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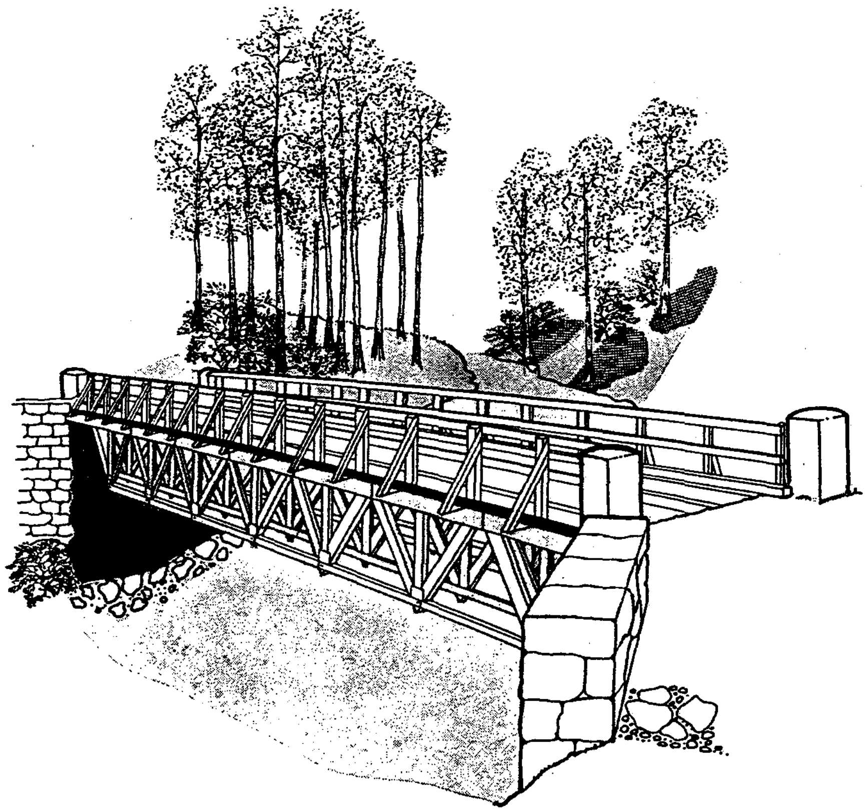
PRE-FABRICATED MODULAR WOODEN BRIDGES



PART 1 • GENERAL DESCRIPTION

prepared for

UNIDO • UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA, AUSTRIA

by

TRADA • TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION, UNITED KINGDOM

V.85-25421

PRE-FABRICATED MODULAR WOODEN BRIDGES

Part 1 General Description *

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* Part 3 Construction and Launching

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FOREWORD

Industrial, agricultural and economic growth are normally interlinked, and dependent to varying degrees upon a good transport network. For most developing countries, road transport is fundamental to progress and to the achievement of social and political stability. Bridges represent a significant part of road construction costs, and in countries where bridge construction is dependent on imported steel and cement, lack of foreign exchange seriously inhibits road development programmes. The United Nations Industrial Development Organization (UNIDO) has therefore been instrumental in introducing the use of timber bridges in such countries, especially for rural feeder roads.

A UNIDO programme in Kenya was responsible for the early development of this prefabricated wooden bridge system, following an original concept by Mr. J. E. Collins in 1973. By 1976, the Kenyan Ministry of Natural Resources had built four bridges, through UNIDO's sponsorship, and at a later date others were added to the rural road network there.

In 1981, following a brief programming mission by another expert, TRADA was awarded a contract from UNIDO to introduce a similar system for use in Latin American regions, initially for the Republic of Honduras. The main objectives at that stage were to evaluate the suitability of indigenous timbers for bridge construction, to initiate and supervise the production of bridge components and to train local staff in the methods which had been used in Kenya.

The programme was subsequently extended to include further development of the system by introducing the use of timber for abutments and approach structures and by implementing the use of timber tension chords in place of steel. A testing machine for the evaluation of each of the modules used in the construction of the bridges was also developed, pursuing a concept of test loading originated in Kenya.

Subsequently it was decided to prepare this full set of manuals, detailing the design and construction of the bridges. The purpose was to 'internationalize' the existing information, which was written first in terms of Kenya, and subsequently for Honduras. This was intended to facilitate introduction of the system in other countries, since by the time the decision was taken, pilot projects had already begun in a number of other regions. During production of the drafts for the manuals, TRADA has assisted UNIDO in coordinating the work on modular wooden bridges which has been undertaken by various UNIDO experts. This has made it possible to incorporate the advice and ideas of many individuals, whose anonymous contributions are acknowledged.

PRE-FABRICATED MODULAR WOODEN BRIDGES

Part 1 General Description

INTRODUCTION

The bridge consists of simple, identical pre-fabricated triangular wooden panels joined top and bottom to make up trusses. These trusses are in turn joined together side by side in pairs and are braced to one another to create a girder construction. The deck is carried on top of the trusses, an arrangement which has several advantages for such an uncomplicated structure. It is built up on site, after the girders are launched, using a nailed laminated construction. The bridge has a slight built-in precamber. Longitudinal running boards direct the wheel loads of vehicles using the bridge. Handrails are normal in rural areas near villages where pedestrian safety is a consideration, although in remote countryside or forests these can be omitted for economy if desired.

The design has proved most economical for spans between 9 metres and 24 metres, although design tables for up to 27 metres are provided. For many rural roads, loadings typified by the H 20 highway loading of the U.S. (AASHTO) design code are appropriate. This is equivalent to a two-axle truck of 18 tons (180 kN) total weight. The tables also provide for heavier loadings such as AASHTO HS 20, a tractor truck with semi-trailer of 32 tons (324 kN) total. Part 2 describes the manufacture of pre-fabricated parts and the design selection procedure.

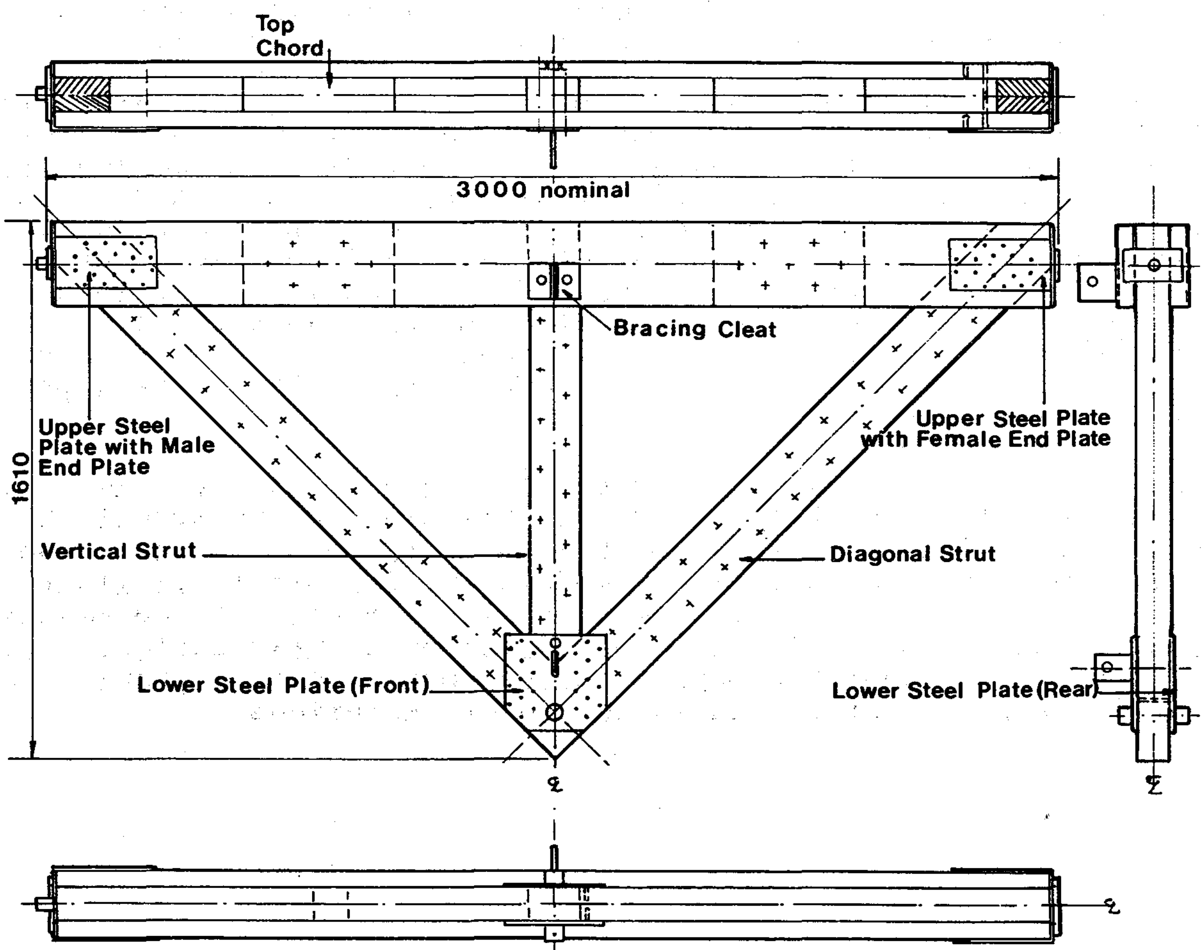
There is now full experience in implementation of the system and of applications in service. An important concept is the use of the local timbers of many of the less-developed countries for a considerable proportion of the structure, thus saving on costly imported alternatives. It is inevitable with a major timber engineering structure such as a road bridge that some steel parts must be used, but low cost and simplicity of these are achieved by using basic pieces welded from mild steel plate or flats that can also be purchased locally. Details of fabrication are provided in these manuals, together with advice on selection, treatment and grading of timbers that will ensure a permanent structure with a long service life.

It has been proven that local unskilled labour can be employed in building the bridge, with a core of technicians and personnel who learn the system by being involved in each site in the country concerned. The basic element, the pre-fabricated modular wooden panel, is light enough to be handled by four to six men. Various forms of abutments and approach spans are possible, and depending upon their design, these can also provide considerable opportunities for local employment. Part 3 describes the construction and launching of the bridge.

The preferred method of launching is to use towers or derricks on each bank, beneath one of which the girder to be launched is assembled. As launching proceeds, the girder is drawn across the span, suspended from an overhead cable. The entire launch can be achieved without cranage, using this twin tower system in conjunction with hand operated winches. Simple bearings are provided, which are finally located after the launch. The superstructure is completed in situ, using low-cost hand tools and generator-operated power saws if desired. Part 4 presents related timber technology and serves as a general reference on strength classification, drying, stress grading and preservation. Part 5 shows plans and full working drawings for typical bridges.

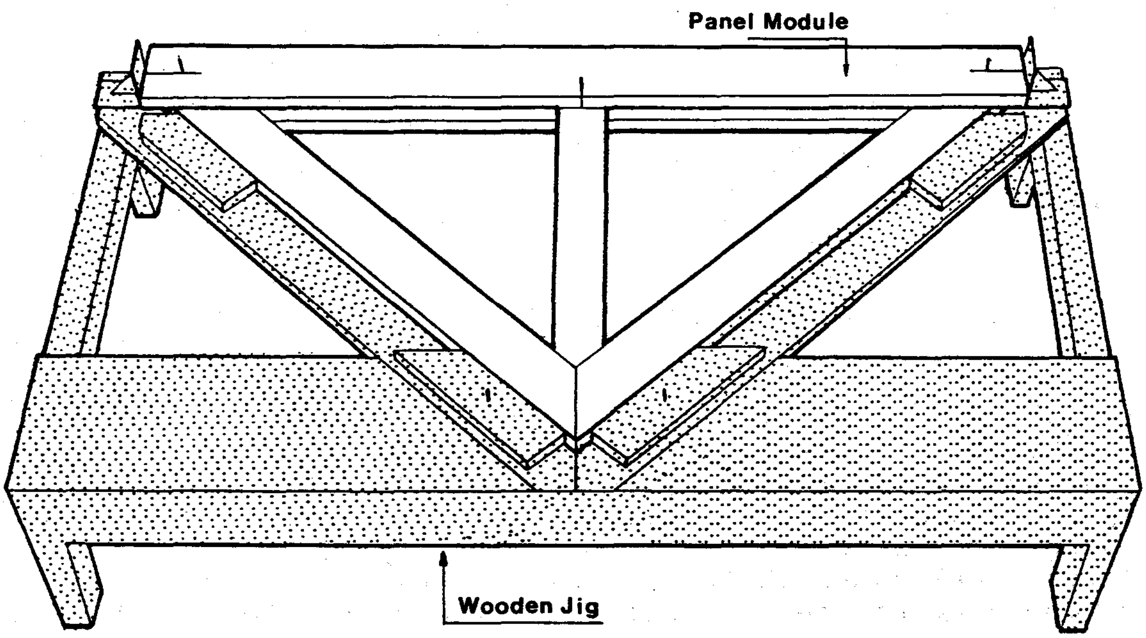
PANELS

The modular wooden panel, also just referred to as a panel, is the basic pre-fabricated element of the design. Bridge spans are provided in 3 metre modules. This dimension is the precise measurement from centre to centre of the lateral pins receiving the lower chords. Each panel is a nominal 3 metres in length, and approximately 1.6 metres in height, see sketch SK. 1 below. The panels consist of vertically nailed laminated members which are formed in a jig. The modular panel with its connecting steel plates and bracing brackets is completely fabricated and tested in a bridge workshop before being transported to the site.



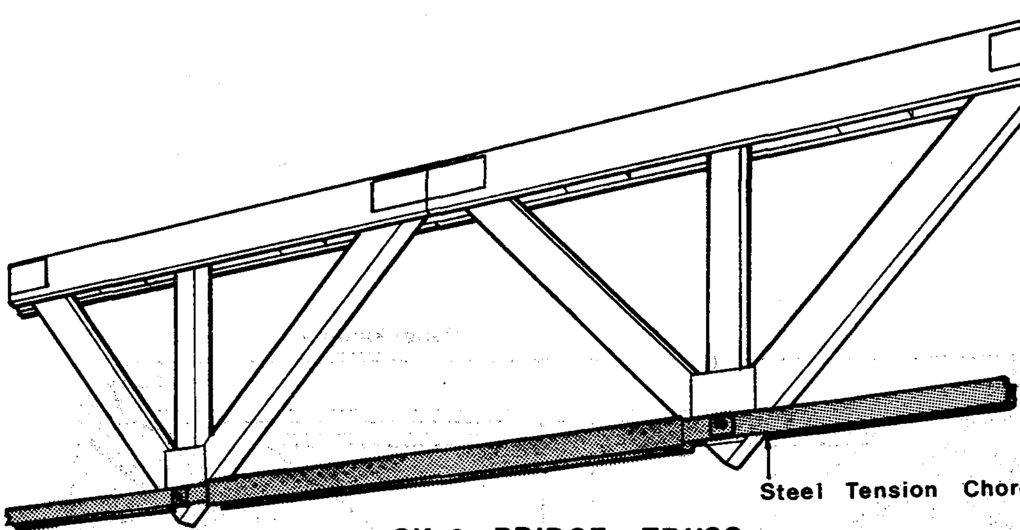
SK.1 MODULAR WOODEN PANEL

It is an important feature of the design that all panels are of identical shape and outline, with their critical dimensions closely controlled. In order to achieve this, they are fabricated and assembled in jigs, one of which is illustrated in sketch SK. 2 below. When fully assembled each panel is load tested.



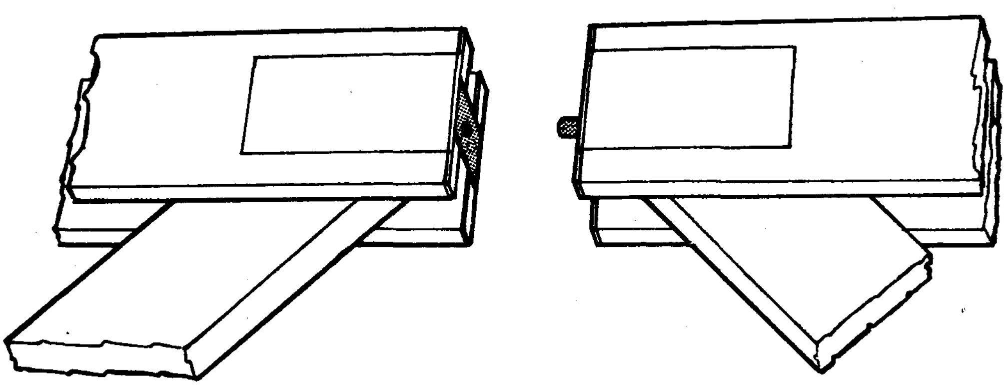
SK.2 ASSEMBLY JIG

To make up bridge trusses, the panels are connected in lines as shown in sketch SK. 3. All connexions between panels are of the type known to the structural engineer as pinned joints.



SK. 3 BRIDGE TRUSS

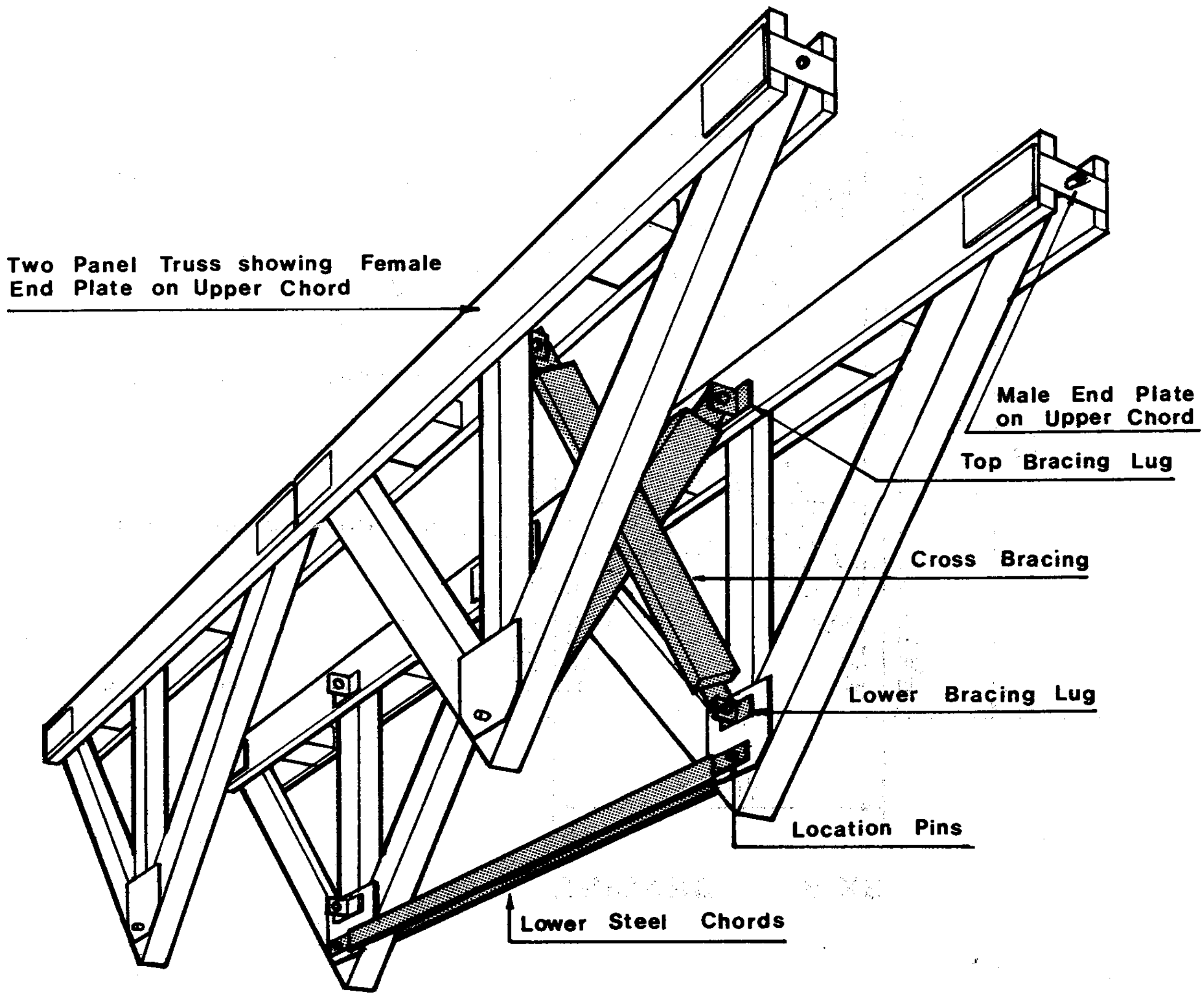
In the top chord of each truss, spigot and socket joints are formed. This is achieved by male and female steel end plates belonging to each panel, as explained previously in SK. 1. The sketch SK. 4, below, shows a pair of panels being joined in this manner. Lower chords are simple steel members which lap onto lateral spigots previously provided on the lower steel panel plates. The process of panel assembly takes place as launching proceeds, following methods detailed in the launching manual.



SK.4 TOP CHORD JOINT

TRUSSES AND GIRDERS

As previously explained, the panel is the basic module, and panels are joined in lines to make trusses; however trusses are never launched singly or used in bridges in this manner because they would be laterally unstable. During assembly under the launching tower the trusses are actually made up in pairs. Each panel has lateral top and bottom bracing lugs, to which are attached cross bracing members, this converts the pairs of trusses into girders. This cross bracing has a vital function in ensuring that the girders act as entire components, sharing the loads between the individual trusses. If panels and bracings are correctly manufactured, and girders are assembled according to the instructions, there is little possibility of dimensional inaccuracies in the finished bridge, either in the span or the width. Sketch SK. 5 explains the principle of girder construction.

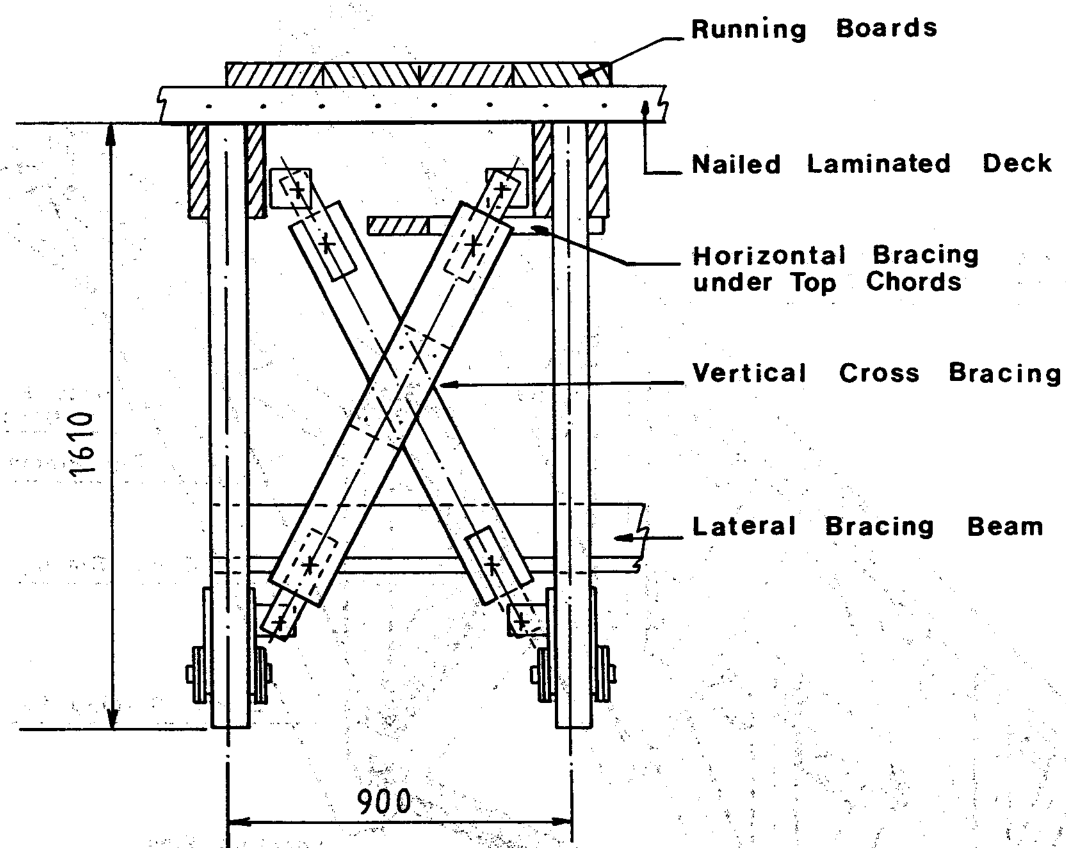


SK.5 GIRDER CONSTRUCTION

BRIDGE SECTIONS

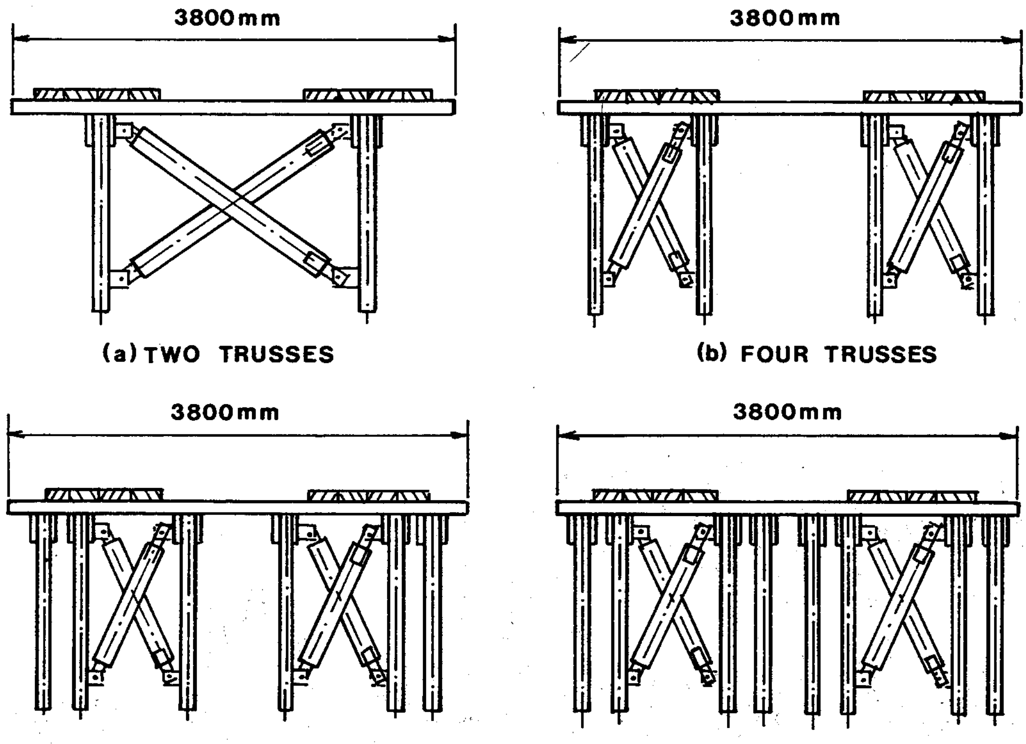
Sketch SK. 6 gives further details of the various forms of bracing, all of which are important and must not be omitted. As well as the vertical cross bracing previously mentioned there are horizontal bracing pieces that are nailed in place during completion of the superstructure, after launching is finished. Lower lateral bracing beams are also included at a later stage, these help to stabilise the lower chords.

Sketch SK. 6 also shows a section of part of the nailed laminated deck and the longitudinal running boards. It can be seen from this section that these parts help to stiffen the upper chords and play a part in distributing the wheel loads to the structure.



SK.6 BRACING

Although the bridge previously illustrated is of 21 metres span, using a total of four trusses, a variety of spans and sections are possible. The basic module is invariable, and spans must always be a multiple of 3 metres. Also there is an economical range of structural duty, as already indicated. However within this range, combinations of required span, loading and proposed timber type, together with possible cross-sectional arrangements are assessed in arriving at a design for a particular bridge. Standard cross-sections are illustrated in SK. 7.



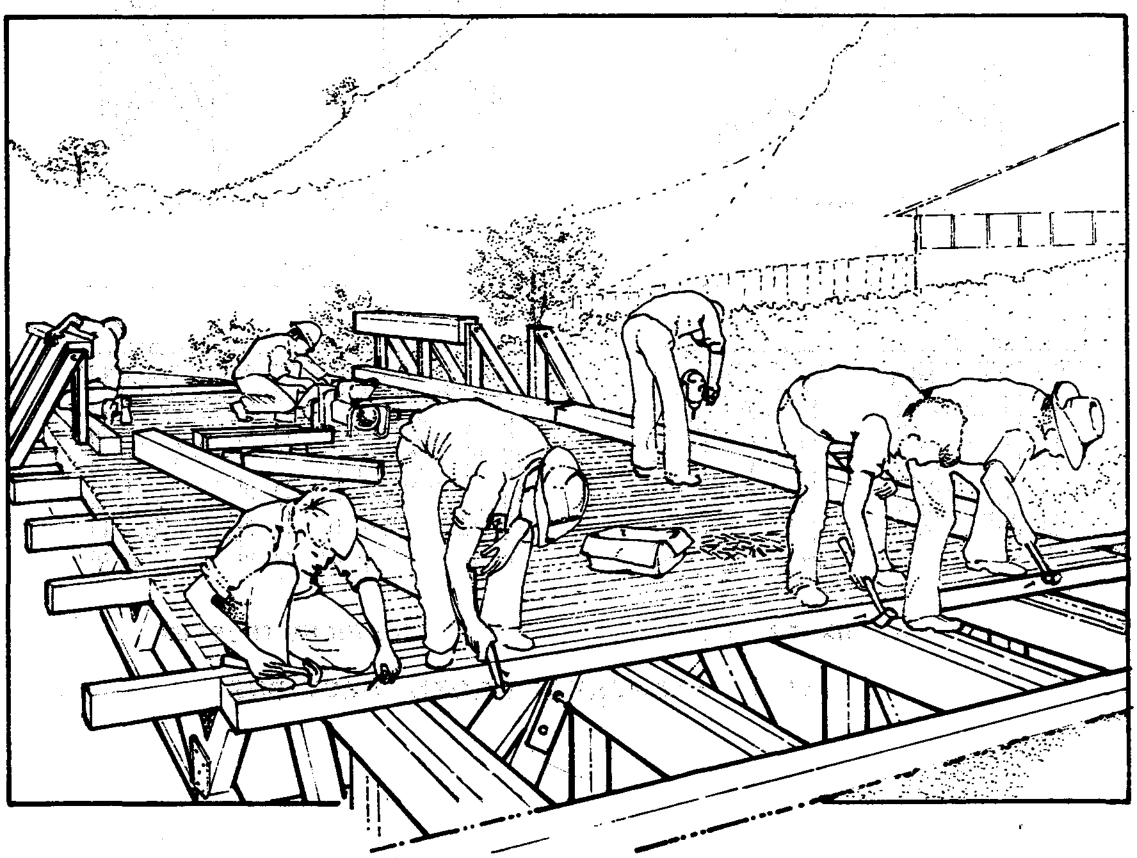
(a) TWO TRUSSES (b) FOUR TRUSSES (c) SIX TRUSSES (d) EIGHT TRUSSES

SK.7 STANDARD CROSS SECTIONS

THE DECK

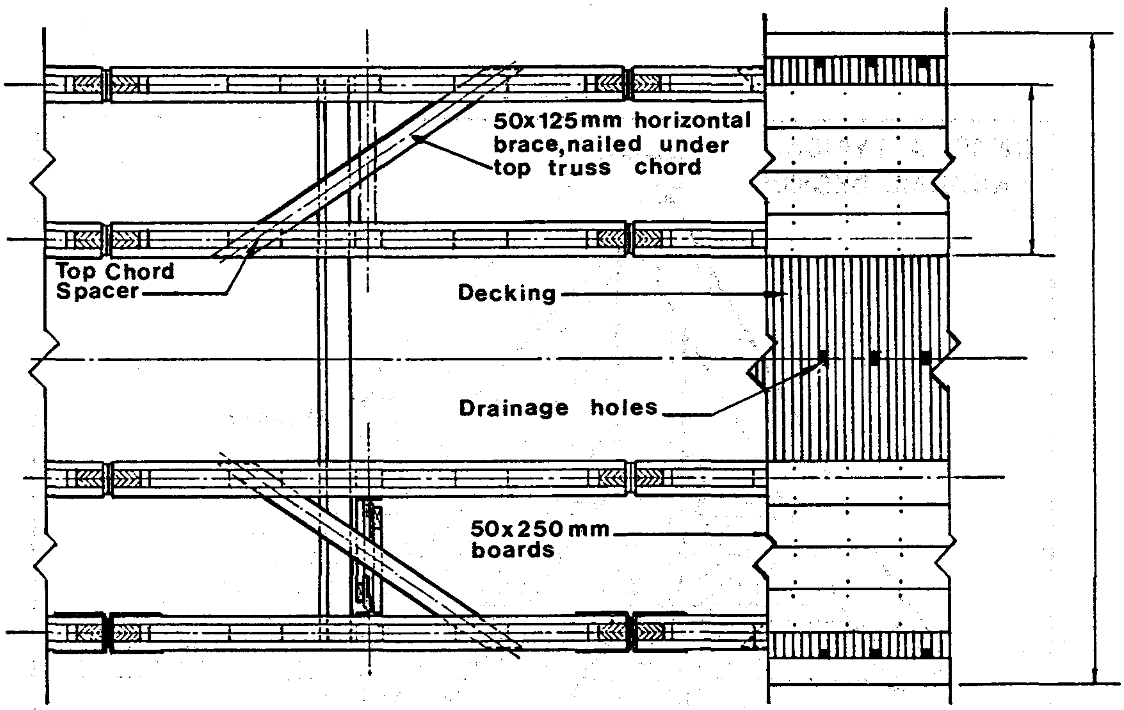
The vertically nailed laminated deck is built in situ as illustrated in SK. 8. This sketch also shows work being started on the kerbs and handrails. As previously mentioned, handrails may be omitted from forestry bridges for example, if local regulations allow.

Timber of 50 mm thickness is used for the deck. This is laid on edge, so the width of the piece becomes the depth of the deck. This dimension varies according to the loading, but 125 mm is typical. Where woodworking machinery is available in the bridge workshop it is desirable to regularise the width of these decking pieces, to ensure a level surface. Occasional decking pieces are extended in length to provide supports for the handrail. Also, a few decking members are made up from several short lengths, instead of a single piece, leaving gaps for deck drainage between the ends. Generally though, the decking is close spaced, and tightly nailed together, as it serves a structural as well as a functional role.



SK. 8 LAYING THE DECKING AND ASSEMBLING KERBS AND HANDRAILS

Sketch SK. 9 shows a part-completed deck in plan. The horizontal bracing beneath the top chords is attached to the top chord spacer packs whose principal purpose is to form each chord into a composite compression member. Each decking piece is nailed to the truss chords and to its neighbour using a detailed nailing schedule.

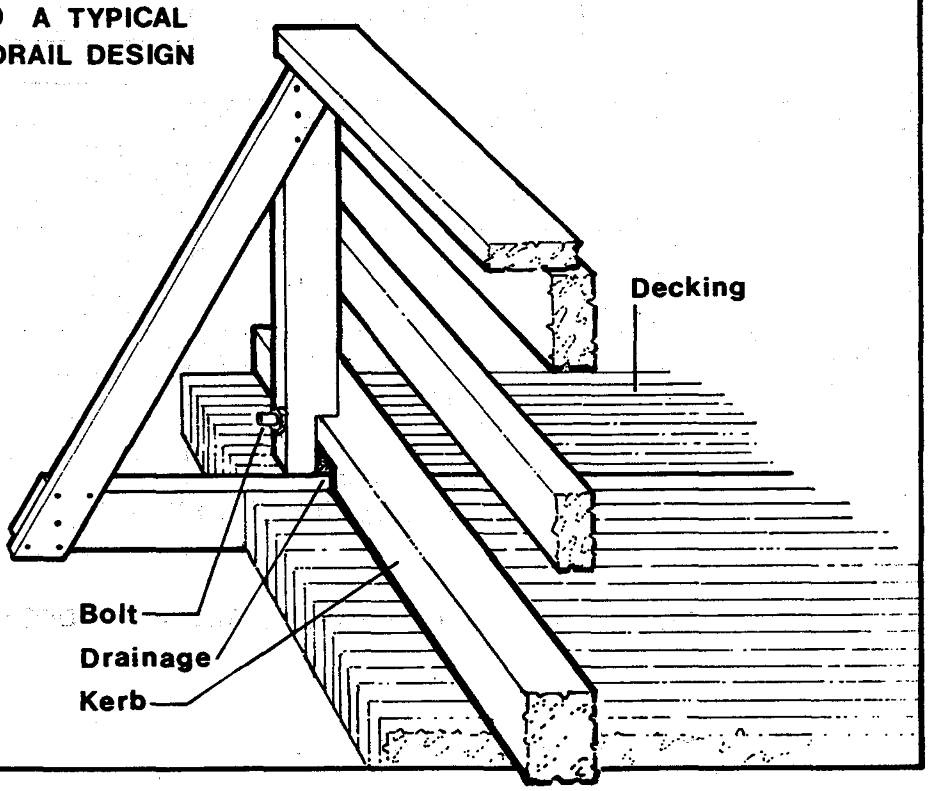


SK. 9 PART SECTIONAL PLAN OF BRIDGE SHOWING DECK BRACING

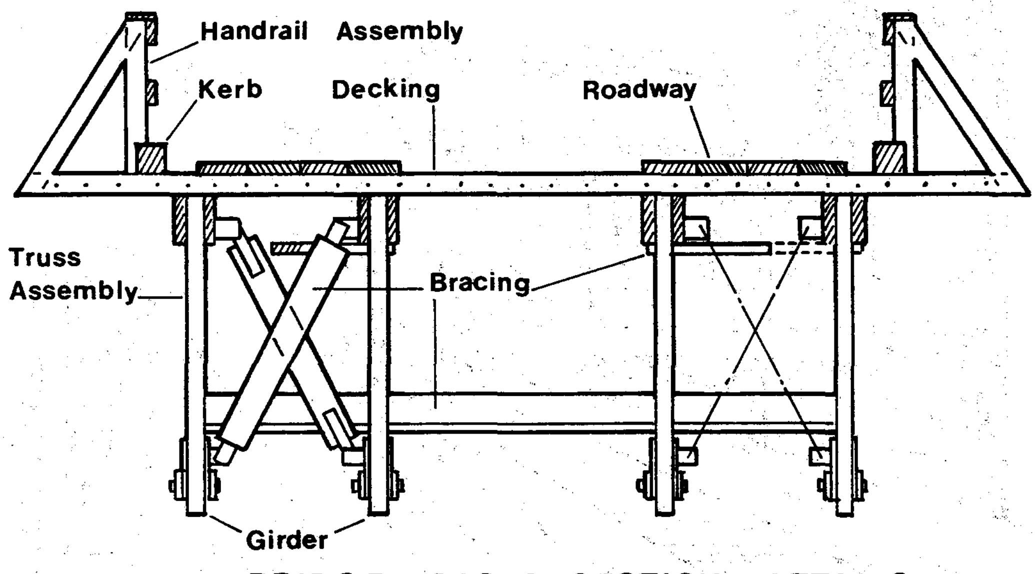
SUPERSTRUCTURE

The kerb and handrail design is illustrated in sketch SK. 10. At intervals of 1.5 metres, extra long decking pieces are extended outwards to support the diagonal braces to the handrail posts. The handrail posts are bolted to the kerbs, and other joints are made by nailing. Notches for drainage should be provided at intervals in the kerb.

SK.10 A TYPICAL HANDRAIL DESIGN

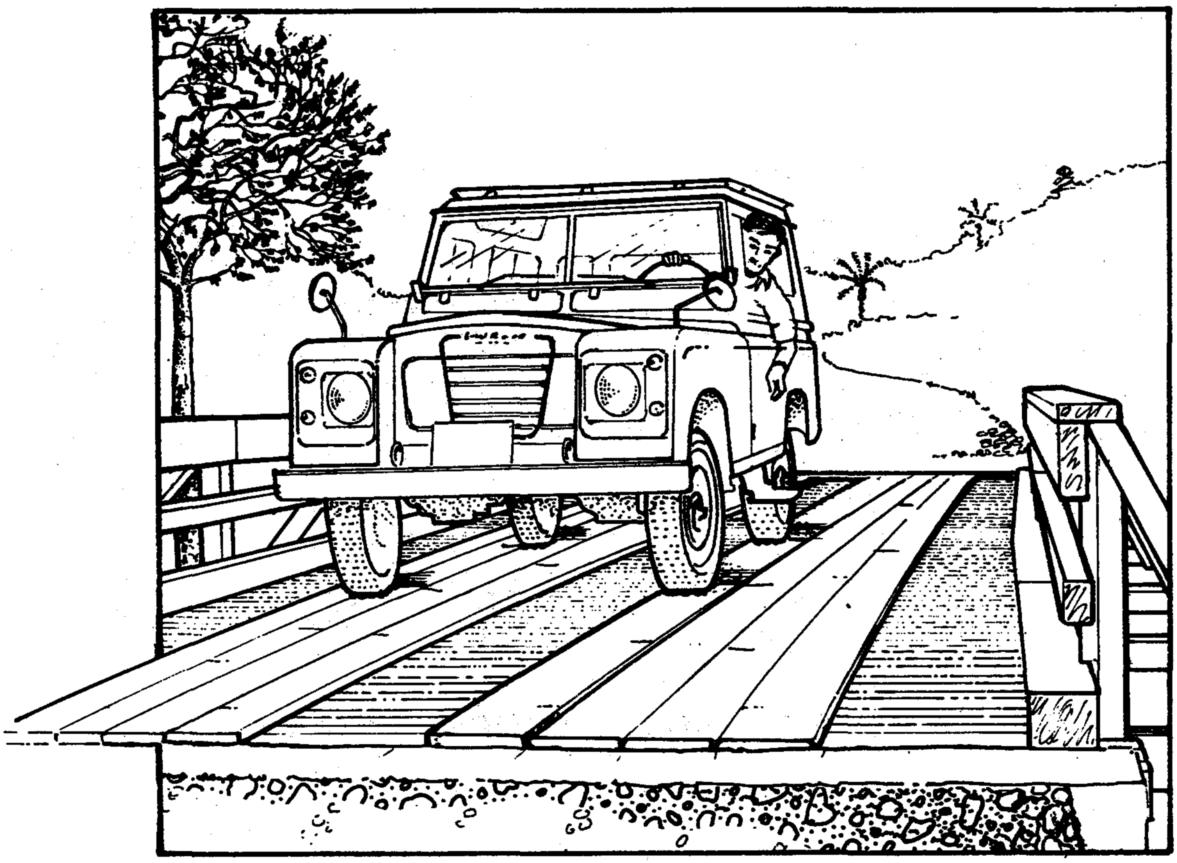


Sketch SK. 11 shows a cross-sectional view of a completed four truss bridge. This includes the longitudinal running boards. In the normal design these are nailed to the deck, but if lag screws are available in a particular region where the design is to be implemented, it may be worth considering their use as they will lead to ease of maintenance when the running boards are worn.



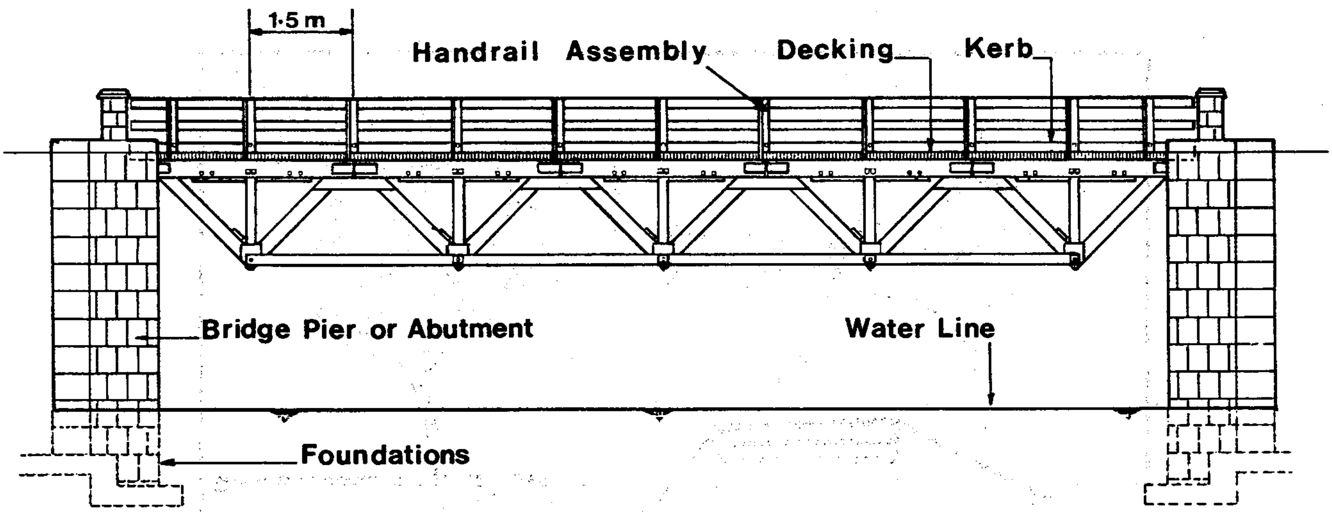
SK. 11 BRIDGE CROSS SECTION - DETAILS

Sketch SK. 12 shows a completed bridge with a vehicle using the running boards. The road surface has been graded almost up to the reinforced concrete caps of the abutments, but left a few centimetres below the level, to avoid sand and mud being washed onto the deck in heavy rains.



SK.12 COMPLETED BRIDGE AND VEHICLE UTILISING THE RUNNING BOARDS

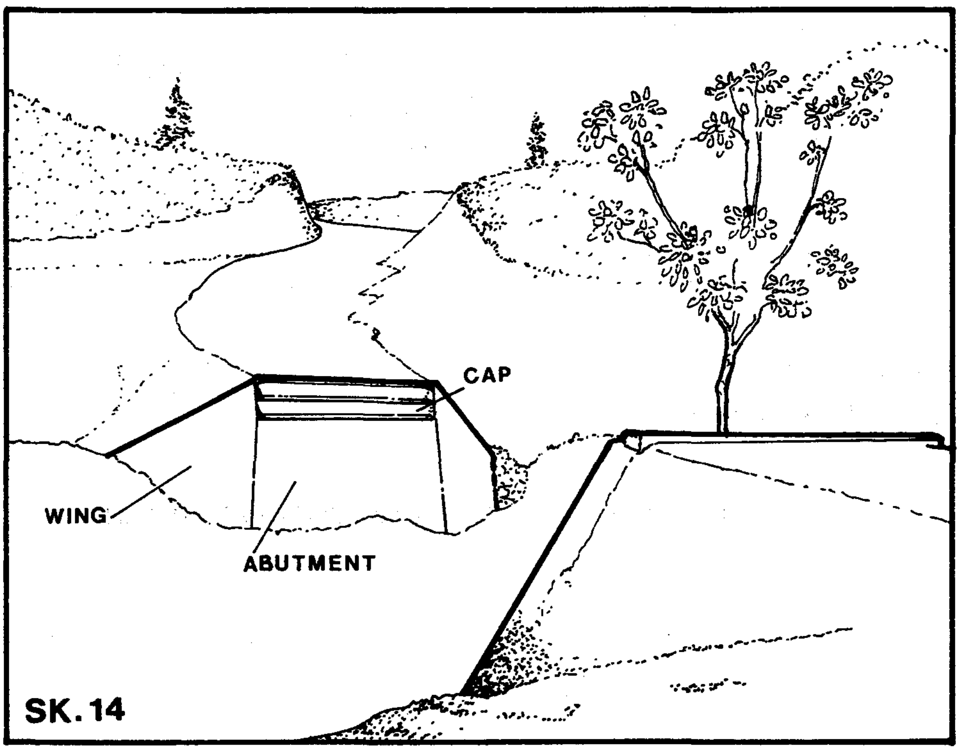
The illustration below, SK. 13, shows a typical elevation of a 15 metre span bridge which has been launched and completely constructed. In this case masonry piers are illustrated, but abutments of reinforced concrete, mass rock-filled concrete and also gabions have been used. In addition a design is available for timber approach spans supported on wood piles. Note that at each end of the handrail, pillars have been built as a visible warning to approaching traffic and a protection to the superstructure.



SK.13 PRE-FABRICATED BRIDGE SUPERSTRUCTURE

LAUNCHING THE BRIDGE

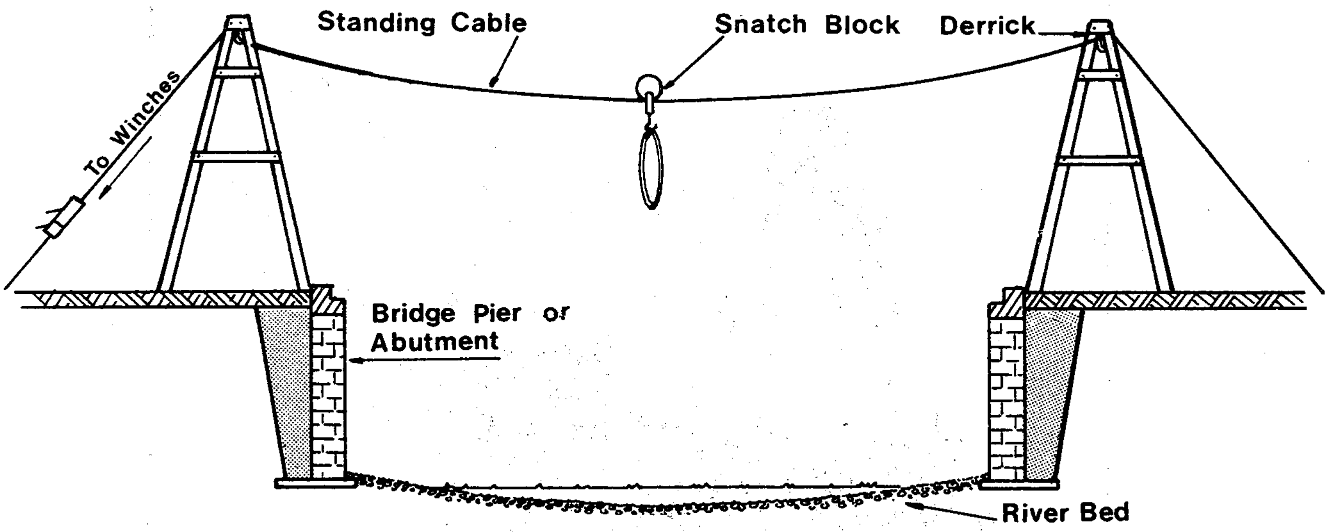
A typical site, prepared for launching, is shown in SK. 14. Note that in addition to a prepared roadway, a working area of firm ground somewhat wider than the normal carriageway is required adjacent to each abutment in order to provide safe bases for the towers and other launching equipment.



SK. 14

A TYPICAL SITE

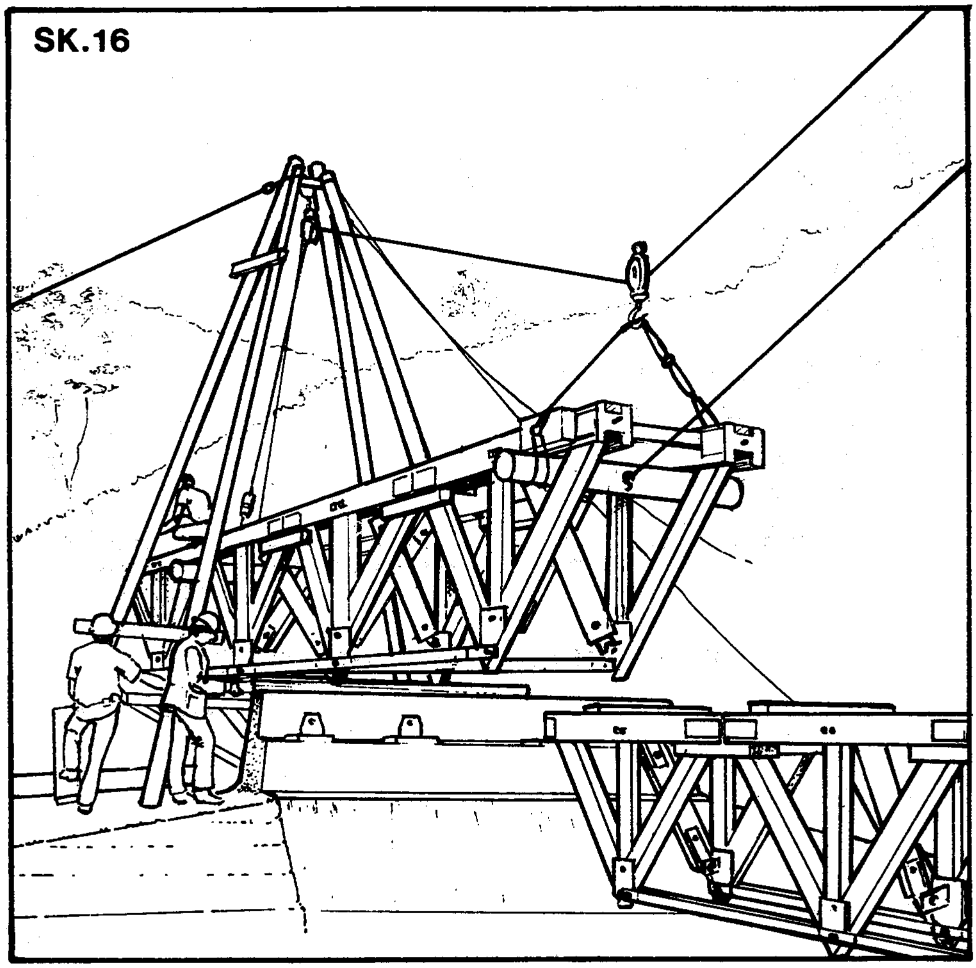
Sketch SK. 15 shows the general arrangement in preparation for launching. The towers, or derricks as they are sometimes called, are made from timber poles 150 mm in diameter at the tips. Alternatively, 100 mm steel tubes have been used. The launching manual gives details of the derrick design. Manually operated winches of the 'Tirfor' or 'Pulman' type are needed, and these are shackled to deadman anchors each side of the span, made by burying a large log with cable attached. The tower tops should be guyed in four directions on plan, using convenient trees, rocks, or additional ground anchors to steady against unforseen overturning forces during the launch.



SK.15 ERECTION EQUIPMENT

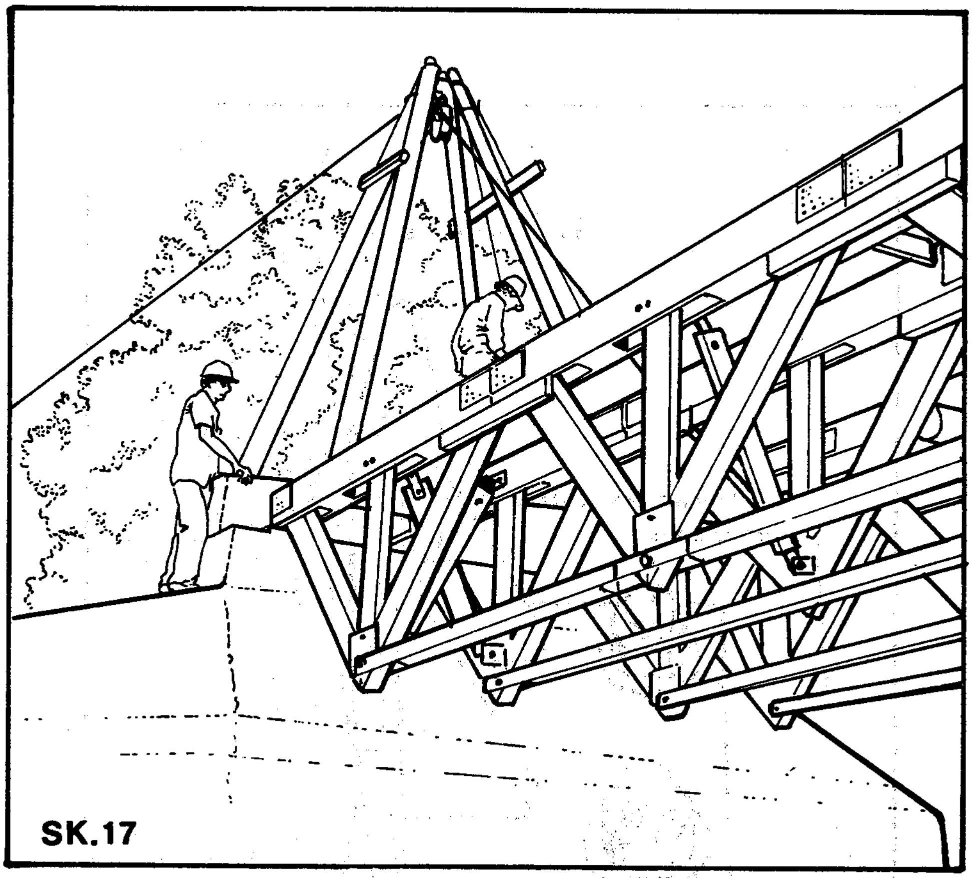
The modular wooden panels are assembled into girders beneath the derrick on the 'near' bank. Sketch SK. 16 shows the launch in progress, with one girder already in place across the span and a second girder in the foreground, suspended from the standing cable. Details of the lifting harness and the packing needed to avoid damage to the timber through cuts from the cables, are included in the launching manual. In this sketch, the roadway has not been completely levelled but a timber working platform at waist height has been built to provide a firm, flat base for the assembly. Temporary lateral bracing pieces are nailed across the girders to stiffen them for launching, also small longitudinal stiffening pieces are added beneath the spigot and socket joints on the top chords, to prevent these from pulling apart prior to completion.

SK.16



LAUNCH IN PROGRESS

As panels are added to the tail of the girder, the nose is drawn forward beneath the suspension cable by another winch on the far bank. Once all panels are in position, the nose of the bridge will be close to the far pier caps and the tail will be resting beneath the crown of the near derrick. At this stage, the standing cable is kept as slack as possible, conducive with having sufficient height to draw the top chord of the nose onto the cap. The tail is gently lifted, using a further winch, and the girder is eased forward onto the bearing pads. Sketch SK. 17 shows the second girder in this position, with the cable used to lower the tail still in place.

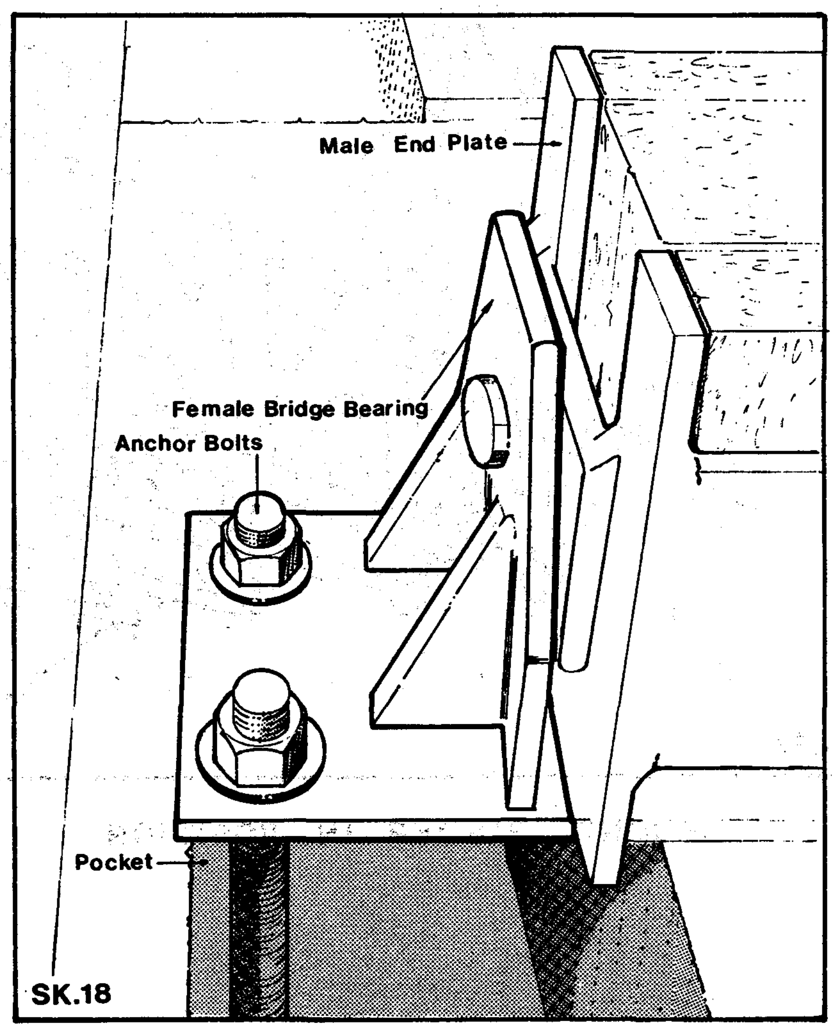


SECOND GIRDER IN POSITION

COMPLETION

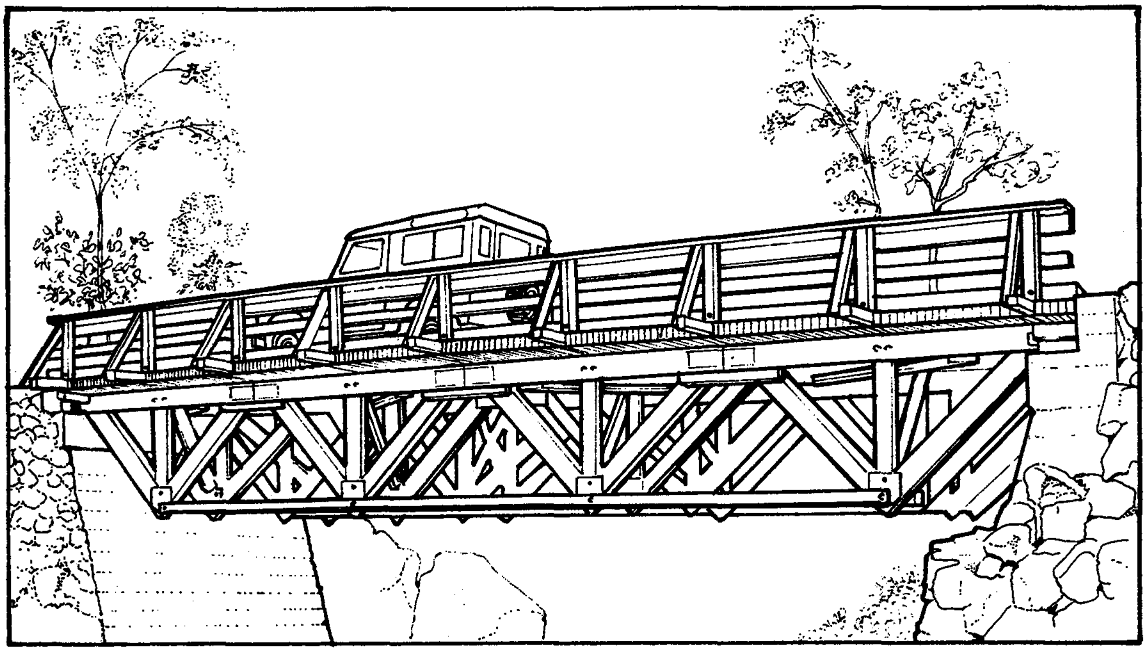
Male and female bearing plates are part of the design, forming supports for the bridge at each end of the span. For wooden bridges of this size, such simple bearings are perfectly adequate, and provision for expansion, such as with rolling bearings, is unnecessary. The bearing plates may be set in position, with cast-in anchor bolts, on the near side of the span, but it is essential to leave open pockets and to grout in the anchor bolts on the far side after launching. This method accommodates slight variations in span and camber which are inevitable, even in an accurately made pre-fabricated design.

Sketch SK. 18 shows a close up view of a holding-down pocket, which is pre-cast in the reinforced pier cap. The female bridge bearing receives the spigot from the top end plate of the last panel in the truss. A corresponding male bearing plate is required on the oppposite bank.



HOLDING-DOWN POCKET

After launching all girders, and aligning them on the bearings, the superstructure is built, as previously described. Whilst deck construction proceeds, temporary bracing is replaced by the specified arrangements. The anchor bolts on the far bank are only grouted into their pockets when nearly all of the dead weight of the superstructure has been added. A small part of the deck at each end of the span is removeable for access and maintenance of the bearings. A completed bridge of 12 metres span is illustrated in SK. 19.



SK. 19 THE COMPLETED BRIDGE

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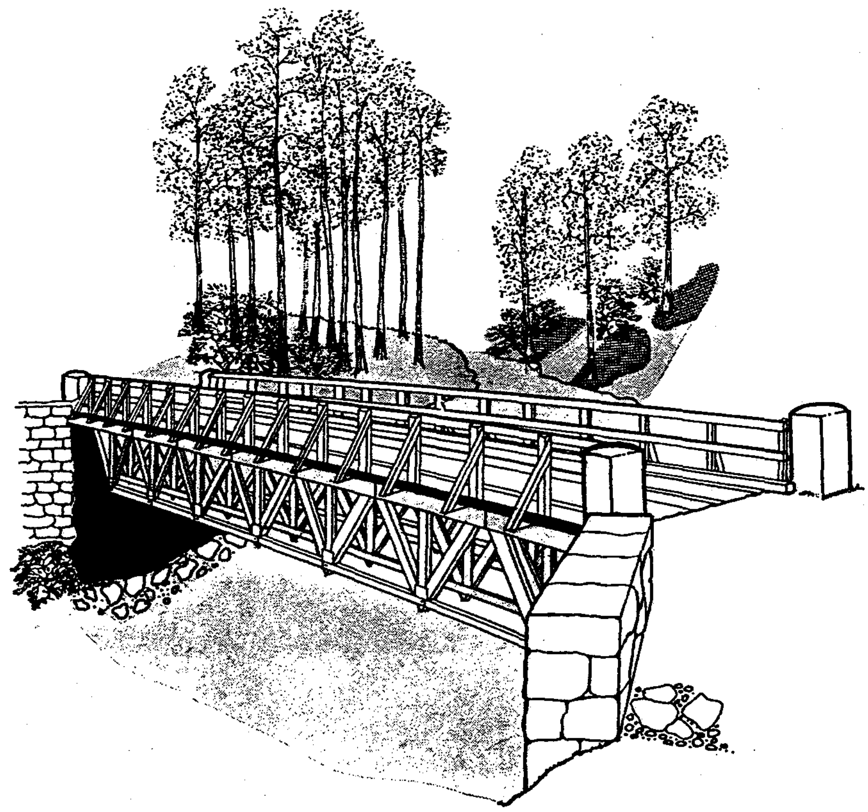

PART 2 • MANUFACTURE OF PRE-FABRICATED PARTS AND DESIGN SELECTION

prepared for

UNIDO • UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA, AUSTRIA

by

TRADA • TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION, UNITED KINGDOM

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PRE-FABRICATED MODULAR WOODEN BRIDGES

Part 2 Manufacture of Pre-fabricated Parts and Design Section

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PRE-FABRICATED MODULAR WOODEN BRIDGES

Part 2 Manufacture of Pre-fabricated Parts and Design Selection

INTRODUCTION

This section of the manual deals with the following:-

Chapter 1 - Manufacture of pre-fabricated parts
Chapter 2 - Design selection process

The object of Chapter 1 is to describe the modular panels in greater detail, and to provide information on their manufacture together with the fabrication of other parts which are prepared before going to site. A related topic is the design selection process, covered in Chapter 2. Information and aids to design are included in the second chapter, and it is only necessary to obtain a thorough understanding of the system in order to complete the selection process for a particular site, no stress calculations or other original design steps are required. A general description of the modular wooden panels forming the trusses of the bridge system, together with an outline of site, bridge construction and launching concepts may be found in Part 1, the General Description section of these manuals. The user will find it helpful to familiarize himself with the first part, before studying the details in this and subsequent parts of the manuals.

The pre-fabricated modular wooden bridges are intended to be manufactured from a wide range of timbers. The chief considerations in choice of timber are: durability, necessitating either natural durability or amenity to treatment, reasonable seasoning characteristics, strength and working properties. Limited information on selection of species and use of the chosen timber in conjunction with the design tables may be found in this section of the manual. Greater details of this aspect are given in Part 4, the Timber Technology section of the manuals. Part 3, Construction and Launching, gives full particulars of those aspects of pre-fabricated modular wooden bridge implementation. A complete set of working drawings based upon a 15 metre span, four-truss bridge is also available, and is reproduced in Part 5, Typical Design.

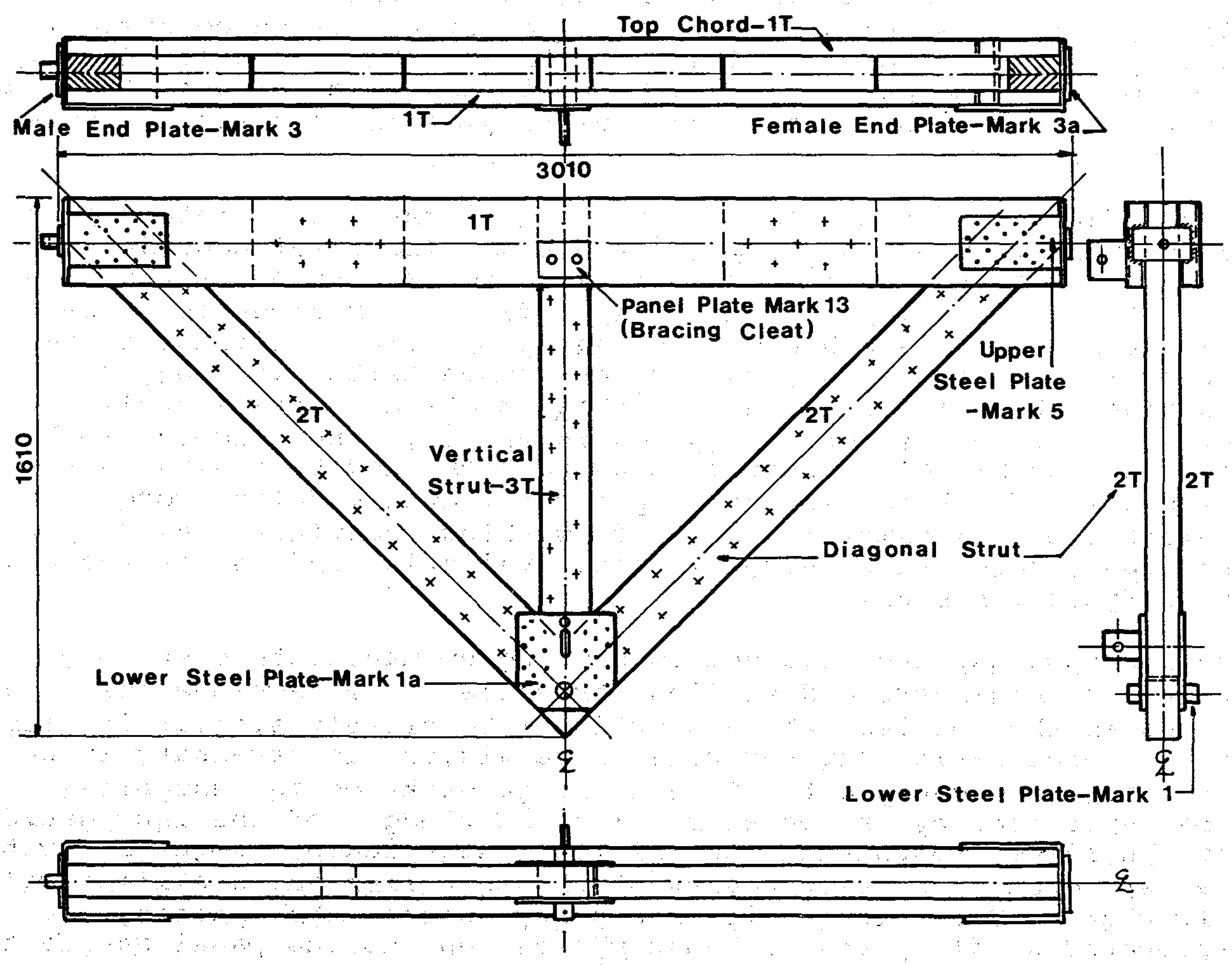
There are some aspects involved in setting up manufacture which must be initiated by engineers and skilled tradesmen. To achieve the accuracy required in the modules, which should all be closely similar in size and shape, careful laying out and close supervision is necessary in setting up the jigs and equipment. Once a bridge workshop is established, it can be supervised by a manager with knowledge of the fabrication of light building components or similar experience, together with a carpenter foreman, a storekeeper/stock controller and a skilled welder/ metalworker. The latter is necessary since the welding of the pre-prepared steel plate sub-assemblies and during panel manufacture, must be of a good quality, as befits structural work.

Chapter 1 - MANUFACTURE OF PRE-FABRICATED PARTS

BASIC DESCRIPTION OF THE PRE-FABRICATED PARTS

The following description of the pre-fabricated parts is intended as a more detailed introduction. Whilst giving information additional to Part 1, it is nevertheless essential that reference is also made to the full engineering drawings, Part 5, before detailed plans for manufacture are implemented.

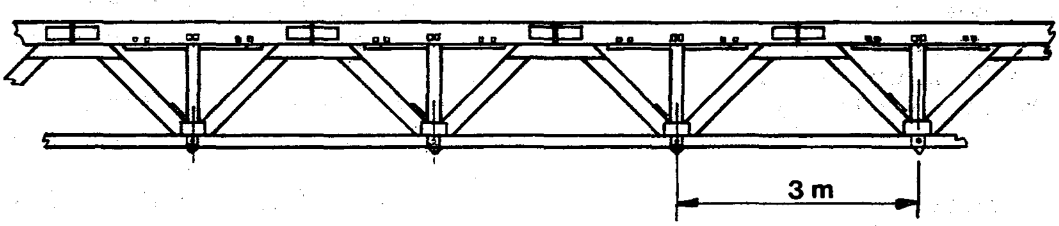
As mentioned in Part 1, the modular wooden panel, also just referred to as a panel, is the basic pre-fabricated element of the design. It is this that gives the bridge system its 3 metre module of span. Sketch SK. 1 shows the principal parts of a panel, together with the steel panel plates and the identification numbers of the steel and wooden parts.



SK.1 MODULAR WOODEN PANEL - LIGHT CHORD

When panels are formed into trusses, as shown in sketch SK. 2, the precise measurement from centre to centre of the lateral pins on the lower steel plates of the panel (Mark 1 and 1a) is 3 metres. The precise length of the top chords, from face to face of the end plates, is however 3010 mm, and it is this difference in length which provides the in-built camber to the design.

At this stage, it should be noted that design selection can be made both for what are known as light-chord designs, and also for heavy-chord types. The original designs carried out in Kenya had a single standard set of steel parts corresponding approximately to what is now known as the light-chord type. Later, it was realised that with higher strength timbers, the design of the steel parts rather than that of the timber could be critical, and the heavy-chord design was introduced.



SK.2 TRUSS ARRANGEMENT

Table 1 below provides references to the 'Mark numbers' of the steel sub-assemblies and components which are affected by the choice of light or heavy chords.

TABLE 1

Description and part numbers of steel parts, distinguishing between light and heavy chord designs

Description	Part number: Common	Light chord	Heavy chord
Upper steel plates	Mark 5	-	-
End plates (male and female)	-	Mark 3 (m) Mark 3A (f)	Mark 10 (m) Mark 10A (f)
Bracing cleat (top chord)	Mark 13	-	-
Lower steel plates (with and without bracing cleat)	- -	Mark 1 (no cleat) Mark 1A (cleat)	Mark 9 (no cleat) Mark 9A (cleat)
Lower steel chords (with and without extensions)	-	Mark 2 (no extension) Mark 2A (extension)	Mark 6 (no extension) Mark 6A (extension)
Bridge bearing plates (male and female)	-	Mark 14 (m) Mark 14A (f)	Mark 15 (m) Mark 15A (f)
Bracing end plate	Mark 8	-	-

The description of the basic parts continues at this stage mainly with reference to the light-chord design, which is more commonly suitable for moderate bridge spans on rural feeder roads.

All the timber of a modular panel is of 50 mm basic thickness, whilst the depth of each member varies from 100 mm to 250 mm according to its duty. Each timber module consists of two identical half-panels, each constructed in a jig and subsequently nailed back-to-back. The top chords are separated by spacer blocks but other members are two-piece thick vertically nailed laminated members. There are a number of advantages of this form of design, including the following:

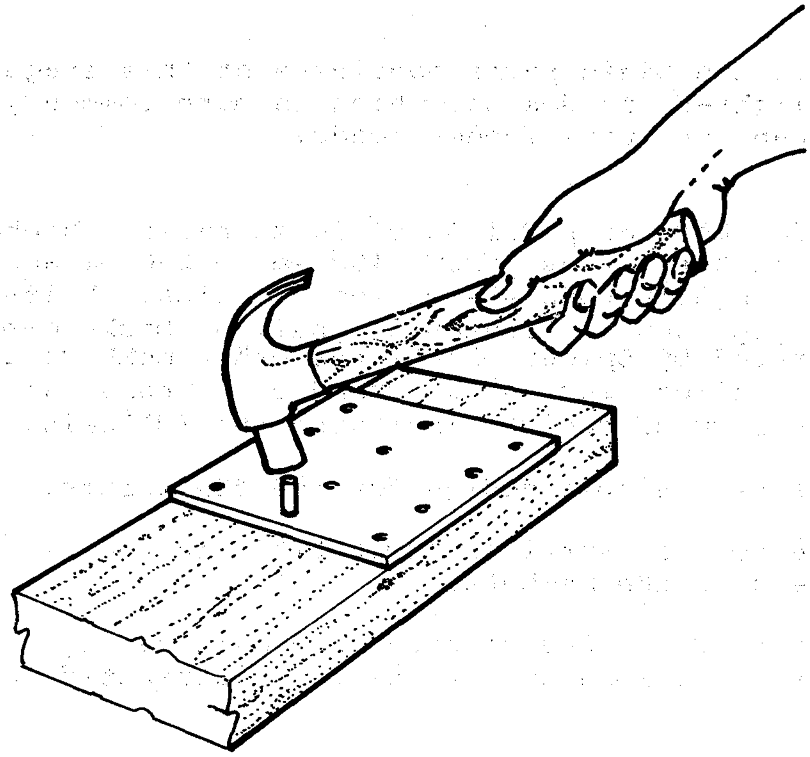
* It facilitates a simple design for the top joints.

* The simple form of vertical lamination increases the strength and stiffness of the members.

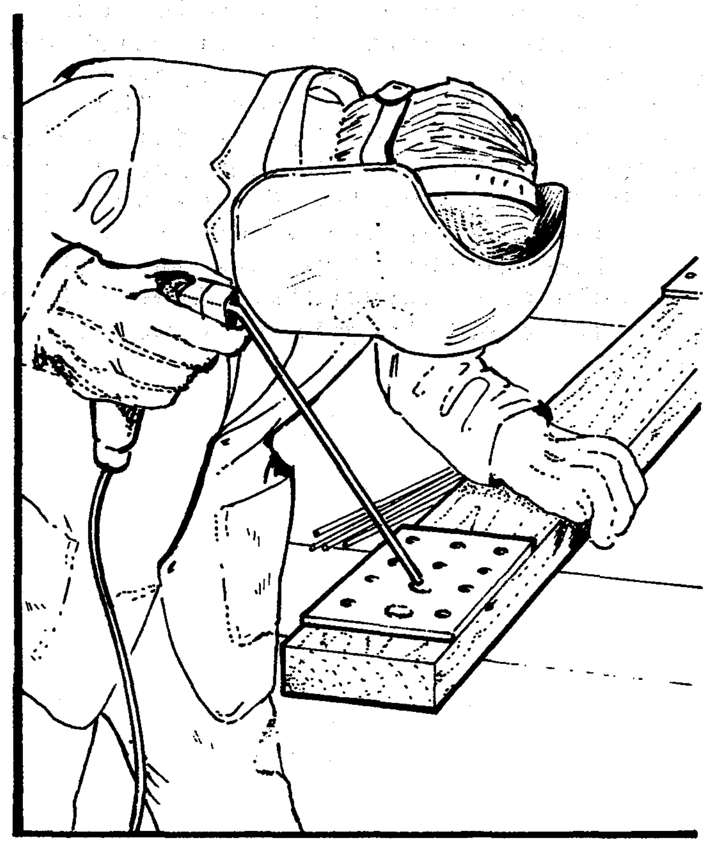
* Knots, sloping grain and fissures are more easily controlled in the thinner sections and are better distributed throughout the component.

* Timber can be effectively treated with preservative, if necessary and economically dried to the correct moisture content.

Structural joints are required between the members of the module and the steel plates connected to them. These joints are effected by a very strong and simple method making use of plain mild steel rods. The rods are welded to the plates to form a doweled joint which has a rigid head, and which bears onto the wood in a manner approaching pure shear, considered ideal in bolted wood structures. The rods are a light interference fit in the wood, achieved by careful choice of the wood drill. They are tapped into the wood through pre-drilled holes in the plates, as shown in sketch SK. 3. on the following page. After panel assembly is complete, the dowel heads are welded to the plates, as shown in sketch SK. 4. All joints of this type are made with 12 mm diameter dowels, which must be of weldable structural steel of the same type as the plates. Only two different lengths of dowel are found in the various parts of the design.

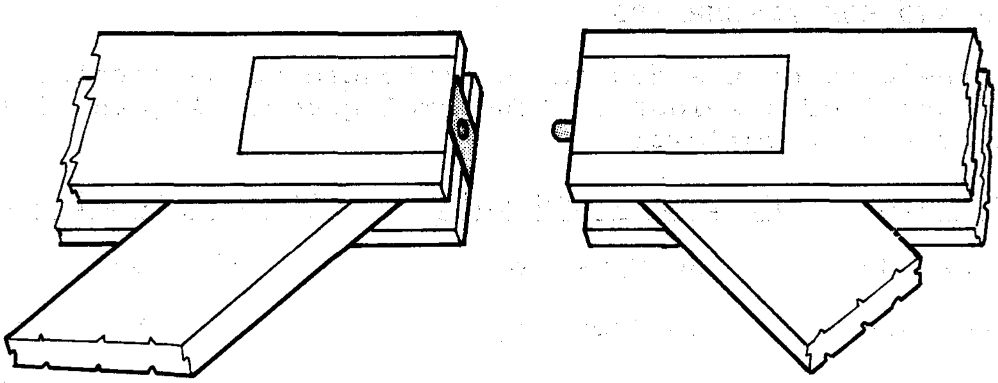


SK. 3 TAPPING IN MILD STEEL DOWELS



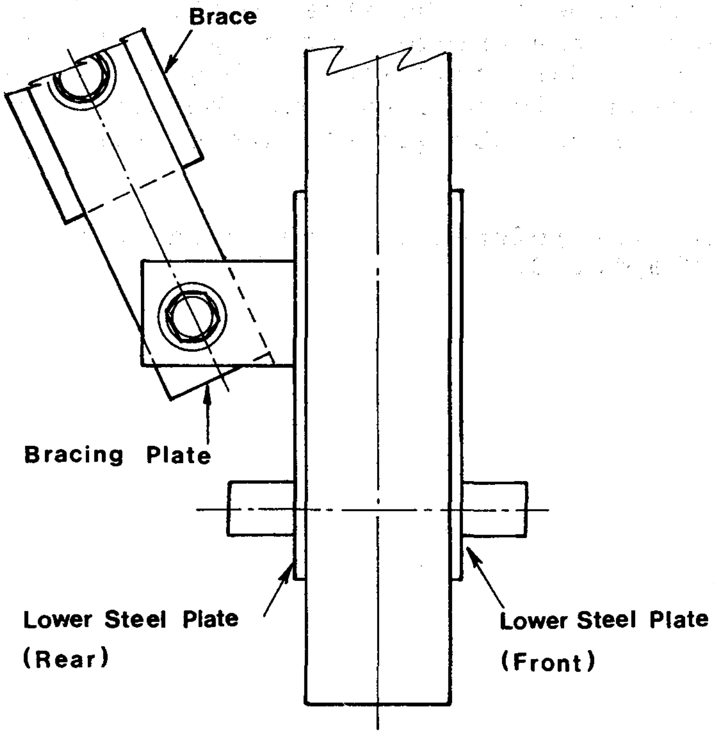
SK. 4 WELDING THE DOWEL HEADS

Several of the steel plates in the panel have pins or sockets to enable the modules to be assembled into trusses. At one end of the top chord of each panel a pin projects in the direction of the span. This pin locates in a corresponding socket at the other end of the top chord of the neighbouring panel, as shown in sketch SK. 5. These pin and socket joints are fabricated by welding individual panel plates during manufacture, as described in later details.



SK. 5 TOP CHORD FIXING

At each side of the lower steel plates lateral pins project, to enable the lower steel chords to be fitted during site assembly. The inner lower steel plate also has a bracing cleat. The end elevation of this part of the panel is shown in sketch SK. 6.



SK. 6 END ELEVATION ON PANEL BOTTOM

Both types of pin described on the previous page vary in diameter according to whether a light chord or a heavy chord design is required. The top chord pins are 32 mm diameter for the light chord type, and 38 mm for heavy chords, whilst the lower pins are 38 mm or 50 mm.

STEEL PLATES AND SUB-ASSEMBLIES

The entire steelwork of the design is intended to be carried out with a normal mild steel of a weldable structural grade. Alternative typical specifications are as follows:

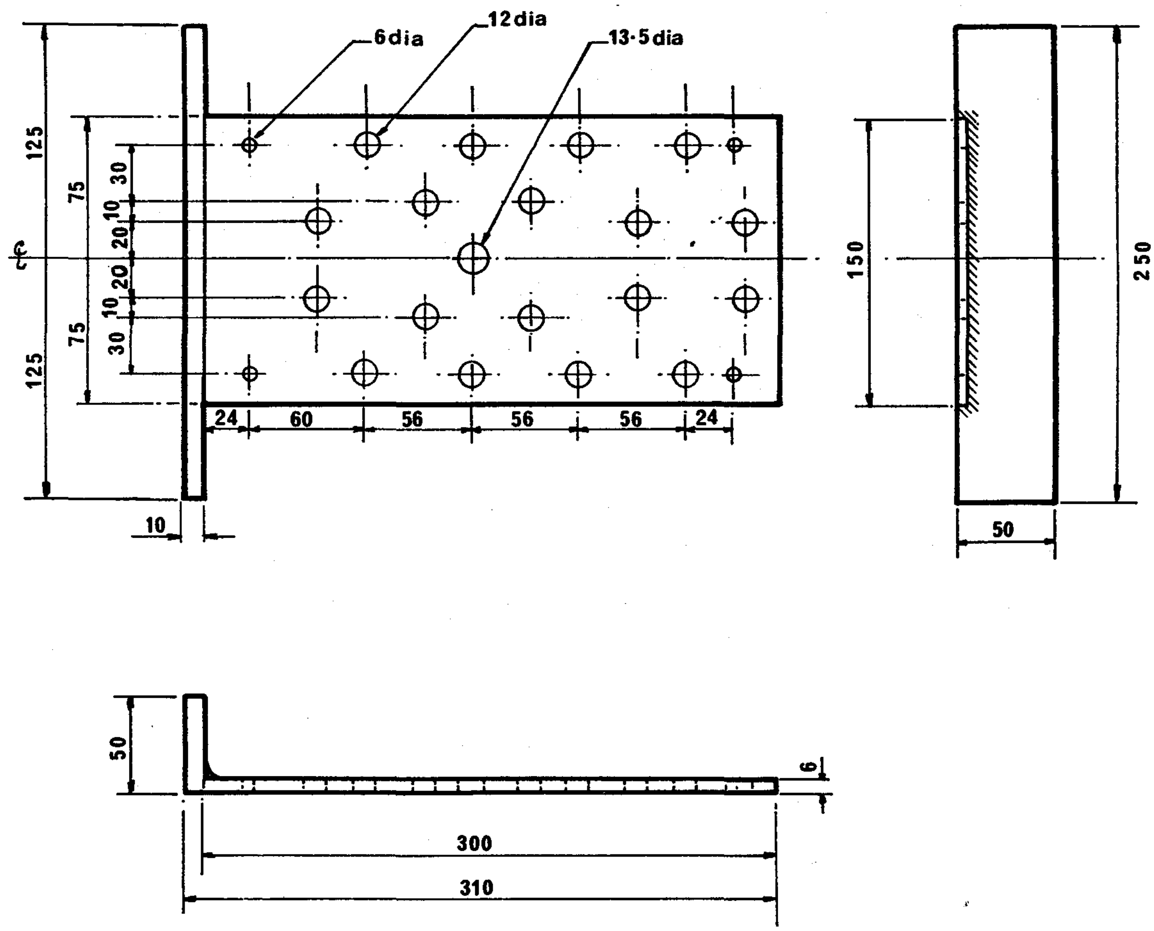
Standard grade	Minimum yield point	Ultimate tensile strength
BS 449 grade 43A	236 N/mm sq	435 - 494 N/mm sq
ASTM grade A36	248 N/mm sq	400 - 552 N/mm sq

Protection against corrosion is not specified, since conditions and considered cost benefits vary. Attention is drawn to the fact that this ought at least to be considered in any particular project however. Treatments can vary from two coats of red lead or zinc rich paint preceded by wire brushing, which is considered just a little better than a decorative finish, to galvanizing after shot or grit-blasting. In any event, attention is also drawn to the need for thorough surface preparation and the treatment of both faces and all edges of the plates. Further information on these topics can be obtained in BS 5493 (Reference 1)* and Overseas Building Note No. 171 (Reference 2).

Pages 9 to 14 describe all the steel plates and steel sub-assemblies which must be made in the bridge workshop or by sub-contractors before panel assembly and bridge launching can begin. All the welding shown in the next seven sketches is carried out before panel manufacture. Some further welds described subsequently are carried out during the course of assembly.

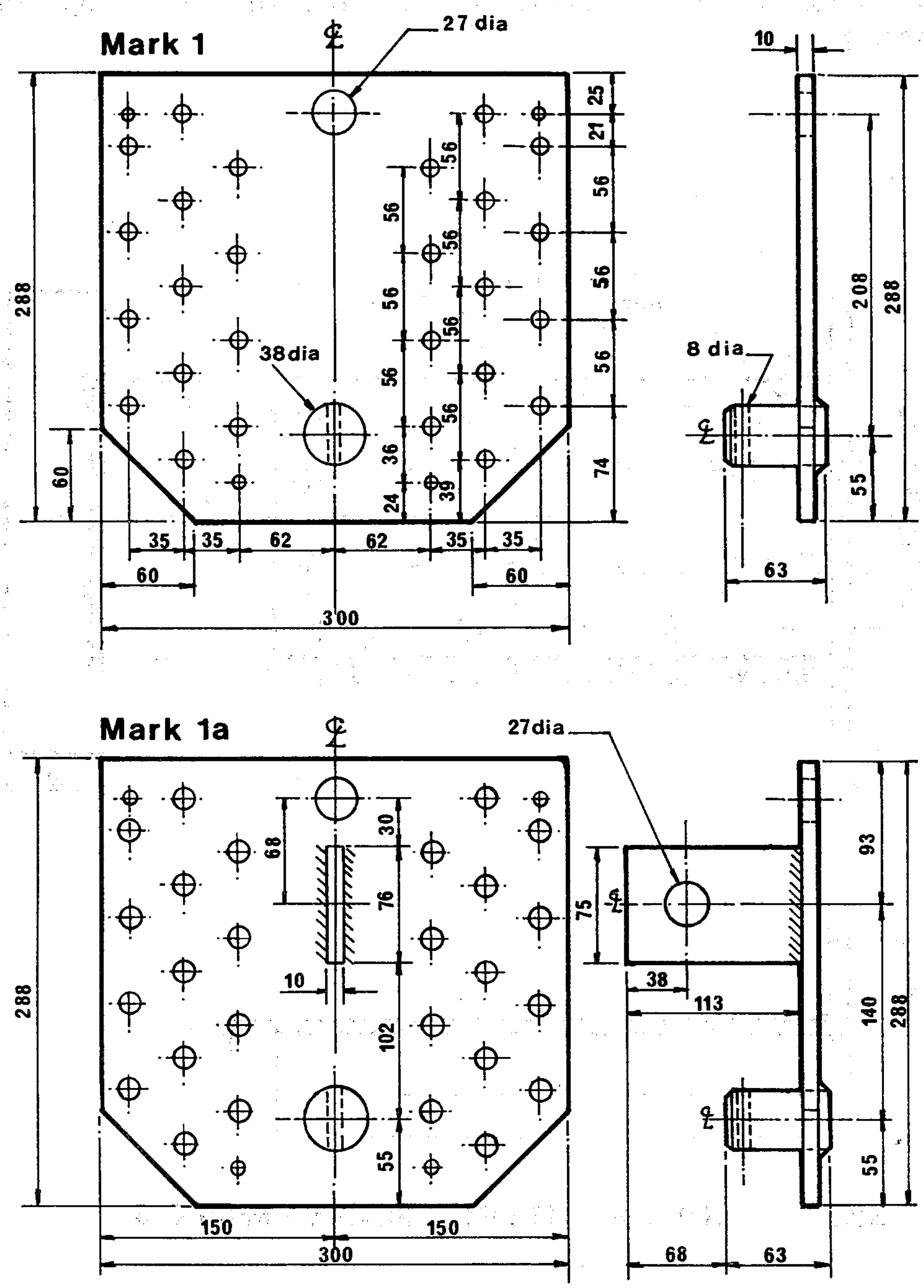
* A section giving the references indicated in this manual may be found at the end of Chapter 2.

Sketch SK. 7 shows the upper steel plate sub-assembly which is located at the sides of each end of the top chord of the panel. It is a symmetrical design and so does not need to be in leftand right-hand pairs. It has no bracket or pin attachments, consequently it is listed as 'common' in Table 1. Four such plates, known as Mark 5, are required for each modular panel of either light or heavy chord type. In addition to eighteen holes for subsequent insertion of dowels, the plate has four smaller holes for temporary location during panel assembly. It also has one slightly larger hole for a bolt which passes through the plate on each side, gripping the double thickness of timber in between, thus stitching together the whole assembly. The function of the 10 mm thick flange welded before panel manufacture to this sub-assembly is to provide support for another plate added during manufacture, and also to protect the ends of the individual timbers in the top chords from mechanical damage.



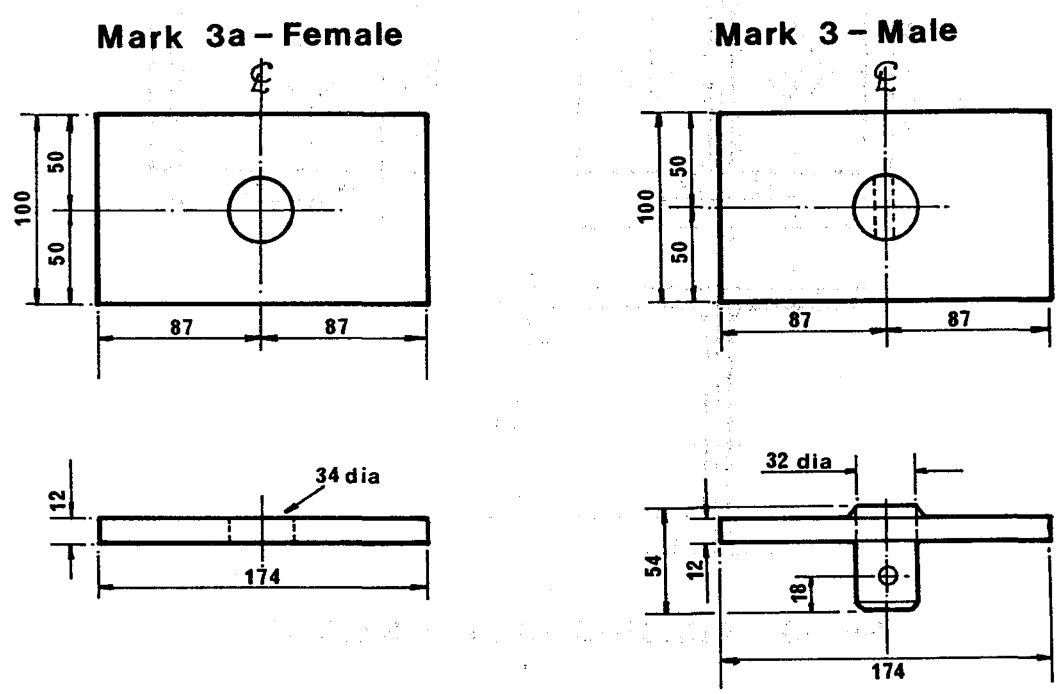
SK.7 UPPER STEEL PLATE - MARK 5

The lower steel plates fitted to the inverted apex of the panel at each side are shown in sketch SK. 8. These have lateral pins for subsequent lower chord attachment which vary in diameter according to the use of light or heavy chords. In addition they are made in pairs, and the plate which is placed innermost when the panel is assembled into a girder has a laterally projecting bracing cleat to receive the diagonal vertical bracing. Light chord lower steel plates without cleats are known as Mark 1, as indicated in Table 1, which also shows that Mark 1A is the light chord plate with a cleat, and Mark 9 and 9A are the corresponding heavy chord types.



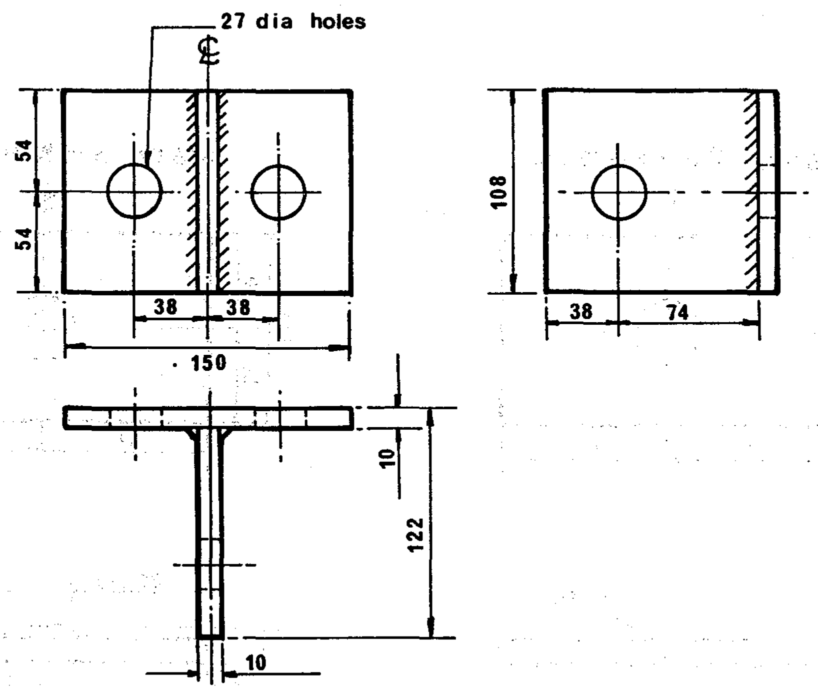
SK.8 LOWER STEEL PLATES

Sketch SK. 9 shows the male and female end plates Mark 3 and 3A. These are located at the ends of the top chords, one male and one female on each panel. They are welded to the upper steel plates, Mark 5, during panel manufacture. The end plates form the pinned connections between adjacent sections of the top chord. These connections remain in commpression. As with the lower steel plates, the end plates have different diameters of pin for heavy chords and in this case the male and female plates are known as Mark 10 and 10A respectively. In either type of design, the male plates have lateral holes pre-drilled in the pins to receive split pins which prevent the panels from sliding apart during bridge assembly.

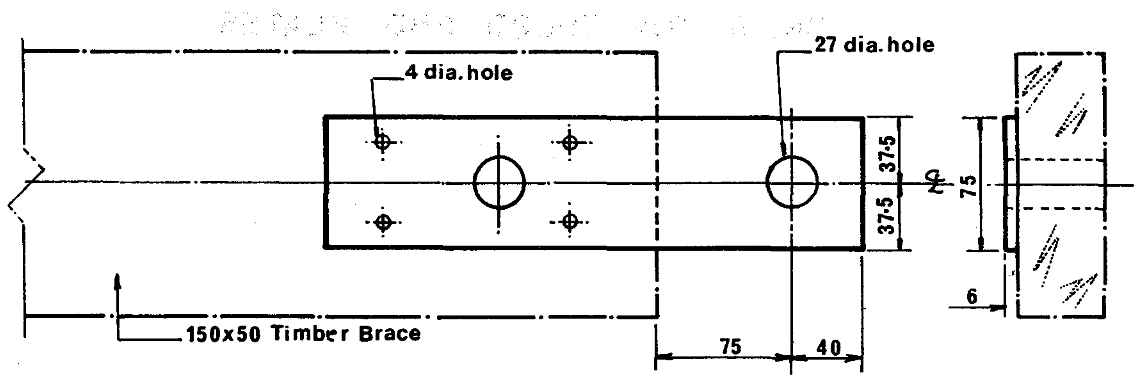


SK. 9 TOP CHORD END PLATES

Sketch SK. 10 shows a bracing cleat Mark 13, common to both light and heavy chords, which is bolted to the back of the top chord of each panel, during manufacture. The bolts used for this purpose also help to unite the top chord pieces. The cleat forms an attachment for the upper ends of the lateral diagonal bracing during girder assembly. The lower end of the bracing attachment has already been shown in sketch SK. 6. The diagonal bracing is of importance in providing structural stability. In addition it is accurately pre-fabricated on a simple jig rather than being added as a carpentry piece on site. This ensures the correct lateral spacing of the trusses in the girders. Because of this need for strength and accuracy, a simple flat plate, Mark 8, shown in sketch SK. 11 is used to join the ends of the braces to the cleats.

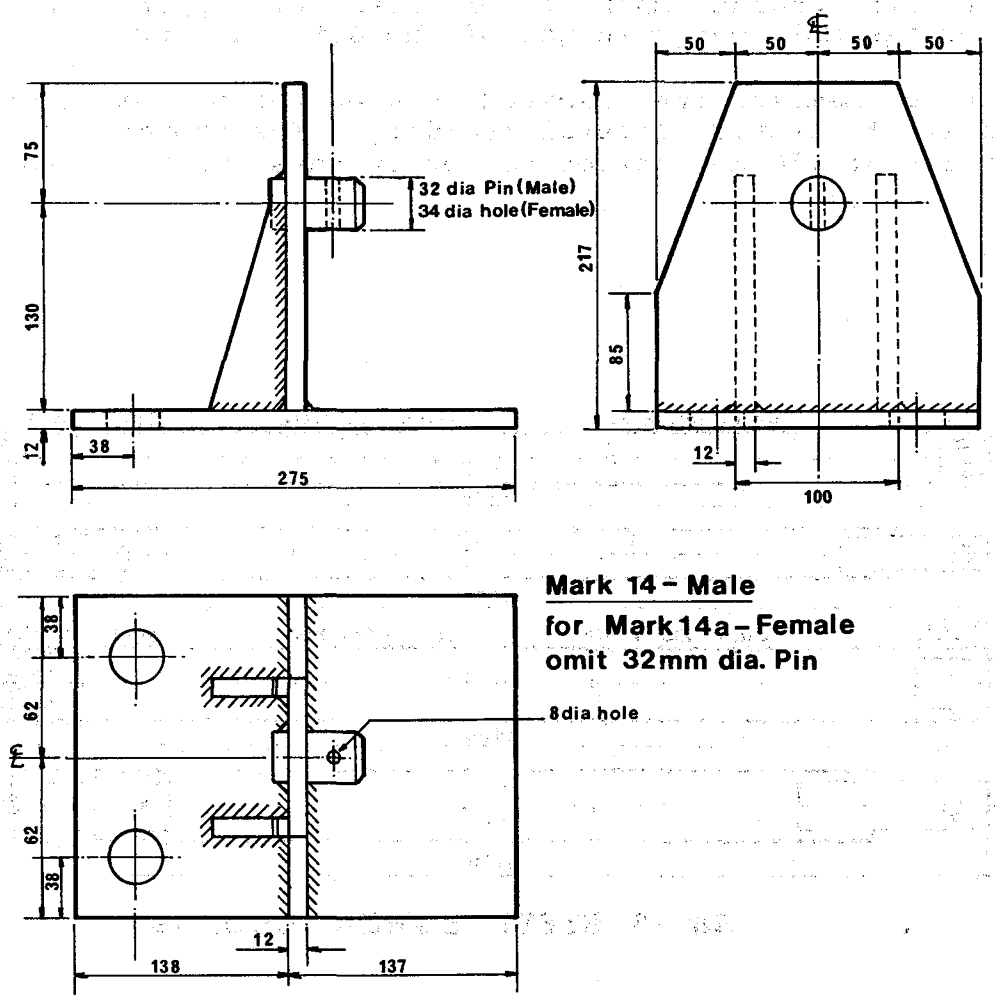


SK. 10 BRACING CLEAT - Mark 13



SK. 11 BRACING PLATE - MARK 8

Sketch SK. 12 depicts the male and female bridge bearings which are not required until the launching stage but which are pre-fabricated in the same way as other plate assemblies. Light chord bearings are referred to as Mark 14 (male) and Mark 14A (female). The heavy chord types are Mark 15 and 15A. As described in Part 3, the bearings are anchored to the pier caps after launching, using prepared pads and pockets in the concrete. Each truss requires to be positioned in a male bearing at one end of the span and a female at the other. At this point it is convenient to mention that a convention is adopted that panel manufacture is completed with male and female end plates to the left and right of the jig respectively. This ensures that all panels have the top and bottom lateral bracing cleats facing the same way with respect to the male and female plates Mark 3 and 3A. Provided this practice is adopted there is no need to regard the modules as 'left hand panels' or 'right hand panels'. In Part 3 of the manual the launching instructions make it clear that bearings are not cast into their pockets until after launching, therefore either male or female bearing plates, Mark 14 or 14A, can then be used as appropriate at that stage.

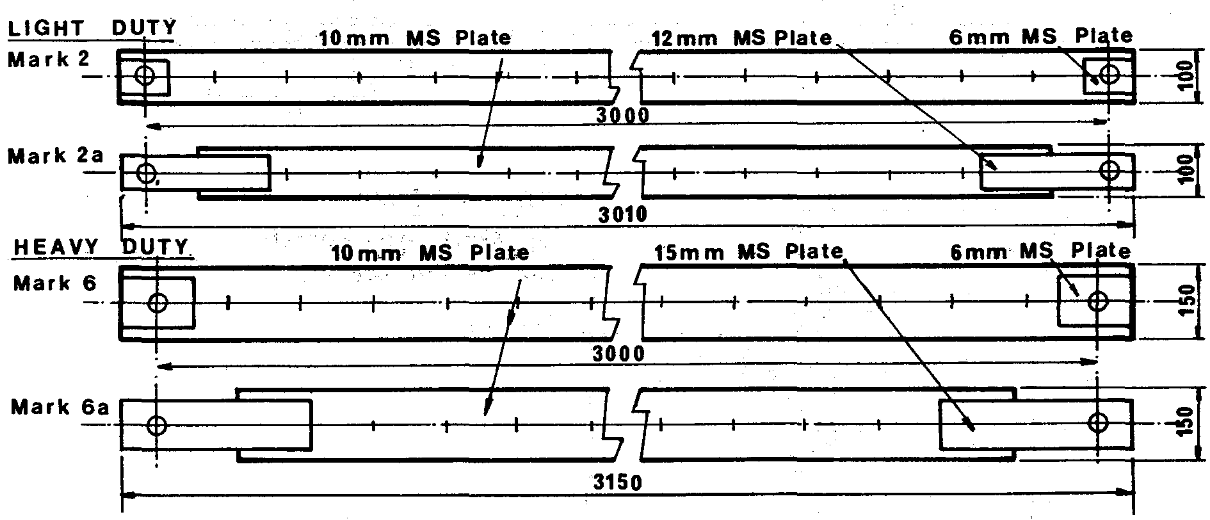


SK.12 BRIDGE BEARING

It has already been mentioned that light and heavy chord designs are available, and these differences are of course reflected in the dimensions of the lower steel chords themselves. Sketch SK. 13 shows both types. The lighter size is always used with panels made from timber of Australian stress grade F8 or less. Higher strength timbers indicate a choice in the design selection process, described later. Light chords Mark 2, are of 10 mm x 100 mm cross-section with 6 mm thick rectangles added to reinforce the areas near the holes. Heavy chords Mark 6 are 10 mm x 150 mm in section, also with 6 mm thick reinforcements.

It will be noted that in addition to lower chords Mark 2 or Mark 6, types Mark 2A (light) or 6A (heavy) are provided. The intention is to alternate between use of Mark 2 and Mark 2A along the line of lower chords in each truss (or similarly in the case of 6 and 6A). This notion was introduced because in some countries the standard length of steel flats is 20 feet. It is possible to make one chord type 2 and one type 2A from each length, using this design. Welded extensions of 12 mm x 75 mm section (light chord) or 15 mm x 100 mm (heavy chord) are included in the alternate chords. If the steel supply situation is such that the chord types with extensions are unecessary, the entire bridge can be built with chords Mark 2 or Mark 6. There is no special structural or assembly merit in use of the alternate types.

Timber packing members are inserted between the bottom chords during truss assembly, to provide lateral rigidity. The chords are pre-drilled with 6 mm holes at 150 mm centres to permit these to be fixed.



SK.13 STEEL LOWER CHORDS

TIMBER FOR PRE-FABRICATED PARTS

Part 4, Timber Technology, gives information on drying, treatment and stress grading. It is important that these recommendations are followed, since the pre-fabricated wooden panels form stressed, engineered structures. Bridge collapse could occur if these points are totally ignored, for example if a considerable quantity of wrongly identified or ungraded wood is included in a girder. Fortunately the laminated design together with various aspects of load sharing preclude risk from the odd misgraded piece, but this should not be relied upon. Similarly there is a real possibility of premature collapse from decay if the recommendations in Part 4 concerning natural durability or preservation are ignored. On the other hand, with correct selection and preservation treatment if needed, there is no reason to suppose that a design service life equal to, or better than 50 years cannot be expected.

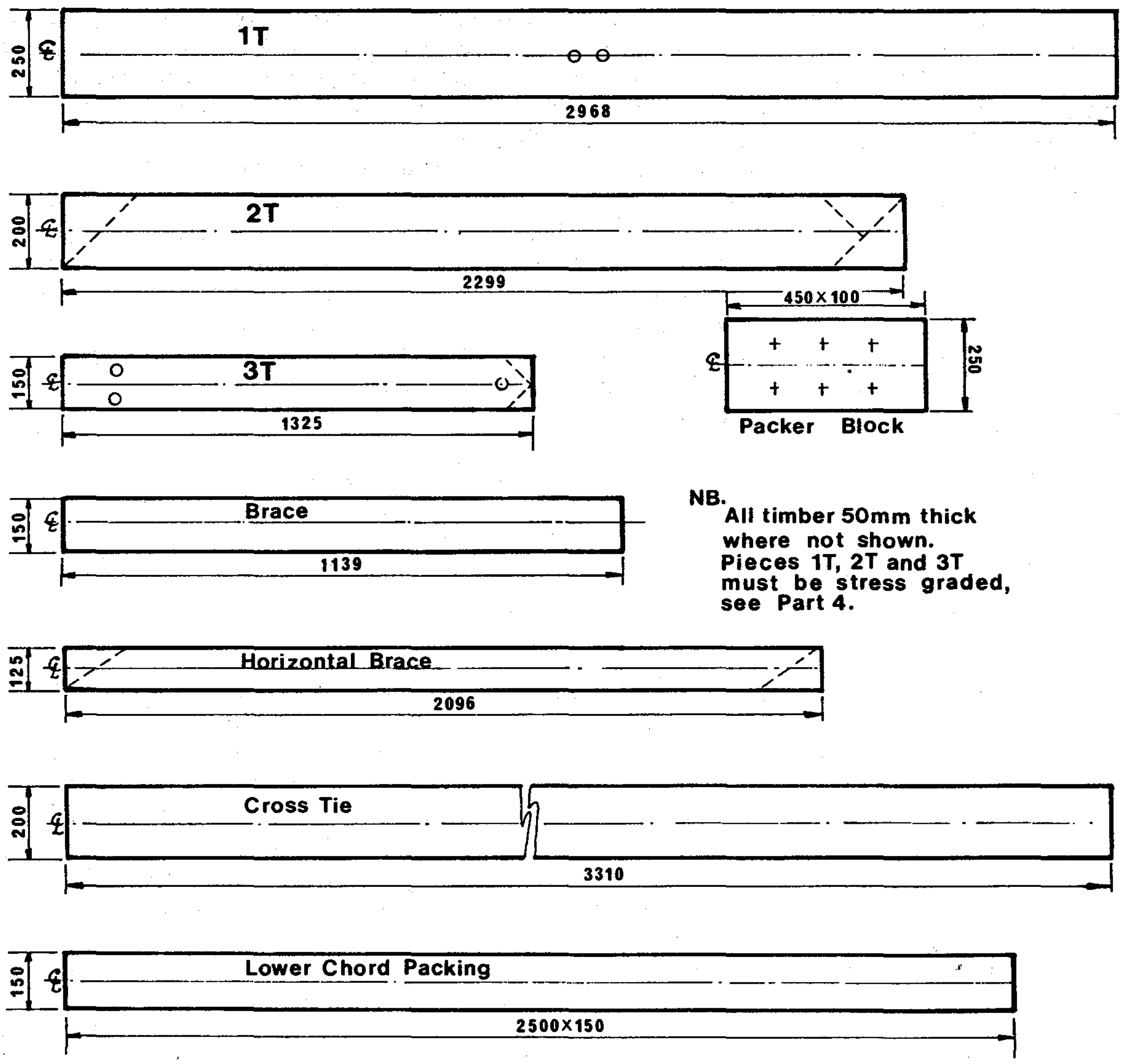
The design of the modular pre-fabricated panel is such that it is not essential to use planed material for its manufacture; sawn timber has been used sucessfully in several implementations of the system. The tolerances of sawn timber may leave something to be desired in certain situations in less developed countries however, and when variations in sawn thickness exceed about 2 mm, and differences in width are more than about 4 mm, difficulties will occur for two reasons. Firstly there will be problems in fitting the various sized pieces in the jigs and aligning the sub-assemblies to one another when the parts are manufactured, secondly experience has shown that trusses and girders built from less accurately shaped panels have in themselves a greater tendency to take on a distorted shape and to snake and twist during launching and construction. For these reasons it is preferable wherever possible to use timber that has at least been regularised in thickness by planing or other suitable means, and where possible to use timber that is accurately planed on all four sides.

The procedure adopted in purchasing material and bringing it in a suitable condition to the assembly stage will vary according to local circumstances and to the choice which is made from the various methods recommended in Part 4 for selection, preservation treatment, drying and stress grading.

One possible sequence, found convenient in Honduras, was to locate a suitable supply of timber of a quality likely to give a satisfactory yield of the stress grade required. This was only available in a rather inaccurately sawn condition, and pressure treatment for preservation was considered desirable and practicable for the species concerned. The timber was brought to the bridge workshop and stacked for air drying according to the recommendations in Part 4. After reaching equilibrium moisture content for the climate concerned, which was nearly constant throughout the year, the timber was machined. This consisted of planing on all four sides, cross cutting to the lengths and angles indicated for the wood members concerned in the panels, and carrying out all possible drilling. The timber was then conveyed to the plant where pressure treatment was carried out. Finally it was returned to the workshop and after another period of air drying to remove the moisture gained during preservation treatment, it was used for panel assembly.

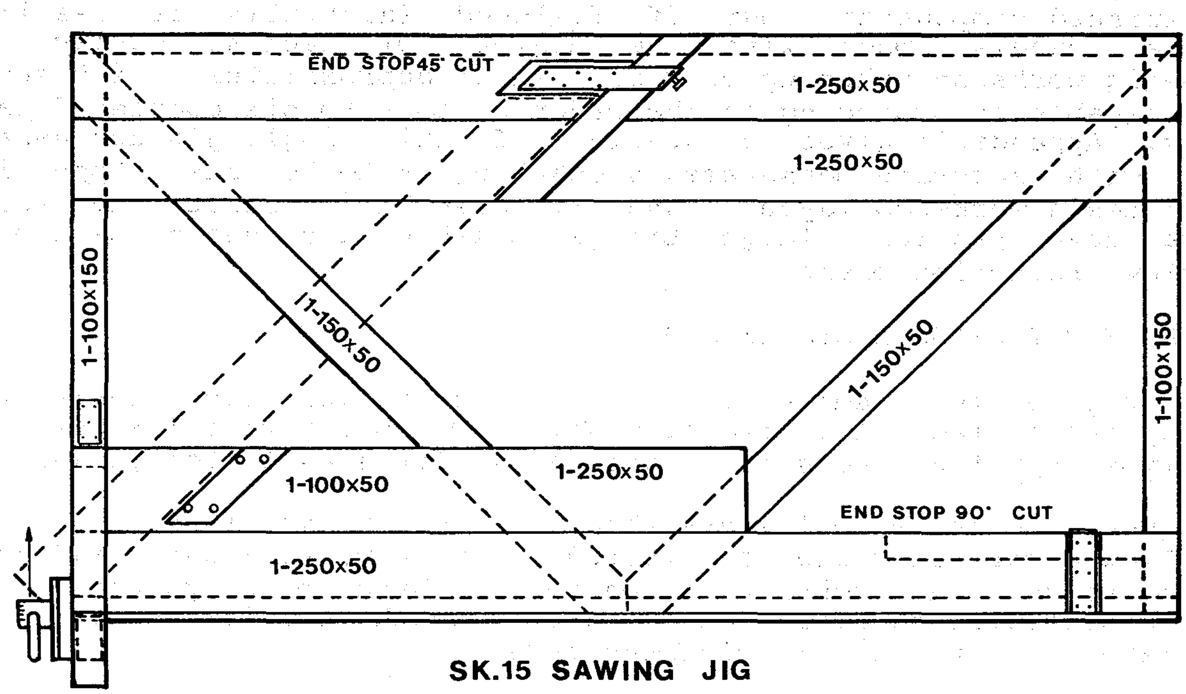
It should be noted that this is the correct and recommended sequence for members of components in critical applications requiring pressure treatment. Although more expensive in terms of transport than treating material before delivery, it is the only effective way of ensuring thorough treatment, and incidentally it saves the cost of treating material later to be machined away.

Sketch SK. 14 shows the timber parts of the modular panel. Reference should of course be made to the engineering drawings in Part 5 for full details. Table 2 gives an indication of timber quantities per panel. The packer blocks are not included in the volume as these can normally be made from scrap material such as that rejected during stress grading. Cutting to length and angle is extremely simple as all cross cuts are either at 45 or 90 degrees.



SK.14 TIMBER COMPONENTS

Sketch SK. 15 below shows a sawing jig, recommended for use in workshops with limited power tool faclities and where panel parts may have to be cut using hand saws.



SK.15 SAWING JIG

TABLE 2

Quantities of timber per panel

Member	Size (mm)	Length ordered (m)	Qty. per panel	Volume (cubic metres)
(1T)	50 x 250	3.3	2	0.0825
(2T)	50 x 200	2.4	4	0.0960
(3T)	50 x 150	1.7	2	0.0255
			TOTAL	0.2040

PANEL MANUFACTURE

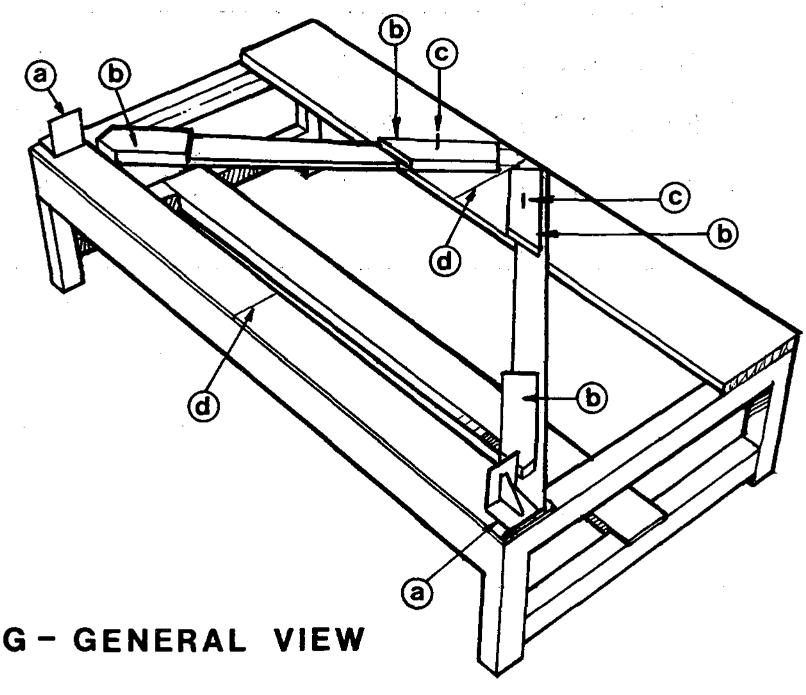
The simplest method of panel manufacture makes use of a single jig into which the individual pieces are placed and built up step by step into modular panels. The process involves considerable re-handling of the part finished components, but if followed faithfully it results in accurate panels, made with the minimum of capital outlay. The single-jig workshop takes up only an area of approximately 6 x 9 metres, and is capable of producing in the order of four to six completed panels per day. Appendix 1 gives a drawing of this single jig and assembly table, with accurate measurements enabling it to be made. Appendix 2 illustrates a workshop layout, and includes a manufacturing sequence that was developed for a larger bridge workshop, designed to be operated on a flow production basis.

PANEL ASSEMBLY USING A SINGLE JIG

A modular panel is assembled in two similar halves, each consisting of one top chord piece (1T), two diagonals (2T), one vertical strut (3T), plus timber spacing pieces and steel panel plates as listed in Table 1.

The sequence described below has been proven by experience. It should be followed carefully and not altered in any way, at least until it has been put to use and contrary experiences have been gained. It is possible otherwise to arrive at a stage at which remedial measures have to be taken to correct half-finished panels.

As outlined previously, the assembly jig consists of a bench, sketch SK. 16, with various stops and attachments. Reference should be made to the engineering drawings, Part 5, for orthogonal views to make a bench and jig top. Right-angled steel plates (a) provide end stops for the top chord pieces of the panel. Diagonal members forming part of the bench top support timber guides (b) against which the diagonals of the panel are located. Pins (c) and a loose steel template are used to locate plates on the panel. Centre marks (d) are also provided on the jig.

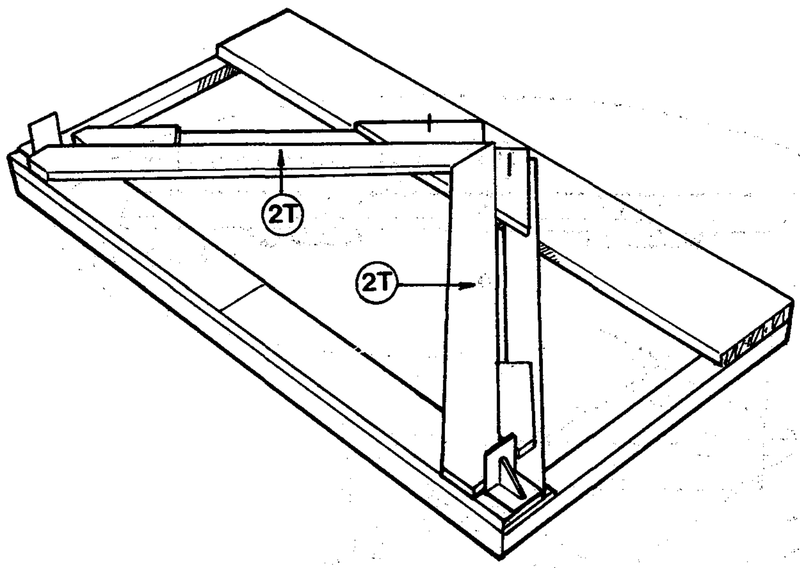


SK. 16 ASSEMBLY JIG - GENERAL VIEW

For simplicity, the assembly sequence is described with reference only to the types of plate used on light chord panels. Table 1 provides references for descriptions and part numbers for both light and heavy chord designs.

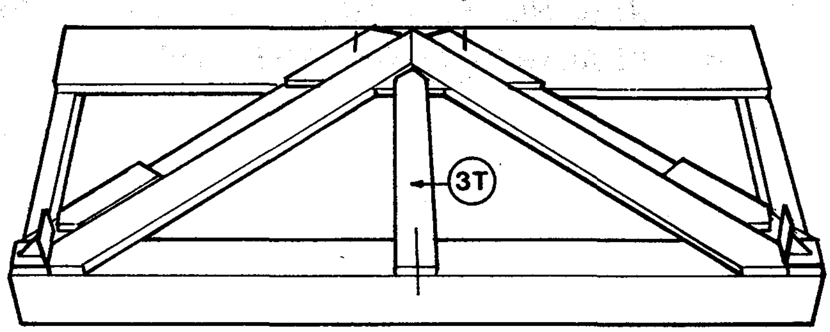
The assembly sequence begins as follows, making first a half-panel with a plain lower steel plate, Mark 1, without a bracing cleat:-

1. The two 50 mm x 200 mm diagonals (2T) are located with their outer edges against the diagonal timber guides of the jig, as shown in sketch SK. 17.



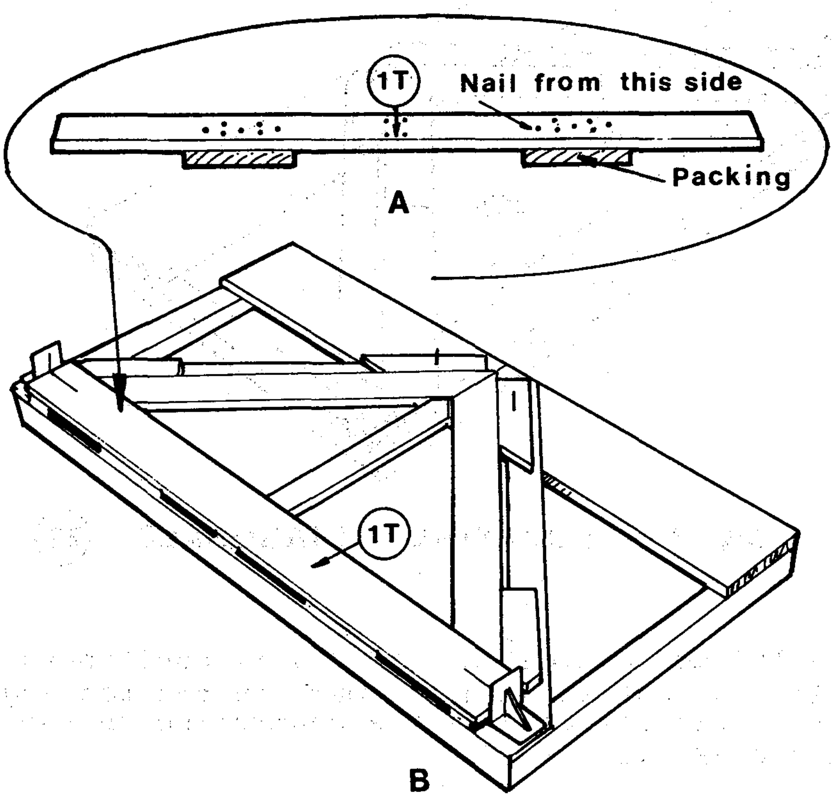
SK.17 LOCATING DIAGONALS (2T)

2. The 50 mm x 150 mm vertical strut (3T) is positioned between the diagonals and centred using a mark on the top edge of the piece which should coincide with a centreline on the edge of the jig, sketch SK. 18.



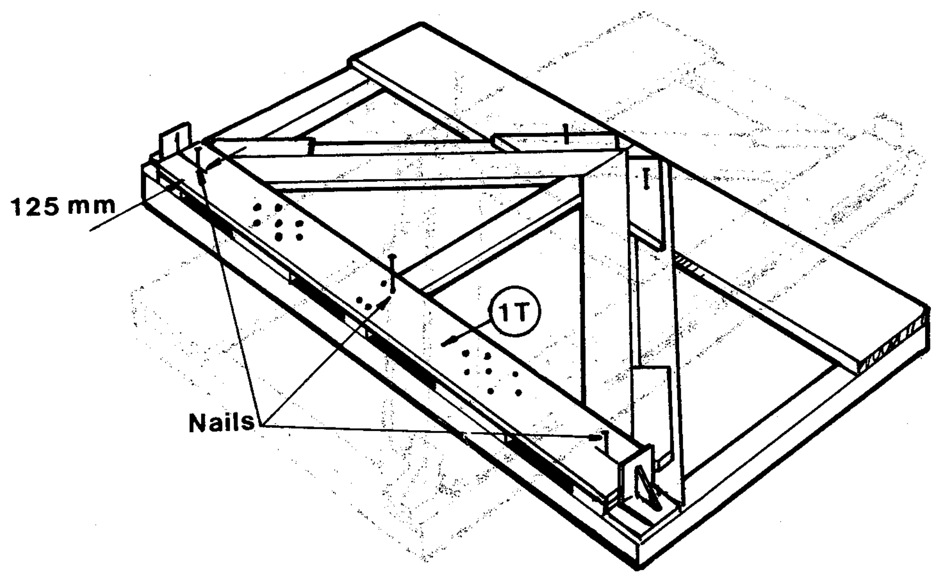
SK.18 CENTRING STRUT (3T)

3. Prior to placing a 50 mm x 250 mm top chord piece (1T) in the jig, 50 mm x 250 mm x 450 mm long packing pieces are nailed at two positions along the length of the piece using nailing details specified in the drawings (Part 5). It is essential to carry out this step, illustrated in sketch SK. 19(a), in order later to complete the top chord packing correctly. The top chord piece complete with one thickness of packs is placed across the diagonals already in the jig, and correctly located.



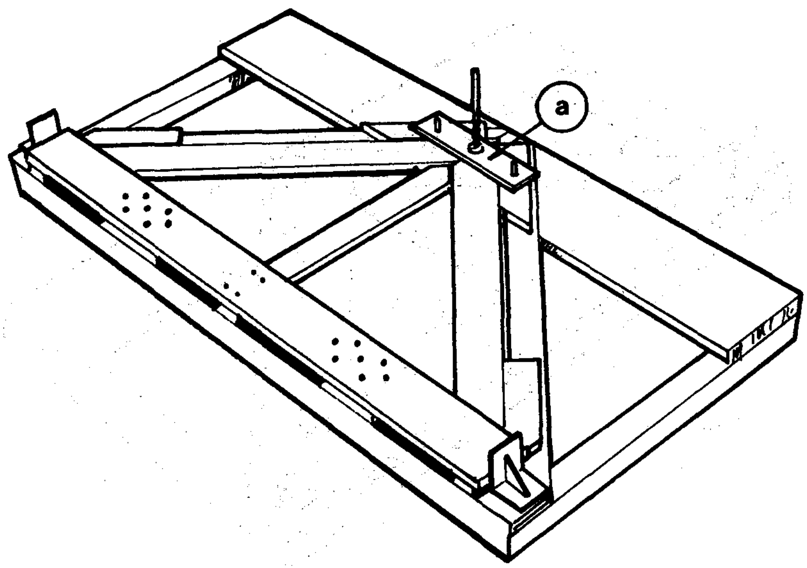
SK. 19 A NAILING PACKING TO TOP CHORD (1T)
B PLACING (1T) ON THE JIG

4. The top chord piece (1T) is centred using a mark on its wide face scribed 125 mm down from its top edge. In this way any irregularity in the depth of the member is lost to the inner shape of the panel, which is less critical than the outline. Sketch SK. 20 shows the top chord piece located in this way, with its mark corresponding to an engraved mark on the steel jig plates. The first four members are then fixed to one another at each node on the top chord using one 100 mm long nail at each position. This is only a temporary fixing, but the nails can be driven fully and left in place.



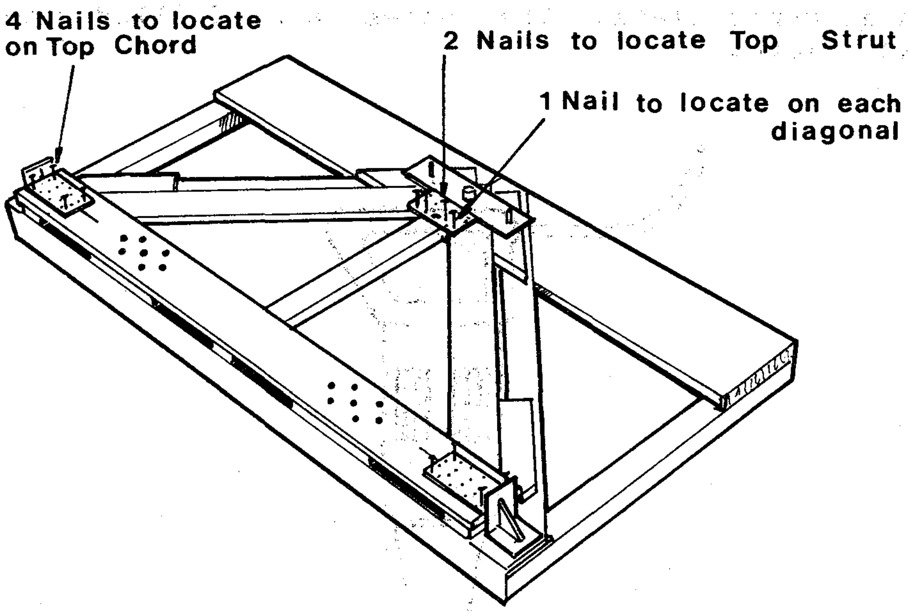
SK.20 CENTRING AND TEMPORARY NAILING OF TOP CHORD (1T)

5. The loose steel template, which is a jig attachment, is placed over the lower node, using the locating pins provided on the jig, sketch SK. 21. This is first used to find the centre for a recess which must be provided under the pin position of the lower steel plate Mark 1. The recess is needed because there is a weld fillet at the back of the plate pin. It can be cut to a diameter of 63 mm and a depth of approximately 12 mm with an expansion bit on a slow-speed hand held power drill or with a brace and bit.

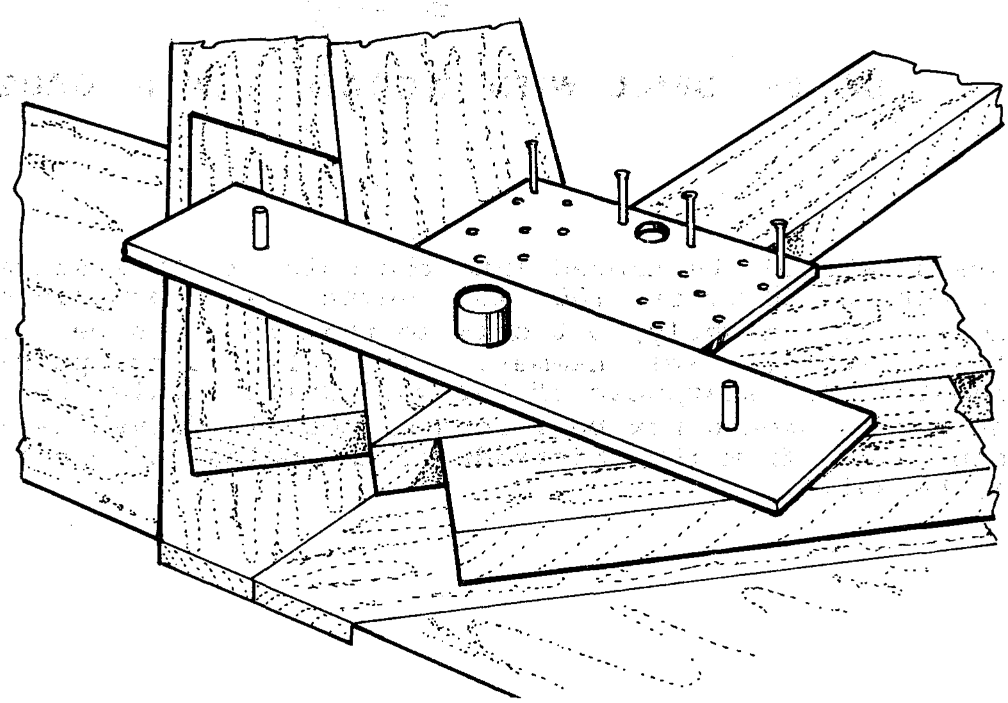


SK. 21 USING STEEL TEMPLATE (a) TO LOCATE RECESS

6. The upper steel plates Mark 5, and the lower steel plate Mark 1 are positioned on the timber in the jig and temporarily fixed by 50 mm long nails through previously-provided locating holes in the plates, sketch SK. 22. The top chord plates are centred and located using marks on the jig and on the timber. The lower plate is located with the steel template which fits over the lateral plate pin, sketch SK 23.

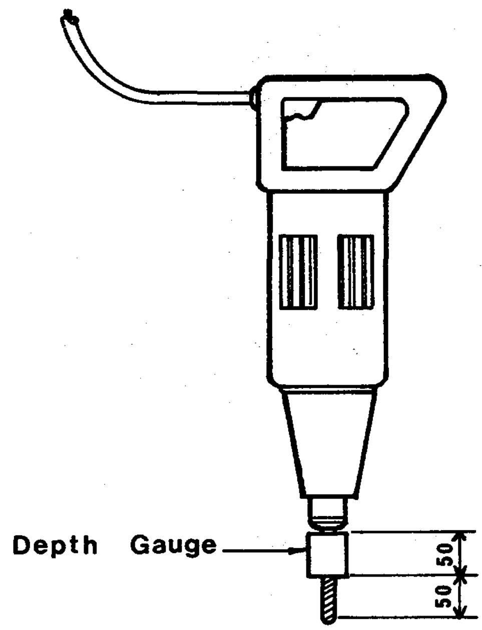


SK. 22 TEMPORARY FIXING OF STEEL PLATES



SK. 23 LOCATING LOWER STEEL PLATE

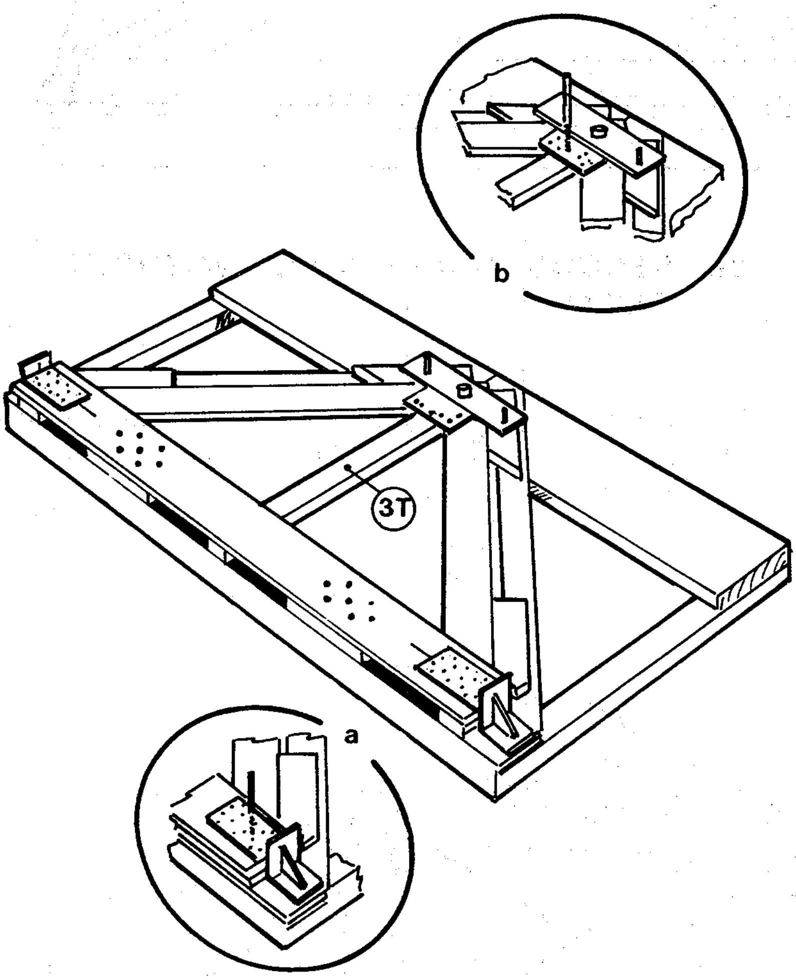
7. The plates are attached to the panel using plain steel dowels, as explained previously, see sketch SK. 3 on page 6. Dowels are provided in two lengths, 50 mm and 100 mm. The length chosen depends upon whether a single or double wood thickness lies beneth each pre-drilled plate hole. In the case of the upper plates, Mark 5, all but two of the holes are drilled to a 100 mm depth. For the lower plate, all holes are only 50 mm deep. A simple wooden depth gauge, sketch SK. 24, should be used to avoid damage to the wooden parts of the jig itself. Sketch SK. 25(a) shows holes for the dowels being drilled through an upper plate. The holes are drilled similarly in the lower plate.



SK. 24 DRILL WITH WOODEN DEPTH GAUGE

8. Dowels should be tapped into the holes at this stage, using the correct 50 mm or 100 mm length as appropriate. They should fit tightly, but only so that they can be tapped in with a light (1 Kg) hammer. If this is not possible, the diameter or sharpness of the wood drill should be checked. The dowels should not be forced or heavily driven as wood will chip away from the underside of the holes and panel members may be split.

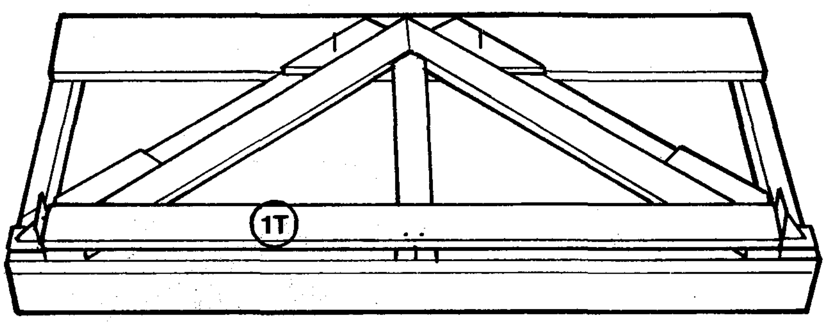
9. Sketch SK. 25(b) shows a hole being drilled through plate Mark 1 into the vertical strut (3T) to accomodate a 25 mm diameter bolt when the two halves are eventually assembled. There are bolt holes beneath the centre of the two plates Mark 5 which can also be drilled at this stage.



SK. 25 (a) DRILLING DOWEL HOLES IN UPPER STEEL PLATE

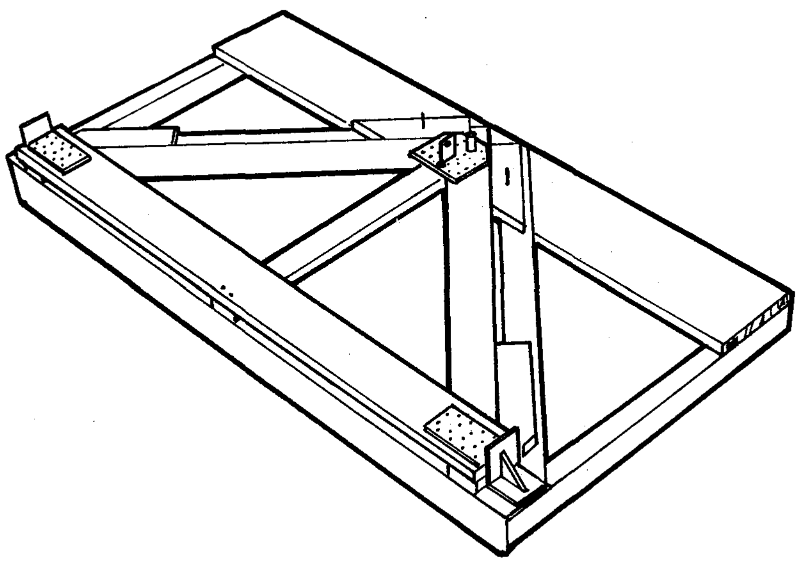
(b) DRILLING HOLE FOR 25 mm dia. BOLT IN LOWER STEEL PLATE

10. The completed half-panel is lifted from the jig and set to one side. The second half, with a lateral cleat on the lower steel plate, Mark 1A, is made following exactly the same sequence except that packs are NOT nailed to the upper chord (1T) before placing it on the jig, sketch SK. 26.



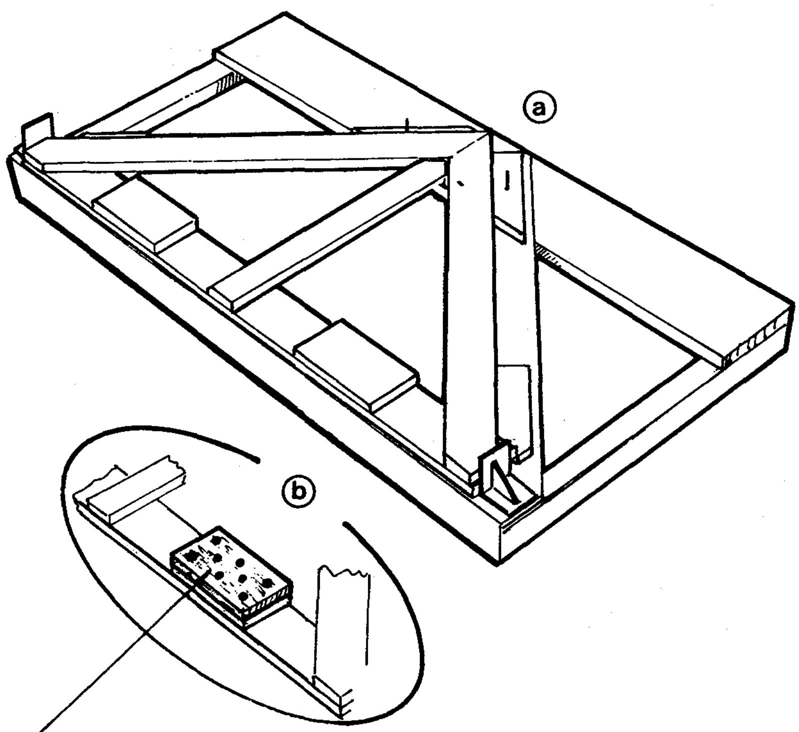
SK. 26 SECOND HALF-PANEL WITHOUT PACKS

11. Sketch SK. 27 shows the completed second half-panel with lower plate Mark 1A. It is removed from the jig when prepared to this stage.



SK 27. COMPLETED SECOND HALF-PANEL

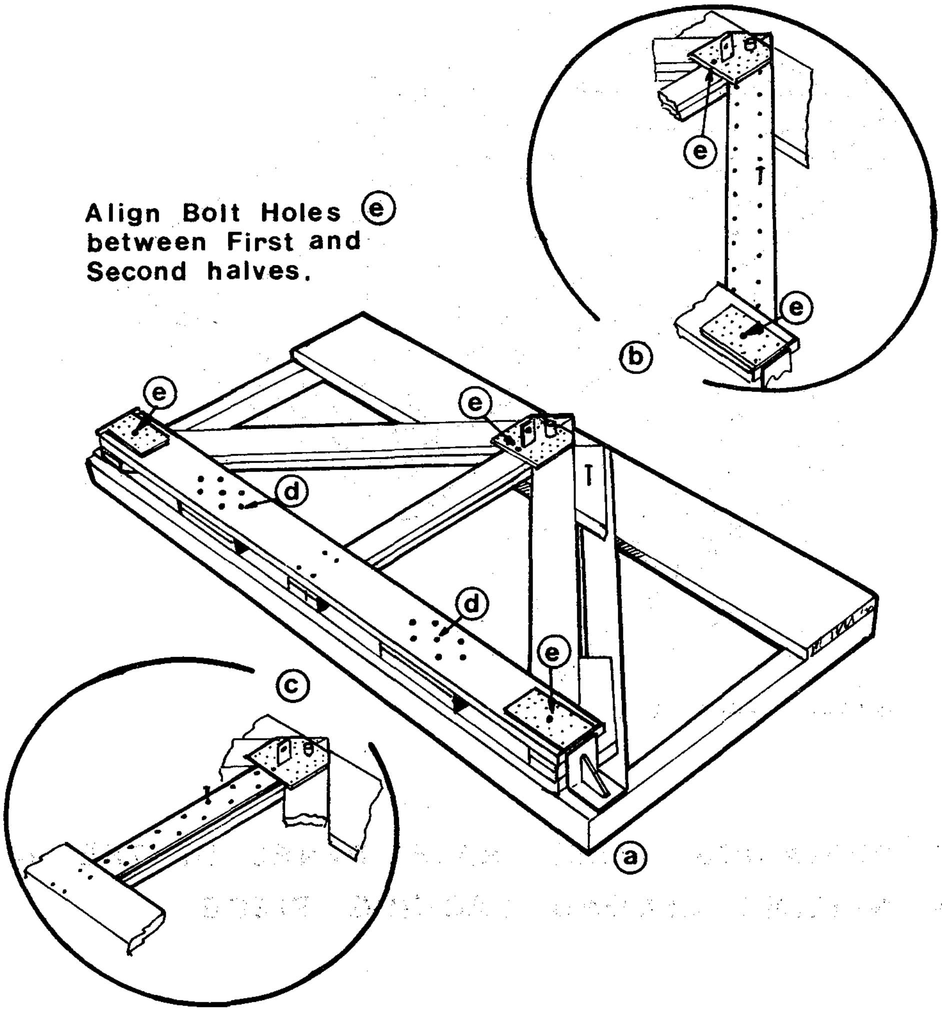
12. The first half is replaced in the jig in an inverted position as shown in sketch SK. 28. A second thickness of packs is nailed to the first using an alternate nailing pattern shown in the engineering drawing.



SK.28 ⓐ REPLACING FIRST HALF PANEL IN THE JIG
ⓑ NAILING SECOND PACKING PIECE

13. The second half-panel is placed on the first with its lower steel plate cleat facing upwards, SK 29(a). Views (b) and (c) of sketch SK. 29 show nailing templates in use to mark nail positions to unite the two halves. This vertical laminating is carried out after ensuring that the two halves are well aligned above one another so that it is possible to fit the through-bolts when the stage arrives to bolt the halves together.

View SK. 29 (d) shows completion of nailing of the top chord packs. This is performed reverting to the first nailing pattern so that the final set of nails, driven in from the outside, does not clash with the points of the previously driven nails.

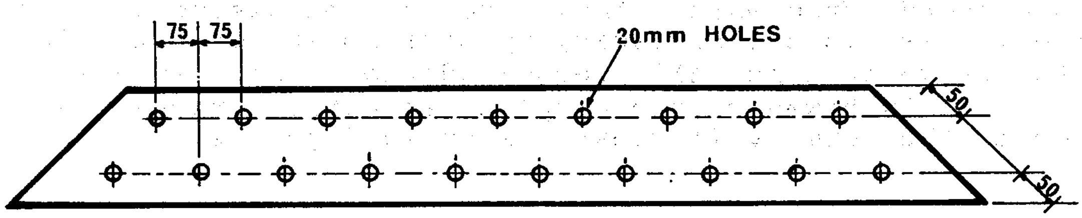


SK. 29 (a) SECOND HALF-PANEL ON FIRST WITH CLEAT UPPERMOST

(b) and (c) NAIL LAMINATING THE TWO HALVES USING NAILING TEMPLATE AND WITH REGARD TO (e)

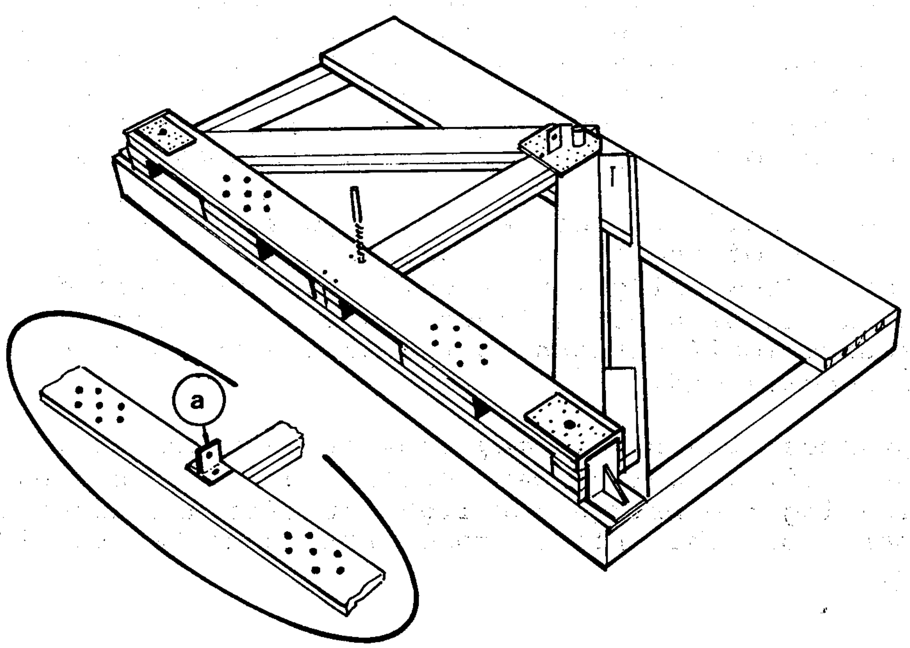
(d) NAILING PATTERN OF PACKING

14. Sketch SK. 30 shows a plan view of the nailing template for the diagonals (2T). A similar template should be made for the strut (3T). These can be made from aluminium sheet or good quality plywood.



SK. 30 NAILING TEMPLATE

15. To complete the steps of manufacture that are carried out in the jig, holes are drilled for the two 25 mm x 250 mm bolts which pass right through the top chord at the strut position, and which hold in place the bracing cleat Mark 13. This is illustrated in sketch SK. 31. It is convenient at this stage to lift the panel about 45 cm, a corner at a time, and actually insert all the through bolts, with their respective washers and nuts.



SK. 31 DRILLING TOP CHORDS TO ACCEPT BRACING CLEAT (a)

Chapter 2 - DESIGN SELECTION PROCESS

DESCRIPTION OF THE PROCEDURE

Design selection involves considerations of the bridge site; the duty of the bridge and a series of processes concerning the structural timber to be used. The object is to choose the number of trusses and the type of panel and chords from which they are to be assembled, for the bridge concerned. It is not necessary to perform structural calculations in order to arrive at this; all recommendations are given in tabular form below. Firstly however, the complete selection process is described in relation to the summary flowchart given in Figure 2.1.

Site investigations

During the early stages of a project, visits will be made to various sites at which it is proposed to use the modular wooden bridge system. In considering which of the suggested locations are suitable for bridges built with this system, several factors should be investigated concerning the road design and the site itself. Some of these factors have a direct bearing on the resulting bridge design.

1. Present and final road alignments

Often there will be an existing roadway, and this will more or less determine the alignment, but there may be opportunities for improvement. Where straight, level approaches are impossible, gentle curves should be provided on the approaches to the bridge, in preference to sharper corners. Smooth changes in gradient are also desirable, if level approaches cannot be provided. Overtaking must be prevented by road design or forbidden by warning signs before traffic encounters the bridge, which is normally a single carriageway design.

The traverse should be as near as possible perpendicular to the direction of flow of the stream, unless there are special reasons for a skew crossing. Skew bridges as such, rather than standard bridges which are rectangular in plan but aligned in a skew direction relative to the stream, require modifications to the design by an experienced engineer, and are not recommended.

In some instances, the bridge may provide an alternative river crossing to a ford or drift, which can still be used by heavier commercial vehicles, leaving the bridge for light traffic and two-axle vehicles. If this is part of the plan, road realignments should be designed accordingly.

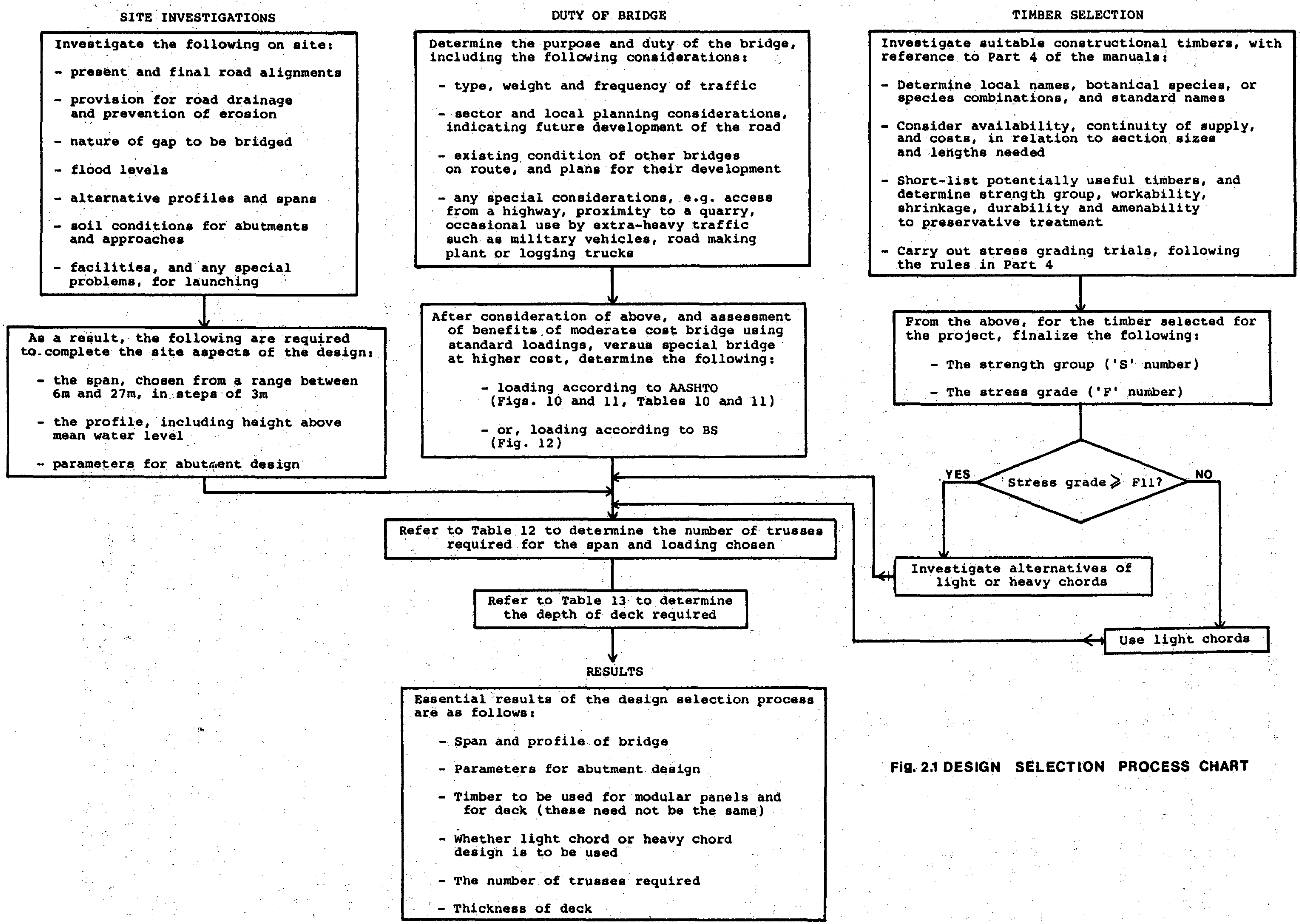


Fig. 2.1 DESIGN SELECTION PROCESS CHART

2. Provision for road drainage and prevention of erosion

Valuable information on the planning and construction of rural roads, including methods to prevent erosion by rain storms, can be found in 'Earth Roads' (Reference 3). The reader is recommended to that text for information which is beyond the scope of these manuals. Diversion banks and lead-off drains can be constructed to protect the road itself, and to stop silt and mud being washed down the road onto the bridge.

3. Nature of the gap to be bridged

Initial surveys of a region, together with a list of proposed sites prepared in conjunction with the relevant government department, will quickly reveal which crossings are likely to be suitable for the modular wooden bridge system. As noted elsewhere, the method is most applicable to spans varying between 9 and 27 metres. Multiple spans are believed to be possible, but have not been attempted at the time of writing. The general nature of the gap to be bridged - whether it is a shallow crossing where the stream has been forded, or whether it is a deep cutting or rocky site, will need to be taken into account. During the first survey, photographs and sketches should be supplemented by data on the terrain; flood levels; rights of way and land holdings; map references; compass directions, including bearing of the existing road and stream and notes on possible solutions by means of the bridge system, where its use is thought to be feasible.

4. Flood levels

The conditions of development and classes of road under which the bridges will serve will be such that published or scientifically recorded data on flood levels will not normally be available. Reliance must therefore be placed on local information, observation and experience. Much can be learnt from a careful examination of the river banks adjacent to the site and from questioning people who live nearby. Judgement must be exercised in the final decision as to the level of placement of the bridge supports. To provide an economical structure, for example, one which may be expected to survive a once in twelve to twenty five year flood, could well require only about a third of the span and considerably less cost, than the construction of a bridge at a level to withstand once in fifty year events. In the early stages of development of a road system, including bridges, the existence of a means of communication should normally be the prime consideration.

The chances of a bridge surviving a flood can be improved by careful planning of the precise location and alignment. Wherever possible, the river at the crossing should be straight, with a clear channel, and no pools in which eddies form, no underscour on either shore, and no obstacles which will trap debris during a flood. Sound banks are also important, and if not naturally occurring, these can be provided by simple improvements using appropriate techniques. Often it is possible to provide additional precautions against the bridge being washed away by accumulation of debris during a storm. For example, it may be advisable to construct a level drift or a culvert, located to one side of the bridge, about a dozen metres away from the approaches. This will act as a 'safety valve', providing a spillway whose level is below the underside of the structure. If this is breached during a storm, it will enable the main flood to bypass the bridge, and will be much less expensive to repair.

5. Profiles

A profile is a diagram showing in longitudinal section the river or stream bed to be traversed by the bridge, together with the changes in level of the adjacent banks and terrain. It should be drawn to definite horizontal and vertical scales, so giving an accurate indication of the slopes and levels of the site. A typical profile is shown in Figure 2.2. Several such profiles may be necessary for each site to assess alternative road lines. The profiles should be measured and plotted carefully, but a high degree of precision in the readings is not necessary. They may be taken using simple equipment such as levels, string lines and a tape. Alternatively, road tracers or Dumpy levels may be used, if available.

The purpose of the profile is to plan the elevation of the abutments and of the bridge itself. To assist in this, once the profile of the original site has been obtained, a series of transparent overlays can be used. Figure 2.3 shows a standard diagram for an 18 metre span bridge and abutments, which can be reproduced on clear film. A whole series of these transparent overlays can easily be made, on photoreprographic equipment, or by tracing, giving profiles of the spans and abutments normally used in a particular project. The overlays are used in conjunction with diagrams like Figure 2.2 to assess the effects of positioning the abutments at various spots and elevations on the site. The options help to estimate the amount of cut-and-fill required, the slopes of the approach roads, and the clearances under the lower chords.

Figure 2.4 shows a proposed elevation, determined by the simple method described above. The 2.5 metre minimum clearance from normal water level to the underside of the lower chords is regarded as the minimum desirable in the terrain and under the weather conditions in which the system was developed. Elsewhere, local conditions would have to be taken into account.

6. Soil conditions for abutments and approaches

Although the design and construction of the road and support works are beyond the scope of these manuals, it will clearly be necessary to examine and test the soil conditions at the site and to consider what foundations will be required for the abutments. Drainage details to avoid seepage and loss of supports during storms will also be important considerations.

As an alternative to mass rock-filled concrete, or masonry abutments usual for the earlier bridges constructed under the UNIDO system, information has recently been provided, enabling a timber piled wooden approach span to be designed. Appropriate drawings are given in Part 5. To date, this method has not been implemented, but it is believed to be of value where soil conditions are suitable, and where pile driving, or auger drilling equipment can be used.

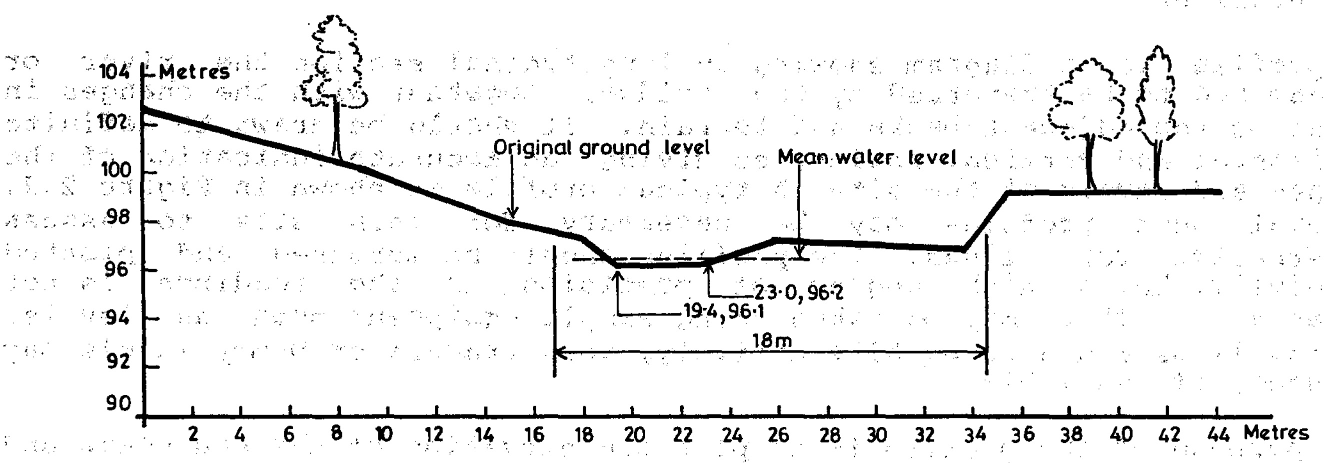


Fig. 2·2 A typical profile

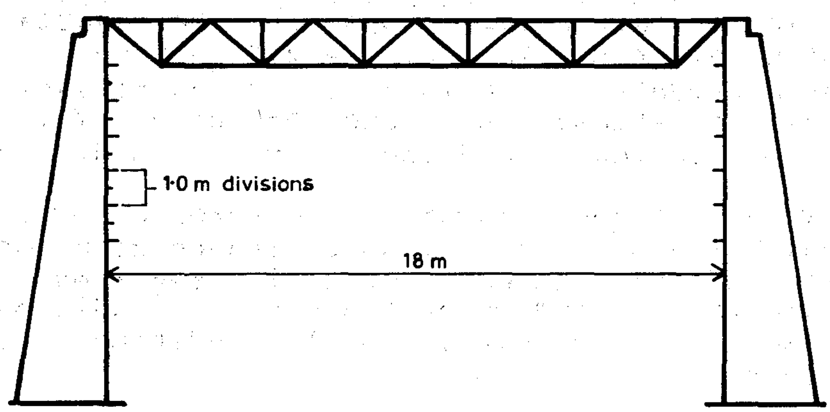


Fig. 2·3 A standard overlay

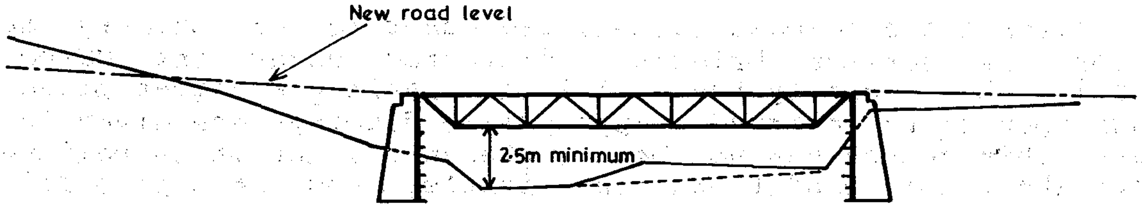


Fig. 2·4 A proposed elevation

7. Facilities for launching

The site investigations include consideration of how the launch is to be carried out. Once a team is experienced in the twin tower, overhead cable method, described in Part 3, this will be found to be by far the easiest technique under normal circumstances. The method requires an area of flat and stable ground on each bank however, and on occasions this may not be available. The alternative dry launching method was developed for use at a particularly rocky, sloping and curved site, where it was preferable to erect a wooden derrick on the stream bed.

During the survey, note should be taken of any special anchorage points, obstacles, or clearance required before work can commence. Provision should also be made for accomodation and feeding of personnel and transport and storage of equipment.

Results of site investigations:-

As a result of the site investigations, the following must be produced in order to proceed with the design of the bridge:

1. The profile of the site must be drawn, showing in longitudinal section the river bed, embankments and abutments in their envisaged finished state, together with the elevation of the bridge.

2. The span must be chosen from a range between 6 metres and 27 metres, in 3 metre increments - i.e. 6 m - 9 m - 12 m etc.

3. The abutment design must be carried out.

Duty of the bridge

In this part of the design selection process, careful consideration should be given to the purpose and duty of the bridge. Critical decisions are made which balance the benefits of a moderate cost bridge, possibly in keeping with the currently available low-speed road and light traffic, versus a structure which can cope with expanded and improved facilities.

1. Type, weight and frequency of traffic

The type, weight and frequency of traffic must be determined. The objective of bridge projects of the type for which the UNIDO system was devised is to improve national road networks with emphasis on rural development and access roads. Bridge design needs to be considered in conjunction with road design. The latter involves decisions on the layout of the road in the terrain, its horizontal and vertical alignments, and its width. These factors have a direct bearing upon the type, weight and frequency of traffic that can be expected. There are no published standards specifically for developing countries which relate to road design; however appropriate recommendations are available. These have been drawn up by the Transport and Road Research Laboratory (TRRL) of the U.K. (Reference 4). In addition, there are categories described by the Intermediate Technology Design Group (ITDG), which are useful for very low-performance roads, common in many developing countries (Reference 3).

ITDG define 'village' roads as dealing with a few vehicles per day, plus wheelbarrows, handcarts, animal-drawn and pedal-driven devices; 'market' roads cope with up to about fifty vehicles per day. At this stage, TRRL definitions take over, with 'rural access' roads taking fifty to a hundred vehicles daily, dependent upon whether they are earth or gravelled roads, and 'collector' roads taking fifty to eight hundred vehicles per day (gravelled) or one hundred to one thousand vehicles (paved). Operational duties greater than this, including arterial roads, are considered beyond the scope of the UNIDO bridge system.

As regards frequency of traffic, the UNIDO system is intended primarily for use along comparatively low volume roads. This is the purpose for which it was recommended by TRRL (Reference 5). Although no direct relationship can be stated between frequency of traffic and the maximum loading a bridge may experience, there is a greater likelihood of overloading on heavily trafficked roads. In addition, the effects of wear and fatigue caused by numerous heavy vehicles could be deleterious. Frequency of traffic and loadings must be expected to increase, once bridges are provided, and roads become continuous. However with the limited resources of developing countries, unrealistically high standards of loading should not be adopted. The existence of any reasonable means of communication which is available at all seasons is preferable to waiting years for bridges to be designed and built to the top highway loading specifications of industrialized countries (who often themselves in practice fail to meet these specifications on many existing bridges).

2. Sector and local planning

Sector and local planning considerations will be reviewed at the start of projects, and these will indicate the regions within a country where bridge development is to be concentrated. Regional self-help schemes or road and bridge developments in conjunction with other rural development or work-generation schemes may be taken into account in planning. In other instances, aspects such as disaster relief may require concentration on a particular district.

3. Existing conditions

Normally, plans involve the improvement of existing roads rather than building in a completely new direction. Clearly it is essential to plan the entire route, and design bridges to carry traffic densities and loadings in keeping with the remainder of the scheme.

In general, when constructing or improving a road network where economic constraints apply, the most obvious solution for one link in the network, such as a particular road or bridge, may not necessarily be the best solution for the network as a whole. The cost of implementing one project to high standards may consume resources that would be better spent over the network as a whole, or in filling gaps in the network to a lower standard.

4. Special considerations

Special local considerations, such as the possible use of a bridge by construction, logging or military traffic must also be borne in mind.

Results of consideration of duty:-

The important result of the above considerations, as far as the design selection process is concerned, is a choice of load specification. Two systems of loading are provided as a basis. These are American Association of State Highway and Transportation Officials of the USA, known as AASHTO loadings (Reference 6), and British Standard Specification - BS 153 and Modified BS loadings (Reference 7).

1. AASHTO loadings

These consist of defined, standard trucks, or of lane loads which are equivalent to truck trains. For the lengths of span provided under the system, the standard trucks themselves are of greater significance. Two sets of loads are provided, those corresponding to two-axle vehicles, designated H (M), Figure 2.5; and those corresponding to tractor-trailer configurations, designated HS (MS), Figure 2.6.

Tables 3 and 4 show the actual values of these loadings, for information purposes. To select a design, reference is made to later tables according to the load type chosen.

TABLE 3

H (M) Loadings

Load Type	Front Axle	Rear Axle
H20 - 44 (M18)	36 kN	144 kN
H15 - 44 (M13.5)	27 kN	108 kN
H10 - 44 (M9)	18 kN	72 kN

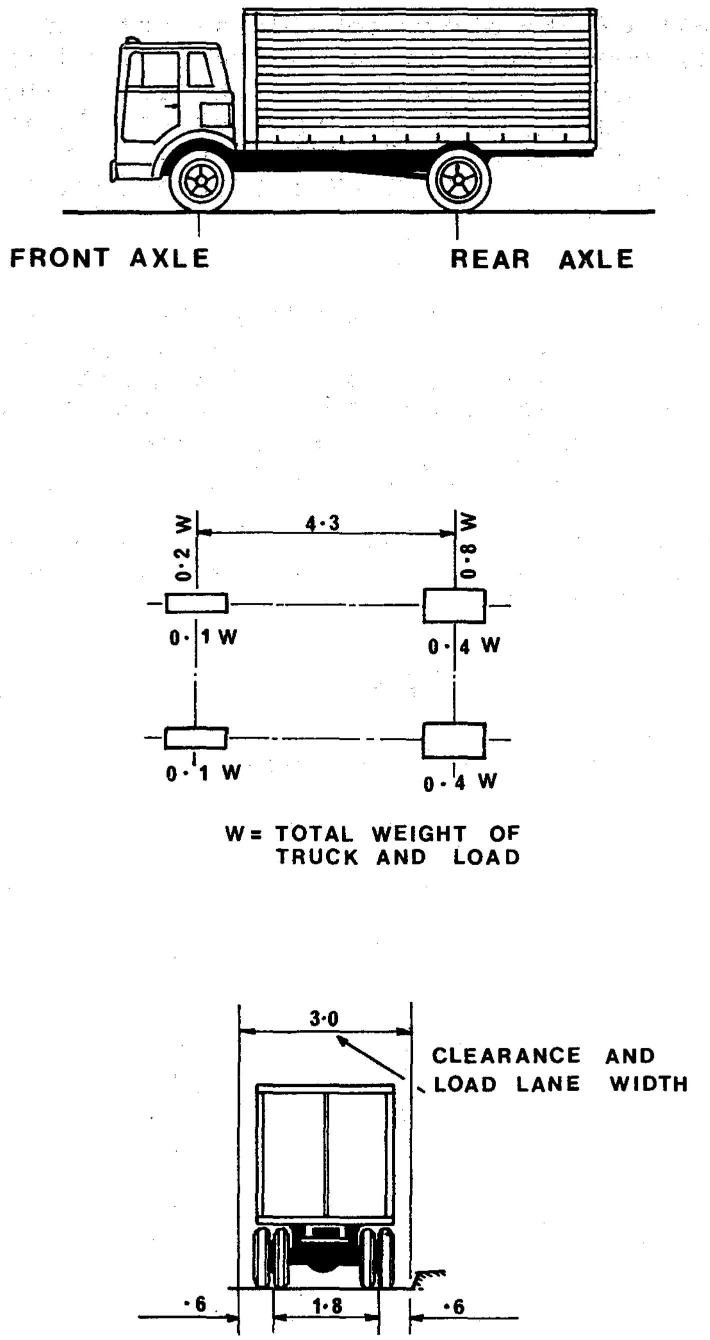


Fig. 2.5 STANDARD H (M) TRUCKS

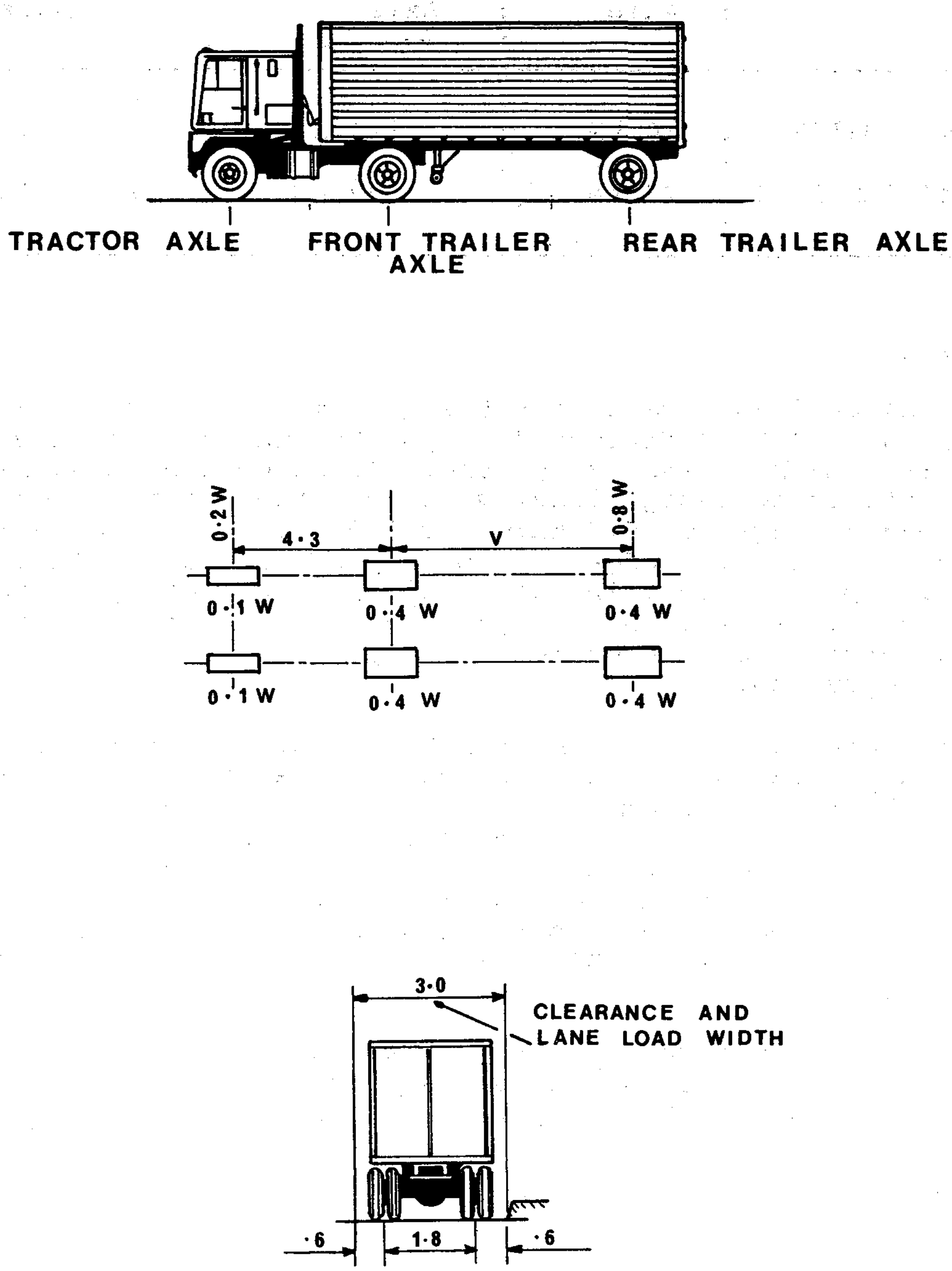


Fig.2.6 STANDARD HS (MS) TRUCKS

TABLE 4

HS (MS) Loadings

Load Type	Tractor Axle	Front Trailer Axle	Rear Trailer Axle
HS20 - 44 (MS18)	36 kN	144 kN	144 kN
HS15 - 44 (MS13.5)	27 kN	108 kN	108 kN

2. BS loadings

The BS loading used as a basis for the system is that designated as HA in BS 153, Part 3A: 1972 (Reference 7). Type HA, which is followed in Kenya, Malaysia, Sri Lanka, and many other Commonwealth countries, has a uniformly distributed design loading which varies from a high value for 1 metre of loaded length to 5.8 kN/m for 900 metres of loaded length. In addition there is a knife edge load of 120 kN per lane. These values are inclusive of impact. According to BS 153, the uniformly distributed load has a constant value of 31.5 kN per metre of lane for loaded lengths between 6.5 metres and 23.0 metres, covering the majority of applications of this bridge system.

The British Standard HA loading has been shown to be relatively severe compared with standards adopted in some developing countries for the types of vehicle most commonly using rural access and collector roads (Reference 8). For this reason, the practice was developed in Kenya, for example, of using a modified BS loading on some bridges. This consisted of two-thirds of the normal values for both the uniformly distributed, and the knife edge load. Both standard HA loading and 2/3 HA are provided for in the design tables which are given later in this Chapter of the manual.

The load specification for the bridge is chosen after consideration of all the factors discussed above, and should be one of the types designated in Table 3 or Table 4, (AASHTO); or BS type HA; or modified BS type 2/3 HA.

Timber selection

Properties of timbers from many developing countries, together with information on strength grouping, stress grading and general timber technology are given in Part 4 of the manuals. The selection of timbers included has been made with care, listing only those which satisfy various criteria. Factors considered were whether the timber was likely to be suitable for bridge construction; whether it would probably be available at a suitable cost, and whether it would be sufficiently durable or capable of being treated. Inevitably however, individual circumstances, and even individual advice, will give rise to cases in which it is required to assess or use a timber not provided for in the manual. Sufficient information is given in Part 4, therefore, to enable the more experienced user to make his own further selection, based on the recommended criteria.

The following steps must be taken by every user of the manuals when dealing with the timber selection stage of the design process:

1. Timber nomenclature

It is necessary to determine the local names, and also the botanical species or combinations of species, of timbers which are on offer. These timbers must be in the form of material which is likely to be available in the sizes and quantities suitable for bridge building. The names given must be linked with the standard timber names, as explained below, and with the information provided in Part 4.

The strength of timber depends considerably upon the species of tree from which the wood is taken. For international scientific purposes, the Latin name of the tree species is also associated with the timber itself. Trees have been treated in the same way as other plants by botanists, and the scientific naming system has evolved over several centuries. For this reason, the Latin description implied in the botanical name may actually refer to some feature of the tree itself, rather than a characteristic of the wood. Nevertheless, despite certain limitations and difficulties in its application, the botanical naming system is the most reliable means of reference, since common, commercial and vernacular names of trees and woods are often imprecise or misleading.

Attempts have been made to standardize trade names, and to relate accepted commercial names of timbers to their scientific names. For example, British Standards 881 and 589:1974 (Reference 9) cover most timbers known to the trade in Britain, which is a prolific importing country, drawing from many sources of supply. ASTM D 1165 (Reference 10) gives a standard nomenclature used in the USA. International standardization is promulgated by FAO, who select a preferred vernacular name and designate it, in capital letters, as a pilot name (Reference 11). Various tropical timber producing countries also publish national standards aimed at conformity of nomenclature (Reference 12).

Further information on nomenclature is included in Part 4. The essential consideration, from the point of view of a person in the field concerned with timber selection for a bridges project, is to obtain a positive identification of timbers offered commercially or recommended locally as suitable. No single piece of simple advice can be given; normally it is desirable to contact national forestry or timber research organizations. TRADA is also able to provide advice, and if help can be requested in a moderate, concise and orderly manner, this may be provided free of charge.

2. Availability

In considering the timbers to be used, practical considerations such as availability, continuity of supply and cost must be paramount. There is a particular tendency in some developing countries, often having a strong tradition of forestry dating back to the colonial era, to issue publications and lists from national institutions which describe a large variety of species which are uncommercialized, infrequently occuring, or which grow only in remote or unlogged regions. Some of these may at first sight appear suitable for bridge building, being described for example as 'very durable'. However, unless good supplies can be made readily available in the required dimensions, then these apparently excellent choices must be rejected in favour of more common timbers.

Chapter 1 of this manual indicates the principal sizes required for the modular panel, the pieces of which are all 50 mm thick, ranging in width from 150 mm to 250 mm. Lengths of up to 3.3 m are required for the modules, and 3.8 m for the normal deck timbers. These size requirements in themselves will preclude the use of many of the finer and more decorative timbers, which tend to be sawn in random dimensions, for non-structural use. In some countries, where a ready market does not already exist calling for wood for local constructional purposes, it may first be necessary to locate sawmills capable of producing the sizes and quality of cutting required, and then to negotiate with them over the species for which suitable logs can be obtained and cut.

3. Assessment

Further assessments should be made, after having determined and verified, the identity of a list of local timbers thought likely to be suitable for bridge building. At this stage, the requirements of availability and continuity of supply should also have been considered. The assessment should then follow the methods given in Part 4. Only a few essential points are mentioned in this section, therefore.

The immediate requirement, from the point of view of the design selection process described in this chapter, is to decide the strength group and hence stress grade, into which the possible timbers fall. The method by which this decision is taken is further described below. At the same time however, a number of other timber technological properties should be examined, following the classifications given in Part 4. This process will further refine the list, eliminating timbers which are less suitable for various reasons. The properties classified in Part 4 are density, strength group, workability, shrinkage, durability and amenability to preservative treatment.

Preservative treatment of timber involves the introduction into the wood structure of stable chemicals which protect it from wood destroying organisms such as fungi or insects. The processes used are well understood, with a long history of successful use. Many wooden bridges, (of older types of design than the UNIDO system) which have been properly protected are still providing service after more than 50 years. The properties relevant to this consideration are durability and amenity to preservation. Durability refers to the natural resistance of the timber to decay and insect attack.

The timbers classified in the highest durability grouping in Part 4 have considerable resistance to fungi, beetles and termites under tropical conditions, even without treatment. However a problem with reliance upon natural durability as an alternative to preservation is that, regardless of how durable the heartwood may be, the sapwood of practically all timbers is perishable. Furthermore, the ease by which sapwood may readily be distinguished from heartwood by rapid visual inspection varies considerably from species to species. Therefore unless assured supplies of sap-free timber in a durable species can be obtained from a reliable source, preference should be given to preservative treatment, ideally by one of the pressure methods described in greater detail in Part 4.

4. Stress grading

Stress grading is an established technique for the selection of structural timber which is intended to ensure that each piece does not contain features that would have an excessively weakening effect. It is impracticable merely to state in specifications that 'all timber shall be free from defects'. Stress grading must be carefully and effectively carried out on the timber chosen for the pre-fabricated modular panels.

During the early stages of a project, this will entail several processes, including some form of training or provision of stress grading skills, and a consideration of the grading aspects of the species shortlisted. Two forms of visual stress grading are described in Part 4. These are for tropical hardwoods and conifers respectively. Both sets of rules provide for two pass grades, or structural qualities of timber. All four grades are equally satisfactory and suitable for use, provided that the grading is performed correctly, and the choice is taken into account in arriving at the final 'stress grade'. 'Stress grade' is a term given a very special and precise meaning, as further explained in Part 4. It indicates a combination of a particular visual grade of structural timber, with a particular strength grouping of the timber concerned. Only when it has been decided which 'stress grade' can be used, is it possible to enter the design tables given below, and choose the number of trusses needed for a given span and loading.

Having studied and practised the simple visual stress grading rules given in Part 4, it will be necessary to carry out trials of the rules on commercial samples of the timbers which have been shortlisted in accordance with the recommendations given above. Once the grade has been identified which can produce satisfactory yields, and the strength group of the timber or timbers selected has been determined, then the final stages of the design selection process can proceed. The rules for selection of the 'stress grade' are explained by means of a worked example in the following section.

Selection of 'stress grade':-

Part 4 explains in more detail how timbers used in the pre-fabricated modular wooden bridge system are allocated 'strength groups'. The basis of this grouping is the inherent strength of the type of timber concerned, as determined from tests on small pieces free from defects. Determination of the strength group is only one step therefore in deciding the 'stress grade'. To find the strength group of a timber listed in Part 4, it is merely necessary to look this up, in column (2) of the general classification tables. It will be noted that there are seven strength groups and that these are designated by means of 'S' numbers, with strength group S1 being the strongest, and S7 the weakest.

As an example of the determination of the strength group for a hardwood, the following extract from Table 8 of Part 4 (properties of timbers from Africa) shows that Ekki (Lophira alata) is classed as a strength group S1 timber:

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Lophira alata	EKKI Azobe Kaku Bongossi Eba	H	S1	B	C	A	P/R

In a similar way, as an example of the determination of the strength group of a conifer, reference to Table 5 of Part 2, giving properties of timbers from Central America, will show that Caribbean pitch pine (Pinus caribaea) is classed as a strength group S4 timber.

Relationship between strength group, visual grade and stress grade:-

The following extract of Table 2(a) from Part 4 shows how the strength group is linked with the visual grade in order to arrive at the 'stress grade' of the timber.

Visual grade	Strength group						
	S1	S2	S3	S4	S5	S6	S7
No. 1 Structural	F27	F22	F17	F14	F11	F8	F7
No. 2 Structural	<u>F22</u>	F17	F14	F11	F8	F7	F5

The 'F' number in this table indicates the 'stress grade'. To continue the worked example: supposing it had been determined, from the study of the stress grading rules and trials of their use described earlier, that the visual grade of structural timber known as 'No. 2 Structural' could efficiently be produced in sufficient quantities using Ekki, the S1 group timber referred to previously, then the 'stress grade' indicated would be F22, as shown by the underlined figure in the extract table given above. A similar exercise carried through to this conclusion for the other example, which was the S4 strength group conifer Caribbean pitch pine, supposing the visual grade known as 'No. 3 Structural' had been decided upon, leads to the 'stress grade' F8. This may be verified by reference to Table 2(b) in Part 4.

OBTAINING RESULTS FOR THE DESIGN SELECTION PROCESS

<u>Selection of the number of trusses required for the bridge</u>

Having established the span of the bridge, its load type (H20, HA etc.), and the 'stress grade' (F number) of the timber to be used for the modular panels, it is finally necessary to establish the number of trusses required to make up the girders of the bridge. This is a very simple process using the following tables. One further small but important decision may be required however, dependent upon the stress grade of timber selected.

Use of light- or heavy-chord designs:-

As explained in Chapter 1, both light-chord and heavy-chord designs are available. The latter were introduced because the design of the original steel parts became more critical than that of the timber, when the possibility of using high 'stress grades' was provided for. The decision to use light or heavy chords affects not only the choice of the steel or timber lower chords themselves, but also the type of plates used in the modular wooden panel. Table 1, Chapter 1 and the drawings in Part 5 give further details of this.

The use of heavy chords is only considered for 'stress grades' F11 and higher, so the decision is quite simple. If a lesser stress grade than F11 is involved then there is no question of needing heavy-chord panels and steel chords. For F11 itself, it may be economical, or more convenient in a particular project, to use light-chords for bridges of lower loading designations, such as H20 and for spans up to about 18 metres. With the higher loadings (such as HA and HS20) using F11 timber, and with all the higher stress grades from F14 to F27 inclusive, it is normally recommended to use the heavy-chord designs. In some instances, in the following tables giving the number of trusses needed for a given span and loading, the possibility of using either type of chord has been provided for. For complete clarity, the letter symbols 'L' or 'H' are used in the tables for stress grades F11 and higher, to designate the number of trusses required in light-chord and heavy-chord designs.

Truss Tables

Tables 5 to 11 are used to establish the number of trusses required in a particular bridge design, in accordance with the recommendations given above.

TABLE 5

Number of trusses needed for a given span and loading for Stress Grade F4

Loading	Span (m)							
	6	9	12	15	18	21	24	27
H10	4	4	4	4	6	6	8	-
H15	4	6	6	6	8	-	-	-
H20	4	6	6	6	8	-	-	-
HS15	6	6	8	8	-	-	-	-
HS20	6	6	8	8	-	-	-	-
2/3HA	4	4	6	8	-	-	-	-
HA	6	8	-	-	-	-	-	-

TABLE 6

Number of trusses needed for a given span and loading for Stress Grade F5

Loading	Span (m)							
	6	9	12	15	18	21	24	27
H10	2	2	2	4	4	6	6	-
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	-	-	-	-
2/3HA	2	4	6	8	-	-	-	-
HA	6	6	8	-	-	-	-	-

TABLE 7

Number of trusses needed for a given span and loading for Stress Grade F7

Loading	Span (m)							
	6	9	12	15	18	21	24	27
H10	2	2	2	4	4	4	6	-
H15	4	4	4	4	4	6	6	-
H20	4	4	4	4	6	8	-	-
HS15	4	4	6	6	8	8	-	-
HS20	4	4	6	6	8	-	-	-
2/3HA	2	2	4	6	8	-	-	-
HA	4	6	6	8	-	-	-	-

TABLE 8

Number of trusses needed for a given span and loading for Stress Grade F8

Loading	Span (m) 6	9	12	15	18	21	24	27
H10	2	2	2	2	4	4	6	-
H15	2	2	4	4	4	6	6	-
H20	2	4	4	4	4	6	8	-
HS15	4	4	4	4	6	8	8	-
HS20	4	4	4	6	6	8	-	-
2/3HA	2	2	4	6	6	8	-	-
HA	4	4	6	8	-	-	-	-

TABLE 9

Number of trusses needed for a given span and loading for Stress Grade F11

Loading	Span (m) 6	9	12	15	18	21	24	27
H10	2L	2L	2L	2L	4L 2H	4L 4H	6L 4H	6H
H15	2L	2L	4L	4L	4L	6L 4H	6L 4H	- 6H
H20	2L	2L	2L	4L	4L	6L 4H	- 6H	- 6H
HS15	4L	4L	4L	4L	6L 4H	6L 6H	- 6H	- 8H
HS20	2L	4L 2H	4L 4H	6L 4H	6L 4H	- 6H	- 6H	- 8H
2/3HA	2L	2L	4L 2H	6L 4H	6L 6H	8L 8H	- 8H	-
HA	2L	4L	4L	6L 4H	- 6H	- 8H	- -	- -

TABLE 10

Number of trusses needed for a given span and loading for Stress Grade F14

Loading	Span (m)							
	6	9	12	15	18	21	24	27
H10	2L	2L	2L	2L	4L 2H	4L 4H	4L 4H	– 4H
H15	2L	2L	4L	4L	4L	6L 4H	6L 4H	– 4H
H20	2L	2L	2L	4L 2H	4L 4H	6L 4H	– 4H	– 6H
HS15	4L	4L	4L	4L	6L 4H	6L 4H	– 6H	– 6H
HS20	2L	4L 2H	4L 4H	4L 4H	6L 4H	– 6H	– 6H	– 8H
2/3HA	2L	2L	4L 2H	6L 4H	6L 4H	– 6H	– 8H	– –
HA	2L	4L	4L	6L 4H	– 6H	– 8H	–	–

TABLE 11

Number of trusses needed for a given span and loading for Stress grades F22 and F27

Loading	Span (m) 6	9	12	15	18	21	24	27
H10	2L	2L	2L	2L	4L 2H	4L 4H	4L 4H	- 4H
H15	2L	2L	4L	4L	4L	6L 4H	6L 4H	- 4H
H20	2L	2L	2L	4L 2H	4L 2H	6L 4H	- 4H	- 6H
HS15	4L	4L	4L	4L	6L 4H	6L 4H	- 6H	- 6H
HS20	2L	4L 2H	4L 4H	4L 4H	6L 4H	- 6H	- 6H	- 8H
2/3HA	2L	2L	4L 2H	6L 4H	6L 4H	- 6H	- 8H	- 8H
HA	2L	4L	4L	6L 4H	- 6H	- 8H	-	-

Design of the deck

The use of a vertically nailed laminated deck, consisting of 50 x 100 mm or deeper timbers closely nailed across the girders, increases the bending resistance of the whole bridge. The deck is a stress-carrying part of the design, and must not be varied without the advice of a responsible engineer. It should be assembled to the girders, with each vertical lamination nailed to its neighbour, in accordance with the drawings.

Tables 12 and 13 indicate the greater transverse dimension of the pieces to be used for these structural deck members, according to the wheel loading and stress grade of timber concerned. Table 12 should only be used for the less common two-truss type of bridge. Normal four, six, and eight truss bridges require the decking indicated in Table 13.

It should be noted that there is no special reason why the same timber should be used for the decking as for the modular panels themselves; a different 'stress grade' may be chosen if convenient. The use of the less dense stress grades such as F4 to F7, may give difficulty due to more rapid wear through stones, grit and light traffic which does not pass along the running boards. Under such circumstances, a denser stress grade, from about F8 to F14, should if possible be obtained for the running boards.

TABLE 12

Greater transverse dimension (millimetres)
for structural deck members for two-truss bridges

Wheel load (tonnes)	Stress grade								
	F4	F5	F7	F8	F11	F14	F17	F22	F27
1	100	100	100	100	100	100	100	100	100
2	125	125	100	100	100	100	100	100	100
3	150	150	125	125	100	100	100	100	100
4	-	-	150	125	125	100	100	100	100
5	-	-	-	150	125	125	100	100	100
6	-	-	-	-	150	125	125	100	100
7	-	-	-	-	150	125	125	100	100

TABLE 13

Greater transverse dimension (millimetres)
for structural deck members for four-, six- and eight-truss bridges

Wheel load (tonnes)	Stress grade			
	F4	F5	F7	F8-F27
1	100	100	100	100
2	100	100	100	100
3	100	100	100	100
4	125	100	100	100
5	150	125	100	100
6	150	125	125	100
7	150	125	125	100

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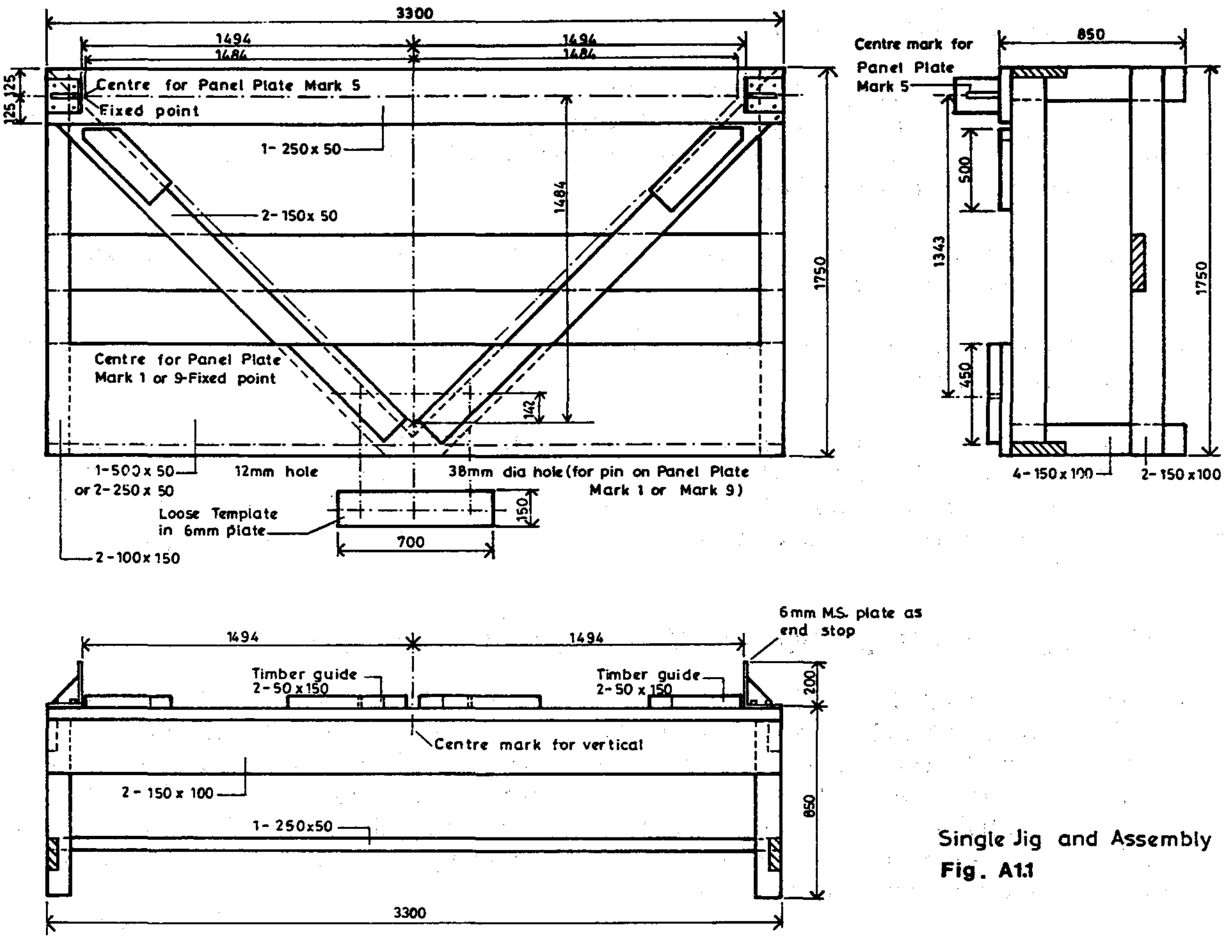
APPENDIX 1

SINGLE JIG AND ASSEMBLY TABLE FOR MODULAR PANEL MANUFACTURE

The drawing below (Figure no. A1.1) gives details and dimensions for the construction of a single jig and assembly table, necessary for the manufacture of the modular wooden panel as indicated in the instructions in Chapter 1 of Part 2, from pages 18-29.



Single Jig and Assembly Table
Fig. A1.1

APPENDIX 2

RECOMMENDED LAYOUT FOR A WORKSHOP

The following details relate to Figure A2.1 which gives a layout for a workshop, to be used when higher volume production than the four to six panels per day for which the single jig in Appendix 1 of Part 2, is designed. Following the layout and explanation, a list is given of the recommended equipment for the setting up of such a workshop.

Description of the timber processing sequence

1. Bring a set of unprocessed timber from the timber storage area to the machine conveyor. Simple handling equipment such as bogies may be used to facilitate this. Average timber lengths are from 3.6 - 4.5m, but for certain parts, such as the deck members which are extended to support the handrails, lengths of up to 5.5m are provided for in the layout.

2. First pass, over the machine : the timber is surfaced on one face, or on an edge in the case of decking. At this stage, a limited amount of trueing of distorted pieces can be undertaken with the planer/thicknesser machine.

3. Second pass, through the machine : the timber is finished to the required thickness or width.

4. Cross-cutting at 90 degrees or at other angles required to produce the finished members.

5. Timber members are transported and held for a short term in the assembly area. Dependent upon the need for preservative treatment and the system adopted, the members may at this stage be moved for treatment. Otherwise they may continue for panel assembly.

Description of jigs and workstations for panel assembly

6. This jig provides for the assembly of a plain half panel. This being the half panel with Panel Plates Mark 1 (light chord) or Mark 9 (heavy chord) and no bracing cleats. The jig is as given in Chapter 1, except that provision should be designed in for the location of the central bolt hole in Panel Plate Mark 5 (see sketch SK. 7 on page 9, Chapter 1). Assembly generally follows the procedures given in Chapter 1.

7. At this jig the bracketed half panel is assembled. This is the half panel with Panel Plates Mark 1a (light chord) or Mark 9a (heavy chord), including bracing cleats. This panel must be on top of the assembly in a later stage (jig 11).

8. Drilling jig. This includes two stand-mounted, Wolf Model 3806 large capacity electric drills or eqivalent, provided with morse-taper sleeves and drill chuck options. Provision must be made for panels to slide longitudinally on this jig to enable both apex and central chord holes and also the holes in Panel Plate Mark 5, to be bored truly vertical. This work-station serves both plain and bracketed half panels.

8a/ 9. Jigs 8a and 9 make provision for the inversion, temporary storage and sliding area for plain half panels. The plain halves taken from drilling jig (8) are placed on roller conveyors or timber rails, turned over face plated side down, and slid towards jig (11). Plain halves must be placed on jig (11) before the bracketed halves.

10/ 10a. This is a platform to rotate the bracketed halves with conveyors or slides to move these half panels onto jig (11). This work-station should be made up as a flat boarded, plain topped platform on bench-type braced legs.

11. Final assembly jig. The half panels are bolted and nailed together here. Locating jig plates are not necessary as the halves have been restrained to shape in jigs (6) and (7), also bolt holes have been bored on the same jig (8) for both halves. This jig must be strong enough to permit hammering without bounce but should allow access to the undersides of the panels for bolt insertion and tightening. It should consist of four or more deep parallel wood rails on bench-type braced legs.

12. This consists of a platform to rotate the completely assembled panels towards the welding beds. Construction of the platform should be similar to (10/10a).

13. The welding bed. This is also required to give firm support to the panels and good access to both sides or the facilty to turn them over. It may be possible to weld both sides by standing the panel vertically, apex upwards. Location jigs for welding End Plates Mark 3 and 4 (light chord) or Mark 10 and 11 (heavy chord) should be used at this workstation.

14. This work-station is used to descale and wire brush the panel plates and remove the panels to the store, using roller conveyors or timber rails.

TYPICAL WORKSHOP ARRANGEMENT FOR ASSEMBLY OF MODULAR BRIDGE PANELS

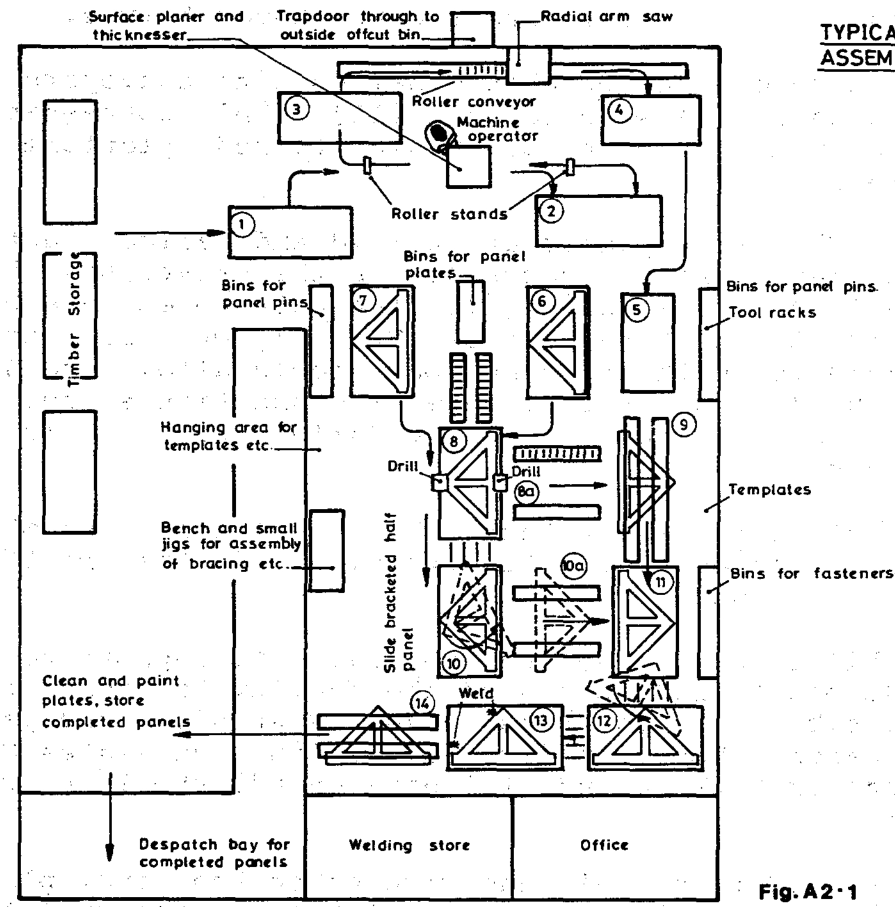


Fig. A2·1

Key to Stage numbers:

1. Set of unprocessed timber
2. One face surfaced (or edge for decking)
3. Surfaced and thicknessed
4. Finished, cross-cut members
5. Timber members awaiting assembly
6. Assembled plain half panel
7. Assembled bracketed half panel
8. Panel moves laterally for corners to be drilled

8a Turn plain panel over and slide to Stage 9

9. Parking area for plain half panel and slide to Stage 11
10. Rotate bracketed half panel by 180°

10a Slide bracketed half panel onto plain half

11. Bolt and nail together the half panels
12. Rotate panel by 90°
13. Welding bay
14. Descale and park for removal to despatch bay

RECOMMENDED WORKSHOP EQUIPMENT

1. Combined surface planer and thicknesser

Minimum thicknessing capacity	510 x 230 mm
Length of thicknessing table	765 mm
Length of infeed surfacing table	972 mm
Fence canting angle	up to 45 deg
Minimum power of cutter block motor	5.5 kw
Power of feed motor	0.75kw
Range of feed speeds (should be variable)	6 to 18 m/min

Voltage and frequency will depend on the country.

Recommended makes and models :

a) Wadkin-Bursgreen BTS 500
supplied by Wadkin Ltd., Green Lane Works, Leicester LE5 4PF, UK.

b) Robinson Type EW/T
supplied by Thomas Robinson and Son Ltd., Railway Works, Rochdale, Lancashire OL16 5NB, UK.

2. Radial arm cross-cut saw

Minimum diameter of saw	400 mm
Capacity of cross cut width - Standard arm at 90 deg.	390 x 133 mm 450 x 25 mm
Capacity of cross cut width - Standard arm at 45 deg.	110 x 133 mm 260 x 25 mm
Minimum capacity of ripping	760 mm
Minimum power of motor	4.5 kw

Recommended make and model :

a) Wadkin-Bursgreen BRA 400
supplied by Wadkin Ltd., Green Lane Works, Leicester LE5 4PF, UK.

3. Complete set of arc welding equipment

Consisting of welder's kit (electrode holders,helmet hand shield etc.)

Input voltage	230/380/415 V
Frequency	50/60 HZ
Open circuit voltage	75 V
Welding amperage range	40 - 200 amp

Recommended make and model :

BOC Transarc AC 240
supplied by BOC Ltd., Hertford Road,
Waltham Cross, Herts. EN8 7RP, UK.

4. Electric drill (heavy duty) with stand

Maximum size of drill bit (for steel and hardwood) 32mm
Voltage and frequency will depend on the country.

Recommended makes and models :

a) Wolf drill model 3806 and stand model 0421
supplied by Kango Wolf Power Tools Ltd.,
Hanger Lane, London W5 1DS, UK.

b) Black and Decker drill model HD 1125 and
stand model SD 0506
supplied by Black and Decker Ltd., Cannon Lane,
Maidenhead, Berks., UK.

5. Portable electric saw (heavy duty)

Minimum size of saw 225 mm
Voltage and frequency will depend on the country.

Recommended makes and models :

a) Wolf circular saw model 6089
supplied by Kango Wolf Power Tools Ltd.,
Hanger Lane, London W5 1DS, UK.

b) Black and Decker circular saw model HD 2086
supplied by Black and Decker Ltd., Cannon Lane ,
Maidenhead, Berks., UK.

6. Flame cutting equipment

(Only required if blanks for plates are cut locally).

Oxy-acetylene flame cutter with accessories

Recommended make :

BOC oxy-acetylene cutter
supplied by BOC Ltd., Hertford Road,
Waltham Cross, Herts., EN8 7RP, UK.

7. Power-driven hacksaw

(Only required if blanks and pins are cut locally).

Features to include variable cutting speeds and vice unit with mitre cutting capacity (mild steel up to 60 mm diameter).

Recommended make and model :

Starlite Sawmec power hacksaw model MS150
suplied by Tunes's Engineering Service Ltd.
Ipswich Road, Trading Estate, Slough, Berks., UK.

8. Hand tools and accessories

Description	Quantity
Toolbox	2
Mechanics' vice (4" - heavy duty)	1
Woodworkers' vice (13")	1
Hand grinding wheel	1
Spanners: (all heavy duty)	
12" adjustable	1
15" adjustable	1
Set of combination wrenches (6 - 26mm)	1
Set of sockets with ratchet handle (6 - 26mm)	1
Set of allen keys (1.5 - 10mm)	1
Set of spanners (6 - 26mm)	1
G cramp (18" -heavy duty)	2
Adjustable bench plane - cutter width 2"	1
Hacksaw adjustable (250/300 mm)	2

Hand tools

Blades for hacksaw	24
Sledge hammer (8lb) with handle	1
Hammer (2 1/2lb)	2
Claw hammer (20 oz)	4
Hand saw (26" -6 pt - 5 teeth)	2
Saw set	1
Machinist scriber	2
Scribe with swivel handle for slope of grain	1
Tin snips (300mm)	1
Wire brushes	2
Sliding bevel (9")	1
Measuring calipers (spring type - 300mm)	1
Steel rule (metric)	1
Tape (3m)	3
Tape (30m)	2
Try square (10")	1
Roofing square (great neck)	1
Spirit level	1

High speed shank drills	
28 mm	4
25.5 mm	4
12.7 mm	8
Files (6" triangular)	6
Files (10" mill saw)	4
Carborundum stone	1
Extension leads (15 amp)	3
Steel template (24 gauge)	1
Oil can	1
Plywood sheet (9mm - marine)	2
Moisture meter (for timber)	1
Electrodes for general fabrication and for deeper penetration (according to British Standards 639)	400 doz.

APPENDIX 3

STEEL AND FASTENER QUANTITIES FOR BRIDGES

Steel quantities for one light chord bridge

(15 metre span - 5 panel - 4 truss)

The following list details the steel plates required to complete a fifteen metre span, four truss bridge. Each truss consists of five, three metre modular panels. List a) is for a bridge having steel lower chords, whilst b) is for a bridge with wooden lower chords.

a) Steel quantities for one steel light chord bridge

The list should be read in conjunction with the Figure numbers in Part 5 of the manuals, or the SE-245- drawings referenced.

Grade 43A weldable structural steel to BS 449 and BS 4360 with a minimum ultimate tensile strength of 435 Newtons per square millimetre and a minimum yield strength of 236 Newtons per square millimetre, should be used for all items including the round bar stock.

ITEMS FROM MILD STEEL PLATE

Component mark	Figure number	Drawing number	Piece code	Overall size (mm)	Quantity required
1	8	SE-245-30	a	10 x 300 x 288	20
1A	8	SE-245-30	a	10 x 300 x 288	20
			c	10 x 75 x 113	20
2	10	SE-245-33	a	10 x 100 x 3100	16
			b	6 x 75 x 100	32
2A	10	SE-245-33	a	10 x 100 x 2670	16
			b	12 x 75 x 365	32
3	9	SE-245-31	a	12 x 100 x 174	20
3A	9	SE-245-31	a	12 x 100 x 174	20
5	8	SE-245-30	a	6 x 150 x 300	80
			b	10 x 50 x 250	80
8	12	SE-245-4	-	6 x 75 x 300	40
13	9	SE-245-31	a	10 x 100 x 150	20
			b	10 x 100 x 112	20

ITEMS FROM MILD STEEL PLATE continued.....

Component mark	Figure number	Drawing number	Piece code	Overall size (mm)	Quantity required
14	11	SE-245-32	a	12 x 200 x 205	4
			b	12 x 200 x 275	4
			d	12 x 50 x 130	8
14A	11	SE-245-32	a	12 x 200 x 205	4
			b	12 x 200 x 275	4
			c	12 x 50 x 130	8

ITEMS FROM MILD STEEL ROUND BAR

Component mark	Figure number	Drawing number	Piece code	Overall size (mm)	Quantity required
1	8	SE-245-30	b	38 dia. x 63	20
			*	12 dia. x 50	480
1A	8	SE-245-30	b	38 dia. x 63	20
			*	12 dia. x 50	480
3	9	SE-245-31	b	32 dia. x 54	20
5	8	SE-245-30	*	12 dia. x 50	160
			*	12 dia. x 100	1280
14	11	SE-245-32	e	32 dia. x 57	4

* The 12mm diameter dowels are not marked on the referenced figures and drawings but are associated with the components detailed there.

b) Steel quantities for one timber light chord bridge

The following list details the steel required to complete one light chord, fifteen metre span, four truss bridge. Each truss consists of five, three metre modular panels.

The list should be read in conjunction with the Figures in Part 5 of the manuals, or the SE-245- drawings referenced.

Grade 43A weldable structural steel to BS 449 and BS 4360 with a minimum ultimate tensile strength of 435 Newtons per square millimetre and a minimum yield strength of 236 Newtons per square millimetre, should be used for all items including round bar items.

ITEMS FROM MILD STEEL PLATE

Component mark	Figure number	Drawing number	Piece code	Overall size(mm)	Quantity required
1	8	SE-245-30	a	10 x 300 x 288	20
1A	8	SE-245-30	a	10 x 300 x 288	20
			c	10 x 75 x 113	20
3	9	SE-245-31	a	12 x 100 x 174	20
3A	9	SE-245-31	a	12 x 100 x 174	20
5	8	SE-245-30	a	6 x 150 x 300	80
			b	10 x 50 x 250	80
8	12	SE-245-4	-	6 x 75 x 300	40
13	9	SE-245-31	a	10 x 100 x 150	20
			b	10 x 100 x 112	20
14	11	SE-245-32	a	12 x 200 x 205	4
			b	12 x 200 x 275	4
			d	12 x 50 x 130	8
14A	11	SE-245-32	a	12 x 200 x 205	4
			b	12 x 200 x 275	4
			c	12 x 50 x 130	8
+	14	SE-245-40/1	-	12 x 75 x 552	64
+	14	SE-245-40/1	-	6 x 150 x 150	128

+ Components associated with timber tension chord have no component mark.

ITEMS FROM MILD STEEL ROUND BAR

Component mark	Figure number	Drawing number	Piece code	Overall size (mm)	Quantity required
1	8	SE-245-30	b	38 dia. x 63	20
			*	12 dia. x 50	480
1A	8	SE-245-30	b	38 dia. x 63	20
			*	12 dia. x 50	480
3	9	SE-245-31	b	32 dia. x 54	20
5	8	SE-245-30	*	12 dia. x 50	160
			*	12 dia. x 100	1280
14	11	SE-245-32	e	32 dia. x 57	4
+	14	SE-245-40/1	-	38 dia. x 146	64
+	14	SE-245-40/1	-	12 dia. x 50	896

* The 12mm diameter dowels are not marked on the referenced figures and drawings but are associated with the components detailed there.

\+ Components associated with timber tension chord have no component mark.

FASTENER QUANTITIES FOR ONE STEEL LIGHT CHORD AND ONE TIMBER LIGHT CHORD BRIDGE

This list details the bolts, nuts, washers and split pins required to complete one steel light chord and one timber light chord bridge. Each fifteen metre span bridge consists of four trusses made from five three metre long modular panels. The specifications in this instance are based on British Standards. The example given was used in a situation where galvanizing treatment was decided upon for all the fasteners.

General

All bolts and nuts are hexagonal-round-hexagonal with coarse threads to BS 4190 and of grade designation 4.6. Thread lengths are standard unless noted otherwise. All washers are of mild steel. Fasteners and accessories are to be hot dip galvanized to BS 729. All diameters and lengths are in millimetres.

BOLTS

Component mark or location description	Bolt size - diameter and length	Thread length	Total no. for two bridges
1 + 1A	M10 x 150	-	80
	M24 x 150	-	40
5	M12 x 240	-	80
8	M24 x 100	-	80
8 + 13	M24 x 50	Full length	80
13	M24 x 260	-	80
Vert.bracing	M24 x 170	-	20
Hand rail	M12 x 260	-	44
	M12 x 180	-	88
Anchor bolts	M24 x 300	-	32
Timber chord	M12 x 150	-	64*

* Qty. for one bridge

SQUARE WASHERS

Component mark or location description	Washer size	To take bolt size	Total no. for two bridges
8 + 13	75 x 75 x 6	M24	160
Handrail	50 x 50 x 3	M12	132
Vert.bracing	75 x 75 x 6	M24	40

ROUND WASHERS

Component mark or location description	Washer size	To take bolt size	Total no. for two bridges
1/1A	22 dia x 1.5	M10	160
	45 dia x 2	M24	80
5	25 dia x 1.5	M12	160
8 x 13	45 dia x 2	M24	320
Anchor bolts	56 dia x 2	M24	32
Timber chord	25 dia x 1.5	M12	128*

* Qty. for one bridge

SPLIT PINS

Component mark or location description	Split pin size diameter and overall length	Total no. for two bridges
1 + 1A + 3 + 14 +timber chord*	7 dia x 100	256

* Qty. for one bridge

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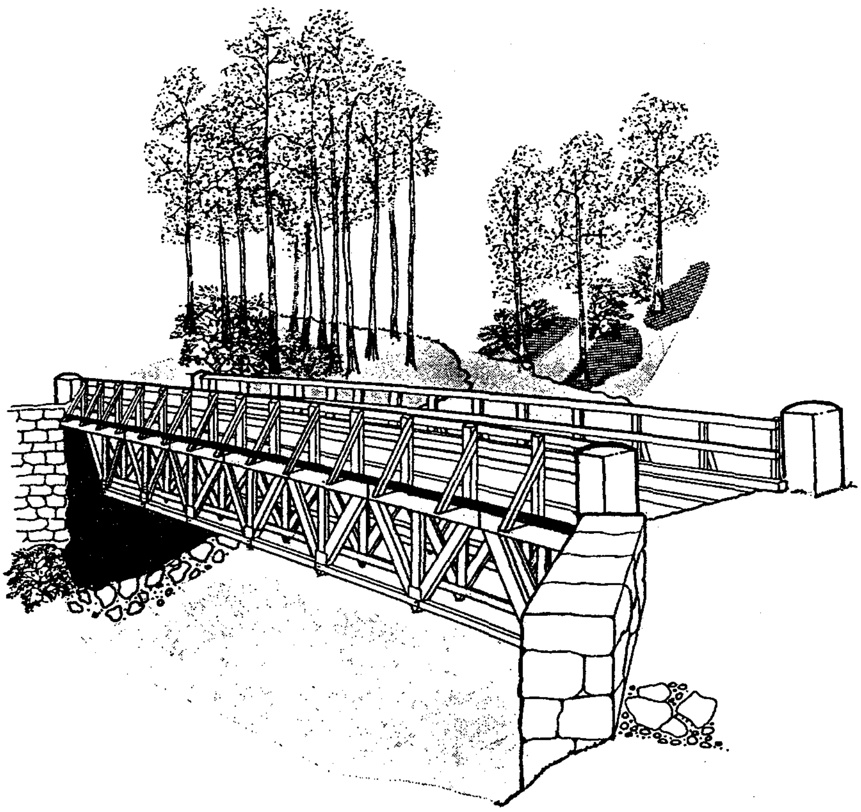
PRE-FABRICATED MODULAR WOODEN BRIDGES



PART 3 • CONSTRUCTION AND LAUNCHING

prepared for

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by

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PRE-FABRICATED MODULAR WOODEN BRIDGES

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PRE-FABRICATED MODULAR WOODEN BRIDGES

Part 3 Construction and Launching

INTRODUCTION

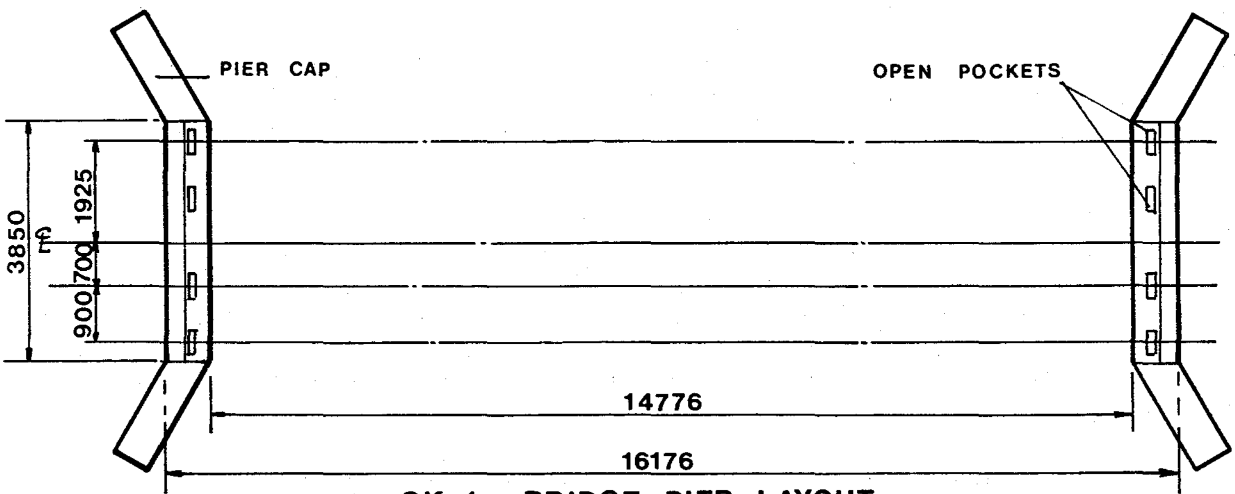
This section of the pre-fabricated modular wooden bridge manual describes the construction and launching procedures, starting with the required layout of piers and details of holding down pockets and the various critical span dimensions. Two basic methods of launching are described, the preferred method using towers or derricks on each bank to support an overhead cable from which the girders are suspended, and a method using a single derrick on the stream bed, which is useful for small spans at awkward sites, where access to the river bed is possible.

Details of the launching equipment are provided and these are supplemented by equipment lists in Appendix 1. The wet crossing method, using twin towers, is explained step-by step and the construction of the deck and superstructure is given. Appendix 2 gives additiional information on launching forces. Careful positioning of the derrick on the stream bed is important in the dry crossing method, and this is also explained in detail.

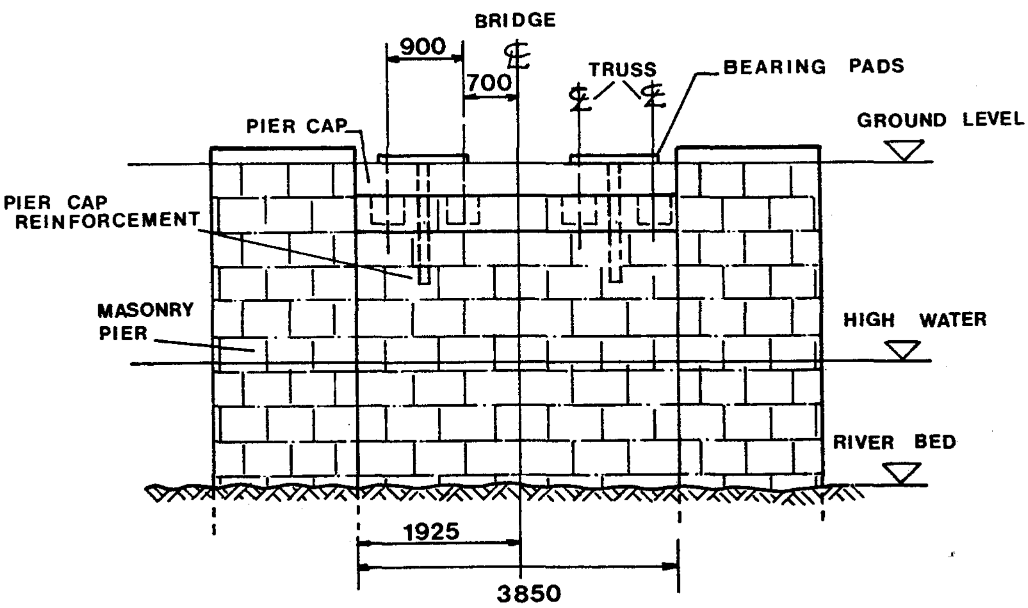
Before a full explanation of the launching methods, the following section gives information on the dimensions and details of the pier caps and bearing arrangements, since it is necessary to have an understanding of these in order to complete preparation of the permanent supports of the bridge, before launching can take place.

DIMENSIONS AND DETAILS OF PIER CAPS

The sketches below, SK.1a and SK.1b, show a typical bridge pier layout in plan and elevation. The details are for a four truss bridge, but from the sectional drawings which follow for two, six and eight truss sections, it is a simple matter to determine the pier layout for these other constructions, as the principle of using open pockets remains the same.



SK.1a BRIDGE PIER LAYOUT

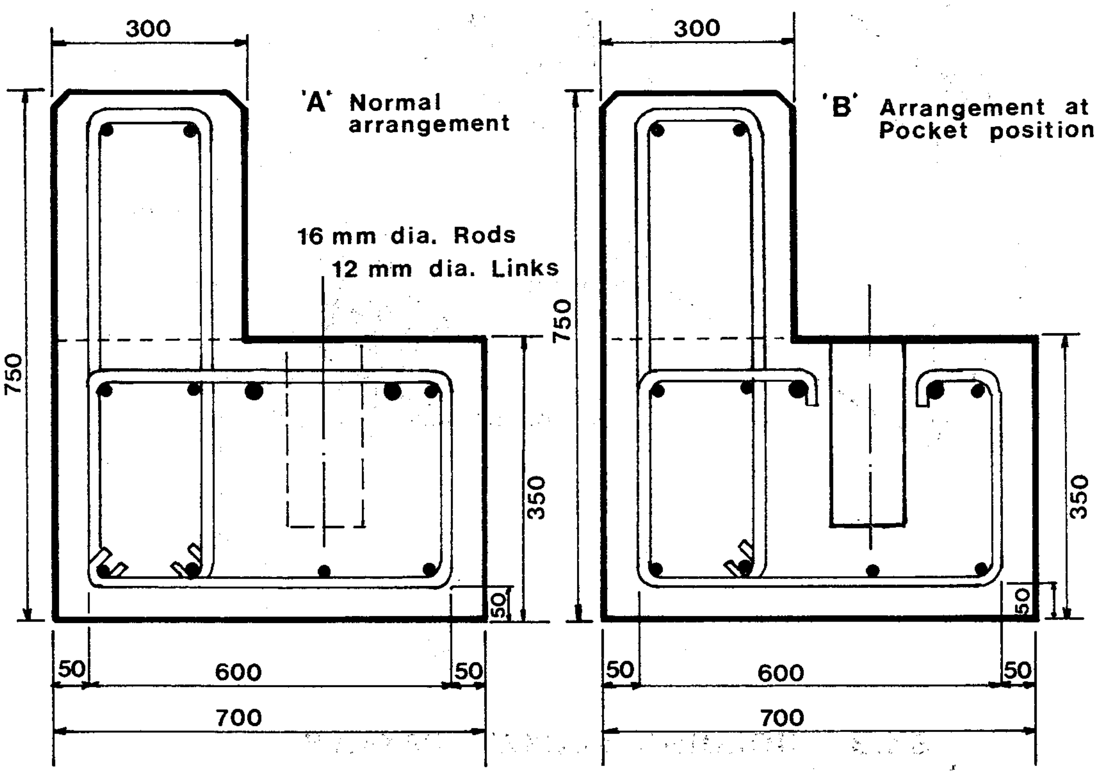


SK.1b ELEVATION ON BRIDGE PIER

Possible forms of support for the bridge structure include masonry piers as shown here; mass rock-filled concrete abutments and also gabions. It is assumed that any of these will be designed for the particular site in question using normal civil engineering methods and calculations. A separate design has been produced by TRADA showing a further alternative, which is the use of timber approach spans based on driven wood piles. Detail drawings of this are given in Part 5.

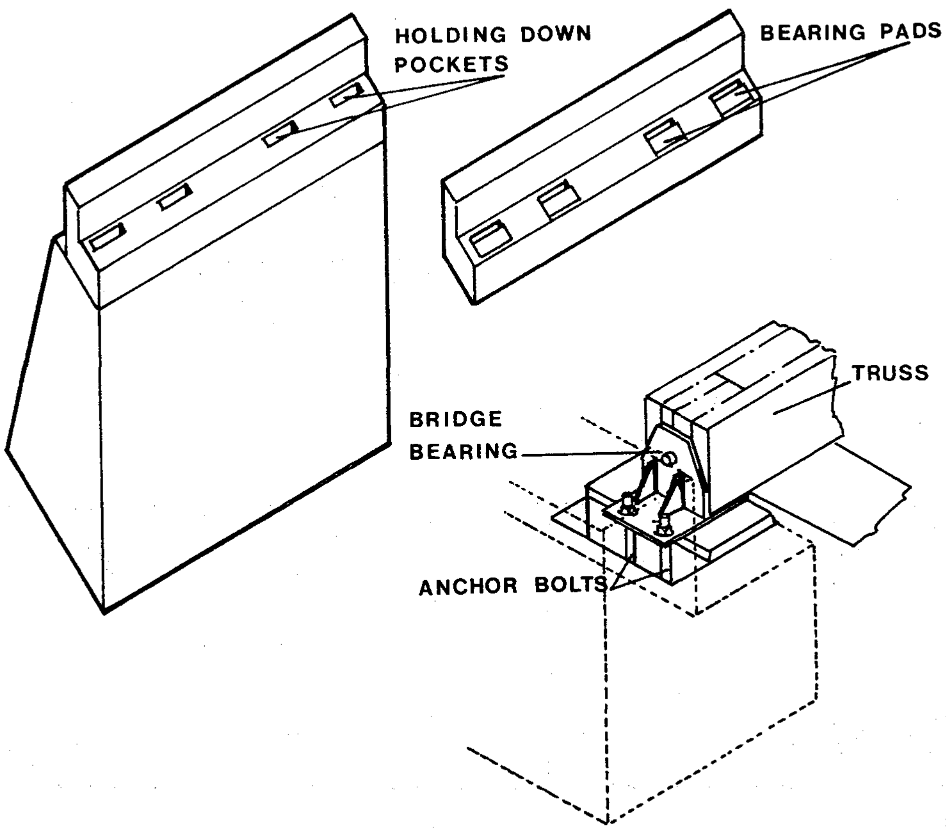
Whatever type of support is used, care and attention should be paid to the design of the foundations; consideration should be given to earth retention and drainage, and connections should be provided between the bases and the pier caps. In the case of the masonry or mass filled concrete types of pier, these connections should be formed by reinforcing bars carried through from the bases to the caps.

The caps themselves are also reinforced, sketch SK.2 shows the design of the reinforcing steel within these parts, using 16 mm diameter rods and 12 mm diameter links. Concrete in the pier caps should be of a structural quality, and test cubes should be taken when they are cast.



SK.2 CONCRETE PIER SECTION SHOWING REINFORCEMENT OF CAPS

The bearings for the bridge girders are positioned and fixed after launching. This is most important, as even with an accurate manufacturing system such as that provided by use of the pre-fabricating jigs, minor variations in assembled girder length are inevitable, and casting-in-place of anchor bolts before launching leads to problems and delay. Sketch SK.3 shows the holding down pocket details in the pier caps. The pockets are left open during launching, and only the front part of the bearing pads for the steel bridge bearing plates are cast beforehand. After launching and alignment, the 25 mm diameter anchor bolts are grouted into the pockets, as shown in the final stage of the sketch.



SK.3 HOLDING POCKET DETAILS

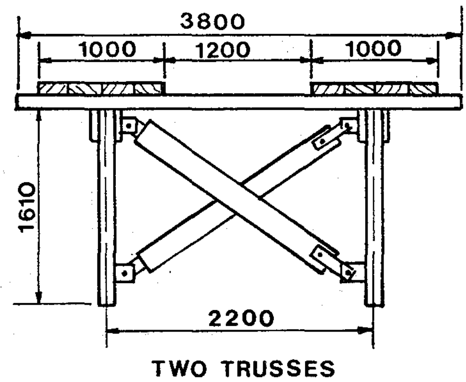
There are a number of critical span-wise dimensions that must be set out correctly during the final stages of construction of the site works. These are given for four truss bridges of spans ranging from 6 to 21 metres in TABLE 1.

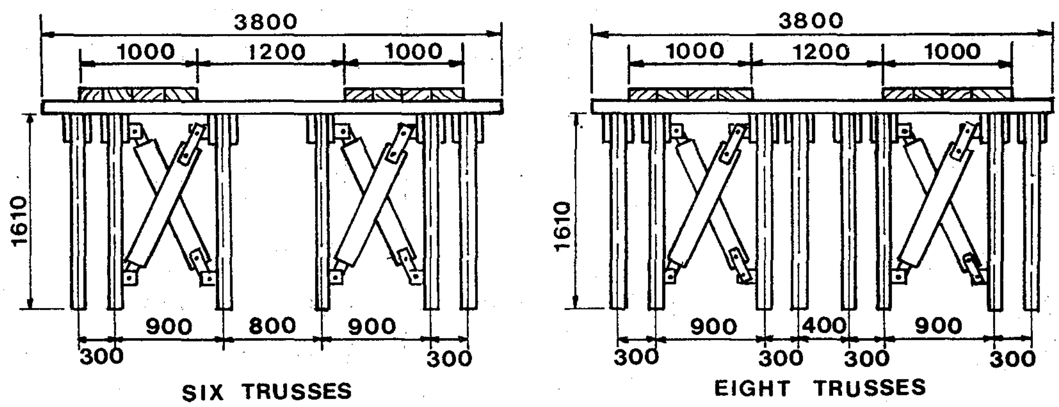
TABLE 1

CRITICAL SPAN DIMENSIONS FOR CONSTRUCTION OF PIER CAPS
FOR STANDARD BRIDGES FROM 6m TO 21m SPAN

MEASUREMENT \ SPAN	6m	9m	12m	15m	18m	21m
OVERALL TRUSSED GIRDER LENGTH	6020	9030	12040	15050	18060	21070
PIER WALL FACE TO PIER WALL FACE	5746	8756	11766	14776	17786	20796
℄ OF POCKETS TO ℄ OF POCKETS	6291	9301	12311	15321	18331	21341
INSIDE FACE OF CAP UPSTAND TO INSIDE FACE OF CAP UPSTAND	6546	9556	12566	15576	18586	21596
REAR FACE OF CAP UPSTAND TO REAR FACE OF CAP UPSTAND	7146	10156	13166	16176	19186	22196

The cross sections shown in sketch SK.4 below give alternative lateral dimensions for bridges of two, six and eight truss forms. From these it is possible to plan the pier and cap setting out details for these other types.

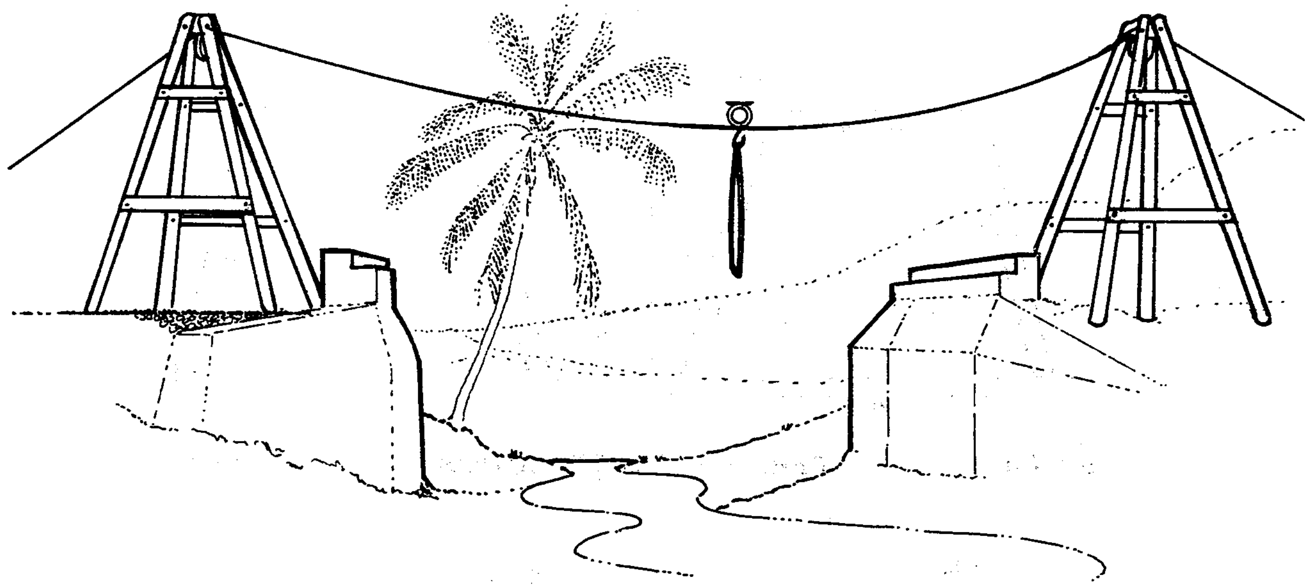




SK. 4 ALTERNATIVE TRUSS ARRANGEMENTS & DIMENSIONS

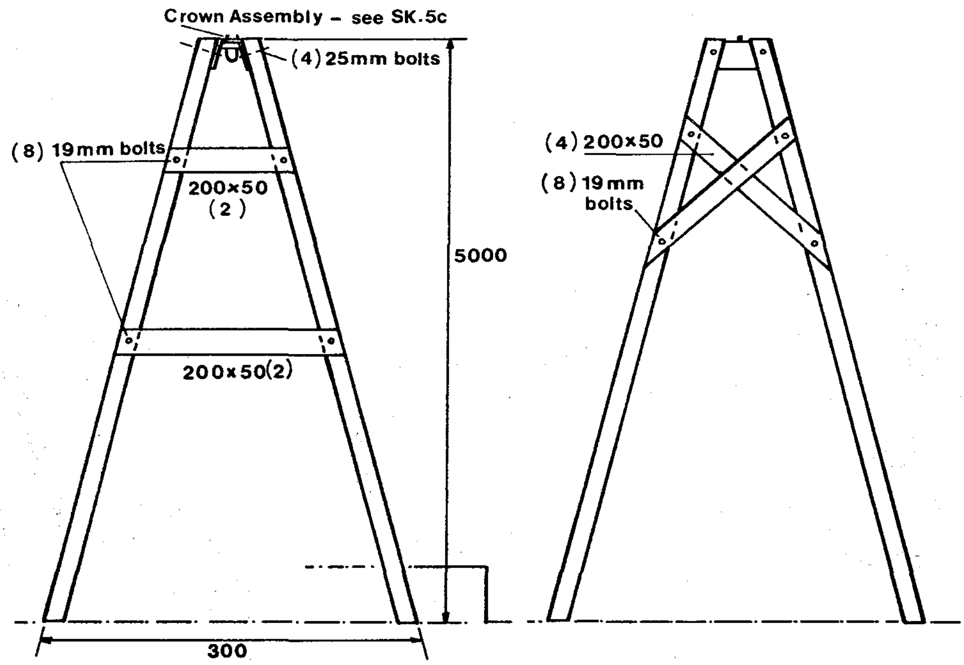
PREPARATION FOR LAUNCHING USING THE OVERHEAD CABLE METHOD

The preferred method of launching is to use twin towers or derricks on each bank, as shown in sketch SK.5. The girder to be launched is assembled beneath one of the towers, on what is known as the 'home bank'. As launching proceeds, the girder is drawn across the span, suspended from an overhead cable. This is also referred to as the wet crossing method, since it is suitable for use when the water is too deep for work to be carried out from the stream bed. Appendix 1, lists all the equipment recommended to carry out launching by the method described. The text following the sketch below describes the construction of the launching towers for the wet crossing method.

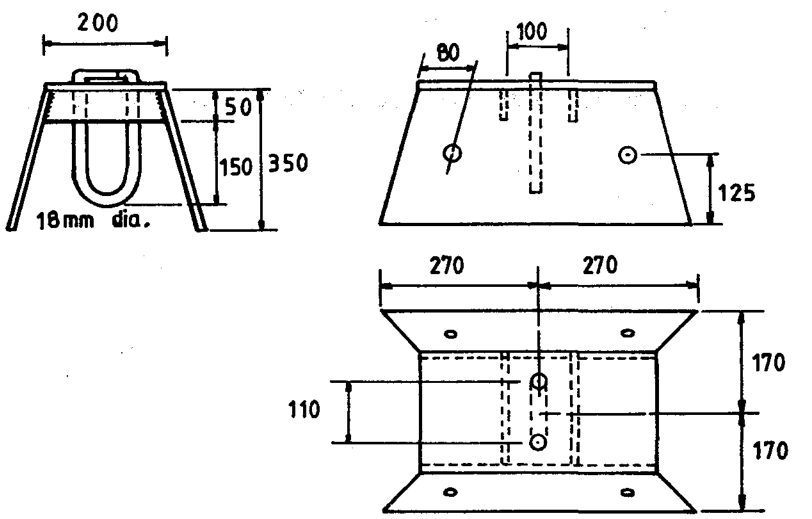


SK.5 ERECTION OF DERRICKS AT THE SITE

The launching towers are made from 150mm top diameter wooden poles or 100mm diameter steel tubes. Details of the derrick construction are shown in sketches SK.6a and 6b (elevations) and SK.7 (steel crown assembly). The 5 metre height of derrick shown in SK.6 is the minimum practicable; it permits a maximum of approximately 4 metres sag in the standing cable when a small bridge is being launched over a short span. Throughout the launch, forces in the cables and the tendency for the towers to topple are minimised if the sag in the standing cable is kept to the maximum possible compatible with moving the girders into place. For longer and heavier bridges, taller towers are required therefore. As an example, for a cable sag of 5.5 metres, 7 metre high towers are used. Further information on launching forces is provided in Appendix 2.



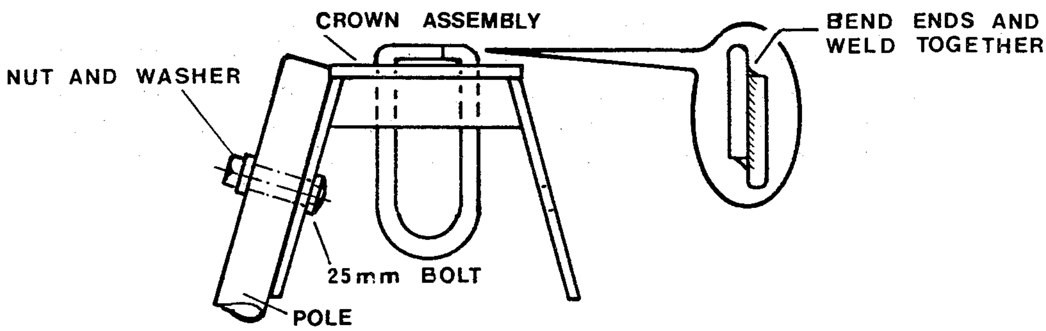
SK.6a DERRICK CONSTRUCTION SK 6b



SK.7 CROWN ASSEMBLY DETAILS

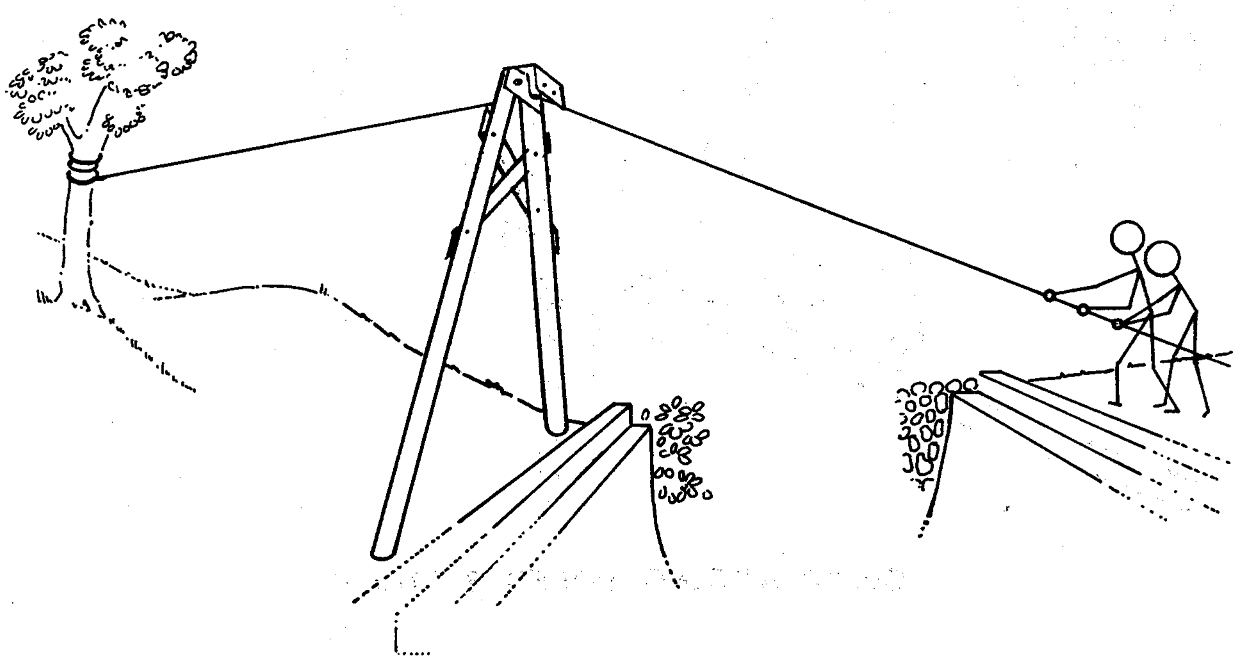
Assembling and lifting the towers

The crown assembly is bolted to two of the derrick poles on the ground, using a 25 mm bolt, with nut and washer as shown in sketch SK.8. The angles of the crown plates provide a guide for the correct splay of the tower legs.



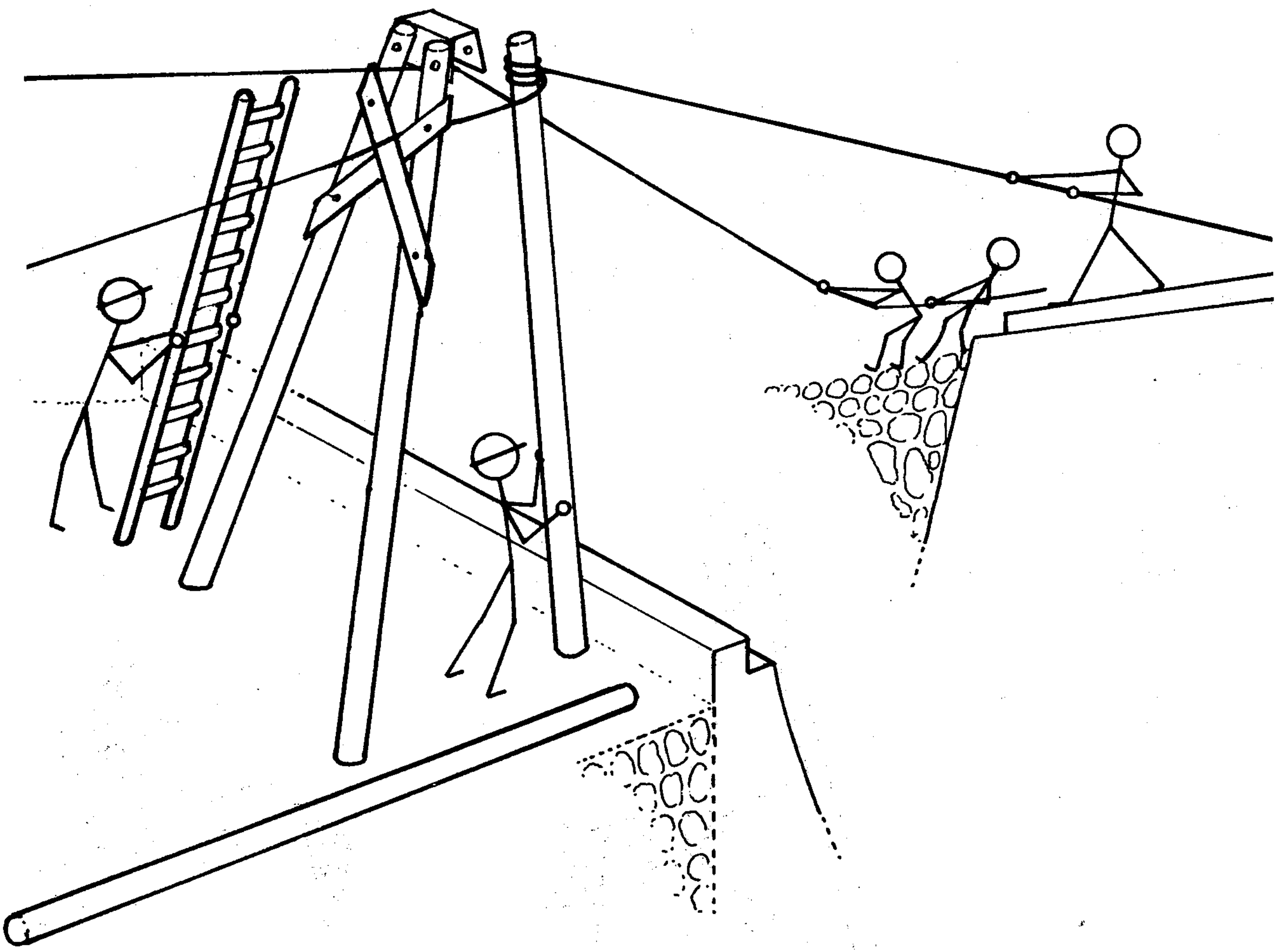
SK.8 FIXING THE CROWN ASSEMBLY

The 50 x 200 mm section crossed bracing pieces (see sketch SK.6) are bolted to the poles using 19 mm diameter bolts. The first pair of poles are then lifted, using a rope anchored at its far end to a tree or other convenient point. The rope can be attached to the U cleat of the crown assembly. It is quite possible to lift the poles as shown in sketch SK. 9, using manpower, provided sensible precautions are taken to ensure safety.



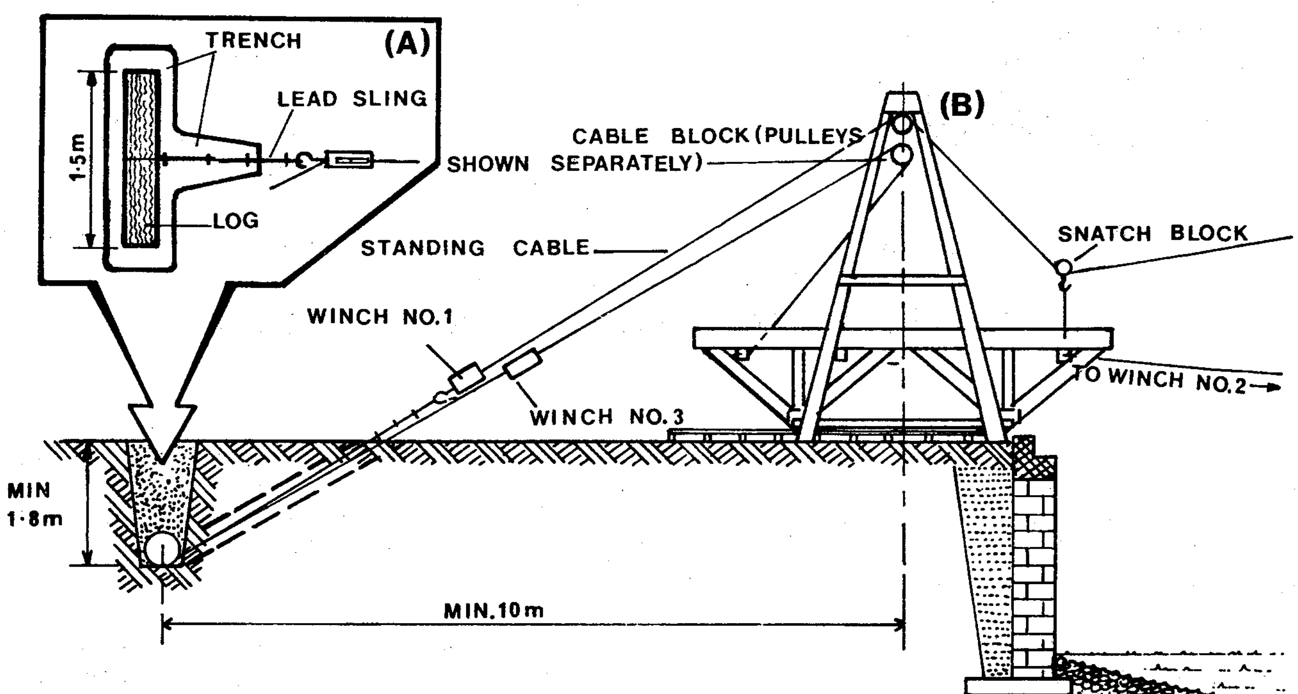
SK.9 LIFTING THE FIRST PAIR OF POLES

The third and fourth poles are roped into postion individually, as shown in sketch SK.10. At this stage, plenty of manpower is required, as it is necessary to place a ladder against the first pair of legs whilst they are held up by a team of men hauling on ropes. The tips of the third and fourth poles are bolted in place in this way, after which the tower becomes self-supporting. Horizontal bracing pieces of 50 x 200 mm section (sketch SK.6) are bolted onto the side legs to complete the tower assembly. The towers should be guyed at approximately 2 o'clock, 5 o'clock, 7 o'clock and 10 o'clock positions on plan,(relative to the longitudinal centre line of the span), taking the guy ropes back to convenient strong points such as trees, rocks or buried log anchors. It is strongly recommended that this precaution should be taken, as overturning of the towers is highly dangerous and this can otherwise be caused by inadvertent snatches on the cables during the launching process.



SK.10 ADDING POLES 3 AND 4

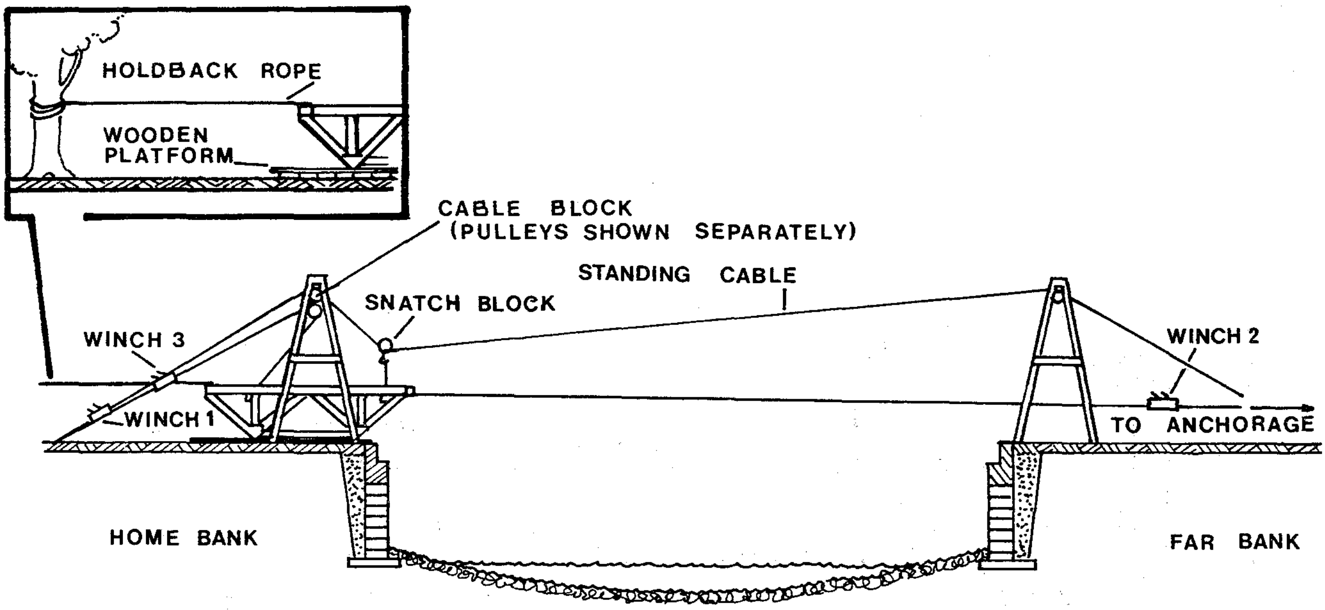
After erecting a second derrick in a similar manner on the far bank, 'deadman' anchors are dug to provide fixing points for the standing cable. Trenches are dug at least 1.8 metres deep for this purpose. As previously explained, erection forces are reduced with maximum sag and with the deadman anchors as far as possible back from the towers. The minimum permissible distance is 10 metres back from the vertical centreline of the tower assembly. Slings are led through grooves cut in the trench sides so that the cable may be attached along the span-wise centreline of the derrick assembly. Sketch SK.11 (A) shows the arrangement. The log should be about 1.5 m long and 250 mm in diameter. During and after refilling of the trench, the soil should be firmly compacted.



SK.11 CABLE ANCHORAGE DETAILS

Assembly of launching cables

Sketches SK.11 (B) on the previous page, and SK.12 below show the arrangement of the cables and ropes required for launching. The following section describes their assembly. It should be noted that the pulley blocks, or sheave blocks as they are sometimes known, are double blocks in the case of the home bank (and can usefully be double in both cases). To clarify the explanation, the two pulleys, which are actually on the same axle, are drawn separately in the diagrams.



SK.12 COMPLETE ARRANGEMENT OF WET CROSSING

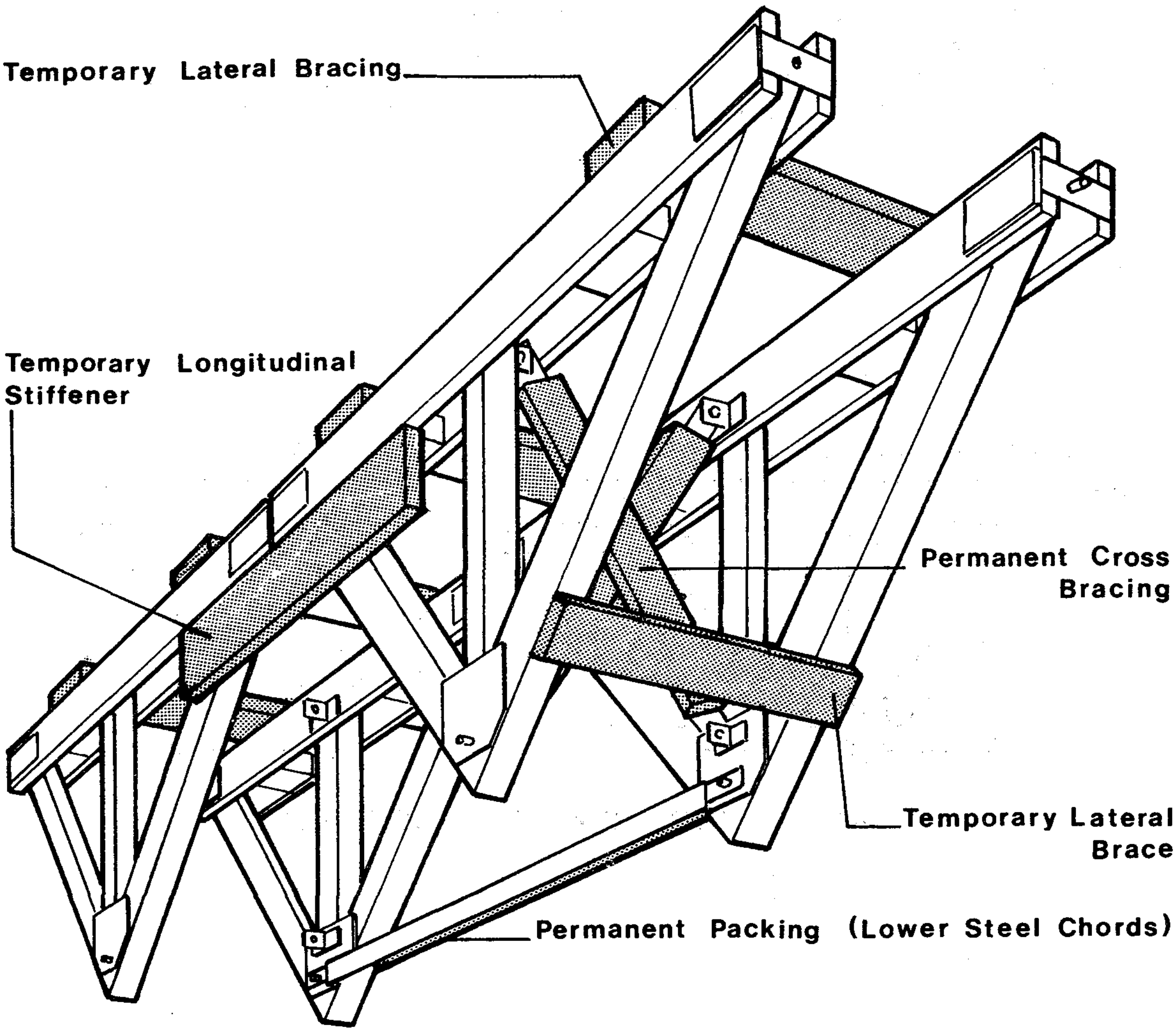
The standing cable is shackled to the sling leading from the deadman on the far bank. It is passed through the pulley of the cable block on the far bank crown assembly, through one pulley of a double pulley block on the near derrick, and finally attached to a 'Tirfor'or 'Pullman' winch which is in turn shackled to the near deadman.

Since the girder which is about to be launched must be assembled in a true fashion beneath the home tower, it is often necessary to construct a level wooden platform on the ground here. Timber later to be used for the decking of the bridge may be borrowed for this purpose, provided reasonable care is taken of it.

As launching commences, two other winches are required. Their positions and arrangement are shown in SK.12. Winch No.2 is anchored directly to the deadman on the far bank, and is used gradually to draw the girder across the span as launching proceeds. Winch No.3 is used in conjunction with a hold-back rope anchored to a strong point well behind the launching area. The purpose of these two attachments is to control, and when necessary to lift, the tail of the girder assembly.

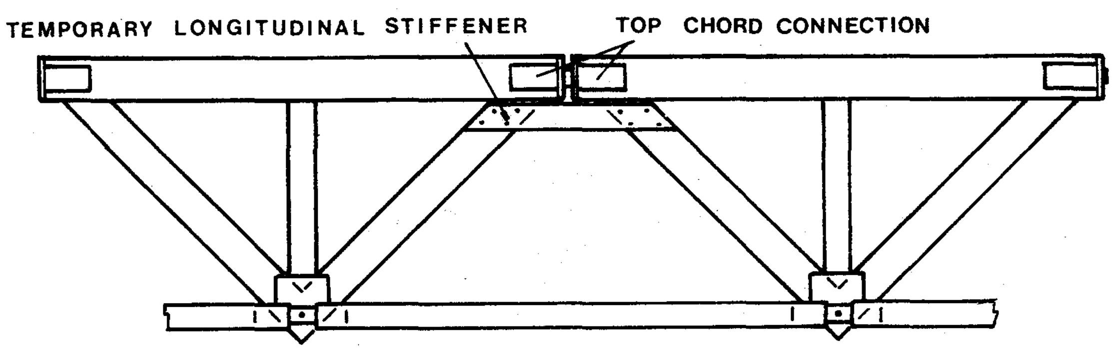
Initial assembly of girder

Before commencing to cross the gap, a short girder consisting of two pairs of panels is assembled beneath the tower on the home bank, as shown in sketches SK.11 and SK.12. A girder partly put together in this way is shown in sketch SK.13.



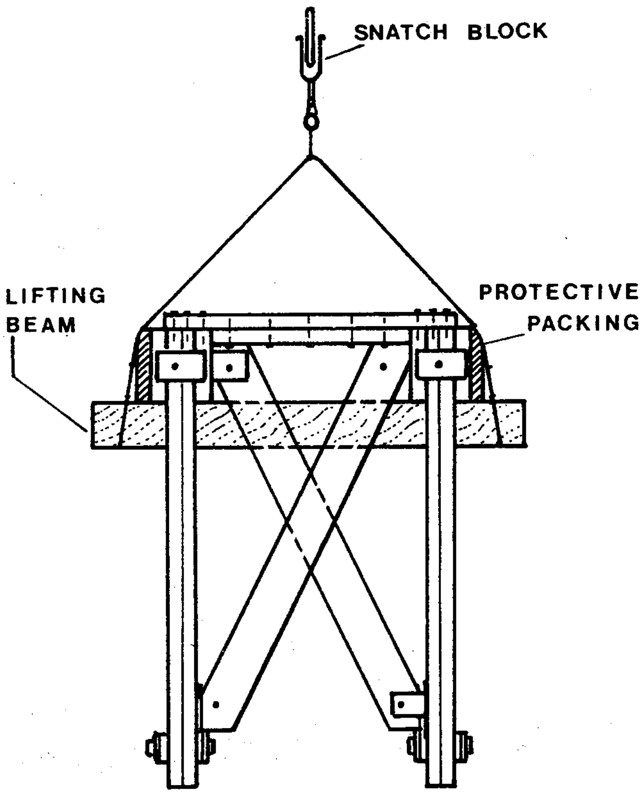
SK. 13 GIRDER BRACED FOR LAUNCHING

The trusses are assembled as indicated, with the top chord spigot and socket joints pinned with 6 mm split pins and the bottom steel chords, similarly attached. The 125 x 150 mm permanent packing pieces are fitted between the lower chords; slight cutting and shaping of these may be required. They are nailed between the chords using holes provided in the steel. The permanent cross bracing is bolted between the pairs of trusses, checking at this stage that the pairs have the correct lateral spacing of 900 mm between centres. Additional temporary stiffeners and bracing are required to ensure that the girder is reasonably rigid during launching and to prevent the pinned joints from parting. Temporary lateral bracing is nailed across the top chords, two pieces of about 50 x 100 mm section for each pair of panels, and extra pieces on the timber diagonals may be found useful, particularly for the first few modules in each girder. Temporary longitudinal stiffeners are nailed beneath the spigots of the top chord, in the position shown in SK.14. These are of approximately 50 x 125 mm section. If desired, these may be cut and fitted neatly, and left in place when the bridge is complete.

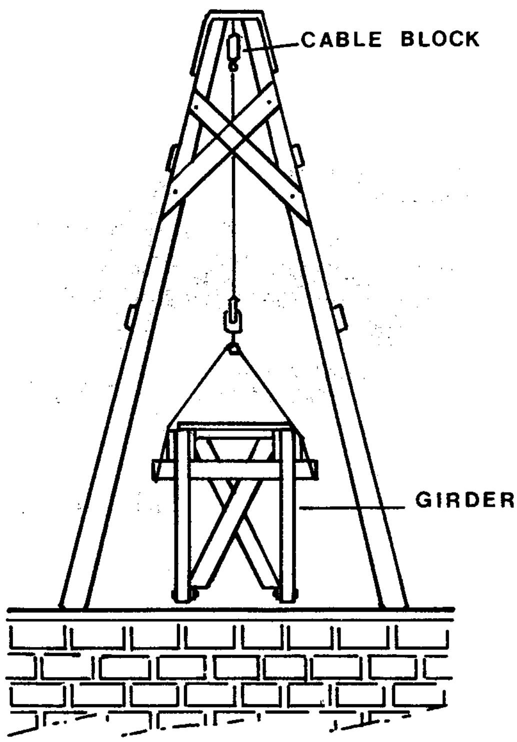


SK. 14 TEMPORARY STIFFENER

A harness is fitted as shown in sketch SK.15. Packing should be nailed in the position where the slings of the harness touch the top chords, to prevent cutting by the wire rope. A strong lifting beam is required; in one project it was found convenient to use offcuts from the tower poles for this purpose. Sketch SK.16 shows the two-module long girder ready to launch, viewed from the opposite bank.



SK. 15 HARNESS



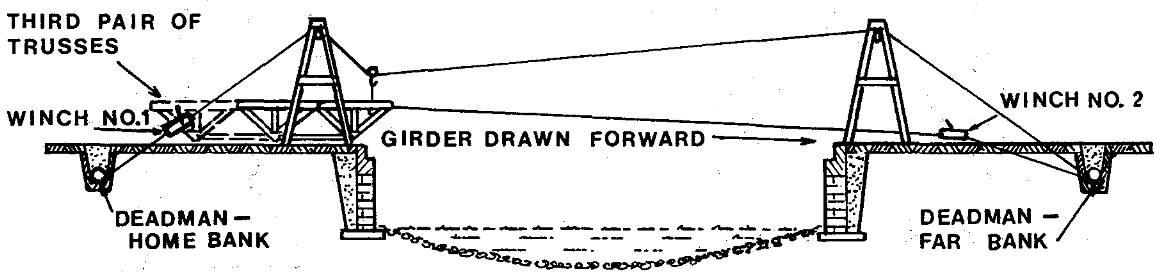
SK. 16 GIRDER READY FOR LAUNCHING

LAUNCHING PROCEDURE

Following all the preparations described above, the actual launch should proceed quite straightforwardly as follows:

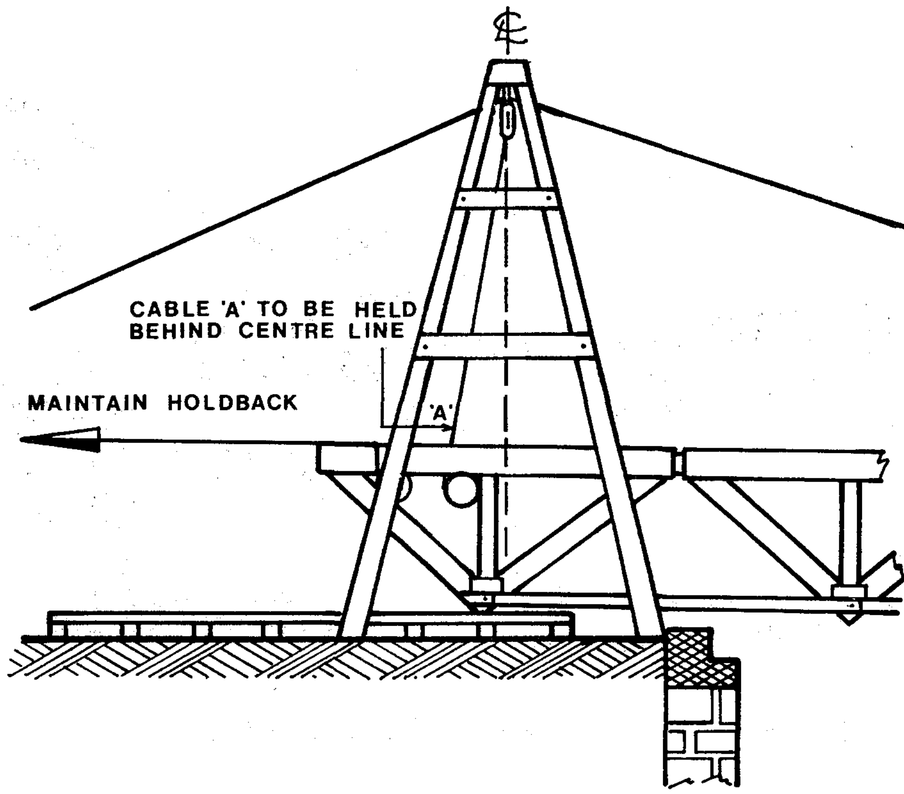
Affix winch no.2 to the deadman on the far bank and fasten its cable around the beam of the lifting harness. The bridge should now appear as in sketch SK.17 below. The idea of the launching method is that as further pairs of modular panels are added to the back of the girder, such as the pair shown in a dashed outline in SK.17, the girder is drawn across the gap so that its nose is suspended from the standing cable.

The nose of the girder is lifted mainly by pulling with winch no.1, which tightens up the standing cable, hence raising the lifting harness. It should be borne in mind however that an important part of the skill of a successful launch is in balancing the tensions of the various cables in such a way that the maximum possible sag is retained at all times, since as explained earlier, this minimises the strain on the cables. In addition, although winch no.3 can be used to ease the friction on the platform and help the girder assembly to slide forward, it is vital that winch no.3 should not lift the tail of the bridge clear of the platform until the nose is well past the mid-span of the standing cable.



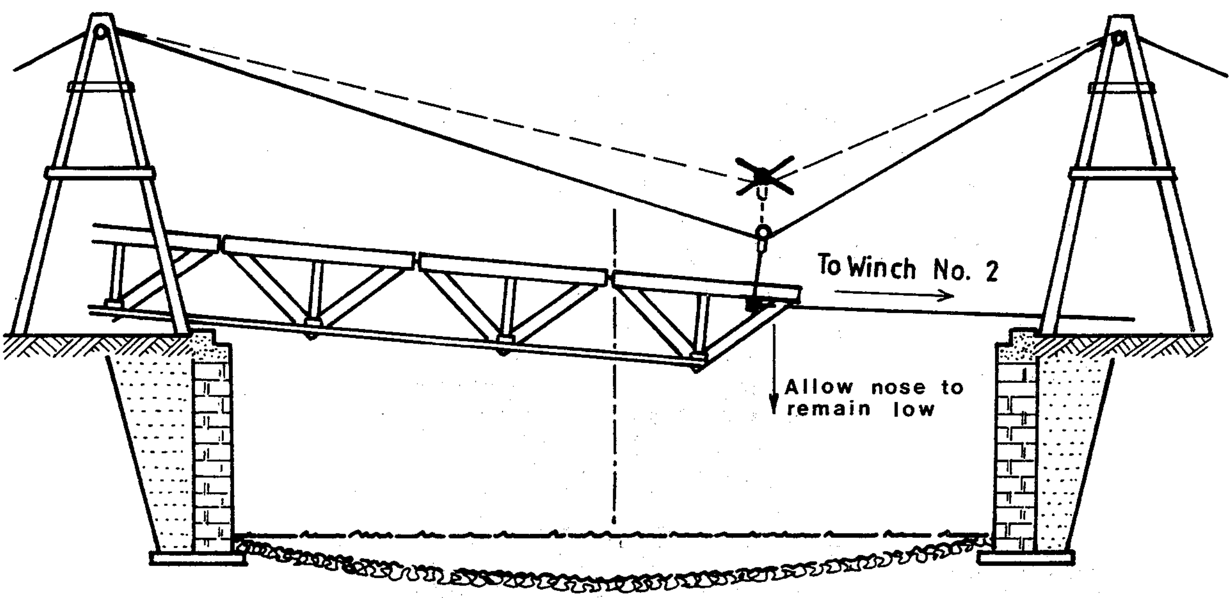
SK.17 STARTING TO LAUNCH

Sketch SK.18 illustrates how the cable from winch no.3 should be kept angled back as it comes over the crown of the derrick down onto the girder. Unless it is kept at this angle, it will tend to resist the effort gradually to ease the assembly across the span. Also, as shown in SK.18, the holdback should be maintained at all times until the mid-span is reached. This is because there is a considerable force tending to pull the bridge forward as the snatch block tries to roll 'downhill' on the standing cable. Once the block has passed the middle, it is climbing 'uphill' on the standing cable as the girder is drawn further forward, and the danger stage for a sudden uncontrolled rush forward is over.



SK. 18 ARRANGEMENT OF CABLES TO PREVENT FORWARD SURGE OF GIRDER

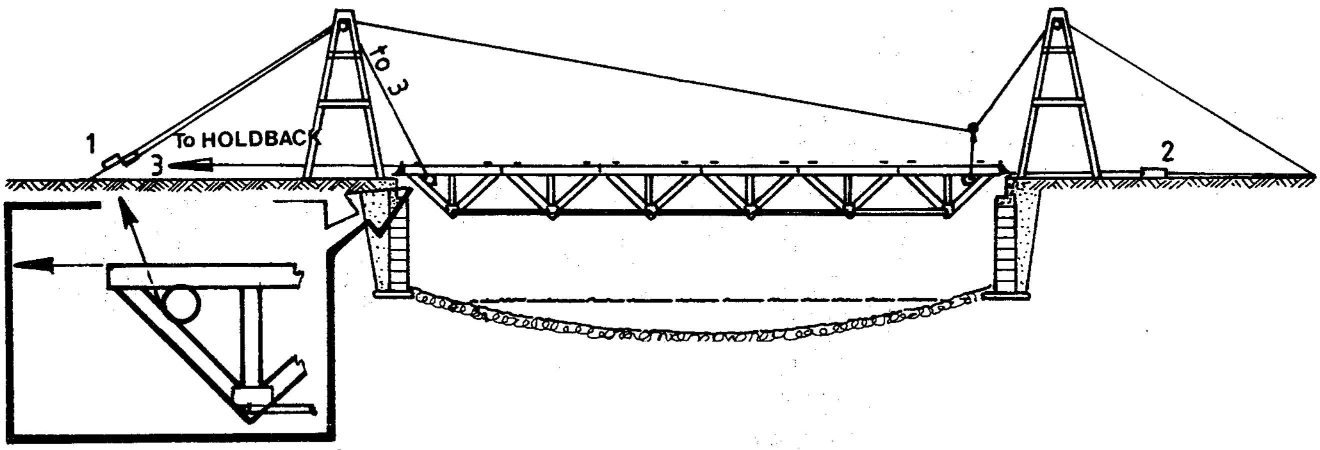
The launch continues by adding further pairs of modular panels and steel chords at the back of the girder, ensuring that the whole assembly remains reasonably well aligned as it goes forward (there is an opportunity to perfect the alignment afterwards). The permanent diagonal bracing and the temporary lateral bracing and longitudinal stiffening is added all the while. Sketch SK.19 shows the girder past the half-way point on the overhead cable. At this stage it is safer to allow the nose to dip quite considerably, as shown in the sketch. There is a considerable weight suspended from the standing cable, and the wire should not be kept too taught by excessive hauling on winch no. 1.



SK.19 LAUNCHING, PAST HALFWAY

Landing the girder

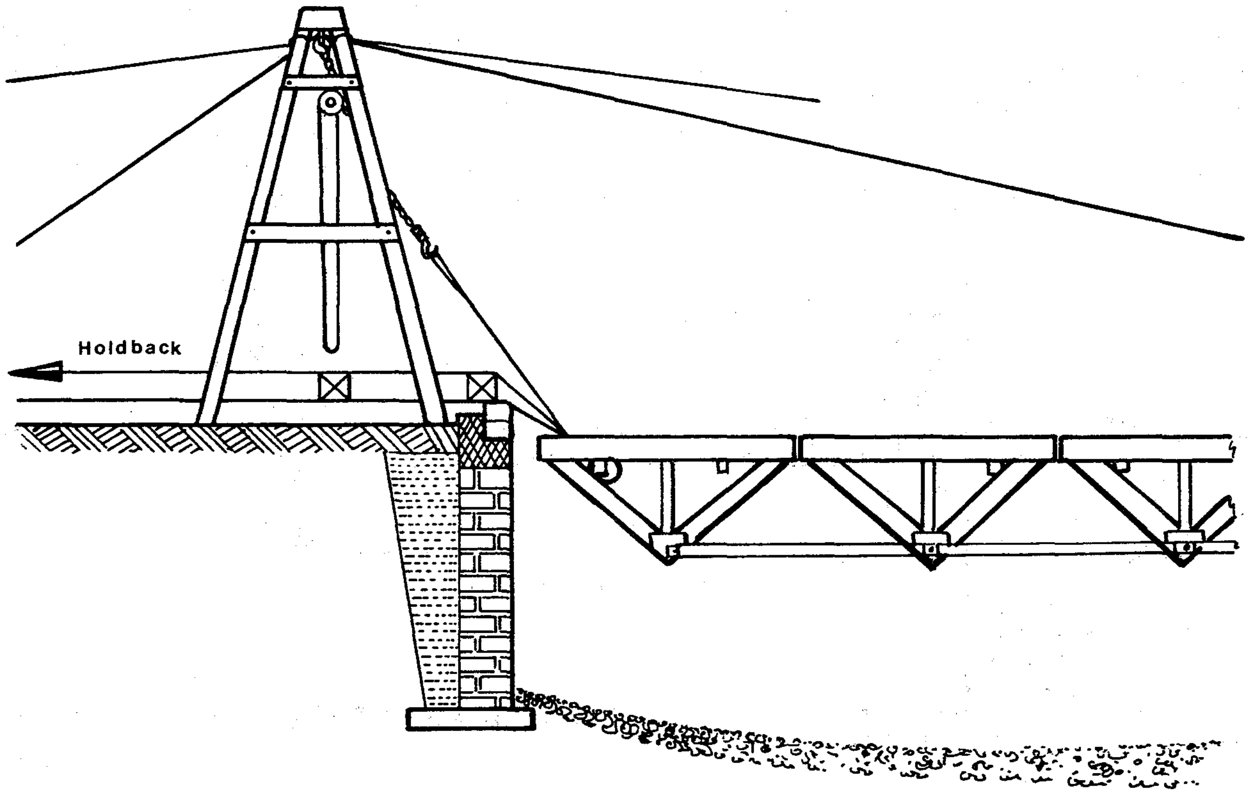
As the last pair of panels are added to the rear of the assembly, the cable from winch no.3 should be attached to a lifting beam passing through the top rear corner of this last pair, rather than having the beam near the centre post of the panel, which is the case in the earlier stages. This new position is shown in sketch SK.20, where the girder is nearly ready for landing on the pier caps. Some renewed use of the holdback rope may be necessary at this stage, because the procedure to get the tail off the bank platform and down into the gap is as follows: As winch no.3 is slackened off, its cable attaching it to the lifting beam is allowed to swing forward of vertical, since the girder is being pulled from winch no.2 on the far bank. At the same time, the descent of the assembly, which is eased with timber levers and packings as required, is controlled by use of the holdback rope. In this way, the tail of the girder can be carefully slid off the platform and allowed gradually to drop into the gap. Once again, overstraining of the overhead cable by excessive tightening of winch no.1 should be avoided.



New position of rear Lifting Beam when launch is nearing completion

SK.20 PREPARATION FOR LANDING

A slight variation of the above, which has been found to give good control of the latter stages of the launch, provided suitable equipment is available, is to use a chain block instead of winch no.3. This is shown on sketch SK.21 on page 20. The chain can be hooked to a cable linked to the rear lifting beam, and a similar procedure to the above followed.

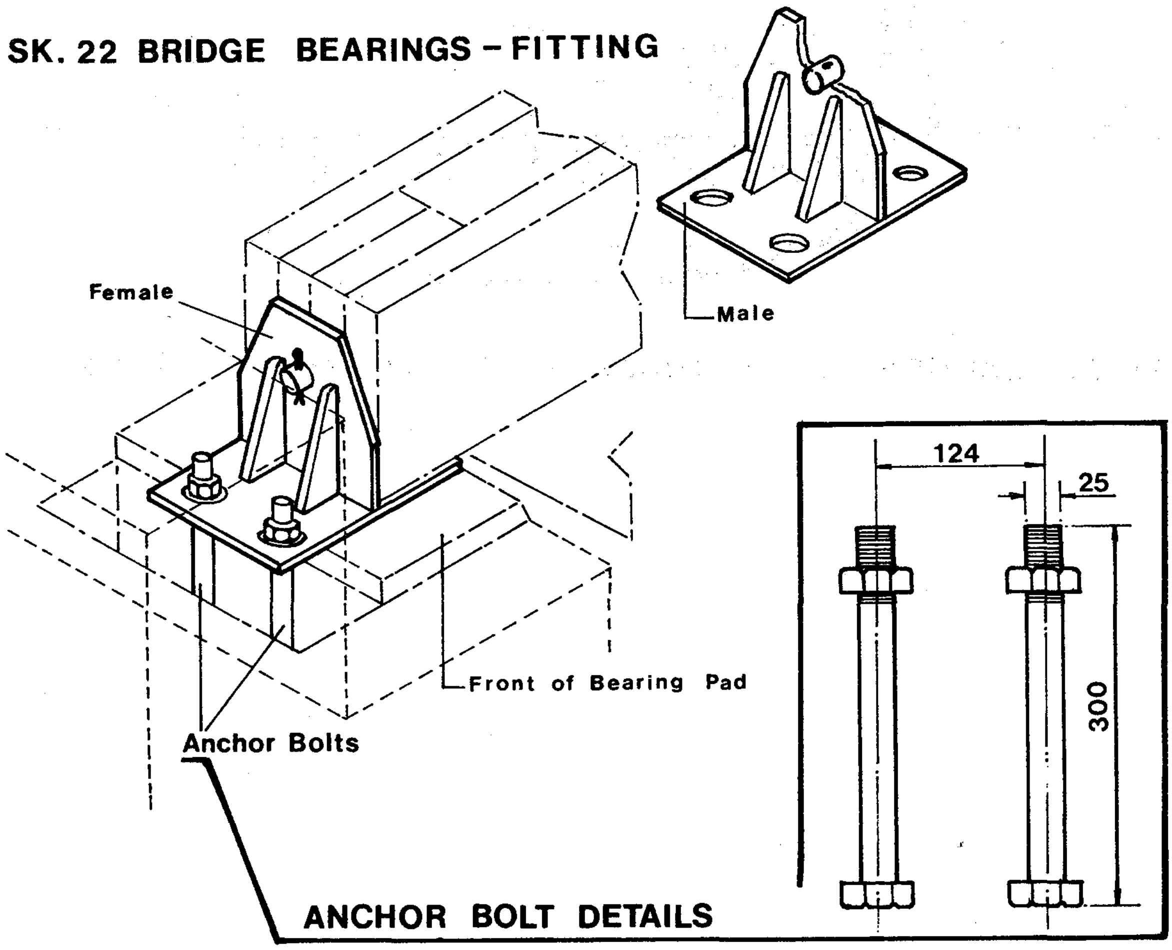


SK. 21 USING CHAINBLOCK TO LOWER TAIL OF GIRDER ONTO CAPS

Attachment of bearings

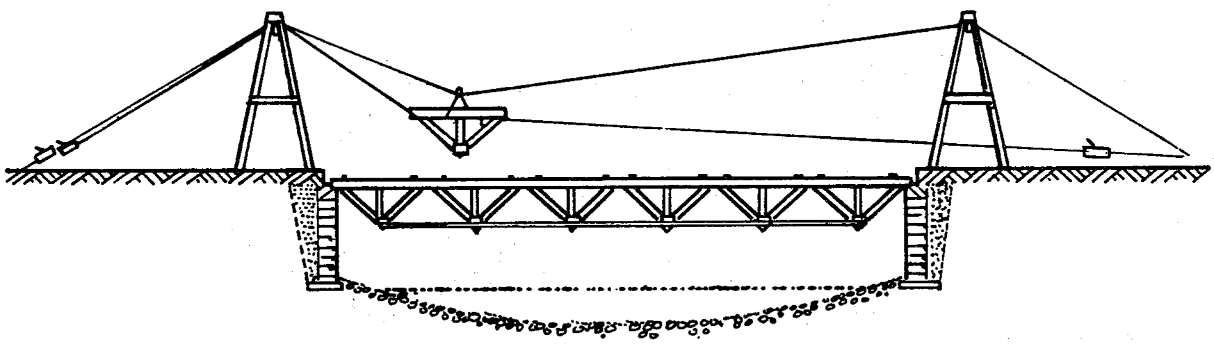
Whilst the girder is still suspended a few centimetres above the bearing pads, as shown in SK.20, it is a convenient time to fit the bearings. Sketch SK.22 on page 21 shows this stage. After attaching the bearings by sliding them onto the spigot or into the socket of the last panel in each truss, they may be pinned in place, using the split pins indicated in the design. The 25 mm diameter x 300 mm long anchor bolts may also be placed in the holes provided in the bearings. The front part of the bearing pads should already have been cast, as shown in SK.22, but the anchor bolt pockets must be left open at this stage. The girder should be lowered gently onto the pads, adjusting the bearing plates and bolts as this proceeds. If necessary the girder can be levered sideways at either end, using crowbars, before all its weight is allowed to rest on the pads. In this way it is possible to correctly locate the ends laterally, and to finish up with the girder landed and the anchor bolts dangling in the pockets. Note that these pockets are still left open, even after the individual girders are landed. This is because construction of the deck and superstructure adds weight to the bridge which takes out part of the pre-camber, so longitudinal movement must be allowed until most of the dead weight is added.

SK. 22 BRIDGE BEARINGS - FITTING



Launching of additional trusses

When bridges consisting of more than four trusses are to be built, two girders are first launched by the standard wet crossing method as described previously. Once the four trusses of these first two girders are correctly aligned, their anchor bolts can be temporarily wedged with wood pieces into the pockets and lateral and longitudinal boards temporarily fixed to the tops of the girders to provide a rigid, stable working platform. The remaining trusses are assembled in-situ, swaying the individual panels out onto the platform from the overhead cable, as shown in SK.23.

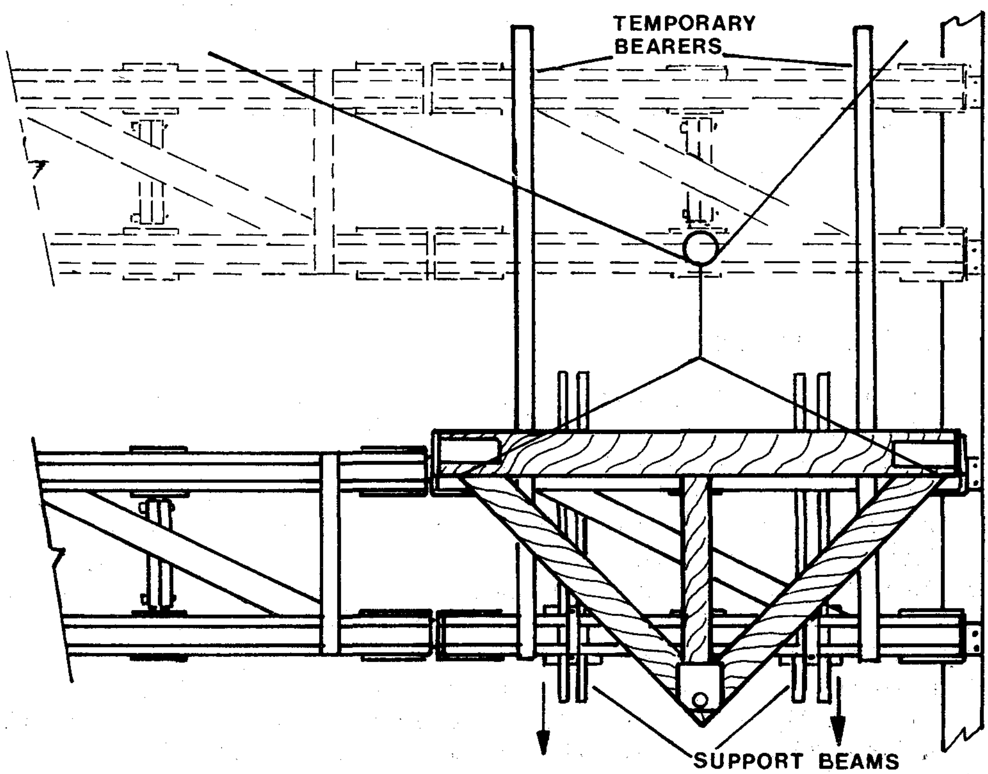


SK. 23 LAUNCHING OF TRUSSES IN EXCESS OF FOUR

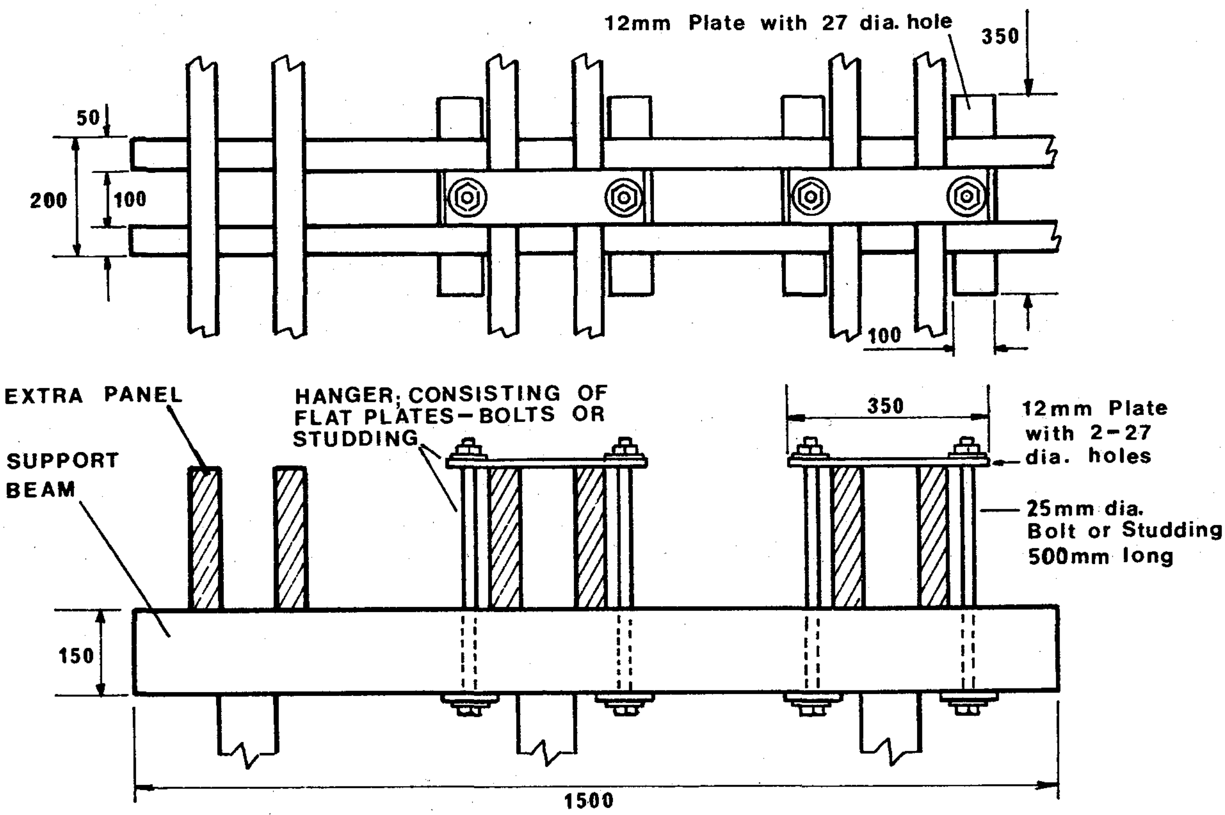
To support the panels which are to be assembled in this way, temporary lateral bearers are nailed to the tops of the girders, and strong support beams are bolted to the undersides of the top chords. This general arrangement is shown in sketch SK.24, whilst sketch SK.25 gives details of the fixings for the temporary cross beams. The temporary support beams need to project about 400 mm beyond the side faces of the existing top chords in order to support the additional trusses.

The panels are hung on the support beams alongside the existing girders, using small pieces of packing if necessary, to adjust to the correct height. The lower chords can be connected, working from platforms of temporary boarding placed across the lower chords already present.

It is important to note that each additional truss is highly unstable laterally until the deck and permanent bracing is fixed, so temporary supports must be retained at all times until this stage is reached. Also, no attempt must be made to 'launch' an individual truss in a manner similar to that described for the girders, even if it is thought to be well stiffened with temporary pieces. This method was attempted, and caused an accident.



SK.24 SLIDING IN EXTRA PANEL



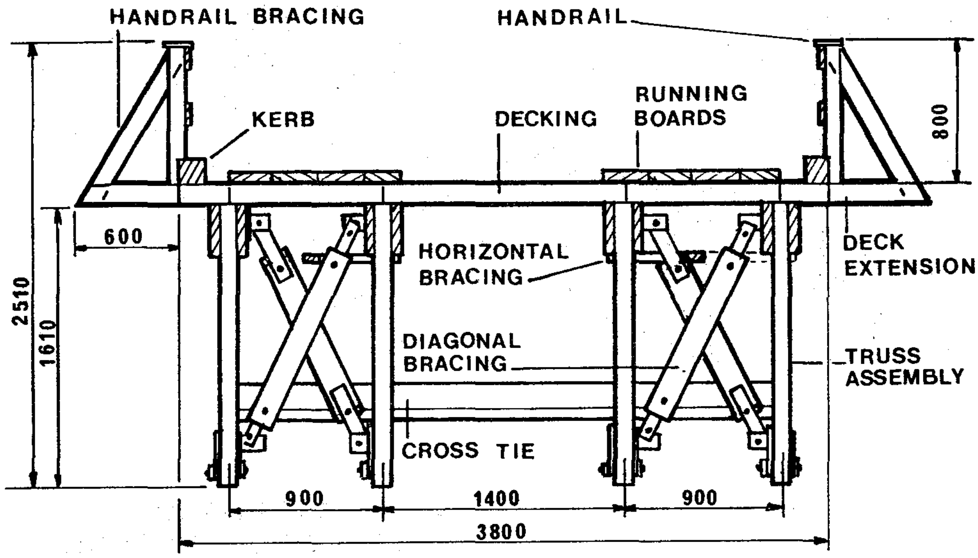
SK.25 TEMPORARY PANEL SUPPORT

Final alignment of girders

Once all the girders are launched and landed, with their bearing plates located but not yet grouted in, a final check should be made on all the lateral dimensions and the longitudinal alignment of the girders. Some lateral deflection or snaking of the trusses may have occurred, particularly if it has not been possible to use thicknessed timber for the modules. This must be taken out as far as possible, by hauling from fixing points beside the span. Winches attached to trees, rocks or ground anchors should be fixed by cable to the girders with a line of pull as nearly perpendicular as possible to the span. The worst girder should be straightened first in this manner, and then temporarily fixed by nailing extra temporary pieces, others can then be adjusted as necessary. It may also be useful to improvise a windlass to pull two girders together. This can be done by putting a loop of rope around the girders and tightening the rope by twisting with a stout timber.

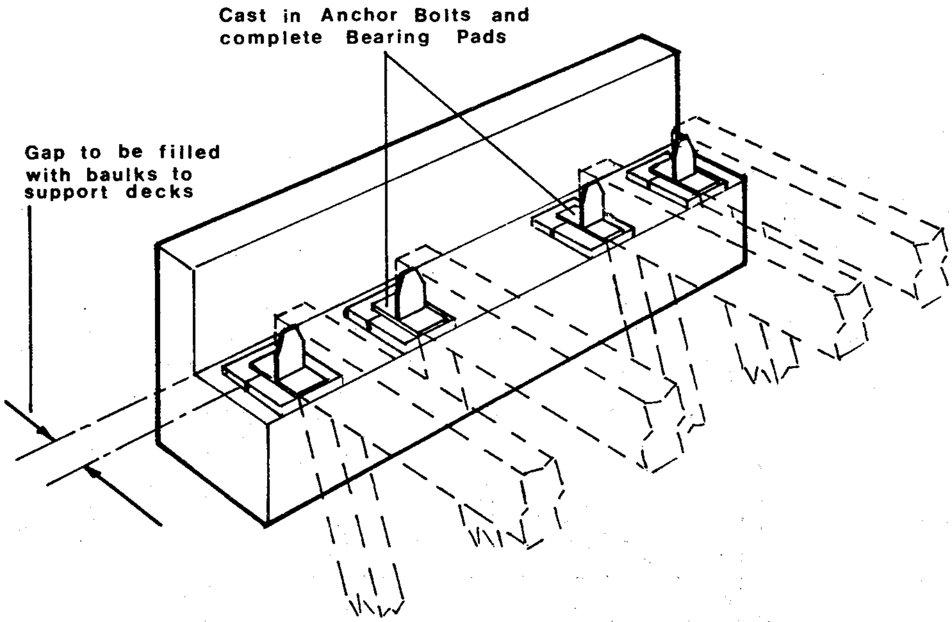
CONSTRUCTION OF SUPERSTRUCTURE

The vertically nailed laminated deck, permanent horizontal bracing and bracing cross-beams, running boards, kerb and handrail if required, are all built in-situ after the girders are placed. A section showing all these parts of the superstructure for a typical four truss bridge is shown in SK.26 and the following describes the sequence of construction.

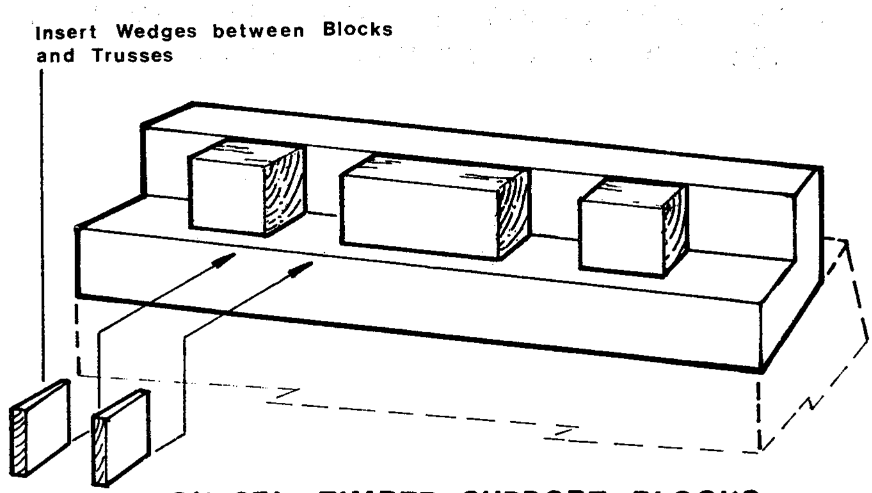


SK. 26 TYPICAL FOUR TRUSS BRIDGE-SECTIONAL VIEW -DETAILS OF SUPERSTRUCTURE-

At one end only, the anchor bolts of the bearings should be cast in, and the rear of the bearing pads completed. This step is shown in sketch SK.27a. There is a short gap between the back of the upright of each bearing plate and the face of the pier cap upstand, at which position there is nothing to support the deck. As it is desirable for the deck to be removable in this area so that maintenance is possible, it has been found practicable to fill this gap with short blocks cut from timber baulks. The blocks are simply wedged in place between the trusses, as shown in sketch SK.27b. Normal decking timbers are then laid on the blocks, nailed together and into the blocks.



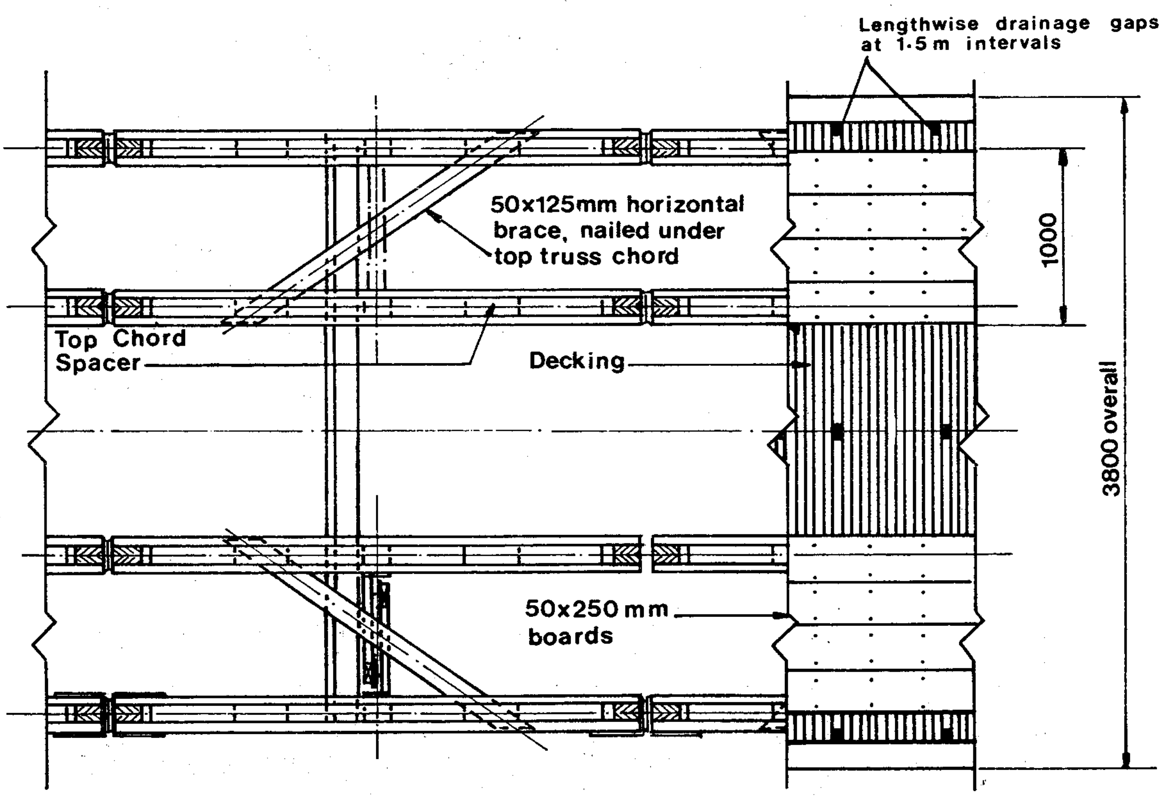
SK. 27 a COMPLETION OF ANCHORAGE - ONE END ONLY-BEFORE DECKING



SK. 27b TIMBER SUPPORT BLOCKS FOR DECK AT PIER CAPS

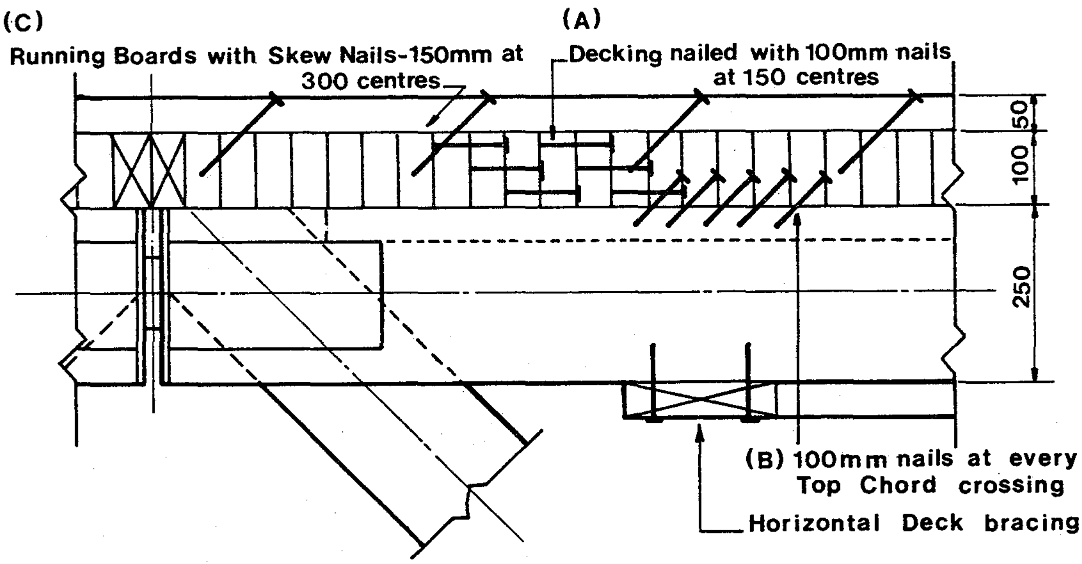
The temporary horizontal bracing is removed one bay at a time, and replaced by permanent horizontal deck bracing of 50 x 125 mm section which is nailed to the undersides of the top chords using eight 100 mm long x 3.5 mm diameter nails at each truss crossing point. It is generally possible to take advantage of the top chord spacing packs to receive some of these nails, as well as the chord members themselves. As soon as these steps have been carried out in the first bay, decking can proceed.

A sectional plan view of the deck is shown in sketch SK.28. The deck consists of 50 mm thickness timbers laid on edge and close spaced with nailed fixings to produce a vertically nailed laminated slab. The width of each timber deck piece becomes the depth of the deck when laid in this manner. The actual depth chosen depends upon the loading, and should be determined according to the sets of TABLES in Chapter 2 of Part 2. Occasional decking pieces at 1500 mm intervals along the span, are extended in length by 600 mm each side to provide supports for the handrail. Also, at 1.5 metre intervals along the span, the strip of decking is made up from several short lengths, instead of a single piece, leaving gaps for deck drainage between the individual ends.

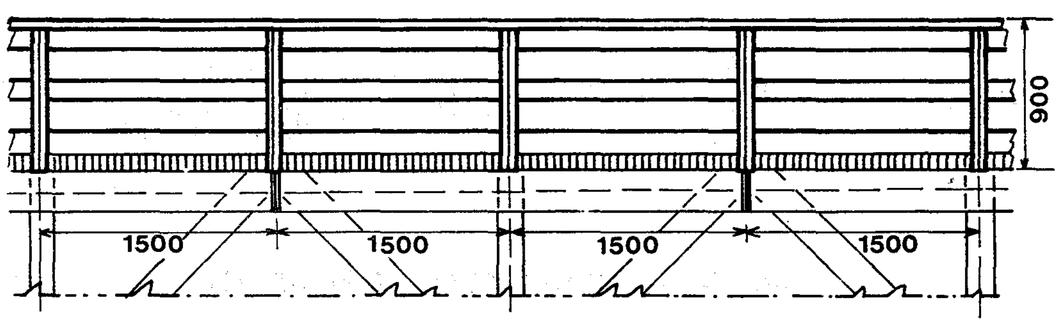


SK. 28 SECTIONAL PLAN VIEW OF DECK

Sketch SK.29 shows the nailing details of the deck. Decking work should be supervised by a responsible person, and carried out following the details with care, as this part of the construction serves a structural as well as a functional role. The decking pieces are side nailed to one another using 100 mm long x 3.5 mm diameter nails at 150 mm centres, as shown at position (A) of SK.29. As each piece is laid, the current row of nails is driven at a slightly higher position on the side face of the piece than the previous row, until the fourth time, when the pattern reverts to the first position. Also the 150 mm centre-to-centre spacing should be alternated. Each deck piece should also be skew nailed to each individual top chord piece where they cross, using the same size of nail, as shown at position (B) of SK.29. The running boards are shown skew nailed to the deck with 150 mm long x 4 mm diameter nails in the engineering drawings and at position (C) of SK.29. If preferred, these may be fixed to the deck with lag screws, the faces of the boards being countersunk to receive the heads. Although a more expensive method, this would save time and trouble when the running boards need replacement through traffic wear.

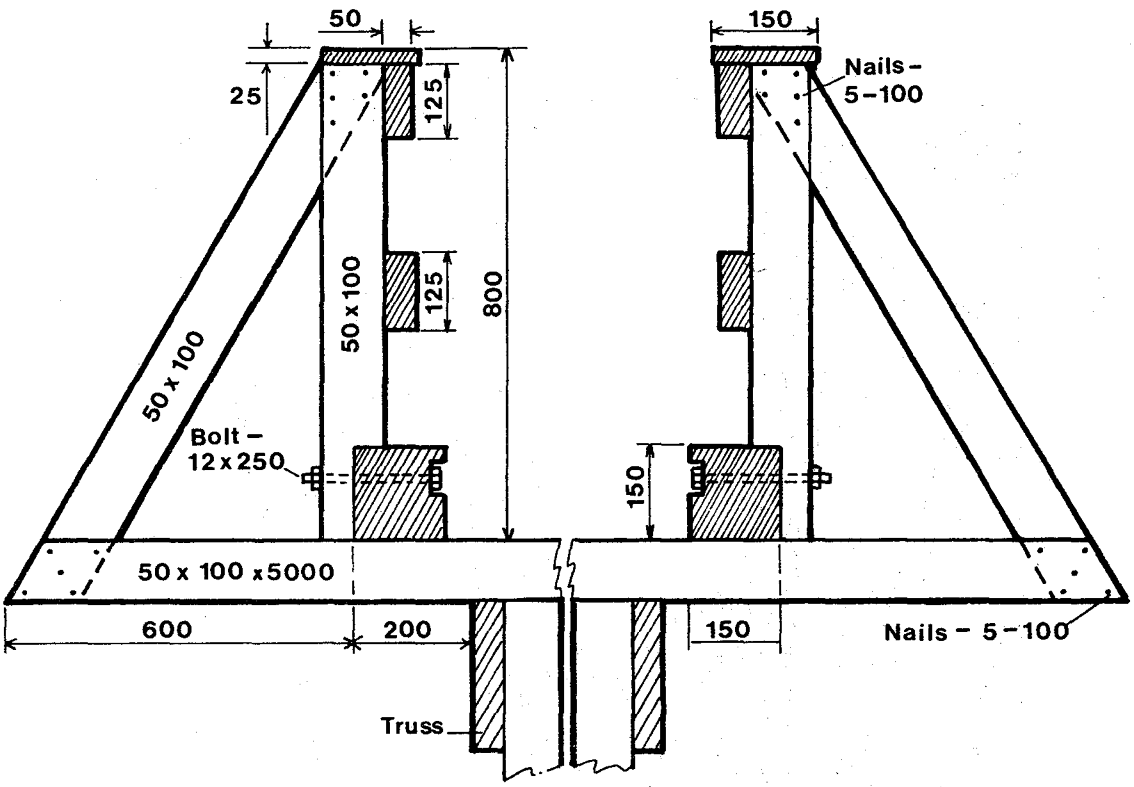


SK.29 DECK DETAILS

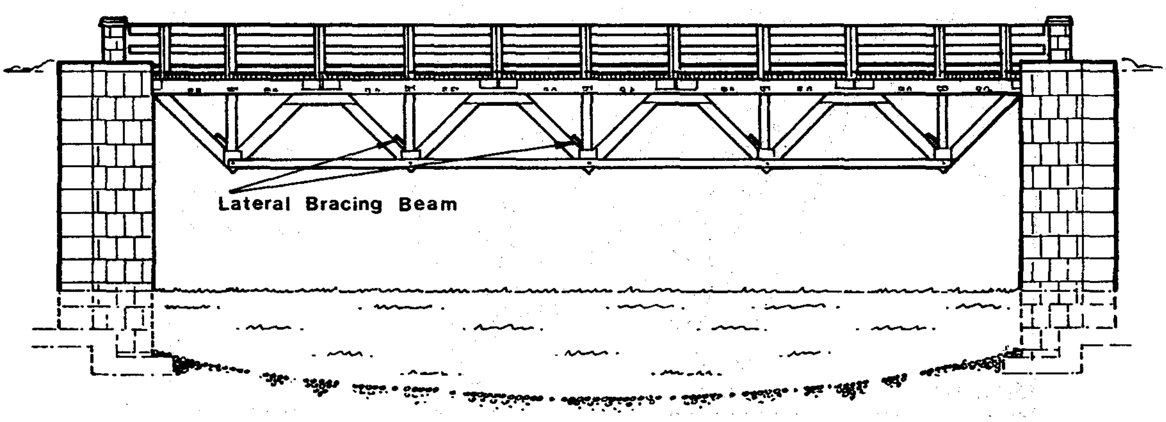


SK.30 HANDRAIL-SIDE ELEVATION

Construction of the kerb and handrails should be started before the last metre or so of deck is completed, in order to add as much of the dead weight as possible before final grouting of the anchors at the second end of the span. Sketches SK.30 and 31 give general details of this part of the superstructure. Reference should be made to the engineering drawings in part 5 for full information on all the fixings.

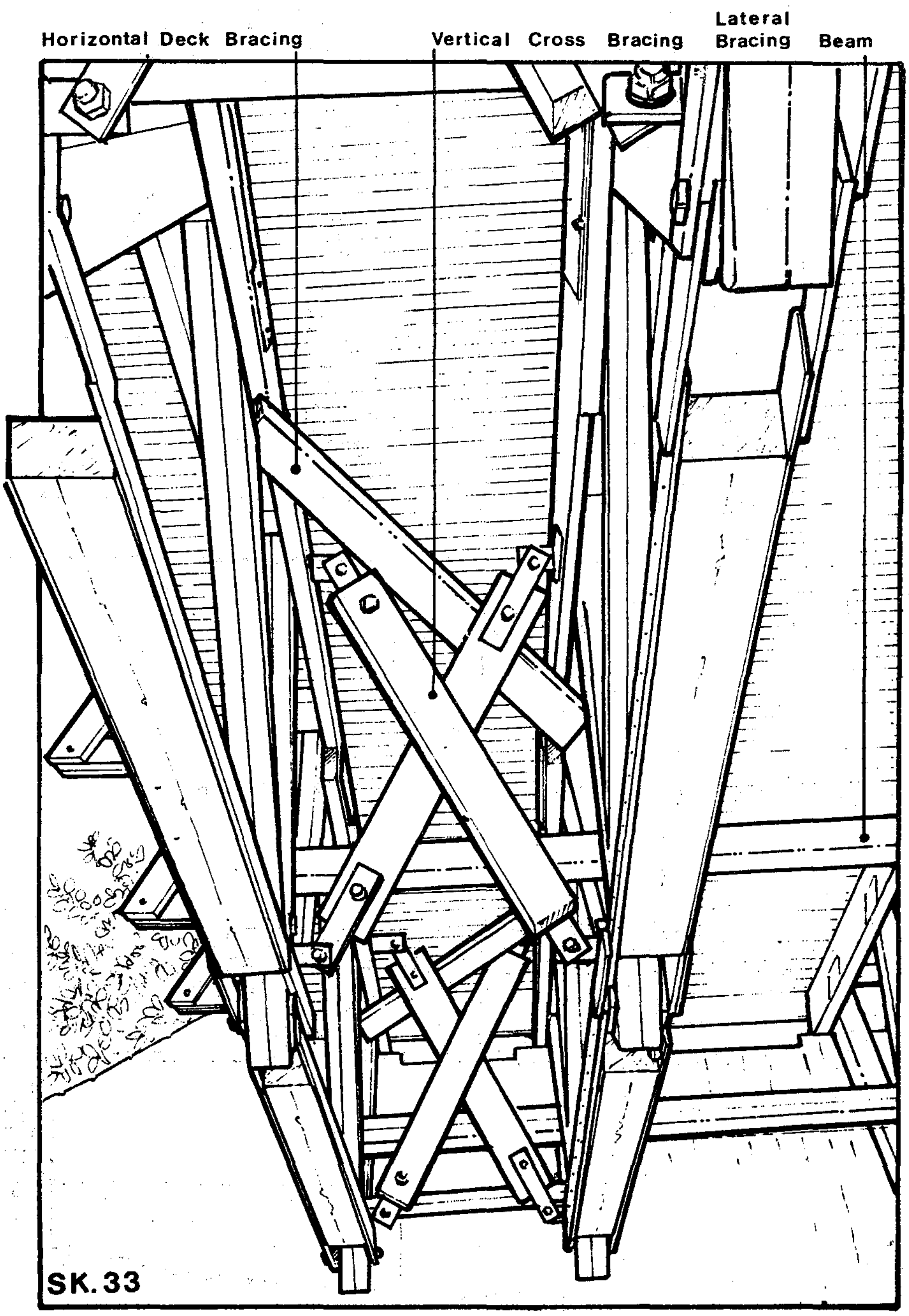


SK.31 HANDRAIL CONSTRUCTION



SK. 32 POSITION OF LOWER BRACING BEAMS

To complete the structure of the bridge, lower lateral bracing beams are fixed right across all the trusses, passing through each module at a point just above the lower steel panel plate, as shown in sketch SK. 32. There is one beam to each panel of the span, and they are fixed to the edges of the diagonals with six 100 mm long x 3.5 mm diameter nails at each crossing point. Sketch SK.33 shows a view from beneath the completed bridge, illustrating the girder construction and all three types of permanent bracing.

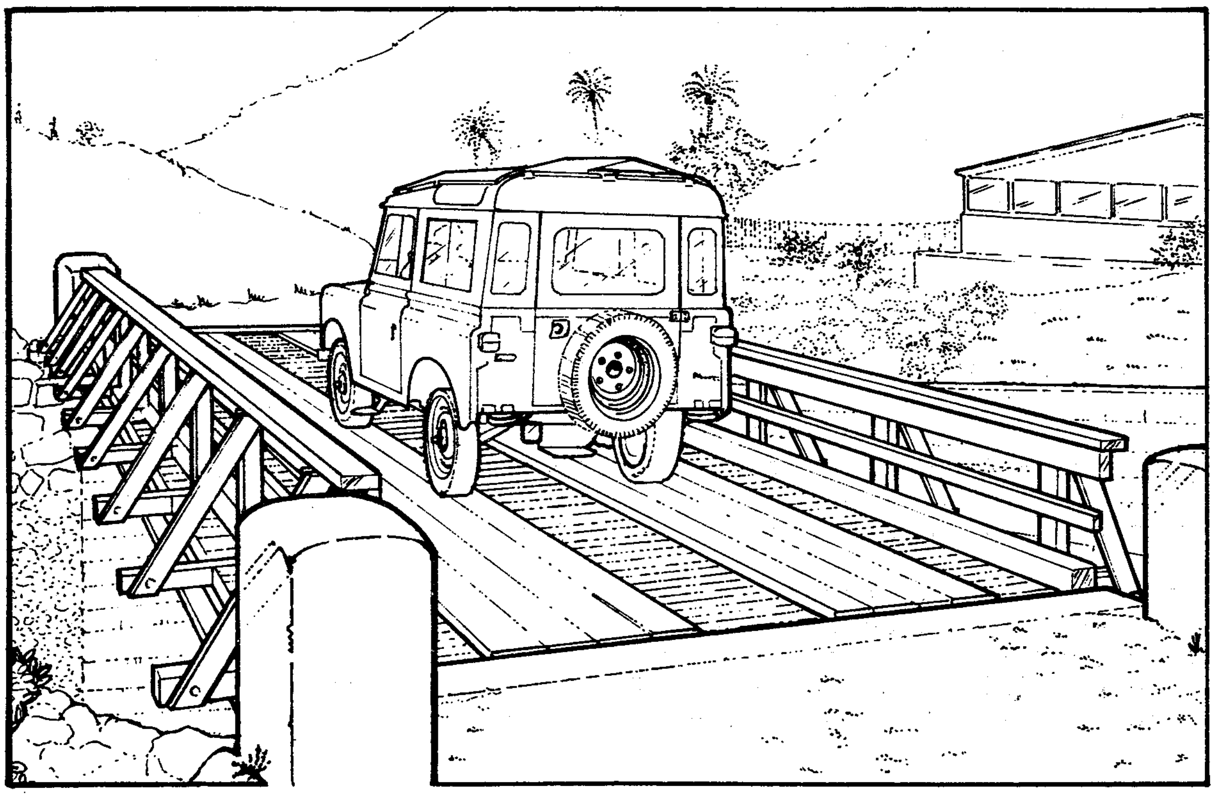


VIEW FROM BENEATH BRIDGE SHOWING GIRDER CONSTRUCTION AND BRACING METHODS

COMPLETION OF SITE

Once the structure is complete, the area approaching the spans, used for launching, is cleared of all temporary equipment. Retaining walls at the sides of the abutments should be completed, if not already finished, and provision made for lateral run-off of flood water to avoid silt being washed down the road onto the bridge deck. Various designs for the approaches are of course possible, but it is always worth considering some form of protection to the superstructure, so that traffic will be led towards a correct line when driving onto the bridge. The bridge illustrated on the cover of the manuals has raised masonry approach 'wings' which tend to guide vehicles in the right direction. Another method which has been used is to construct concrete pillars at the ends of the handrails, as shown in sketch SK.34. These will obviously not prevent damage to the bridge by a large vehicle which is out of control, but they will tend to deter casual collisions against the superstructure.

Frequently bridges will be designed for highway loadings less than the maximum occurring in the country concerned, e.g. for rural feeder roads in a country where U.S. (AASHTO) highway loadings are followed, H 20 may apply to the bridge, whereas HS 20 may be usual on the trunk roads. In this case it is essential that large traffic signs be posted clearly at an appropriate distance for each direction of traffic, announcing the maximum permissible loading for the bridge.



SK. 34 COMPLETED BRIDGE WITH ROAD LEVELLED AND COMPLETED, SHOWING PILLARS TO PROTECT THE HANDRAILS

Soil poisoning

The bridges will often be built in areas where termite attack is a major potential threat to the longevity of the wooden structure, even if treated timber is used, and soil poisoning should be considered as an effective way of helping to prevent this. Treatment of the soil with poisonous chemicals must be avoided however if water from the river is used locally for drinking or for livestock. Consequently local custom and regulations with respect to termite control should be taken into account when considering such measures. The types of insecticide used for soil poisoning are known as persistent chlorinated hydrocarbons, and there may be local legal restictions upon their use, which should be determined.

The chemicals dieldrin, aldrin and chlordane have been found to be the most reliable measures against subterranean termites, and by their use at a bridge site, where the soil is not kept as dry as that beneath the floor of a house, it should be possible to obtain protection for about three years. The exact period of efficacy will obviously depend upon general weather conditions, flooding etc. but repeat dosages should be part of the planned maintenance of the bridge site.

Recommended dosages, based on information given in Building Research Establishment (UK) Overseas Building Note No. 170 are given in TABLE 2 below.

TABLE 2

Dilution rates, using water, for insecticides for treatment against subterranean termites

Chemical	Concentration
'Dieldrin 20' 'Aldrin 20'	1 litre diluted in 40 litres to give 0.5 % emulsion
'Dieldrin 18' 'Aldrin 18'	1 litre diluted in 36 litres to give 0.5 % emulsion
'Chlordane 20'	1 litre diluted in 20 litres to give 1.0 % emulsion

It is advisable to carry out soil poisoning when the soil is fairly dry and when rain is not pending, otherwise there is a risk of the chemical being washed away before being absorbed into the soil.

All insecticides and preservatives are toxic and should be handled with care. Some are extremely toxic if swallowed or allowed to remain in contact with the skin for too long. Overalls, rubber gloves, eye shields and even possibly face masks should be worn whilst applying them. The manufacturer's safety and first-aid instructions should be obtained and read.

The area to be treated at each end of a span is approximately 5 metres x 5 metres. This area should be excavated to a depth of about 30 centimetres, heaped up, mixed with 100 litres diluted to the concentrations given above, and replaced for re-compaction.

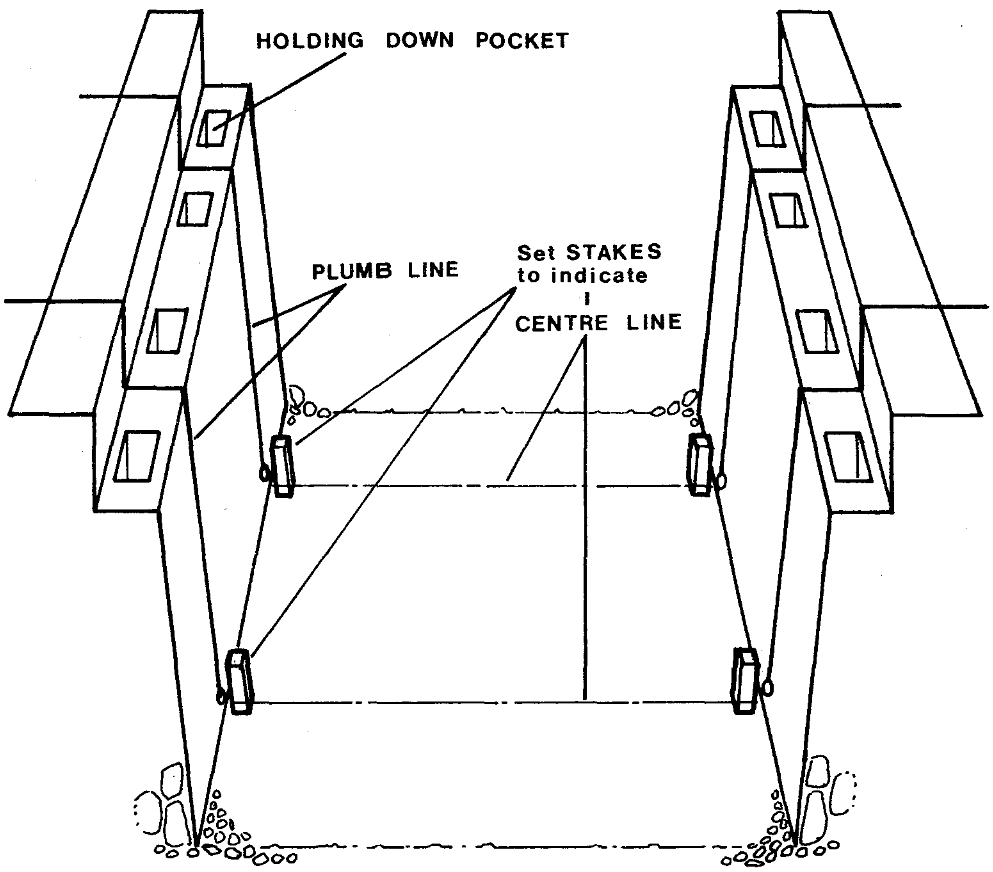
DRY LAUNCHING METHOD

For spans of a maximum of 15 metres, where the stream is shallow, and access can be gained to the river bed, an alternative launching procedure known as the 'dry launching method' has been adopted. This may be particularly useful for minor roads in difficult terrain, where approaches may not be sufficiently long or level for the preferred twin-tower 'wet launch' method.

The method entails the use of a tall tower, or four-legged derrick, which is erected on the stream bed, and which is used as a form of crane, to provide a straight lift to an almost-complete girder. The entire girder, minus one module of span, is lifted onto the pier caps at one end of the span, propped in position using trestles, and completed by lowering the last module in place, securing the last set of lower steel chords in-situ. The following describes the dry launch procedure in detail.

Setting out the tower position

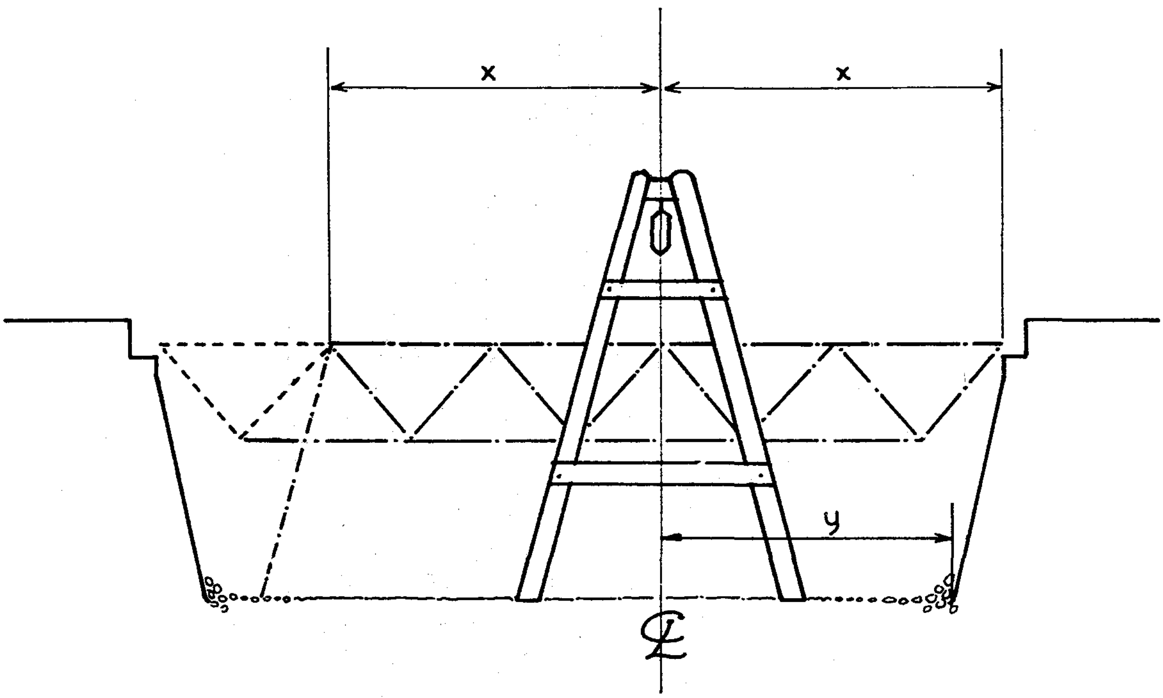
Before constructing the derrick, lateral and longitudinal centre lines must be established. It is advisable to take some care over this, as the convenience of the central-tower launching method very much depends upon having the point-of-lift accurately placed. Drop a plumb line down each abutment face between the centres of each pair of holding-down pockets, as shown in sketch SK.35, and use this to set stakes, or make marks on the abutment faces, to indicate the longitudinal centre line of each girder. Run a string line across the river bed to show this centre line for the first girder to be launched. Rubbish, driftwood etc. on the stream bed should of course be removed before this stage, and small or medium-sized boulders (up to about 60 cm diameter) can also be taken out if they get in the way of the setting out, but consideration should be given before removing large boulders and rocks, since this may disturb the course of the stream and lead to future erosion of the abutments.



SK. 35 ESTABLISHING LONGITUDINAL CENTRES

A lateral centre line for the tower must now be fixed, and this is determined by calculating half the length of the girder to be launched, distance 'x' in sketch SK.36, below. As previously mentioned, the girder is one module less than the full span in length, as shown in the sketch. A peg driven in where the lateral centre line of the derrick occurs will enable the points of the individual tower legs to be found. Some work with crowbars and shovels may be necessary to ensure a firm and level seat for the bottom of each pole of the derrick.

As with the wet launch method, the derrick should be guyed back to convenient trees, rocks or ground anchors, to prevent overturning in the case of inadvertent out-of-vertical forces during the launch. A working platform may be built under the tower to provide a level base for assembly of the girder. If the stream bed is uneven, this can be supported on wooden bearers bolted to the legs of the derrick, some 30 - 45 centimetres off the bed. The derrick should be assembled using hauling ropes and manpower, in a similar way to that described for the wet launch method.

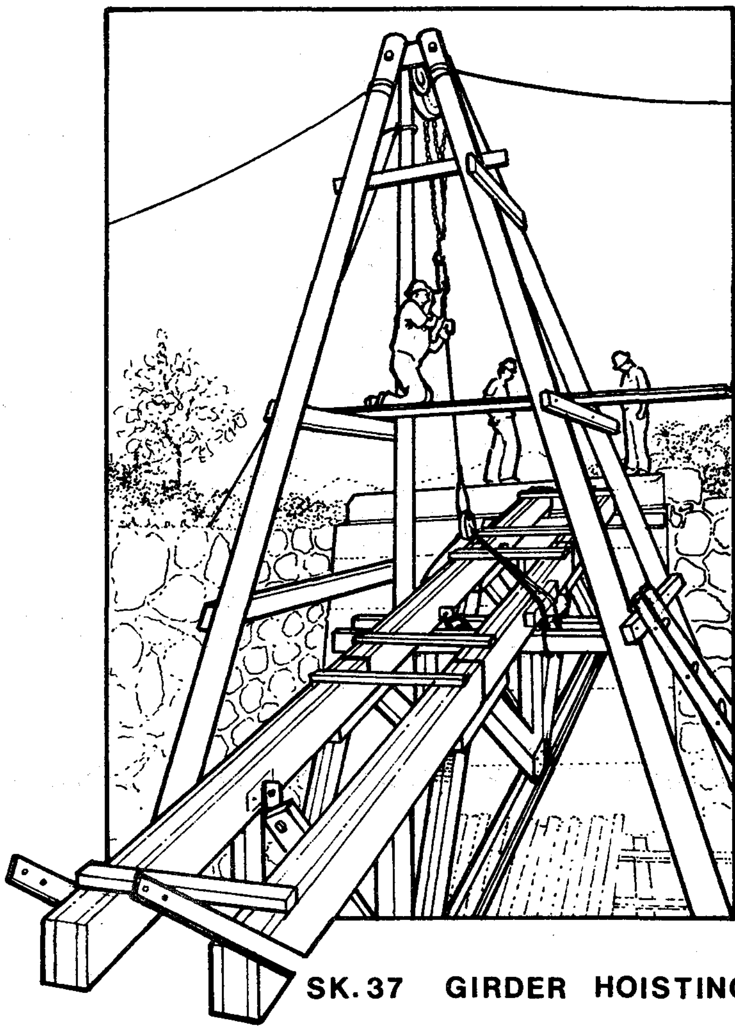


SK. 36 CONSTRUCTION POINT OF THE DERRICK

Assembling and lifting the girder

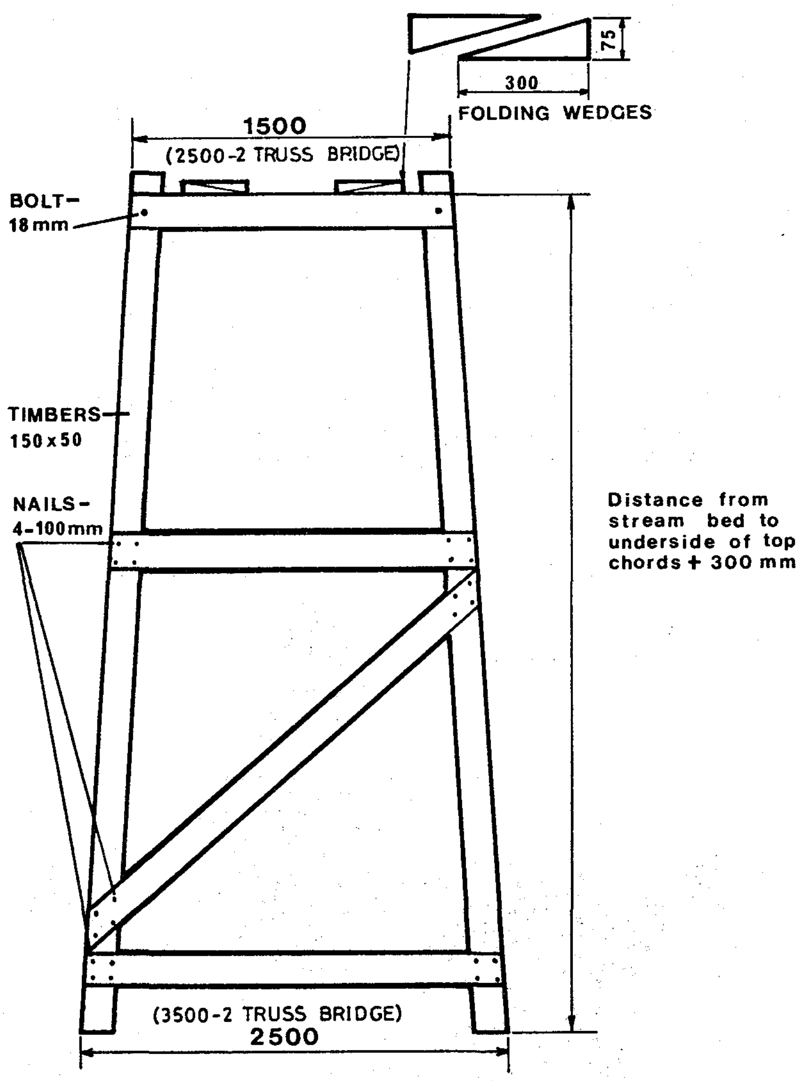
A chain block is hung from the crown of the derrick, for use in lifting the girder. The entire girder, of length one module less than the span, and including permanent vertical cross bracing and temporary lateral and longitudinal spacing and bracing pieces, is assembled on the platform under the tower. Where the design of the abutment includes a batter on the near-vertical faces of the walls facing onto the span, the length available in the spanwise direction (dimension 'y' in SK.36) will obviously be rather less than the length needed to lay out the girder. This difficulty may be overcome by asembling it in a slightly skewed line on plan, and swinging it into the true logitudinal line as it is lifted into place.

Sketch SK.37 shows a girder being hoisted using the central tower, dry launch method. Blocks are placed under the sling, to protect the top chord from cutting. The lower steel chords, belonging to the absent last module, are fitted to the penultimate module, and can be seen projecting in a temporary position at the front of the illustration.



SK.37 GIRDER HOISTING

Trestles are required to support the free end of the girder, after hoisting and before completion of the span. A design for these trestles, two of which should be made, is given in sketch SK.38 below. As indicated in the sketch, the height of the trestle should match the maximum distance from the stream bed to the underside of the top chords, plus 300 mm.

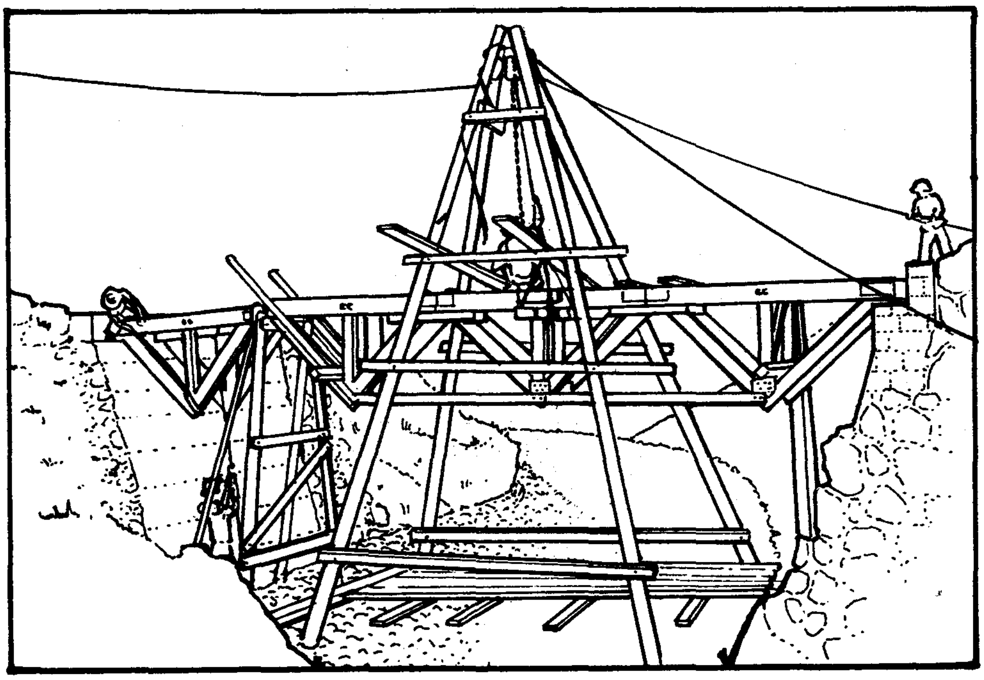


SK. 38 TRESTLE SUPPORT

Using the chain block hung from the central tower, the girder is lifted to the correct height. This may require several stages of lifting and re-adjusting of slings, dependent upon the amount of travel available in the arrangement. After lifting, and a slight rotation in plan, which as mentioned earlier, may be necessary to correctly line up on the longitudinal centre line, the girder is lowered onto the pier caps at the landward end, and onto a trestle at the free end. Folding wedges are inserted over the top beam of the trestle to adjust the girder to the correct height. This stage is illustrated in sketch SK.39. Also illustrated is the launching of the last truss; with the girder correctly positioned, propped, temporarily fixed and braced, the last pair of panels are lowered into position, after assembly (including cross bracing and temporary stiffeners) on the far bank. Modules in this form can be lowered into the gap using ropes and props with a team of about eight men. The spigot and socket joints are brought together on the top chords: the extra module must then be propped so that the bottom chords can be swung down into place in their correct positions and connected to the lateral pins.

When the span is complete, bearings are attached, as described for the wet launch procedure. Again, the anchor bolts are not at this stage cast into place in the pockets of the caps. The trestle and other temporary props, are removed once the entire girder is in place on the bearing pads.

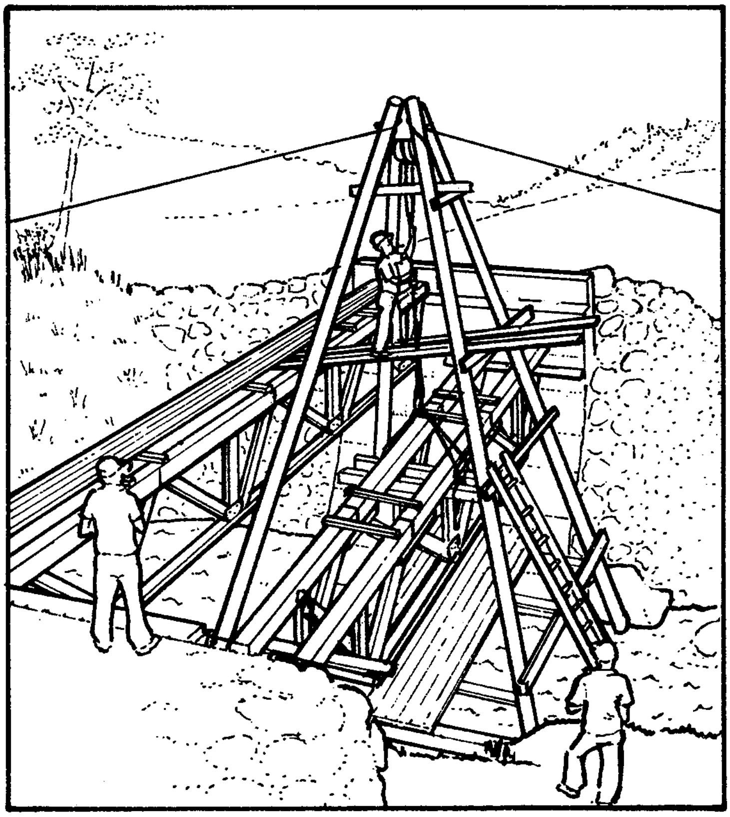
General instructions for procedures such as temporary wedging of anchor bolts in the open pockets, and correct alignment of trusses are as described previously for the wet launch method.



SK.39 LOCATING THE LAST MODULE

Lifting subsequent girders and completing the bridge

The derrick must be dismantled and moved to straddle the intended position of the second girder. Positioning of the tower is as previously described. In sketch SK.40, a second girder is about to be lifted, whilst to the left of the bridge, temporary longitudinal boards have been placed on the first girder to provide access and a working platform.



SK.40 LIFTING A SECOND GIRDER

It is possible to construct a six truss bridge of moderate span using the dry launch method. All that is necessary is to follow the procedure given so far, and to use the method described in the wet launch for provision of temporary lateral support beams for extra panels, which may be assembled in-situ.

Once all the girders are lifted into place, the derrick is finally dismantled, and construction of the superstructure, permanent bracing details and completion of site all follow the recommendations already given.

APPENDIX 1

RECOMMENDED ERECTION EQUIPMENT

The launching equipment listed below has been carefully selected to be of adequate capacity for all weights of timber and spans of bridge designated, provided the launching recommendations are carefully followed. Two capacties of winch are listed, and the heavier type is recommended throughout for panels with weights corresponding to strength group S4 and higher, particularly for spans of 15 metres or more. An alternative, given on Page 43, is to improve the mechanical advantages of winches using pulley block arrangements.

	Description	Quantity
1.	Handling equipment and ancilliaries	
	Winches (Tirfor type)	2 - 4 tonne and 2 - 6 tonne
OR	Winches (Tirfor type)	4 - 6 tonne
	Double sheave snatch blocks 3 tonne	2
	Bow shackles 2 tonne)	3
	Bow shackles 3 tonne) BS 3032 : 1968	6
	Bow shackles 5 tonne)	8
	Steel wire rope (hard eye one end) -12mm (1/2 in) dia and 60m long	2
	Steel wire rope (hard eye one end) -12mm (1/2 in) dia and 40m long	3
	Steel wire rope (hard eye one end) -12mm (1/2 in) dia and 1m long	2
	Soft eyed slings 5 tonne, 3m	2
	Soft eyed slings 5 tonne, 2m	2
	Chain block, 2 tonne, 8m	1
	Manila rope 100mm diameter, 100m long	1
	Tape 30m	1
	Timber poles 150mm top dia. and 9m long or 100mm dia steel tubes	12
	Steel plate (12mm) for derrick	1
	Sledge-hammer 3.5 kg (8 lb)	1
	Set of spanners (10-32mm)	1
	Set of sockets with ratchet handle -(10-32mm)	1
	Adjustable spanner (350mm handle)	1
	Auger bits (25mm)	3
	Auger bits (13mm)	3
	Auger bits (11mm)	3
	M.S. bar 18mm dia	1
	Oil can	1
	Petrol/diesel can - 5 litre	2

2. <u>Hand tools</u>

Hand tools	Quantity
Shovels long handle	2
Shovels short handle	2
Pick	2
Crowbars	2
Wheelbarrow	2

3. <u>Electrical equipment</u>

a) Electricity generator with trailer
   - diesel or petrol ; capacity 10 kw

Recommended makes are :

i) T.W. generators, supplied by T.W. Generators Ltd., Tring Road, Long Marston, Herts. HP23 4QL, UK.

ii) WEMS generators, supplied by Wems Manufacturing Ltd., Hadleigh Road, Ipswich, Suffolk IP2 6EB, UK.

b) Portable electric drill 32mm - heavy duty
   Voltage and fequency will depend on the country.

Recommended makes and models are :

i) Wolf model 3806, supplied by Kango Wolf Power Tools Ltd., Hangar Lane, London W5 1DS, UK.

ii) Black and Decker model HD 1125, supplied by Black and Decker Ltd., Cannon Lane, Maidenhead, Berks. SL6 3PD, UK.

4. <u>Chain saw</u>

Chain saw - size 350 mm

Recommended makes :

i) Oregon chainsaws, supplied by Omark UK Ltd., 6 Station Drive, Bredon, Tewkesbury, Gloucestershire GL20 7HQ, U.K.

ii) Stihl chainsaws, supplied by G.C.Stern and Son, Rodmersham Green, Sittingbourne, Kent, U.K.

Use of blocks to increase capacity of winches

It is always possible to use a snatch block (a single pulley fitted with side plates and an attachment ring) to increase the power of a manually operated pulling winch. Such measures should always be considered, rather than risking overstraining of the winches. The introduction of blocks increaese the length of wire cable that must be used, and it also increases the length that must be cranked through the winch to move the load any given distance. On the other hand it is a simple and effective way of increasing capacity and avoiding the breakdown of valuable winches needed for launching. Figure A 1.1 shows a possible situation in which a single snatch block has been used to increase the power of a 3 tonne winch used in the position described as Winch No. 1 in the manual. In this case the power is increased to approximately 5.7 tonnes. Figure A 1.2 is for general information, showing this and other arrangements for increasing winch pulling capacity by the use of blocks.

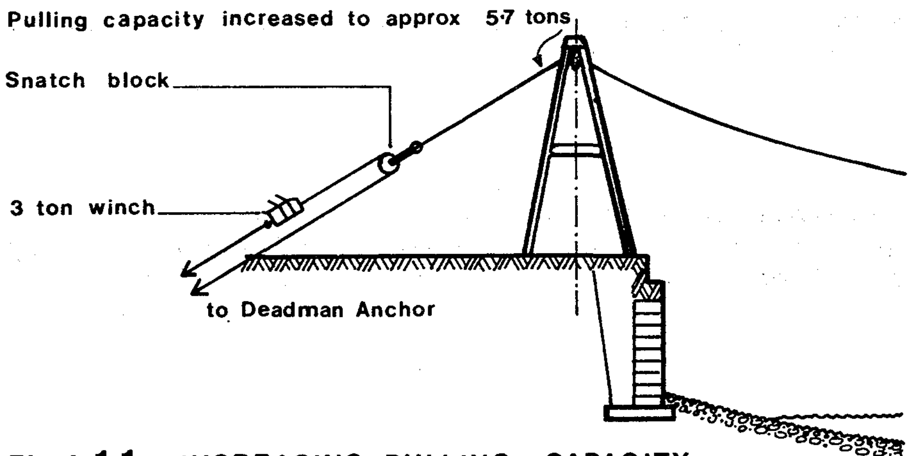


Fig. A 1·1 INCREASING PULLING CAPACITY USING A PULLEY BLOCK ARRANGEMENT

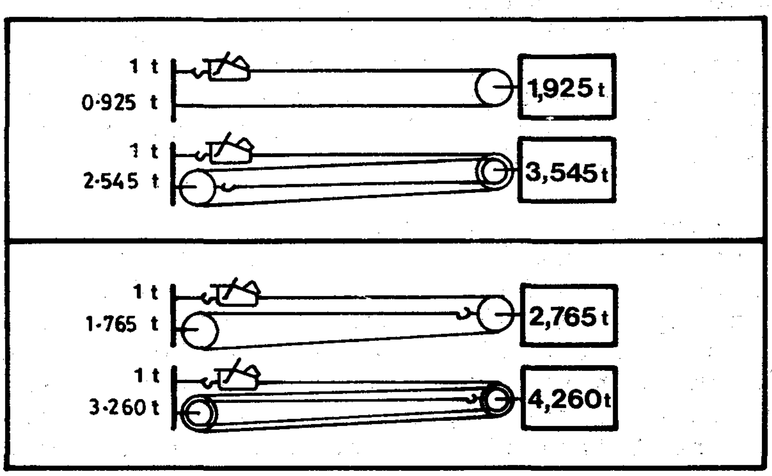


Fig. A 1·2 INCREASING PULLING CAPACITY - FOUR TYPICAL EXAMPLES

APPENDIX 2

LAUNCHING FORCES

General

The purpose of this Appendix is to provide information on launching forces which should help those in charge of the operation to appreciate the magnitudes and directions of the tensions involved at various stages, and through gaining this understanding, to avoid potential accidents. Simplifications and idealizations have been made in the analyses upon which the information is based, but the senses and magnitudes of the forces indicated are reasonable approximations to the true situation, provided the launching recommendations are closely followed. Possible sources of danger during a launch include overturning of the derricks and fracture of cables and associated equipment such as cleats and winches. The launching instructions given in the body of the manual are based on considerable experience, and in order to minimise risks, variations upon them should be avoided, at least until an expert or bridge team has built up equal experience of its own.

Equipment

The launching equipment listed in Appendix 1 has been carefully selected to be of adequate capacity for all weights of timber and spans of bridge designated, provided the launching recommendations are carefully followed.

Forces

The greatest force involved in launching is the tension in the standing cable. This is very dependent upon the amount of sag in the part of the cable which is stretched between the two towers. The sag is measured from the blocks at the tops of the derricks down to the snatch block supporting the nose of the girder, Figure A 2.1 (a). The LESS the sag, the GREATER the tension in the standing cable. Since it is desirable to minimise this tension, the derricks should be as high as conveniently possible. Also, the harness supporting the nose of the girder should be rigged so that is as short as possible, so as to avoid using up height unnecessarily, Figure A 2.1 (b).

In addition to the tension in the standing cable, another major force to be taken into account acts in a horizontal direction. This must be resisted by holdbacks, as explained in the body of the manual. Until the girder is approximately half way across the span, the tendency is for it to roll 'downhill' on the standing cable, and there is a horizontal pull away from the launching bank, which must be resisted with the holdback, so that the launch is well controlled. In the final stages, on the other hand, a positive pull from the far bank is needed to make the snatch

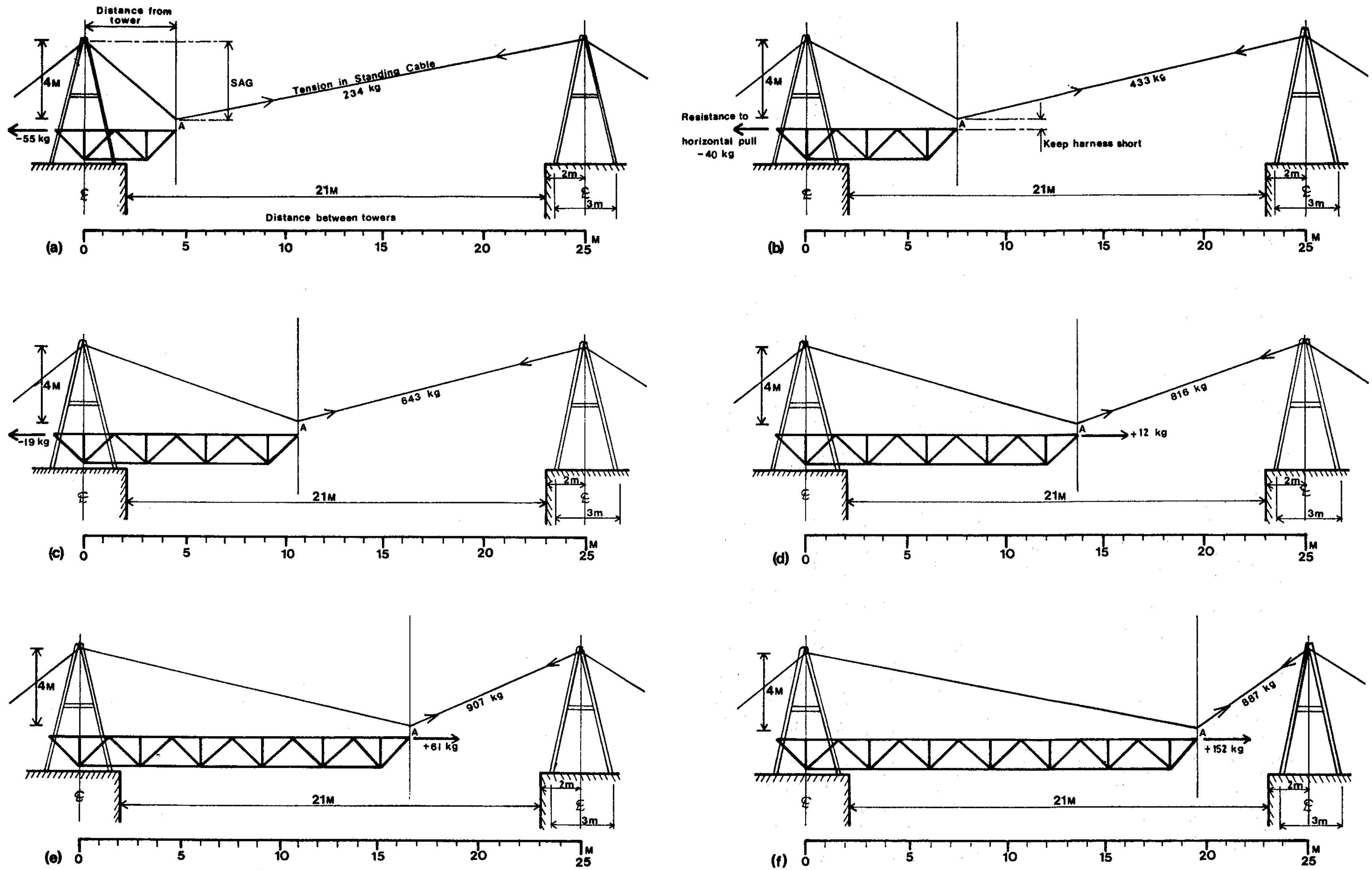


Fig A2-1 LAUNCHING FORCES FOR 21m BRIDGE - 4m SAG block roll 'uphill' and to get the nose towards the landing position. At this stage, as much slack as possible should be left in the standing cable, to minimise the tension in it. This slack should be maintained even at the expense of increasing the pull required to draw the girder across, because of the steeper 'hill' which the snatch block must climb. It is dangerous to over-tension the standing cable at the later stages of the launch, when it is supporting the greatest weight of girder.

Diagrams and tables of launching forces

Figure A 2.1 shows several stages of a girder being launched for a 21m span bridge. In the case illustrated, the standing cable has a sag of 4 m. Tensions in the standing cable and horizontal forces for this, and a series of other spans, have been calculated and are given in Tables A 2.1 to A 2.3. The tables are based on a unit weight of panel, which means the forces must be adjusted by a ratio allowing for the true panel weight, as detailed below. Tables A 2.1 [a] and A 2.1 [b] give the cable tensions and the horizontal forces for a sag of 4 m; Tables A 2.2 [a] and [b] give similar values for a sag of 5 m and Tables A 2.3 [a] and [b] cover a sag of 6 m. Values for intermediate sags may be interpolated if required. Negative values in the tables giving horizontal forces in the holdback cable indicate a pull that must be applied to restrain the girder from rolling towards the centre of the span. Positive values indicate a force required to haul it towards the far bank.

TABLE A 2.1

LAUNCHING FORCES PER 100 kg OF PANEL WEIGHT

[a] Tension in standing cable (kg)
for a sag of 4 metres

Span (m) :-		9	12	15	18	21	24	27
No. of panels assembled in each truss	Distance from tower(m)	Tension in cable (kg)						
2	4.5	183	201	215	225	234	240	246
3	7.5	283	335	375	407	433	453	470
4	10.5	****	424	512	584	643	691	731
5	13.5	****	****	573	704	816	909	986
6	16.5	****	****	****	728	907	1064	1196
7	19.5	****	****	****	****	887	1117	1322
8	22.5	****	****	****	****	****	1048	1331
9	25.5	****	****	****	****	****	****	1211

TABLE A 2.1 (Cont.)

LAUNCHING FORCES PER 100 kg OF PANEL WEIGHT

[b] Horizontal tension in holdback cable (kg) for a sag of 4 metres in standing cable

Span (m) :-		9	12	15	18	21	24	27
No. of panels assembled in each truss	Distance from tower(m)	Tension in cable (kg)						
2	4.5	-29	-40	-47	-52	-55	-57	-59
3	7.5	21	-8	-23	-33	-40	-45	-49
4	10.5	****	53	15	-6	-19	-28	-34
5	13.5	****	****	86	38	12	-5	-16
6	16.5	****	****	****	119	61	29	9
7	19.5	****	****	****	****	152	84	46
8	22.5	****	****	****	****	****	184	106
9	25.5	****	****	****	****	****	****	217

TABLE A 2.2

LAUNCHING FORCES PER 100 kg OF PANEL WEIGHT

[a] Tension in standing cable (kg) for a sag of 5 metres

Span (m) :-		9	12	15	18	21	24	27
No. of panels assembled in each truss	Distance from tower(m)	Tension in cable (kg)						
2	4.5	160	175	187	196	204	210	215
3	7.5	244	283	315	341	362	379	393
4	10.5	****	363	427	483	529	568	600
5	13.5	****	****	490	585	670	743	804
6	16.5	****	****	****	623	753	871	974
7	19.5	****	****	****	****	760	927	1082
8	22.5	****	****	****	****	****	899	1105
9	25.5	****	****	****	****	****	****	1040

TABLE A 2.2 (Cont.)

LAUNCHING FORCES PER 100 kg OF PANEL WEIGHT

[b] Horizontal tension in holdback cable (kg) for a sag of 5 metres in standing cable

Span (m) :-		9	12	15	18	21	24	27
No. of panels assembled in each truss	Distance from tower (m)	Tension in cable (kg)						
2	4.5	-31	-44	-52	-58	-62	-65	-68
3	7.5	23	-8	-27	-39	-47	-53	-57
4	10.5	****	59	18	-7	-23	-33	-41
5	13.5	****	****	97	44	14	-6	-19
6	16.5	****	****	****	135	72	35	11
7	19.5	****	****	****	****	174	99	56
8	22.5	****	****	****	****	****	213	126
9	25.5	****	****	****	****	****	****	251

TABLE A 2.3

LAUNCHING FORCES PER 100 kg OF PANEL WEIGHT

[a] Tension in standing cable (kg)
for a sag of 6 metres

Span (m) :-		9	12	15	18	21	24	27
No. of panels assembled in each truss	Distance from tower(m)	Tension in cable (kg)						
2	4.5	145	158	169	178	185	191	196
3	7.5	220	250	276	298	316	331	344
4	10.5	****	324	373	417	455	488	515
5	13.5	****	****	437	509	576	634	684
6	16.5	****	****	****	556	653	746	829
7	19.5	****	****	****	****	679	804	925
8	22.5	****	****	****	****	****	804	959
9	25.5	****	****	****	****	****	****	931

TABLE A 2.3 (Cont.)

LAUNCHING FORCES PER 100 kg OF PANEL WEIGHT

[b] Horizontal tension in holdback cable (kg) for a sag of 6 metres in standing cable

Span (m) :-		9	12	15	18	21	24	27
No. of panels assembled in each truss	Distance from tower(m)	Tension in cable (kg)						
2	4.5	-31	-44	-52	-58	-62	-65	-68
3	7.5	23	-8	-27	-39	-47	-53	-57
4	10.5	****	59	18	-7	-23	-33	-41
5	13.5	****	****	97	44	14	-6	-19
6	16.5	****	****	****	135	72	35	11
7	19.5	****	****	****	****	174	99	56
8	22.5	****	****	****	****	****	213	126
9	25.5	****	****	****	****	****	****	251

It is important to note that the tables are based on a standard panel weight of 100 kg, but this is simply a convenient way of presenting the information, actual panels nearly always weigh more than this. For any particular case, in a new project, or when a new timber is being used, a complete set of panels, lower chords and bracing members forming a girder should be weighed. The total should be divided by the number of individual panels in the girder, to obtain an estimate of the actual average weight per panel. The values in Tables A 2.1 to 2.3 should be multiplied by the ratio:

$$\frac{\text{actual average weight per panel}}{100}$$

This ratio, generally between 1.6 and 3.7, will give a close estimate of the actual launching forces for the construction concerned.

Initially, it may be required to carry out a launch or to determine the forces before a girder can be weighed, and a less precise estimate may be based upon the values given in Table A 2.4.

TABLE A 2.4

Approximate weight of panel and associated parts

Strength group*	Approximate weight per panel (kg)
S7	160
S6	190
S5	220
S4	250
S3	280
S2	320
S1	370

* See Part 4, Timber Technology, for definition of this term.

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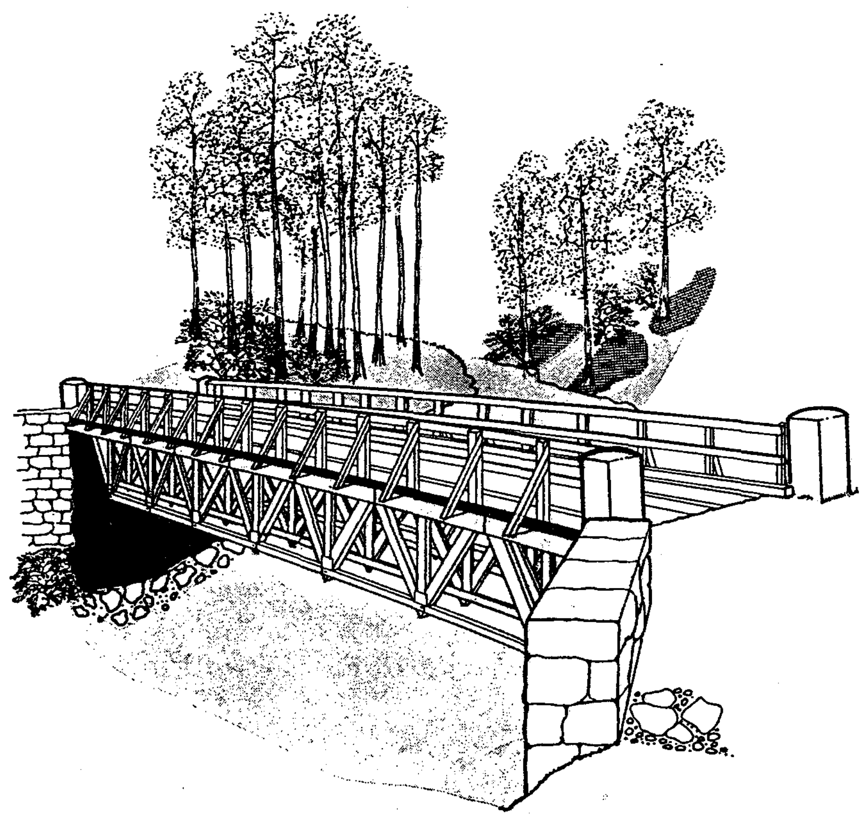
PRE-FABRICATED MODULAR WOODEN BRIDGES



PART 4 • TIMBER TECHNOLOGY

prepared for

UNIDO • UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA, AUSTRIA

by

TRADA • TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION, UNITED KINGDOM

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PRE-FABRICATED MODULAR WOODEN BRIDGES

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PRE-FABRICATED MODULAR WOODEN BRIDGES

Part 4 Timber Technology

INTRODUCTION

This section of the manual deals with the following :-

Chapter 1 - Strength properties of timber
Chapter 2 - General classification of properties of timbers
Chapter 3 - Stress grading
Chapter 4 - Moisture content and seasoning
Chapter 5 - Preservation treatment

The properties of timbers from many less developed countries have been tabulated. This has been done selectively, choosing for inclusion only those timbers from each region which are felt to be especially suitable for bridge construction. In addition to these timbers there are many others which could possibly be used. Information is given that would enable the manual user to make his own further selection, or refer to other authorities.

At certain stages of pre-fabricated panel manufacture, depending upon the precise preservation and fabrication sequence chosen in each case, correct control of moisture content and of seasoning of the wood will be necessary in order to obtain staight, correctly treated timber members.

It should also be noted that many timbers which are not inherently durable can be made so by preservation treatment using efficient preservatives and current techniques, information on which is to be found in this section.

Stress grading is an established technique for the selection of structural timber to ensure that each piece does not contain features which have an excessively weakening effect. It is important that it is carefully and effectively carried out on the timber chosen for the pre-fabricated modular wooden panels.

Chapter 1 - STRENGTH PROPERTIES OF TIMBER

THE STRENGTH OF WOOD

The strength of wood depends considerably upon the species of tree from which the timber is taken. For this reason it is necessary to standardise timber names, and for international scientific purposes the Latin name of the tree species is also associated with the wood itself. The greatest range of strength is found amongst the various tropical timbers. The conifers, commonly used for construction in temperate regions, tend to fall near the middle of the range of tropical timber densities and strength. To illustrate the great range of tropical woods, a timber from Malaysia known as Bitis (botanical species Madhuca utilis) has a bending strength about seven times that of Balsa (Ochroma pyramidale) from Ecuador.

The range of strength of timbers suitable for bridge building is of course somewhat less, since the very low density woods are excluded for many practical reasons. It is nevertheless quite considerable. Just as an example, there are two potentially useful African woods, mentioned because both have good natural durability. One of these, known as Ekki (Lophira alata), has a bending strength about twice that of the other, known as Niangon (Tarrieta utilis).

It is clear from the above that in attempting to specify possible timbers for use in the pre-fabricated bridge system that may be used anywhere in the world, quite a confusing and large list of difficult-to-pronounce Latin names and diverse strength properties would ensue from an attempt to deal with timbers on an individual basis. To avoid this, a grouping system has been adopted throughout the manuals that is largely based on one developed and used for many years in Australia, a country where there was a special need for such a system due to the diversity of indigenous timbers used for construction.

The usual way of establishing the strength of wood is to use standard test methods on small pieces which are carefully cut to avoid any defects which would influence their properties. (There is another, more expensive method applied to a few important timbers used in industrialized countries, but details of this need not be mentioned). These test pieces are known as small clear specimens. By placing timbers into groups according to their small clear properties, it is possible to classify them quite concisely, and to cover thousands of species whose properties have been measured in this way in various timber laboratories throughout the world.

The small clear property strength groups help considerably in providing a brief classification for strength, and bring us some way towards having short sets of tables for designs such as those for the modular bridges. Unfortunately, they do not go all the way. This is because the properties measured from the tests on small, perfect specimens are much too high safely to be used in structural design. Stresses used in structural timber codes such as BS 5268 (Reference 1)* or AS 1720 (Reference 2) are reduced in several stages from those originally derived from test. Reductions have to be made to allow for facts such as that timber strength is naturally quite variable, even from one perfect piece to another; timber strength varies according to the duration over which the load is applied, and of course like any other structural material, safety factors are necessary. In addition to these reductions, another set of ratios are needed to allow for the influence of features such as grain deviation, knots and other characteristics, that have to be allowed in structural sized pieces of wood as opposed to small clear pieces.

Chapter 3 explains in greater detail how wood is graded for structural purposes. Information is given on simplified grading rules for tropical hardwoods and conifers that have been developed for use in UNIDO projects. Stresses are listed in various structural timber codes for timber graded in a similar manner, following rules that are available in the national standards of the countries concerned. Most industrialized timber-using countries and quite a number of less-developed countries have national stress grading rules. Unfortunately there is some confusion over the names used for the 'safe working stresses'. The British code calls them 'grade stresses', whereas the Australian code refers to them as 'stress grades'. This confusion of nomenclature is unavoidable since both terms are so firmly rooted in all the codes, standards and regulations of the respective countries, that there is little the reader can do but understand and remember the two usages.

The following section gives further details of the strength groups and stress grades that are used for the manuals.

* A section giving the general references indicated in this manual may be found at the end of Chapter 5. Specific references relating to the classification of timber properties are given at the end of Chapter 2.

STRENGTH GROUPS AND STRESS GRADES

Strength groups

As outlined above, timbers used in the pre-fabricated modular wooden bridge system have been allocated 'strength groups'. The following definition, given in an Australian Standards Miscellaneous Publication, MP 45 (Reference 3), explains briefly what is meant by this term :

> Where the structural species of timber used in a country are easily identifiable and few in number, it may be appropriate that specific structural design properties be published for each of these species. However, in many countries numerous species are used and it is not practicable to have long lists of design data. Rather it is preferable to group the timber and to provide structural design properties for a limited number of strength groups. In general each strength group will cover a large number of species and commercial mixtures of species. The timbers listed in the following tables are grouped into seven classes according to the Australian system of strength classification.

Full details of the strength grouping method are given in MP 45, but essentially the process consists of ensuring that the small clear properties of the timber concerned are equal to or greater than those for the appropriate group indicated in Table 1, which shows minimum standard strength classifications based on small clear specimens.

TABLE 1

Minimum standard strength classification
based on small clear specimens

		PROPERTIES			
Strength group	Moisture condition	Modulus of rupture (MPa)*	Modulus of elasticity x 10^3 (MPa)	Maximum crushing strength (MPa)	Maximum shear srength (MPa)
S1	Green	103.0	16.3	52.0	13.1
	12%**	158.0	18.7	81.0	18.7
S2	Green	86.0	14.2	43.0	11.0
	12%**	134.0	16.3	71.0	16.7
S3	Green	73.0	12.4	36.0	9.1
	12%**	114.0	14.2	62.0	15.0
S4	Green	62.0	10.7	31.0	7.7
	12%**	94.0	12.4	53.0	13.1
S5	Green	52.0	9.1	26.0	6.5
	12%**	79.0	10.7	46.0	11.7
S6	Green	43.0	7.9	22.0	5.5
	12%**	67.0	9.1	40.0	10.3
S7	Green	36.0	6.9	18.0	4.6
	12%**	57.0	7.9	34.0	9.1

* 1 Megapascal = 1 N/mm^2 = 145 lbf/in^2 = 10.2 kgf/cm^2
** Seasoned values estimated from corresponding green values

Stress grades

Design information in the bridge manuals, such as the tables showing the number of trusses required for each loading and span, are based on a determination of the 'stress grade' of the timber concerned. In this context 'stress grade' has the special meaning given in the Australian Standard Timber Engineering Code (Reference 2). The standard's definition of this item is as follows:

> 'The classification of a piece of timber for structural purposes by means of either visual or mechanical grading to indicate primarily the basic working stress in bending for purposes of design and, by implication, the basic working stresses for other properties normally used in engineering design. The stress grade is designated in a form such as 'F7' which indicates that, for such a grade of material, the basic working stress in bending is approximately 7MPa.'

In Australia, stress grades are derived either through visual methods or by mechanical grading techniques based on measurement of local stiffness. There are set ratios in the relationship between visual grade, strength group and stress grade. All three increment by a factor of 1.25 between each step. As a consequence, there is considerable economy in the actual range of numbers shown in the stress grade tables, since many of the values work out equal and consequently they mesh together. Thus, for a specific grade, timber species from different strength groups may be interchanged. Table 2a and Table 2b show the relationship between visual grade, strength group and stress grade for the simplified grading rules for tropical hardwoods and for conifers which are given in this manual.

It should be noted that a strength group classification system is introduced in the British Standard, BS 5268: Part 2 (Reference 1). The British Standard makes use of 'strength classes' which are defined as 'a classification of timber based on particular values of grade stress'. In a straightforward intepretation of the UNIDO modular wooden bridge system following the methods given in these manuals, structural timber engineering calculations are not necessary. All data for choice of the number of trusses in a bridge are to be found in tables. Under special circumstances where it is required to make calculations however, information may be obtained from TRADA if it is desired to relate Australian strength groupings to design recommendations given in the British code.

Relationship between strength group, visual grade and stress grade

TABLE 2 (a)

Hardwood stress grades

Visual grade	Strength group						
	S2	S2	S3	S4	S5	S6	S7
Structural No.1	F27*	F22	F17	F14	F11	F8	F7
Structural No.2	F22	F17	F14	F11	F8	F7	F5

TABLE 2 (b)

Softwood stress grades

Visual grade	Strength group						
	S1	S2	S3	S4	S5	S6	S7
Structural No.3	F17*	F14	F11	F8	F7	F5	F4
Structural No.4	F14	F11	F8	F7	F5	F4	F3

* The 'F' numbers in the body of the table indicate the Australian 'stress grade'

Chapter 2 - GENERAL CLASSIFICATION OF PROPERTIES OF TIMBER

INTRODUCTION TO THE CLASSIFICATION AND NOMENCLATURE

In this Chapter, the relevant properties of timbers considered suitable for pre-fabricated wooden bridges have been tabulated for easy reference and access. All common names occuring in the literature are listed, together with the botanical name.

It is found in the case of timbers from all over the world, but especially so with tropical hardwoods, that a timber which has a standardized trade name may in fact be produced from more than a single botanical species. In addition, an unfortunate and widespread custom has been to borrow names of familiar timbers and apply them to other quite distinct species. The Dipterocarpus genus, in Malaysia, includes dozens of species. Many of these may legitimately be described as 'keruing'. This practice is approved of by wood technologists and standards bodies, and is fully explained in the relevant documents, (see for example References 4, 5 and 6). There are examples of name transference which may give rise to confusion on the other hand, and which may be contrary to recommended practice. These occur for example, with woods known as 'mahoganies', 'oaks' and their corresponding translation to 'robles' in Spanish. If in doubt over nomenclature, it is always wise to refer to standards such as those listed, for further guidance.

In the case of nearly all of the timbers listed in this Chapter, a standardized common name appears in upper case letters in the tables. This distinguishes it as the pilot name recommended by the Food and Agriculture Organization (FAO) of the United Nations, (Reference 6).

The six sets of tables have been drawn up according to world geographical regions, although it should be noted that occurence of the timbers is not always precisely limited by these boundaries. In addition to the listed timbers, there are of course others that may well be suitable for bridge construction. Furthermore, some timbers included may be more commonly used for higher value purposes such as furniture or veneer. However, local conditions can be so varied, and factors such as availability from the sawmill, market structure and government policies are so unpredictable, that the selection given in this manual must always be verified by local enquiries.

It is expected that when a new modular wooden bridge project is started, the expert and counterparts will review the timbers which are normally used in the country concerned for building and civil engineering purposes. Local state forestry organizations and research establishments concerned with timber may also be contacted. The Timber Research and Development Association (TRADA) will in addition be willing to provide advice. If the preliminary steps just mentioned are taken, and the tables and accompanying text given in this manual are thoroughly studied, the advice requested from TRADA should be of a brief nature and may thus be provided free of charge.

For convenience, the references pertaining to each geographical region have been listed separately, and these may be found at the end of the relevant tables. The following sections explain the classifications given in the tables, and provide supplementary information in a brief form :

DENSITY

Density varies substantially amongst different wood species. It is the single most significant simple indicator of many other properties. Mechanical properties such as strength and stiffness are well correlated with density, particularly when the whole range available between species is considered. The very low density species, occuring mainly amongst certain types of tropical timber, are not considered for structural purposes such as bridge building.

To provide an extremely simple, and therefore somewhat arbitrary classification, the average densities of the species considered, (when measured at 12 to 15 per cent moisture content) are grouped as follows:

	Kilogrammes per cubic metre
Light - L	up to 500
Medium - M	500 to 650
Upper - U	650 to 800
High - H	800 and above

WORKABILITY

The term 'workability' summarizes suitability for sawing, machining, nail holding, gluing and other related properties, all of which have been taken into account in deriving the overall broad classification. The timbers are grouped as follows :

A - good workability

B - moderate

C - poor

SHRINKAGE

The shrinkage coefficient used for the classification is based on the relation between tangential and radial shrinkage, multiplied by volume shrinkage from green to oven dry as follows :

Tangential to radial shrinkage - X

A - up to 1.4 per cent

B - 1.4 to 1.8 per cent

C - 1.8 per cent and up

Volume shrinkage - Y

A - up to 10 per cent

B - 10 to 15 per cent

C - 15 per cent and up

Shrinkage coefficient - (X x Y)

A - up to 14 per cent

B - 1 to 27 per cent

C - 27 per cent and up

NATURAL DURABILITY

The natural durability classification embraces the whole complex of natural durability and resistance to decay and insect attack, including termites and marine borers. It is important to note that it has been considered in relation to tropical, rather than temperate conditions.

The durability classification is particularly based on the estimated service life of the wood under different conditions and its resistance to insect and fungal attack as follows :

Conditions of Exposure	Expected Life Under Durability Class		
	A	B	C
a) In continuous contact with moist ground	5 years and up	3 - 5 years	very short
b) Exposed only to weather but kept from becoming soaked in water and properly ventilated	10 years and up	several years	very short
c) Under the roof, not in contact with moist ground and properly ventilated	indefinitely long	very long	several years
d) As above but properly maintained and regularly painted	indefinitely long	indefinitely long	20 years
e) Attack by subterranean termites	rare	rapid	very rapid
f) Attack by powder post beetles	none	infrequent	very rapid

AMENABILITY TO PRESERVATIVE TREATMENT BY PRESSURE METHODS

This classification shows the amenability of the timber to treatment with preservatives by pressure methods, as described in Chapter 5. There are two letters against each entry in the table, the first indicating the permeability of the sapwood and the second that of the heartwood.

Class	Description
P	These timbers can be penetrated completely under pressure without difficulty and can usually be heavily impregnated by the hot - and - cold open tank process.
M	These timbers are not very easily penetrated completely but it should be possible to obtain a lateral penetration of 6 - 18 mm in about 2-3 hours under pressure.
R	These timbers are very difficult to impregnate even under pressure.

KEY TO WORLD REGIONS FOR CLASSIFICATION

The following section presents the general classification of the properties of tropical hardwoods and tropical softwoods (conifers), in tabular form, divided into geographical regions and appropriately referenced.

The map below depicts the zones in which these timbers may be found :

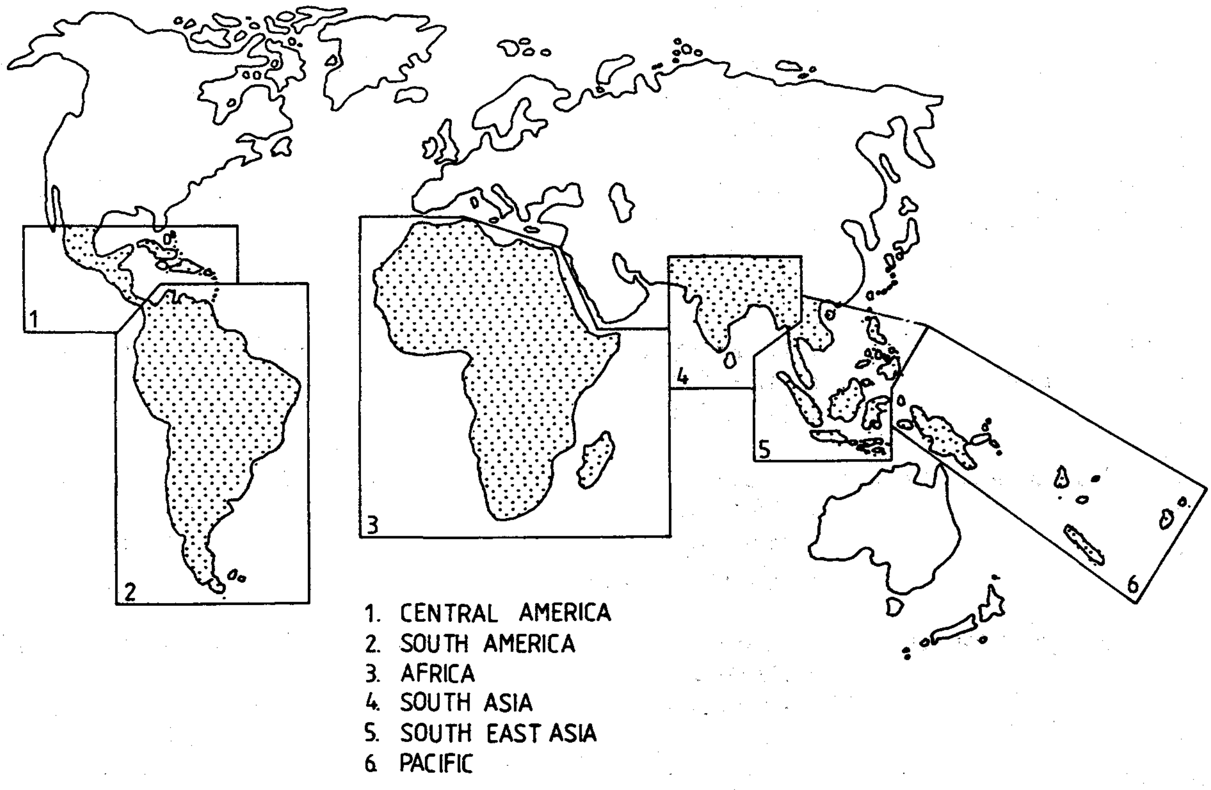

TABLE 4

PROPERTIES OF TIMBERS FROM
CENTRAL AMERICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Achras zapota	SAPODILLA Zapota Nispero	H	S3	C	C	A	M/R
Andira inermis	ANGELIN Almendro Batseed Coraro Amargoza	U	S3	B	A	B	P/M
Bucida buceras	UCAR Bullywood Pucte	U	S1	C	C	B	R/R
Calophyllum brasiliense	SANTA MARIA Palo Maria Krassa Galba	M	S4	B	B	B	P/R
Dicorynia guianensis	BASRALOCUS Angelica Angelique	U	S3	A	B	A	R/R
Dipholis salicifolia	BUSTIC Jubilla Chachiga Nispero amarillo	U	S3	B	B	B	-/R
Dipteryx odorata	TONKA Kumaru Koemaroe	H	S1	B	C	A	M/R

KEY TO COLUMNS:-
(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

For all tables in this section see map on page 13 for key to regions

TABLE 4 (Continued)

PROPERTIES OF TIMBERS FROM
CENTRAL AMERICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Hymenaea courbaril	COURBARIL	H	S3	B	B	A	P/R
	Teina						
	Guapinol						
	Cuapinol						
	Copal						
Licania ternatensis	BOIS GRIS	H	S2	C	B	B	-/R
	Bois diable						
	Bois de masse						
Manilkara bidentata	BALATA	U	S1	B	B	A	R/R
	Bulletwood						
	Ausubo						
	Purgo						
Symphonia globulifera	MANNI	M	S3	A	A	B	R/R
	Barillo						
	Cerillo						
	Leche Maria						
Tabebuia guayacan	GUAYACAN	H	S1	C	C	A	R/R
	Lapacho						
Terminalia amazonia	Nargusta	U	S3	A	B	A	M/R
	Fakadi						
	Guayabo						
	White Oliver						

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 5

PROPERTIES OF TIMBERS FROM
CENTRAL AMERICA

CONIFERS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Pinus caribaea	Caribbean pitch pine Constanero Aste Pinoauau Pino macho	M	S4	A	B	B	P/M
Pinus oocarpa	Ocote pine Pino ocote Pino blanco Ocote	M	S4	A	B	B	P/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

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TABLE 6

PROPERTIES OF TIMBERS FROM
SOUTH AMERICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Achras zapota	SAPODILLA Zapota	U	S3	B	B	A	M/R
Aspidosperma dugandii	CARRETO Carapanauba Paddle wood Parelhout Bois pagais	H	S2	B	B	A	-
Bagassa guianensis	TATAJUBA Bagasse	U	S2	A	A	A	M/R
Brosimum utile	SANDE Amapadoce	M	S3	A	B	C	-
Bucida buceras	UCAR Bulletwood Jucaro Black olive Oxhorn bucida	U	S1	C	C	B	R/R
Calophyllum brasiliense	JACAREUBA Balsamaria Alfaso Bella Maria Palo Maria Wild calabash	M	S5	A	B	B	P/R
Chlorophora tinctoria	AMOEIRA Palo amarillo Insira caspi Moral fina Dinde Fustic	U	S2	B	A	A	R/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 6 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH AMERICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Dicorynia guianensis	BASRALOKUS Angelica Angelique	U	S3	A	B	A	R/R
Diplotropis purpurea	SUCUPIRA Congrio Tatabu	H	S1	B	B	A	-
Eperua falcata	WALLABA Wapa	H	S2	B	B	A	R/R
Eschweilera longipes and E. subglandulosa	MANBARKLAK Kakaralli Machinmango Majaguillo	H	S1	C	B	A	R/R
Goupia glabra	CUPIUBA Capricornia Saino Kopi Kabukalli Congrio blanco	H	S4	A	B	A	-
Humiria balsamifera	TAURONIRO Turamira Quinilla Oloroso Nina Basra bolletrie Bois rouge	H	S2	B	B	A	-

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workabilty
(4) Shrinkage
(5) Durabilty
(6) Amenability to preservative treatment, sap/heart

TABLE 6 (Continued)

PROPERTIES OF TIMBERS FROM SOUTH AMERICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Hymenaea courbaril	COURBARIL	H	S3	B	B	A	R/R
	Jatoba						
	Sirari						
	Copal						
	Algarrobo						
	Locust						
Manilkara bidentata	BALATA	H	S1	–	C	A	–
	Bullet wood						
	Massaranduba						
	Purguo						
	Balata franc						
	Bolletri						
	Quinilla pamashto						
Mora excelsa	MORA	H	S1	B	B	A	P/R
	Peto						
Ocotea rodiaei	GREENHEART	H	S1	B	B	A	M/R
	Itabua						
	Ispingo moena						
	Viruviru						
	Beeberoe						
Ocotea rubra	WANA	M	S4	A	B	A	M/R
	Louro vermelho						
	Ishpingo maraco						
	Gringon franc						
	Determa						

KEY TO COLUMNS:-
(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 6 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH AMERICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Peltogyne pubescens	PURPLEHEART	H	S2	B	B	A	P/R
	Pau roxo						
	Palo violeta						
	Morado						
	Amarante						
Qualea rosea	MANDIOQUEIRA	M	S4	A	C	B	M/M
	Gronfolo						
	Gringon fou						
Symphonia globulifera	ANANI	U	S4	A	B	B	R/R
	Azufre						
	Machare						
	Perman						
	Manni						
	Mataki						
	Manil						
Terminalia amazonia	GUAYBO	U	S3	A	B	A	M/R
	Pau mulato brancho						
	Roble amarillo						
	Fukadi						
	Guacharaco						
Vouacapoua americana	ACAPU	H	S2	B	B	A	M/R
	Sara						
	Bruinhart						

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 7

PROPERTIES OF TIMBERS FROM SOUTH AMERICA

CONIFERS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Pinus elliottii	Slash pine	M	S5	A	B	B	P/R
Pinus radiata	Radiata pine	M	S5	A	B	C	P/P

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

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TABLE 8

PROPERTIES OF TIMBERS FROM AFRICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Afzelia africana	DOUSSIE Afzelia Apa Papao	U	S3	B	A	A	M/R
Afzelia bella	DOUSSIE Afzelia Arinjan	M	S4	B	A	A	M/R
Afzelia bipindensis	DOUSSIE Yellow afzelia Bolengu	U	S2	B	A	A	M/R
Afzelia pachyloba	DOUSSIE White afzelia	U	S2	B	A	A	M/R
Autranella congolensis	MUKULUNGU Uku Elang Mtua	H	S2	A	C	A	-
Brachylaena hutchinsii	MUHUHU Muhugwe	U	S3	-	A	A	M/R
Burkea africana	WILDESERING Siri Pinimo Kolo Mukalati Mukarati Musheshe	H	S2	B	A	A	P/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 8 (Continued)

PROPERTIES OF TIMBERS FROM
AFRICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Celtis soyauxii	OHIA	U	S2	A	B	C	-
	Ba						
	Esa						
	Odou						
	Luniumbu						
Chlorophora excelsa	IROKO	U	S4	B	B	A	P/R
	Odum						
	Mvule						
	Kambala						
Copaifera salikounda	ETIMOE	U	S2	A	B	A	M/R
	Entedua						
	Ovbialeke						
	Anzem						
	Bofelele						
Coula edulis	COULA	H	S2	-	B	A	M/R
	Srah						
	Attia						
	Ebo						
	Nkula						
	Ewome						
	Kumunu						
	Okolla						
Cryptosepalum staudtii	TANI	H	S2	-	C	B	M/R
	Ekop-tani						
Cylicodiscus gabunensis	OKAN	H	S2	C	C	A	-
	Boueman						
	Denya						
	Adoum						
	Edoum						

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 8 (Continued)

PROPERTIES OF TIMBERS FROM
AFRICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Distemonanthus benthamianus	MOVINGUI Ayan Gwadau Bonsamdua Barre Oguemimia	H	S4	-	B	B	M/R
Erythrophloeum ivorense and E.suaveolens	TALI Sasswood Erun Eloun Muave Potrodum Missanda N'kassa Munara	H	S3	C	B	A	M/R
Gilbertiodendron dewevrei	LIMBALI Balu Abeum Vaa Ekobem Ekpogoi	U	S2	B	C	A	P/R
Guarea cedrata	BOSSE Divuiti Scented guarea Guarea	M	S5	A	B	A	P/R
Guibourtia arnoldiana	MUTENYE Kouan	U	S3	B	B	A	M/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 8 (Continued)

PROPERTIES OF TIMBERS FROM AFRICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Guibourtia coleosperma	COPALWOOD Mushibi	M	S5	-	B	A	M/R
Heritiera utilis	Niangon Ogoue	H	S2	C	C	A	R/R
Lophira alata	EKKI Azobe Kaku Bongossi Eba Akoura Hendui Bankile	H	S1	B	C	A	P/R
Mammea africana	OBOTO Mung Djimbo Bom pegua Ologbomidu Abotzok	U	S2	-	C	B	M/R
Manilkara lacera	Aganokwi Fou Kpangkuu Berekankum Basipi Adzancon Aboga	H	S1	C	A	A	P/R
Microberlinia brazzavillensis	ZINGANA Zebrano	U	S4	A	C	A	P/R

KEY TO COLUMNS:-
(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 8 (Continued)

PROPERTIES OF TIMBERS FROM AFRICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Morus mesozygia	KANKATE Difou Wonton Aye Kesse	U	S1	A	B	C	M/R
Nauclea diderrichii and N.gilletti	BILINGA Kusia Opepe Gulu-Maza	U	S4	A	B	A	P/M
Nesogordonia papaverifera	KOTIBE Baa Danta Aborbora Tsanya Kondofindo	U	S3	A	B	A	M/R
Oldfieldia africana	African Oak Angouran Esson Fu Etu Fou Esui	H	S1	B	B	A	R/R
Olea hochstetteri	East African Olive Musheragi	U	S2	B	B	C	M/M
Olea welwitschii	LOLIONDO Elgon Olive	U	S3	B	B	B	R/R
Oxystigma oxyphyllum	TCHITOLA Lolagbola Tola Kitola	M	S4	A	B	A	-

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 8 (Continued)

PROPERTIES OF TIMBERS FROM AFRICA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Cylicodiscus gabunensis	Okan Denya Adoum	H	S2	C	C	A	-
Piptadeniastrum africanum	DABEMA Gaw Dahoma Ekkimi Toum	U	S4	B	B	A	M/R
Prosopis africana	GUELE	H	S3	-	C	A	P/R
Saccoglottis gabonensis	TALA Cherry Akouapo Niouka Tiabutuo Ozongo Ozouga	H	S2	B	C	A	-
Tarrietia utilis	NIANGON Nyankom Ogoue Wishmore	M	S5	A	B	A	-
Terminalia ivorensis	FRAMIRE Emire Idigbo	M	S5	A	B	B	M/R
Tieghemella africana	DOUKA Okola	U	S4	A	B	A	M/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 9

PROPERTIES OF TIMBERS FROM AFRICA

CONIFERS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Cedrus deodara	Deodar	M	S5	B	B	B	M/R
Cupressus lusitanica	Cypress	M	S6	A	B	B	M/M
Juniperus phoenicea	Sabina	U	S4	B	B	A	M/R
Pinus canariensis	Canary Island Pine	M	S4	A	B	B	P/R
Pinus elliottii	Slash pine	M	S5	B	B	B	P/R
Podocarpus henkelii	Falacate yellow wood	M	S5	A	B	C	M/M

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

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TABLE 10

PROPERTIES OF TIMBERS FROM SOUTH ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Albizzia lebbeck	KOKKO Siris	M	S4	C	B	B	P/M
Albizzia odoratissima	BLACK SIRIS Thit-pyu Mara	M	S2	B	B	C	P/R
Albizzia procera	SAFED SIRIS White siris Burda Sibok	M	S5	B	B	C	P/R
Anogeissus latifolia	AXLE WOOD Dindal Dhawa Yerma	U	S3	B	C	B	P/R
Bruguiera spp.	BLACK MANGROVE	H	S2	C	B	C	P/P
Dipterocarpus spp.	GURJUN Hora	U	S3	B	B	B	P/P
Dipterocarpus tuberculatus	ENG Pluang In	U	S3	A	B	B	P/M
Hardwickia binata	ANJAN Kamra Chhota Dundhera Yepi	U	S4	C	C	A	-/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 10 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Kingiodendron pinnatum	PINEY	M	S4	A	B	B	M/R
Lagerstroemia lanceolata	BENTEAK Nana Vevala	U	S4	B	C	B	-/R
Mesua ferrea	Mesua Nahor Nangal Gangaw Na	H	S2	C	B	A	-/R
Mimusops hexandra and M. elengi M. littoralis	BULLETWOOD Kaya Palu Bukal Malsari	U	S3	C	B	A	-/R
Ougeinia oojeinensis	SANDAN	U	S5	A	B	A	-
Pterocarpus dalbergioides	PADAUK	M	S3	B	A	A	P/R
Pterocarpus marsupium	BIJASAL	U	S4	B	B	A	P/R
Tectona grandis	TEAK Sagwan Teka Kyun	M	S4	B	A	A	M/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 10 (Continued)

PROPERTIES OF TIMBERS FROM SOUTH ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Terminalia paniculata	KINDAL Pekarakai Marwa Neemeeri	M	S4	B	B	B	M/R
Terminalia alata	LAUREL Sain Taukkyan	U	S3	B	C	B	P/M
Shorea robusta	SAL Shal Sala Sakwa	U	S3	B	B	B	-/M
Xylia dolabriformis	PYINKADO Pyin Pran Irul	U	S2	A	B	A	-/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 11

PROPERTIES OF TIMBERS FROM
SOUTH ASIA

CONIFERS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Abies pindrow							
Cedrus deodara	Cedar Deodar Diar Dadar	M	S5	A	B	A	M/R
Pinus longifolia	Longifolia pine Chir pine Chil						

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

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TABLE 12

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Anisoptera spp. inluding A. costata A. curtisii A. laevis A. marginata A. scaphula	MERSAWA KRABAK Pengiran Mai Bak Ven Ven	U	S5	B	B	B	P/M
Balanocarpus heimii (Neobalanocarpus heimii)	CHENGAL Takhian-chan	U	S1	A	B	A	M/R
Calophyllum curtisii C. inophyllum C. retusum + many other C. species	BINTANGOR Tanghon Bitaog Bintangur	M	S4	A	B	B	P/M
Canarium littorale + other C. species Dacroydes costata + other D. species	KEDONDONG Kenari Makern Kalisau	M	S5	B	B	C	-/R
Cotylelobium malayanum C. melanoxylon also see Vatica species	RESAK Giam	H	S2	B	B	B	R/R
Cynometra malaccensis + other C. species	KEKATONG Manghka Dila dila Katong	H	S2	B	B	B	P/M

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 12 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Dialium patens	KERANJI	H	S2	C	B	A	-/R
D. platysepalum							
D. wallichii							
+ other D. species							
Dipterocarpus spp.	KERUING (Malaysian)	U	S3	B	C	B	M/M
including	Yang						
D. baudii	Apitong panau						
D. cornutus							
D. costulatus							
D. crinitus							
D. grandiflorus							
D. kerrii							
Dipterocarpus spp.	YANG	U	S3	A	C	B	M/M
including	Apitong						
D. gracilis							
D. grandiflorus							
D. lasiopodus							
Dipterocarpus spp.	YANG	U	S3	B	C	B	M/M
including							
D. alatus							
D. turbinatus							
Dryobalanops	KAPUR	U	S3	B	C	A	P/R
aromatica	Keledan						
D. oblongifolia	Petanang						
Durio spp.	DURIAN	M	S5	A	B	C	P/P

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 12 (Continued)

PROPERTIES OF TIMBERS FROM SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Eugenia chorantha	KELAT	U	S4	A	B	B	M/R
E. filiformis	Wa						
E. grandis	Obar						
E. griffithii	Salam						
E. longiflora							
E. syzygioides							
+ many other species							
Eusideroxylon zwageri	BELIAN	H	S1	B	B	A	P/R
	Kayn-ulin						
	Tambulian						
Fagraea fragrans	KANKRAO	H	S3	A	B	A	P/R
	Tembusu						
	Temesu						
	Urung						
Gluta spp.	RENGAS	U	S3	B	A	A	-
Heritiera javanica	MENGKULANG	U	S4	b	b	b	-/R
H. simplicifolia	Chumprak						
+ other H. species							
Hopea ferrea	GIAM	U	S1	C	B	A	M/R
H. helferi	Dalingdingan						
H. nutans	Malut						
+ other dense H. species							

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 12 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Hopea spp. including	MERAWAN	U	S3	A	-	B	M/M
H. mengarawan	Takhian-Tong						
H. nervosa	Thinagan						
H. odorata							
H. pubescens							
H. sangal							
H. sulcata							
+ many other							
H. spp. of moderate density							
Intsia palembanica	MERBAU	U	S3	A	A	A	R/R
Koompassia exelsa	TUALANG	H	S2	A	B	B	R/M
Koompassia malaccensis	KEMPAS	H	S2	B	B	B	P/P
	Tongbueng						
	Menggris						
	Impas						
Madhuca utilis	BITIS	H	S1	B	B	A	M/R
Melanochyla auriculata + M. spp.	RENGAS	U	S3	B	A	A	P/R
Mesua ferrea	BUNNARK	H	S1	B	B	A	P/M
	Penaga						
	Nagasari						

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 12 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Palaquium spp. plus others of light to medium density	NYATOH	U	S5	B	B	B	-/R
Palaquium ridleyi P. stellatum	BITIS	H	S1	B	B	A	M/R
Pometia pinnata + other P. spp.	KASAI Malugai	U	S4	B	B	B	P/P
Scorodocarpus borneensis	KULIM	H	S2	B	B	B	P/M
Shorea spp. including: S. collina S. guiso S. kunstleri S. ochrophloia	BALAU-RED Guiso	H	S3	B	B	B	P/R
Shorea atrinervosa S. foxworthyi S. glauca S. laevis S. maxwelliana S. submontana + other S. spp. of high density	BALAU Yakal	H	S1	B	C	A	P/R
Shorea laevifolia	BANGIKARAI	H	S1	B	A	A	P/R

KEY TO COLUMNS:-
(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 12 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Shorea superba plus other similar S. spp. of density below 880 kg/cu.m.	SELANGAN BATU NO.2	U	S3	B	A	A	P/R
Shorea spp. including: S. faguetiana S. multiflora	MERANTI-YELLOW	U	S5	A	B	B	M/R
Shorea spp. including: S. bracteolata S. hypochra	MERANTI-WHITE Pa-nong	M	S5	B	B	B	M/M
Shorea spp. including: S. curtisii S. pauciflora S. platyclados	MERANTI-DARK RED	U	S5	A	B	B	M/R
Shorea laevis S. seminis + other S. species of density above 880 kg/cu.m	SELANGAN BATU NO 1	H	S1	B	C	A	P/R
Sindora coriaceae S. echinocalyx S. velutina S. wallichii	SEPETIR MAKHAR TAE Sindur	U	S4	B	B	B	P/R
Swintonia spp.	MERPUAH Pitoh	M	S4	B	B	C	P/M

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 12 (Continued)

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Terminalia citrina	BINGGAS	H	S2	B	C	A	-
	Samor						
	Talisai						
	Kempas-belang						
Tetramerista glabra	PUNAH	U	S3	A	B	B	M/R
	Punak						
	Entuyut						
	Tuyot						
Vatica cinerea	RESAK	U	S3	A	B	B	R/R
V. cuspidata	Narig						
V. odorata	Kulim Papa						
+ other V. species							
Vitex parvifloria	MOLAVE	U	S4	A	B	A	-
	Leban						
	Tiennok						

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 13

PROPERTIES OF TIMBERS FROM
SOUTH EAST ASIA

CONIFERS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Pinus kesiya	Benguet pine	U	S5	A	B	B	-
Pinus merkusii	Merkus pine	M	S5	B	B	B	P/M
Pinus parviflora	Taiwan white pine	M	S4	A	B	B	P/M
Pinus taiwanensis	Taiwan red pine	U	S4	B	B	B	P/M

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

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TABLE 14

PROPERTIES OF TIMBERS FROM PACIFIC REGION

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Anisoptera polyandra	PNG Mersawa	M	S5	C	B	B	R/R
Celtis philippensis C. latifolia	Hard celtis Malaiknio	M	S4	B	A	B	P/M
Cleistocalyx spp.	Yasi-yasi	U	S2	B	C	A	M/R
Eucalyptus deglupta	Kamarere	M	S4	B	B	B	P/R
Fagraea gracilipes	Buabua	H	S1	B	A	A	P/R
Flindersia ifflaiana	Hickory ash	H	S1	B	B	B	P/R
Garcinia myrtifolia	Laubu Kadis	U	S3	A	B	C	P/M
Geijera salcifolia	Green satinheart	U	S2	A	B	A	M/R
Gonystylus punctatus	Mavota Ramin	M	S3	B	B	C	P/P
Heritiera littoralis	Herritiera Tulip Mangrove	U	S3	-	C	B	P/R
Heritiera ornithocephala	Rosarosa	U	S3	C	A	A	P/R
Homalium foetidum	Malas Takaliu Aranga	H	S2	B	C	B	P/M

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 14 (Continued)

PROPERTIES OF TIMBERS FROM
PACIFIC REGION

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Hopea glabrifolia H.iriana	Heavy hopea	H	S1	B	B	A	M/R
Hopea papuana	Light hopea	M	S2	B	A	A	R/R
Intsia bijuga	Kwila Vesi	U	S2	C	A	A	M/R
Intsia palembanica	Merbau	M	S2	B	A	A	M/R
Manilkara kanosiensis	Manilkara	H	S1	-	B	A	R/R
Maranthes corymbosa	Busu Plum	U	S2	B	B	B	P/M
Nothofagus spp.	PNG beech	M	S3	B	B	B	R/R
Palaquium hornei	Sacau	U	S3	C	C	C	P/R
Parinari insularum	Sa	M	S3	C	B	B	P/M
Parinari nonda P. salomonensis	Solomon Island Parinari	U	S2	C	B	B	P/P
Pometia pinnata P. tomentosa	Taun	M	S4	A	B	B	M/R
Pterocarpus indicus	Warara Linggi Liki	M	S4	A	A	A	R/R
	PNG Rosewood	M	S4	A	A	A	R/R
Syzygium spp.	PNG Water Gum Yasiyasi 1	U	S3	B	A	C	P/M

KEY TO COLUMNS:-
- (1) Density
- (2) Strength group
- (3) Workability
- (4) Shrinkage
- (5) Durability
- (6) Amenability to preservative treatment, sap/heart

TABLE 14 (Continued)

PROPERTIES OF TIMBERS FROM
PACIFIC REGION

HARDWOODS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Terminalia catappa T. microcarpa T. canaliculata T. impediens	Terminalia (Red brown group)	M	S5	B	B	C	R/R
Vitex coffasus + V. species	Vitex	M	S3	A	B	B	M/R

KEY TO COLUMNS:-

(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

TABLE 15

PROPERTIES OF TIMBERS FROM
PACIFIC REGION

CONIFERS

BOTANICAL NAME	PILOT/Common names	(1)	(2)	(3)	(4)	(5)	(6)
Pinus elliottii	Slash pine	M	S5	B	B	B	P/R
Pinus caribaea	Fiji pine	M	S6	B	B	A	P/M
Podocarpus neriifolius	Podocarp Kuasi	M	S4	B	B	A	P/M
P. archboldii	Black pine						
P. rumphii	Thitmin						

KEY TO COLUMNS:-
(1) Density
(2) Strength group
(3) Workability
(4) Shrinkage
(5) Durability
(6) Amenability to preservative treatment, sap/heart

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Chapter 3 - STRESS GRADING RULES

Stress grading is simply the sorting of timber into categories on the basis of predicted strength. It is important if structural timber is to be used efficiently and safely. A number of characteristics of timber which may be considered defects from an appearance grading point of view, such as stain not associated with decay, and pin holes, can be accommodated in structural material with little or no loss in strength. Certain characteristics such as slope of grain, however, require careful limitation and there are two main methods of achieving this, namely visual grading and machine grading.

Visual grading

Visual grading assesses the timber by visual inspection and measurement of the main characteristics such as slope of grain, knots, fissures, etc. which require careful limitation. Recommended grading rules are given in Table 16 for tropical hardwoods and in Table 18 for tropical coniferous timbers.

Machine grading

In machine grading, the timber is passed between rollers of a specially designed machine which deflects it and automatically measures its elasticity. Machine grading has many advantages but costs involved are high.

SIMPLIFIED STRESS GRADING RULES FOR TROPICAL HARDWOODS

These stress grading rules are designed so that each piece of timber of a given size in a grade will have a certain minimum strength, thus allowing the working stress appropriate to that grade to be applied confidently to each piece. Permissible limits of characteristics for two visual stress grades, namely STRUCTURAL NO.1 GRADE and STRUCTURAL NO.2 GRADE, are given in Table 16. Table 17 gives the grade ratio for each grade. This ratio indicates the appropriate relationship between the stress which can safely be sustained for timber of a particular grade, to the stress which can safely be sustained by a similar structural sized piece of timber, which contains the strength reducing defects.

MEASUREMENT OF DEFECTS

Figure 3.2 shows a grain scribe in use. It is drawn steadily along the length of the piece. With a little practice this simple technique will lead to the needle forming a groove in the true direction of the inclined grain of the wood. Grain indication is expressed as "one in x", where x is the length of AC measured in terms of BC, Figure 3.3.

a) Slope of grain

The slope of grain should be measured over a distance of sufficient length to determine the general slope, disregarding slight local variations. This distance should normally be over 300mm. The measurement should be taken on the surface where the slope is most severe, using for preference, a cranked scribe (Figure 3.1), with a freely swivelling handle.

b) Interlocked grain

Interlocked grain is a normal feature of certain tropical hardwoods. It results from fibres of successive growth layers being inclined in different directions. Figure 3.4 shows the formation of interlocked grain in a section of the growing tree. Interlocked grain causes the surface fibres to "pick up" differently when the wood is sawn or planed, according to whether the local grain is inclining towards, or away from the machining direction. This helps in recognising the feature, as a stripe or ribbon figure is apparent on the radial surface of the wood. Figure 3.5 shows the appearance of interlocked grain on a sawn piece taken from the log of Figure 3.4.

To the extent that it is normal in tropical hardwood, the effect of interlocked grain on strength properties may be considered to have been taken into account at the stage of testing the small clear specimens. Thus it can usually be ignored in grading. The exceptions are those pieces showing severe interlocking, with a local slope of the fibres worse than in 1 in 4, (1 in 6 for Structural No. 1 grade), which are better rejected. Also, in special cases, such as thin strips of structural wood for laminating, care must be taken. However, this is not of concern for bridge timbers in the UNIDO system.

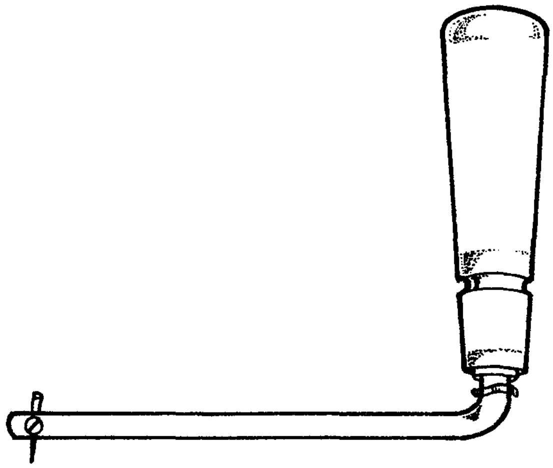


Figure 3.1 SWIVEL HANDLED SCRIBE FOR DETERMINING SLOPE OF GRAIN

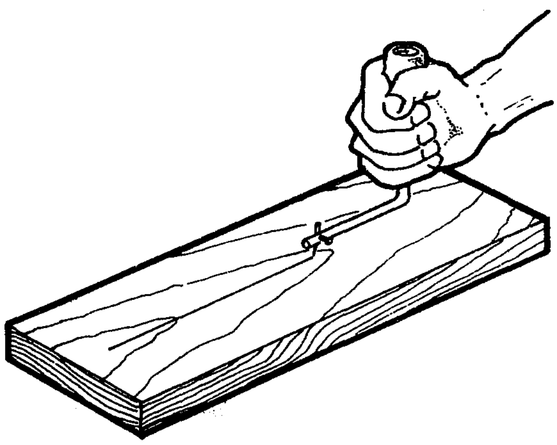
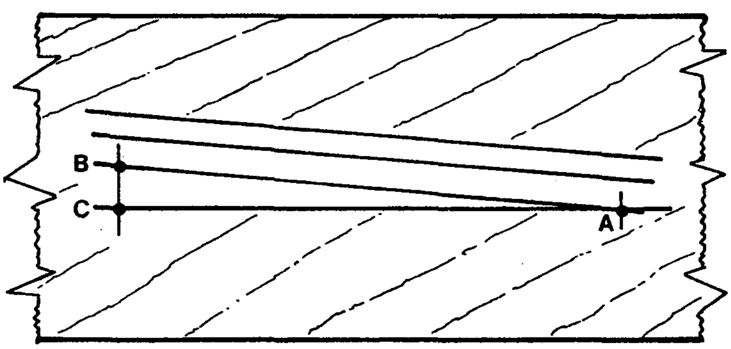


Figure 3.2 USE OF SCRIBE



Slope of grain = 1 in $\frac{AC}{BC}$

Figure 3.3 MEASUREMENT OF SLOPE OF GRAIN

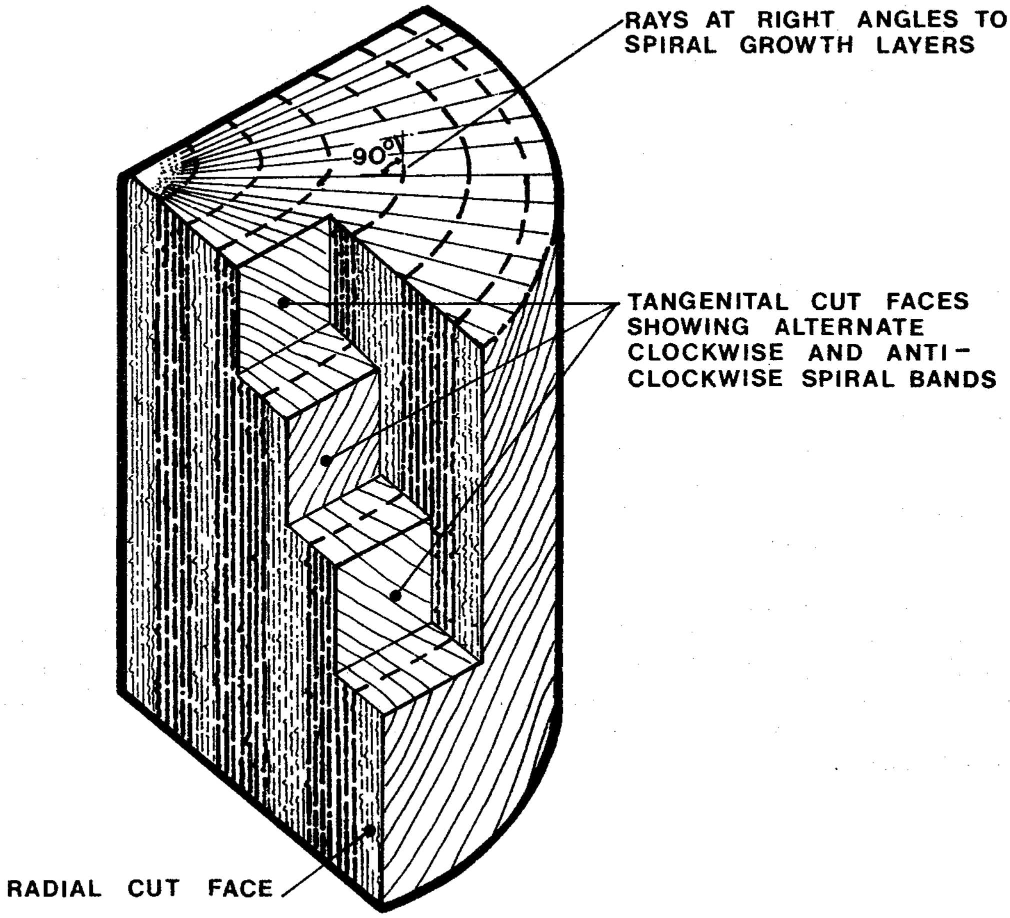


Figure 3.4 FORMATION OF INTERLOCKED GRAIN

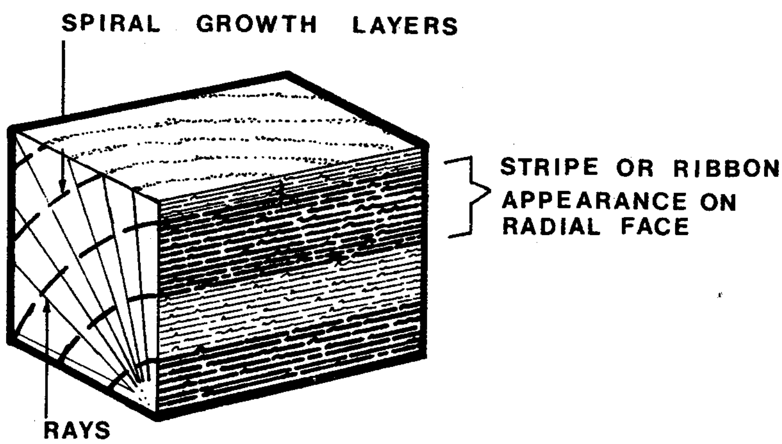


Figure 3.5 INTERLOCKED GRAIN

c) Knots

The limiting dimension of any type of knot shall be taken as the distance between lines containing and touching the knot and parallel to the arris. For example, in Figure 3.6 a) the limiting dimension of the knot on the edge would be x, and this would be compared with the thickness of the piece, t. That of the knot on the face, y, would be compared with the depth of the piece,d. In practice two such knots could not appear at the same location.

Sligthly more care is required where the single knot can be seen on both edge and face. The appropriate method shall be used as follows:-

If the knot emerges from within the cross section on to an arris, and neither of the exposed sections of the knot is definitely elongated (Figure 3.6 b), the knot shall be measured on both edge and face by taking the distance between the arris and lines touching the knot and parallel with the arris. The greater of the two measurements shall be the limiting dimension and this shall be related to the THICKNESS of the piece.

A knot showing on both edge and face but cut so that one of its exposed sections is definitely elongated (Figure 3.6 c), shall be measured only on the surface upon which the elongated portion DOES NOT appear, using one of the methods described above. The limiting dimension shall be related to the thickness or width upon which the knot measurement is taken.

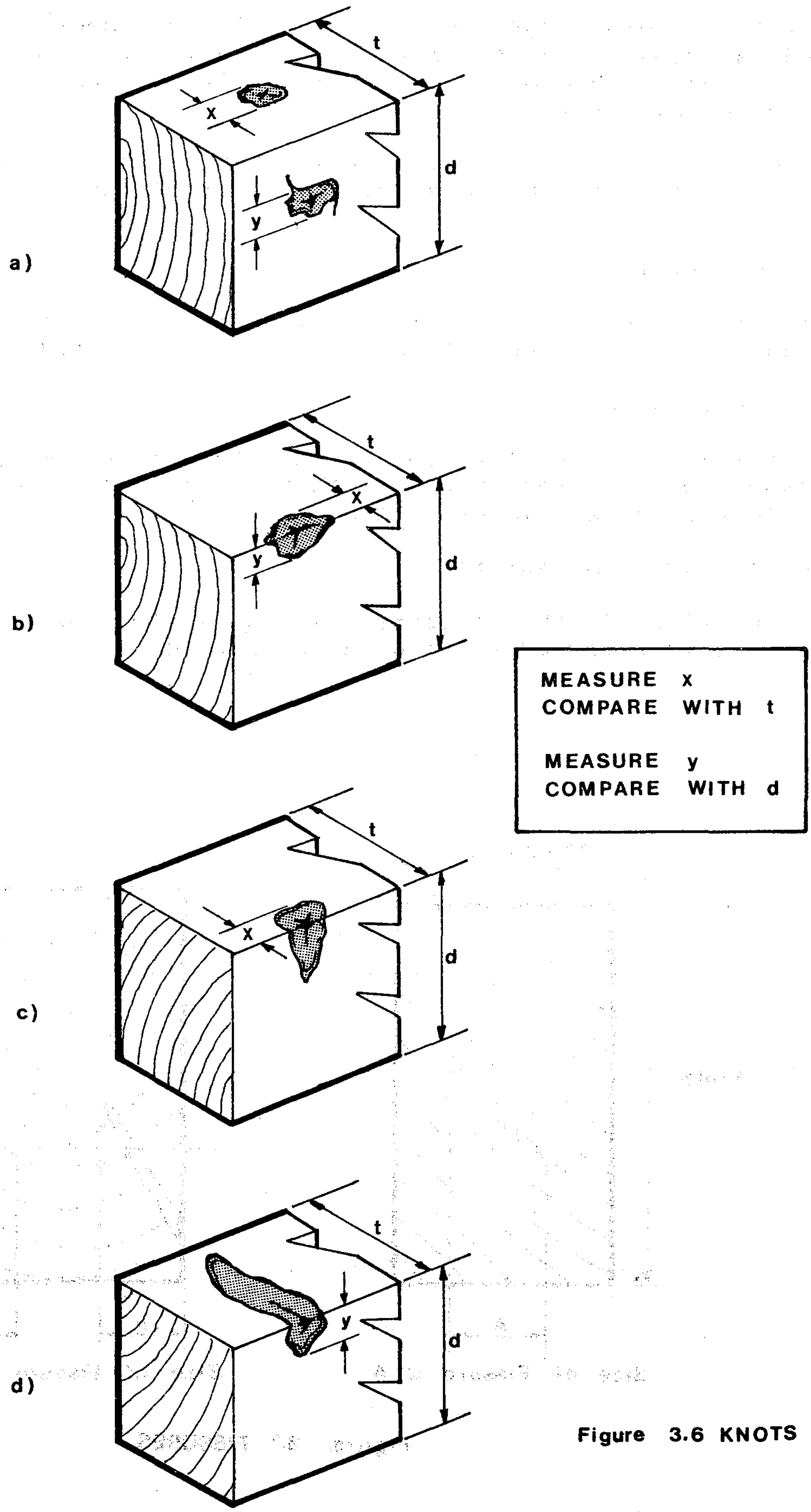


Figure 3.6 KNOTS

d) Fissures (see Figure 3.7)

In stress grading the term 'fissure' is used for all forms of longitudinal separating of the fibres in the sawn piece. There are many trade and wood technology terms such as checks, shakes and splits which give rise to this feature.

The size of a fissure shall be taken as the distance between lines enclosing the fissure and parallel to a pair of opposite surfaces.

Shallow fissures

When the size of the fissure is less than one-third of the thickness of the piece, it is referred to as a shallow fissure.

Moderate fissures

If the size of the fissure is greater than one-third of the thickness of the piece but less than the thickness of the piece, it is referred to as a moderate fissure.

Large fissures and splits

When the size of the fissure is equal to the thickness of the piece, it is referred to as a large fissure.

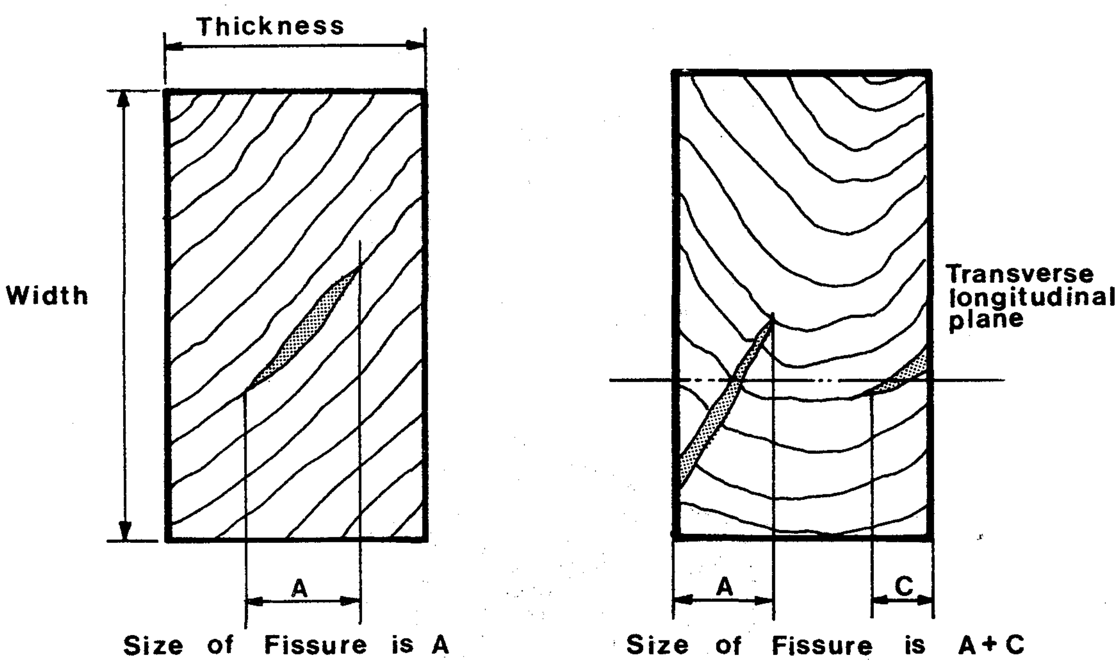


Figure 3.7 FISSURES

e) Resin pockets (see Figure 3.8)

Resin pockets shall be estimated and measured as for fissures.

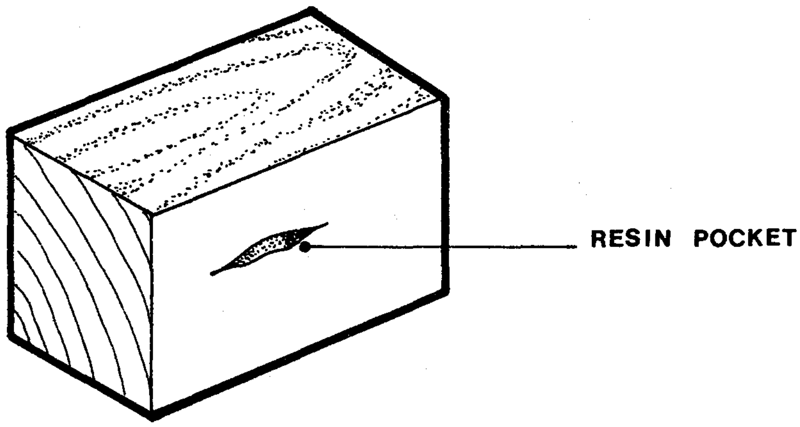
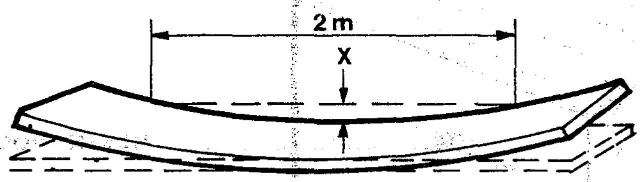


Figure 3.8 RESIN POCKETS

f) Distortion (see Figure 3.9)

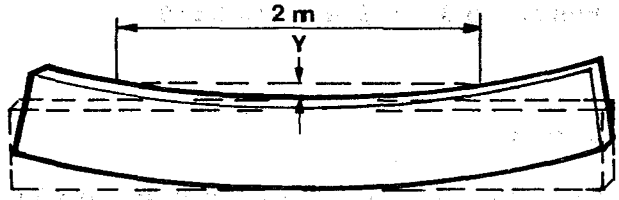
Where length permits, the bow spring and twist shall be measured over a two metre length. Cup should be measured over the full width of the piece. In pieces of square cross section, curvature shall be measured in the direction in which it is worse and this measurement shall be regarded as spring.

BOW



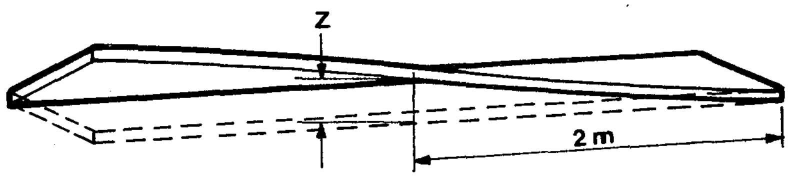
Bow is X

SPRING



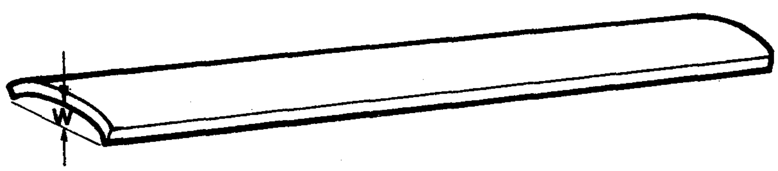
Spring is Y

TWIST



Twist is Z

CUP



Cup is W

Figure 3.9 MEASUREMENT OF BOW, SPRING, TWIST AND CUP

g) Insect holes (see Figure 3.10)

The size of an insect hole shall be taken as the maximum diameter of its visible cross section wherever it occurs.

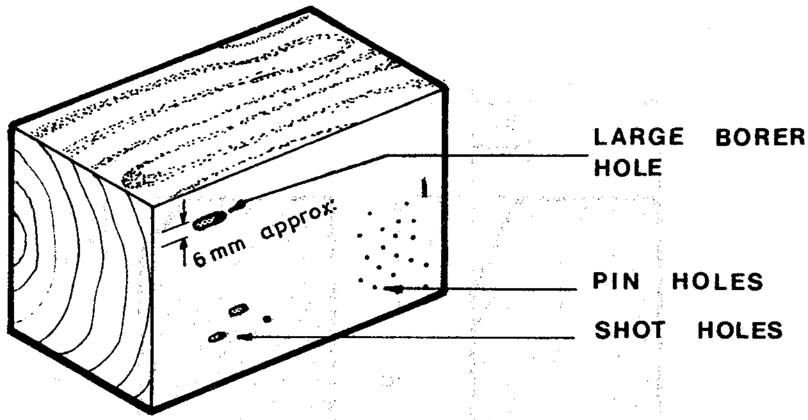


Figure 3.10 INSECT HOLES

h) Wane

Wane is a defect introduced during conversion of the timber. It consists of inclusion of parts of the original round, outer surface of the log in the sawn piece, Figure 3.11.

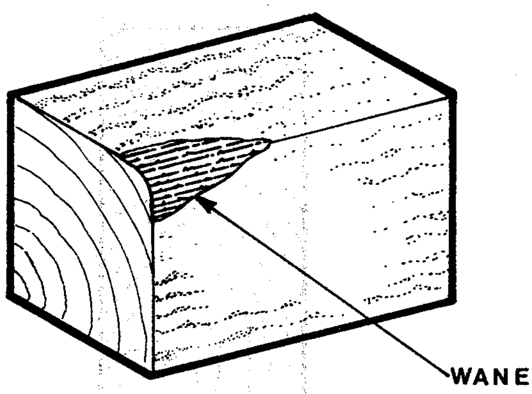
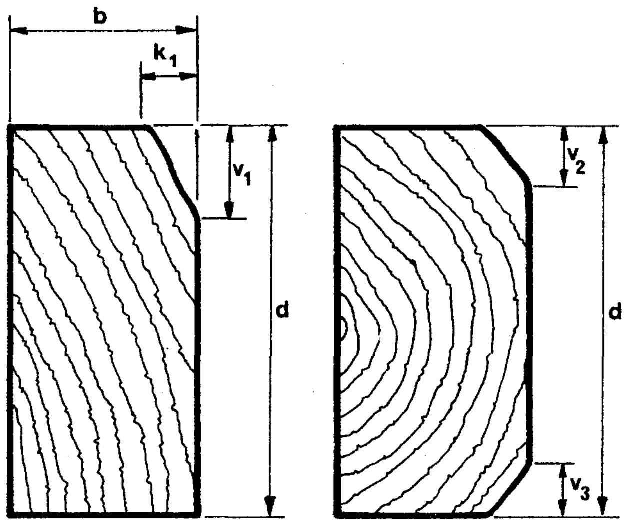


Figure 3.11 WANE

The amount by which the transverse dimension of a face or edge reduced owing to wane is called the width of the wane on that surface. The amount of wane as defined in these rules is found by adding together the widths of wane on any two adjacent faces and expressing their sum as a fraction of the sum of the widths of the two faces concerned. (See Figure 3.12).



AMOUNT OF WANE ON THE FACE OF THE PIECE SHALL BE EXPRESSED AS THE RATIO

$\frac{v_1}{d}$ or $\frac{v_2 + v_3}{d}$

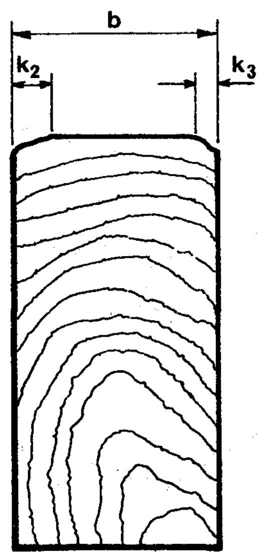


Figure 3.12 WANE

AMOUNT OF WANE ON THE FACE OF THE PIECE SHALL BE EXPRESSED AS THE RATIO

$\frac{k_1}{b}$ or $\frac{k_2 + k_3}{b}$

i) Compression failures and brittleheart

In tropical hardwoods in the light and medium density class, abnormal wood sometimes develops in the centre of the growing tree, a zone known as brittleheart may extend to about one-third of the diameter. This material should be eliminated in good sawmilling practice. Certainly, no timber including brittleheart should be ever be supplied where the material is intended for structural use. Because its effect, particularly in reducing impact resistance is appreciable, care should be taken during grading that no pieces passed fit for use include this feature.

Brittleheart, shown in Figure 3.13, is often associated with abnormally low density locally in the piece, and this may give a clue to its detection. It can also be seen fairly easily on the ends of a piece, where it gives rise to a pitted appearance, and on planed material, where fine, regularly distributed compression creases can be seen on the surface of the piece. Compression failures and brittleheart are hard to detect on sawn surfaces, and wherever possible, timbers liable to contain this type of defect should be stress graded after planing.

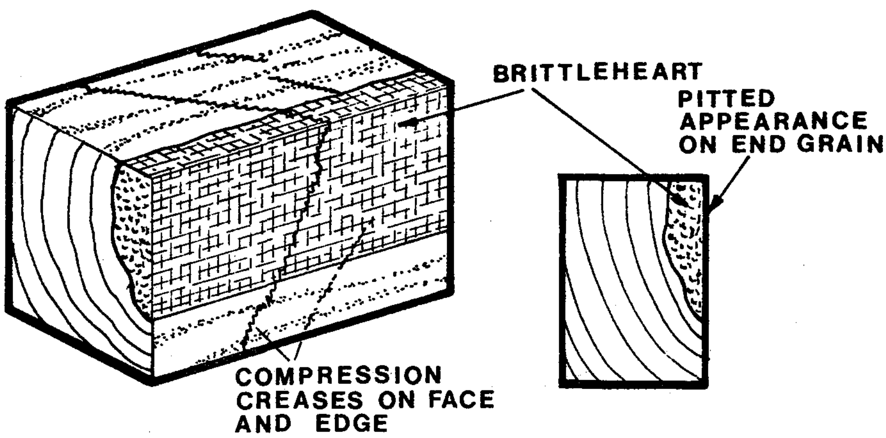


Figure 3.13 BRITTLEHEART

TABLE 16

UNIDO SIMPLIFIED STRESS GRADING RULES FOR TROPICAL HARDWOOD TIMBERS

MAXIMUM PERMISSIBLE DEFECTS FOR EACH GRADE		
TYPE OF DEFECT	STRUCTURAL NO. 1	STRUCTURAL NO. 2
Slope of grain	1 in 16	1 in 11
Interlocked grain	1 in 6	1 in 4
Knots-		
Limiting dimension	One eigth of the thickness or width to which it is related up to a maximum of 38 mm diameter.	One quarter of the thickness or width to which it is releateed up to a maximum of 75 mm diameter.
Longitudinal separation	Only one knot allowed per metre of length.	Only one sizeable knot allowed per metre of length. Where two or more knots are separated lengthwise by less than twice the width of the piece, the sum of the knots shall be checked against the limiting dimension.
Fissures*		
Shallow fissures	Not to exceed one sixth of the thickness	Permitted
Moderate fissures	None	In length, not to exceed 0.2 times the length or 1.5 times the width, whichever is the lesser.
Large fissures and splits	None	permitted only at the ends and limited as above.

* refer to the definitions on page 57

TABLE 16 continued

UNIDO STRESS GRADING RULES FOR TROPICAL HARDWOOD TIMBERS

MAXIMUM PERMISSIBLE DEFECTS FOR EACH GRADE		
TYPE OF DEFECT	STRUCTURAL NO. 1	STRUCTURAL NO. 2
Resin pockets	As for fissures	As for fissures
Distortion-		
Spring	3.5 mm in 2 m length	7 mm in 2 m length
Twist	None	1 mm per 25 mm of width in any 2 m length
Cup	None	1 mm per 25 mm of width
Bow	None	15 mm per 2 m length
Insect holes-		
Pin holes	16 pinholes in a square of 100 mm sides	32 pinholes in a square of 100 mm sides
Shot holes and grub holes	2 in a square of 100 mm sides	4 in a square of 100 mm sides
Large borer holes	None	2 holes of 6 mm dia. max. in a square of 100 mm sides
Wane	1/6 the sum of width and thickness	1/4 the sum of width and thickness

TABLE 16 continued

UNIDO STRESS GRADING RULES FOR TROPICAL HARDWOOD TIMBERS

MAXIMUM PERMISSIBLE DEFECTS FOR EACH GRADE		
TYPE OF DEFECT	STRUCTURAL NO. 1	STRUCTURAL NO. 2
Bark pockets and included phloem	None	The length of bark pockets and strands of included phloem intersecting the ends of a piece shall not exceed the width of the piece. Elsewhere not to exceed 1.5. times the width of the piece.
Stain free from decay	Permitted	Permitted
Other defects		
Compression failures	None	None
Tension wood	None	None
Fungal decay	None	None
Brittleheart	None	None
Boxed heart	Not permitted in basic sawn sizes where either the thickness is equal to, or less than 100mm, or the width is equal to or less than 225mm.	

TABLE 17

GRADE RATIOS FOR STRUCTURAL NO. 1 AND STRUCTURAL NO. 2 HARDWOOD TIMBERS

PROPERTY	RATIO	
	Structural No.1 Grade	Structural No.2 Grade
Bending	0.80	0.67
Tension*	0.60*	0.60*
Compression parallel to grain	0.90	0.88
Compression perpendicular to grain	0.83	0.75
Shear parallel to grain	0.83	0.67
Mean modulus of elasticity	1.00	0.95

* of bending i.e. 0.60 x 0.80 - Structural grade No. 1
or 0.60 x 0.67 - structural grade No. 2

GRADING RULES FOR TROPICAL SOFTWOODS

Permissible limits of characteristics for two visual stress grades namely STRUCTURAL GRADE No.3 and STRUCTURAL GRADE No.4 are given in Table 18 and allowable stress levels for each grade are given in Table 19.

Measurement of characteristics

The measurement of characteristics for softwood grading require the same limitations as for tropical hardwoods, with the exception of brittleheart, which does not apply, knots and rate of growth.

Knots - definition

Splay knot - A knot cut more or less parallel to its long axis so that the exposed section is definitely elongated (see Figure No. 3.14).

Arris knot - A knot which emerges on an arris (see Figure No. 3.15).

Edge knot - a knot on the edge of the material other than a splay knot or arris knot (see Figure No. 3.14).

Margin knot - a knot appearing on a face outside the middle half of the depth of the face near to or breaking through an edge (see Figure No. 3.16).

Face knot - a knot appearing within the middle half of the depth of the face (see Figure No. 3.14).

KNOT MEASUREMENTS

STRUCTURAL No. 3 GRADE – ⅓ of the dimension
STRUCTURAL No. 4 GRADE – ½ of the dimension

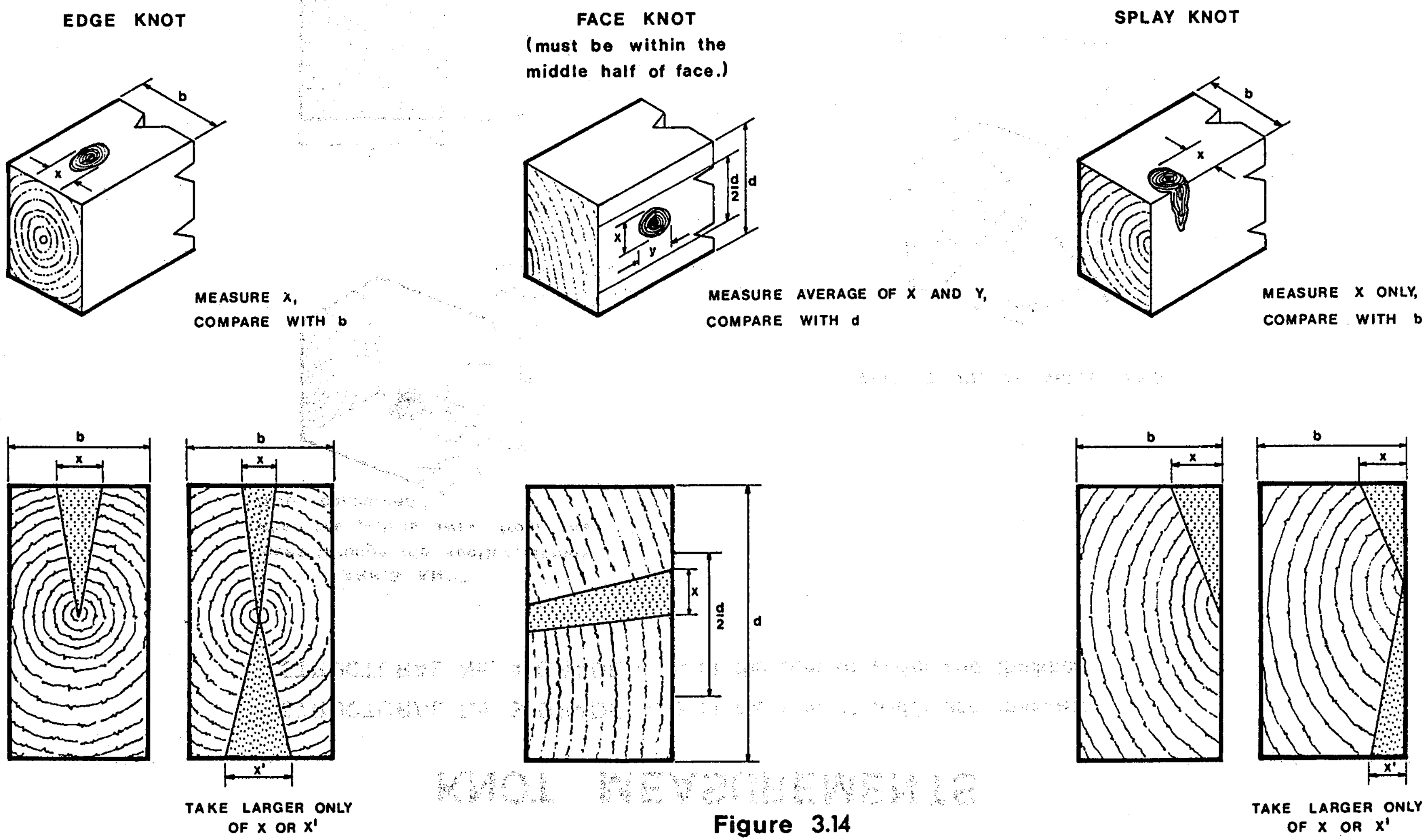


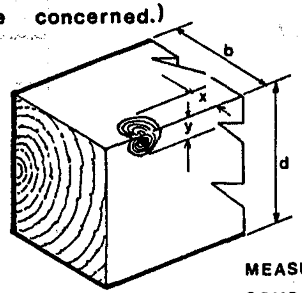
Figure 3.14

KNOT MEASUREMENTS

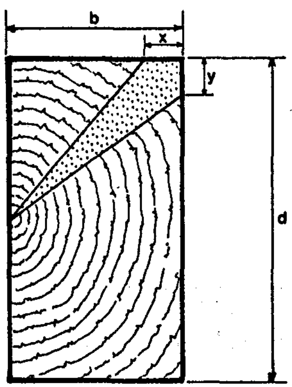
STRUCTURAL No. 3 GRADE – $\frac{1}{6}$ of the sum of width and thickness

STRUCTURAL No. 4 GRADE – $\frac{1}{5}$ of the sum of width and thickness

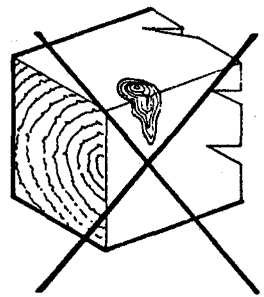
ARRIS KNOT
(goes through the section, occurs when the pith is away from the face concerned.)



MEASURE X AND Y
COMPARE (x+y) WITH (b+d)



THIS IS NOT AN ARRIS KNOT



IT IS A SPLAY KNOT

Figure 3.15

KNOT MEASUREMENTS

STRUCTURAL No. 3 GRADE – 1/5 of the dimension
STRUCTURAL No. 4 GRADE – 1/3 of the dimension

MARGIN KNOT

FACE KNOTS - OTHER THAN THOSE CONTAINED WITHIN THE MIDDLE HALF OF THE FACE.

KNOT CLUSTERS

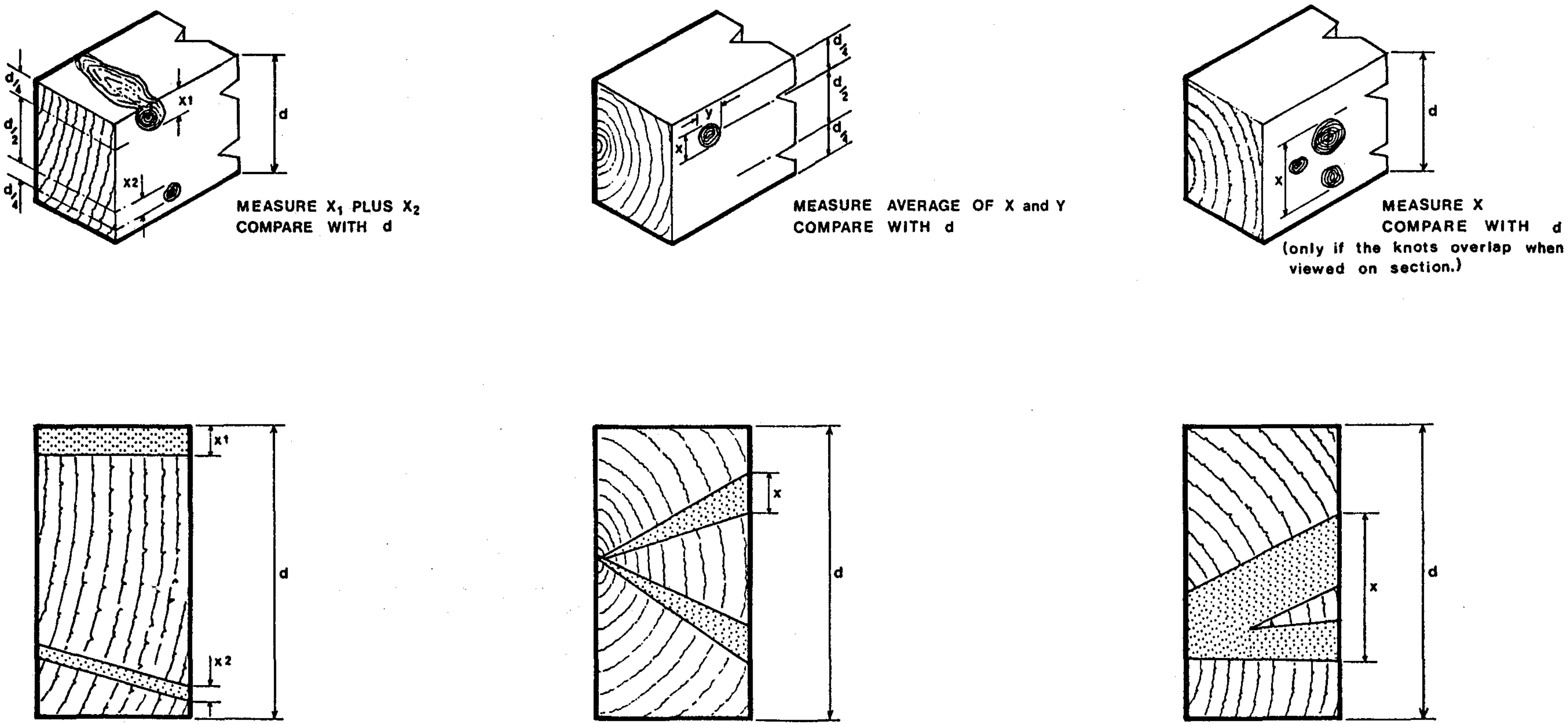


Figure 3.16

Rate of growth (see Figure 3.17)

Measurement of growth rate is taken at one end of the piece. The rule should be laid with the zero at the pith, the first 25mm from the pith being disregarded due to the erratic nature of the rate of growth initially. The reading is taken over a span of 75mm , from 25 - 100mm and the numbers of complete years growth rings are counted. The answer is then divided by 3 to establish the number of rings per 25mm.

Should the pith not be present, a line of 75mm at right angles to the growth rings, passing through the centre of the end section can be taken. Divide the number of rings crossing the line by 3 as described above.

Where the grade limitations are only just met the other end of the piece should also be examined.

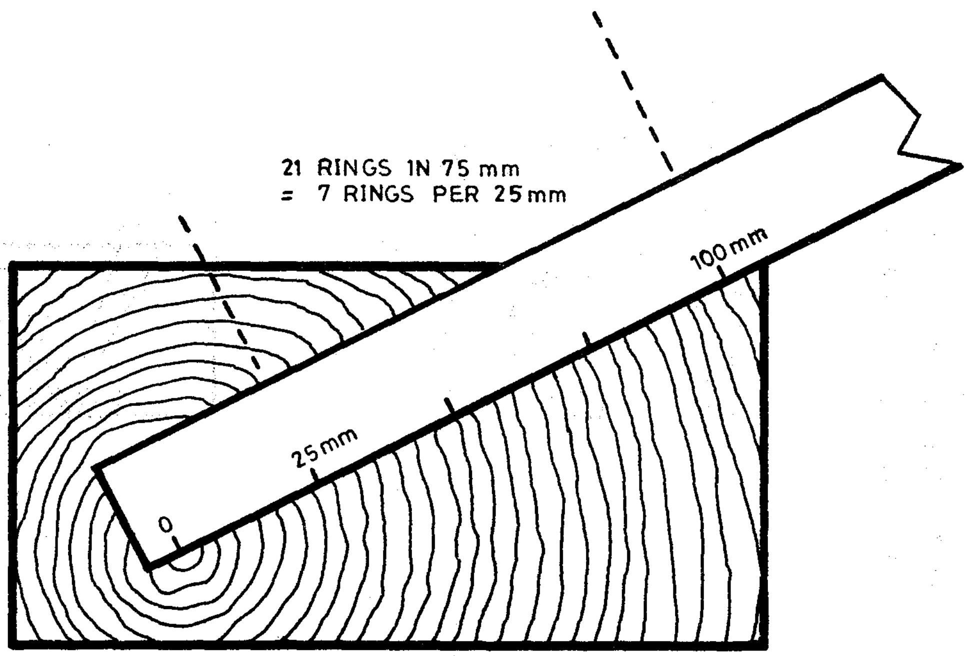


Figure 3.17 MEASURING GROWTH RATE

TABLE 18

UNIDO SIMPLIFIED STRESS GRADING RULES FOR TROPICAL SOFTWOOD TIMBERS

TYPE OF DEFECT	MAXIMUM PERMISSIBLE LIMITS FOR EACH GRADE	
	Structural No. 3 grade	Structural No. 4 grade
Slope of grain	1 in 10	1 in 6
Knots -		
Edge knots) Splay knots) Face knots)	1/3 of the dimension of the face on which it appears	1/2 of the dimension of the face on which it appears
Arris knots	1/6 of the sum of the width and thickness	1/5 of the sum of the width and thickness
Margin knots /knot clusters	1/5 of the thickness	1/3 of the thickness
Fissures*		
Shallow fissures	Not to exceed 1/6 of the thickness of the piece	permitted wherever they occur
Moderate fissures	Not more than 1/4 of the length to a maximum of 600mm	Not more than 1/4 of the length to a maximum of 900mm
Large fissures	None	Not more than 600mm shall be permitted at the end of the piece if their length does not exceed 1.5 times the width of the piece
Resin pockets	As for fissures	As for fissures

TABLE 18 continued

UNIDO SIMPLIFIED STRESS GRADING RULES FOR TROPICAL SOFTWOOD TIMBERS

TYPE OF DEFECT	MAXIMUM PERMISSIBLE LIMITS FOR EACH GRADE Structural No. 3 grade	 Structural No. 4 grade
Approximate limits of distortion		
Bow (per 2m length)	In a thickness of 38mm should generally not exceed 30mm In a thickness of 75mm and greater should generally not exceed 10mm (Intermediate sizes may be determined by interpolation)	
Spring (per 2m length)	In a width of 63 mm should not exceed 10 mm In widths of 250mm and greater should not exceed 5mm (Intermediate sizes may be determined by ineterpolation)	
Cup	Should generally not exceed 1mm per 25mm of width	
Twist (per 2m length)	Should generally not exceed 1.5mm per 25mm of width	
Wane	1/4 of the thickness or 1/4 of the width depending on the surface on which it occurs	1/3 of the thickness or 1/3 of the width depending on the surface on which it occurs**
Rate of*** growth, average width of annual ring	Not more than 6mm	Not more than 10mm
Insect holes	Pinholes and wormholes are permitted to a slight extent in a few pieces provided that there is no active infestation. Wood wasp holes are not permitted.	
Stain free from decay	Blue stain in sapwood to an acceptable extent for appearance	

TABLE 18 continued

UNIDO SIMPLIFIED STRESS GRADING RULES FOR TROPICAL SOFTWOOD TIMBERS

MAXIMUM PERMISSIBLE LIMITS FOR EACH GRADE		
TYPE OF DEFECT	Structural No. 3 grade	Structural No. 4 grade
Tension wood Fungal decay Other abnormal defects	None	None

* Refer to the definitions on Page 57

** Except where it is not nearer than 300mm from either end of the piece, the amount of wane may be upto one half the dimension of the surface on which it occurs, within a single continuous length not exceeding 300mm.

*** Refer to page 70 for measuring instructions.

TABLE 19

GRADE RATIOS FOR STRUCTURAL NO. 3 AND STRUCTURAL NO. 4 SOFTWOOD TIMBERS

PROPERTY	RATIO	
	Structural No.3 grade	Structural No.4 grade
Bending	0.50	0.35
Tension	0.35	0.24
Compression parallel to grain	0.63	0.44
Compression perpendicular to grain	0 76	0.68
Shear parallel to grain	0.54	0.54
Mean modulus of elasticity	1.00	0.90

Chapter 4 - MOISTURE CONTENT AND SEASONING

Timber in the wet ('green') condition contains a large amount of water; to enable the timber to give satisfactory service in use, most of this water has to be removed.

The object of seasoning timber is to remove the extra moisture under controlled conditions with as little damage as possible, thus making the timber more stable. When it is dried, the strength properties and workability of wood improves and liability to insect and fungal attack decreases.

Hygroscopic materials, including wood, have a tendency to change dimensions in response to changes in moisture content; expanding or decreasing as the moisture content responds to changes in relative humidity. This response is referred to as moisture movement.

Wood, drying from the wet ('green') condition which existed in the tree, retains its original dimensions until the contained moisture falls to about 30 per cent of the dry weight of the timber. From this level, known as the fibre saturation point, the wood shrinks as it dries. Similarly, expansion occurs as moisture is increased in dried wood to a maximum of about 30 per cent. Any increase beyond this level will not result in further expansion. Moisture movement can involve distortion such as bow, twist or spring.

For structural work, timber should be dried to within five per cent of equilibrium moisture content (EMC). This value refers to the moisture content which would be attained in service. EMC depends upon the relative humidity and the temperature of the surroundings and the following may be considered a rough guide.

	Precentage of EMC
Hot dry regions (desert, semi-desert and savanna)	10 - 12
Tropical highlands (above 1500M)	12 - 14
Low tropical regions, rain forests	14 - 18

(Other climatic conditions not are not included).

MEASURING MOISTURE CONTENT

The moisture content of wood may be assessed by several means. Two methods have become established as standard practice:

a) Oven test method.

Small samples are selected as representative, and cut from the wood to be tested. The cut samples are weighed, dried at 100 deg. C and reweighed. The moisture content is calculated from the formula:-

$$\frac{\text{Initial weight (wet weight) - Final weight (dry weight)}}{\text{Final weight (dry weight)}} \times 100$$

- moisture content per cent

or

$$\frac{\text{Weight of water}}{\text{Dry weight}} \times 100$$

- moisture content per cent

Oven testing indicates the moisture content of the whole sample. Generally, moisture in a piece of wood does not occur uniformly throughout the thickness, width and length, the moisture content at the surface often being very different from that of the core of the wood. The gradients of moisture content produced by these variations are difficult to assess by the oven test method without destroying much of the tested timber. Obviously, if moisture contents are required of manufactured items then the method may be quite unsuitable as the samples are usually permanently damaged.

b) Electrical resistance moisture meter method

Purpose manufactured instruments are available which measure the variations in electrical resistance caused by differing moisture contents. Moisture contents are read directly from the meters or adjusted by a speciesfactor. Insulated probes are available which penetrate the wood and will indicate moisture content at the depth of the probe tips. Such probes may be used to assess moisture contents anywhere within a timber consignment or item at any depth in a piece of wood, limited only by the length of the probes. The portable instruments in general use are reasonably accurate only betweem the moisture contents of about 6 and 24 per cent, a range that covers all moisture contents commonly recommended for normal service conditions.

METHODS OF DRYING

The two most practical methods of drying timber are air drying and kiln drying:

Air drying

In air drying, green timber is stacked in open sheds on a level well-drained site, (see Figure 4.1). Stacks should be erected on good solid foundations and in order to allow ample ventilation, the bottom layers should be raised above the ground. Where a concrete base is not possible, the soil under the stack should be poisoned with an appropriate insecticide solution. The layers of timber should be separated by using piling sticks of clean dry timber, the thickness of the sticks varying from 13mm to 38mm depending on the timber species and outside temperatures. Wherever possible, different species and thicknesses should be stacked separately.

Timber may also be air dried by the stacking and self-crossing of poles, see Figure No. 4.2. The bottom layers must be also be raised above the ground and the soil treated as above.

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

One of the commonest forms of degrade which occurs during air seasoning is checking or splitting at the ends of boards. This maybe reduced by applying to the ends a moisture proof coating such as bituminous paint or wax emulsion.

Kiln Seasoning

In kiln seasoning the timber is placed in a chamber or a kiln (see Figure No. 4.3) in which the temperature, humidity and the flow of air can be controlled to achieve the maximum rate of drying and to reduce the development of defects. The timber has to be carefully stacked so that a uniform air circulation can be achieved. Various kiln schedules have been devised to dry timber as rapidly as possible without the development of defects. Since the rate of drying will depend, in addition to other factors, upon the cross-section of the timber, it is important that a kiln should always be loaded with wood of similar dimensions. Kiln seasoning allows timber to be dried to any desired moisture content appropriate to its end use in a predictable time. A further advantage is that special treatments, such as reconditioning and sterilisation can be carried out using the same equipment.

Solar Drying

Solar drying uses the sun to heat the air inside the kiln where timber is already stacked. The heated air is circulated through the timber stack using fans. This method is not yet in substantial commercial use.

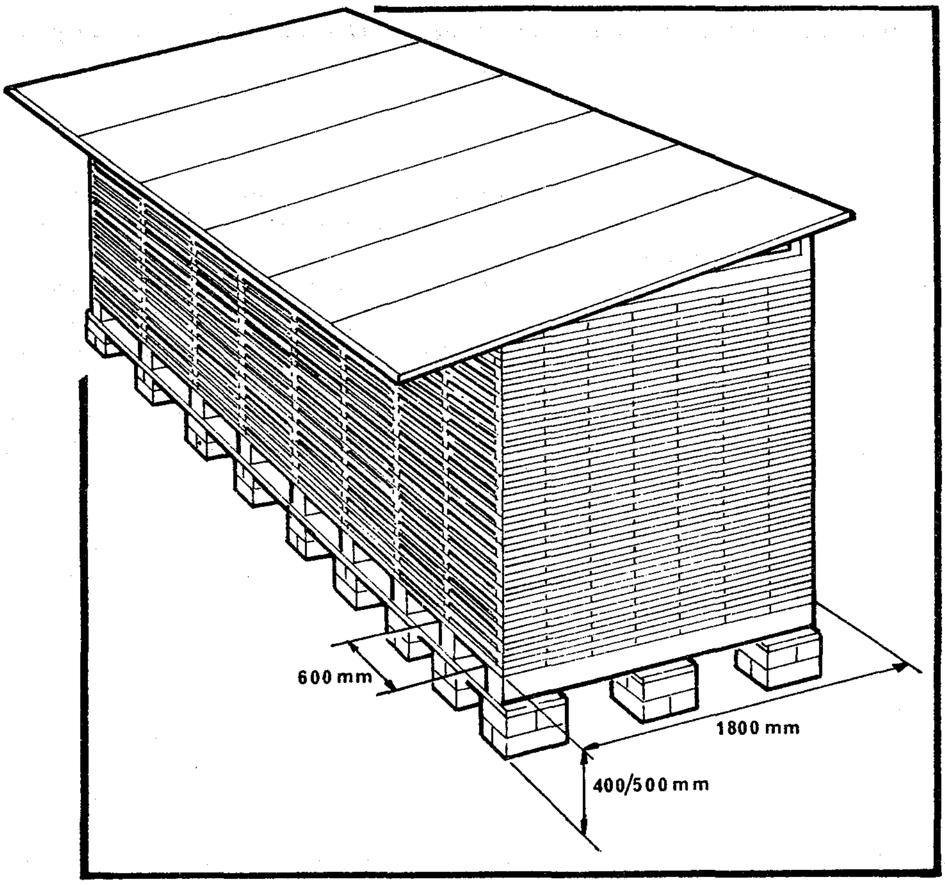


Figure 4.1 AIR SEASONING OF TIMBER

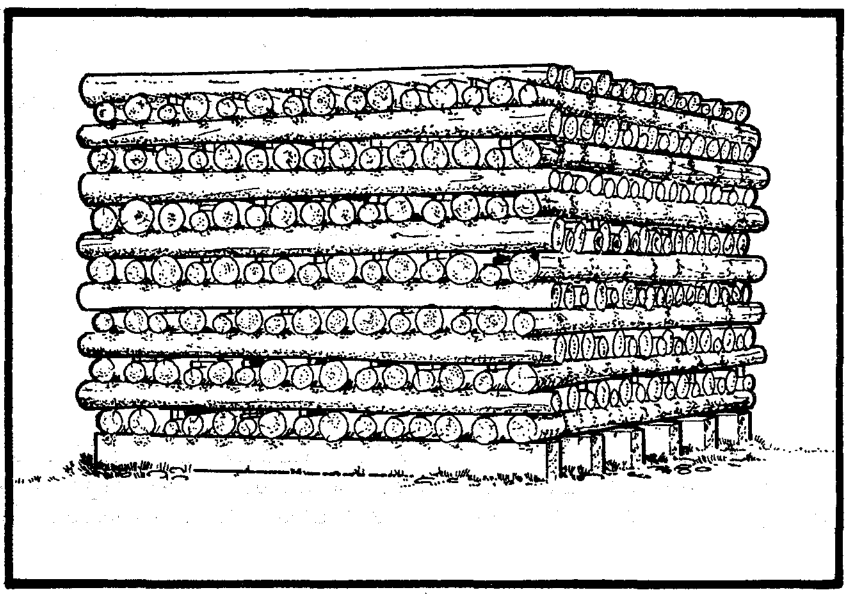


Figure 4.2 SELF - CROSSING OF POLES

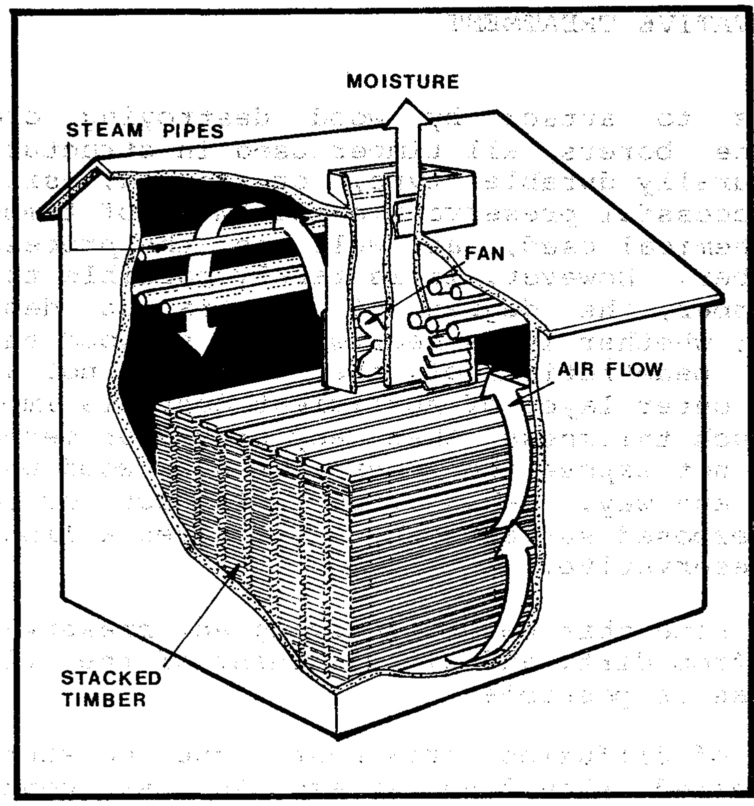


Figure 4.3 KILN WITH OVERHEAD FAN

Other Methods of Drying

There are many other methods of drying timber such as salt seasoning, solvent seasoning, boiling in oily liquids, vacuum drying, drying in superheated steam, vapour drying, press drying, radio frequency drying, etc. None of these however, are in general commercial use, nor are they likely to be encountered in projects such as the prefabricated modular bridge system.

Chapter 5 - PRESERVATIVE TREATMENT

As timber is liable to attack by wood destroying organisms, fungi, insects and marine borers, all timber used in structural work should either be of a naturally durable type, or treated, using an appropriate preservative. Successful preservative treatment of timber depends upon the preservative chemical used, as well as the process by which it is applied to the timber. However, it is rarely possible to obtain complete impregnation of timber, the degree of penetration depending upon the species of timber: whether it is heartwood or sapwood and the treatment process. Complete penetration of the wood is not always necessary, provided that an outer layer of sufficient depth is impregnated. This layer must be of such thickness that any cracks or mechanical damage to the timber will not expose the inner untreated wood when the treated layer is broken in any way. When timber is cut or bored after being treated the newly exposed surfaces should be given a liberal application with a suitable preservative.

It is important to note that before applying any preservative, the timber should be free from dirt, and all machining of the timber should be completed, as far as is possible.

With the exception of diffusion treatment, the moisture content of the timber to be treated should not exceed 30 per cent. The maximum permissible moisture content depends to some extent upon the process, type of preservatiuve and the kind of timber.

TYPES OF PRESERVATIVE CHEMICALS

Wood preservatives may be divided into three main groups, namely tar oils, water borne and organic solvents.

<u>Tar-Oil Preservatives</u>

a) creosote

b) creosote - coal - tar solutions

c) creosote - petroleum solutions

These compounds are resistant to leaching and hence suitable for exterior work, in water or in ground contact. They are not as a rule corrosive to metals. The principal advantages of creosotes are their high toxicity against fungi, insect and marine borers. The disadvantages being that treated timber has a strong odour and is difficult to paint. These tar-oil preservatives, detailed above, may be applied by vacuum/pressure, hot and cold open tank, brushes, spraying or immersion. For exterior work, the recommended methods are either vacuum/pressure or hot and cold open tank.

Water-borne Preservatives

Copper/Chrome/Arsenate - CCA

Chromated Zinc Chloride - CZC

Fluor/Chrome/Arsenate/Phenol - FCAP

Ammoniacal Copper Chromate - ACC

Borofluoride/Chrome/Arsenic - BFCA

Sodium Borate/Boric Acid Compounds

These preservatives require special methods of application to ensure deep penetration and are not suitable for brush treatment. Drying of the timber is necessary after treatment. The treated timber is odourless and can be painted over when it is dry.

Water-borne preservatives based on a combination of copper, chrome and arsenic are applied to seasoned timber by vacuum/pressure methods, whilst boron compounds are applied to green timber by diffusion.

Timber treated with preservatives containing CCA compounds is suitable for use in wet or dry conditions, including ground contact.

Organic Solvent Preservatives

Pentachlorophenol

Metallic Napthenates (Copper and Zinc Napthenates)

Tributyl tin oxide

Organo chlorine compounds (Lindane and Dieldrin)

Pentachlorophenyl Laurate

These preservatives are readily absorbed by the timber and so may be applied by brush, spray or immersion. For a deeper penetration, methods such as double vacuum may be used. They do not cause timber to swell.

Treated timber may be painted and is not corrosive to metals.

METHODS OF TREATMENT

The method used in applying a preservative is as important as its chemical composition and there are two main techniques, namely pressure and non-pressure methods.

Tar oil preservatives such as Creosote are applied by pressure treatment, hot and cold open tank methods, and also by immersion and brushing. Water-borne chemicals are normally used in pressure treatment and diffusion processes, while organic solvents are used in double vacuum or other non-pressure methods.

Brushing and Spraying

The simplest method of applying wood preservative is by means of a brush. However, there is always the risk of incomplete coverage and of not allowing the timber to take up as much liquid as it would if completely immersed. Therefore, the preservative should be applied liberally, allowing the timber to absorb as much as possible, particularly in the areas of end grain, splits and joints. A certain amount of protection can be expected from this method but is slight compared with that of other methods.

For timber which is fully exposed, it is of little value.

Immersion

Immersion simply involves dipping timber in a tank of preservative. The method is a little better than brushing and spraying because all surfaces of the timber can absorb liquid freely. The method is often referred to as dipping when the timber is immersed for less than 10 minutes and steeping when it lasts for several hours or days. Even the more thorough forms of this treatment however, can provide little protection to timber under severe conditions, since the preservative does not penetrate deeply enough.

Diffusion Treatment

Diffusion treatment can be applied only on green timber. The process is to apply a water-borne preservative, usually as a concentrated solution, to the surface of the timber and to store it close-piled (block-stacked) and wrapped in plastic sheeting, (see Figure 5.1). The chemicals normally used are either Boron compounds or Fluorine compounds and sometimes a combination of both. The process time required for diffusion is several weeks depending upon the species, thickness of the timber and its moisture content at the time of treatment. After diffusion has occurred the timber is seasoned in the normal way. Since there is a possibility of the preservative being slowly washed out if exposed, timber treated by diffusion should not be used in contact with the ground or exposed to the weather. To overcome this to a greater extent, double diffusion treatment is employed using preservative salts which are highly resistant to leaching. This is done by soaking green timber in one chemical solution and then in a second solution of another chemical. After diffusion, the two chemicals react with one another to form an insoluble precipitate.

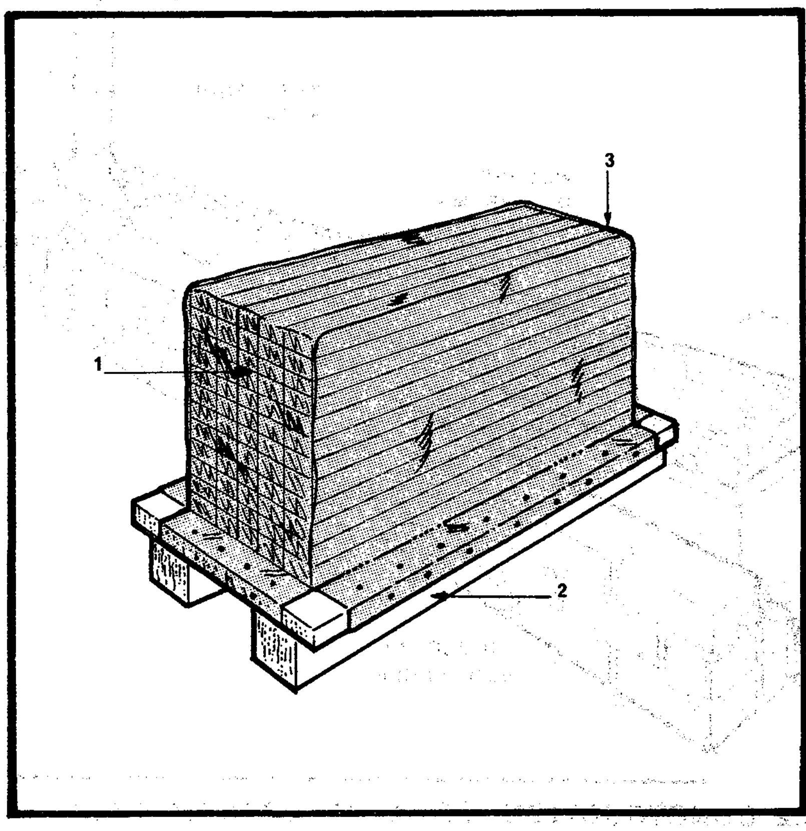


Figure 5.1 TIMBER STACKED FOR DIFFUSION TREATMENT

Hot and Cold Open Tank Method

In this method, timber is immersed in cold preservative which is then heated to about 85 to 95 degrees C, and maintained at this temperature for an hour or more. The preservative is then allowed to cool down before the wood is removed. It is important that the timber is kept completely submerged during the whole process, which normally takes several hours. The temperature and the time can be varied to some extent, depending upon the species and the size of the timber. Any preservative that remains stable when heated may be used with the hot and cold open tank process, and in most cases creosote is used.

The open tank process is a simple method of obtaining a good level of treatment, (see Figure 5.2).

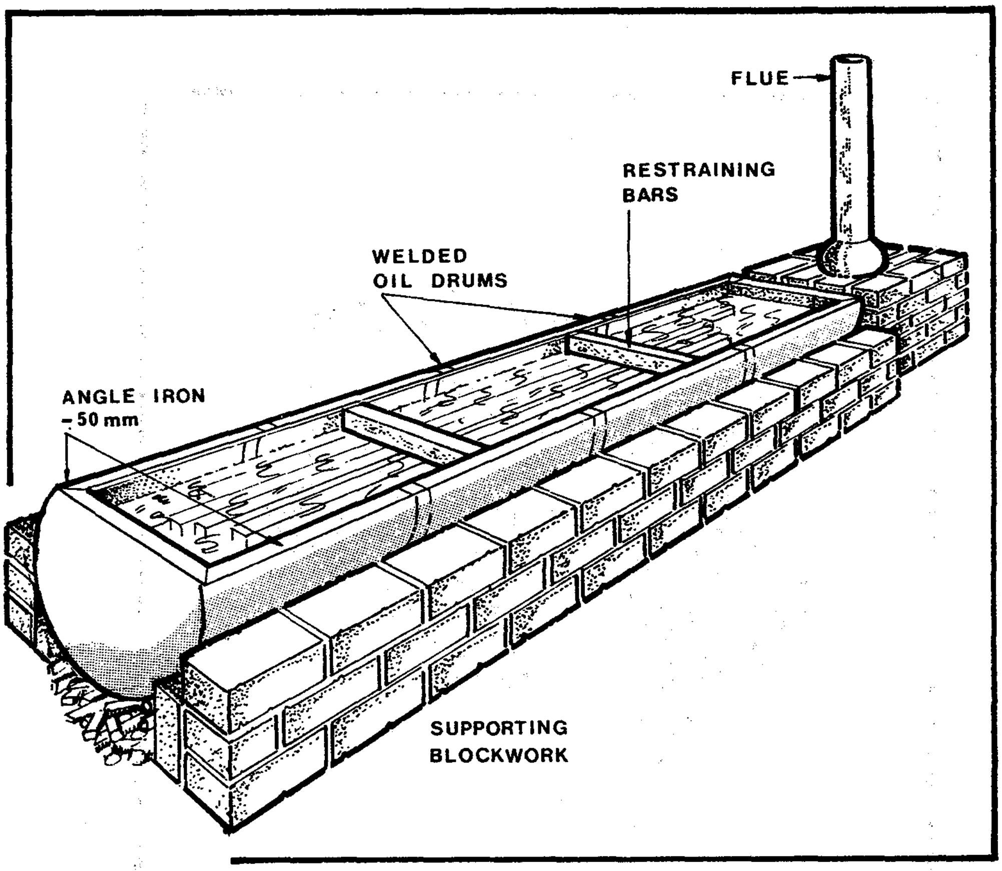


Figure 5.2 CONSTRUCTION OF A TREATMENT TANK

Sap Displacemwnt Methods

In sap displacement methods, the sap in freshly-felled timber is displaced with an aqueous solution of preservative. The method can only be applied to green poles and posts.

Boucherie Method

In this, freshly cut unpeeled poles or posts are placed on the ground with butt ends slightly elevated. Water-tight caps are fitted into the butt end and these caps are connected to a container at a higher level (normally about 10M high). The container holds a water-borne preservative such as CCA. It takes several days to penetrate the sapwood completely with little or no penetration of the heartwood.

A variation of this is the Gewecke process which employs suction at one end while applying hydrostatic pressure at the butt end.

Pressure Methods

Pressure impregnation methods are the most important and successful techniques for applying preservatives to timber. The procedure is to stack timber in a steel pressure vessel and to force chemical into the timber under pressure. Pressure methods give deeper and more uniform penetration as well as higher retentions of preservative in the timber. Hence, they provide more protection than the other methods. Although there are a number of different processes which involve pressure treatment, the essential layout of the plant and equipment is always similar. Pressure processes are mainly of two types, either full-cell or empty-cell treatments, depending upon how the application of vacuum and pressure is carried out. (See Figure 5.3 below).

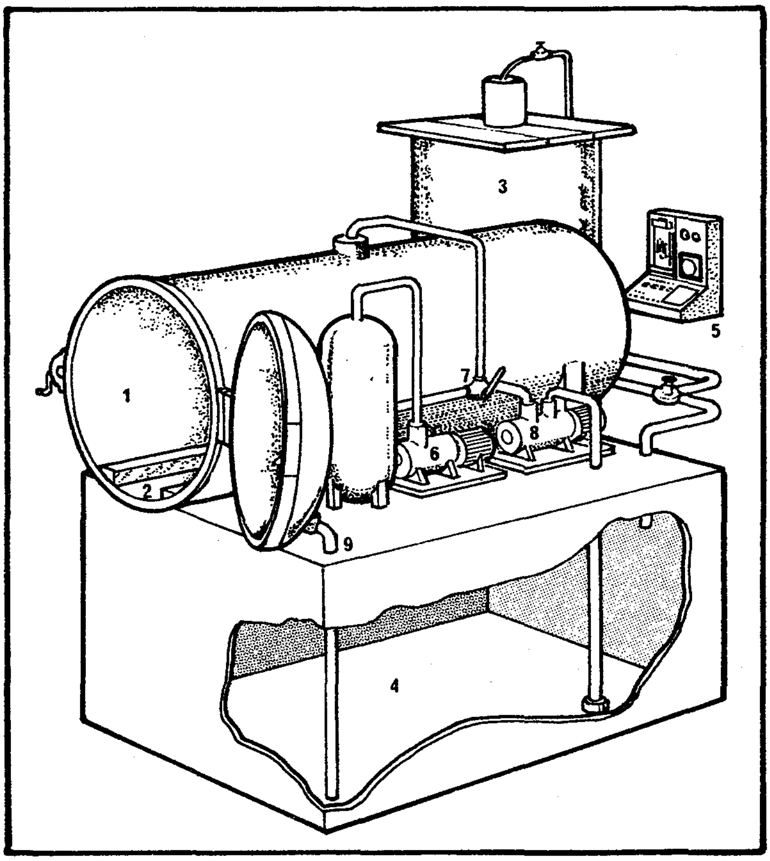


Figure 5.3 VACUUM/PRESSURE PROCESS EQUIPMENT

Process summary

Load to be treated is moved into pressure vessel (1) on the rails (2). Preservative mixed (3) to give correct solution and transferred to storage tank (4), controlled by console (5). Initial vacuum drawn (6) and solution pumped into vessel via (7). Pressure increased (8), held for specified time and released. Solution drained (9). Final vacuum drawn (6) to partly dry wood surface.

Double Vacuum Treatment

The double vacuum method employs a cylinder in which the timber is enclosed, see Figure 5.4 below. From this, an initial vacuum is drawn and held for a period of time before the cylinder is flooded with preservative liquid, normally an organic solvent. The vacuum is then released so that the pressure in the cylinder increases, normally to atmospheric pressure. The preservative liquid is forced into the wood at this stage. The timber may be left to soak for a period before the preservative is removed from the cylinder, and then a final vacuum is applied. A further process, the full cell vacuum-pressure impregnation process is detailed in Figure 5.5 on the following page.

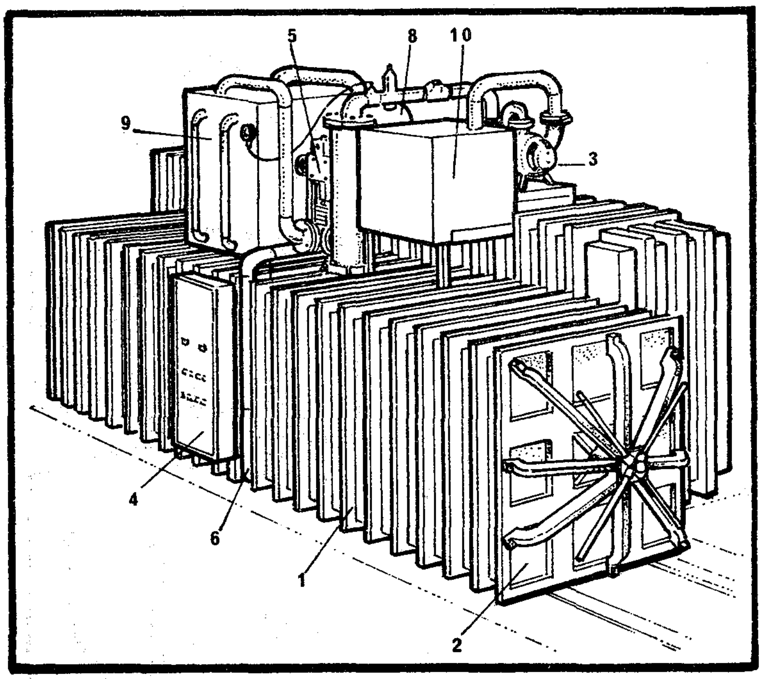


Figure 5.4 DOUBLE VACUUM PROCESS EQUIPMENT

Process summary

Load wheeled into treatment vessel (1) and door (2) sealed. Vacuum pump (3) activated (4) and air drawn from vessel via valve (5) and exhausted to atmosphere (6). Drain valve opened, vessel flooded with preservative (7). Pressure increased to atmospheric (6) or to 2.06 x 10X N/mx by compressor (8) and held for specified time. Preservative drained back to storage (7), final vacuum drawn, held for a time then released; amount absorbed is measured (9).

SCHEMATIC DIAGRAM OF THE FULL CELL VACUUM - PRESSURE IMPREGNATION PROCESS

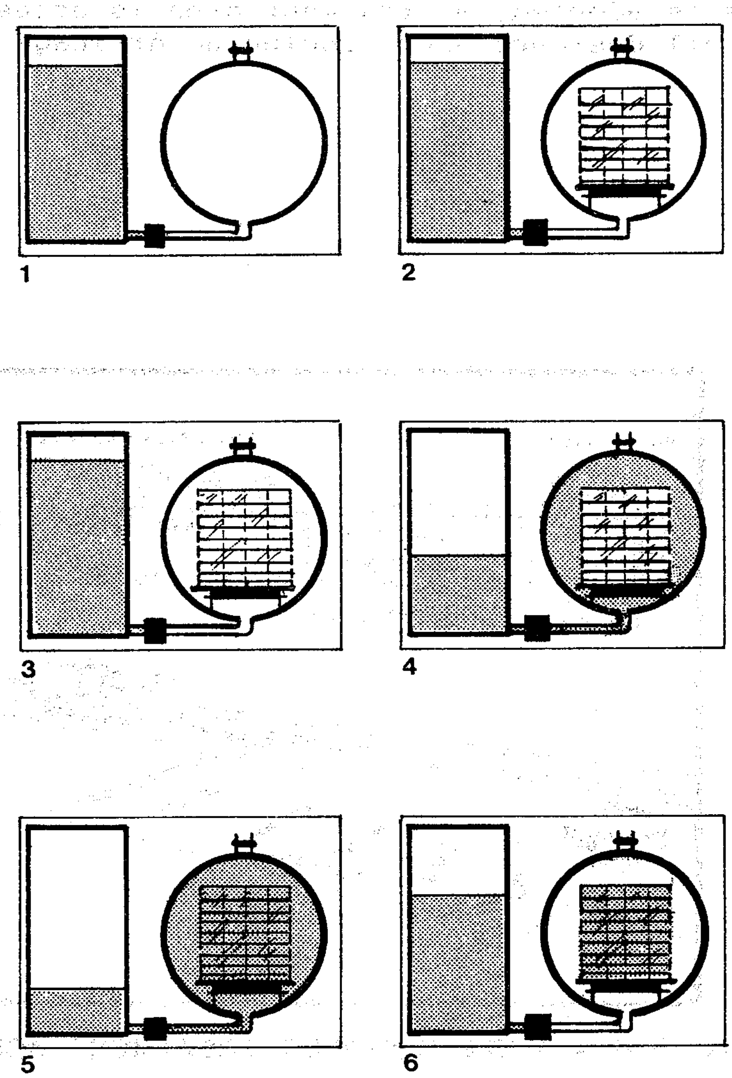


Figure 5.5

1) Treatment plant before use, with storage tank filled with preservative. Pressure chamber empty.

2) A charge of wood has now been moved into the pressure chamber; the chamber is then sealed.

3) The pressure chamber and wood is evacuated by means of the vacuum pump.

4) Preservative is drawn into the pressure chamber by means of the vacuum.

5) Pressure is applied to the preservative in the chamber; preservative is forced deep into the wood.

6) Surplus preservative is pumped back into the storage tank, leaving preserved wood ready for removal from the pressure chamber.

Treatment areas

Whichever process is adopted, a treatment area is necessary, Figure 5.6 below depicts a well designed area, including drainage facilities.

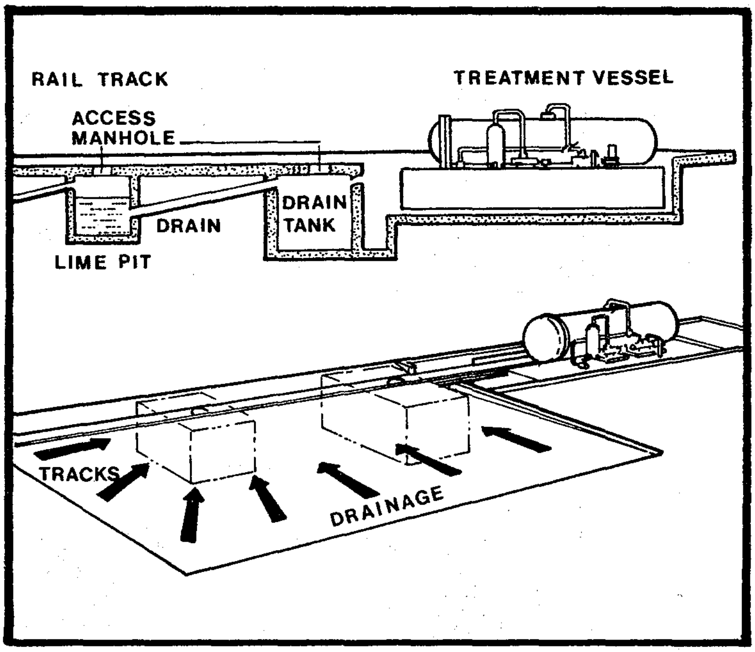


Figure 5.6 A WELL-DESIGNED TREATMENT AREA

Selecting a Method of Treatment

The following table provides a guide on the selection of an appropriate method of treating the timber for different end uses. For detailed recommendation, relevant country standards or codes of practice should be consulted.

TABLE 20

Methods of Applying Wood Preservative

Usage	Suitable Processes				
	Pressure	Open tank	Double vacuum	Diffusion	Immersion
Sea or fresh water	*				
In contact with the ground	*	*			
Outside but not in ground contact –					
unpainted	*	*	*		*
painted	*		*	*	*
Interior timbers – High humidity heavy condensation	*		*	*	
Interior timbers – insect attack low risk of decay	*		*	*	*

Based on D. F. Purslow, BRE.

TABLE 21

RECOMMENDED RETENTION OF PRESERVATIVE FOR BRIDGE TIMBERS

	Kilogrammes per cubic metre	Pounds per cubic foot
Creosote	96	6
Creosote - coal - tar solutions	96	6
Creosote - petroleum solutions	112	7
Water-borne Preservatives		
Copper/Chrome/Arsenate (Celcure, ASCU Greensalt, Wolman salts CCA, Erdalith, Langwood, Tanalith, Treatim CCA)	8	0.5
Ammoniacal Copper/aresnate (Chemonite)	5	0.3
Chromated Zinc Arsenite (Boliden Salts)	8	0.5
Organic Solvents		
Pentachlorophenol (Protim G.C.)	96	6
Copper Napthenate (Arborsan 101, Camosan 2Y63, Celpruf, Cuprinol exterior)	96	6

GENERAL REFERENCES

In addition to the references cited at the end of each Table of Properties of Timber, the following publications were referred to and some of the figures were directly copied:-

British Standards Institution. Definition of the calorific value of fuels. British Standard 526. London. 1961.

British Standards Insitution. Nomenclature of commercial timbers, including sources of supply. British Standard 881 (Hardwoods) and 589 (Softwoods). London. 1974.

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Part 1. Limit state design, materials and workmanship (for later publication).

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Part 3. Code of practice for trussed rafter roofs, (in course of preparation).

Part 4. Fire resistance of timber structures.
Section 4.1 Method of calculating fire resistance of timber members.
Section 4.2 Method of calclating fire resistance of timber stud walls and joisted floor constructions. (In course of preparation).

Part 5. Preservative treatment for constructional timber. (Revision in course of preparation).

Part 6. Code of practice for timber frame wall design, (for later publication).

Part 7. Recommendations for the calculation basis for span tables (in course of preparation).

British Standards Institution. Tropical hardwoods graded for structural use. British Standard 5756. London, 1980.

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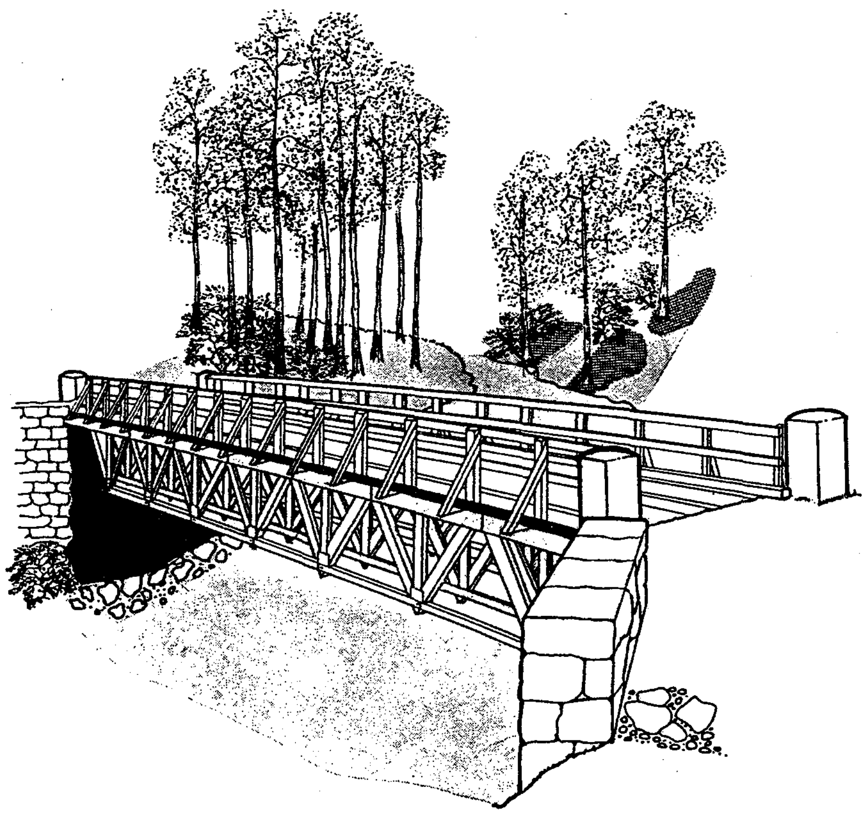
PRE-FABRICATED MODULAR WOODEN BRIDGES



PART 5 • TYPICAL DESIGN • 15m SPAN 4 TRUSS BRIDGE

prepared for

UNIDO • UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA, AUSTRIA

by

TRADA • TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION, UNITED KINGDOM

V.85-25425

PRE-FABRICATED MODULAR WOODEN BRIDGES

PART 5 Typical design - 15m 4 truss bridge

COMPONENT IDENTIFICATION...FIGURE 1

Item number	Description		Figure number
1	Truss modular unit assembly (Drg. no. SE-245-19)	- Light chord	5
	(Drg. no. SE-245-21)	- Heavy chord	15
1a	Timber members for truss modular unit assembly (Drg. no. SE-245-3)	- Light and Heavy chord	6
1b	Nailing pattern for above (Drg. no. SE-245-17)		7
2	Panel plates Mark 1 and 1a (Drg. no. SE-245-30)	- Light chord	8
	Panel plates Mark 9 and 9a (Drg. no. SE-245-34)	- Heavy chord	16
3	Panel plate Mark 5 (Drg .no. SE-245-30)	- Common	8
3a	Panel plates Mark 3 and 3a (Drg. no. SE-245-31)	- Light chord	9
	Panel plates Mark 10 and 10a (Drg. no. SE-245-34)	- Heavy chord	16
4	Panel plate mark 13 (Drg. no. SE-245-31)	- Common	9
5	Steel tension chord, Mark 2 and 2a (Drg. no. SE-245-33)	- Light chord	10
	Steel tension chord, Mark 6 and 6a (Drg. no. SE-245-36)	- Heavy chord	17
5a	Timber tension chord (Drg. no. SE-245-41/1)(40/1)	- Light chord	13/14
	Timber tension chord	- Heavy chord	19/20

COMPONENT IDENTIFICATION...Figure 1 continued

Item number	Description	Figure number
6	Bridge bearing plates Mark 14 and 14a (Drg. no. SE-245-32) - Light chord	11
	Bridge bearing plates Mark 15 and 15a (Drg. no. SE-245-35) - Heavy chord	18
6a	Holding down details - (Drg. no. SE-245-37)	2
	and - (Drg. no. SE-245-20)	3
7	Vertical brace arrangement - (Drg. no. SE-245-38)	24
	Timber members - (Drg. no. SE-245-3)	6
	and - (Drg. no. SE-245-4)	12
	Panel plate Mark 8 - (Drg. no. SE-245-4)	12
8	Details on longitudinal view of assembled bridge (Drg. no. SE-245-8)	21
9	Deck details - (Drg. no. SE-245-8)	22
	and - (Drg. no. SE-245-9)	23
	and - (Drg. no. SE-245-38)	24
10	Horizontal timber brace - (Drg. no. SE-245-8)	21/22
11	Timber tie - (Drg. no. SE-245-8)	21
12	Cross tie - (Drg. no. SE-245-8)	21/22
	and - (Drg. no. SE-245-38)	24
13	Handrail barrier details - (Drg. no.SE-245-8)	21
	and - (Drg. no.SE-245-38)	24
	and - (Drg. no. SE-245-9)	25

COMPONENT IDENTIFICATION...Figure 1 continued

GENERAL NOTES RELATING TO ALL DRAWINGS

1). The following notes are relevant to all of the drawings in this manual and their recommendations should at all times be observed.

All steel in the fabrications detailed to be weldable structural mild steel, flat plate or round bar to specifications on the drawings. The steel should be bright mild steel and prefrably to conform to BS 449 'Specification For The Use Of Structural Steel In Building' and BS 4360 'Weldable Structural Steels'. The steel, flat or bar, to have a minimum ultimate tensile strength of 435 N/mm^2-494 N/mm^2, and a minimum yield stress of 236 N/mm^2.

All welding in the fabrications to be fillet welds as detailed and should be manual shielded arc welding by experienced welders, see A.W.S. 'Code For Welding In Building Construction' for further information. Welding should be in accordance with BS 5135 'Metal-Arc Welding of Carbon and Manganese Steels'. Fillet welds must be to the size specified, and without discontinuities and undercutting of metal.

All steel fabrications in flat plates to be bench marked from the centre line and baseline as detailed in the drawings. All holes to be accurately set-out by scribing and centre-punching. Holes for positioning the steel pins, as in Figure no's. 8, 9, 11, 13, 14, 16, 18, 19, and 20, to be accurately set-out by scribing on the steel plate upper faces, centre-punching for the diameter of the centreline position and pilot drilling using a 4mm diameter pilot drill. Accuracy in the setting-out and marking of all steel fabrications is essential for ease and correctness of truss element assembly.

Holes in steel fabrications, for fitting bolts and steel pins exceeding 12mm finished diameter should be opened-out in stages from the pilot drilling diameter to the finished diameter, as detailed on the drawings, using drilling increments of 12mm diameter as appropriate, to achieve the finished diameter required.

The steel pins detailed in the drawings should be machined to the finished specified diameter. Holes in the steel fabrications to be opened out as necessary during final fitting of the steel pins.

All bracing cleats, secondary plates and steel pins specified as being square to the main plates, should be checked with a steel square whilst tack welding, prior to final assembly.

All burrs and swarf to be removed from steel fabrications after final cutting and drilling.

All steel flat plate and round bar in fabrications to be clean and free from dirt, grease, surface corrosion or scale prior to welding.

2). The notes which follow, referring to critical dimensions, must be closely adhered to.

Critical dimensions are those which must be set-out as first priority dimensions, since the accuracy of the modular truss units and of subsequent bridge trussed construction will depend upon these critical dimensions being acheived.

Critical dimensions should be checked whenever a new jig is made or an exsisting one modified, and during quality control checks of manuafctured panels.

3). The following notes refer to individual fabrications and their appropriate Figure/Drawing no's:-

Panel plates Mark 1, 1a, 9, 9a and 5 to be drilled with 12mm diameter holes, as detailed on Fig. no's. 8 and 16 (Drawing no's. SE-245-30 and 34) to receive the mild steel panel plate dowel pins. These holes may require opening-out to 13.5mm (17/32 inches) diameter to provide a hand sliding fit of the dowel pins into the panel plates.

Panel plates Mark 1, 1a, 9 and 9a, (Fig. no's. and drawing no's. as above) to be fabricated in reverse sided pairs to ensure alignment of all bolt receiving holes and main bearing pins. These plate pairs should be marked for identification and preferably wire bound together.

The 6mm thick mild steel reinforcing End Plate to Tension chord Members Mark 2 (Fig. no. 10, Drawing no. SE-245-33) to be welded to the 10mm thick mild steel Chord Plates and the centreline distance marked-out, before drilling the 40mm diameter bearing holes.

The 40mm diameter bearing holes to Tension Chord Members Mark 2a (Fig. no. 10, Drawing no. SE-245-33) may be drilled in the 12mm mild steel Extension Plates before welding, but, if this is done, a timber bed-jig with distance pins attached must be used for setting-out before final welding.

The 6mm thick reinforcing End Plates to Tension Chord Members Mark 6, (Fig. no. 17, Drawing no. SE-245-36) are to be welded to the 10mm thick mild steel Chord Plates and the centreline distance marked out before drilling the 52mm diameter bearing holes.

The 52mm diameter bearing holes to tension Chord Mark 6a, (Fig. no. 17, Drawing no. SE-245-36) may be drilled in the 15mm mild steel Extension Plates before welding, but, if this is done, a timber bed-jig with distance pins must used for setting-out before final welding.

Panel Mark 8, (Fig.no. 12, Drawing no. SE-245-4) to be set-out in position on the timber Brace Member, and located using nail fixings. The timber Brace Member is then drilled out using Panel Plate Mark 8 as the drilling template. Bolts should be fitted through the timber Brace Member and the steel Panel Plate with the bolt integral heads seating onto the face of Panel Plate Mark 8, (bolt shanks away from the panel plates).

NB. The mild steel dowels used in the Panel plates to be 12mm diameter to correspond with the Panel Plates acceptance holes. The drill depth stop for timber members receiving mild steel dowels, should be pre-set to 50mm and 100mm respectively and the drilling of timbers receiving mild steel dowels to be carried out with the panel plates located in their positions. Mild steel dowels are to be a sliding fit into the receiving holes of the Panel Plates.

4). The following notes refer to the timber members that are detailed in the drawings in this manual.

All timber sections to be preservatively treated by one of the methods given in the Part 4, Timber Technology.

Sawn timber in section should be cut to a width and thickness tolerance on each section dimension of +2mm -3mm maximum in respect of the sawn section dimensions as detailed on Fig.no. 6, (Drawing no. SE-245-3). Critical length dimensions to be cut as accurately as posssible, and all timber members detailed on the drawings to be cut to length, including shaped ends where shown, unless oterwise stated. Holes for bolt fixings to be drilled as specifically noted.

5). The following notes refer to the nailing and fixing of timber members and steel fabrications used in the assembly of modular truss units.

All nailing positions to be pre-drilled to a diameter of 4.00mm prior to receiving 4.88mm diameter (20d) nails, but after the assembly of each truss unit half. The exception to this are the location nails for the Panel Plates Mark 5, 1 and 1a, which may be drilled and nailed at assembly of each truss unit half. Reference should be made to Drawing no. SE-245- 17 for the nailing patterns to attach spacing packs between the Upper Chords.

Bolts, should be Hexagon-Round-Hexagon, Metric Course Threaded; Black Mild Steel Bolts and Nuts. Shank and overall lengths to be as detailed in the drawings. Mild steel washers to be provided as detailed. Bolts to be of an engineering quality, at least complying with the requirements of BS 4190 or similar specifications.

6). The following notes refer to the decking, bracing, handrail construction and completion of a typical modular wooden bridge.

Camber to the bridge trussed-girder structure is automatically provided during assembly and for a 15.0 metre bridge span the camber of the deck level is likely to be in the order of a 60mm to 70mm rise at mid-span.

The timber spacer lengths between adjacent pairs of Tension Chords Mark 2 and 6, (Fig, no's. 10 and 17, Drawing no's. SE-245-33 and 36), are not detailed in the cutting schedule, (Fig. no. 6, Drawing no. SE-245- 3). These lengths should be pre-marked and pre-drilled (using the Tension Chords as templates) with 4.0mm diameter drillings to receive the 4.88mm diameter by 65mm long (6 S.W.G.) fixing nails, as detailed on Fig. no. 26 (Drawing no. SE-245-12). The timber spacer lengths should be preservatively treated.

The 150mm by 50mm section, splay-cut timber tie pieces on the trussed-girder assembly top-chords, are nominal members fixed to each side of the assemblies by nailing, as detailed on Fig no. 21 (Drawing no. SE-245-8). They are primarily required to retain top chord compression joints during erection and launching stages. These members may be left in place in the finished bridge construction. It should be noted that they are not detailed on the cutting schedule Drawing no. SE-245-3 (Figure no. 6) and should be preservatively treated.

The 200mm by 50mmm section trussed-girder assembly Cross Tie timbers Fig. no's. 21/22 (Drawing no's. SE-245-8 and 38), are to be fixed in postion after launching and final positioning of the trussed-girders.

The 100mm by 50mm section by 5000mm long special deck boards are to be laid in pairs as detailed, their positions along the bridge deck being suitably selected as decking proceeds. It is recommended that special deck board pairs be drilled for bolt positions prior to final fixing of the boards. NOTE: Special deck board ends may be left square-cut at brace connections if desired, the alternative is to site-cut the end to suit the line of bracing as shown on Fig. no. 24 (Drawing no. SE-245-38).

The 150mm by 25mm section handrail-barrier capping, as supplied in random length timbers, is to be site-cut to suit construction requirements and fixed in position by nailing, as detailed in Fig. no. 25, (Drawing no. SE-245-9). Capping sections are to be square cut at the ends and butt-jointed, the capping joint positions being staggered from the side rail butt-joints by at least 1200mm.

The 125mm by 50mm section handrail-barrier side rails are to be site-cut to suit the bridge dimensions and fixed in position by nailing as detailed in Fig. no. 25, (Drawing no. SE-245-9). Side rail sections are to be square cut at the ends and butt-jointed over the barrier centreline positions as shown.

The 100mm by 100mm section handrail-barrier support posts may be workshop-cut to the required length, the ends rebated and drilled for bolt positions, as detailed in Fig. no. 25 (Drawing no. SE-245-9).

The 100mm by 50mmm handrail-barrier diagonal brace timbers are to be site-cut (including the shape cut ends), and drilled for bolt positions to suit support post and deck board arrangements.

The 150mm by 150mmm section kerbing timbers, supplied in random lengths, are to be site-cut and jointed as detailed in Fig. no. 25 (Drawing no. SE-245-9), to suit the construction. It is recommended, once kerbs have been cut and laid out to suit their final positions, that they should be marked and drilled for bolt positions before nail fixing into their final position commences.

The 250mm by 50mm section running boards, supplied in random lengths, are to be site-cut and nail fixed as detailed in Fig. no. 24 (Drawing no. SE-245-38). Running boards may be square cut and butt-jointed longitudinally. Butt-joints must be staggered from adjacent board joints by at least 1200mm, and should be avoided over trussed-girder connection positions.

All nails in handrail-barrier timber components are to be counter-punched and set below the surface of the timbers.

Nail fixings are to be as detailed in the drawings and are specified according to the Imperial Standard Wire Gauge (S.W.G.) with corresponding diameters also given. Alternative nails may be used, but they should correspond as closely as possible to the diameters specified. Nail lengths and type to be as detailed in the drawings.

All bolts, mild steel washers for steel and wood, to be as specified in the drawings.

It is recommended that the 3,66mm diameter 100mm long (9 S.W.G.) nails specified for deck board fixings should be 'Lost Head' type or similar.

The 75mm diameter by 2.5mm thick mild steel, flat machined bearing washers, (drilled to receive 50mm diameter pins), are intended to be used to space Panel Chords Mark 2 and 6 linkages off Panel Plates 9 and 9a faces, thus avoiding fouling of the dowel pin fixings to the Panel Plates.

Split pins are to be used on trussed-girder assembly to retain top-chord Panel plates Mark 10 and 11, and Panel Plates Mark 9 and 9a bearing pin assemblies, with steel chord Mark 2 and 6 linkages.

7). The following notes are concerned with the bridge pier abutments:

Opposing pier abutments should be formed square on to one another, and not skewed or offset. Opposing pier caps, particulary at bearing level, should be flat and with a maximum vertical difference between them of no more than 20mm.

Concrete in pier caps should be of structural quality and conform to the following requirements regarding constituents:

(i) Structural Quality Hydrating Cement.

(ii) Minimum cement content by weight of 360 kg. per cubic metre of concrete produced.

(iii) Maximum aggregate size of 20mm, well graded for structural concrete use.

(iv) Suggested water/ cement ratio at production of 0.4 to 0.45.

The strength of the concrete should be as follows:

(i) 20 N/mm^2 Cube strength at 7 days after casting.

(ii) 30 N/mm^2 Cube strength, (Characteristic Strength) at 28 days after casting.

Four test cubes should be taken during the casting of the concrete from each bridge pier cap mix, (eight in total), with 2 by 2 being tested after 7 days and 2 by 2 tested after 28 days.

Grout used at the bearing positions to consist of Structural Quality Hydrating Cement and fine graded aggregate. The strength of the grout should be as follows:

(i) 17 N/mm^2 Cube strength at 7 days after casting.

Two test cubes to be taken at the grouting stage from each bridge pier cap mix (four in total) and to be tested after 7 days.

The reinforcement to the pier caps is to be of mild steel round bar with a minimum ultimate tensile strength of 435 N/mm^2 - 494 N/mm^2 ; and a minimum yield stress of 236 N/mm^2 . Chamfers on the pier cap upstands to be 15mm by 15mm.

Four 16mm diameter mild steeel bars , each 1000mm long, are to be used to each abutment pier cap to provide a continuity tie between the pier caps cast in-situ and general abutment masonry. The bars are to be embedded into the general abutment masonry to a depth of 600mm. NOTE: The bars are not shown on Fig .no 2, Drawing no. SE-245-37, (Holding Down Details). For the construction sequence at the bearings, see Fig. no. 3, Drawing no. SE-245-20.

PRE-FABRICATED MODULAR WOODEN BRIDGES - GENERAL LAYOUT FOR COMPONENT IDENTIFICATION

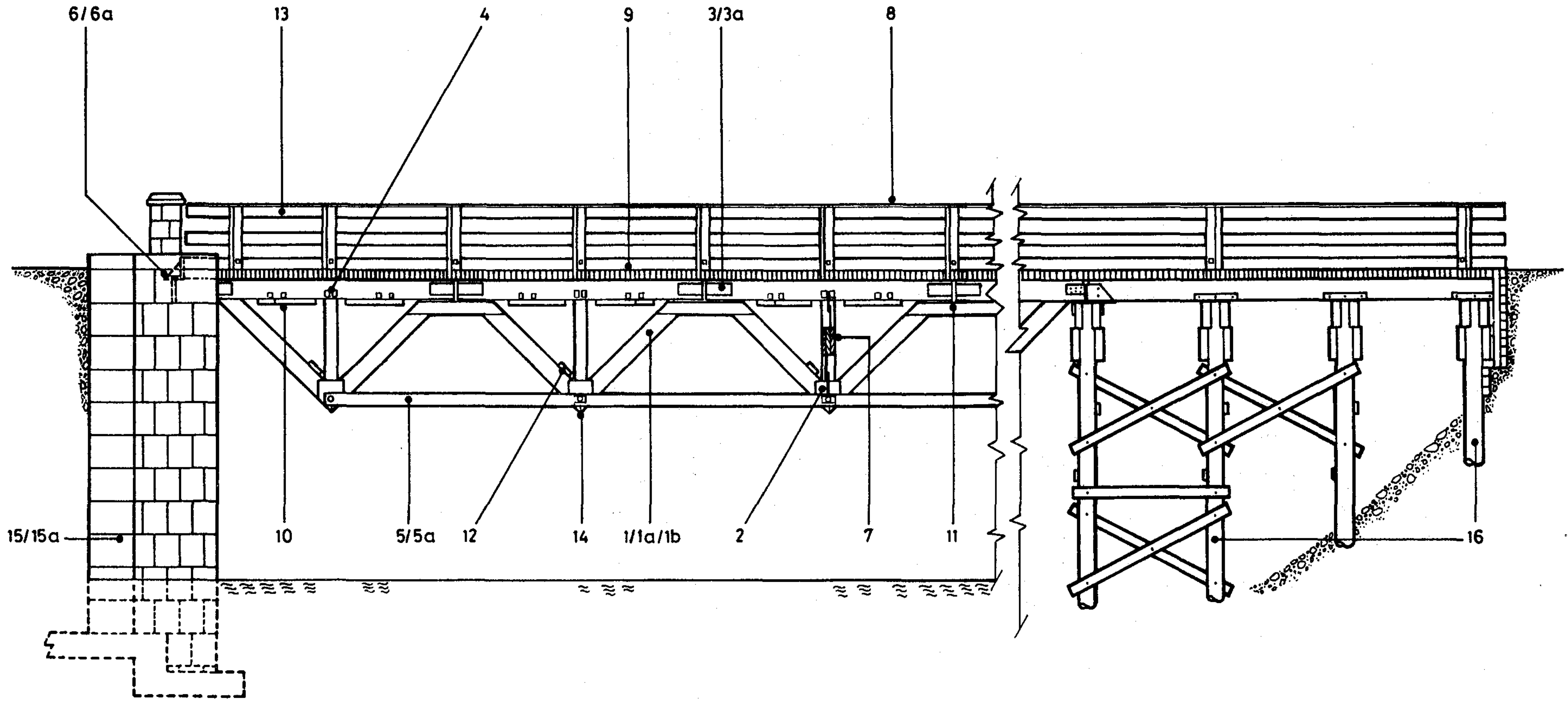


Figure 1

MASONRY/ CONCRETE ABUTMENT DETAILS (SHEET 1)

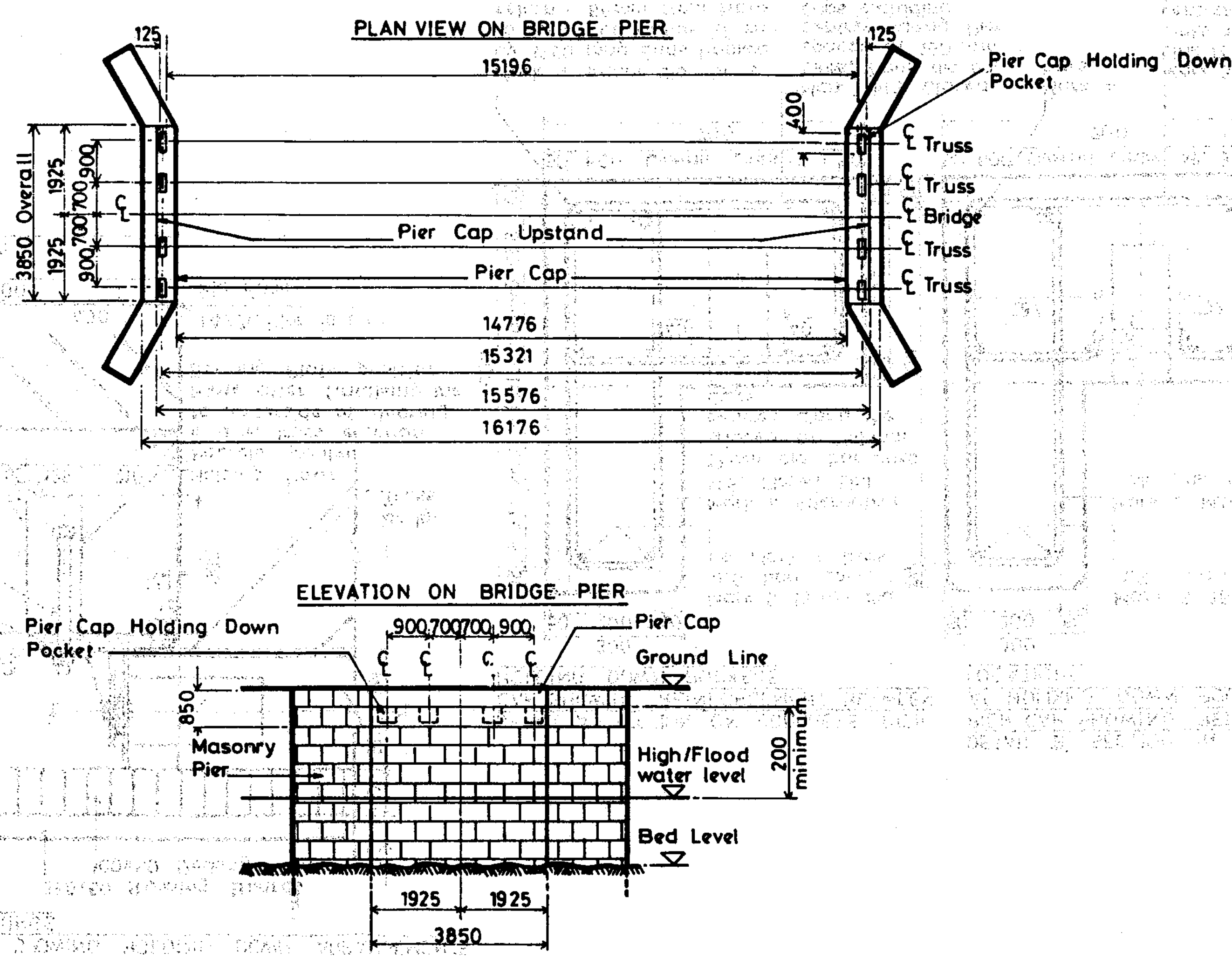
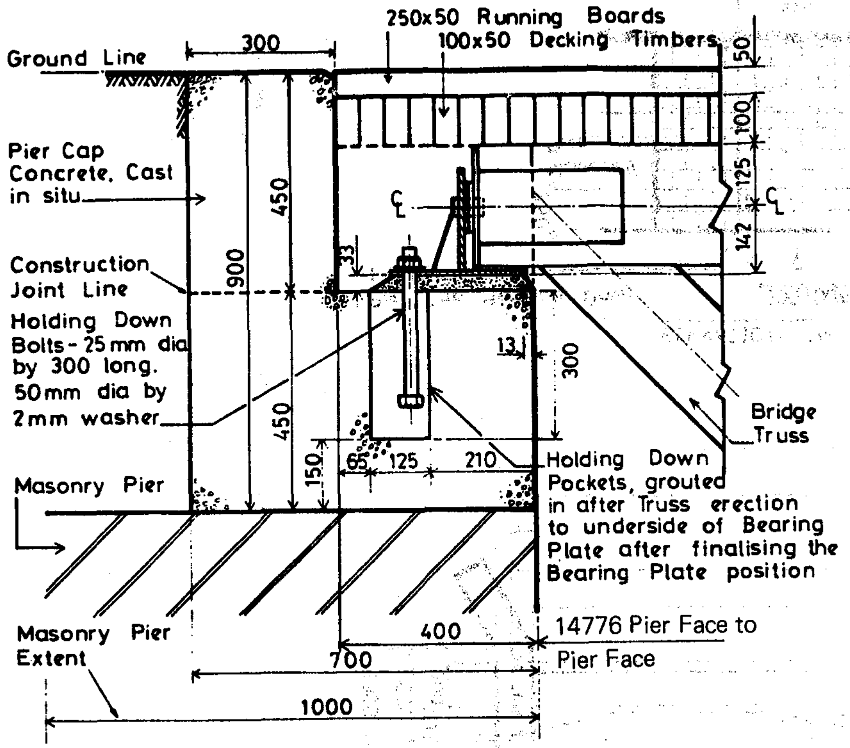


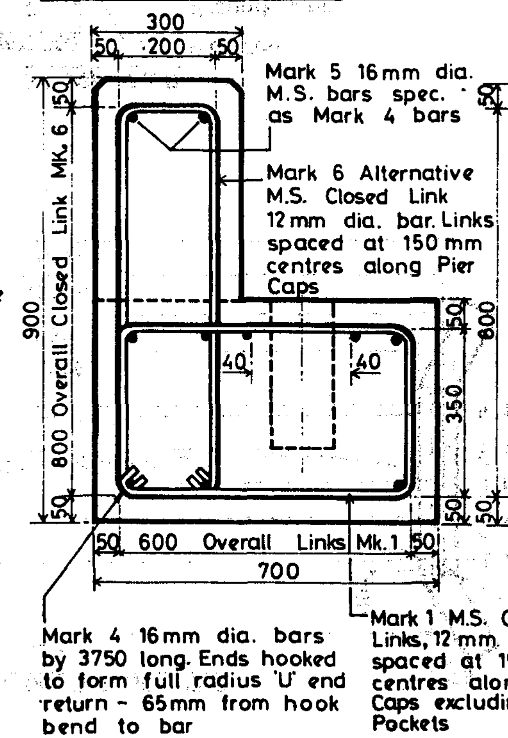
Figure 2

MASONRY/CONCRETE ABUTMENT DETAILS (SHEET 2)

SECTION THROUGH PIER CAP SHOWING HOLDING DOWN ARRANGEMENTS FOR BRIDGE TRUSS BEARINGS



DETAIL 'A' - SECTION ON CONCRETE PIER CAP SHOWING REINFORCEMENT BETWEEN HOLDING DOWN POCKETS



All cover to reinforcement to be 50 mm.

DETAIL 'B' - SECTION ON CONCRETE PIER CAP SHOWING REINFORCEMENT AT HOLDING DOWN POCKET LOCATIONS

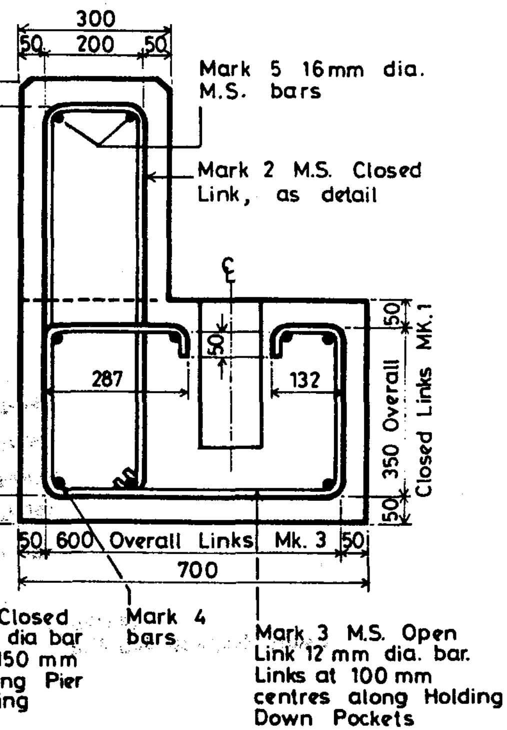
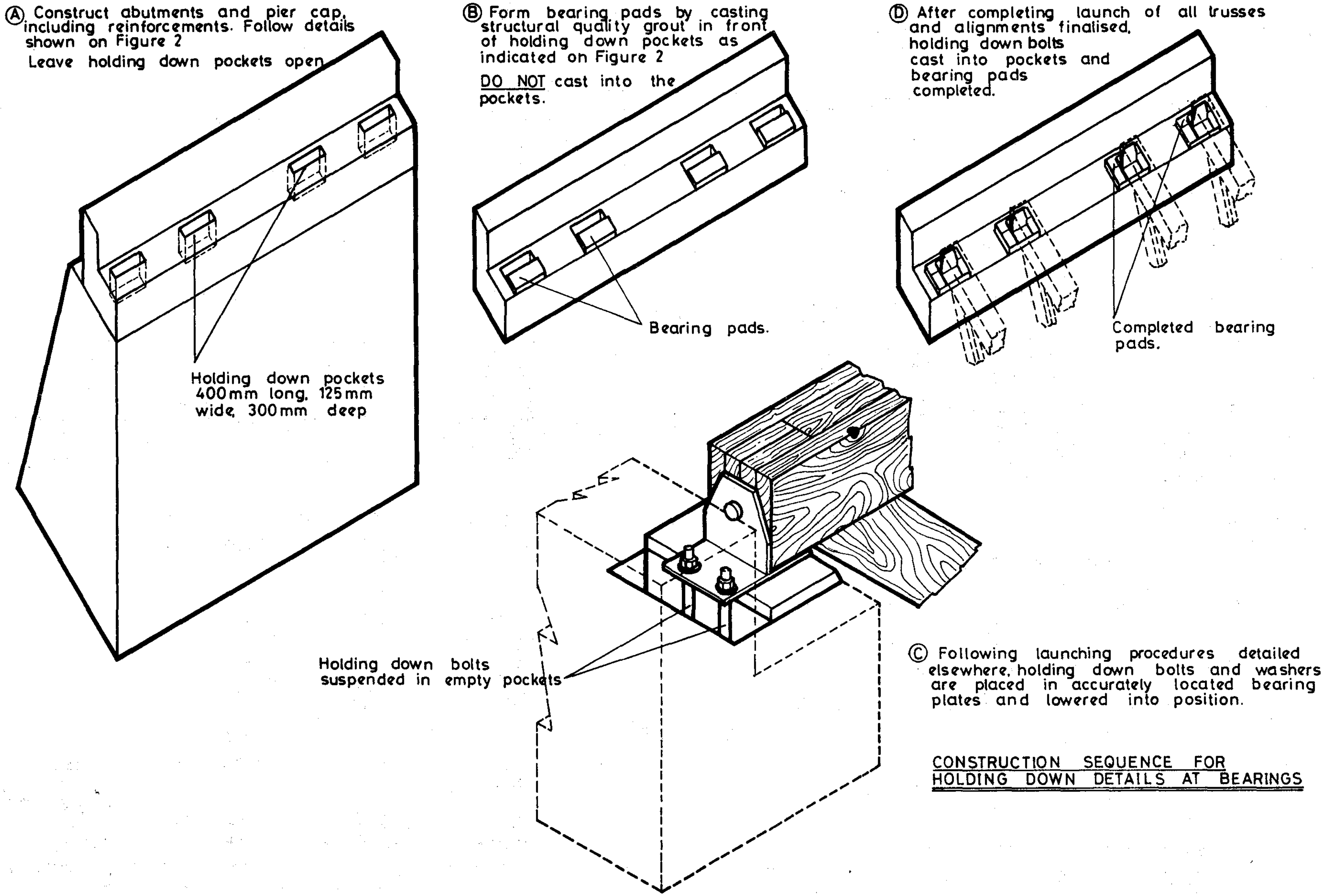
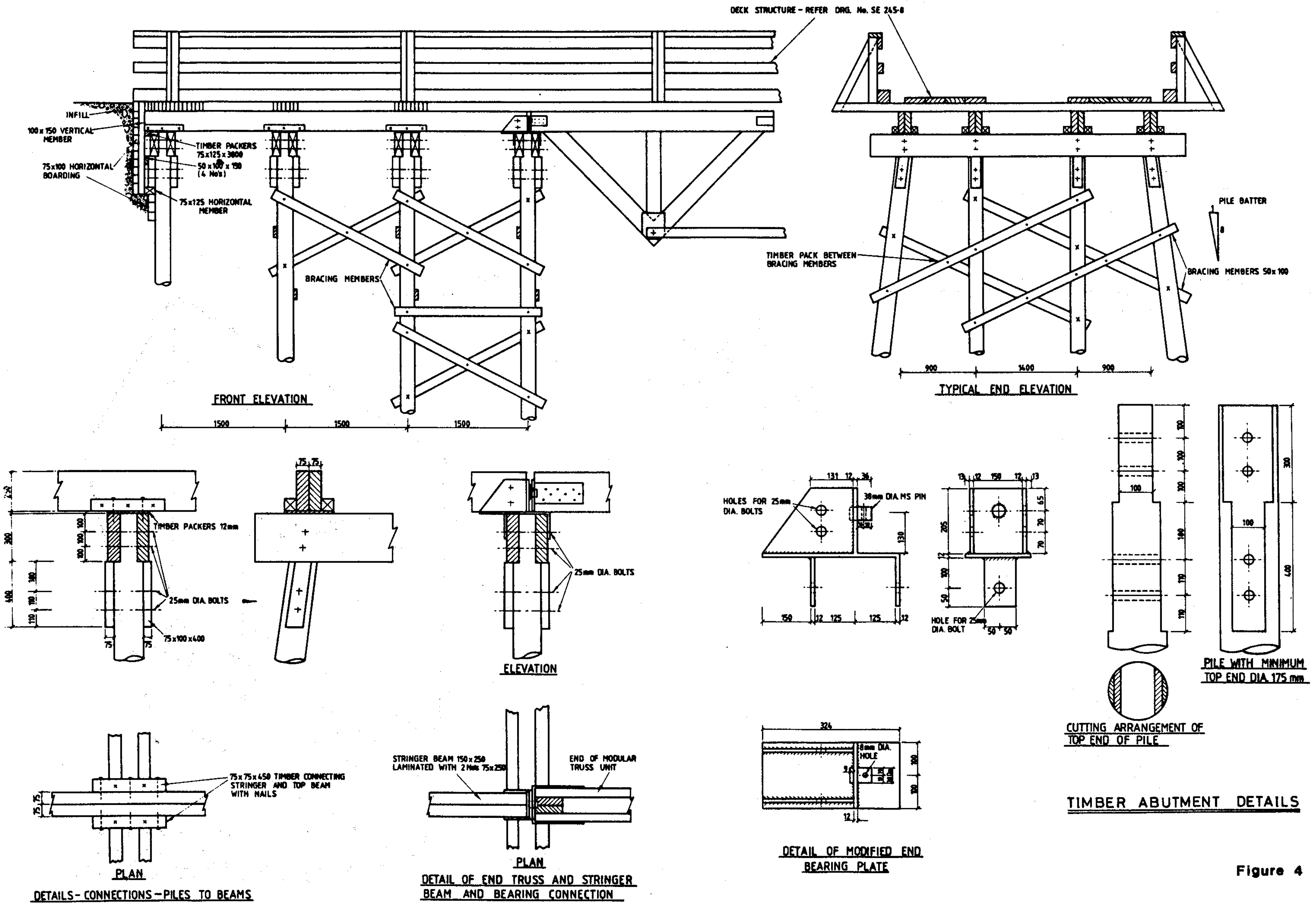


Figure 2 continued



CONSTRUCTION SEQUENCE FOR HOLDING DOWN DETAILS AT BEARINGS

Figure 3



TIMBER ABUTMENT DETAILS

Figure 4

TRUSS MODULAR UNIT ASSEMBLY...Figure 5 (Light chord)

Notes:- PLAN VIEW ON Y-Y

With panel plate Mark 3a welded in final position, drill through members 2T with a 40mm drill to a depth of 42mm from bearing face of panel plate Mark 3a to accomodate spigot pin.

MEMBER 1T

All four corners of 1T to be eased by 6mm chamfers to accomodate welds.

MEMBER 2T

A total of 21 4.88mm diameter (6 S.W.G.) x 100mm nails at 150mm centres in each row. Nails are driven in from side uppermost on drawing.

MEMBER 3T

A total of 13 4.88mm diameter (6 S.W.G.) x 100mm nails at 150mm centres in each row. Nails are driven in from side uppermost on drawing.

PANEL PLATE MARK 5

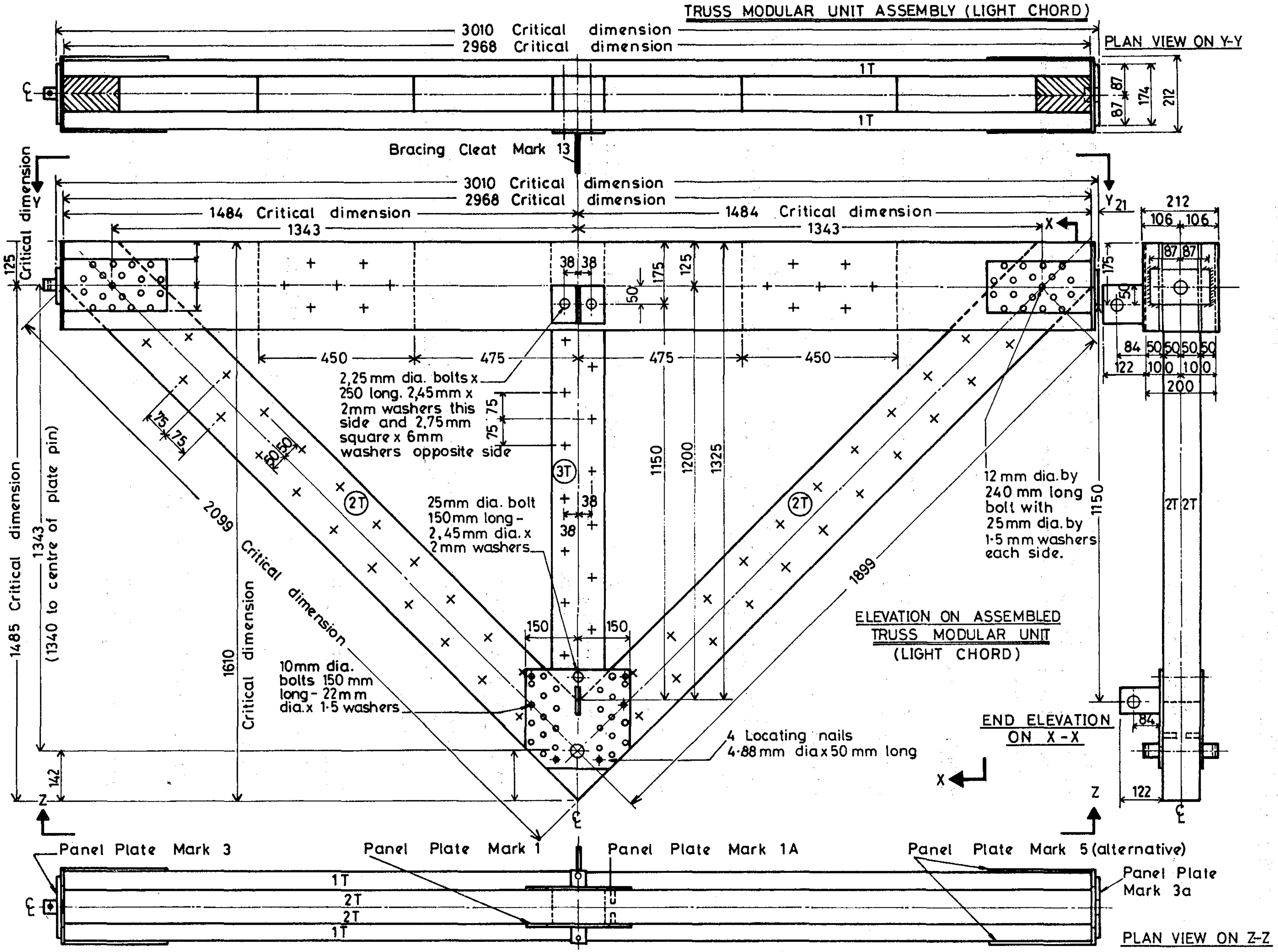
A total of 16 12mm diameter M.S. dowels x 100mm long and 2 off 12mm diameter M.S. dowels x 50mm long to each plate.

PANEL PLATES MARK 3 and 3a

Panel plates Mark 3 and 3a are welded to panel plate mark 5 with 6mm fillet welds on 2 by 3 sides (see detail).

PANEL PLATES MARK 1 and 1a

A total of 24 12mm diameter M.S. dowels 50mm long to each panel plate.



TRUSS MODULAR UNIT ASSEMBLY (LIGHT CHORD)
3010 Critical dimension
2968 Critical dimension
PLAN VIEW ON Y-Y
1T
1T
87 87
174
212
Bracing Cleat Mark 13
Critical dimension
1484 Critical dimension
1343
125 Critical dimension
38 38
50
175
125
21
212
106 106
87 87
84 50 50 50 50
122 100 100
200
450
475
2,25mm dia. bolts x 250 long. 2,45mm x 2mm washers this side and 2,75mm square x 6mm washers opposite side
75 75
75 75
50 50
3T
2T
2099
Critical dimension
25mm dia. bolt 150mm long - 2,45mm dia. x 2mm washers
38
1150
1200
1325
12 mm dia. by 240 mm long bolt with 25mm dia. by 1·5 mm washers each side.
1150
2T 2T
1899
ELEVATION ON ASSEMBLED TRUSS MODULAR UNIT (LIGHT CHORD)
1485 Critical dimension
1343 (1340 to centre of plate pin)
1610 Critical dimension
10mm dia. bolts 150 mm long - 22mm dia. x 1·5 washers
150
150
4 Locating nails 4·88mm dia x 50 mm long
END ELEVATION ON X-X
84
122
142
Panel Plate Mark 3
Panel Plate Mark 1
Panel Plate Mark 1A
Panel Plate Mark 5 (alternative)
Panel Plate Mark 3a
1T
2T
2T
1T
PLAN VIEW ON Z-Z

Figure 5

TIMBER MEMBERS FOR TRUSS MODULAR UNIT ASSEMBLY(LIGHT AND HEAVY CHORD)

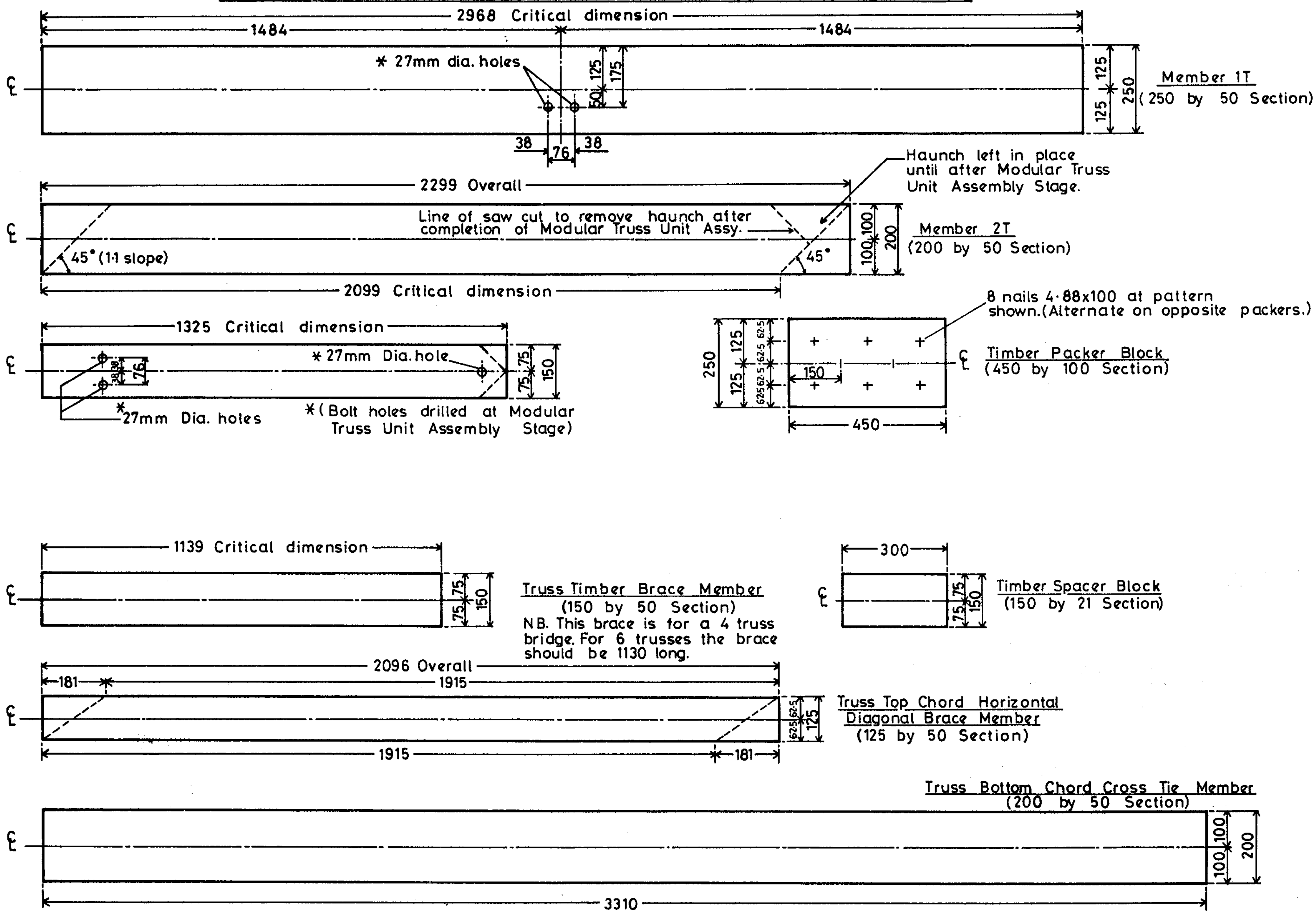
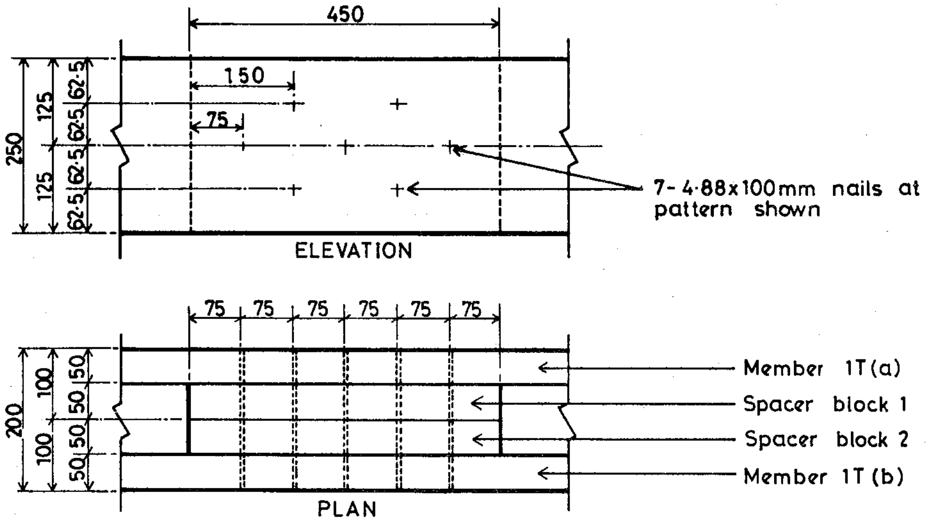
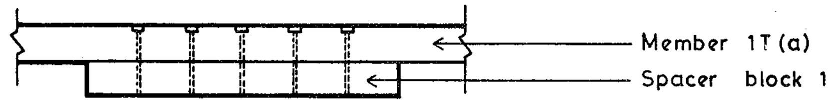


Figure 6

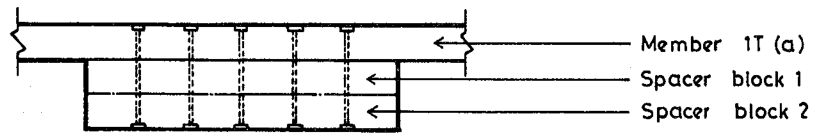
NAILING PATTERN FOR MEMBERS 1T



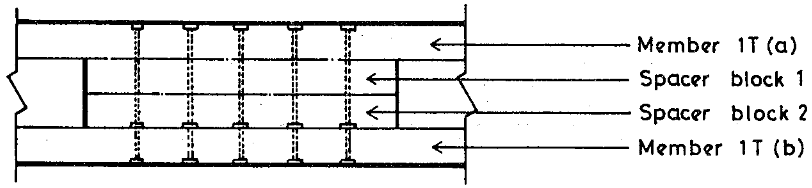
STAGE 1 - Locate spacer block 1 to member 1T(a) using member 1T nailing pattern



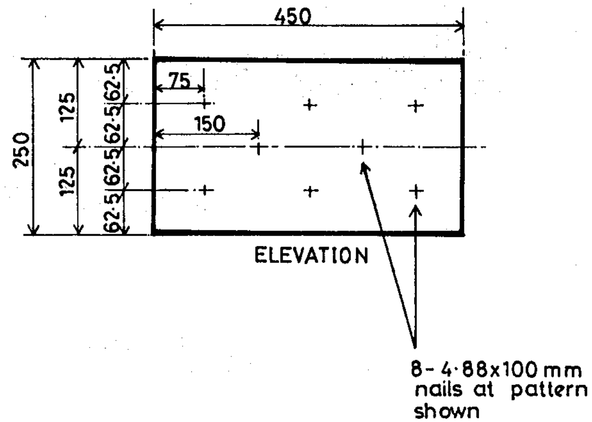
STAGE 2 - Nail spacer block 2 to spacer block 1 using spacer block nailing pattern



STAGE 3 - Nail member 1T(b) to spacer block 2 using nailing pattern for member 1T



NAILING PATTERN FOR SPACER BLOCKS



NAILING PATTERNS FOR TIMBER MEMBERS

Figure 7

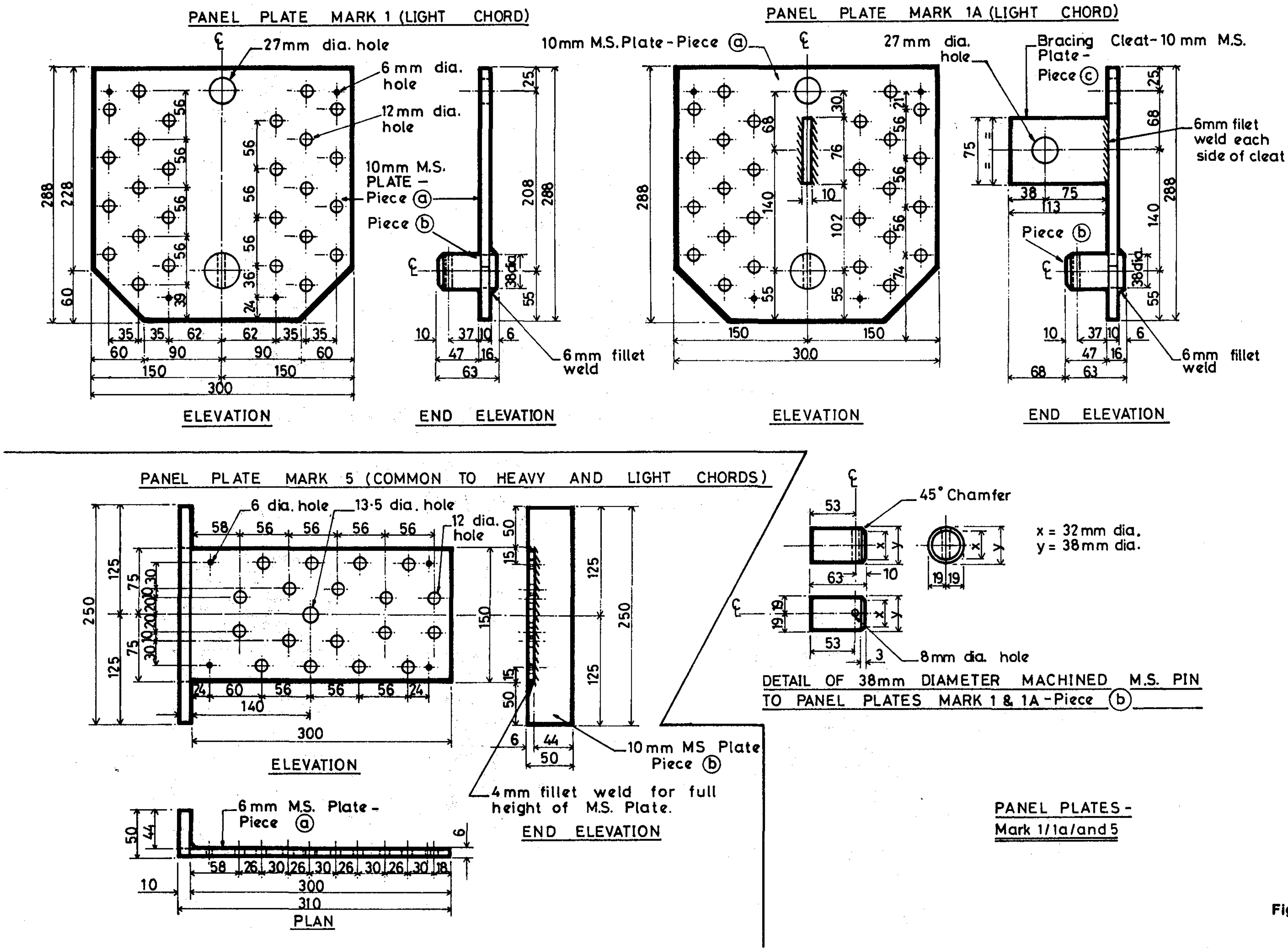
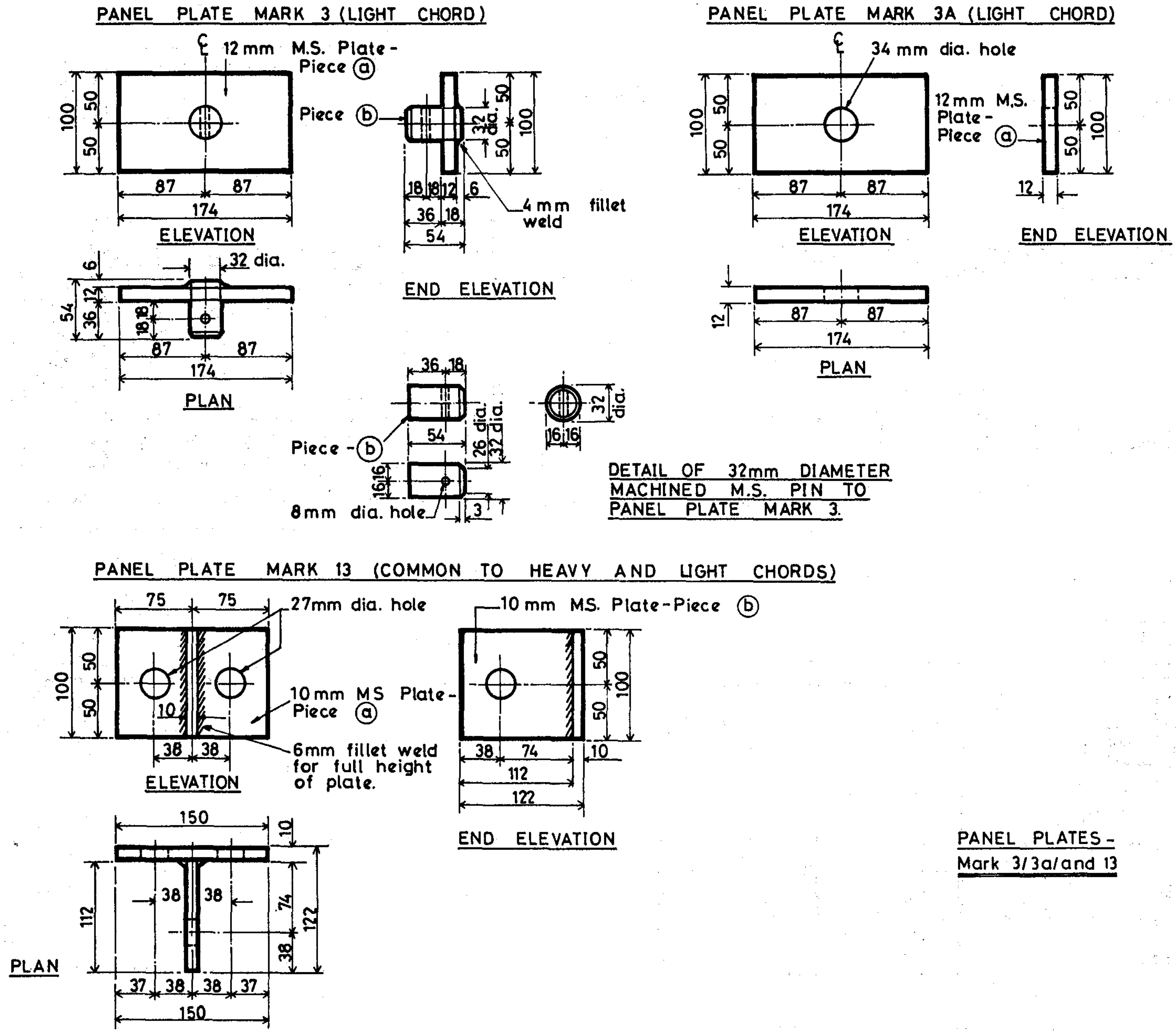
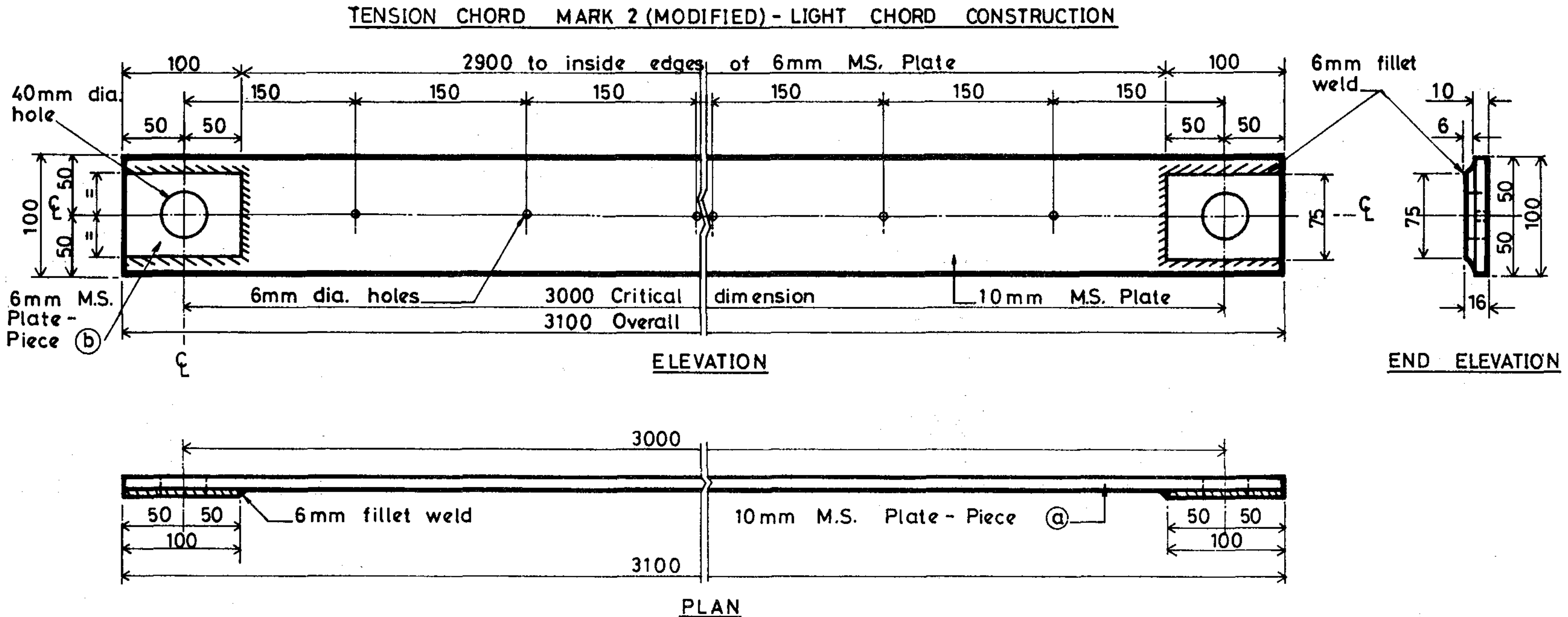

PANEL PLATE MARK 1 (LIGHT CHORD)
27mm dia. hole
6 mm dia. hole
12mm dia. hole
10mm M.S. PLATE - Piece (a)
Piece (b)
6mm fillet weld
ELEVATION
END ELEVATION
PANEL PLATE MARK 1A (LIGHT CHORD)
10mm M.S. Plate - Piece (a)
27mm dia. hole
Bracing Plate - Piece (c)
Cleat - 10 mm M.S.
6mm filet weld each side of cleat
Piece (b)
6mm fillet weld
ELEVATION
END ELEVATION
PANEL PLATE MARK 5 (COMMON TO HEAVY AND LIGHT CHORDS)
6 dia. hole
13·5 dia. hole
12 dia. hole
ELEVATION
10mm MS Plate Piece (b)
4mm fillet weld for full height of M.S. Plate.
END ELEVATION
6mm M.S. Plate - Piece (a)
PLAN
45° Chamfer
x = 32mm dia.
y = 38mm dia.
8mm dia. hole
DETAIL OF 38mm DIAMETER MACHINED M.S. PIN TO PANEL PLATES MARK 1 & 1A - Piece (b)
PANEL PLATES - Mark 1/1a/and 5

Figure 8

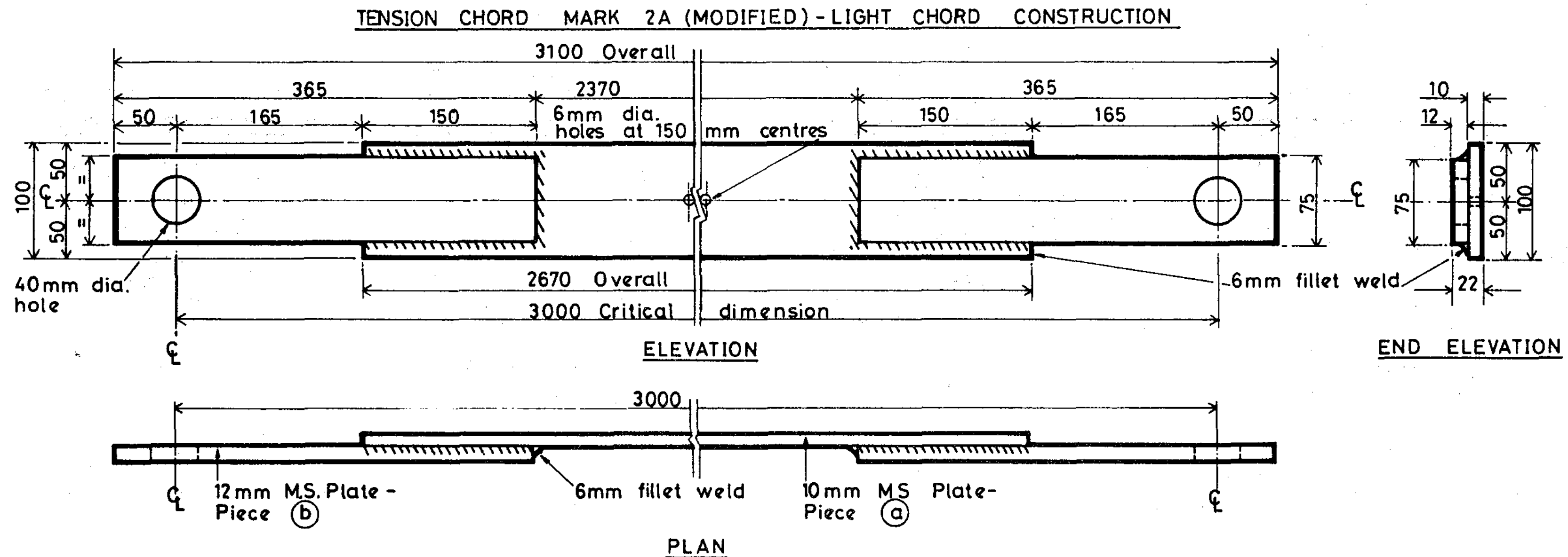


PANEL PLATES -
Mark 3/3a/and 13

Figure 9



TENSION CHORD MARK 2 (MODIFIED) - LIGHT CHORD CONSTRUCTION
2900 to inside edges of 6mm M.S. Plate
40mm dia. hole
6mm M.S. Plate - Piece (b)
6mm dia. holes
3000 Critical dimension
10mm M.S. Plate
3100 Overall
6mm fillet weld
ELEVATION
END ELEVATION
6mm fillet weld
10mm M.S. Plate - Piece (a)
PLAN



TENSION CHORD MARK 2A (MODIFIED) - LIGHT CHORD CONSTRUCTION
3100 Overall
6mm dia. holes at 150 mm centres
40mm dia. hole
2670 Overall
3000 Critical dimension
6mm fillet weld
ELEVATION
END ELEVATION
12mm M.S. Plate - Piece (b)
6mm fillet weld
10mm M.S Plate- Piece (a)
PLAN

Figure 10

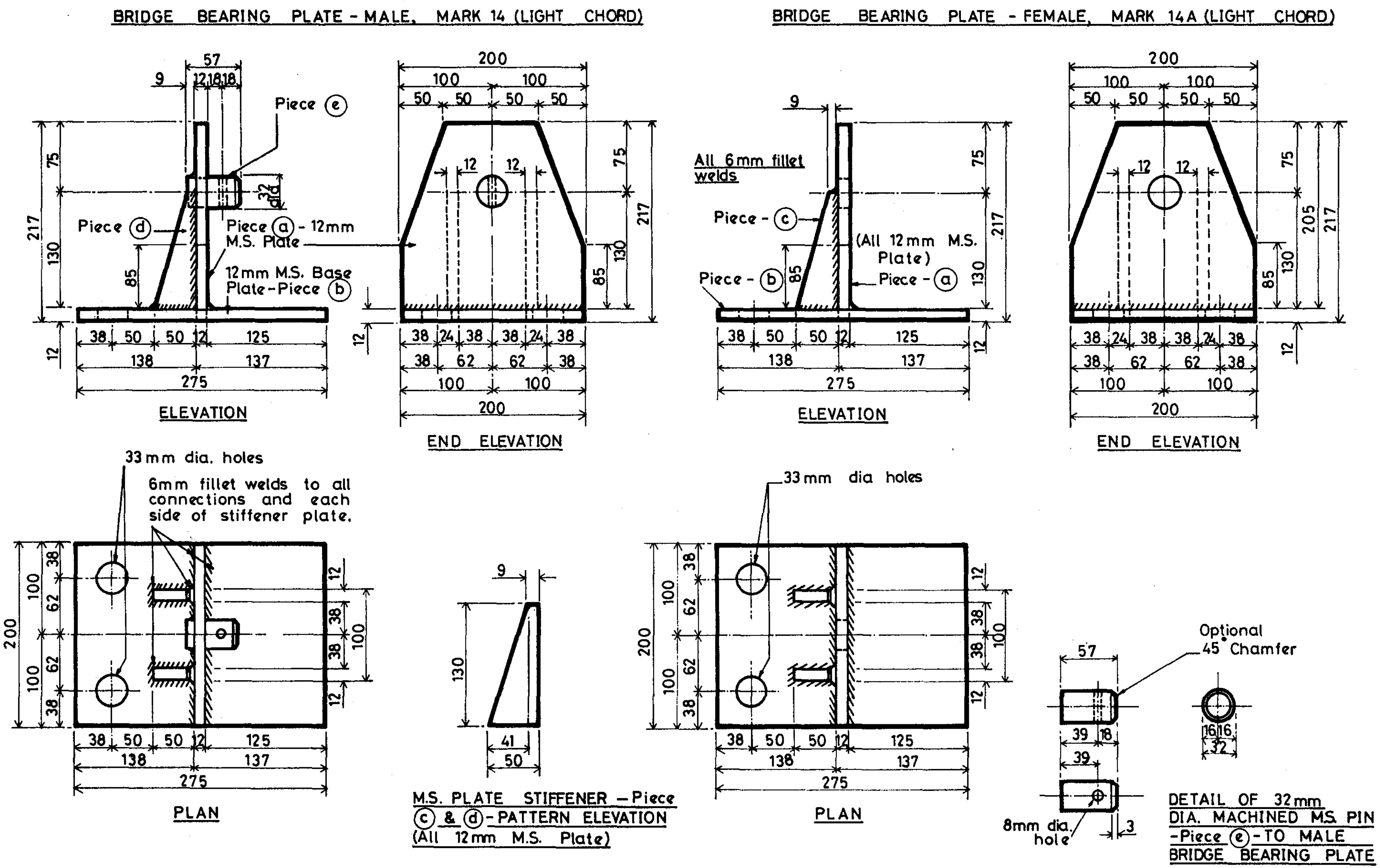

BRIDGE BEARING PLATE - MALE, MARK 14 (LIGHT CHORD)
BRIDGE BEARING PLATE - FEMALE, MARK 14A (LIGHT CHORD)
Piece (e)
Piece (d)
Piece (a) - 12mm M.S. Plate
12mm M.S. Base Plate-Piece (b)
ELEVATION
END ELEVATION
All 6mm fillet welds
Piece - (c)
(All 12mm M.S. Plate)
Piece - (a)
Piece - (b)
33mm dia. holes
6mm fillet welds to all connections and each side of stiffener plate.
PLAN
M.S. PLATE STIFFENER - Piece (c) & (d) - PATTERN ELEVATION (All 12mm M.S. Plate)
Optional 45° Chamfer
8mm dia. hole
DETAIL OF 32mm DIA. MACHINED M.S. PIN -Piece (e) - TO MALE BRIDGE BEARING PLATE

Figure 11

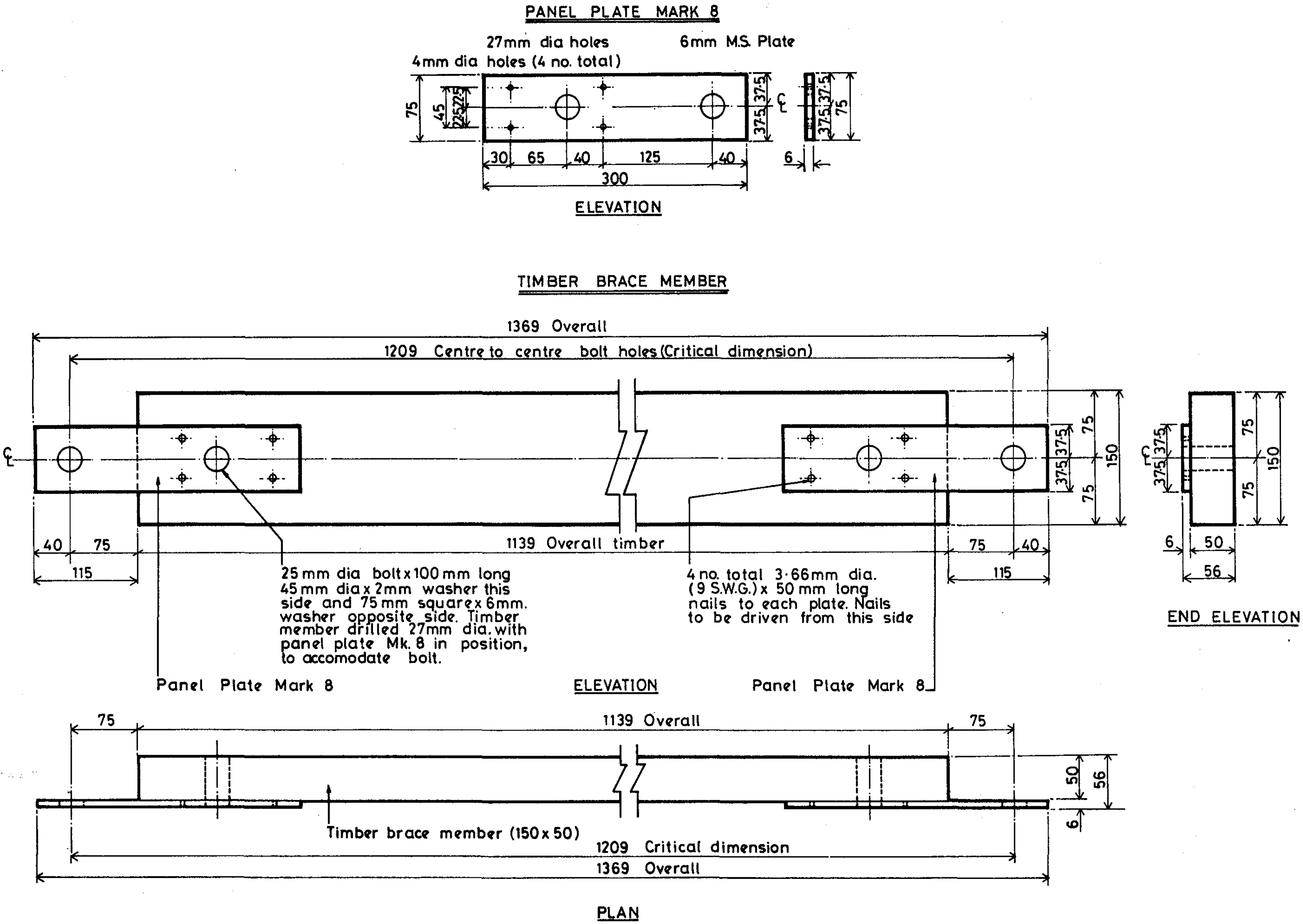

PANEL PLATE MARK 8
27mm dia holes
6mm M.S. Plate
4mm dia holes (4 no. total)
ELEVATION
TIMBER BRACE MEMBER
1369 Overall
1209 Centre to centre bolt holes (Critical dimension)
1139 Overall timber
25 mm dia bolt x 100 mm long 45 mm dia x 2mm washer this side and 75 mm square x 6mm. washer opposite side. Timber member drilled 27mm dia. with panel plate Mk. 8 in position, to accomodate bolt.
4 no. total 3·66mm dia. (9 S.W.G.) x 50 mm long nails to each plate. Nails to be driven from this side
Panel Plate Mark 8
ELEVATION
Panel Plate Mark 8
END ELEVATION
1139 Overall
Timber brace member (150 x 50)
1209 Critical dimension
1369 Overall
PLAN

Figure 12

TIMBER TENSION CHORD...Figure 13 (Light chord)

The following items are required for Figure 13, (Drawing no. SE-245-40/1).

Nails

Diameter	4.88mm
Pennyweight	20d
Length	100mm

DOWEL PINS

Dowel pins, 12mm diameter by 50mm long are driven in from both sides of the assembly. The heads are then welded to 6mm MS plates in accordance with the standard bridge panel plate method.

SPLIT PINS

Diameter	8mm
Length	55mm

TIMBER TENSION CHORD (LIGHT CHORD CONSTRUCTION)

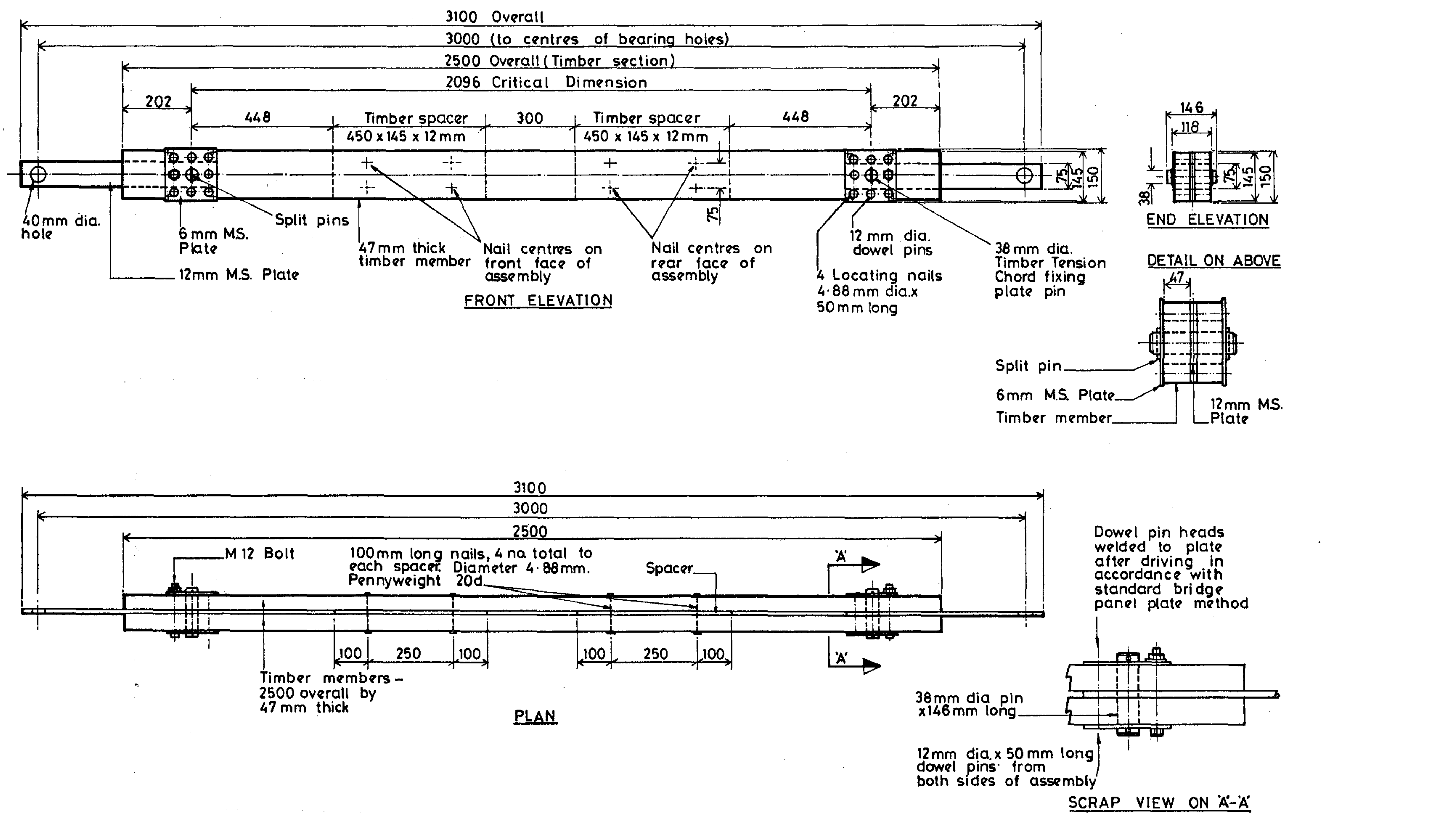
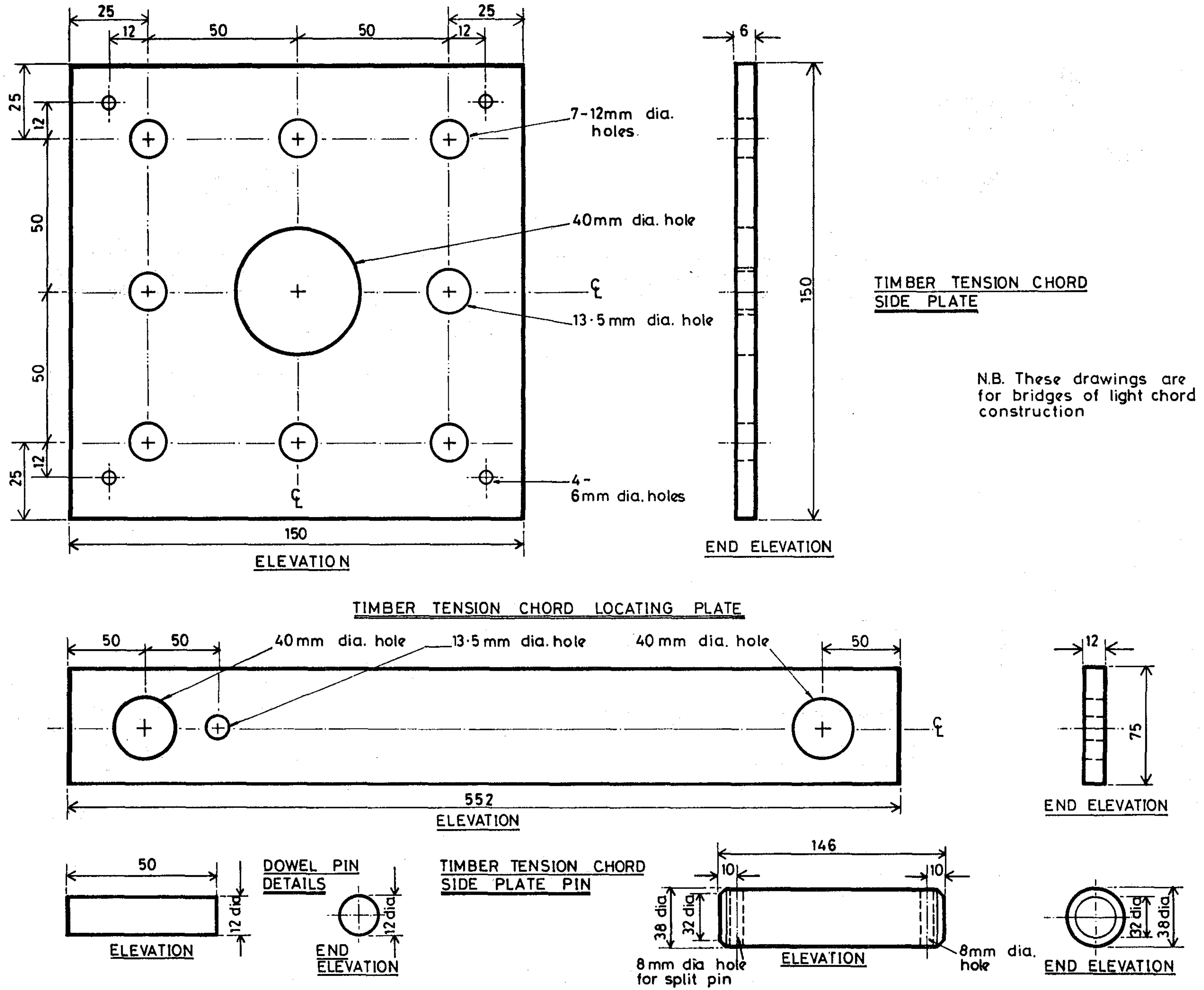


Figure 13



TIMBER TENSION CHORD SIDE PLATE
7-12mm dia. holes.
40mm dia. hole
13·5 mm dia. hole
4-6mm dia. holes
150
ELEVATION
6
END ELEVATION
N.B. These drawings are for bridges of light chord construction
TIMBER TENSION CHORD LOCATING PLATE
40 mm dia. hole
13·5 mm dia. hole
40 mm dia. hole
552
ELEVATION
12
75
END ELEVATION
DOWEL PIN DETAILS
50
12 dia
ELEVATION
END ELEVATION
TIMBER TENSION CHORD SIDE PLATE PIN
146
10
38 dia
32 dia
8mm dia hole for split pin
ELEVATION
8mm dia. hole
END ELEVATION

Figure 14

TRUSS MODULAR UNIT ASSEMBLY...Figure 15 (Heavy chord)

Notes:- PLAN VIEW ON Y-Y

With panel plate Mark 10a welded in final position, drill through members 2T with a 40mm drill to a depth of 42mm from bearing face of panel plate Mark 10a to accomodate spigot pin.

MEMBER 1T

All four corners of 1T to be eased by 6mm chamfers to accomodate welds.

MEMBER 2T

A total of 21 4.88mm diameter (6 S.W.G.) x 100mm nails at 150mm centres in each row. Nails are driven in from side uppermost on drawing.

MEMBER 3T

A total of 13 4.88mm diameter (6 S.W.G.) x 100mm long nails at 150mm centres in each row. Nails are driven in from side uppermost on drawing.

PANEL PLATE MARK 5

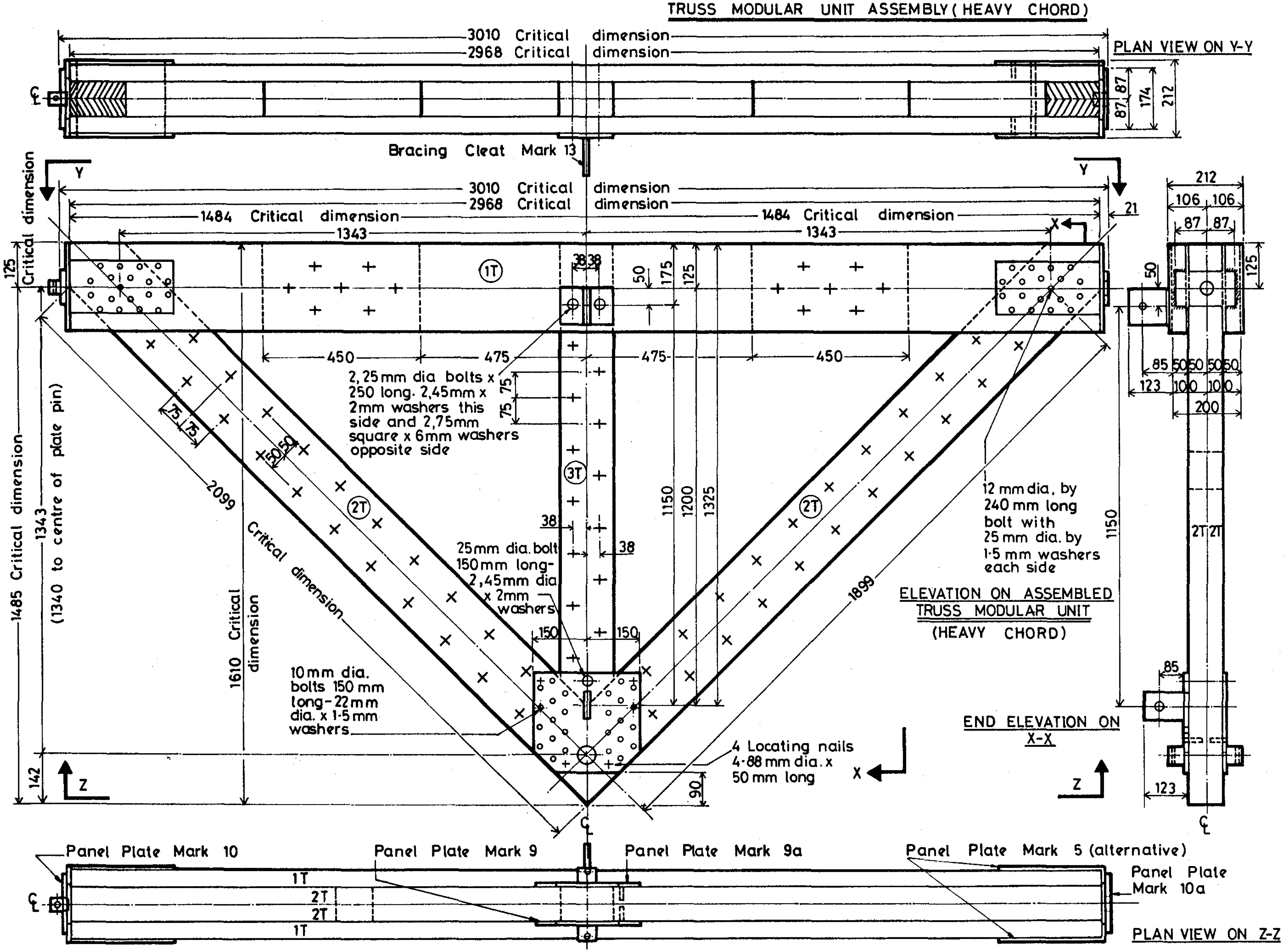
A total of 16 12mm diameter (6 S.W.G.) x 100mm long and 2 off 12mm diameter M.S. dowels x 50mm long to each panel plate.

PANEL PLATES MARK 10 and 10a

Panel plates Mark 10 and 10a are welded to panel plate Mark 5 with 6mm fillet weld on 2 by 3 sides (see detail).

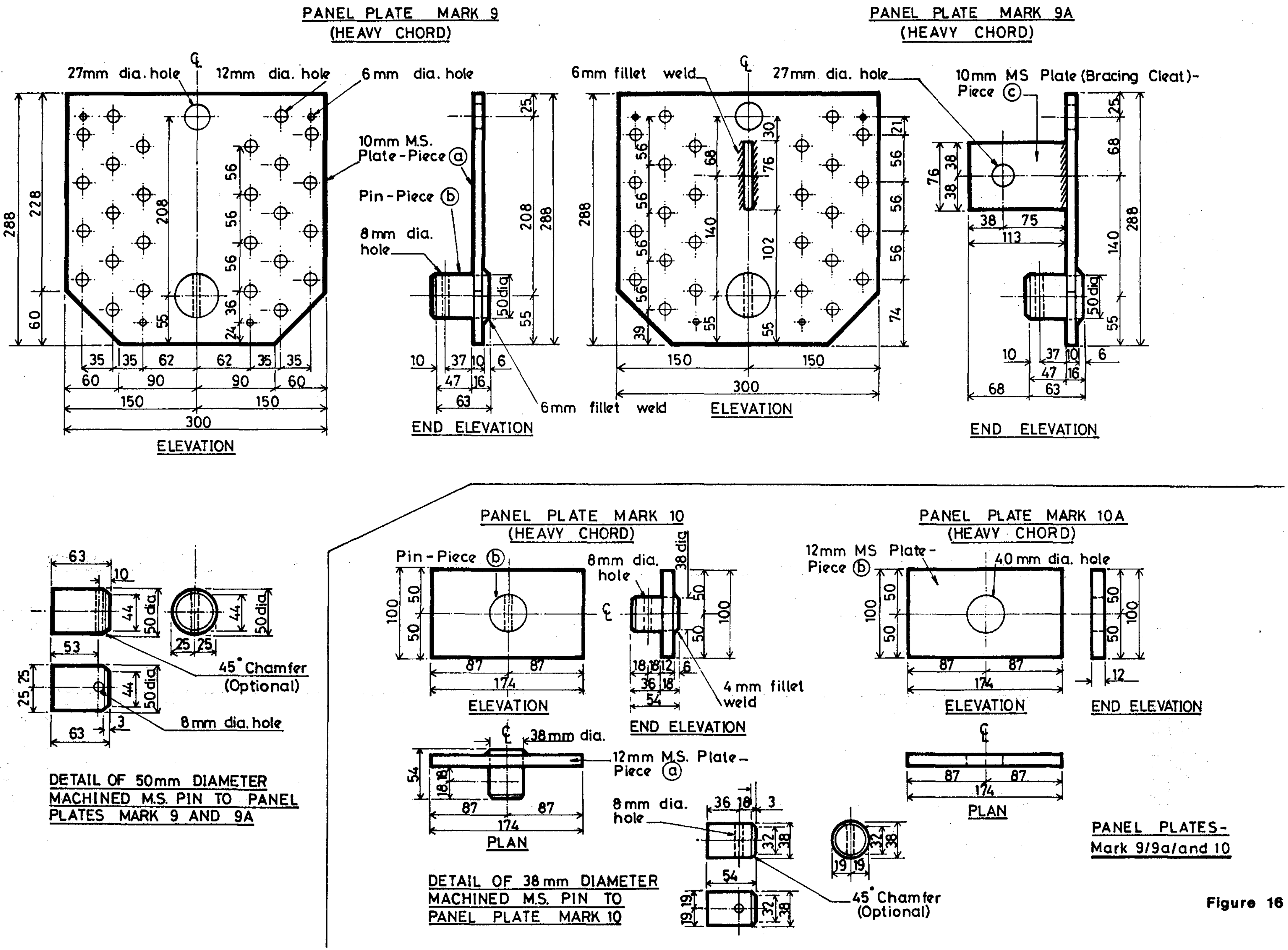
PANEL PLATES MARK 9 and 9a

A total of 24 12mm diameter M.S. dowels x 50mm long to each panel plate.



TRUSS MODULAR UNIT ASSEMBLY (HEAVY CHORD)
PLAN VIEW ON Y-Y
3010 Critical dimension
2968 Critical dimension
Bracing Cleat Mark 13
1484 Critical dimension
1343
2,25mm dia bolts x 250 long. 2,45mm x 2mm washers this side and 2,75mm square x 6mm washers opposite side
25mm dia. bolt 150mm long-2,45mm dia x 2mm washers
10mm dia. bolts 150 mm long-22mm dia. x 1·5mm washers
4 Locating nails 4·88 mm dia. x 50 mm long
12 mm dia. by 240 mm long bolt with 25 mm dia. by 1·5 mm washers each side
2099 Critical dimension
1899
1610 Critical dimension
1485 Critical dimension
1343 (1340 to centre of plate pin)
125 Critical dimension
ELEVATION ON ASSEMBLED TRUSS MODULAR UNIT (HEAVY CHORD)
END ELEVATION ON X-X
Panel Plate Mark 10
Panel Plate Mark 9
Panel Plate Mark 9a
Panel Plate Mark 5 (alternative)
Panel Plate Mark 10a
PLAN VIEW ON Z-Z

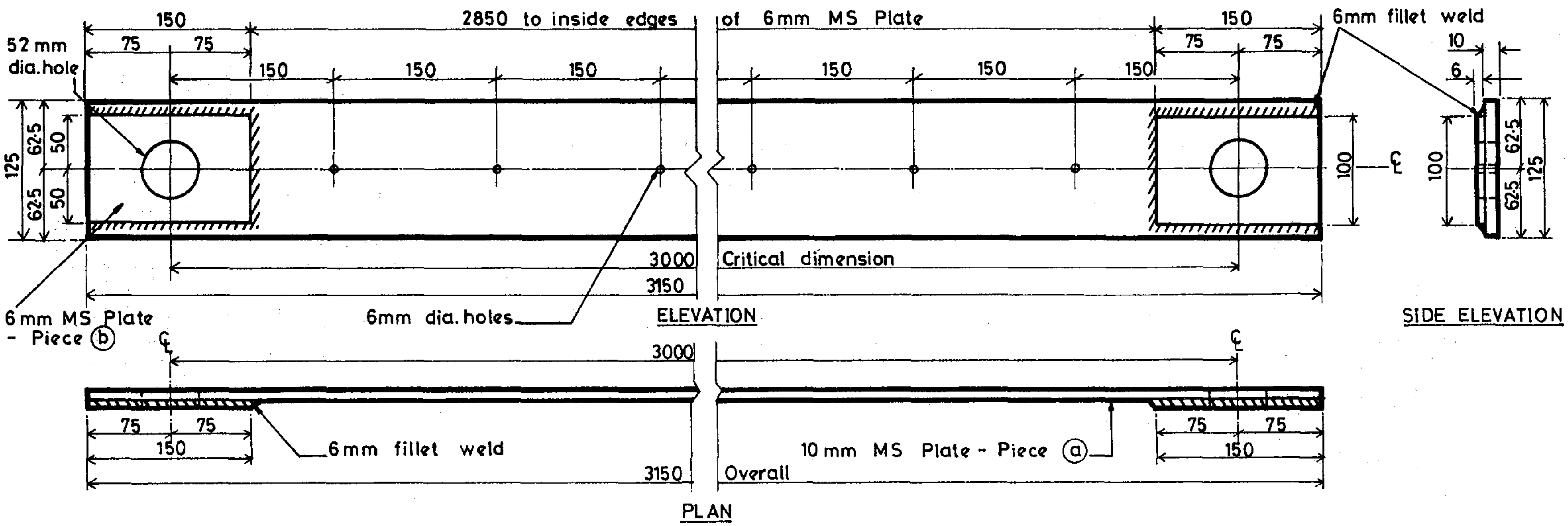
Figure 15



PANEL PLATES-
Mark 9/9a/and 10

Figure 16

TENSION CHORD MARK 6 (MODIFIED) - HEAVY CHORD CONSTRUCTION



TENSION CHORD MARK 6A (MODIFIED) - HEAVY CHORD CONSTRUCTION

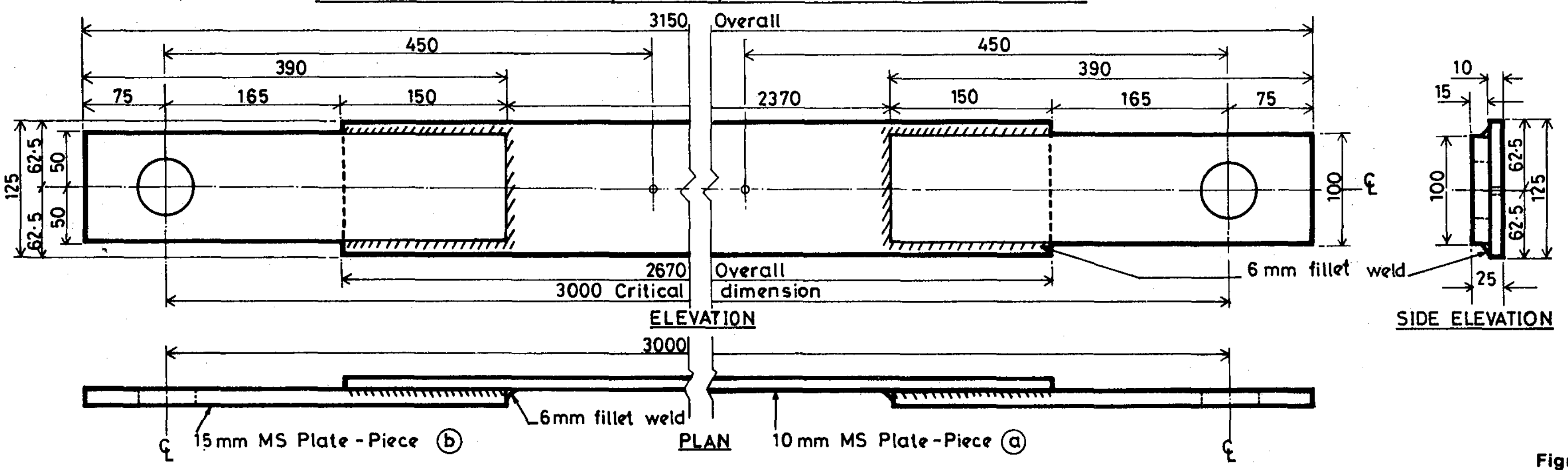
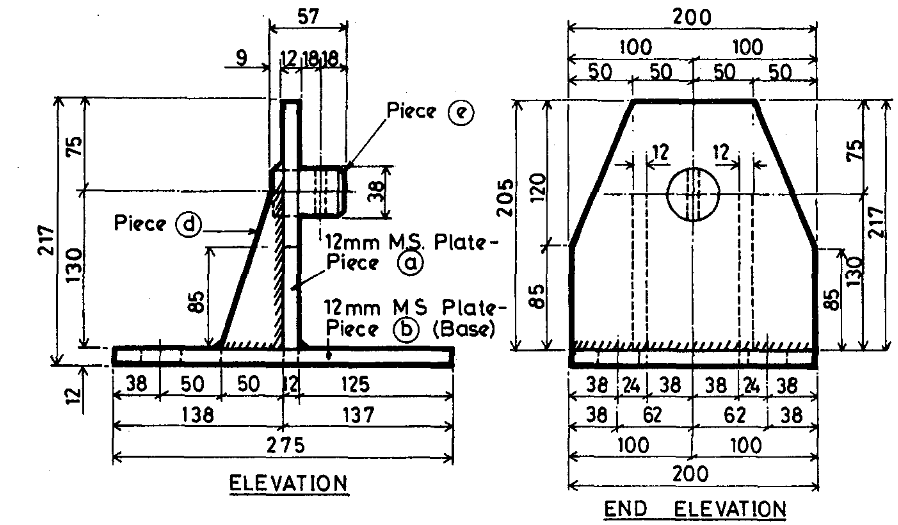
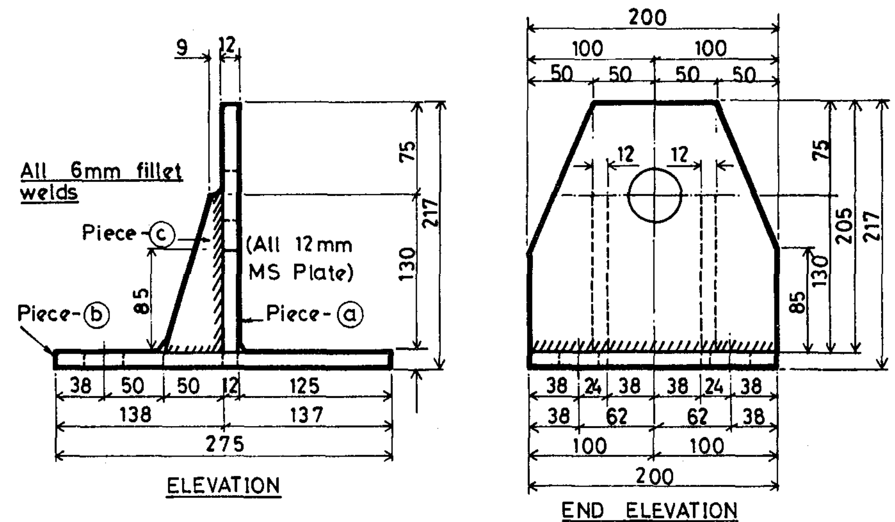


Figure 17

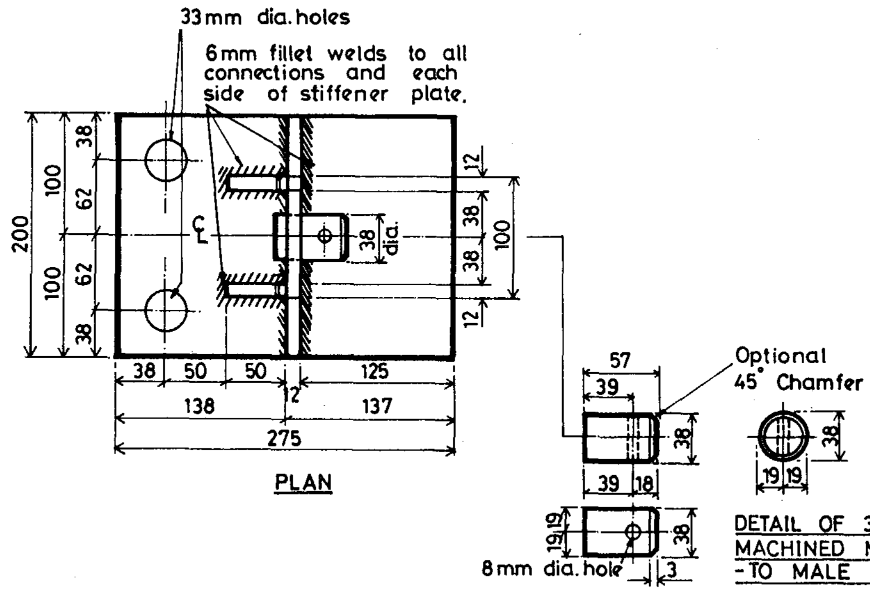
BRIDGE BEARING PLATE - MALE, MARK 15 (HEAVY CHORD)



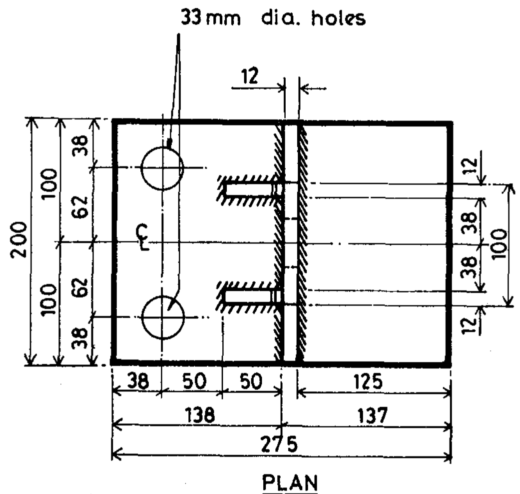
BRIDGE BEARING PLATE - FEMALE, MARK 15A (HEAVY CHORD)

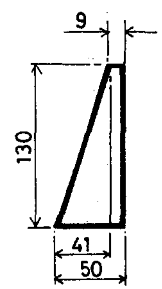


BRIDGE BEARING PLATES AND DETAILS



DETAIL OF 3 mm DIAMETER MACHINED M.S. PIN-Piece (e) -TO MALE BRIDGE BEARING PLATE





M.S. PLATE STIFFENER - Piece (c) & (d) - PATTERN ELEVATION (All 12mm M.S. Plate)

Figure 18

TIMBER TENSION CHORD...Figure 19 (Heavy chord)

The following items are required for Figure 19.

NAILS

Diameter	4.88mm
Pennyweight	20d
Length	100mm

DOWEL PINS

Dowel pins , 12mm diameter by 50mm long are driven in from both sides of the assembly. The heads are then welded to the 6mm MS plates in accordance with the standard bridge panel plate method.

SPLIT PINS

Diameter	8mm
Length	55mm

TIMBER TENSION CHORD (HEAVY CHORD CONSTRUCTION)

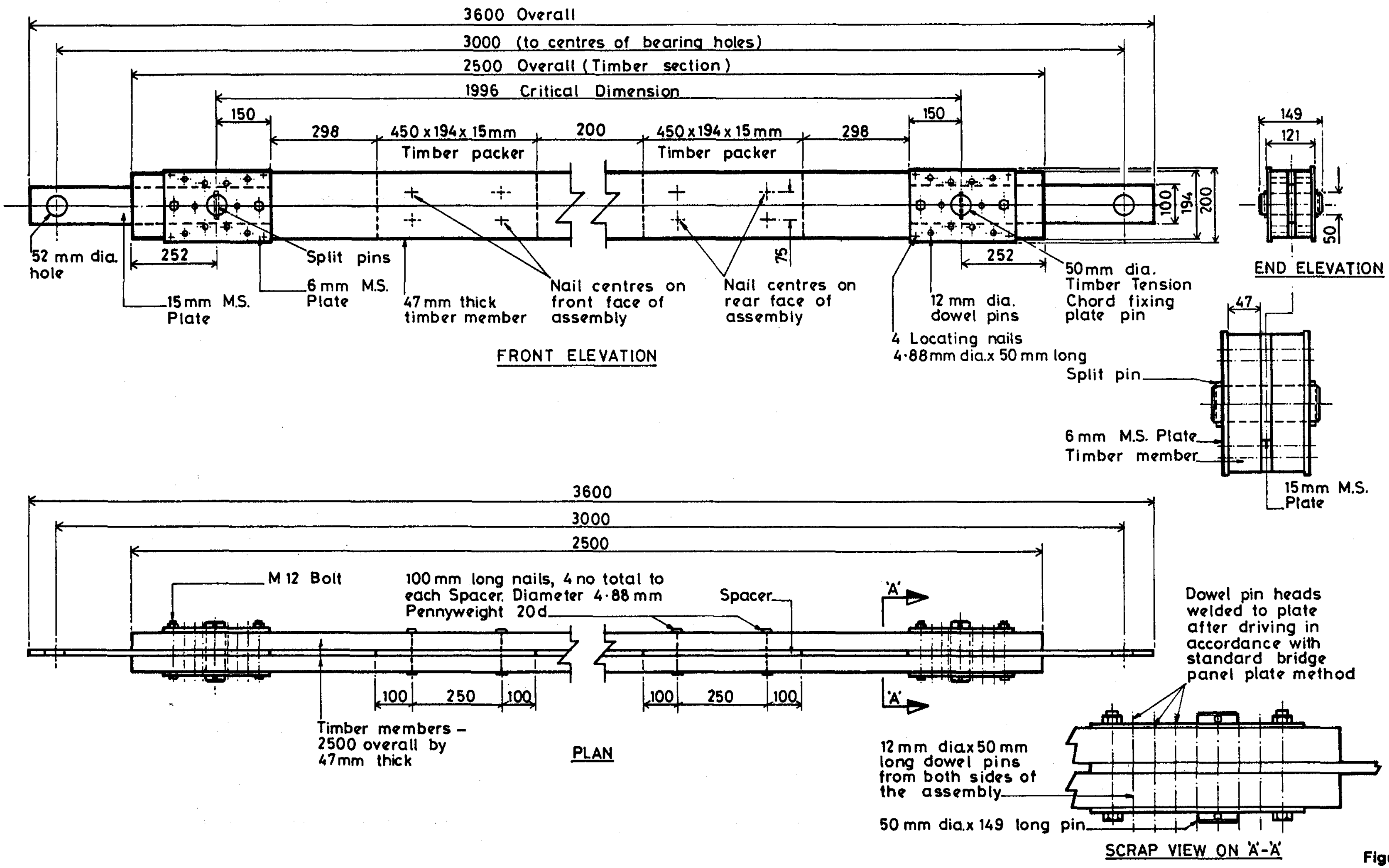
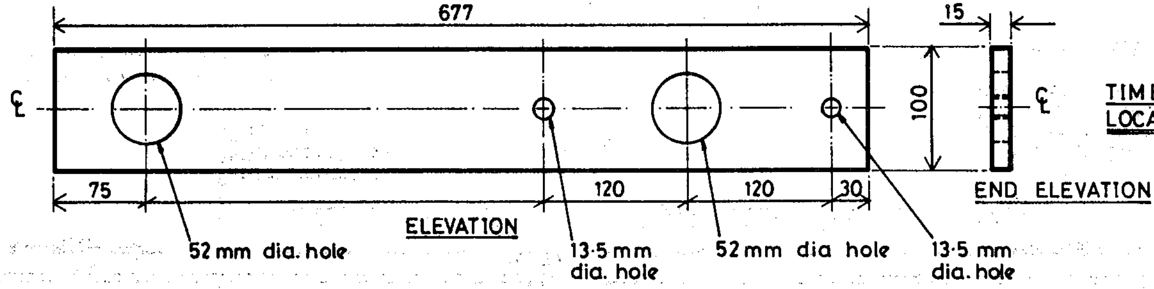
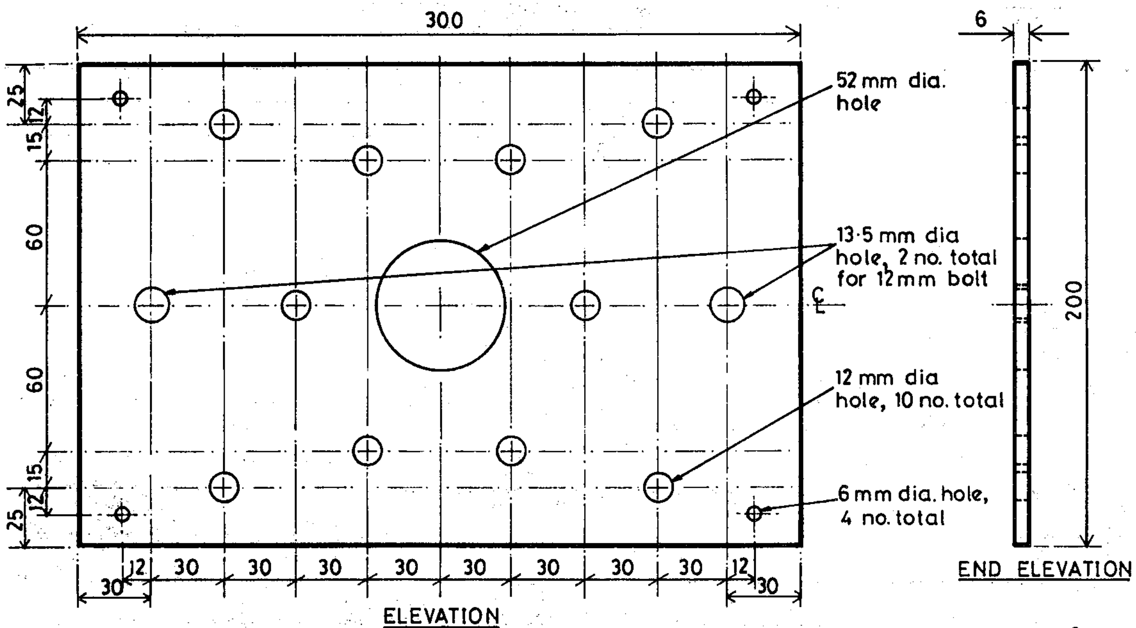


Figure 19

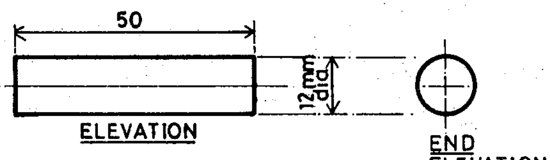


TIMBER TENSION CHORD LOCATING PLATE (Scale 1:4)

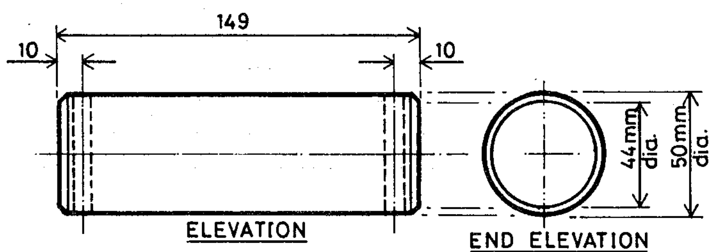


TIMBER TENSION CHORD SIDE PLATE (Scale 1:2)

N.B. These drawings are for bridges of heavy chord construction



DOWEL PIN DETAIL (Scale 1:1)



TIMBER TENSION CHORD SIDE PLATE PIN (Scale 1:2)

Figure 20

PART SECTIONAL LONGITUDINAL VIEW ON ASSEMBLED BRIDGE

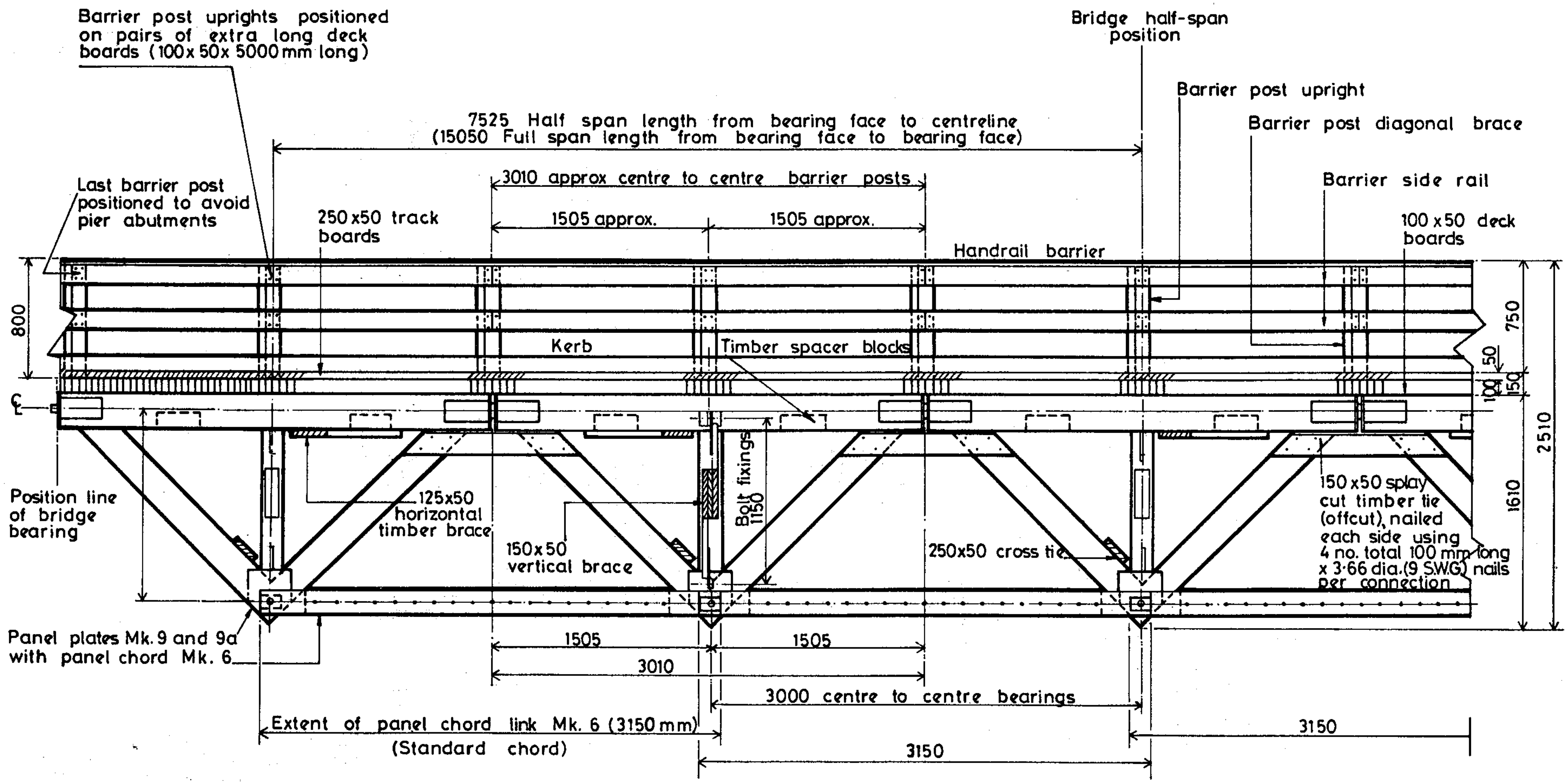


Figure 21

PART SECTIONAL PLAN VIEW ON ASSEMBLED BRIDGE

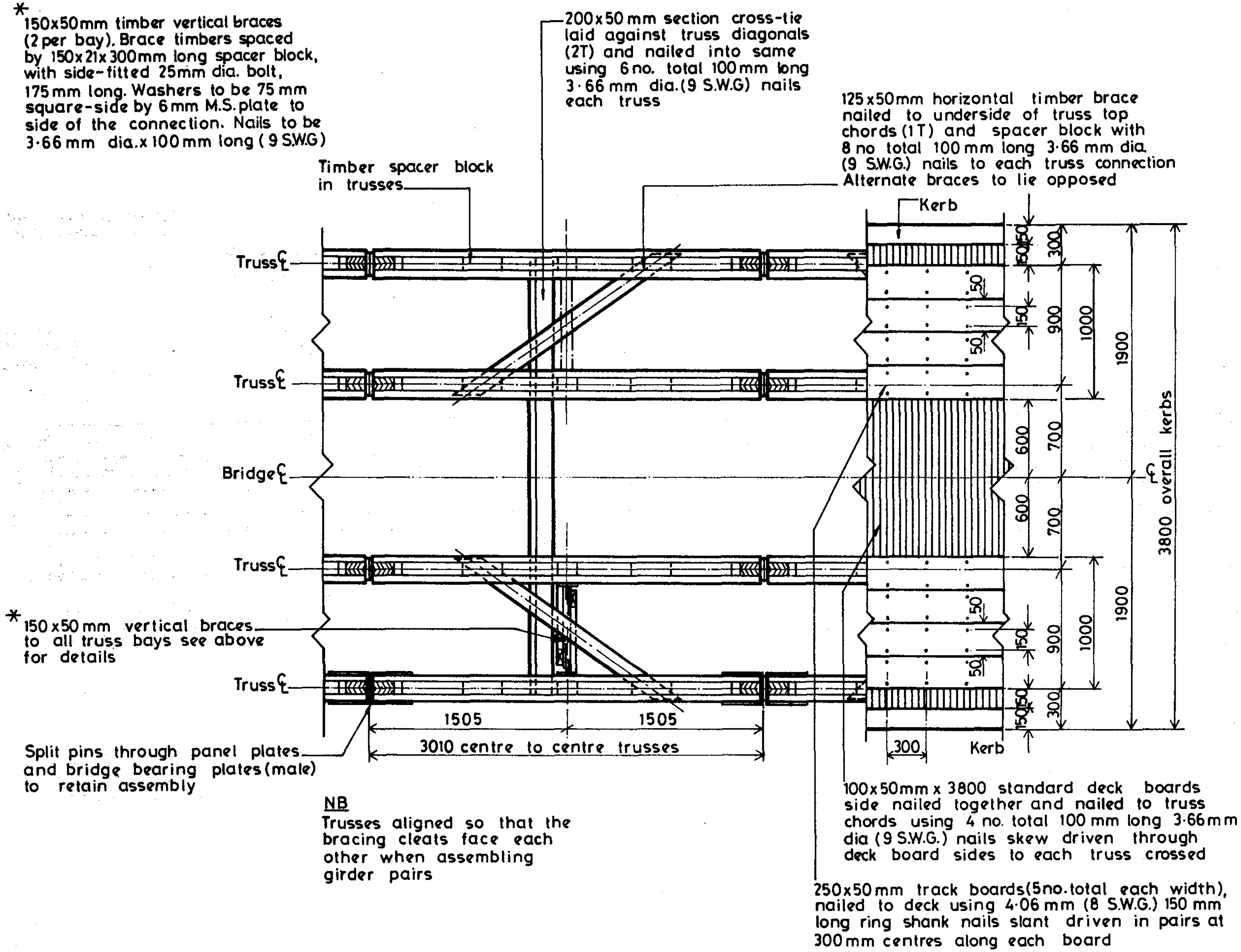
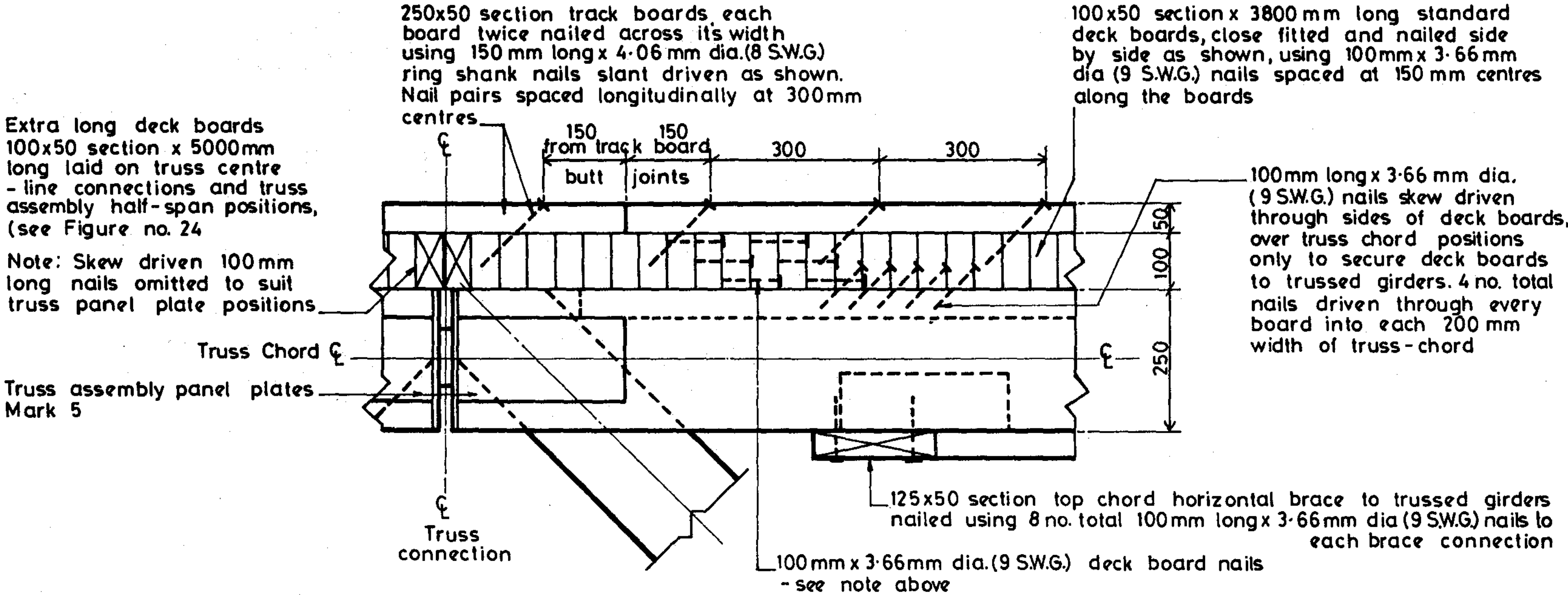
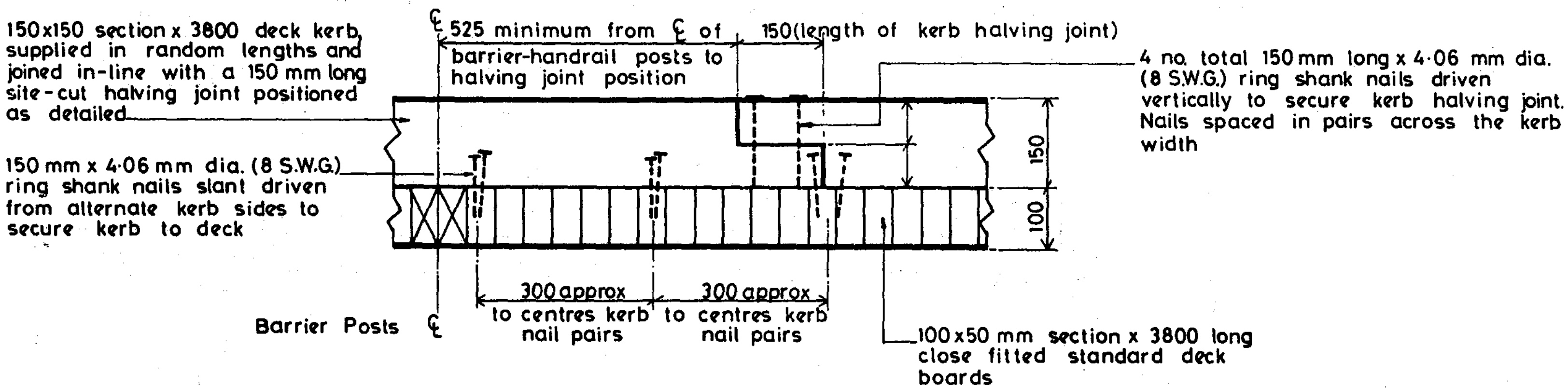


Figure 22

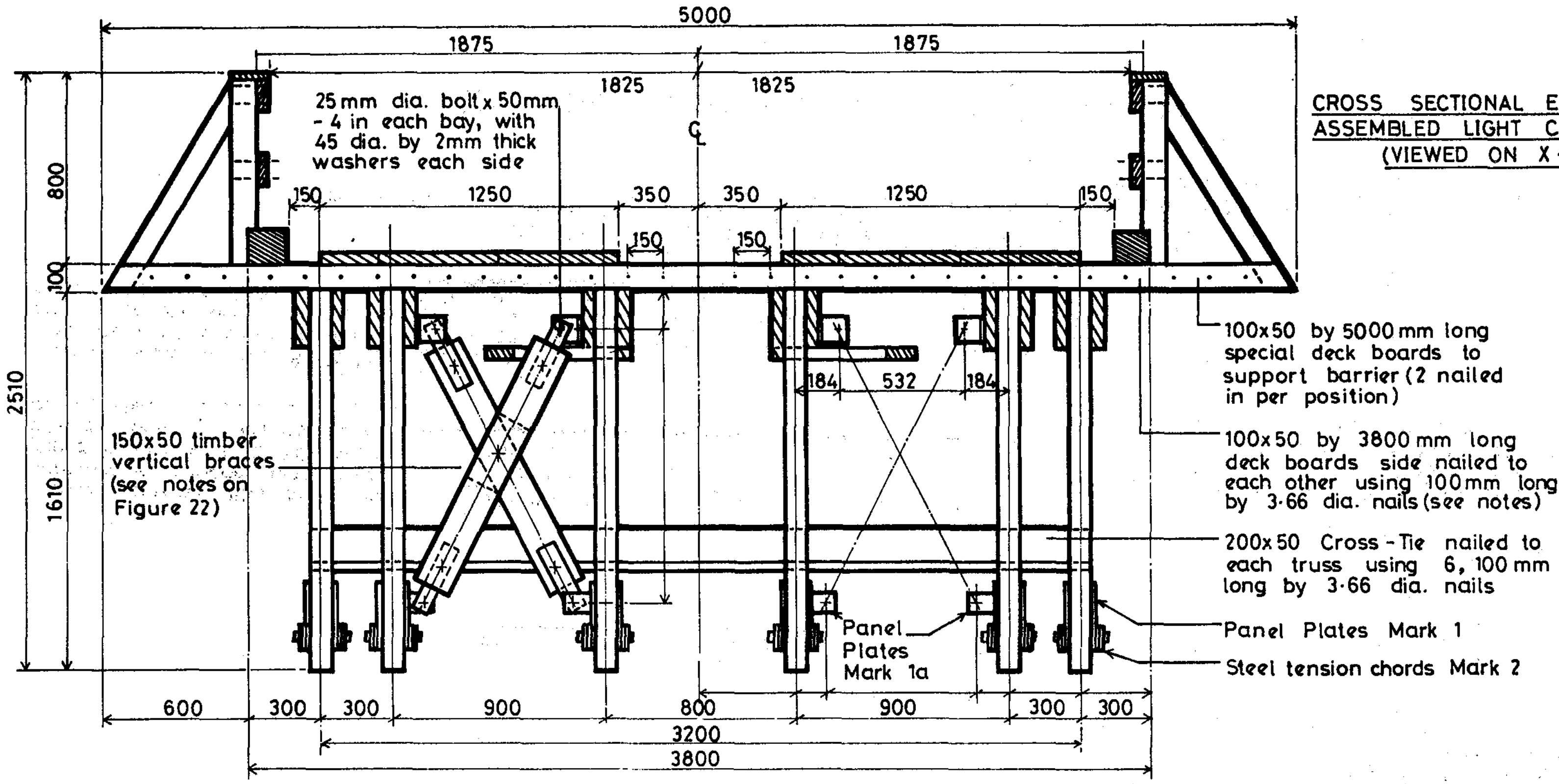


TYPICAL ELEVATION SHOWING BRIDGE DECK FIXING DETAIL

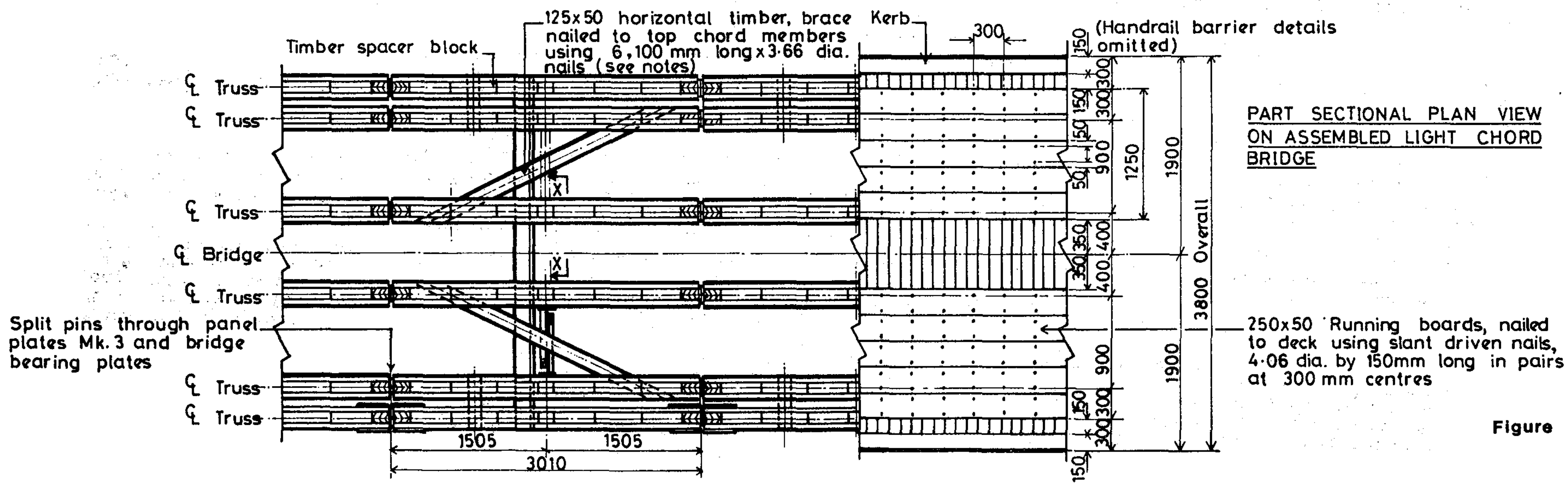


TYPICAL ELEVATION SHOWING BRIDGE DECK KERBING DETAIL

Figure 23



CROSS SECTIONAL ELEVATION ON ASSEMBLED LIGHT CHORD BRIDGE (VIEWED ON X-X)



PART SECTIONAL PLAN VIEW ON ASSEMBLED LIGHT CHORD BRIDGE

Figure 24

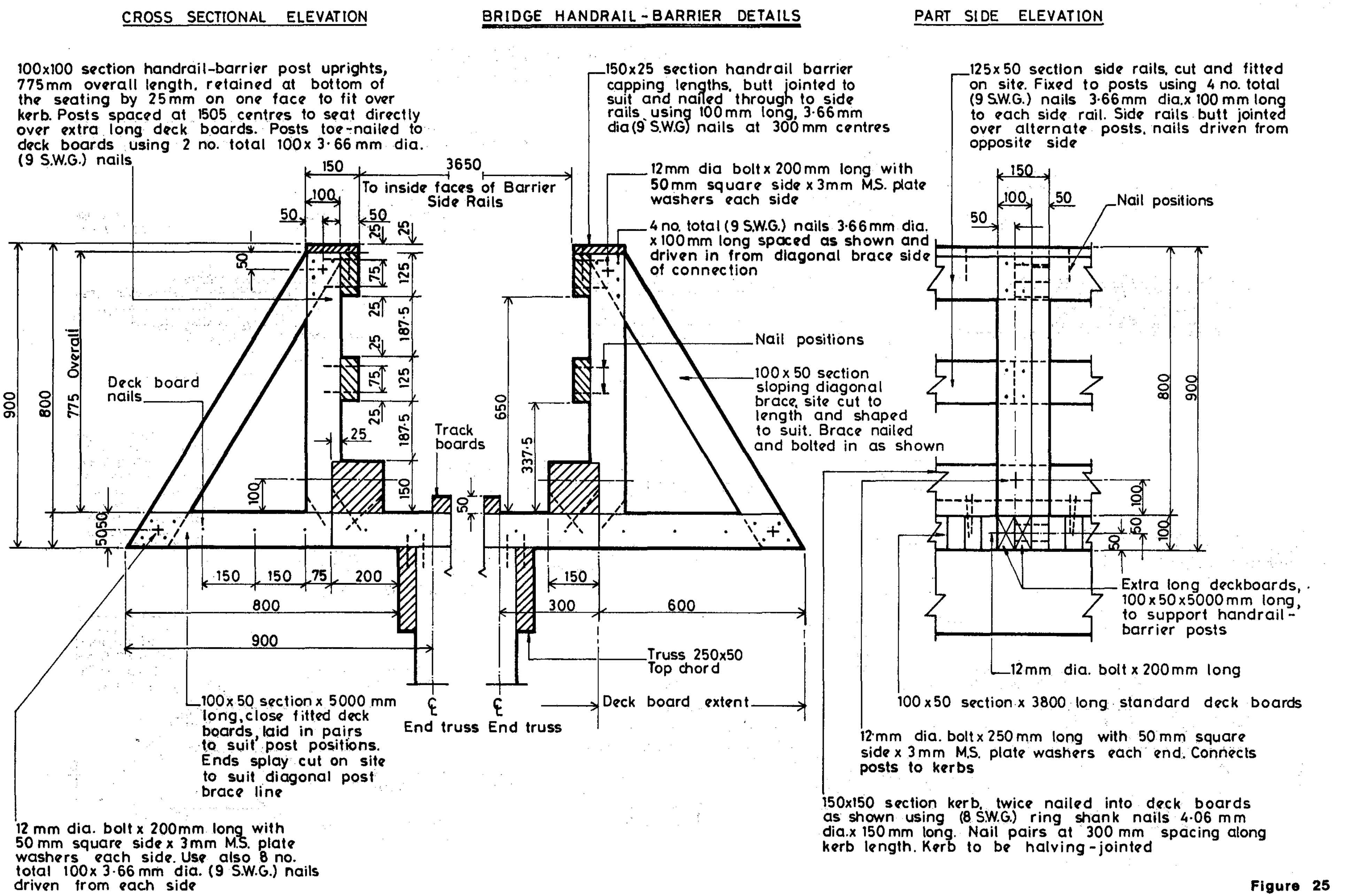
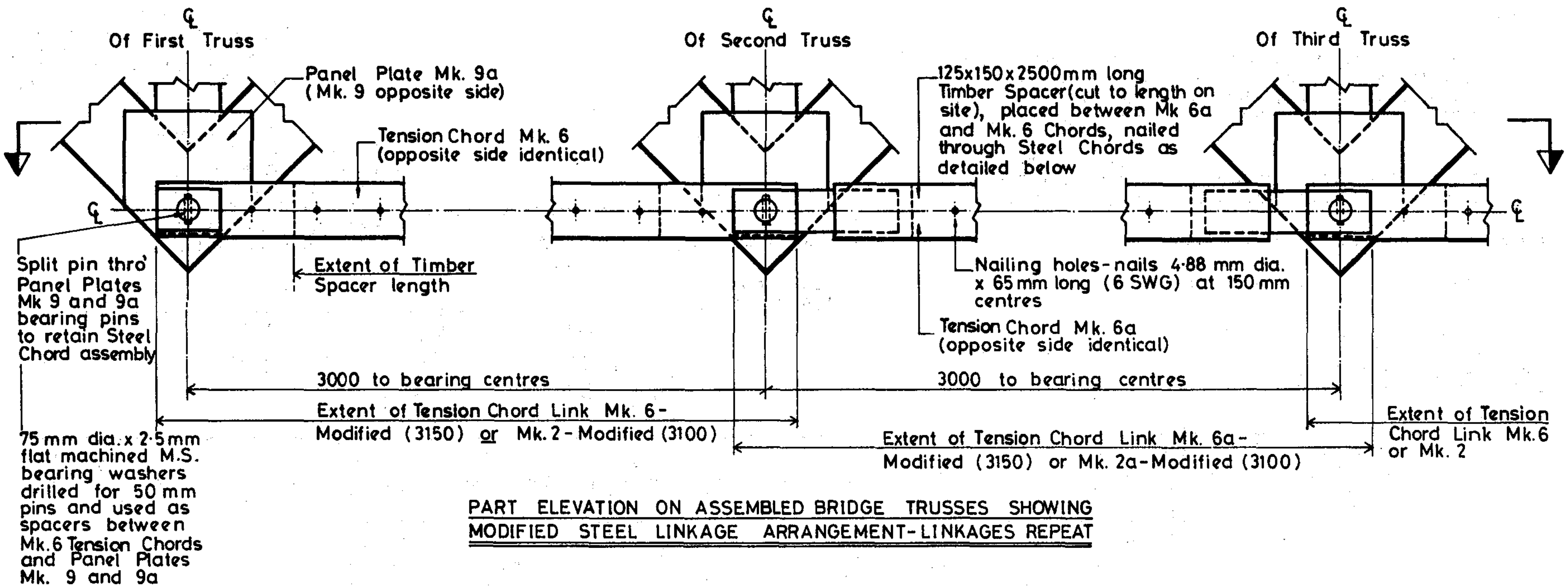
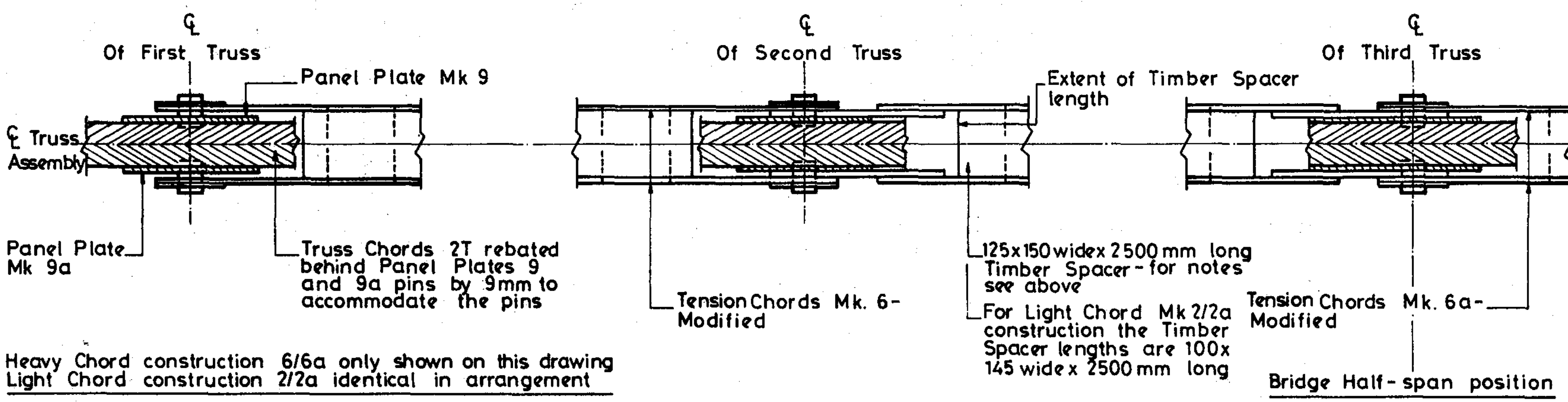

CROSS SECTIONAL ELEVATION
BRIDGE HANDRAIL - BARRIER DETAILS
PART SIDE ELEVATION
100x100 section handrail-barrier post uprights, 775mm overall length, retained at bottom of the seating by 25mm on one face to fit over kerb. Posts spaced at 1505 centres to seat directly over extra long deck boards. Posts toe-nailed to deck boards using 2 no. total 100x 3·66 mm dia. (9 S.W.G.) nails
150x25 section handrail barrier capping lengths, butt jointed to suit and nailed through to side rails using 100mm long, 3·66mm dia (9 S.W.G) nails at 300mm centres
125x50 section side rails, cut and fitted on site. Fixed to posts using 4 no. total (9 S.W.G.) nails 3·66mm dia.x 100 mm long to each side rail. Side rails butt jointed over alternate posts, nails driven from opposite side
3650
To inside faces of Barrier Side Rails
12mm dia bolt x 200mm long with 50mm square side x 3mm M.S. plate washers each side
4 no. total (9 S.W.G.) nails 3·66mm dia. x 100mm long spaced as shown and driven in from diagonal brace side of connection
Nail positions
Nail positions
100 x 50 section sloping diagonal brace, site cut to length and shaped to suit. Brace nailed and bolted in as shown
Deck board nails
Track boards
775 Overall
900
800
650
337·5
Truss 250x50 Top chord
Deck board extent
End truss
End truss
100x 50 section x 5000 mm long, close fitted deck boards, laid in pairs to suit post positions. Ends splay cut on site to suit diagonal post brace line
12 mm dia. bolt x 200mm long with 50 mm square side x 3mm M.S. plate washers each side. Use also 8 no. total 100x 3·66 mm dia. (9 S.W.G.) nails driven from each side
Extra long deckboards, 100 x 50 x 5000 mm long, to support handrail-barrier posts
12mm dia. bolt x 200mm long
100 x 50 section x 3800 long standard deck boards
12mm dia. bolt x 250 mm long with 50 mm square side x 3 mm M.S. plate washers each end. Connects posts to kerbs
150x150 section kerb, twice nailed into deck boards as shown using (8 S.W.G.) ring shank nails 4·06 mm dia.x 150 mm long. Nail pairs at 300 mm spacing along kerb length. Kerb to be halving-jointed

Figure 25

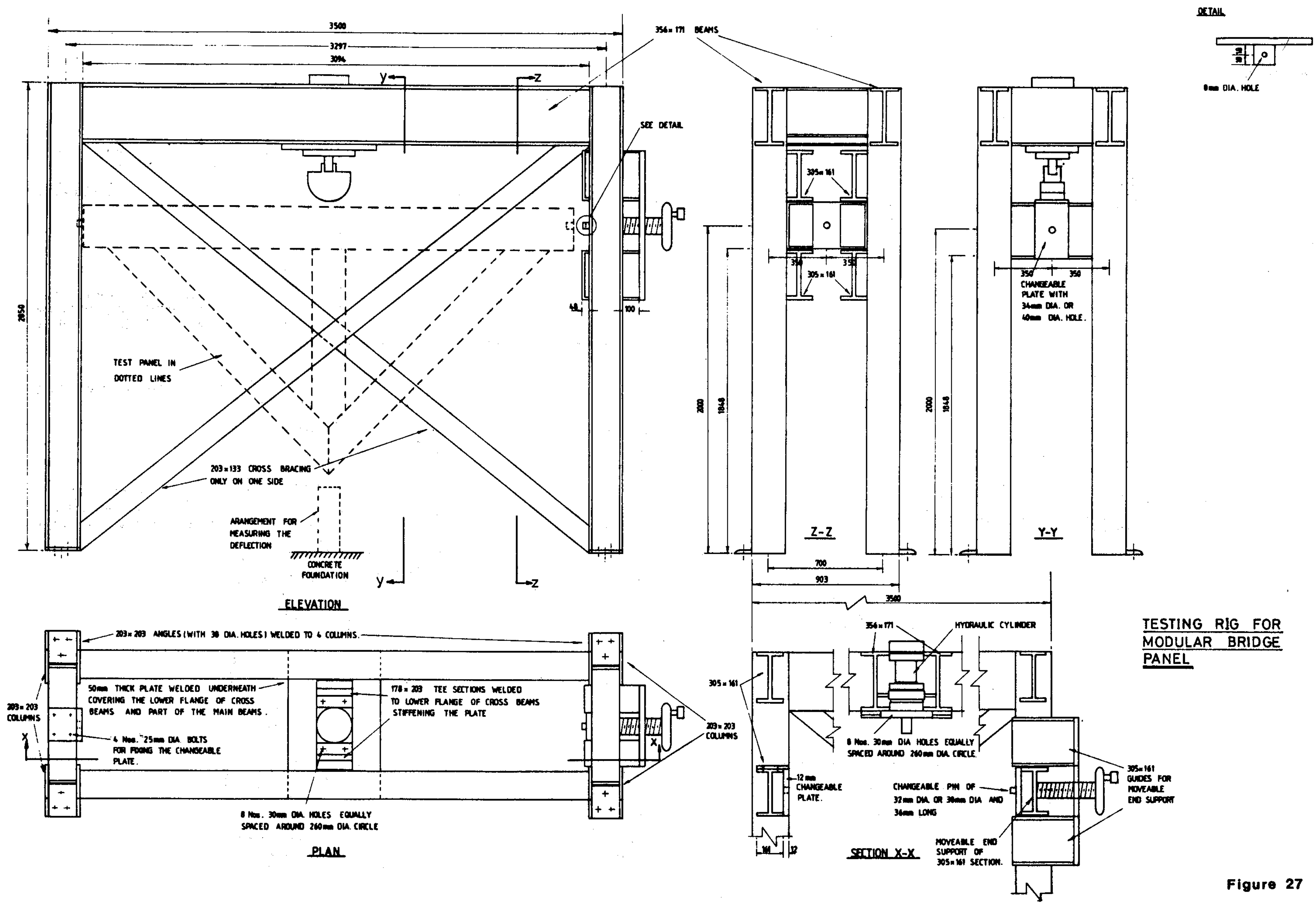


PART ELEVATION ON ASSEMBLED BRIDGE TRUSSES SHOWING MODIFIED STEEL LINKAGE ARRANGEMENT - LINKAGES REPEAT



PART SECTIONAL PLAN VIEW ON 'W-W' SHOWING MODIFIED ARRANGEMENT OF STEEL LINKAGES TO EACH TRUSS ASSEMBLY

Figure 26



TESTING RIG FOR MODULAR BRIDGE PANEL

Figure 27

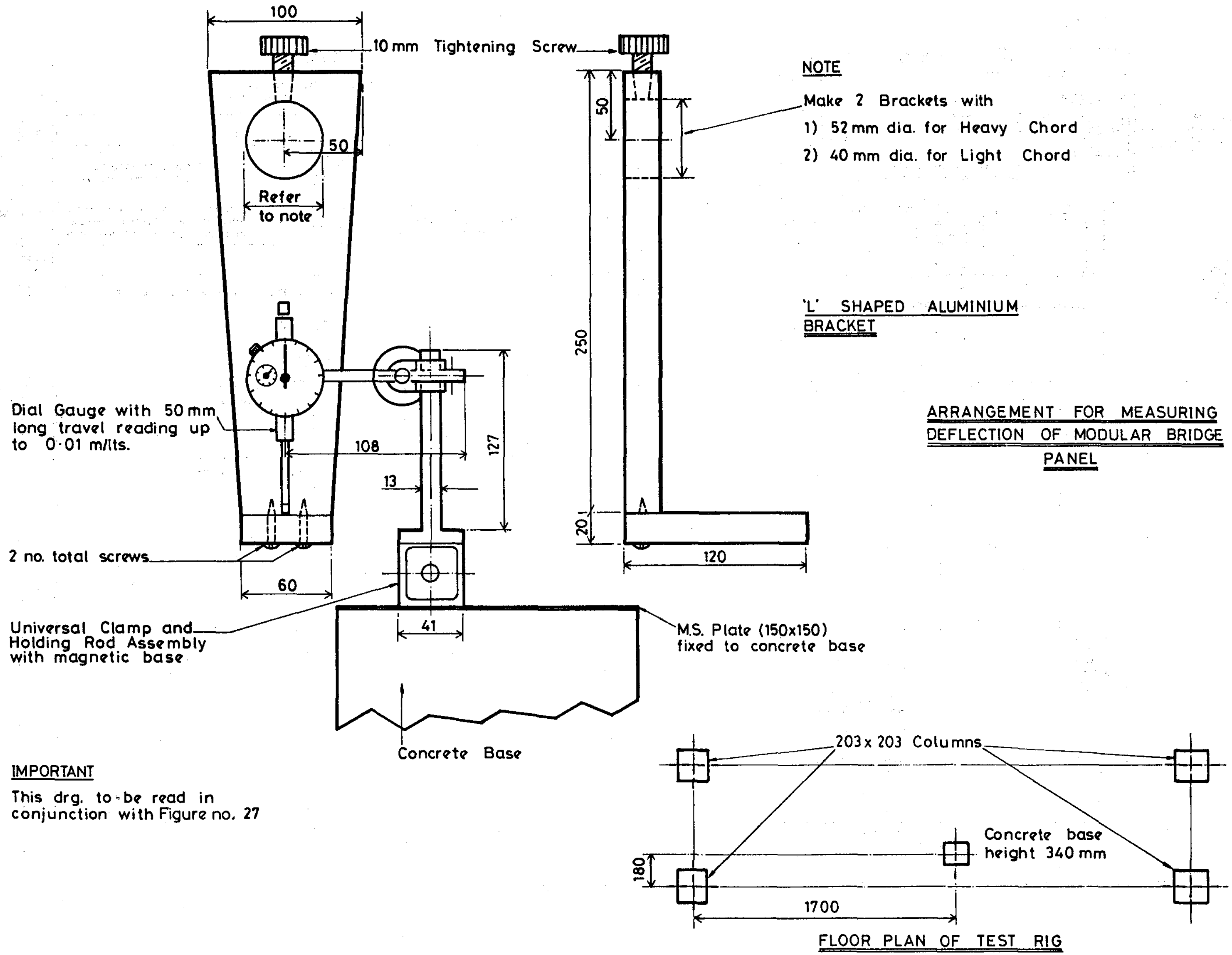
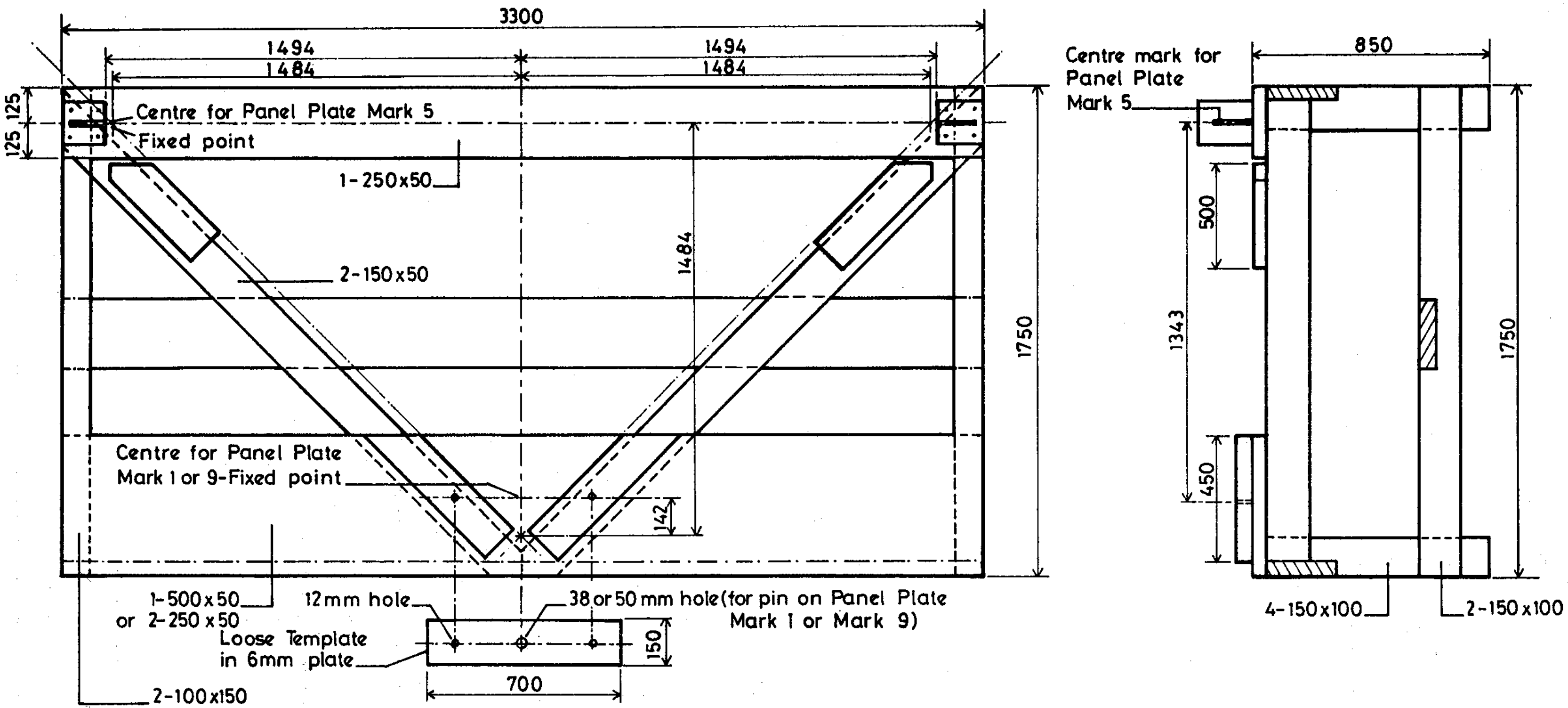
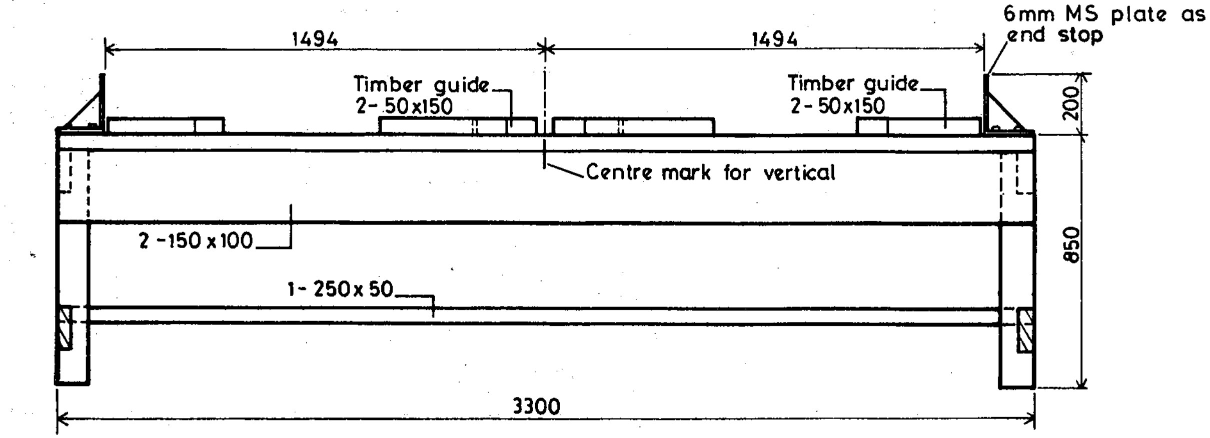

100
10 mm Tightening Screw
50
Refer to note
NOTE
Make 2 Brackets with
1) 52 mm dia. for Heavy Chord
2) 40 mm dia. for Light Chord
50
250
20
120
'L' SHAPED ALUMINIUM BRACKET
Dial Gauge with 50 mm long travel reading up to 0·01 m/lts.
108
127
13
ARRANGEMENT FOR MEASURING DEFLECTION OF MODULAR BRIDGE PANEL
2 no. total screws
60
41
Universal Clamp and Holding Rod Assembly with magnetic base
M.S. Plate (150x150) fixed to concrete base
Concrete Base
IMPORTANT
This drg. to be read in conjunction with Figure no. 27
203 x 203 Columns
Concrete base height 340 mm
180
1700
FLOOR PLAN OF TEST RIG

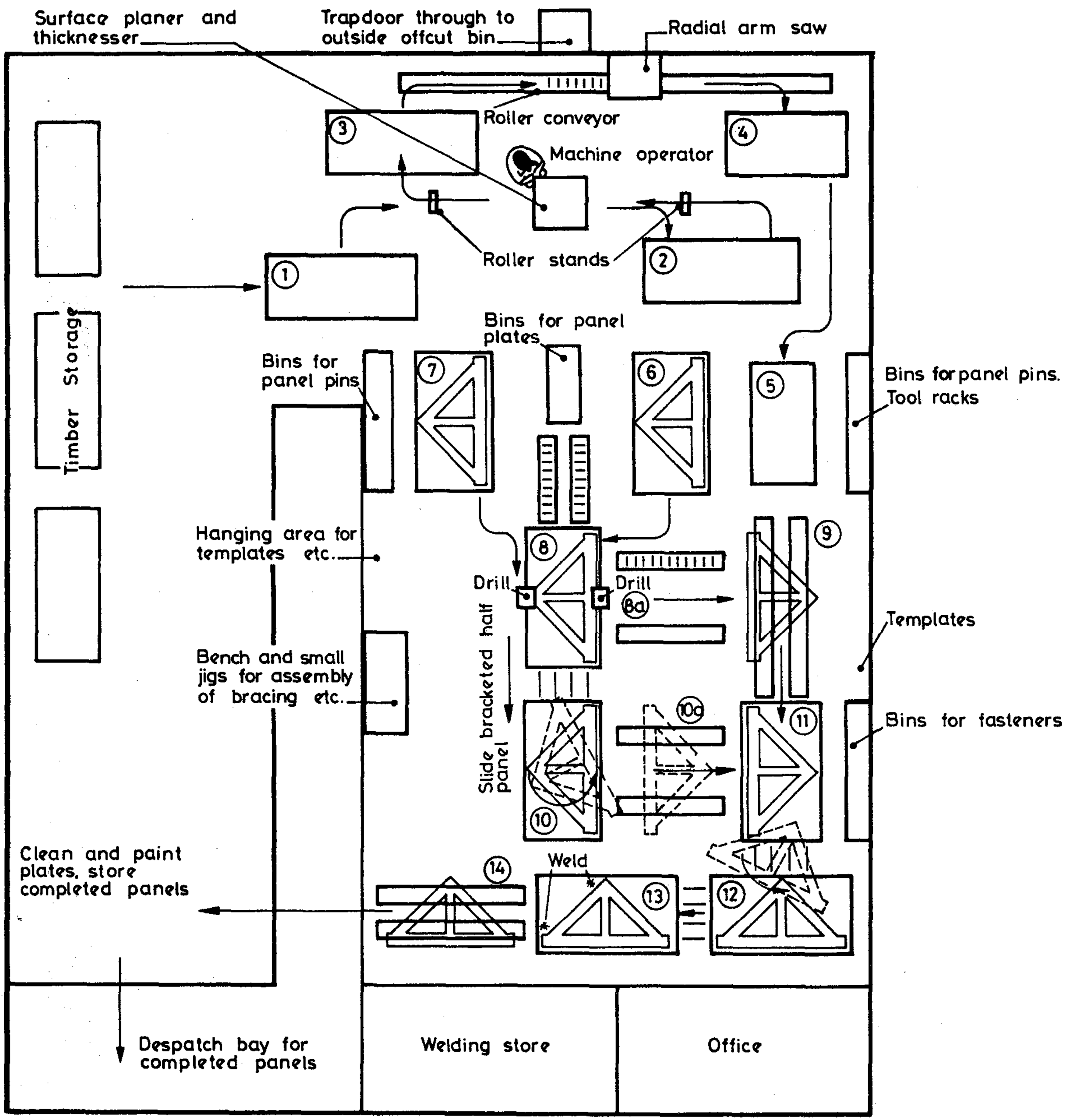
Figure 28





SINGLE JIG AND ASSEMBLY TABLE FOR MODULAR PANEL MANUFACTURE

Figure 29



TYPICAL WORKSHOP ARRANGEMENT FOR ASSEMBLY OF MODULAR BRIDGE PANELS

Key to Stage numbers:

1	Set of unprocessed timber
2	One face surfaced (or edge for decking)
3	Surfaced and thicknessed
4	Finished, cross-cut members
5	Timber members awaiting assembly
6	Assembled plain half-panel
7	Assembled bracketed half-panel
8	Panel moves laterally for the corners to be drilled
8a	Turn plain panel over and slide to stage 9
9	Parking area for plain half-panel and slide to stage 11
10	Rotate bracketed half-panel by 180°
10a	Slide bracketed half-panel onto plain half
11	Bolt and nail together the half-panels
12	Rotate panel by 90°
13	Welding bay
14	Descale and park for removal to despatch bay

Figure 30