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3) DEVELOPMENT OF TIMBER ENGINEERING INDUSTRIES.

DP/KEN/75/027.

KENYA,

Technical report: Low-cost modular prefabricated wooden bridges

Prepared for the Government of Kenya by the
United Nations Development Organization,
executing agency for the United Nations Development Programme

000030

Based on the work of James E. Collins, expert in timber structures engineering

31 Aug.79

United Nations Industrial Development Organization
Vienna

id.78-7335

Explanatory notes

References to tons (t) are to metric tons.

Besides the common abbreviations and symbols, the following have been used in this report:

AASHO	American Association of State Highway Officials
BS	British Standard
EMC	equilibrium moisture content
kN	kilonewton

Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

ABSTRACT

In response to a request by the Government of Kenya to the United Nations Development Programme (UNDP) and the United Nations Industrial Development Organization (UNIDO), the services of a timber structures engineer were provided for the period 30 January 1975 to 15 October 1976 and from 3 January to 30 April 1977, and those of an associate expert in timber engineering from 6 October 1975 to 5 October 1978. The purpose of the missions was to assist and train employees of the Kenya Forestry Department in design and testing programmes for low-cost modular prefabricated wooden bridges and other timber-engineered products.

The present report is based on a manual on design, production and erection of timber bridges which was used by the team of experts during their work in Kenya. The approach to bridge building as described in the report has a number of objectives among which are the following:

(a) The utilization of the country's natural resources instead of relying on imported building materials;

(b) The provision for employment of unskilled local labour in developing areas, leading to a reduction in the outlay of foreign currency;

(c) The introduction of bridges which can be produced at low cost and with a minimum need for graduate engineers and site technicians;

(d) The provision of a simple solution in many instances where it is necessary to open up new areas of the country for development of its natural resources, these low-cost bridges being commensurate with the quality of the laterite roads for which they are built.

The low-cost modular prefabricated wooden bridges have the following technical characteristics:

(a) They are made up of triangular truss elements, 3 m long and about 1.5 m high;

(b) The maximum clear span is 30 m and the maximum designed live load is 40 tons;

(c) Elements are joined at two ends by a male and female metal plug, which is welded on to the metal gusset plates at each end. These are riveted to the wooden frames of the elements;

(d) The timber used has cross sections of 50 mm x 150 mm, 50 mm x 200 mm and 50 mm x 250 mm respectively. These chors are nail laminated to make up 100 mm thicknesses where applicable. Nail laminations allow for visual quality control with respect to both spacing of nails and any bending in driving them in;

(e) The roadway is made up of planking over the top of the composite trusses;

(f) A minimum of two and a maximum of eight composite trusses made up of 3 m elements are used, depending on loading, span and characteristics and grade of the timber species used. These elements are braced;

(g) The abutments are either hollow core cement blocks, concrete or logs anchored in the embankment using embedded logs and cables;

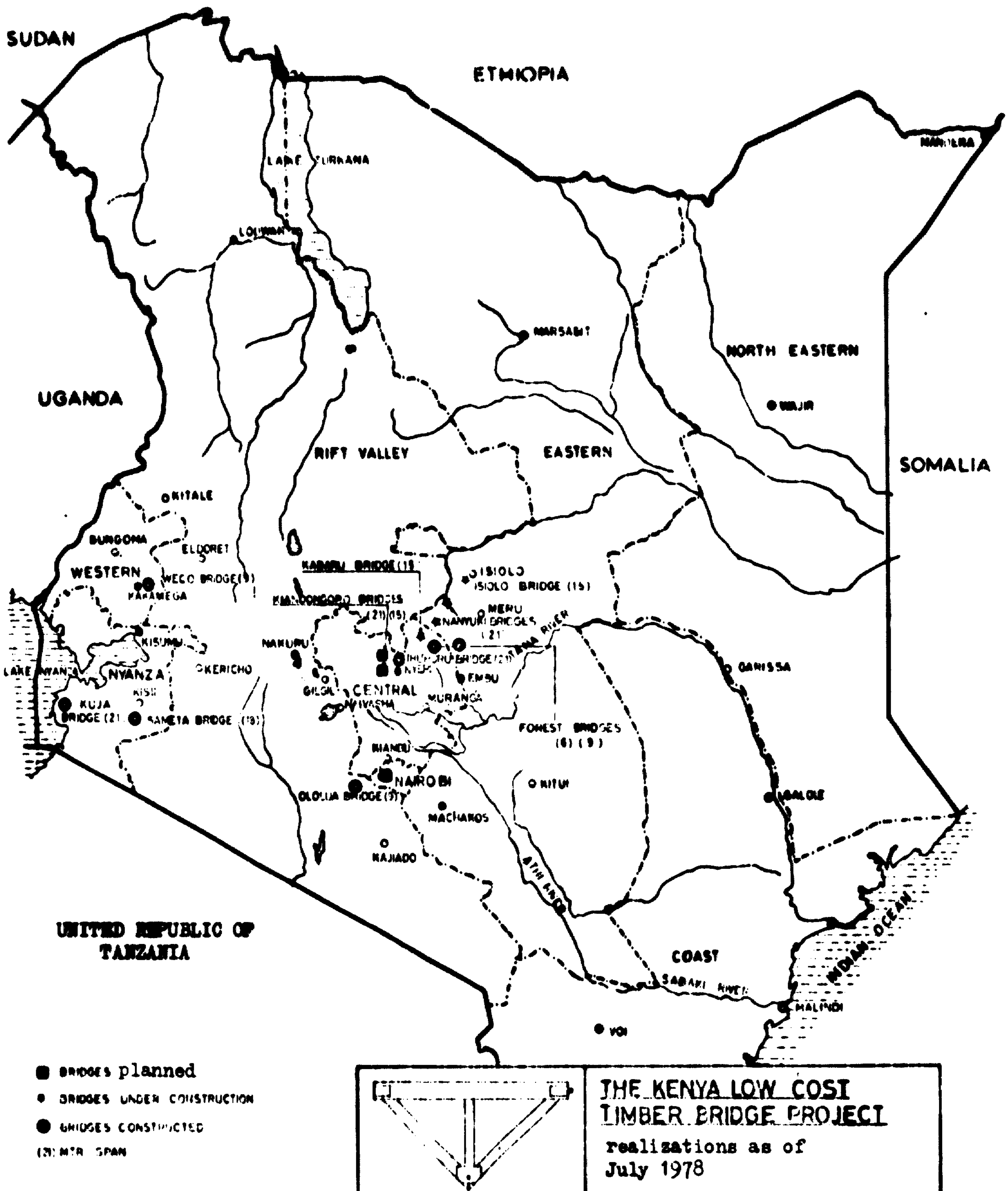
(h) The launching of the bridge is done using a pair of tripods, pulleys and a set of cables, one of which is the catenary holding the elements and the other is the cable pulling the assembled elements over the chasm.

CONTENTS

Annexes

Tables

Figures **Page**



The boundaries shown on
this map do not imply
official endorsement or acceptance by the United Nations.

INTRODUCTION

In connection with the low-cost type bridge which had been devised in 1973 by James E. Collins, who was then working at the Kenya Forestry Department, government officials quickly recognized that the design could be used in many areas of the country and could also be applied in other developing countries.

In 1974, because of its extreme interest in this seemingly flexible approach to bridge building, as well as the associated cost savings and substantial reduction in foreign exchange requirements in pursuing necessary expansion and upgrading of the road transport system, the Government of Kenya requested assistance from the United Nations Development Programme (UNDP) and the United Nations Industrial Development Organization (UNIDO) for the completion of the design and testing programmes, as well as for transforming the fabrication and erection of the bridges into a fully commercial venture. The services of James E. Collins were provided by UNIDO in the capacity of expert in timber structures engineering for the period from 30 January 1975 to 15 October 1976, and from 3 January to 30 April 1977, while the services of Svend K. Petersen, in the capacity of associate expert in timber engineering, were also provided over the period of 6 October 1975 to 5 October 1978. Both of these experts worked alongside their counterparts in the Department of Forestry, Ministry of Natural Resources, in the development of these bridges and other timber-engineered products.

While other departments of the Government, such as Agriculture and Ministry of Works, have been interested in making use of the prefabricated low-cost bridge, the main benefactor has been the Forestry Department, which continues to favour its use. The map shows the development of this system of bridge construction throughout Kenya: as of July 1978 a total of seven bridges had been completed, four were under construction and two were in the planning stage. Since the introduction of the system in Kenya, similar assistance has been provided to other developing countries through UNDP- or UNIDO-financed projects.

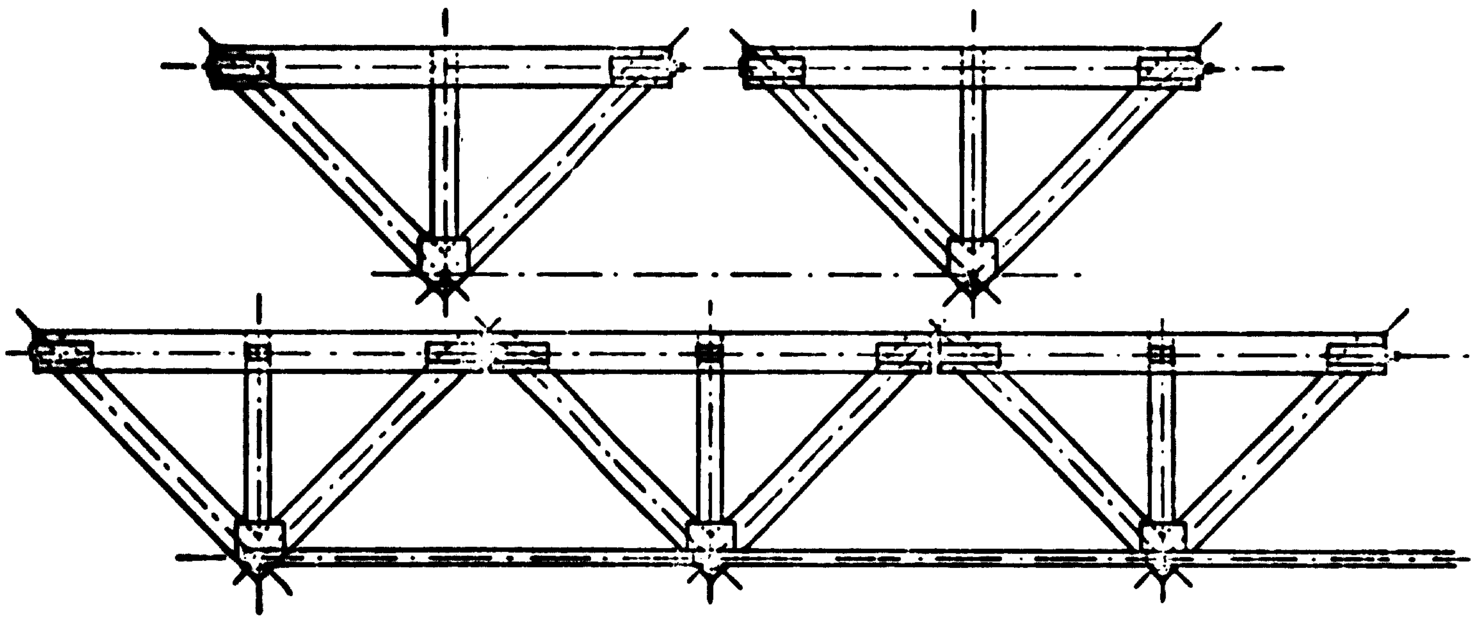
This technical report is based on a manual on design, production and erection of timber bridges which was used by the team of experts during their work in Kenya.

It describes bridges with spans up to 30 m. Designs are given for a number of load specifications including American (AASHO) and British (BS) loadings.

Any timber may be used given reasonable seasoning, strength and working properties and designs for a number of species may be obtained from the tables.

The basic element or module of construction is a timber panel of 3 m length. A number of these are joined with light steel chords to form a truss, the full length of which is a multiple of 3 m. Two or more trusses are used to make a bridge.

Figure 1. Design with bridge deck placed across the top of the trusses



Fabrication and erection can be carried out with a minimum of skilled labour and the heaviest component can be lifted by four or six men, depending on timber species.

Chapter I, dealing with the design of the bridges, is intended for persons with an engineering background. However, the design method is simple and, with some training, persons without formal qualifications should be able to select an appropriate design.

Chapters II and III on procurement of materials, assembly and erection, are intended for trained technicians. Close supervision is important and emphasis is placed on the use of jigs and templates to achieve the required accuracy. In particular, weldings must be of good quality to ensure the working loads indicated in the design tables.

The proof test described in annex I serves to varify the stress grade for given timber. Annex II contains timber grading rules and annex III is a list of stress grades for most of the commonly utilised timber species. The photographs shown in annex IV illustrate the site work.

I. DESIGN

A. Basic dimensions and bracing elements

It is assumed in the design of the bridges described in this report that each truss carries an equal share of any load. However, this is only true for single-carriageway bridges. Bridges with more widely-spaced trusses or having wider carriageways will require special consideration.

Camber is built into the bridge so that deflection will not prove a significant factor in design provided the indicated span limits are observed.

Figure 2. Bridge arrangements

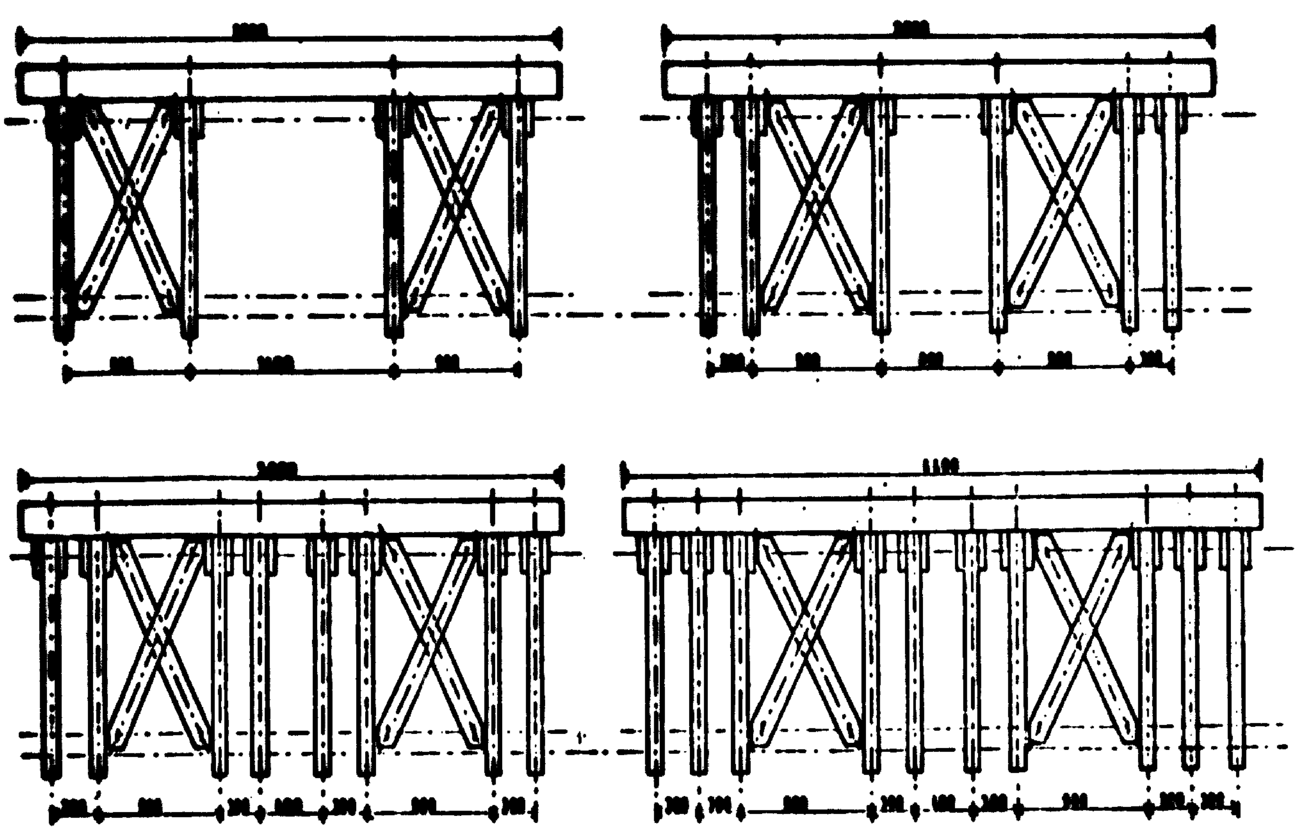


Figure 3. Panel

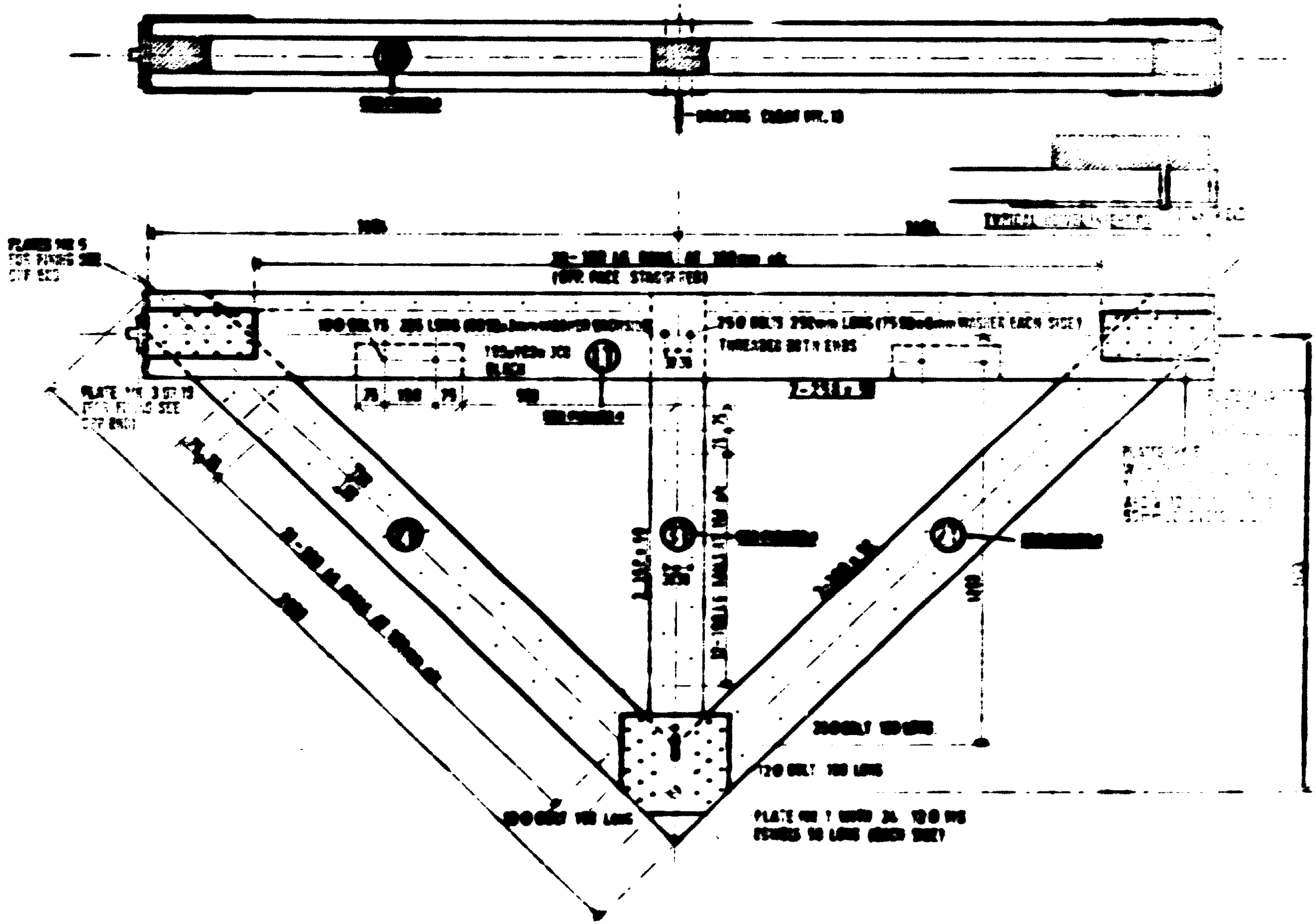


Figure 4. Timber panel components

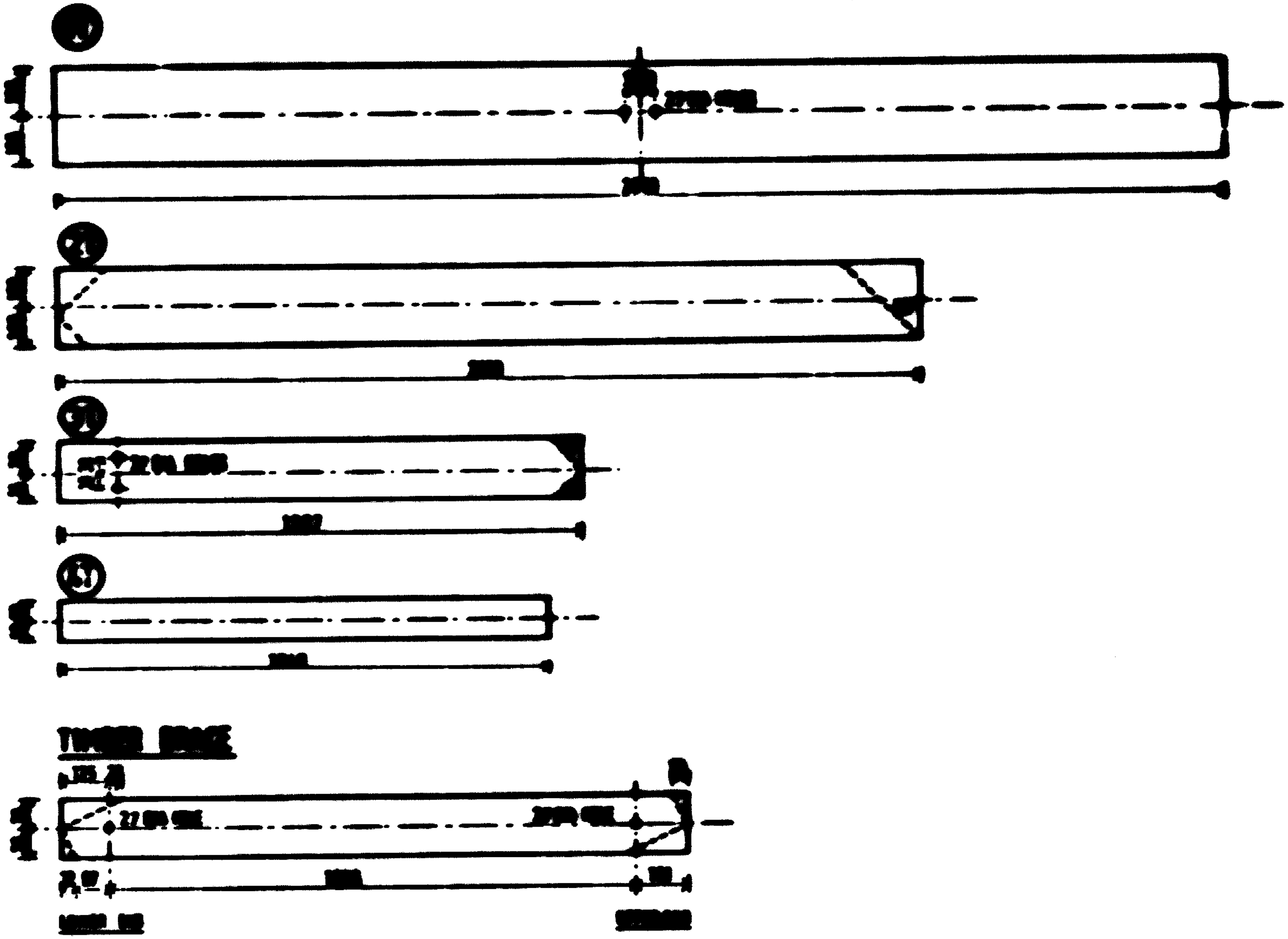
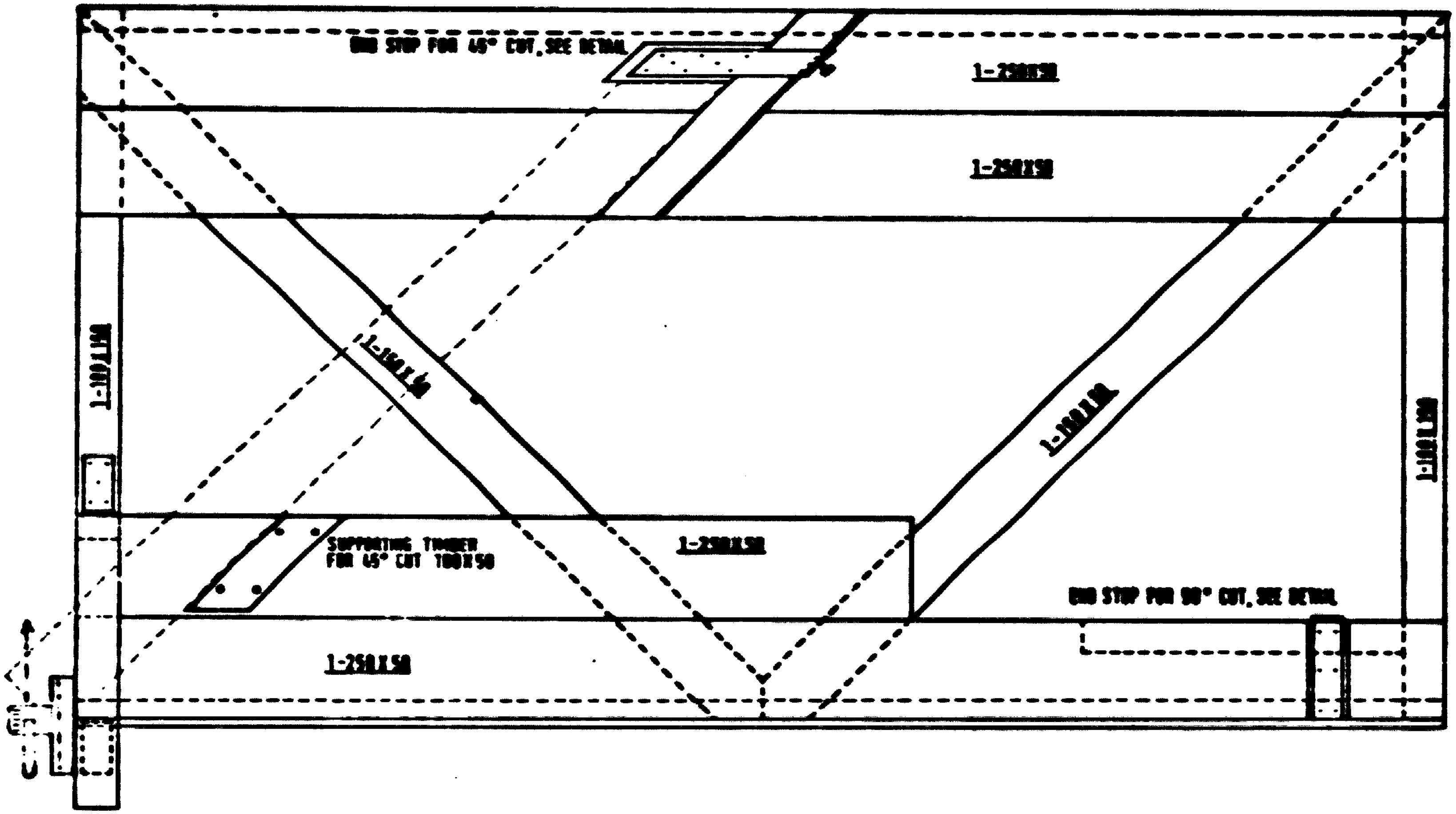


Figure 5. Component sawing jig



Basic components

Modular panel

Modular panels are joined with pairs of chords to form a truss (see figure 6). They consist of 50 mm (2") sawn timber members connected with steel plates and dowels. At one end of the top chord there is a pin projecting in the direction of the span which locates in the hole of the next panel as shown in figure 7. At the bottom of the panel pins are projecting on each side at right angles to the plane of the panel to receive the chords. The pins are in two sizes depending on the timber used and the load carried. Where the light chord is used the bottom pins are 38 mm in diameter and where the heavy chord is required they have a diameter of 50 mm. The top pins are either 32 mm or 38 mm in diameter, the heavier pins being used with timbers whose stress grade is F 11 and above.

Figure 6. Fabrication of a panel

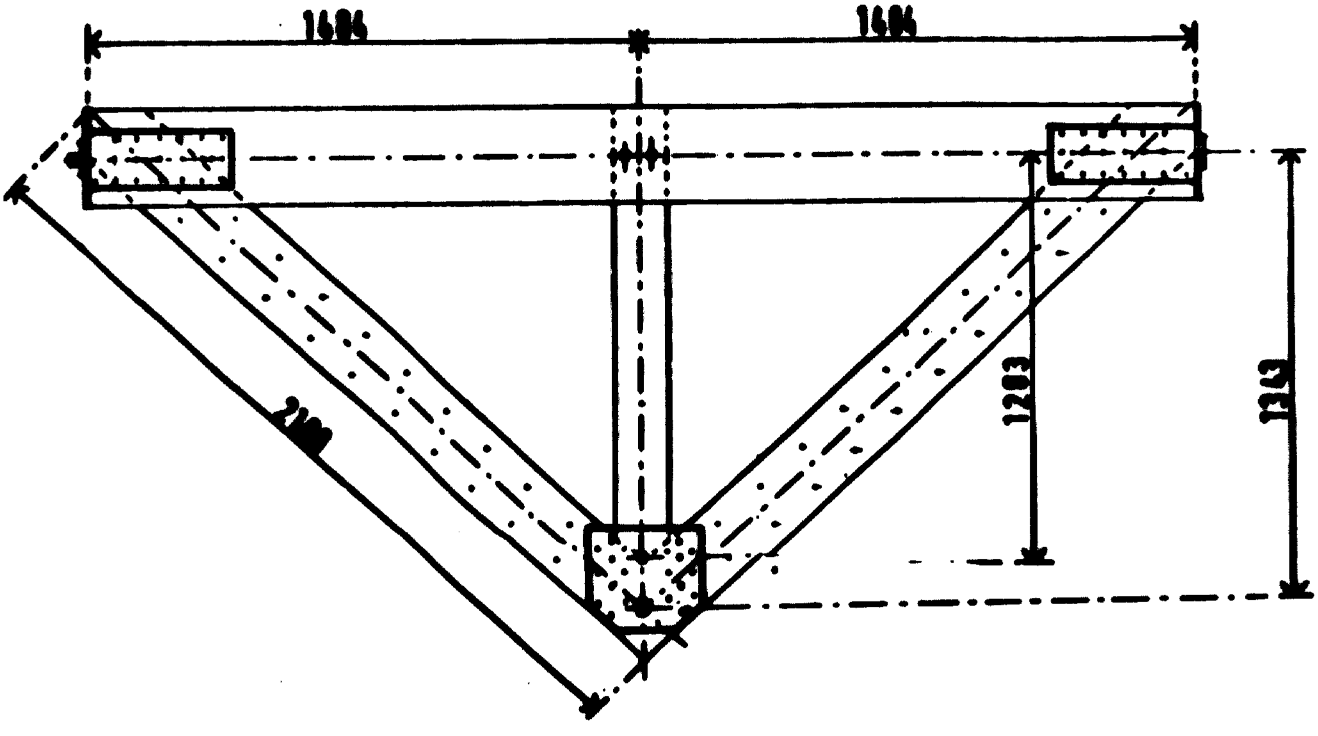
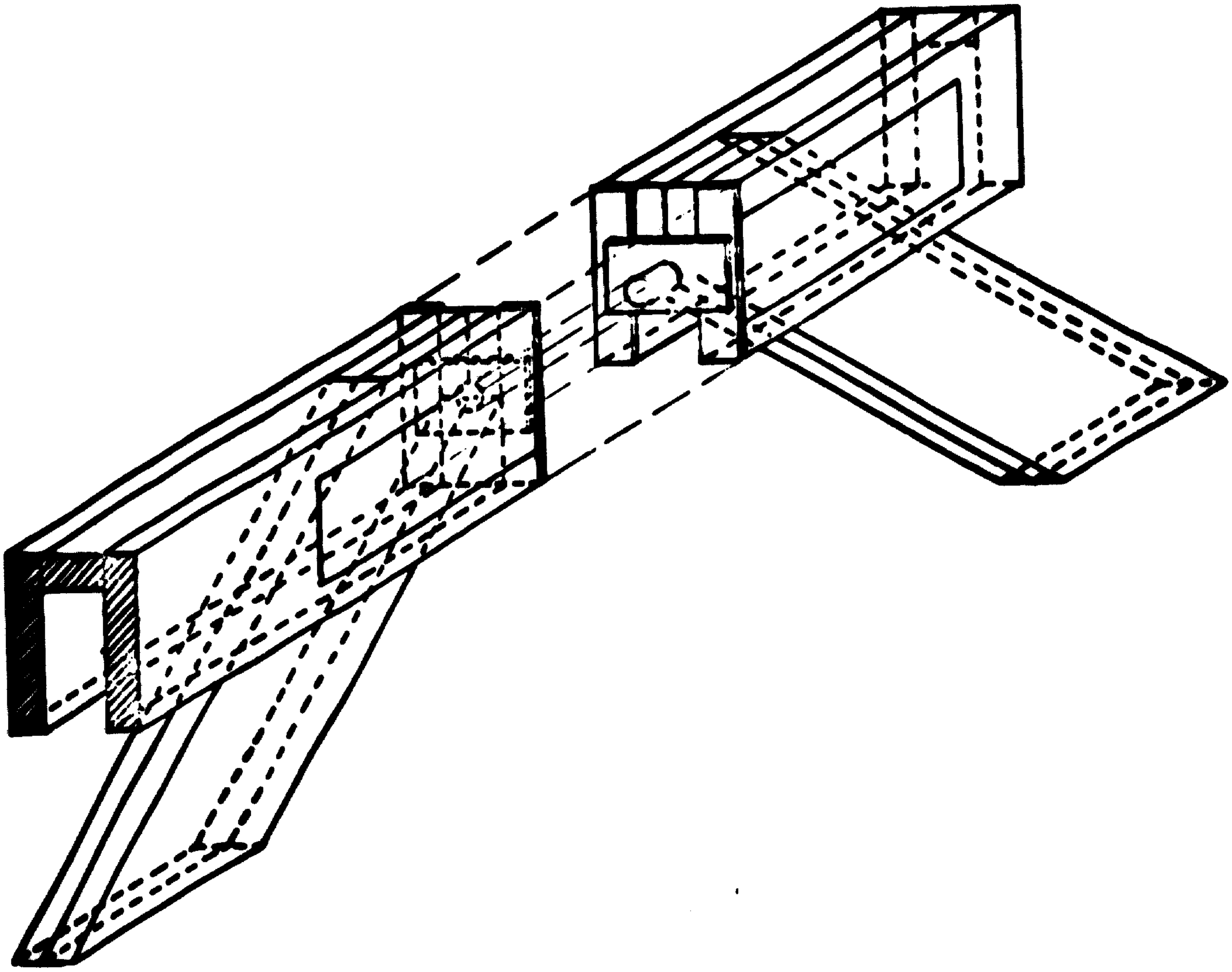


Figure 7. Truss assembly method



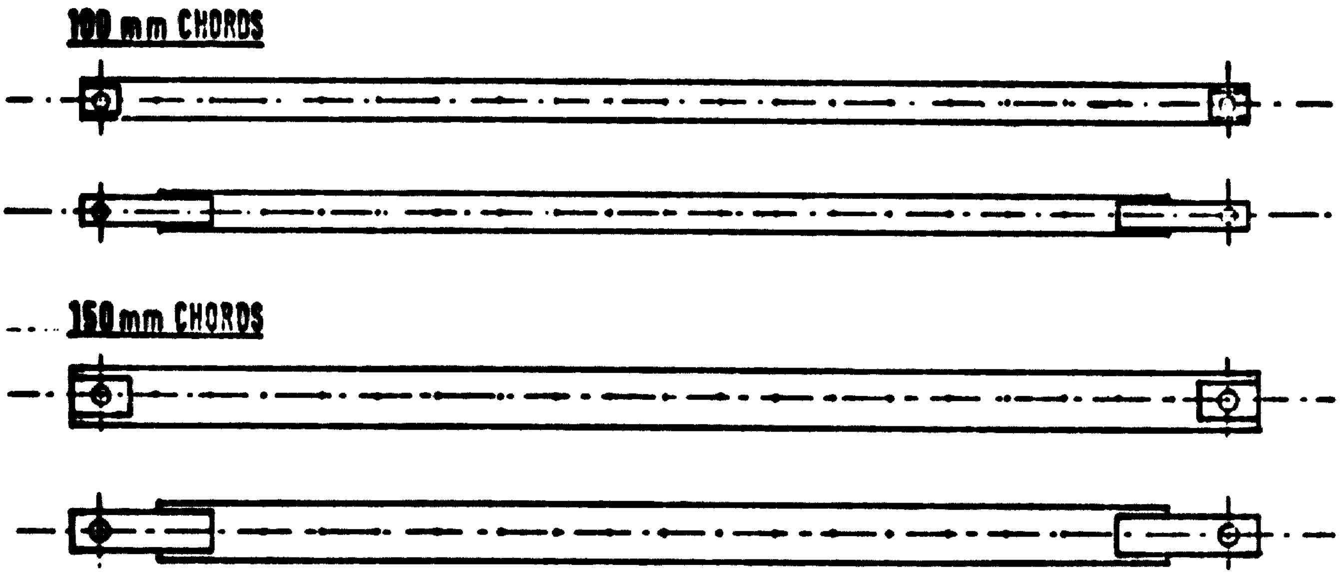
Chords

Chords have been designed in two basic sizes. The lighter size is generally used with timbers of stress grades F 8 or below and the heavier one for stronger timbers.

Trusses

The modular panels are assembled into trusses. The number of trusses needed for different loadings, species and spans is given in table 1.

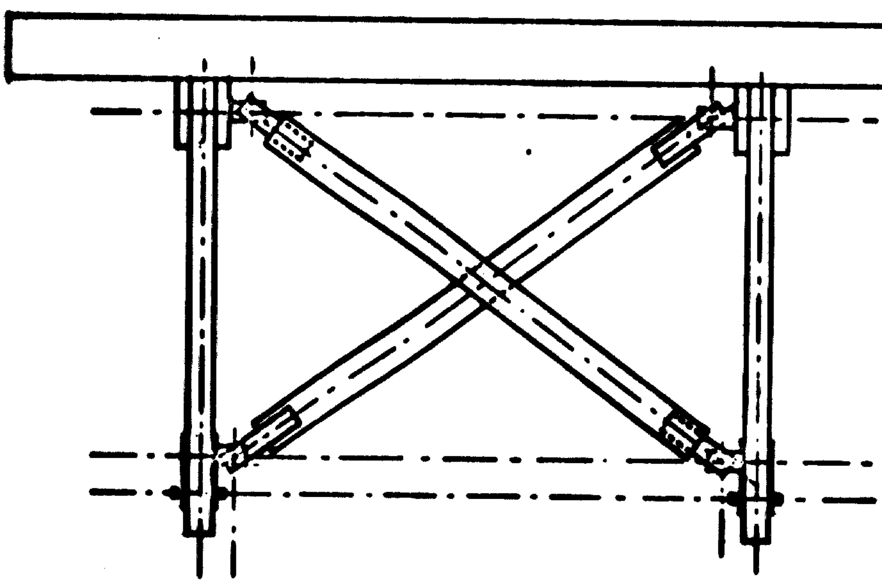
Figure 8. Chord designs



Vertical bracing

There are two types of vertical bracings. In a two-truss bridge, the bracing is used to impart lateral stability to the panels and it does not act as a load sharing device.

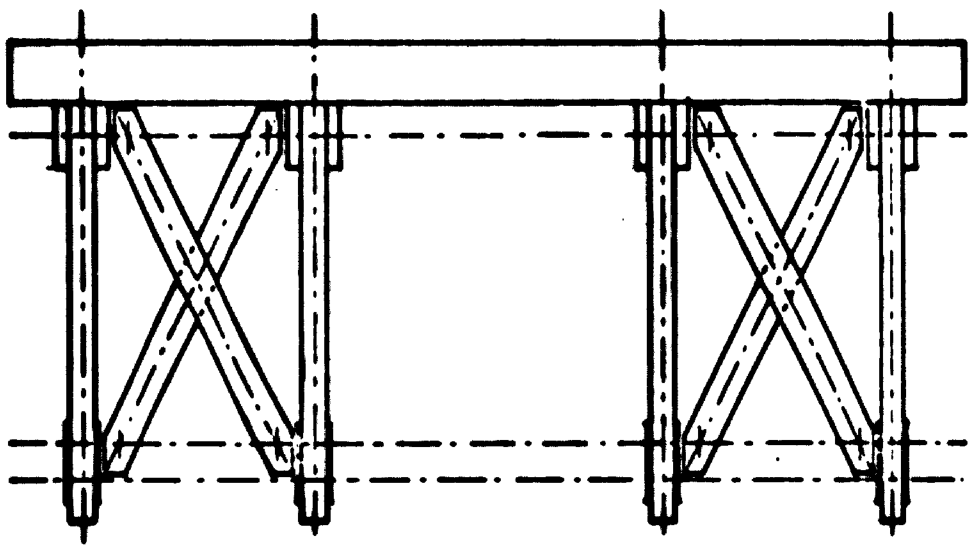
Figure 9. Truss bracing for a two-truss bridge



The component consists of a simple 150 mm x 50 mm member with 6-mm (¼") steel connector plates nailed to each end. These are bolted with 100 mm x 25 mm diameter (4" x 1" diameter) bolts into the bracing lugs on the panel.

In a bridge with four or more trusses the bracing is intended to give lateral stability and to share the load between the trusses thus connected.

Figure 10. Truss bracing for four-, six- and eight-truss bridge



They are bolted onto the bracing cleats with 25-mm diameter (1") bolts with a 50-mm (2") square washer under the nut on the timber face.

Deck bracing

The deck bracing consists of 150 mm x 50 (6" x 2") mm members nailed diagonally to the underside of the trusses with 100 (4") mm nails driven into spacers inserted between the chords.

Deck

The deck is made from 50 mm (2") wide timber nailed together in a depth which depends on the wheel loading (see table 4) and spanned across the trusses as shown in figures 9 and 10. Running boards are fixed on top of these members in the direction of the span which have an essential function in distributing wheel loads over several cross members and should not be omitted or reduced in size.

Figure 11. Four-, six- and eight- truss bridge bracing

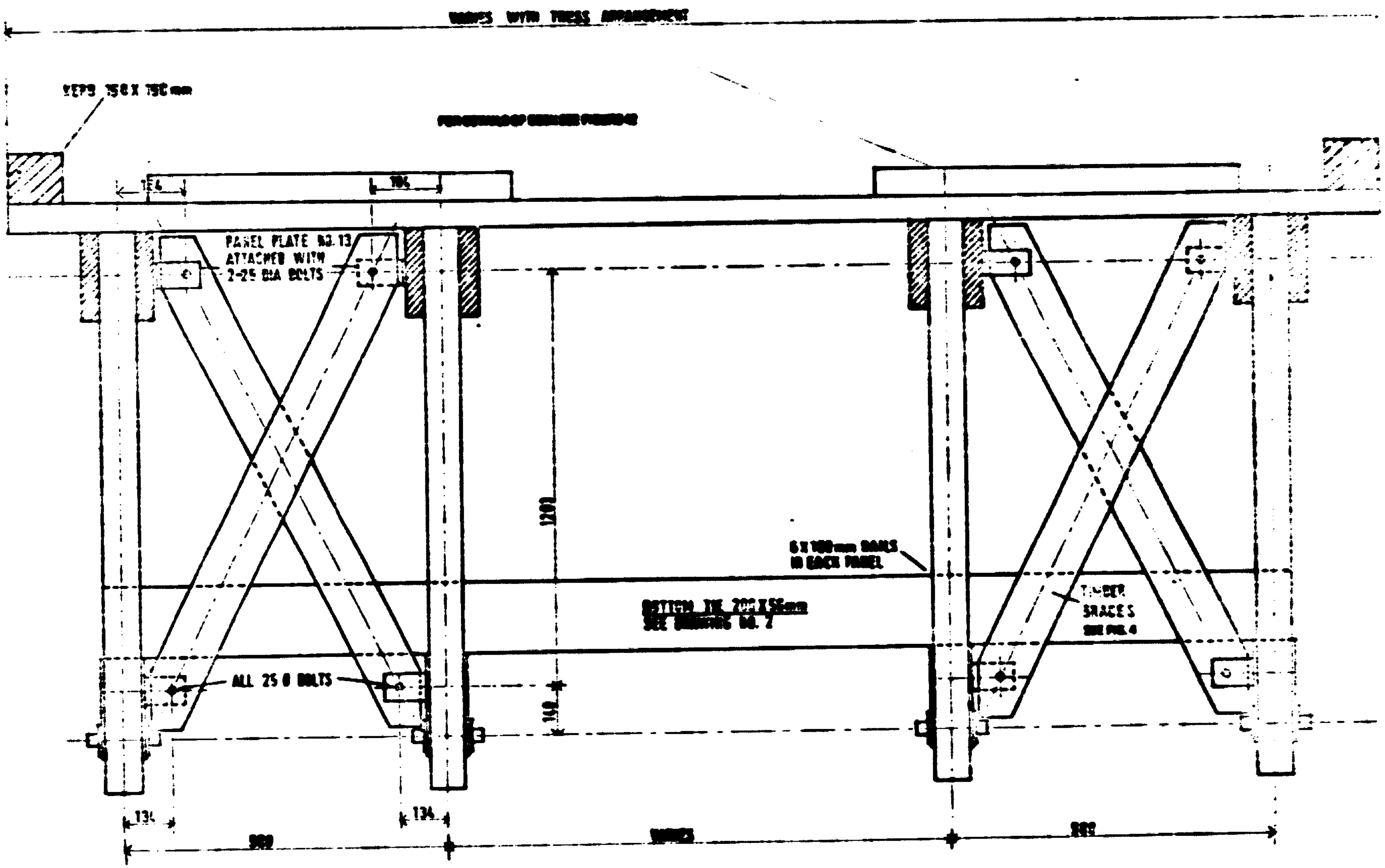


Figure 12. Two-truss bridge bracing

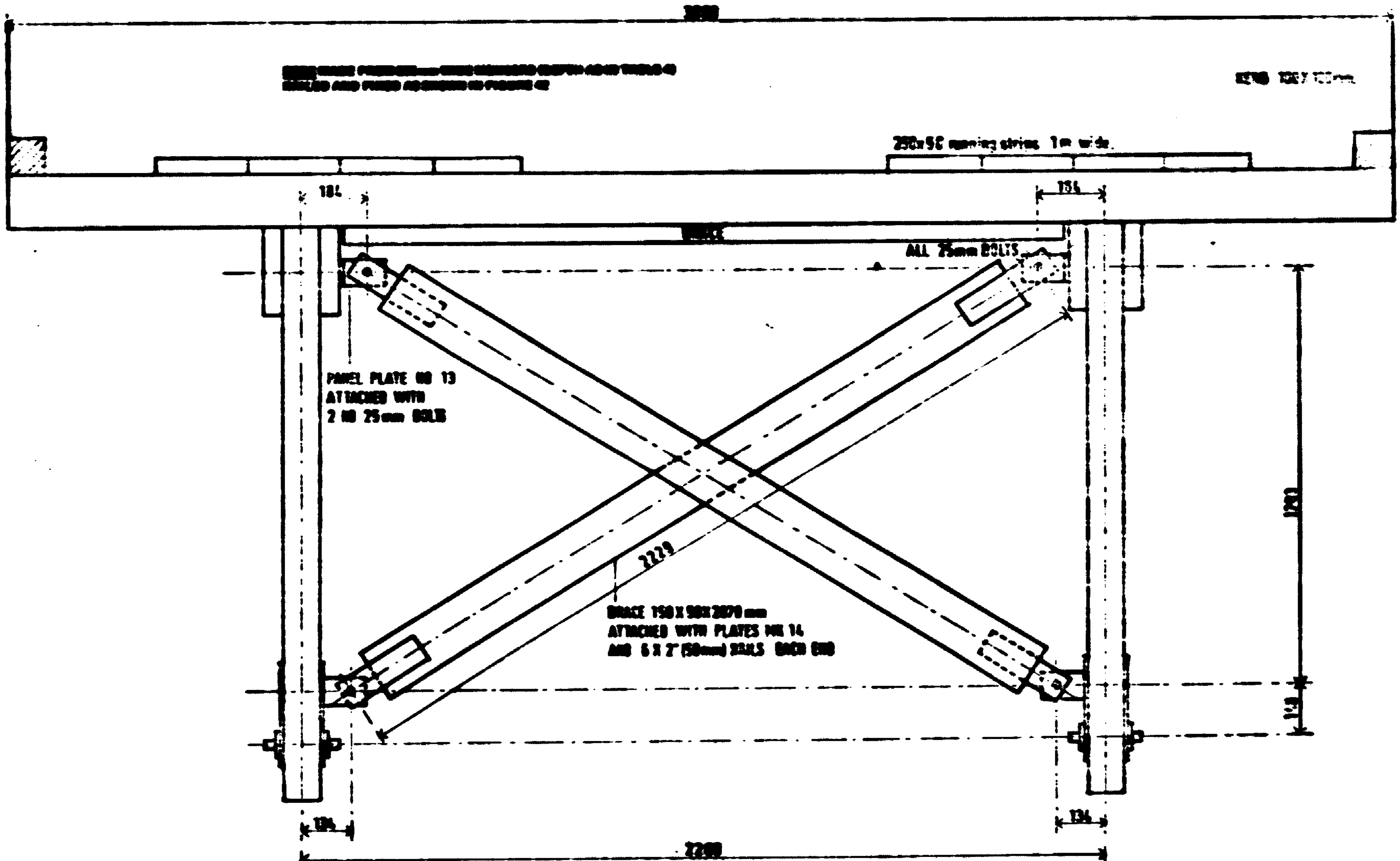
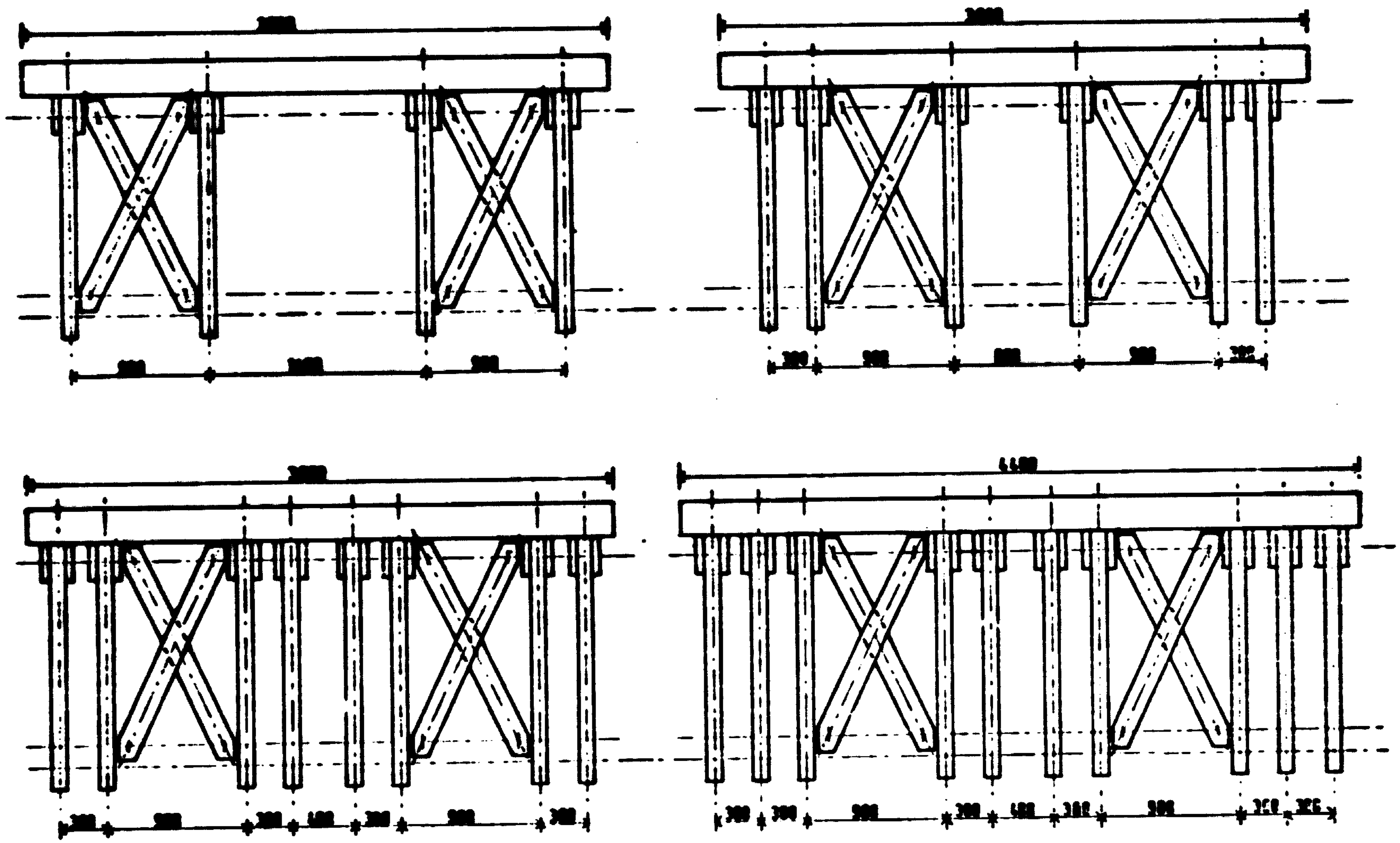


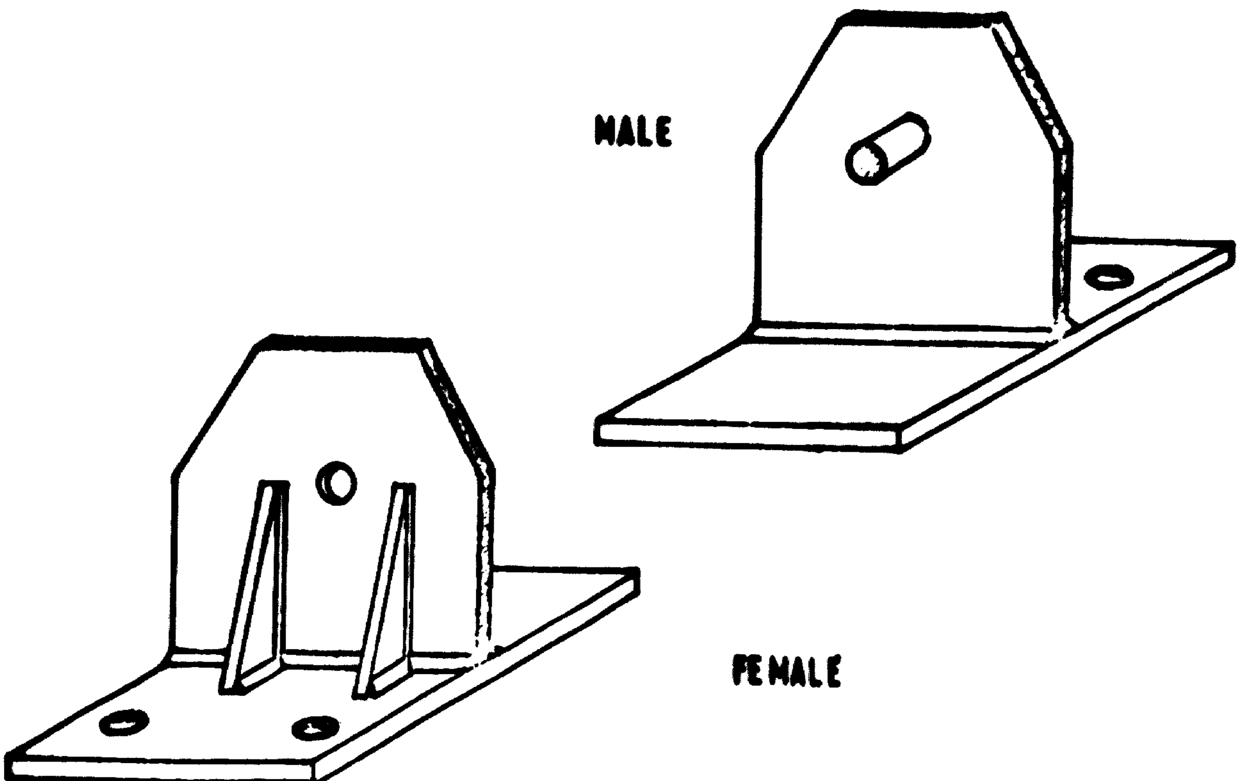
Figure 13. Truss and bracing arrangements



Bearings

Male and female bearings are located in the ends of the basic panels (see figure 14). A 12 mm plate is used throughout, the off-cuts from the top corners serving as stiffeners. The pin size depends on the pin used in the panels and will be either 32 mm or 38 mm.

Figure 14. Bearings located in the basic panel ends



B. Design process

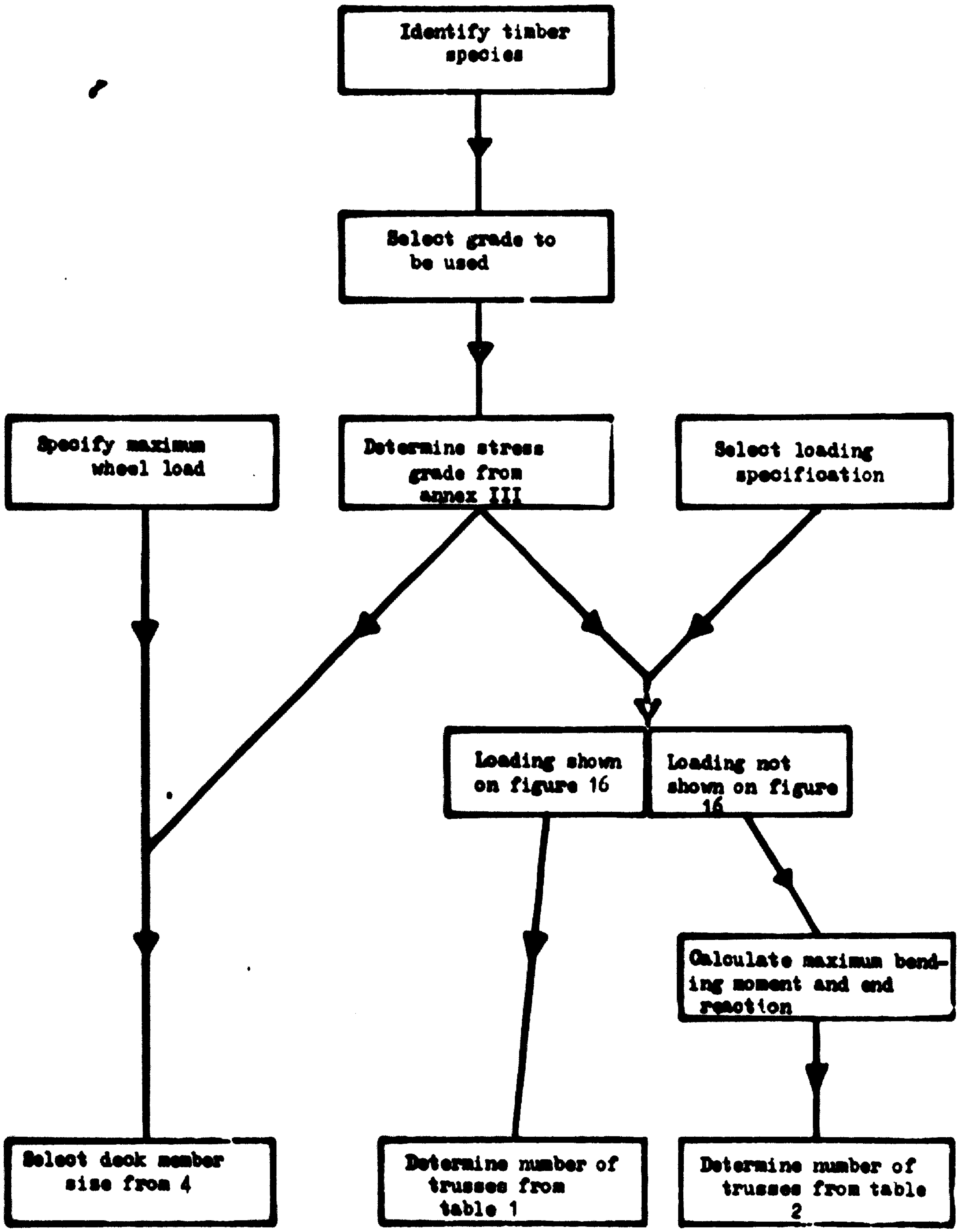
The sequence is indicated graphically in figure 15.

Selection of timber-species and stress grade

Tables of timber species from different parts of the world are given in annex III. This is not a comprehensive listing but it includes suitable timbers made known to the expert by about 50 national forest departments. Botanical names are given to avoid confusion when using trade or vernacular names.

Grading rules (see annex II) are used to classify timber from any particular species as being of grade 75%, 60% or 48%. These grades are then used in annex III to determine the stress grade for the bridge design. It is

Figure 15. Design process



obvious that a standard set of grading rules has to be used where standard designs are involved. Local grading rules may be used provided that they are comparable with the standard set. It has to be ensured that the local grading rules include all the defects given for any grade in annex II, and that the maximum defect permitted is not exceeded.

If the stress grade for a timber which is not included in the list has to be determined, the stress grades applying to unidentified timber of that region should be used. It should be noted, however, that there are many timbers which by virtue of their durability, seasoning characteristics and working properties are unsuitable for bridge-building.

In doubt refer to the local forest departments.

Loading

Designs for 12 different load specifications are given in figure 16, including loadings H and HS of the American Association of State Highway Officials (AASHO) and British Standard HA loadings. Typical truck and trailer configurations are also shown in figure 16 for comparison with the standard loadings.

Highway bridges, on which there is likely to be heavy truck loading, should normally be designed for a minimum load of H20. Bridges for rural access roads can be designed for less heavy loadings but it should be remembered that there is a tendency in all countries for loads to increase. Bridges of a limited capacity should be protected against over-loading by height barriers or maximum load signs and when traffic loads increase considerably the capacity of the bridge should be augmented by the addition of extra trusses.

Determining the design (number of trusses)

After determination of the timber stress grade and selection of the loading applicable in a given situation, the design (number of trusses) can be read directly from table 1. For loads which are not indicated in table 1, the maximum live-load bending moment and the end-reactions have to be determined first. Designs can then be read from table 3 which shows available live-load bending moments and end-reactions for different spans and timber stress grades.

The safe load tables (table 2) give the maximum capacity of single-carriageway bridges when supporting a single-tracked vehicle with its weight evenly distributed over 4 m.

Figure 16. Loadings

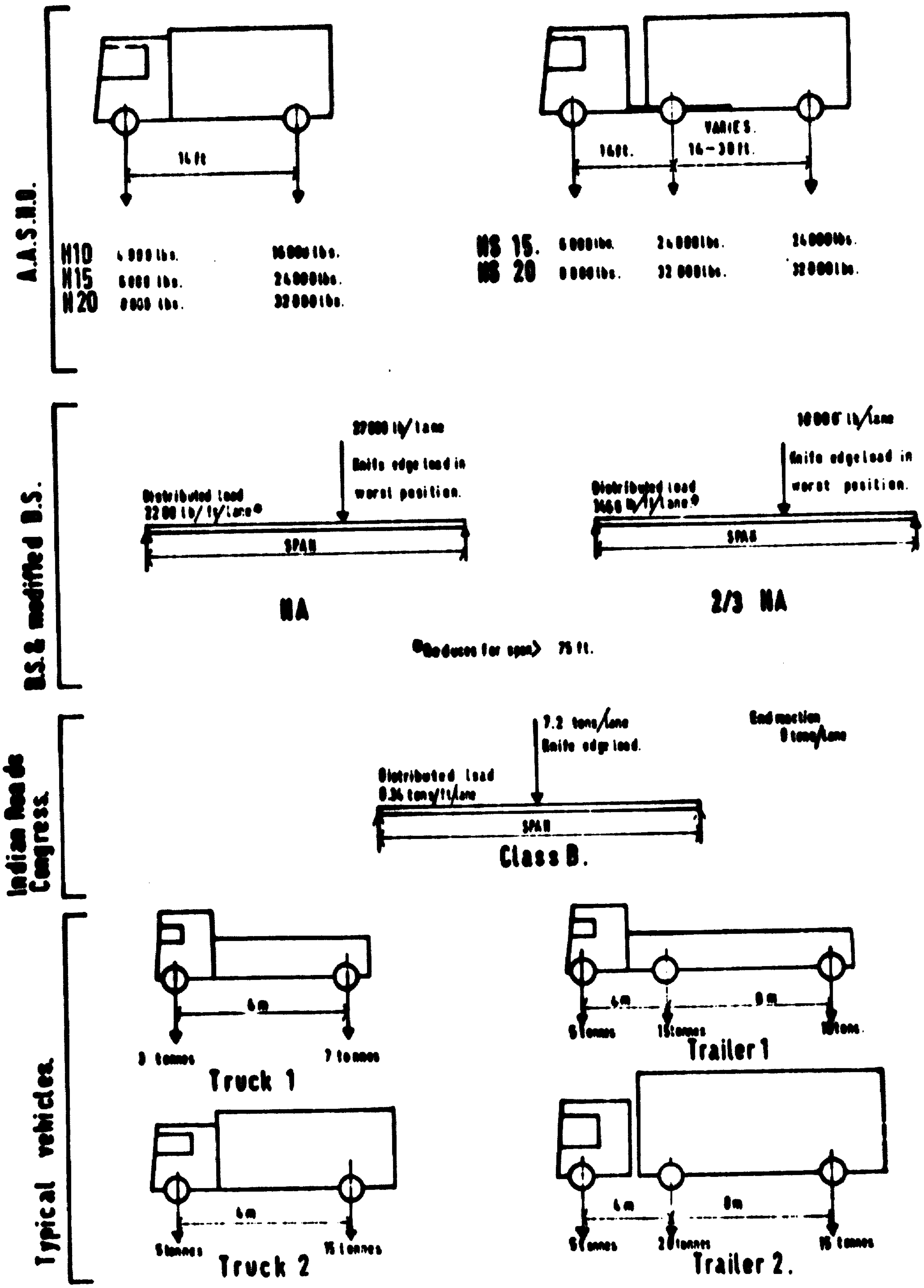


Table 1. Number of trusses needed for a given span and loading

A. Stress grade F4

Loading a/	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	4	4	4	4	6	6	8	-	-
H 15	4	6	6	6	8	-	-	-	-
H 20	4	6	6	6	8	-	-	-	-
HS 15	6	6	8	8	-	-	-	-	-
HS 20	6	6	8	8	-	-	-	-	-
2/3 HA	4	4	6	8	-	-	-	-	-
HA	6	8	-	-	-	-	-	-	-
Indian B	4	4	4	6	8	-	-	-	-
Trailer 1	6	6	6	6	8	-	-	-	-
Trailer 2	6	8	8	8	-	-	-	-	-
Truck 1	2	4	4	4	6	6	8	8	-
Truck 2	6	6	6	8	8	-	-	-	-

B. Stress grade F5

Loading a/	Span (m)								
	6	9	12	15	18	21	24	27	30
H10	2	2	2	4	4	6	6	8	-
H15	4	4	4	6	6	8	-	-	-
H20	4	4	4	6	6	8	-	-	-
HS15	4	6	6	8	8	-	-	-	-
HS20	4	6	6	8	-	-	-	-	-
2/3 HA	2	4	6	8	-	-	-	-	-
HA	6	6	8	-	-	-	-	-	-
Indian B	2	2	4	6	8	-	-	-	-
Trailer 1	4	4	6	6	8	-	-	-	-
Trailer 2	6	6	6	6	-	-	-	-	-
Truck 1	2	2	4	4	4	6	6	8	-
Truck 2	4	4	6	6	8	8	-	-	-

C. Stress grade F7

Loading a/	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	2	2	2	4	4	4	6	6	3
H 15	4	4	4	4	4	6	6	3	-
H 20	4	4	4	4	6	8	-	-	-
HS 15	4	4	6	6	3	3	-	-	-
HS 20	4	4	6	6	8	-	-	-	-
2/3 HA	2	2	4	6	3	-	-	-	-
HA	4	6	6	8	-	-	-	-	-
Indian B	2	2	4	4	6	8	-	-	-
Trailer 1	4	4	4	4	6	8	-	-	-
Trailer 2	4	4	4	6	8	-	-	-	-
Truck 1	2	2	2	2	4	4	6	6	3
Truck 2	4	4	4	4	6	8	3	10	-

D. Stress grade F8

Loading a/	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	2	2	2	2	4	4	4	6	6
H 15	2	2	4	4	4	6	6	8	3
H 20	2	4	4	4	4	6	3	-	-
HS 15	4	4	4	4	6	8	3	-	-
HS 20	4	4	4	4	6	8	-	-	-
2/3 HA	2	2	4	6	6	3	-	-	-
HA	4	4	6	8	-	-	-	-	-
Indian B	2	2	2	4	4	6	8	-	-
Trailer 1	4	4	4	4	6	6	8	-	-
Trailer 2	4	4	4	4	6	8	-	-	-
Truck 1	2	2	2	2	4	4	4	6	6
Truck 2	4	4	4	4	4	6	6	8	-

E. Stress grade F11

Loading a/	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	2	2	2	2	4 2	4	6 4	6	8 6
H 15	2	2	4	4	4	6 4	6 4	8 6	6
H 20	2	2	2	4	4	6 4	8 6	- 6	- 8
HS 15	4	4	4	4	6 4	6	8 6	- 8	- -
HS 20	2	4 2	4	6 4	6 4	8 6	- 6	- 8	- 8
2/3 HA	2	2	4 2	6 4	6 6	8 8	- 8	-	-
HA	2	4	4	6 4	6	8	-	-	-
Indian B	2	2	2	4	4	6	8 6	- 8	-
Trailer 1	2	2	4 2	4	4	6	8 6	8	-
Trailer 2	4	4	4	4	6	8 6	8	-	-
Truck 1	2	2	2	2	4 2	4	4	6 4	6 4
Truck 2	2	2	4 2	4	4	6 4	6	8 6	- 8

F. Stress grade F14

Loading a/	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	2	2	2	4 2	4	4	4	6 4	8 4
H 15	2	4	4	4	4	6 4	6 4	8 4	- 6
H 20	2	2	4 2	4 2	4	6 4	8 4	- 6	- 8
HS 15	4	4	4	4	6 4	6 4	8 6	- 6	- 8
HS 20	2	4 2	4	4	6 4	- 6	- 6	- 8	- 10
2/3 HA	2	2	4 2	6 4	6 4	8 6	- 8	-	-
HA	2	4	4	6 4	- 6	- 8	-	-	-
Indian B	2	2	2	4 2	4	6 4	8 6	- 6	- 8
Trailer 1	2	2	4 2	4	6 4	6 4	8 6	- 6	- 8
Trailer 2	2	2	4	4	6 4	8 6	- 6	- 8	- 10
Truck 1	2	2	2	2	4 2	4 2	4	6 4	6 4
Truck 2	2	2	4 2	4 2	4	6 4	8 4	8 6	- 6

G. <u>Stress grade F17</u>

Loading[a]	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	2	2	2	2	4 2	4 4	4	6 4	8 4
H 15	2	2	4	4	4	6 4	6 4	8 4	- 6
H 20	2	2	4 2	4 2	4	6 4	8 4	- 6	- 8
HS 15	2	2	2	4 2	6 4	6 4	8 4	- 6	- 6
HS 20	2	4 2	4	4	6 4	8 4	- 6	- 8	- 8
2/3 HA	2	2	4 2	6 4	6 4	- 6	- 8	- 8	- -
HA	2	4	6 4	8 4	- 6	- 8	-	-	-
Indian B	2	2	2	4 2	4	6 4	8 4	- 6	- -
Trailer 1	2	2	4 2	4 2	4	6 4	8 6	- 6	- 8
Trailer 2	2	2	4 2	4	6 4	8 6	- 6	- 8	- 10
Truck 1	2	2	2	2	4 2	4 2	- 4	6 4	8 4
Truck 2	2	2	4 2	4 2	6 4	6 4	8 4	- 6	- 6

H. <u>Stress grades F22, 27 and 34</u>

Loading[a]	Span (m)								
	6	9	12	15	18	21	24	27	30
H 10	2	2	2	2	4 2	4	6 4	6 4	8 4
H 15	2	4	4	4	4	6 4	6 4	8 6	- 6
H 20	2	2	4 2	4 2	4 2	6 4	8 4	- 6	- 8
HS 15	4	4	4	4	6 4	8 4	8 6	- 6	- 8
HS 20	2	4 2	4	6 4	6 4	8 6	- 6	- 8	- 8
2/3 HA	2	2	4 2	6 4	6 4	- 6	- 8	- 8	- -
HA	2	4	6 4	8 4	- 6	- 8	-	-	-
Indian B	2	2	2	4 2	6 4	6 4	8 6	- 6	- 8
Trailer 1	2	2	4 2	4 2	6 4	6 4	8 6	- 6	- 8
Trailer 2	2	2	4	4	6 4	8 6	- 6	- 8	- -
Truck 1	2	2	2	2	4 2	4 2	6 4	6 4	8 4
Truck 2	2	2	4 2	4 2	6 4	6 4	8 4	- 6	- 6

a/ For details see figure 16.

Table 2. Safe loads
(Tons)

A. Two-truss construction

Stress grade	Span (m) 6	9	12	15	18	21	24	27	30
F 4	5.3	4.4	3.9	2.7	2.2	1.6	1.2	0.8	0.5
F 5	6.7	5.5	4.9	3.4	2.8	2.0	1.4	0.9	0.6
F 7	8.1	7.0	6.3	4.5	3.7	2.8	2.1	1.5	0.8
F 8	10.9	9.0	8.1	5.8	4.7	3.6	2.6	2.0	1.4
F 11	13.8	11.5	8.6	6.0	4.9	3.7	2.8	2.1	1.5
			10.4	7.4	6.1	4.7	3.7	2.9	2.1
F 14	17.0	13.0	8.4	5.8	4.7	3.5	2.6	1.9	1.3
		14.1	12.8	9.7	7.9	6.2	5.0	3.9	3.0
F 17	16.8	12.8	8.2	5.5	4.5	3.3	2.4	1.6	1.0
		13.9	12.6	10.0	8.2	6.4	5.0	4.0	3.0
F 22 27 and 34	16.7	12.6	7.9	5.1	4.3	3.0	2.1	1.3	0.4
		13.7	12.3	9.6	8.0	6.1	4.7	3.7	2.7

B. Four-truss construction

Stress grade	Span (m) 6	9	12	15	18	21	24	27	30
F 4	5.5	4.6	4.1	3.0	2.3	1.6	1.2	0.8	0.5
F 5	6.9	5.7	5.2	3.8	3.0	2.1	1.6	1.1	0.8
F 7	8.8	7.3	6.7	4.9	3.7	2.8	2.2	1.6	1.1
F 8	10.7	9.4	8.6	6.4	4.8	3.7	2.9	2.2	1.6
F 11	14.1	11.9	9.1	6.6	5.0	3.8	2.9	2.2	1.6
			10.9	8.1	6.2	4.8	3.8	3.0	2.3
F 14	17.4	13.5	9.0	6.5	4.8	3.6	2.7	3.0	1.3
		14.6	13.4	10.4	8.0	6.3	5.0	4.0	3.1
F 17	17.3	13.4	8.9	6.3	4.6	3.4	2.5	1.7	1.0
		14.7	13.3	10.8	8.3	6.5	5.1	4.0	3.1
F 22 27 and 34	17.2	13.2	8.7	6.1	4.4	3.1	2.2	1.3	0.6
		14.4	13.1	10.6	8.1	6.2	4.8	3.7	2.7

C. Six-truss construction

Stress grade	Span (m) 6	9	12	15	18	21	24	27	30
F 4	5.6	4.6	4.2	3.1	2.3	1.8	1.3	1.0	0.7
F 5	7.0	5.8	5.3	3.9	3.0	2.3	1.8	1.3	1.0
F 7	8.9	7.4	6.8	5.1	3.9	3.0	2.4	1.9	1.4
F 8	11.3	9.5	8.7	6.5	5.0	4.0	3.2	2.5	2.0
F 11	14.3	12.6	9.3	6.8	5.2	4.1	3.2	2.6	2.0
			11.0	8.3	6.4	5.1	4.1	3.3	2.7
F 14	17.6	13.6	9.2	6.7	5.1	4.0	3.1	2.4	1.8
		14.8	13.6	10.6	8.3	6.6	5.4	4.4	3.6
F 17	17.5	13.6	9.1	6.6	5.0	3.8	2.9	2.2	1.5
		14.8	13.5	11.1	8.6	6.9	5.5	4.5	3.6
F 22 27 and 34		13.4	9.0	6.4	4.8	3.6	2.6	1.9	1.2
		14.6	13.4	10.9	8.4	6.7	5.3	4.2	3.3

D. Eight-truss construction

Stress grade	Span (m) 6	9	12	15	18	21	24	27	30
F 4	5.6	4.7	4.4	3.2	2.4	1.8	1.4	1.0	0.8
F 5	7.0	5.9	5.4	4.0	3.1	2.4	1.9	1.5	1.1
F 7	8.9	7.5	6.9	5.1	4.0	3.1	2.5	2.0	1.6
F 8	11.3	9.6	8.8	6.6	5.1	4.1	3.3	2.7	2.1
F 11	14.3	12.1	9.4	6.9	5.4	4.3	3.4	2.7	2.2
			11.1	8.4	6.6	5.3	4.3	3.5	2.9
F 14	17.6	13.7	9.3	6.8	5.3	4.1	3.3	2.6	2.0
		14.9	13.7	10.7	8.4	6.8	5.6	4.6	3.8
F 17	17.5	13.6	9.2	6.6	5.1	4.0	3.1	2.4	1.8
		14.8	13.6	11.2	8.8	7.1	5.8	4.7	3.9
F 22 27 and 34	17.4	13.5	9.1	6.6	5.0	3.8	2.9	2.2	1.5
		14.7	13.5	11.1	8.6	6.9	5.6	4.5	3.6

Table 3. Live load bending moments and end reactions

A. Stress grade F 4

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
	a	71	68	64	61	56	54	51	47	-
2	b	226	214	196	173	145	111	73	29	-
	c	226	214	196	173	145	111	73	29	-
	a	147	142	138	133	129	124	120	115	111
4	b	460	444	420	389	352	308	257	200	135
	c	460	444	420	389	352	308	257	200	135
	a	223	217	212	206	200	195	189	184	178
6	b	694	673	644	606	560	505	442	370	290
	c	694	673	644	606	560	505	442	370	290
	a	299	292	285	279	272	265	258	252	245
8	b	928	903	867	822	767	702	626	541	445
	c	928	903	867	822	767	702	626	541	445

B. Stress grade F 5

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
	a	89	85	81	78	74	70	66	62	58
2	b	283	268	248	222	190	153	109	60	5
	c	283	268	248	222	190	153	109	60	5
	a	184	179	174	169	164	159	154	149	145
4	b	574	555	528	495	453	404	347	283	211
	c	574	555	528	495	453	404	347	283	211
	a	278	272	266	260	253	247	241	235	229
6	b	865	841	809	767	716	655	586	506	418
	c	865	841	809	767	716	655	586	506	418
	a	373	366	358	351	343	336	329	321	314
8	b	1 155	1 128	1 089	1 039	979	906	824	730	624
	c	1 155	1 128	1 089	1 039	979	906	824	730	624

C. Stress grade F 7

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
2	a	114	110	105	101	96	92	88	83	79
	b	360	344	320	291	254	211	161	105	42
	c	360	344	320	291	254	211	161	105	42
4	a	234	229	223	217	212	206	200	195	189
	b	729	708	679	640	593	538	474	401	320
	c	729	708	679	640	593	538	474	401	320
6	a	355	348	341	334	327	320	313	306	299
	b	1 099	1 073	1 037	990	932	864	786	697	598
	c	1 099	1 073	1 037	990	932	864	786	697	598
8	a	475	467	459	450	442	434	426	418	409
	b	1 469	1 438	1 395	1 339	1 271	1 191	1 098	993	875
	c	1 469	1 438	1 395	1 339	1 271	1 191	1 098	993	875

D. Stress grade F 8

Number of trusses		Span (m) 6	9	12	15	16	21	24	27	30
2	a	146	141	136	131	126	120	115	110	105
	b	459	440	413	379	337	287	230	165	93
	c	459	440	413	379	337	287	230	165	93
4	a	299	293	286	280	273	267	260	254	247
	b	928	904	870	827	773	710	637	555	463
	c	928	904	870	827	773	710	637	555	463
6	a	452	444	437	429	421	413	405	397	389
	b	1 398	1 369	1 328	1 275	1 209	1 133	1 045	944	832
	c	1 398	1 369	1 328	1 275	1 209	1 133	1 045	944	832
8	a	606	596	581	578	569	559	550	541	532
	b	1 868	1 833	1 785	1 722	1 646	1 556	1 452	1 334	1 202
	c	1 868	1 833	1 785	1 722	1 646	1 556	1 452	1 334	1 202

E. Stress grade F 11

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
	a	184	179	173	167	161	155	150	144	138
2	b	483	461	430	390	343	283	220	146	63
	c	578	557	526	487	439	382	317	242	159
	a	376	370	363	356	348	341	334	326	319
4	b	978	950	912	862	802	730	647	554	449
	c	1 170	1 143	1 104	1 054	994	922	840	746	641
	a	571	562	553	544	535	527	518	509	500
6	b	1 473	1 440	1 393	1 334	1 260	1 174	1 074	961	835
	c	1 762	1 728	1 682	1 622	1 549	1 462	1 362	1 249	1 123
	a	764	754	743	733	722	712	702	691	681
8	b	1 969	1 930	1 875	1 805	1 719	1 618	1 501	1 368	1 220
	c	2 353	2 314	2 260	2 189	2 104	2 002	1 885	1 753	1 605

F. Stress grade F 14

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
	a	227	220	213	206	200	193	186	180	173
2	b	479	455	420	374	319	253	178	92	-
	c	734	708	674	628	573	508	432	347	251
	a	463	455	446	438	430	421	413	404	396
4	b	975	943	899	843	773	692	597	490	371
	c	1 483	1 451	1 408	1 351	1 282	1 200	1 105	998	879
	a	700	690	680	670	660	649	639	629	619
6	b	1 470	1 432	1 379	1 311	1 228	1 130	1 016	838	744
	c	2 232	2 194	2 141	2 073	1 990	1 892	1 779	1 650	1 507
	a	936	925	913	901	889	878	866	854	842
8	b	1 965	1 921	1 859	1 779	1 682	1 568	1 435	1 286	1 118
	c	2 981	2 937	2 875	2 796	2 699	2 584	2 452	2 302	2 134

G. Stress grade F 17

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
	a	225	217	209	202	194	186	179	171	164
2	b	477	448	408	357	294	219	133	36	0
	c	769	740	700	649	586	511	425	328	219
	a	461	451	442	433	423	414	404	395	385
4	b	972	936	886	822	744	651	544	423	283
	c	1 555	1 520	1 470	1 406	1 328	1 235	1 128	1 007	872
	a	697	686	675	663	652	641	629	618	607
6	b	1 466	1 423	1 364	1 287	1 194	1 083	955	811	649
	c	2 342	2 299	2 240	2 163	2 070	1 959	1 831	1 687	1 525
	a	934	920	907	894	881	868	854	841	828
8	b	1 960	1 911	1 842	1 753	1 644	1 515	1 366	1 198	1 010
	c	3 128	3 079	3 010	2 920	2 812	2 683	2 534	2 366	2 178

H. Stress grades F 22, 27 and 34

Number of trusses		Span (m) 6	9	12	15	18	21	24	27	30
	a	222	213	205	196	187	178	169	160	151
2	b	473	440	394	334	261	174	74	0	0
	c	765	732	686	626	553	466	367	254	128
	a	458	447	436	425	414	403	393	382	371
4	b	967	926	869	795	705	598	475	336	180
	c	1 551	1 510	1 453	1 379	1 289	1 182	1 059	920	764
	a	694	681	668	655	642	629	616	603	590
6	b	1 461	1 412	1 344	1 256	1 149	1 022	876	710	525
	c	2 337	2 288	2 200	2 132	2 025	1 898	1 752	1 586	1 401
	a	930	915	900	885	870	855	839	824	809
8	b	1 955	1 898	1 819	1 717	1 593	1 446	1 277	1 085	870
	c	3 123	3 066	2 987	2 885	2 761	2 614	2 445	2 253	2 038

Key: a. Available shear (kN)

b. Available bending moment light chord (kN m)

c. Available bending moment heavy chord (kN m)

Design of the deck

Table 4 indicates recommended sizes for deck members for different wheel loads and timbers of various stress grades. If timbers are used that are likely to wear quickly, a harder or denser species should be used for the running boards. This will probably be the case with most timbers of stress grade F11 and below. An alternative is to fix a chequer plate on top of the boards which acts as a wearing surface.

Table 4. Deck design
(depth of deck required in mm)

A. Two-truss bridges

Wheel load (t)	Stress grade									
	F4	F5	F7	F8	F11	F14	F17	F22	F27	F34
1	100	100	75	75	75	75	75	75	75	75
2	125	125	100	100	100	75	75	75	75	75
3	150	150	125	125	100	100	100	75	75	75
4	-	-	150	125	125	100	100	100	75	75
5	-	-	-	150	125	125	100	100	100	75
6	-	-	-	-	150	125	125	100	100	100

B. Four-, six- and eight-truss bridges

Wheel load (t)	Stress grade									
	F4	F5	F7	F8	F11	F14	F17	F22	F27	F34
1	75	75	75	75	75	75	75	75	75	75
2	100	75	75	75	75	75	75	75	75	75
3	100	100	100	75	75	75	75	75	75	75
4	125	100	100	100	75	75	75	75	75	75
5	150	125	100	100	100	75	75	75	75	75
6	150	125	125	100	100	100	75	75	75	75

II. PROCUREMENT OF MATERIALS AND ASSEMBLY

A. Steel procurement

It is assumed that steel with a maximum tensile strength of 435-494 N/mm^2 (28-32 t/in^2) and a minimum yield stress of 236 N/mm^2 (15.25 t/in^2) is used. Mild steel from the majority of produoers will comply to this standard; sub-standard steel should not be used. In case of doubt government or private materials testing laboratories should be consulted regarding the quality of the steel in question. In some places difficulties have been experienced in obtaining supplies of bars of a larger diameter. If they are not available from stuructural steel merchants, mechanical engineering suppliers may have shaft steel of the required size on stock. Shaft steel is usually made of an alloy different from steel and has to be welded with special rods, depending on its composition.

The quantities of steel required per panel are given in table 5.

B. Timber procurement and treatment

Procurement

Timber of the species and stress grade foreseen in the design should be ordered and the timber should be allowed to dry. The actual time required for drying will depend on the species, the method of drying, and the climate.

It is an advantage to order timber in such lengths that pieces can be cut with a minimum of wastage. Even if a premium is charged on orders for specific lengths, this will normally still be cheaper than having a high rate of wastage when cutting from random lengths.

A check should be made on dimension and green timber must be sawn oversize to allow for shrinkage during drying. The actual amount of oversize will again depend on the species.

Cutting to size

The dimensions of the panel components are given in figure 4. The jigs shown on figure 5 can be used for cutting to size. Timber can be sawn green; this will be necessary if the diffusion method of treatment is used.

Table 5. Quantities of steel required per panel

(Weights and surface areas of steel plates include drill holes and bevel offcuts)

Figure number	Plate	Surface (m^2)				Weight (kg)				Length of round bar (m)		
		6 mm	9 mm	12 mm	15 mm	6 mm	9 mm	12 mm	15 mm	32 mm ø	38 mm ø	50 mm ø
19	1		0.086				6.05				0.055	
20	1A		0.094				6.64				0.055	
23	2 chord	0.325				15.27						
23	2A chord	0.268	0.054			12.59		5.07				
26	3		0.017	0.017				1.64				
26	4		0.017	0.017				1.64		0.055		
28	5	0.056	0.012			2.64	0.84					
24	6 chord	0.485	0.015			21.85	1.05					
25	6A chord	0.402			0.077	18.88			9.28			
27	8	0.022				0.32						
21	9		0.086				6.05					0.06
22	9A		0.094				6.64					0.06
26	10		0.017				1.64					
26	11		0.017				1.64					
27	13		0.012				0.84					
29	Bearing (male)			0.091				8.55		0.055	(0.055) a/	
29	Bearing (female)			0.091				8.55				

a/ Heavy duty.

Dowels per panel

68 pcs 58 mm long; 48 pcs 100 mm long;
Length of 12 mm ø round bar: approx. 8.2 m

Nails or panel

100 mm x 4.88 mm ø approx. 1.1 kg

Bolts per panel

12 mm ø 2 pcs 150 mm long
25 mm ø 1 pcs 150 mm long

25 mm ø 2 pcs 250 mm long, with 2.75-mm washers

The 27-mm diameter holes can be drilled at this stage, although it is permissible to do this after the assembly, provided that the holes are individually treated with preservative.

A tolerance of 2 mm can be regarded as acceptable for pre-sawn timber components. Oversize components will not fit the assembly jig. Quantities of timber required per panel are given in table 6.

Table 6. Quantities of timber required per panel

Member a/	Size (mm)	Length ordered (m)	Number per panel	Volume (m^3)
1T	250 x 50	3.3	2	0.0825
2T	200 x 50	2.4	4	0.0960
3T	150 x 50	1.7	2	0.0255
4T	100 x 50	1.3	2	0.0130
Total				0.2170 b/

a/ See figure 4.

b/ Net volume in assembled panel = 0.191 m^3.

Drying

It is outside the scope of this report to describe fully all methods of timber seasoning. The design calls for timber dried to within 5% of the equilibrium moisture content (EMC). EMC is the value which would be attained in service and which depends on the humidity of the air and the tropical region. The following may be used as a rough guide:

	EMC (%)
Hot dry region (desert, savannah or scrub land)	10-12
Tropical highland (above 1,500 m)	12-14
Tropical coast and rain forest	14-18

The moisture content is most conveniently measured by using a moisture meter. Ensure that the probes are long enough to reach the centre of the timber. Steep moisture gradients are found in some timbers and measurement at the surface may give a false impression of the moisture content of the whole piece.

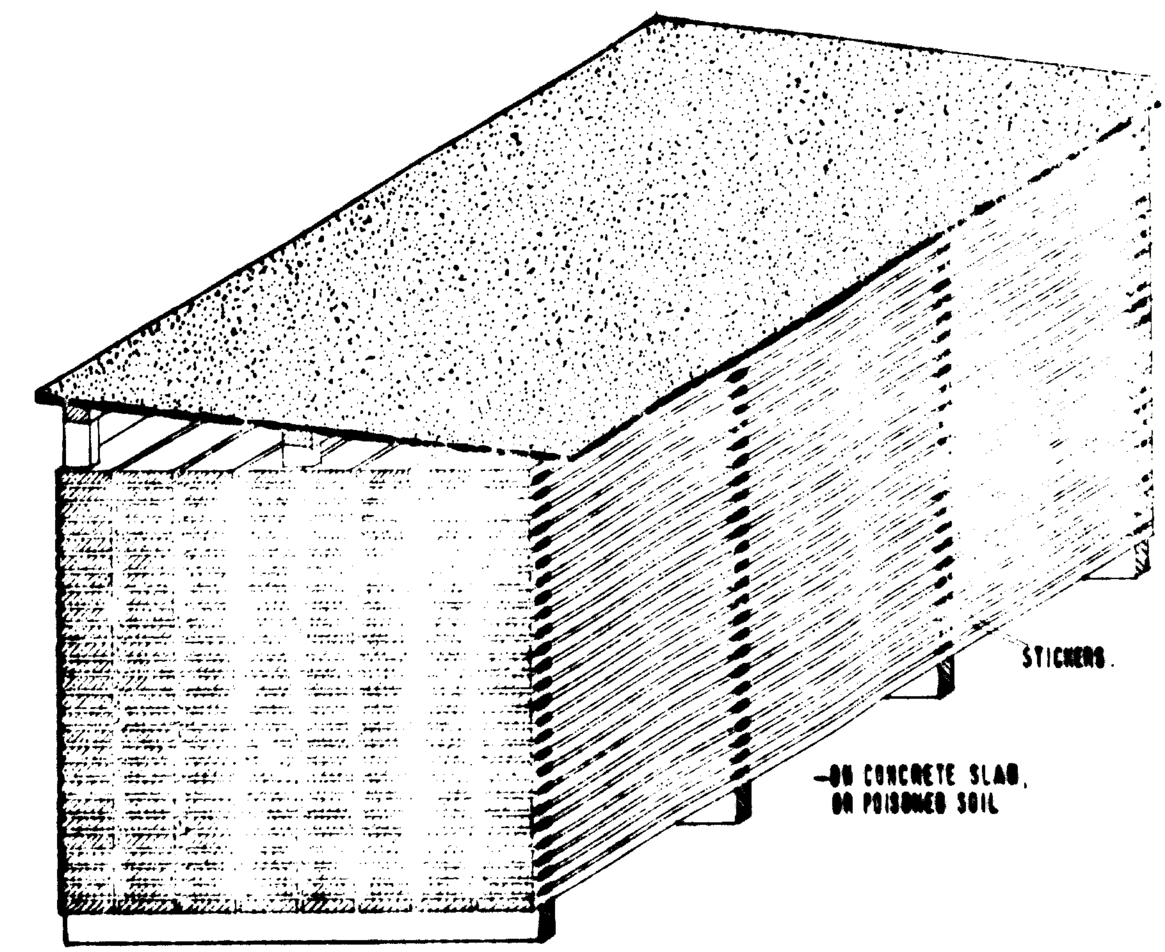
Most moisture meters are calibrated for species from the temperate zone; therefore officers of the National Forest Departments should be asked for calibration data required for local timbers.

Air drying

For air drying, which is the most common method, timber should be stacked under cover on a well-drained surface, clear of the ground, as shown in figure 17.

Where a concrete base is not practicable the soil under the stack should be poisoned with an appropriate insecticide solution having long activity to prevent possible termite attack.

Figure 17. Stacking procedure for air-drying of timber



The thickness of the stickers will usually be about 18 mm. For timbers known to be difficult to season 12 mm-stickers should be used. The stickers should be placed directly under one another.

The time required for seasoning will depend on the species and the climate. Some softwoods in tropical climates require only 6 weeks while some of the denser hardwoods need at least 25 weeks.

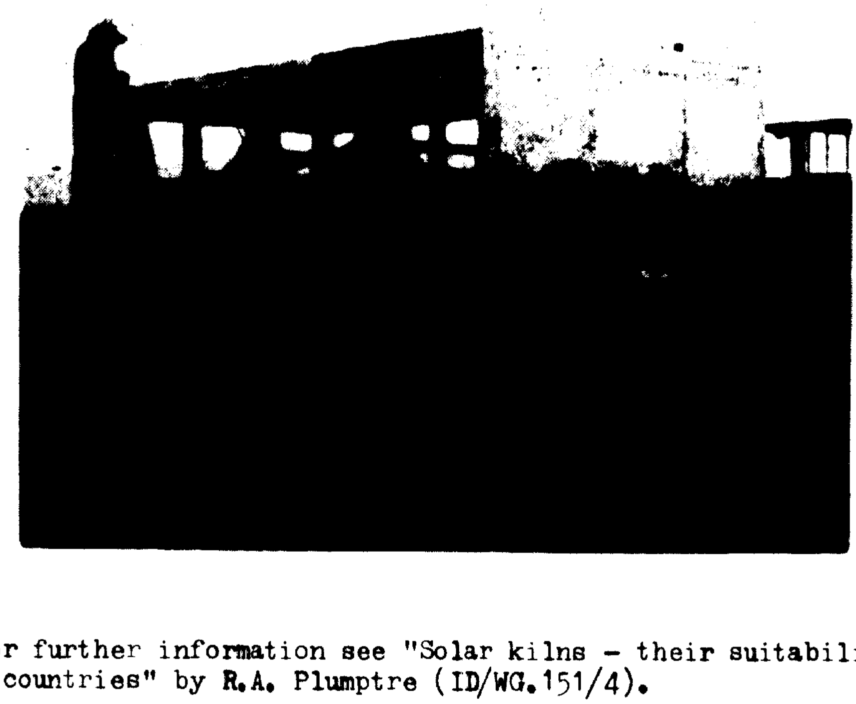
The ends of members tend to dry more quickly than the other part and should be covered with polythene or painted with bitumen to prevent splitting. This is particularly important for dense hardwoods.

Solar kilns

Figure 18 shows a solar kiln based on a design developed for the Uganda Forest Department.1/ In this type of kiln air is heated in the roof cavity and then circulated around the timber stack by one or more fans. With this method the time required to dry hardwoods could be reduced by up to 50% and it would clearly be attractive where plain air drying presents difficulties.

Figure 18. Solar kiln

A. View from the rear with fans above the absorber



1/ For further information see "Solar kilns - their suitability for developing countries" by R.A. Plumptre (ID/WG.151/4).

B. Front view showing absorbers and method of powering fans

The amount of vent used, the stacking arrangements and the volume of air flow will depend on the species being dried and some experimenting will be needed to determine these. Experience with the original kilns indicated that the air flow should be reduced in the early stages of drying, when high moisture gradients are to be avoided, but can be greatly increased later.

Conventional kiln drying

This method will only prove economical when production of the bridges is linked to the manufacture of other products requiring dried timber.

Low-cost hot air kilns using oil drums or similar means should be employed with caution as severe degrade has been experienced with this type of driers.

Treatment

The heartwood of most of the hardwoods listed in annex III can be regarded as durable. Where sapwood, softwoods or non-durable hardwoods are used some method of chemical treatment will be necessary. Of the two methods described hereunder - diffusion and pressure treatment - the former has the advantage of requiring little capital expenditure but is not suitable in cases where timber is continually wet.

The diffusion process

A concentrated solution of suitable chemicals is applied to the outer surface of green timber; the solution diffuses into the interior of the material by molecules moving down a concentration gradient. The chemical usually applied in this process is known as BFCA and is a borofluoride-chrome-arsenic-compound which is highly termiticidal. Fungal growth is prevented by adding 1% sodium pentachlorophenate. The chemical is soluble in cold water, and a solution of 30% by weight in water is recommended.

The minimum moisture content required in the timber is 50% which means that the treatment should be carried out within a week or two after felling. By this method the precut pieces are simply dipped in the solution (alternatively a spray race may be used), then stacked closely and wrapped in plastic sheeting. The timber is left for four to eight weeks depending on the species and then stacked to season in the usual way.

The depth of penetration may be tested by using the following test reagents:

(a) Solution A: Add 10 g of turmeric powder to 100 ml of 95% methanol/alcohol and boil the mixture for one hour under a reflux condensor. Cool and filter the solution. This solution should be prepared freshly every two months;

(b) Solution B: Add 20 ml concentrated hydrochloric acid to 30 ml of 95% ethanol/methanol and saturate the solution with salicylic acid. Allow solution to stand and filter off excess solids. This solution will not spoil.

Control pieces of 1 m length are treated with the standard components. After treatment thin biscuits (10 mm thick) are cut, at least 200 mm away from the end of the piece. The slices are dried if not already seasoned. Then solution A is sprayed uniformly across the entire surface of a piece. After five minutes solution B is evenly sprayed on, taking care to saturate the wood. The samples should then be allowed to stand for 10 minutes.

A red colour indicates 0.3% boric acid equivalent. In general a 9-mm depth of penetration of 0.3% treatment can be regarded as satisfactory. If the depth is less than 9 mm, a larger diffusion time is required.

It is important to remember that the salts are poisonous and dangerous both in dry form and as a solution. All persons handling the material should wear protective clothing and wash their face and hands before breaks and at the end of the day.

Pressure treatment

Two processes are in general used, one called the "full-cell" process and the other the "empty-cell" process. In the full-cell process water-borne preservatives are applied while for the empty-cell process - except in cases of very severe exposure - oil-borne preservatives are used. The standard preservatives are:

<u>Preservative oils and oil-borne preservatives</u>

Creosote
Creosote-coal-tar solutions
Creosote-petroleum solutions
Pentachlorophenol
Copper naphthanate

<u>Water-borne preservatives</u>

Chromated zinc chloride (CZC)
Copperized chromated zinc chloride (CCZC)
Tanalith (Wolman salts)
Acid copper chromate (Celoure)
Chromate copper arsenate (ASCU, Greensalt, Endalith) (CCA)
Zinc meta arsenite (ZMA)
Ammonical copper arsenite (Chemonite)
Chromated zinc arsenite (Boliden salt)

The choice of the preservative to be used depends on its availability and its cost. All preservatives are reported to be effective against termite attack; for use in tropical climates it is recommended to add to the pentachlorophenol at least 1% of a persistent chlorinated hydrocarbon insecticide such as Lindane or Aldrin.

(a) <u>The full-cell process</u>: Use timber which has been seasoned to near its final moisture content.

1. Seal the timber in the treatment cylinder and apply a vacuum to remove the air from the cylinder and, as much as possible, from the wood.

2. Heat the preservative to slightly above treatment temperature and feed it into the cylinder without admitting air. Treatment temperatures for oil-borne and most water-borne solutions should be between 88°C and 93°F and 200°F); those for chromium salts should be about 70°C (160°F) to avoid precipitation of the preservative.

3. When the cylinder is filled, apply pressure until the required retention of oil has been achieved. (Recommended retentions are given below.) The pressure and the time of treatment required to achieve these retentions depends on the species and the pressure used, ranging from 7 to 14 kg/cm^2 (100 to 200 lb/in^2). Many softwoods are sensitive to high temperatures and pressures and damage may occur at pressures above 10 kg/cm^2 (140 lb/in^2).

4. Withdraw the preservative from the cylinder.

5. Apply a short final vacuum to remove excess preservative.

6. Leave the timber to dry until it reaches service moisture content.

(b) The empty-cell process: Two empty-cell processes are in common use, the Rueping and the Lowry process. The following is the general procedure for the Rueping process:

1. Seal the timber into the treatment cylinder and introduce air under pressure. The pressure used and the time of application varies according to the species. Usually pressures of 2 to 14 kg/cm^2 (35 to 200 lb/in^2) are applied for about 10 minutes or less.

2. Pump the preservative into the cylinder and allow the air to escape while maintaining the initial pressure. This is achieved by using an equalizing tank.

3. When the cylinder is full of preservative increase the pressure and maintain it for a sufficiently long time to give the required retention. Pressures will vary between 10 and 14 kg/cm^2 (140 and 200 lb/in^2) with softwoods being treated at the lower pressures.

4. Apply a final vacuum to remove surplus preservative from the cylinder.

The Lowry process is similar to the Rueping process, the only difference being that no initial air pressure is used and that the air expelled from the cylinder by the introduction of preservative is at atmospheric pressure.

Recommended retentions for bridges

	Net retention	
	kg/m^3	lb/ft^3
Creosote	96	6
Creosote-coal-tar solutions	96	6
Creosote-petroleum solutions	112	7
Pentachlorophenol	96	6
Copper naphthenate	96	6

	Net retention	
	kg/m^3	lb/ft^3
Celcure	8	0.5
Chemonite	5	0.3
Chromated zinc chloride	12	0.75
Tanalith	6	0.35
Boliden salt	8	0.50
Chromated copper arsenate	8	0.50

Facilities for checking the net retention usually exist in most government materials laboratories.

C. Steel components

Cutting and drilling

Dimensions of steel components are shown in figures 19-29. All components except the chords may be flame cut provided the tolerances of ±1 mm for chords and ±1 mm for all other steel components are not exceeded. Drill holes should be set out by centre-punching through templates made from 24-gauge steel sheets.

In some countries the standard length of the 100 mm x 6 mm strip from which the steel chords are made is 6 m. This means that there is considerable wastage if the standard chord Mk 2, which is 3.1 m long, is cut from a standard strip. In such cases it is preferable to use the alternative chords 2A and 6A shown in figures 23 and 25.

Welding

When testing steel components, most failures have been found in welds. It is important, therefore, to follow the drawings in regard to weld size rigourously, particularly when a pin is inserted through a hole in a plate and welded on the reverse side, such as in panel plates 1 and 9.

Under no circumstances should components be made up by welding together shorter or smaller pieces of steel except where specifically indicated on the drawings.

Where steels of different composition are to be welded together the remarks made under section A "steel procurement" of chapter II apply.

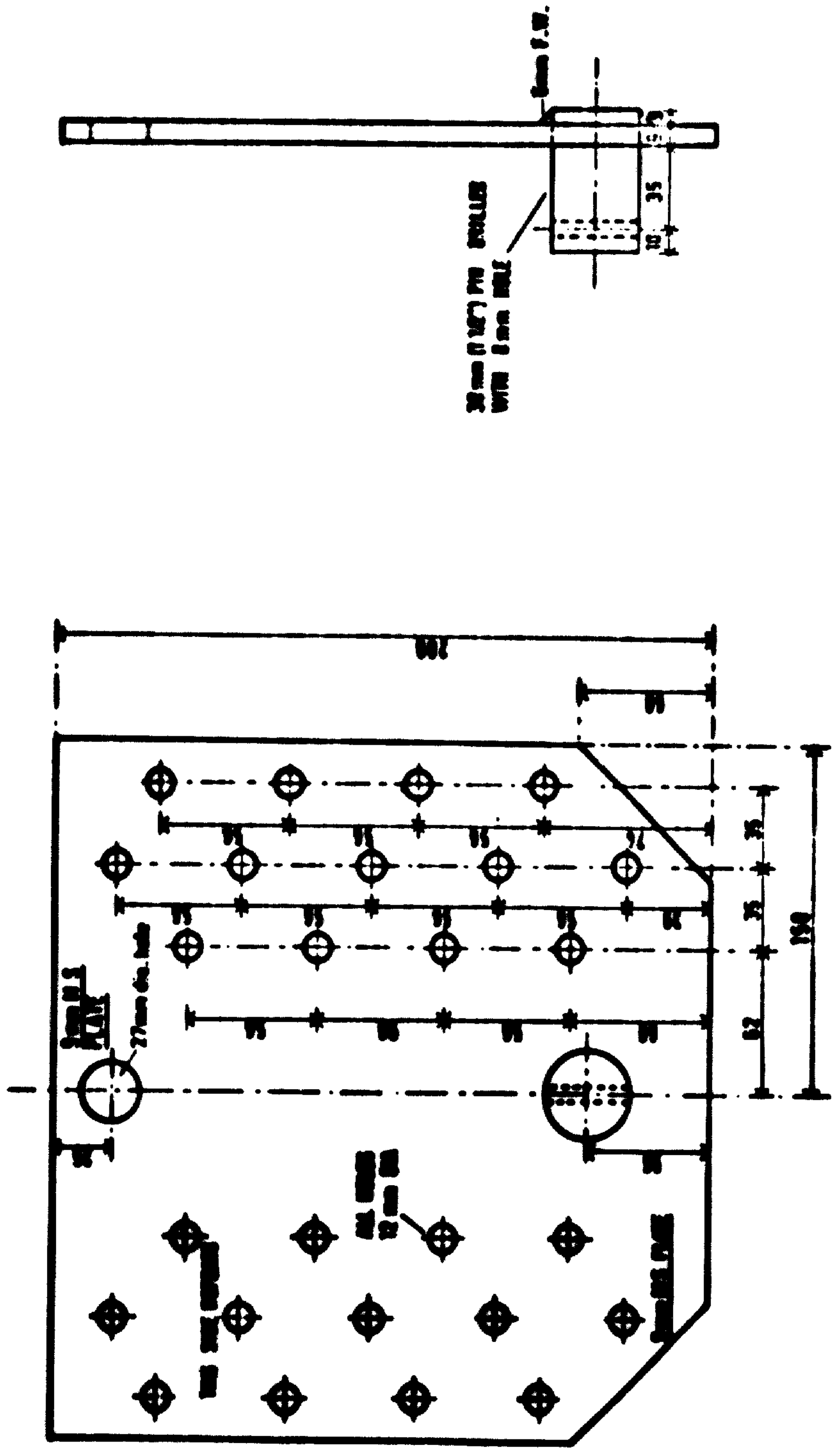
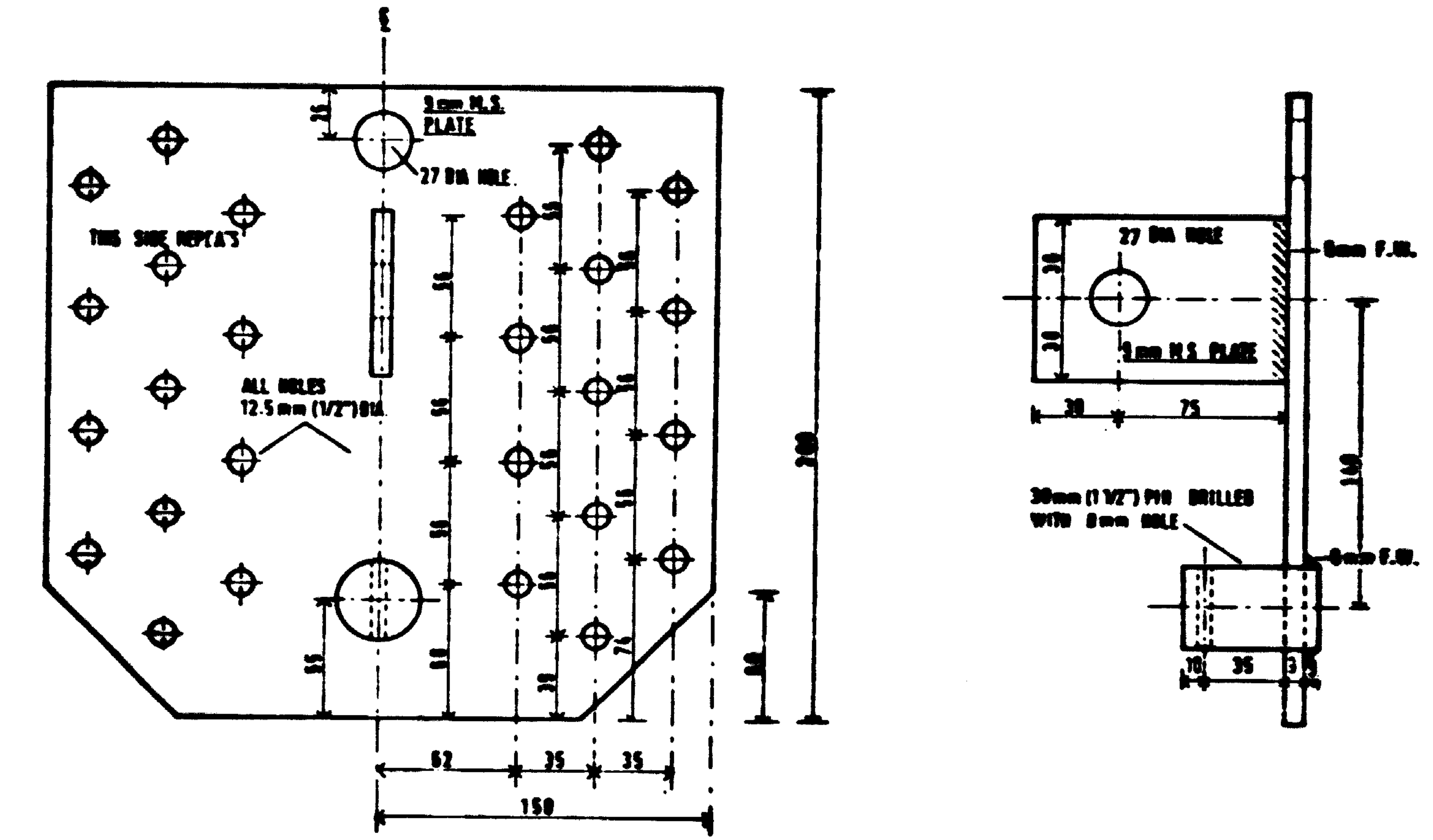


Figure 19. Panel plate 1

Figure 20. Panel plate 1A



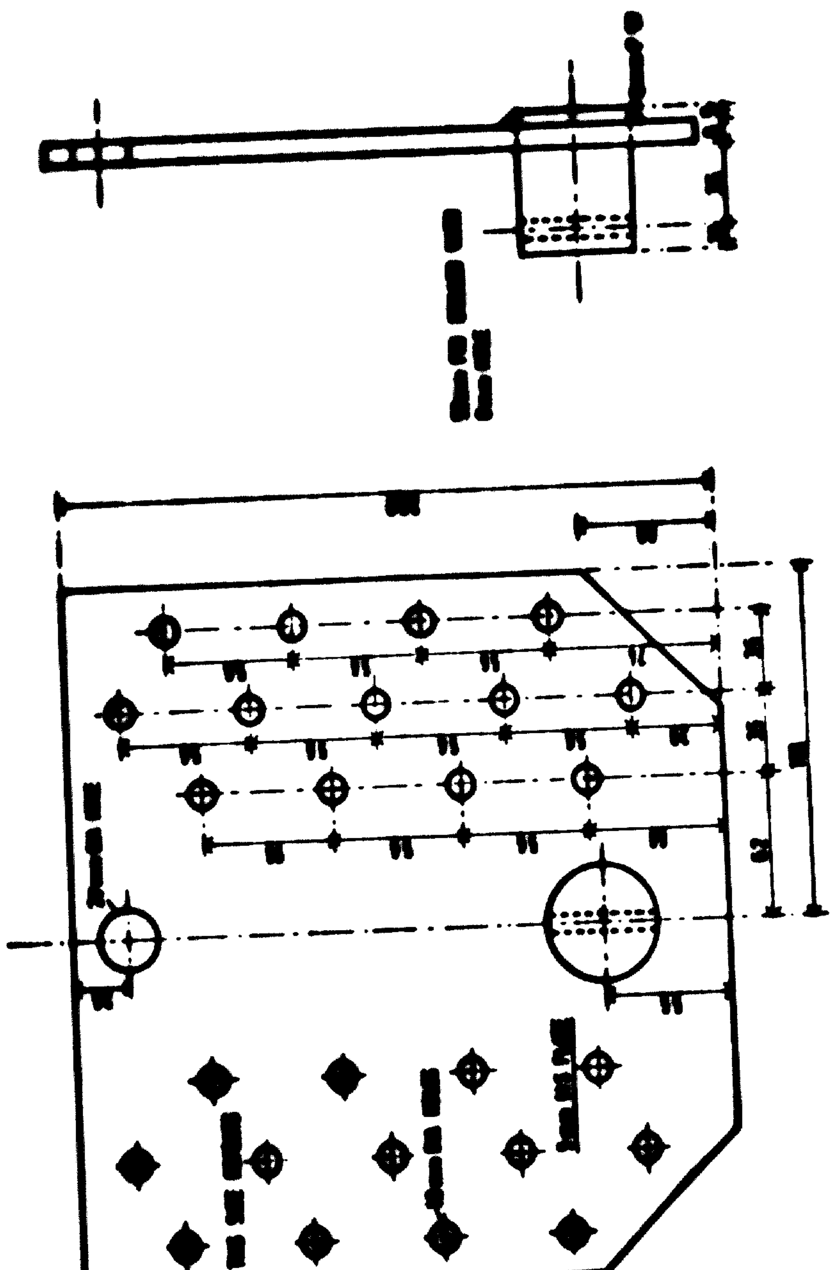


Figure 21. Panel plate 9

Figure 22. Panel plate 9A

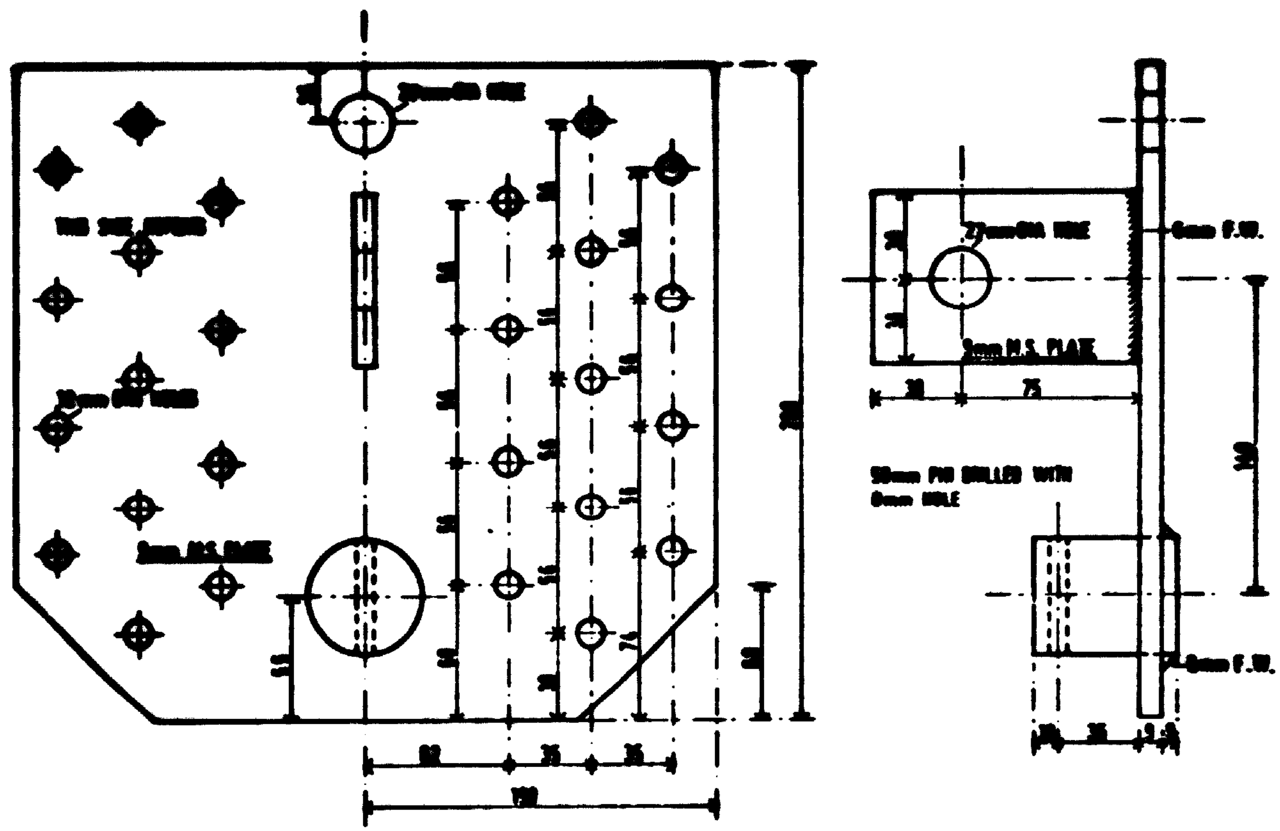


Figure 23. Chords 2 and 2A

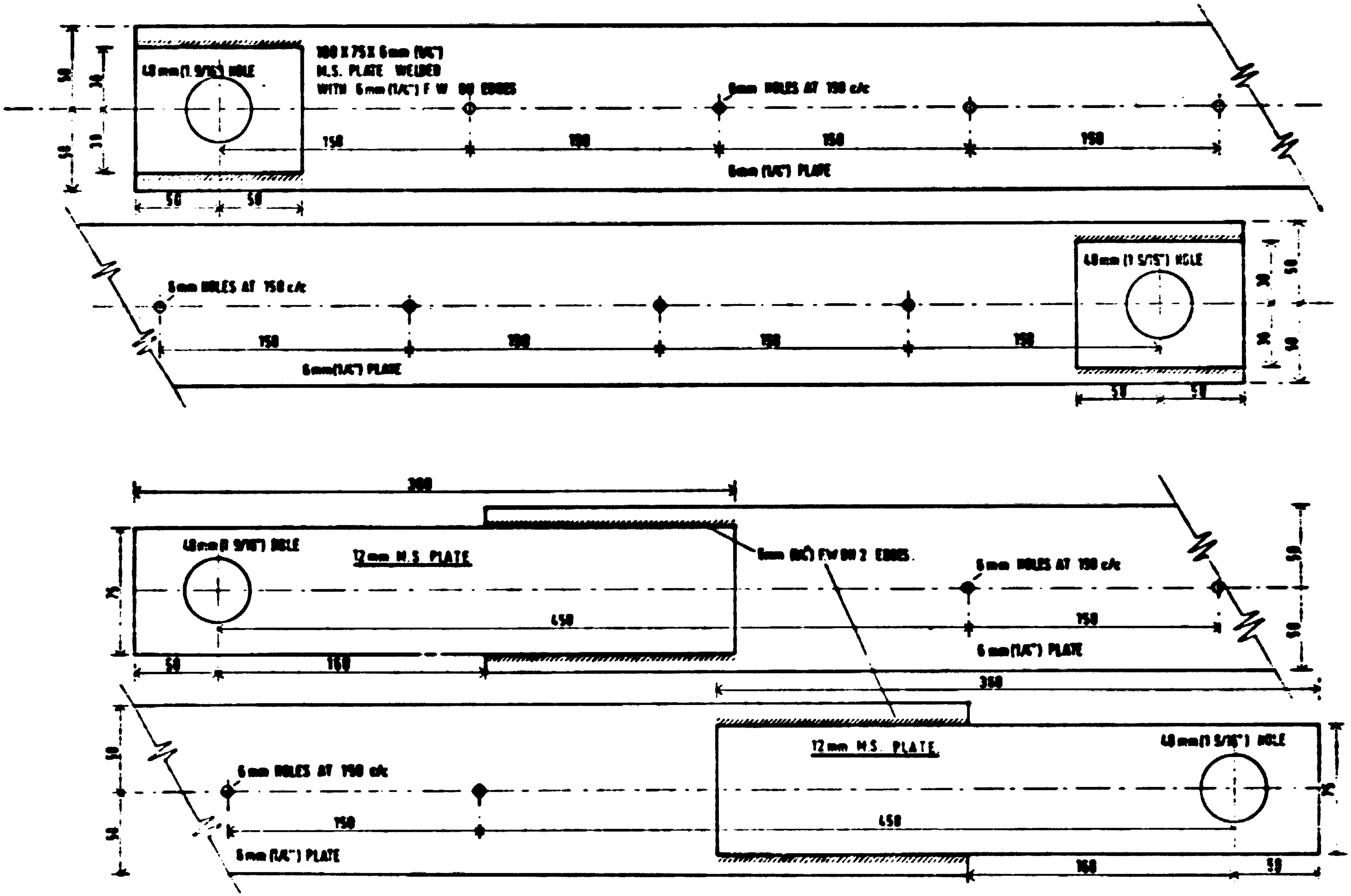


Figure 24. Chord 6

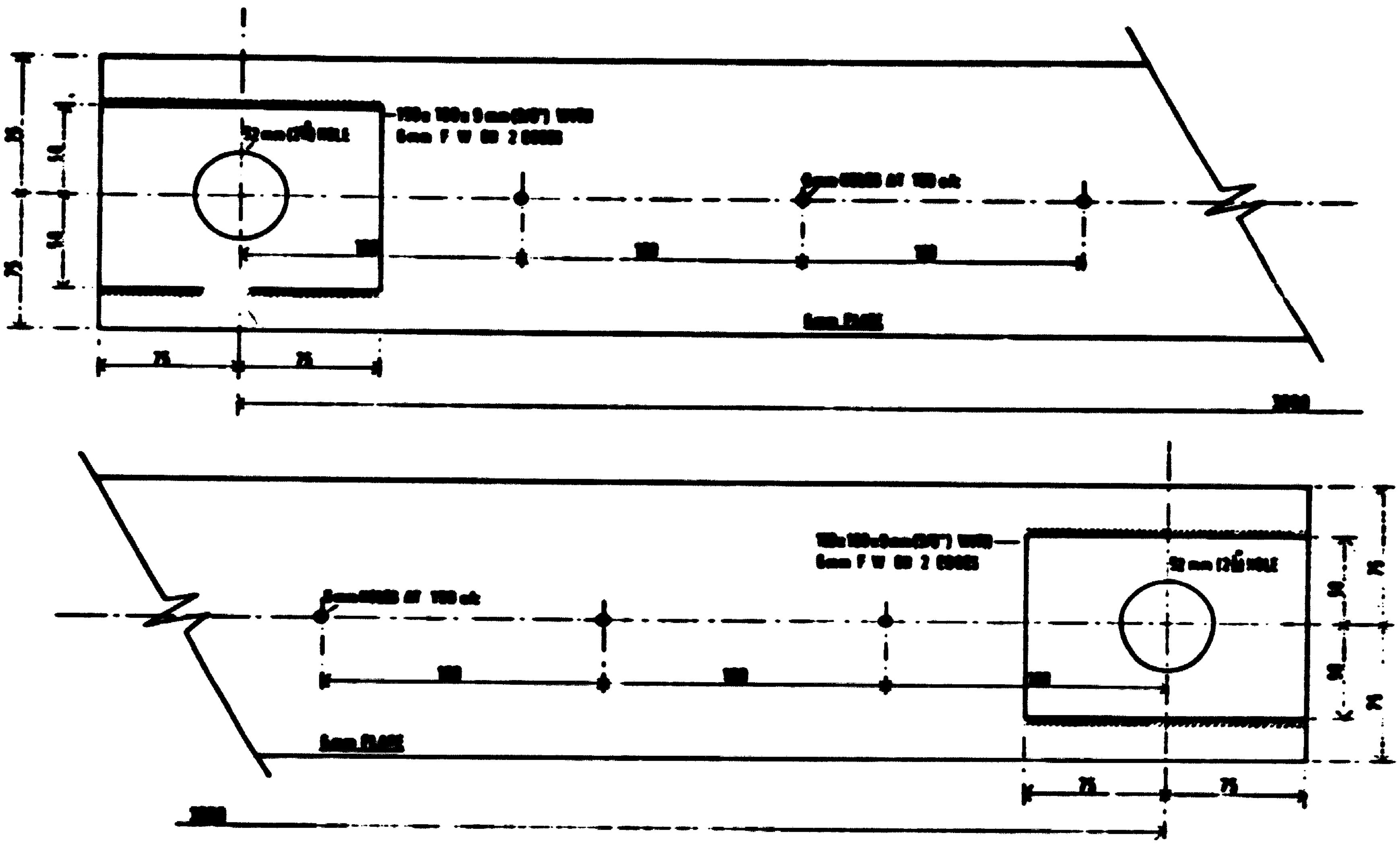


Figure 25. Chord 6A

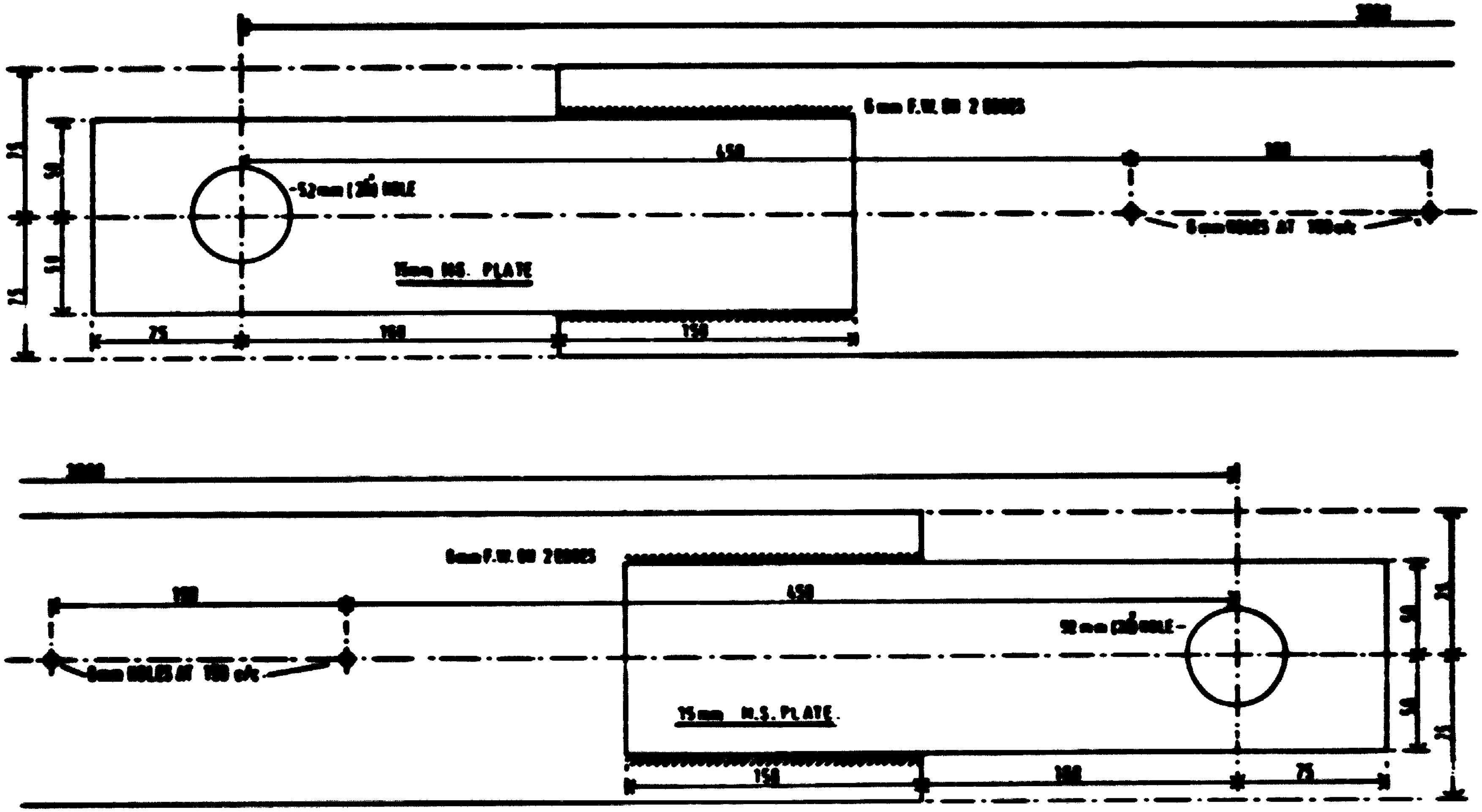


Figure 26. Panel plates 3, 4 10 and 11

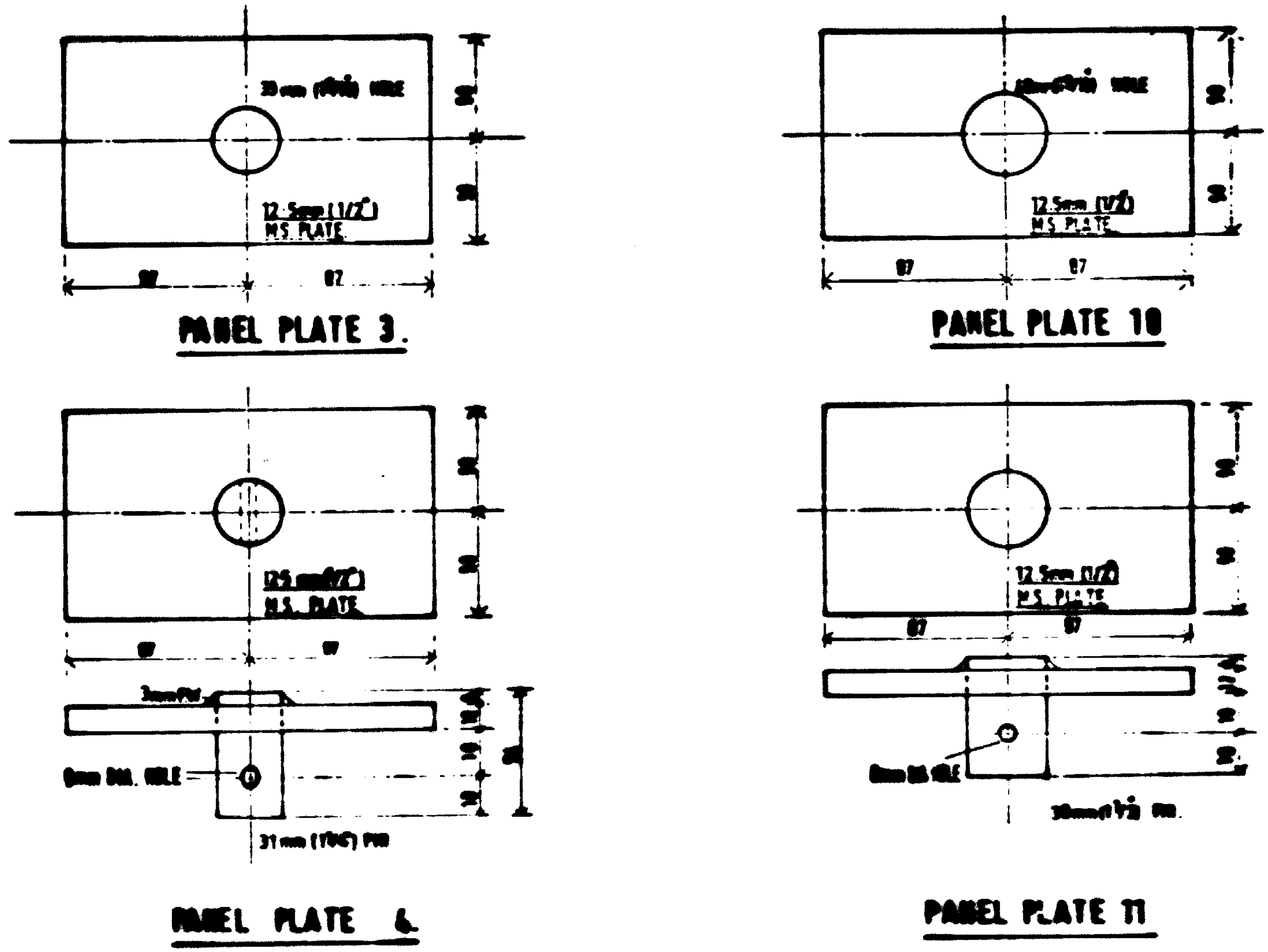


Figure 27. Panel plates 8 and 13

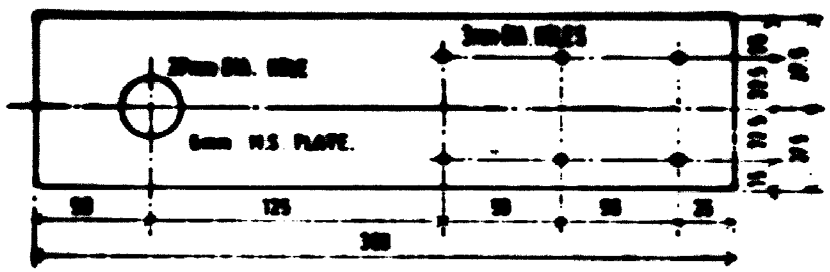
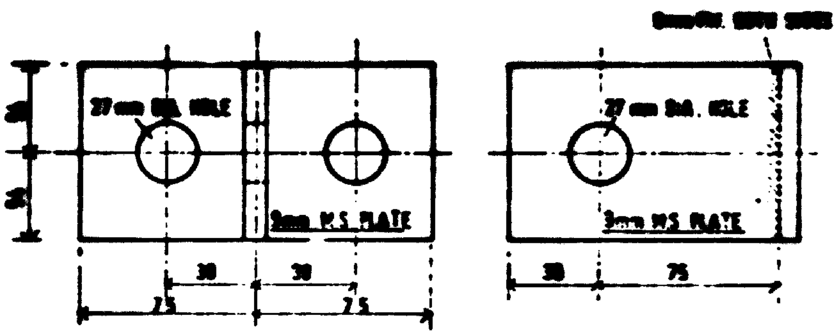


PLATE 8



BRACING CLEAT 13

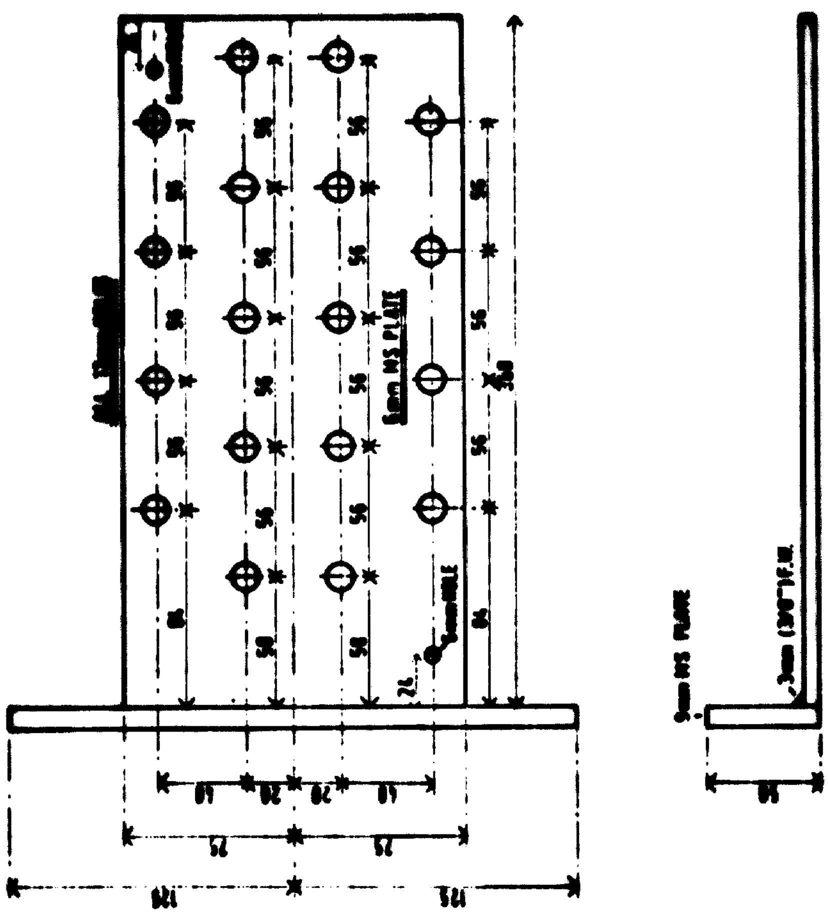
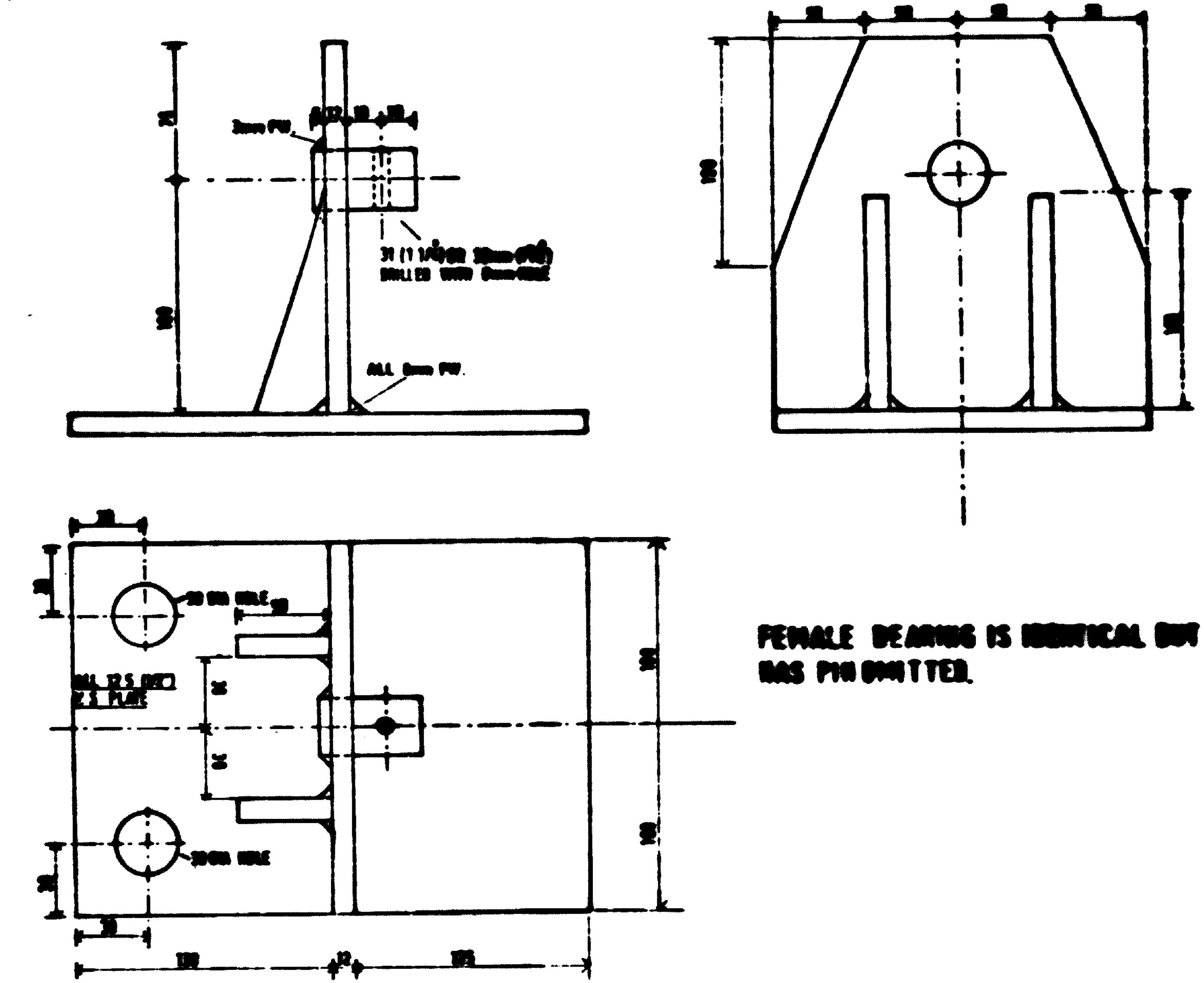


Figure 28. Panel plate 5

Figure 29. Bearings



D. Panel assembly

The assembly jig is shown in figures 30 and 31. The truss is assembled in two halves, each consisting of one piece mark 1T, two pieces mark 2T, one piece mark 3T and two pieces mark 4T.

Preservative treatment by one of the methods previously described should should have been carried out after cutting.

The two 200 mm x 50 mm (8" x 2") diagonals mark 2T are placed in the jig with their upper edges against the diagonal guides and the strut mark 3T is positioned between them and centred. The 250 mm x 50 mm (10" x 2") chord mark 1T is placed across the diagonals and centred on the marks shown on the end guides. These members are then fixed in position with a 100 mm (4") nail at each intersection.

Plates 5 and 1 or 1A (9 or 9A for heavy construction) are placed in position. One half of the panel is assembled using plate 1 (or 9), the other half using plate 1A (or 9A) so that the completed panel will have a bracing cleat on one side only. Use the loose template, as shown in figure 30, to position plates 1 or 9.

A hole of a diameter equal to that of the pin plus 6 mm and having a depth of 6 mm is then drilled or cut in the members mark 2T to allow plate 1 or 9 to lie flat. All plates are centered using the marks on the jig and fixed in position with 50-mm (2") nails in the 3-mm (1/8") holes provided. Drill 12-mm holes through the plates into the timber using a stop on the drill as shown in figure 32 to give a hole of 50 mm (2") depth where the hole is over a single member and of 100 mm depth where the 200 mm x 50 mm diagonal crosses the 250 mm x 50 mm chord. Insert in all holes dowels of a length equal to the depth of the hole by tapping with a light (1 kg) hammer.

Assemble the second half of the panel in the same way. Now lift the half panel with plate 1 (or 9) and place it in the jig, face down, i.e. with the connector plates against the jig bed. Place the other half with 1A (or 9A), face up, on top of its and centre all plates again on the centre marks. Drill the two diagonals with 4-mm (5/32") holes using the template shown in figure 33 and nail with 100-mm (4") nails. It has been assumed that 100 mm nails will be 4.88 mm (SWG 6) thick.

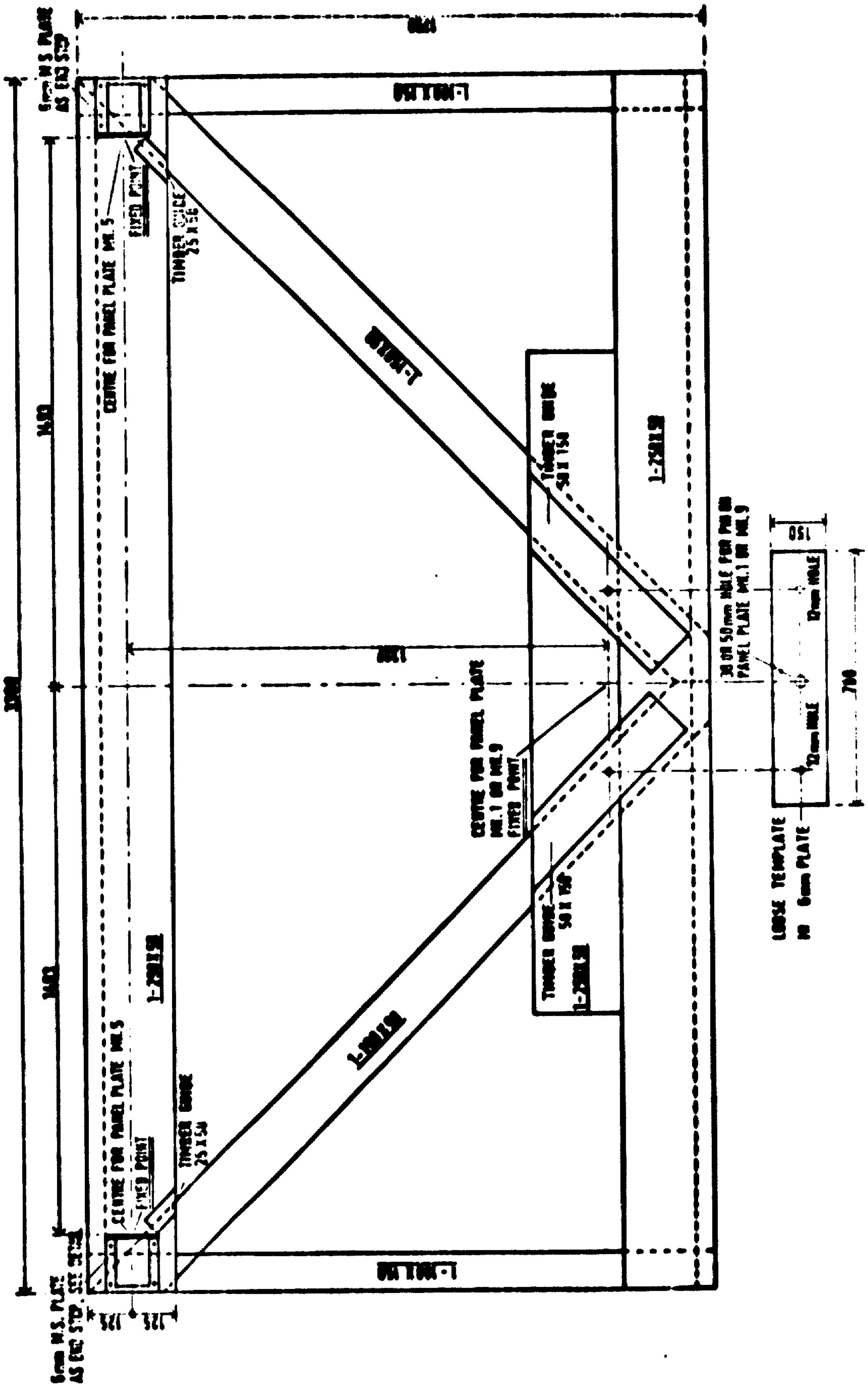


Figure 30. Assembly jig-plan

Figure 31. Assembly jig-elevations

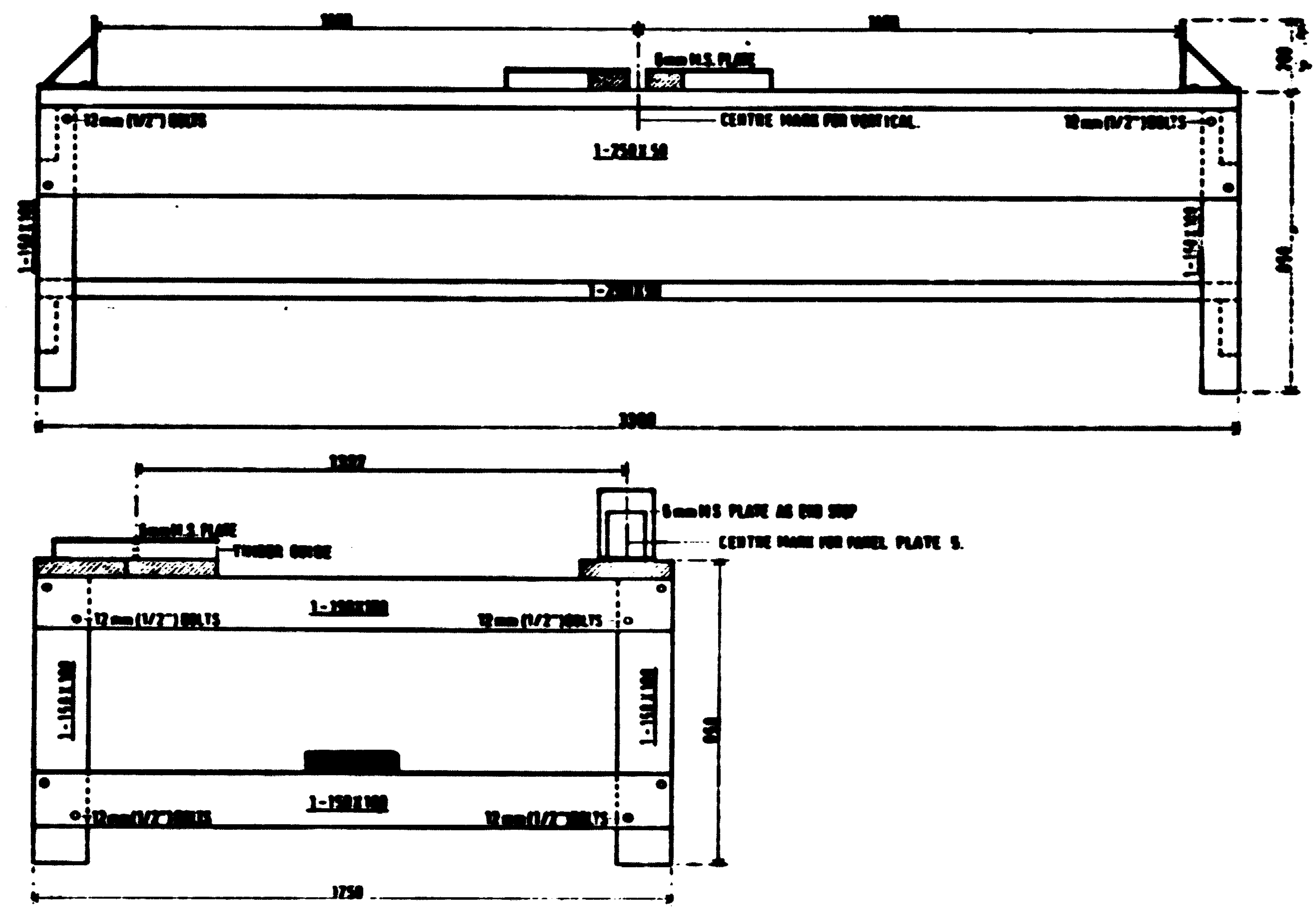
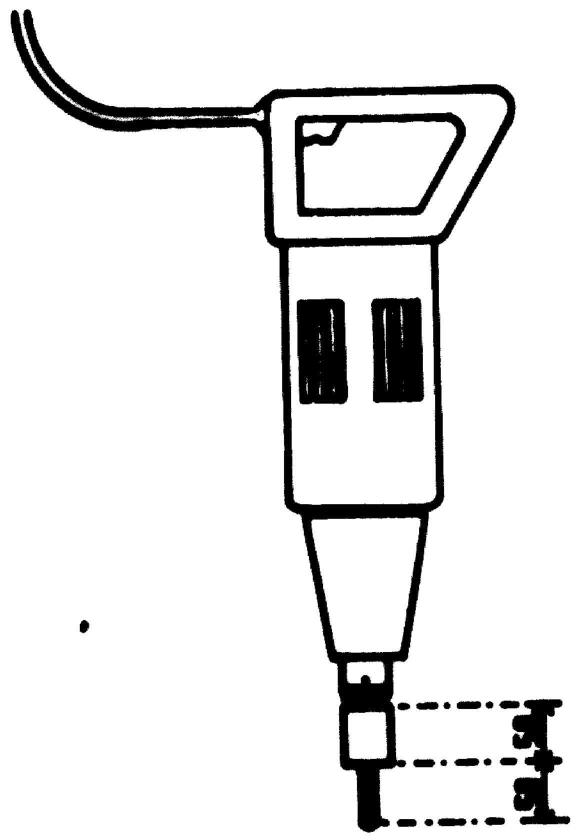


Figure 32. Jig for drilling holes through the plates

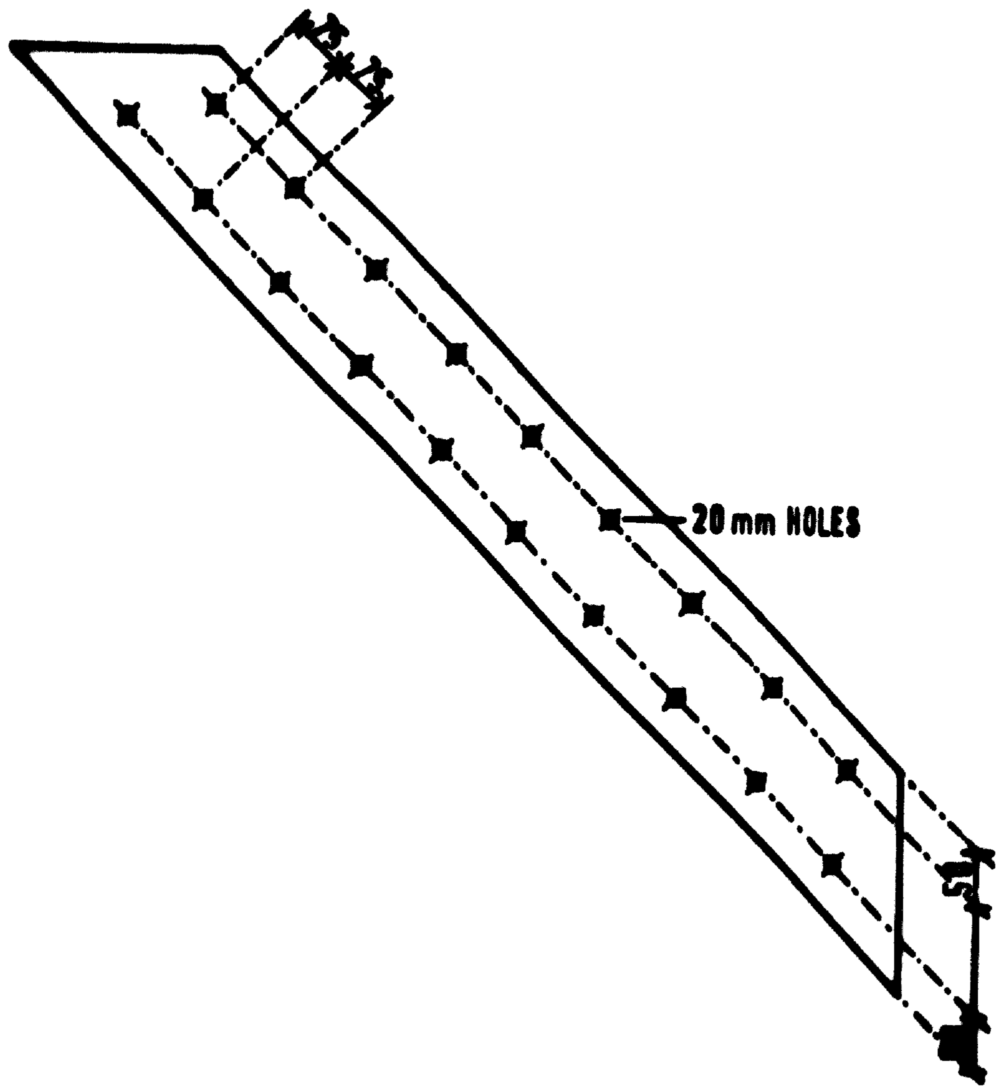


Insert two fillets mark 4T between the chords mark 1T and drill and nail with 100 mm (4") nails at 150 mm (6") centres. Then drill and fix with two 12 mm ø bolts using 50 mm square washers, 3 mm thick on each side.

Lift the panel out, turn it over and nail fillets mark 4T from the other side ensuring that nails are staggered by 75 mm (3"). Stack vertically ready for welding.

The dowels are tack-welded first. Ensure that the welds do not project from the face of the plate by more than 2 mm (1/16"). Now weld plate 3 (or 11) at one end and plate 4 (or 12) at the other, each in the centre of the vertical faces of plates 5 and 5A. Ensure that a full-length 6-mm (1/4") weld is made on all vertical edges.

Figure 33. Nailing template



Complete the panel by fitting two 275-mm (11") bolts in the chord with washers on the unprotected timber faces and one 175-mm (7") bolt in the bottom of the strut. One bracing cleat 13 is fitted at this stage. Do not attempt to force the bolts through the holes; they should be inserted by tapping with a light hammer.

III. ERECTION

Concrete or hollow-block foundations are not described in this report; it is assumed that these will have been prepared beforehand. The distances required between the faces of the abutments are indicated in figure 34 together with details assumed at the bearings.2/

A. Components and erection equipment

Table 7 lists all components required for constructing a bridge according to the instructions given in this report.

Erection equipment for wet crossing

Table 8 lists the equipment required for a crossing where intermediate supports cannot be used. The winches are of the "Tirfor" type and while these are not essential they have been found to be very satisfactory in use. In all cases the maximum load per cable - when the dimensions in table 9 are applied - is 1.6 t (except where noted).

Erection equipment for dry crossing

The dry-crossing method does not require the purchase of special equipment such as winches etc. and is preferable if continuous intermediate support is available under the span.

B. Wet-crossing method

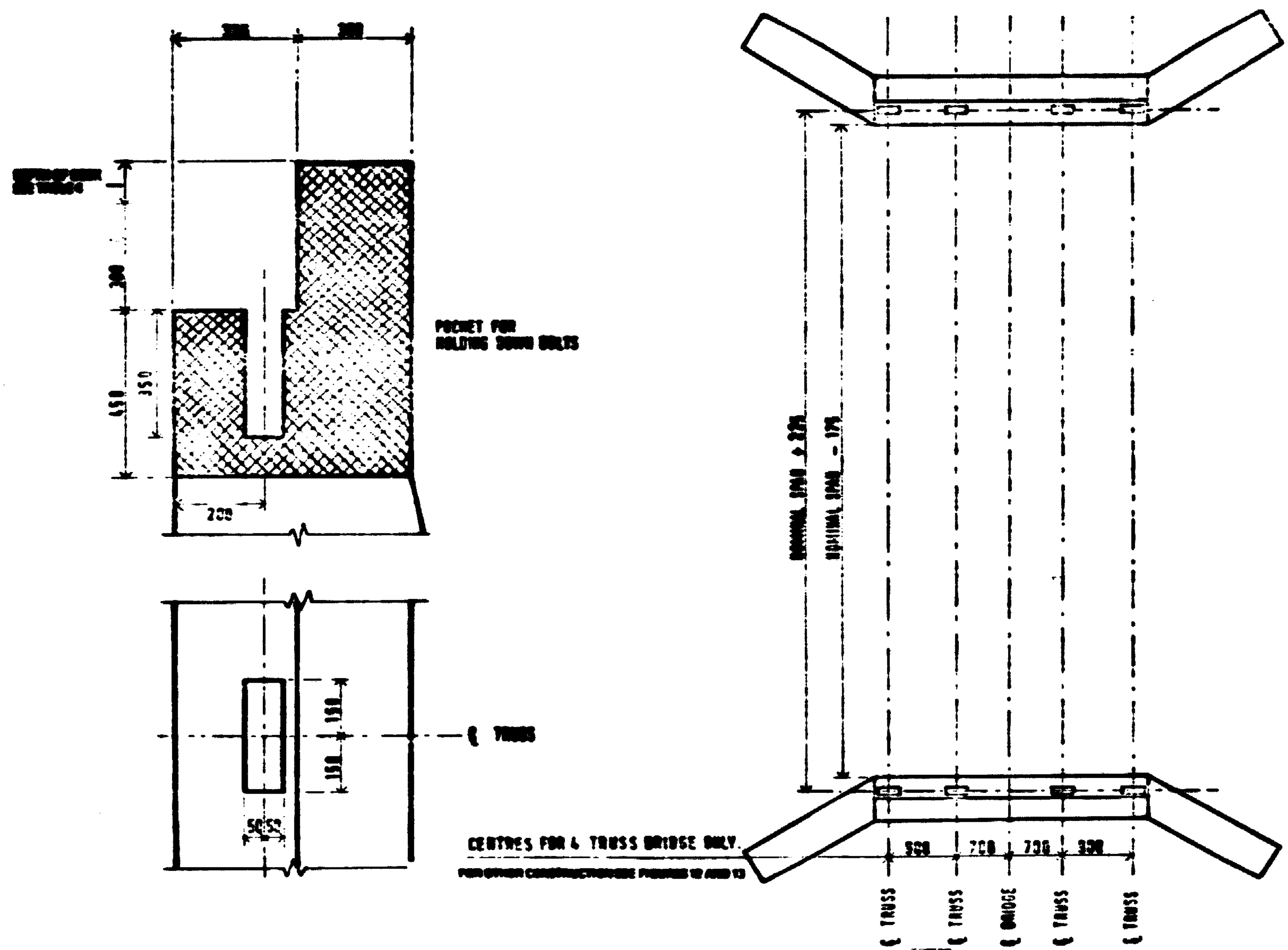
Preparation

Erect shear legs on either bank (see figure 35). These are made from 130 mm (6") diameter timber poles or 100 mm (4") steel tubes (see figure 36).

Establish anchors on the line of the shear legs for cable anchorage. This is made by burying a log with a steel rope attached in a trench as shown in figures 37 and 39. Ensure that the rope is led through the side of the trench by cutting a groove as shown in the drawing. Alternatively a tree growing in a suitable location may be used.

2/ Under the new project "Development of new timber products" (DP/KEN/77/007) timber abutments will be tested and their design and production will be the subject of a separate technical report supplementing the present one.

Figure 34. Foundation setting out



A standing cable is inserted between the shear legs as shown in figure 35 and attached to winch No. 1 which is in turn shackled to an anchor on the far side. Adjust the slack in the wire to give the required length hanging between pulleys (see table 9).

Table 7. Components

A. Two-truss bridge

	Span (m)								
Component	6	9	12	15	18	21	24	27	30
Panel	4	6	8	10	12	14	16	18	20
Chord	4	8	12	16	20	24	28	32	36
Vertical bracing	4	6	8	10	12	14	16	18	20
Bracing bolts (each with 2 nuts 1 washer)	8	12	16	20	24	28	32	36	40
Horizontal bracing	2	3	4	5	6	7	8	9	10
Decking,[a] excluding waste (m)	456	684	912	1 140	1 368	1 596	1 824	2 052	2 280
Running strips,[a] excluding waste (m)	48	54	72	90	108	126	144	162	180
Kerb,[a] excluding waste (m)	12	18	24	30	36	42	48	54	60
Bearings	4	4	4	4	4	4	4	4	4
Bearing bolts (each with 1 nut)	8	8	8.	8	8	8	8	8	8
150-mm (6 in) nails (kg)	14	22	30	37	44	52	60	67	74
100-mm (4 in) nails (kg)	53	78	104	130	155	180	205	232	258
Temporary erection bracing (m)	20	30	40	50	60	70	80	30	100

B. Four-truss bridge

Component	Span (m)								
	6	9	12	15	18	21	24	27	30
Panel	8	12	16	20	24	28	32	36	40
Chord	8	16	24	32	40	48	56	64	72
Vertical bracing	8	12	16	20	24	28	32	36	40
Bracing bolts (each with 2 nuts, 1 washer)	16	24	32	40	48	56	64	72	80
Horizontal bracing	4	6	8	10	12	14	16	18	20
Decking,[a] excluding waste (m)	456	584	912	1 140	1 368	1 596	1 624	2 052	2 280
Running strips,[a] excluding waste (m)	48	54	72	90	108	126	144	162	180
Kerb,[a] excluding waste (m)	12	18	24	30	36	42	48	54	60
Bearings	8	8	8	8	8	8	8	8	8
Bearing bolts (each with 1 nut)	16	16	16	16	16	16	16	16	16
150 mm (6 in) nails (kg)	14	22	30	37	44	52	50	57	74
100-mm (4 in) nails (kg)	53	78	104	130	155	180	205	232	258
Temporary erection bracing (m)	24	36	48	60	72	84	96	108	129

C. Six-truss bridge

Component	Span in metres								
	6	9	12	15	18	21	24	27	30
Panel	12	18	24	30	36	42	48	54	60
Chord	12	24	36	48	60	72	84	96	108
Vertical bracing	8	12	16	20	24	28	32	36	40
Bracing bolts (each with 2 nuts, 1 washer)	16	24	32	40	48	56	64	72	80
Horizontal bracing	4	6	8	10	12	14	16	18	20
Decking, a/ excluding waste (m)	456	684	912	1 140	1 388	1 596	1 824	2 052	2 280
Running strips a/ excluding waste (m)	48	54	72	90	108	126	144	162	180
Kerb a/ excluding waste (m)	12	18	24	30	36	42	48	54	60
Bearings	12	12	12	12	12	12	12	12	12
Bearing bolts (each with 1 nut)	24	24	24	24	24	24	24	24	24
150 mm (6 in) nails (kg)	14	22	30	37	44	52	60	67	74
100 mm (4 in) nails (kg)	53	78	104	130	155	180	206	232	258
Temporary erection bracing (m)	24	36	48	60	72	84	96	108	120

B. Eight-truss bridge

Component	Span (m) 6	9	12	15	18	21	24	27	30
Panel	16	24	32	40	48	56	64	72	80
Chord	16	32	48	64	80	96	112	128	144
Vertical bracing	8	12	16	20	24	28	32	36	40
Bracing bolts (each with 2 nuts, 1 washer)	16	24	32	40	48	56	64	72	80
Horizontal bracing	4	6	8	10	12	14	16	18	20
Decking,[a] excluding waste (m)	456	684	912	1 140	1 368	1 596	1 824	2 052	2 280
Running strips[a] excluding waste (m)	48	54	72	90	108	126	144	162	180
Kerb[a] excluding waste (m)	12	18	24	30	36	42	48	54	60
Bearings	16	16	16	16	16	16	16	16	16
Bearing bolts (each with 1 nut)	32	32	32	32	32	32	32	32	32
150-mm (6 in) nails (kg)	14	22	30	37	44	52	60	67	74
100-mm (4 in) nails (kg)	53	78	104	130	155	180	205	232	258
Temporary erection bracing (m)	24	36	48	60	72	84	96	108	120

a/ For sizes see table 4 and figure 42.

Table 8. Wet crossing equipment

Item	Number required
Tirfor winches or similar 1.6 t or 3 t (see table 9)	4
Double-sheaved blocks safe working load 3 t	2
Single-sheared block, safe working load 3 t	1
Bow shackles, safe working load 2 t	8
Anchor wires (see figure 37)	2
Suspension wire with safety hook, 1 = 30 m a/	1
Rear and forward haul wires with safety hooks, 1 = 15 m a/	2
Rear and forward harness (see figure 39)	2
Shear legs	2
Temporary horizontal bracing (100 x 50)	See table 7
Nails for the above	

a/ 1 = hanging length between pulleys (see table 9).

Table 9. Launching data

Span (m)	Length (1) hanging between vertical shear legs (m)	Maximum permissible sag (h) in cable between shear legs (m)	Maximum wieght of panel when using 1.6-t winch a/ (kg)
6	12.4	4	-
9	12.4	4	-
12	15.5	4	-
15	19.0	4.5	240
18	22.5	5	240
21	26.0	5	240
24	28.8	5	200
27	32.3	5.5	190
30	35.1	5.5	160

a/ For heavier panels use 3-t winches.

Stress grade	Approximate weight of panel (kg)
F4	108
F5	118
F7	131
F8	147
F11	165
F14	186
F17	208
F22, 24, 27	237

Figure 35. Components and erection equipment (wet crossing)

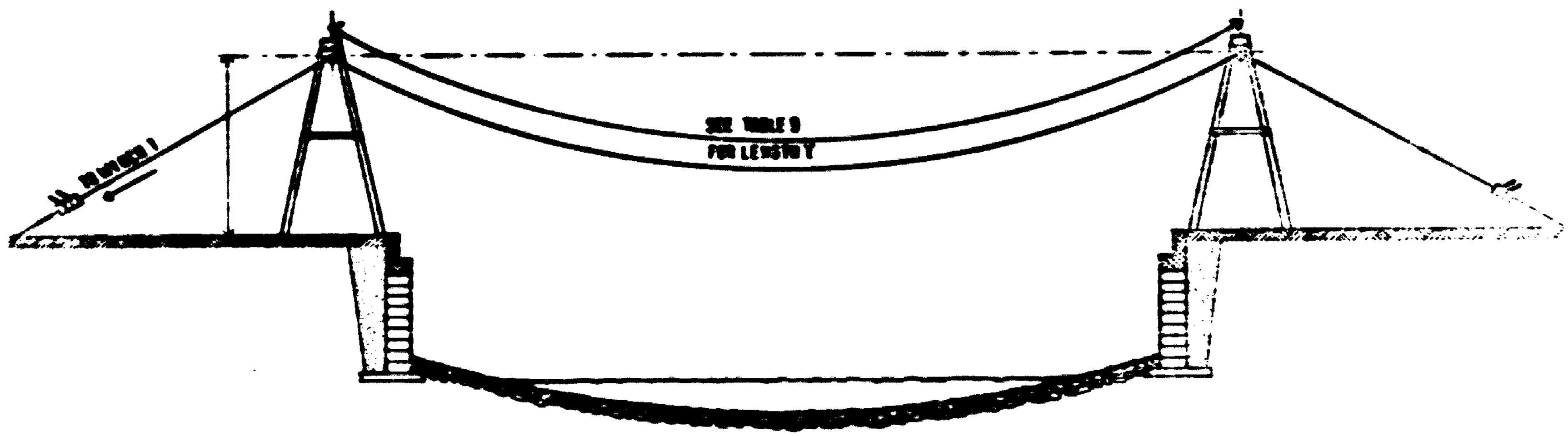


Figure 36. Shear legs

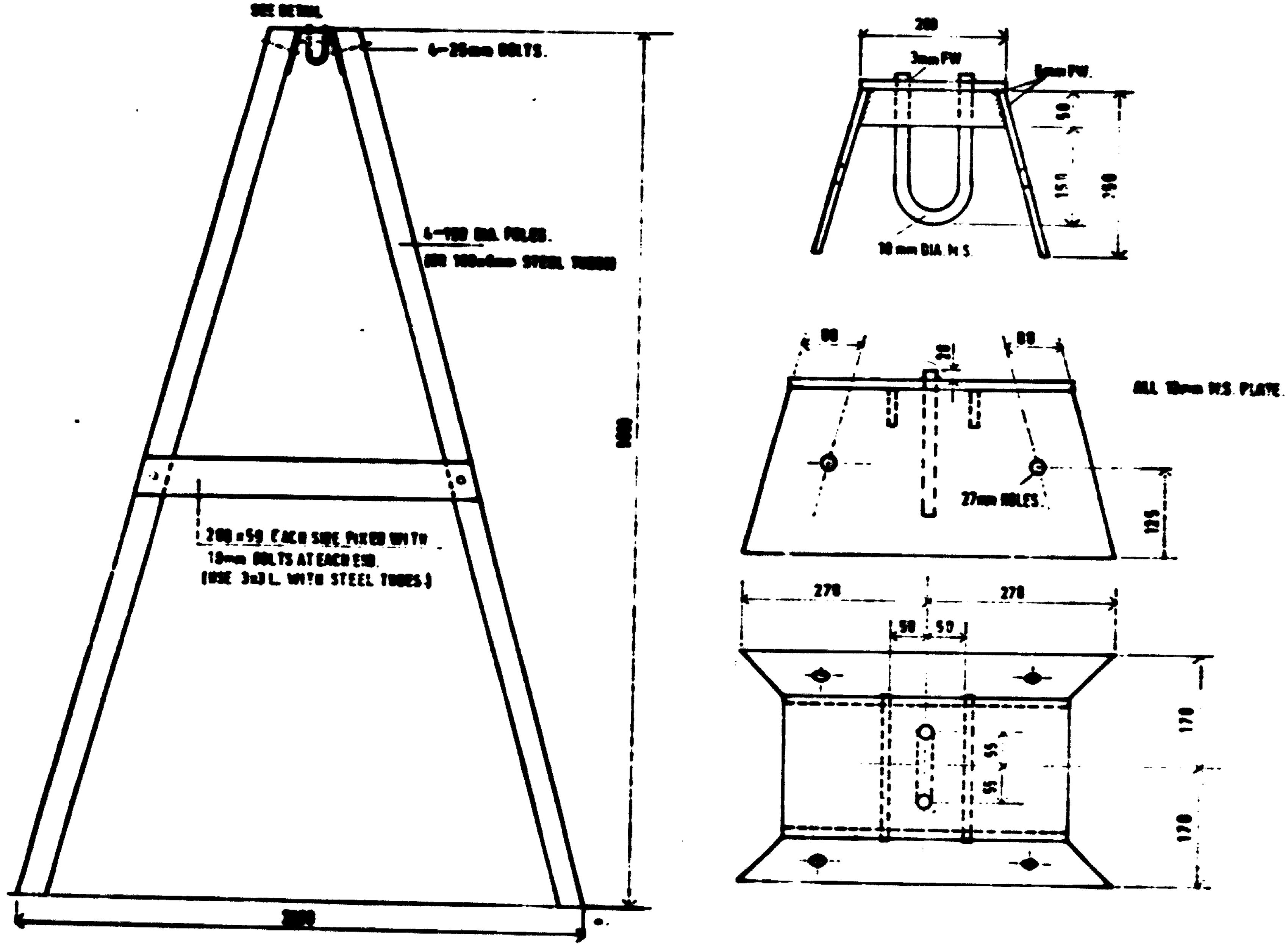


Figure 37. System for the establishment of cable anchorage and assembly of trusses (wet crossing)

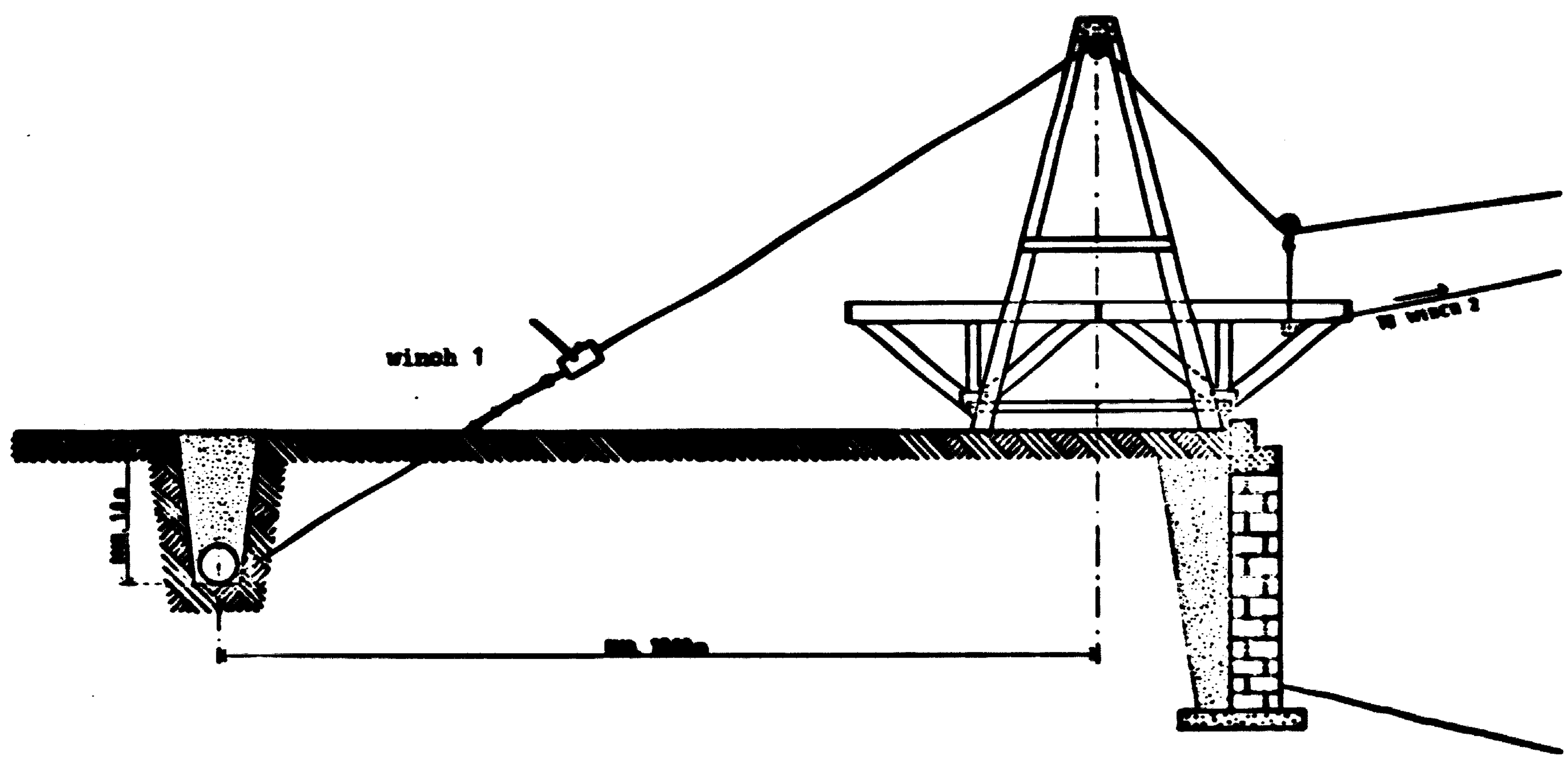


Figure 38. Erection equipment for wet crossing showing shear legs and lifting harness

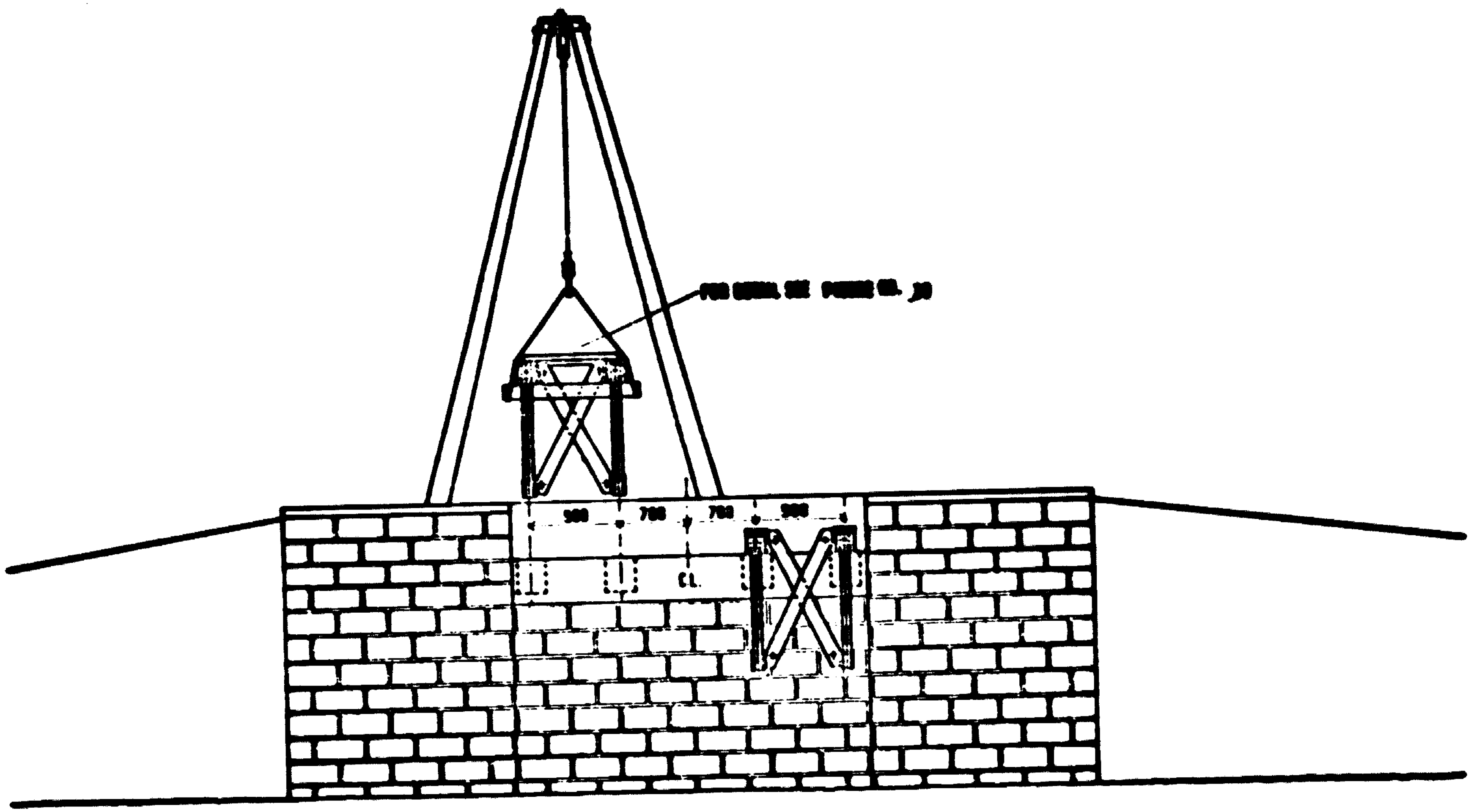
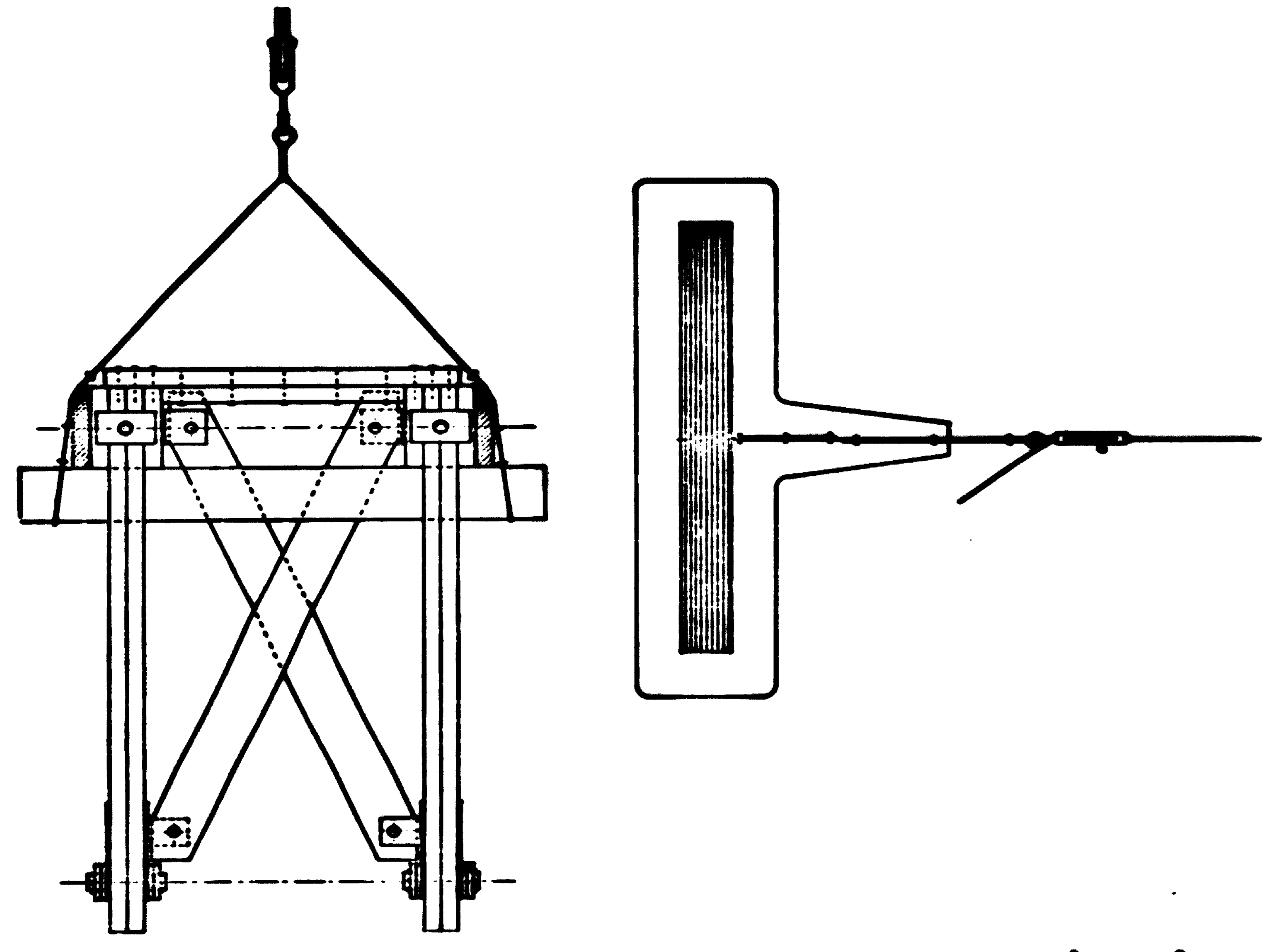


Figure 39. Wet-crossing erection system and lifting harness



Initial assembly

The trusses having vertical bracing between them are erected first. Assemble two pairs of panels together with the chords under the centre of one shear leg with permanent vertical bracing and temporary horizontal bracing in position as shown in figure 37. Secure the chords with 6-mm pins or nails and nail 100 mm x 100 mm fillets between them. Note that one truss is reversed to allow the bracing lugs to face inwards. Attach the lifting harness shown in figure 39 to the front of the leading panels.

Shackle snatch block to the harness and attach it to the standing cable. Shackle winch no. 1 to anchorage, lead the rope through the double sheave block and attach it to the front harness as shown in figure 37.

Initial launch

Use winch no. 2 to pull the assembly out onto the span using timber levers to ease the bottom of the panels over obstructions. It is important that the bottom chords are always in tension and initially it may be necessary to use winch 1 to ensure this.

Successive launches

Attach a further pair of panels to the assembly together with the permanent vertical and temporary horizontal bracing. Use winch no. 2 to pull the assembly out onto the span as shown in figure 40. Repeat the process until all the panels in the span have been assembled.

Final stage

Shackle winch no. 3 to its anchor. Use winches 2 and 3 to bring the ends of the assembled truss over the bearings. Before lowering the truss, attach it to the end panels and secure it with nails in holes. Lower the assembled truss onto the bearings using winches 2 and 3 and slackening winch 1 at the same time. While lowering, the trusses can be moved easily sideways by using levers at each end (see figure 41).

Figure 40. Launching of trusses (wet crossing)

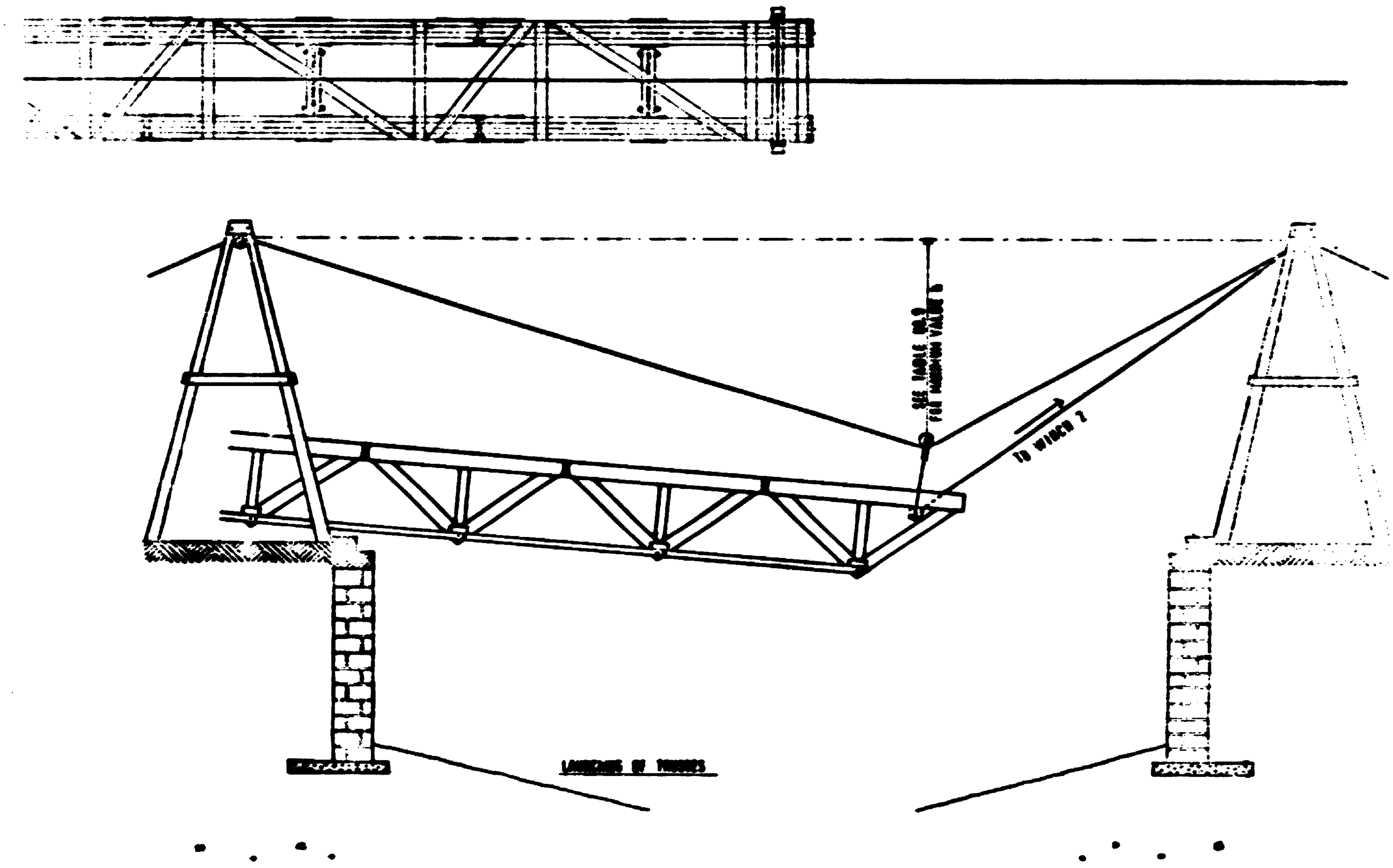
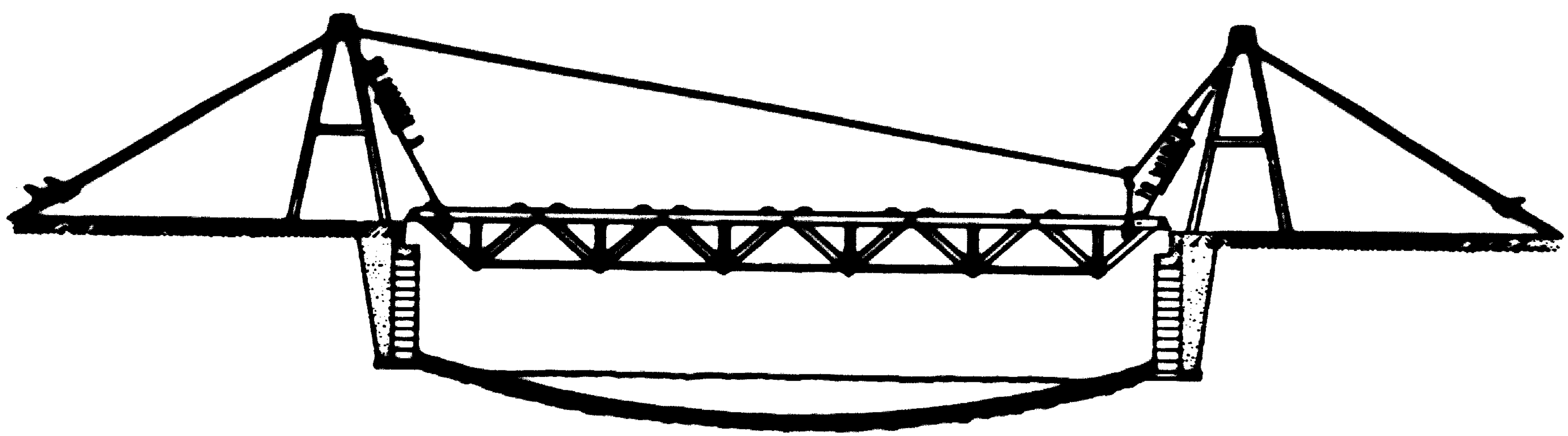


Figure 41. Launching of trusses - final stage



Decking

The decking is fixed as shown in figure 42. The temporary horizontal bracing is removed from one bay at a time and the deck, together with the permanent horizontal bracing, is fixed in position. A new bay can be started when the previous one has been completed.

Erect the decking on the first bay when all extra trusses have been fixed in bay 2. Repeat this procedure for the remaining bays, erecting the deck progressively one bay in arrears.

Extra trusses

The method described above can be used satisfactorily for bridges with two or four trusses. For more than four trusses the additional panels are launched one at a time before the permanent horizontal bracing and decking is fixed. The standing cable and winches 1 and 2 are used to carry the panels to their final location.

Attach the first panel with a wire sling to the snatch block on the standing cable, and use winches 2 and 3 to transport it to the first position (see figure 43). Place two 100 mm x 100 mm (4" x 4") bearers of 4 m length across the erected trusses and lower the panel into them with the bottom facing its final location (see figure 44). Slide the panel into vertical position using the winches and bearers as levers and locate it in bearing. Level the top of the panel with the erected trusses and secure temporarily with the support shown in figure 45.

Erect the remaining panels in the first bay using the same means. Place staging across chords of erected trusses in the first and second bays. Position the panel in bay 2 using the same procedure as for bay 1 and attach the chord to first and second panels. Remove the temporary support by slightly raising the panels and use it to support the second panel. Repeat for all panels in bay 2, and for all remaining bays.

Completion

Complete the bridge by adding kerbs, handrail and running strips (see figures 42 and 46 to 49).

Figure 42. Deck construction

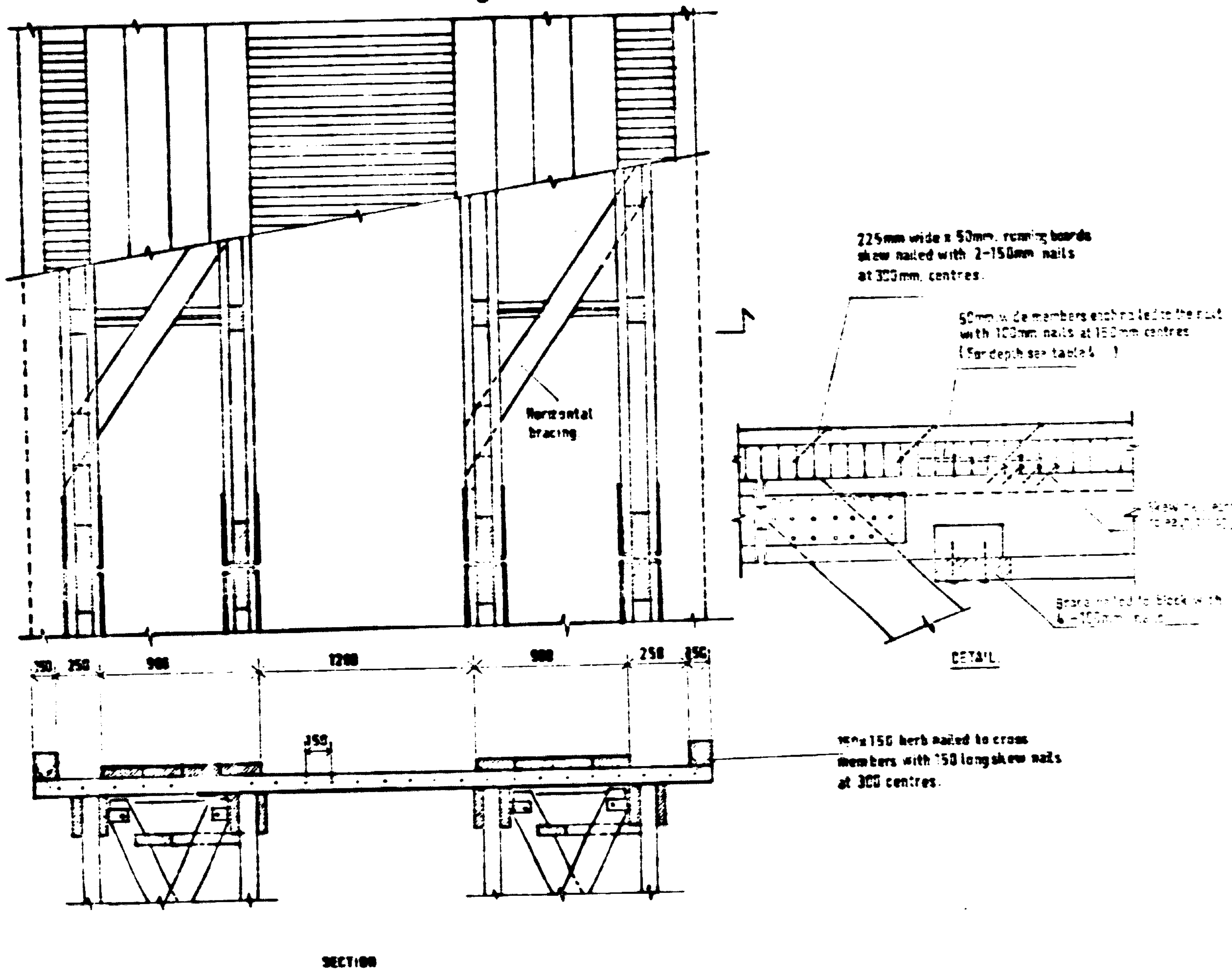


Figure 43. Launching of additional panels where the number of trusses exceeds four

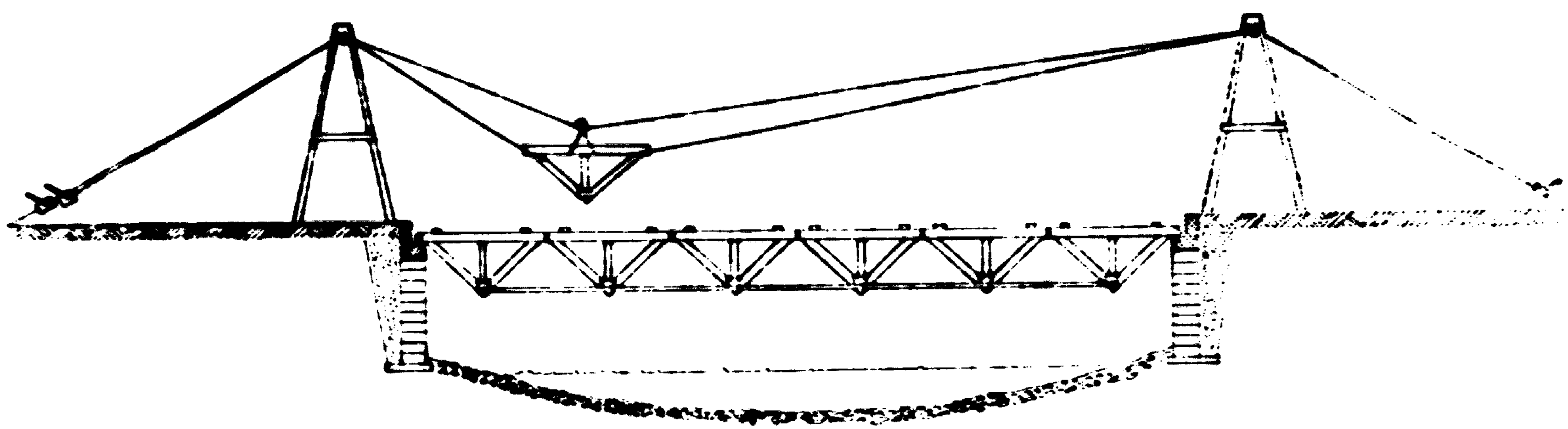


Figure 44. Sliding extra panel into position

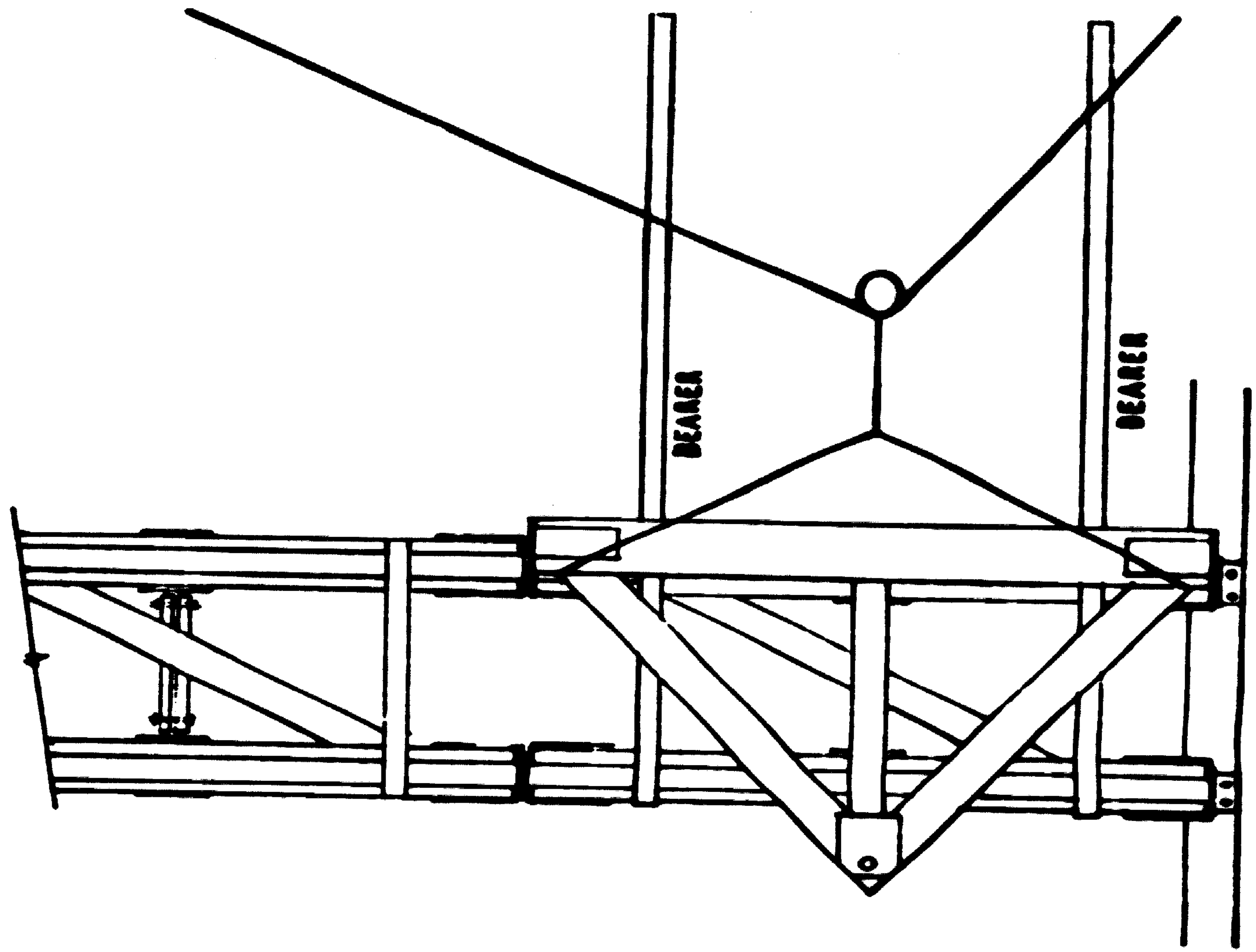
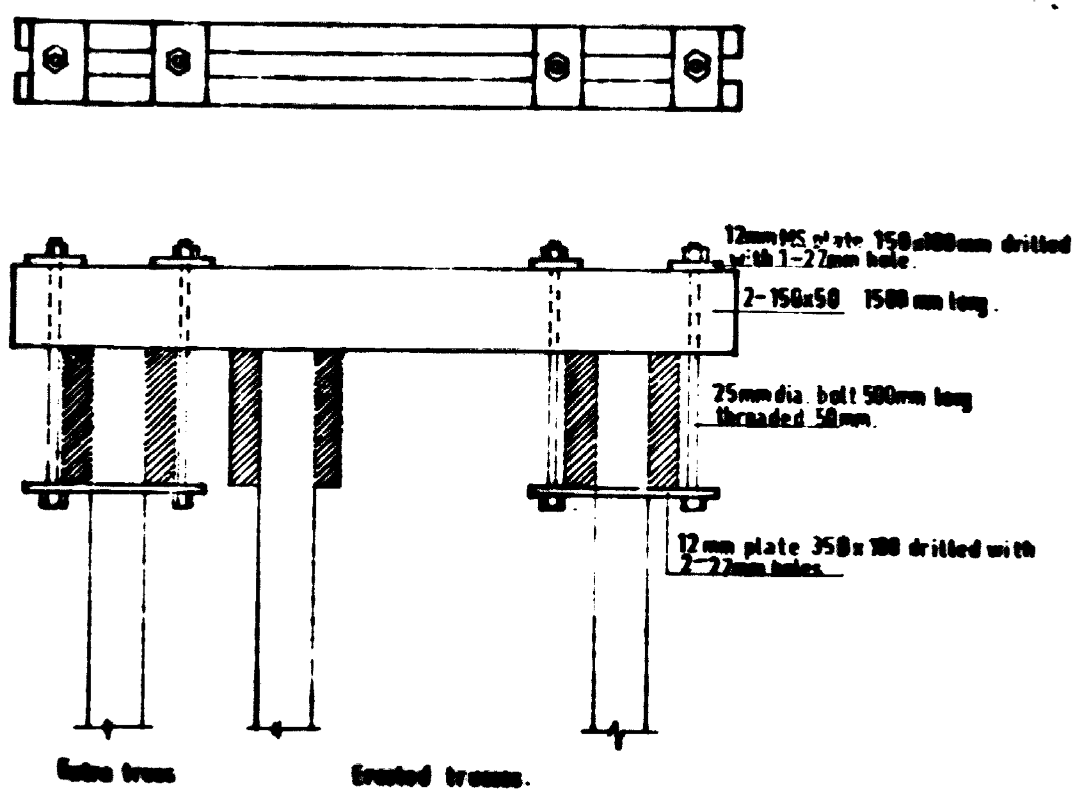


Figure 45. Applying temporary support of the panel to the erected truss



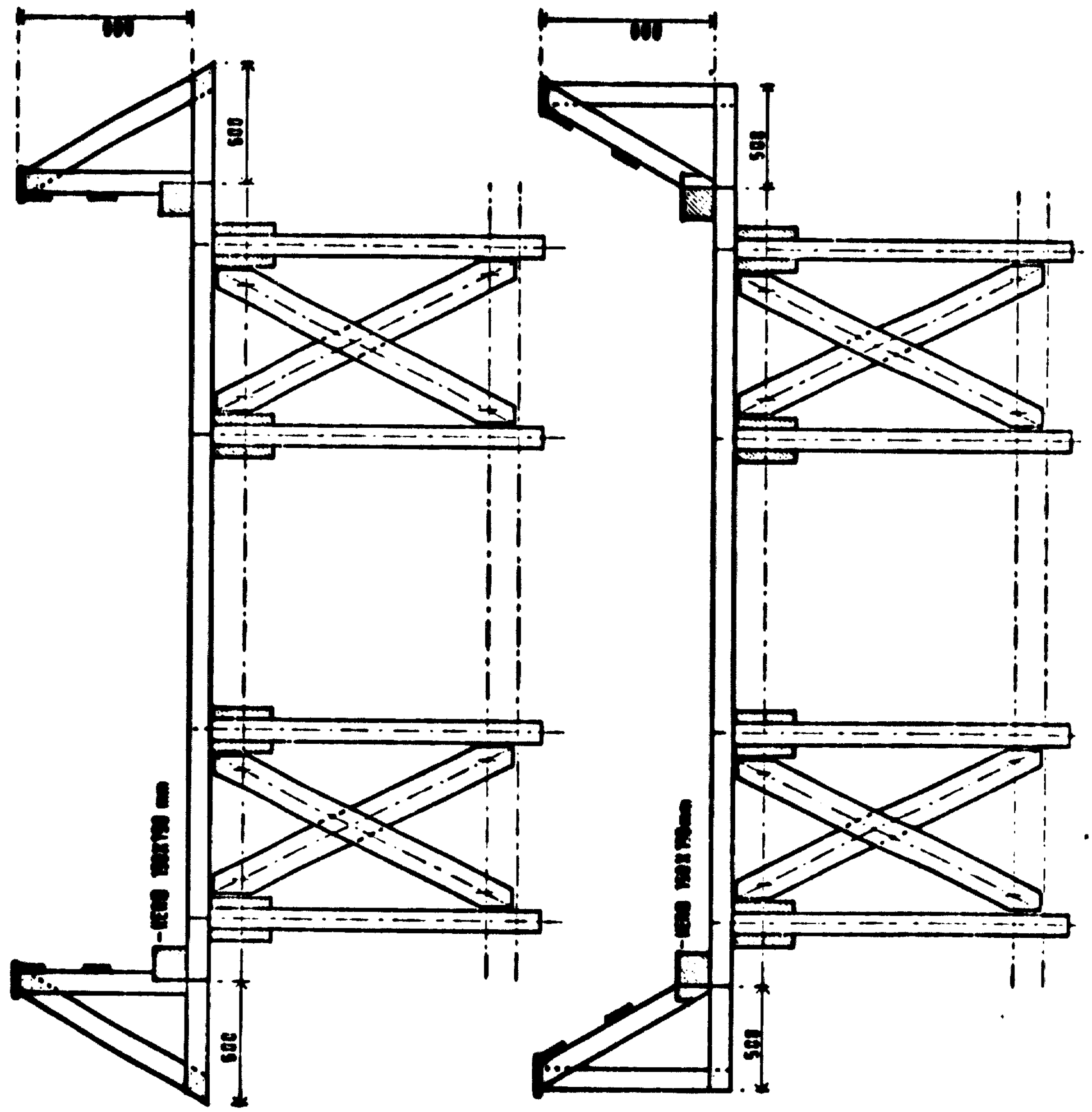


Figure 46. Handrail designs

Figure 47. Handrail detail

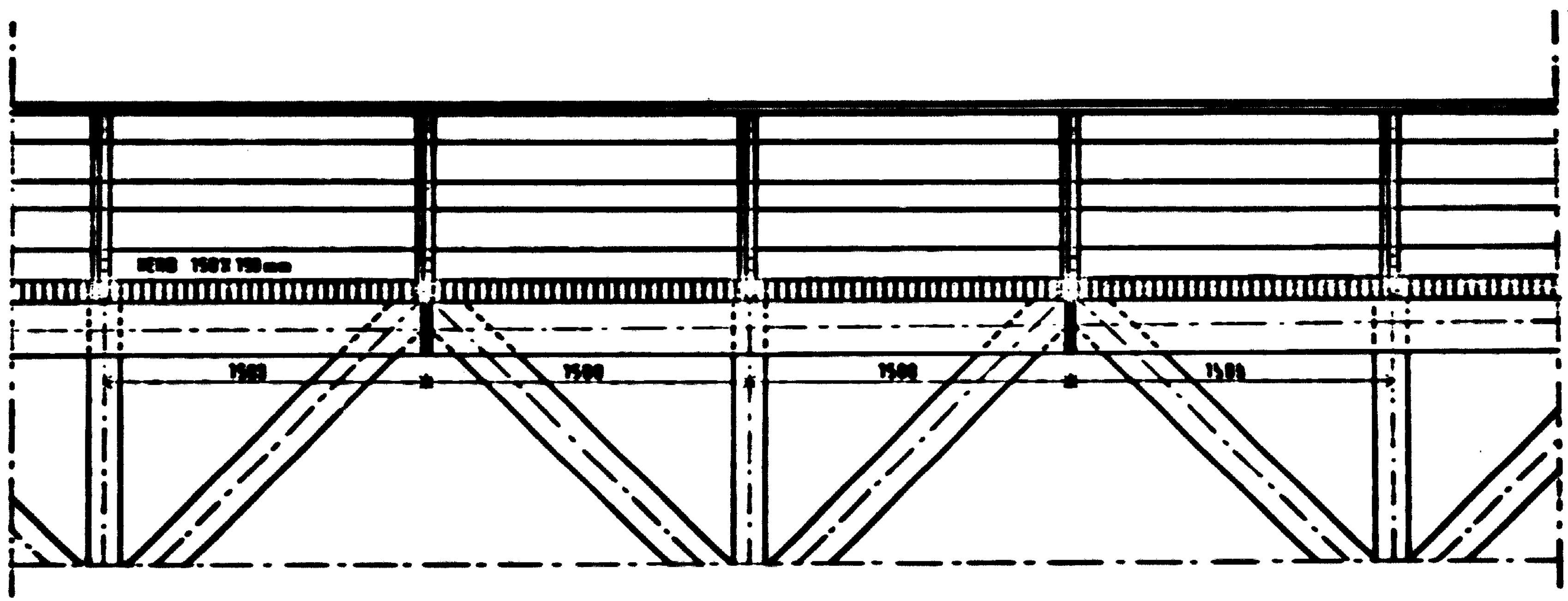


Figure 48. Handrail A - detail

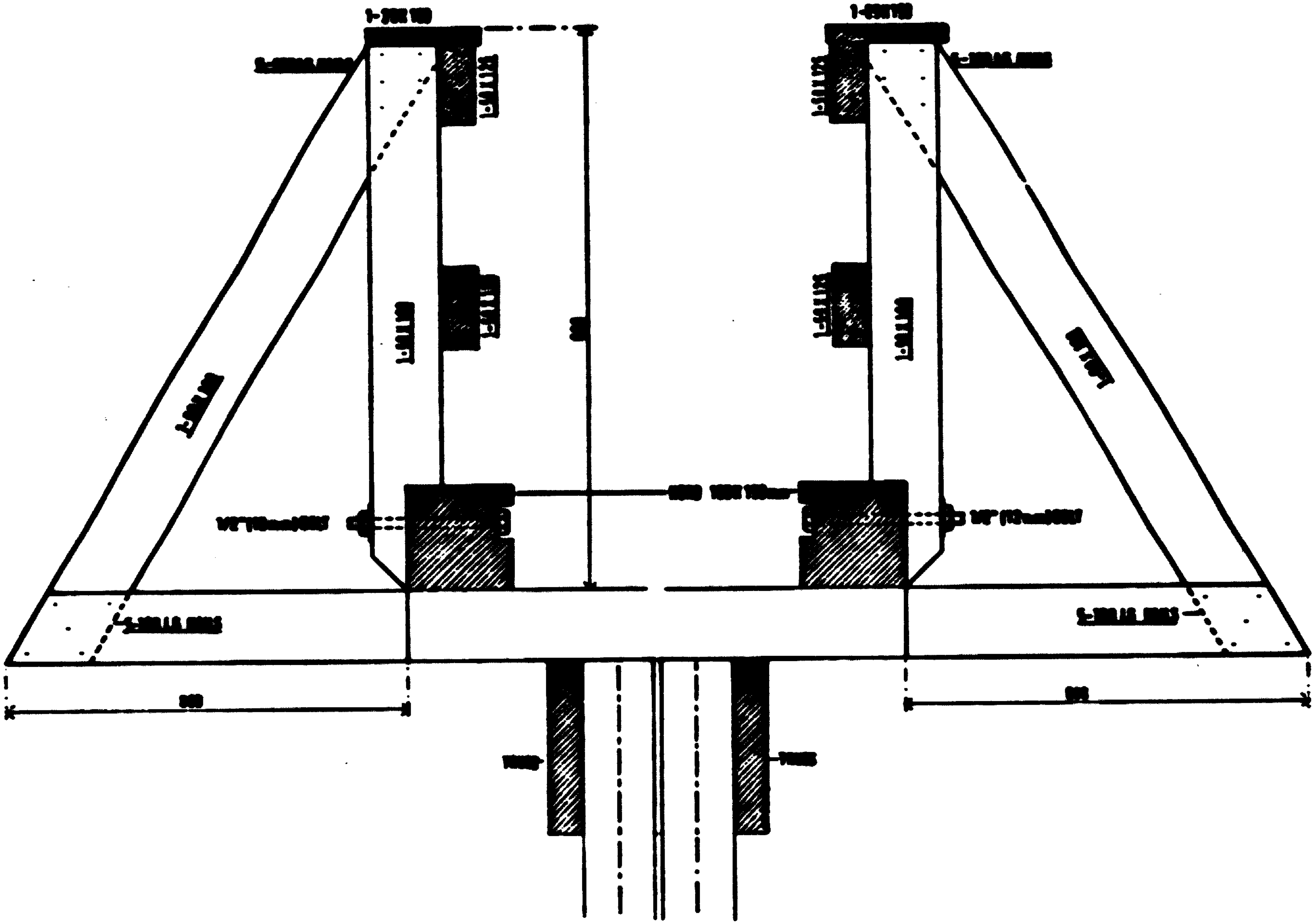
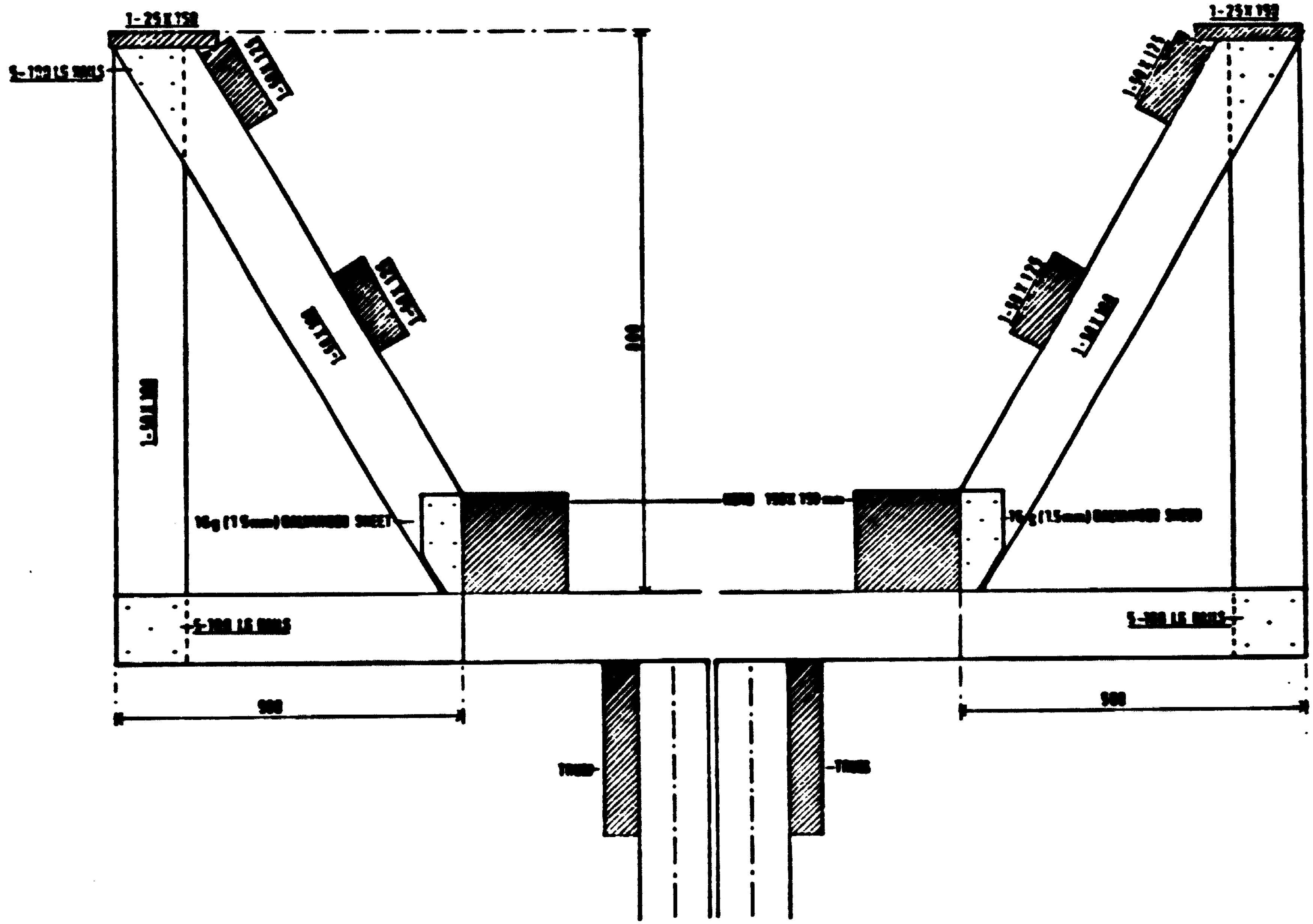


Figure 49. Handrail B - detail



C. Dry-crossing method

Erection frames

Frames of the type shown in figure 50 should be prepared. Only two are required for spans up to 15 m and three for spans longer than this. The height should be the maximum distance between the stream bed and the underside of the panel top chords plus 300 mm (12").

Levelling

Stretch a line across the span close to the final position of the outermost truss. It should be at the level of the top of the panel at the nearside end and 10 mm per metre of span higher at the far end to allow for camber in the trusses. This means that only the first bay of panels will be level with the stringline and that the remaining ones will be successively below this level.

Truss erection

As with the wet-crossing method the pairs of trusses with vertical bracing are erected first.

Place one female and one male bearing on the foundation and fit two panels onto them with the other ends supported by an erection frame (see figure 51). Position both panels level with the stringline by moving the bottom of the frame in the line of the span and by adjusting the folding wedges. Attach the permanent vertical bracing and permanent horizontal bracing as shown in figure 39.

Repeat the process using a second erection frame on another pair of panels as shown in figure 52. When all bracing has been fixed remove the first frame. Successive frames, up to a maximum of five pairs, are then added in a similar manner.

When the span is longer than 15 m leave one frame in position as a temporary support and continue the process using one additional frame.

Final stage in truss erection

When the last bay has been erected place the bearings at the end of each panel. If these do not touch the foundation, folding wedges have to be placed under each bearing before the temporary staging is removed. These may be knocked out when the structure is free.

Figure 50. Dry-crossing support

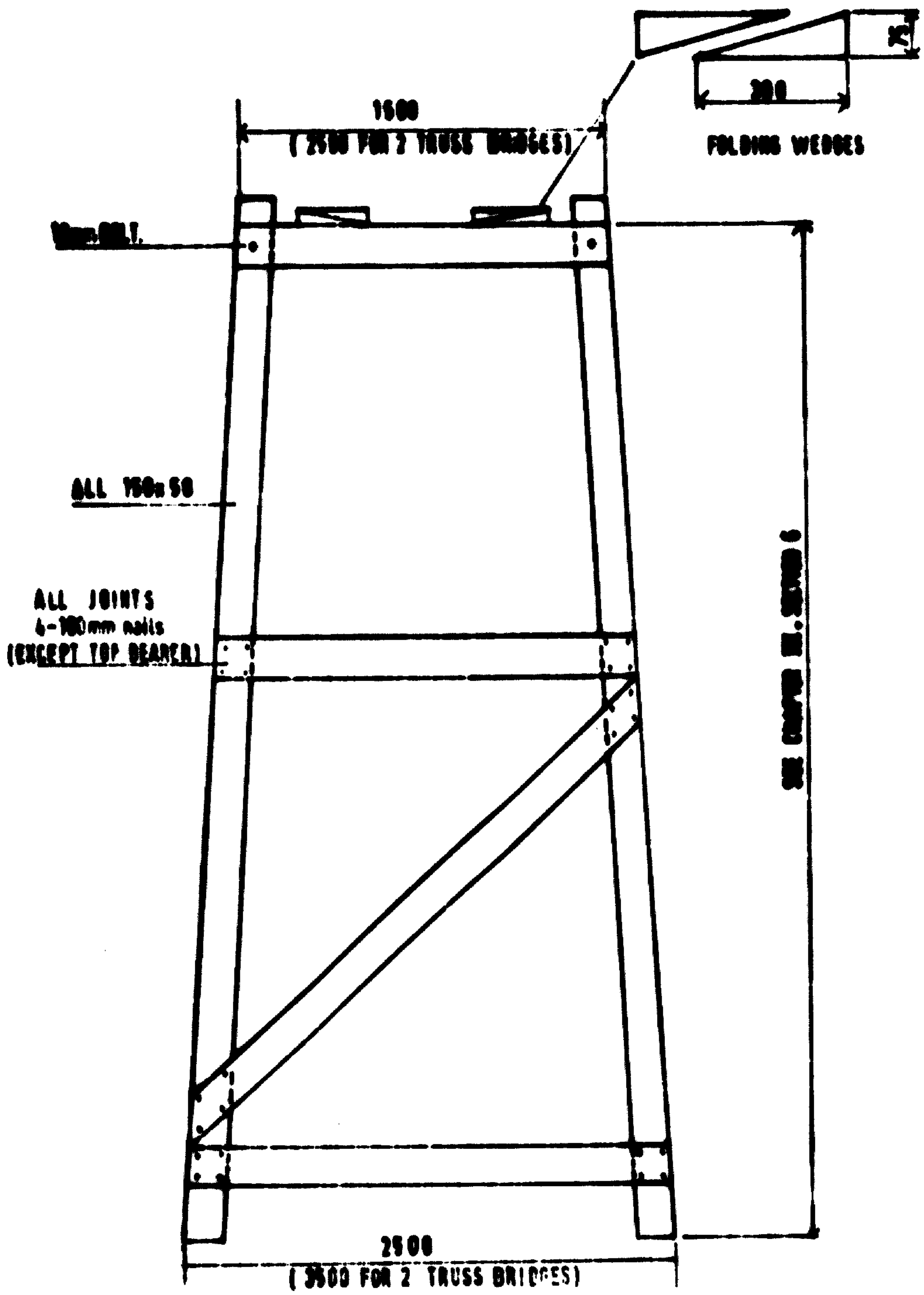


Figure 51. Truss erection method (dry crossing) - first truss

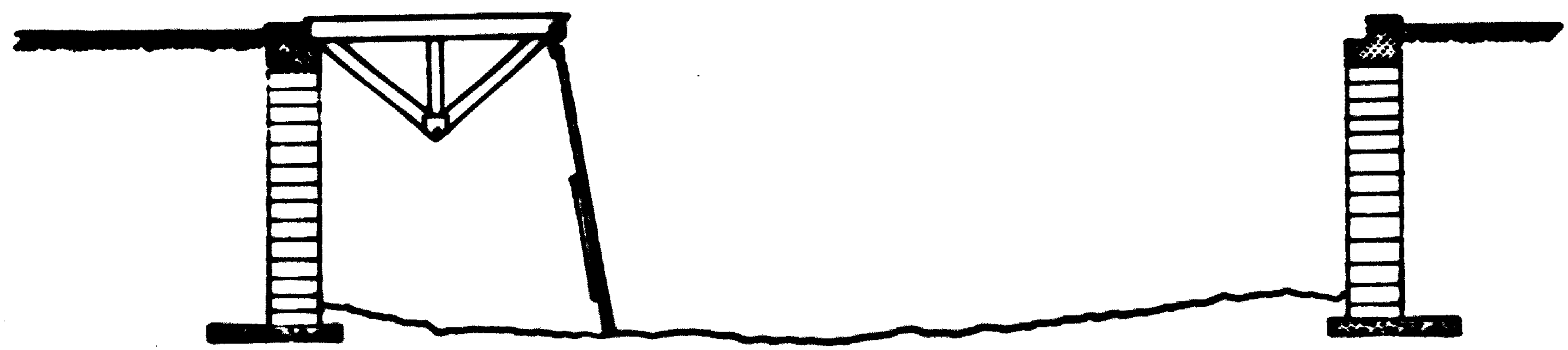
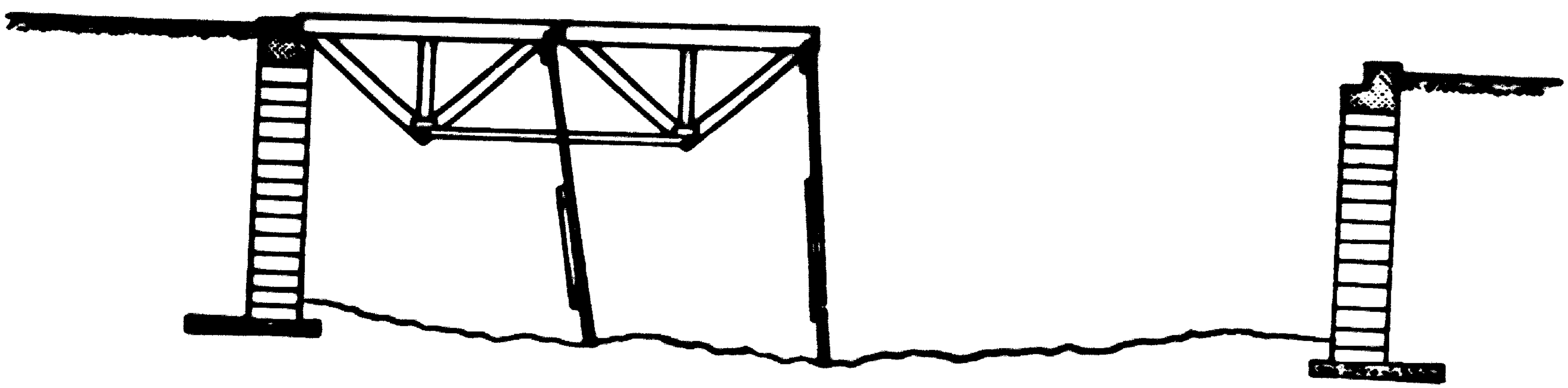


Figure 52. Truss erection method (dry crossing) - second truss



Erect the remaining trusses in the same way. Single trusses may be erected using the same scaffolding frames but each panel must be attached at both ends to a fully-braced pair after erection.

When all the trusses have been erected complete the structure as described for the wet-crossing method (p. 78).

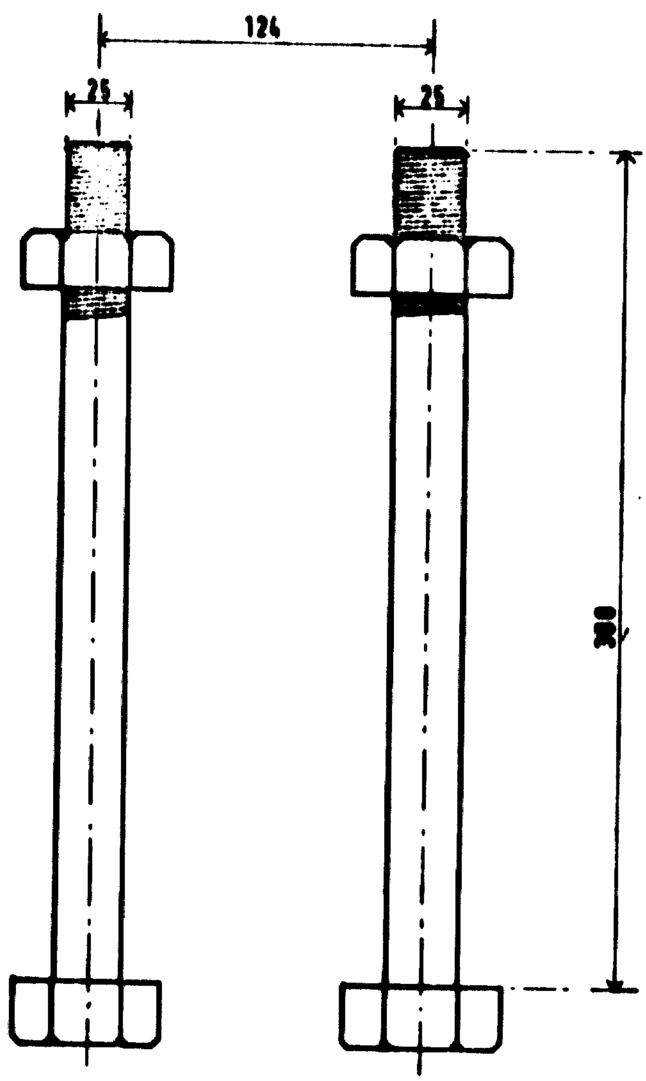
D. Concreting and earthworks

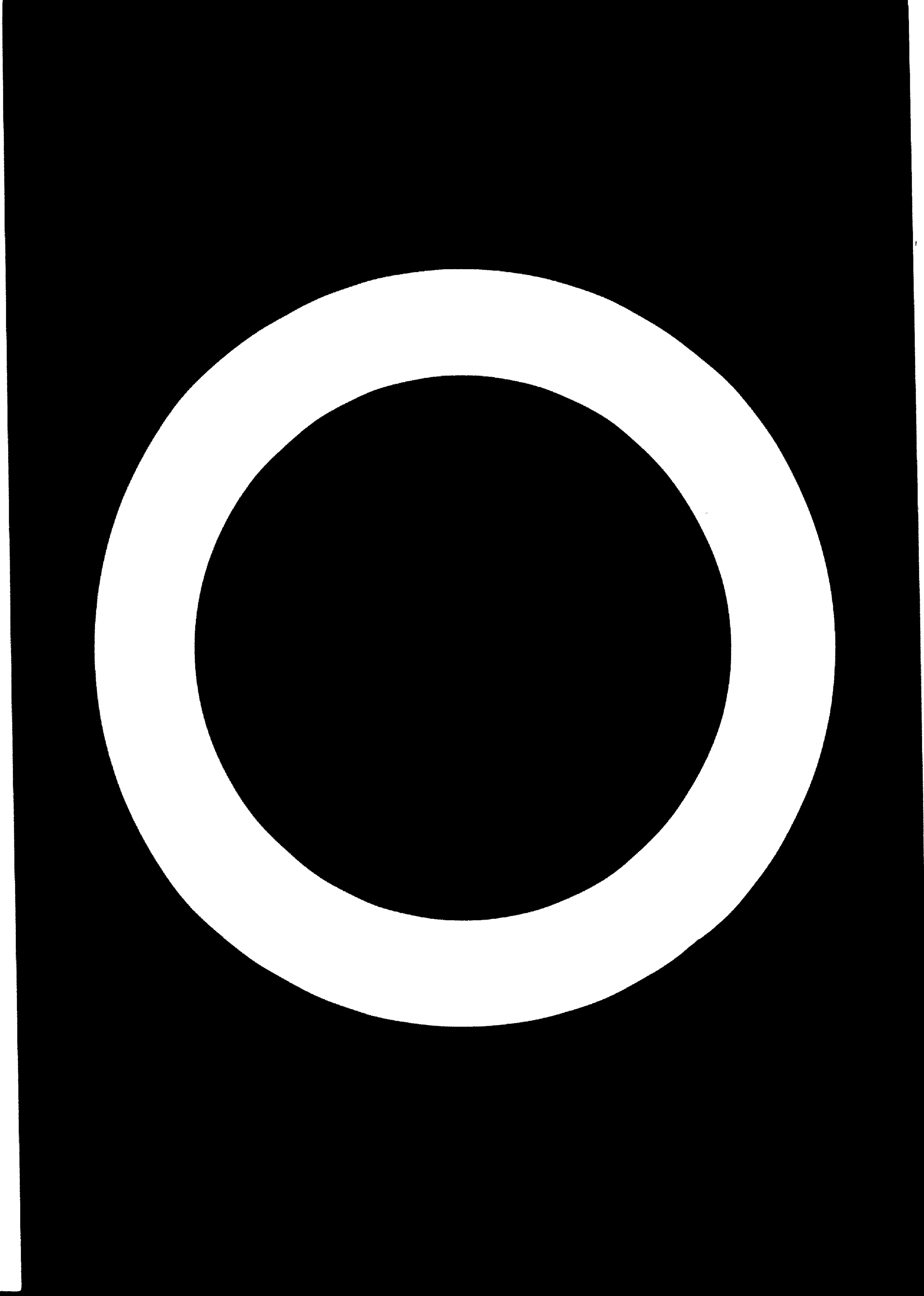
Place holding-down bolts in the pockets provided and grout with a 1:3 cement mortar (see figure 53). Backfill foundation to finished road level.

Soil poisoning should now be carried out where termite attack is endemic: An area of about 5 m x 5 m should be excavated to a depth of 300 mm and the soil heaped. Mix the heaped soil with 100 litres of one of the following water emulsions: aldrin 0.5%; dieldrin 0.5%; chlordane 1.0%; or benzene hexachloride 0.8%. Replace the soil and compact as usual.

Complete the bridge by concreting behind the bearings to give a level running surface.

Figure 53. Anchor bolts





Annex I

PROOF TEST FOR TIMBER PANELS

This test is not intended to give an absolutely reliable proof of bridge strength but should be used to determine or verify the correct stress grade of a given timber. The test is suitable up to grade F 14; above this grade failure in the steel dowels is to be expected.

Specifically the test is to proof the strength of the diagonals in tension; this is considered a good overall indication, as timber strength tends to be more variable in tension than under other loadings.

For the test proceed as follows:

Place a panel in the rig shown in figure 54 and support it on two standard bearings. Remove the 250-mm through bolts from the top chord together with any nails used at this intersection for temporary fixing. The 150 mm x 50 mm central strut is strengthened by the addition of two 150 mm x 50 mm members, 0.75 m long, nailed on either side with 100 mm nails at 150 mm centres. Insert a mild 25 mm x 75 mm steel key of 150 mm length in the strut to rest on the top of the lower plates (1 or 9) to give a stronger connection at this point. Place a hardwood loading pad on top of the strut and ensure that the pad is clear of all members and able to pass between them. Finally place dial gauges calibrated to read 0.1 mm at each end of the panel in the positions shown in figure 54.

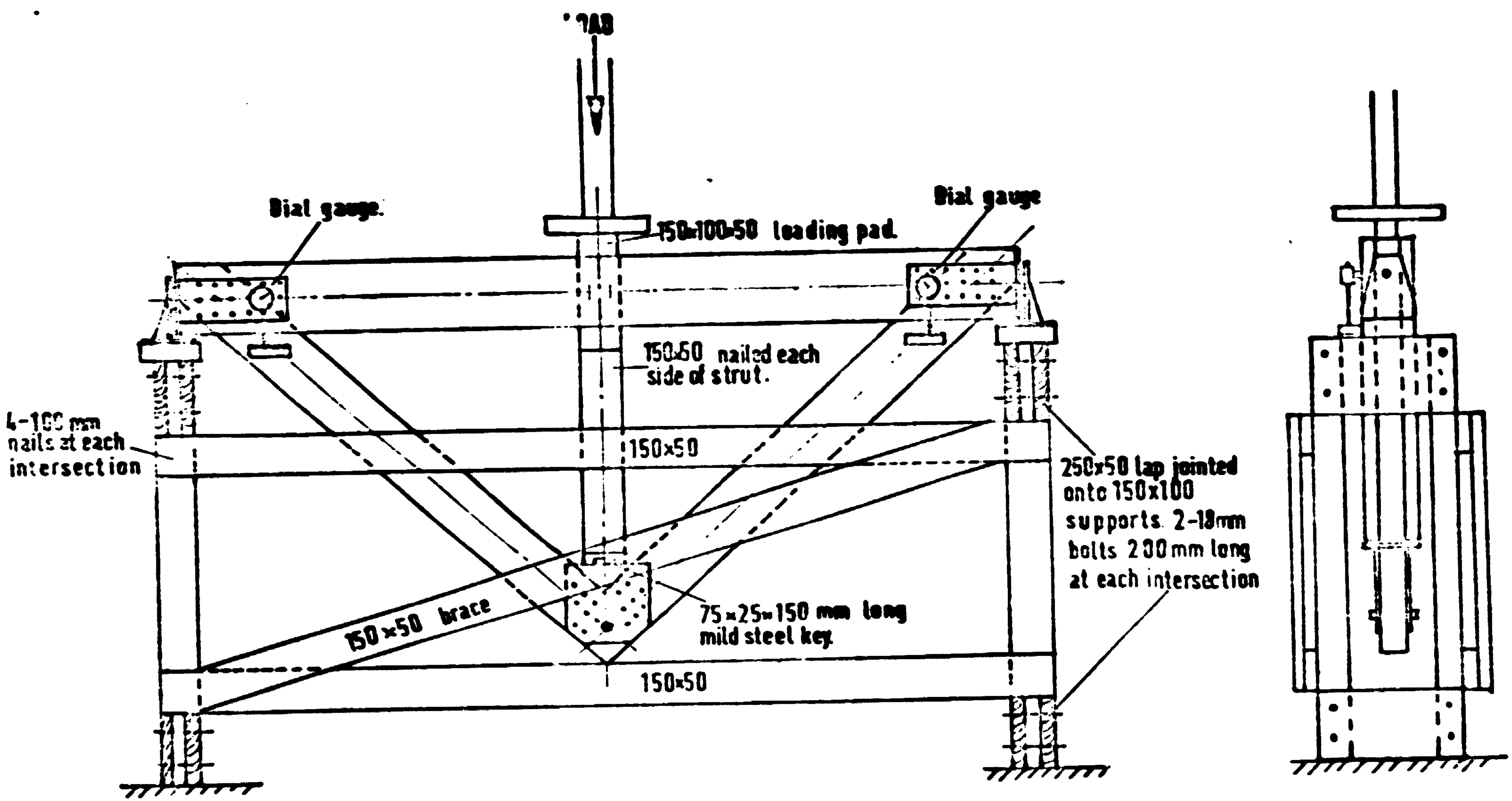
Two tests are considered necessary.

<u>Design load test</u>

Depending on the stress grade of the panel to be tested, the following design loads should be applied:

Stress grade	Design load (t)
F4	7.8
F5	9.7
F7	12.3
F8	15.6
F11	19.6
F14	24.8

Figure 54. Jig for proof test of panels



Apply the load over a period not exceeding 15 minutes and then maintain it for 24 hours. Take readings of each gauge 15 minutes after application of the load and later at one hour intervals. The load is then released and a final reading taken 15 minutes later.

The panel is regarded as satisfactory when:

(a) The rate of increase of deflection during the 24 hours of the test is the highest at the beginning and decreases towards the end of the test;

(b) The residual deflection is not more than 2 mm.

Ultimate load test

The panel should now be loaded to destruction over a period not exceeding 30 minutes. The following minimum ultimate loads are regarded as satisfactory:

Stress grade	Minimum ultimate load (t)
F4	19.5
F5	24.2
F7	30.7
F8	39.0
F11	49.0
F14	62.0

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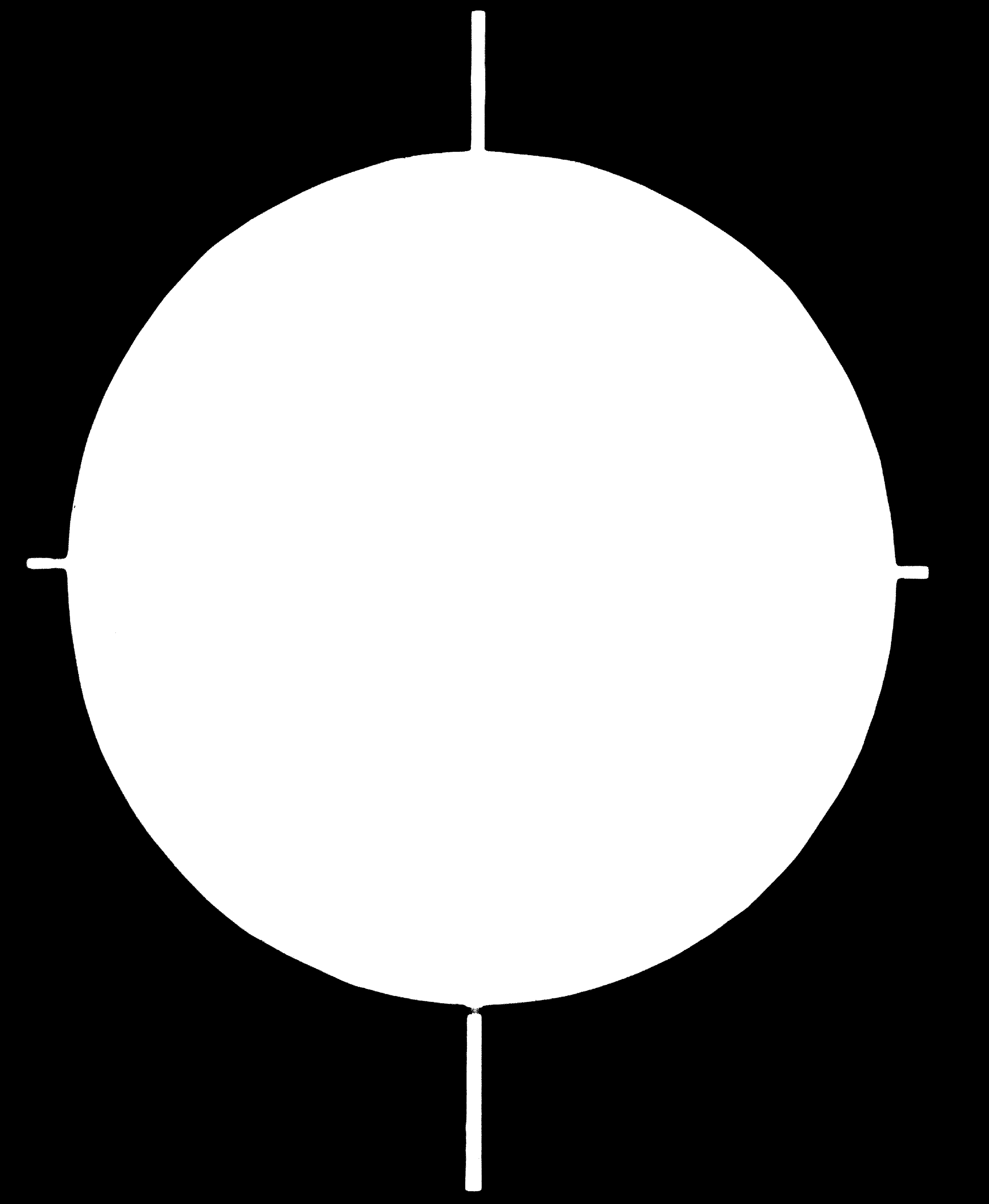
81.05.27



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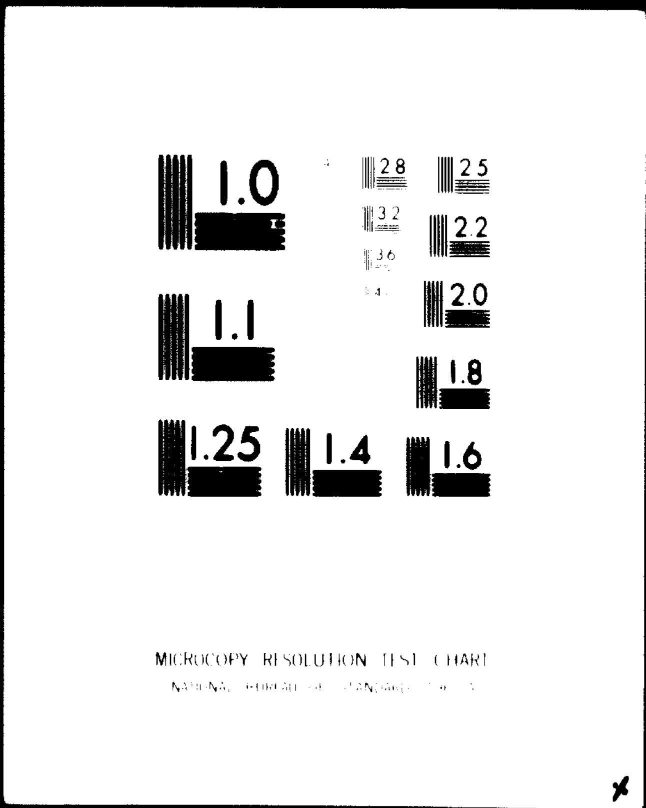


24x

D

Annex II

GRADING RULES FOR TIMBER

Each piece of timber should be truly sawn and be free from decay, shakes, splits, fractures and occluded branch stubs.

The following imperfections are permitted for the three grades under consideration, subject to the indicated limits.

75% grade

1. Maximum knot size:

Depth of section (mm)	Knot size (mm)	
	On face	On edge
250	40	12
200	30	12
150	20	12
100	15	12

The overall dimension of knots in groups should not exceed these values.

2. The slope of the grain should not exceed 1 in 15.

3. Seasoning checks should not exceed 400 mm in length and 3 mm in width and must not extend from one surface to another.

4. The following maximum permissible values (in mm) for spring, bow and twist should be observed:

Member	Spring	Bow	Twist
1T	5	20	10
2T	6	15	10
3T	3	10	5
4T	3	5	5
Vertical bracing	3	10	5
Deck	12	20	5

per 3 m of length

5. No wane or sapwood susceptible to insect attack should be permitted.

6. Fissures admitting a feeler gauge of 0.15 mm thickness should not be longer than 15 mm in 50-mm wide members and 30 mm in 100-mm wide members.

7. Gum pockets or overgrowths of injury should not exceed 300 mm in length or 12 mm in width on one face of the timber. Where a pocket extends from one face to another the width should be less than 6 mm.

60% grade

1. Maximum knot size:

Depth of section (mm)	Knot size (mm)	
	On face	On edge
250	60	20
200	50	20
150	35	20
100	25	20

The overall dimensions of knots in groups should not exceed these values.

2. Slope of grain should not exceed 1 in 10.

3. Seasoning checks should be not longer than 400 mm.

4. Spring, bow and twist should not exceed the values given for 75% grade.

5. Wane or sapwood susceptible to insect attack should be maximally $\frac{1}{4}$ of the width of the face being considered.

6. Fissures admitting a feeler gauge of 0.15 mm thickness should not be longer than 20 mm in 50-mm wide members and 40 mm in 100-mm wide members.

7. Gum pockets or overgrowths of injury should not exceed 300 mm in length or 20 mm in width on the face of the timber. Where a pocket extends from one face to another the width should be less than 6 mm.

48% grade

1. Maximum knot size:

Depth of section (mm)	Knot size (mm)	
	On face	On edge
250	75	25
200	60	25
150	45	25
100	30	25

The overall dimensions of groups of knots shall not exceed these values.

2. Slope of grain should not exceed 1 in 8.

3. Seasoning checks should not be longer than 600 mm.

4. Spring, bow and twist should not exceed the values given for 75% grade.

5. Wane or sapwood susceptible to insect attack should be maximally $\frac{1}{4}$ of the width of the face being considered.

6. Fissures admitting a feeler gauge of 0.15 mm thickness should not exceed 25 mm in 50-mm wide members and 50 mm in 100-mm wide members.

7. Gum pockets or overgrowths of injury should not exceed 300 mm in length or 25 mm in width on the face of the timber. Where a pocket extends from one face to another the width should be less than 9 mm.

Annex III

STRESS GRADES OF COMMON TIMBER SPECIES

A. Indian timbers

Species	Strength group	Visual grade[a]		
		48%	60%	75%
Pterocarpus marsupium	S4	F8	F11	F14
Soymida febrifuga	S2	F14	F17	F22
Xylia xylocarpa (syn. X. dolabriformis)	S1	F17	F22	F27
Pterocarpus dalbergioides	S3	F11	F14	F17
Tectona grandis	S4	F8	F11	F14
Albizia lebbeck	S4	F8	F11	F14
Lagerstroamia lanceolata	S4	F8	F11	F14
Kingiodendron pinnatum	S4	F8	F11	F14
Xylocarpus granatum (syn. Carapa granatum)	S5	F7	F8	F11
Albizia odoratissima	S2	F14	F17	F22
Madhuca longifolia var. latifolia	S5	F7	F8	F11
Dalbergia sisoo	S4	F8	F11	F14
Dalbergia latifolia	S4	F8	F11	F14
Cedrus deodara	S5	F7	F8	F11
Ougeinia oojemeimensis	S5	F7	F8	F11
Dysoxylum malabaricum	S4	F8	F11	F14

B. South and central American timbers

Species	Strength group	Visual grade[a/]		
		48%	60%	75%
Dicornynia guianenis	S3	F11	F14	F17
Clathrotropis spp.	S2	F14	F17	F22
Bagassa guianenis	S2	F14	F17	F22
Manilkara bidentata	S1	F17	F22	F27
Ocotea rubra	S5	F7	F8	F11
Ocotea rodiaei	S1	F17	F22	F27
Qualea rosea	S3	F11	F14	F17
Goupia glabra	S3	F11	F14	F17
Eschweilera longipes and E. subglandosa	S1	F17	F22	F27
Symphonia globulifera	S3	F11	F14	F17
Mora excelsa	S2	F14	F17	F22
Terminalia amazonia	S2	F14	F17	F22
Pinus caribaea	S4	F8	F11	F14
Peltogyne spp.	S2	F14	F17	F22
Calophyllum spp.	S4	F8	F11	F14
Hieronyma spp.	S3	F11	F14	F17
Diplotropis purpurea	S1	F17	F22	F27
Humiria spp.	S3	F11	F14	F17
Tectona grandis	S4	F8	F11	F14
Eperua spp.	S1	F17	F22	F27

C. West African timbers

Species	Strength group	Visual grade[a/] 48%	60%	75%
Pericopsis elata (syn. Afrormosia elata)	S3	F11	F14	F17
Afzelia africana	S3	F11	F14	F17
A. bella				
A. bipindensis				
A. pachyloba				
A. quanzensis	S4	F11	F14	F17
Aningeria spp.	S6	F5	F7	F8
Baillonella spp.	S4	F11	F14	F17
Autranella congolensis	S2	F14	F17	F22
Burkea africana	S2	F14	F17	F22
Chlorephora excelsa	S5	F7	F8	F11
Coula edulis	S2	F14	F17	F22
Cryptosepalum staudtii	S2	F14	F17	F22
Piptadenia gabunensis (syn. Cylicodiscus gabunensis)	S2	F14	F17	F22
Distemonanthus denbthamianus benthamianus	S4	F11	F14	F17
Eucalyptus paniculata	S1	F17	F22	F27
Eucalyptus propinqua	S2	F14	F17	F22
Guarea cedrata	S5	F7	F8	F11
Guibourtia spp.				
G. arnoldiana	S3	F11	F14	F7
G. coleosperma	S5	F7	F8	F11
G. demeusei	S3	F11	F14	F17
G. ehie	S1	F17	F22	F27
G. pellegriniana	S1	F17	F22	F27
G. tessmanii	S2	F14	F17	F22
Khaya spp.				
K. anthoteca, K. ivorensis, K. nyasica	S6	F5	F7	F8
K. grandifolia, K. senegalensis	S4	F8	F11	F14

Species	Strength group	Visual grade		
		48%	60%	75%
Lophira spp.	S2	F14	F17	F22
Mammea africana	S4	F8	F11	F14
Manilkara lacera	S1	F17	F22	F27
Mansonia altissima	S4	F8	F11	F14
Microberlinea brazzavillenenis	S4	F8	F11	F14
Mimusops spp.				
M. callophilloides M. oboyata M. djare (syn. Baillonella toxisperma)	S3	F11	F14	F17
M. congolensis syn. (syn. Autronella congolensis)	S2	F14	F17	F22
M. heckeli (syn. Tieghemella heokeli)	S5	F7	F8	F11
M. africana (syn. Tieghemella africana)	S4	F8	F11	F14
Morus mesozygia	S1	F17	F22	F27
Nauclea spp.	S4	F8	F11	F14
Nesogordonia papaverifera	S3	F11	F14	F17
Oxystigma oxyphyllum	S4	F8	F11	F14
Dacryodes edulis	S4	F8	F11	F14
Pinus spp.				
Low density (below 600 kg/m^3)	S7	F4	F5	F7
High density (above 600 kg/m^3)	S5	F7	F8	F11
Prosopsis africana	S3	F11	F14	F17
Pterocarpus angolensis	S5	F7	F8	F11
Pterocarpus eriaceus	S3	F11	F14	F17
Pterocarpus soyauxii	S4	F8	F11	F14
Sacoglottis gabonensis	S2	F14	F17	F22
Strombosia spp.	S2	F14	F17	F22
Heritiera utilis (syn. Terrietia utilis)	S5	F7	F8	F11
Terminalia ivorensis	S5	F7	F8	F11

D. Timbers from the Pacific region

Species	Strength group	Visual grade[a]		
		48%	60%	75%
Calophyllum kajewski	S4	F8	F11	F14
Pometia pinnata	S4	F8	F11	F14
Intsia bijuga	S2	F14	F17	F22
Intsia palembioa	S3	F11	F14	F17
Pterocarpus indicus	S4	F8	F11	F14
Eucalyptus deglupta	S7	F4	F5	F7
Homalium foptidum	S2	F14	F17	F22
Hopea papuana	S2	F14	F17	F22
Hopea forbesii	S3	F11	F14	F17
Hopea iriana	S1	F17	F22	F27
Hopea glabrifolea	S1	F17	F22	F27
Tectona grandis	S4	F8	F11	F14
Eucalyptus tereticornis	S3	F11	F14	F17
Manilkara kanosiensis	S1	F17	F22	F27
Heritiera littoralis	S3	F11	F14	F17
Palaquium gornei	S3	F11	F14	F17
Terminalia spp.				
T. brassi, T. kaernbachii T. faveolata	S7	F4	F5	F7
T. catappa, T. microcarpa T. canaliculata, T. complanata T. calamansanii	S5	F7	F8	F11
T. solomonensis, T. sparggrea T. capelandi	S6	F5	F7	F8
Syzygium spp.	S3	F11	F14	F17
Araucaria guntsteinii	S6	F5	F7	F8
Cleistocalyx spp.				
(syn. Acicalyptus spp. (except those below)	S2	F14	F17	F22
Cleistocalyx myrtoides	S4	F8	F11	F14
(syn. (A. myrtoides)				

Species	Strength group	Visual grade		
		48%	60%	75%
Alstonia scholaris	S7	F4	F5	F7
Amoora cucullata	S6	F5	F7	F8
Anisoptera polyandra	S5	F8	F11	F14
Anthocephalus chinensis	S7	F4	F5	F7
Campnosperma brevipetiolata	S7	F4	F5	F7
Dracontomelum puperulum	S5	F8	F11	F14
Elmerrillia papuana	S6	F5	F7	F8
Endospermum medullosum	S7	F4	F5	F7
Eucalyptus deglupta	S4	F8	F11	F14
Vitex coffassus	S7	F4	F5	F7
Agathis dammara (syn. (A. alba))	S7	F4	F5	F7
Fagraea gracillpes	S1	F17	F22	F27
Myristica spp.	S6	F5	F7	F8
Podocarpus neriifolius	S4	F8	F11	F14
Garcinia myrtifolia	S3	F11	F14	F17
Gonystylus punctatus	S3	F11	F14	F17
Heritiera ornithocephala	S3	F11	F14	F17
Sevianthes myriademia	S5	F7	F8	F11
Dacrydium intricatus	S6	F5	F7	F8
Agathis vitiensis	S5	F7	F8	F11

E. South-East Asian Timbers

Species		Strength group	Visual grade 48%	Visual grade 60%	Visual grade 75%
Hopea plagata		S1	F17	F22	F27
Hopea phillippinensis		S2	F14	F17	F22
Vatica mangachapoi		S2	F14	F17	F22
Intsia bijuga		S2	F14	F17	F22
Ctenolophon philippinensis		S2	F14	F17	F22
Fagraea fragrans		S3	F11	F14	F17
Eusideroxylon zwageri		S1	F17	F22	F27
Madhuca utilis		S1	F17	F22	F27
Palaquium ridleyi		S3	F11	F14	F17
Palaquium stellatum		S3	F11	F14	F17
Balanocarpus gheimii		S1	F17	F22	F27
Vatica spp.		S3	F11	F14	F17
Dipterocarpus spp.		S3	F11	F14	F17
Dryobanalops spp.		S3	F11	F14	F17
Koompassia malaccensis		S2	F14	F17	F27
Hopea acuminata		S2	F14	F17	F27
Shorea spp.					
S. glauca S. maxwelliana S. seminis S. laevis S. albida (heavy variety)	balau	S1	F17	F22	F27
S. collina S. guiso S. kunstleri S. ochrophloia	red balau	S3	F11	F14	F17
S. pauciflora S. curtisii S. pachphylla S. platyclados	dark red meranti	S5	F7	F8	F11

Species		Strength group	Visual grade		
			48%	60%	75%
S. albida S. argentifolia S. leptoclados S. rugosa S. acuminata S. leprosula S. macroptera S. ovalis S. parvifolia S. smithiana	light red meranti	S6	F5	F7	F8
S. assamica S. bracteolata S. hypochra S. resinosa S. sericeiflora	white meranti	S4	F8	F11	F14
S. faguetiana S. gibbosa S. hopeifolia S. multiflora S. resina-nigra S. acuminatissima	yellow meranti	S5	F7	F8	F11
Shorea and parashorea spp.					
P. malaanonan S. almon S. sqamata P. plicata Penacme conforta	Philippine light red mahogany	S5	F7	F8	F11
Shorea spp.					
S. nogrosensis S. polysperma	Philippine red mahogany	S5	F7	F8	F11
Heritiera spp.		S4	F8	F11	F14
Anisoptera spp.		S6	F5	F7	F8

Species	Strength group	Visual grade a/		
		43%	60%	75%
Gonystylus spp.	S4	F8	F11	F14
Sindora spp.				
Capaifera spp.	S4	F8	F11	F14
(syn. Pseudosindora spp.)				

F. East African timbers

Species	Strength group	Visual grade a/		
		43%	60%	75%
Capressos lusitamica	S6	F5	F7	F8
Pinus spp.	S7	F4	F5	F7
Podocarpus spp.	S5	F7	F8	F11
Juniperus procera	S5	F7	F8	F11
Brachylaena hutchinsii	S4	F8	F11	F14
Celtis soyauxii	S4	F8	F11	F14
Entandrophragma utile	S5	F7	F8	F11
Entandrophragma cylindricum	S7	F4	F5	F7
Eucalyptus paniculata	S3	F11	F14	F17
Eucalyptus caligna	S5	F7	F8	F11
Khaya anthotheca	S6	F5	F7	F8
Olea hochstetteri	S3	F11	F14	F17
Prunus africanus	S4	F8	F11	F14
Vitex keniensis	S7	F4	F5	F7

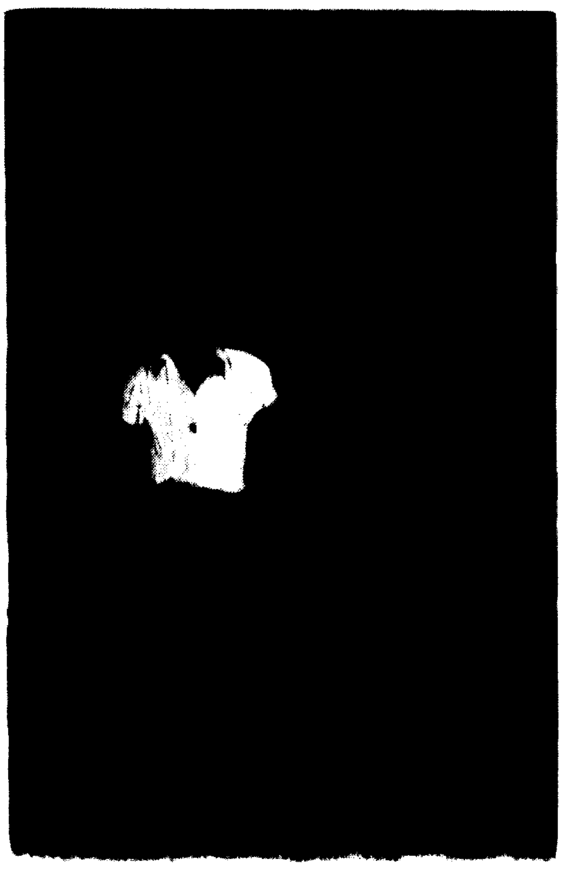
a/ See annex II.

Annex IV

PHOTOGRAPHS OF SITE WORK ON SOME BRIDGES IN KENYA BY THE PROJECT STAFF

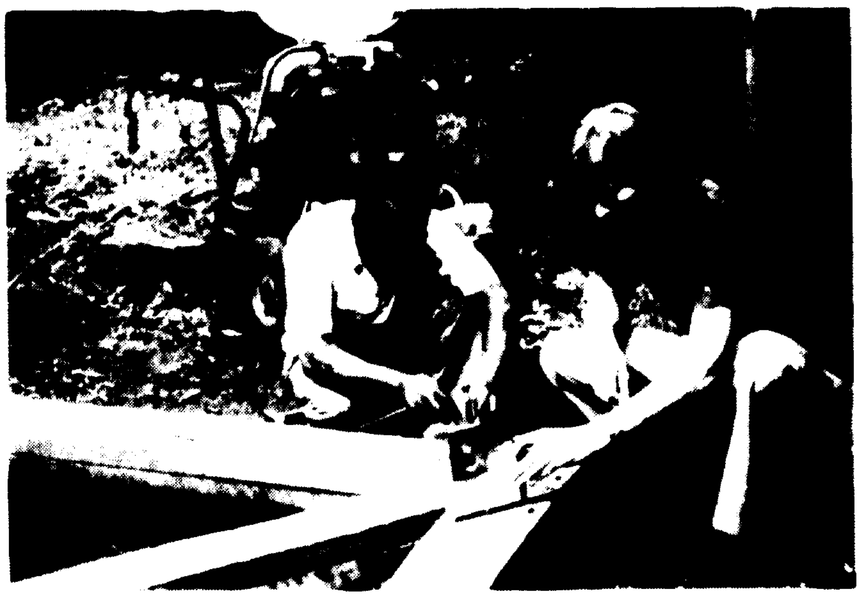
1. Storage of sawn timber

2. Treatment by dipping into preservative solution

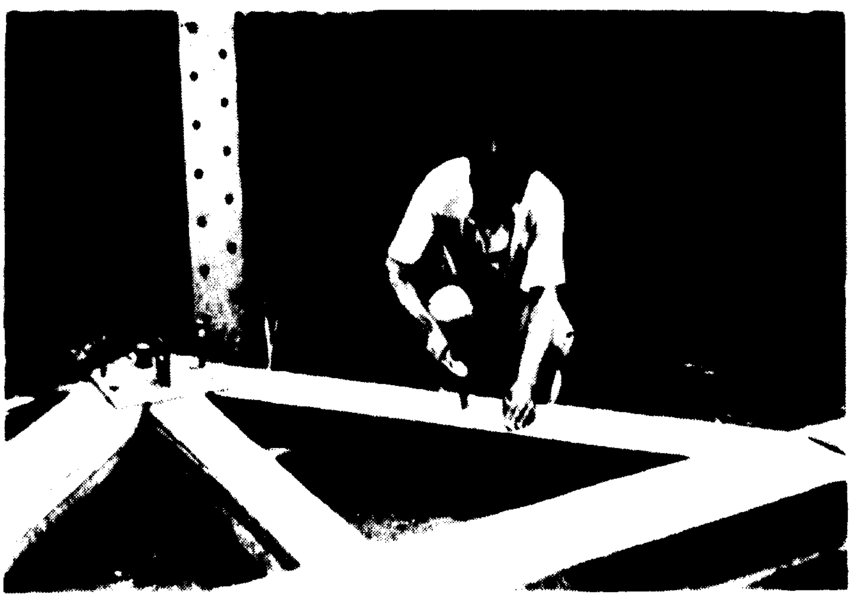


3. Assembly of sawn components onto jig

4. Assembly detail of apex of prefabricated element



5. Bolting metal gusset plate on apex of element

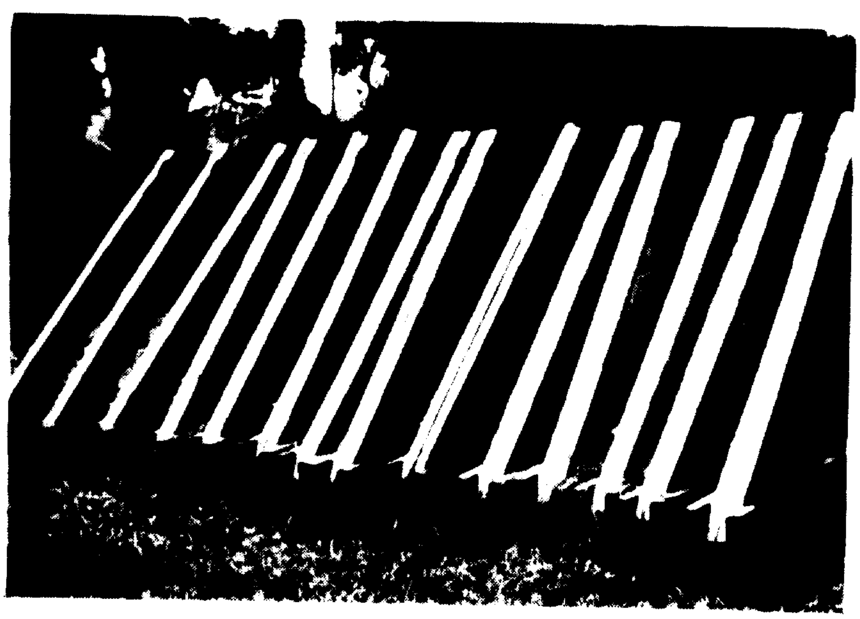


6. Nail lamination of prefabricated element

7. Welding of metal component for assembling two adjacent elements

8. Welding of lugs for fixing of cross bracing

9. Completed elements prior to shipment to site



10. Erection of tower supporting the cable used for launching

11. Digging of trench to anchor the cable used for launching

12. **Anchor of cable used for launching (in position in trench)**

13. Filling up of trench

14. Inserting cable used for launching block

15. Assembly of two elements showing permanent cross bracing and temporary studs for alignment

16. Launching of a pair of trusses a/

17. Inside of bridge showing decking construction and incomplete railing

18. View of bridge with incomplete and complete railings

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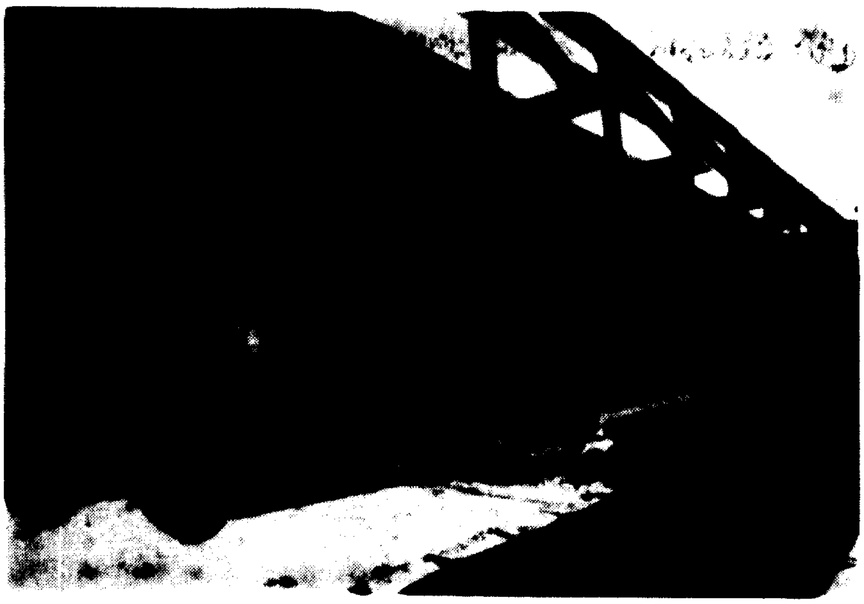
a/ This photograph was taken on a different project site. In this case the tower used for

19. Detail of completed railing



20. Detail of trusses supporting decking

21. Completed bridge, side view

22. Completed bridge, showing construction of abutments

23. Completed bridge in use

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