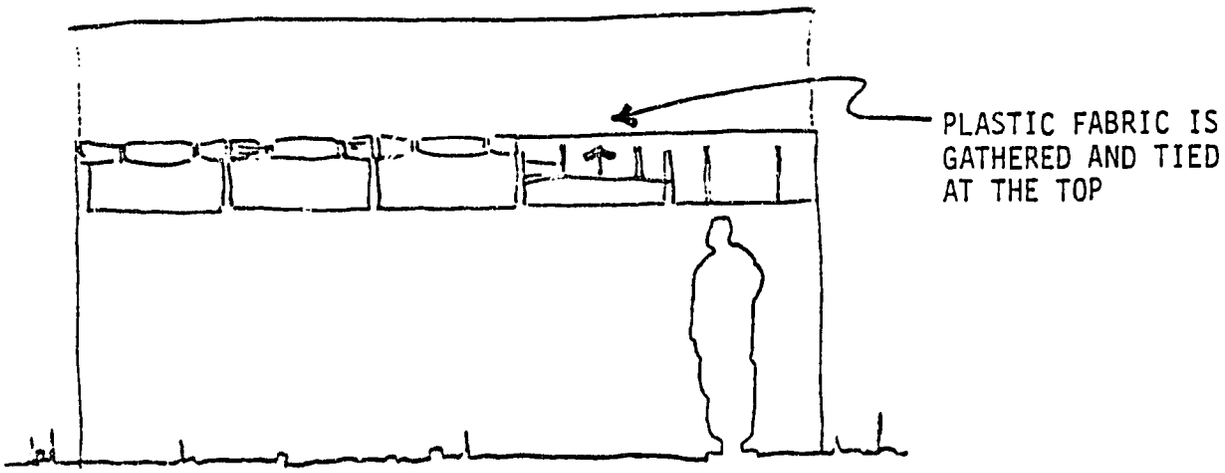
- (1) Reducing internal temperatures
  (2) Reducing internal humidity levels
  (3) Increasing internal air movement

Because both door and window openings also serve to ventilate the enclosed space, two vent openings totaling one square meter each are sufficient for an enclosed area of 50 square meters, unless special conditions prevail.

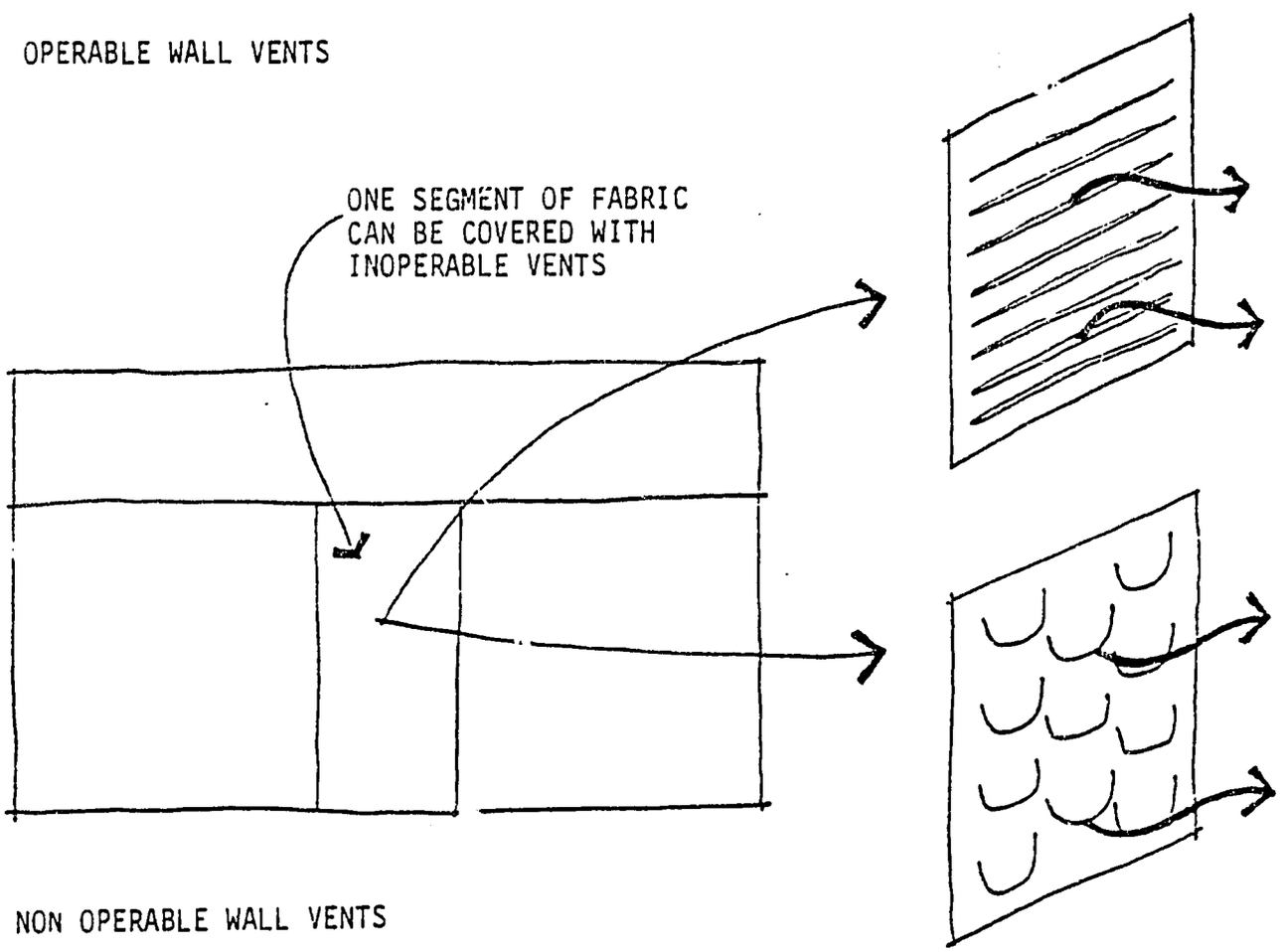


VENT OPENINGS OVER DOOR AND WINDOW OPENINGS

DOORS, WINDOWS, AND OPENINGS	No.
VENTS	3.83 - 2

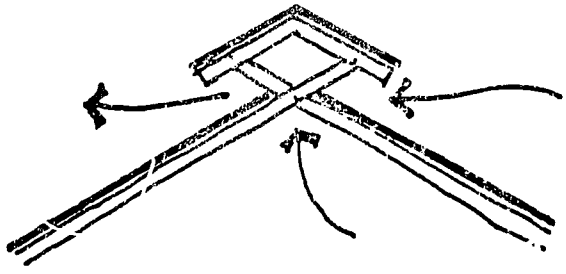


OPERABLE WALL VENTS

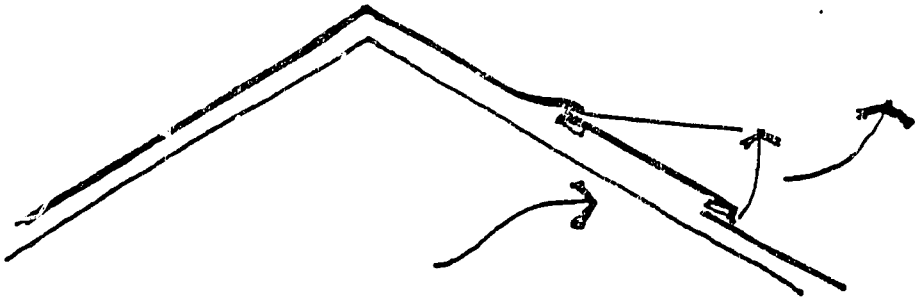


NON OPERABLE WALL VENTS

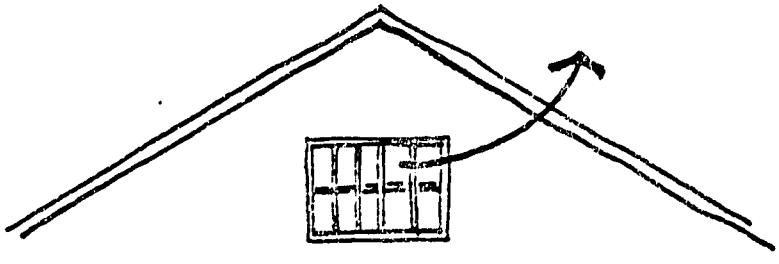
DOORS, WINDOWS, AND OPENINGS	No.
VENTS	3.83 - 3



RIDGE VENT



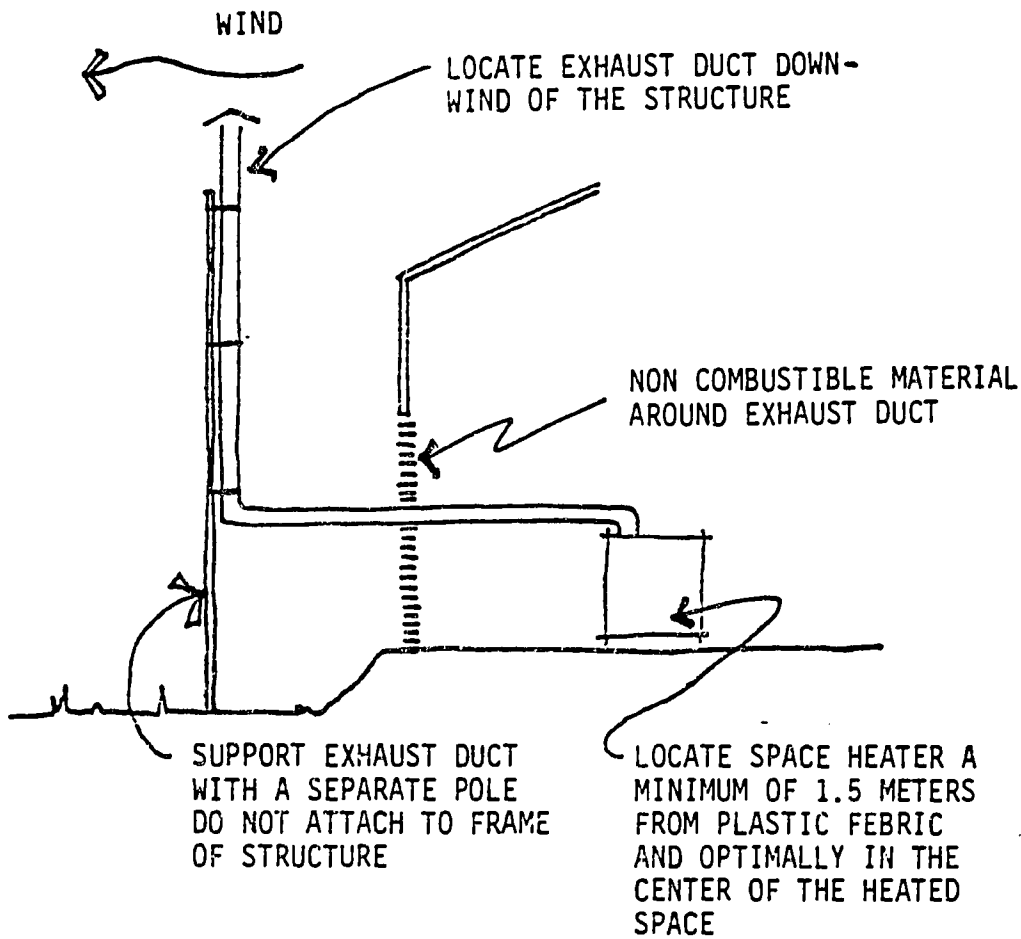
ROOF VENT



GABLE VENT

DOORS, WINDOWS, AND OPENINGS	No.
CHIMNEY OPENINGS	3.84 - 1

In cold climates, some form of internal heating will be required. Because the plastic sheeting does not breathe, and because in a cold climate door, window, and vent openings will be sealed, it is critically important for the fumes of the space heater to be vented to the outside. This is typically done through the use of an exhaust duct or chimney. The chimney opening should be in a wall, not the roof, to minimize water penetration problems. Locate the opening on the downwind side of the structure to minimize the amount of cold air blowing into the structure and to keep any sparks coming out of the chimney from landing on the roof. The space heater should not be located closer than 1.5 meters from any plastic fabric on the walls and optimally should be located in the center of the enclosed space.

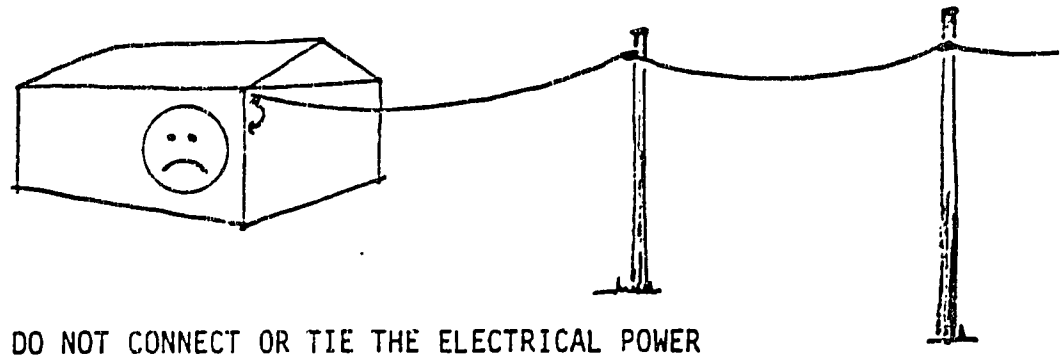


ELECTRICAL SERVICE ENTRY

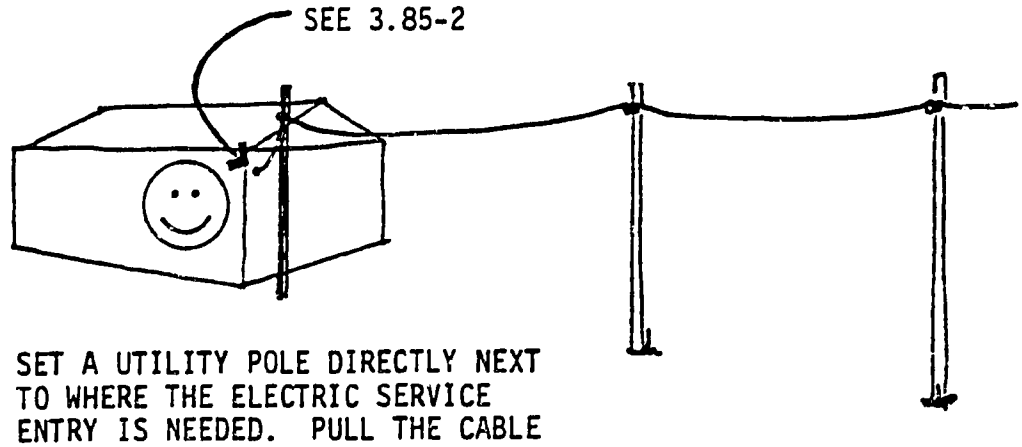
In the event that a temporary electrical generator is used (for lighting requirements or to operate equipment), some provisions are required to get the power lines into the structure. Depending on local conditions, the power lines will either be buried or suspended overhead with poles. If the cables are buried, no special fabric penetration details are required. If, however, the power lines are carried overhead, the following guidelines should be followed:

(1) Do not connect or tie the power line or its supporting cable to the frame of the structure. Set up a pole just outside the structure to receive the power line.

(2) Always try not to penetrate the roof; instead, bring the power cable through the wall or gable end to minimize problems with water penetration.



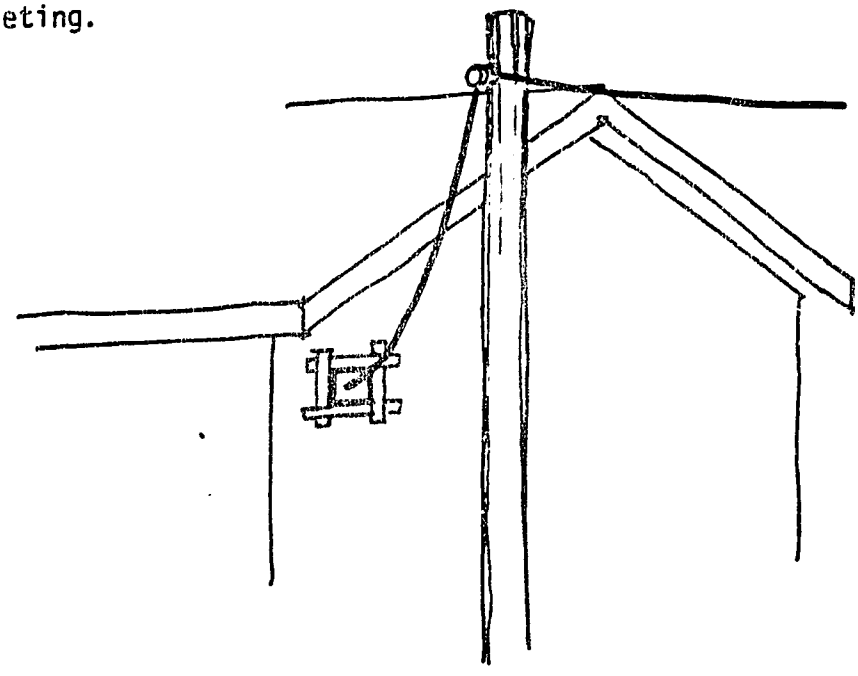
DO NOT CONNECT OR TIE THE ELECTRICAL POWER LINE TO THE FRAME OF THE STRUCTURE



SET A UTILITY POLE DIRECTLY NEXT TO WHERE THE ELECTRIC SERVICE ENTRY IS NEEDED. PULL THE CABLE THROUGH THE WALL AND NOT THE ROOF

DOORS, WINDOWS, AND OPENINGS	No.
ELECTRICAL SERVICE ENTRY	3.85 - 2

3. Reinforce the opening that is used for the electrical service entry by placing plastic tape around the opening on both sides of the plastic sheeting.



3.9 MAINTENANCE AND REPAIR

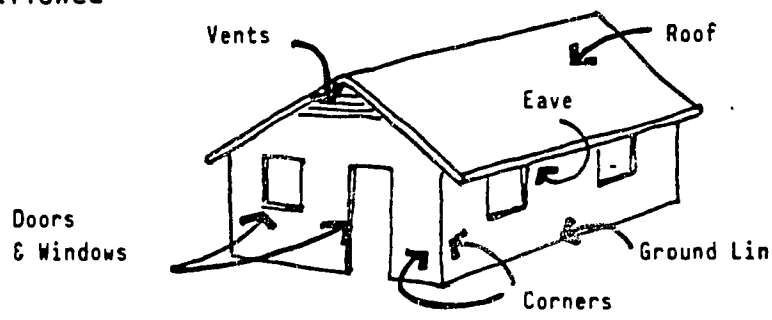
3.91 Maintenance of Plastic Sheeting Covered Structures

3.92 Repair of Plastic Sheeting Covered Structures

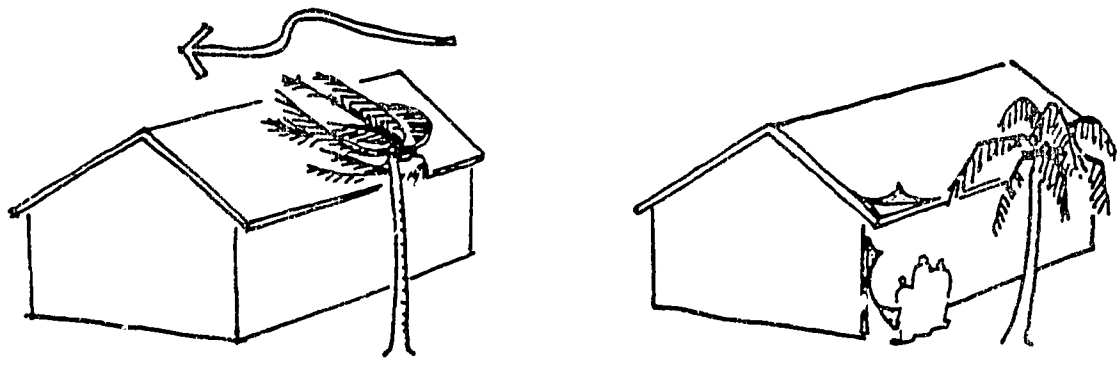
MAINTENANCE AND REPAIR	No. 3.91 - 1
MAINTENANCE OF PLASTIC SHEETING COVERED STRUCTURES	

The plastic sheeting supplied by USAID deteriorates over time and is expected to last with reasonable care for approximately one year. The following procedures should be considered to prevent premature failure of the plastic sheeting.

1. Inspect the structure regularly to detect any damage or wear. The plastic sheeting will rapidly self-destruct if damage is allowed to go uncorrected.

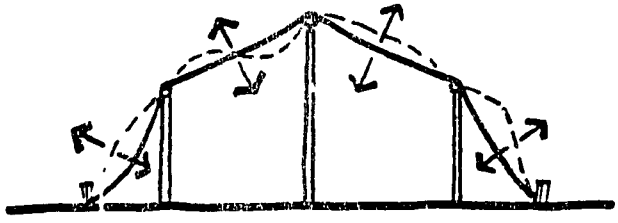


The structure should be inspected weekly and immediately following severe storms.

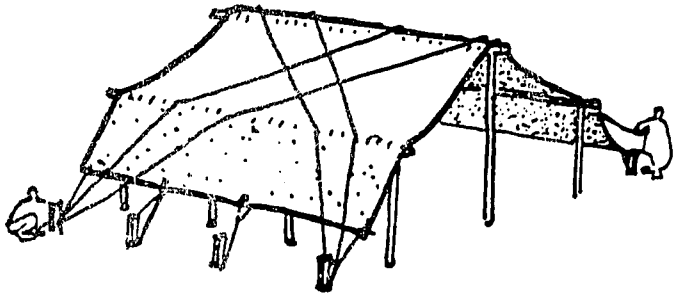


2. During severe storms, be alert to:

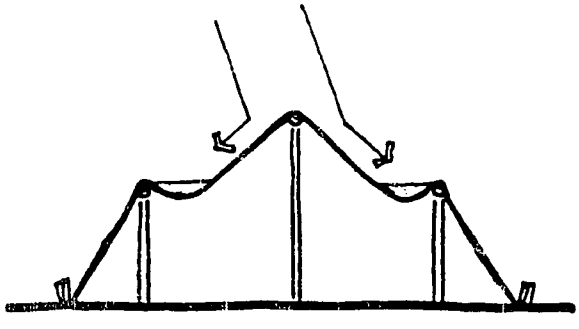
(a) Excessive flapping of the sheeting



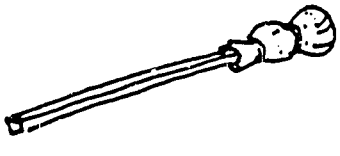
If the flapping is loud and shakes the structure, pull ropes over the structure and secure to the ground.

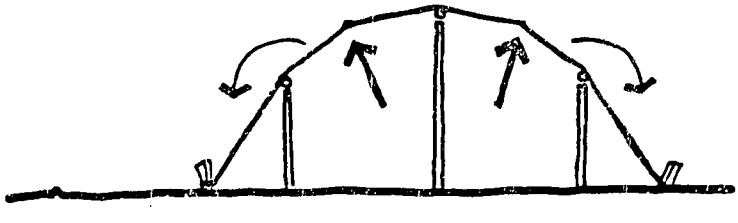


(b) Ponding of water in the sheeting

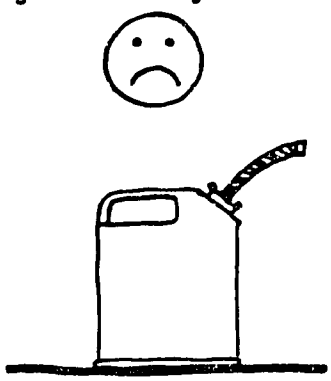


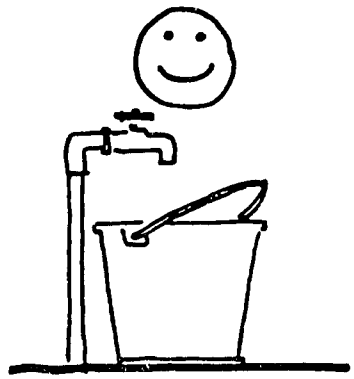
If ponding occurs, use a stick covered with cloth to push the water out.



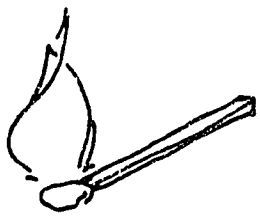


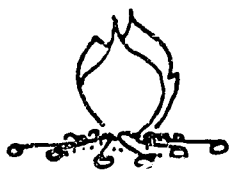
3. DO NOT use gasoline or other petroleum solvents to clean the plastic sheeting. Use only water.

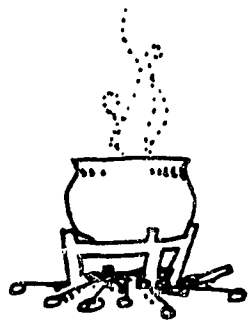




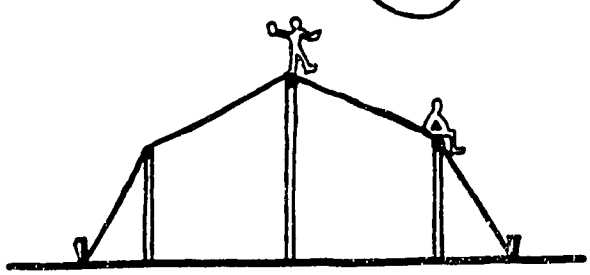
4. DO NOT use any fires or open flames near the plastic sheeting.

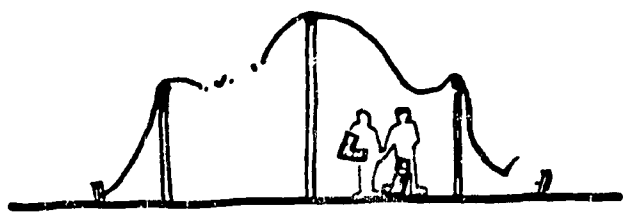






5. DO NOT allow children to play on the plastic sheeting covered structure. It is dangerous to both the children and the structure.

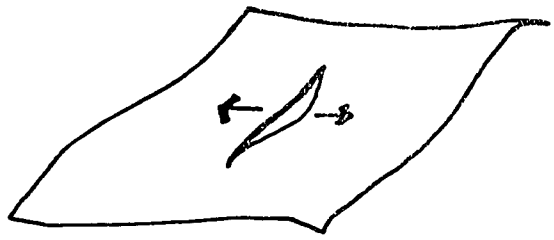




MAINTENANCE AND REPAIR	No. 3.92 - 1
REPAIR OF PLASTIC SHEETING COVERED STRUCTURES	

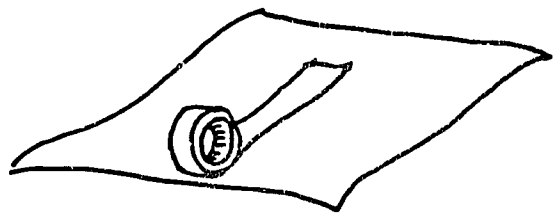
It is inevitable that some damage to the plastic sheeting will occur. It is important that any damage be quickly repaired as the plastic sheeting will quickly deteriorate once it has been damaged. The following drawings illustrate methods of repairing various types of damage.

RIPS OR TEARS

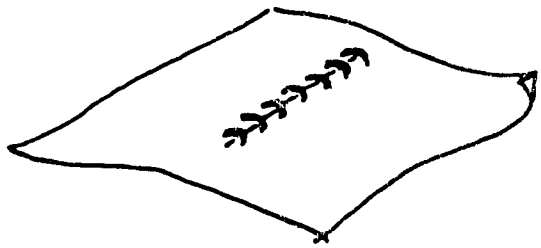


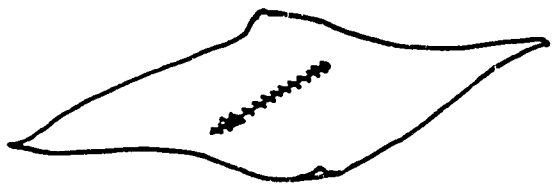
1. Plastic Tape

   The most ideal repair of rips is to apply the plastic tape which was shipped with the sheeting. (See Section 3.62 - Sheeting to Sheeting.)

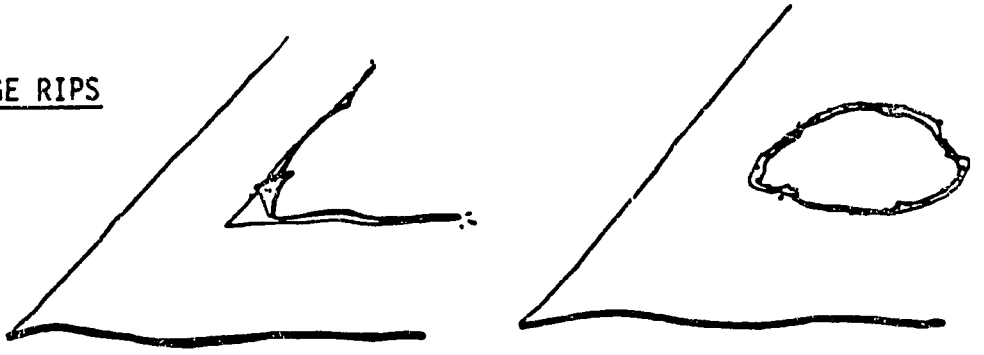


2. Lashing or Sewing



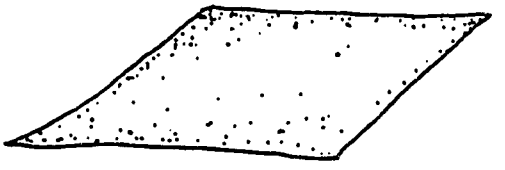


BURNED HOLES OR LARGE RIPS

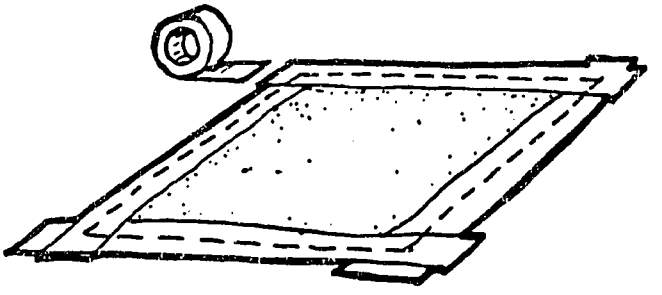


1. Plastic Tape Patch

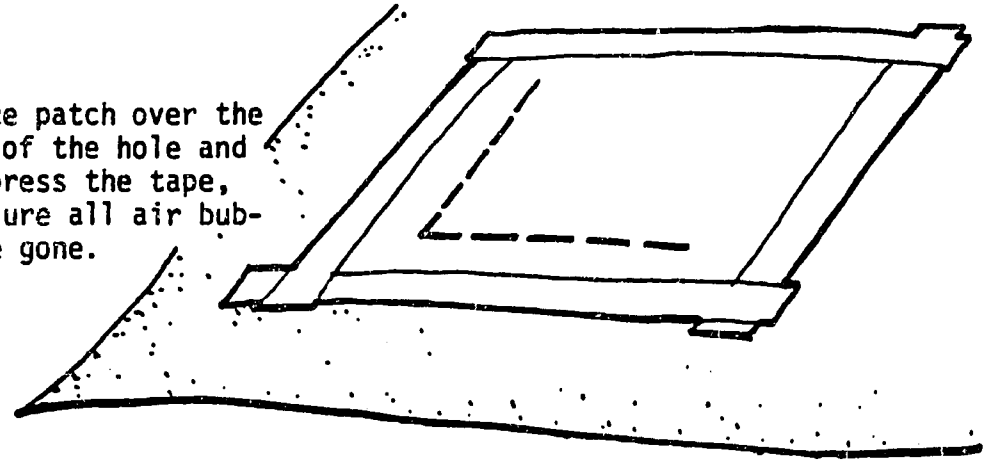
   (a) Cut a piece of plastic sheeting which is larger than the hole or rip to be repaired.



   (b) Firmly attach plastic tape to each edge.

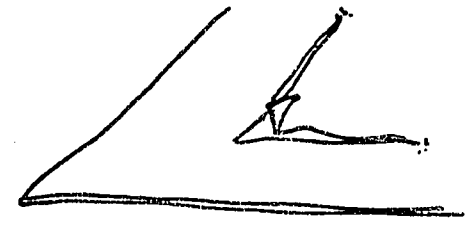


   (c) Place the patch over the outside of the hole and firmly press the tape, making sure all air bubbles are gone.

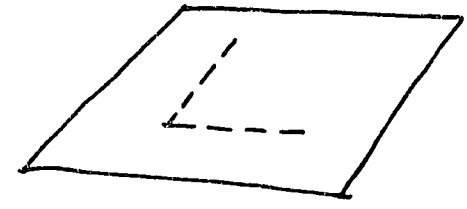


2. Sewn or Lashed Patch

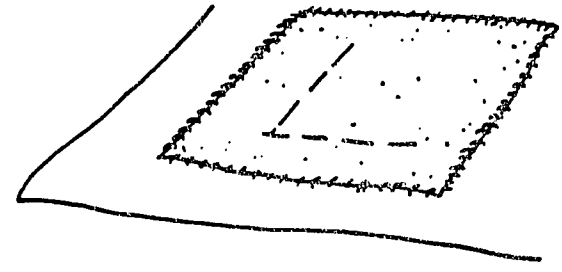
This method is inferior to the plastic tape method because it causes holes which will leak.



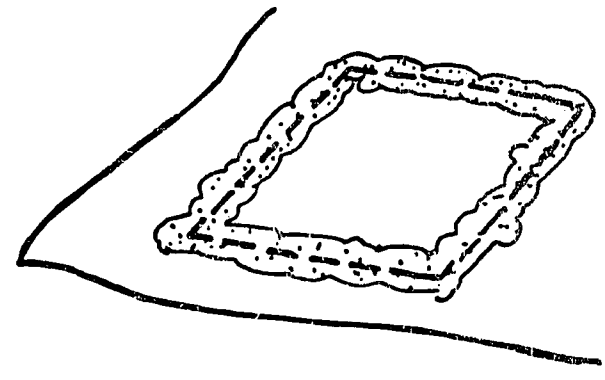
(a) Cut a piece of plastic sheeting which is larger than the hole or rip to be repaired.



(b) Sew or lash it over the hole or rip.

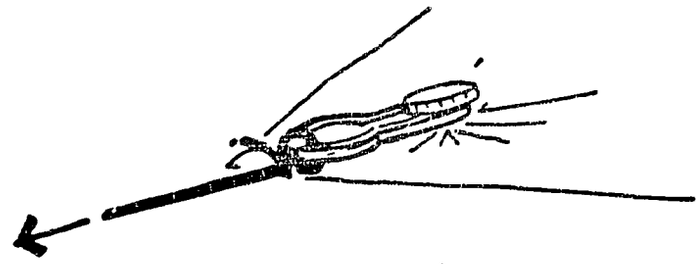


(c) Cover the seams with a sealant for temporary stoppage of leaks. Wax, roofing cement, clay, grease, or other materials may be used.

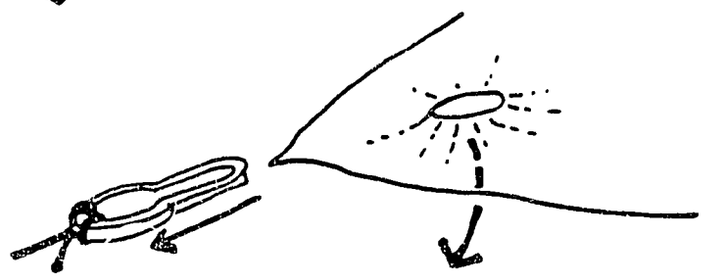


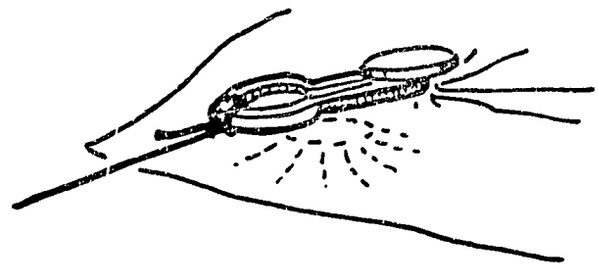
CONNECTOR FAILURE

1. Replacement after slipping



The most likely failure of a plastic connector is for it to slip off. If this happens, replace it in a location just next to where it had been attached. If the connector is damaged, particularly if the star-shaped insert has folded over, use a new connector. Certain sized coins can be used to replace the star-shaped insert.

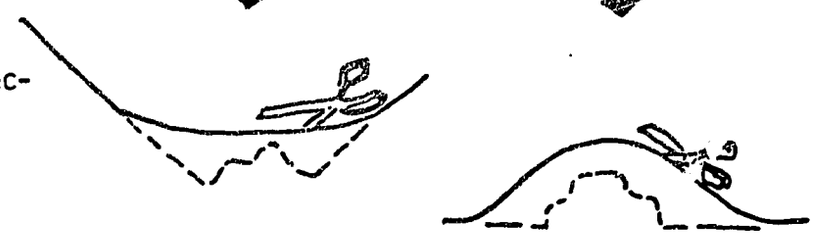




2. Replacement after ripping loose

If the connector has ripped out the plastic sheeting:

(a) Trim away the ripped section of the sheeting.



(b) Replace the connector.

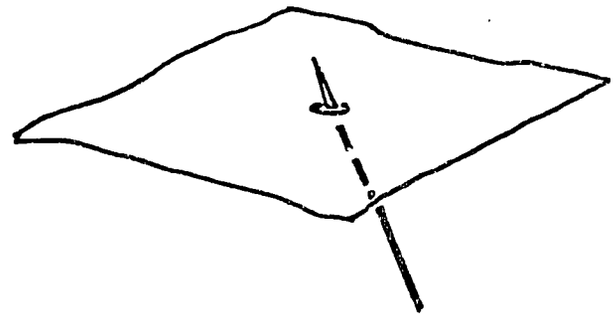
250

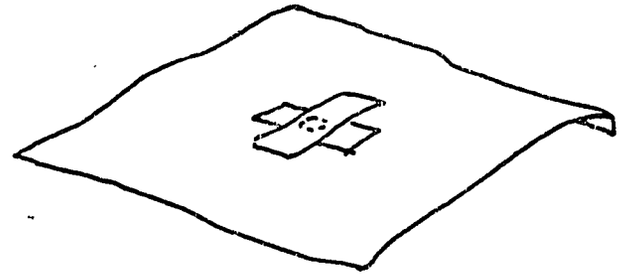
REPAIR OF PLASTIC SHEETING COVERED STRUCTURES

PUNCTURES

Small punctures present more leakage problems than structural problems.

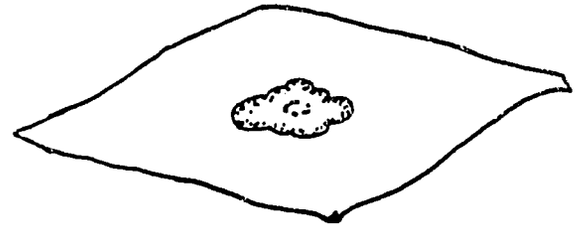
1. Plastic Tape





2. Sealant

Mud, grease, roofing cement, wax, or other materials may be placed over the puncture. They are temporary and will have to be replaced.



4.0 Appendices

APPENDIX 4.1

DISASTER PRONE DEVELOPING COUNTRIES

AFRICA

Cape Verde
Chad
Djibouti
East Africa Regional Profile
Ethiopia
Mali
Mauritania
Niger
Sahel Transportation Survey
Senegal
Somalia
Uganda
Upper Volta
Zaire

ASIA

Bangladesh
Burma
India
Indonesia
Malaysia
Nepal
Pakistan
Philippines

CARIBBEAN

CARICOM Regional Profile
Dominican Republic
Haiti

LATIN AMERICA

Bolivia
Chile
Ecuador
El Salvador
Guatemala
Honduras
Nicaragua
Peru

NEAR EAST

Turkey

SOUTH PACIFIC

Fiji
Tonga
Western Samoa

INDIAN OCEAN

Island Countries of the Indian Ocean

APPENDIX 4.2

BIBLIOGRAPHY

Abeles, Schwartz & Associates, Cost-Effective Housing Systems for Disaster Relief, Volume 4, HUD, Washington, 1974.

Anjomark Research Institute, Booklet describing emergency shelter alternatives, Anjomark Institute, Denver, 1976.

Building Research Establishment, "Earthquake Hurricane Resistant Low-Income Housing." Drawings describing construction of 4 trial houses. BRC/HLDC St. Vincent.

Cain, Allan, Afshar, Farroukh, and Norton, John, "Indigenous Building and the Third World," Architectural Digest, Vol. 4 (1975), pp. 207-224.

Carnegie-Mellon University. Feasibility Test of an Approach and Prototype for Ultra-low-cost Housing. Report by Advanced Building Studies Department, Carnegie-Mellow University, Pittsburgh. Submitted to AID, Washington, 1975.

Carnegie-Mellon University, A Prototype Refugee Shelter. Report by Interdisciplinary Working Party, Carnegie-Mellon University, Pittsburgh, 1974.

Chavda, Vigyadhar, Emergency Habitat, (UIA Competition Project). Ahmedadbad, India.

Ching, Francis D.K., Building Construction Illustrated. New York: Van Nostrand Reinhold, 1975.

Como Hacer Una Casa Mas Segura. Free booklet distributed by Philip Morris, Inc., Guatemala Office after the earthquake in 1976.

Cuny, Frederick C., Disasters and the Small Dwelling: The State of the Art. Keynote address presented at a conference, Disasters and the Small Dwelling, Oxford Polytechnic, Oxford, England, April 1978, (Revision). Dallas: Intertect.

Cuny, Frederick C. & Assoc., Relief Operations Guidebook - Section III: Housing (Draft Copy). Prepared for International Disaster Preparedness Seminar - A.I.D. INTERTECT, Dallas.

Cuny, Frederick C., Davis, Ian R., Kringold, Frederick, Issues and Problems in the Provision of Shelter and Housing, a Review of Experiences and Lessons from Recent Disasters. Appropriate Reconstructions Training and Information Centre (ARTIC), January 1978.

"The Cultural Context of Shelter Provision," Disasters, Vol. 2, No. 2/3 (1978).

Davis, Ian R. Emergency Shelter. Excerpt from The Role of Technology in in International Disaster Assistance, Proceedings of the Committee on International Disaster Assistance Workshop, March 1977. National Academy of Sciences, Washington, 1978.

Davis, Ian, Guatemala, Shelter & Housing Policy in Weeks 1-3 Following the Earthquake, Feb. 4, 1976, The Research & Development Group, Oxford, England.

Davis, Ian, Shelter After Disaster. Oxford Polytechnic Press, England, 1978.

Department of Housing and Urban Development, Office of International Affairs Washington, Handbook for Building Homes of Earth, Department of Housing and Urban Development, Washington, 1979.

Dietz, Albert G. H., Dwelling Housing Construction. Cambridge, Mass., MIT Press, 1974.

Durbahn, Walter E., Revised by Elmer W. Sunderberg. Fundamentals of Carpentry Practical Construction. Chicago: American Technical Society, 1977.

Dynes, Russell R. Definitions of Disaster -- Initial Consideration. Draft prepared for the Committee on International Assistance.

Eaton, Keith J., Buildings and Tropical Windstorms. Overseas Building Notes No. 188. Garston, Waterford: Building Research Establishment, April 1981.

Eaton, Keith J., Low Income Housing and Hurricanes. Reprinted from Wind Engineering: Proceedings of the Fifth International Congress, Fort Collins, Colorado, USA, July 1979. J.E. Cermak, Editor, Oxford: Pergamon Press, 1980.

Eaton, Keith J., How to Make Your Building Withstand Strong Winds. Paper presented at BRE Seminar on Low-Income Housing, St. Vincent, 26-27 March 1980. Garston, Waterford: Building Research Establishment, 1980.

Erkelens, Peter A., Low Cost Papyrus Polyethlene Roof. University of Nairobi, Housing Research and Development Unit, October 1980.

Evaluation Technologies, Inc., Latin America: Housing Survey for Disaster Relief and Preparedness. Prepared by Evaluation Technologies, Inc., Arlington, Virginia, for the Office of U.S. Foreign Disaster Assistance, AID, Washington, D.C., March 1981.

FCH Services, Inc., Seminar on New Techniques of Design and Construction of Low Cost Housing. Washington, 1972.

Foundation for Cooperative Housing, Cooperative Housing and the Minimum Shelter Approach in Latin America, Volume 2. Washington.

Green, A.K., An Assessment of Construction Materials for Use in Emergency Housing Carried out on Behalf of OXFAM. Fulmer Research Institute, England, August 1976.

Hartkopf, Volker H. and Goodspeed, Charles H., "Space Enclosures for Emergencies in Developing Countries", Vol. 3, NO. 4 (1979).

Hatton, E.M., The Tent Book. Boston: Houghton Mifflin Co, 1979.

Hornbostel, Caleb and Hornung, William J., Materials and Methods for Contemporary Construction, Prentice Hall, N.J. 1974.

Howard, Jim and Pice, Ron. Plastic Sheeting: Its Use for Emergency Housing and Other Purposes. An OXFAM Technical Guide. 2nd Revision, February 1981. Oxford, England: OXFAM, 1973.

IL 8 - Nets in Nature and Technics. Institute for Lightweight Structures (IL), University of Stuttgart, direction Frei Otto, with Berthold Burkhardt and Jurgen Hennicke, 1975.

IL 14 - Adaptable Architecture. Institute for Lightweight Structures (IL), University of Stuttgart, direction Frei Otto, with Berthold Burkhardt and Jurgen Hennicke, 1975.

IL 16 - Tents: Pictures of Realized Membrane Structures, Remarks from the Practice, and The Work of Peter Stromeyer. Institute for Lightweight Structures (IL), University of Stuttgart, direction Frei Otto, 1976.

Indigenous Building and the Third World. Publication based on an exhibition in Tehran in April, 1976.

Intertect, Preliminary Proposal: Reduction of NBS High Wind Study Results for Field Use in Developing Countries. Dallas, Texas, 1979.

Kern, Ken, The Owner Built Home: A How-to-do-it Book. New York: Charles Scribners Sons, 1975.

Kliment, Stephen A., Housing in Extreme Winds: Socio-Economic and Architectural Considerations, Vol. 5 of Building to Resist the Effect of Wind. Washigton, U.S. Department of Commerce, National Bureau of Standards, Building Science Series 100, 1977.

"Low Cost Housing for Developing Countries," BRE News 52 (periodical).

May, Gerald W., Proceedings of International Workshop, Earthen Buildings in Seismic Areas, Albuquerque, New Mexico, May 1981, Vol 1.

McClure, F.A., Bamboo as a Building Material. Printed by U.S. Dept. of Agriculture Service, Washington D.C., May 1953. Reprinted by Department of Housing and Urban Development, Office of International Affairs, Washington D.C. June 1972.

Moss, William, Assoc., Air-Drop Short Term Disaster Shelter System, Proposal submitted to National Science Foundation, Washington, 1972.

National Academy of Sciences, Roofing in Developing Countries, Washington, 1974.

Office of U.S. Foreign Disaster Assistance, USAID Latin America Housing Survey for Disaster Relief and Preparedness. Washington, 1981.

Otto, Frei (Editor), Tensile Structures: Design, Structure, and Calculation. MIT Press, Cambridge, 1962, 1966.

Paraskevopoulos, Stephen C.A., Factors Governing the Introduction of Foam Plastics for Housing Use in Underdeveloped Areas of the World, prepared for USAID, Washington, 1966.

Planning and Development Collaborative International (PADCO), Disaster Assistance Manual, Volume I: Transition Housing for Victims of Disaster. Prepared by PADCO under the auspices of the Office of U.S. Foreign Disaster Assistance (OFDA) of the Agency for International Development (AID) in collaboration with the Office of Housing, April 1981.

Planning and Development Collaborative International (PADCO). The Disaster Relief Response in Dominica following Hurricane David, with Particular Emphasis on the USAID Emergency Housing Program. Prepared by PADCO, Inc., Washington, D.C. for the Office of Housing, U.S. Agency for International Development, February 1981.

Rapoport, Amos, House Form and Culture. Englewood Cliffs, N.Y.: Prentice-Hall, Inc., 1969.

Ressler, Everett, Evaluation of CMU/INTERTECT A-Frames as Emergency Shelter in Bangladesh. Submitted to AID, Washington, March 1977.

Ressler, Everett, Issues Related to the Provision of Emergency Shelter in Winter Conditions. May 1977.

Ressler, Everett, Post-Disaster Technical Information Flow for the Reconstruction of Housing. Report submitted to AID, Washington, March 1977.

Rudofsky, Bernard, Architecture without Architects. Garden City, N.Y.: Doubleday & Co., Inc., 1964.

Rudofsky, Bernard, The Prodigious Builders. New York: Harcourt Brace Jovanovich, 1977.

Salyer, Ival O., et.al., Development of Low-Cost Roofing from Indigenous Materials in Developing Nations, USAID Washington, 1975.

Shelter, Bolinas, California: Shelter Publications, 1973.

Shelter II, Bolinas, California: Shelter Publications 1978.

Sinnamon, Ian T. and Van't Loo, G.A., Cyclone-Resistant Rural Primary School Construction: A Design Guide. Educational Building Report 7. Bangkok, Thailand: UNESCO Regional Office for Education in Asia, 1977.

Taylor, Alan, Style in Aid-Giving: Relief versus Development in Guatemala. Paper presented to a symposium, Human Factors in the 1976 Guuatemala Earthquake: Social Science and Disaster Recovery held during the Society for Applied Anthropology Annual Meeting, Merida, Mexico, April 1978.

Ural, Oktay, Construction of Lower-Cost Housing. New York: John Wiley and Sons, 1980.

USAID, Guatemala AID Disaster Relief Program Reports on Post Earthquake Distribution of Building Materials, Washington, 1977.

U.S. Agency for International Development, Disaster Relief Case Report, Guatemala Earthquake, Washington, 1978.

U.S. Army, Reference Manual on Shelters, Natick Laboratories, Mass., 1972.

U.S. Department of Commerce, How Houses Can better Resist High Wind, NBSIR 77-1197, Washington, 1977.

U.S. Printing Office, How to Build a House Using Self-Help Housing Techniques, Washington, 1974.

3.5 STRUCTURAL CONNECTIONS

3.51 Masonry
3.52 Dimensional Lumber
3.53 Bamboo
3.54 Poles
3.55 Rope

ILLUSTRATION CREDITS

This section is not intended to be a complete manual on every type of construction. It does, however, illustrate the details required to construct the frames shown in Section 3.3 Framing System. The individuals responsible for construction of the emergency shelter are assumed to have some knowledge of construction methods and the use of basic tools.

The illustrations in this section are from the publications listed below and are referenced by a number code in the text. For more complete information on building materials and methods refer to these documents, or better yet, local builders.

1. Building Research Establishment. "Earthquake Hurricane Resistant Low-income Housing." Drawings describing construction of four trial houses. BRE/HLDC St. Vincent.

2. Ching, Francis D.K. Building Construction Illustrated. New York: Van Nostrand Reinhold, 1975.

3. Cuny, Frederick C. & Assoc. Relief Operations Guidebook - Section III: Housing (Draft Copy). Prepared for International Disaster Preparedness Seminar - A.I.D. INTERTECT, Dallas.

4. Department of Housing and Urban Development, Office of International Affair, Washington. Handbook for Building Homes of Earth, Department Of Housing and Urban Development, Washington, 1979.

5. Dietz, Albert G.H. Dwelling House Construction. Cambridge, Mass.: MIT Press, 1974.

6. Durbahn, Walter E. Revised by Elmer W. Sunderberg. Fundamentals of Carpentry Practical Construction. Chicago: American Technical Society, 1977.

7. Eaton, K.J. Low Income Housing and Hurricanes. Reprinted from Wind Engineering: Proceedings of the Fifth International Congress, Fort Collins, Colorado, U.S.A., July 1979. J.E. Cermak, Editor. Oxford: Pergamon Press, 1980. pp. 7-21.

8. Eaton, Keith J. How to Make Your Building Withstand Strong Winds. Paper presented at BRE Seminar on Low-income Housing, St. Vincent, 26-27 March 1980. Garston, Waterford: Building Research Establishment, 1980.

9. Hornbostel, Caleb and Hornung, William J. Materials and Methods for Contemporary Construction. Englewood Cliffs, N.J.: Prentice Hall, Inc., 1974.

10. Kern, Ken. The Owner Built Home: A How-to-do-it Book. New York: Charles Scribner's Sons, 1975.

11. Kliment S.A., Raufaste, N.J., and Marshal, R.D. 43 Rules. How Houses Can Better Resist High Wind. Washington,U.S. Department of Commerce, National Bureau of Standards, NBSIR 77-1197, 1977.

12. Kliment, Stephen A. Housing in Extreme Winds: Socio-economic and Architectural Considerations, Vol. 5 of Building to Resist the Effect of Wind. Washington, U.S. Department of Commerce, National Bureau of Standards, Building Science Series 100, 1977.

13. McClure, F.A. Bamboo as a Building Material. Printed by U.S. Department of Agriculture, Foreign Agriculture Service, Washington D.C., May 1953. Reprinted by Department of Housing and Urban Development, Office of International Affairs, Washington, D.C., June 1972.

14. Planning and Development Collaborative International (PADCO). Disaster Assistance Manual, Volume I: Transition Housing for Victims of Disaster. Prepared by PADCO under the auspices of the Office of U.S. Foreign Disaster Assistance (OFDA) of theAgency for International Development (A.I.D.) in collaboration with the Office of Housing, April, 1981.

15. Shelter. Bolinas, California: Shelter Publications, 1973.

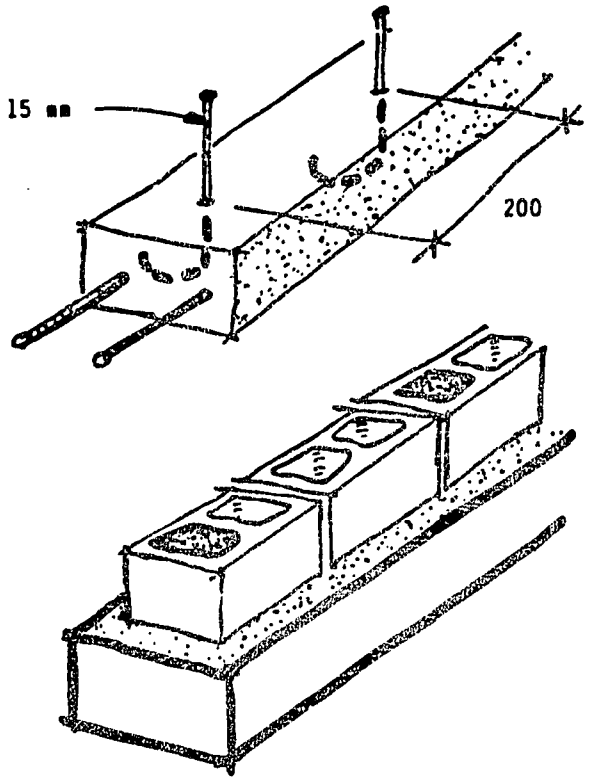
16. Sinnamon, Ian T. and Van'T Loo, G.A. Cyclone-Resistant Rural Primary School Construction: A Design Guide. Educational Building Report 7. Bangkok, Thailand: UNESCO Regional Office for Education in Asia, 1977.

17. Ural, Oktay. Construction of Lower-Cost Housing. New York: John Wiley & Sons, 1980.

CONCRETE FOUNDATION

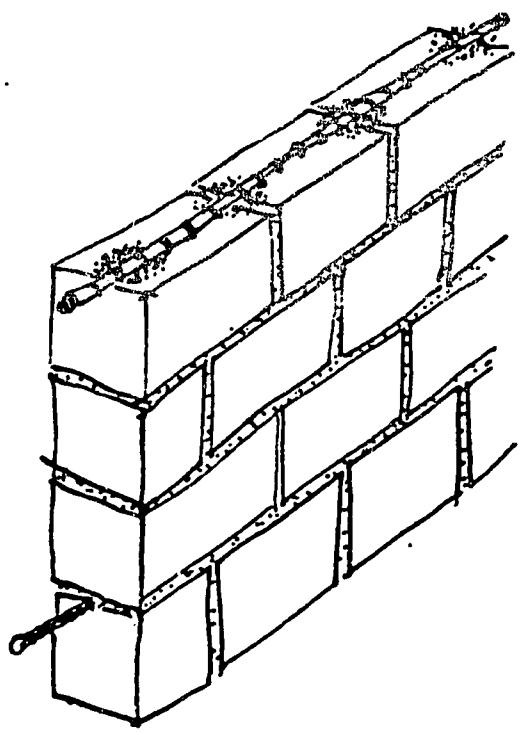
Anchor the first course of open cell concrete blocks to the foundation. 15 mm bars extend out of the concrete foundation every 2 meters.

Fill the cells that fall over the rebar with mortar.



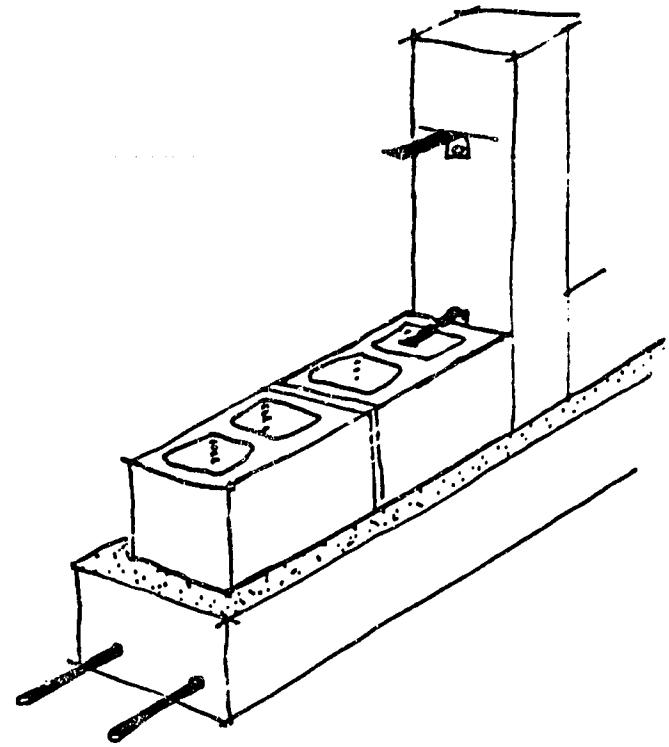
HORIZONTAL REINFORCEMENT

Masonry construction will fail easily from lateral loading unless horizontal reinforcing is used. A variety of materials can be used including the following: deformed steel rods, split cane, bamboo, and barbed wire. Place the steel rods every three courses.

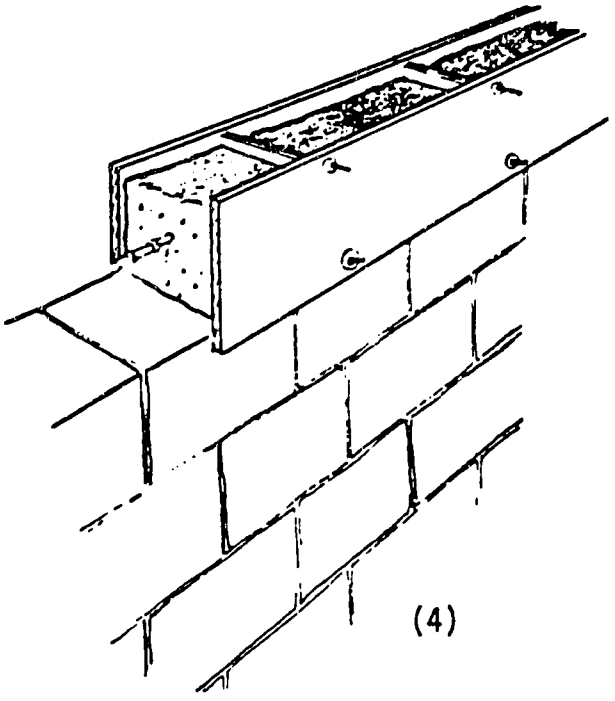


COLUMN TIE

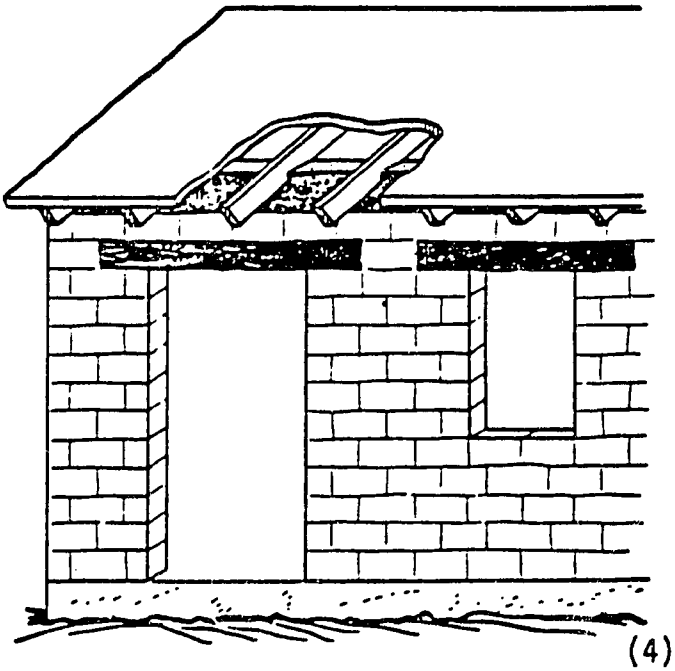
Masonry infill needs to be tied to the structural wall frame (columns) to insure a stable system. Masonry ties should be used every three courses.



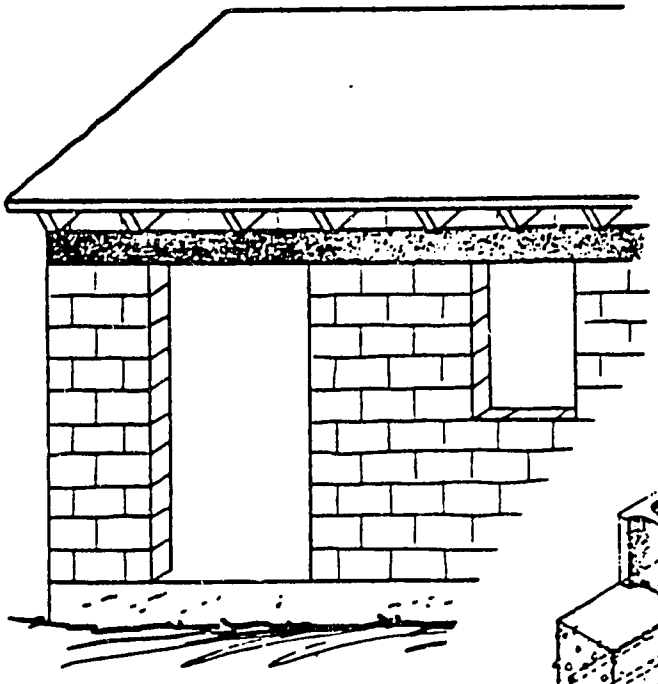
LINTEL DETAILS



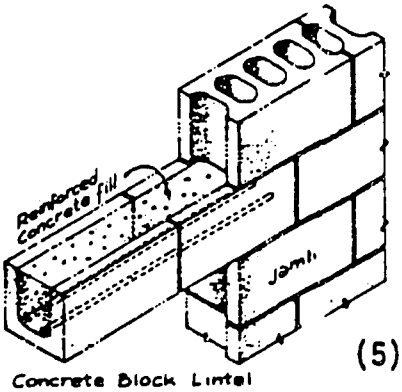
(4)



(4)

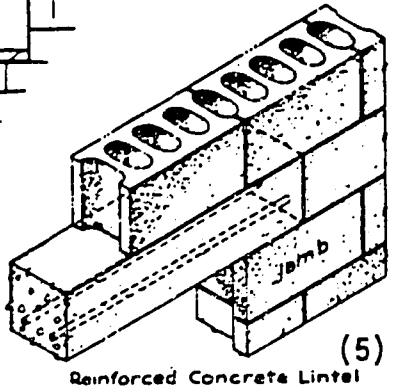


(3)



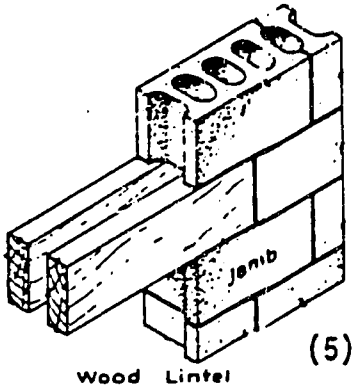
(5)

Concrete Block Lintel



(5)

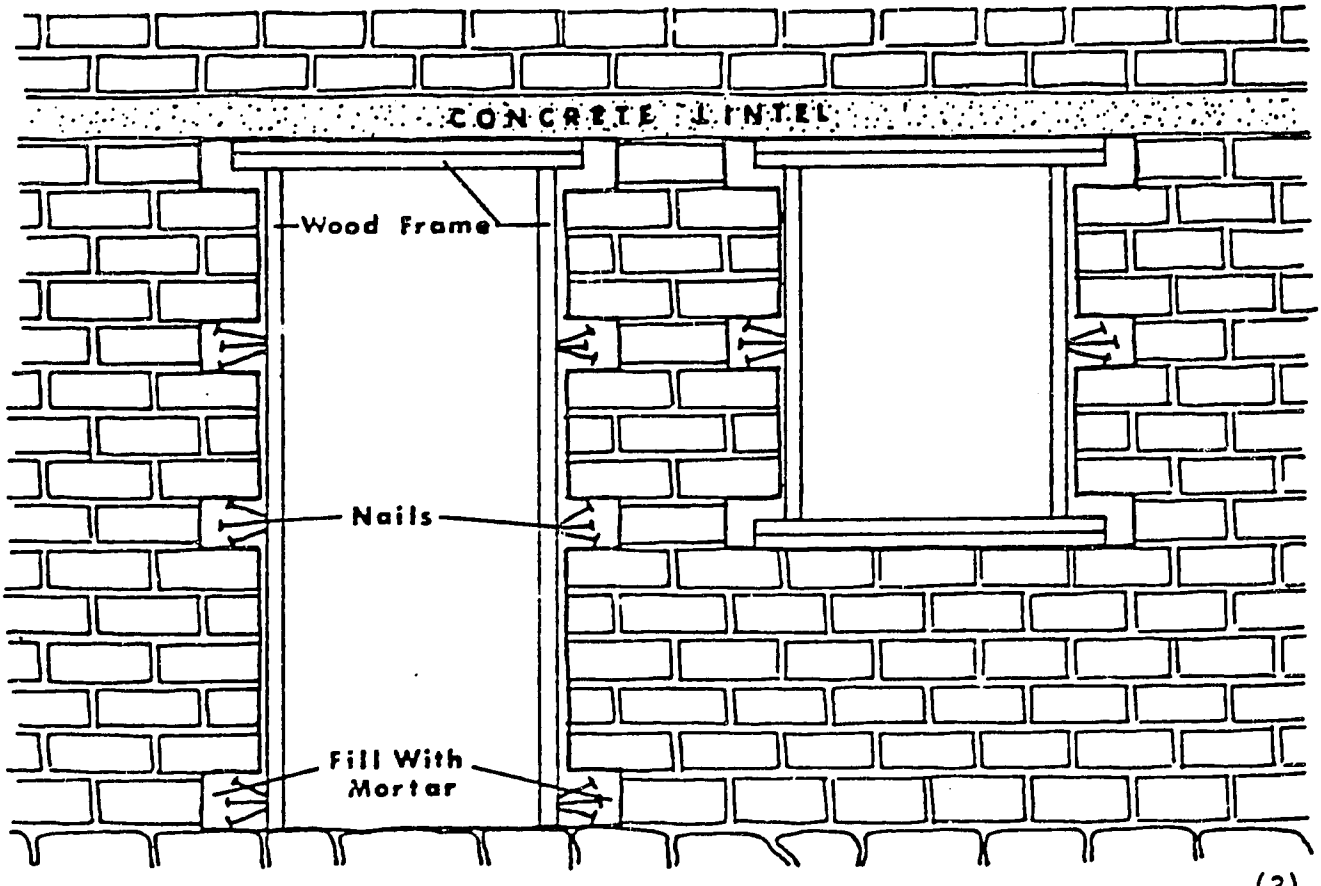
Reinforced Concrete Lintel



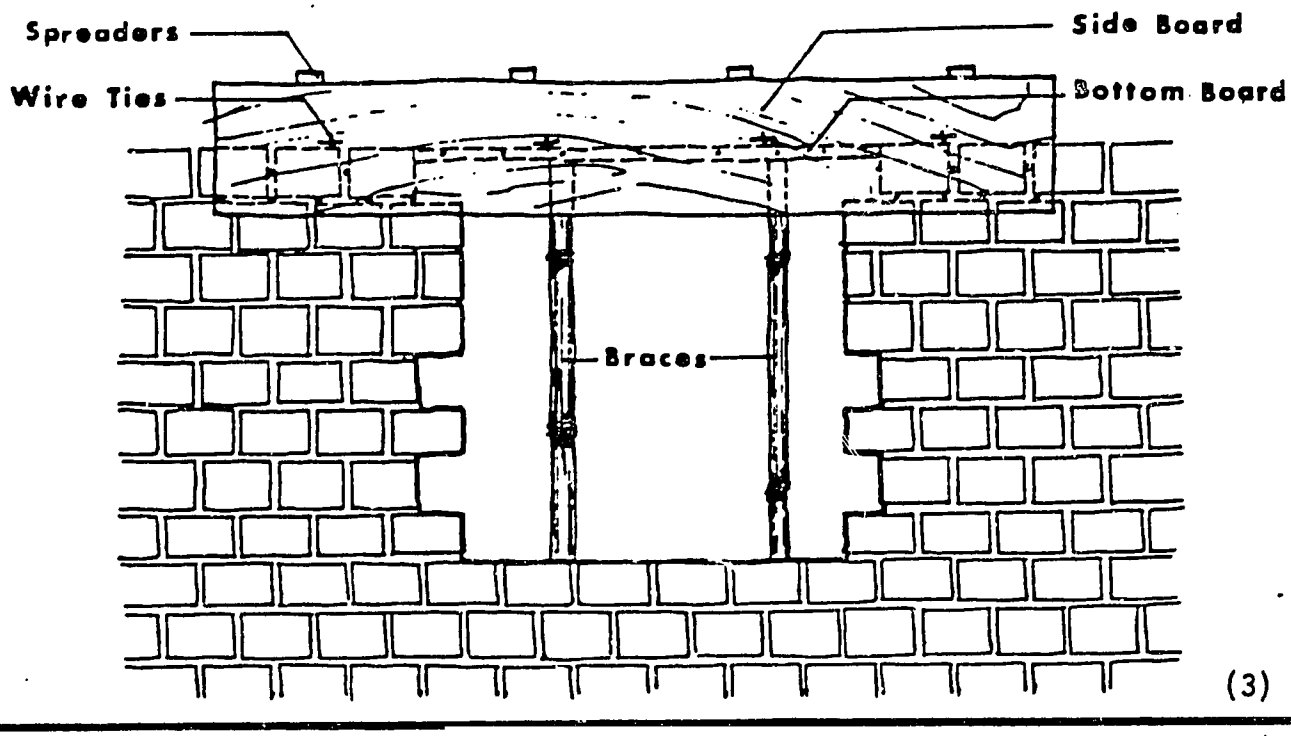
(5)

Wood Lintel

LINTEL DETAILS

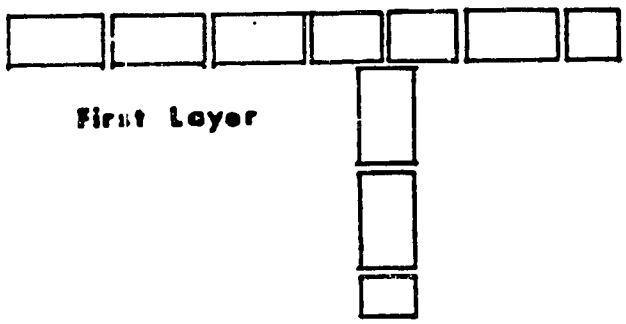


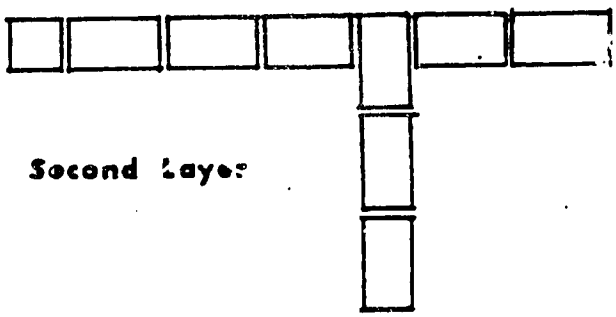
(3)

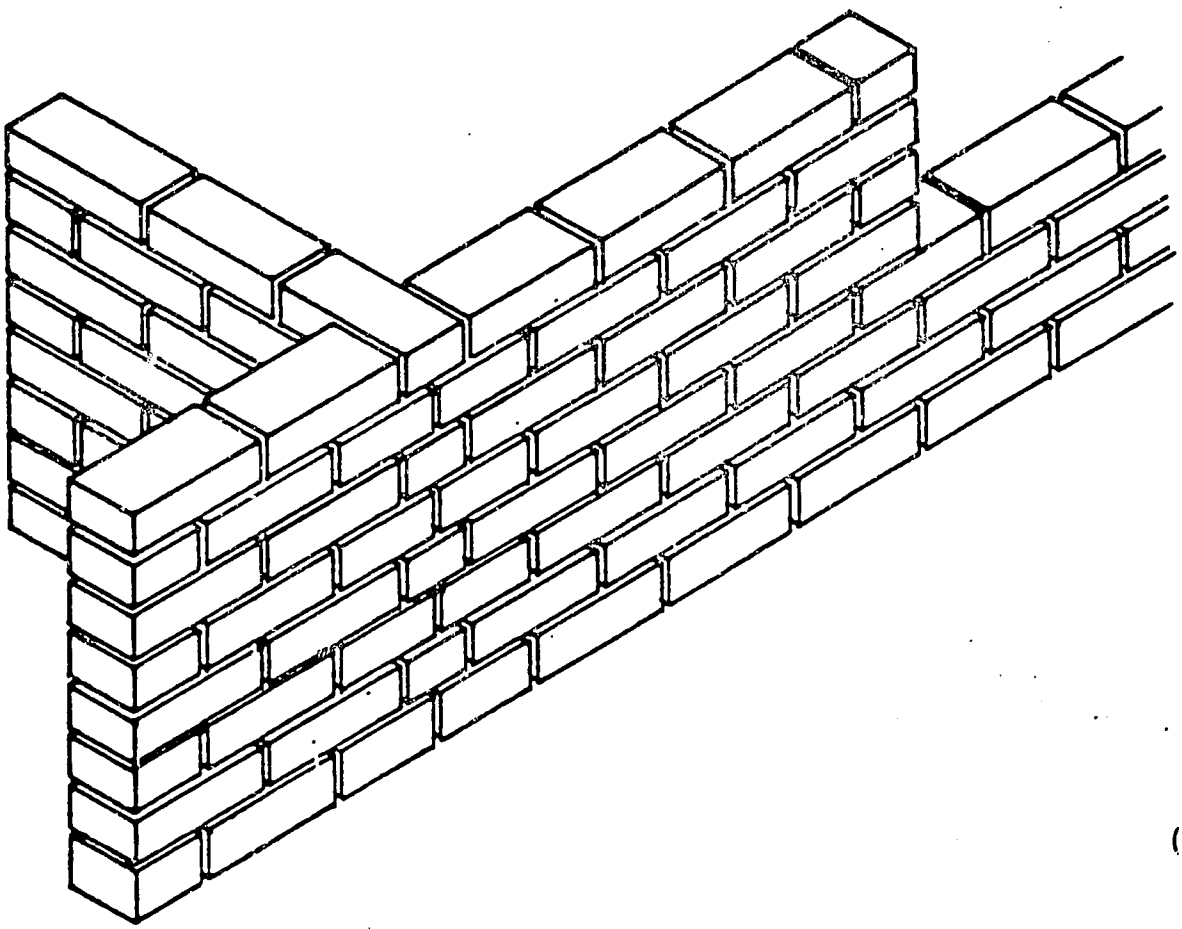


(3)

WALL INTERSECTION

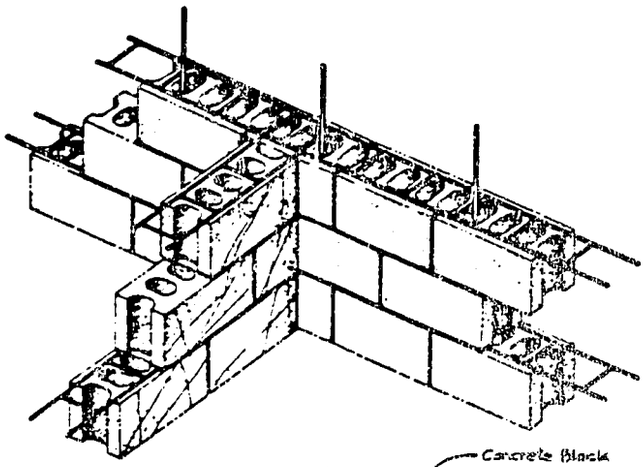


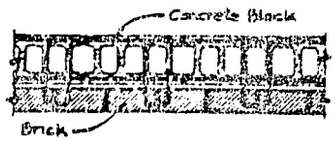




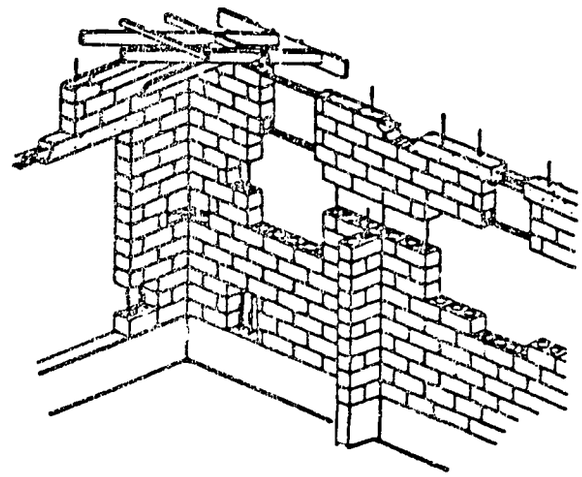
(3)

MISCELLANEOUS DETAILS

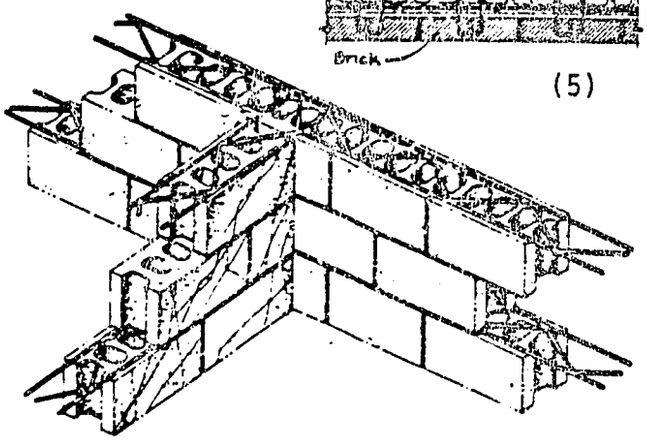


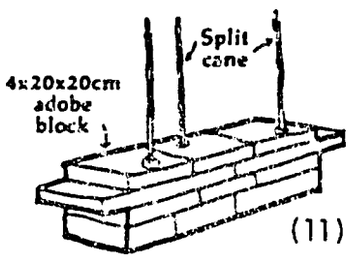


(5)

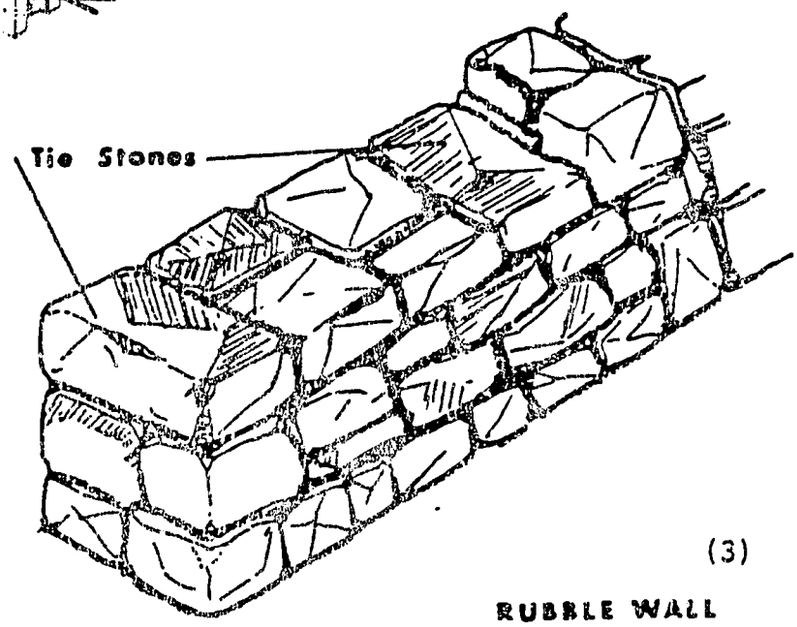


(14)





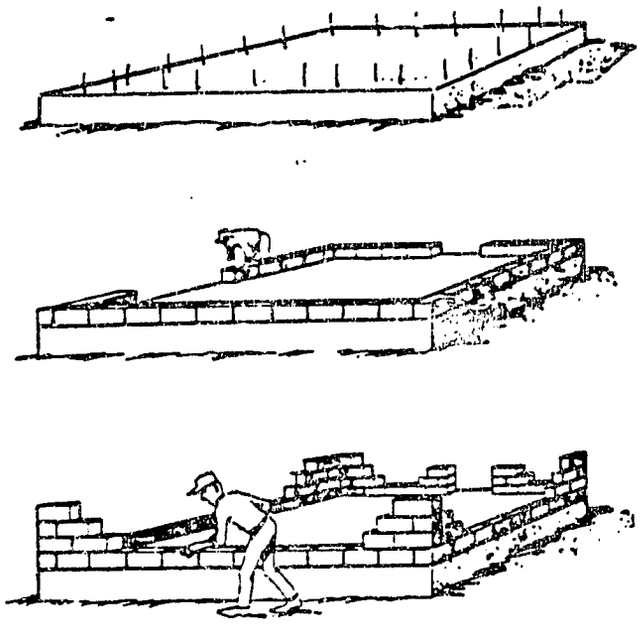
(11)



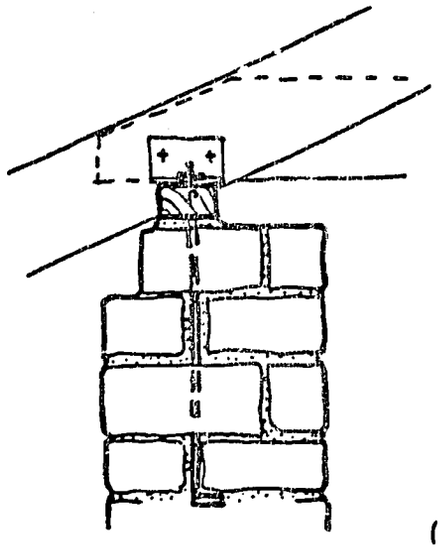
(3)

RUBBLE WALL

MISCELLANEOUS DETAILS



(4)



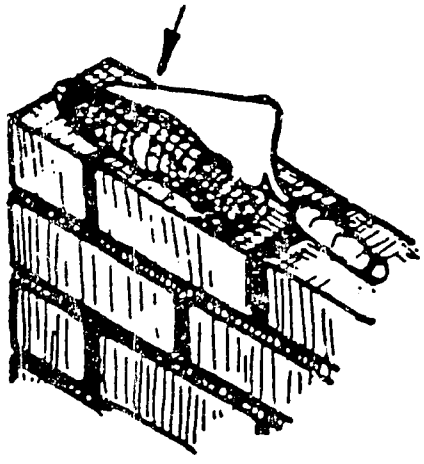
(17)

Mortar Mixes

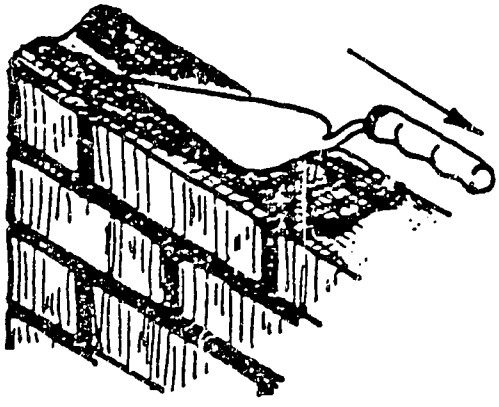
Type of Service	Cement	Hydrated lime or line putty	Mortar sand in damp, loose condition
For ordinary service	1 - masonry cement*	----	2 to 3
	or		
	1 - Portland cement	1 to 1¼	4 to 6
Subject to extremely heavy loads, violent winds, earthquakes or severe frost action. Isolated piers.	1 - masonry cement* plus 1 - Portland cement	----	4 to 6
	or		
	1 - Portland cement	0 to ¼	2 to 3

(13)

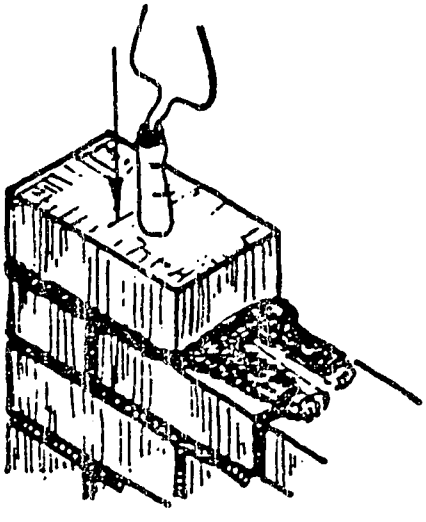
STRUCTURAL CONNECTION	No.
MASONRY	3.51 - 8



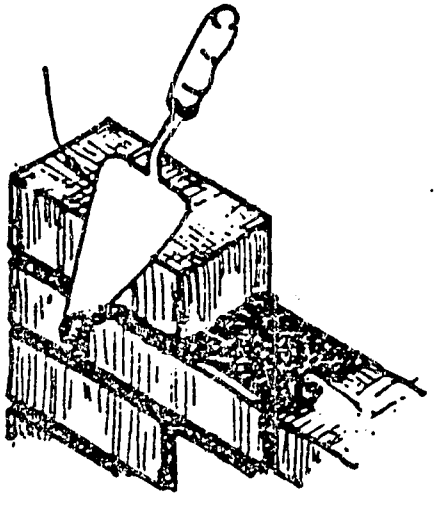
A



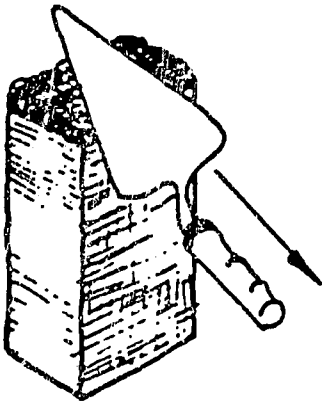
B



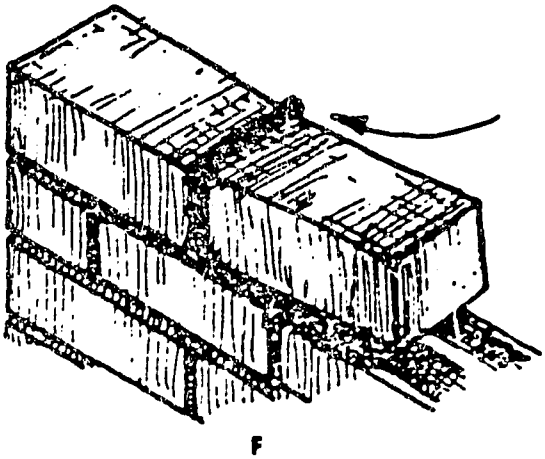
C



D

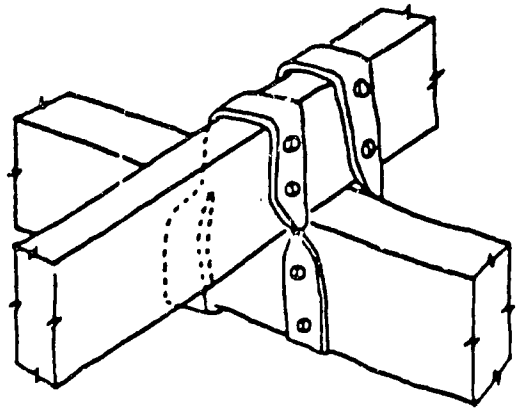


E

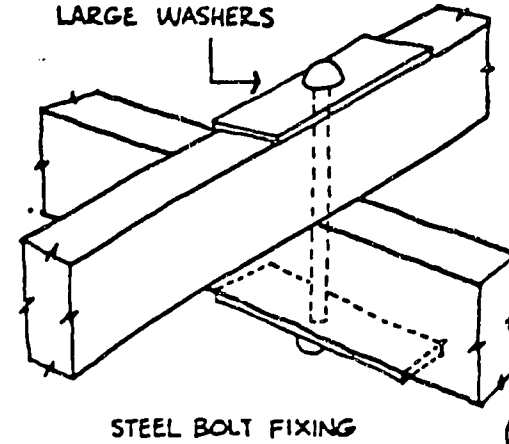


F

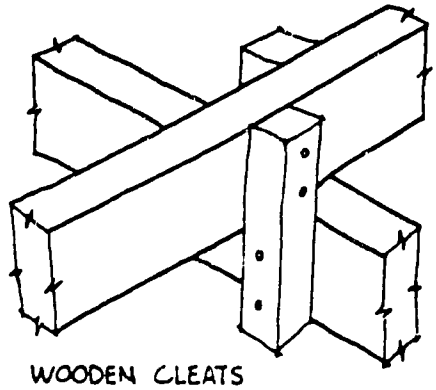
RAFTER/PURLIN CONNECTIONS



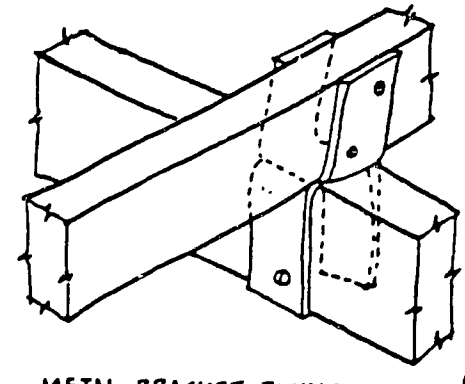
STEEL STRAP FIXING (16)



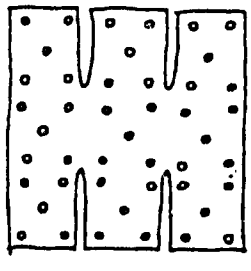
STEEL BOLT FIXING (16)



WOODEN CLEATS
NAILED TO PURLIN AND RAFTER
(16)

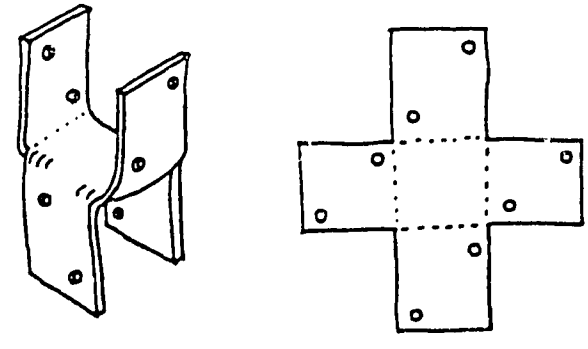


METAL BRACKET FIXING (16)



THIS FLAT SHEET PATTERN CAN BE USED WITH VARIATIONS OF BENDING DIRECTION FOR A NUMBER OF CONNECTIONS

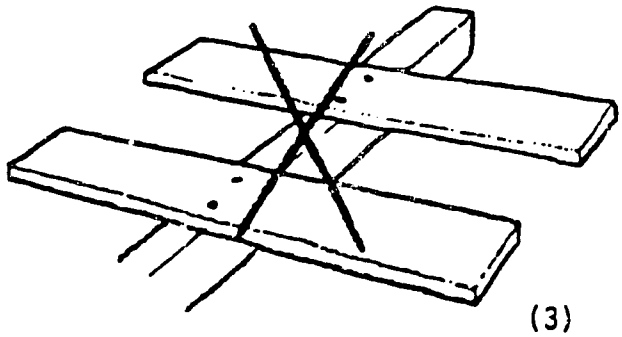
(16)



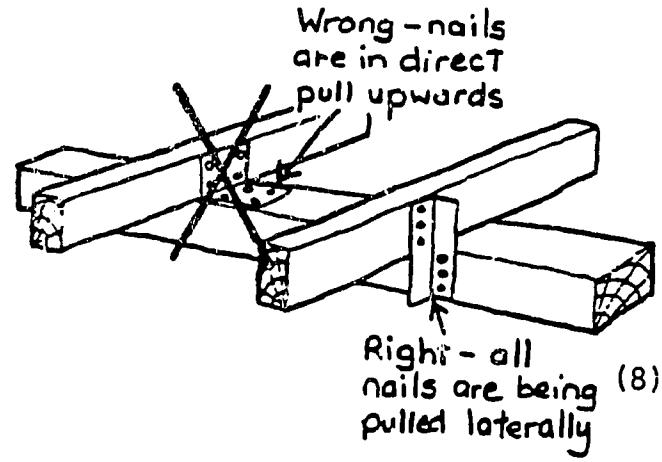
BRACKETS FROM GALVANIZED FLAT SHEET (16)

STRUCTURAL CONNECTION	No.
DIMENSIONAL LUMBER	3.52 - 2

RAFTER/PURLIN CONNECTIONS

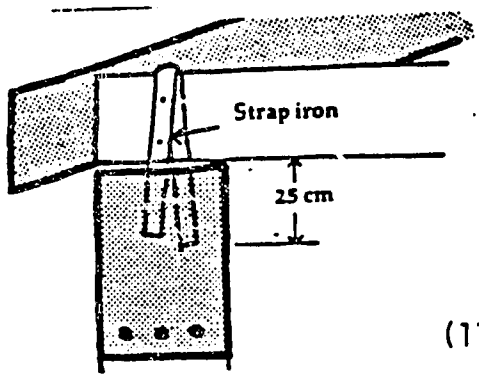


(3)

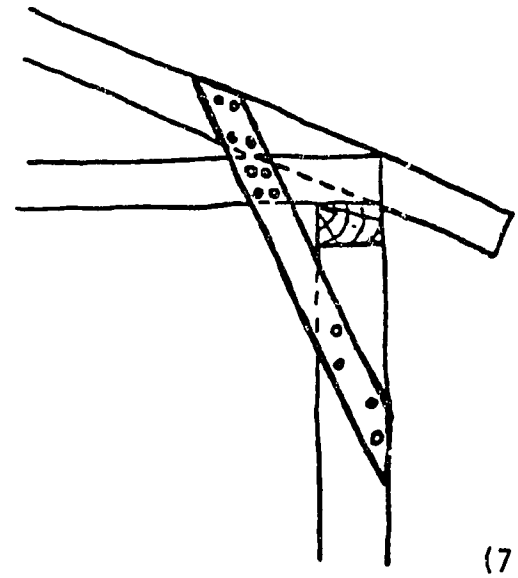


(8)

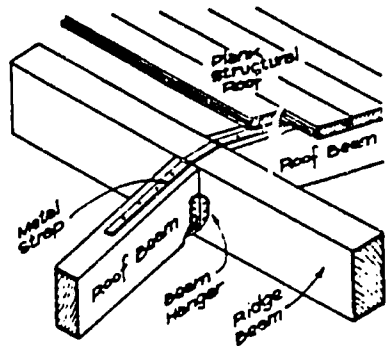
ROOF CONNECTION DETAILS



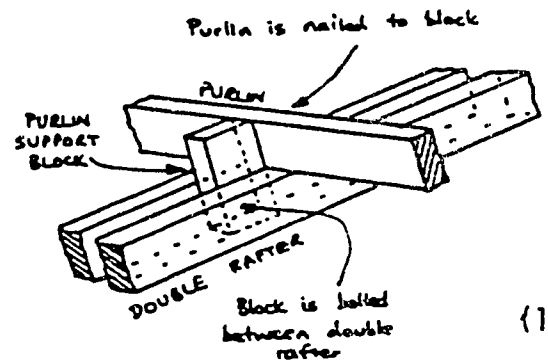
(11)



(7)

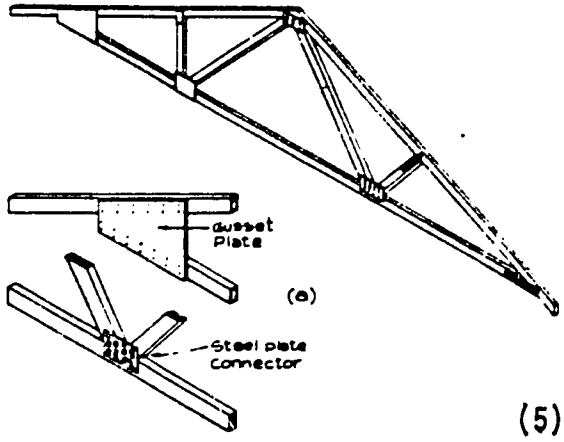


(5)

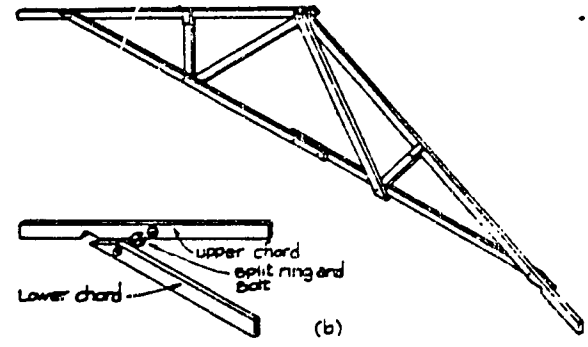


(1)

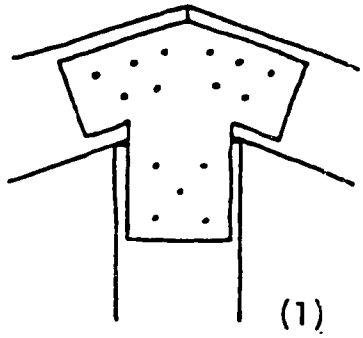
ROOF CONNECTION DETAILS



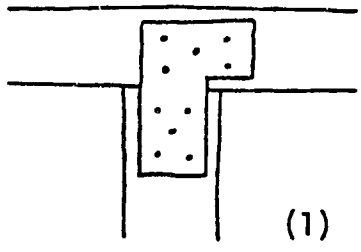
(5)



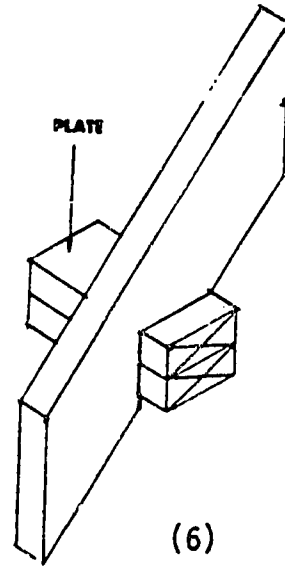
(5)



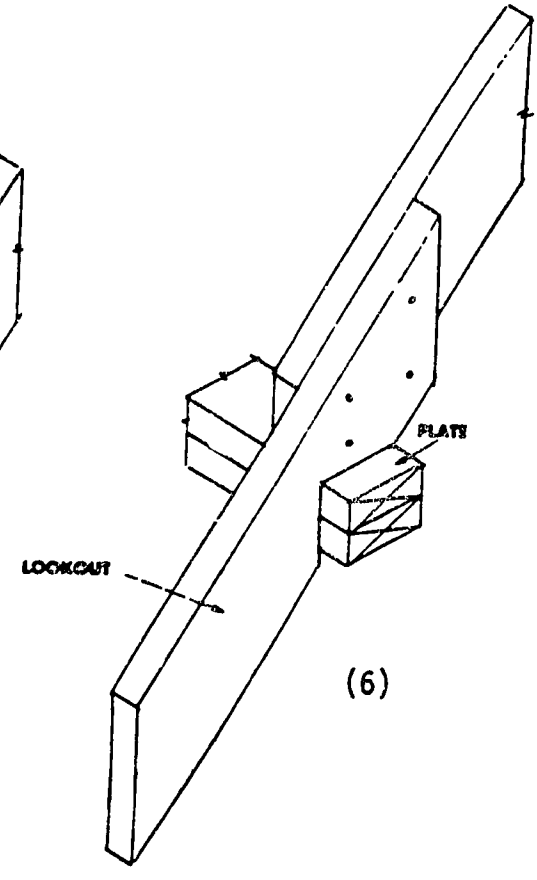
(1)



(1)

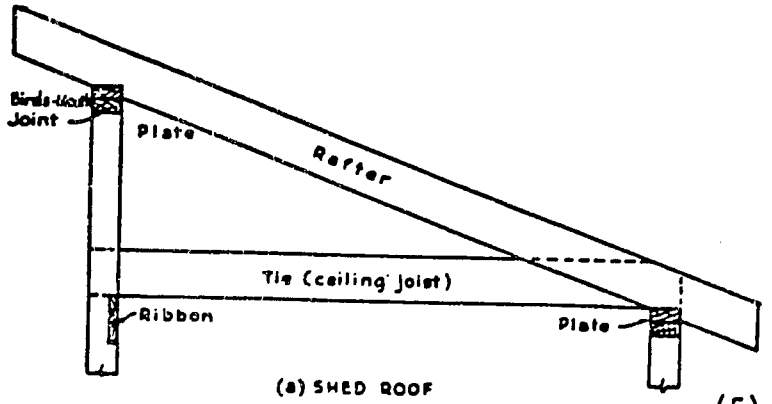


(6)



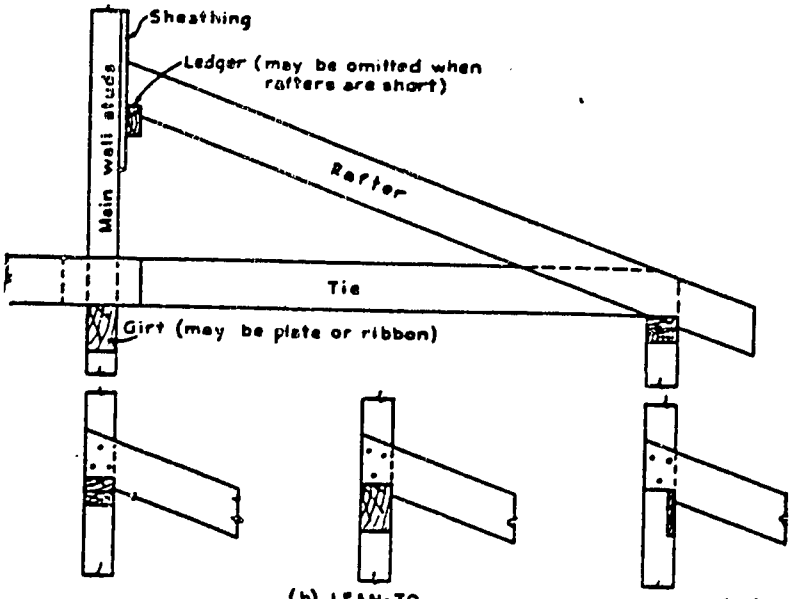
(6)

ROOF CONNECTION DETAILS



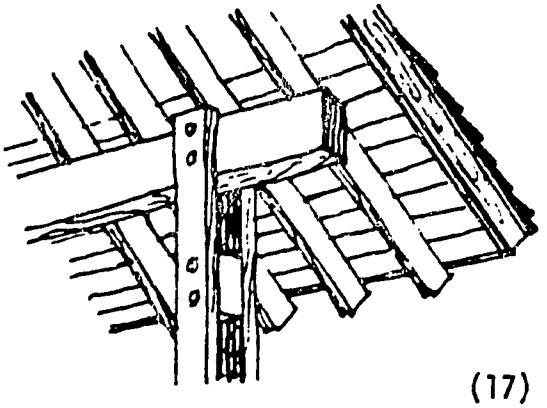
(a) SHED ROOF

(5)



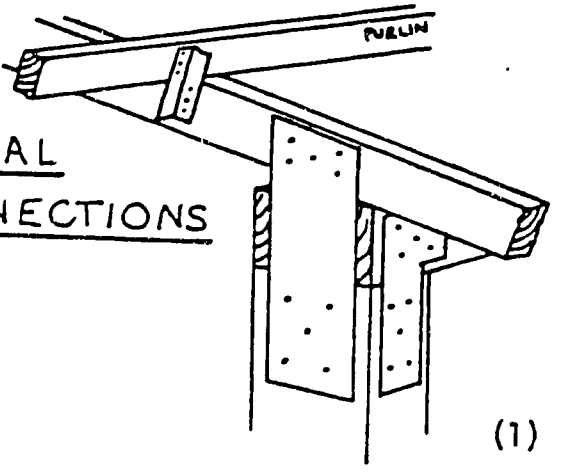
(b) LEAN-TO

(5)



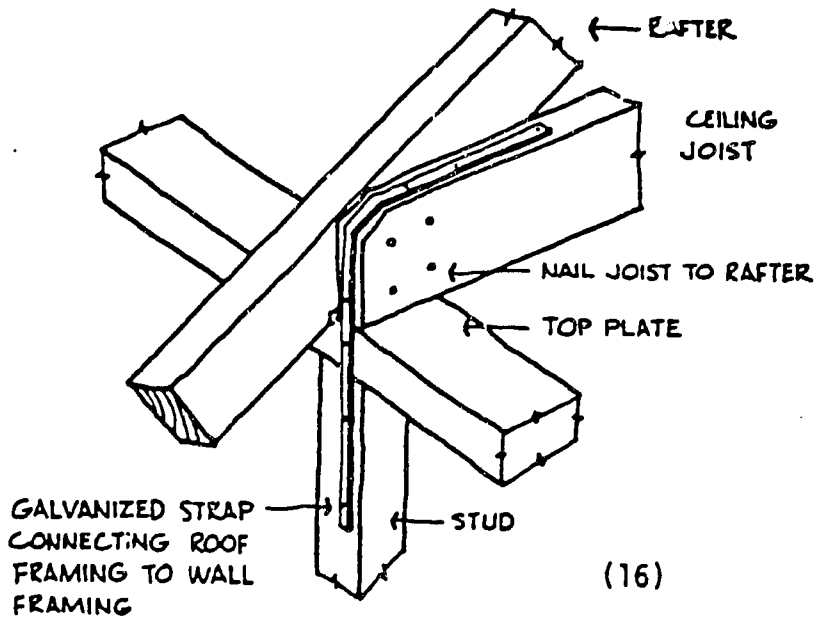
(17)

TYPICAL CONNECTIONS

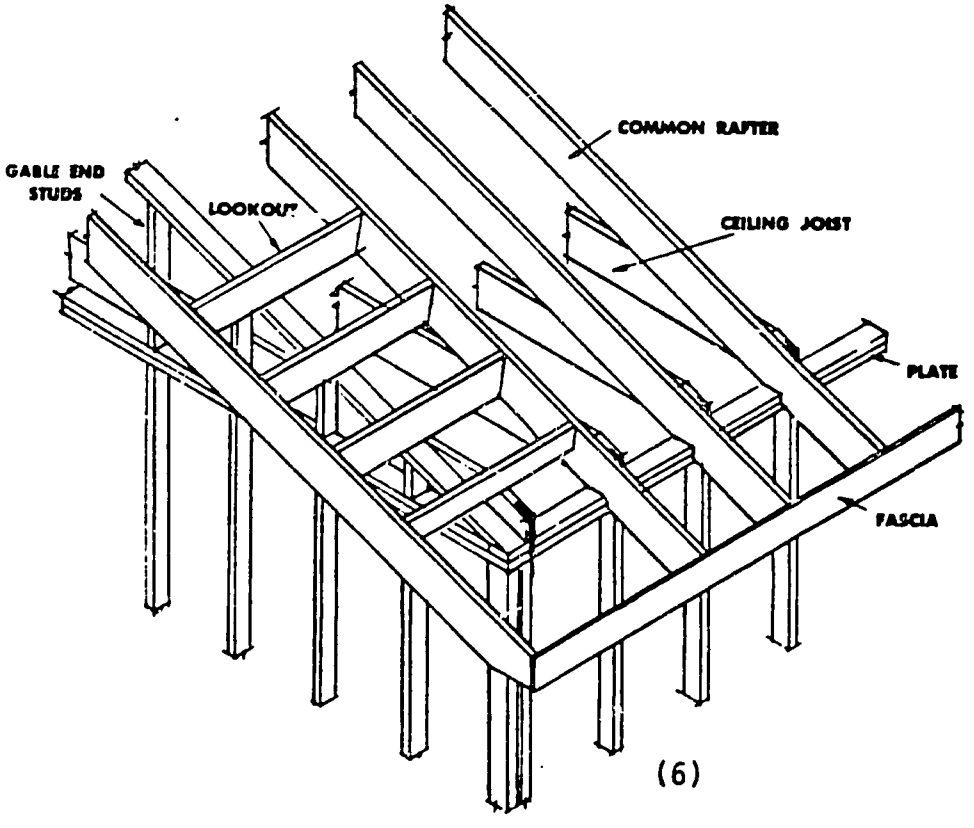


(1)

ROOF CONNECTION DETAILS

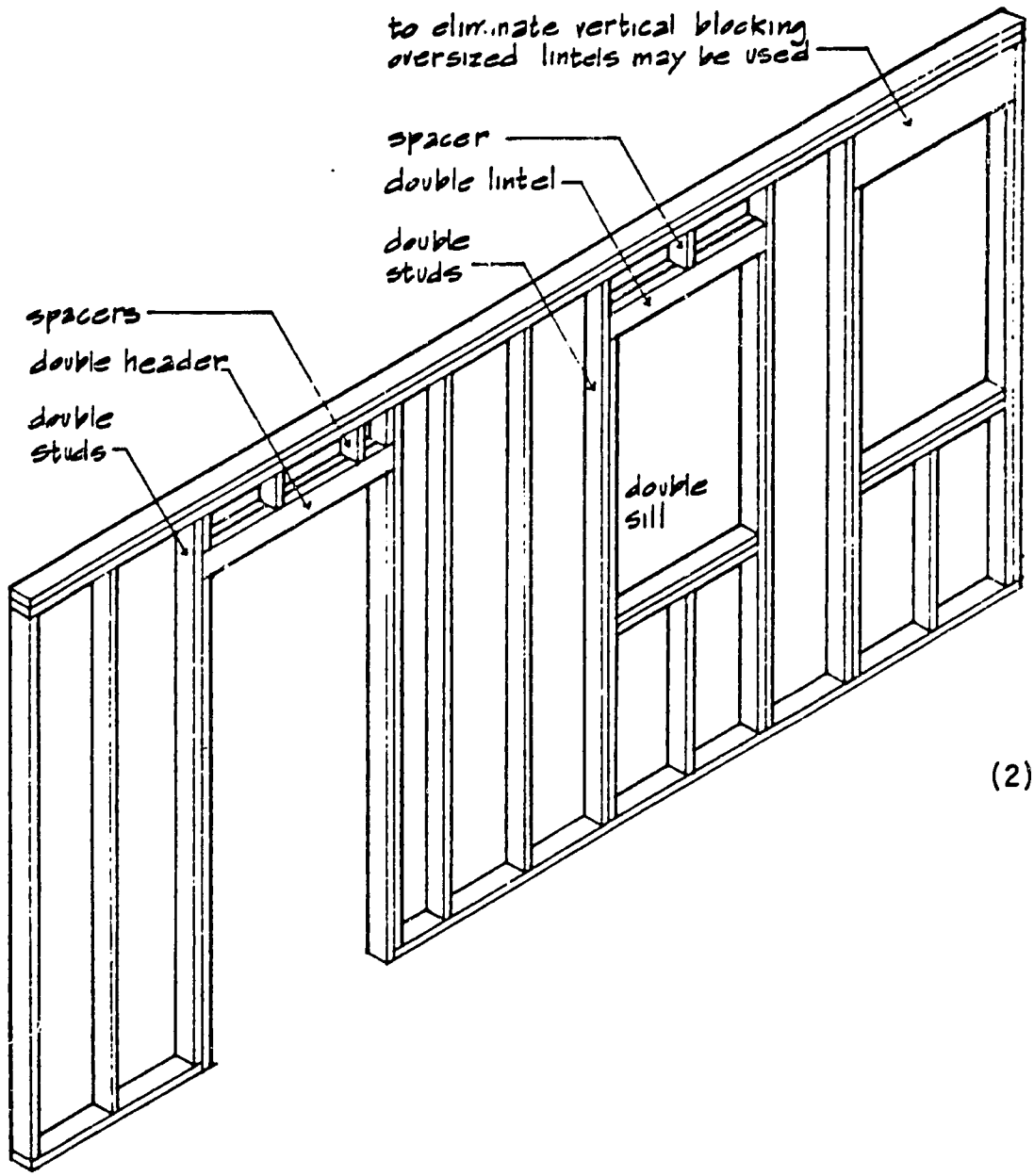


(16)



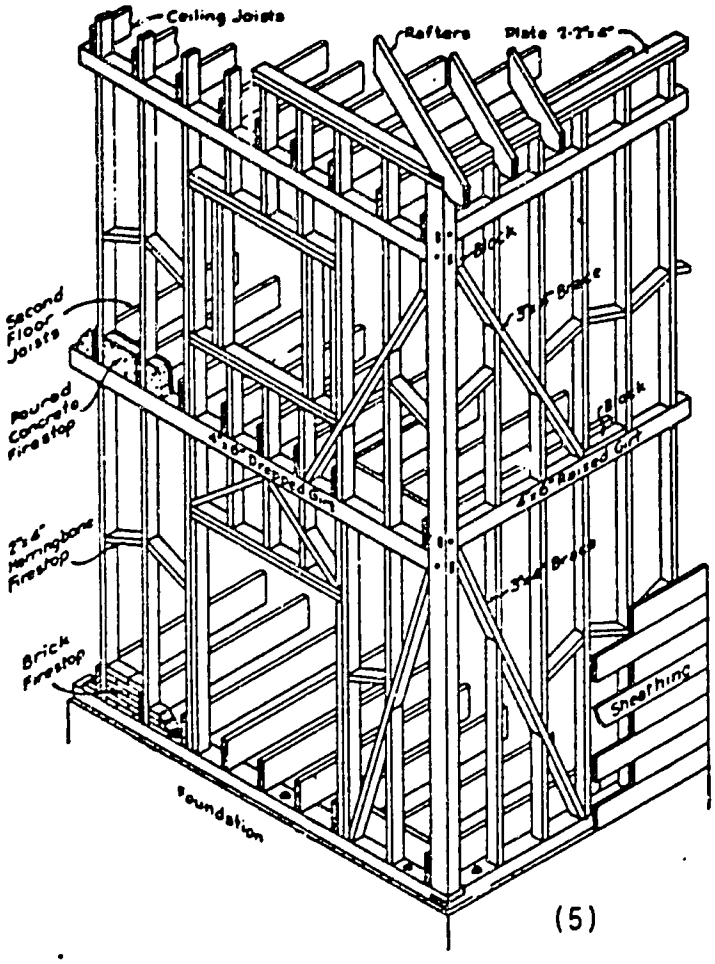
(6)

WALL FRAMING DETAILS

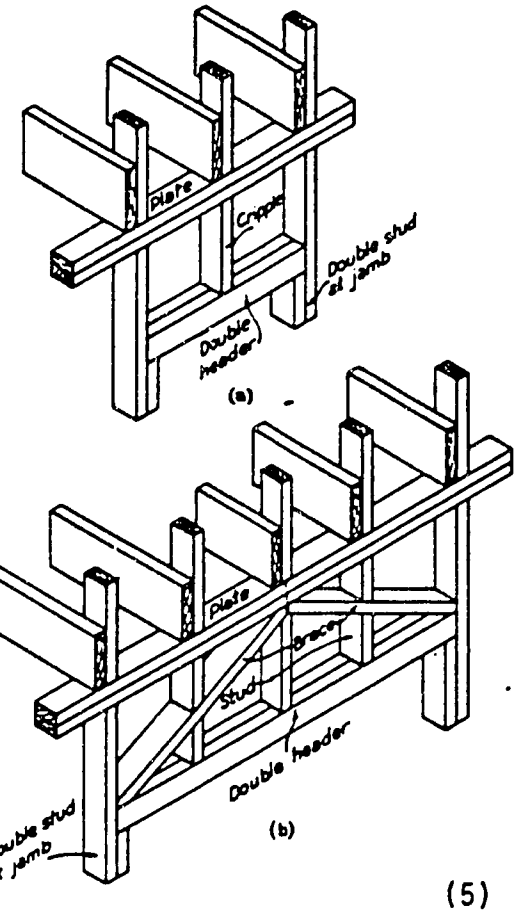


(2)

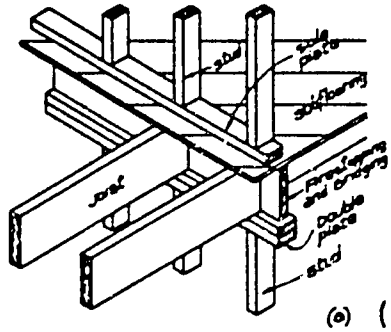
STRUCTURAL CONNECTIONS	No.
DIMENSIONAL LUMBER	3.52 - 7



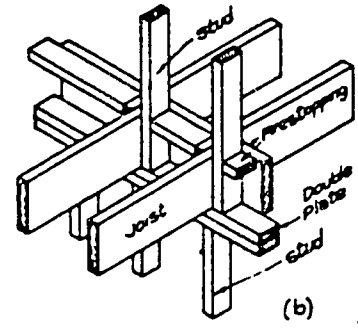
(5)



(5)



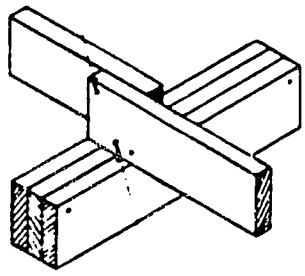
(a) (5)



(b) (5)

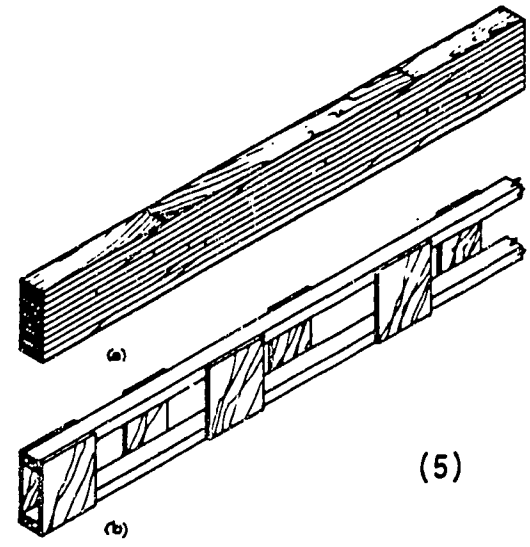
276

MISCELLANEOUS CONNECTION DETAILS

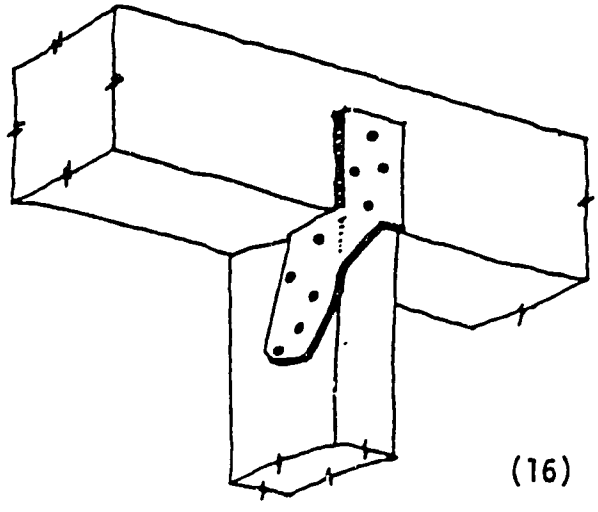


JOISTS BEARING ON WOOD GIRDER, MINIMUM LAP 4"

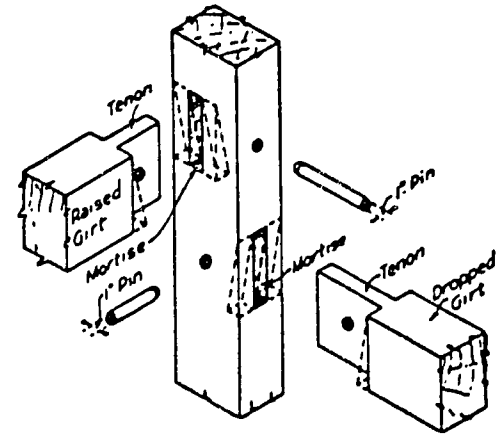
(9)



(5)

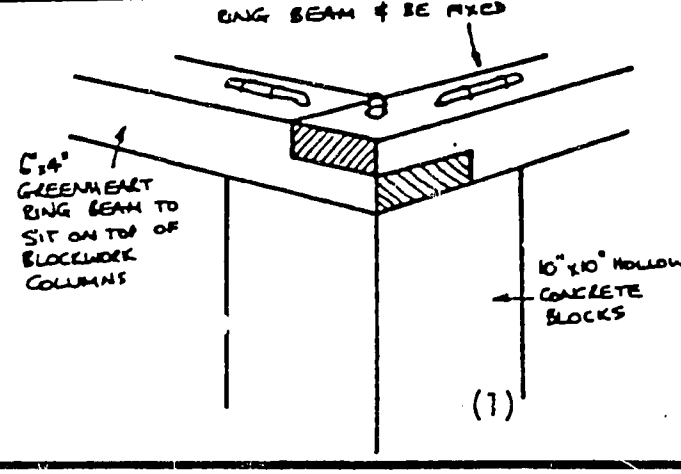


(16)

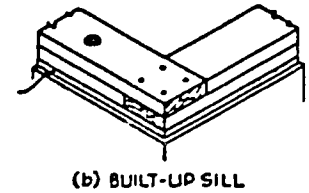


(5)

RING BEAM TO COLUMN CONNECTION



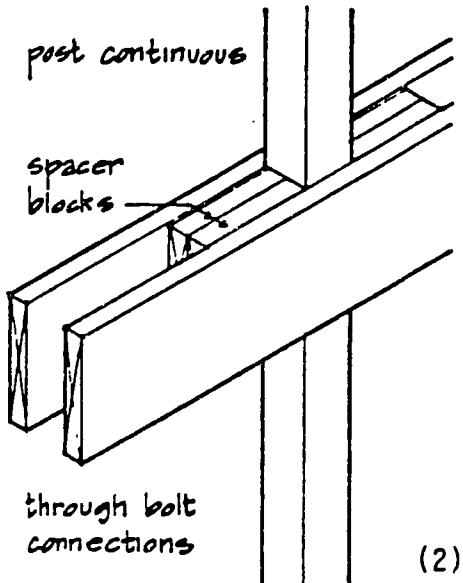
(1)



(b) BUILT-UP SILL

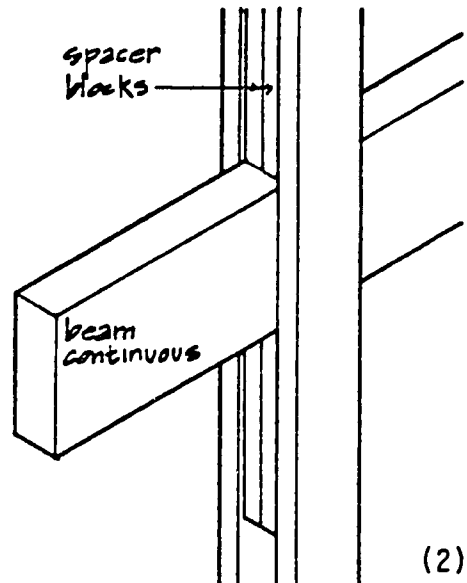
(5)

MISCELLANEOUS CONNECTION DETAILS



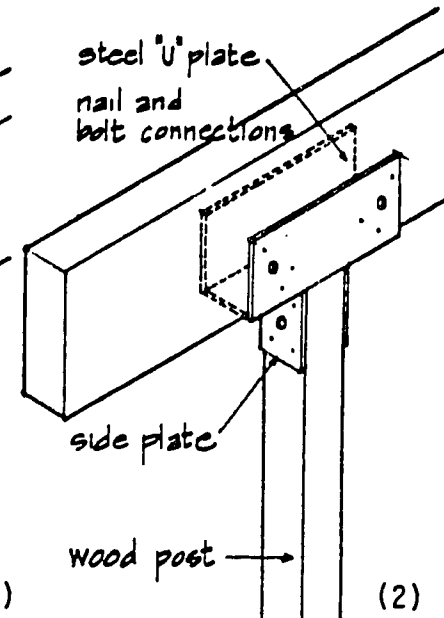
(2)

SPACED BEAM/SOLID POST



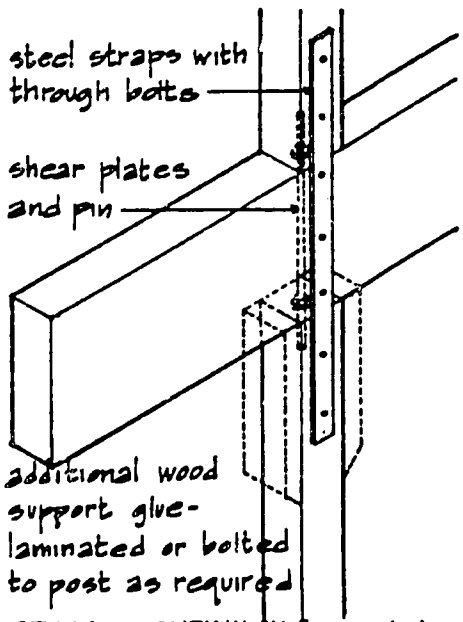
(2)

SOLID BEAM/SPACED POST

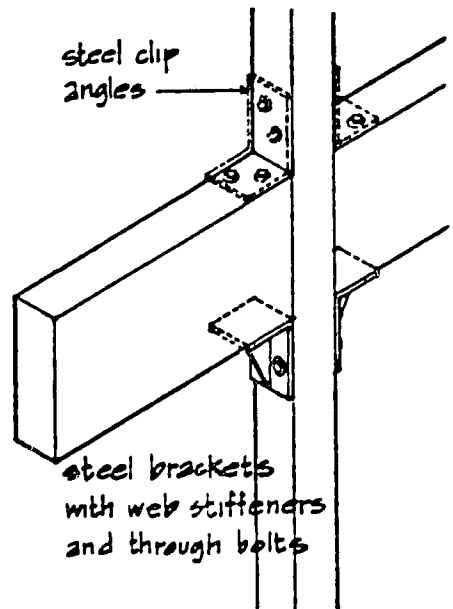


(2)

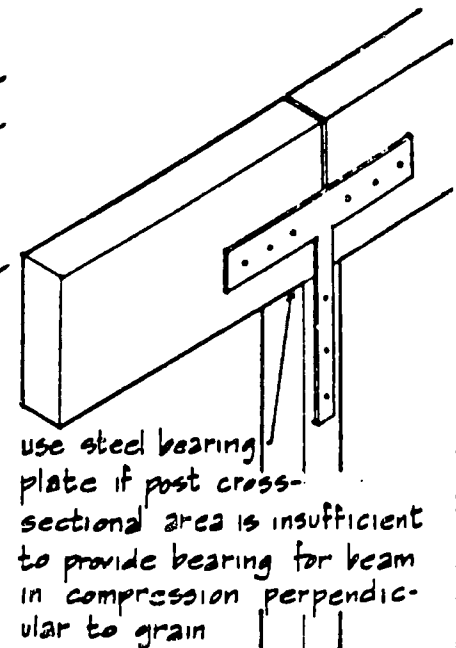
EXPOSED COLUMN CAP



BEAM CONTINUOUS (2)

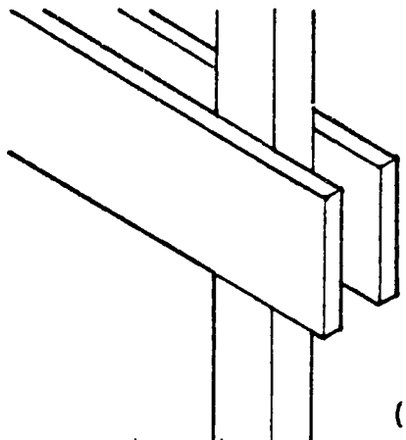


POST CONTINUOUS (2)



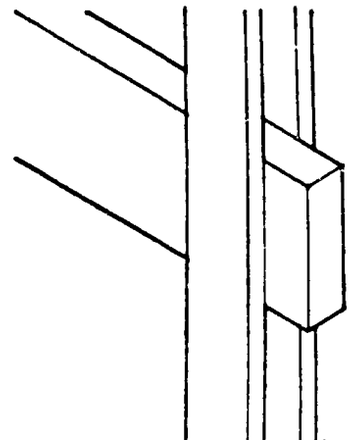
EXPOSED 'T' STRAPS (2)

STRUCTURAL CONNECTIONS	No.
DIMENSIONAL LUMBER	3.52 - 10



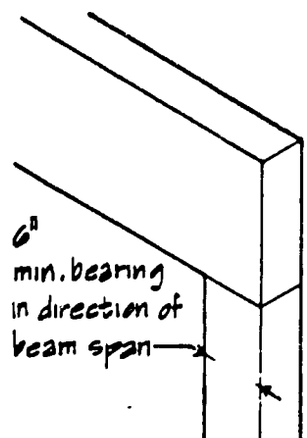
(2)

• spaced beam lapping post



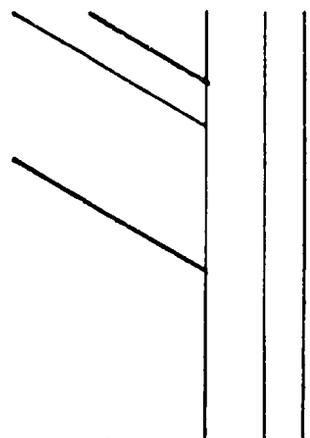
(2)

• spaced post lapping beam



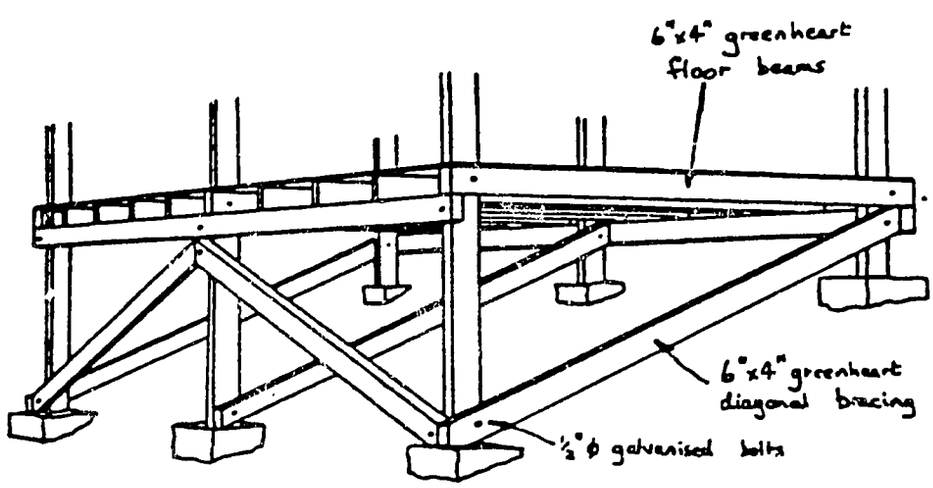
(2)

• beam bearing on post



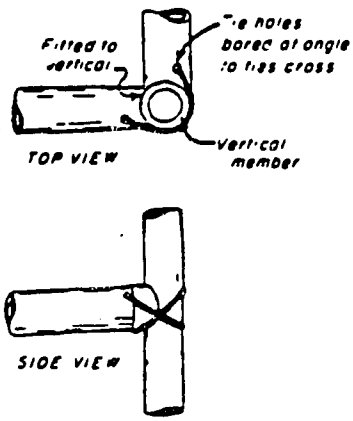
(2)

• beam framing into post

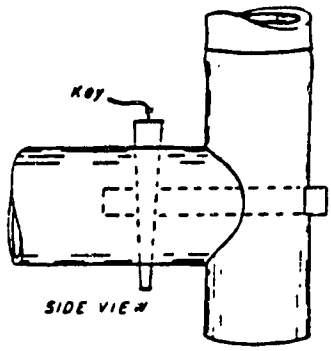


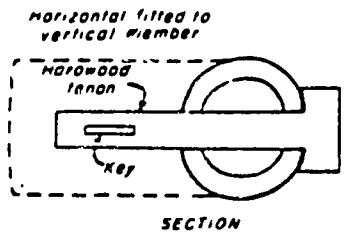
(1)

STRUCTURAL CONNECTIONS	No.
BAMBOO	3.53 - 1

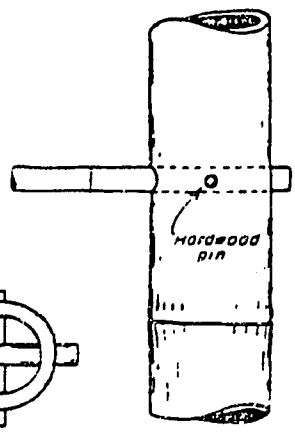


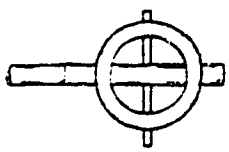
DOUBLE BUTT TIED JOINT





TENON KEY JOINT FOR HEAVY DUTY OR FINE WORK

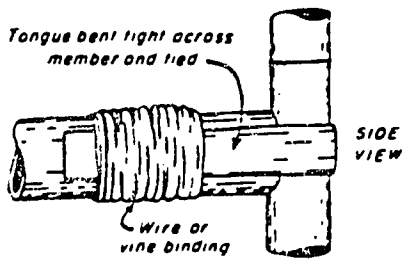


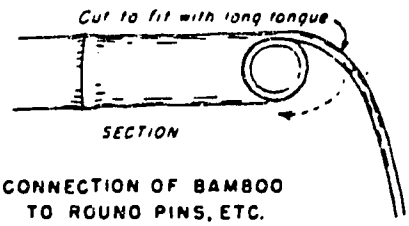


JOINT FOR CONNECTION OF SMALL MEMBERS TO LARGE MEMBERS

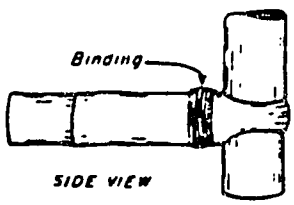
SECTION

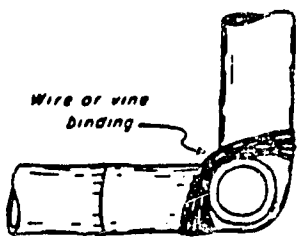
SIDE VIEW

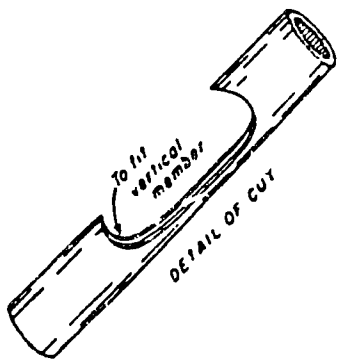




CONNECTION OF BAMBOO TO ROUND PINS, ETC.

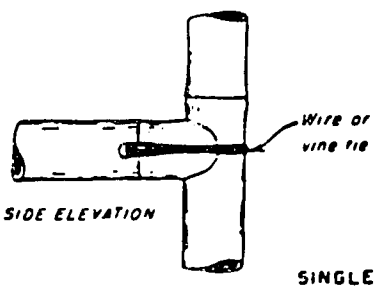




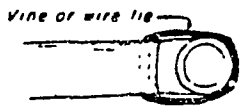


DOUBLE BUTT BENT JOINT

Suitable for furniture and similar uses

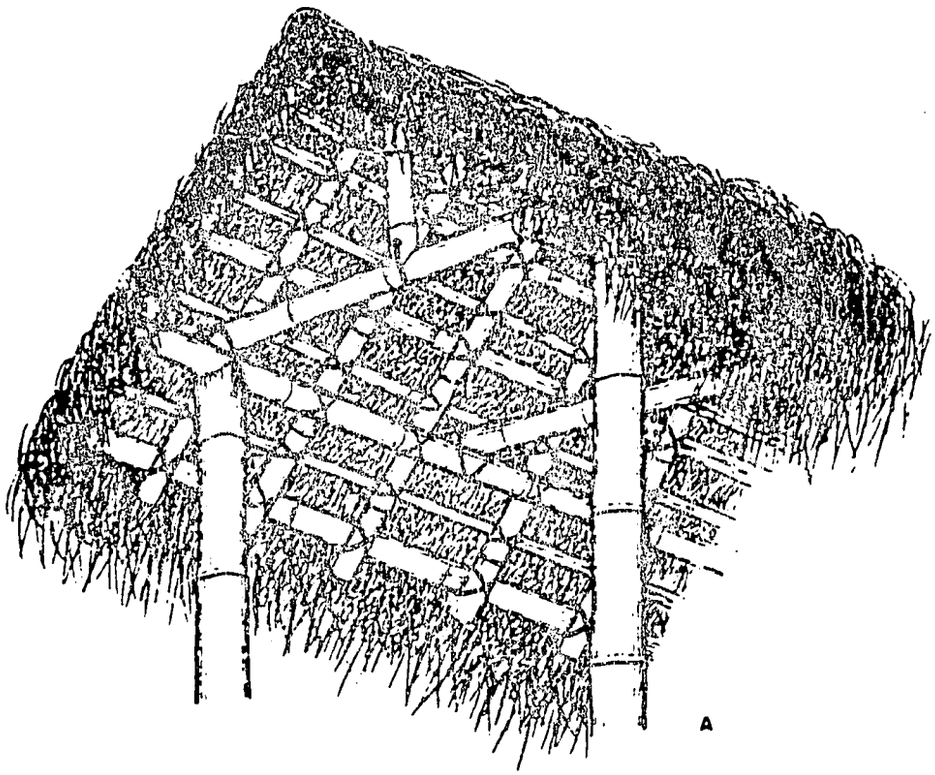


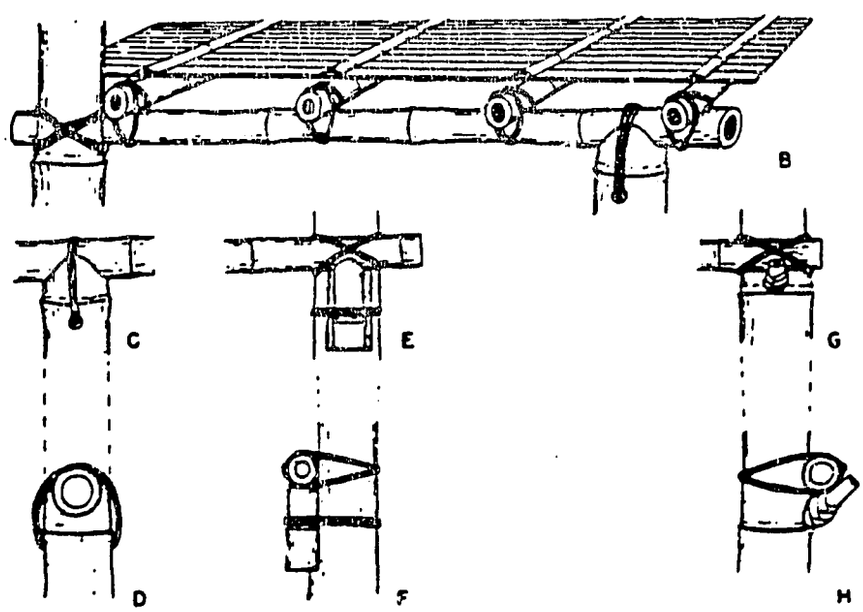
SINGLE BUTT JOINT



280

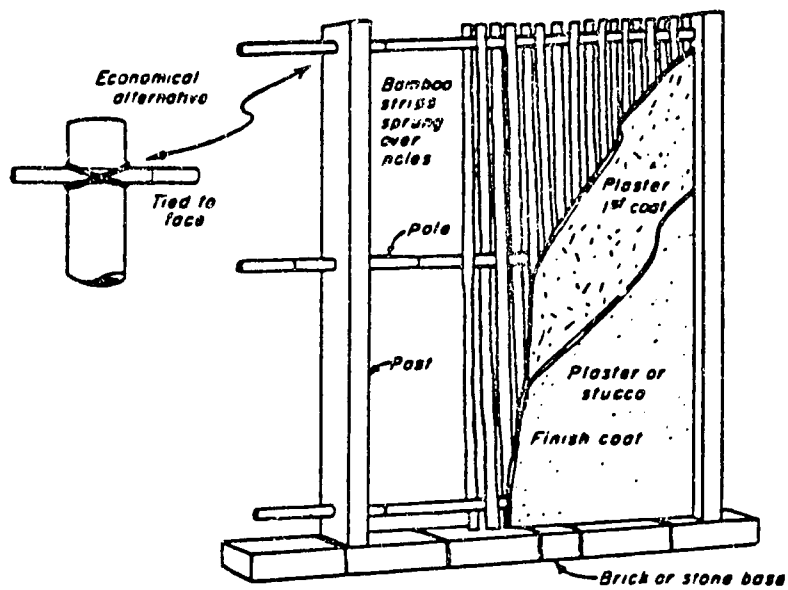
STRUCTURAL CONNECTIONS	No.
BAMBOO	3.53 - 2



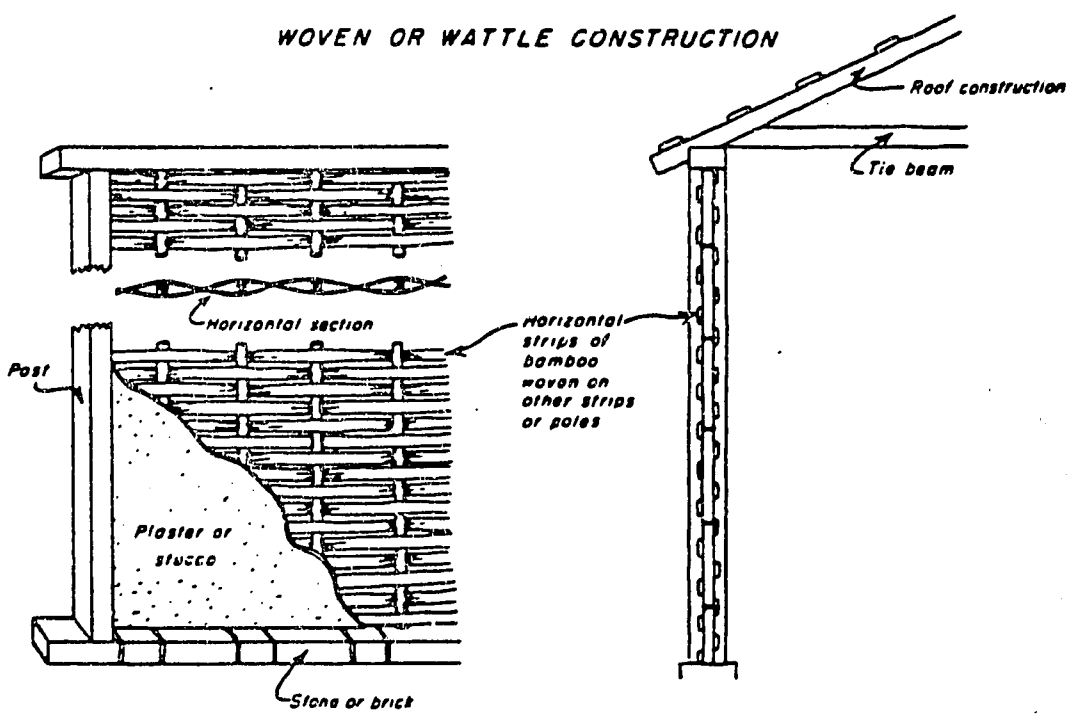


(13)

SPRUNG STRIP CONSTRUCTION



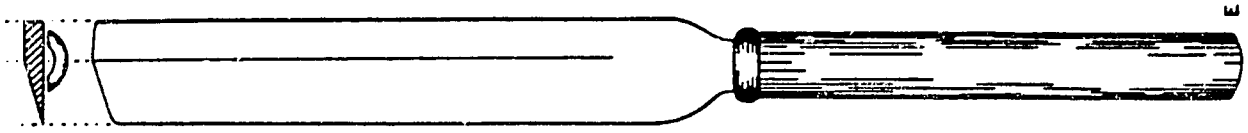
WOVEN OR WATTLE CONSTRUCTION

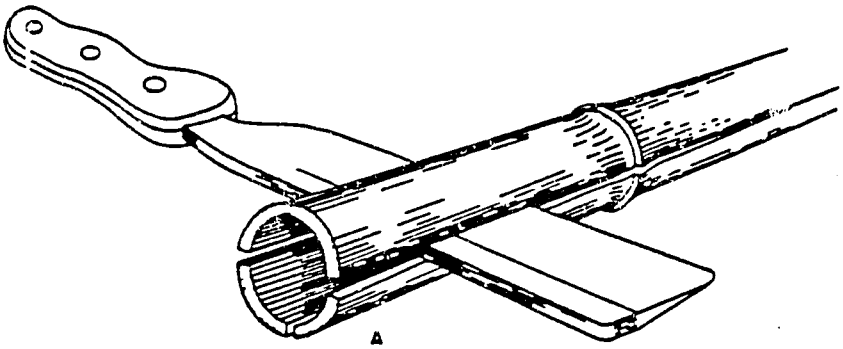


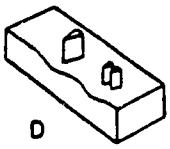
STRUCTURAL CONNECTIONS

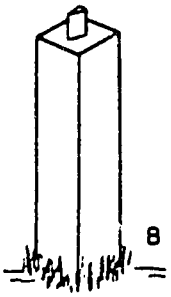
BAMBOO

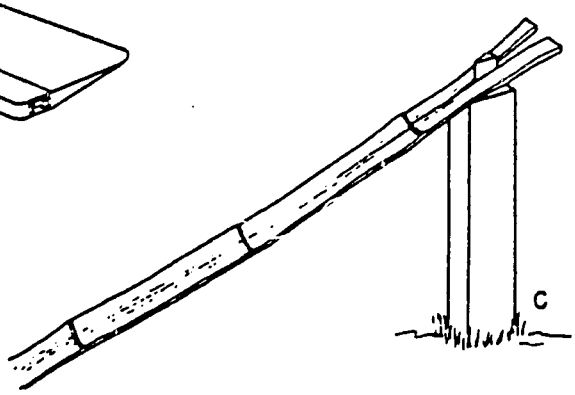
No. 3.53 - 4

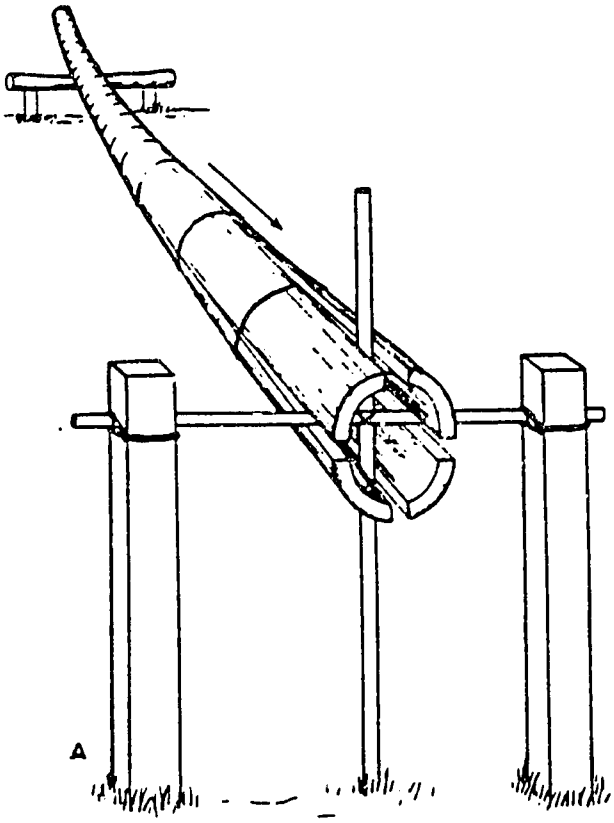


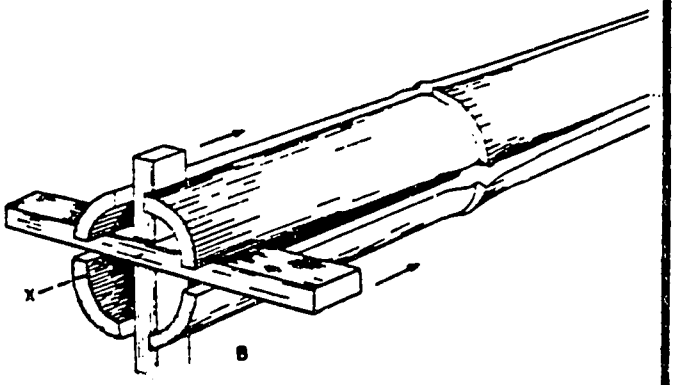


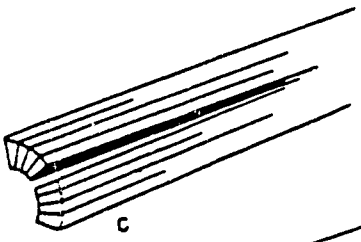


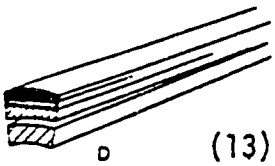


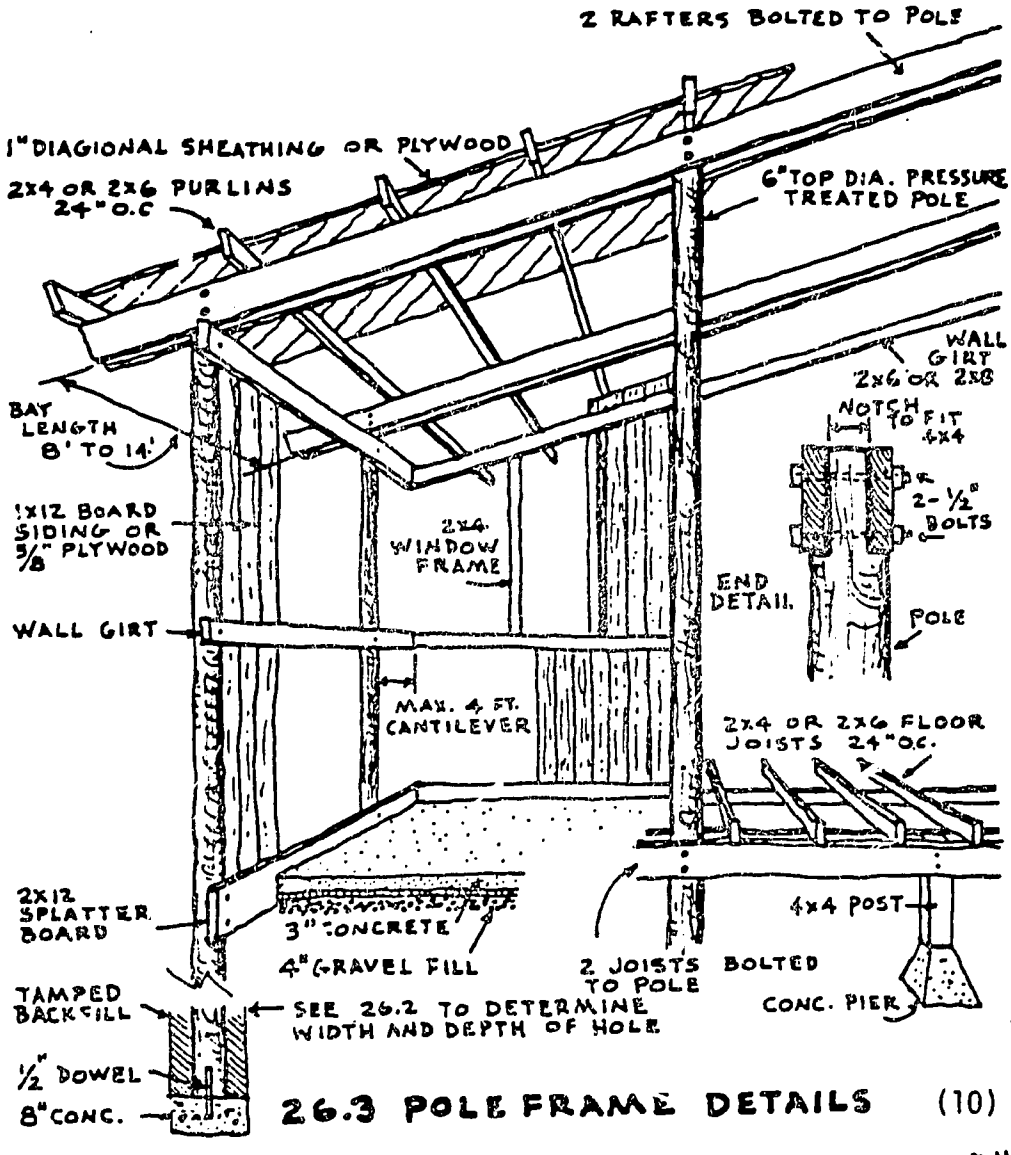




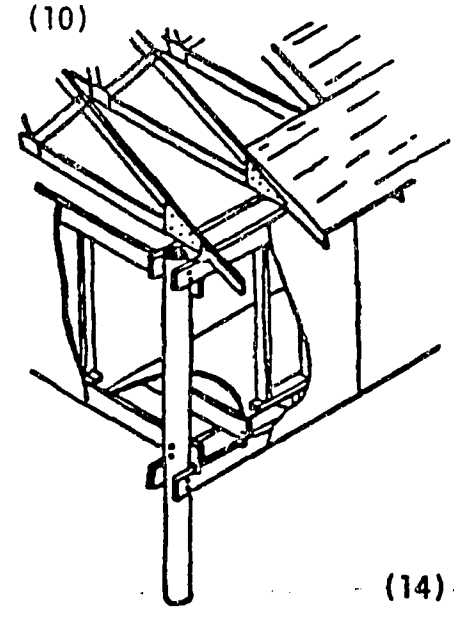






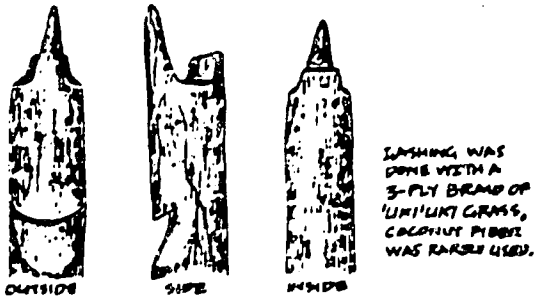


26.3 POLE FRAME DETAILS (10)



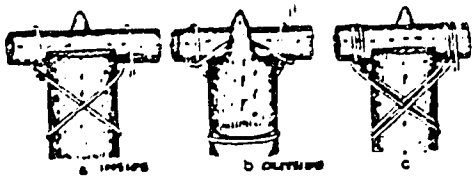
(14)

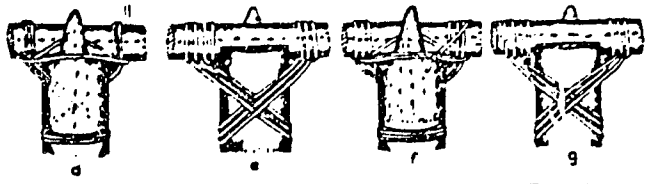
284



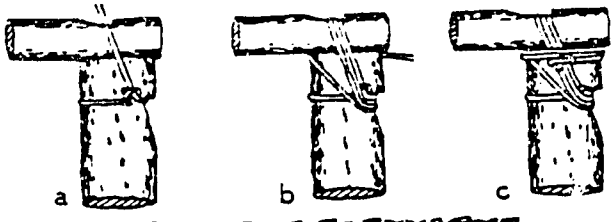
LASHING WAS DONE WITH A 3-PLY BRAID OF 'UKI'UKI GRASS, COCONUT FIBER WAS RARELY USED.

TOP OF WALL POSTS

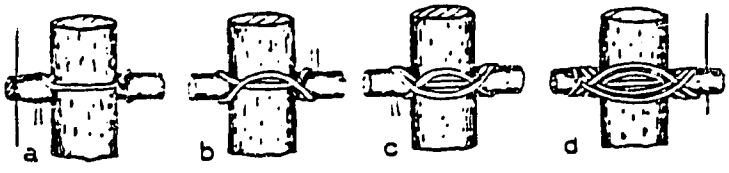




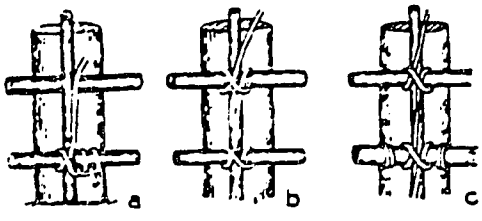
LASHING WALL PLATE TO WALL POST

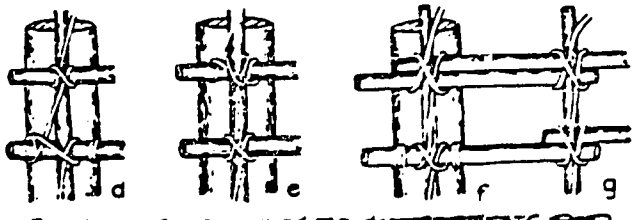


RIDGEPOLE TO RIDGEPOST

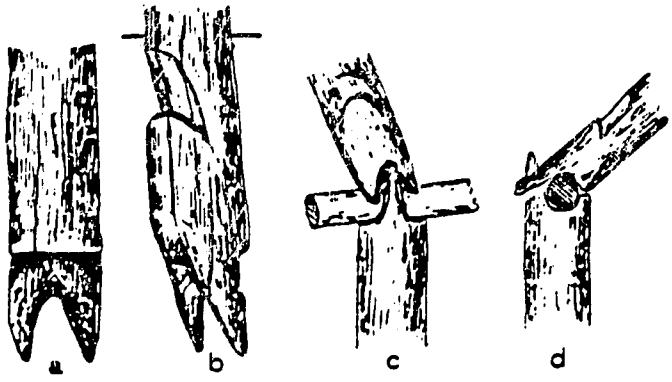


LASHING MAIN PURLINS TO RAFTERS AND POSTS
ORNAMENTAL LASHING VIEWED FROM INSIDE.

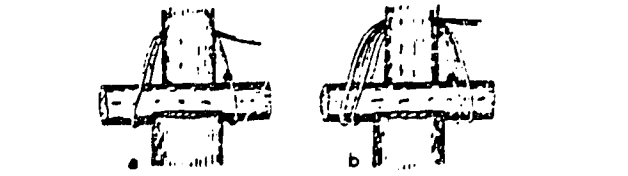


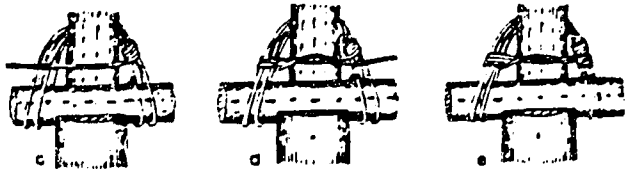


LASHING PURLINS TO SUPPORTING ROD

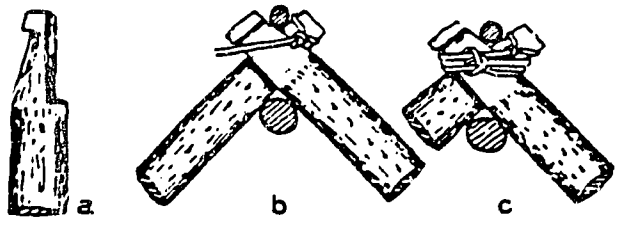


LOWER RAFTER END, AT POST AND WALL PLATE

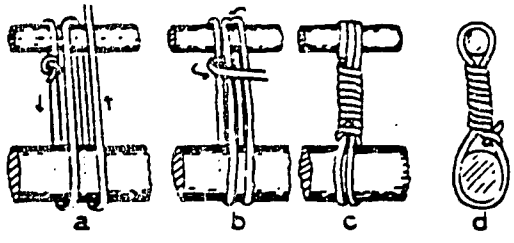




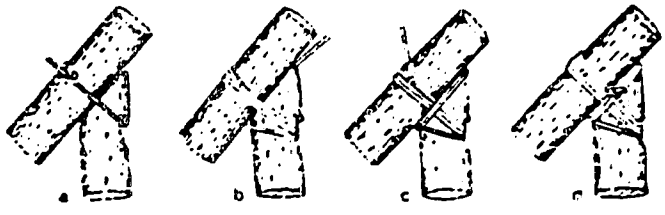
LASHING RAFTER TO WALL PLATE
AT (d), PULL TAUT BEFORE KNOTTING (e)



LASHING RAFTERS AT RIDGE



LASHING RIDGEPOLES TOGETHER



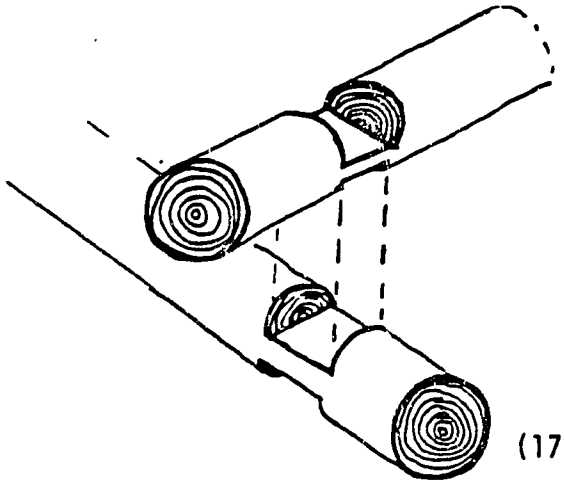
LASHING GABLE POSTS TO GABLE RAFTERS

NOW BASIC FRAME IS COMPLETED. THE PURLINS ARE ADDED TO THE FRAME TO ATTACH THE THATCHING. SEE THE DRAWINGS AT THE ABOVE RIGHT FOR LOCATION OF PURLINS.

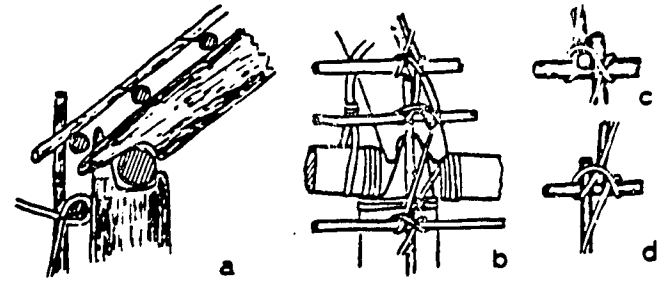
STRUCTURAL CONNECTIONS

POLES

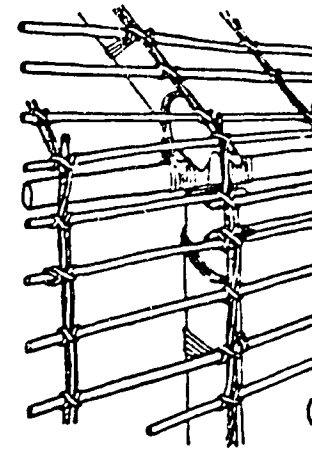
No. 3.54 - 3



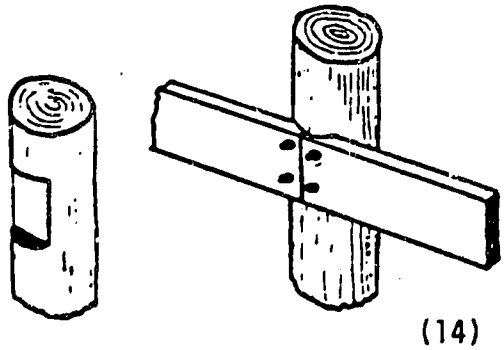
(17)



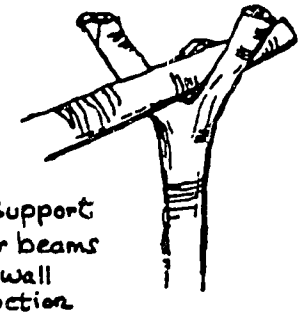
JUNCTION OF ROOF AND WALL RODS



(15)

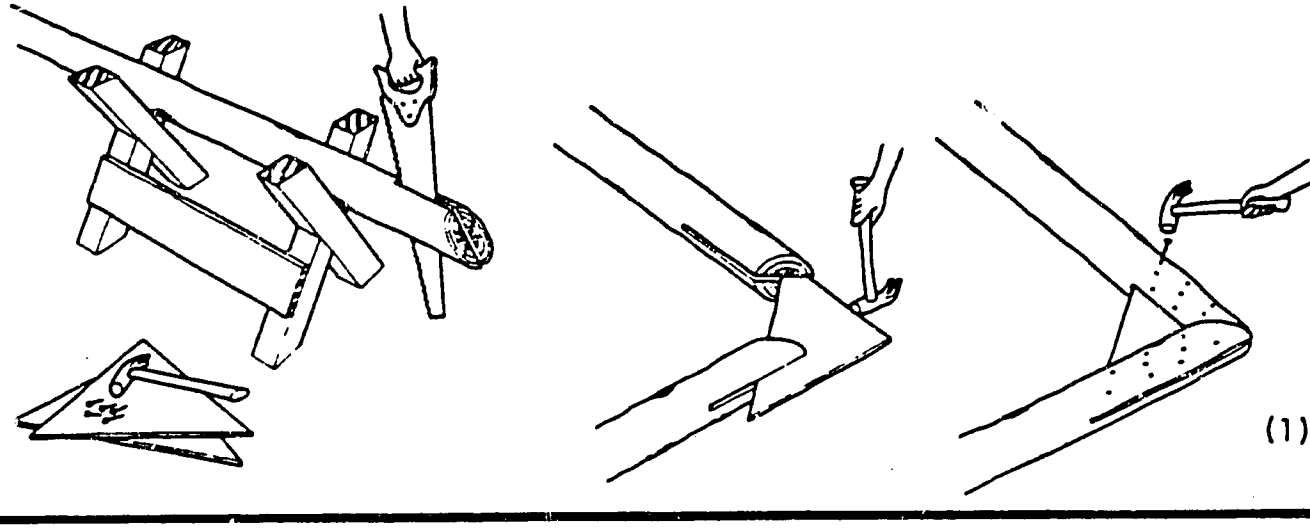


(14)



Crotch support for floor beams in mud wall Construction

(17)

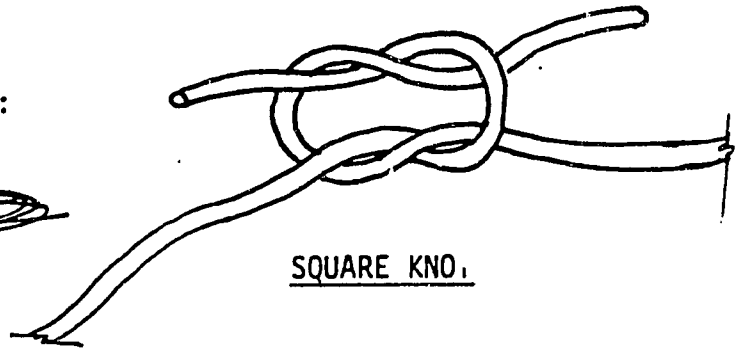


(1)

286

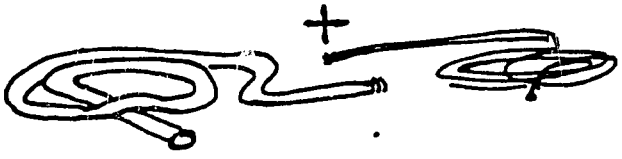
STRUCTURAL CONNECTIONS	No. 3.55 - 1
ROPE	

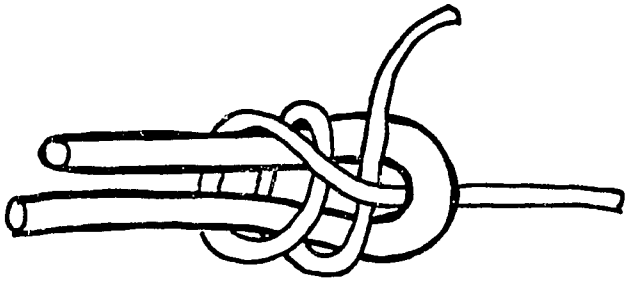
Joining two ropes of the same size:



SQUARE KNOT

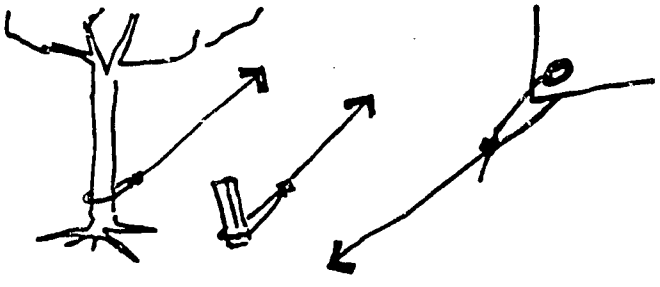
Joining two ropes of different sizes:

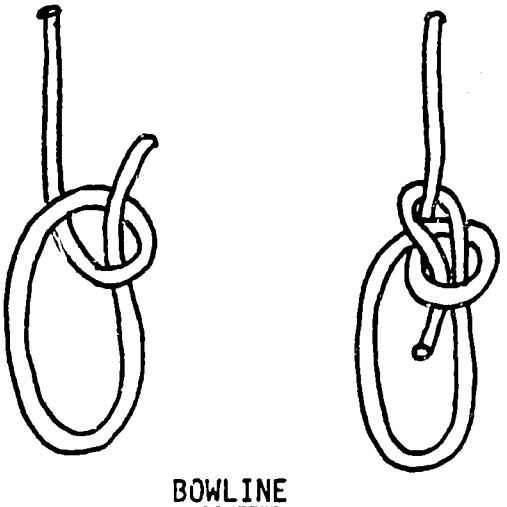




DOUBLE SHEET BEND

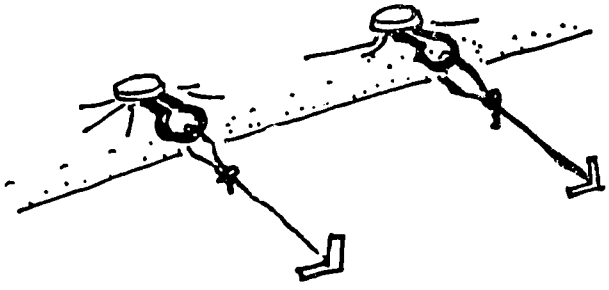
Making a secure loop that can be placed or tied around a post or grommet:

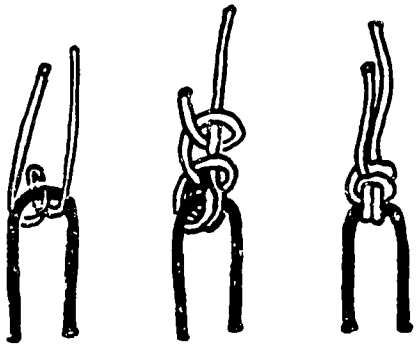




BOWLINE

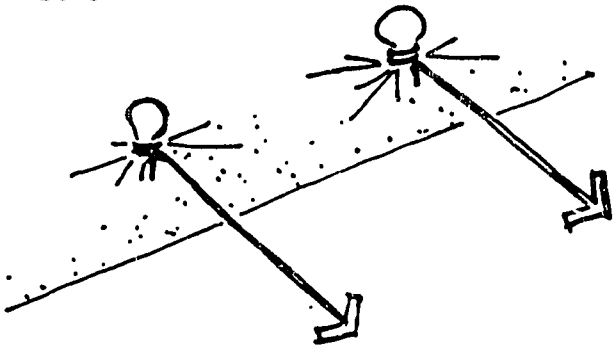
Attaching a rope to a plastic connector:

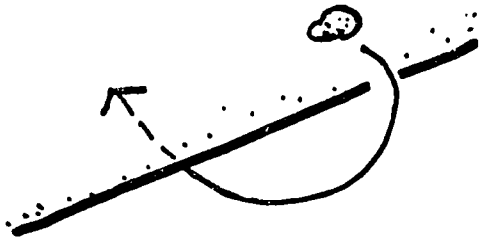


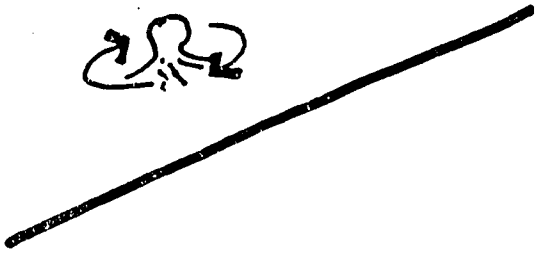


FISHERMAN'S BEND

Tying a rock into the plastic sheeting, as in the Rock Tie Method:

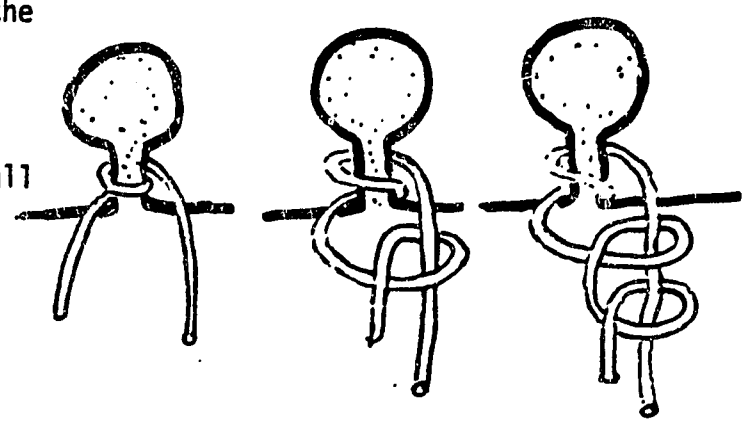






Place a small rock under the plastic sheeting and twist the sheeting tightly around the rock. Wrap the rope around twice, make one half hitch, and pull tight. Then make the second half-hitch and pull tight.

TWO HALF HITCHES

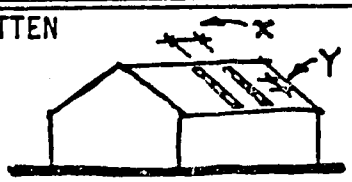
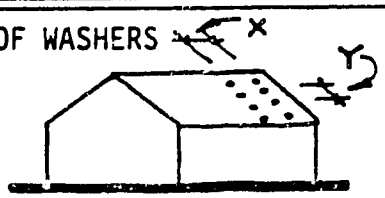
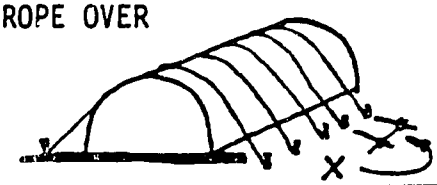
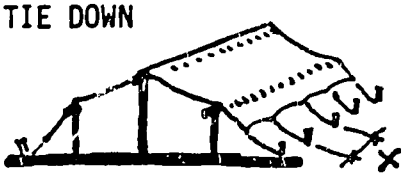


3.6 PLASTIC SHEETING CONNECTIONS

3.61 Connector Spacing Information
3.62 Sheeting to Sheeting
3.63 Sheeting to Masonry
3.64 Sheeting to Dimensional Lumber
3.65 Sheeting to Bamboo
3.66 Sheeting to Pipe
3.67 Sheeting to Rope

PLASTIC SHEETING CONNECTIONS	No.
CONNECTOR SPACING INFORMATION	3.61 - 1

The following chart should be used to determine the proper spacing and size of the connections described in this section.

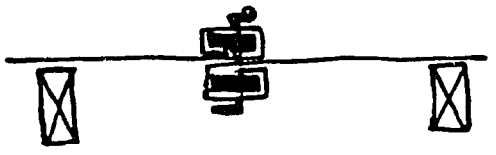
All dimensions in cm unless otherwise noted. NR = Not Recommended	MODERATE STORM 17 meters/sec (38 mph)			TROPICAL STORM 33 meters/sec (75 mph)			MODERATE HURRICANE 49 meters/sec (110 mph)		
CONSTRUCTION TYPE	x	y nail size (mm)		x	y nail size (mm)		x	y nail size (mm)	
		50.8	63.5		50.8	63.5		50.8	63.5
BATTEN 	50	60	90	50	18	25	50	NR	12
	100	30	45	100	9	12.5	100	NR	NR
	150	20	30	150	NR	NR	150	NR	NR
ROOF WASHERS 	50	60	90	50	18	25	50	NR	12
	100	30	45	100	9	12.5	100	NR	NR
	150	20	30	150	NR	NR	150	NR	NR
	x	kg pull	# of men pull	x	kg pull	# of men pull	x	kg pull	# of men pull
ROPE OVER 	50	38	.5	50	134	1.5	50	NR	NR
	100	75	1	100	269	3	100	NR	NR
	150	112	1.25	150	NR	NR	150	NR	NR
TIE DOWN 	50	38	5	50	NR	NR	50	NR	NR
	100	75	1	100	NR	NR	100	NR	NR
	150	112	1.25	150	NR	NR	150	NR	NR

PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO SHEETING - Batten Method	3.62 - 1

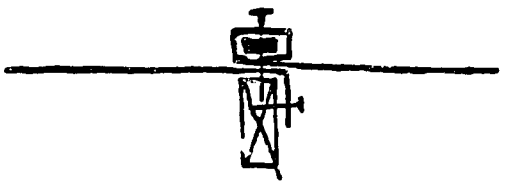
The reinforced plastic sheeting is relatively strong as a single piece. When attempting to join several pieces together, the joint is by far the weakest area. Heat sealing, which makes strong joints in the factory, cannot be done reliably in the field. This section contains several ways to join the plastic sheeting; however, none of them are as strong as a single sheet. It is therefore important, particularly in areas of high wind, to avoid splices where the plastic cannot be anchored to the structure.

BATTEN METHOD

The only way of joining two pieces of plastic sheeting which can be considered strong enough for high winds is by a battened connection or over a structured support. (See Section 3.64 - Sheeting to Dimensioned Lumber.)



Batten to Batten Connector

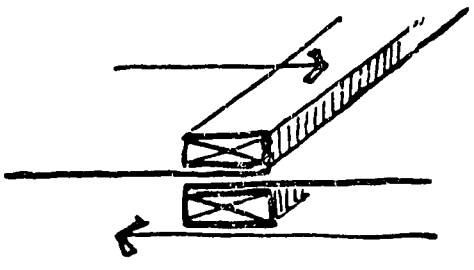


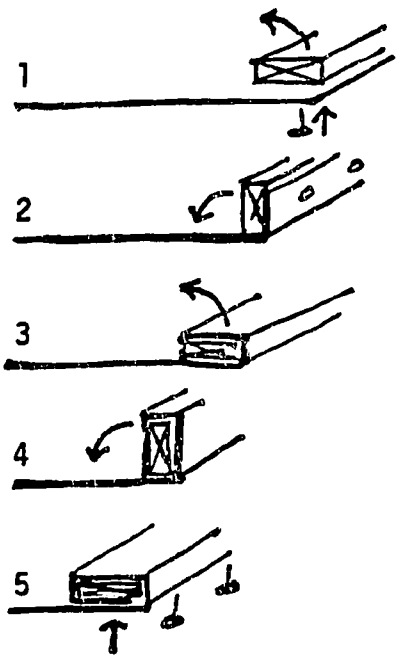
Batten or Structural Support

Strengths	Weakness
• Strong connection	• Uses dimesional lumber
• Allows the sheeting to be tightly stretched	

Procedure

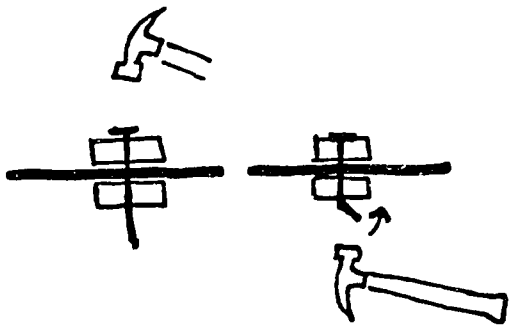
1. Attach both pieces to be joined to a 2.5 cm x 5 cm piece of lumber, as shown.

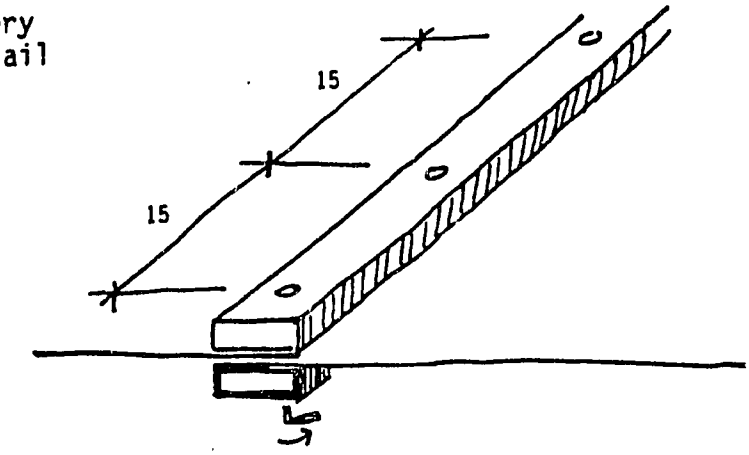




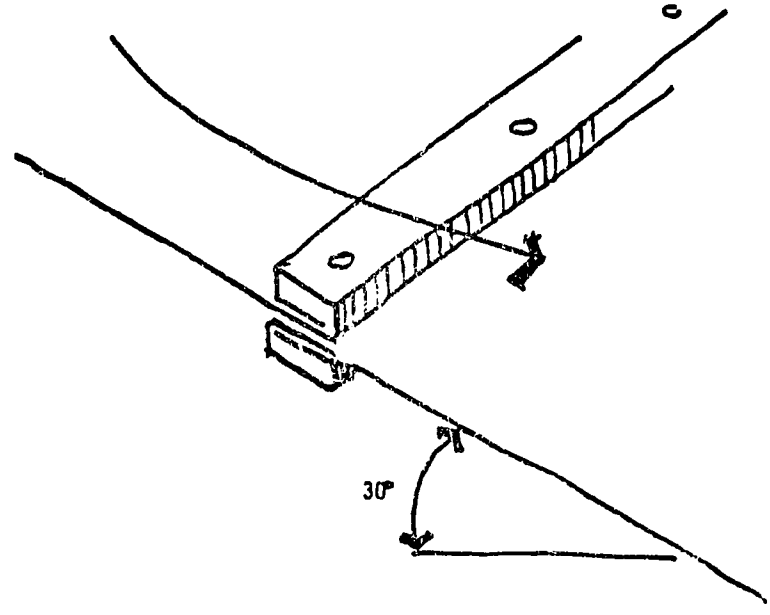
PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO SHEETING - Batten Method	3.62 - 2

2. Nail through the battens every 15 cm and bend the exposed nail over to cinch the two pieces together.





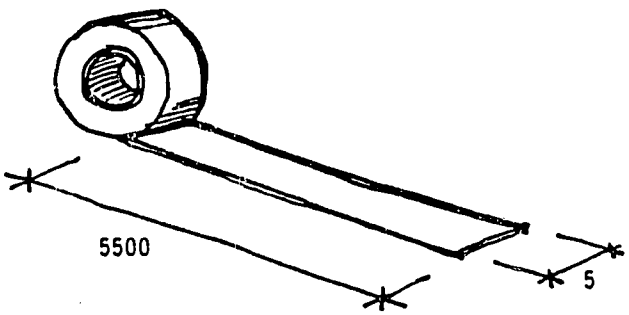
3. Orient the joint on the structure as shown if possible, so that water will not run inside.



PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO SHEETING - Plastic Tape	3.62 - 3

PLASTIC TAPE

The plastic tape included in the box with the plastic sheeting will make relatively strong waterproof joints.

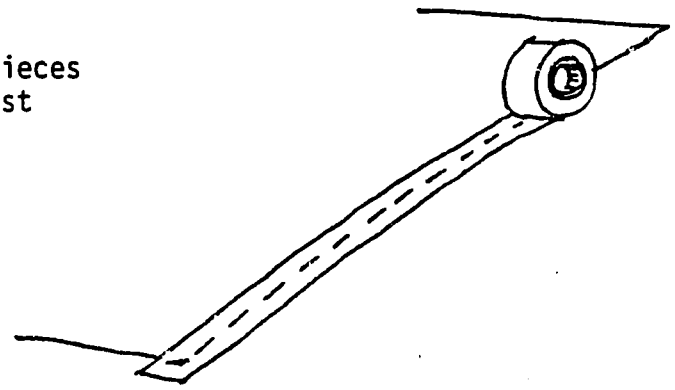


Strengths	Weaknesses
• Quick, waterproof joints	• Strong when intact but rips very easily if punctured, sliced, or torn
• Ideal for non-structural joining of large pieces of sheeting	• Loses strength when hot
• Ideal for securing sheeting around windows, doors, etc.	• Will not bond if the plastic sheeting is wet
• Ideal for patching rips or other damage	

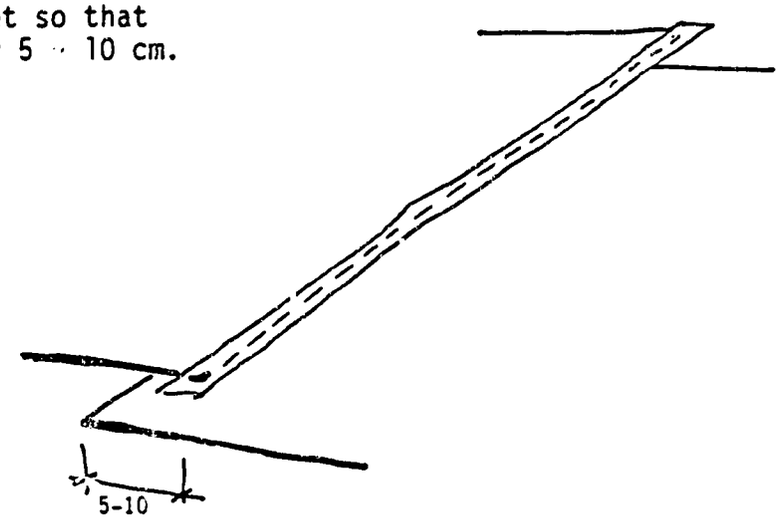
The tape included is Scotch brand Package Sealing Tape manufactured by 3M Company and may be available locally. The roll contains 55 meters of tape, at least 15 meters of which should be reserved for repairs.

Procedure

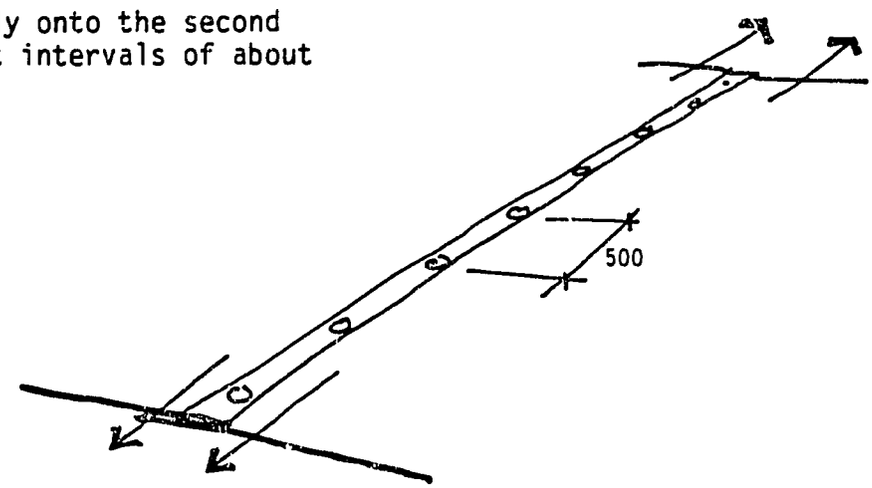
1. Apply the tape to one of the pieces to be joined. The sheeting must be dry.



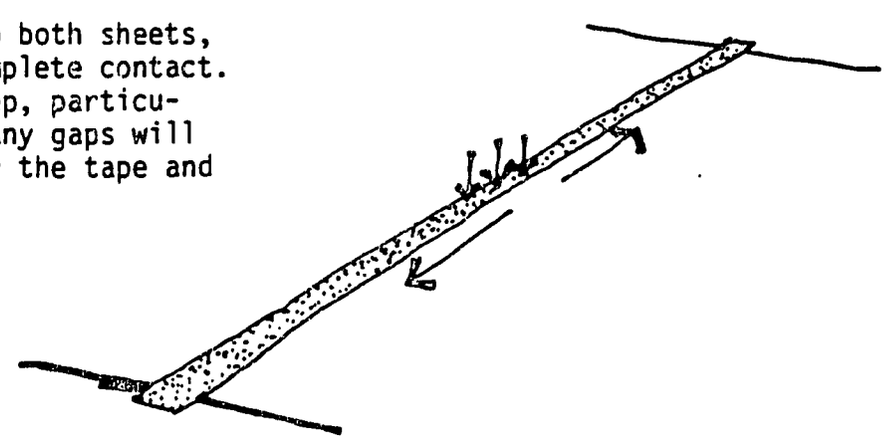
2. Position the second sheet so that it overlaps the first by 5 - 10 cm.



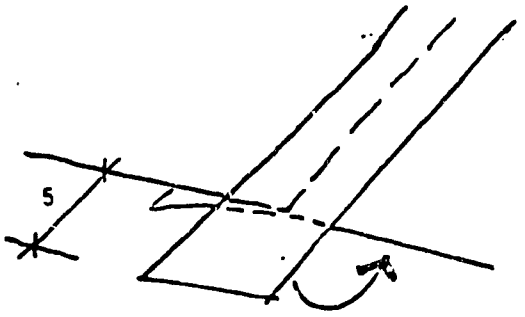
3. Press the tape firmly onto the second sheet, tacking it at intervals of about 500 cm.



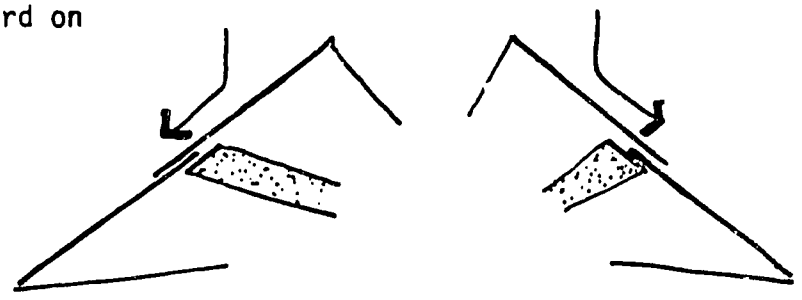
4. Firmly press the tape to both sheets, making sure there is complete contact. This is an important step, particularly in rainy areas. Any gaps will allow water to get under the tape and destroy the bond.



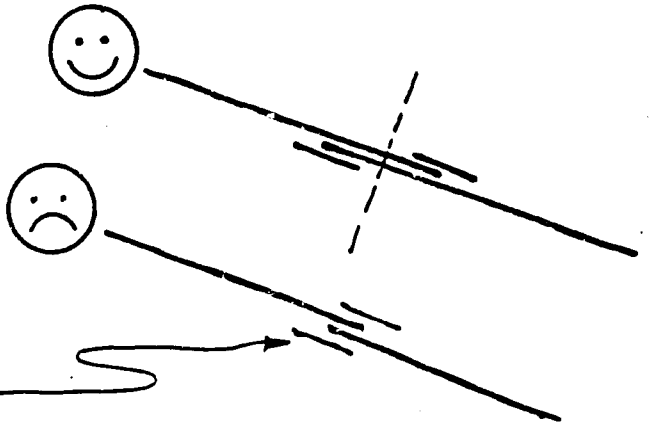
5. At the ends of the joint, lap the end of the tape under about 5 cm.



6. The tape should be positioned on the inside of the structure with the lap joint facing downward on the outside to shed water.

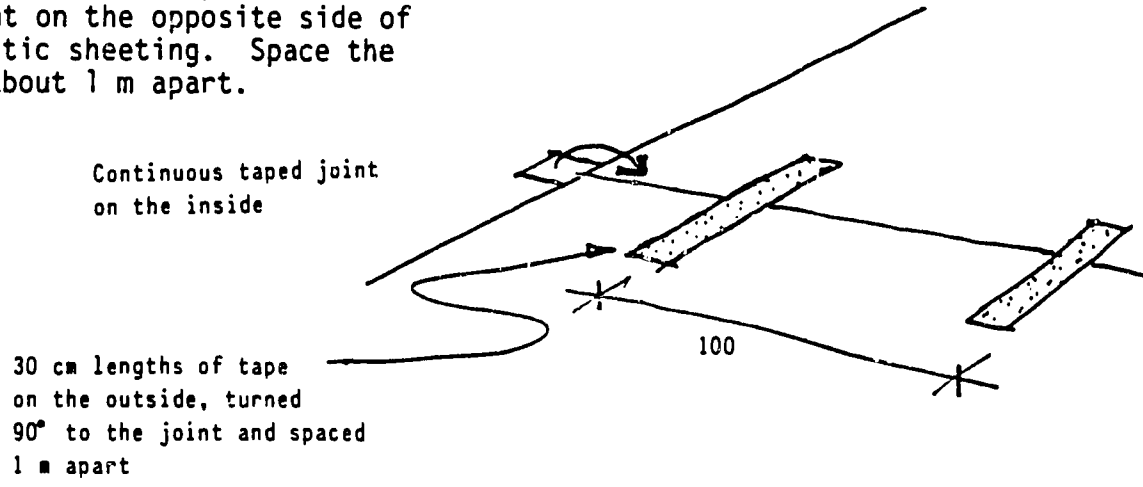


7. For short joints, the tape may be applied on both sides. This considerably increases the strength and security of the joint. DO NOT overlap the coverage of the tape.

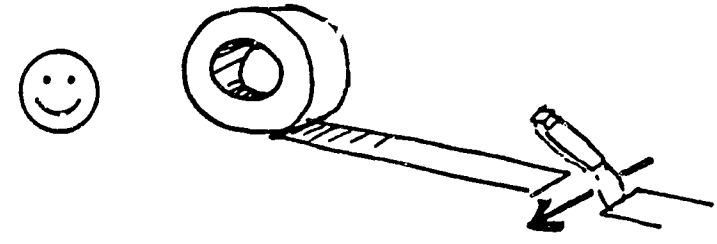


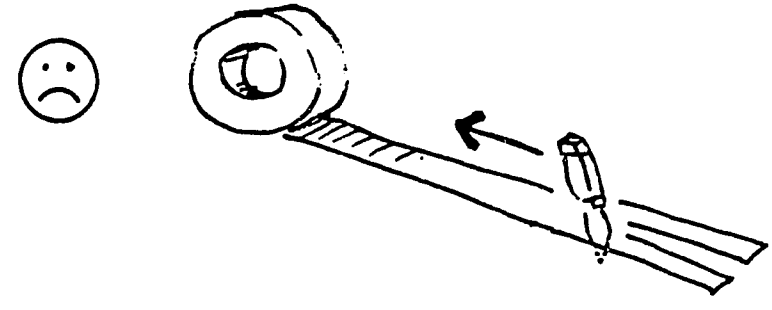
PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO SHEETING - Plastic Tape	3.62 - 6

8. To help prevent migration of rips, short strips can be placed across the joint on the opposite side of the plastic sheeting. Space the strips about 1 m apart.



9. Do not attempt to rip the plastic tape. It must be cut with a knife or sharp object across its length. Any cut along its length will seriously affect the strength of the joint.





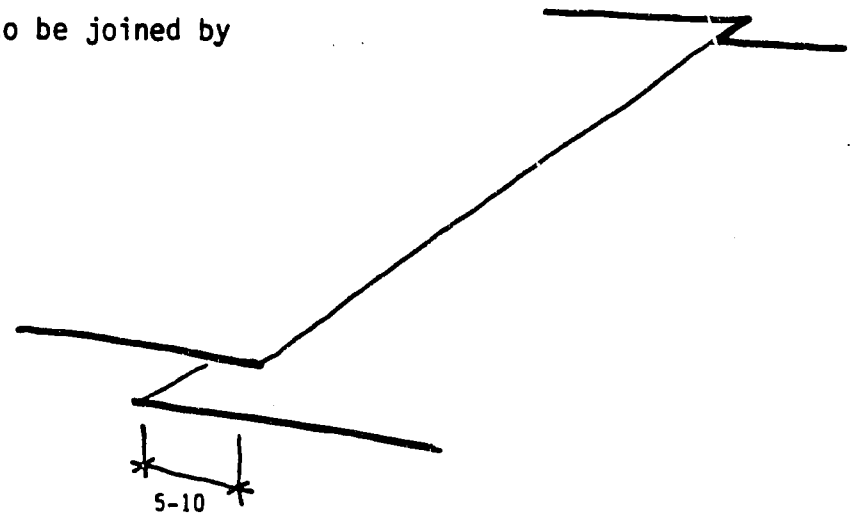
SEWING AND TAPING

Two pieces of plastic may be joined by machine sewing and taping over the sewn joint.

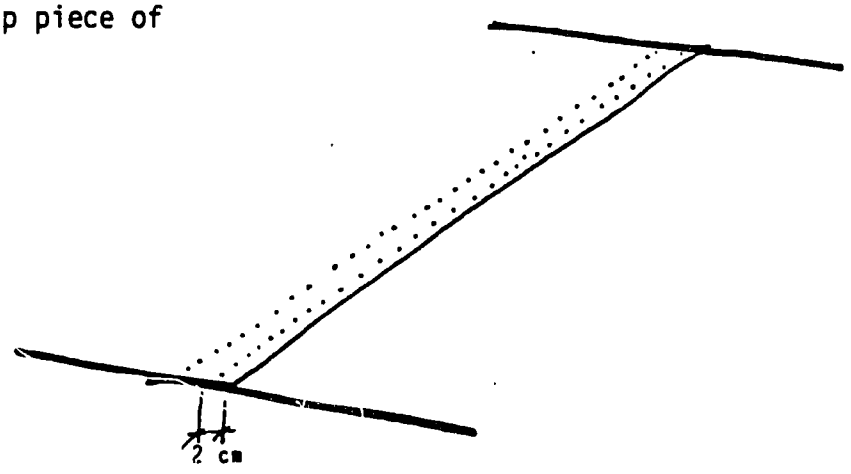
Strengths	Weakness
• Smooth, strong joint	• The sewing somewhat weakens the plastic sheeting
• Waterproof	

Procedure

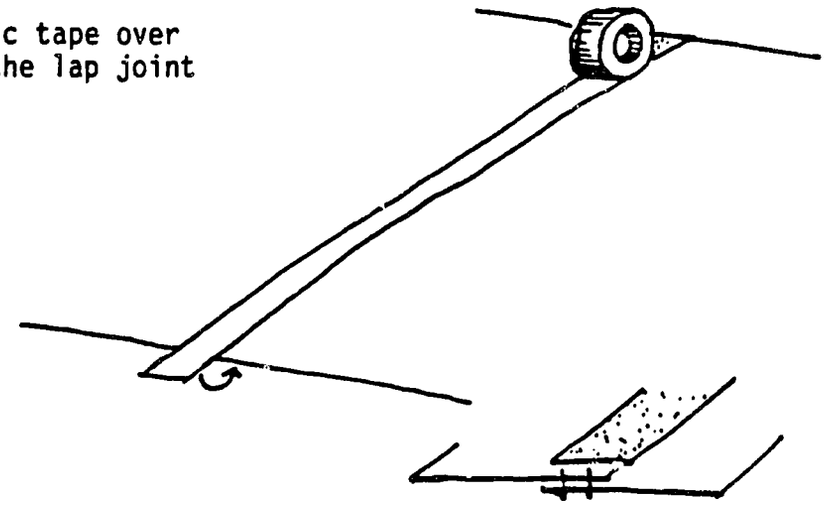
1. Overlap the pieces to be joined by 5 - 10 cm.



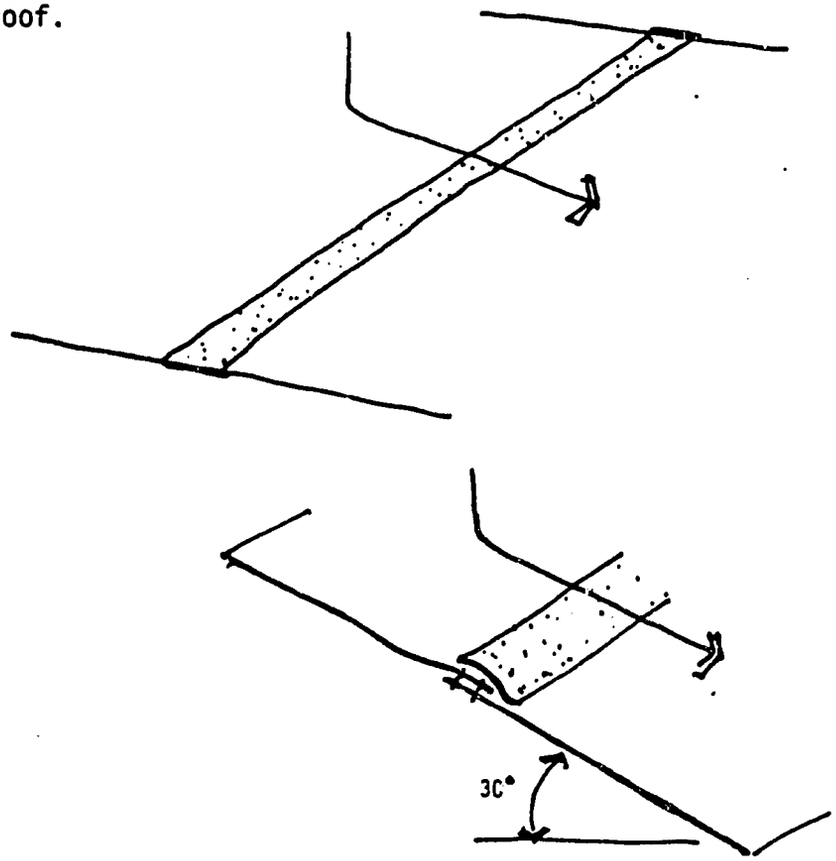
2. Sew the two pieces together with at least two rows of stitches 2 cm from the edge of the top piece of plastic.



3. Firmly place the plastic tape over both the stitches and the lap joint and seal tightly.



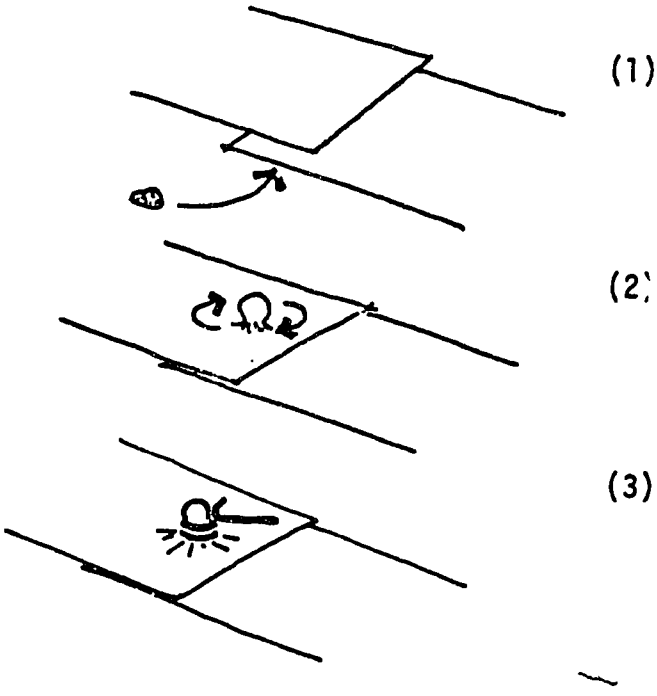
4. If possible, orient the joint so that the lap faces down the roof.



PLASTIC SHEETING CONNECTIONS	No. 3.62 - 9
SHEETING TO SHEETING - Rock Tie Method	

ROCK TIE METHOD

A very crude yet simple way of attaching two pieces of plastic sheeting is to overlap the sheets and tie rocks into the overlap.

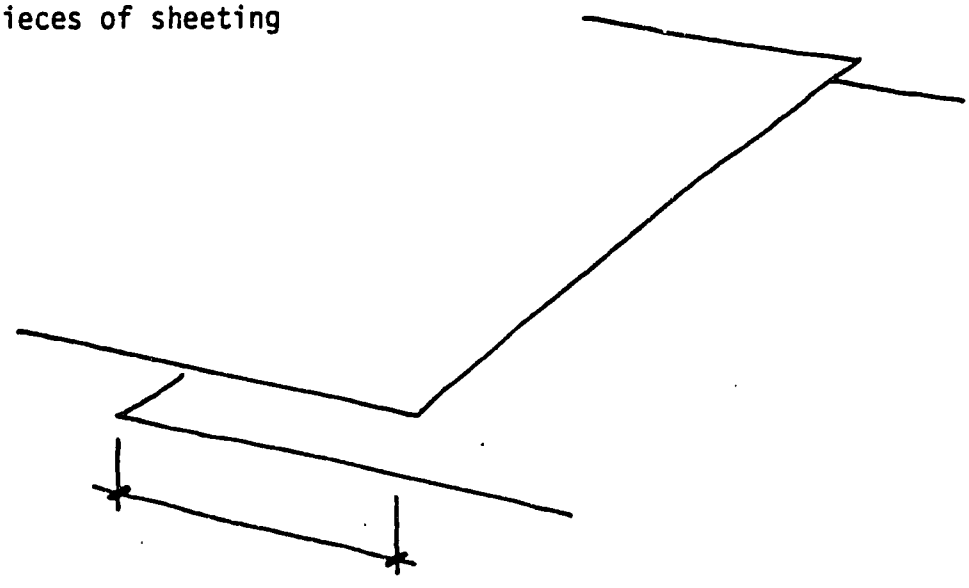


The connectors provided in the package may also be used in this way; however, they are much more useful as a rope connector. (See Section 3.67 - Sheeting to Rope.)

Strengths	Weaknesses
· Very inexpensive	· Not a strong connection
· Waterproof	· Distorts the shape of the fabric. Because it does not stretch, it will not smooth out.

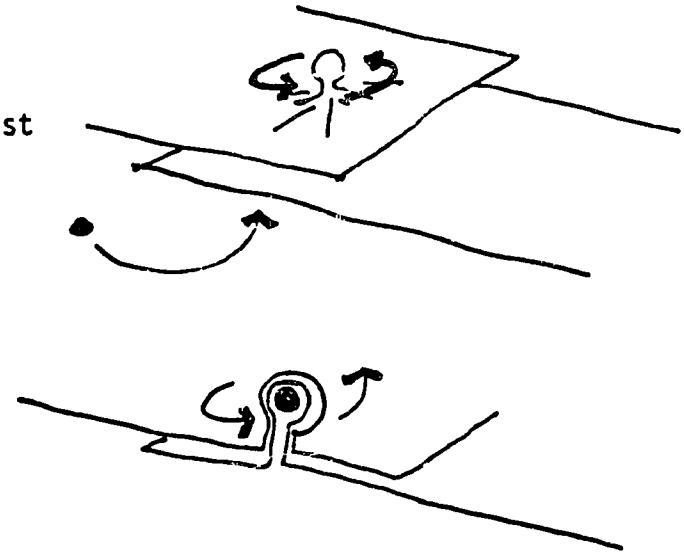
Procedure

1. Overlap the two pieces of sheeting about 25 - 30 cm.

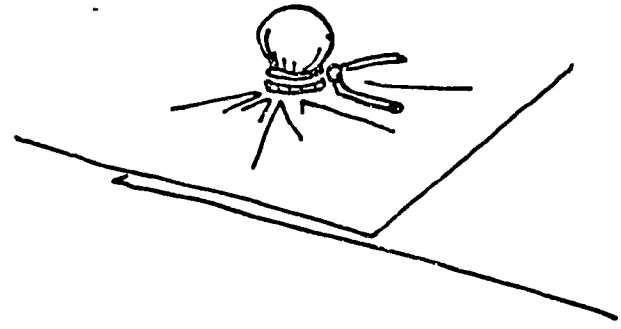


PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO SHEETING - Rock Tie Method	3.62 - 10

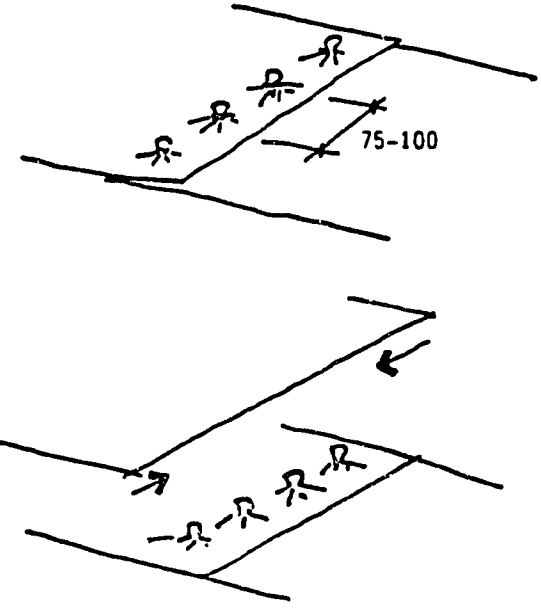
2. Place a 3 - 5 cm smooth rock in the center of the overlap and twist the sheeting around the rock.



3. Tie a piece of twine or small rope around the neck of embedded rock.



4. Space the rock tie connections about 0.75 - 1 m along the joint. REMEMBER - the fabric does not stretch and will bunch up at the rock ties. This will shorten the joined width of material.



300

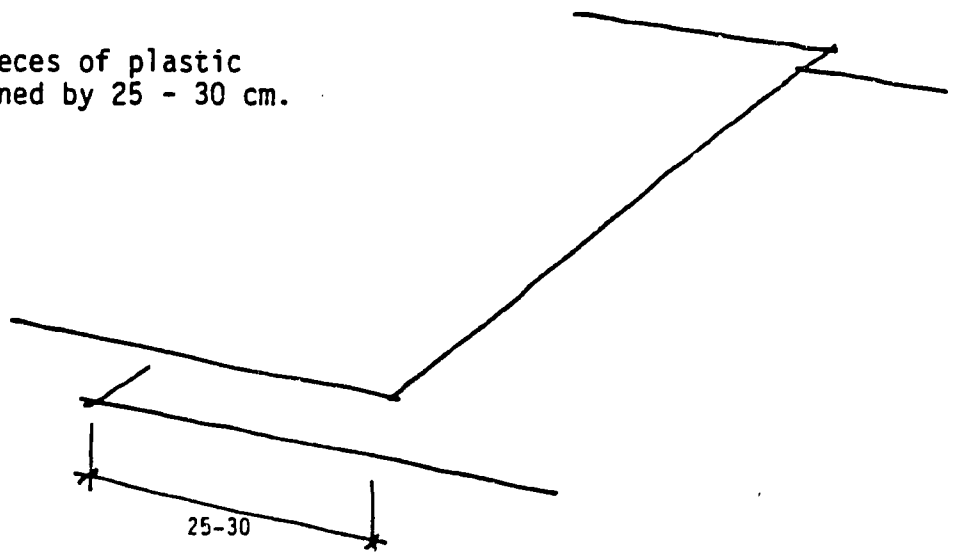
LASHING METHOD

Two pieces of plastic sheeting may be joined by lashing them with twine or light rope. It is also possible to unravel a piece of the reinforcing of the sheeting itself to use as the lashing.

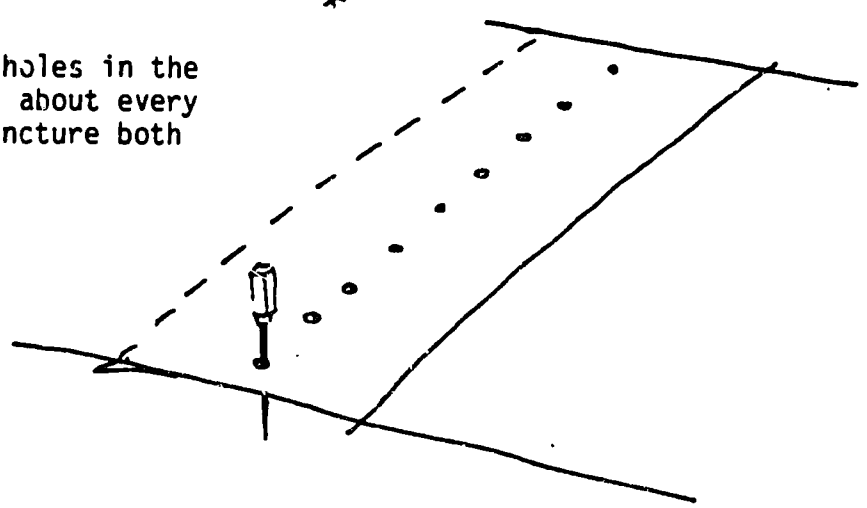
Strengths	Weaknesses
• Inexpensive	• Not a strong joint
• Requires no additional materials	• Weakens the plastic sheeting
	• Not waterproof

Procedure

1. Overlap the two pieces of plastic sheeting to be joined by 25 - 30 cm.

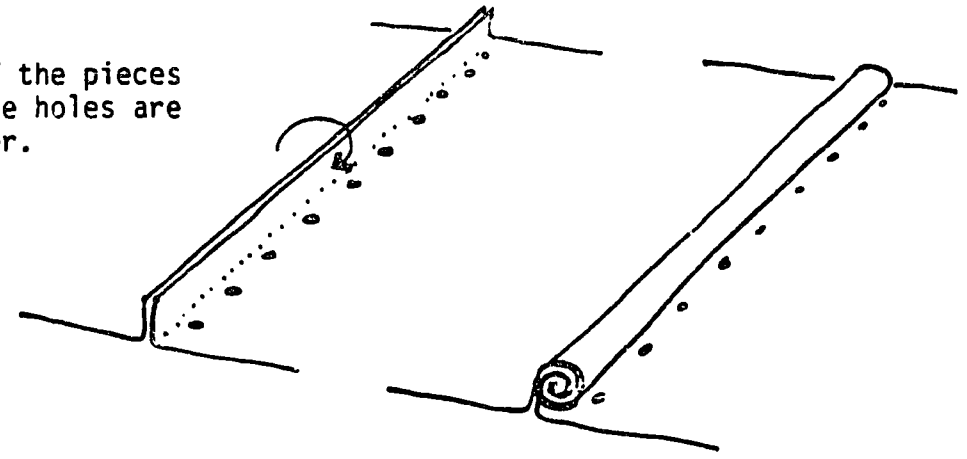


2. Puncture a series of holes in the middle of the overlap about every 15 cm. Be sure to puncture both pieces.

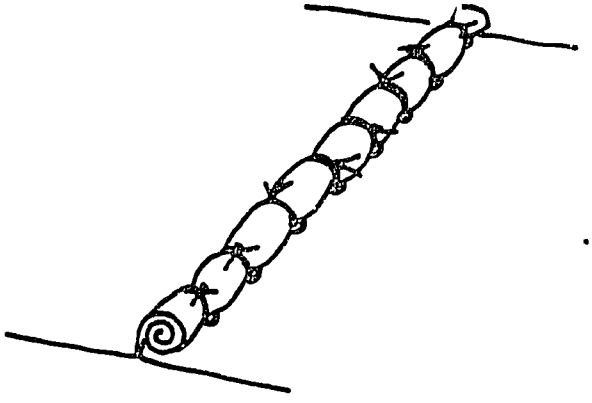


PLASTIC SHEETING CONNECTIONS	No.
SHEETING TO SHEETING - Lashing Method	3.62 - 12

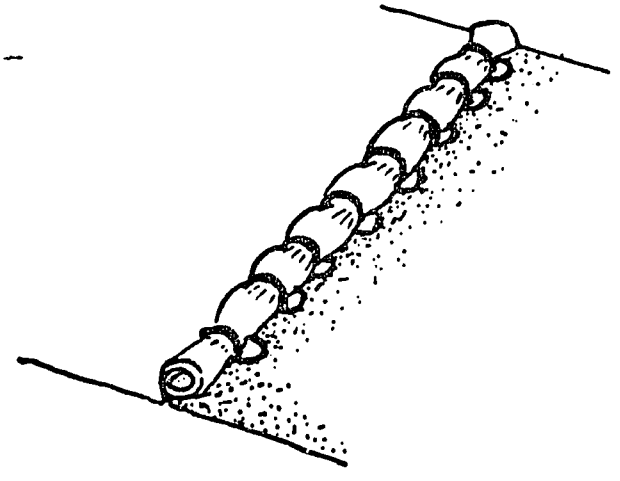
3. Roll the edges of the pieces together until the holes are next to each other.



4. Lash a piece of twine or light rope through the holes and tie securely.



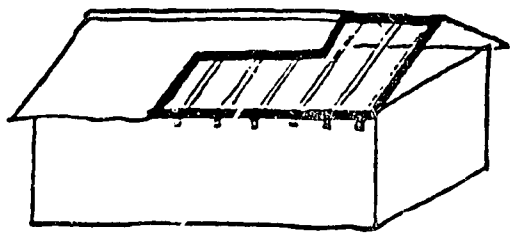
5. The plastic will rip slightly around the lashing holes and water will be able to penetrate. As the plastic will continue to rip over time, any sealant will have to be replaced often.



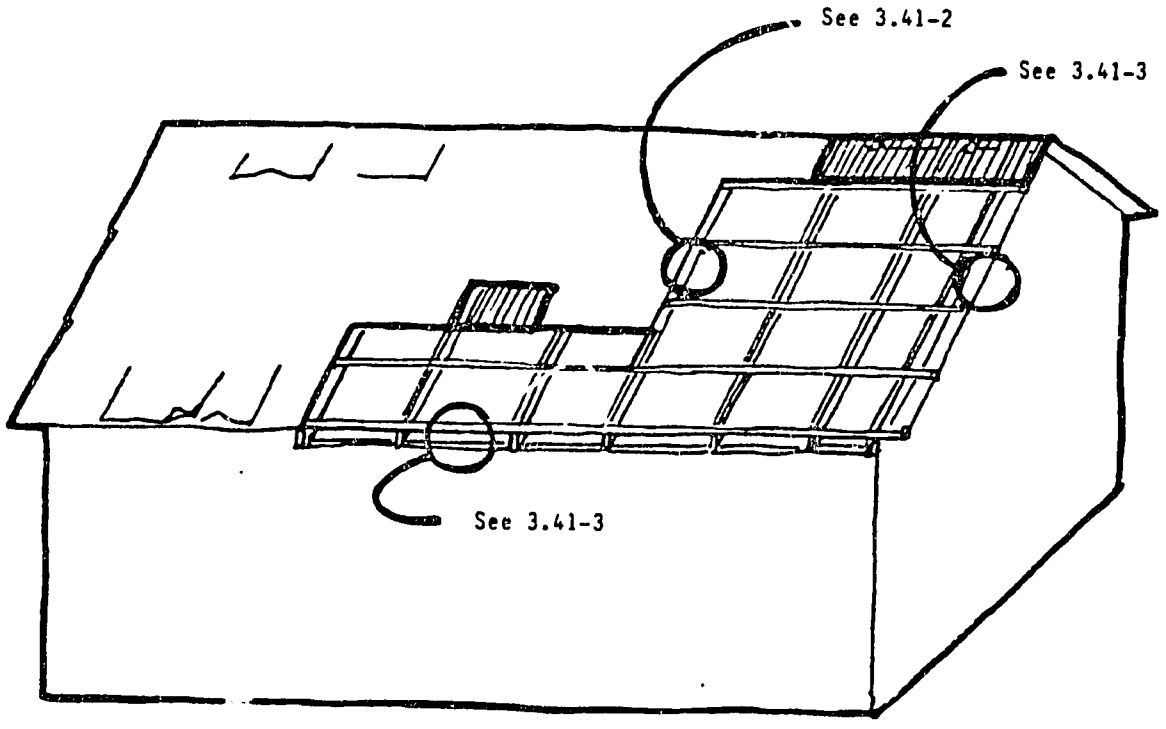
3.4 USE OF PLASTIC WITH EXISTING DAMAGED STRUCTURES

3.41 Partially Blown Off Roof
3.42 Wall Reconstruction
3.43 New Roof
3.44 New Doors and Windows

FRAME TYPE: PARTIALLY BLOWN OFF ROOF	No. 3.41 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	◑		REFERENCE DETAILS 3.5 3.6
HIGH WIND	●		
FLOOD	◔		
FRAME MATERIALS Same as existing materials			

Some structures will only be partially damaged. In this illustration, part of the roofing has been blown off and can be replaced with plastic sheeting.

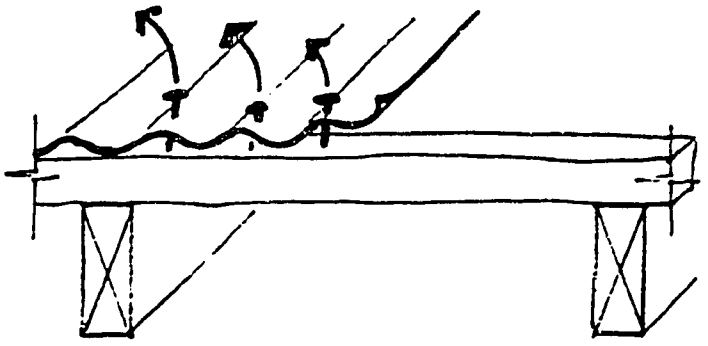


Salvage as much of the existing roofing material as possible. Areas of blown off roofing should be trimmed so as to make simple rectangular spaces to be filled in with plastic sheeting.

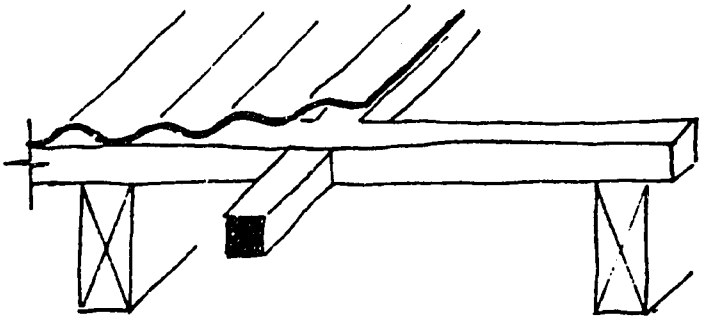
Renail the existing roof covering.

PARTIALLY BLOWN OFF ROOF	No.
REPAIR SEQUENCE	3.41 - 2

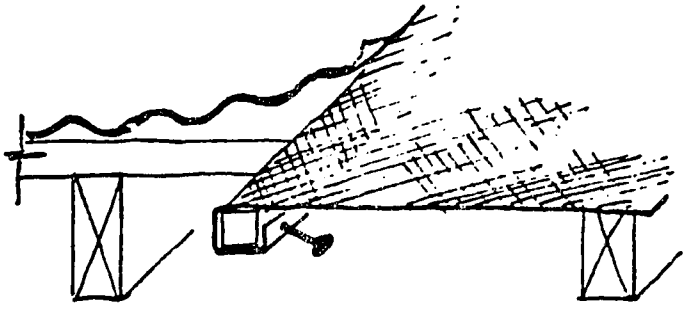
1. Remove nails and pull the existing roofing up along the edge.



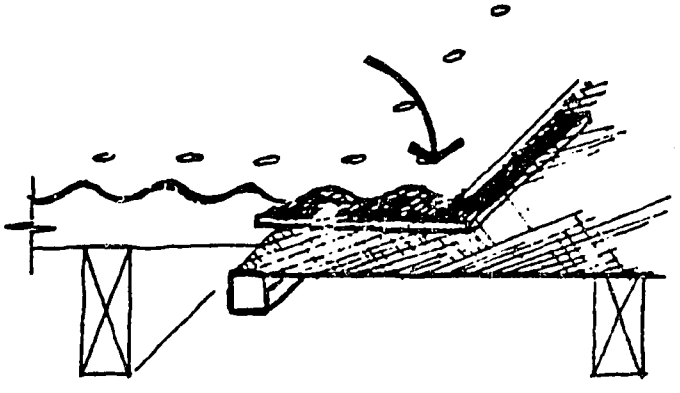
2. Nail a strip under the existing roofing to which the plastic sheeting can be fastened.



3. Stretch the sheeting under the existing roofing and over the nailing strip. Secure it in place.

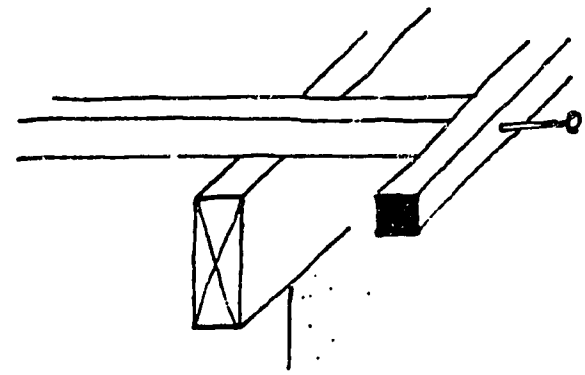


4. Nail the existing roofing over the plastic sheeting. Use a layer of cardboard or cloth between the two roof coverings to prevent the plastic sheeting from ripping.

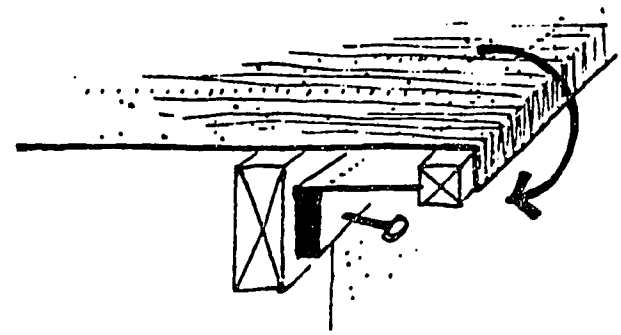


PARTIALLY BLOWN OFF ROOF	No. 3.41 - 3
REPAIR SEQUENCE	

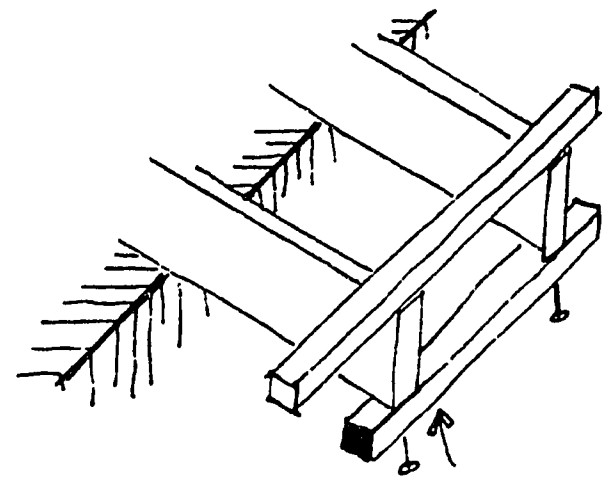
1. Nail a strip at the end of the purlins over which to stretch the plastic sheeting.



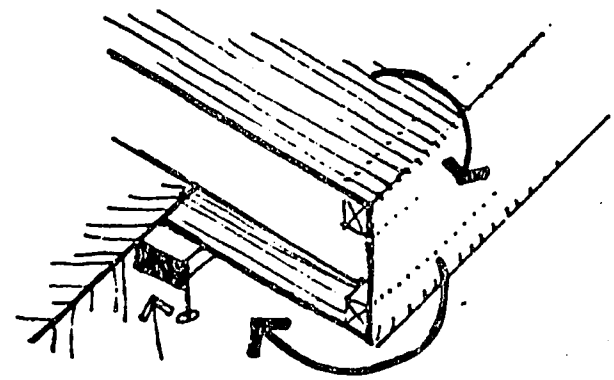
2. Stretch the plastic over the edge and, using a batten, nail the sheeting to the roof joist.



3. Nail a strip under the roof joists so that the sheeting can be stretch back under the joist.

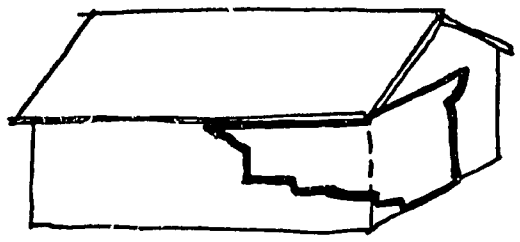


4. Stretch the sheeting under the roof joist and, using a batten, nail the sheeting to the underside of the roof joist.

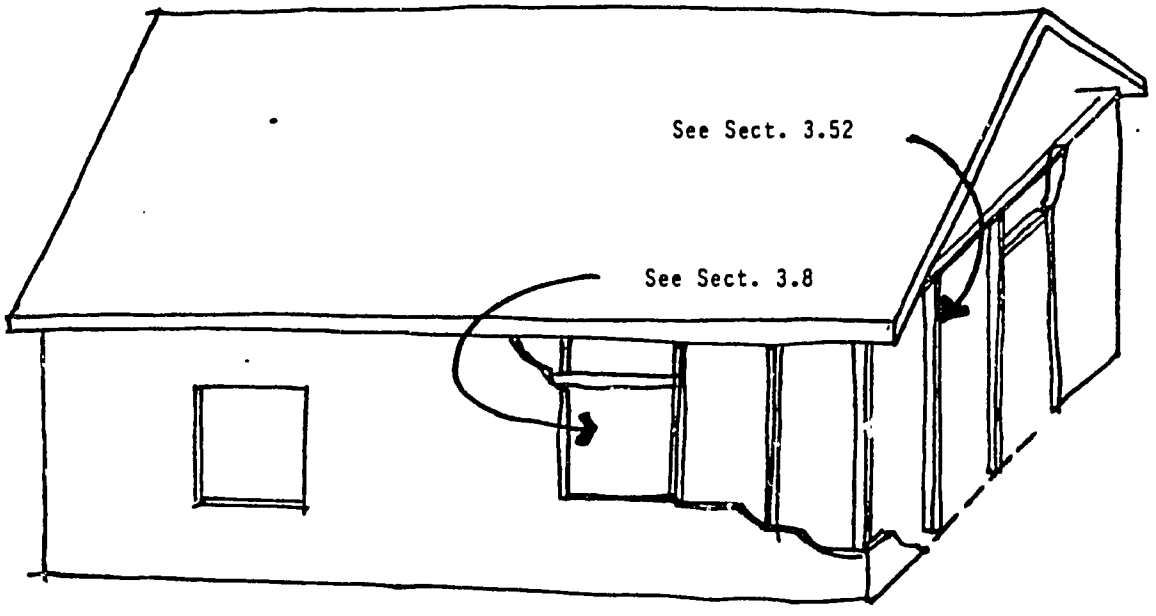


306

FRAME TYPE: WALL RECONSTRUCTION	No. 3.42 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	◑		REFERENCE DETAILS 3.5 3.6 3.8
HIGH WIND	●		
FLOOD	◑		
FRAME MATERIALS Same as existing materials			

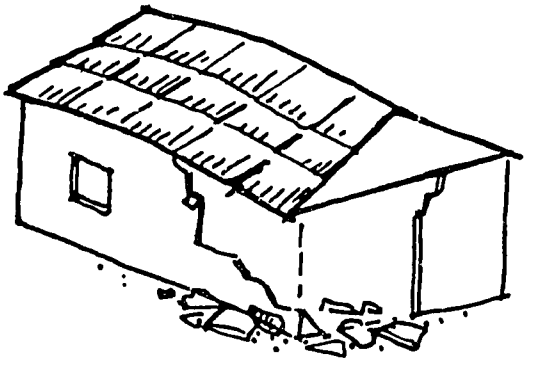
In this illustration, part of the wall has been damaged but the roof and remaining exterior walls are structurally sound.



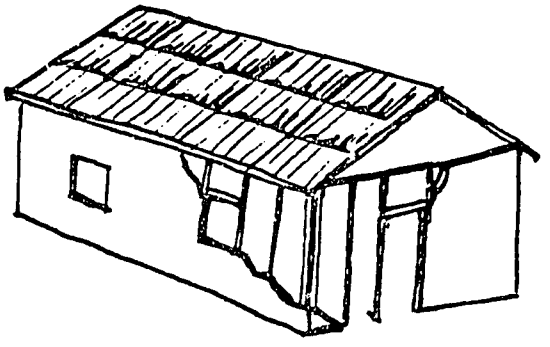
Jack the roof up and frame in the damaged part of the wall.

WALL RECONSTRUCTION	No.
REPAIR SEQUENCE	3.42 - 2

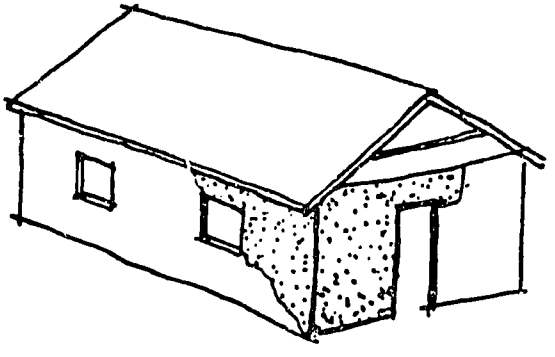
1. Remove debris from the building site and temporarily brace the roof.



2. Jack the roof up to the desired height and frame in the remaining wall. Frame in door and window openings.



3. After the framing is up, remove the temporary bracing and cover the framing with plastic sheeting. Cut out door and window openings.

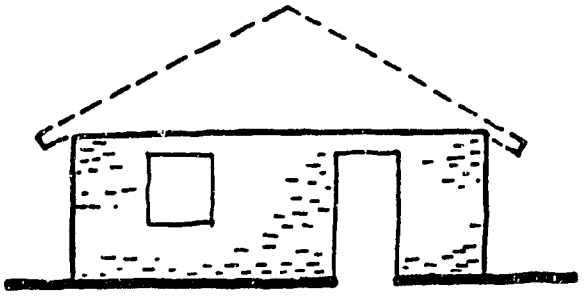


FRAME TYPE: NEW ROOF	No. 3.43 - 1
DRAWING: PERSPECTIVE SKETCH	

SEISMIC	◔
HIGH WIND	◑
FLOOD	◑

FRAME MATERIALS

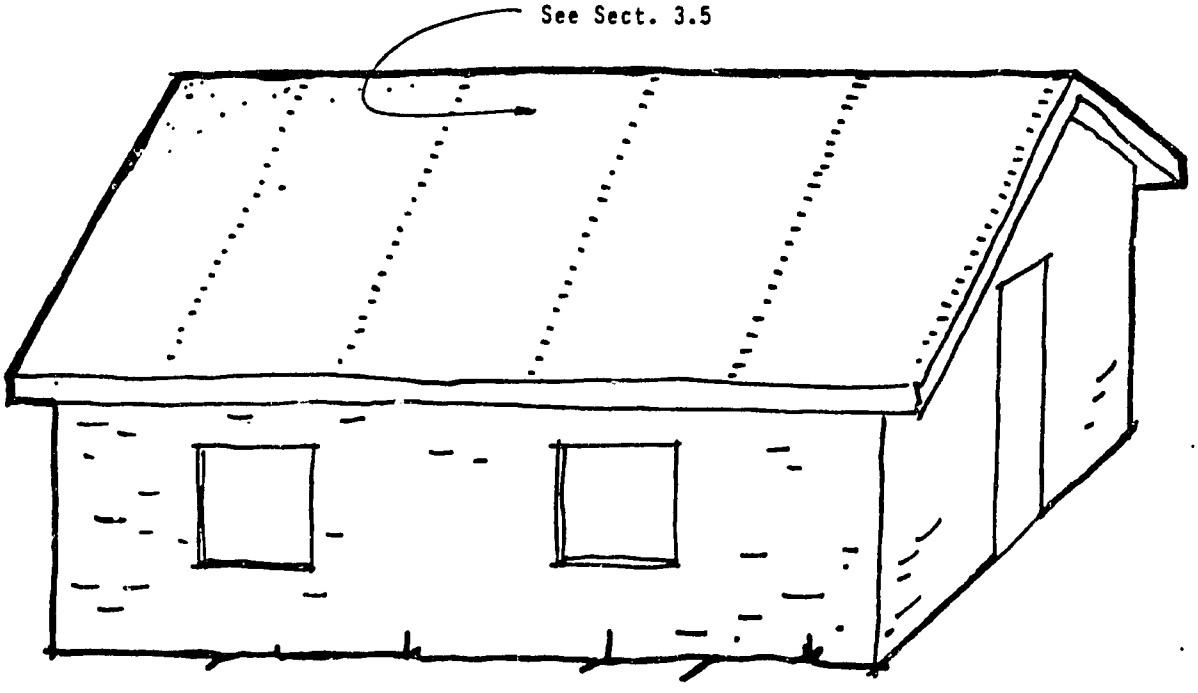
Same as existing materials



REFERENCE DETAILS

3.5
3.6

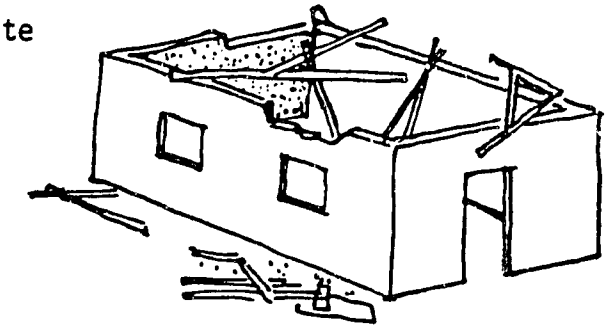
In this illustration, the roof has been blown off and completely destroyed, requiring a new roof frame and covering.



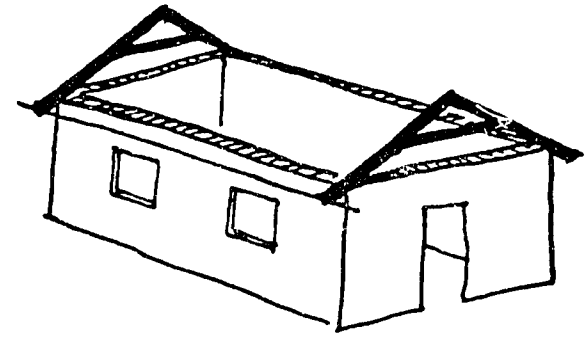
Before putting up new roof framing, inspect the walls for structural damage.

NEW ROOF	No.
REPAIR SEQUENCE	3.43 - 2

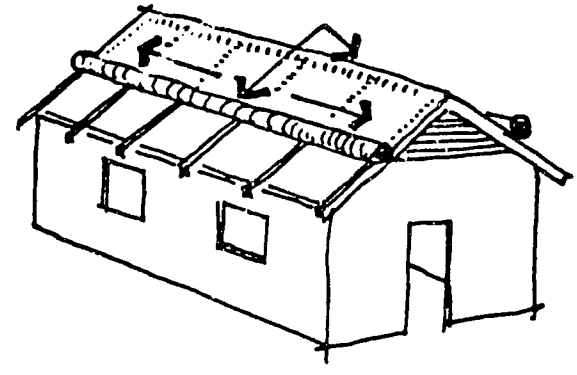
1. Remove debris from the building site and repair the top of the walls.



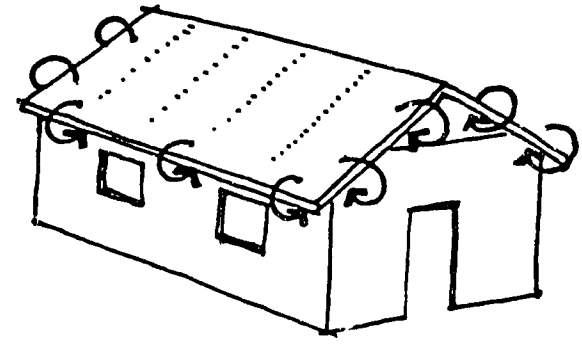
2. Salvage and reconstruct new roof trusses. Set the two end trusses first, then stretch a string between them and set the remaining trusses to the string.



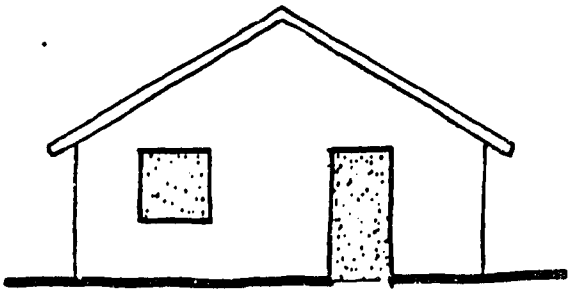
3. If possible, only one piece of plastic sheeting should be used to cover the roof. Cut the sheeting to fit the roof, then roll up the sheeting and carry it onto the roof. Start at the ridge and work down to the bottom. (See Section 3.52.)



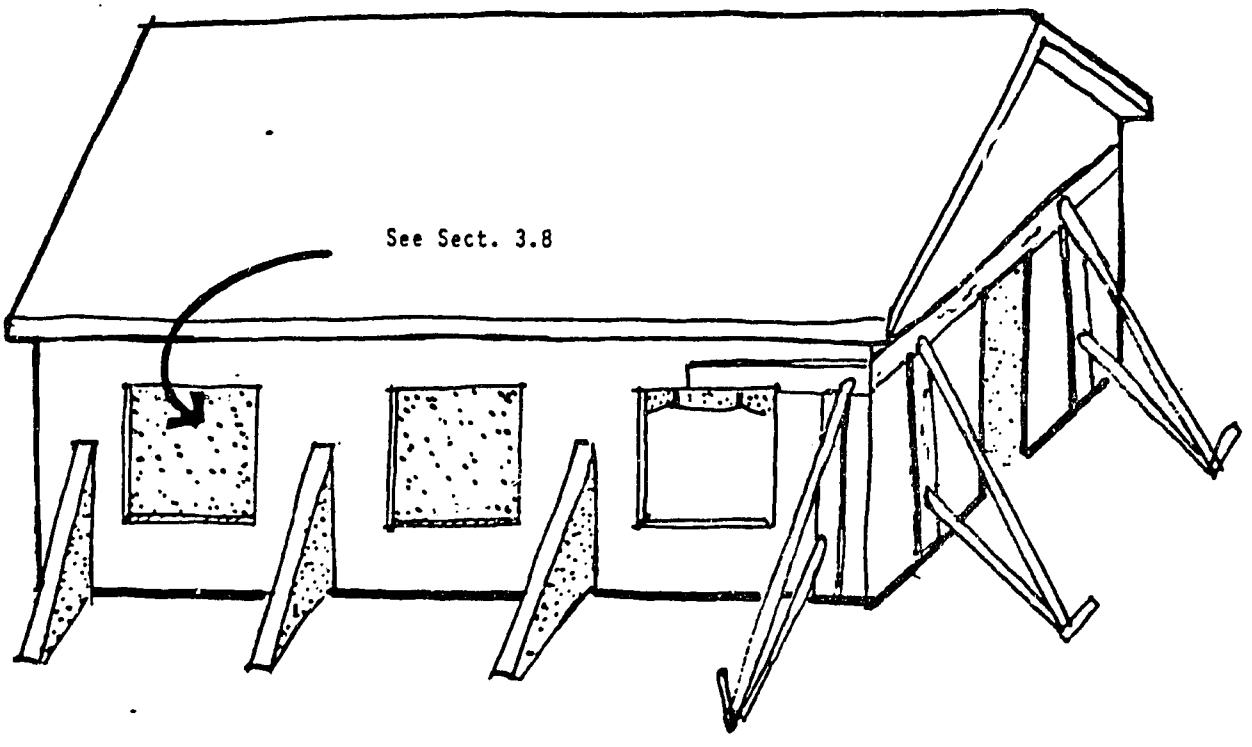
4. After the roof covering is in place, secure the edges. (See Section 3.6.)



FRAME TYPE:	NEW DOORS AND WINDOWS	No.
DRAWING:	PERSPECTIVE SKETCH	3.44 - 1

SEISMIC	○		REFERENCE DETAILS 3.5 3.6
HIGH WIND	◑		
FLOOD	◑		
FRAME MATERIALS Masonry Poles Pipes Dimensional Lumber			

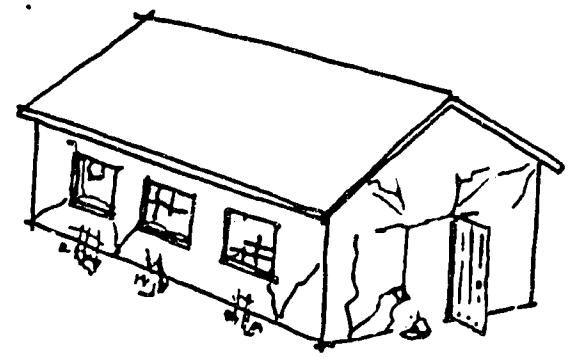
In this illustration, the building is still standing but has several structural problems and must be significantly shored up.



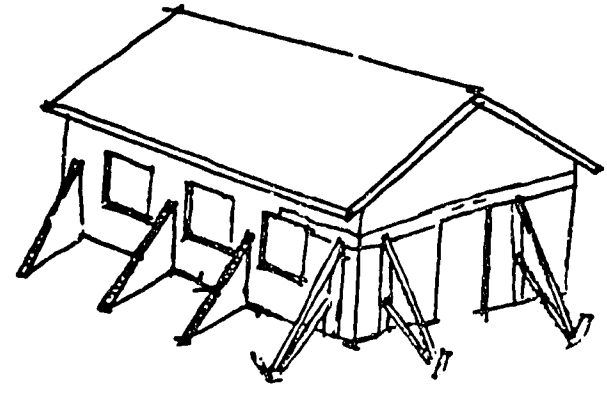
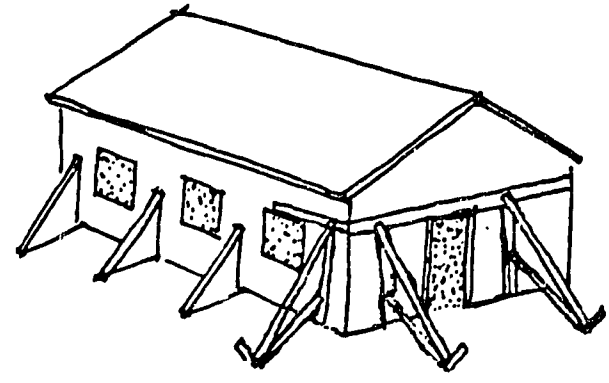
The plastic sheeting is used here to cover the window openings where the glass has been broken; likewise, it has been used to cover door openings where doors have been damaged.

NEW DOORS AND WINDOWS	No.
REPAIR SEQUENCE	3.44 - 2

1. Survey damage to the building and remove debris from the site.



2. If the wall is severely cracked, major buttressing may be required to stabilize the wall.



3. After the building is made structurally sound, doors and windows can be fabricated from the plastic sheeting.