For my friend Ranjanan with best regards.
Chandrashekhar New Delhi, February 28/2004

attained a 20-02-2014

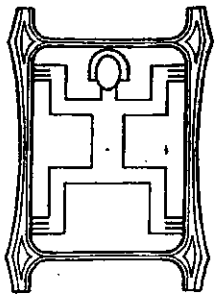
BAMBOO

THE GIFT OF THE GODS

by

Oscar Hidalgo-López

PART-2



Oscar Hidalgo-López
Editor
bamboscar2@007mundo.com

PART 2 of 2

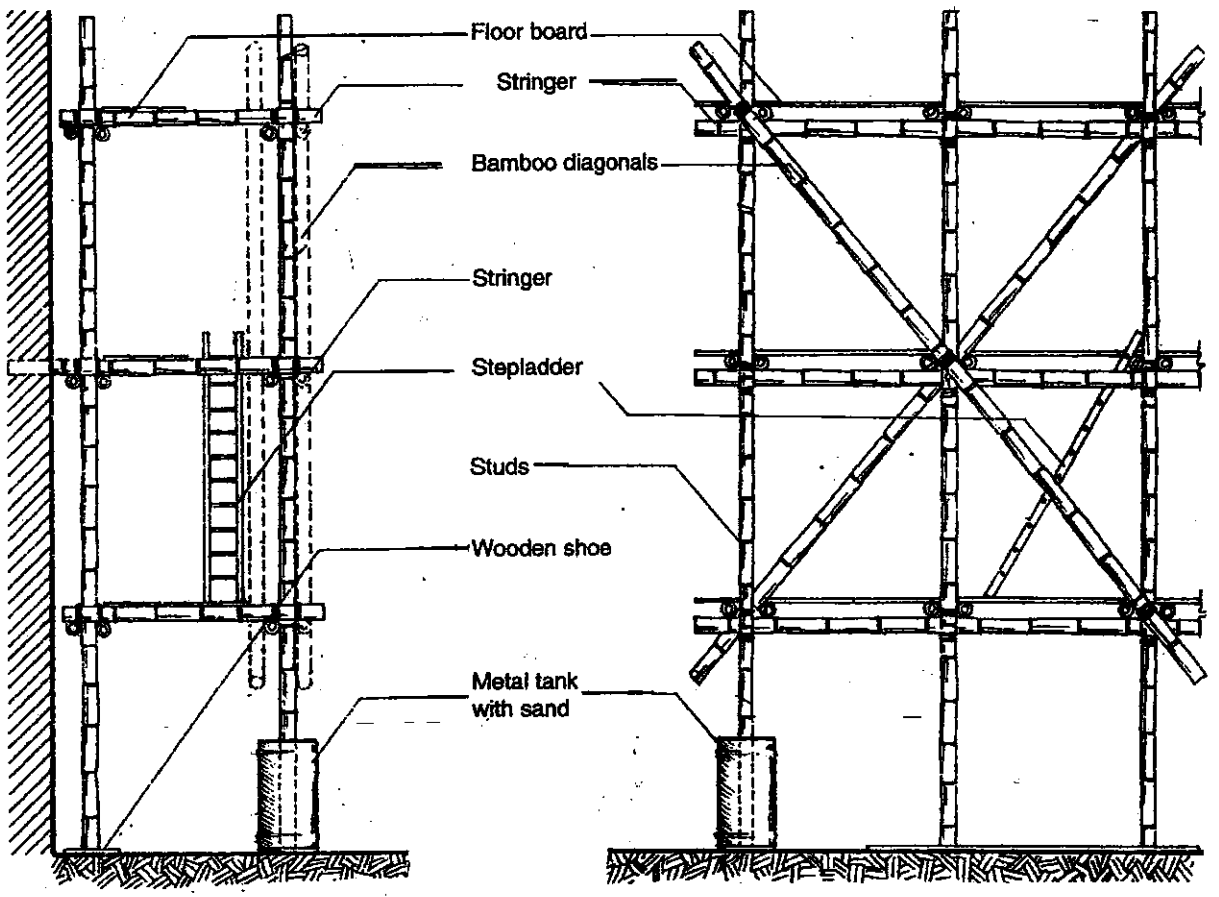
PART 7

Construction of Bamboo Structures

Bamboo bridge (Neuville's drawing)
Geografia Pintoresca de Colombia in 1869.

17 CONSTRUCTION OF BAMBOO SCAFFOLDINGS

Fig. 19.1 SMALL BAMBOO SCAFFOLDING (Colombia)

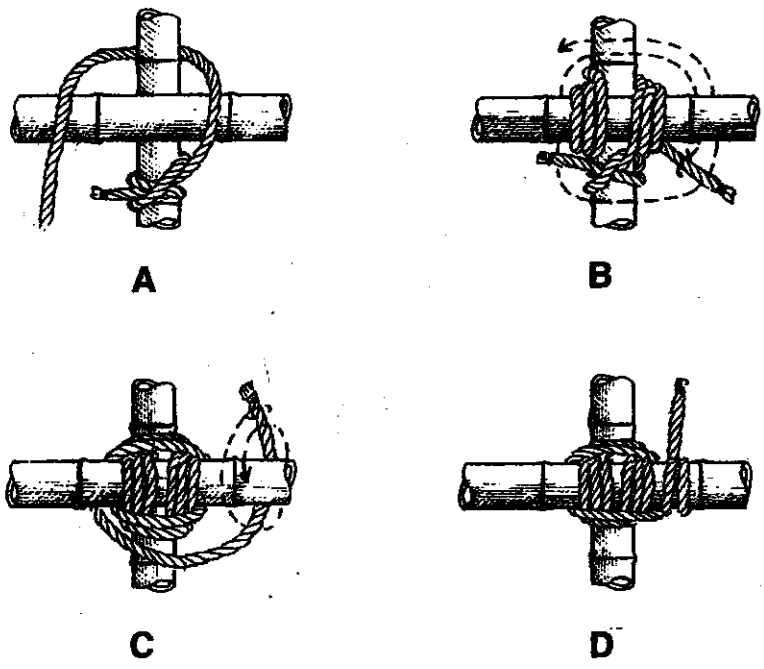


A. Lateral view **B. Front view**

C. *Detail of the wooden shoe. the base of the culms has to have a node.*

TYPES OF KNOTS USED IN THE CONSTRUCTION OF SCAFFOLDINGS

Fig.19.2



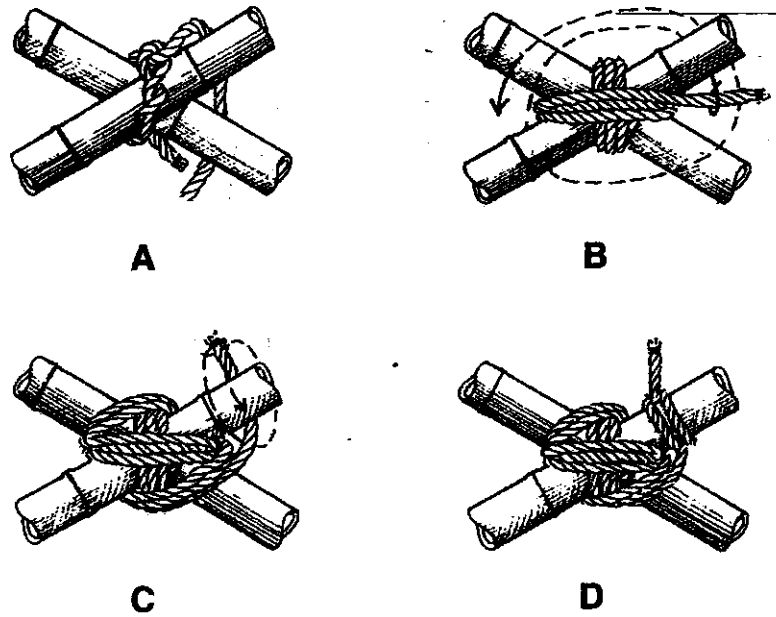
1.-Square or Transom lashing.

(a).-*Start with a clove hitch on the upright. Carry the end up in front of the transom, behind the upright, and down in front of the transom.*

(b).-*Continue in this way, keeping inside previous turns in the upright, and outside previous turns on the transom.*

(c).-*After three to five turns, as described above, conclude with two or three cross turns.*

(d).-*Dispose of the end by tying a clove hitch on the transom.*



2.-Diagonal lashing.

(a).-*Put a tight "timber hitch" diagonally over the crossing.*

(b).-*Continue with three or four tight turns in the same direction as the hitch and the same number at right angles to it.*

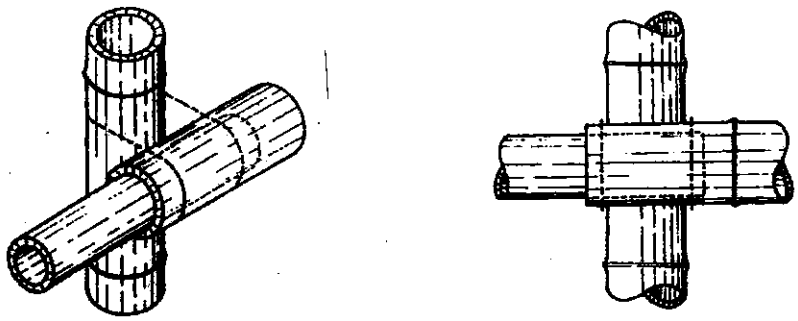
(c).-*Put on frapping turns between the spars.*

(d).-*Finish with a "clove hitch" over one spar.*

KNOTS USED IN SCAFFOLDINGS FOR FIXING HAND-RAILS

Fig. 19.3

Detail 1



Detail 2

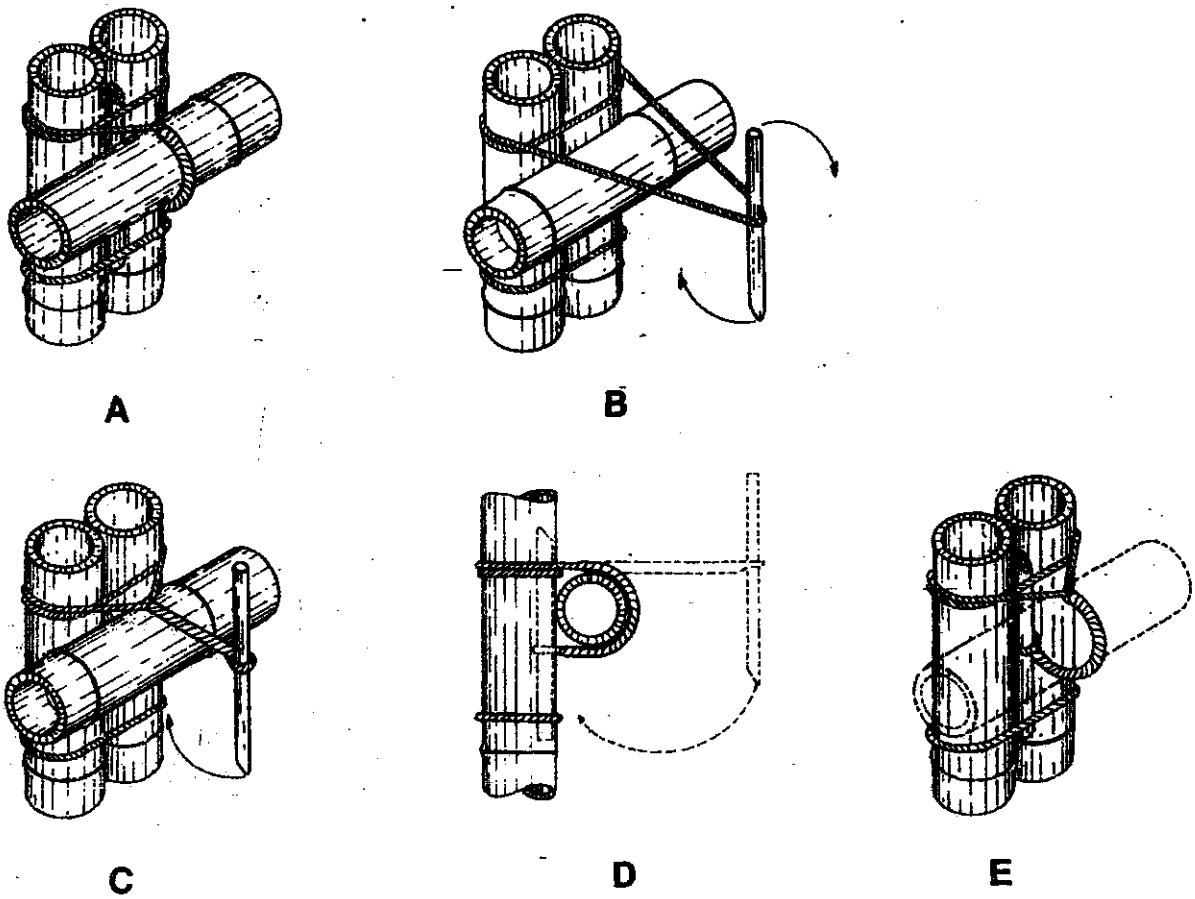
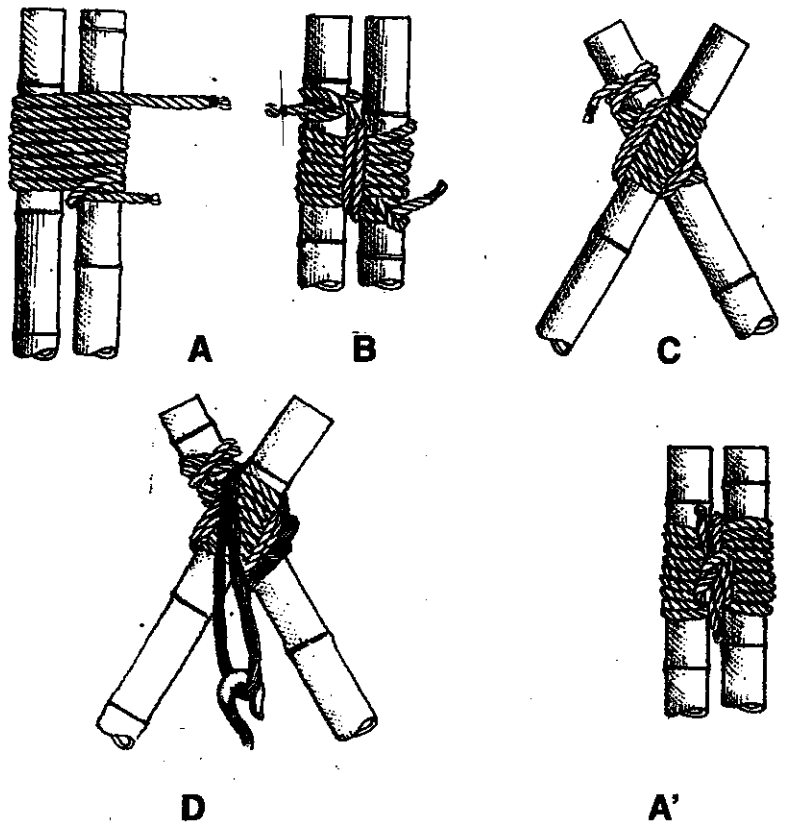


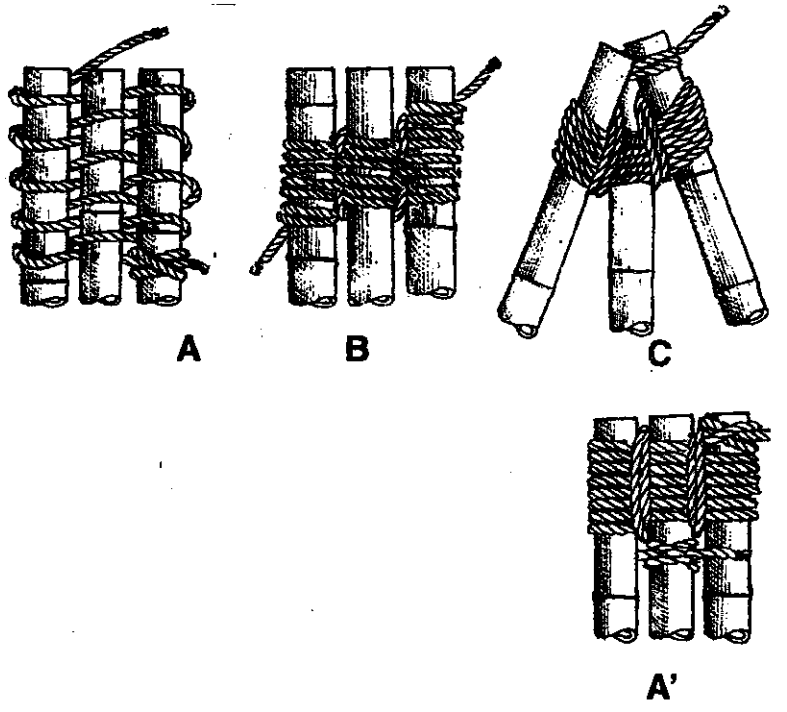
Fig.19.4 BAMBOO BIPOD AND TRIPOD FOR HANGING PULLEYS (CRANE- BOOM)



1. Bipod (Lashing for shears)

(A,B,C,D) First method

(A') Second method



2. Lashing for gin or tripod

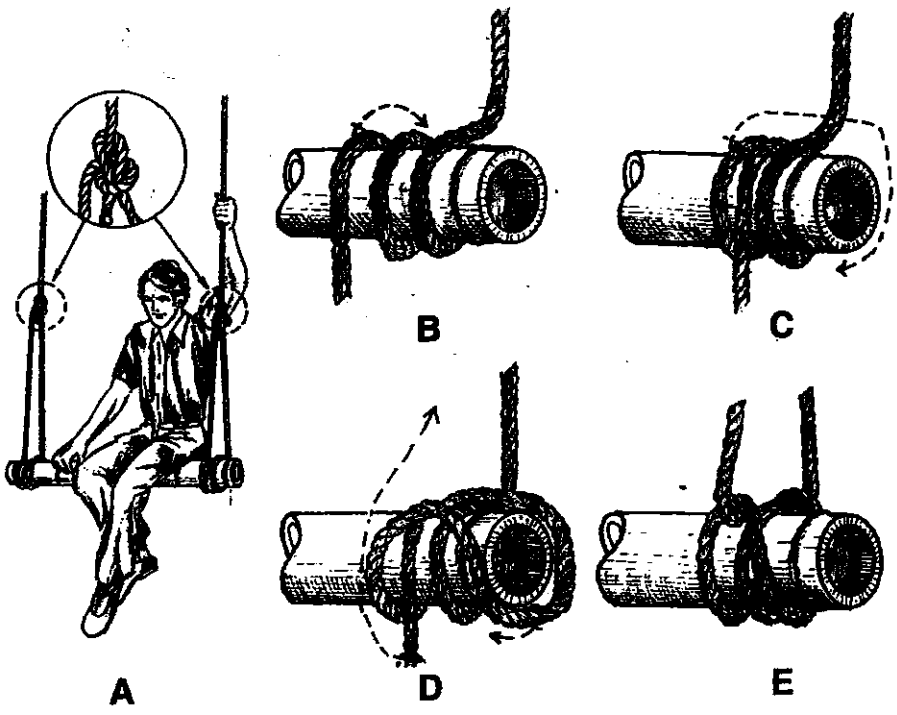
(A,B,C,) First method

(A') Second method

Fig.19.5

HANGING SCAFFOLDS

Detail No 1



1.Scaffold Hitch
(A) The scaffold once finished
(B,C,D,E) details of the knot

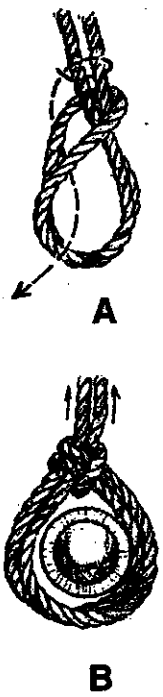
2.-Doble running knot
It is useful when tension comes in on both standing parts
(A First method
(B) Second method

3.-Doble overhand noose
(A,B) Details of the knot

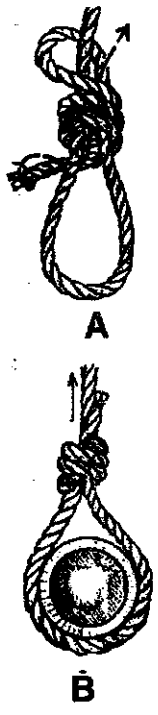
4.-The hangman's noose - knot or Halter.
(A,B) Eight or nine turns

5.- Figure eight noose
(A) First method
(B) Second method

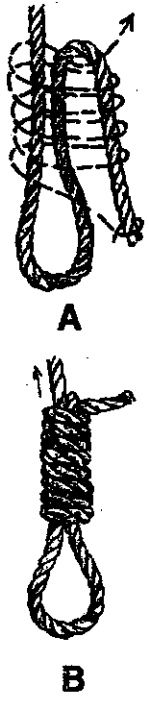
Detail No 2



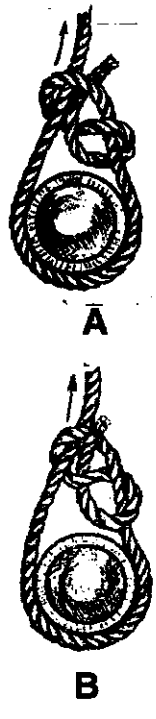
Detail No 3



Detail No 4



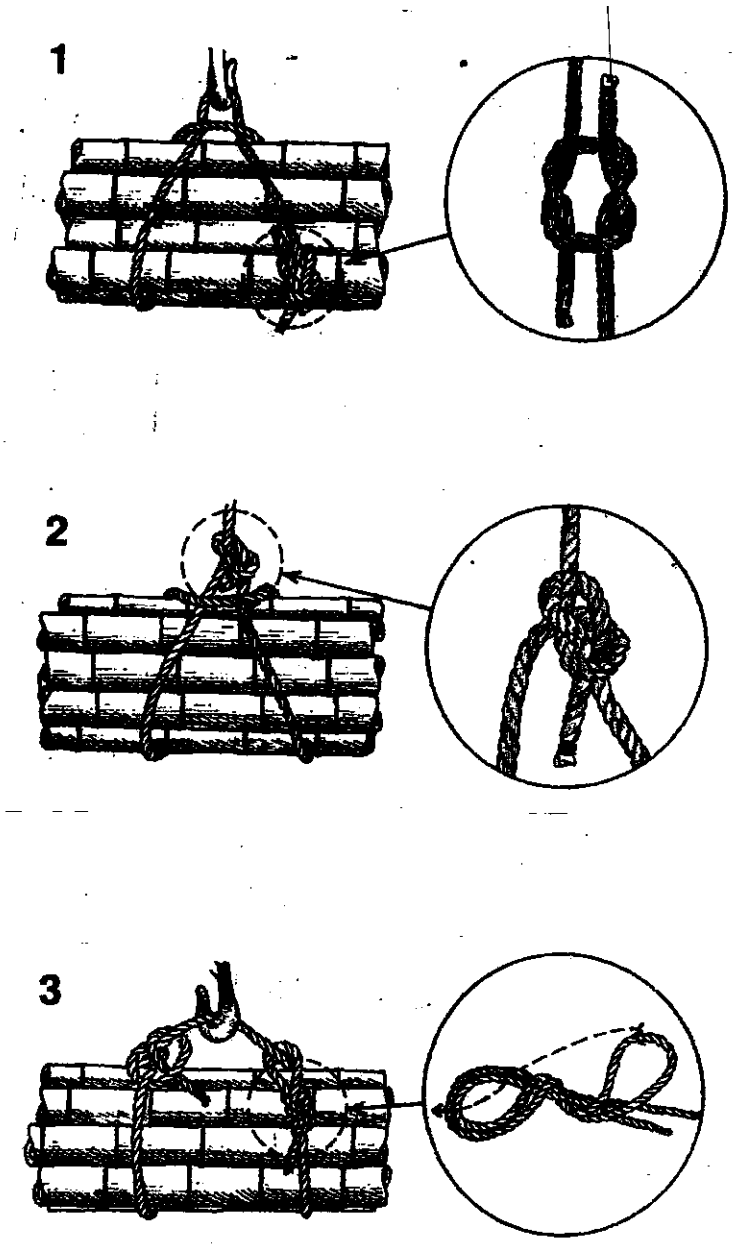
Detail No 5



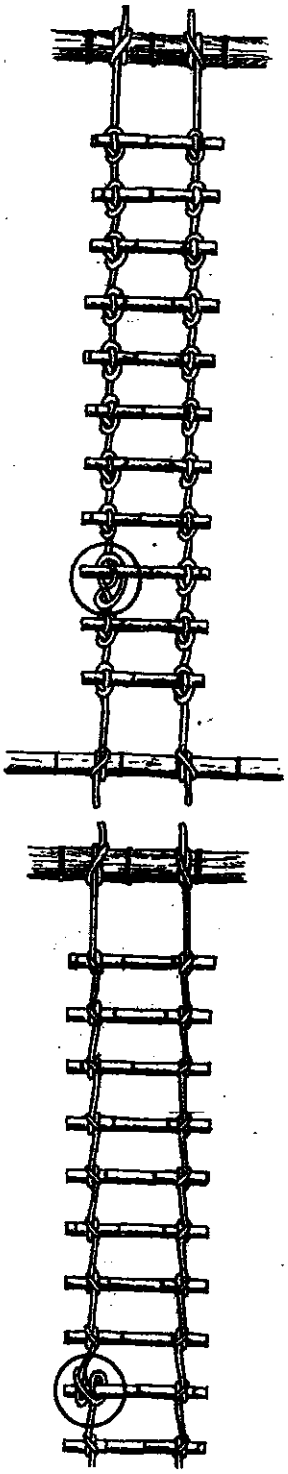
KNOT-TYING FOR VERTICAL TRANSPORTATION OF BAMBOO - Rope ladder

Detail No. 1 -Vertical transportation of bamboo

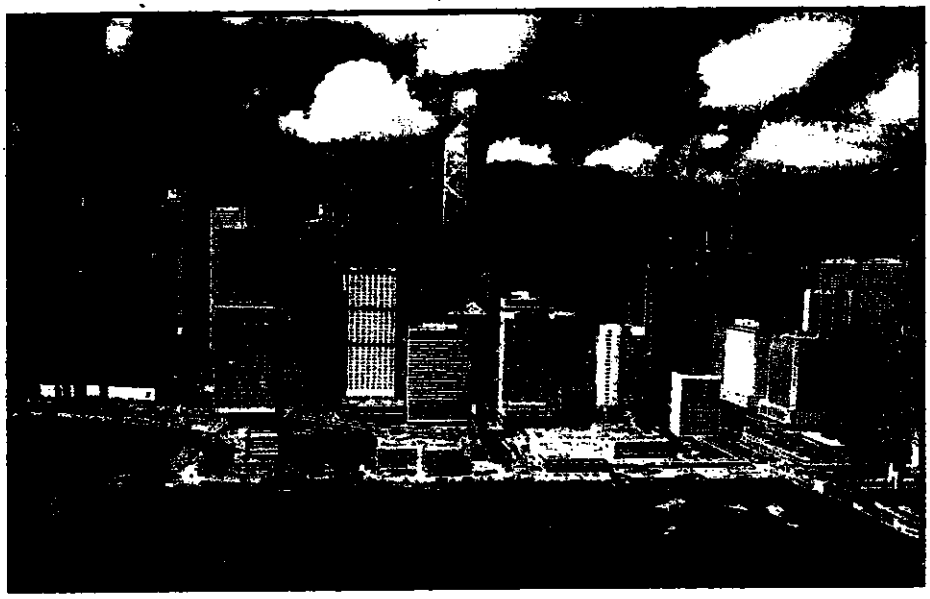
Fig. 19.6



Detail No 2- Rope ladder



CONSTRUCTION OF BAMBOO SCAFFOLDINGS FOR HIGH RISE BUILDING IN HONG KONG



Lau (1994) is right when she said that bamboo scafoldings made simple with bamboo poles lashed together, which skirt up the sides of the skyscrapers in Hong Kong, compared with the sturdy metal scaffolds used in construction in all parts of the world, looks like a flimsy lattice-works, which appear about as structurally sound as a house made of toothpicks. Neverthèles in Hong Kong where typhons are frequent, bamboos goes with the wind rather than standing firm against it like metal. In one recent storm, when a half-completed building collapsed, the bamboo scafolding encircling it remained standing. Despite their woobbly look, bamboo scaffolds seldom collapse on their own.

Most of the bamboo poles used in the construction of scaffoldings in Hong Kong belong to the specie *Bambusa tuldoides* Munro, native of Guandong province, in southern China. The following mechanical properties of this specie have been reported in PROSEA (1995): Density 950-970 kg/m^3; modulus of rupture (with node) 79-94 N/mm^2 ; modulus of rupture (without node) 84.0-115.2 N/mm^2; tensile strength (with node) 95.8-112.0 N/mm^2, without node 98.0-140.5 N/mm^2; Shear strength 50.0-59.0 N/mm^2.

The scaffolds are formed by one or two grids of bamboo poles generally 6 meters long with diameters between 7-10 cm.

Fig.19.7 *About 90% of all scaffoldings used in Hong Kong are made with bamboo. It is considered that they are "cheap (one fifth that of steel scaffolding), strong and quick".*

Fig. 19.8 (Top and bottom) *Bamboo scaffolds have been used in Hong Kong in the erection of high-rise buildings like the 78-story Central Plaza tower. Photography by K. Macgregor.*

Horizontal and upright poles are braced by criss-crossed diagonal ones. In some cases are used bamboos with wider diameters in the bottom of the scaffolding which probably belongs to other specie. It is considered that most poles have a life span of about a year.

Until 15 year ago, thin strips of bamboo were used to bind the poles (See Fig. 19.9). The strips were taken from the outer part of the culm after soaked in water until soft.

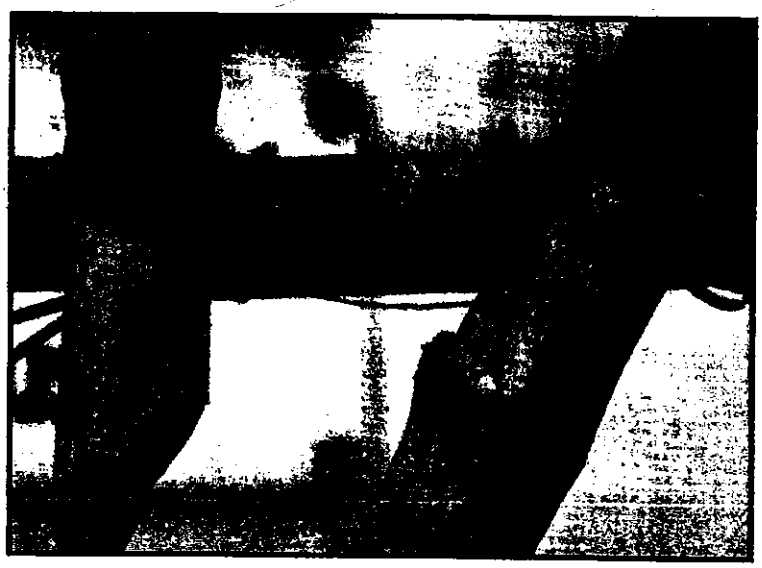
Due to the time taken in the preparation of the bamboo strips and the lack of quality control, bamboo strips were replaced by strips of polystirene (See Fig. 19.10).

Today, most scaffolds are either single-layered or double-layered. The latter type, which allows room for working platforms, is considered safer and is favored in main land China. The former prevails in Hong Kong because it is cheaper; it requires fewer poles to build and is quicker to erect. The down-side with single row structures is that, with no working platform, laborers most carry their tools in waist belts or in buckets, which they tie with ropes to the scaffolding.

Fig. 19.9 *For centuries the craft of erecting bamboo scaffolds has been passed down from generation to generation.*

Compared with metal scaffoldings bamboo has many adventages in the construction of scaffoldings. Bamboo scaffolding can be custom-built according to the shape and size of a given structure, whether it be a gothic cathedral or a Chinese temple. One of its gratest virtues is that it can be tied on to the sides of the buildings in need of upper-story work. Metal scaffolding would have to be built from the ground up, blocking pavements and clogging pedestrian traffic. The cost of a bamboo scaffolding is approximatelly one fifth that of steel scaffolding.

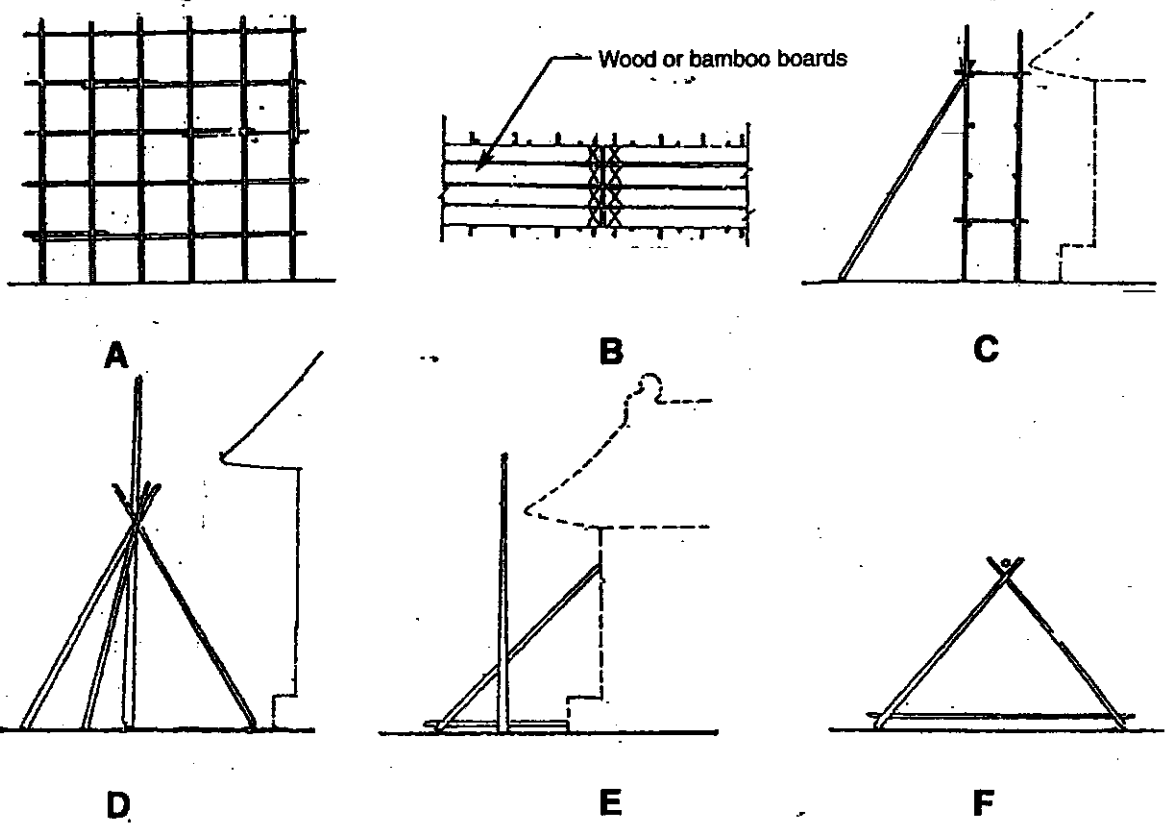
And on those rare occations when the scaffolds do fall, light bamboo poles cause far less damage than heavy metal members, which smash every thing they strike, seriouly hurting buildings, cars, and pedestrian, points out. Lau (1994). Dismantling is a similarly low tech affair. All a scaffolder has to do is cut the ties. Once that is done, the poles are ussually dropped (some times 20 stories or more) along one of the building's side into a batch on the ground. The process, though noisy, is fast and cost efficient. Lau ,(1994)



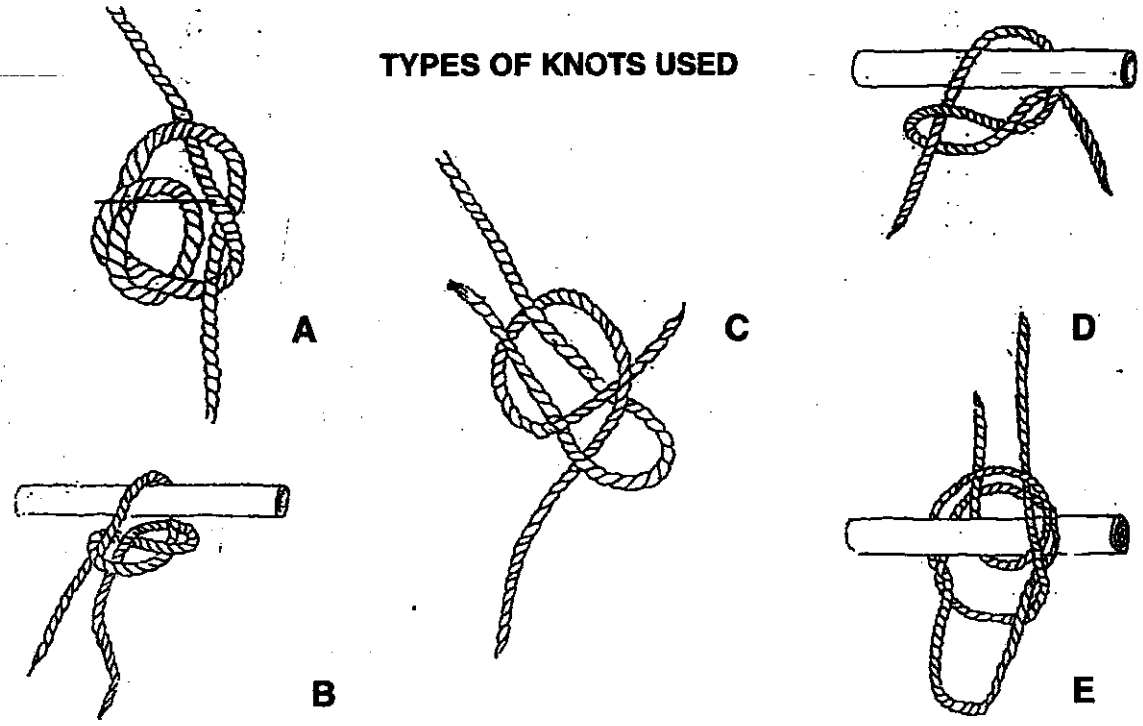
Figs. 19.10 (A and B) *The bamboo strips which were used to bind the poles (A). were replaced about15 year ago by polystirene strips (B)*

SCAFFOLDINGS FOR REPAIR OR BUILDING SMALL STRUCTURES

Fig. 19.11 **BRACING OF WOOD AND BAMBOO POSTS**

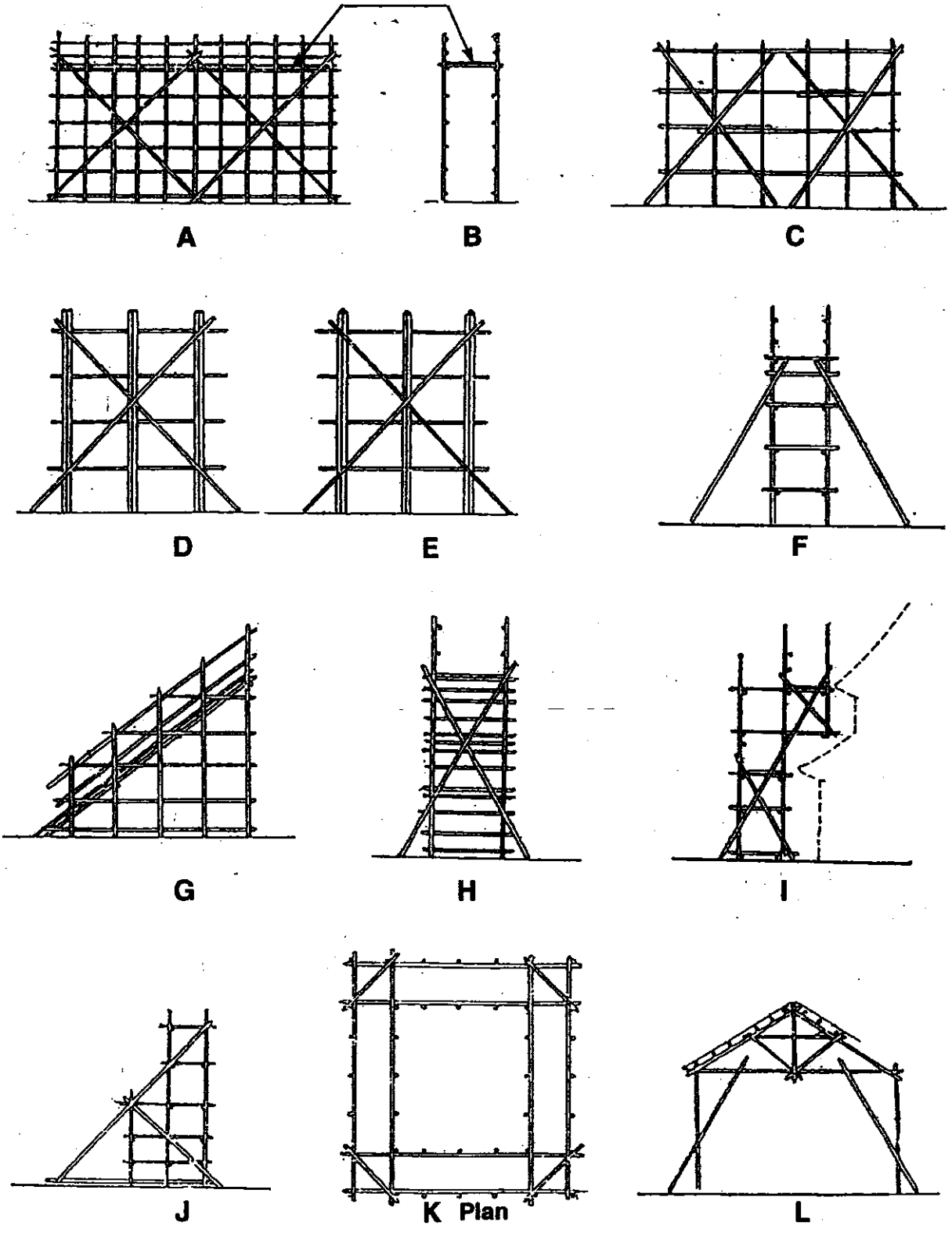


TYPES OF KNOTS USED



Source: Chsui Chingta - China.

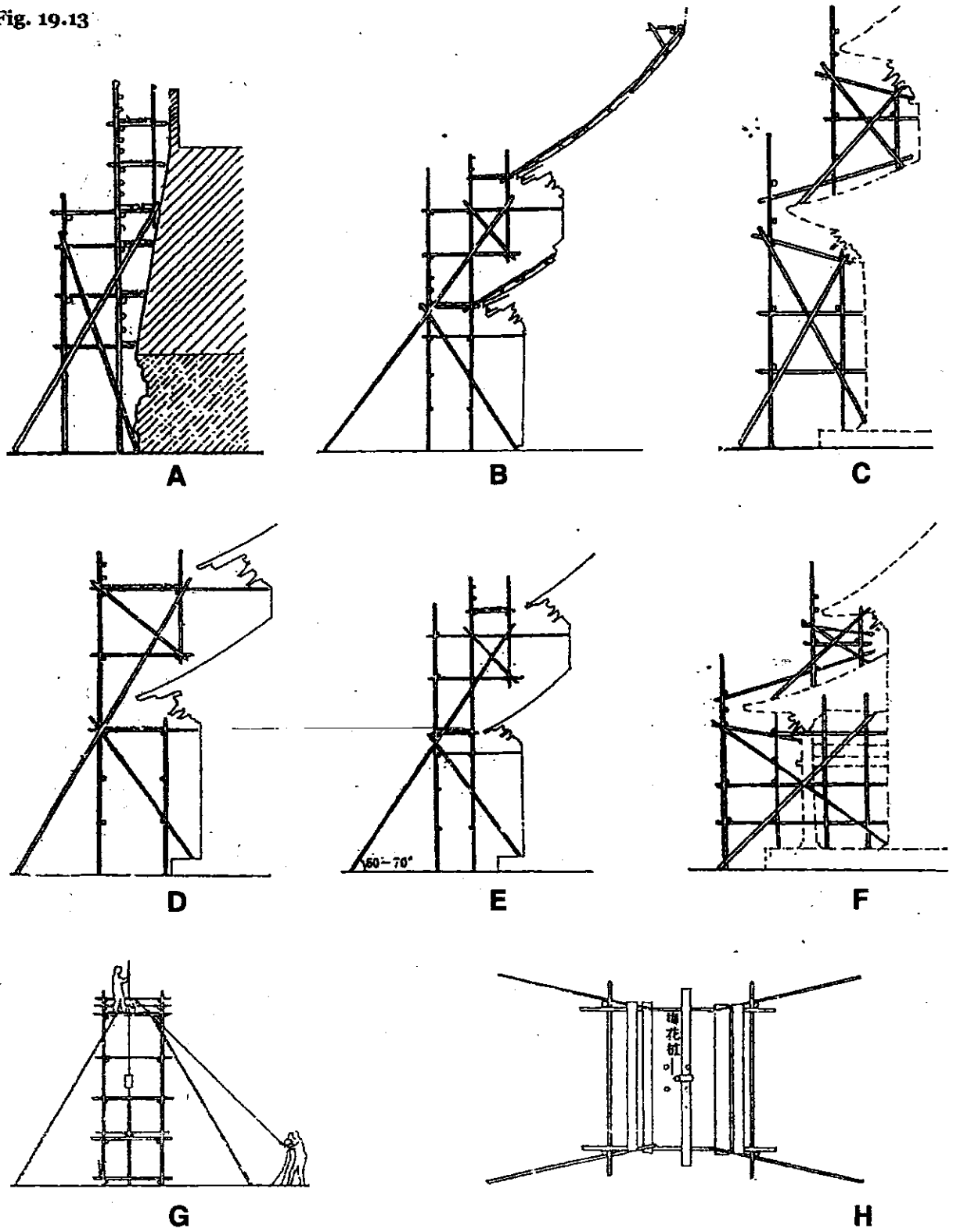
Fig. 19.12 **BRACING OF SCAFFOLDINGS IN CHINA**



Source: Chsui Chingta - China.

DIFFERENT SHAPES OF SCAFFOLDINGS FOR SMALL BUILDINGS (CHINA)

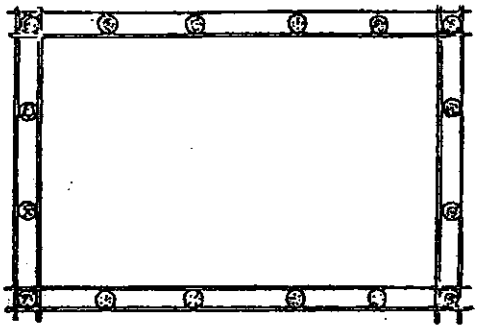
Fig. 19.13



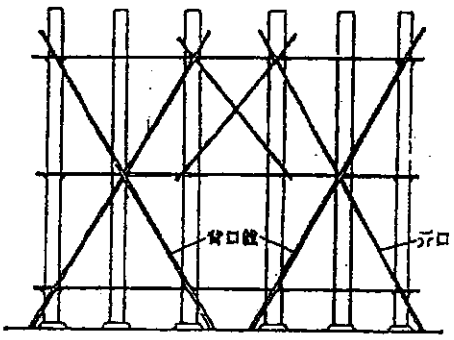
Source: Chsui Chingta - China.

SPLICING AND BRACING OF BAMBOO SCAFFOLDINGS

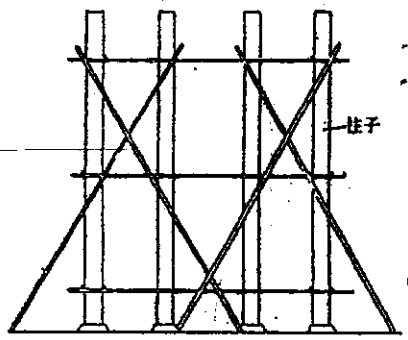
Fig. 19.14 Rectangular scaffoldings



A

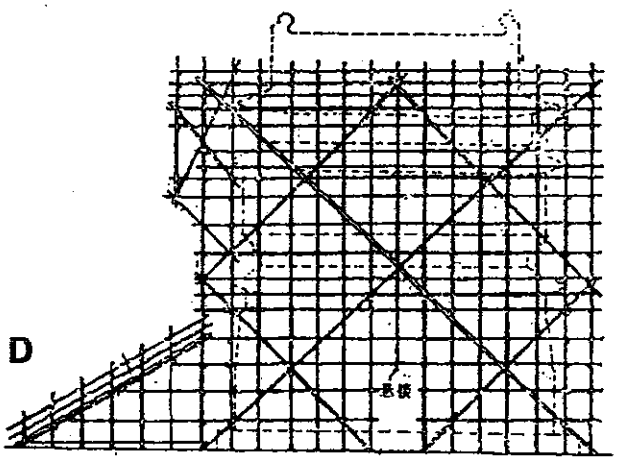


B

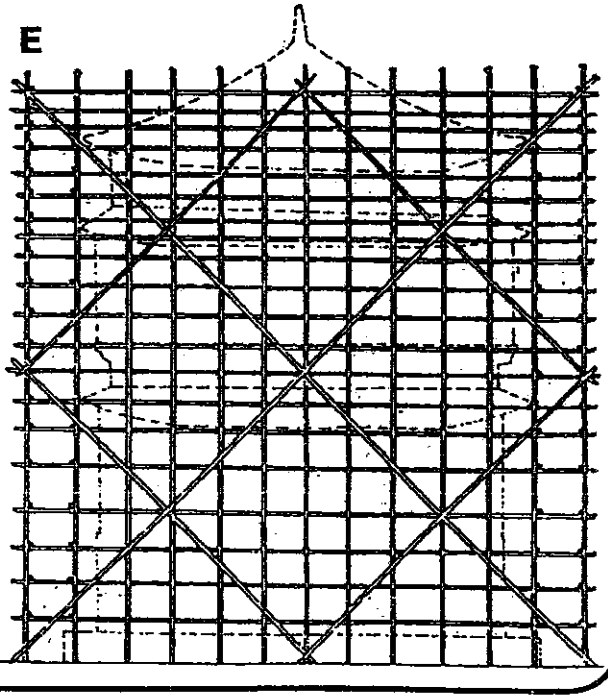


C

Columns



D



E

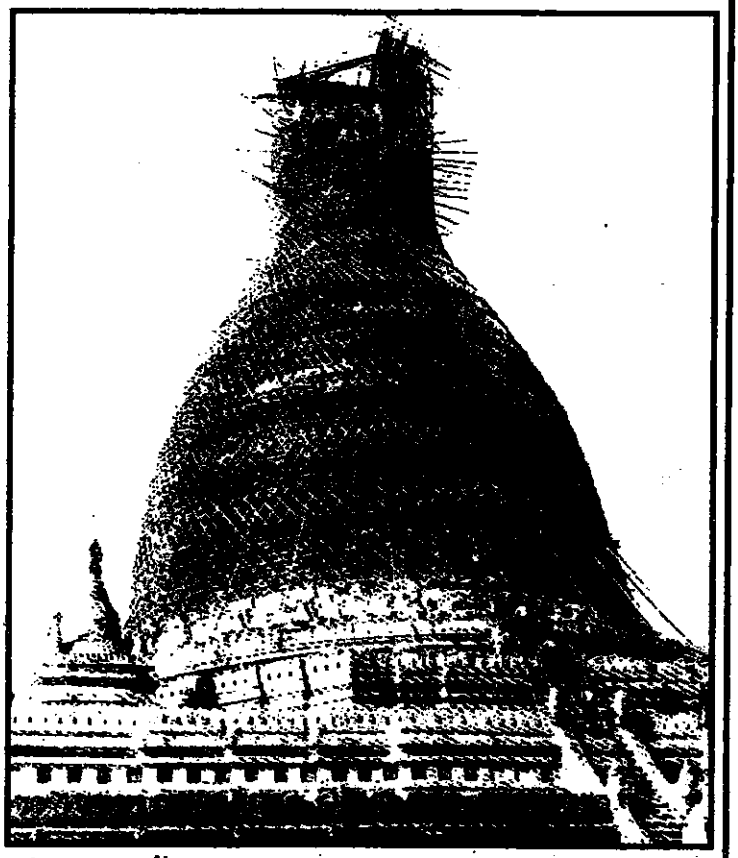
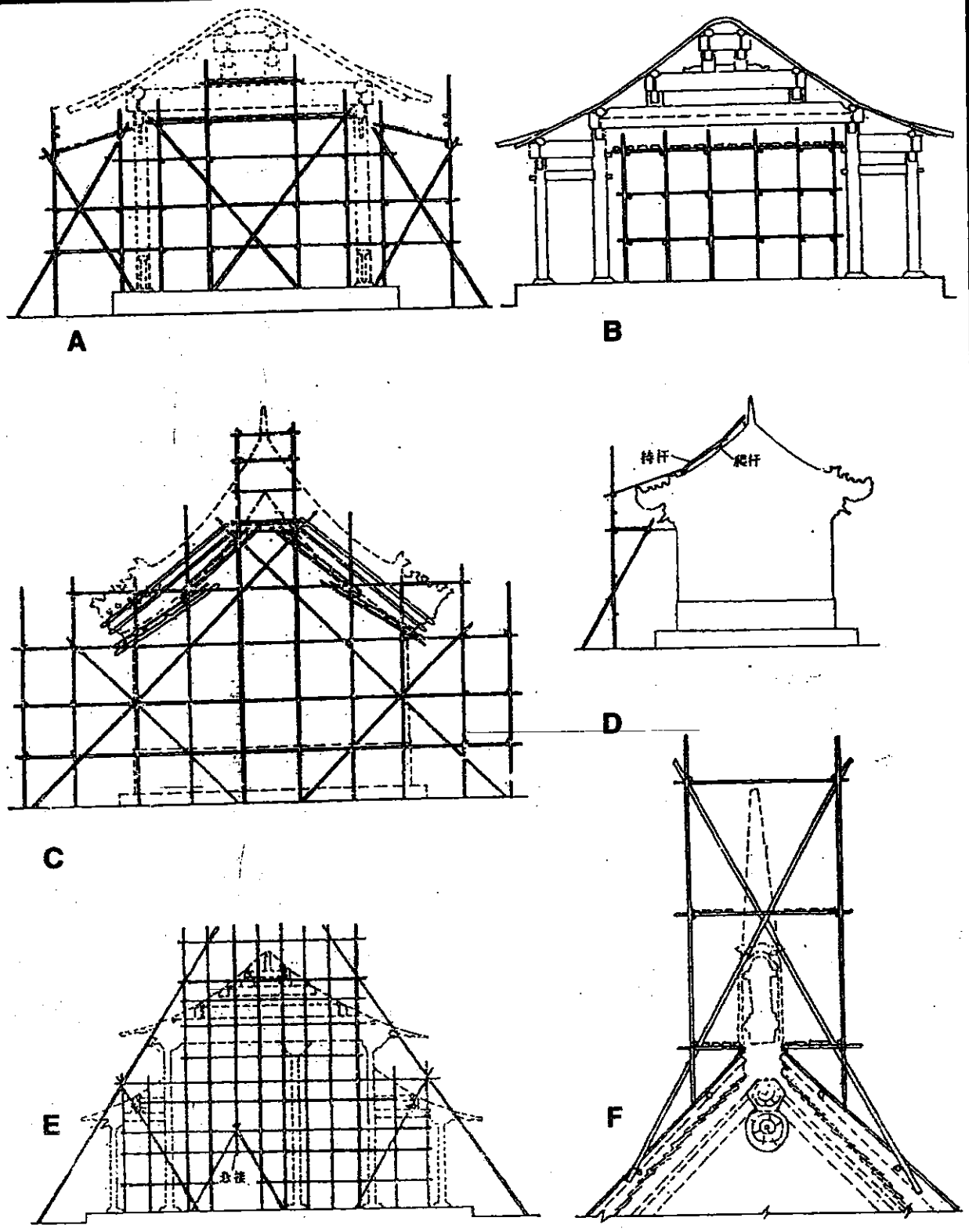


Fig. 19.14 A *Diagonal bamboo scaffoldings are used in the construction or repairing of cupoles of temples like this of the city of Pagan in Birmania.*

Source: Chsui Chingta - China.

Fig.19.15 **BRACING OF BAMBOO SCAFFOLDINGS**



Source: Chsui Chingta - China.

BAMBOO SPATIAL STRUCTURES

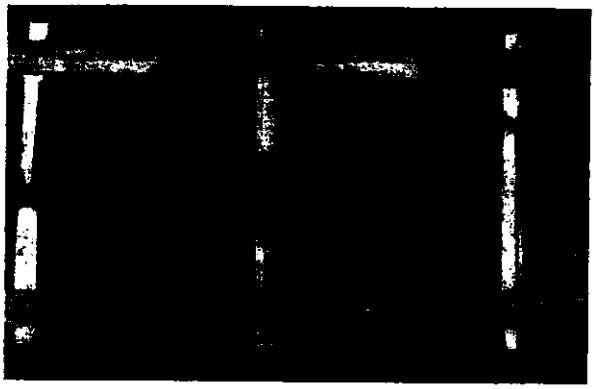
18

Fig. 20.1 TRIANGULAR FLAT BAMBOO SLAT -TRUSSES (WARREN)

The study of the use of bamboo slats in the manufacture of triangular trusses were carried out at the faculty of Engineering of the National University of Colombia as a thesis by W. Carvajal, W. Ortegon and C. Romero (1981). in which I collaborate as adviser.

As can be seen in the photographs this type of trusses offer many posibilities for the construction of very low cost roofs covered with aluminium tyles and spans not longer than 3 meters. Longer trusses present larger deflections the hight varies between 40 to 50 cm.

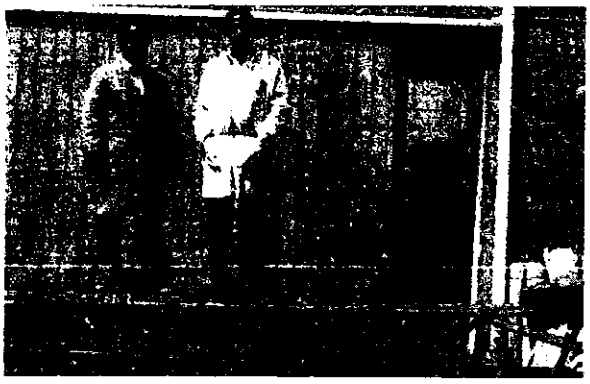
All the structural elements of the flat truss are fixed with low cost screws (Fig. A). The most recomended diagonals are those located with an angle of 60° as shown in the figures B, C and D. In this experiemntes were used the specie *Guadua angustifolia* but is recomended to make tests when are going to be used other species using a pair of trusses as shown.



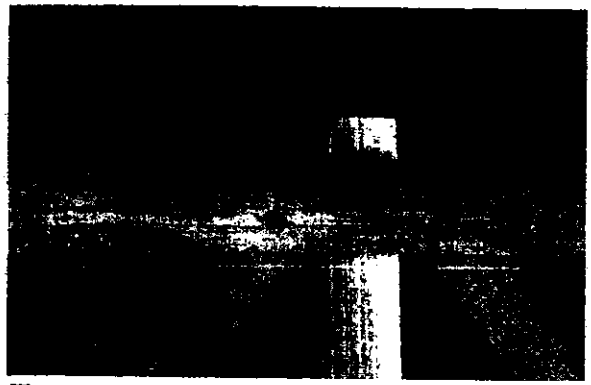
A. *The bamboo slat frame is fixed with screws.*

B. *The truss is very light and its trasportation is very easy.*

C. *Two trusses 3 meters long were experimented.*

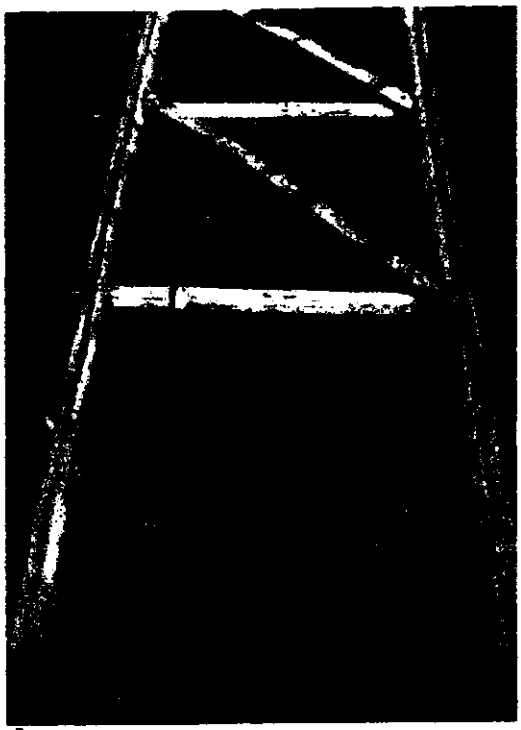


D. *The deflection is very small for 150 kg.*

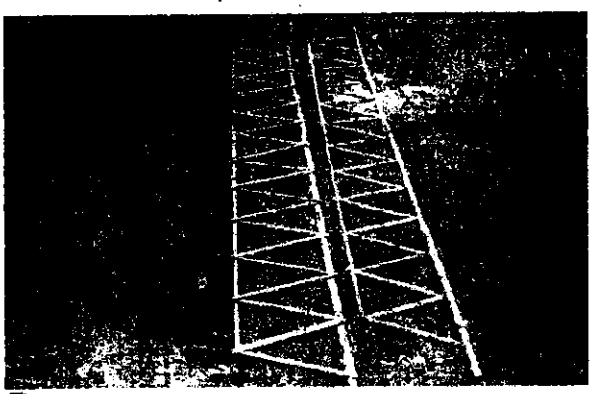


E. *The cost of the bamboo slats and the screws is very low.*

TRIDIMENSIONAL TRIANGULAR BAMBOO SLAT ROOF TRUSSES



A



B

C. *Trusses with different height.*

Fig. 20.2

This study related to the use of bamboo slats in the construction of tridimensional triangular trusses was carried out as a thesis at the Faculty of Engineering of the National University of Colombia in Bogota, by J.Carrasco, J. Junco and J. Quiroga (1982), with my collaboration. This type of truss is also very useful in the construction of low cost roof s with aluminium tyles and spands from 3 to 4 meters. It consists of two triangular bamboo trusses as can be seen in the Figs. A and B

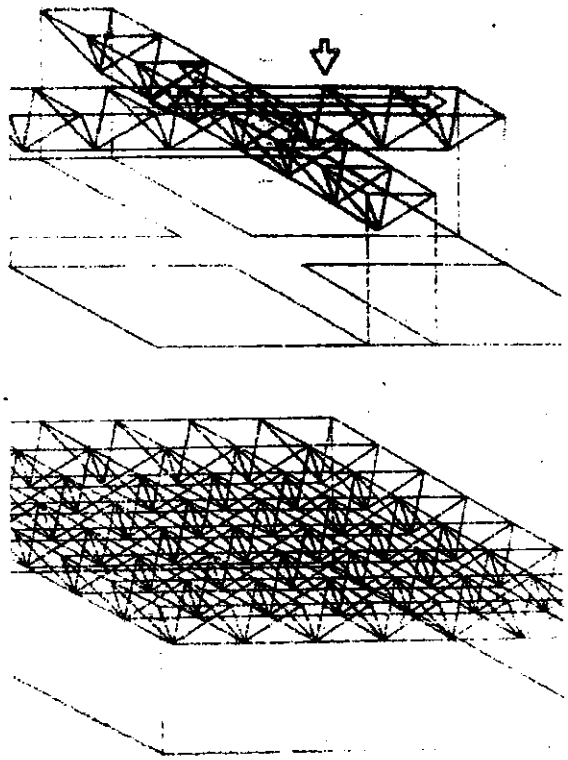
The optimum hight of the truss for lesser deformation was found to be L/8. This means tha if the span is 4 meters the hight of the truss most be 50 cm.

All the joints are fixed with screws and also with galvanized wire. The dimensions of the trusses are shown in the table No.1 (Table 20-1).

For the manufacture of these type of trusses it is recommended to use mature bamboos 3 or more years old, and for the tension member or lower cord or flange it is recomended the use of slats which are taken from the middle part of the culm.

Tridimensional bamboo triangular trusses can be used in the construction of a double layer bamboo space structure as can be seen in the drawing D.

The bamboo truss design depends on the mechanicanical characteristics of the bamboo specie and these varies according to the place where it grows and the elevation above sea level.



D. *Double layer space structure.*

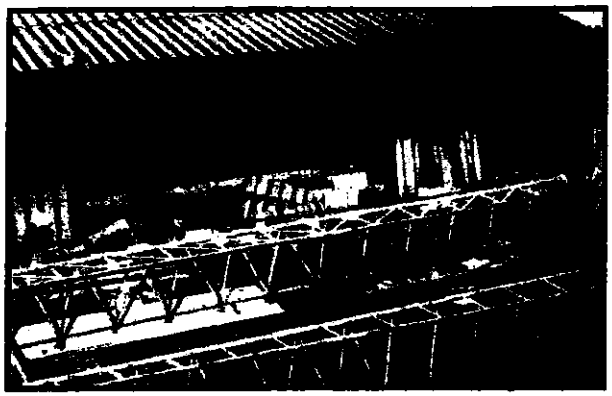
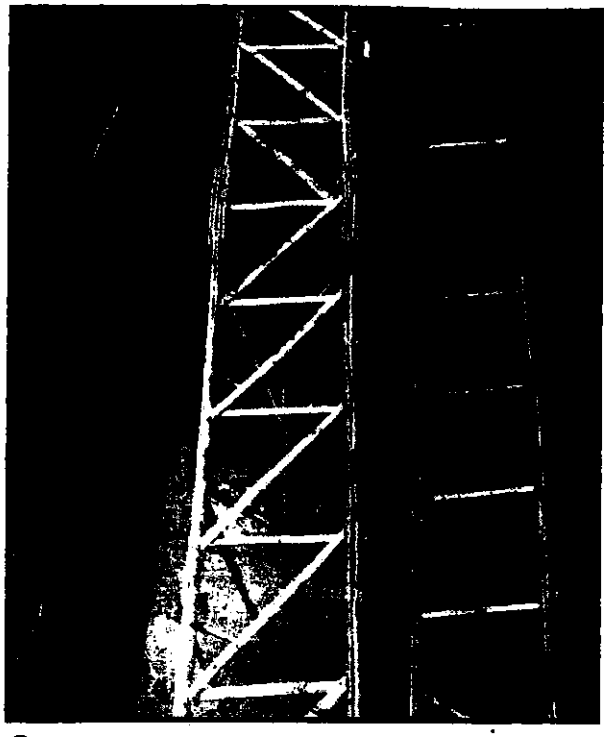


Fig. 20.3 A

B. *This truss could be used for aluminum roof tiles.*



C. *The truss construction.*

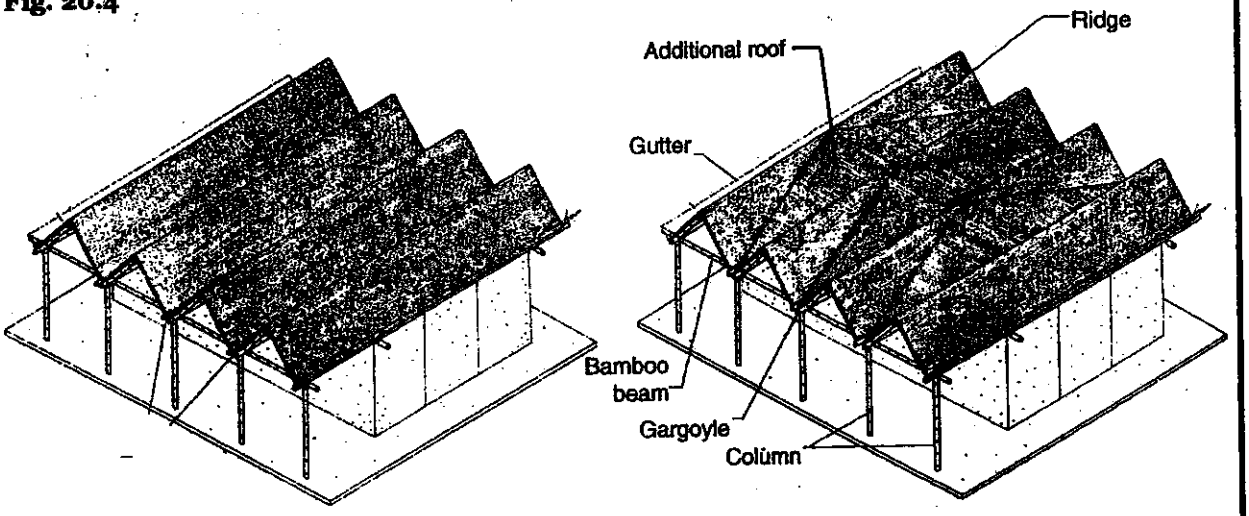
Table 20-1 **PURLINS' GEOMETRY**

Length L mm	LATERAL VIEW dimensions in mm	Separat. chords d(m.m.)	Height of each truss (mm) h= L/8	h= L/10	h= L/10
4000	L= 10 x400, h, Center line	d, h, d=350	500	400	340
5000	L = 10 x 500, h, Center line	d, h, d=420	640	500	400
6000	L = 12 x 500, h, Center line	d, h, d=450	800	600	500

TRIDIMENSIONAL ROUND BAMBOO ROOF TRUSSES

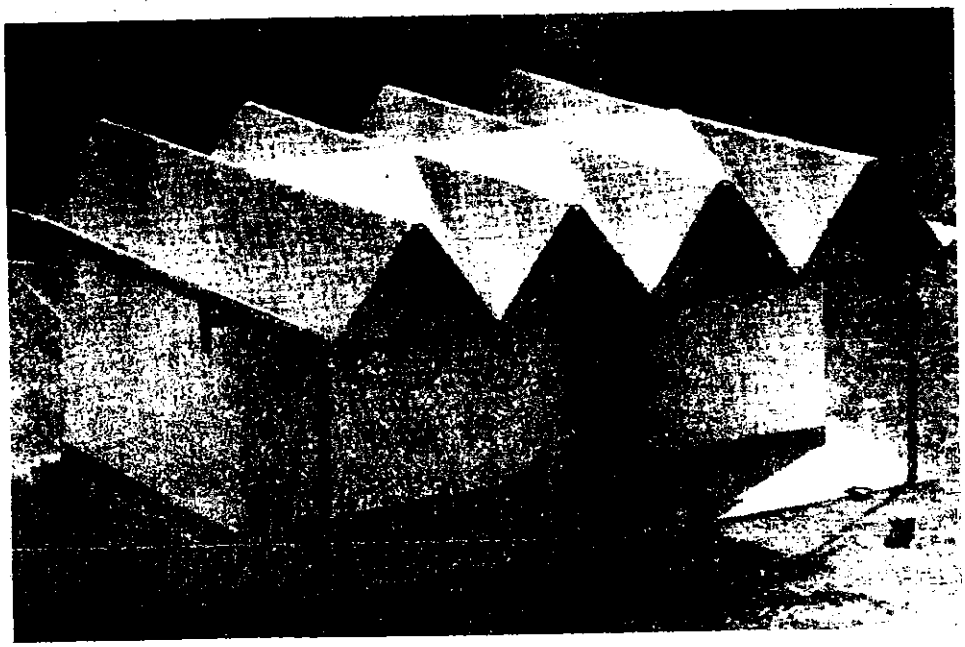
TYPES OF TRIDIMENSIONAL BAMBOO ROOFS

Fig. 20.4



A. With gutters between the trusses

B. With lateral gutters



The picture *shows the school with a roof type B.*

Fig. 20.5 **BAMBOO ROOF TRUSS CONSTRUCTION (1)**

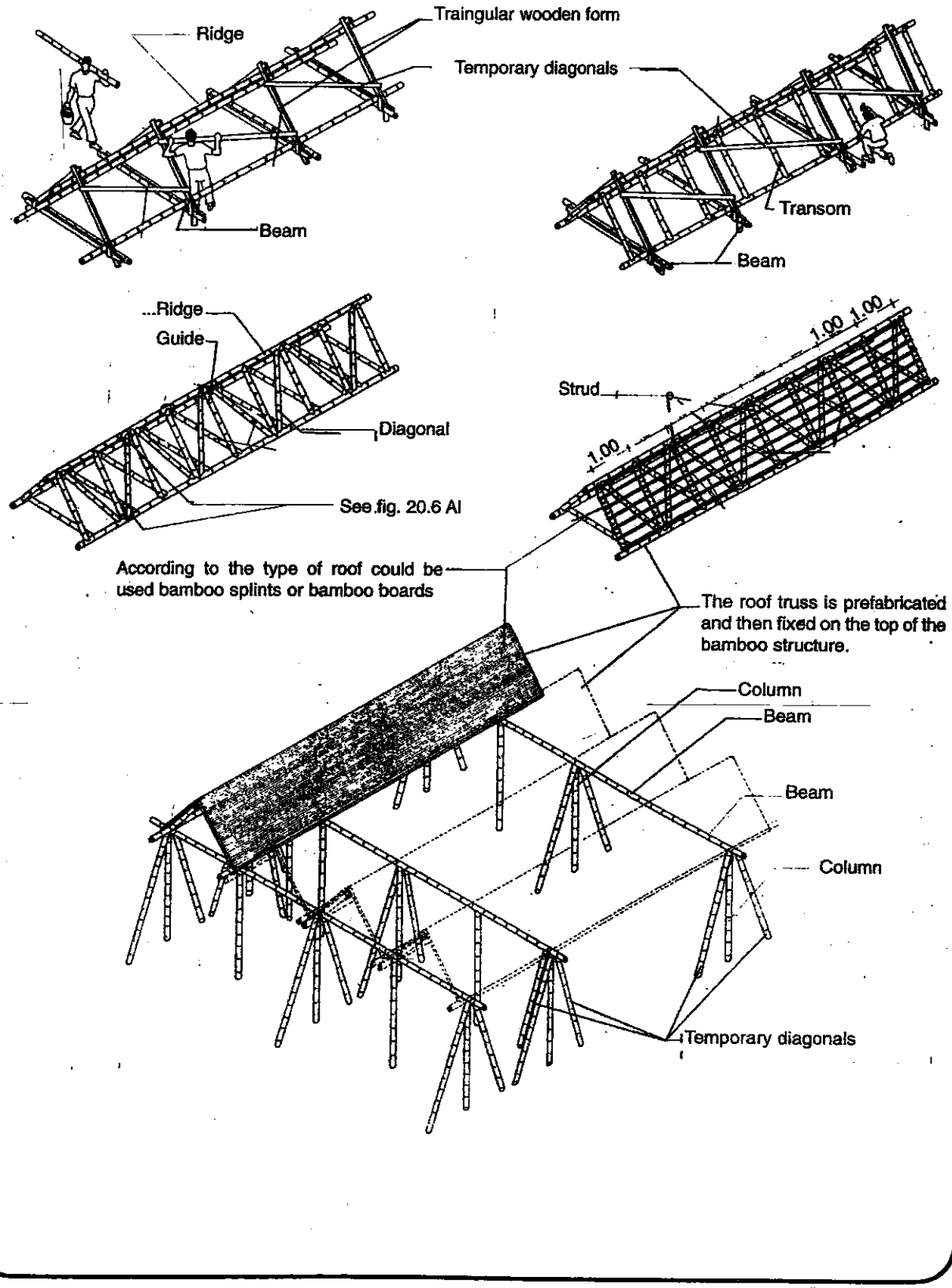


Fig. 20.6 BAMBOO ROOF TRUSS CONSTRUCTION (2)

This is one of the experimental constructions that made in the Bamboo research Center (CIBAM) with the purpose of teaching to the campesinos how to build a low cost rural schools using prefabricated tridimensional bamboo trusses 8 meters long.

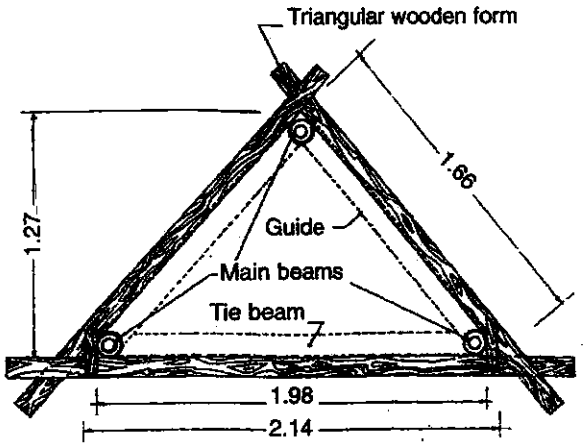
A.-B. The wooden triangles used as guides in the prefabrication of the 6 meter trusses.

C.-Testing the deflection (3 cm)

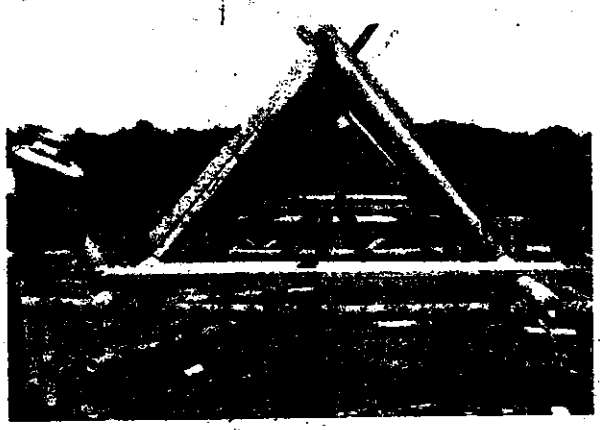
D.-The truss is so light that it can be moved by 4 people.

E.-Once covered the trusses with bamboo boards they were located in the top of the structure by a truck crane which took 20 minute mounting the four roof trusses. The trusses can be also be mounted by 8 persons. It is recomended to build first the walls and then to pumount the trusses. In this case we made the revers while I got the money for building the walls.

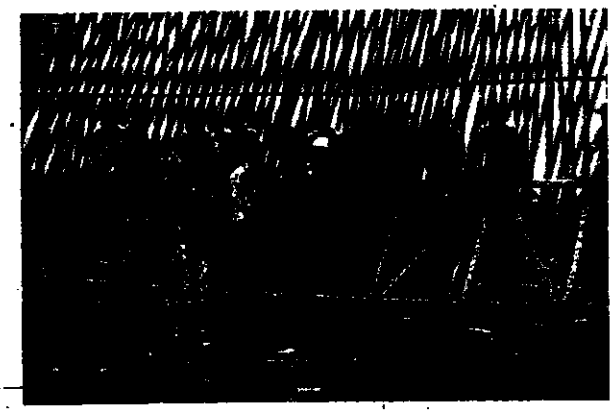
Once the trusses are fixed to the wooden beams, are plastered with a cement mortar (1:2).



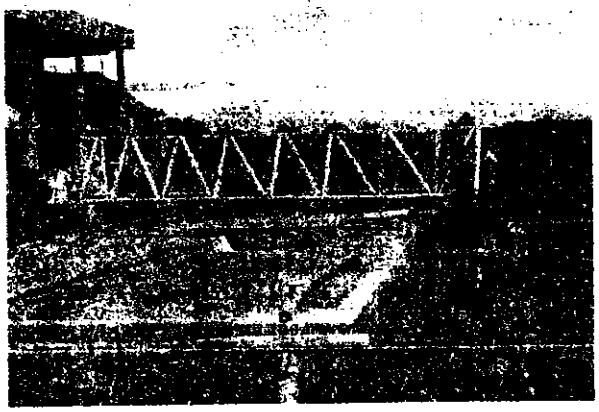
A



B *Show the wooden triangles.*



C *Testing the deflection.*



D *The truss is very ligth and could be transported by 4 workers.*

E *Seventy minutes take in to mount the 4 trusses above the bamboo structure.*

STRUCTURE MADE WITH TIED LAMINATED BAMBOO (not glued)

MOSQUE BUILT WITH TIED LAMINATED BAMBOO IN INDONESIA

Village Mosque was builted in Jakarta, Indonesia in 1971 for the international Subud World Congress. (GATE, 1979).

The most interesting feature of this mosque is that its structure was built with tied laminated bamboo not glued.

Fig. 20.7 shows the front elevation and plan of the Mosque built with a tie laminated bamboo structure (not glued).

Fig. 20.7

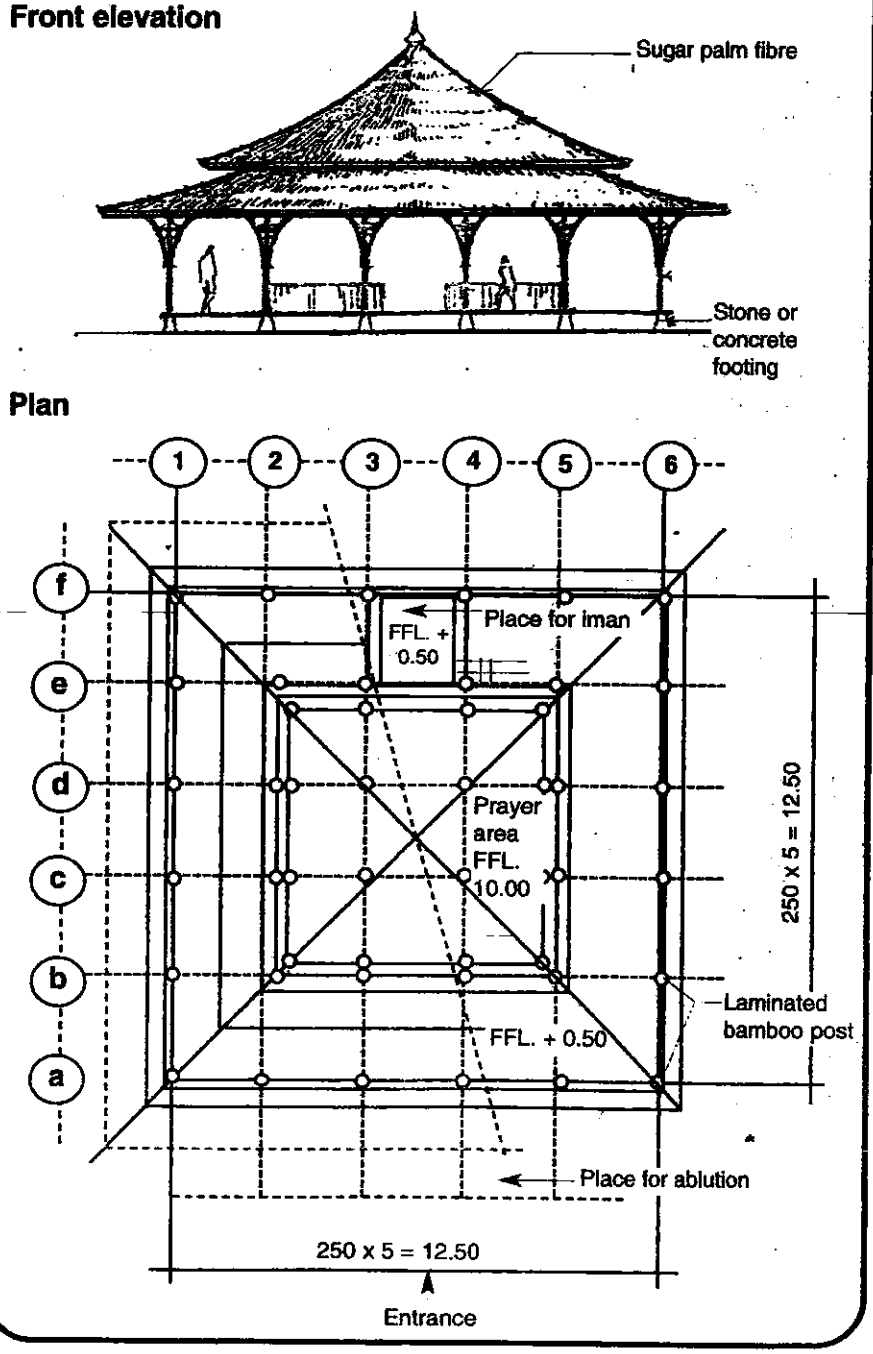


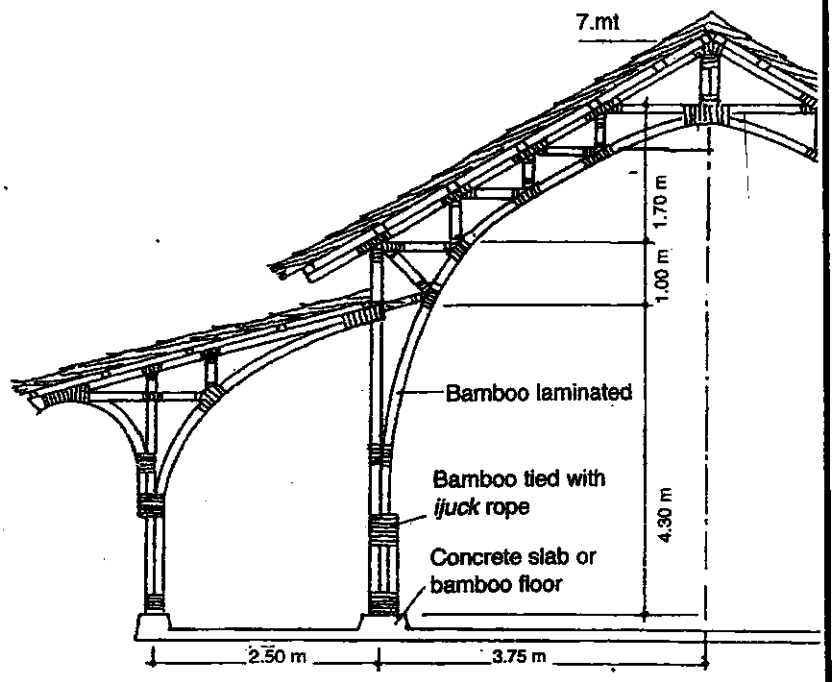
Fig. 20.8

CONSTRUCTION DETAILS

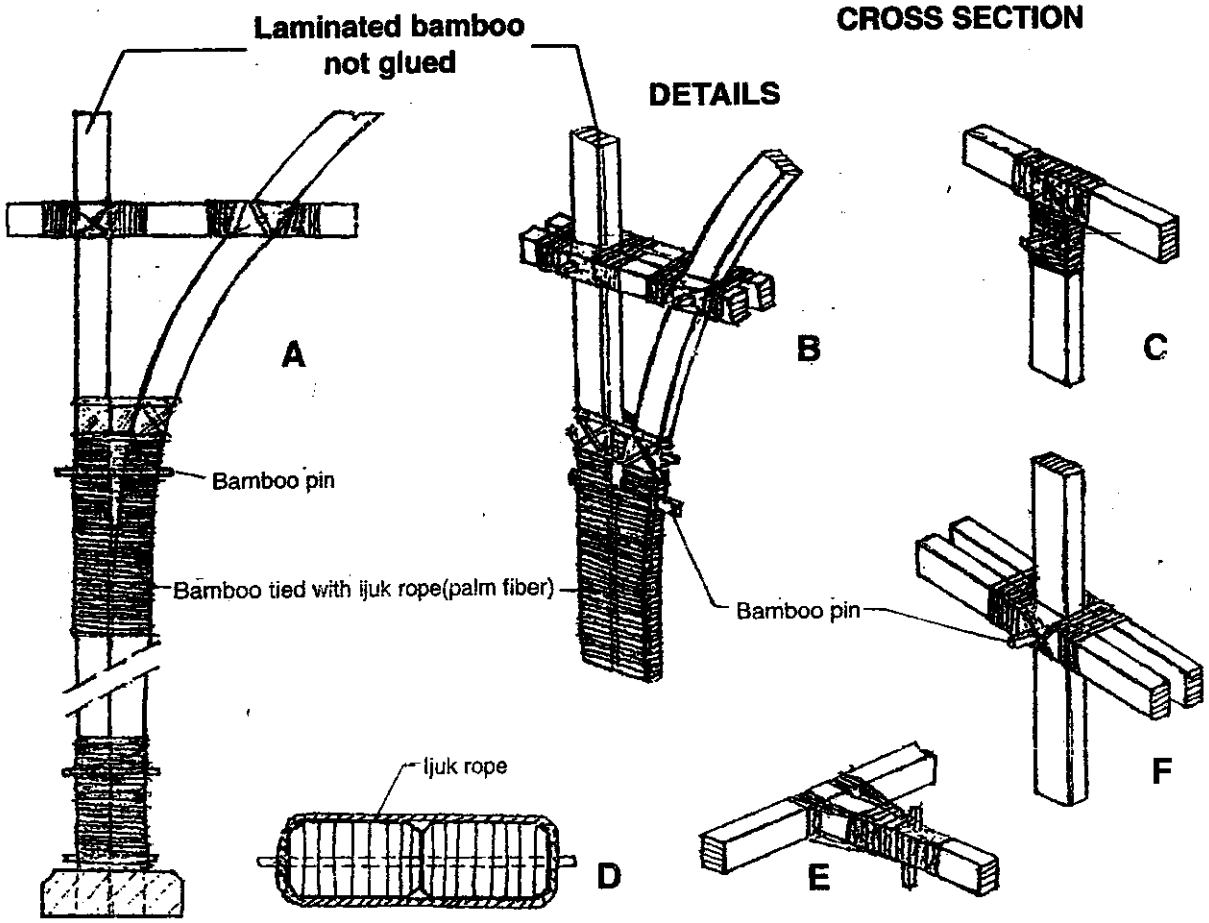
This frame structure was made with bamboo laminated splints, not glued, joined together with bamboo pins and tied with a palm fiber rope known as *ijuck* as can be seen in the details. This palm fiber could last up to 100 years.

The bamboo laminated slats used in its cosnstruction of the structure was not treated and consequently the structure was destroyed by the insects. Probably the bamboo used was less than three years old, or the the interior and soft part of the culm wall was not removed.

This structure has to be made with bamboo slats taken from the exterior part of the culm wall of bamboos three years old or older, following the exterior line of a scale drawing of the structure traced on the concrete floor or using a wooden form of the archs as shown in Fig. 20.9.



CROSS SECTION

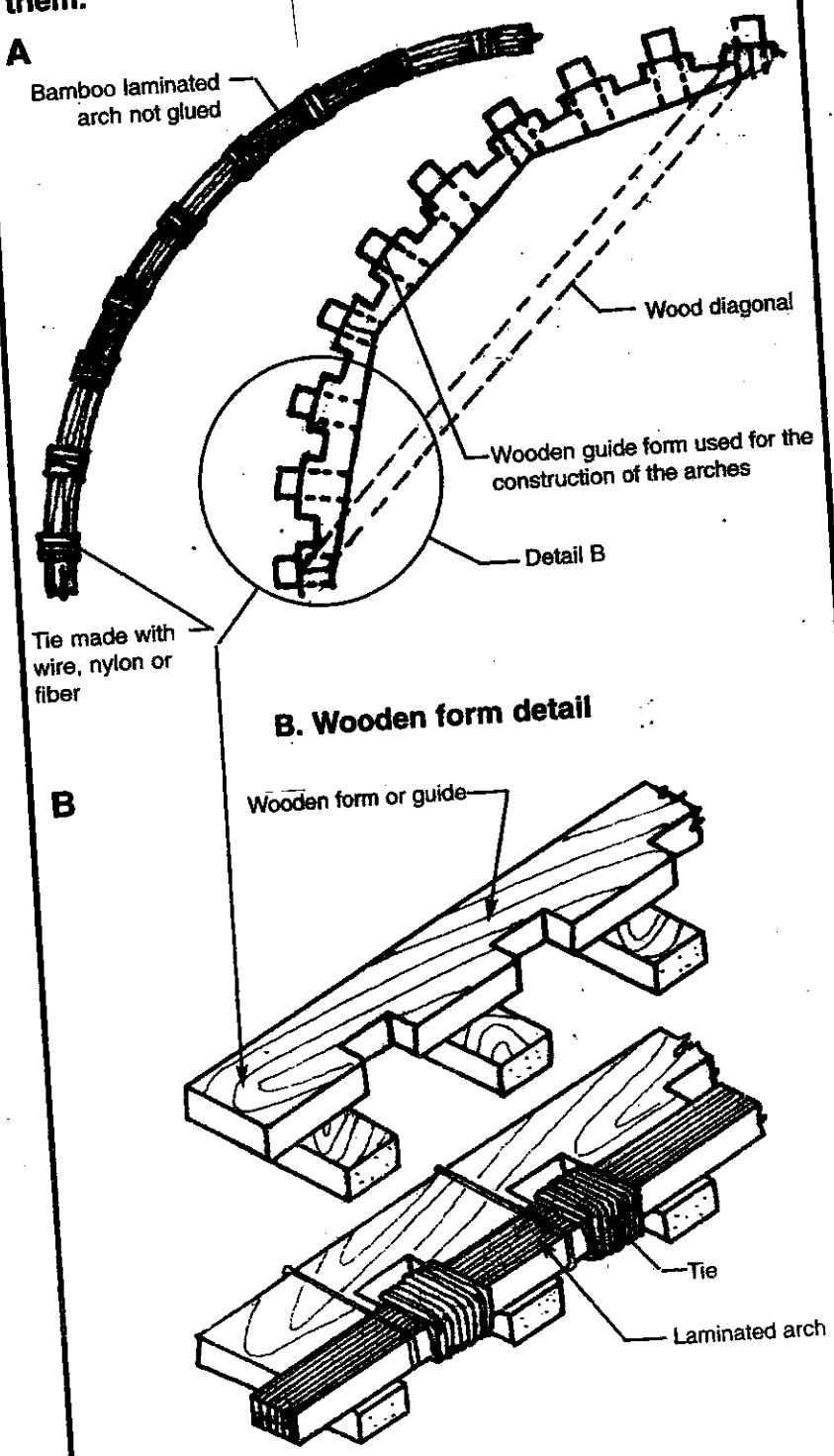


HOW TO BUILD TIED BAMBOO LAMINATED ARCHES

The most simple way for making a tied bamboo laminated arch is drawing a curve with the shape of the arch on the surface of a concrete or a wooden floor and follow this line with the bamboo laminations, but this operation requires a lot of lateral supports or persons for fixing the laminations in their position, unless the floor could be perforated for introducing some vertical bars for fixing the laminations while they are tied.

The best method is to make a wooden form like the one shown in the figures A and B. This form that I designed permit to fix all the laminations and to tie them very easily, because there is enough space below and in the back of the laminated arch for introducing the cords and the fingers as can be seen in figure B.

Fig. 20.9 A.- Type of wooden arch form or guide, that could be used for fixing the laminations before to tie them.



GLUED LAMINATED BAMBOO BEAMS AND ARCHES

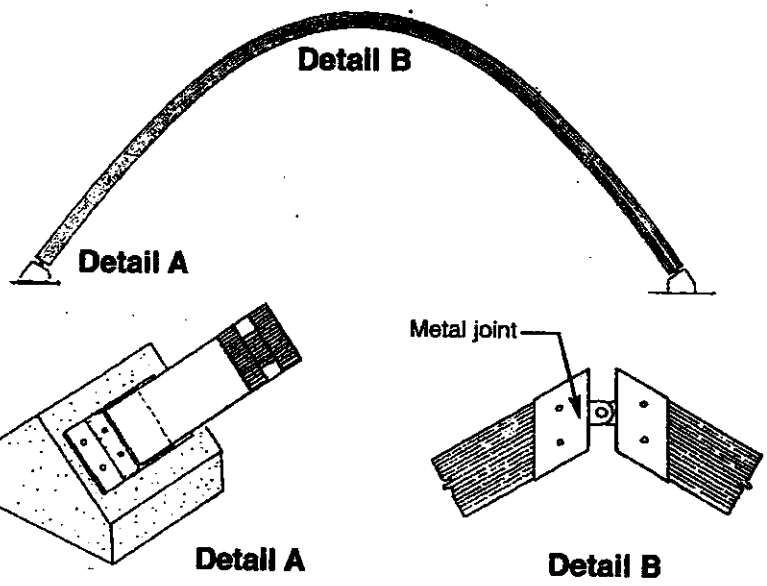
Fig. 20.10 TYPES OF GLUED LAMINATED BAMBOO ARCHES

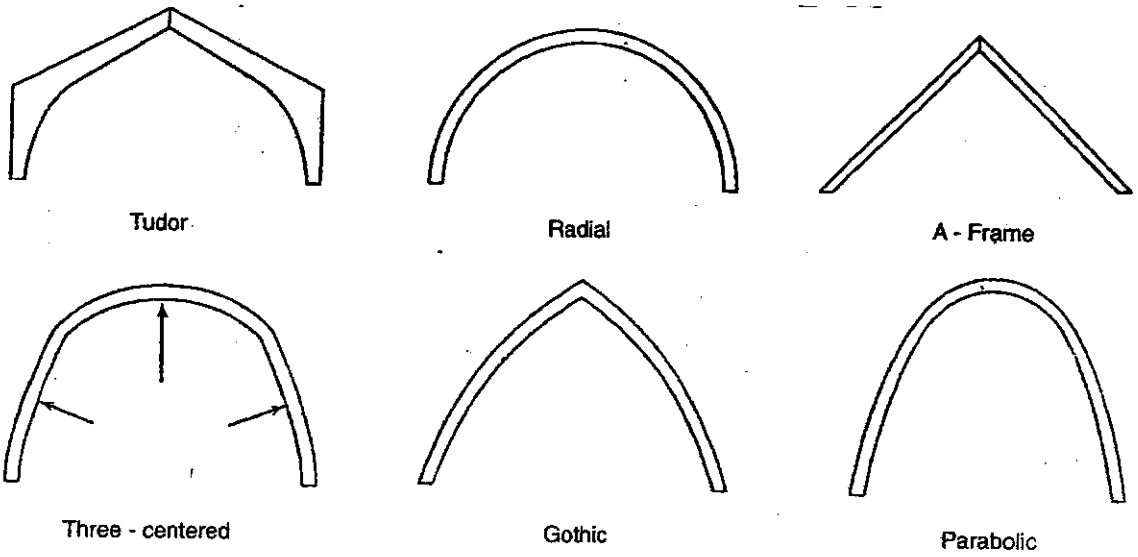
In the manufacture of bamboo glued laminated beams and arches with structural purposes, is followed the same manufacture process indicated for the manufacture of straight and curved glued laminated pieces used for furniture. But there are some differences related to the type of adehesive used and the wide of the laminas used for the manufature of beams and arches

The adhesive used in the manufacture of laminated pieces for furniture is urea formaldehyde, but in the manufacture of bamboo structural laminated pieces must be used fenol-formaldhyde, resorcinol or epoxy.

The width of the beams and arches varies according to the spand or length.

With bambo laminated can be manufactured all types of arches that are builted with wood laminated whic are shown in the drawing below.

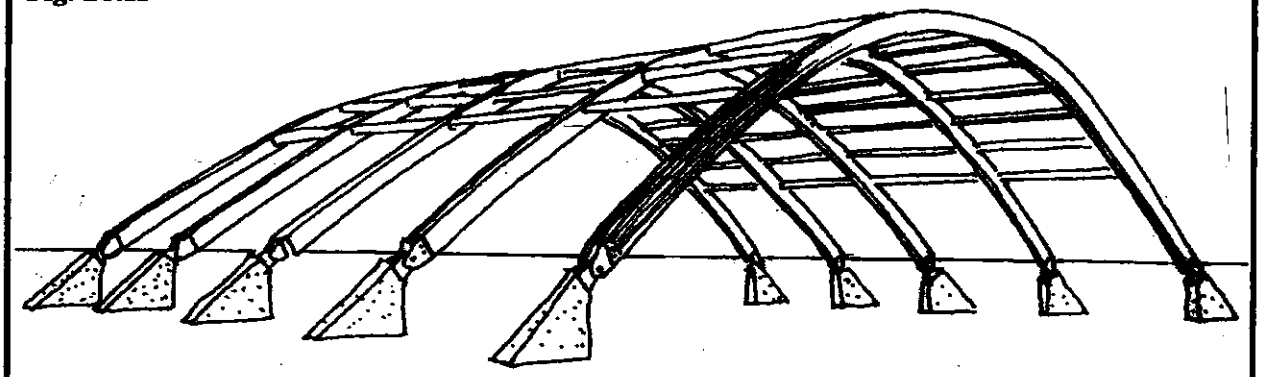




All the above arches can be manufactured with wood laminated or bamboo laminated.

GLUE-LAMINATED BAMBOO ARCHES WITH 2 OR 3 ARTICULATIONS

Fig. 20.11



A. *Glue laminated bamboo arches with two articulations.*

In the manufacture of wood laminated beams there is not a problem with the width of the beams, but in the case of bamboo the maximum width depends on the diameter of the culms. For example if the diameter of the culms is about 10 cm, the maximum width of the laminations that we can get is about 2.5 cm and with a bigger diameter this dimension will increase. We can not make a laminated beam or an arch 2.5 cm wide because of the buckling, but this problem can be solved gluing several arches (2.5 cm wide) in order to increase its width to 5 cm- 7.5 cm or 10 cm or introducing between parallel arches separators or spa-cers, as shown in the Figure 20.10 (detail A). Other solution which takes more time is to make square bamboo culms in order to get bamboo laminations up to 10 cm wide or more depending on the circunference of the culm as shown in Fig. C.

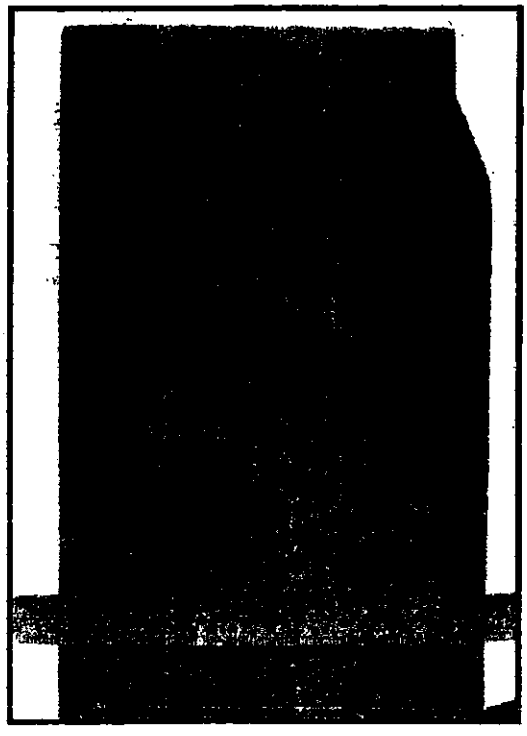


Fig. B. *There is no problem with the hight of the bamboo laminated beam because it could be increased. The problem of the width can be solved as explained above.*

Fig. C. *The four sides of the square bamboo can be used in the manufacture of glue laminated bamboo structures which require laminas wider than 3 cms.*