



# FOOTBRIDGES

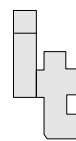
## A Manual for Construction at Community and District Level



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## ABBREVIATIONS AND GLOSSARY OF TERMS

### ABBREVIATIONS

ADV	Animal Drawn Vehicle
DFL	Design Flood Level
IMT	Intermediate Means of Transport
KN	Kilo-Newton (Approximately 100kg)
NMT	Non-motorised Transport
RCC	Reinforced Concrete
USD	United States Dollars
VARBU	Village Access Roads and Bridge Unit (Malawi)

### GLOSSARY OF TERMS

Abutments	Supports at each end of the footbridge
Dead loading	The self-weight of the footbridge resting on the abutments and piers
Deck	The surface of the footbridge that users walk or ride on
Live Loading	The load imposed on the footbridge by users
Piers	Intermediate supports for the footbridge superstructure between the abutments
Shuttering	Boards, usually timber, making up the box-work into which concrete is cast
Stringers	Beams that support the deck. May be timber or steel
Substructure	Abutments and piers that provide the structure supporting the footbridge
Superstructure	The upper part of the footbridge structure comprising the deck, the structure supporting the deck and safety railings



## 1. INTRODUCTION

Much rural travel takes place on local paths, tracks and village roads. These provide essential access to water, firewood, farm plots and the classified road network. Communities and/or local government are generally responsible for this network of paths and tracks. One of the main problems they face is in providing effective water crossings. Particularly in the rainy season, the lack of an adequate crossing can prevent access to services, or detours of many km or taking risks, especially by women and children, on an unsafe crossing.

To provide safe and sustainable crossings, those providing technical assistance to local government and communities need simple, easily applied guidelines on the selection and construction of effective water crossings. A manual, 'Construction and Improvement of Footpaths and Tracks'<sup>1</sup>, contains information on simple water crossings and an introductory chapter on footbridges but within the context of the manual it was not possible to provide the comprehensive guidelines needed for selecting and constructing footbridge designs for specific applications.

This follow-up manual deals specifically with the construction of simple but effective footbridges for spans up to about 20m and is targeted at local technical persons from district council staff, NGOs, local consultants etc. who are involved in providing technical assistance to communities and small contractors in the construction of footbridges. Although the bridges covered in the manual are termed 'footbridges', the designs also allow for use by livestock, IMT (Intermediate Means of Transport) such as oxcarts and the occasional light motorised vehicle, for instance a pick-up.

Before beginning the selection process it is necessary to confirm that a footbridge is the best option for the water crossing. Other options are:

- For shallow crossings, simple stepping stones may be adequate
- For narrow crossings, a culvert may be a better option
- For wide crossings, a ferry may be the most practical option
- For low pedestrian traffic, a cable way may be the cheapest option

Installation of a footbridge is usually a considerable undertaking, particularly for communities, and it is essential to make sure that it is really needed and is a top priority and commitment for the communities involved.

If it is decided that a footbridge is the best option the first step is to carry out a site survey to decide on the alignment of the footbridge and determine its specifications in terms of span (length between supports) and the traffic to be carried. The manual starts from this planning process and works through the process of selecting the most appropriate design of footbridge to meet the specifications. Detailed construction and installation guidelines are then provided on a number of options that are considered the most appropriate. The information is presented largely through pictorial sketches with brief notes of explanation. An understanding of engineering drawing practice is therefore not needed. Text is kept to a minimum.

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<sup>1</sup> *Footpaths and Tracks – a field manual for their construction and improvement*: produced by I.T. Transport Ltd. for the UK Department for International Development (DFID), published by ILO/ASIST as RATP No.6, Geneva, 2002.

A considerable volume of information already exists on footbridges but it is spread around and difficult to access. A major aim of the manual has therefore been to bring this information together and present it in a form suitable for the target users. 5 case studies were carried out in – Nepal, Laos and Indonesia in Asia and Malawi and Ethiopia in Sub-Saharan Africa – to collect data on specific types of footbridges. Library and Internet searches were also carried out, yielding useful information from USA, Australia and the UK. Good information and manuals already exist on certain types of bridges such as cable bridges in Nepal. In these cases the reference sources are given and detailed design information is not included in the manual.

Standard design data is included for the common types of footbridges found in rural areas – bamboo, timber log and sawn timber beam footbridges. These are suited to spans up to 10 to 12m and longer if intermediate pier supports can be used. It is considered that the most appropriate design for longer spans from 10 to 20 or 25m is a steel truss bridge. Standard designs for a version requiring full assembly on site are available from Nepal but no standard designs were found for a modular type which is simpler to construct and assemble on site. A design of the latter type was therefore developed and field-tested in Sri Lanka. An important aspect of the field-test was to test and improve the presentation of data in the manual. Details of the construction and testing of the footbridge are available in a separate publication.

The content and layout of the manual are described in more detail below:

*Chapter 2: Footbridge Specifications*

This chapter covers the planning stage to determine the specifications and layout of the bridge, including the location and alignment of the bridge to specify span, and identification of users to specify width and loading.

The design loading and criteria used in the manual are derived and compared with other footbridge standards

*Chapter 3: Selecting a Footbridge Design*

The range of design options for footbridges is outlined covering characteristics, applications, advantages and disadvantages. Typical examples of each type are illustrated by photographs or drawings, showing basic details of construction. Further sources of information are provided.

The types of designs included are:

- Bamboo bridges
- Timber log and timber pole bridges
- Sawn timber, beam and truss types – glue-laminated designs are also briefly described but are not considered appropriate for this manual
- Steel beam and truss types
- Reinforced concrete footbridges
- Suspended and Suspension bridges

The criteria for selecting a footbridge type are discussed and the above range of options compared against these criteria. The types of footbridges to be covered in detail in the manual are selected.

*Chapter 4: Design of Timber Footbridges*

Detailed designs and examples are given for 3 types:

- Bamboo footbridges
- Timber log footbridges
- Sawn-timber beam bridges

*Chapter 5: Design of Steel Footbridge*

A standard design for a modular steel truss bridge for spans up to 20m is described. Maintenance requirements are outlined

*Chapter 6: Design of Reinforced Concrete Footbridges*

Design details are given for a simple slab type of reinforced concrete (RCC) footbridge and the steps in construction are outlined.

*Chapter 7: Installation of Footbridges*

Details of the construction of abutments and piers are given, covering both timber and masonry types. Procedures for installing and fixing footbridges in position are described.

*Appendix A: Site Survey and Layout of Bridge*

This outlines the steps in carrying out the site survey with a questionnaire to collect the required information for planning the bridge installation.

*Appendix B: Construction of Steel Truss Footbridge*

Detailed step by step instructions are given for the manufacture of the modular steel truss footbridge that was described in Chapter 5.

*Appendix C: Construction of a Footbridge using a Scrap Chassis from a Truck or Bus*

Details are given of a footbridge constructed using a scrap truck chassis to span the crossing and support the deck. It is based on information provided by the Kisii Training Centre in Kenya.

*Appendix D: Contact Details for Sources of Further Information*

Contact details are given for the sources of further information referred to in the manual



## 2. FOOTBRIDGE SPECIFICATIONS

### 2.1 PLANNING

This section summarises the factors that need to be considered in the planning of the design and installation of the footbridge.

#### 2.1.1 Location

The choice of location should try to minimise the cost of the footbridge and the work involved in installing it and maximise the benefits to the communities that will use it. The selection process should consider the overall installation covering both the bridge and the approach paths or tracks. The following factors should be considered:

- Use the shortest possible span (length) of the bridge taking into account the factors below
- The footbridge should be on a straight section of the river or stream, away from bends where erosion can occur.
- Select a location with good foundation conditions for the abutment supports for the footbridge
- The location should be as close as possible to any existing path or track alignment
- The location should provide good clearance against flooding and should minimise the need for earthworks on the approaches to raise the level of the bridge
- The stream/river should have a well defined and stable flow path with little risk of this changing due to erosion of the banks
- The approaches should be across well-drained ground to minimise problems of water-logging and erosion
- The location should be as sheltered as possible to minimise wind problems
- The site should allow good access for materials and workers.
- It is helpful if there is a good local supply of materials that might be used in the construction such as sand and stones.
- The site should be agreed with the local communities

#### 2.1.2 Layout of the Footbridge

A bridge is made up of 2 assemblies:

1. *The superstructure* that provides the crossing for users, comprising the deck (carriageway surface), the structure which supports the deck such as beams or trusses, and railings that provide safety for users. Various superstructure designs are presented in Chapters 4, 5 and 6.

2. *The substructure* that supports the superstructure, comprising abutments that support the ends of the bridge and in some cases piers that provide intermediate supports for longer span bridges. The design of substructures is presented in Chapter 7.

The layout of the bridge is set primarily by the surrounding terrain and the height needed for the superstructure. Three main factors need to be considered in deciding this:

1. The clearance of the deck above the *Design Flood Level* (DFL) to provide acceptable access during flood periods (note that the approach paths/tracks will also need to provide the same level of access) and to minimise potential damage to the superstructure from water and debris washed along in flood waters.
2. The height of the superstructure needed to provide clearance for floating debris and any boats using the stream or river in normal operating conditions (it has to be decided up to what water level it is reasonable to provide access for boats).
3. The height on the banks where it is suitable to locate the bridge abutments in regard to appropriate soil conditions, minimising erosion from flood waters and minimising the difference in elevation between the bridge deck and approach paths/tracks (see Chapter 7).

Figure 2.1 shows the basic layout of a footbridge. Simple, relatively low-cost footbridges using beam structures such as timber log or sawn timber are limited to spans of about 8 to 10m by the available lengths of the beams. For longer spans an important initial decision to be made is whether piers can be used for intermediate supports to allow beam structures or whether it is cheaper to use more complex truss structures to avoid the use of piers. The maximum span of truss type structures is 20 to 25m and above this a decision has to be made whether to use piers or suspension type bridges that are suitable for longer spans. More guidelines on the selection of bridge types are given in Chapter 3 of the manual.

### 2.1.3 Height of Deck

A *Design Flood Level* (DFL) needs to be defined. It may be an 'average' level (the maximum level that occurs in an 'average' year) or a higher level that occurs in 1 in 'n' (10,20 etc..) years.

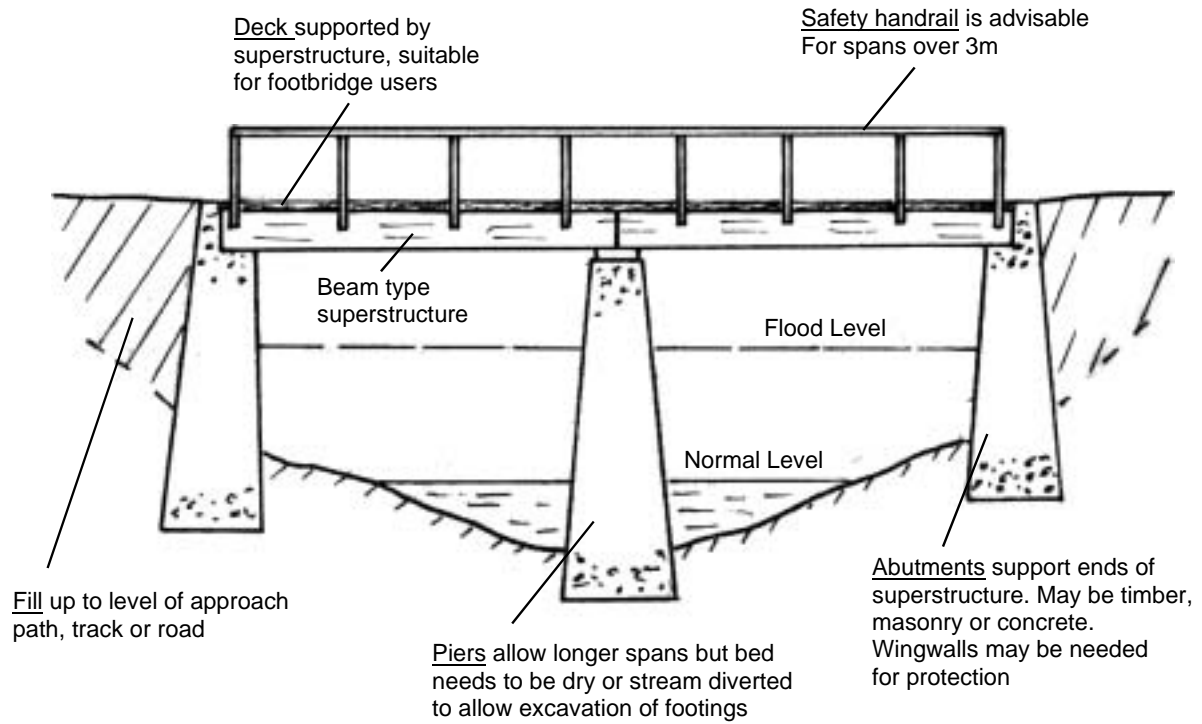
It is suggested that the *average upper level over a 5 year period* is used and the height of the deck is set so that there is clearance under the superstructure to allow for some excess flooding and for debris carried in flood waters. Recommended clearances are:

- In fairly flat areas where flood waters can spread to limit rises in water level a minimum clearance of 1m is recommended.
- As the terrain becomes more hilly and banks are steeper so that flood waters are more confined the clearance should be increased because of the greater variation in flood level. A clearance of up to 5m is recommended for hilly areas with streams/rivers running in steep-sided gorges.

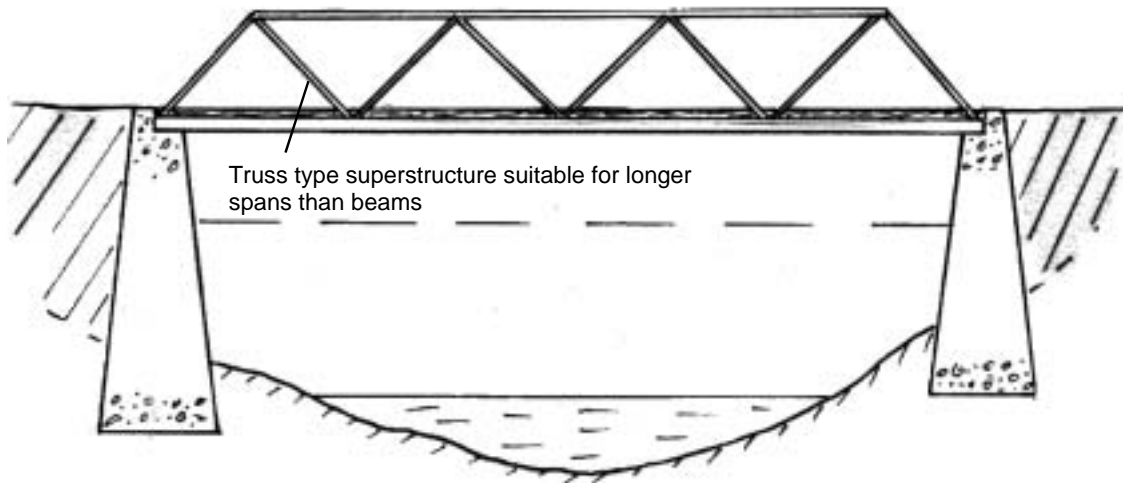
The other critical factors of clearance for boats and the location of abutments also need to be checked to see which criteria sets the minimum height of the deck.

The average flood level can be checked by:





(i) Beam Type Superstructure



(ii) Truss Type Superstructure

**Note:**

Careful consideration needs to be given for the location of abutments and piers to limit their impact on the flow of water and to minimise the erosion they may cause. For example, a central pier is at the point of highest water velocity and is best avoided where the water flow is high. An off-set pier is better if spans allow it. If not 2 piers should be considered.

**Figure 2.1: Layout of Footbridge**

- Site observations – signs of debris caught on vegetation, tide marks, sand/soil deposits
- Discussions with the local population

Setting out the level of the bridge deck is shown in Figure 2.2. Guidelines for survey of the site and locating the positions of the abutments are given in Appendix A.

**Note:**

Increasing the height of the deck will usually lead to increasing its length and cost. However, it is likely to increase the security of the abutment against instability and erosion and reduce the risks of the deck being damaged or washed away by flood waters.

It is therefore necessary to carefully balance the increased cost against the reduced risks. Minimising the risks will be increasingly important as the cost and predicted life of the footbridge increase.

## **2.2 FOOTBRIDGE USERS AND LOADING**

### **2.2.1 Users**

The users of the bridge and expected traffic levels must be clearly identified as these will determine the required deck width of the bridge and the 'live' loading on the bridge.

Although termed "Footbridges", in developing countries these bridges may be required to also carry livestock, pack animals and a range of simple vehicles (Intermediate Means of Transport, IMT) such as bicycles, handcarts, animal-drawn vehicles (ADV), and motorcycles. This need must be clearly defined.

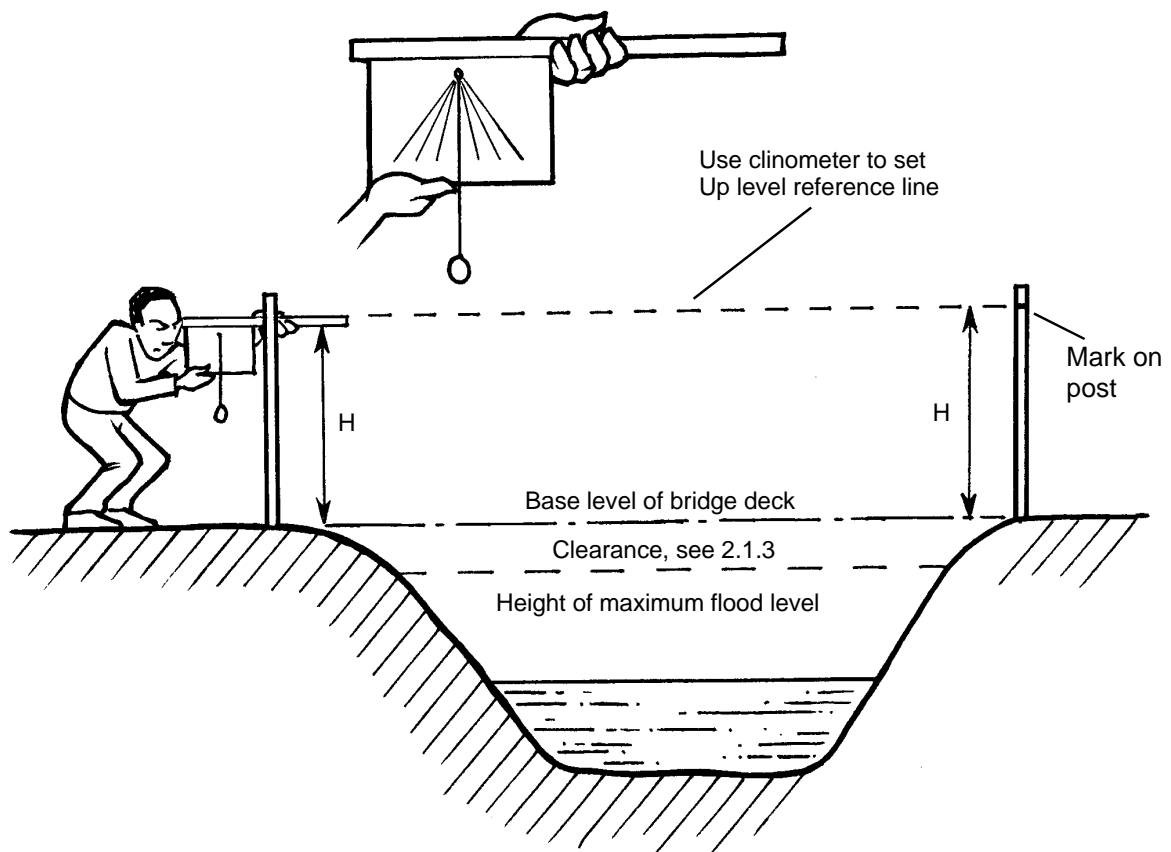
It may also be desirable for the bridge to carry an occasional light motorised vehicle such as a pick-up. For instance if the bridge is on an access track to a village and there is no road to the village.

If the bridge is to allow access for ADVs then it will be difficult to exclude cars and pick-ups. However, the deck width should only just allow access for these vehicles and should prevent access of any heavier vehicles.

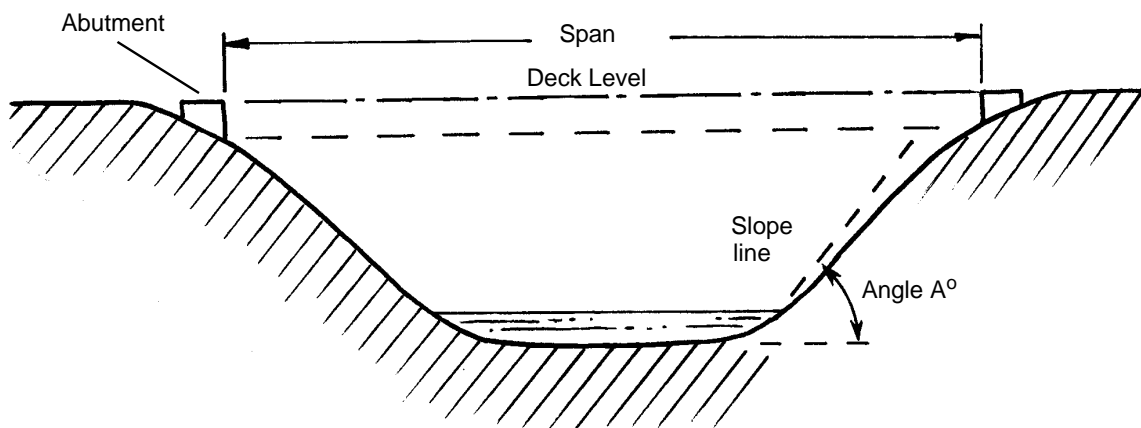
Figure 2.3 shows recommended widths for paths and tracks for different types and levels of traffic. Because of the relatively short lengths of footbridges and the significant costs of construction it is considered that deck widths can be slightly less than those shown in the figure. Two standard widths are therefore recommended in this manual:

- 1.4m for pedestrians, bicycles, livestock, pack animals, wheelbarrows and handcarts, and motorcycles
- 2.1m to also include ADVs and occasional light motorised vehicles

These widths will only allow one-way access of some types of traffic and appropriate warning notices should be put up at each end of the bridge. Also for heavier vehicles such as ADVs, cars and pick-ups, only one vehicle should be allowed on the bridge at a time in order to avoid the need to over-design the bridge for just a few users.



**Note:** Wherever possible the bridge should be perpendicular to the river/stream



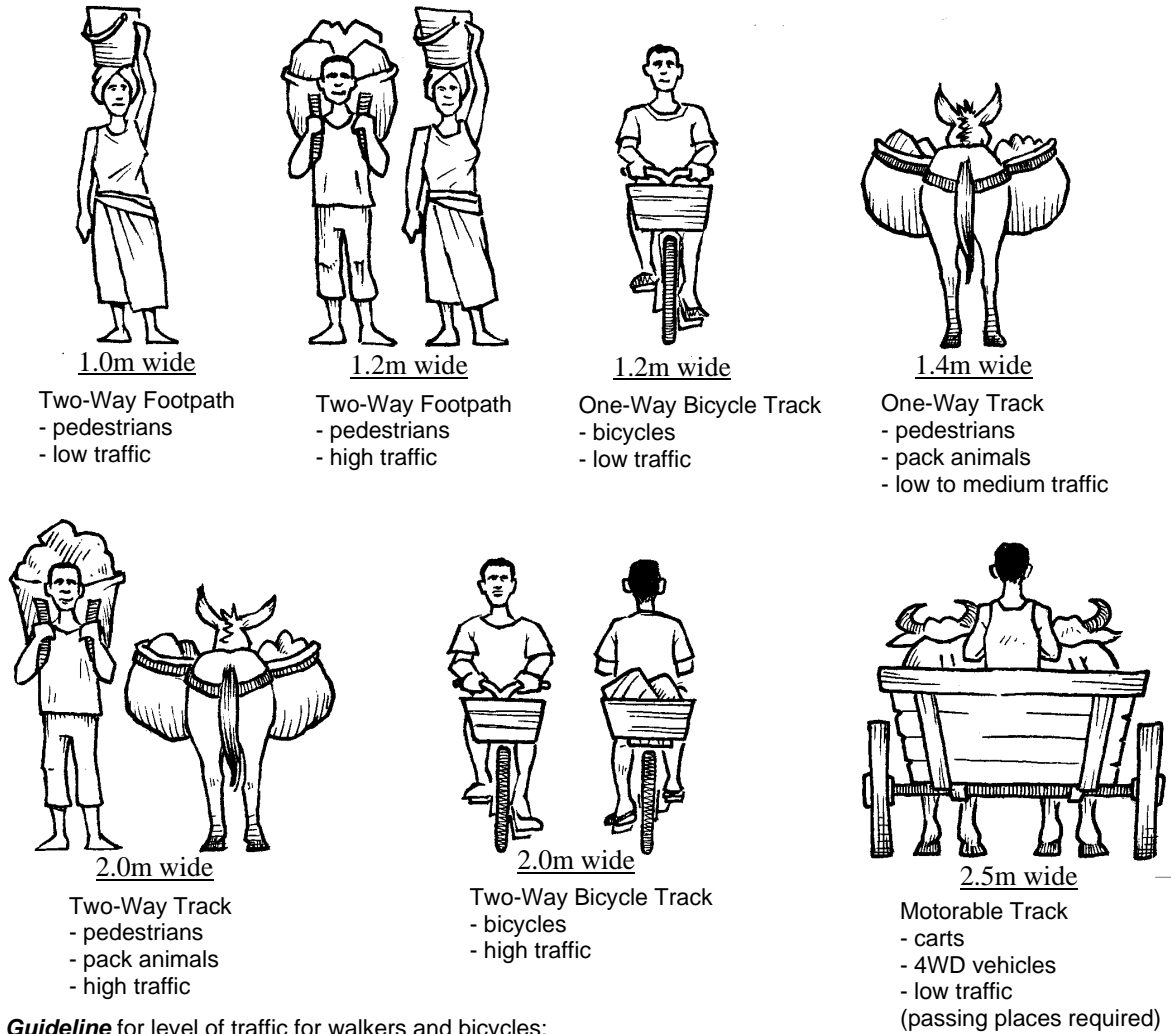
**Note:**

It is important to consider the stability of the banks when choosing the locations for the abutments. The abutments should lie outside a slope line of Angle  $A^\circ$  which will depend on soil conditions.

- For stable rock,  $A$  can be up to  $60^\circ$
- For firm soil  $A$  should not exceed  $45^\circ$
- For loose sand, gravel and soft soil  $A$  should not exceed  $35^\circ$

**Figure 2.2: Level of Bridge Deck**

Standard Widths for Different Paths and Tracks



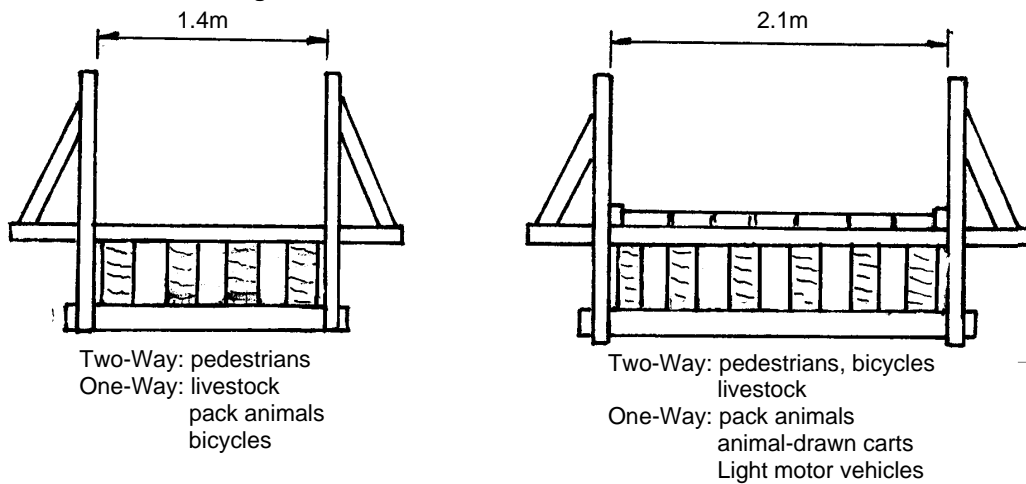
**Guideline** for level of traffic for walkers and bicycles:

Low: less than 50/day

Medium: 50 to 500/day

High: over 500/day

Standard Widths of Footbridges Recommended in Manual



**Note:**  
Footpaths allow comfortable clearance. Because of their short lengths footbridges need provide only minimum clearance.

Figure 2.3: Proposed Standard Widths for Footbridges

**Selection of width** – this needs to be considered carefully. The potential loading on a 2.1m wide bridge is 50% greater than on a 1.4m wide bridge and therefore it has to be made substantially stronger, increasing cost in about the same proportion. If an ADV or motor vehicle is only expected to want to use the bridge occasionally, say 2 or 3 times per month, then the need for access has to be critically assessed with the local communities to make sure the extra cost is justified.

**Restriction of vehicle size** – it is recommended that masonry columns are built at each of the bridge with an opening of 1.9m. These will allow access for a Landrover and medium-size pick-up but prevent larger vehicles from damaging the bridge.

### 2.2.2 Design Loads

Footbridges have to be strong and rigid (without undue flexibility or deflection) to withstand the following forms of loading:

- Vertical loading** -
- (i) *Dead loading* from the weight of the bridge itself (snow loading is not usually considered for footbridges as it is unlikely to be significant when the bridge is being heavily used).
  - (ii) *Live loading* from the users of the bridge

The vertical design load is the combination of *dead load* and the *highest live load* anticipated from the users of the bridge. The dead load is the distributed weight of the superstructure including decking and can readily be evaluated. The highest live load is more difficult to estimate and is discussed below.

- Side loading** -
- (i) From wind pressure
  - (ii) Due to users leaning on or bumping against the safety railings
  - (iii) Due to the possibility of debris carried by the river/stream impacting against the bridge. **Note:** that it is only feasible to design against relatively light impacts. If heavy impacts are possible from larger objects in fast flowing water then the deck clearance (2.1.3) should be increased to reduce the risk of impact and damage.

Side loading to be considered in the design is wind loading acting on the exposed side faces of the bridge members and loads applied by users leaning on or bumping against the safety rails and support posts. Significant impacts from debris will not occur if there is adequate clearance below the bridge.

Design standards for footbridges consider wind velocities up to 140 to 160 km/hr. This imposes a uniform pressure on the exposed side faces of the bridge members of 130 to 140kg/m<sup>2</sup>. The upper figure is used in the designs in this manual. Since there is unlikely to be traffic on the bridge in these high winds, the wind loading is considered separately from vertical live loading.

**Live loads** – two aspects of live loading need to be considered:

- (i) The point load applied to the bridge deck by a person's or animal's foot or the wheel of a vehicle, to check the strength of the decking
- (ii) The load transferred from the decking to the structural members of the superstructure which then transfer it to the bridge supports. These loads will act as a series of short distributed loads or as a continuous distributed load spread along the longitudinal members that support the decking.

The most critical live loads assumed for users of footbridges are shown in Table 2.1. Live loading by other types of users is considered to be less than these cases as explained below:

- *Bicycles and motorcycles* – the point loads will be less than those assumed for livestock and because of the space they take up the load per unit area will be less than for pedestrians
- *Pack animals* – these are assumed to be donkeys, mules, horses or camels. The maximum loading is assumed to be similar to that of livestock which may include oxen.

The design live loads used in this manual are summarised at the bottom of Table 2.1. It is considered that the **point load of 500kg (5kN)** and **distributed load of 400kg/m<sup>2</sup>** provide an adequate margin of safety for all normal users of footbridges. The live load specifications for the two bridge widths are summarised in Table 2.2. Table 2.3 compares these specifications with those from other manuals.

### 2.2.3 Design Criteria

Bridge design standards specify the following design criteria which need to be considered to ensure that footbridges are safe and convenient for anticipated users.

1. **Strength:** the bridge members need to be strong enough to withstand the live and dead loads identified above with an adequate margin of safety to allow for uncertainties in loading, material properties and quality of construction and maintenance.
2. **Deflection:** the footbridge should not deflect to an extent that might cause concern or discomfort to users or cause fixed members to become out of plane. Maximum limits for beam and truss footbridges range from span/180 (5.5mm per m of span) to span/360 (2.75mm per of span). A middle value of span/250 (4mm per m of span) is used in this manual. The limit is the maximum deflection at the centre of the footbridge when loaded by the above live loads.
3. **Dynamic Loading:** it is possible that a footbridge might be set vibrating by winds or by people walking over the bridge. However, this is not usually considered a problem for rural footbridges of the span range covered in this manual.

Table 2.1: Assumed Live Loads on Footbridges

Type of User	Point load on deck	Distributed load on bridge structure
<b>Pedestrians</b>	Weight of person 80kg + load carried 20kg = Total 100kg <u>Point load</u> Assume all load on 1 leg x impact factor of 1.2 = 120kg	Assume crowded bridge with 4 persons/m <sup>2</sup> <u>Distributed load</u> = 400kg/m <sup>2</sup>
<b>Livestock</b>	Assume upper weight of 800kg  <u>Point load</u> Assume normal walking with total weight on 2 legs x impact factor of 1.2 = 400x1.2 = 480kg	Assume weight spread over 2x1m area  <u>Distributed load</u> =800/2 = 400kg/m <sup>2</sup>
<b>Oxen and cart</b>	Upper weight of each oxen 800kg + weight of loaded cart 1200kg = Total 2800kg  <u>Point loads</u> For oxen, total weight on 2 legs x impact factor of 1.2 =400x1.2=480kg For cart, weight per wheel =600kg	Assume total weight spread over area of 4.5x2m  <u>Distributed load</u> 2800/9 = 310kg/m <sup>2</sup>
<b>Light motor vehicle</b>	Assume maximum loaded weight of 3000kg with 1800kg on rear wheels  <u>Point load</u> Load per rear wheel =900kg	Assume weight spread over area of 4x2m  <u>Distributed load</u> 3000/8 = 375kg/m <sup>2</sup>
<b>Design Loads</b> assumed in manual	Pedestrians and livestock ONLY = <b>500kg</b>  Oxcarts but NO motor vehicles = <b>600kg</b>  Motor vehicle = <b>900kg</b>	All cases – <b>400kg/m<sup>2</sup></b>

**Table 2.2: Summary of Live Load Specifications**

Type of loading	1.4m wide footbridge		2.1m wide footbridge	
	Point load	Distributed load	Point load	Distributed load
<b>Vertical</b>	1 animal, 500kg (5kN) load at any position	560kg (5.6kN) per m length	2 animals side by side, 2 x 500kg loads 0.5m apart. OR 1 vehicle wheel 900kg	800kg per m length
<b>Constraints</b>	No oxcarts or motor vehicles		1 Limited to light motor vehicles of maximum loaded weight of 3 tonne 2 Only one ADV or motor vehicle on the bridge at one time	
<b>Side load:</b> check wind load applied to full length of bridge and point loads from users applied to side structures (railings)				
<b>Wind load</b>	140kg/m <sup>2</sup> x side area of bridge elements		140kg/m <sup>2</sup> x side area of bridge elements	
<b>Other side loads from users</b>	Point load of 130kg at height of 1.25m above deck		Point load of 130kg at height of 1.25m above deck	

**Table 2.3: Load Specifications for other Codes**

Details of Code	Vertical loads		Side loads
	Point	Distributed	
<i>Short-Span Trail Bridge Standard, Nepal</i>	None	400kg/m <sup>2</sup> up to 50m span	Wind loading – 130kg/m <sup>2</sup>
<i>Light Bridge Manual, Outdoor Structures Australia</i>	450kg normal 2000kg for small tractors Not specified for livestock	500kg/m <sup>2</sup> for severe crowding 300 to 400kg/m <sup>2</sup> for rural locations	Wind loading – none Loading from users – 10% of vertical load
<i>Footbridges in the Countryside, Countryside Commission for Scotland</i>	812kg for horse and rider (1) 612kg for cattle (1)	230kg/m <sup>2</sup> for normal pedestrian traffic and livestock	Wind loading – 140kg/m <sup>2</sup> Loading from users – 74kg/m for normal pedestrian; 130kg/m for cattle
<i>Specifications for Design of Pedestrian Bridges, American Association of State Highway Transportation Officials (AASHTO)</i>	450kg for horse	405kg/m <sup>2</sup> for pedestrian load	Wind loading – 360kg/m <sup>2</sup> (2)

**Note:** (1) These assume a trotting animal with total weight on one leg. This loading is considered excessive for the applications of this manual which assumes the weight shared between 2 legs.

(2) This apparently assumes a much higher drag coefficient than other codes as it is based on the same wind speed of 160km/hr.



### **3. SELECTING A FOOTBRIDGE DESIGN**

This chapter gives details of a range of footbridge designs, covering basics of construction, applications, advantages and disadvantages and providing sources of further information. The types of designs included are:

- Bamboo bridges
- Timber log and timber pole bridges
- Sawn timber, beam and truss types – glue-laminated designs are also briefly described but are not considered appropriate for this manual
- Steel beam and truss types
- Reinforced concrete footbridges
- Suspension bridges

The Chapter then goes on to discuss the criteria for selection of an appropriate design and on the basis of these selects designs from those above for presentation in more detail in Chapters 4, 5 and 6 of the manual.

## 3.1 BAMBOO BRIDGES

### 3.1.1 Characteristics and Applications

Bamboo grows locally in many rural areas, especially in Asia, and is therefore particularly suited to community construction of footbridges because of its ready availability at little or no cost. This is its main application, few bamboo footbridges are 'technically' designed and constructed.

Because of its hollow structure, bamboo is a considerably more efficient structural material than timber, with strength to weight and stiffness to weight ratios of at least double those for most timbers. Although it can be obtained in lengths of up to 8 to 10m, only sections above about 12cm in diameter are suitable for footbridge beams and therefore bamboo can only be used for *short spans of 3 to 4m*. Longer bamboo footbridges therefore need intermediate supports at a spacing of 4m or less.

Two types of design are common:

1. Suspended bridges for short lengths up to about 10m in which the deck is supported at its centre by poles or ropes from tall posts at the ends of the bridge or from an 'A' frame built above or below the bridge. Figure 3.1 shows an example of the first method but in this case using trees conveniently located on the banks rather than posts.
2. Footbridges with piers made from bamboo posts. Figure 3.2 shows an example of this type. It has a total length of 54m with 13 intermediate support piers. In this case the pier piles are supported by rocks in baskets because of their relatively short length but for higher decks they would need to be driven into the ground and braced (see Chapter 4).

In both the examples shown the deck is made from woven bamboo strips. This is satisfactory for pedestrians and bicycles but would not be strong enough for livestock or ADVs. For the latter, larger diameter bamboo is needed or preferably timber planks although these would substantially increase cost.

Further design details of these types of bamboo bridges are given in Chapter 4. It may also be possible to construct a truss type of bridge similar to that shown in Section 3.2 for timber logs with steel pipe connectors, but as far as is known this has not been attempted. This type of design would be substantially more costly than the types described above.

### 3.1.2 Advantages and Disadvantages

#### **Advantages:**

- The hollow structure gives good strength and stiffness relative to weight
- The surface is hard and clean. There is no bark to remove as with timber
- It is often locally available at little or no cost so communities can build footbridges with little outlay of funds



Bridge is suspended mainly by lengths of bamboo bound to branches of trees growing on the river bank



Cross-members are bound to the suspension members to support the deck



The deck is made from woven strips of bamboo

**Figure 3.1: Suspended Bamboo Footbridge**



Section of bridge  
Total length is 54m  
Comprising:  
12 x 4m spans  
2 x 3m spans



Pier supports comprise  
a cross-member  
supported by 2 posts

Posts are held in place  
by rocks within a  
bamboo basket



The deck is a woven  
bamboo mat that is held  
in place by bamboo  
cross-pieces at 1.2m  
intervals bound to the  
longitudinal stringers

**Figure 3.2: Bamboo Footbridge with Pier Support**

**Disadvantages:**

- Because of the limited cross-sectional size of bamboo the maximum bridge span is only about 4m and more intermediate supports are needed for longer bridges than for timber
- Bamboo has a low natural durability, particularly in soil. Effective application of preservatives is difficult because of the hard surface skin and is likely to be beyond the capability of most communities. Untreated bamboo will last less than 2 to 3 years and therefore bridges need regular maintenance to replace decayed members if they are to last for a reasonable time
- Bamboo has poor resistance to termites
- Joints are often made of natural fibres and have a limited effective life. Binding of joints with galvanised wire increases life but also cost.

**3.1.3 Sources of Further Information <sup>2</sup>**

1. Jules J.A. Janssen: *Building with Bamboo – a Handbook*; Intermediate Technology Publications, London, 1988

This publication has good information on the characteristics of bamboo and on methods of preservation. There is one chapter on footbridges. The designs included are taken from publication 2 below but are presented in a clearer format.

2. *Bamboo in Building Construction: a series of articles collected by Dr Jules J.A. Janssen; 3<sup>rd</sup> Edition 1985 available from Foundation TOOL, Amsterdam, Netherlands, and Intermediate Technology Publications, London, UK.*

This publication provides the source of much of the information presented in (1) above. In addition it provides details on floating bamboo and canvas bridges developed by the British Army in India for transport of army vehicles.

3. Timber Research and Development Association (TRADA); High Wycombe, UK

TRADA is developing designs of bamboo footbridges in the range of 3 to 30m span for applications in India. These are of a more advanced technical design than those presented in this manual.

4. *Bamboo as a building material: see –*  
[www.bambus\new\eng\reports\buildingmaterial\buildingmaterial.html](http://www.bambus\new\eng\reports\buildingmaterial\buildingmaterial.html)

This report has useful information on the characteristics of bamboo and its treatment. There is a short section on footbridges but with limited detail.

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<sup>2</sup> Contact details of all organisations mentioned in the manual are given in Appendix D



## 3.2 TIMBER LOG FOOTBRIDGES

### 3.2.1 Characteristics and Applications

These are made from logs or large branches cut from trees. Timbers should be chosen from those that are locally used for structural purposes. Hardwoods are preferred for higher strength, durability and resistance to termites.

The simplest form of timber-bridge is for the logs to be used as stringers (beams) spanning the river/stream. Maximum spans depend on the sizes of logs available and are likely to be in the range 8 to 12m. However, in some locations logs of 15 to 20m length may be available. 2 to 4 logs are usually used depending on traffic using the footbridge and the span of the bridge. For longer spans, log sizes of at least 40 to 45cm in diameter will probably be needed. This is the diameter needed over the middle one third of the length of the log. It is with the bark removed and should not include sap wood.

Simple, low-cost footbridges for limited traffic, mainly pedestrians, can be made by nailing timber poles of about 7 to 10cm diameter across the log stringers to make a deck. However, for heavier traffic or a range of users, a proper deck of sawn wooden planks will be needed. For spans of over 3 to 4m handrails will be needed for safety and kerbs will be needed if carts or motor vehicles will use the bridge.

Figure 3.3 shows a fairly basic timber log bridge of 13m span installed in Malawi, while Figure 3.4 shows a more 'finished' bridge of 10m span in Australia.

The total span of log footbridges can be increased by providing intermediate pier supports with the log beams (stringers) overlapping at the cross-beam supports.

Further details of the design of timber log footbridges are given in Section 4.3 of Chapter 4.

**Log truss footbridges** provide a means for increasing the span of timber log bridges but design and construction is significantly more complex than the simple log stringer bridges described above. Truss structures are considerably more efficient in carrying loads than beams as the members are mainly in tension and compression rather than bending. Members can therefore be of smaller section, typically about 8cm to 15cm diameter logs. However, the members need to be relatively straight and uniform in section.

The main difficulty in constructing timber truss structures, particularly those made from logs, is in making effective joints where up to 6 to 8 members may need to be joined. Figure 3.5 shows a neat and effective design that has been developed by the American Institute of Sustainable Science and Technology Inc. The design uses log members that fit into joining sockets at their ends made from steel pipe sections. The whole structure is put into compression by tensioned wire cables to provide a good load-carrying capacity. The need for uniform size, straight logs and the cable-tensioning components put this design beyond the scope of most local bridge construction in rural areas.

### 3.2.2 Advantages and Disadvantages

The following comments refer only to log-beam bridges.

#### **Advantages:**

- They are simple to construct and can be built up on site.
- They are relatively low cost



**Figure 3.3: 13m Span Log Bridge in Malawi**  
(Note the running boards on the deck for vehicles)



**Figure 3.4: 10m Span Footbridge in Australia**  
(Details provided by Outdoor Structures, Australia)



A half-size prototype of a truss foot bridge constructed from timber logs with steel pipe connectors. Steel cables tensioned by screwed adjusters are used to pre-compress the truss structure so that the joints are able to better transfer tension forces. The bridge has been developed by the American Institute of Sustainable Science and Technology Inc (see Annex D).

**Figure 3.5: Timber Log Truss Bridge**

- 
- Often they can be built from locally available materials, although in some countries or districts suitable timber is becoming increasingly difficult to obtain because of deforestation

***Disadvantages:***

- Fairly straight logs are needed and the logs for a specific bridge need to be reasonably well matched in size
- Single spans are usually limited to about 10 to 12m but longer spans are possible with the use of piers where conditions are suitable for installing piers
- The natural decay of timber exposed to the weather may limit life of logs to 5 to 10 years although 10 to 20 years should be achieved with appropriate timbers. Durability can be improved by the use of hardwoods, good detail design and use of preservatives. For long life, regular maintenance is needed to recoat with preservatives and repair decayed timber
- It is difficult to replace individual stringers if they show excessive deterioration
- Logs are heavy making them difficult to manually transport and manoeuvre.



### 3.2.3 Sources of Further Information

1. *Timber Pole Construction: prepared by Lionel Jayanetti of the Timber Research and Development Association (TRADA), High Wycombe , UK; published by Intermediate Technology Publications, London, 1990*

Although this publication has only a short section on log bridges it has useful information on the preparation and preservation of logs.

2. United States Department of Agriculture National Wood in Transportation Centre, WV, USA

The USDA provides technical briefs on the design of various types of timber bridges. That on log bridges has been consulted in the preparation of Section 4.3 of this manual.

3. Outdoor Structures Australia, Queensland, Australia

Timber log bridges have been widely used on rural roads in Australia and much experience has been accumulated on their design. A 4-page technical brief is available from the above source and has been consulted in preparation of Section 4.3 of the manual.

4. *Footbridges in the Countryside – Design and Construction: Countryside Commission for Scotland, Perth, UK, 2<sup>nd</sup> Edition 1989.*

This manual contains much useful information on footbridges including design details for log footbridges.

5. Developing Technologies, Acton, London

This is a charity that uses student project work to carry out engineering design work for the developing world. One of its projects is the design of improved timber log bridges.

### 3.3 SAWN TIMBER FOOTBRIDGES

#### 3.3.1 Characteristics and Applications

When logs are sawn into planks the timber loses some of its strength due to the greater influence of the grain structure and also is more affected by defects such as knots and splits so strength reduction factors have to be applied to take into account the quality of the timber. However, the strength/weight ratio of rectangular sawn sections is better than for logs and since more beams can be fitted across the width of the bridge, individual members are lighter and easier to handle.

The regular shape and sizes of sawn timber beams allow bridge designs to be standardized. There are two basic types of designs;

1. **Beam structures** similar to the log-beams discussed above. Single spans are less than for logs, the general range being 5 to 8m with an upper limit of about 10m. Longer spans can be achieved with piers providing intermediate supports. Figure 3.6 shows a 10m span bridge with a central pier. Figure 3.7 shows an alternative option that avoids the use of piers where piers are not practical by providing cantilever supports at each end of the bridge built into the abutments. The span is 15m. It is reported that spans up to 20m can be achieved with this type of design
2. **Truss structures** can be used for longer single spans usually where the use of intermediate supports is not practical. Various truss configurations are possible some with the truss above the deck (through truss) and some with the truss below the deck (deck truss). The latter tend to be used where a deep opening is to be crossed (plenty of clearance below the deck) and are generally the most economical for this purpose.

The *bowstring truss*, which forms the shape of an arc of a circle above the deck, is the most economic form but is limited to about 30m span. *Parallel-chord trusses* in which the truss is a constant height above or below the deck have been used for spans up to 80m in highway bridges, but because of the smaller width of footbridges, footbridges over 30m long need horizontal cable stays to stabilise the bridge against sideways sway. An example of a timber truss bridge (parallel-chord type) from Canada is shown in Figure 3.8. This is about 20m span and at the time of the photo was over 60 years old.

Although it is easier to construct trusses from rectangular sawn sections than round logs, there is still a problem of designing the joints to transmit high forces. Usually steel pins/bolts and steel shear connectors have to be used to obtain effective and reliable joints.

Many timber truss bridges were constructed in the past in countries such as Australia and USA but few are built today because of the high labour costs involved in their construction. However, they are an appropriate design for developing countries where labour costs are low. An advantage is that they can be constructed on site with limited tools. Constraints on their use are the lack of availability of 'ready' designs and of equipment for pressure treatment of the timber with preservatives to obtain long life. However, with use of appropriate timbers and regular hand application of preservatives a life of at least 20 to 30 years should be possible.

Figure 3.9 shows a modular timber truss bridge developed by UNIDO (United Nations Industrial Development Organisation, Vienna, Austria) and TRADA (Timber Research and Development Association, UK) for application in developing countries. It aims at centralised 'factory' production of the 3m long modules that can then be transported to site and pinned/bolted together to produce standard designs. This design could be appropriate for local applications if the modules were readily available for assembly from a central unit. However, the design is probably beyond the scope of local construction.

3. **Glued laminated timber (Glulam):** the major application of timber in bridge construction in developed countries is now in the form of glued-laminated sections. These are formed by gluing together sheets under pressure using a waterproof glue. The advantage is that long beams, both straight and curved, can be produced. The technology is not considered appropriate for the applications covered by this manual.

### 3.3.2 Advantages and Disadvantages

#### **Advantages:**

- Sawn timber is a common construction material and will usually be readily available in a number of sizes. It is less dependent on a local supply of timber than logs
- Sawn beams require little or no preparation, whereas log beams require removal of bark and trimming to even up variations in size
- Sawn timber beams are relatively light and easy to install, making footbridges simple to construct, particularly for short spans
- Truss bridges can be more readily constructed to extend the range of single span bridges where pier supports are not practical
- Sawn timber can be more effectively treated with preservatives than logs so that longer life can be achieved
- Timber bridges can be constructed on site with simple hand tools. The carpentry skills needed will probably be locally available

#### **Disadvantages:**

- The large sizes needed for longer bridges may not be readily available locally
- The cost of sawn timber bridges is likely to be considerably greater than for log bridges
- The cost of good quality timber is tending to increase as availability is reduced by deforestation.

### 3.3.3 Sources of Further Information

1. Michael A. Ritter: *Timber Bridges – Design, Construction, Inspection and Maintenance*; United States Department of Agriculture Forest Service, Washington, D.C., 1997

This large design manual (992 pages) contains a wealth of information on timber and all aspects of timber bridge design. The manual provides information on design procedures rather than examples of standard designs. It is produced for the US forest department and therefore concentrates on timbers commonly used in the US. However, it is a good reference source on the basics of design, treatment of timbers and timber bridge construction.

2. *Standard Plans for Southern Pine Bridges*; United States Department for Agriculture Forest Service, Washington, D.C., August 1995

This includes standard plans for sawn timber beam (stringer) bridges made from Southern Pine. The designs are for single and dual carriage highway bridges but are useful in showing design details for timber beam bridges.

3. *Footbridges in the Countryside – Design and Construction*: Countryside Commission for Scotland, Perth, UK, 2<sup>nd</sup> Edition 1989.

This manual (see 3.2.3 above) contains plans for 2 types of sawn timber beam footbridges with recommended beam sizes for a range of bridge spans.

4. *A Design Manual for Small Bridges*; Overseas Road Note 9, Transport Research Laboratory (TRL) International Division, Crowthorne, UK, 2<sup>nd</sup> Edition 2000

This manual covers the design of bridges up to 12m single span in developing countries. It covers the entire design process from site survey to detail design. It contains basic details of timber beam bridges, log and sawn timber, with recommended sizes for a range of bridge spans. The beam sizes can be reduced in proportion to the section modulus for the lower loading of footbridges. The data has been considered in the preparation of the design details in Chapter 4 of this manual.

5. *Pre-Fabricated Modular Wooden Bridges*; prepared by the Timber Research and Development Association (TRADA), UK for the United Nations Development Organization (UNIDO), Vienna, Austria, 1985

A series of reports describes the setting up of a plant to produce the modules for these timber truss bridges and the design of standard bridges. Although the designs are for road bridges, it is possible to adapt them for footbridges. The application of the design is limited to a certain extent by the truss structure being below the deck, requiring good clearance between the deck and water level.



10m span x 4.5m wide sawn-timber bridge for pedestrians, IMT and low-volume light motorized vehicles (about 10 pick-ups per day)

**Figure 3.6: Sawn-Timber Beam Bridge in Laos**





15m span x 1m wide sawn-timber footbridge for pedestrians and livestock. Note the cantilever supports used to extend the single span of the bridge.

**Figure 3.7: Sawn-Timber Beam Bridge in Nepal**



A 'parallel chord' truss bridge of about 20m span constructed in Canada. This bridge was 62 years old at the time of the photograph.

**Figure 3.8: Example of a Sawn-Timber Truss Bridge**



**Figure 3.9: A Modular Timber Truss Bridge Developed by UNIDO and TRADA.**  
The 18m span bridge in Madagascar was erected in 4 days on prepared abutments

## 3.4 STEEL FOOTBRIDGES

### 3.4.1 Characteristics and Applications

For the same weight there is not a great deal of difference in the strength of steel and hardwoods. However, for the same section size steel is stronger so designs are more compact. Steel is therefore particularly suited to construction of truss type bridges where joining of the members is also easier than for timber. This type and steel cable bridges are likely to be the main application of steel for footbridges in developing countries.

Appropriate steel sections for footbridges are less likely to be available in rural areas than timber and construction of steel footbridges will probably need to be carried out in medium sized workshops in towns and urban centres. Components can be transported to site and assembled by bolting or riveting.

Providing it is adequately protected against corrosion, steel will have a considerably longer life than timber. Protection by simple hand methods of brushing or spraying is likely to be more effective than for timber and maintenance will be less. Hot-dip galvanising is likely to be the most effective method of protection but will probably be unavailable in many areas. Coating with 2 or 3 layers of anti-rust paint should also be effective. With regular, effective maintenance, steel bridges should last at least 30 years.

Steel bridges will usually have timber decks. These are best made up into integral panels to minimise problems in attaching them to the steel structure.

There are two types of steel footbridges, beam bridges and truss bridges. Suspension bridges using steel cables are described separately in Section 3.6 below.

**Steel Beam bridges** are usually constructed from 'I'- sections as these are the most efficient in bending. Standard lengths for these are 8, 12 and 15m so that single spans can be longer than for timber beams if suitable sizes are available. Beams can also be joined to give longer lengths using bolted, riveted or welded connectors but very careful consideration needs to be given to the design of the connectors to make sure they are strong enough, particularly welded joints.

Figure 3.10 shows a steel beam bridge in Indonesia designed for low-volume motorised traffic. The bridge has a span of 13m, total length of 14m and a width of 4.4m. It has 4 I – beams of section 400mm deep x 150mm wide x 8mm thickness. The deck is made of sawn timber planks. The cross-members are 200 x 50mm section and are bolted in position through holes drilled in the top flanges of the outer beams by 16mm diameter U-bolts. The longitudinal runners for vehicle wheels are 150 x 100mm in section. The replacement of worn and rotting deck timbers is usually the main maintenance requirement and cost for steel bridges. The handrails are made from steel angle section and are welded directly to the flanges of the outer beams. It should be pointed out that attachments to the beam flanges, either by welding or drilling is not good practice as these are areas of maximum stress. It is better to make attachments on the central part of the web where stresses are low.

The availability of steel I-section beams will probably be quite limited in many countries, especially in rural areas, and therefore this type of bridge is not considered a first-level option for footbridges.



A low cost alternative that has been suggested for footbridges is to use a scrap chassis from a large truck or bus for the beams. An example of this is included in Appendix C.

**Steel Truss bridges** use members in an arrangement where the load is carried mainly by direct forces, tension and compression, in the members rather than in bending as in beam bridges. This is a more efficient use of the material and allows a wider range of sections to be used. Steel truss bridges are often made from angle or channel sections. These sections are likely to be available in a reasonable range of sizes in most countries, particularly angle section, and therefore this type of bridge provides a good option for spans beyond the range of timber beam bridges i.e. greater than about 10m. The maximum span for this type of bridge is about 25m. Truss bridges may also be made from rectangular hollow tube but this section is less likely to be available in the sizes needed.

Most steel truss bridges are of the parallel chord type. Although joints are easier to make than in timber trusses they still need to be reinforced with gusset plates to increase the area for joining. Joints may be bolted, riveted or welded. The bridge will usually be made in a workshop and the choice of joint may well depend on the problem of transporting the bridge to site. If the site is remote and the bridge has to be carried a significant distance then individual components of the truss may be manufactured and drilled in the workshop, transported to site and bolted together on site. This requires considerable accurate manufacture in the workshop and careful assembly on site. A simpler procedure is to fabricate panels of the bridge in the workshop and bolt these together on site. If there is direct access for vehicles to the site then complete modules may be made in the workshop and transported to site to be bolted together. It is important to note that for this procedure of preconstruction of components and assembly on site it is essential to assemble and test the footbridge in the workshop to ensure everything is satisfactory before transporting it to site.

Figure 3.11 shows an example of the construction of a steel truss footbridge installed in Ethiopia. In this case the components were transported individually to site and bolted together. The footbridge is 12m long and 1.5m wide and is designed for pedestrians and livestock. It is constructed from 60 x 60 x 6 mm and 60 x 60 x 5mm angle section with 7mm thick gusset plates.

For a given installation the cost of materials for a beam and truss bridge is likely to be fairly similar but the labour cost for the truss bridge will be significantly higher. Applications for truss bridges will therefore be mainly for spans exceeding the limit for beam type bridges (timber or steel) of 8 to 12m or where suitable beams sections are not available.

### 3.4.2 Advantages and Disadvantages

#### Advantages:

- Steel can be more effectively protected using simple hand methods of brushing or spraying and therefore steel bridges are likely to have a longer life and lower maintenance costs than timber bridges
- Steel truss bridges are more straightforward to fabricate than timber truss bridges and are likely to be more appropriate for spans of intermediate length

#### Disadvantages:

- More complex tools and equipment are needed to construct steel bridges compared to timber bridges and in most cases construction will need to be in a workshop and components or sections transported to site for assembly



View of bridge showing the timber decking



View of the underside of the bridge showing the 4 I-section steel beams. Note the cross-bracing that is used to prevent twisting of the beams under load

**Figure 3.10: Steel Beam Bridge for Low-Volume Traffic**



**Figure 3.11: Details of Construction of a Steel Truss Footbridge Installed in Ethiopia**

This bridge was designed by Bridges to Prosperity Inc., an American charity that specialises in providing technical assistance and training for construction of footbridges in developing countries. It organises the supply of steel while the local communities (the beneficiaries of the bridge) provide all the sand, gravel and rock as well as all the labour. This labour is then guided and trained by Bridges to Prosperity technicians during the construction and installation of the bridge.

### 3.4.3 Sources of Further Information

1. *Footbridges in the Countryside – Design and Construction. Countryside Commission for Scotland, Perth, UK, 2<sup>nd</sup> Edition 1989.*

The manual contains details of 2 designs for steel beam footbridges for spans up to 16m, including notes on protection of the steel from corrosion

2. His Majesty's Government of Nepal  
Ministry of Local Development  
Department of Local Infrastructure Development and Agricultural Roads (DOLIDAR)  
Trail Bridge Section

A range of steel truss bridges in increments of span up to 30m have been developed in collaboration with HELVETAS ([www.helvetasnepal.org.np](http://www.helvetasnepal.org.np)) and the Swiss Association for International Co-operation. The designs involve the manufacture of individual members in a workshop and transport of these to site to be bolted together. Detailed Engineering drawings are available.

## 3.5 REINFORCED CONCRETE (RCC) BRIDGES

### 3.5.1 Characteristics and Applications

These bridges comprise a concrete slab reinforced with steel bar that spans the crossing. The slab may either be of a plain solid rectangular section or a thinner slab strengthened on its underside by integral beams that run along and across the bridge (see Chapter 6). The latter type of slab will use less material than a plain slab but will involve considerably greater difficulty and effort in preparation for pouring the concrete.

For footbridges the top surface of the concrete slab can be the walkway surface saving the need for a separate deck. The upper limit of span for a RCC bridge is about 12m. Piers are needed for longer spans. When large cranes are available slabs can be pre-cast and lifted into position. However, in situations covered by this manual, slabs will be cast in situ. This therefore requires the construction and support of wooden box-work (shuttering) in which the reinforcing steel is supported and the concrete poured. This will involve considerable time inputs from skilled carpenters and will prevent the use of RCC bridges where the river-bed does not allow the construction of timber scaffolding to support the shuttering.

Figure 3.12 shows a RCC footbridge constructed in Malawi. This has a span of 15m with a central masonry pier support. The bridge is provided with steel handrails bolted to the concrete side. The bridge was constructed by a local contractor in a reported time of 1 month and at a reported cost of USD \$28,000.

### 3.5.2 Advantages and Disadvantages

#### Advantages:

- The main advantages of RCC bridges are their long life, at least 50 years, and their low maintenance costs. Therefore although their initial cost may be higher than other types, their “total life” cost may be lower as their maintenance costs will be lower and other types may need to be replaced one or more times during the life of the RCC bridge.

#### Disadvantages:

- The main disadvantages in regard to local construction are the effort and skills needed, particularly in erecting the shuttering for the concrete slab. The mixing and pouring of concrete will also require good organisation and experience. For example, the amount of water used to mix the cement affects the strength of the concrete. Some skilled and experienced labour will therefore be needed with possibly support from the local community in carrying out less skilled tasks.

### 3.5.3 Sources of Further Information

1. *A Design Manual for Small Bridges; Overseas Road Note 9, Transport Research Laboratory (TRL) International Division, Crowthorne, UK, 2<sup>nd</sup> Edition 2000*

The manual gives design details for plain slab RCC bridges for low-volume traffic. The designs cover use by trucks up to a gross loading of 20 tonne and are therefore considerably beyond the requirements for footbridges that might have to carry light vehicles such as pick-ups. An engineer competent in RCC design would be needed to adapt these designs for applications covered by this manual.





View Showing Details of Bridge and Handrail



View from Below Showing Integral Beam Reinforcement and Central Pier

**Figure 3.12: A 15m Span Reinforced Concrete Footbridge with Central Pier in Malawi**

Note: Standard design used by Ministry of Works, Government of Malawi

## 3.6 SUSPENSION AND SUSPENDED FOOTBRIDGES

### 3.6.1 Characteristics and Applications

Where support piers are not possible the span of beam and truss type footbridges may be extended by partly supporting them with cables. This involves building towers at one or both ends of the bridge that are tall enough to achieve effective angles for the support cables. The other ends of the cables must be firmly anchored in the ground. A schematic arrangement of this type of suspension bridge is shown in Figure 3.13. This has 3 timber truss sections but other bridge types can also be used with careful design of the cross-beam supports at the joints between the sections.

The more conventional type of *suspension* bridge uses continuous cables supported by towers at each end of the bridge which hang in a catenary to support vertical hanging cables from which the bridge deck is suspended. A schematic outline of this type of bridge is shown in Figure 3.14. The bridge deck may be flexible or rigid but must be strong enough to support the traffic load between the support cables and also to resist wind loading. The end towers need to be tall enough to allow a sag of the cables of between 1:8 and 1:11.

Figure 3.15 shows an example of a suspension bridge in Nepal. This has a span of 30m and width of 1m and is used by pedestrians and livestock. The masonry towers are about 5m tall. The deck comprises timber planks supported on timber beams. These are a weakness of the design since the timber tends to rot and may need replacing after 10 years or so, whereas the steel cables and masonry towers may have a life of over 50 years. The reported cost of this bridge that was built 10 years ago was \$7,600, comprising \$1,000 for supports, \$4,400 for materials and \$2,200 for labour.

There has been a major programme of development of suspension bridges in Nepal, covering spans of up to 300m. The programme also encompasses *suspended* bridges that are less costly and require lower technical inputs than suspension bridges but also have some limitations on their applications. In *suspended* bridges the actual deck is attached to a sagging lower cable with an upper cable for the handrail. So unlike *suspension* bridges when the deck can be kept fairly level by using hanging suspender cables or rods of appropriate length, the deck of a *suspended* bridge has an inherent sag. The specified sag is  $\text{span}/20$  for spans less than 80m and  $\text{span}/22$  for spans over 80m. This gives quite a steep slope of about 1 in 5 at each end of the bridge. Figure 3.14 shows a schematic outline of this type of bridge. Because of the sag of the deck this type of bridge needs good clearance above the water level and is therefore suited to ravines or rivers with high banks. Suspended footbridges are limited to mainly pedestrian traffic, livestock and pack animals. In Nepal they tend to be used more in mountainous regions with suspension bridges being used more on the plains.

Figure 3.16 shows an example of a suspended footbridge. Note the steel deck. This provides a much longer life than timber decking.

### 3.6.2 Advantages and Disadvantages

#### Advantages:

- The main applications of cable type footbridges, suspension and suspended, are for spans over 20 to 25m where intermediate pier supports are impractical. In these situations they may be the only option, particularly where a ferry is not feasible. They are a cost-effective solution for light to moderate traffic of pedestrians, pack animals and livestock, for medium to long spans.

**Disadvantages:**

- *Suspended* footbridges are limited to use by pedestrians and livestock. Standard designs available for *suspension* footbridges also appear to be limited to this type of traffic although they could be developed for carts and light vehicles
- Note that careful attention needs to be given to the stability of cable bridges, particularly for short spans. The centre of gravity of users of the bridge needs to be well below the anchor points of the cables.
- Cables and associated components, especially for suspension footbridges, are unlikely to be available locally and possibly not nationally. The introduction of cable bridges may need to be supported by a national development programme
- Some skilled labour will be needed, particularly for the cable work, which will probably have to be brought in from outside the local area.

**3.6.3 Sources of Further Information**

1. *Short-Span Trail Bridge Standard*: Compiled by His Majesty's Government of Nepal, Trail Bridge Section of the Department of Local Infrastructure Development and Agricultural Roads, Kathmandu, Nepal;  
With assistance from HELVATAS Nepal, and Swiss Association for International Cooperation;  
Published by SKAT, Swiss Centre for Development Cooperation in Technology and Management, Switzerland, 2002

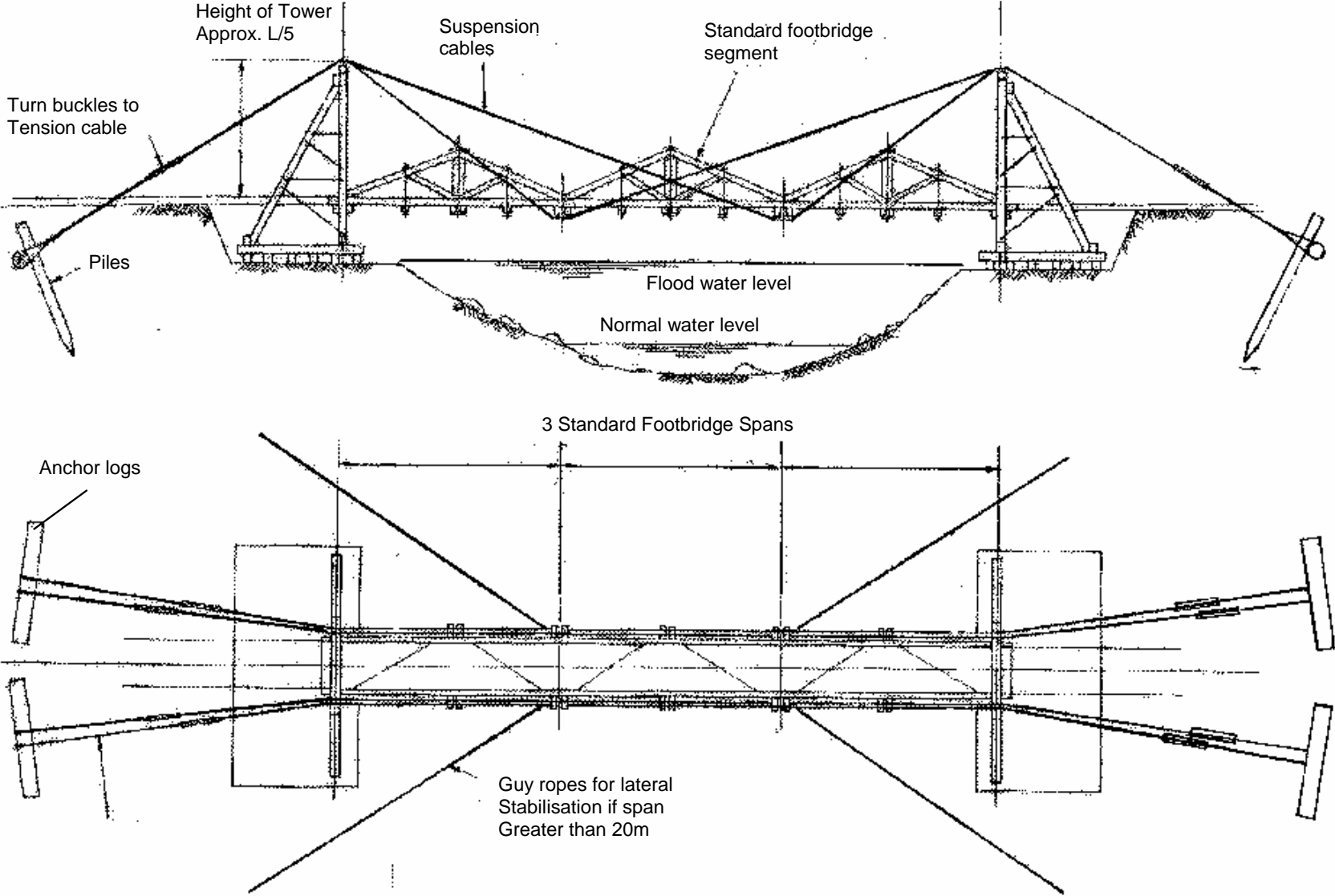
Cable-type bridges are well suited to the terrain of Nepal and there has been a major programme of development and construction supported by the Swiss Association for International Cooperation. This manual deals with the design, construction and installation of *suspended* bridges. Information is also available from this source on *suspension* bridges.

2. *Guidelines for the Design and Construction of Suspension Footbridges*: ILO/ASIST; Harare, Zimbabwe, 2000.

These guidelines are based on experience from the above programme in Nepal and more particularly on lessons learned from a pilot programme of construction of suspension bridges in Zimbabwe. The guidelines have limited technical detail but the Department of Roads in the Ministry of Transport and Communications, Government of Zimbabwe, has developed standard designs for spans of 20 to 160m in 20m increments.

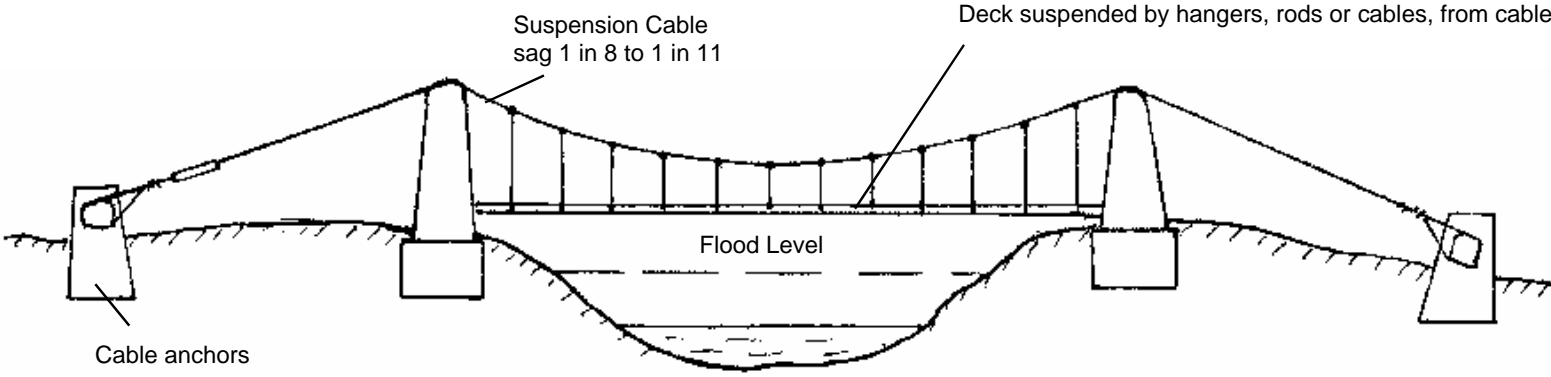
3. *Footbridges in the Countryside – Design and Construction*: Countryside Commission for Scotland, Perth, UK, 2<sup>nd</sup> Edition 1989.

This gives details of a low technology suspension bridge for spans up to about 25m

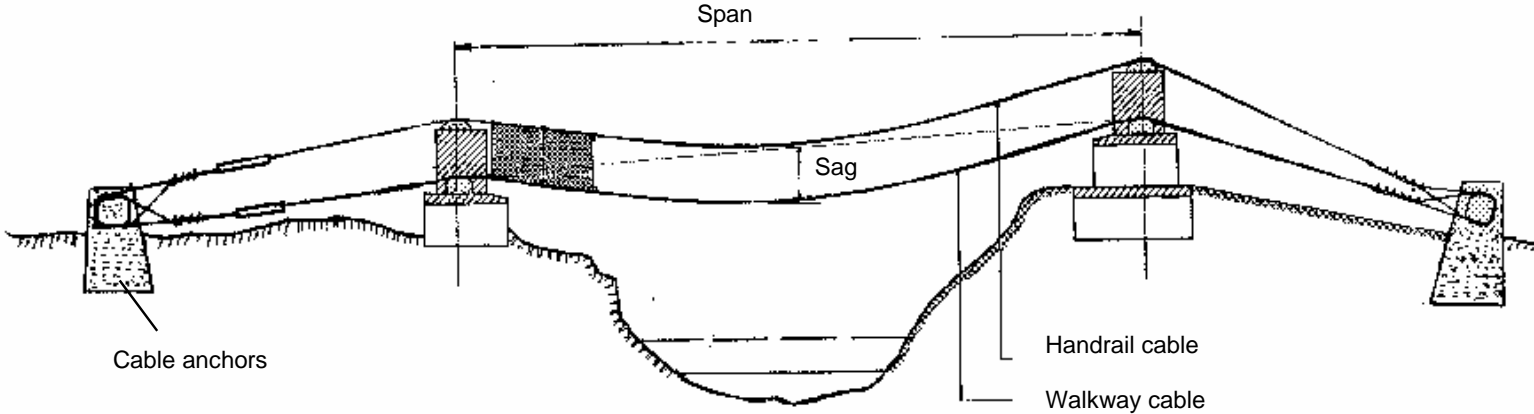


**Figure 3.13: Schematic Design for a Simple Suspension Bridge**  
(Design suggested by Gatton Sawmilling Co., Queensland, Australia)





(i) Schematic Layout of Suspension Bridge



(ii) Schematic Layout of Suspended Bridge

Figure 3.14: Schematic Layouts of Cable Suspended Footbridges



**Figure 3.15: 30m Span Suspension Footbridge in Nepal**



**Figure 3.16: Example of a Suspended Footbridge in Nepal**  
(Photograph provided by Chris Rollins, Bridges to Prosperity Inc.)

### 3.7 SELECTION OF TYPE OF FOOTBRIDGE

#### 3.7.1 Selection Criteria

##### 1. *Span*

The location of the abutments and the required span of the footbridge are found from the site survey (Appendix A). The typical range of unsupported span lengths for the various types of footbridges are summarised in Table 3.1 below. This provides an initial choice of possible options.

If the river bed allows the construction of pier supports then any of the options can be used. For example if a 20m span bridge is needed then the options are:

- Beam or RCC footbridge with 1 or 2 pier supports, the spacing of piers depending on the beam lengths available
- Steel or timber truss bridge with no pier supports
- Suspended or suspension bridges might also be considered although this is at the bottom end of their normal range

The selection will depend on other criteria discussed below.

##### 2. *Traffic*

The manual covers mainly footbridges for pedestrians, livestock and IMTs but allows for the occasional light vehicle such as a pick-up with a gross loaded weight up to about 3.0 tonne. Most of the footbridge types can cope with this with the following limitations:

Bamboo bridges - pedestrians, bicycles, smaller livestock such as goats, sheep and possibly donkeys, and pushed motorcycles

Suspended bridges - pedestrians, pushed bicycles, livestock and pack animals

Suspension bridges - available standard designs appear to have capacity for pedestrians, bicycles and pushed motorcycles, livestock, wheelbarrows and small carts. They could be adapted for heavier traffic by a qualified engineer but with a proportionate increase in cost.

##### 3. *Availability of materials*

An important criteria for construction at local level will be whether materials are locally available or readily available from larger resource centres that are readily accessible. It is unlikely that at this level it will be possible to organise importation of materials.

##### 4. *Technical support and special skills needed*

Bamboo bridges can be constructed by the community with little or no technical assistance. For other types of footbridges, technical assistance and supervision will be needed. In some cases labour with special construction skills and experience not locally available may also have to be brought in. The manual prioritises selection of options where technical assistance can be provided at District level and where labour skills are locally available.

## 5. *Life of footbridge*

Most footbridge materials will deteriorate over a period of time and eventually the bridge will need to be replaced. The rate of deterioration and life of the bridge will depend on the initial choice of material, how well it is protected against deterioration and how well it is maintained to retain the protection. In some cases particular parts of the bridge may deteriorate and need to be replaced. For example, timber decks tend to deteriorate quite quickly due to wear from traffic and the difficulty of effectively protecting the timber.

Careful consideration must also be given to possible changes in future traffic. A significant improvement in prosperity of the area could cause a change in modes of transport used from walking to carts and motorised forms. A footbridge built for pedestrians and livestock only could therefore become obsolete and have to be replaced.

## 6. *Cost of footbridge*

Two factors need to be considered in comparing the costs of options for footbridges:

1. *Initial cost* - which is the cost of constructing and installing the footbridge including abutments and any piers
2. *Total life cost* - this the total cost of providing the footbridge over a period of time, which includes initial cost, maintenance costs and replacement costs if the time period is greater than the estimated life of the footbridge.

For example, if the estimated life of a RCC footbridge is 60 years, and that of a timber bridge 20 years with the timber deck of the latter replaced every 10 years, the comparison of the *Total Life* costs of the footbridges over 60 years is:

*RCC footbridge* – Initial cost + 60 x (annual maintenance cost)

*Timber footbridge* – Initial cost + 60 x (annual maintenance cost) + Replacement cost of bridge at 20 and 40 years + Replacement cost of deck at 10, 20, 30, 40 and 50 years.

(Note – to be theoretically correct the comparison of costs needs to take into account the time value of money and inflation. However, if it assumed that labour and material costs will continue to be roughly in the same proportion to the cost of living then a straightforward comparison of costs will be reasonably reliable)

Although the *Initial cost* of the RCC footbridge may be higher than that of the timber footbridge, the *Total life* cost will probably be substantially lower.

The lowest *Total life* cost gives the most cost-effective option for a footbridge and should be used in selection wherever possible. However, in many cases there will be budget constraints and the lowest *Initial cost* option may have to be selected.

The reported initial costs of various types of bridges obtained from case-studies are compared in Table 3.1. The data shows consistent unit costs for some types of low-volume traffic bridges but there is insufficient data to give reliable cost-estimates for footbridges.

It should be noted that the costs in Table 3.1 include abutments and piers (where used) and therefore it is not possible to compare the cost per m span for the different types of bridge structures.

Unit costs obtained from the case studies gave the following comparison of material costs for a 1.4m wide footbridge based on the designs presented in Chapters 4, 5 and 6. Note that these include only the deck structure and decking i.e. the features that differ for the three types.

Type of Footbridge	Cost Component	Material Cost US\$/m	Additional Costs
Sawn-Timber Beam	Timber @ \$250/m <sup>3</sup>	\$85	Installation
	Nails, preservative etc. @ 15%	\$13	
	<b>Total</b>	<b>\$98</b>	
Steel Truss	Steel @ \$0.6/kg	\$52	Workshop and Installation
	Timber deck @ \$250/m <sup>3</sup>	\$13	
	Bolts, paint etc @ 25%	\$16	
	<b>Total</b>	<b>\$81</b>	
Reinforced Concrete	Cement @ \$6/50kg (sand and stones not costed)	\$28	Construction of shuttering and installation
	Reinforcing steel @ \$0.6/kg	\$63	
	<b>Total</b>	<b>\$91</b>	

Adding labour costs, the overall cost of Sawn-Timber Beam and Steel Truss footbridges are likely to be similar for these unit costs, but timber footbridges will require intermediate piers for spans over 8 to 10m. Reinforced concrete footbridges will have a higher initial cost due to the higher input of experienced labour needed.

Comparative material costs (including average portorage costs) for footbridges in Nepal were reported as:

Steel truss \$100/m, Reinforced Concrete \$80/m, Cable Suspension \$100/m

### 7. National policy on bridge design

A National roads department may decide to concentrate on particular bridge types that are generally suitable for the country in order to develop standard designs and make the materials needed readily available (for instance treated timbers, steel sections or steel cables and components). This would then dictate selection.

#### 3.7.2 Comparison of Footbridge Types Against Selection Criteria

Table 3.1 compares the range of footbridge types in relation to the above selection criteria.

Table 3.1: Reported Costs of Footbridges and Low-Volume Traffic Bridges

Country	Classification (1)	Span (m)	Width (m)	Abutments	Piers	Deck	Design Life (yrs)	Age (yrs)	Costs in USD at present value			
									Materials	Labour	Total	Cost/m <sup>2</sup>
<b>1. Timber log bridges</b>												
Malawi	Low volume	27	3.7	Masonry	3 x masonry	Sawn timber	10	4	22,640(2)	13,280(2)	36,000	360
Malawi	Low volume	13.5	3.7	Timber log	None	Sawn timber	10	7	10,000	Community 5,000 (Est.)	15,000 (Est.)	300 (Est.)
Malawi	Footbridge (iii)	50.5	2.5	Masonry	9 x masonry	Sawn timber	5	2	3,000	1,500	4,500	36
<b>2. Sawn timber beam bridge</b>												
Nepal	Low volume	15	5	Sawn timber	3 x sawn timber	Sawn timber	30	24	20,800	5,200	26,000	347
Nepal	Footbridge (ii)	12	1.2	Masonry	None	Sawn timber	50	30	8,100	2250	10,350	719
Laos	Low volume	9.5	4.5	Sawn Timber	1 x sawn timber	Sawn timber	10 to 15	2	15,000	500	15,500	362
<b>3. Steel truss bridge</b>												
Ethiopia	Footbridge (ii) (3)	12	1.5	Existing	None	Sawn timber	40	1.5	4,700	6,450	11,150	620
<b>4. Reinforced concrete bridge</b>												
Malawi	Footbridge (ii)	15	1.5	Masonry	1 x masonry	Concrete	50	1	18,500	7,500	26,000	1155
Nepal	Low volume	10	5	RCC	None	Concrete	100	2	8,200	3,500	11,700	234
Nepal	Low volume	9	3.6	Masonry	None	Concrete	100	2	9,300	3,000	12,300	380
<b>5. Suspension bridge</b>												
Nepal	Footbridge (ii)	30	1	Masonry		Sawn timber	50	10	5,400	2,200	7,600	253

- Notes:**
- (1) Classifications covered – (i) Low Volume, rural road bridge for low volumes of motorised traffic; (ii) Footbridge, mainly pedestrian and livestock.  
(iii) Footbridge and NMT, pedestrian and non-motorised vehicles.
  - (2) 5% was contributed by the community as a precondition of receiving funding.
  - (3) This was a high quality bridge built by the NGO 'Bridges to Prosperity'. All members were pre-drilled and transported individually to site for assembly. Fabrication costs were therefore high.

Table 3.2: Comparison of Footbridges Against Selection Criteria

Type of Bridge	Span Range (1)	Traffic	Availability of materials	Technical support needed	Life and maintenance	Cost
Bamboo	Up to 4m	Pedestrian, bicycles, small livestock	Often grown locally	None	Normally 2 to 3 years(2); regular replacement of bamboo	Generally constructed and replaced by community with little or no material cost
Timber log beams	8 to 10m; up to 12m	All types	May be available from local forests otherwise will be a problem	District technical supervision of local carpenters and community	Logs – 10 to 15 years; decking 5 to 10 years; Regular maintenance of deck	<i>Initial</i> - Logs low cost if locally available. Sawn timber deck raises cost. <i>Long term</i> – medium to high
Sawn timber beams	8 to 10m	All types	May need to be obtained from larger timber suppliers	District technical supervision of local carpenters and community	Beams – 10 to 25 years depending on quality of hardwood; decking 5 to 10 years; Regular maintenance of deck	<i>Initial</i> – cost of good timber beams will be high <i>Long term</i> – medium to high
Sawn timber truss	Up to 25m	All types	Smaller sections than for beams and more likely to be locally available but quality may not be adequate for construction of a truss	Standard designs need to be developed by qualified engineer. Workshop inputs needed for joint reinforcements	10 to 25 years or more depending on quality of hardwood; decking 5 to 10 years; Regular maintenance of truss and deck	<i>Initial</i> – cost of timber may be lower than for beams but construction costs will be higher <i>Long term</i> – medium to high
Steel beams	Up to 15m	All types	Availability likely to be a problem  Scrap beams may be a low cost possibility	Workshop inputs needed; District technical supervision of local carpenters and community	Steel – 30 to 40 years and longer if well maintained with repainting every 2 to 3 years decking 5 to 10 years; Regular maintenance of beams and deck	<i>Initial</i> – similar to good sawn timber beam bridge <i>Long term</i> – medium
Steel truss	Up to 25m	All types	Should be generally available	Workshop construction of standard design. District technical supervision of installation by carpenters and community	Steel – 30 to 40 years and longer if well maintained with repainting every 2 to 3 years; decking 5 to 10 years; Regular maintenance of steel, joints and deck	<i>Initial</i> – similar to sawn timber and steel beam bridges <i>Long term</i> – medium
Reinforced concrete	Up to 12m	All types	Should be generally available	District technical supervision of construction of standard design. Labour needed with experience of RCC work	At least 50 years Low maintenance	<i>Initial</i> – may be higher than timber or steel bridges due to high labour cost <i>Long term</i> – low
Suspended	Up to 150m	Pedestrian, livestock	Cables and components may not be readily available	Experienced engineer and labour needed	Cables over 40 years; if timber deck used, 5 to 10 years. Regular maintenance of joints and deck	<i>Initial</i> – may be high for short lengths but unit cost will decrease with length <i>Long term</i> – medium
Suspension	Up to 150m	Pedestrian, bicycle, livestock				

**Notes:** (1) Span Range is without piers. Span can be increased incrementally with addition of piers.

(2) It is reported that some species of bamboo in Central and Southern America have a life up to 10 years

### 3.7.3 Selection of Type of Footbridge

The factors considered in selecting footbridges for inclusion in the manual are summarised in Table 3.3 below.

**Table 3.3: Summary of Selection of Footbridge Types**

Type of Footbridge	Factors considered in selection	Recommendations
Bamboo	Where bamboo is available these footbridges can be built by the community with no technical assistance and at little or no cost. They are suited to only light traffic and need to be rebuilt every 2 to 3 years	<i>Standard designs included in Section 4.2. of manual</i> For more developed designs see TRADA, Section 3.1.3
Timber Log	These are an option if suitable logs are locally available. Reasonably straight and uniform logs are needed for a good bridge. Can be built by community with local technical assistance. Initial cost will be lowest for general traffic but life may be only 10 to 15 years.	Standard design <i>included in Section 4.3. of manual</i>
Sawn Timber Beam	Beams may need to be obtained from larger timber suppliers. Good hardwood is needed for long life. Can be built by community with local technical assistance. Initial cost will be higher than for logs but life should be longer	Standard design <i>included in Section 4.4. of manual</i>
Sawn Timber Truss	Suited for spans of 10 to 25m where piers not possible but availability of the consistent shapes and sizes needed for construction may be a problem. Steel truss bridges are considered a better option for standard designs because of consistency of material.	<i>Not included in manual.</i> Possible option is the UNIDO bridge (Section 3.3.3) where local construction is established
Steel Beam	Suitable beam sections probably not generally available.	<i>Not included in manual</i> An alternative using a scrap truck chassis is described in Appendix C
Steel Truss	Steel sections needed for truss bridge likely to be generally available. Size and shape reasonably consistent to allow construction of standard design in competent workshop.	<i>Included in manual, Chapter 5, for spans of 10 to 20m.</i>
Reinforced concrete	May have higher initial cost but likely to be most cost-effective in long term due to low maintenance and long life. Applications may be constrained by need to erect box-work for in-situ casting supported by piers. Labour with experience in RCC work needed.	Should be considered. Most Roads Departments at provincial level will have standard designs for RCC bridges that can be adapted by a qualified engineer. Designs for plain slab RCC footbridges for spans of 4 to 10m are included in Chapter 6
Suspended and Suspension bridges	The ready availability of cables and components may depend on there being a national programme to introduce these bridges. Qualified engineer needed together with workers who have experience in cable installation	Good manuals already available – see section 3.6.3. Therefore <i>not included in manual</i>



### 3.7.4 Recommended Selection Options

#### 1. **Spans up to 10 to 12m**

- *Bamboo footbridge (Section 4.2)* that can be built by community for little or no cost for light traffic and where community is prepared to regularly replace the deteriorated bamboo
- *Timber log footbridge (Section 4.3)* for general traffic where suitable logs are locally available
- *Sawn-timber beam footbridge (Section 4.4)* where logs not available or better quality bridge wanted
- *Reinforced concrete footbridge (Chapter 6)* where budget allows consideration of long-term cost and necessary technical assistance is available

#### 2. **Spans 10 to 20 or 25m – No piers possible**

- *Steel truss footbridge (Chapter 5)* constructed in competent workshop and transported to site

#### 3. **Spans over 20 to 25m – No piers possible**

- *Suspended or suspension bridge* where these are feasible

#### 4. **Spans over 10m – Piers possible**

- Consider all types to assess which is most feasible and cost-effective

A selection procedure is outlined in Table 3.4

Table 3.4: Procedure for Selection of Footbridge Type

SELECTION CRITERION	TYPE OF FOOTBRIDGE					
	BAMBOO	TIMBER LOG	SAWN TIMBER BEAMS	STEEL TRUSS	REINFORCED CONCRETE	CABLE SUSPENSION
1. USERS <b>Category 1:</b> pedestrians, bicycles, livestock, donkeys, handcarts	✓	✓	✓	✓	✓	✓
<b>Category 2:</b> Above + animal drawn carts and light motorised vehicles	X	✓	✓	✓	✓	X
2. SPAN RANGE	--	-----	-----	-----	-----	-----
2.1 Piers NOT possible	4m max ●●●●●●●●●●	10 to 12m ●●●●●	8 to 10m ●●●●●	25m ●●	10 to 12m ●●●●●	50 to 150m
2.2 Piers possible, number needed	Piers at 3 to 4m	Piers at 10 to 12m	Piers at 8 to 10m	Piers at 20 to 25m	Piers at 10 to 12m	Piers not needed
3. MAIN MATERIALS NEEDED	Bamboo  100 to 150mm size	Hardwood Logs  200mm for 5m span 400mm for 12m span	Hardwood Beams  150x75mm for 5m span 300x150mm for 10m span	Steel Angle  40x40x6mm 50x50x6mm 60x60x6mm	Cement; sand Stone aggregate Steel reinforcing bar up to 25mm	Steel cable Cable attachments
Are these available? Mark ✓ or X						
4. SKILLS AND INPUTS						
4.1 Community only	✓	X	X	X	X	X
4.2 Technical Supervision and Community		✓	✓	X	X	X
4.3 Outside inputs needed				Workshop	Experienced RCC workers	Technical and construction experience
5. TRANSFER OF MATERIALS TO SITE	✓	✓	✓	✓	✓	✓
5.1 Flat/undulating terrain						

SELECTION CRITERION	TYPE OF FOOTBRIDGE					
	BAMBOO	TIMBER LOG	SAWN TIMBER BEAMS	STEEL TRUSS	REINFORCED CONCRETE	CABLE SUSPENSION
5.2 Hilly paths/tracks	✓	X	Difficult	Individual parts	✓	✓
6. SUMMARY OF OPTIONS POSSIBLE FROM ABOVE MARK ✓ OR X						
<b>COMPARISON OF OPTIONS – the <u>more</u> stars the <u>better</u></b>						
7. Ease of Installation	****	**	*****	****	**	*
8. Maintenance Needed	*	**	**	***	*****	***
9. Life	*	**	**	***	*****	***
10. Initial Cost	*****	****	***	**	**	**
11. Long-Term Total Life Cost	***** Cheap to replace	*** Fairly cheap to replace	**	***	*****	***
12. Summary of main features	<ul style="list-style-type: none"> <li>- Community can build at little or no cost</li> <li>- Needs replacement every 2 to 3 years</li> </ul>	<ul style="list-style-type: none"> <li>- Reasonable cost where logs available</li> <li>- Difficult to transport and install</li> <li>- Limited life</li> </ul>	<ul style="list-style-type: none"> <li>- Easy to install</li> <li>- Cost of timber tending to increase</li> <li>- Limited life if not maintained</li> </ul>	<ul style="list-style-type: none"> <li>- Workshop needed</li> <li>- Easy installation</li> <li>- Materials needed from main centres</li> <li>- Suited to medium spans</li> </ul>	<ul style="list-style-type: none"> <li>- Materials usually available</li> <li>- Labour intensive construction</li> <li>- Low maintenance and long life</li> </ul>	<ul style="list-style-type: none"> <li>- Special technical skills and materials needed</li> <li>- Suited to long spans</li> </ul>
PROCEDURE:	<ul style="list-style-type: none"> <li>• Steps 1 to 5 identify the options that are possible. Summarise these in Step 6.</li> <li>• Steps 7 to 11 compare the features of the possible options.</li> <li>• Choose the <u>possible</u> option with the best combination of features, particular <u>Life</u> and <u>Total Life</u> cost, that fits in with the community or district resources.</li> </ul>					



## 4 DESIGN OF TIMBER FOOTBRIDGES

### 4.1 INTRODUCTION

This Chapter presents details of three types of timber footbridges that are selected in Section 3.7.4 as being appropriate for local construction and installation. These are:

1. Bamboo footbridges – these can be constructed by communities in areas where suitable size bamboo is readily available at little or no cost. Details of construction are described in Section 4.2.
2. Timber log footbridges – these are appropriate where suitable logs are readily available from local forests. Logs need to be reasonably straight and uniform to construct a good quality bridge. They have a higher load capacity than bamboo footbridges and are likely to have the lowest initial cost after bamboo. However, life may only be 10 to 15 years, possibly only about half of that of sawn timber footbridges. Details are presented in Section 4.3.
3. Sawn-timber beam footbridges – these may be selected when suitable timber logs are not available or when funds available allow the construction of a higher quality, longer life footbridge. Details are presented in Section 4.4.

The other type of timber bridge considered in Section 3.7 is a timber-truss bridge. These are suitable for longer spans than the above beam (stringer) footbridges but it is considered that the quality of timber sections readily available at local level might not be good enough for construction of truss type footbridges. It is considered that steel is a better option for truss type footbridges because of the greater uniformity of section, ready availability in many areas and simpler construction of joints. The design of a steel truss bridge is presented in Chapter 5.

## 4.2 BAMBOO FOOTBRIDGES

### 4.2.1 General Design Notes

Bamboo grows locally in many rural areas, particularly in Asia. It can also be readily cultivated. It is a hollow circular log with a hard, shiny outer skin. Diaphragms, closed sections, occur at regular nodes along the length of the log. Logs used in construction should be cut just outside a node to reduce the risk of the log splitting.

Bamboo is very susceptible to attack by moisture and insects such as termites. It therefore has a short life, possibly 2 to 3 years in reasonably dry conditions and only 1 to 2 years under water or in moist soil. It is difficult to treat with preservatives because of the hard skin. A number of traditional and chemical treatments are available (see Jules J.A. Jansen, 1988) but the only one that seems appropriate for situations covered by this manual is to submerge the logs for 2 to 3 months immediately after cutting and then allow them to dry away from sunlight. This is said to reduce the risk of attack by insects. However, it is not recorded what increase in life can be obtained.

Where bamboo is available it is likely that there will be good local knowledge on its use and this should be used in selecting, cutting and treating bamboo logs for footbridges.

The strength of bamboo depends on its density which can vary from about 550kg/m<sup>3</sup> for dry bamboo up to about 800kg/m<sup>3</sup> for green bamboo. Dry bamboo has a higher strength per unit weight than green bamboo.

Bamboo bridges comprise longitudinal beams, stringers, supported on cross-beams. Quite large size beams are needed to support the loads of bridge users and because bamboo logs reduce in size along their length the maximum unsupported span that is possible is quite short.

*The maximum unsupported span for bamboo footbridges is about 4m.* For longer spans pier supports will be needed under the deck or support from a structure above the bridge if piers are not possible. Examples of each of these types are given in this section of the manual.

Table 4.1 shows allowable loads for single bamboo stringers for a span of 4m. Allowable loads for other spans can be found from proportion. For example, loads for a 3m span can be 4/3 x those in the table.

**Table 4.1: Allowable Loads for a Bamboo Stringer for 4m Span**

<b>Outside Diameter of Stringer mm (1)</b>	<b>80</b>	<b>80</b>	<b>100</b>	<b>100</b>	<b>120</b>	<b>120</b>	<b>140</b>	<b>140</b>
<b>Wall thickness mm</b>	6	8	8	10	8	10	10	12
<b>Allowable central concentrated load kg</b>	29	36	59	70	89	105	149	171
<b>Allowable distributed load kg/m</b>	14	18	30	35	44	53	74	75

**Note:** (1) This is the diameter at the centre of the span, approximately the average along the length of the stringer.

An average diameter of 100mm gives an allowable point load of 59kg and using 8 stringers across a 1m width, a distributed loading of  $30 \times 8 = 240 \text{kg/m}^2$ . This may be just about adequate for situations in which bamboo footbridges are used if there is good transfer of load between stringers. However, it is advisable to reduce the span for this average size of stringer to 3m.

Recommendations for the design of bamboo bridges are given in Table 4.2.

**Table 4.2: Design of Bamboo Footbridges**

Width of Footbridge	Type of users	Average Diameter of Stringers (mm) (1)	Maximum Span between Supports	Number of Stringers per m width
1.2 to 1.4m	Pedestrians; bicycles; goats; sheep; small carts	100	3	8
		120	4	7
2.1m	Above plus other livestock, donkeys and ADVs	120	3	7
		140	4	6

- Notes:** (1) This is the diameter mid-way between the supports  
 (2) Cross-members should be used at mid-span to distribute the loading across the footbridge between the stringers. Since bamboo is flexible these should be quite effective.

#### 4.2.2 Basic Construction of Bamboo Footbridge

Figure 4.1 shows the basic construction of a bamboo footbridge. The footbridge is intended for use by pedestrians and cyclists. The main construction features are further illustrated by the photographs in Figure 4.2 and outlined below.

Stringers – 9 stringers of 120 to 150mm diameter are used for a 1.2 to 1.3 m wide deck. They are supported at intervals of 4m by piers.

Abutments - the ends of the stringers rest on 2 lengths of bamboo held in position by bamboo stakes along their length and at their ends. To increase their life the abutment logs should rest on a bed of stones. To hold the footbridge in position the stringers should be bound to the stakes.

Piers – each comprises 2 props of 120 to 150mm bamboo supporting a cross-beam of 80 to 100mm bamboo. Slots are cut in the tops of the props just above nodes, the cross-beam fitted in and bound to the props. In the example shown in the figures, the props are fixed by wedging them with rocks contained in baskets made with bamboo strips. They are not sunk into the ground. This method is satisfactory when the height of the deck above the river-bed is relatively small, say up to 2m, but for greater heights the props need to be cross-braced as shown in Figure 4.3. Larger baskets should also be used or props sunk into the ground.

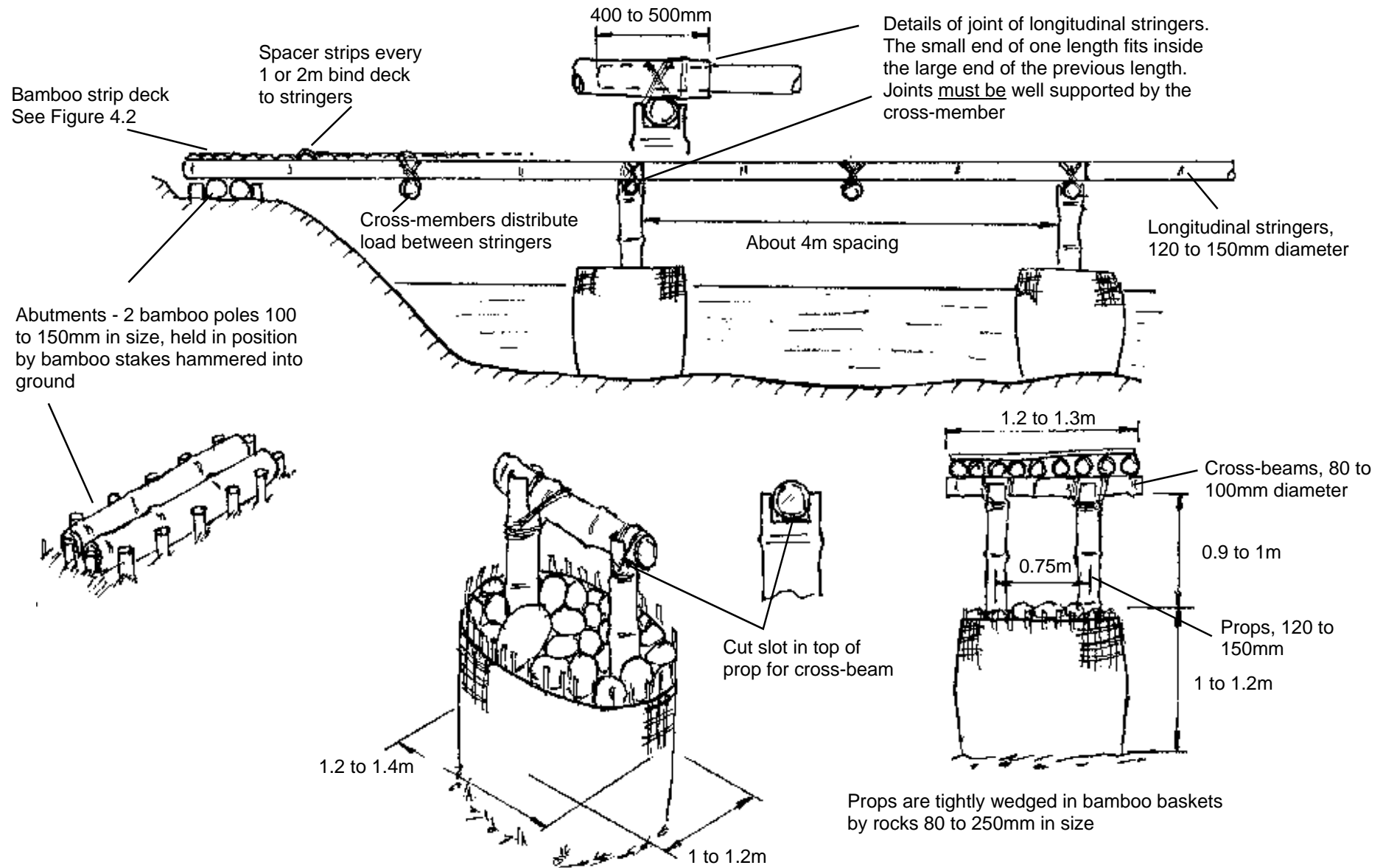


Figure 4.1: Design of a Simple Bamboo Footbridge





The bamboo stringers are supported at about 4m intervals by piers comprising 2 vertical props held in position in bamboo baskets by rocks 80 to 250mm in size.



Details of the support of the longitudinal stringers by the props and cross-beam. The stringers are bound to the cross-beam with strong vines from the forest. Note also the cross-members (top of photograph) that help to distribute the load across the width



Details of the deck formed from woven bamboo strips. The arrows indicate spacer strips located at 1 or 2m intervals to clamp the deck to the stringers. The spacer strips are bound to the longitudinals with vines.

**Figure 4.2: Details of a Simple Bamboo Footbridge from Laos**

Deck – this is made of weaved strips of bamboo. It is held in position by spacer strips that have slots cut to locate longitudinal strips of the matting. Stronger matting is needed for the 2.1m wide bridge to accommodate the heavier users.

Binding – traditionally, strong natural vines are used. Galvanised wire gives a stronger, longer life option with lower maintenance but introduces costs to the construction. Synthetic fibre rope is often locally available and may also be used.

### 4.2.3 Improved Bamboo Footbridge

The footbridge type shown in Figures 4.1 and 4.2 is a basic but effective design. With regular replacement of bamboo members it has been in place for 30 years even though, because the deck is too low, it is regularly submerged during the monsoon season.

There will be many cases in which the deck has to be at a higher level above the river-bed than that shown in Figure 4.2. This will require improved design of the piers and also a safety rail for footbridges over about 3m span.

Figure 4.3 shows improved designs for 1.4m and 2.1m wide footbridges. The main features are:

- The pier props (posts) are sunk into the river bed to increase stability. A depth of 0.5m may be adequate if rock supports are also used and 1.2 to 1.5m without the rocks. Posts can be hammered into the ground with a sledgehammer or long-handled mallet or using a dropping weight as described in Chapter 7. A piece of hardwood should be held over the top end of the post to distribute the impact blows and limit damage to the bamboo  
Note – if the river-bed does not allow sinking of posts then increased support with rocks can be used with baskets wider and deeper than those shown in Figure 4.1
- The pier posts are cross-braced to increase stability
- The maximum height of piers is about 3m. For piers over about 2m tall, stability in the axial direction (along the bridge) may be increased by adding props each side of the pier.
- The footbridge is fitted with a safety rail for pedestrians and the 2.1m wide bridge with a kerb for wheeled vehicles.

Other basic features of the design are the same as in Figure 4.1. The Details of spans and numbers and sizes of longitudinal stringers are obtained from Table 4.2.

The design in Figure 4.3 relies quite heavily on joints bound with vines, rope or wire. The following methods may be used to increase the rigidity of bound joints:

- Tighten the binding as much as possible. Tying a short stick of bamboo in the binding at the joint and twisting to tighten the binding is effective. The stick can be forced under the loops of binding to prevent the joint untwisting
- Anchoring the binding around the nodes of the bamboo to prevent it slipping
- Cutting a hole through the bamboo member at the joint, preferably at a node, and hammering in a bamboo peg to be used as an anchor for the binding.

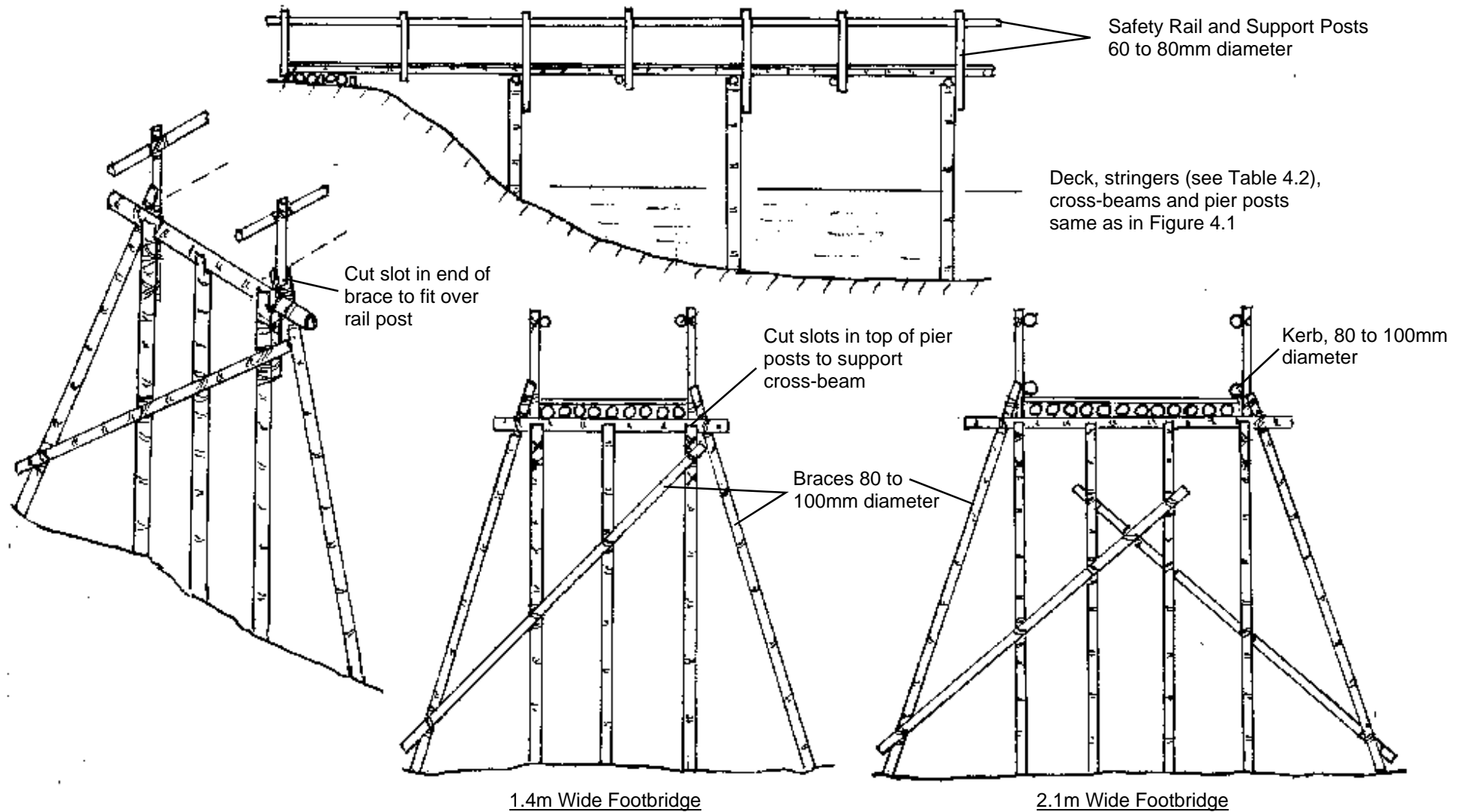


Figure 4.3: Improved Design of Bamboo Footbridge

**Abutments:**

For the 1.4m wide footbridge the abutment can be the same as that shown in Figure 4.1. For a 2.1m wide footbridge 2 pairs of bearing poles should be used as shown in Figure 4.3.

**4.2.4 Longer Span Bamboo Footbridge**

If it is not practical to use pier supports, the span of bamboo footbridges can be increased by using support from a structure constructed above the bridge. A fairly crude example of this is shown in Figure 3.1(Chapter 3) where the deck of the bridge is supported by bamboo poles attached to branches of trees growing on the banks of the river.

Figure 4.4 shows a neater construction based on a design from Indonesia. This is suitable for spans up to about 12m but should only be used for widths of 1.2 to 1.3m because of the lack of central support for the cross-beams that support the stringers. In this case the deck is supported from an 'A' frame, the bottom ends of which rest on the banks of the stream/river.

It is important that the feet of the 'A' frame do not sink into the bank as this will upset the seating of the stringers and deck. The feet should be seated on flat rocks set in holes about 0.5m deep in the bank.

The design uses the method of cutting holes through bamboo members and inserting pegs to provide positive support for cross-beams instead of relying only on joints bound with vines or wire. The joints should still be securely bound.

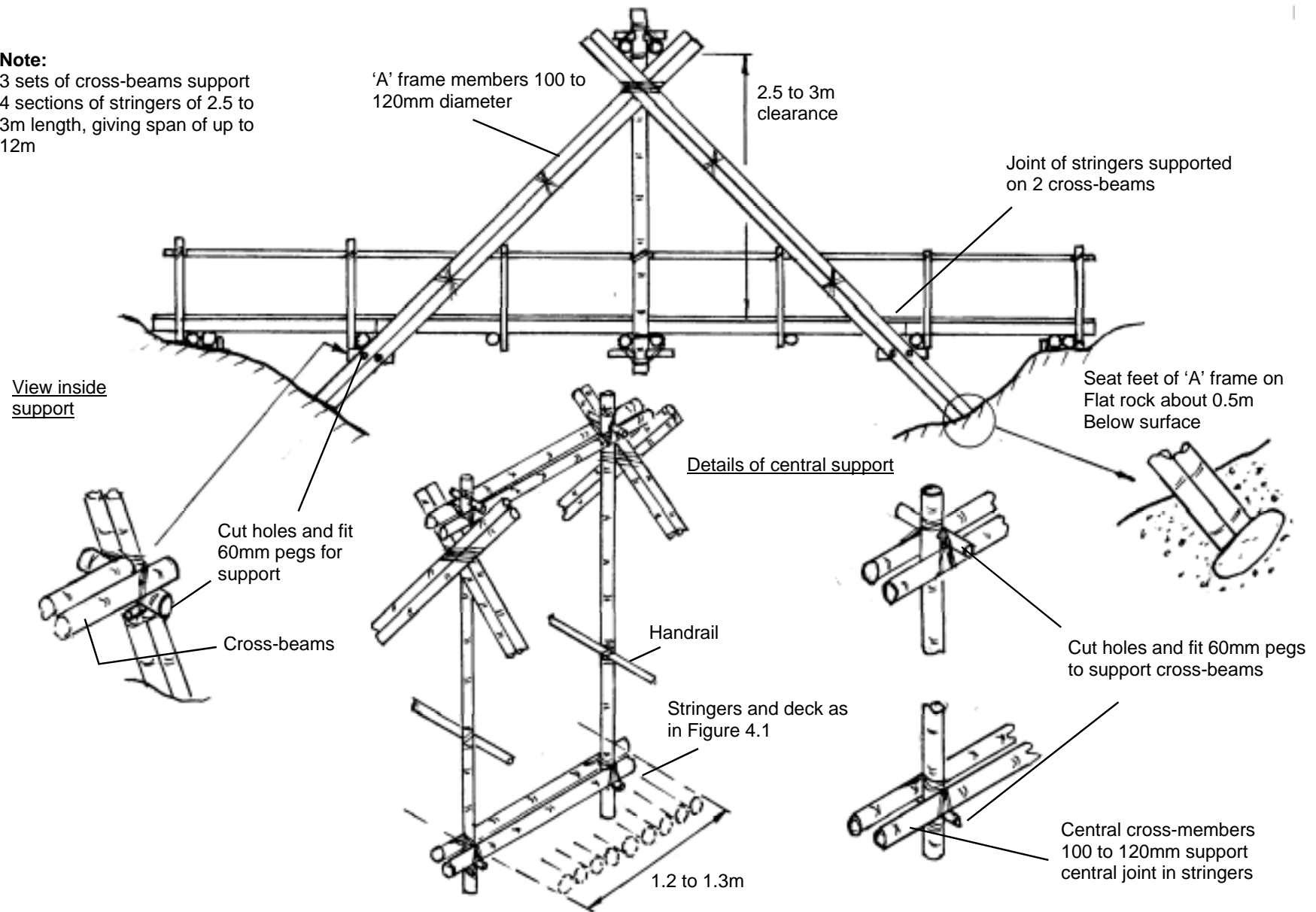
**4.2.5 Maintenance of Bamboo Footbridges**

The main maintenance requirements are:

1. To check joints about every 6 months and retighten or replace any that are not secure
2. To regularly check and replace any deck matting and bamboo members that have deteriorated. It is particularly important to carry out a thorough inspection after the rainy season.

**Note:**

3 sets of cross-beams support 4 sections of stringers of 2.5 to 3m length, giving span of up to 12m



**Figure 4.4: Design of Bamboo Footbridge for Spans up to 12m**

### 4.3 TIMBER LOG FOOTBRIDGES

#### 4.3.1 General Design Notes

If suitable logs are locally available this type of footbridge will probably have the least *initial cost* after bamboo bridges. The main cost will be from sawn timber planks for the deck. However, due to difficulties of treating the logs with preservatives the life may be only 10 to 15 years depending on the quality of the timber used. The *total life cost* will therefore be medium to high.

These footbridges can readily be constructed by communities with some technical assistance in choosing logs and attaching decking and handrails. Spans are usually 8 to 10m but can be up to 12m if suitable logs are available. Longer spans are possible where intermediate piers can be constructed.

**Selection of logs:** hardwood logs are preferred. Desirable properties are – durable, resilient (resistant to shock loading) and resistant to splitting. Figure 4.5 shows factors to be taken into account in selection in regard to size and shape.

Logs should be as straight as possible and have a low number of branches. Running a string from one end to the other, the maximum deviation from straightness should not be greater than about 100mm.

The 2 or 3 logs used for a footbridge should be matched in size as closely as possible, say within about 15% between the smallest and largest logs.

**Log sizes:** the log sizes needed for 1.4m and 2.1m wide bridges of various spans are listed in Table 4.3.

**Table 4.3: Timber Log Sizes for Footbridges**

Span (m)	Size and Spacing of Logs			
	Up to 1.0m Wide	Up to 1.4m Wide	2.1m Wide	
	2 Logs at 600mm	3 Logs at 600mm	3 Logs at 800mm	4 logs at 600mm
	Size (mm)	Size (mm)	Size (mm)	Size (mm)
4	225	200	250	220
6	275	250	300	275
8	325	300	350	325
10	375	350	400	375
12	425	400	450	425

- Notes:**
- (1) The size is the diameter of the heartwood after the bark is removed and not including the sapwood.
  - (2) The size should be the minimum diameter over at least the middle 33% (one third) of the log stringer.
  - (3) Based on live load of 400kg/m<sup>2</sup> + dead load and maximum fibre stress in bending of 10MPa.

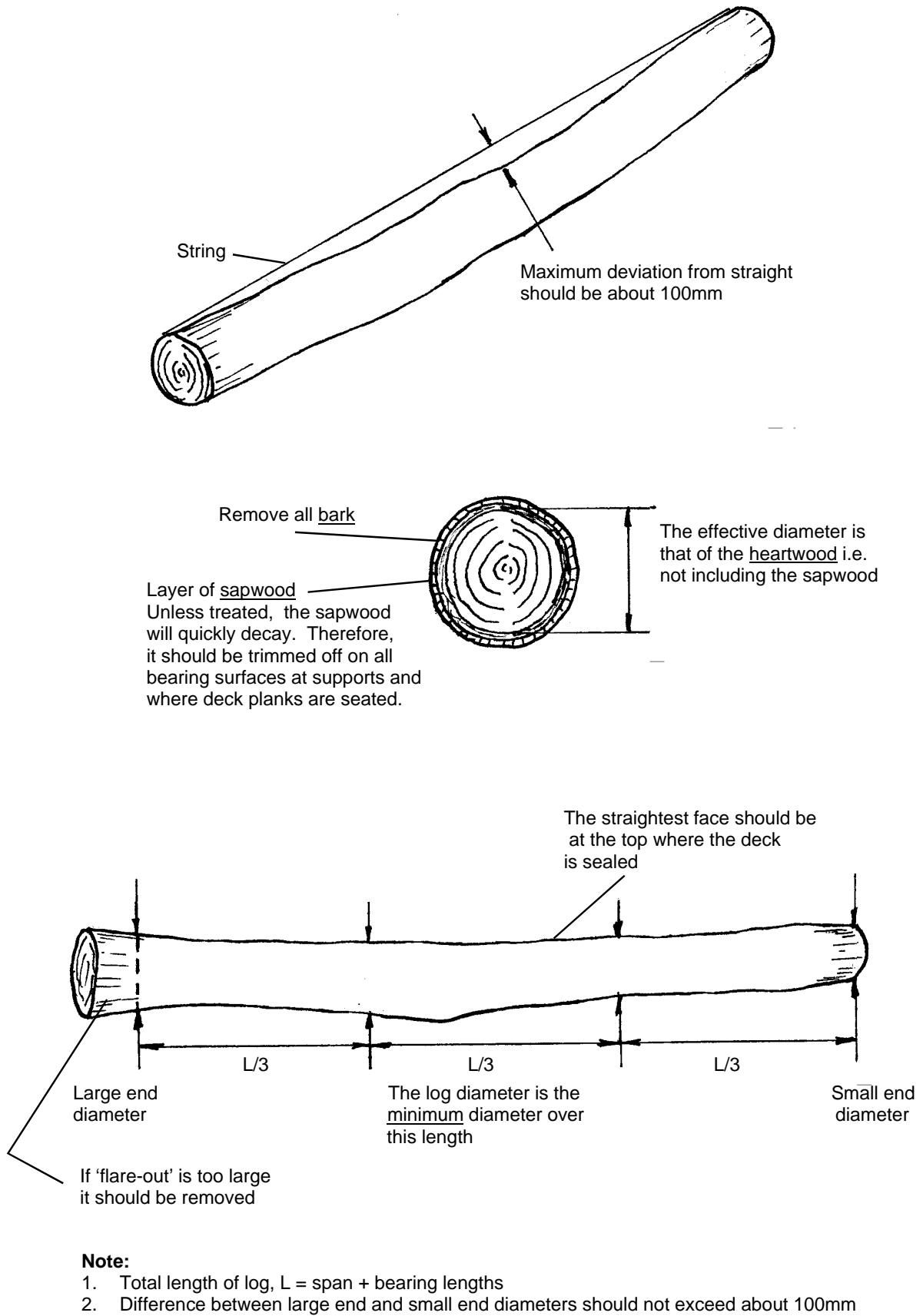


Figure 4.5: Selection of Timber Logs

**Preparation of logs:** all branches should be cut off just above the joint to the trunk. The bark should be completely stripped from the log.

**Treatment of logs:** to extend the life of the logs the procedures outlined in Section 4.3.4 should be followed as far as is possible.

**Decking:** a very crude deck can be constructed by nailing smaller logs, at least 75mm in size, across the log stringers. This is only suitable for low levels of pedestrian traffic. For more general traffic a deck of sawn timber planks will be needed. The minimum sizes of plank needed are:

Up to 1.4m wide deck– 175 wide x 50mm thick

2.1m wide deck – for 3 logs, 150 x 75mm \*; for 4 logs, 150 x 50mm

(\* An alternative is to use 150 x 75mm cross-members at 500mm spacing supporting longitudinal runners of minimum size 150 x 50mm. This will probably reduce cost.)

Deck planks should be nailed to the log stringers with 125 or 150mm long galvanised nails through pre-drilled holes if this is possible. Since nails tend to work loose, those with ribs to counter this should be used if available. Nails may be dipped in sump oil before inserting them to limit the effects of moisture penetration along the nails.

Soaking the deck planks in sump oil or brushing it on may help to preserve their life. Surfaces should be recoated at regular intervals.

### 4.3.2 Basic Design of Timber Log Footbridge

Figure 4.6 shows the design and construction of a basic timber log footbridge. The steps in construction are outlined below:

1. Locate the positions of abutments and, if the span is greater than 8 to 10m, piers, as outlined in Appendix A.
2. Construct the abutments and piers as described in Chapter 7. These may be existing rocks, or constructed from timber poles or masonry depending on the local situation and materials available. Guidelines on the choice are discussed in Chapter 7.
3. Logs should be prepared and cut to length before being transported to site. A 400mm diameter log 10m long may weigh up to about 1.2 tonne so handling and moving the logs will be difficult. They will probably have to be dragged into position on rollers. A tractor or team of oxen would be helpful.
4. **Bearing seats:** depending on the choice of abutments and piers the log stringers may be seated on timber, concrete or masonry sills. The seats need to be constructed so that the tops of the logs are as near level as possible
  - For timber log sills, grooves are cut to seat the stringer, the depth of groove being used to level the tops of the stringers. The maximum depth of groove should not exceed a quarter of the diameter of the sill. A layer of bitumen should be put in the groove to prevent trapping of moisture on the seat of the stringer.



Use level to check the top surfaces of the log stringers but also check along the stringers to balance the differences in height to minimise work in leveling the deck planks

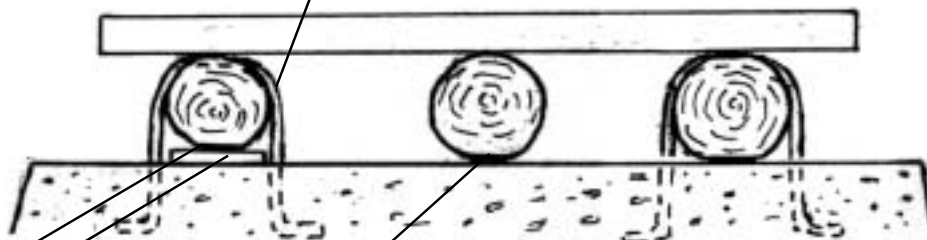


**Log Sill**

Cut grooves in sill so that tops of stringers are fairly flat. Seal seat with bitumen.

Secure stringers to sill with galvanised wire bound to 10mm anchor pins hammered into sides of sill

Embed lengths of 12mm reinforcing bar each Side of stringer and hammer ends over into Groove to fix stringers on abutment

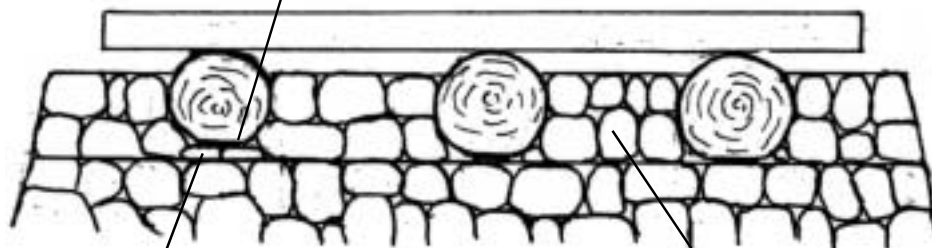


**Concrete or Masonry Sill**

Cut flats up to about 80mm wide on smaller logs and 160mm on larger logs for bearing seats and to level tops of logs

For small logs packing pieces may be needed

Seat logs on 10mm rubber pads 5mm smaller all round than bearing seat of log



**Masonry Sill**

Stone packing

Build up masonry to hold Log stringers in position

**Figure 4.6: Bearing Supports for Log Stringers**

- For concrete and masonry sills a flat at least 40mm wide should be cut on the log stringer to seat it on the sill surface. The width of flat can be adjusted to level the tops of the stringers but should not exceed about 80mm for a 200mm log and 160mm for a 400mm log. If the end of a log is particularly small a packing piece can be inserted to level up the top of the log. If available, a hard rubber pad should be inserted on the seat of the stringer. This should be about 5mm smaller all round than the flat cut on the stringer log to avoid trapping water.

**Note:** In both cases it is important to remove any sapwood from the bearing surface.

5. Prepare the ends of the log stringers before installation, making sure that the straightest surface of the log will be on top. Also if log sills are to be used, prepare these before installation using the end measurements of the logs to size the grooves needed.
6. Use one of the methods shown in 7.4.1 or other means to install the stringer logs in position on the support sills.
7. Adjust the bearing supports by trimming and packing to achieve the best balance in differences in height of the top surfaces of the stringers over their length i.e. to minimise the trimming and packing needed to bed the decking planks.
8. The stringer logs need to be securely fixed on the sills of both abutments and piers. There are various options for this. The methods shown avoid drilling of the timber.
9. **Seating of deck planks** – it is important that the deck planks are level and rest as evenly as possible on the stringers. Preparation of the stringers and fixing of the decking is shown in Figure 4.7. The top surfaces should be trimmed to produce flats for the deck planks to sit on. It is important to remove any sapwood from the logs where the deck planks are seated.

**Typical examples:** Figure 4.8 shows examples of basic log bridges in Malawi, one with timber sills and the other with masonry sills. These are both bridges for low-traffic rural roads and therefore have larger and more log stringers to support vehicle loads. Figure 4.9 shows a well-constructed timber log footbridge in Nepal. In this example the abutments are constructed from rocks that are obviously readily available in the environment shown.

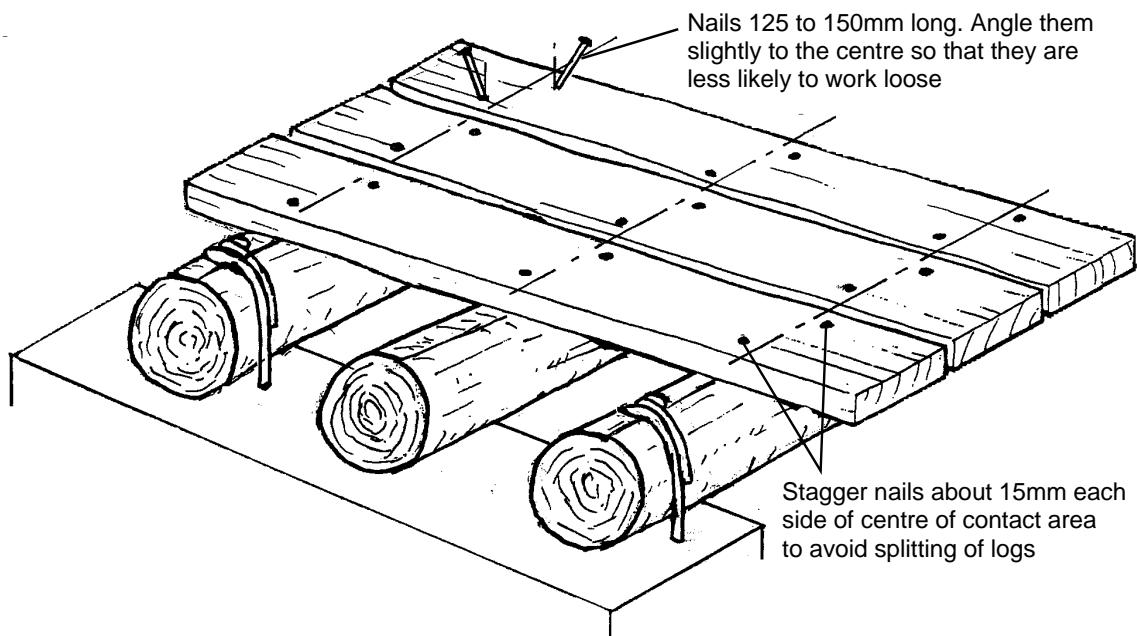
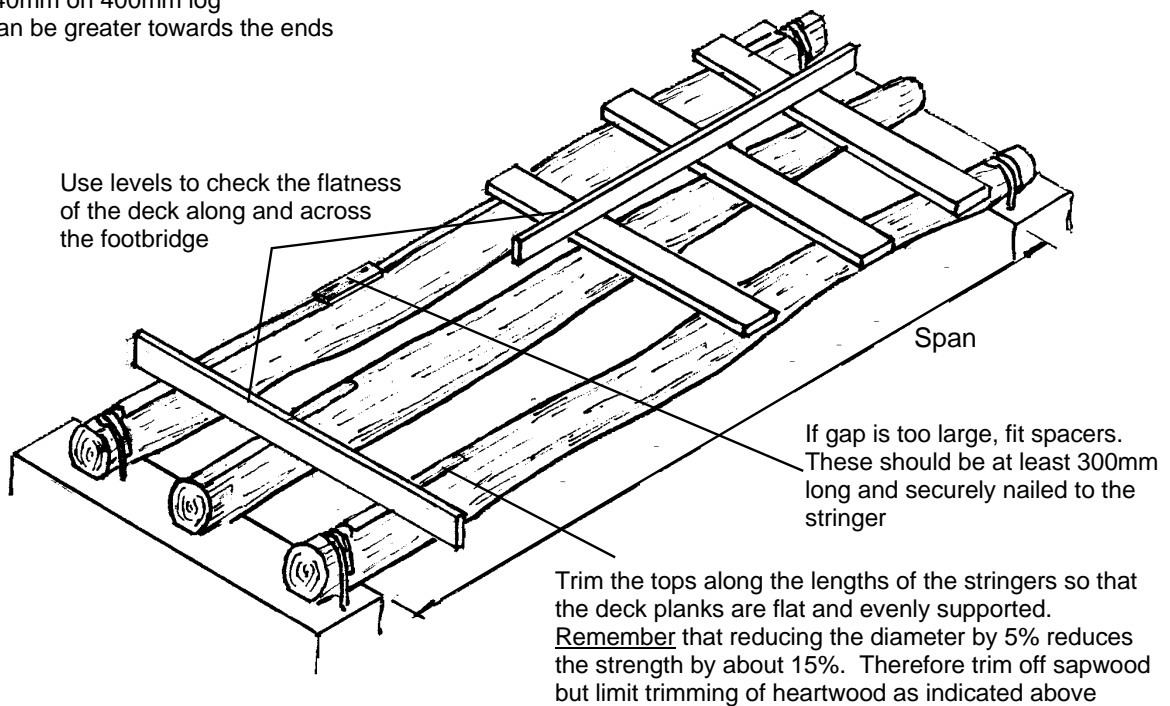
**Limits for trimming:**

Maximum width of flat on heartwood over central 1/3 of span:

80mm on 250mm log

140mm on 400mm log

Can be greater towards the ends



**Figure 4.7: Fitting the Decking on the Log Stringers**



Timber log bridge supported on timber crib abutments and with timber log wing walls



Timber log bridge supported on masonry abutments and piers. Note the way in which the masonry has been built up to support the stringer logs of different sizes and also between the logs to locate them in position.

**Figure 4.8: Timber Log Bridges in Malawi**

(Note that these are both bridges for low-volume rural roads and therefore are wider with more stringer logs than footbridges)



**Figure 4.9: Basic Timber Log Footbridge in Nepal**

Note the use of readily available rocks for construction of the abutments  
(Photo supplied by Bridges to Prosperity)

### 4.3.3 More Developed Timber Log Footbridge

For spans over about 3m footbridges should be fitted with safety rails, especially if mixed traffic will use the bridge. If wheeled vehicles will use the bridge (other than bicycles) then kerbs should also be fitted.

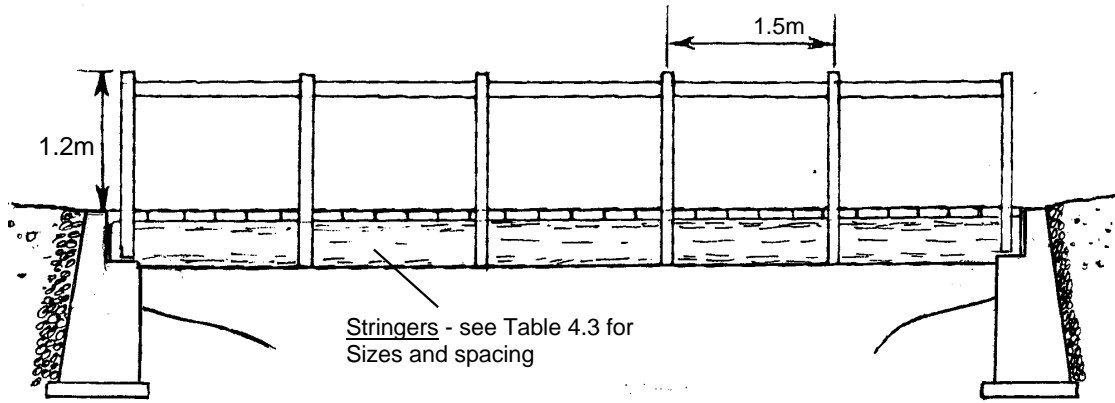
A low cost safety rail can be made from smaller logs, about 100mm diameter, if good straight logs are available. The logs should be stripped of bark and painted with creosote or other preservative, especially where the logs are cut to make joints. A neater construction of handrail can be obtained with sawn timber but this will increase cost.

Figure 4.10 shows suggestions for construction of both types of handrails.

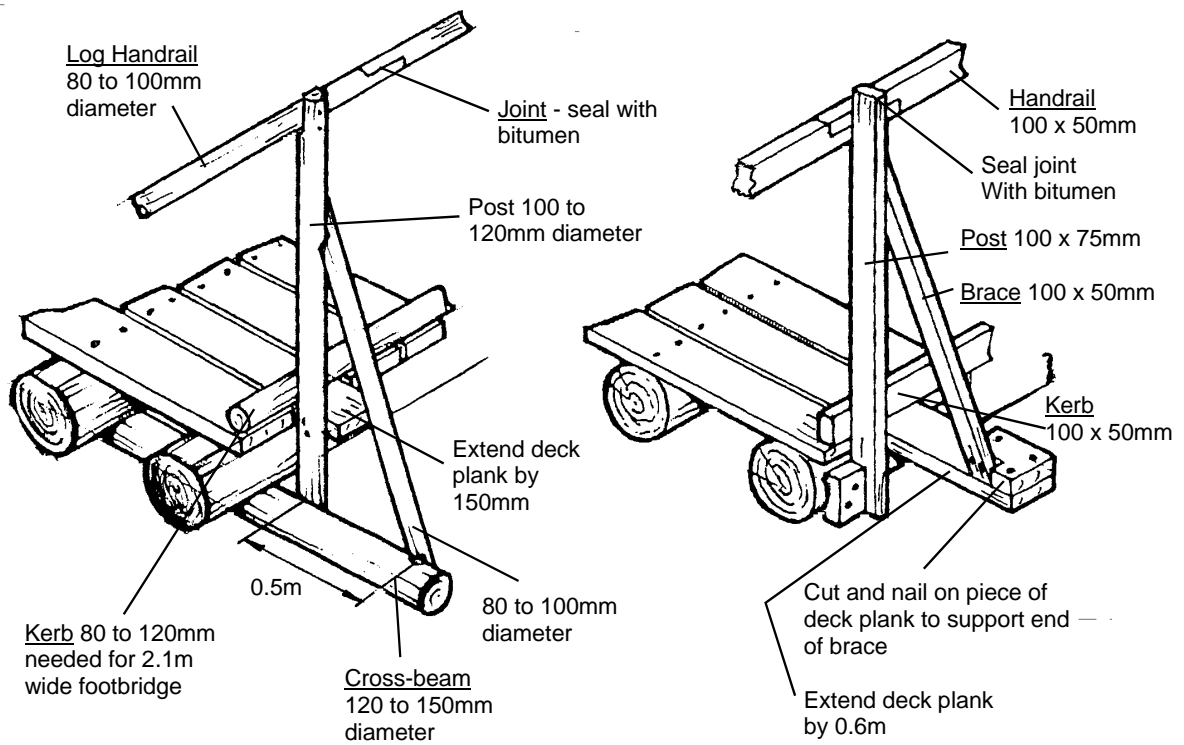
### 4.3.4 Treatment of Timber

Timber is susceptible to decay by rotting from contact with moisture and attack by insects. Some hardwoods are very resistant to this but in general the life of timber can be significantly extended by effective treatment with preservatives. Unfortunately these treatments are unlikely to be available for the footbridges covered in this manual and hand treatments are not very effective because of lack of penetration of preservatives. It is therefore recommended that the following procedures are adopted. These are applicable to both timber logs and sawn timber.

- Choose timbers that are resistant to rotting and insect attack
- Avoid direct contact between the timber and soil, particularly the ends of the timber
- Provide barriers to access of insects to the timber
- Avoid details that could trap moisture – make sure surfaces are well drained and ventilated
- Protect the sawn ends of timber and contacting surfaces where moisture could be trapped – bearing surfaces for beams and decking – with bitumen/tar
- The best alternative to pressure treatment is to soak the timber in a preservative. For example, timber poles to be sunk into the ground can be treated by soaking in a 50/50 mixture of diesel and creosote for 2 weeks.
- If hand brushing is the only option, this should be repeated regularly as soon as there are signs that the surface treatment is weathering. All surfaces that are cut, trimmed or drilled should in particular be treated in this way. Creosote, a tar derivative, may be used, or a low-cost alternative is sump oil.



For details of abutments see Section 7.2



**Timber Log Handrail and Kerb**

**Sawn Timber Handrail and Kerb**

**Protection:** Stringers - coat cut surfaces (flats) with 2/3 coats of creosote. Protect ends with bitumen  
Handrails and Kerb - 2/3 coats of creosote  
Deck Planks - soak in or brush with engine sump oil  
Nails: use galvanised nails and dip in sump oil to protect holes against moisture

**Figure 4.10: Construction of Timber Log Footbridge**

## 4.4 SAWN TIMBER BEAM FOOTBRIDGE

### 4.4.1 General Design Notes

If timber logs are not available the next choice for a simple-to-construct footbridge would be sawn timber beams or stringers, although the cost will be significantly higher than for logs. Prices reported for hardwood beams in the case-studies ranged from USD250 to 650/m<sup>3</sup>. Therefore a typical size of 150 x 250mm would cost from USD9.50 to 24.40/m length.

Sawn timber beams have advantages over logs – lighter and easier to handle; little preparation is needed; they are more regular in shape and therefore produce neater designs; and they can be more effectively treated with preservatives.

However, their strength is more affected by defects such as splits and knots. Beams should be carefully inspected and those with excessive defects that could cause local weaknesses, especially near the top and bottom surfaces and over the middle 50% of the length of the beam, should not be used.

#### **Sizes and Number of Beams (Stringers) Needed**

The stringers carry the footbridge loading in bending. For cost-effective use of the timber the depth of the stringer should be at least 2 x its width. However, the depth should not be more than 3 x width to avoid the risk of the stringer twisting under load.

Table 4.4 shows recommended stringer sizes and number needed for spans up to 10m. These are based on standard sawn timber sizes with depth/width ratios of about 2 to 2.5.

**Table 4.4: Sizes and Numbers of Stringers Needed for Various Footbridge Spans**

Footbridge Span	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Beam Size (mm)	Number needed	Total Area m <sup>2</sup>	Beam Size (mm)	Number needed	Total Area m <sup>2</sup>
4m	75 x 150	7	0.079	75 x 200	7	0.105
	75 x 200	5	0.075	100 x 200	6	0.120
	100 x 200	4	0.080			
6m	100 x 200	7	0.140	100 x 200	10	0.200
	100 x 250	5	0.125	100 x 250	7	0.175
	150 x 250	4	0.15			
8m	100 x 250	7	0.175	100 x 250	11	0.275
	150 x 300	5	0.225	150 x 300	6	0.270
	150 x 350	4	0.210			
10m	150 x 300	6	0.270	150 x 300	8	0.360
	150 x 350	5	0.263	150 x 350	6	0.315
	150 x 400	4	0.240			

- Note:** (1) In order to adequately support deck planks, the minimum number of stringers are – **4** for 1.4m wide footbridge: **6** for 2.1m wide footbridge  
 (2) The Total Area of cross-section gives a comparison of the costs of the options  
 (3) Based on live loading of 400kg/m<sup>2</sup> + dead load and maximum fibre stress in bending of 8MPa.



#### 4.4.2 Design and Construction of a Sawn Timber Beam Footbridge

The steps involved in the construction and installation of sawn-timber bridges are basically the same as for timber log bridges (see 4.3.2)

Abutments and piers are most likely to be constructed from sawn timber or masonry. Masonry is preferred since it gives a long life with low maintenance and provides better protection for the sawn timber stringers.

For the same span the weight of sawn-timber stringers will be considerably less than for log stringers so movement and installation of the stringers will not be as difficult. The weight of a 150 x 300mm section stringer of 10m length will be about 350 to 400kg. They may be installed using similar methods to those used for logs.

Figure 4.11 shows construction details for a sawn timber beam footbridge with timber abutments and Figure 4.12 shows construction details with masonry abutments. The details of the construction of the footbridge itself are the same in both cases. The main features are outlined below.

**Stringers:** Recommended sizes and numbers are listed in Table 4.4. Stringers should be protected with 2 or 3 coats of a preservative such as creosote. Engine sump oil may be used if preservatives are not available. The ends of stringers should be coated with bitumen. The top surfaces where the deck planks are attached should also be sealed with bitumen or tar.

**Decking:** provided that at least 4 stringers are used for the 1.4m wide footbridge and 6 for the 2.1m bridge the minimum plank size needed for the deck is 150 x 50mm.

The planks are nailed to the stringers with 100 to 125mm long galvanised nails. Nails with ribs to prevent them working loose should be used if available, and should be dipped in sump oil before being inserted. Pre-drilled holes should be used if possible. Nails should be staggered to avoid splitting the wood and inserted at an angle to reduce the risk of them working loose.

Deck planks should be soaked in or brushed with engine sump oil.

**Abutments:** If timber abutments are used a bearing seat length of at least 150mm is required and the seat should be sealed with a layer of bitumen. On masonry and concrete a hard rubber pad at least 10mm thick should be used on the bearing seat if possible. This should be about 5mm smaller all-round than the seat to avoid trapping of water on the seat.

It is important to prevent contact of the ends of the stringers with the surrounding soil as the risk of rotting of the timber is greatest at the ends. On masonry abutments this is easily achieved by a raised lip or step around the sill. On timber abutments a barrier is needed. This may be formed from timber boards, steel sheet (for example, flattened oil drums) or a masonry wall.

Stringers should be firmly fixed on the abutment.

**Piers:** Similar arrangements should be used for supporting the stringers as for the abutments. Joints between stringers should be centrally located on the pier with each stringer having a bearing length of at least 150mm. This means that for butt joints (end to end) the pier will need to be at least 300mm wide OR joints will need to be overlapped. If butt joints are used, the joints should be covered by deck planks and sealed with bitumen.

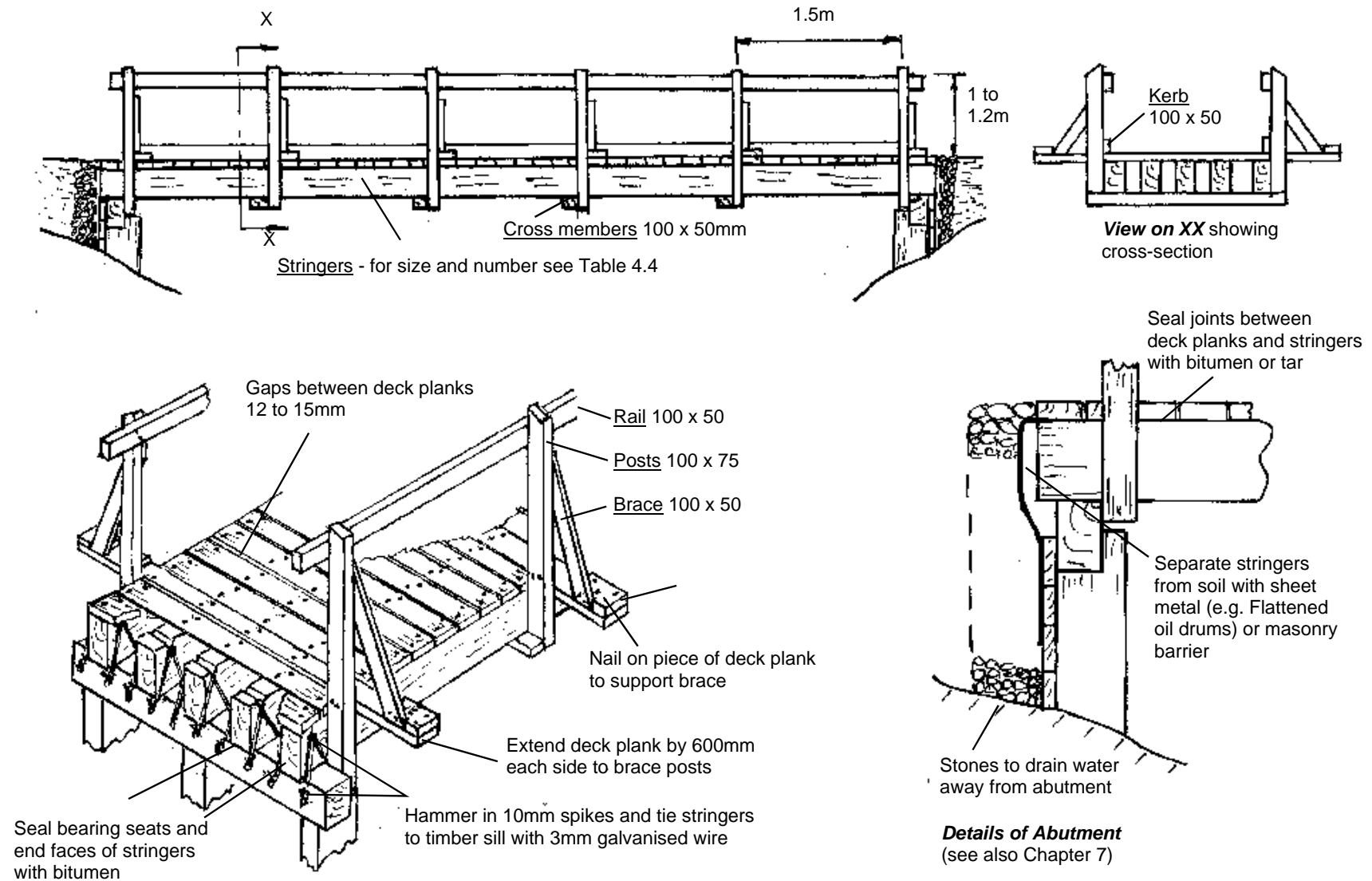


Figure 4.11: Construction of Sawn Timber Footbridge with Timber Abutments

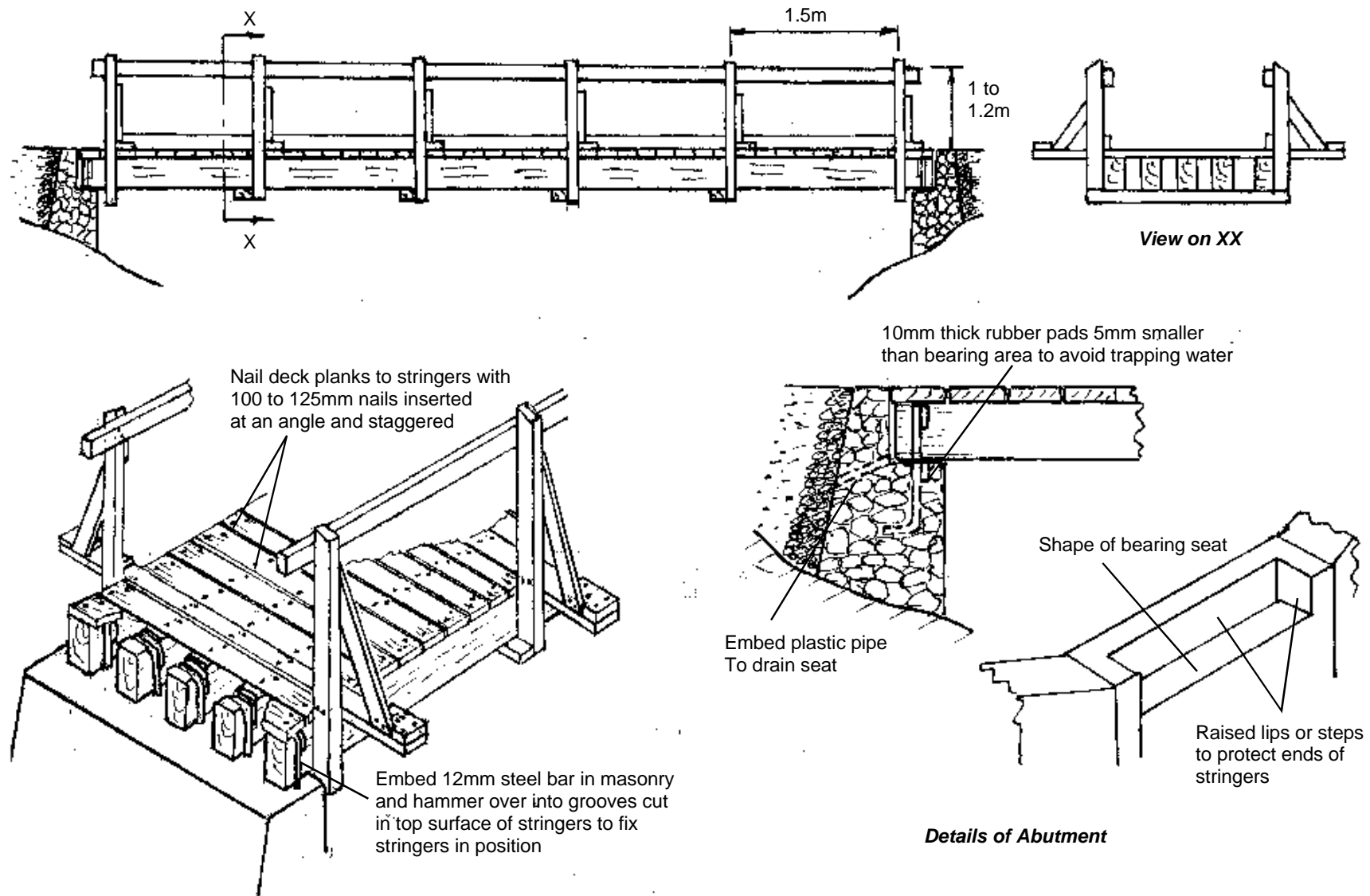


Figure 4.12: Construction of Sawn Timber Footbridge with Masonry Sills

**Handrails:** Sturdy handrails are needed that will safely support users leaning on them. They should be painted with creosote and joints should be sealed with bitumen.

Figure 4.13 shows details of typical examples of abutments, pier supports and attachment of handrails.

#### **4.4.3 Increasing the Span of Timber Stringer Footbridges**

Where intermediate piers cannot be used the span of timber stringer footbridges can be increased by using cable supports as in Figure 3.13 or using cantilever abutment supports as shown in Figure 4.14. In the cantilever arrangement there needs to be enough area of logs/beams buried within the abutment together with enough weight of rocks and fill covering it to balance the cantilever load from the footbridge deck. It is reported that spans up to 20m are possible.



Detail of sawn timber abutment with sill supported by 3 posts. Note the timber behind the abutment and the wing wall to protect against erosion of the bank.



Detail of pier support of timber stringers. Note the butt joint of stringers with 2 cross-beams supporting the ends of the stringers.

**Figure 4.13: Examples of Details of Sawn Timber Bridges**

(Photographs from Laos Case Study)





Details of Footbridge



Details of cantilever support. The moment from the weight of the rocks acting on the cantilever beams must balance that from the cantilever load at the support of the footbridge

**Figure 4.14: Use of Cantilever Supports to Increase the Span of a Sawn Timber Footbridge**

(Photographs supplied by Bridges to Prosperity)

## 4.5 MAINTENANCE OF TIMBER FOOTBRIDGES

The main causes of deterioration of timber structure are attack by insects and rotting due to contact with moisture. The first should be overcome by use of local knowledge in choosing hardwoods that are resistant to attack by insects.

Attention to detail in the design and construction of the footbridge can do much to increase resistance against rotting and prolong the life of the bridge. Some of the main factors are:

- Avoid construction features, especially at joints, that could trap water. Grooves and holes can be used to drain away water and good ventilation can reduce surface moisture. Where water might run into joints a sealant such as bitumen can be used in the joint. Engine sump oil can be used to provide some protection against moisture on nails and in pre-drilled holes
- Avoid direct contact with soil. For example in the designs shown above a barrier of timber, steel sheet or masonry is recommended at the ends of the stringers to prevent contact with the soil. Where timber posts are sunk into the ground their life may be increased by soaking them in a 50/50 mixture of creosote and diesel fuel or in engine sump oil for about 2 weeks.
- Protect the vulnerable ends of timber beams, particularly of stringers, with a sealant such as bitumen

To be effective, hand application of preservatives such as creosote needs to be carried out regularly over a period of at least one to two years. This is unlikely to be practical on footbridges, especially for the stringers. Therefore, if timber bridges are being widely used in a district or region it may be a good idea to keep a store of prepared and treated timber components, so that those used in a particular application have been treated over a sufficiently long period to develop reasonable protection.

Regular inspection and maintenance of footbridges can also extend their life. Factors to look for in particular are:

- Areas of timber where there is excessive deterioration, try to identify and rectify the causes. For example dirt and debris that could trap moisture should be cleaned out.
- Deck planks where defects or worn areas are trapping water should be turned over or replaced
- Nails that have worked loose should be hammered in. If they are badly corroded replace them
- Inspect regularly for any signs of insect attack, for instance termites. Since termites have to gain access to the timber structure via the abutments or piers, it is good practice to place metal caps on the top of timber abutments or piers to clearly show if termites are crossing the metal cap to reach the timber stringers and deck.
- Timber that has rotted, especially any that could cause a safety hazard, should be replaced as soon as possible.

Periodic maintenance to be carried out every 1 or 2 years should include the re-treatment of surfaces that were originally treated with preservatives.





## 5 DESIGN OF STEEL TRUSS FOOTBRIDGE

### 5.1 INTRODUCTION

A steel truss footbridge was selected in Section 3.7.3 as the best option for spans of 10 to 20m, and possibly up to 25m, when it is not possible to construct piers for intermediate supports for beam type footbridges. It should also be considered for spans over 10m when piers are possible. The advantages are considered to be:

- The steel sections needed should be available in main resource centres
- The sections are likely to be more uniform in shape and size than timber sections, allowing straightforward construction of standard truss designs
- Joints are easier to make than in timber trusses

It should be possible to construct a standard design in a medium sized workshop in convenient sized parts for transport to site. Assembly on site involves bolting the parts together and fitting a timber deck, tasks that can be carried out under supervision of a competent technician by local carpenters and others skilled in using their hands.

There are 3 levels at which the bridge may be broken down into parts for transportation:

1. Individual members that are predrilled in the workshop, transported and bolted together on site. An example is shown in Figure 5.1. In this case each piece had to be carried 24km from the road down a steep track to the footbridge site. This method requires considerable accurate drilling of holes in the workshop and careful assembly on site.
2. The steel members are cut and welded up into panels in the workshop and the panels drilled for bolting together. Panels are transported to site and bolted together on site. This significantly reduces pre-drilling and assembly work. Panels may weigh up to about 100kg.
3. Panels are bolted together in the workshop into modules that are transported to site. The modules are bolted together on site. This will require the least assembly work on site. Modules are likely to weigh up to 300 to 400kg and will be quite bulky to transport. This method is only likely to be possible if there is access for trucks directly to the footbridge site.

**Level 2** is selected as the best compromise for ease of transport and least pre-drilling and assembly operations. Standard designs have therefore been developed for a modular steel truss footbridge which is made up as panels in a workshop and the panels transported to site and bolted together on site.

This option is suited to mainly flat to moderate rolling terrain. On steeper hilly paths and tracks it may be difficult to carry the panels and using option 1 above may be more practical.

The standard designs are described in this Chapter. The detailed design and construction of the footbridge is included in Appendix B. This includes step-by-step instructions for construction, and templates and jigs needed for accurate manufacture of the footbridge.



Members were carried individually 24km from the road down a steep track to the footbridge site.



The members being bolted together to form the modular truss footbridge

**Figure 5.1: Transportation of Individual Members of a Steel Truss to Site and Assembly on Site**

(Photographs from Bridges to Prosperity, the NGO that designed and supervised the installation of the footbridge)

## 5.2 DESIGN OF MODULAR STEEL TRUSS FOOTBRIDGE

Two basic designs have been developed based on the specifications of Figure 2.3 and the loads stated in Table 2.2.

1. A 1.4m wide footbridge with sides 1.5m high
2. A 2.1m wide footbridge with sides 1.8m high. The higher sides are to carry the larger loading on the 2.1m footbridge.

Standard layouts of panels are used for each design but panel lengths vary depending on the required span of the footbridge. Some members of the 2.1m wide footbridge are larger in section than for the 1.4 m wide bridge.

The standard design covers Spans of 10m (6 modules) to 20m (12 modules). An important factor is that **there must be an even number of panels** so that the left and right halves of the bridge are the same.

Three angle sections are used – 40 x 40 x6 mm; 50 x 50 x6 mm; 60 x 60 x6 mm. Small variations from these can be used. Gussets for the joints are made from 60 x 6 flat bar.

The method designed for bolting the modules together keeps bolt-hole diameters down to a size that should be within the drilling capacity of medium size workshops. M16 bolts are used on the 1.4m wide footbridge and M20 bolts are used on the 2.1m wide footbridge.

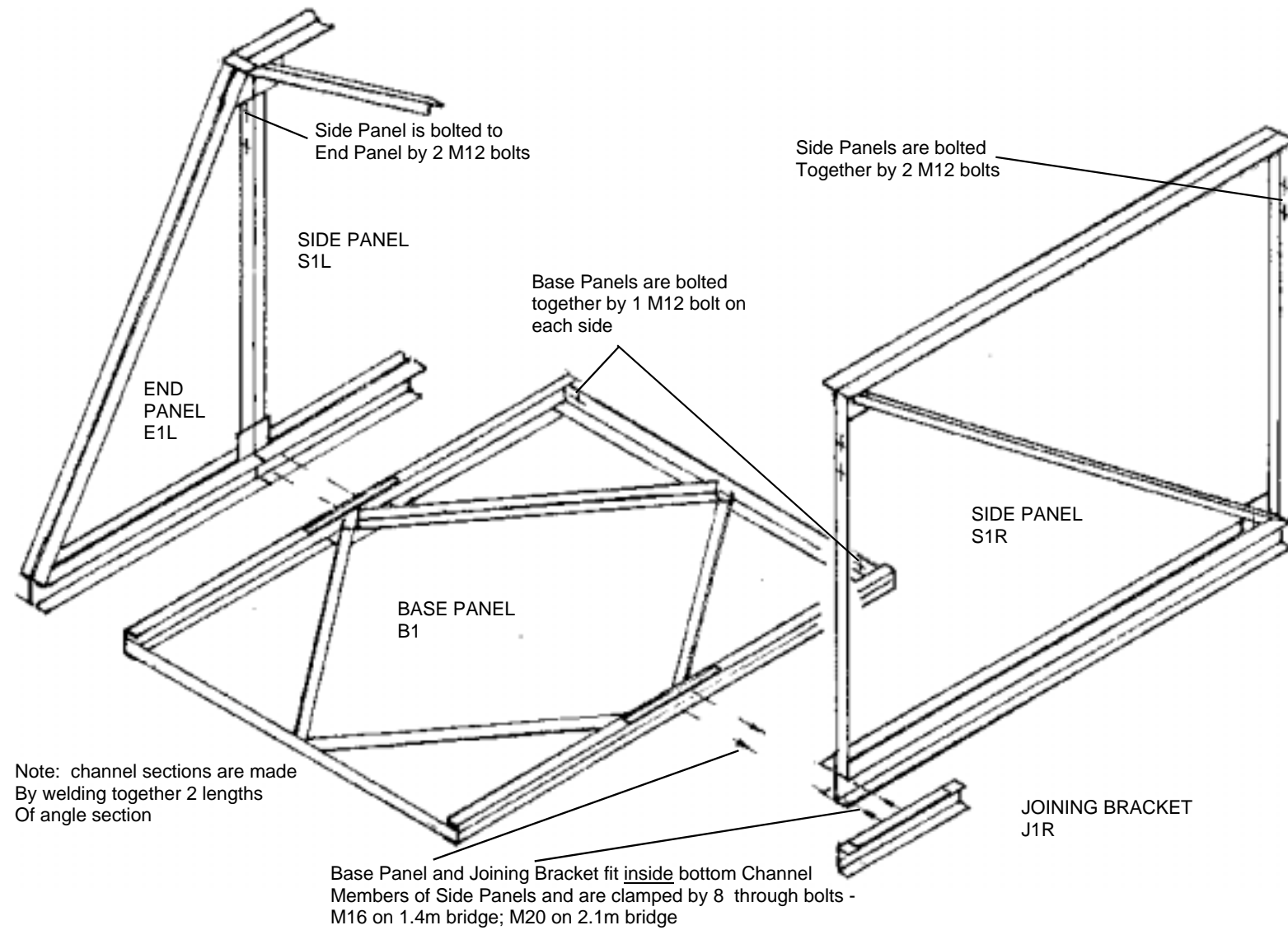
This Chapter describes the design concept and assembly. Step by step instructions for manufacture are contained in Appendix B.

### 5.2.1 Design Concept

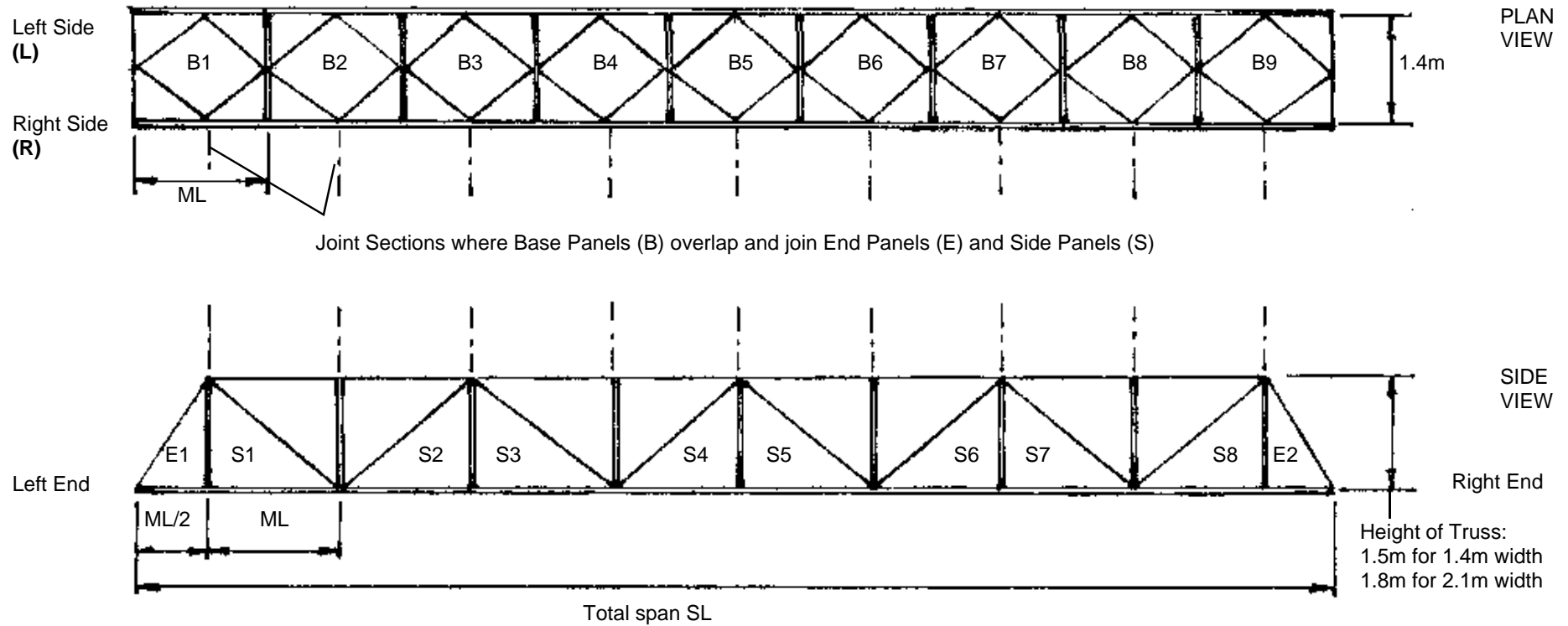
The design concept is explained in [Figure 5.2](#) which shows the geometry of the panels and how they fit together. Note that the base panels overlap the end and side panels.

[Figure 5.3](#) shows the arrangement of the modules and the reference index used for the panels.

The number and lengths of modules for spans from 10 to 20m are listed in [Table 5.1](#). Note that since there must be an even number of side panels and there are half-length panels at each end, the number of full module lengths and base panels is always odd.



**Figure 5.2: Details of Geometry and Assembly of Panels**



- Panels Needed:
- End Panels (E) - 2 Left Side, 2 Right Side
  - Side Panels (S) - Even number; Note half have diagonal Top Left to Bottom Right  
And half have diagonal Bottom Left to Top Right
  - Base Panels (B) - Number of side panels + 1

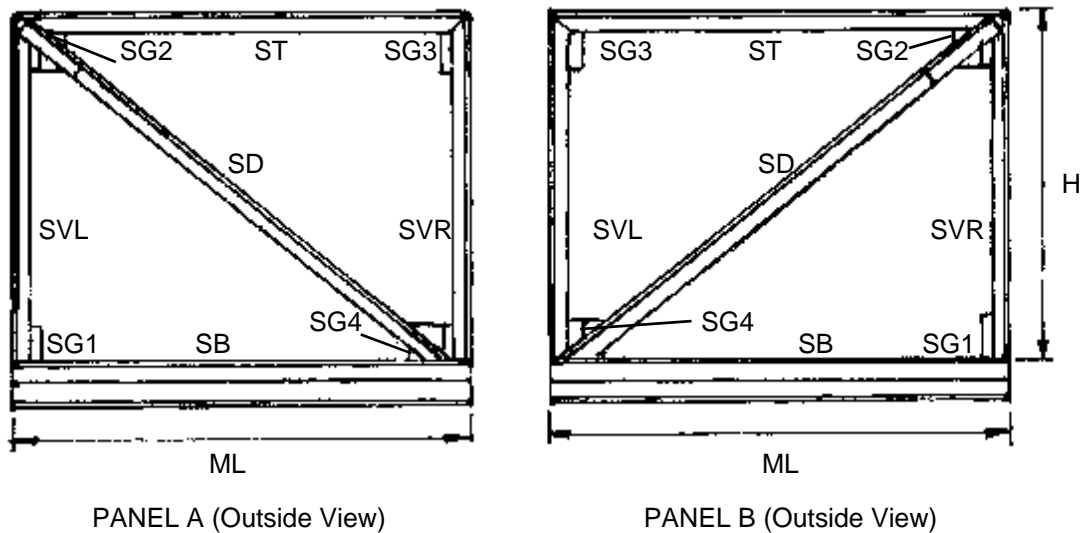
**Figure 5.3: Details of Modular Design**

**Table 5.1: Numbers and Lengths of Modules for the Range of Spans**

Span (m)	Number of Side Panels/side	Number of Base Panels	Length of Module (ML) m	Length of End Modules m
10	4	5	2.0	1.0
11	6	7	1.6	0.8
12	6	7	1.7	0.85
13	6	7	1.9	0.95
14	6	7	2.0	1.0
15	8	9	1.7	0.85
16	8	9	1.8	0.9
17	8	9	1.9	0.95
18	8	9	2.0	1.0
19	10	11	1.7	0.85
20	10	11	1.8	0.9

### 5.2.2 Details of Side Panels

Figure 5.4 shows the layout of the Side panels. Half have diagonals sloping from top left to bottom right (Panel A) and half bottom left to top right (Panel B).. The arrangement and numbering of side panels is shown in Figure 5.3. The dimensions, ML and H, are given in Table 5.1.



ML from Table 5.1

H = 1.5m for 1.4m width; 1.8m for 2.1m width

**Figure 5.4: Members of Side Panels**

The materials list for the 2 standard designs is given in Table 5.2.

**Table 5.2: Materials List for Side Panels (*per panel*)**

Member	Materials for 1.4m wide footbridge			Materials for 2.1m wide footbridge		
	Section	Length mm	Number	Section	Length	Number
Bottom Longitudinals (SB)	50x50x6mm angle	ML	4	60x60x6 mm angle	ML	4
Top Longitudinals (ST)	60x60x6mm angle	(ML – 12)mm (2)	2	60x60x6 mm angle	(ML – 12)mm (2)	2
Verticals (SVL & SVR)	50x50x6mm angle	1450mm	2	50x50x6 mm angle	1750mm	2
Diagonals (SD) (1)	50x50x6mm angle	Measure and fit	2	50x50x6 mm angle	Measure and fit	2
Gusset SG1	60x6 flat bar	220 mm	1	60x6 flat bar	240 mm	1
Gusset SG2	60x6 flat bar	120 mm	2	60x6 flat bar	120 mm	2
Gusset SG3	60x6 flat bar	120 mm	1	60x6 flat bar	120 mm	1
Gusset SG4	60x6 flat bar	220 mm	2	60x6 flat bar	240 mm	2
Spacer SS	60 x 6 flat bar	40mm	2	60 x 6 flat bar	40mm	2

**Notes:** (1) The outside of the panel should be welded up first and then the required length of the diagonals measured. The approximate lengths for material requirements are:

1.4m wide bridge – 2.23m for ML= 1.7m, to 2.48m for ML = 2.0m  
 2.1m wide bridge – 2.45m for ML = 1.7m, to 2.66m for ML = 2.0m

(2) The length is 2 thicknesses of angle (2 x 6mm) less than ML to allow for the Vertical members at each end.

### ***Design and Construction of Side Panels***

Figure 5.5 shows the details of the design and construction of a side panel. This is a Panel A with diagonal running from Top Left to Bottom Right. For Panel B the diagonal runs from Bottom Left to Top Right and the gussets are moved to suit this.

The module length, ML, is obtained from Table 5.1 for the span of the footbridge. The section details and lengths are obtained from Table 5.2.

Details of the construction of the side panel members are given in Appendix B.

When the members have been manufactured, they need to be drilled and assembled in sequence as explained in Appendix B.

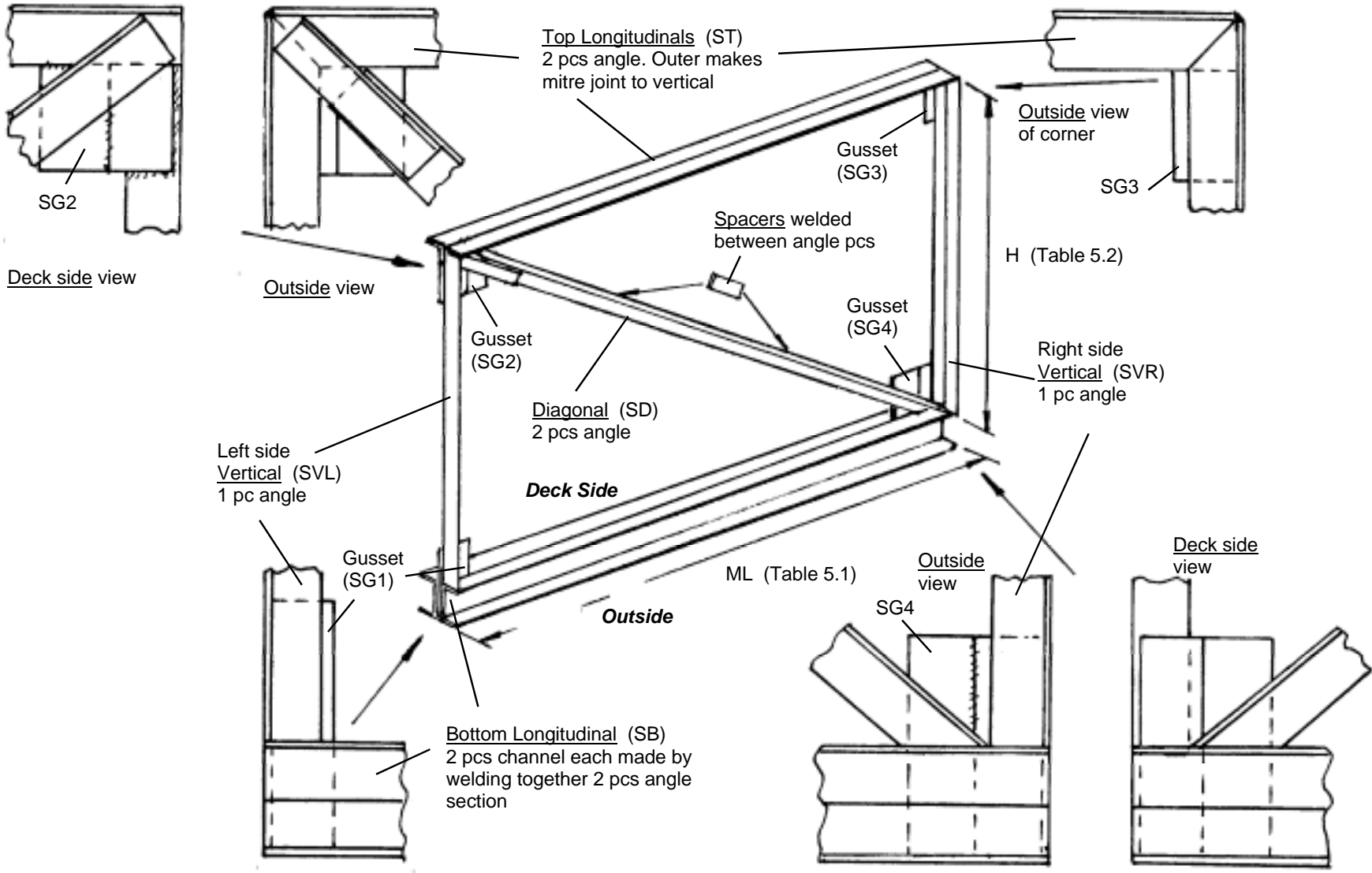


Figure 5.5: Design of Side Panel A (Panel B has SD bottom left to top right)



### 5.2.3 Details of End Panels

Figure 5.6 shows the details of the design of the end panels. Two pairs are needed, a left and right hand panel for each end. The one shown is a Right Side panel at the Left End of the bridge.

Table 5.3 shows the list of materials for an end panel.

**Table 5.3: Materials List for End Panel (Single panel)**

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (EB)	50x50x6mm angle	ML/2	4	60x60x6mm angle	ML/2	4
Vertical (EV)	50x50x6mm angle	1450mm	1	50x50x6mm angle	1750mm	1
Diagonal (ED)	50x50x6mm angle	Measure and fit (1)	2	60x60x6mm angle	Measure and fit	2
Gusset EG1	60x6 flat bar	210mm	1	60x6 flat bar	240mm	1
Gusset EG2	60x6 flat bar	260mm	1	60x6 flat bar	300mm	1
Gusset EG3	60x6 flat bar	220mm	2	60x6 flat bar	220mm	2
Gusset EG4	60x6 flat bar	180mm	1	60x6 flat bar	200mm	1

**Note:** (1) Weld the Vertical to the Base Longitudinal then measure up and cut the Diagonal to fit neatly into position. The approximate lengths for material requirements are:

1.4m footbridge – 1.68m for ML=1.7m to 1.77m for ML=2m  
 2.1m footbridge – 1.95m for ML= 1.7m to 2.02m for ML = 2m

Details for the construction of the end panels are given in Appendix B.

The module length, ML, is obtained from Table 5.1 for the span of the footbridge. The section details and lengths are obtained from Table 5.3.

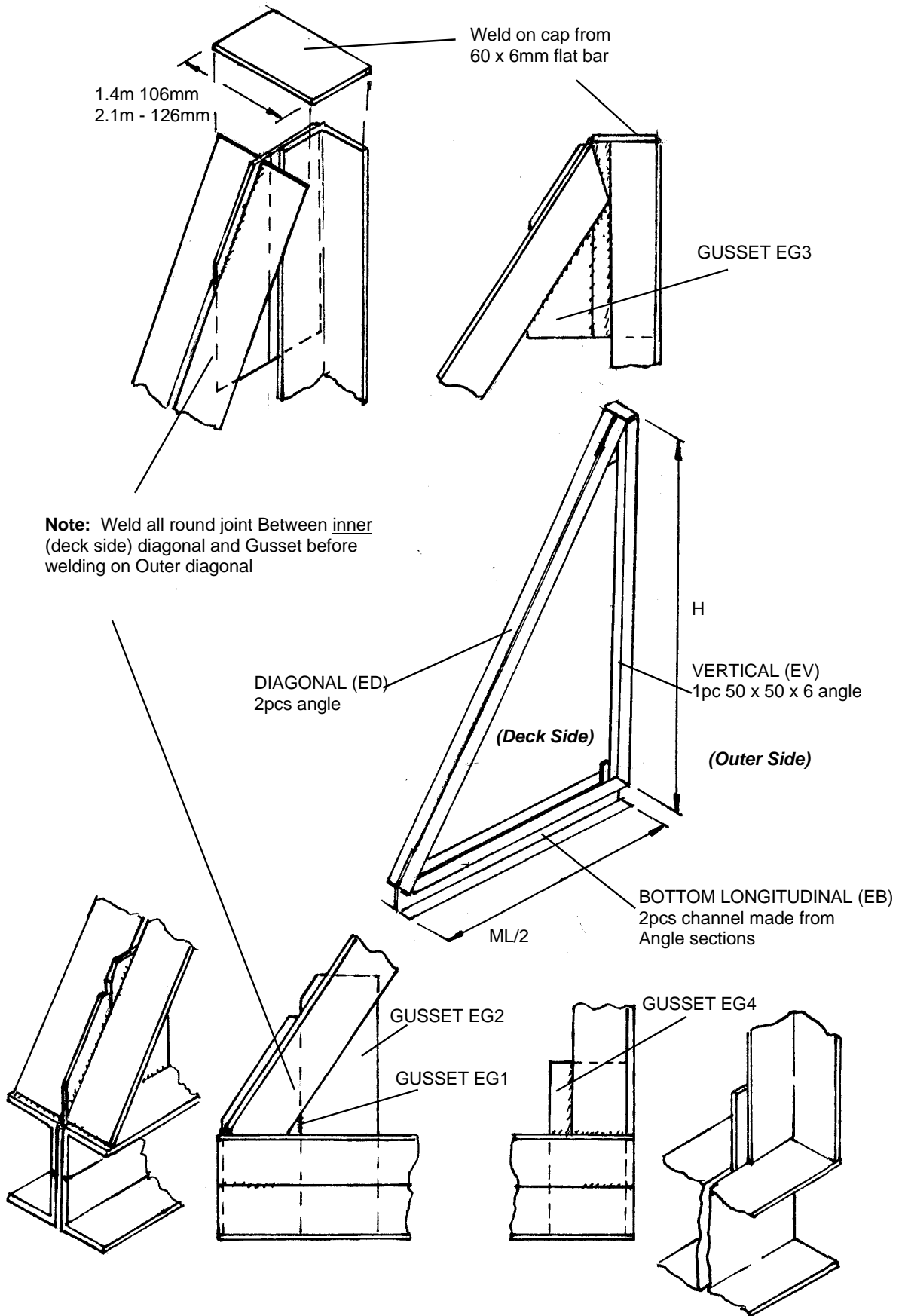


Figure 5.6: Details of Construction of End Panel (see Table 5.3 for materials)

### 5.2.4 Details of Base Panel

Figure 5.7 shows the design of the base panel.

Table 5.4 shows the list of materials for a Base Panel.

**Table 5. 4: Materials List for Base Panel (Single panel)**

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (BL)	40x40x6mm angle	ML	4	50x50x6mm angle	ML	4
Stiffeners for longitudinal	30x3 flat bar	500mm	4	40x3 flat bar	500mm	4
Diagonals (BD)	50x50x6mm angle	Measure and fit (1)	4	60x60x6mm angle	Measure and fit	2
Cross members (BC)	60x60x6mm angle	1486mm	2	60x60x6mm angle	2186mm	2
Gusset BG1	60x6 flat bar	200mm	2	60x6 flat bar	200mm	2

**Note:** (1) Weld the outside of the panel, longitudinals and cross members, then measure and cut the diagonals to fit. The approximate lengths for material requirements are:

1.4m footbridge – 1.1m for ML = 1.7m to 1.3m for ML = 2.0m  
 2.1m footbridge – 1.3m for ML = 1.7m to 1.5m for ML = 2.0m

Details for the construction of the base panels are given in Appendix B.

The module length, ML, is obtained from Table 5.1 for the span of the footbridge. The section details and lengths are obtained from Table 5.4.

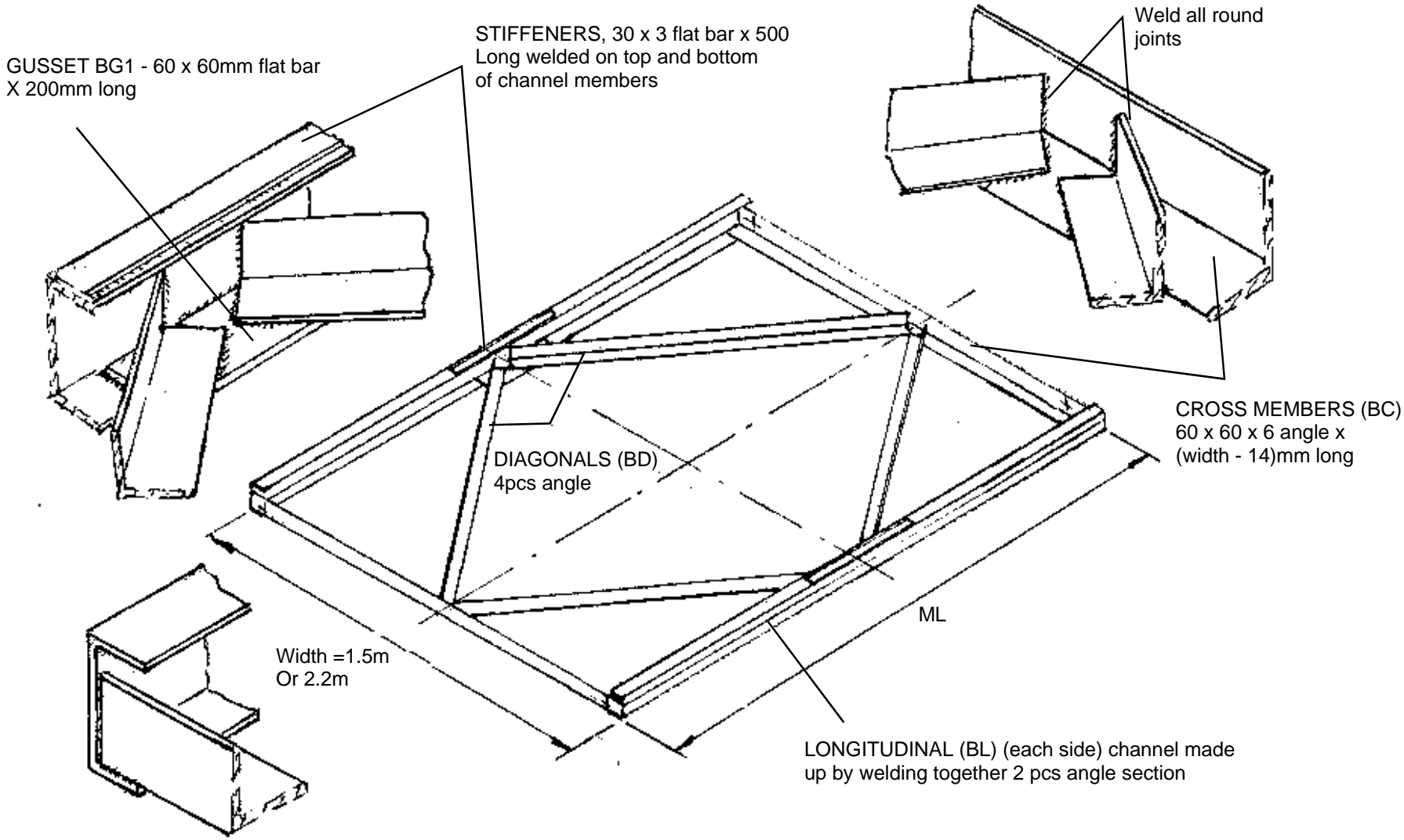


Figure 5.7: Details of Base Frame (see Table 5.4 for materials)

### 5.2.5 Details of Joining Bracket and Drilling Instructions

Figure 5.8 shows the details of the Joining Bracket and of drilling the holes for the bolts that bolt the panels and modules together.

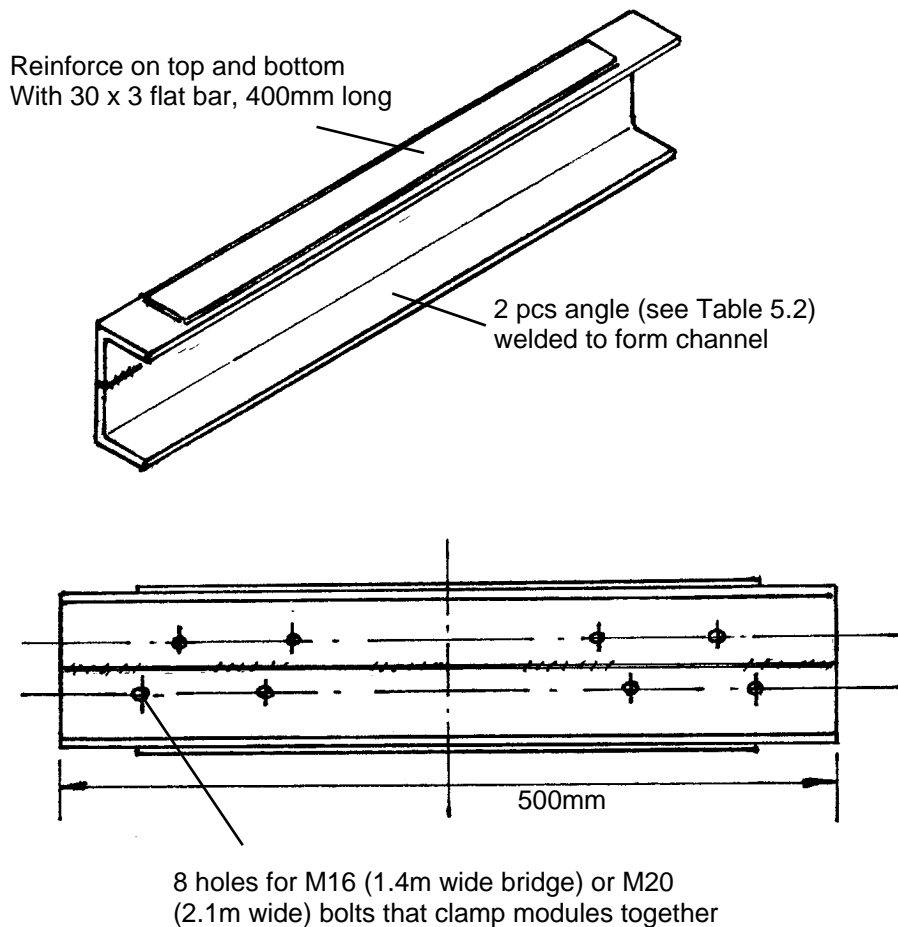
The number of joining brackets needed = the number of side panels + 1 on each side

i.e. if there are 8 side panels/side, number of joining brackets/ side =9 and total for footbridge = 2 x 9 = 18

Table 5.5 gives the materials list for the joining brackets

**Table 5. 5: Materials List for Joining Bracket**

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Joining bracket	40x40x6mm angle	500mm	2	50x50x6mm angle	500mm	4
Stiffeners for bracket	30x3 flat bar	400mm	2	40x3 flat bar	400mm	2
Joining bolts/joint	M16	50mm	8	M20	50mm	8



**Figure 5.8: Joining Bracket (JL or JR)**

### 5.2.6 Assembly and Welding of Panels

The footbridge modules are bolted together at 3 positions – bottom longitudinals of Side and End Panels; tops of Verticals; ends of cross-members of Base Panels.

To ensure that holes line up to bolt the modules together –

1. Parts must be clearly marked and kept in the same order as they were drilled
2. All the joints between adjacent modules must be bolted and lined up in an assembly jig before welding the members together. The panels must therefore be assembled and welded in sequence starting from the LH end.

Design of simple jigs for assembling 1.4m and 2.1m wide bridges are shown in Appendix B.

For ease of setting up and welding, the base panels should be completed first and then the 2 sets of side panels.

The assembly procedure is illustrated in Appendix B. The final assembly of an example of the modular steel truss footbridge is illustrated in Figure 5.9.

### 5.2.7 Assembly and Testing of Footbridge

Before transporting the footbridge to site it should be fully assembled in the workshop to make sure all panels bolt together without problems

When assembled the footbridge should be tested to its design load to check that it behaves satisfactorily and that its deflection is within the design limit (4mm/m span).

The preferred method of testing is by “crowd loading”, equivalent to 4 persons/m<sup>2</sup>. Therefore, for a 1.4m wide footbridge the loading should be 6 persons/m and for a 2.1m wide footbridge 8 person/m.

### 5.2.8 Bracing of Vertical Posts

Each pair of vertical posts where the modules are bolted together on both sides of the footbridge are braced against side loads applied to the posts or top verticals by users of the footbridge.

Details of the bracing is shown in Figure 5.10. The angle braces are bolted to each end of a channel section cross-beam formed by welding 2 pieces of angle together. The cross-beams are clamped under the bottom longitudinals after the footbridge has been assembled.

### 5.2.9 Fixing of Footbridge on Abutments

It is important that the footbridge is securely fixed on the abutments but at the same time steel expands and contracts with changes in temperature. This must be allowed for in the method of fixing or the bridge may buckle. A suggested arrangement is shown in Figure 5.11. In this, one end of the footbridge is bolted down to the abutment while the other is prevented from moving sideways but allowed to slide longitudinally.

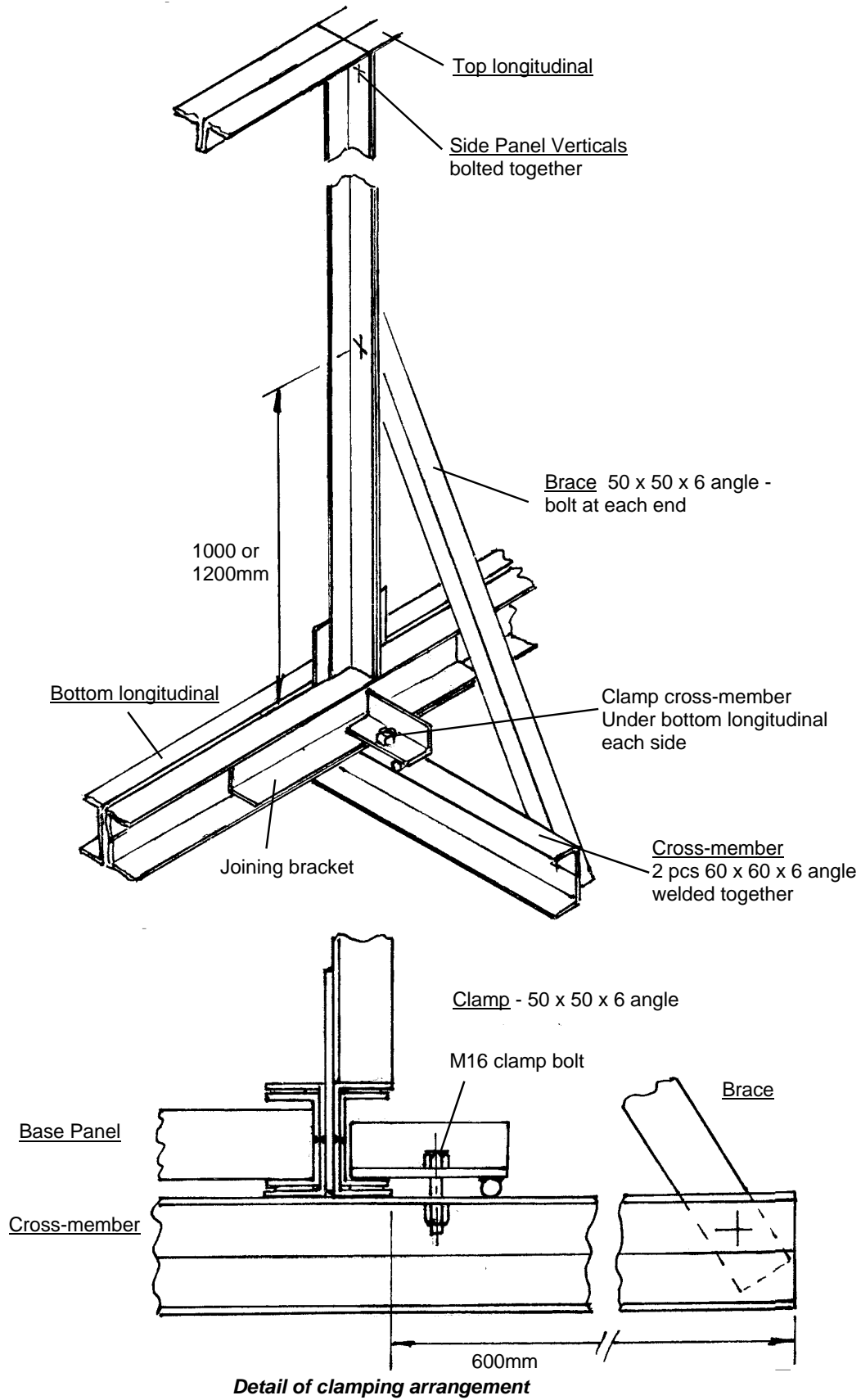


Details of construction and attachment of decking



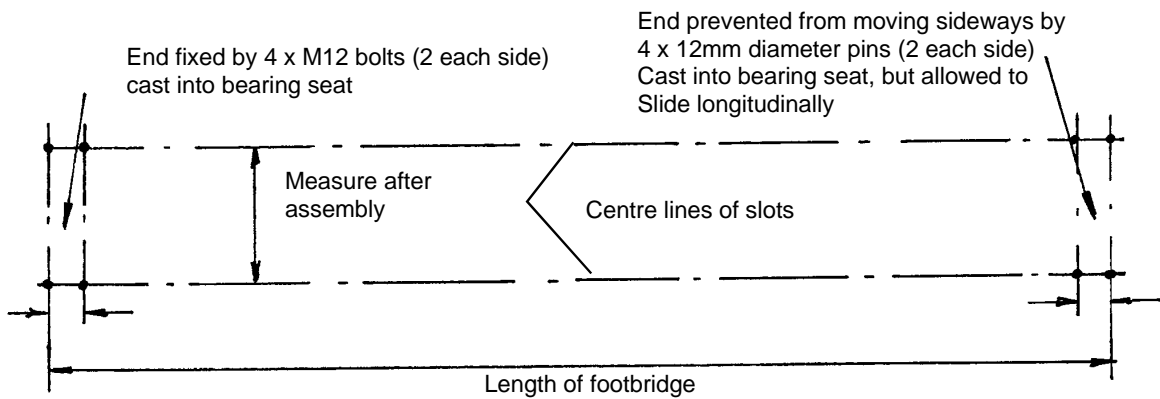
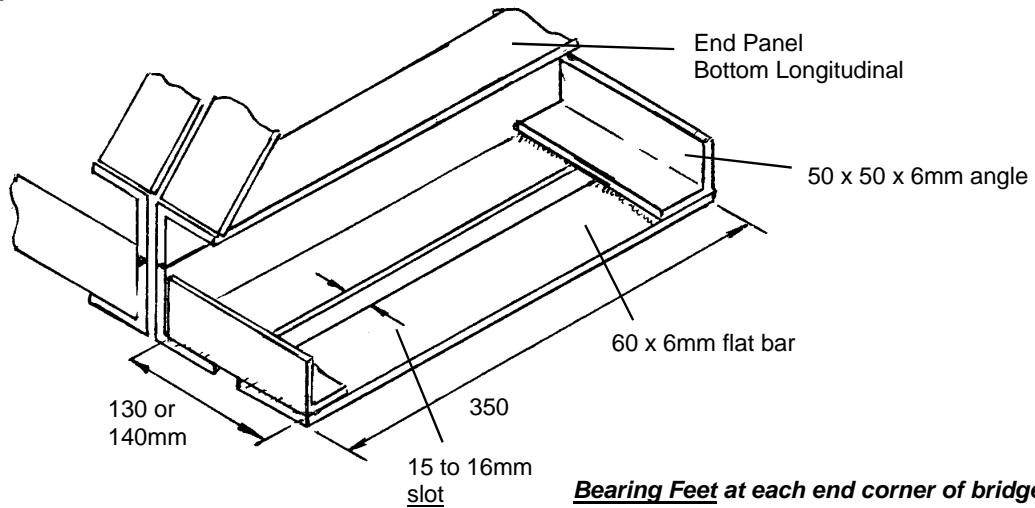
Details of frame  
(Note that braces for vertical are not yet fitted)

**Figure 5.9: Illustration of Modular Steel Truss Footbridge**

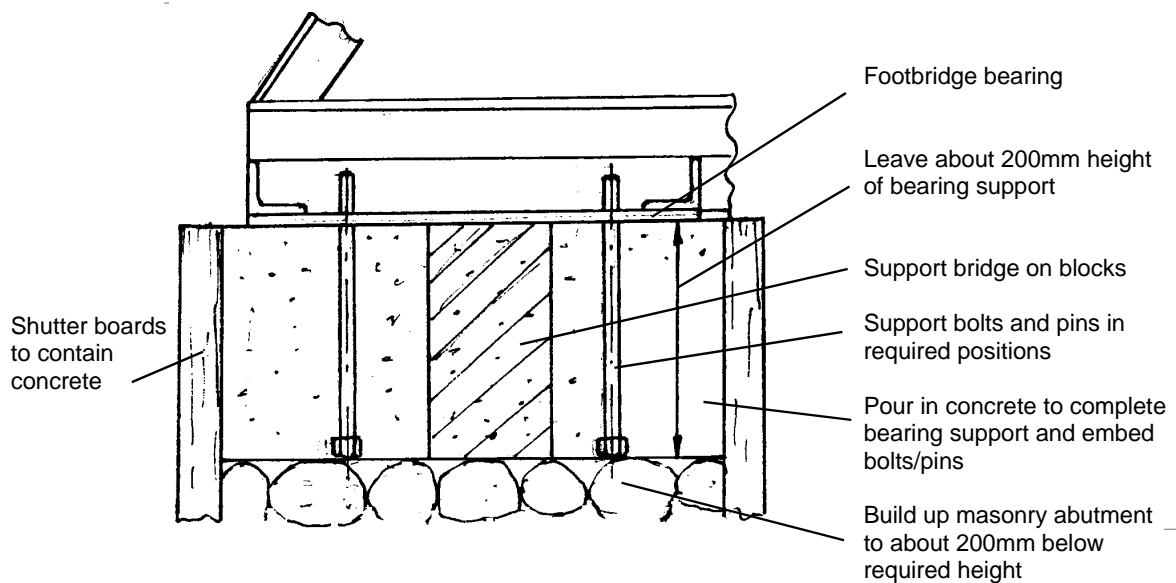


**Figure 5.10: Detail of Side-Way Bracing of Side Panels**  
(Brace all vertical posts each side of bridge)





Locating the fixing bolts and pins accurately in the abutments is a problem. A method of overcoming this is to cast in the bolts and pins after the bridge is installed in position as shown below



**Figure 5.11: Bearing Supports and Anchors for Footbridge**

### 5.2.10 Protective Treatment

The steel needs to be protected as effectively as possible against corrosion. The most effective method is galvanising all components but this treatment is unlikely to be available. The following treatment is therefore recommended before bolting together the panels:

1. On completion of welding the panels clean up all welds and weld splatter by grinding and wire brushing
2. Thoroughly wire brush all surfaces to remove scale and any rust
3. Paint all surfaces with a good quality, oil-based, anti-corrosion paint by spraying or brushing. This should comprise 3 coats – a primer/undercoat followed by 2 top-coats. Careful attention should be given to getting into all corners, inside drilled holes and sealing joints such as along the top longitudinals
4. A particular problem is to protect the inner surfaces between the channels of the bottom longitudinals of the end and side panels where there is only a 6mm gap. This can be achieved most successfully by spraying the paint. If this is not available a means of spreading the paint with an improvised brush having sufficiently long bristles or a suitable cloth or scraper blade that can be passed through the gap and pulled along the length of the gap should be used.

**Bolts** – ideally, plated bolts, nuts and washers should be used. If these are not available then the threaded and rounded section of the bolt should be coated with grease and the exposed head and nut painted after assembly

**After installation** all surfaces should be carefully inspected and any places where the paint has been damaged should be recoated.

### 5.2.11 Maintenance

The steelwork should be carefully inspected at intervals of about 1 year, paying particular attention to:

- Tightening of any bolts that have worked loose
- Repairing any areas of paintwork that have deteriorated
- Checking for any cracks around welded joints
- Cleaning out any soil or rubbish that has accumulated in corners, joints etc.

The footbridge should be completely repainted every 2 to 3 years.

## 5.3 DECKING

### 5.3.1 Design of Decking

Good quality hardwood planks should be used for the decking. It should be installed by competent local carpenters.

The cross planks are supported at each end on the bottom longitudinals of the end and side panels. Since the planks are not supported at the centre it is important to use planks that are strong enough to support the bridge user loads over the relatively long span between the longitudinals.

Because of the quite large sections of the cross planks it will probably be more economical to use these at spaced intervals to support smaller section longitudinal runners rather than to have a continuous deck of cross planks.

The recommended arrangement is shown in Figure 5.12. The required sections for the deck planks for the 1.4 and 2.1m wide footbridges are listed in Table 5.6 below.

**Table 5.6: Timber Plank Sizes for Decking**

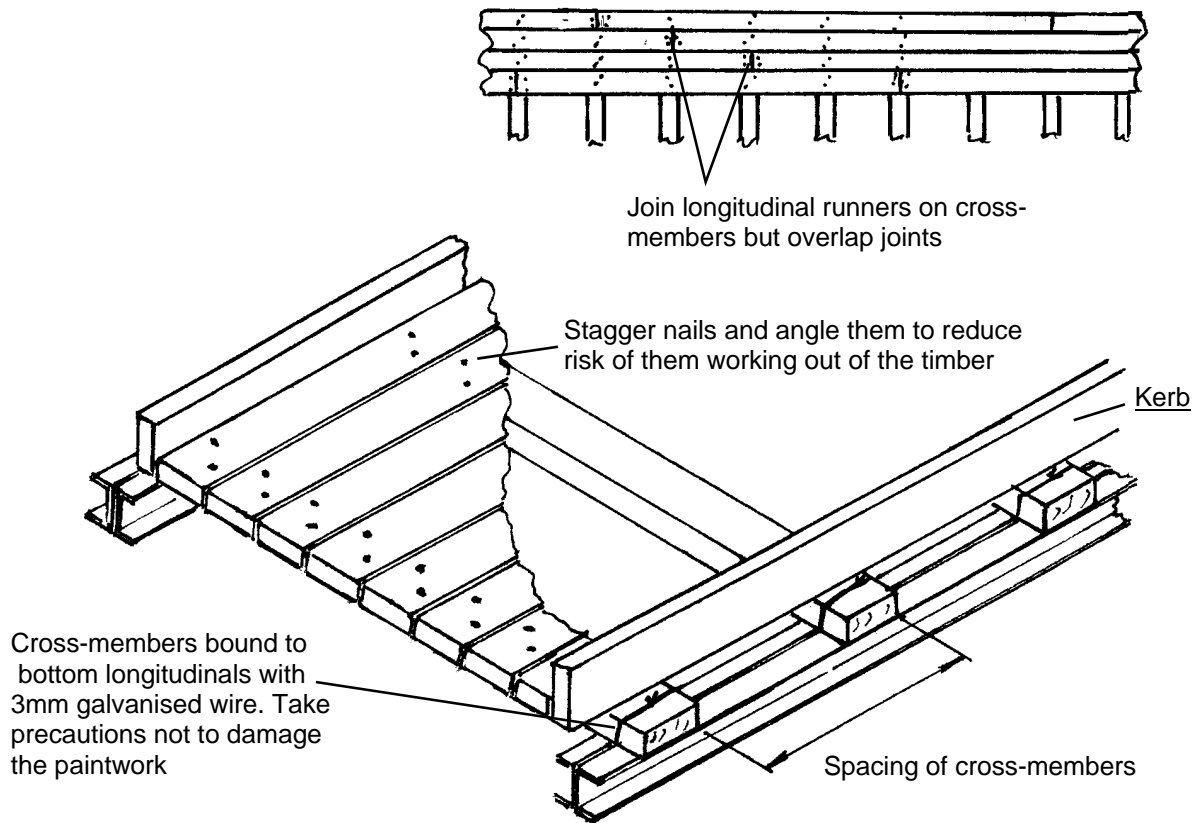
Longitudinal Runners		Cross Beams			Kerb
Section Width x Thickness	Number across deck	Spacing (1)	Section Width x Thickness	Length	Section Width x Thickness
<b>1.4m Wide Footbridge</b>					
150x50mm	8 with gaps of about 11mm	600mm	150x75mm or 200x75mm	1.6m	150x50mm
<b>2.1m Wide Footbridge</b>					
150x50mm	12 with gaps of about 15mm	400mm	200x100mm or 150x125mm	2.3m	150x50mm
OR 150x75mm	12 with gaps of about 15mm	750mm	200x100mm or 150x125mm	2.3m	150x50mm

**Note:** (1) The spacing between cross-beams depends on the support needed for the longitudinal runners. Therefore increasing the section and strength of the longitudinal runners increases the spacing that can be allowed between the cross-beams.

### 5.3.2 Protective Treatment of Timber Decking

Protective treatment of the timber planks is likely to be limited to simple hand brushing methods. These are unlikely to achieve significant penetration into hardwood surfaces but may provide some protection. The methods suggested are:

1. Soaking the planks in a bath of engine sump oil or brushing on sump oil; or (2) Brushing on creosote.



**Figure 5.12: Details of Fixing Timber Decking**

2. The end grains are the most vulnerable surface and could be protected with a coating of bitumen, such as bitumen paint.

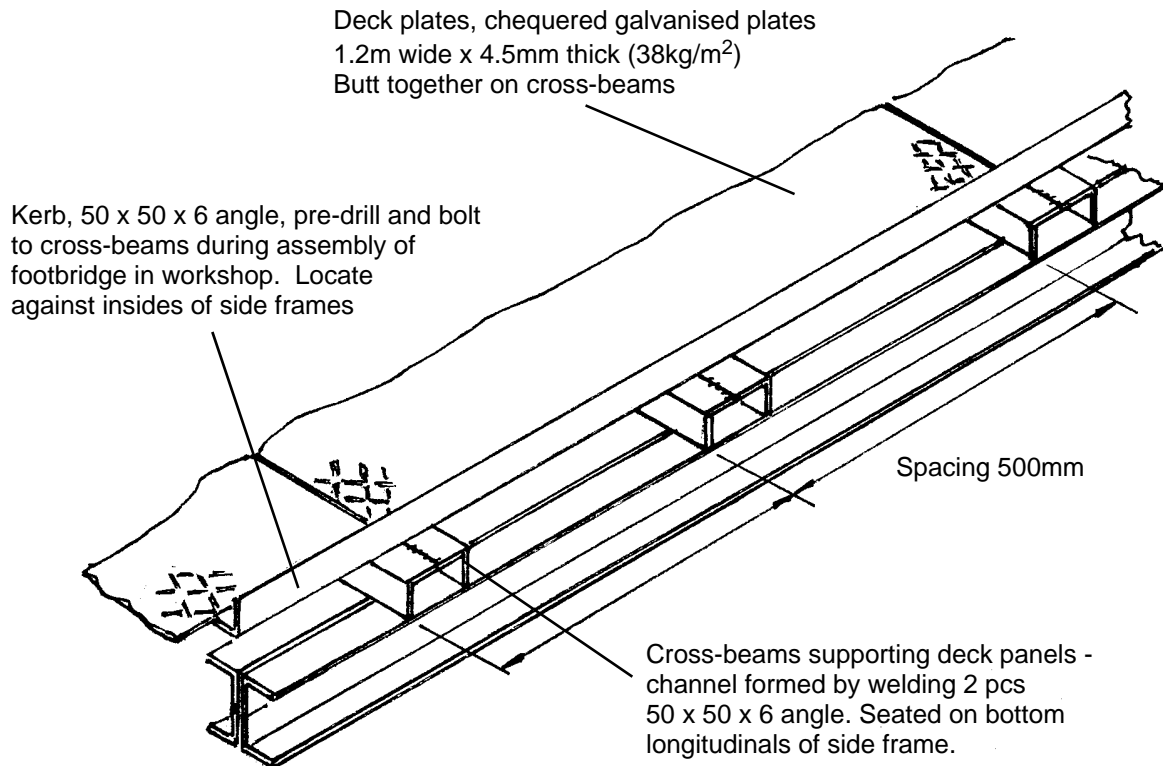
### 5.3.3 Maintenance of Decking

The decking should be inspected every year. Loose nails should be hammered in and any planks that are significantly deteriorated or worn should be replaced. Exposed timber surfaces should be recoated at 12 month intervals.

### 5.3.4 Alternative Option Using Steel Plate

The timber deck will decay (rot) and need to be replaced several times during the life of the steel truss structure. It may therefore be worth considering a longer life alternative for the deck.

An alternative option is to use galvanised steel floor plates supported on steel cross-beams. A layout of this arrangement is shown in Figure 5.13.



**Figure 5.13: Alternative Option for Deck Using Galvanised Steel Floor Plates**

Based on the material costs only and the assumed unit prices shown the estimated comparative costs of the timber and steel decks for a 1.4m wide footbridge are as follows:

Timber @ \$400/m<sup>3</sup> – (\$3/m for 150 x 50 section) – cost/m = \$42

Steel @ \$0.60/kg (\$2.70/m for 50 x 50 x 6 angle) – cost/m = \$54.5

In each case the estimated weight of the deck is 80 to 85kg/m. The initial cost of the materials for the steel deck is seen to be about 25% higher than for the timber deck. But since it will probably last at least 3 times as long it has a much lower “Total Life” cost. Even if the unit price of timber is only half that shown the steel deck still has a slightly lower “Total Life” cost.



## 6 REINFORCED CONCRETE FOOTBRIDGES

### 6.1 INTRODUCTION

This type of bridge comprises basically a concrete slab reinforced with steel bars. Since concrete has a very low tensile strength, the primary steel bars are located near the bottom of the slab to carry all the tensile bending stresses. The concrete is assumed to carry all the compressive bending stresses.

The main advantages of reinforced concrete footbridges (RCC) are:

- All the materials needed – cement, sand, stone aggregate and steel bar – will be locally available in most locations
- For footbridges, the concrete can serve as the deck surface so that timber or other forms of decking are not needed
- The bridges have a long life and require little maintenance. Therefore, although their initial cost may be higher than other types, their “total life” cost will probably be lower

The main problems of local level construction of RCC footbridges are:

- The concrete slab has to be cast “in-situ” which requires considerable preparation work in setting up the formwork into which the concrete is poured. The dead weight of the concrete slab is high so that strong supports are needed for the formwork. Therefore, apart from quite short spans, props will be needed from the riverbed to support the formwork at intervals of 1 to 2 m so that RCC footbridges are only possible where the riverbed is suitable for this
- Setting up the steel reinforcement in the shutter boxes (boxes into which the concrete is poured) and the mixing and pouring of the concrete requires workers with appropriate skills and experience. These will probably have to be brought in from outside, increasing construction costs. It is possible that the formwork can be constructed by local carpenters under the supervision of an experienced technician.

The maximum unsupported span of RCC footbridges is about 12m. For longer spans intermediate pier supports will be needed. Therefore RCC footbridges can only be used for crossings of greater than about 10-12m width when the riverbed allows the construction of support piers. This will be mainly in areas of flat to moderate rolling terrain.

Within the limitations outlined above, RCC footbridges should be considered alongside other possible types. The main selection considerations are likely to be initial cost and whether the skilled and experienced labour needed is available. If neither of these factors rule out the use of RCC footbridges then they should be strongly considered because of their long life and low maintenance.

### 6.2 DESIGN OF REINFORCED CONCRETE FOOTBRIDGE

#### 6.2.1 Plain Slab design

Figure 6.1 shows the layout of a RCC footbridge. The simplest design is a plain slab deck as shown in the figure. Other options such as a ‘T’ section (see Figure 6.5) or box section

will reduce weight and material costs but require more complex formwork and are therefore more difficult and costly to construct. For footbridges, the savings in weight and material costs are not likely to be great and therefore the simple plain slab type is recommended.

The section details for a range of spans from 4 to 10m are shown in [Figure 6.2](#). The primary reinforcement is the bottom axial reinforcement A and this increases with span as does the depth of the slab. Other reinforcement maintains the integrity of the slab but does not carry the bending load on the footbridge. The material properties assumed are at the bottom of the possible range so that the designs are quite conservative. Estimated quantities of materials for the various spans are shown in Table 6.1.

**Table 6.1: Estimated Quantities of Materials for RCC Footbridge**

Span m	Depth of Slab mm	Volume of concrete m <sup>3</sup>	Bags of cement (50kg)	Length of reinforcing bar (m)		
				20 (1) or 25 (2)mm	12 mm	10mm
<b>1.4m wide footbridge</b>						
4	180	1.6	10	45 (1)	60	95
6	240	2.9	18	100 (1)	90	140
8	320	5.0	30	120 (2)	115	190
10	400	7.6	46	200 (2)	145	240
<b>2.1m wide footbridge</b>						
4	180	2.2	14	65 (1)	75	120
6	240	4.1	25	150 (1)	110	175
8	320	7.1	43	175 (2)	145	235
10	400	10.9	66	295 (2)	180	300

Details of the bearing supports for the RCC footbridge are shown in [Figure 6.3](#). If the span of the footbridge is greater than about 10m intermediate pier supports will be needed. Concrete or masonry abutments and piers should be used to give a life compatible with that of the footbridge. Concrete bearing caps are cast onto the top of the abutments and piers. The attachment is reinforced with steel dowels cast into the masonry and concrete. At ONE END ONLY of the footbridge deck these dowels extend into the deck slab to locate the footbridge on the bearing supports. At the other end the deck slab should be free to move.

Details of an arrangement for attaching safety handrails are shown in [Figure 6.4](#). The posts are attached by bolting to anchor brackets cast into the sides of the concrete deck. The method allows the prefabrication of parts in a workshop and assembly on site. It is important to use a method of attaching the rails that does not require the accurate location of posts. In the figure timber rails that can be drilled on site are bolted to the posts. An alternative arrangement is to clamp lengths of the 50x50x6mm angle section to the posts using U-bolts fitted through predrilled holes in the posts.

### **Steps in Construction**

1. Locate and mark out positions of abutments (and of piers if these are needed) as indicated in Appendix A
2. Excavate footings and construct abutments and piers (if needed) to designs shown in Figures 7.4 and 7.8 respectively. The steel dowels should be cast into the tops of the abutments and piers as shown in Figure 6.3



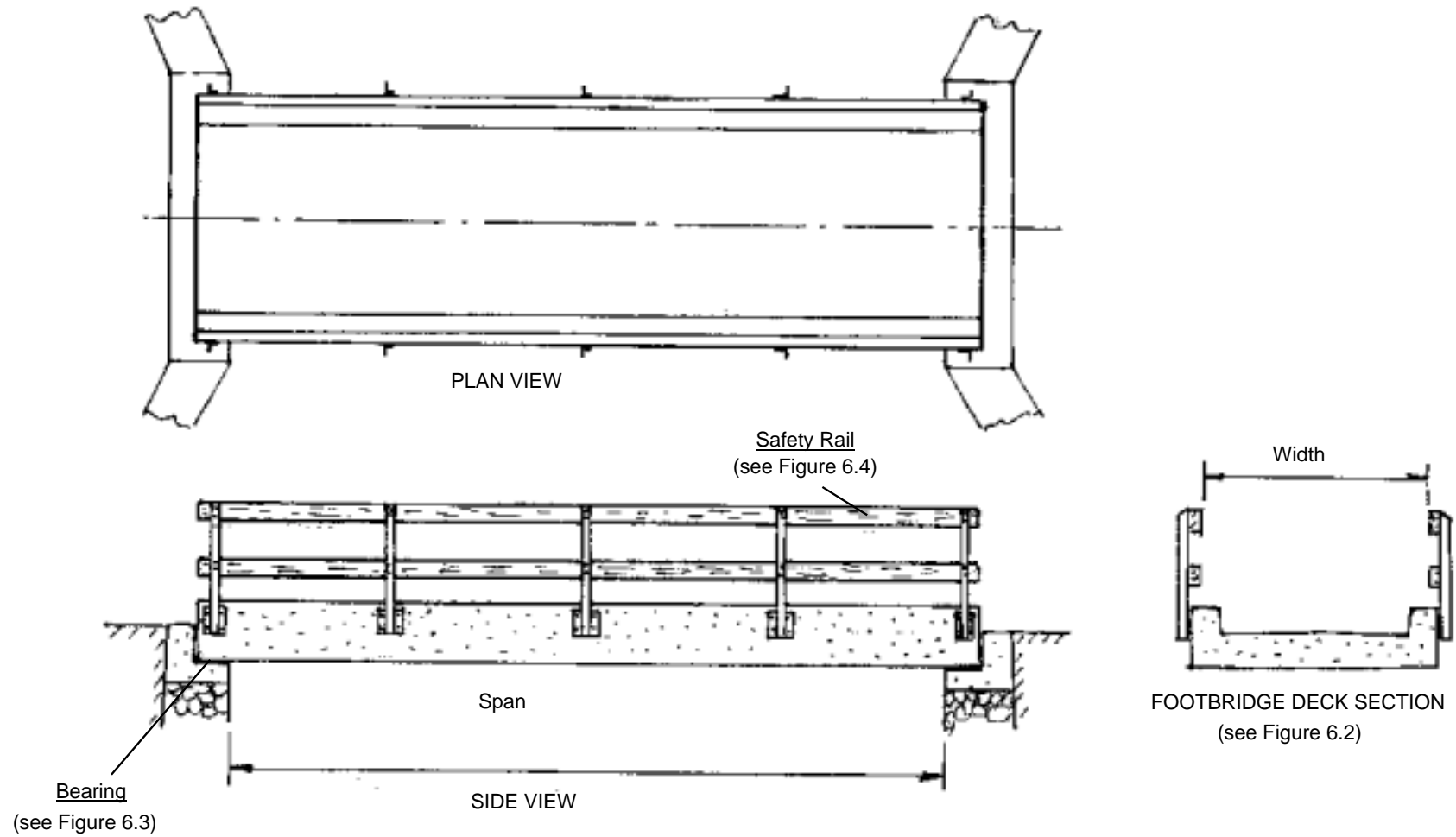
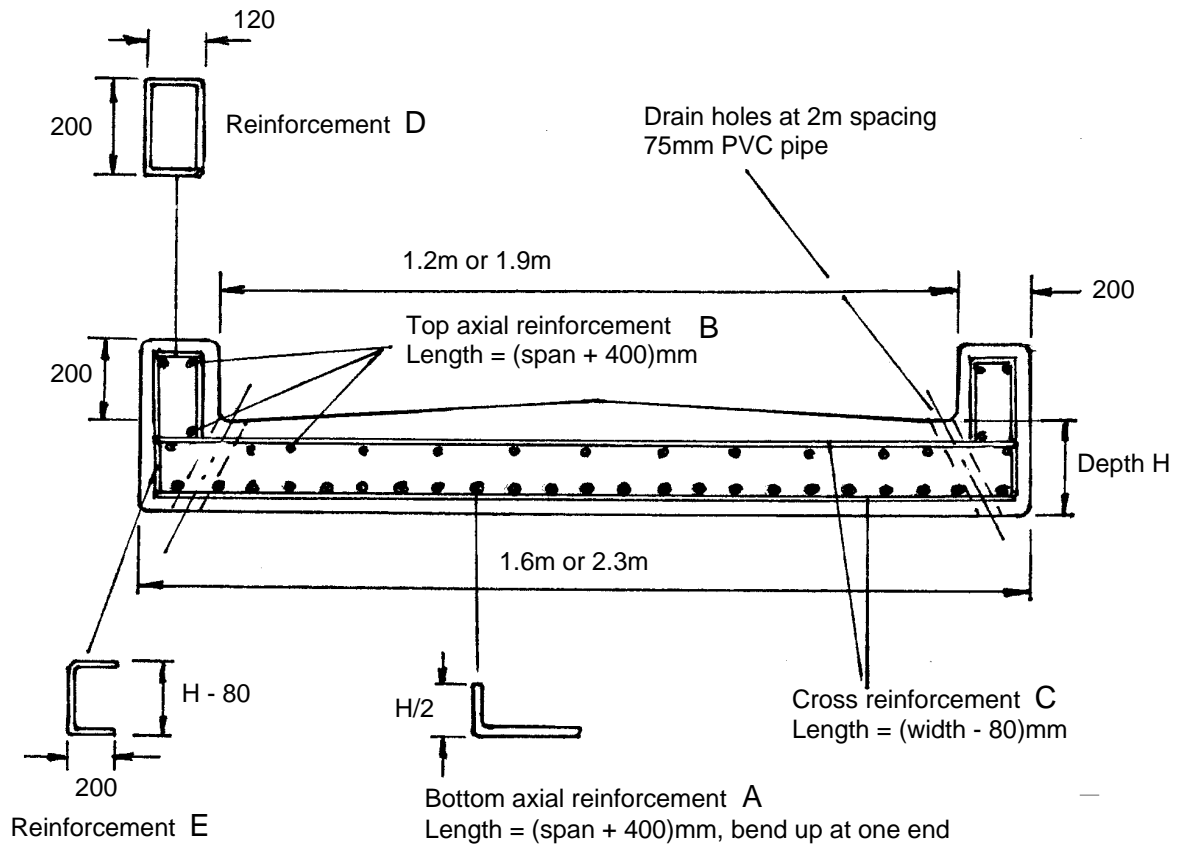


Figure 6.1: Layout of Reinforced Concrete Footbridge

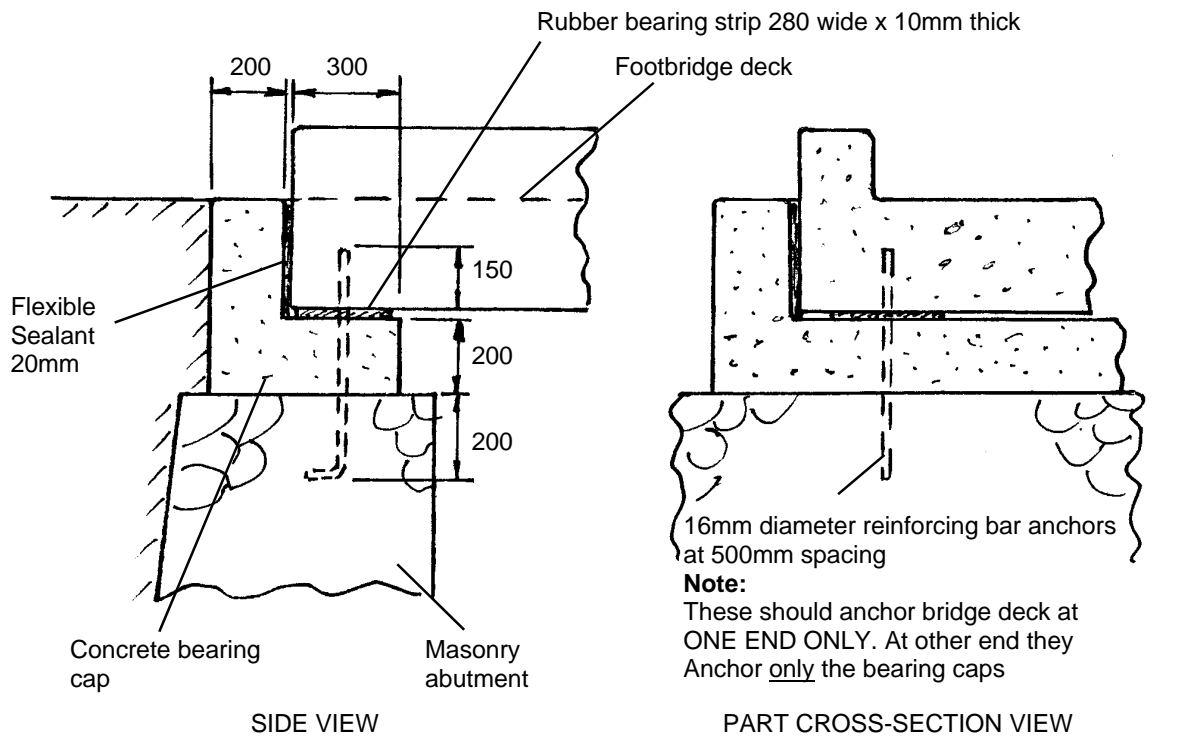


Span M	Depth Hmm	Details of Steel Reinforcement – Size @ Spacing (mm)				
		A	B	C	D	E
4	180	20 @ 160	12 @ 200	10 @ 250	10 @ 250	10 @ 250
6	240	20 @ 100	12 @ 200	10 @ 250	10 @ 250	10 @ 250
8	320	25 @ 110	12 @ 200	10 @ 250	10 @ 250	10 @ 250
10	400	25 @ 80	12 @ 200	10 @ 250	10 @ 250	10 @ 250

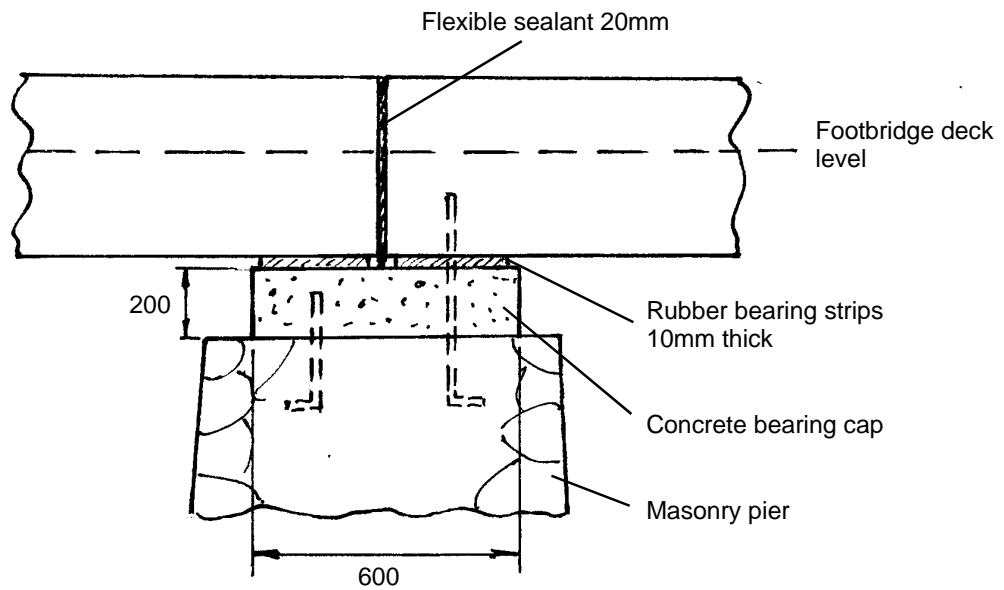
**Specifications:**

- Concrete mix 1:2:4 with maximum aggregate size of 20mm – assumed minimum strength 17N/mm<sup>2</sup>
- Reinforcing steel – mild steel bar with minimum yield strength 210N/mm<sup>2</sup>
- Single lengths of reinforcing bar but if 2 lengths needed the minimum overlap should be 50 x diameter
- Minimum thickness of cover of reinforcement is 40mm

**Figure 6.2: Sections of Plain Slab Reinforced Concrete Footbridges**

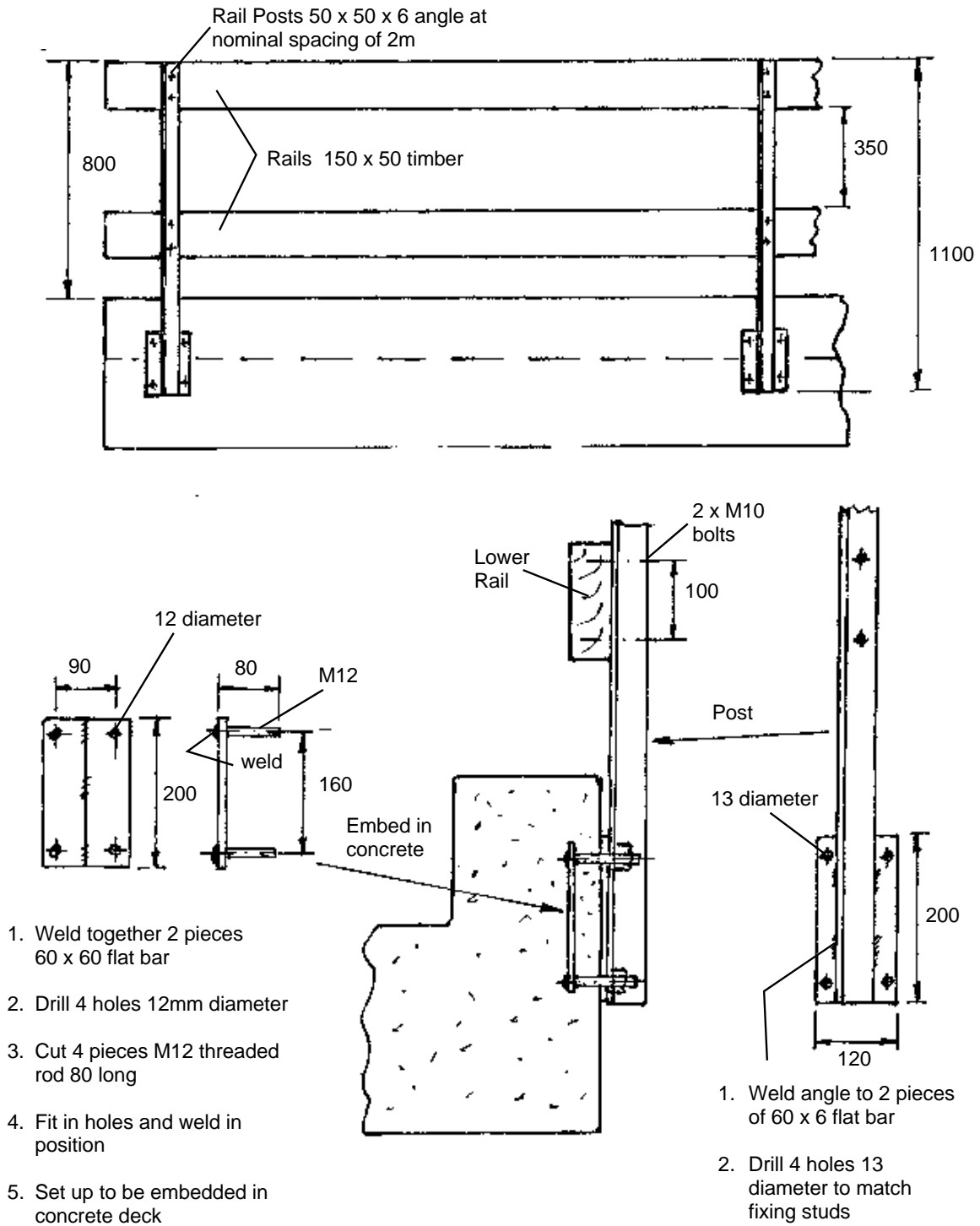


(a) Abutment Bearing



(b) Pier Bearing

Figure 6.3: Details of Bearing Supports for RCC Footbridge

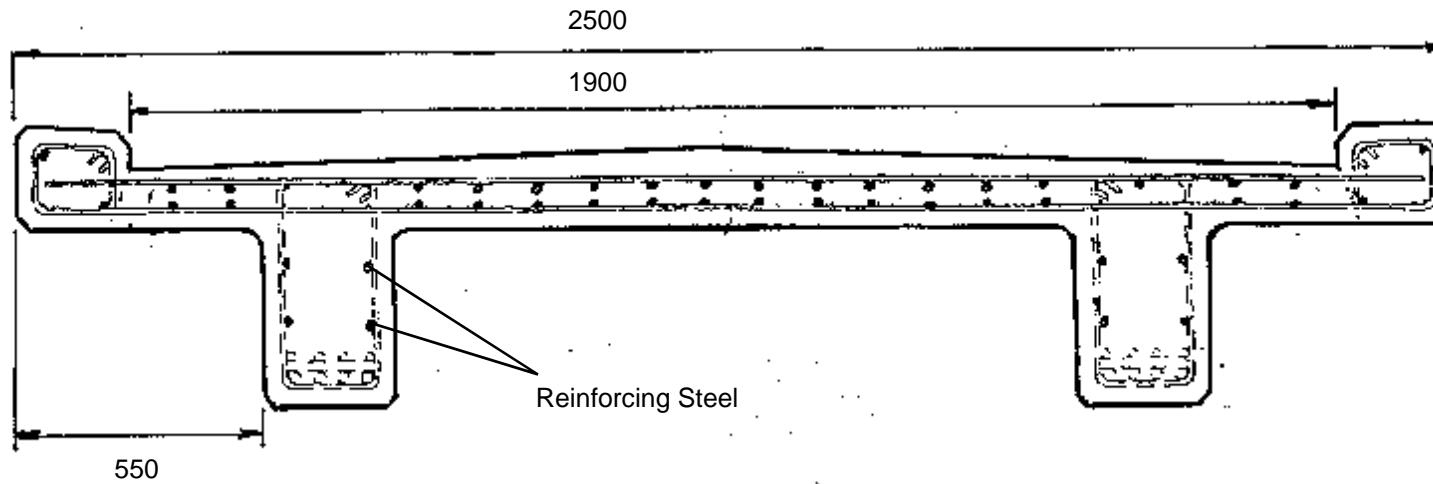


**Figure 6.4: Attachment of Safety Rail to Deck of RCC Footbridge**

3. Use blockboard and/or timber planks to construct the shutter boxes for the concrete bearing caps as shown in Figure 6.3. Timber poles may be used to prop the boxes in position
4. Mix and shovel concrete into the shutter boxes. Tamp it in to ensure it is densely packed with no air holes. Leave for 7 days, keeping damp with wet bags, and then remove shuttering
5. Construct the shutter box for the deck slab using lengths of timber. The box members should be securely supported and all joints should be free from gaps that might allow escape of the concrete. The box should be supported between its ends by T-shaped timber pole or post props located at 1 to 2m intervals. The inside faces of the box should be coated with oil to prevent sticking of the concrete
6. Cut and shape the reinforcing steel bars as shown in Figure 6.2. Use spacer blocks made from mortar to fix the reinforcing bar in position. Make sure there is a minimum gap of 40mm between the steel bars and the sides of the box to give the specified concrete cover of the steel. Spacer bars cut from the bar may be used to accurately locate the upper and lower layers of reinforcement. Where pieces of bar cross or join the joints should be securely bound with galvanised wire. Also locate the anchor brackets for the handrail posts in position. The steel bar should be cleaned to remove oil, dirt and flaking rust that could reduce the bond strength with the concrete
7. Mix the concrete to the specification shown in Figure 6.2, using a container to measure out the proportions accurately rather than shovels. Sand and stones should be clean and free from organic materials. Mixing should be on a clean, firm surface, not earth, to avoid contamination of the concrete. Note it is important to use the correct proportion of water to cement of 0.55 to 1 to achieve the required strength. If too much water is used the aggregate will sink and reduce the strength of the concrete
8. Mixing and transport of the concrete should be well organised to enable the whole slab to be cast in one continuous operation. Walkways should provide access to all parts of the slab. The concrete should be tamped to produce a dense structure and levelled with shovels and lengths of timber
9. When the slab is completed it should be kept damp for 7 to 14 days with wet bags to allow proper curing of the concrete to produce the required strength. The slab should not be walked on for at least 5 days
10. Once the slab has cured the formwork can be removed. The prefabricated rail posts can then be bolted in position and the rails attached.

### 6.2.2 Beam Section Design

In this design the primary bending strength is provided by reinforced concrete beams that are integral with a deck slab of reduced thickness compared to a plain slab. A typical section is shown in Figure 6.5 taken from standard designs used by the Ministry of Works in Malawi. Because of the deep beams this is a more efficient section, saving in weight and cost of concrete. The estimated saving of a standard 8m long slab compared with a plain slab design is about 15%. However, the formwork for the beam section design is more complex to construct and set up.

**Notes:**

1. All dimensions in mm
2. Drawing NOT TO SCALE
3. Design should only be adapted by qualified engineer

**Figure 6.5: Typical Section for a Reinforced Concrete 'T' Beam Footbridge**

## 7. INSTALLATION OF FOOTBRIDGES

### 7.1 INTRODUCTION

This Chapter deals with the installation of footbridges. It covers the following:

- 7.2 Construction of abutments for supporting the ends of the footbridge, including bearing arrangements
- 7.3 Construction of piers for providing intermediate support to the footbridge
- 7.4 Procedures for erecting the footbridge
- 7.5 Notes on the organisation of the work

## 7.2 ABUTMENTS

The location of abutments is covered in Appendix A. Factors to be considered in the design and construction of the abutments include:

- The soil characteristics and allowable bearing pressure to determine the minimum contact area or footing area of the abutment on the soil
- The stability of the soil – Appendix A defined a maximum slope of the bank at the location of the abutments of 60° for stable rock down to 35° or less for soft soil and gravel. In the latter case piles may be needed and anchors to stabilise the abutment
- The flood level in relation to the abutments and whether protective measures are needed to counter erosion of the bank around the abutments
- The bearing area of the abutment where the footbridge is supported, especially for timber footbridges
- The arrangements for fixing the footbridge in position so that it is not easily washed away.

### 7.2.1 Selection of Type of Abutment

The long-term sustainability of any bridge is largely dependent on the strength and stability of its abutments. The proper selection, design and construction of abutments are therefore critical to the life of the bridge.

The forms of construction include:

1. Existing rocks: if suitably large and stable rocks are available on the banks of the stream/river they can be used as abutments. Masonry or concrete can be used to build up an even bearing seat for the footbridge.
2. Timber: either timber logs or sawn timber beams may be used depending on availability. Logs will be cheaper. The bearing sill may rest on the ground or may be raised by supporting it on posts sunk into the ground.
3. Masonry: if suitably large stones are locally available they can be bound together with mortar to produce a relatively low-cost and long-life abutment.
4. Mass concrete: this is plain concrete without steel reinforcement. A larger section and therefore more concrete is needed than for reinforced concrete.
5. Reinforced concrete: this involves a more complex construction and the need for experienced workers

#### **Selection:**

Existing rocks: provide a low-cost, long-term solution but with limited situations where it is possible.

Selection from the other types will depend mainly on the type of footbridge, the availability and cost of materials and soil conditions. Selection considerations are outlined in Table 7.1



**Table 7.1: Selection of Type of Abutment**

<b>Footbridge Type</b>	<b>Considerations in Selecting Abutment</b>	<b>Preferred Type of Abutment</b>
1. <b>Steel and RCC</b>	<ul style="list-style-type: none"> <li>Replacing an abutment is very difficult. Its life should therefore be at least equal to that of the footbridge structure. <u>Timber</u> abutments are therefore not considered appropriate. If suitable stones are available, <u>Masonry</u> is preferred to <u>Concrete</u> for lower cost.</li> </ul>	<ol style="list-style-type: none"> <li>Masonry</li> <li>Mass Concrete</li> <li>Reinforced Concrete</li> </ol>
2. <b>Timber</b>	<ul style="list-style-type: none"> <li>Timber will probably require installation of posts in the ground. This may not be practical on rocky or stoney ground.</li> <li>Masonry and concrete will require excavation of footings requiring significant labour inputs.</li> <li>Masonry and concrete may initially be more costly but will probably be cheaper in the long-term. It will probably be possible to use the same abutments when the footbridge has to be replaced.</li> </ul>	<ol style="list-style-type: none"> <li>Masonry</li> <li>Depends on soil conditions and local availability and cost of materials.</li> </ol>

### 7.2.2 Building an Abutment on Existing Rocks

It will probably be necessary to build on top of the rock to raise the level of the bearing surface and/or provide a level bearing seat. This may be done with masonry and/or concrete depending on how much the seat has to be raised.

It is important to achieve a good key between the added material and the existing rock. The surface of the rock should be roughened up with a hammer and chisel or sledgehammer and possibly holes made to insert pieces of reinforcing bar to be embedded in the concrete/masonry cap. This is illustrated in Figure 7.1.

### 7.2.3 Timber Sill Abutments

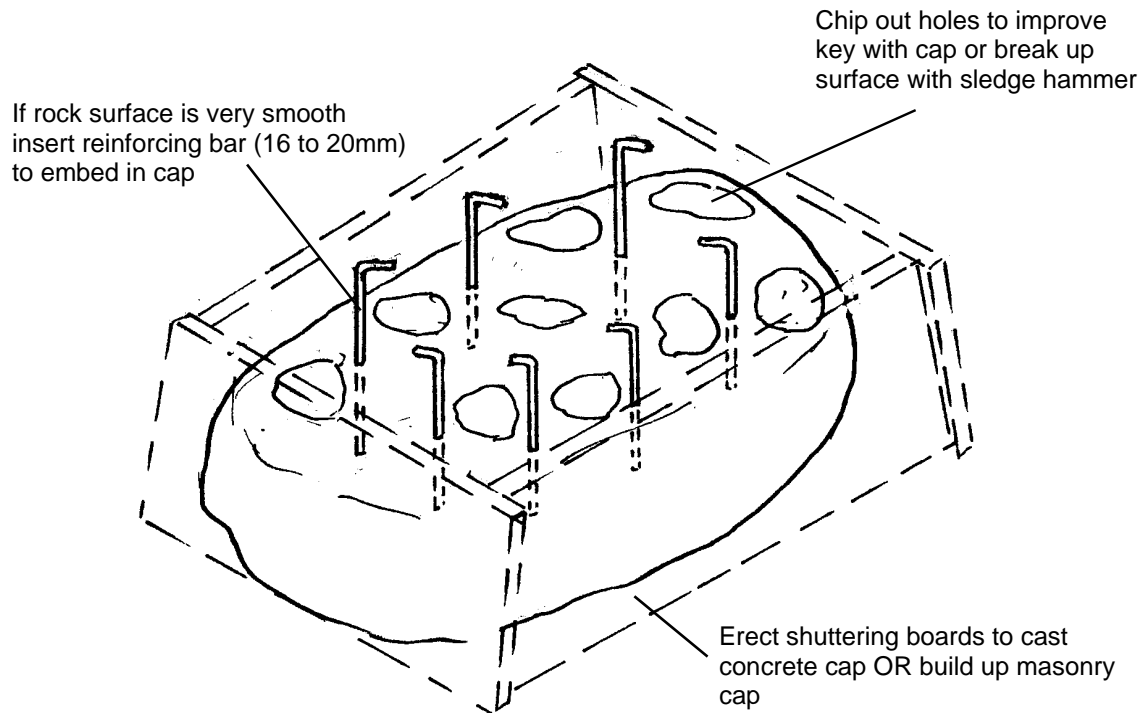
If the height of the abutment and bank soil conditions are suitable, the simplest form of abutment is a timber log or beam sill resting directly on the ground. It may be necessary to excavate the ground to provide a flat, well-drained seat for the sill.

The construction of timber sill abutments is shown in Figure 7.2. The sill may be a log or sawn timber beam. It is important to make sure there is enough bearing area between the stringers and sill to support the load on the footbridge. This is not a problem for sawn timber beams if the correct sizes are used but grooves need to be cut in the top surface of log sills to give adequate contact area with the stringers. A guide on the area needed is given in Figure 7.2.

Sawn timber stringers may also be supported on log sills. In this case flats will need to be cut into the top of the sill to provide adequate bearing area.

The sill must be securely fixed in position on the bank and the stringers secured to the sill. In Figure 7.2 this is achieved by driving posts into the bank around the sill and binding the sill to the posts with galvanised wire. The stringers in turn are bound to the sill.

Timber sills will have limited durability, but a number of steps can be taken to prolong their life:

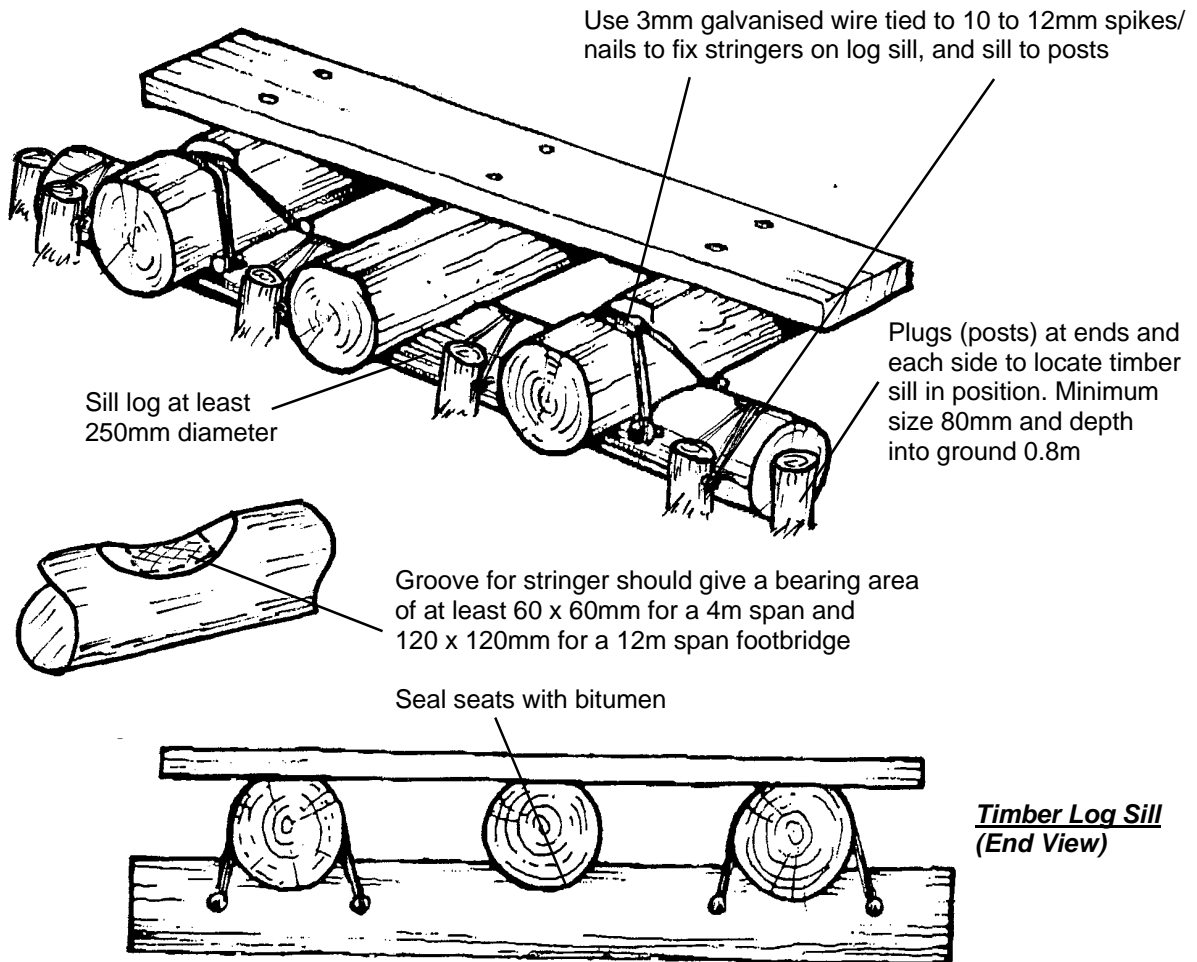
**Note:**

A number of adjacent rocks could be used. Rocks should be stable and firmly embedded in the ground.

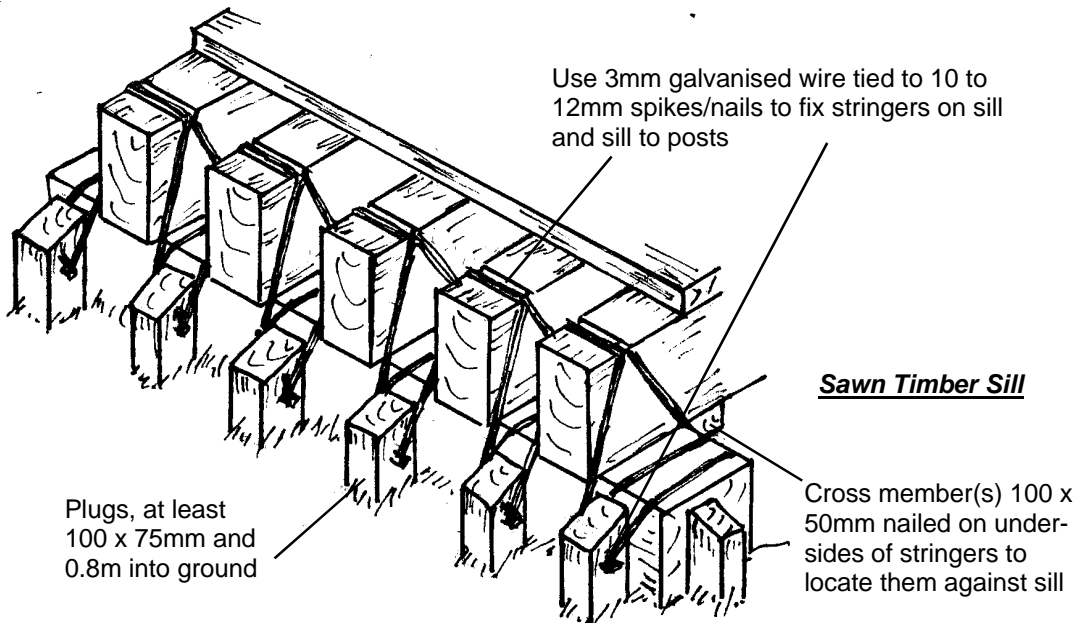
**Figure 7.1: Constructing an Abutment on Existing Rock(s)**

- Use good quality hardwood
- Seat the sills on a bed of stones or rocks to drain away water and prevent contact with moist soil. A layer of geotextile material could be used if available.
- Seal the bearing area between stringer and sill with bitumen to exclude water
- Seal the ends of the sill and tops of the posts with bitumen and coat other surfaces with creosote or engine sump oil.

The ends of the deck stringers resting on the sills should be separated from contact with soil by a barrier of sheet steel, timber or a masonry wall as shown in Figures 4.10 to 4.12.



**Note:** It is best to seat the sills on a bed of stones to prevent contact with moist soil and reduce risk of sill rotting



**Figure 7.2: Timber Sill Abutments**

### 7.2.4 Raised Timber Abutments

Often the level of the sill will need to be raised to match the level of the footbridge deck to the level of the path or track leading to and from the bridge, or to provide adequate clearance of the deck above flood waters.

Figure 7.3 shows two possible options for relatively flat banks where the sills have only to be raised a limited amount.

Option (i) is suitable where the soil is stable and reasonably firm. A flat base needs to be excavated. The stringers rest on a timber crib that is filled with stones/rocks and rubble to stabilise the abutment. Stability is further increased by sinking anchor posts at the four corners and binding the stringers to these with galvanised wire.

Option (ii) is suitable where the soil is less stable and the bank steeper. The sill log is supported on each side by piles sunk into the ground. The abutment is further stabilised by linking it to anchor posts sunk into the ground higher up the bank.

In both options the area up the bank from the abutment will probably need to be backfilled to build it up to the level of the path/track. This will need to be protected against flood-water, especially if the abutment is more than about 0.8m high. Large rocks and gabions (baskets filled with stones) may be used. Grass and plants with deep roots should be planted on exposed areas of soil.

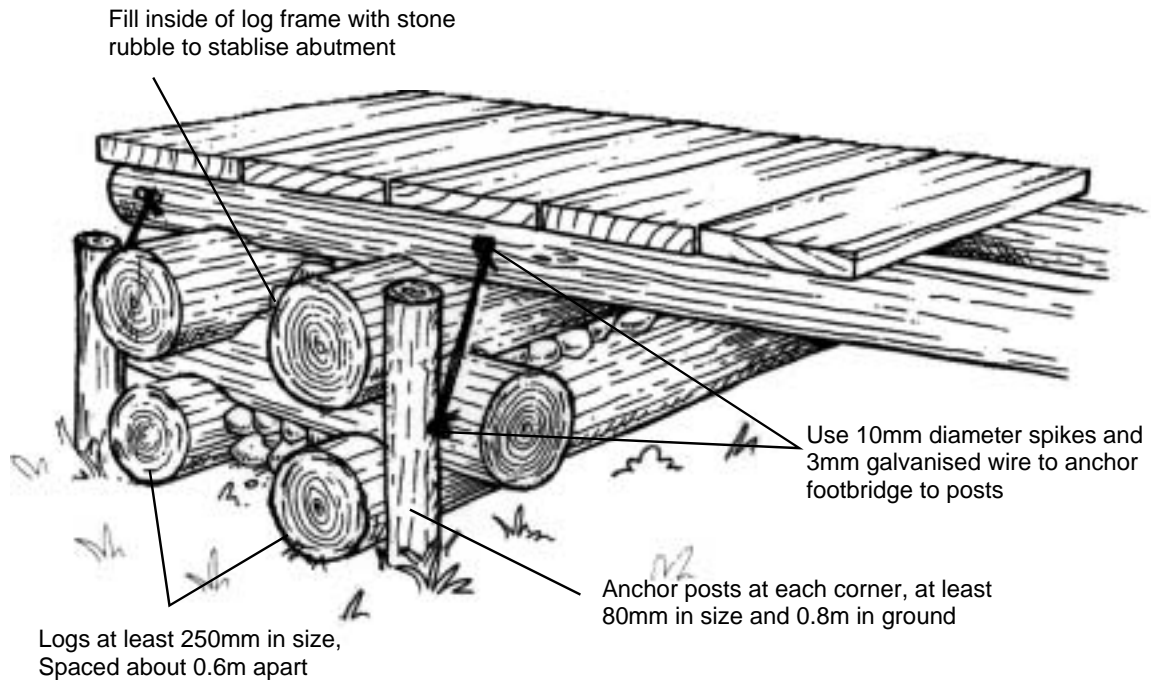
Wing-walls may be used for protection of back-fill for taller abutments.

Figure 7.4 shows examples of taller timber abutments with timber wing-walls for use on steeper banks. As well as protecting the back-fill, abutments and banks against erosion the wing-walls help the smooth flow of flood waters around the abutments. They can also be used to stabilise the abutment by linking it to anchor posts higher up the bank where the soil may be more stable. They are normally aligned at about 45° to the abutment.

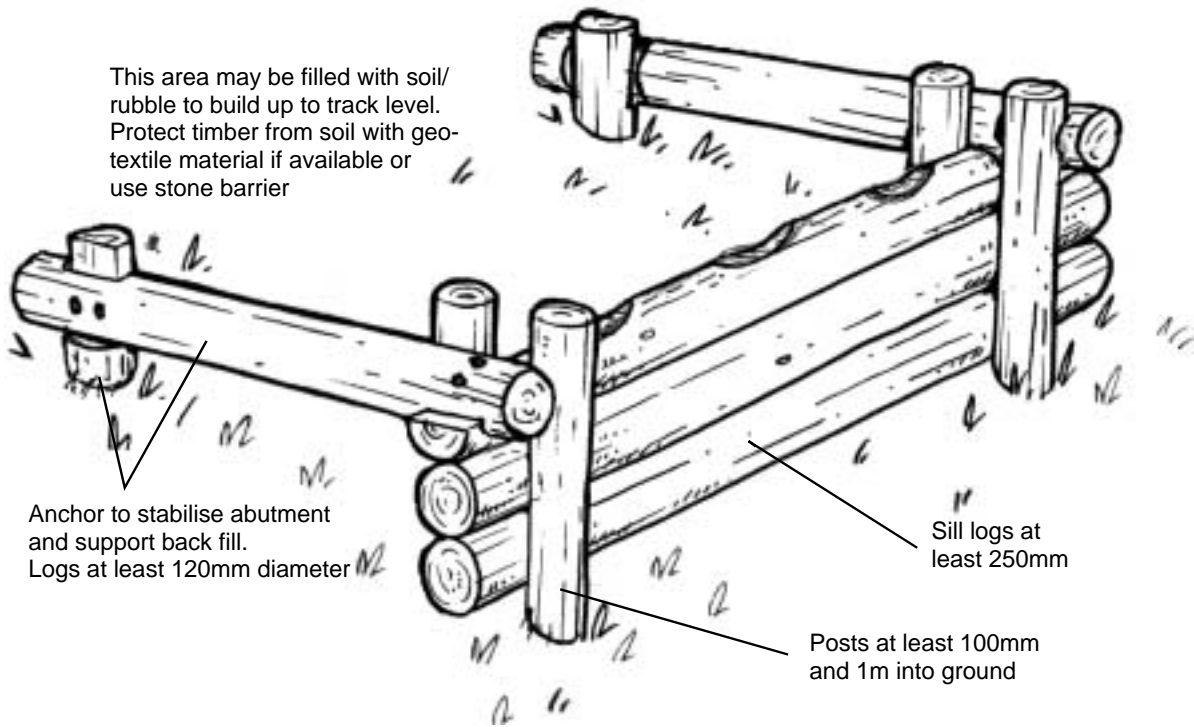
The back faces of abutments and wing-walls should be separated from back-fill with a barrier of stones to drain water away from the timber and protect it from moist soil that may cause rotting.. The other protective measures listed in Section 7.2.3 should also be used.

An example of a timber log bridge with log abutments and wing walls is shown in Figure 4.8 (Chapter 4).

**Note:** The maximum height recommended for the designs shown in Figure 7.4 is about 2m. Above this the design should be checked by a qualified engineer.

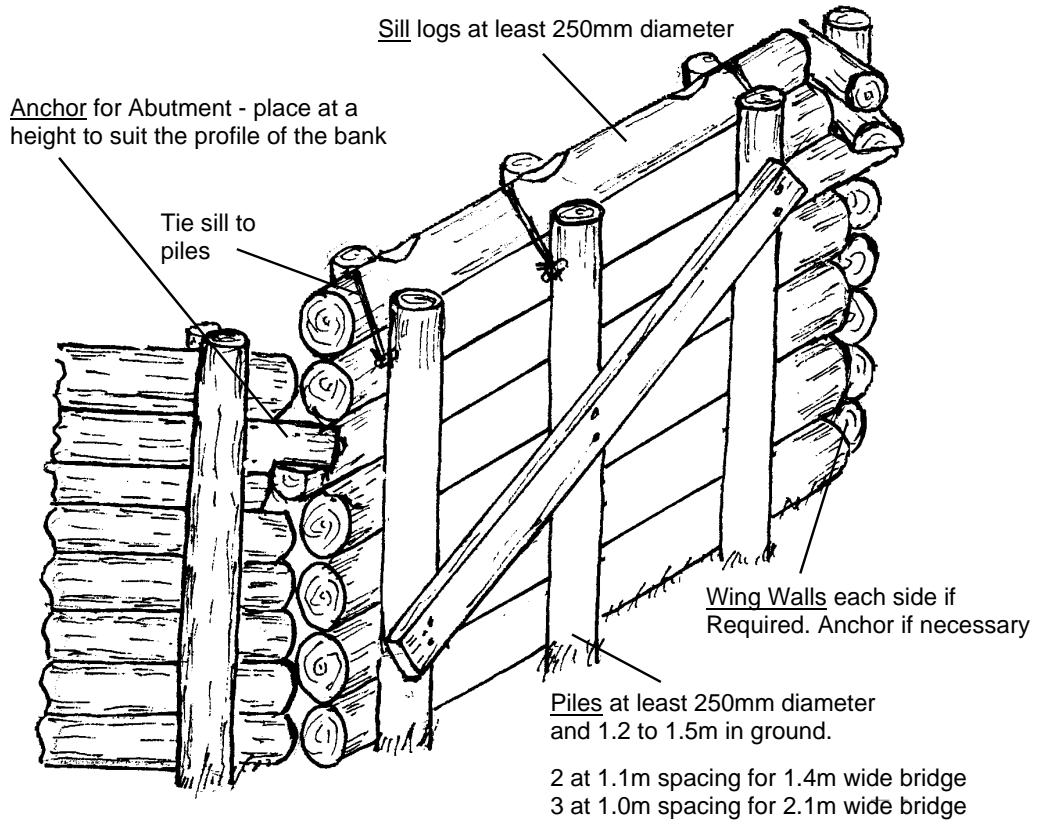


**(i) Log Crib Abutment - suitable for fairly flat stable bank. If necessary excavate base for crib. Seat logs on a stone bed**

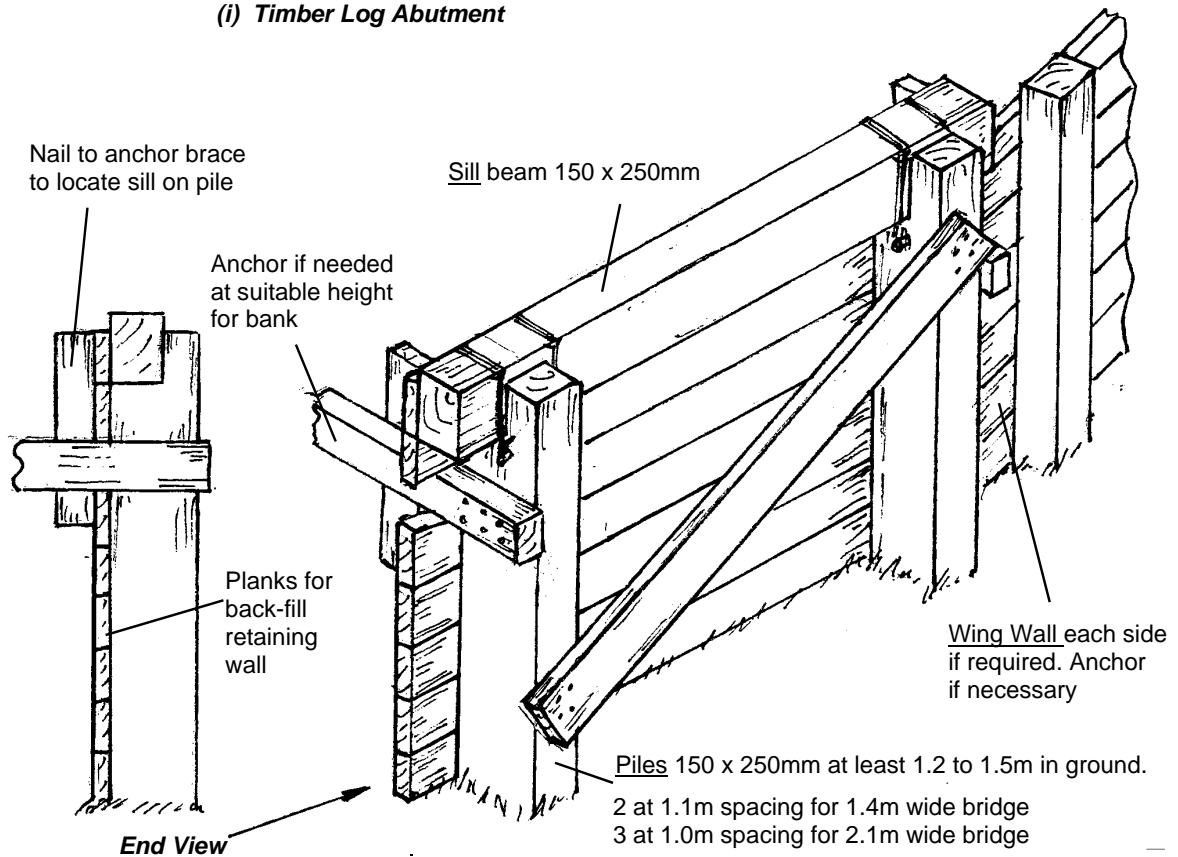


**(ii) Log Abutment - suitable for medium slope bank**

**Figure 7.3: Log Sill Abutments for Low to Medium Slope Banks**



(i) Timber Log Abutment



(ii) Sawn-Timber Abutment

Figure 7.4: Timber Abutments for Steep Banks or where Footbridge Deck has to be Substantially Raised

### 7.2.5 Concrete and Masonry Abutments

These will be considerably more durable and longer lasting than timber abutments but will also be more costly. They require the excavation of footings and the construction of formwork to produce the shape of the abutment. They will therefore need workers, including masons and carpenters, with some experience in this type of work.

Figure 7.5 shows an example of a mass concrete or masonry abutment with an integral wing-wall. If suitable stones are readily available the masonry construction will be cheaper than a concrete construction. The maximum height recommended for local construction of this type of abutment is about 3m (i.e. about 2.2m above ground). For stability, the base dimensions increase with the height.

The area of the footing must be compatible with the bearing strength of the soil where the abutment is to be located. A guide to the allowable bearing pressures for different soils is given in Table 7.1.

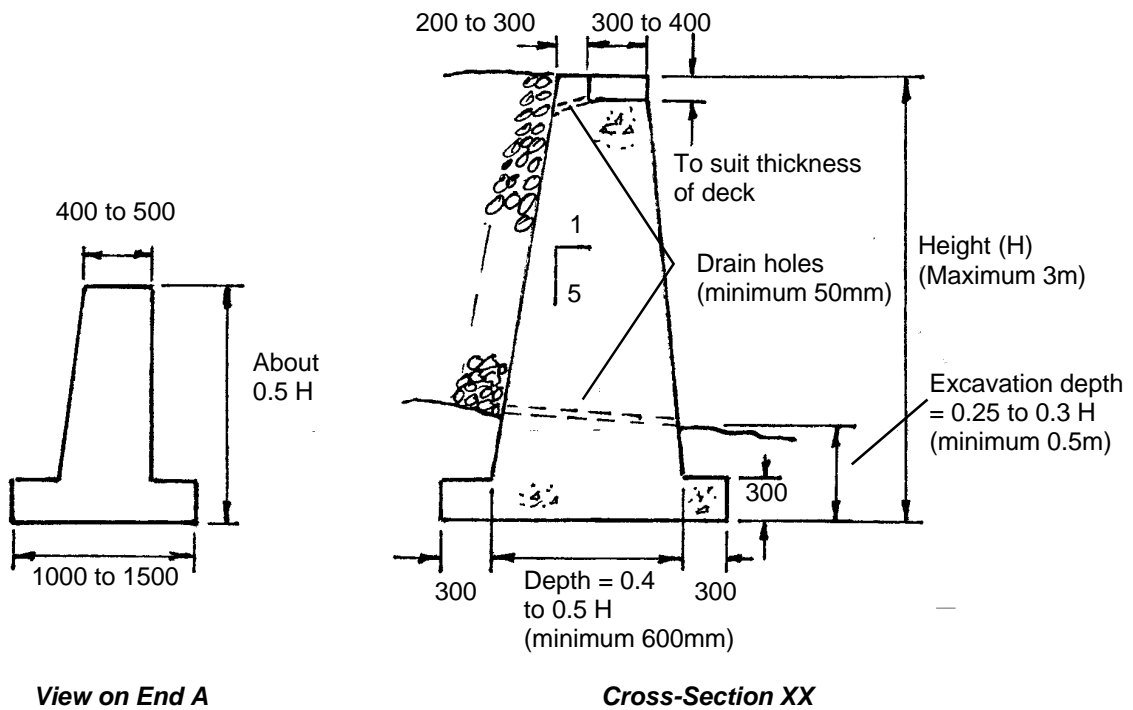
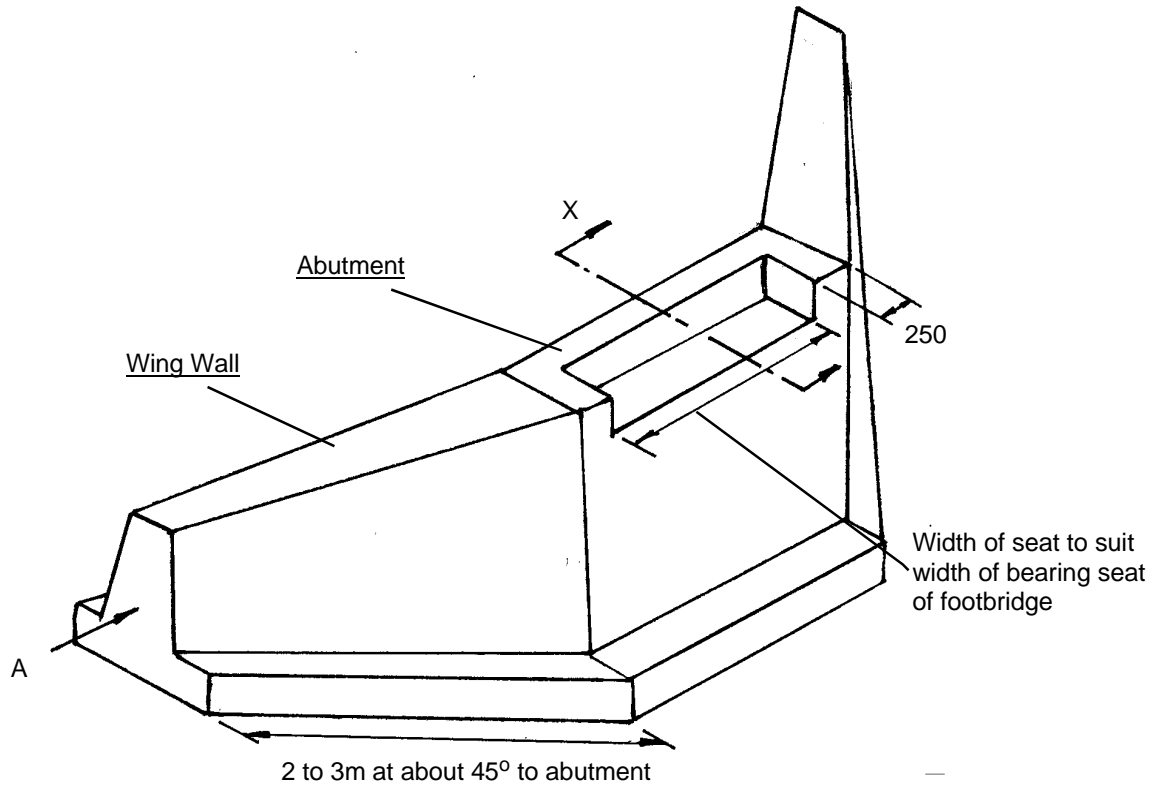
**Table 7.1: Allowable Bearing Pressures for Various Soil Types**

Nature of Soil	Allowable Bearing Pressure in KN/m <sup>2</sup>
Rock	4,000
Dense sands and gravels	400
Medium dense sands and gravels	200
Loose sand and gravel	75
Firm clayey soil	100
Soft clayey soil	35

The maximum design load on the bearings for a 10m span x 1.4m wide footbridge is about 50KN/bearing. The minimum footing area for the abutment design in Figure 7.5 is about 2.4m<sup>2</sup>. The footing area is therefore adequate for all soil types. However, it is advisable to avoid soft clayey soils where possible.

#### ***Construction of a Masonry Abutment***

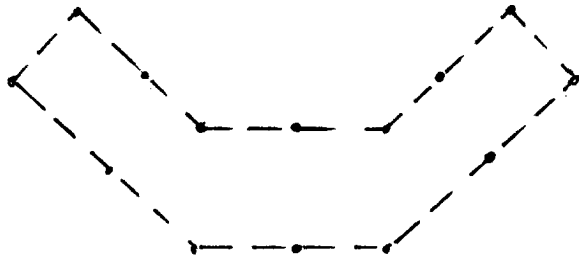
If suitable stones are locally available it is considered that a masonry abutment provides the best compromise between cost, long life and ease of construction. The steps in the construction of a masonry abutment are shown in Figure 7.6.



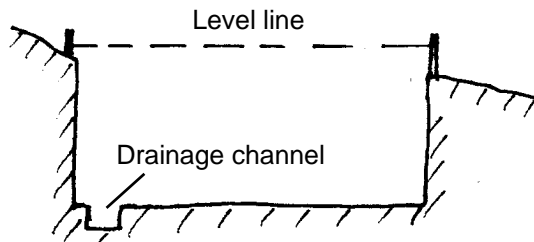
**Materials:** Mass concrete base 1 : 2 : 6 cement : sand : aggregate  
 Masonry - well packed stones in 1 : 4 cement : sand mortar

**Figure 7.5: Mass Concrete or Masonry Abutment**

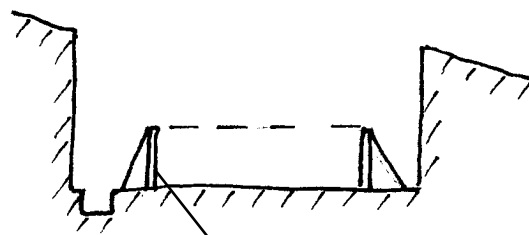




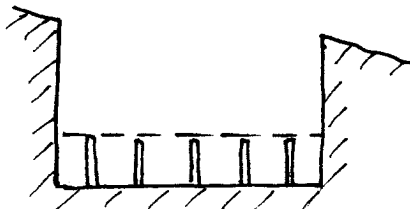
Mark the area to be excavated with pegs



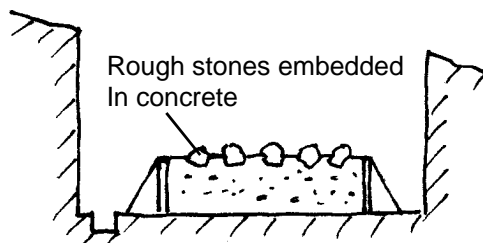
**Section through excavation**



Timber shutters

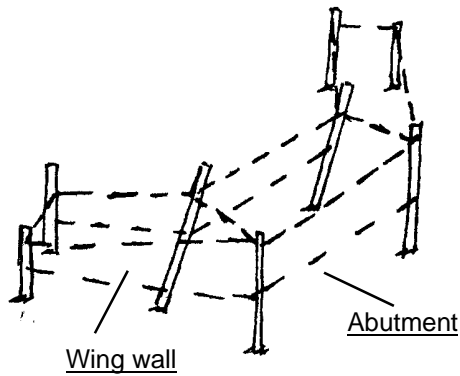


Dry foundation - pegs show depth of concrete

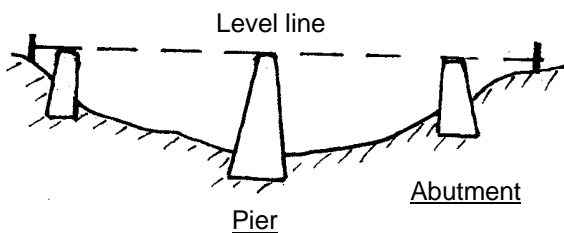


1. The site survey will have located the positions of the abutments and their height. Use Figure 7.5 for the design and dimensions of the abutments. Use pegs to mark out the footings for excavation.
2. From the condition of the soil (Appendix A) and the design of the abutments, determine the depth of excavation needed. Set up a reference level to check the depth and excavate to a level base. If the foundation has seeping water provide a drainage channel. A pump may be needed if there is excessive build-up of water.
3. Set up timber shutters (boards) for the shape of the concrete footing. If the footing is to be cast on rock break up the surface of the rock with a sledgehammer to key the concrete to the base. If this is not considered adequate insert steel reinforcing bar into the rock.
4. If the foundation is dry, shutters will not be needed. Hammer in pegs to show the required depth of concrete.
5. Use a mix of 1 : 3 : 6 for the concrete footing. Embed rough, large stones in the top surface to provide a good key for the masonry

**Figure 7.6 (Sheet 1): Construction of Masonry Abutment**



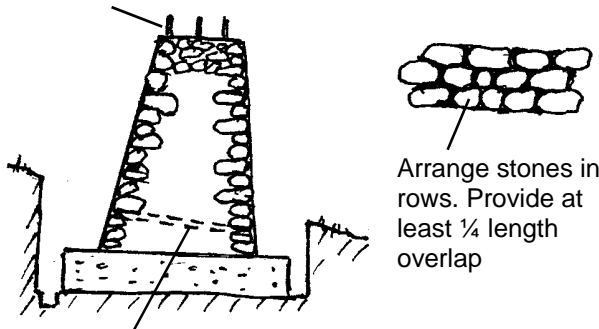
6. Mark out the outline of the abutment and wing walls with posts and string as a guide for construction



7. Check that the tops of the abutments are level. If the footbridge installation includes intermediate piers, also check the level of the top of the pier.

8. Begin construction of the masonry at the corners.

Reinforcing bar for key with concrete bearing cap (if needed)



Stones should be at least 200mm in size. The length/thickness should not exceed 3 : 1.

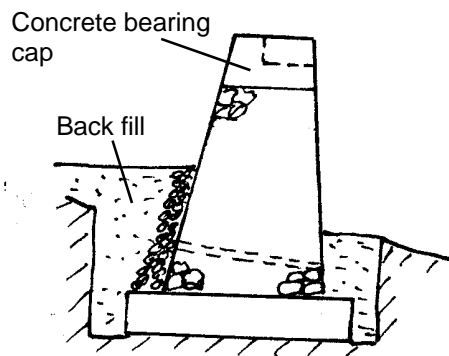
Pack stones closely together making sure they overlap and interlock. There should be mortar between all stones.

Use larger stones on the faces with through stones at regular intervals to bind in the face. Smooth face off with mortar.

Weep holes for drainage about 1m apart 50mm minimum size on 1 in 10 slope

9. For steel and RCC footbridges a concrete bearing cap should be cast on top of the masonry. Masonry may be used for seating timber stringers.

Backfill should be placed in layers and compacted



**Figure 7.6 (Sheet 2): Construction of Masonry Abutment**  
(Based on information provided by the Malawi Village Access Roads and Bridges Unit)

### 7.3 PIERS

Cases will often occur when the width of a crossing is greater than the maximum unsupported span for a footbridge superstructure. If the riverbed conditions are suitable it may be possible to increase the length of the footbridge by using intermediate pier supports. These are unlikely to be feasible in more hilly areas where banks are steep and where the bridge deck may be a considerable height above the stream/river bed.

Piers should be evenly spaced at intervals as close as possible to the maximum unsupported span of the type of footbridge being used. For example if the width of the crossing is 25m and the maximum unsupported span of the footbridge type is 10m, 2 piers will be needed at about 8.3m spacing.

As with abutments, piers may be constructed from timber, masonry, mass concrete or reinforced concrete. The same comments apply with regard to selection and construction.

#### ***Selection of type of construction:***

- As with abutments, the long-term life of piers should be compatible with that of the footbridge. Therefore masonry or concrete piers should be used for steel and reinforced concrete bridges. Masonry is recommended where suitable stones are locally available.
- If suitable stones are locally available, masonry piers are also recommended for timber bridges as they are likely to give the lowest 'Total Life' cost. Timber piers, particularly using logs, will give a lower initial cost but limited life, maybe only 15 to 20 years. However, where there is all-year round flow of the stream/river that prevents excavation of footings for masonry or concrete piers, timber piers may be the only possible option.

#### ***Constraints:***

Because piers have to be built in the stream/river bed there are more constraints on their construction outlined below:

- To excavate the footings for masonry or concrete piers, the riverbed needs to be dry in the dry season or to have limited water flow so that dams can be built to divert the water away from where the foot of the pier will be located. However, if this is not the case, it may be possible to sink timber piles in shallow water if the stream/river bed is suitable.
- The condition of the riverbed. For example, the use of timber piles may be difficult on stony or rocky beds. However, if rocks are suitable large and stable it may be possible to use them as a foundation for a masonry pier.
- The required height of the footbridge deck above the riverbed. The recommended maximum height for local construction is about 2 to 2.5m above the bed surface.

Piers obstruct the water flow and in the rainy season debris carried in flood-water may build up around the pier. If this is likely to be a significant problem the upstream end of the pier may need to be rounded to streamline the flow. Since the maximum water flow occurs at the centre of the stream/river it is best to locate piers away from this area if possible.

### 7.3.1 Timber Piers

Figure 7.7 shows piers constructed from timber logs and sawn timber beams. Piers support the joint between two bridge spans and therefore need to provide adequate bearing area for the ends of the two sets of joining stringers. In Figure 7.7 two cross-beams are used, each supporting one set of stringers.

The cross-beams must be securely fixed on the tops of the piles and also the stringers to the cross-beams.

The steps listed in Section 7.2.3 above should be taken to increase the durability of the piers. The length to be inserted in the ground should be soaked in a 50/50 mixture of creosote and diesel for a minimum of 2 weeks.

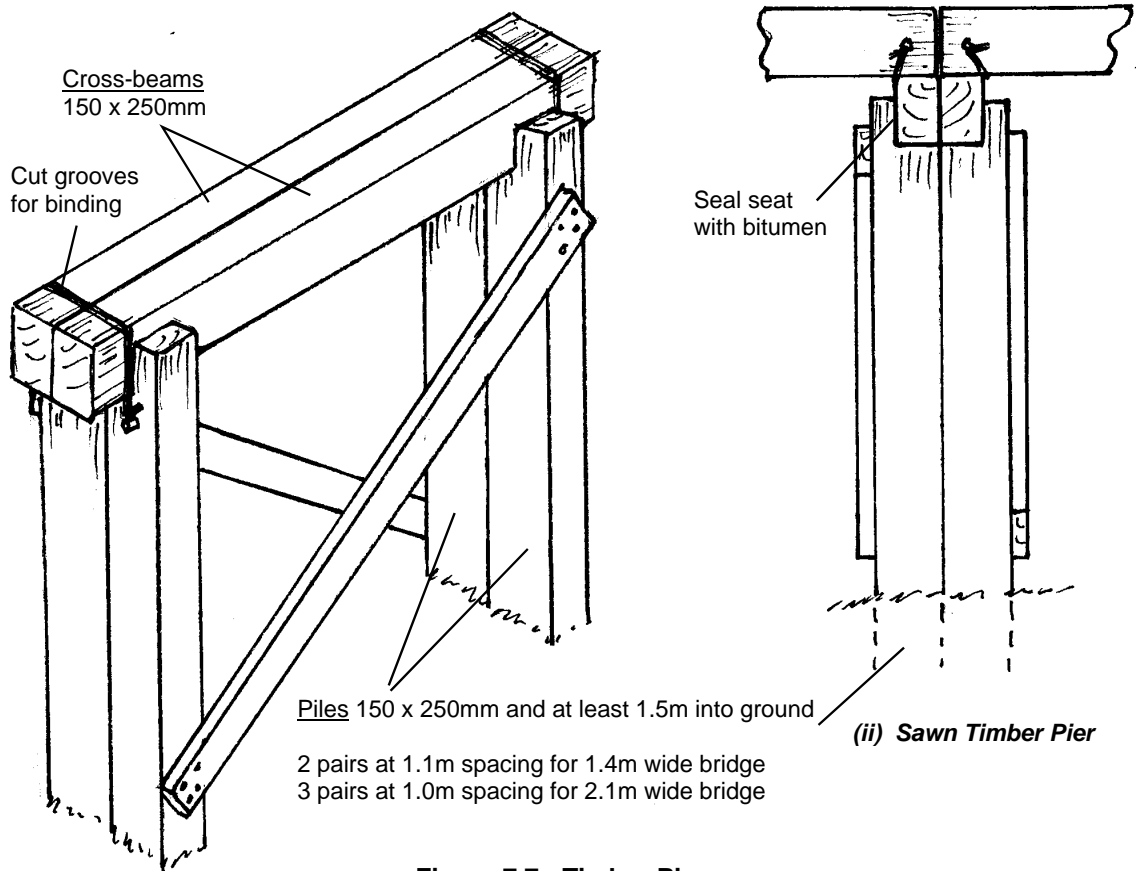
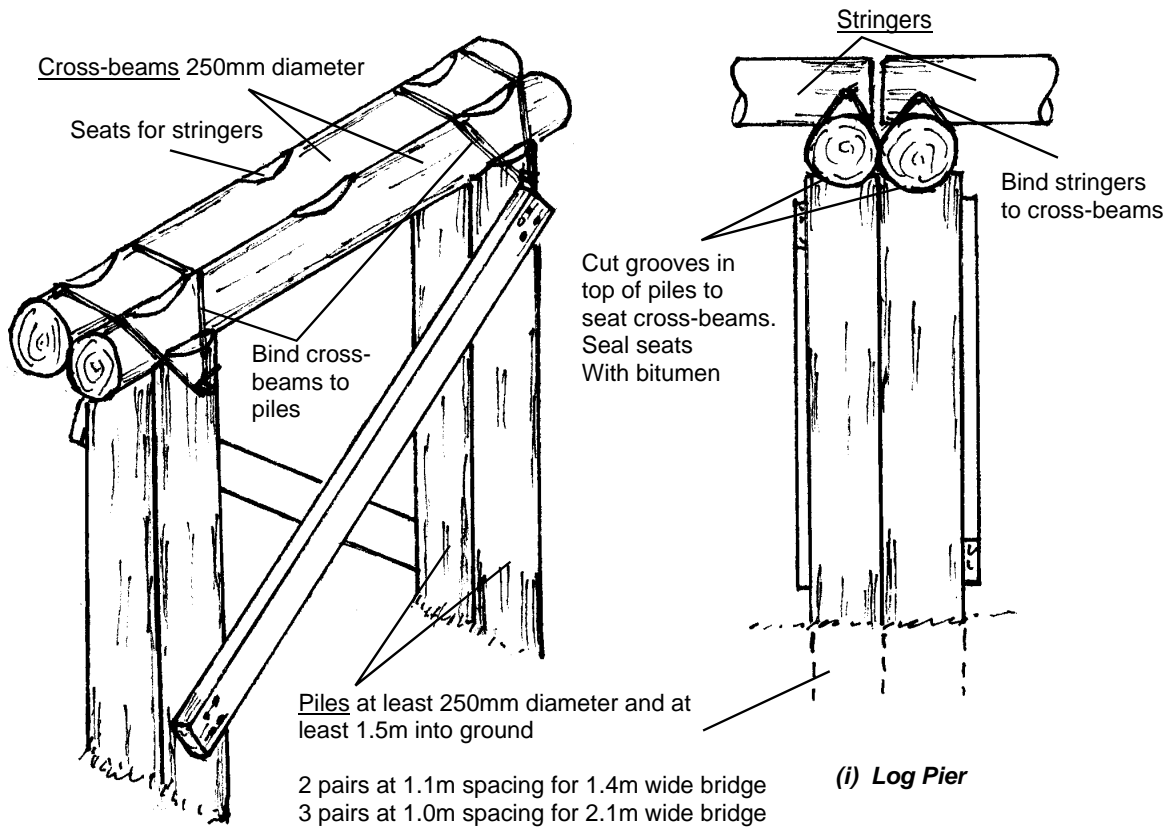
### 7.3.2 Installing Timber Piles

Constructing timber abutments and piers requires the sinking of timber piles into the ground. Up to about 0.8m this can be done by excavating a hole, installing the pile, back-filling and compacting the fill with hand rammers. For depths greater than 0.8m this becomes increasingly difficult and piles will need to be hammered into the ground.

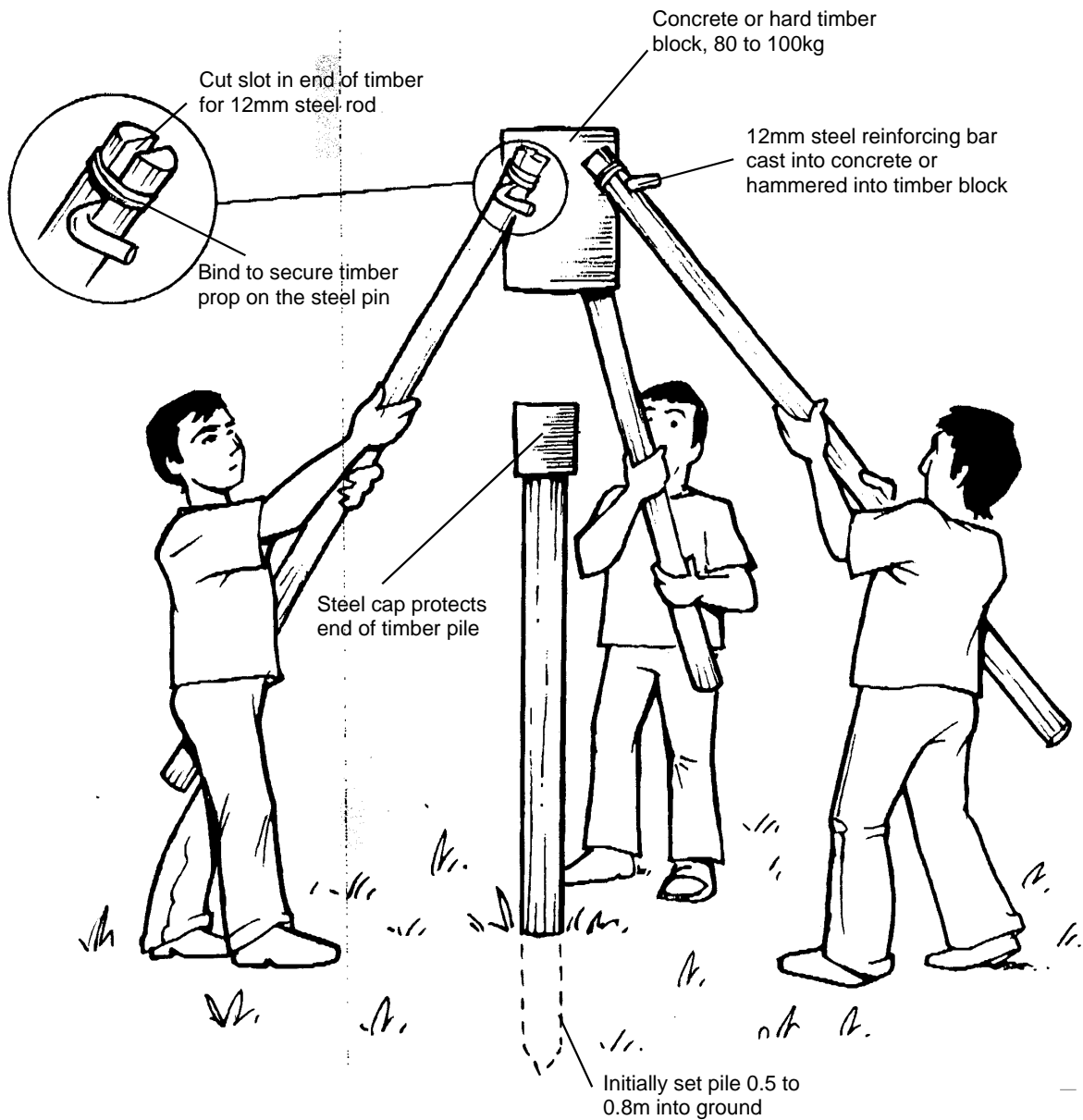
Small diameter piles can be hammered in with a sledgehammer. Larger piles will need a larger impact. Figures 7.8 and 7.9 show two possibilities using concrete or hardwood blocks of about 100kg.

Figure 7.8 shows a fairly simple method in which the weight is lifted and dropped by 4 or more persons using timber poles attached to the block. The poles must be securely attached to the block but allowing rotation of the steel pin in the slot in the end of the timber pole. Different length poles may be needed for different heights of the pile above the ground.

Figure 7.9 shows a more complex method using a tripod, pulley and rope.



**Figure 7.7: Timber Piers**



**Note:** At least 4 persons (the nearest person has been omitted to show the details of the method) repeatedly lift the block 1 to 1.5m above the top of the pile and allow it to fall freely onto the steel cap.

**Figure 7.8: Simple Method for Hammering Piles into Ground**

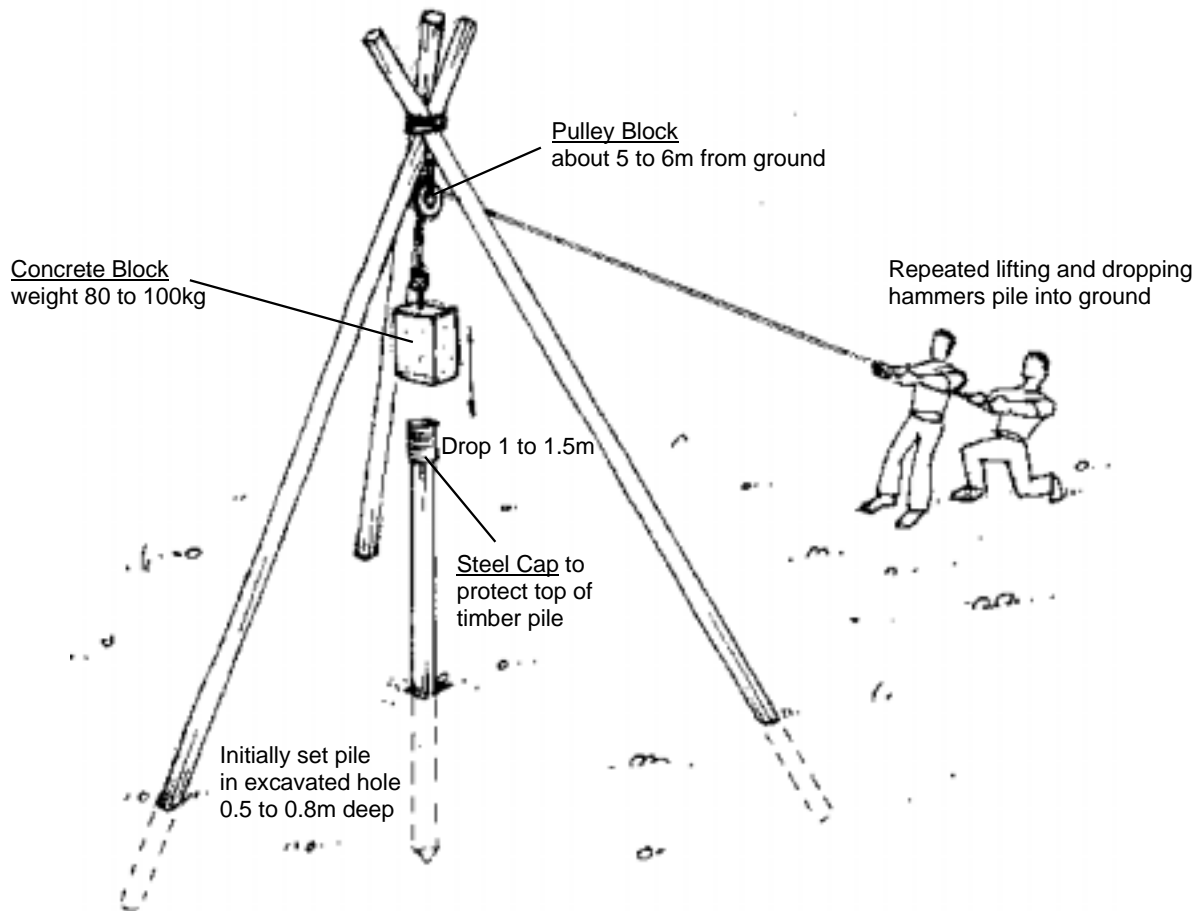
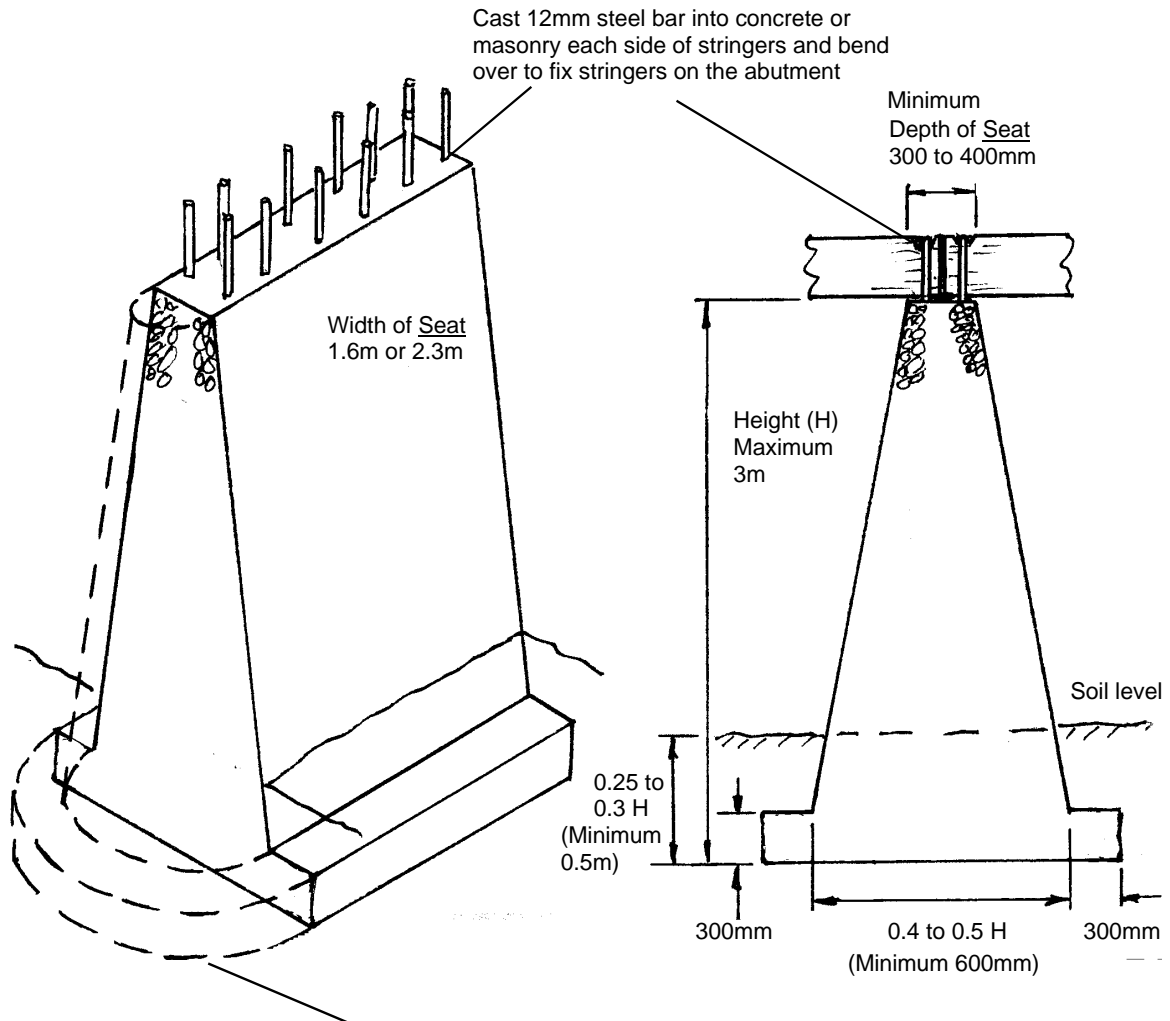


Figure 7.9: Sinking of Piles into Ground

### 7.3.3 Concrete and Masonry Piers

Figure 7.10 shows a suggested design for a concrete or masonry pier. Although more costly than timber piers these will require little or no maintenance and will have a much longer life. Their total life cost will therefore probably be lower than timber piers.

The pier needs to have a seat depth of 350 to 400mm to provide adequate bearing area for the two spans that join at the pier. It is recommended that hard rubber pads at least 10mm thick are used for the bearing surfaces. These should be about 5mm smaller all round than the bearing area to avoid trapping water on the seat. If suitable rubber is not available the seats should be sealed with bitumen.



If there is high water flow during the rainy season rounding the ends of the pier will help to reduce the disturbance to the flow

**Materials:** Mass concrete base 1 : 2 : 6  
Masonry - well packed stones in 1 : 4 mortar

**Notes:**

1. The figure shows construction details for the support of timber beam stringers. Bearing seat details for steel and reinforced concrete footbridges are given in Chapters 5 and 6.
2. Construction procedures are similar to those given for masonry abutments in Figure 7.6.

**Figure 7.10: Concrete or Masonry Pier**



### 7.3.4 Bearing Arrangements

Although the footbridge spans must be fixed securely in position on the abutments and piers, care must be taken that the fixing arrangement does not set up forces in the bridge and support structures.

The main factor is to allow for expansion and contraction of the footbridge as temperatures change.

This is not a problem for timber bridges that do not change much in length with temperature so that both ends can be securely fixed.

However, the length of steel bridges changes significantly with temperature so that only one end of the span should be fixed. RCC can also change by a few mm in length so that only one end should be rigidly fixed.

***Steel and RCC footbridges should therefore be fully clamped at one end but allowed to slide in the axial (lengthwise) direction at the other end while restrained in the side direction.*** A suggested arrangement for steel footbridges is shown in Figure 5.11 (chapter 5).

On piers where two spans of a steel or RCC footbridge join, the bearing of one span may be sliding while the bearing for the next span is fixed.

## 7.4 ERECTION OF FOOTBRIDGES

Although beam (stringer) types of footbridges can be built up on site, the individual beams may weigh up to 1200kg. They may also need to be lifted a considerable height above the river bed.

The total weight of a 20m span steel truss bridge (without the decking) will be about 2.5 tonne.

Simple methods that can be used by the local community under the guidance of a technical supervisor are therefore needed to erect heavy stringers or an assembled footbridge.

Three methods are shown in this section:

1. Using light beams to support the stringers
2. Construction of temporary scaffolding from the river-bed
3. The use of tripods and hoists.

### 7.4.1 Erection Using Light Logs (beams)

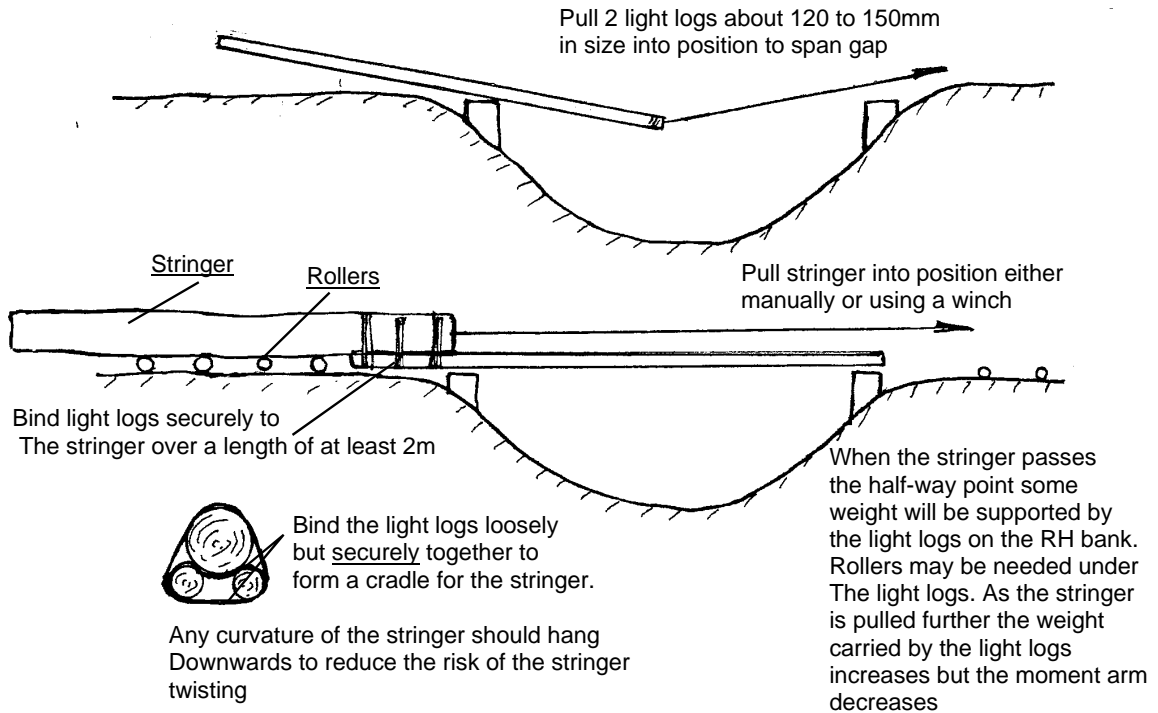
Figure 7.11 illustrates this simple method. 2 light logs, 120 to 150mm diameter are first dragged across the opening between the abutments. These will each weigh about 120 to 150kg so it will be possible for 2 to 3 persons to pull them into position (at least half the weight will be supported on the LH bank). The LH ends of the light logs are then strapped securely to the end of the stringer and the stringer pulled across the opening. As the end of the stringer passes half-way the light logs will begin to support some of its weight and this will increase as the stringer is pulled further. However, at the same time the bending arm on the logs gets smaller so that they will be strong enough to support the stringer. The stringer can be pulled and levered into position on the abutments.

Figure 7.12 shows an alternative method in which the two light logs are bound together and placed across the abutments at the largest possible angle to the centre line whilst remaining securely supported. The stringer is then pulled across the light logs.

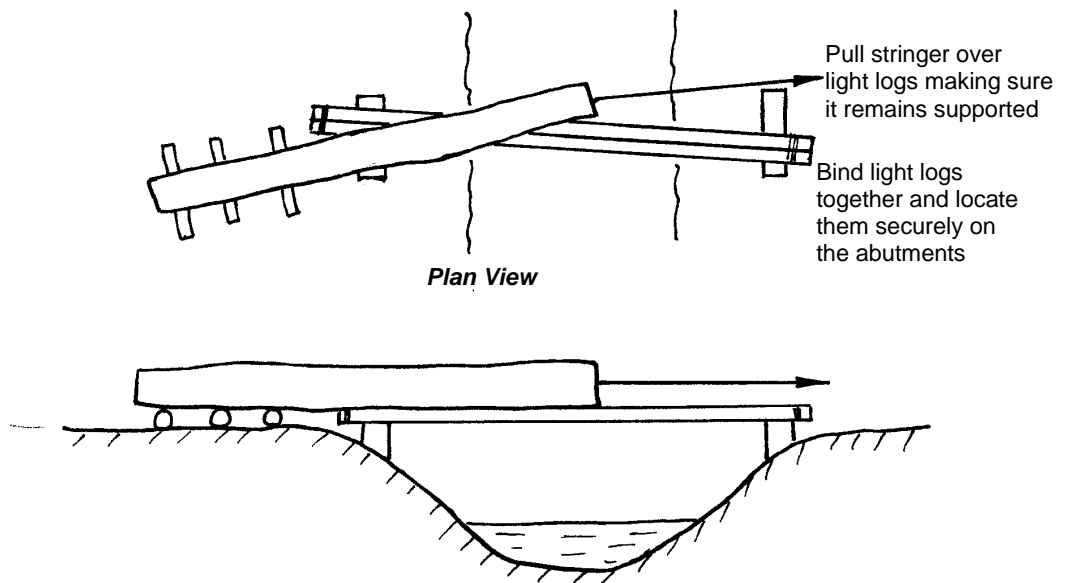
### 7.4.2 Construction of Temporary Structure/Scaffolding Across Gap

Although this may involve considerable work it is possibly the most straightforward method. However, it depends on being able to build up the temporary structure from the river-bed and may not be suitable where the deck height above the bed is more than 3 to 4m. A suitable approach area is also needed to the abutment on the near bank over which the stringer or bridge can be dragged on rollers.

Figure 7.13 shows the basic method. The structure must be securely lashed together and well braced against the forces used to pull the stringers/bridge into position. The stringer/bridge may be pulled into position by hand if enough labour and space is available but using a winch will be easier and give more control over the operation.



**Figure 7.11: Installation Using Light Logs to Support Stringers**



**Figure 7.12: Use of Light Logs to Support Stringer**  
(Method suggested by VARBU, Malawi)

### 7.4.3 Use of Cable Way to Lift Stringers/Bridge into Position

This is probably the most difficult and costly option but it may be the only one possible in some situations, especially for wider crossings. It will require the acquisition, possibly by hiring, of hoists or winches, cables and ropes and pulley blocks. It will also need careful technical supervision from a person with experience in this type of operation.

Figure 7.14 shows the simplest method. Towers or tripods are mounted on each bank to support a cable on which a pulley block travels, supporting the stringer being installed. The legs on the river side must be securely fixed in the ground and the structures well braced with guy ropes to prevent them tipping towards the river. Ropes are used on each side to control the pulling of the stringer into position.

Care must be taken to pull the stringer evenly.

A winch should be used for pulling if possible. If not the pulling rope should be wrapped around an anchor post to prevent the traveller running backwards. A lifting device such as a chain hoist is needed on the traveller to lower the end of the stringer onto the abutment.

The sag in the cable should be about 10% of the distance between the 2 tripods. This will give a maximum tension in the cable of about 1.3 x the weight being moved (assuming half the weight is supported on the nearside bank).

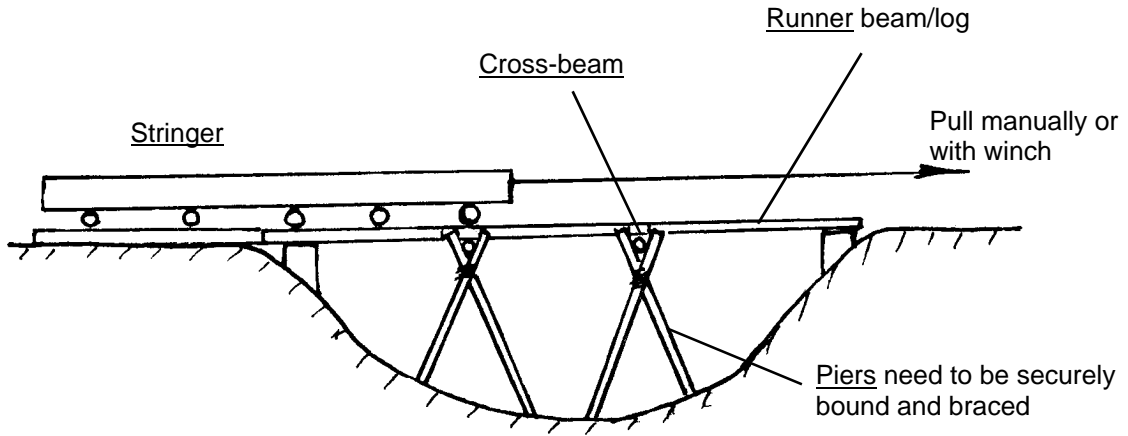
Allowable loads in cables (assuming they are sound and not frayed) are 1.0 tonne for a 6mm cable and 2.5 tonne for a 10mm cable.

Safe working loads in ropes are:

- Manila (fibre) ropes – 1 tonne for 25mm; 2 tonne for 32mm; 2.5 tonne for 36mm
- Blue polypropylene ropes – 1.4 tonne for 10mm; 2 tonne for 12mm; 3.5 tonne for 16mm

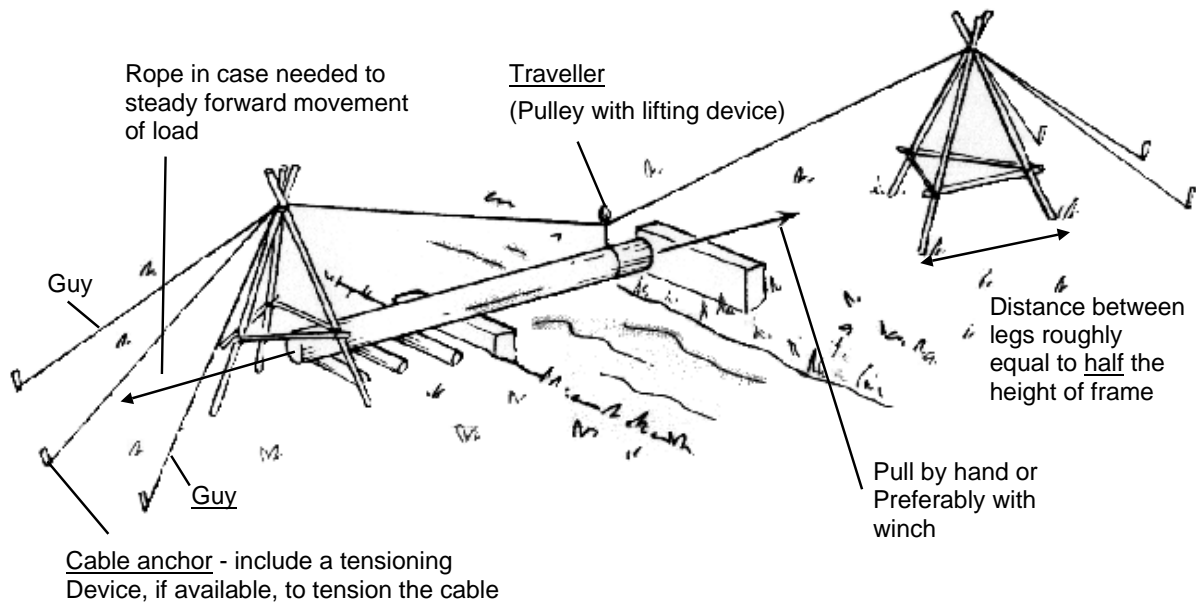
The method is particularly suitable for the installation of modular truss footbridges where the bridge can be built up close to the tripod on the nearside bank as it is lifted and pulled over the crossing.

An example of this is shown in Figure 7.15. In this case the cables and guy ropes have been anchored to trees on each side of the river because the soil (paddy fields) was not suited to putting anchor posts in the ground. Note that a platform has been erected on the near side of the river on which the footbridge is assembled module by module.



Erect temporary piers with cross beams to support runners (logs/beams) on which stringer can be pulled across gap

**Figure 7.13: Installation Using Temporary Piers**



**Figure 7.14: Installation Using Hoists**



**Figure 7.15: Use of Cable Trolley to Install a Modular Steel Truss Footbridge**

## 7.5 ORGANISATION OF WORK

The work programme can be split into three main components –

(1) Planning and preparation; (2) Implementation; (3) Ongoing maintenance.

### 7.5.1 Planning and Preparation

In most cases, footbridges will be installed along paths or tracks for which the local community is responsible. The request for a footbridge is likely to have come from the community. It is therefore important to liaise closely with the local communities at all stages of the work programme and especially during the planning and preparation stage. Decisions, costs and inputs should be agreed with the communities.

It is very important to emphasise to the community that the installation of a footbridge is a major undertaking and will require a great deal of commitment from the community in labour and possible other resources. It is likely to overshadow any other community projects and there will need to be a consensus from the community that a footbridge is by far their number one priority.

Guidelines on working with communities and providing technical assistance are discussed in detail in a previous publication on footpaths (see footnote on Page 1). Important issues are to keep the communities informed, to get agreement on decisions regarding the footbridge and to draw up contracts on expected community inputs in regard to funds, materials, labour and ongoing maintenance.

The main activities in the planning and preparation stage are outlined below.

1. **Site survey:** (see Appendix A). This should provide a plan of the site and give the specifications of span and width for the footbridge. The plan should show the topography of the banks and river-bed at the proposed crossing and give details of surface and soil conditions. The possibility of using intermediate pier supports if needed should be clearly identified. The location of abutments and piers (if used) should be shown.
2. **Selection of type of footbridge:** this is discussed in Chapter 3. The main factors to be considered are – span; if piers can be used where the span exceeds about 8 to 10m (4m for bamboo bridges); the availability of materials; skills needed; and both initial and long-term (total life) cost.
3. **Design of footbridge:** this will probably be based on a standard design from Chapters 4, 5 or 6 or some other source of information. A sketch should be prepared showing all dimensions, details and materials. From this a materials and cost list should be drawn up as indicated in Table 7.1 below.

**Table 7.1: Materials and Costs List**

Item	Material	Section and Size	Length or Volume	Number Needed	Source of Supply	Unit Cost	Total Cost

Table 7.1 will give an estimate of the material cost of the footbridge. Costs of consumable items such as paint and preservatives should also be estimated. If the construction of the footbridge is carried out in a workshop, such as with a steel truss footbridge, then appropriate workshops should be provided with the design sketches and asked to quote a price for construction.

The labour inputs and costs then need to be estimated by identifying the steps in the construction process and the inputs required for each step. Some guidance can be obtained from Chapters 4, 5 and 6, Appendix B, previous experience and discussions with relevant craftsmen. Inputs can be listed in a table such as Table 7.2.

**Table 7.2: Estimate of Labour Inputs and Costs**

Item	Activity or Operation	Tools needed	Type of Skills needed	Estimate of work days needed	
				Skilled	Unskilled

Adding up the work-days in Table 7.2 gives the total work-days needed for each skill (type of craftsman) and for unskilled workers. This in turn gives an estimate of the inputs needed from the community and any inputs that have to be imported. The labour cost for constructing and erecting the footbridge can then be found by multiplying work-days that have to be paid for (community inputs may be unpaid) by average unit rates in the area.

All activities involved in the construction and erection of the bridge (not abutments and piers which are considered separately below) should be included in Table 7.2, including:

- Collection of materials
- Transport of materials and components to site
- Handling of materials and components on site
- Construction and assembly processes
- Preparations for erecting the footbridge as indicated in Section 7.4 above, for example preparing surfaces for rolling stringers or footbridge, setting up lifting gear etc.
- Erection of the footbridge
- Backfilling to link the footbridge to approach paths/tracks.

**4. Design of Abutments and Piers:** a similar procedure should be followed as for the footbridge. Tables similar to 7.1 and 7.2 can be used. Erection may involve clearing of the site, excavation of foundations and sinking of piles. Standard unit rates for the first two are:

- Clearing – 50m<sup>2</sup> per work-day for heavy vegetation to 150m<sup>2</sup> per work-day for light vegetation
- Excavation – 3 to 5m<sup>3</sup> per work-day (does not include the movement of excavated soil)

Times for sinking of piles can be estimated from experience for the size of pile, depth into ground, nature of soil and method used.



**5. Identify total inputs and resources needed and potential sources of supply:** the above steps will provide an estimate of the total inputs needed comprising labour, materials, costs of materials, tools and equipment. These need to be split into two components:

1. What can be provided by the local communities that will benefit from the footbridge. This will need to be discussed in detail with communities and an agreement drawn up and signed by the communities to confirm their commitment
2. What needs to be obtained from outside the communities. This will be mainly a total cost which cannot be met by the communities for materials, skilled labour that has to be imported and tools/equipment that have to be hired or purchased.

If outside assistance is needed a proposal will need to be prepared justifying the funds requested against the benefits of the footbridge. This will require an assessment of the access improvements provided by the footbridge and the number of people who will benefit. Improvements in access may include:

- Providing access to services where no access exists at present. This is likely to relate to access in the rainy season. Providing access to health, education and market facilities is especially important
- Saving time in access to services. Again saving time in access to health, education and market facilities is especially important
- increasing the amount of produce transported to markets to increase household incomes. Careful assessment is required to obtain realistic estimates based on discussions with the communities and local traders to assess potential for increased household production, potential for increased market sales and the possible impact of increased market inputs on prices.

The proposal should be realistically prepared and submitted to potential funders.

### 7.5.2 Implementation

The planning stage will have identified all activities involved in installing the footbridge and the estimated work-days needed for each activity. Based on the work force available the days required for each activity can be estimated. This information should be put into an implementation chart or table similar to that shown in Table 7.3. This will show the activities, the sequence in which they need to be carried out and when they should be completed. A copy of the chart should be put up in a prominent place in the communities involved and kept up to date to show progress.

**Table 7.3: Implementation Chart**

Activity	Person or Group responsible	Period over which the Activity is to be carried out. X shows the scheduled completion date. Include notes to explain any delays					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
1. Clear site	Community A	X					
2. Mark out abutments	Supervisor		X				
3. Acquire and prepare suitable logs	Community B				X		

All activities should be included and the total weeks scheduled for installing the footbridge.

### **7.5.3 Maintenance**

***Ongoing maintenance to a regular schedule is very important to prolong the life of the footbridge and to achieve good value from the time, effort and funds invested in installing the footbridge.***

A Maintenance Schedule should be drawn up showing activities required, when they are to be carried out and who is responsible for them. This should be discussed and agreed with the responsible communities who should sign a contract agreeing to carry out the work.

Guidelines on the maintenance needed for timber footbridges is given in Section 4.5 and for steel truss footbridges in Sections 5.2.11 and 5.3.3

## APPENDIX A

### SITE SURVEY AND LAYOUT OF BRIDGE

The factors to be considered in locating the bridge are listed in Section 2.1.1. Once the location has been selected the site needs to be surveyed to establish the specifications for the bridge and its abutments. The survey needs to determine two main factors:

1. The location of the abutments and the span of the bridge based on: (i) the Design Flood Level and clearance needed below the bridge to allow for debris carried in flood waters; (ii) clearance needed for any boats using the stream/river during non-flood conditions; (iii) the slope and soil conditions on the banks
2. The width of the bridge based on the types and levels of traffic that will use the bridge.

#### Location of Abutments

The survey procedure is shown in Figure A1 and involves the following steps:

**Step 1** Identify and mark with pegs the Design Flood Level based on inspection of the banks and discussions with local persons.

*For medium traffic levels (less than 500/day) and normal access needs the DFL could be the maximum flood level reached on average every 5 years*

*For high traffic levels (over 500/day) and/or critical access needs the DFL could be the maximum level reached on average every 10 years*

**Step 2** Place marker poles on each bank along centre-line of bridge location.

**Step 3** Obtain information on debris carried in flood-waters and decide on clearance needed above the DFL. Mark this clearance on the marker pole on one bank.

**Step 4** Obtain information on any boats or canoes that use the river/stream and the normal level of water on which they operate. Estimate the clearance needed for these boats and mark this height on the marker pole.

**Step 5** The top level of Steps 3 and 4 will set the initial height and location of the abutments. Use a clinometer or line level to give a horizontal reference line to locate the abutment on the other bank at the correct height.

**Step 6** It is now necessary to check that the initial locations on the two banks are suitable for the abutments. The soil condition should be stable and as firm as possible. Based on the stability of the soil a slope line should be established for each bank to indicate a safe region for location of the abutments.

**Step 7** Establish the profile up and down each bank to at least 3m above and 4m below the abutment location by taking height measurements at 1m intervals from a horizontal level line. Plot these on a sheet of paper.

**Step 8** Draw a line from the bottom of the profile at an angle to suit the soil condition. Recommended angles from the horizontal (see Figure 2.2) are as follows:

- for stable rock angle can be up to 60°
- for firm, stable soil the angle should not exceed 45°
- for soft soil and sand the angle should not exceed 35°

If the locations of the abutments lie OUTSIDE this line (Case A) they should be satisfactory. If INSIDE this line (Case B) it is necessary to relocate the abutment outside the line. Careful consideration needs to be given to this as increasing the span of the bridge will increase cost. On the other hand it is imperative that the bank and footings do not slip or collapse due to the weight on the abutments.

**Step 9** The suitability of the soil for abutment foundations at the proposed location can be checked with a cone penetrometer. The procedure for this is outlined in Figure A.2.

**Step 10** Once the locations of the abutments have been finalised measure the profile along the bank for 3m each side of the centre line of the bridge. This should be reasonably level to minimise excavation of the footings for the abutments.

**Step 11** Record the conditions and decisions taken in Table A1.

### **Traffic that will use the Bridge**

The type of traffic that will use the bridge determines the maximum *width* of the bridge needed to provide access for regular users of the bridge. If the type setting the width of the bridge uses the bridge less than 1 or 2 times per month then careful consideration needs to be given as to whether it is worthwhile to increase the width and cost of the bridge to accommodate this low-frequency user. This has to be judged in terms of the need for access and the availability of other access routes.

The type and level of traffic, particularly the amount on the bridge at any one time, determines the loading that the bridge has to carry.

The data on users of the bridge should be obtained from traffic surveys and discussions with local communities and recorded in Table A1. The user setting the width of the bridge should be clearly identified.

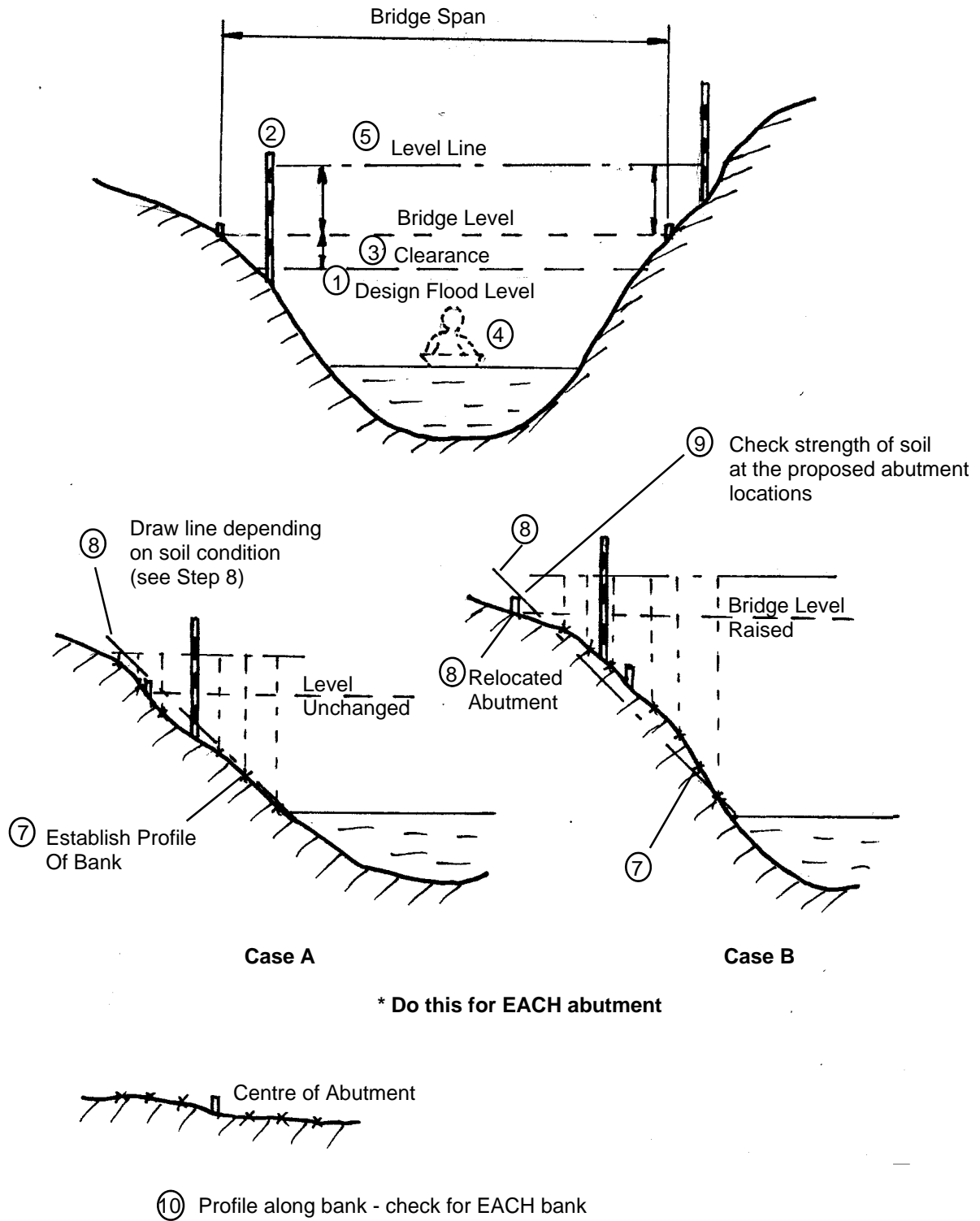
### **Plan of Area of Abutments**

If necessary, make a sketch with explanatory notes of the areas where the abutments are to be located and show any obstructions which will need to be moved and any signs of erosion that could affect the footings of the abutments.

### **Option of Using Piers**

If the span is found to be greater than about 8m then the option of using piers should be considered to allow the use of timber stringer type bridge structures (timber logs or sawn timber beams) or to reduce the strength and size needed of truss type structures. Piers may be located at about 8 to 10m centres depending on the lengths of logs or beams that are available.

If the use of piers is a possibility, additional information will be needed from the site survey as indicated below.



**Note:**  
The numbers in the circles refer to the Step Numbers in 'Location of Abutments'.

**Figure A1: Site Survey and Location of Abutments**

What is the average depth of water during the dry season? .....m

1. What is the average width of the stream/river during the dry season? .....m

2. Describe the condition of the stream/river bed at locations where piers might be located. This need to be considered particularly in regard to the types of footings that may be used for the piers (see 4). Make a sketch showing important features.

.....  
.....

3. Which type of footing would be most appropriate for the piers?

(i) A crib (a timber or steel structure that rests on the surface and is weighed down by rocks) .....

(ii) Timber or steel piles driven into the bed .....

(iii) Masonry or concrete piers constructed on rocks in the river/stream bed .....

(iv) Masonry or concrete piers with excavated footings .....

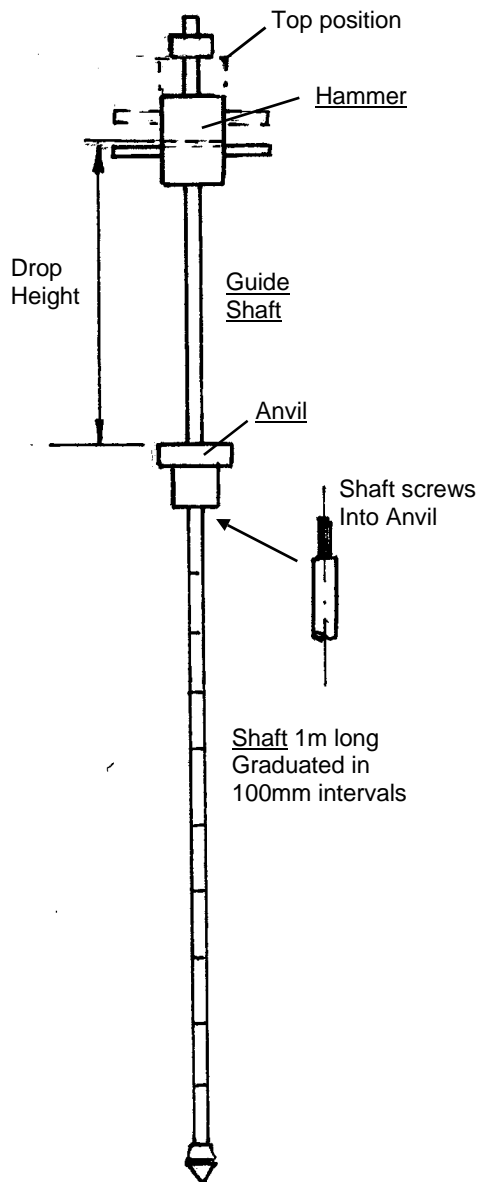
4. Use a level line or the water surface as reference to measure the depth of the stream/river bed at 1m intervals in order obtain the profile of the bed. Measure the vertical height of the level from the level of the abutments as indicated in Figure A1.

**Table A1: Record of Conditions and Decisions**

<b>Factor Considered</b>	<b>Condition or Decision</b>				
Design Flood level	Frequency of flood considered: Average yearly ..... 1 in 5 years ..... 1 in 10 Years .....				
	How accurate/reliable is this? Good .....; Medium .....; Poor .....				
Use of river/stream by boats	If river/stream is used by boats, how often? Average number/day in dry season ..... Average number/day in wet season .....				
Level of bridge	What was factor that set level of bridge? (i) Design Flood Level ..... (ii) Clearance for boats .....				
	If (i) what clearance is provided above DFL .....  If (ii) what clearance is provided for boats .....				
Soil condition at location of abutments	Tick which of the following best classifies the condition of the soil at the abutments:				
	1	Stable rock formation			
	2	Shale and soft sandstone			
	3.	Soft limestone Dense sands and gravels Hard clayey soils			
	4	Medium dense sands and clayey soils			
5	Loose sands, gravels and soft soils				
Relocation of abutments	Have the abutments been relocated because of the slope of the bank or soil conditions? No ..... ; Yes .....				
Span of bridge	1 Span of bridge for initial location of abutments .....m				
	2 Bridge span after relocation of abutments .....m				
<b>Traffic that will use the bridge (4) - Type</b>	<b>Average number/day</b>	<b>Maximum number/day</b>	<b>Maximum likely on bridge at one time</b>	<b>Typical (1) maximum weight (kg)</b>	<b>Typical (1) maximum load carried (kg)</b>
Pedestrians					
Bicycles					
Livestock -	Donkeys				
	Cows/oxen				
	Buffalo				
Pack animals (2)					
Motorcycles					
Wheelbarrows					
Handcarts					
ADVs – Animal (3)					
	Cart				
Car/pick-up					

- Notes:**
1. Less than 5% would exceed this
  2. State type
  3. State type, number and maximum weight PER ANIMAL
  4. Which of these determines the width needed for the bridge?  
.....  
What is the access width needed? ..... m.  
How often would this type use the bridge? Times/month .....

**Bridge specifications:**      **Span** ..... m  
                                                 **Width** ..... m



### ***Using a Cone Penetrometer to Test the Strength of the Soil***

- a. With the cone resting on the ground and the instrument held in a vertical position, raise the Hammer to its top position and allow it to fall freely onto the Anvil.
- b. Repeat this process and record the number of blows for the cone to be driven 100mm into the soil.
- c. Continue the process and record the number of blows for each 100mm of penetration.
- d. If at 1m of penetration a sound foundation base has still not been reached (see guide below), unscrew the anvil from the shaft and insert a 1m extension of the shaft.
- e. Continue the above process until a sound base is reached. However, because of the problems of excavation in soft soils, careful consideration should be given to relocation of the abutments if a suitable stable base has not been reached by about 1.2m depth.

### ***Guidelines on suitability of soils for abutments and piers***

(Based on notes by the VARBU in Malawi)

- Below 15 blows per 100mm penetration – soil not suitable
- 15-20 blows per 100mm – not suitable for shallow foundations
- Over 20 blows per 100mm – generally suitable

**Figure A.2: Checking the Soil Strength for Location of Abutments and Piers**



## APPENDIX B

### CONSTRUCTION OF MODULAR STEEL TRUSS FOOTBRIDGE

#### B1 INTRODUCTION

Chapter 5 contains the design details of a steel truss footbridge for spans of 10 to 20m. Two standard widths are included, 1.4m and 2.1m. However, the design can readily be adapted to other widths by changing the width of the base panels.

The design is made up of modules formed by bolting together 2 side panels and a base panel. The construction of the panels is the same for all footbridge sizes but with changes in the lengths and widths (heights) of panels and some changes in section sizes.

This Appendix contains step-by-step instructions for construction of a footbridge with working drawings for manufacture of all the components. In order to provide a self-contained set of instructions some details from Chapter 5 are repeated here.

In order to cover the range of footbridge sizes the overall dimensions are given in terms of the – Modular Length (ML); Modular Height (H); and Modular Width (W). These dimensions are obtained from Tables B1 and B2.

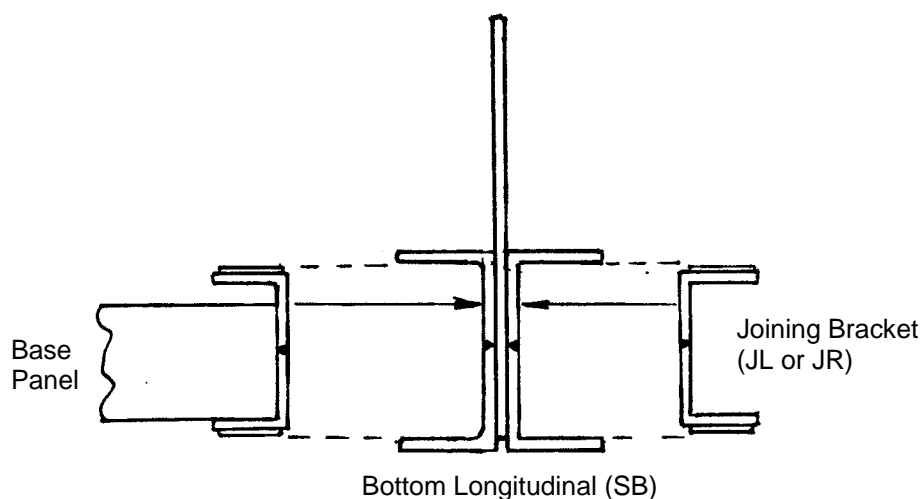
Brackets are provided on the drawings for the construction supervisor to fill in the specific dimensions for the workshop technicians.

Panels and Modules have to be bolted together on site to assemble the footbridge. It is therefore **very important** that a systematic approach is used in construction to ensure that panels fit together without problems. The following instructions are important.

#### MANUFACTURING NOTES:

1. In the manufacture of the panels described below, **ALL bolt holes must be drilled BEFORE the panels are assembled and welded. Joining parts must be clamped together for drilling to ensure holes line up.**
2. All members should be **clearly marked** using the panel index from Figure B1 and the assembly drawings. This should ensure that panels match up and bolt together without problems. Marking should be with weld deposit or punch as chalk or paint may rub off.
3. The Joining Brackets (JL and JR) and the Longitudinals of the Base Panels (BL) have to fit inside the Base Longitudinals of the End Panels (EB) and Side Panels (SB) as shown below. Check this is satisfactory before welding. Leave gaps of 1 or 2mm between the angles for EB and SB and weld in the gap
4. Welding of the panels **MUST** be carried out using an assembly jig and **MUST** be done in sequence starting from the Left or Right Hand end of the bridge. Joining members **MUST** be bolted together during the welding up of the panels to make sure holes line up when the footbridge is being assembled.

5. The strength of the footbridge depends on the joints of the panels being **fully and properly welded**. Make sure all joints are fully welded all round with good penetration of the welds. Note in particular that angle sections (verticals and diagonals) must be welded both to the gussets at the joints **and also to the joining channels or angles**.



The Joining Brackets and Base Panels must fit inside the channels of the Bottom Longitudinals so that the faces bolt together without gaps

### ***Construction Details of Footbridge***

The guidelines for construction of a footbridge are presented as follows:

- Figure B1: Details of Footbridge Modules
- Figure B2: Assembly of Panels
- Table B1: Numbers and Lengths of Modules needed for Range of Spans

#### **STAGE 1: Construction of Side Panel Members**

- Figure B3: Details of Side Panel Members
- Table B2: Parts List for Side Panel
- Figure B4: Manufacture of Side Panel Members (Sheets 1, 2 and 3)

#### **STAGE 2: Construction of End Panel Members**

- Figure B5: Details of End Panel Members
- Table B3: Parts List for End Panel
- Figure B6: Manufacture of End Panel Members (Sheets 1 and 2)

#### **STAGE 3: Construction of Base Panel Members**

- Figure B7: Details of Base Panel Members
- Table B4: Parts List for Base Panel
- Figure B8: Manufacture of Base Panel Members

**STAGE 4: *Drilling of joining members***

Figure B9: Manufacture of Joining Bracket and Drilling Template

Figure B10: Drilling Template for Verticals and Base Panel Cross-Members

Figure B11: Drilling Procedure

**STAGE 5: *Assembly and Welding Procedure***

Figure B12: Construction of Assembly Jig

Figure B13: Assembly and Welding Procedure (Sheets 1, 2 and 3)

**STAGE 6: *Assembly and Testing of Footbridge***

**B2: DETAILS OF FOOTBRIDGE MODULES**

Figure B1: Shows the arrangement of modules

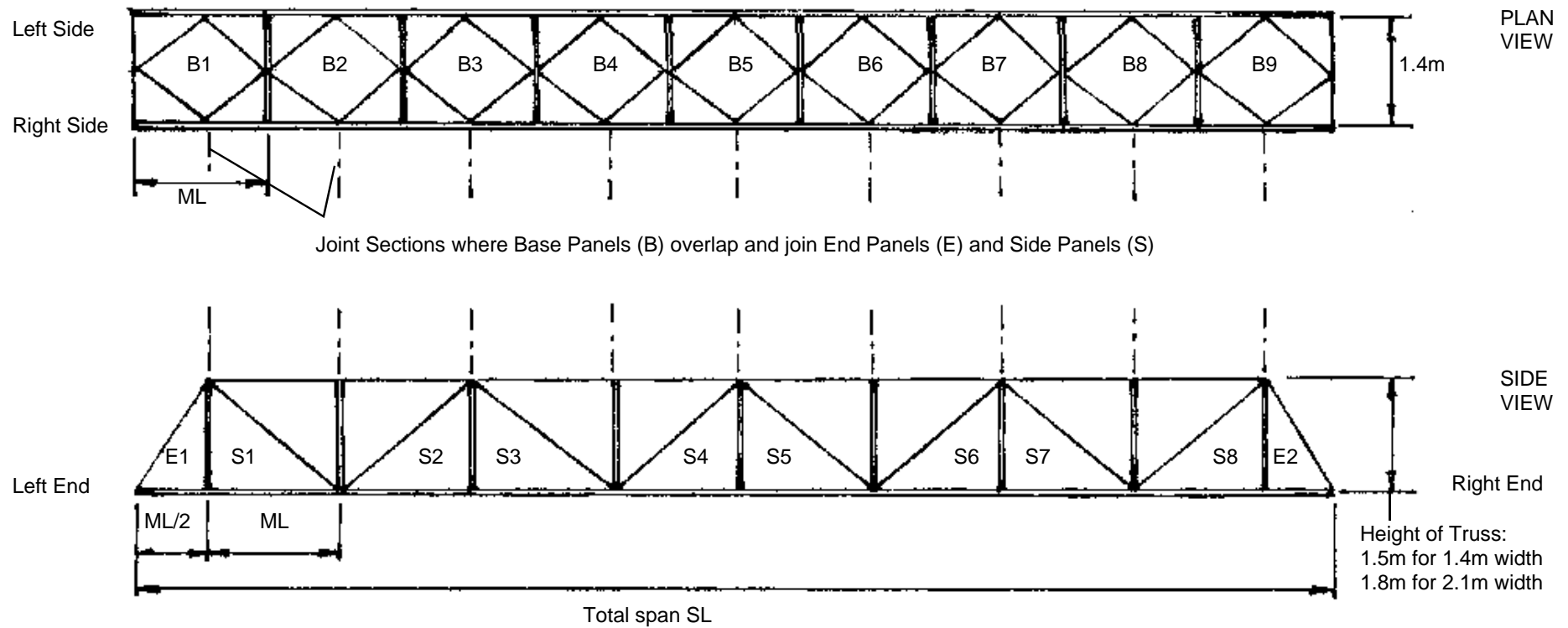
Figure B2: Shows how the panels are bolted together to form and join the modules

Table B1: Gives the number and lengths of the modules for the range of bridge spans in approximately 1m intervals. Note that the number of Side Panels always has to be EVEN for symmetry. The length of the End Panels is half that of the Side Panels.

Therefore Module Length ML = Bridge Length / (Number of Side Panels + 1)

**Table B1: Numbers and Lengths of Modules for the Range of Spans**

Span (m)	Number of Side Panels/side	Number of Base Panels	Length of Module (ML) m	Length of End Modules m
10	4	5	2.0	1.0
11	6	7	1.6	0.8
12	6	7	1.7	0.85
13	6	7	1.9	0.95
14	6	7	2.0	1.0
15	6	9	1.7	0.85
16	8	9	1.8	0.9
17	8	9	1.9	0.95
18	8	9	2.0	1.0
19	10	11	1.7	0.85
20	10	11	1.8	0.9



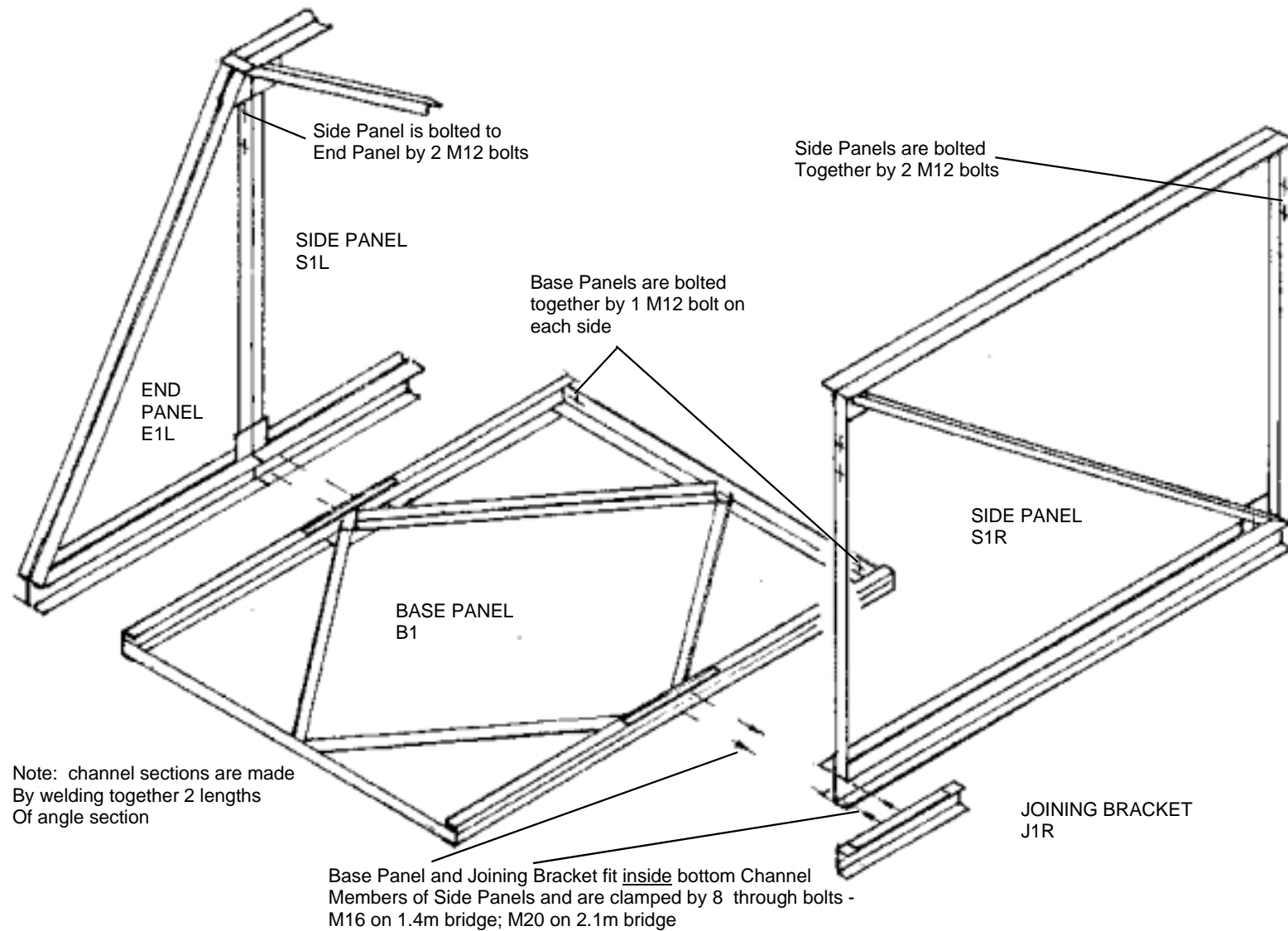
Panels Needed: End Panels (E) - 2 Left Side, 2 Right Side

Side Panels (S) - Even number; Note half have diagonal Top Left to Bottom Right  
And half have diagonal Bottom Left to Top Right

Base Panels (B) - Number of side panels + 1

**Note:** The drawing shows 8 Side Panels. The actual number needed depends on the span, see Table B1.

**Figure B1: Details of Modular Design**



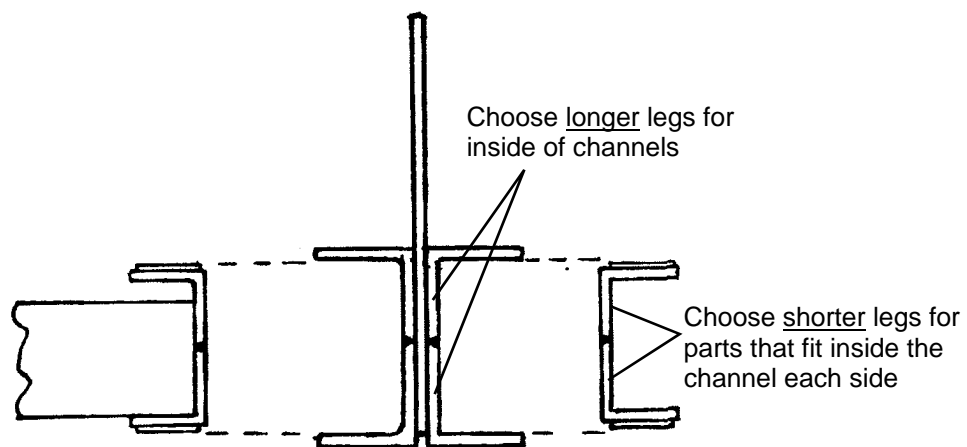
**Figure B2: Details of Geometry and Assembly of Panels**

### B3: CONSTRUCTION DETAILS OF FOOTBRIDGE

**Note:**

Remember the Joining Brackets (JL and JR) and the Base Panel longitudinals (BL) have to fit inside the Side Panel longitudinals (SB) and End Panel longitudinals (EB). All these members are channel sections formed by welding 2 pieces of angle section together. Note that Joining Brackets and Base Panel longitudinals also have 3mm thick reinforcing strips welded on top and bottom.

Since the dimensions of angle section may vary slightly and may not be equal it is important to orientate the angle as shown in the sketch below and to check that the members fit together as specified.



If legs of angle are unequal, position them so they help in fitting the channels together

**STAGE 1: Construction of Side Panel**

Figure B3: Shows details of the Side Panel assembly and members. Note that on each side of the bridge half the Side Panels will have diagonals sloping from Top Left to Bottom Right and half Bottom Left to Top Right.

Table B2: Gives the materials list for a Side panel.

**Table B2: Materials List for Side Panels (per panel)**

Member	Materials for 1.4m wide footbridge			Materials for 2.1m wide footbridge		
	Section	Length mm	Number	Section	Length	Number
Bottom Longitudinals (SB)	50x50x6mm angle	ML	4	60x60x6 mm angle	ML	4
Top Longitudinals (ST)	60x60x6mm angle	(ML-12)mm (2)	2	60x60x6 mm angle	(ML-12)mm (2)	2
Verticals (SL & SR)	50x50x6mm angle	1450mm	2	50x50x6 mm angle	1750mm	2
Diagonals (SD) (1)	50x50x6mm angle	Measure and fit	2	50x50x6 mm angle	Measure and fit	2
Gusset SG1	60x6 flat bar	220 mm	1	60x6 flat bar	240 mm	1
Gusset SG2	60x6 flat bar	120 mm	2	60x6 flat bar	120 mm	1
Gusset SG3	60x6 flat bar	120 mm	1	60x6 flat bar	120 mm	1
Gusset SG4	60x6 flat bar	220 mm	2	60x6 flat bar	240 mm	1
Spacer SS	60 x 6 flat bar	40mm	2	60 x 6 flat bar	40mm	2

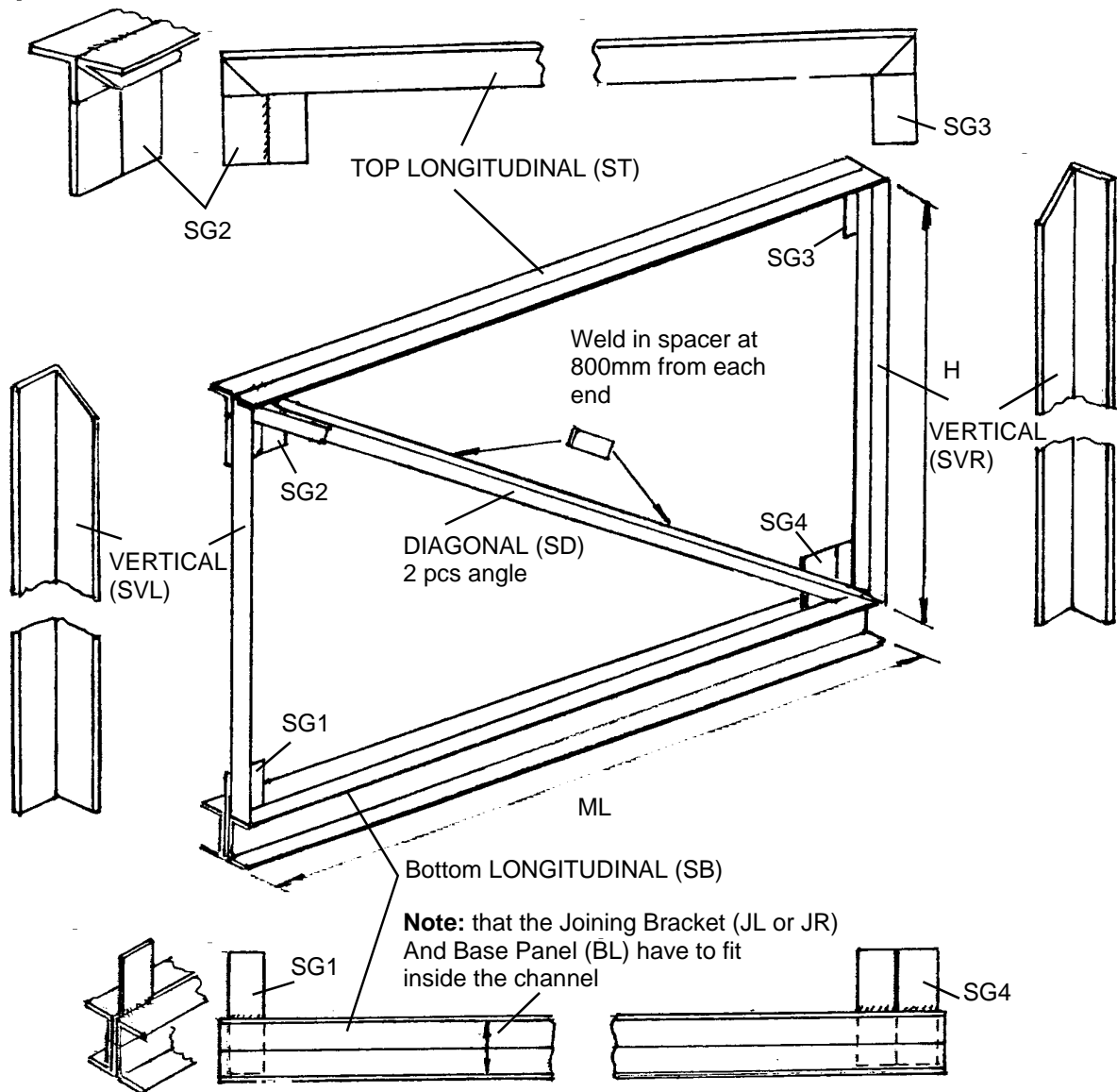
**Notes:** (1) The outside of the panel should be welded up first and then the required length of the diagonals measured. The approximate lengths for material requirements are:

1.4m wide bridge – 2.23m for ML= 1.7m, to 2.48m for ML = 2.0m

2.1m wide bridge – 2.45m for ML = 1.7m, to 2.66m for ML =2.0m

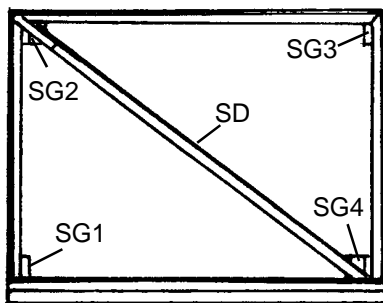
(2) The length is 2 thicknesses of angle (2 x 6mm) less than ML to allow for the Vertical members at each end.

Figure B4: Gives instructions for the manufacture of the members of the Side Panel. Note that drilling is carried out in STAGE 4 and assembly and welding in STAGE 5.

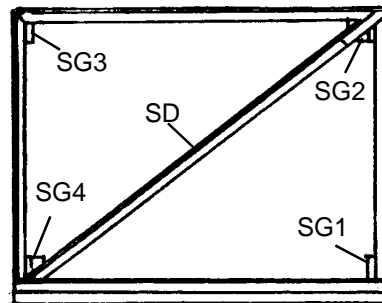


**Note:**

The number of Side Panels needed is given in Table B1. Half will have diagonals Sloping from top left to bottom right (Type A) and half bottom left to top right (Type B) as shown below



Side Panel A



Side Panel B

*Side Views from OUTSIDE Bridge*

**Figure B3: Details of Construction of Side Panel**

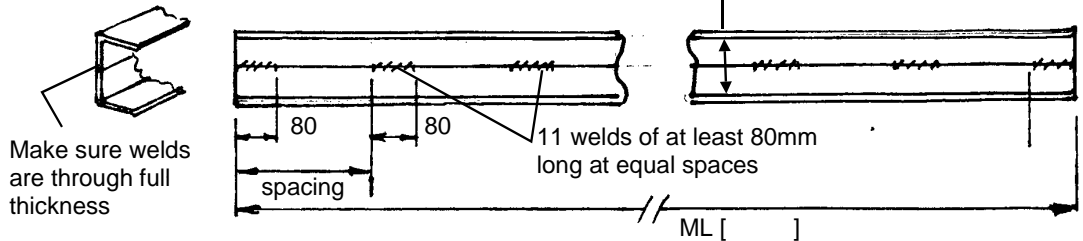


1. **Bottom Longitudinal (SB)**

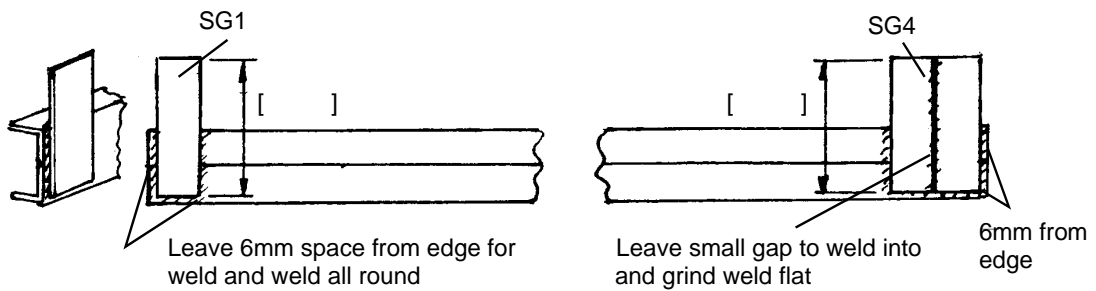
(Note: half as shown (A) and half with Gussets SG2 and SG3 reversed (b))

1.1 Cut 2 pcs angle (see Table B2) x ML long and stitch weld together to form channel section

**Note:** The Base Panel Longitudinals and Joining Brackets have to fit inside this space. Therefore check fit before welding. Leave 1 or 2m gap and weld into gap



1.2 Weld on Gussets from 60 x 6mm flat bar



1.3 Make up second channel as in 1.1 (this has no gussets attached)

1.4 Clamp second channel accurately in position to gussets of first and weld at gussets

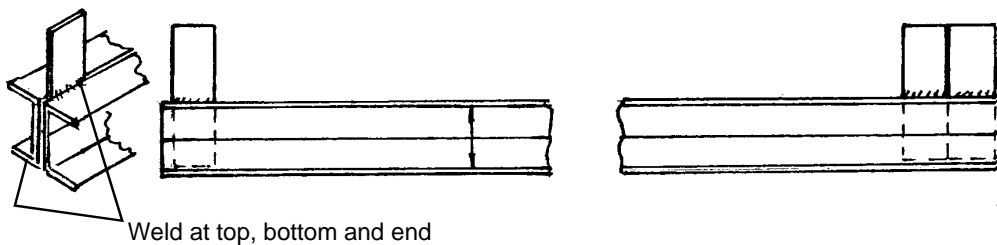
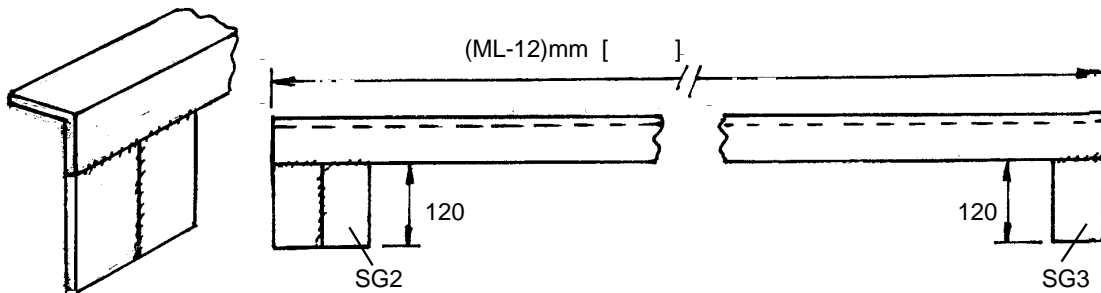


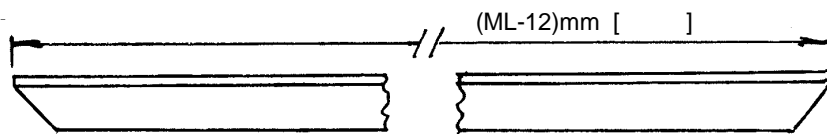
Figure B4 (Sheet 1): Manufacture of Members for Side Panels

**2. Top Longitudinal (ST)**

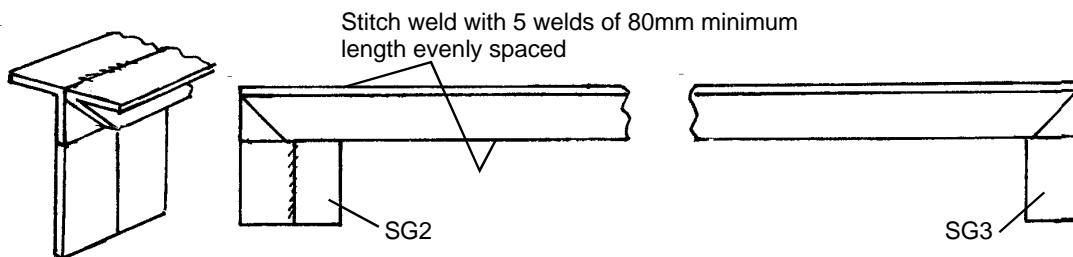
- 2.1 Cut length of 60 x 60 x 6 angle of length (ML-12)mm  
Weld on gussets cut from 60 x 6mm flat bar



- 2.2 Cut second pc 60 x 60 x 6mm angle with 45° angles at each end for mitre joints with verticals.

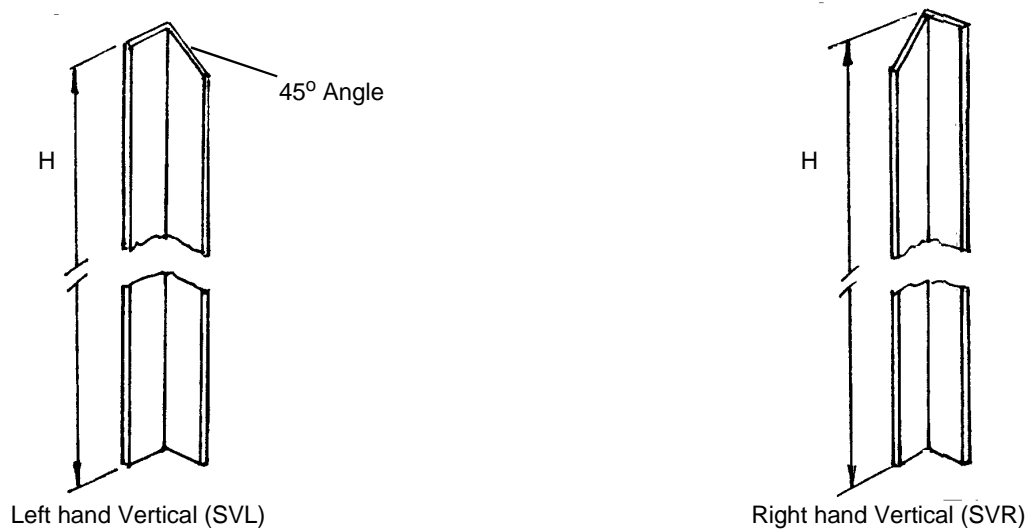


- 2.3 Weld angle sections together along top and bottom joints.



**3. Vertical members (SVL and SVR)**

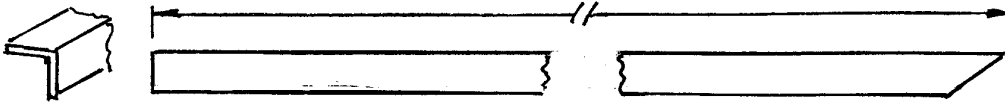
- 3.1 Cut 2 pcs 50 x 50 x 6mm angle to length H (see Table B2). Cut top end at 45° angle for Mitre joints with Top Longitudinal



**Figure B4 (Sheet 2): Manufacture of Members for Side Panels**

4. **Diagonal (SD)** (Cut when panels are being assembled and welded in Stage 5)

4.1 Weld up outside frame of Side Panel and measure length of diagonal. Cut pc 50 x 50 x 6mm angle for deck side of panel for full length of diagonal.



4.2 Cut pc 50 x 50 x 6mm angle for Outside of panel. This is a little shorter than first pc since it fits on Gusset SG2 and butts up against the edges of the angles of the Top Longitudinal (SV) and Vertical (SV). Cut short length of 40 x 40 x 6mm angle to make up the full length into the corner joint..

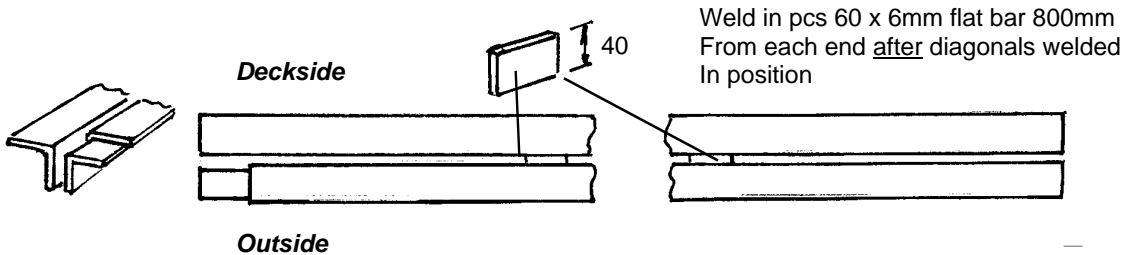
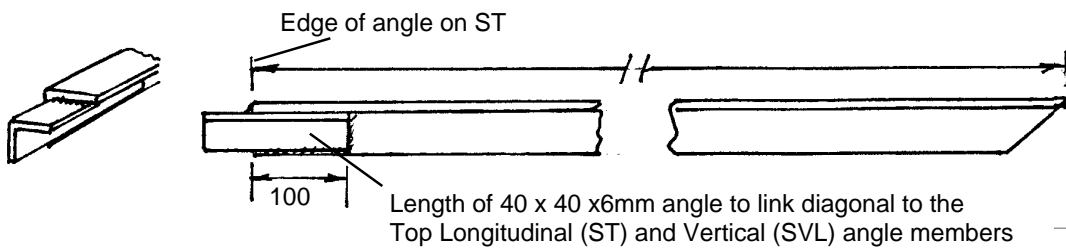


Figure B4 (Sheet 3): Manufacture of members for Side Panels

**STAGE 2: Construction of End Panel**

Figure B5: Shows the details of the End Panel assembly and members. Note that there are 4 End Panels. 2 have diagonals sloping bottom left to top right and 2 have bottom right to top left.

Table B3: Gives the materials list for an end panel.

**Table B3: Materials List for End Panel (*Single panel*)**

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (EB)	50x50x6mm angle	ML/2	4	60x60x6mm angle	ML/2	4
Vertical (EV)	50x50x6mm angle	1450mm	1	50x50x6mm angle	1750mm	1
Diagonal (ED)	50x50x6mm angle	Measure and fit (1)	2	60x60x6mm angle	Measure and fit	2
Gusset EG1	60x6 flat bar	210mm	1	60x6 flat bar	240mm	1
Gusset EG2	60x6 flat bar	260mm	1	60x6 flat bar	300mm	1
Gusset EG3	60x6 flat bar	220mm	2	60x6 flat bar	220mm	2
Gusset EG4	60x6 flat bar	180mm	1	60x6 flat bar	200mm	1

**Note:** (1) Weld the Vertical to the Base Longitudinal then measure up and cut the Diagonal to fit neatly into position. The approximate lengths for material requirements are:

- 1.4m footbridge – 1.68m for ML=1.7m to 1.77m for ML=2m
- 2.1m footbridge – 1.95m for ML= 1.7m to 2.02m for ML = 2m

Figure B6: Shows details of the manufacture of the End Panel members.

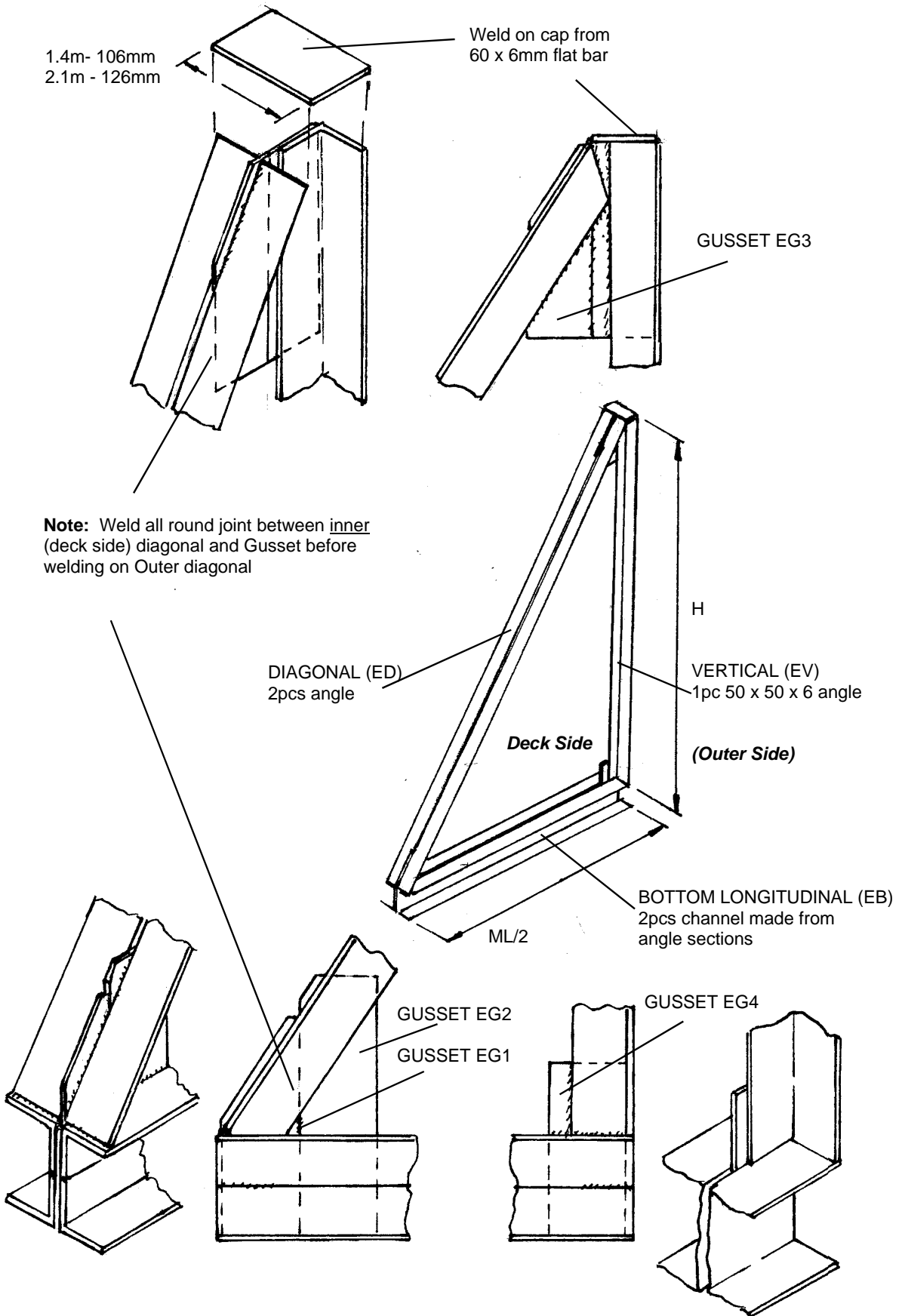
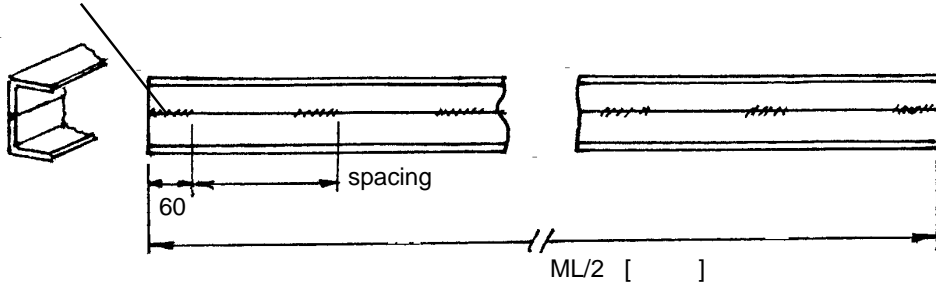


Figure B5: Details of Construction of End Panel (see Table B3 for materials)

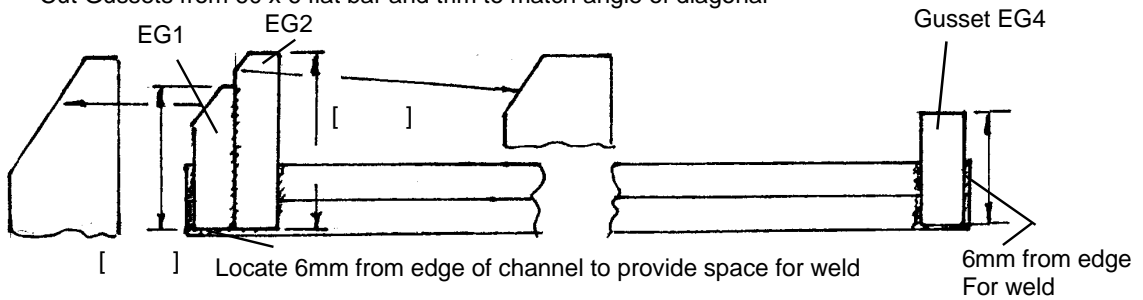
**End Panel Members**

1. **Base longitudinal (EB)** - 2 pcs channel made from angle sections (see Table B3)

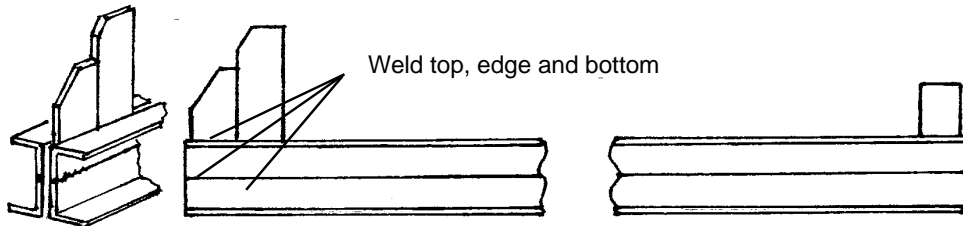
1.1 Cut 2 pcs angle x ML/2 (see Table B1) long and stitch weld to form channel. 8 welds at least 60mm long at equal spacing. Leave gap of 1 to 2mm between angle pieces to weld into



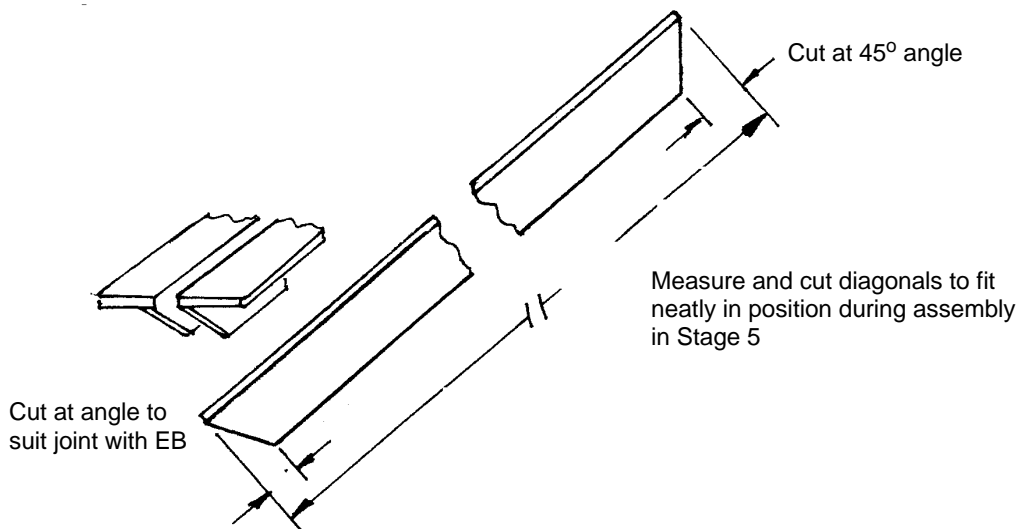
1.2 Cut Gussets from 60 x 6 flat bar and trim to match angle of diagonal



1.3 Make up second length of channel section as in 1.1 (this has NO gussets). Position accurately and weld to gusset plates

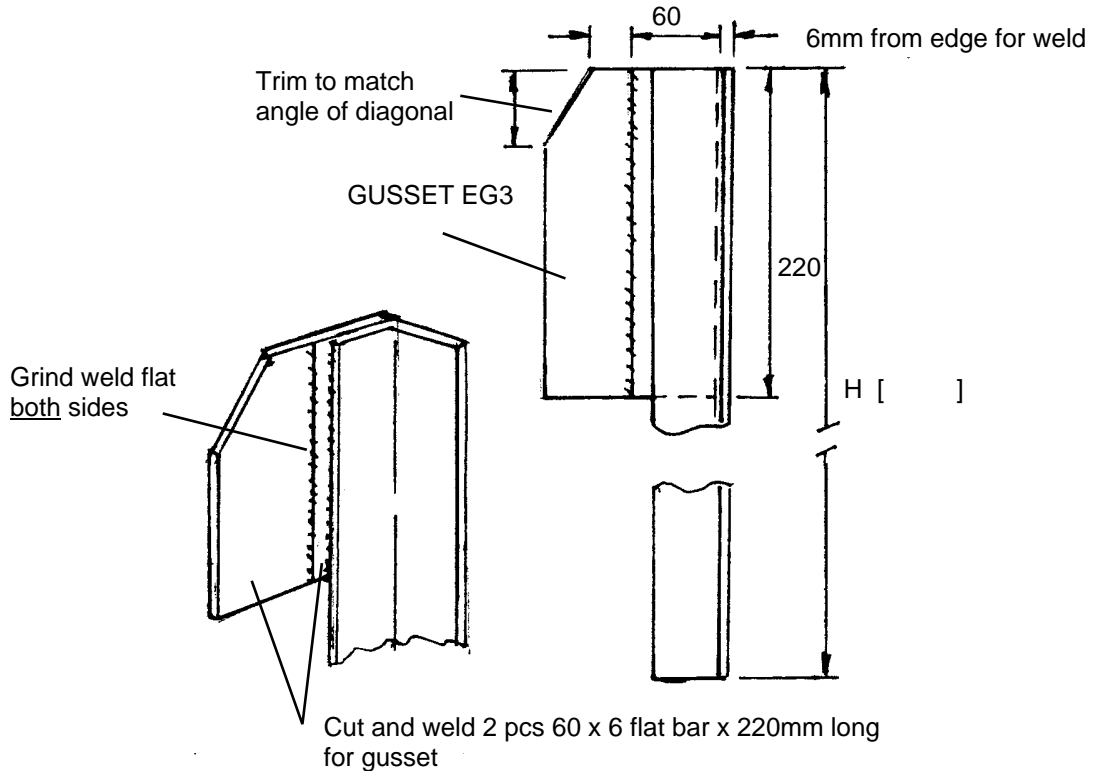


2. **Diagonal (ED)** - 2 pcs angle (see Table B3). Measure and cut to length during assembly (Stage 5)

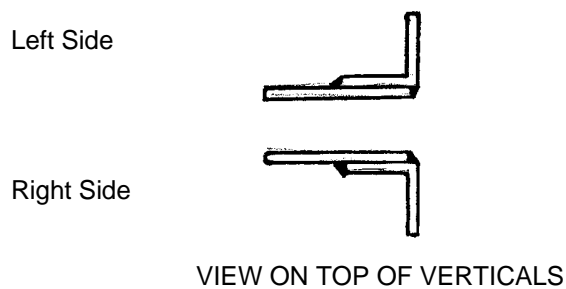


**Figure B6 (Sheet 1): Members for End Panel**

- 3. **Vertical (EV)** - 1 pc 50 x 50 x 6mm angle
- 3.1 Cut pc of angle of length H (see Table B3)
- 3.2 Cut 2 pcs of 60 x 6 flat for Gusset EG3 and weld in position



**Note:** A LH and RH Vertical are needed for each End Panel as shown below



**Figure B6 (Sheet 2): Members for End Panel**

**STAGE 3: Construction of Base Panel**

Figure B7: Shows the details of the Base Panel assembly and members. The length of the Panel (ML) is obtained from Table B1 and the width from Table B4.

Table B4: Gives the materials list for a Base Panel

**Table B4: Materials List for Base Panel (Single Panel)**

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (BL)	40x40x6mm angle	ML	4	50x50x6mm angle	ML	4
Stiffeners for longitudinal	30x3 flat bar	500mm	4	40x3 flat bar	500mm	4
Diagonals (BD)	50x50x6mm angle	Measure and fit (1)	4	60x60x6mm angle	Measure and fit	2
Cross members (BC)	60x60x6mm angle	1486mm	2	60x60x6mm angle	2186mm	2
Gusset BG1	60x6 flat bar	200mm	2	60x6 flat bar	200mm	2

**Note:** (1) Weld the outside of the panel, longitudinals and cross members, then measure and cut the diagonals to fit. The approximate lengths for material requirements are:

1.4m footbridge – 1.1m for ML = 1.7m to 1.3m for ML = 2.0m  
 2.1m footbridge – 1.3m for ML = 1.7m to 1.5m for ML = 2.0m

Figure B8: Shows the details of the manufacture of the members of the Base Panel.



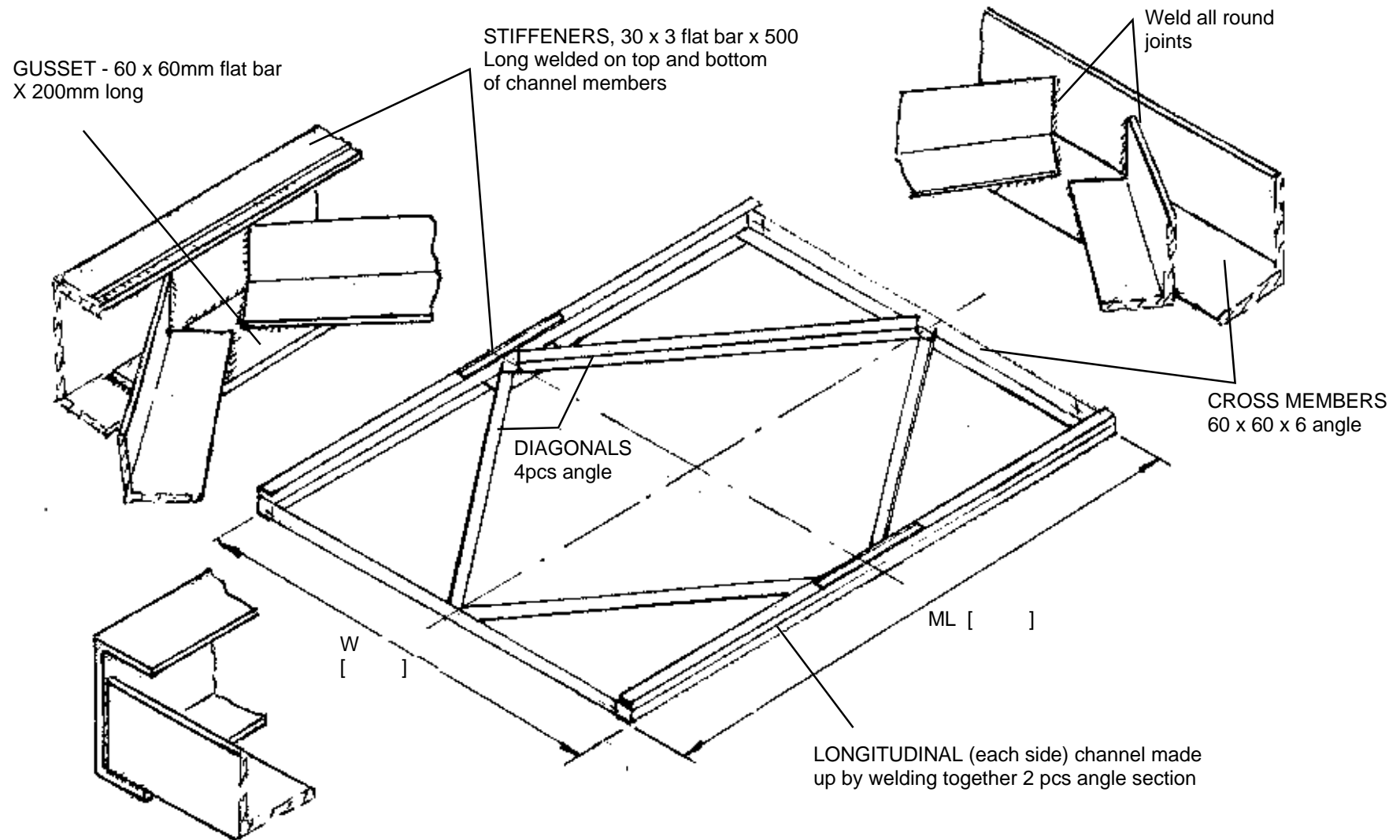
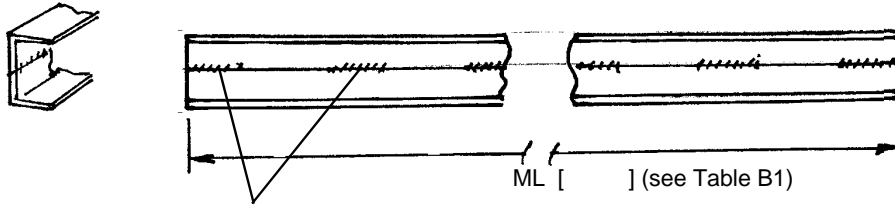


Figure B7: Details of Base Frame

**Base Frame Members**

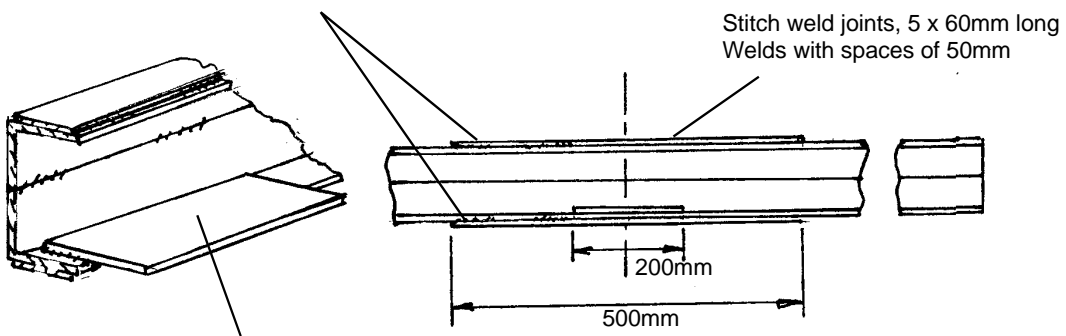
**1. Longitudinals (BL)**

1.1 Cut 2 lengths angle (see Table B4) and stitch weld together to form channel section. 2 pcs needed



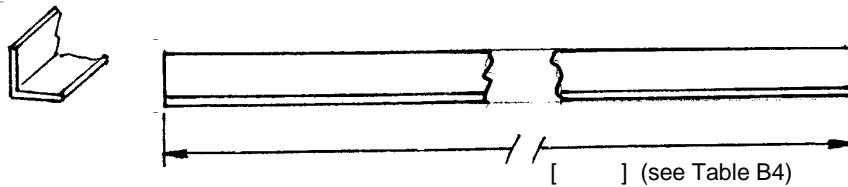
Stitch weld - 11 welds at least 60mm long at equal spacing

1.2 Weld on stiffeners, 30 x 3 flat bar x 500 long, top and bottom at centre of longitudinal.



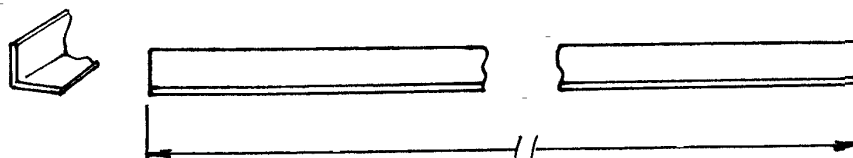
Weld on gusset, 60 x 6mm flat bar x 200mm long, at centre of bottom flange of channel

**2. Cross-Members (BC)**



2 pcs 60 x 60 x 6 angle

**3. Diagonals (BD)**



Measure and cut to fit during assembly (Stage 5)

4 pcs angle (see Table B4)

**Figure B8: Members for Base Panel**

**STAGE 4: Construction of Joining Brackets and drilling of Joining Members.**

Figure B9: Shows the details of the construction of the Joining Brackets (JL and JR) and of the drilling template needed for drilling the holes for bolting the modules together.

Table B5: Gives the materials list for the Joining Bracket

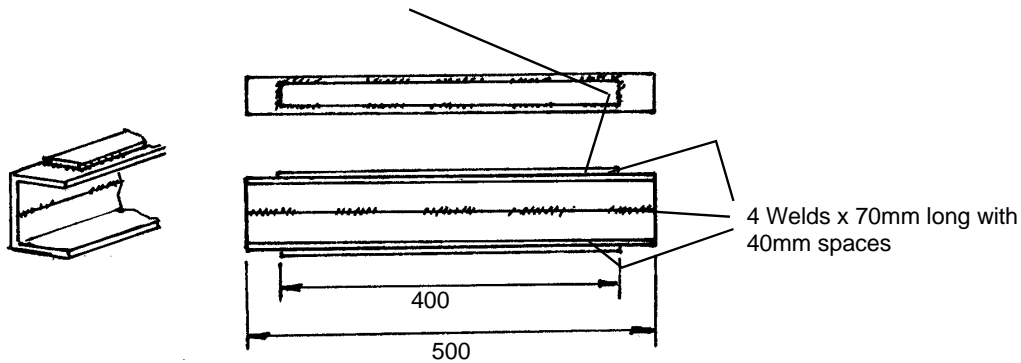
**Table B5: Materials List for Joining Bracket**

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Joining bracket	40x40x6mm angle	500mm	2	50x50x6mm angle	500	2
Stiffeners for bracket	30x3 flat bar	400mm	2	40x3 flat bar	400mm	2
Joining bolts/joint	M16	50mm	8	M20	50mm	8

Figure B10: Shows the details of the construction of the templates for drilling the Vertical members of the Side Panels (SV) and the cross-members of the Base Panels (BC).

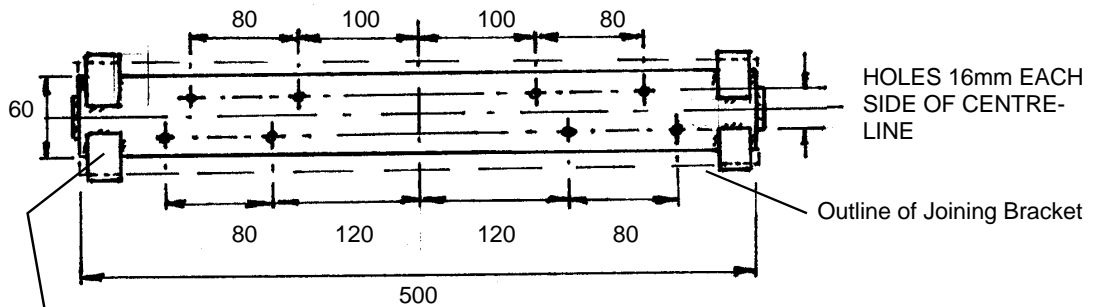
**1. Joining Bracket**

- 1.1 Cut 2 pcs angle (see Table B5) x 500mm and stitch weld to form channel
- 1.2 Weld on stiffeners, 30 x 3 (or 40 x 3) flat bar x 400mm long on top and bottom

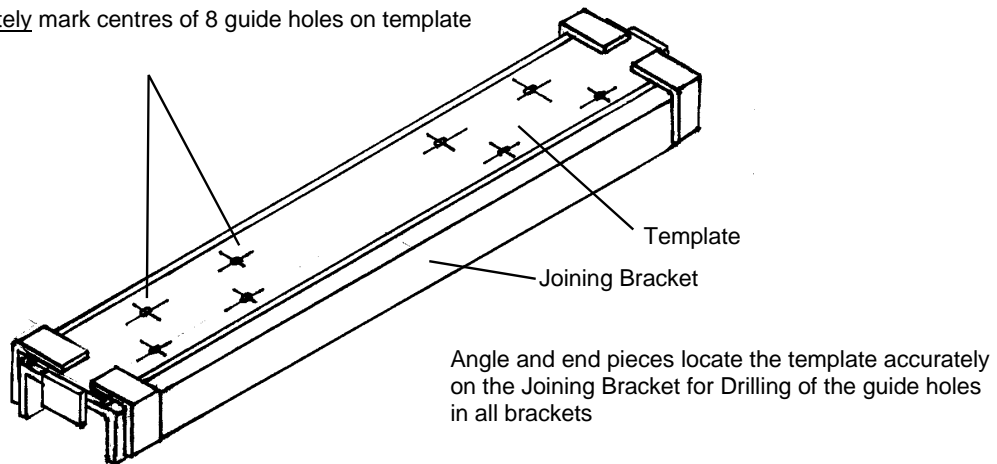


**2. Drilling Template for Side Panel Joints (1 needed)**

- 2.1 Cut pc 60 x 6mm flat bar x 500mm long



- 2.2 Weld on 4 pcs 40 x 40 x 6mm angle x 25mm long to locate the template centrally on the Joining Bracket
- 2.3 Weld on pc 30 x 3mm flat bar x 25mm long at each end of template
- 2.4 Accurately mark centres of 8 guide holes on template

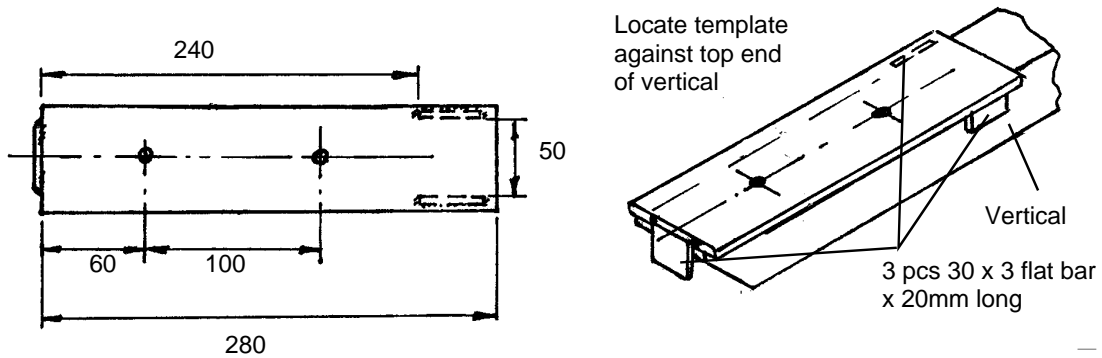


- 2.5 Drill guide holes 6 to 8mm diameter

**Figure B9: Details of Joining Bracket and Drilling Template**

**3. Template for Drilling Vertical Members (1 needed)**

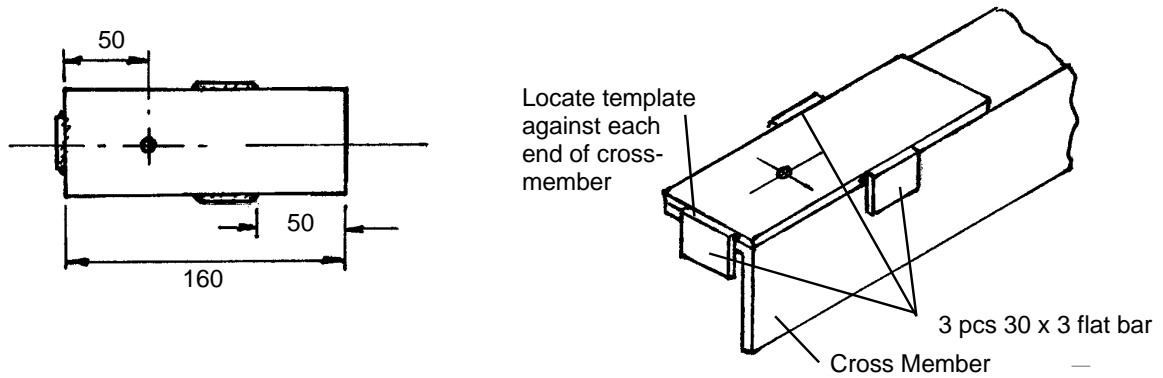
3.1 Cut pc 60 x 6mm flat bar x 280mm long



3.2 Weld on 3 pcs 30 x 3 flat bar x 20mm long to locate template on 50 x 50 x 6mm angle.

3.3 Accurately mark centres of 2 guide holes and drill 6 to 8mm diameter

**4. Template for Drilling Cross Members of Base Panel (1 needed)**



4.1 Cut pc 60 x 6mm flat bar x 160mm long

4.2 Weld on 3 pcs 30 x 3 flat bar x 20mm long to locate template on 60 x 60 x 6 angle cross-member

4.3 Accurately mark centre of guide hole and drill 6 to 8mm diameter

**Figure B10: Details of Templates for Drilling Vertical Members of Side Panels and Cross-Members of Base Panels**

### 5. Drill holes for joining Side Panels - starting at LH end

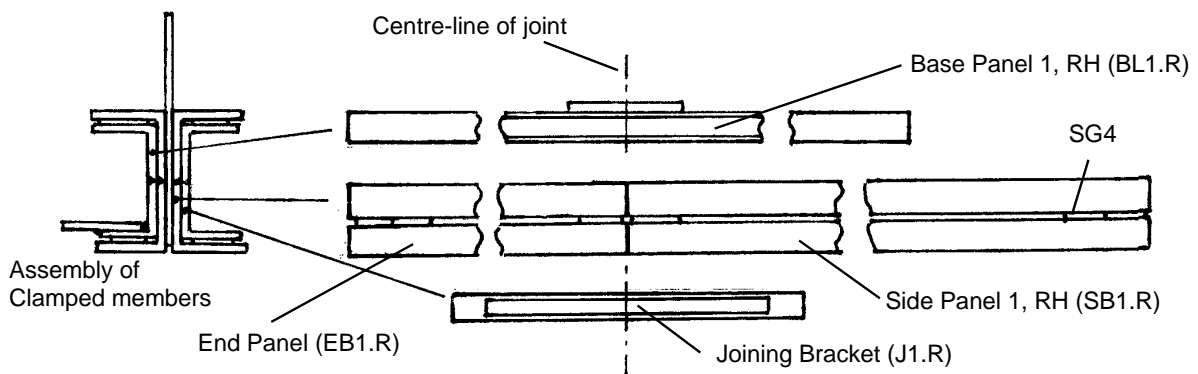
The panels and modules are bolted together by 8 bolts at each joint between the modules on each side of the footbridge as indicated in Figures B1 and B2.

At each joint an End Panel and Side Panel OR 2 Side Panels are bolted together by a Joining Bracket and Base Panel. The End and Side Panels are bolted together at their Bottom Longitudinals.

***It is essential that the parts that bolt together are drilled together to ensure that bolt holes line up during assembly of the bridge. Drilling must be done before the panels are welded up. All parts must be clearly and permanently marked so parts are assembled in the same combination as they are drilled. There is no interchangeability of parts.***

The procedure is explained in the steps below. This follows the order of modules shown in Figure B1. The joining parts at each joint are clamped accurately together and then pilot holes of 6 to 8mm diameter are drilled. Holes are then opened up to the required size:

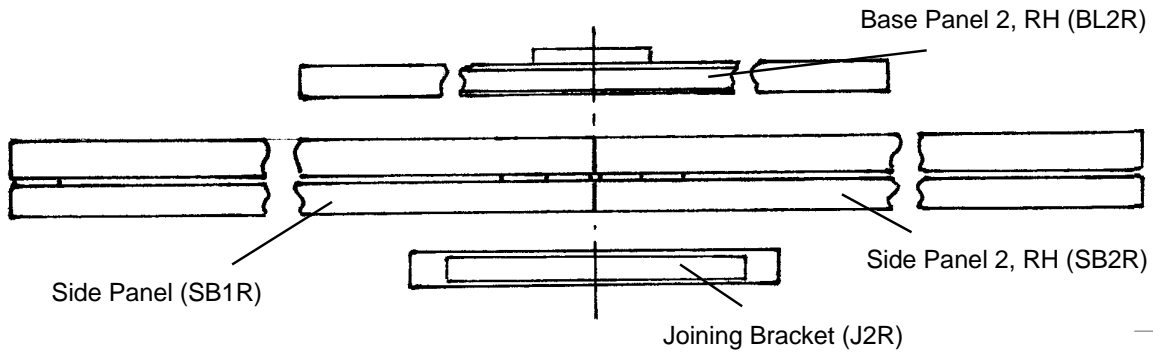
- 17mm for M16 bolts for 1.4m wide bridge
- 21mm for M20 bolts for 2.1m wide bridge



***Joint between End Panel and Side Panel 1 (Right Side)***

- 5.1 Use drilling template to drill guide holes in Joining Bracket J1.R (Number 1, Right Side).
- 5.2 Accurately mark the centre lines of the Base Panel and Joining Bracket and line up with the joint of End and Side Panels. Firmly clamp the 4 members together.
- 5.3 Drill through the guide holes in the Joining Bracket.
- 5.4 Remove clamps and drill out each hole to **17mm** diameter (1.4m wide bridge) or **21mm** (2.1m wide) in 2 or 3 stages.
- 5.5 Repeat Steps 1.1 to 1.4 to LH side members of Module.
- 5.6 Move on to joint between Modules 1 and 2

**Figure B11 (Sheet 1): Procedure for Drilling Bolt Holes**



- 5.7 Repeat Steps 5.1 to 5.4 for RH members shown in sketch and also for LH members.
- 5.8 Continue working in pairs of members as above to RH end of footbridge. The procedure is summarised in Table B6.

**Note:**

Make sure the Gussets on the Bottom Longitudinals are in the correct order for the diagonals. The diagonals attach to the double gusset. The slopes of the diagonals are shown by / and \ in Table B6 looking from the right side of the bridge as in Figure B1

**Table B6: Procedure for Drilling Holes for Joining Bolts**

RIGHT HAND SIDE OF BRIDGE				LEFT HAND SIDE OF BRIDGE			
Joint – see Figure B1	Members that are clamped and drilled together			Joint – see Figure B1	Members that are clamped and drilled together		
	End and/or Side Bottom Longitudinals	Joining Bracket	Base Panel Longitudinal		End and/or Side Bottom Longitudinals	Joining Bracket	Base Panel Longitudinal
E1.R to S1.R	EB1.R + SB1.R / \	J1.R	BL1.R	E1.L to S1.L	EB1.L + SB1.L / \	J1.L	BL1.L
S1.R to S2.R	SB1.R + SB2.R \ /	J2.R	BL2.R	S1.L to S2.L	SB1.L + SB2.L \ /	J2.L	BL2.L
S2.R to S3.R	SB2.R + SB3.R / \	J3.R	BL3.R	S2.R to S3.R	SB2.L + SB3.L / \	J3.L	BL3.L
S3.R to S4.R	SB3.R + SB4.R \ /	J4.R	BL4.R	S3.R to S4.R	SB3.L + SB4.L \ /	J4.L	BL4.L
S4.R to S5.R	SB4.R + SB5.R / \	J5.R	BL5.R	S4.R to S5.R	SB4.L + SB5.L / \	J5.L	BL5.L
S5.R to S6.R	SB5.R + SB6.R \ /	J6.R	BL6.R	S5.R to S6.R	SB5.L + SB6.L \ /	J6.L	BL6.L
S6.R to S7.R	SB6.R + SB7.R / \	J7.R	BL7.R	S6.R to S7.R	SB6.L + SB7.L / \	J7.L	BL7.L
S7.R to S8.R	SB7.R + SB8.R \ /	J8.R	BL8.R	S7.R to S8.R	SB7.L + SB8.L \ /	J8.L	BL8.L
S8.R to E2.R	SB8.R + EB2.R / \	J9.R	BL9.R	S8.R to E2.R	SB8.L + EB2.L / \	J9.L	BL9.L

**Note:**

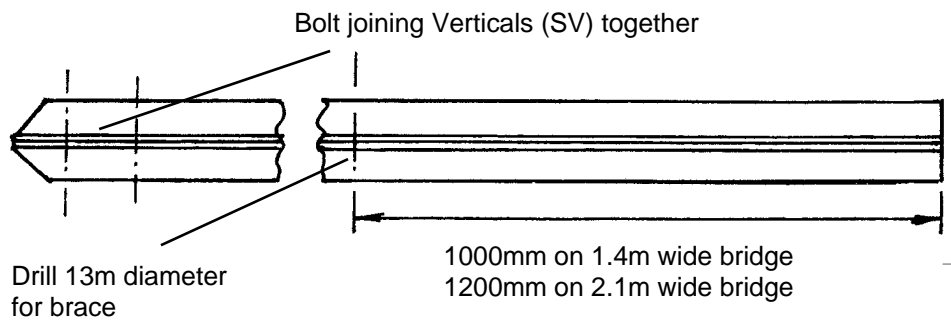
This is the procedure for 9 modules (8 full modules + 2 end modules). The procedure for less or more modules follows the same pattern.

**Figure B11 (Sheet 2): Procedure for Drilling Bolt Holes**

**6. Drill holes in Side Panel Verticals and Base Panel Cross-Members**

- 6.1 Locate correct template accurately on each member (see Figure B10) and drill through guide hole(s).
- 6.2 Drill out each hole to **13mm** diameter.
- 6.3 Drill the holes in the vertical members for the side braces (STAGE 6).

Bolt the joining members together as shown below and drill 13mm hole for an M12 bolt at position shown.



**Figure B11 (Sheet 3): Procedure for Drilling Bolt Hole**



**STAGE 5: Construction of Assembly Jigs and Assembly of Panels**

***It is essential that panels are assembled and welded up on a jig to ensure shape and size are consistent.***

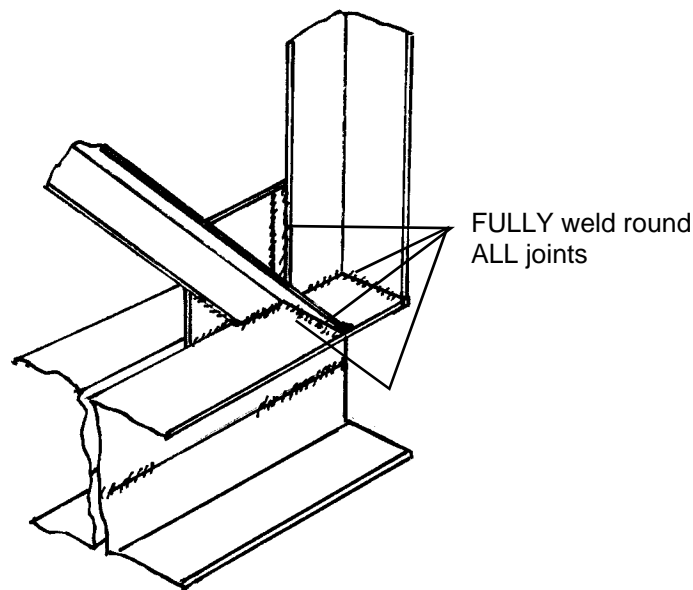
Joining parts must be bolted together before welding to ensure holes line up when the panels are assembled.

Figure B12: Shows the details of the assembly jigs

Figure B13: Shows the assembly and welding up of the base panels

Figure B14: Shows the assembly and welding up of the side panels

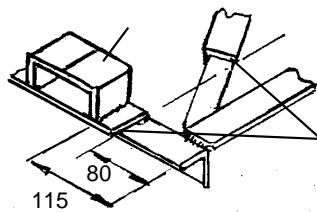
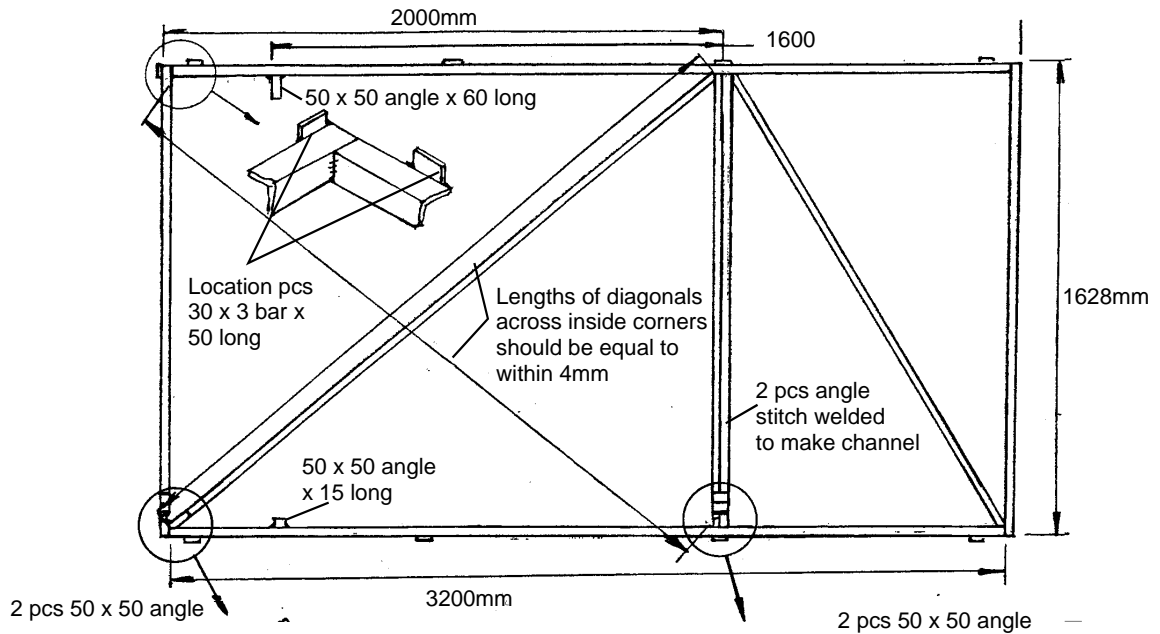
***Note: The assembled panels are shown set up on the jig. The members are shaded so that they show up clearly.***

**Welding Instructions**

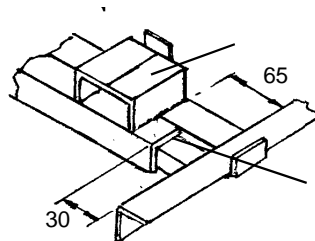
When the panel has been tack-welded and checked for correctness ALL joints should be fully Welded.

***It is important to weld BOTH between Members and Gussets and also between the Members (angle to angle, angle to channel).***

1. Cut main frame members from 50 x 50 x 6 angle and tack weld, checking all corners are square
2. Build jig on a flat surface so that top face for assembling panels is flat.
3. Check lengths of diagonals and when within 4mm, cut and weld in diagonals.
4. Weld up frame



Cut 50 x 50 angle and  
weld in 160mm length  
of 40 x 40 angle



Cut 50 x 50 angle and  
weld in pc 40 x 40  
angle x 100mm long

(i) Jig for 1.4m Wide Footbridge

Figure B12 (Sheet 1): Details of Assembly Jigs

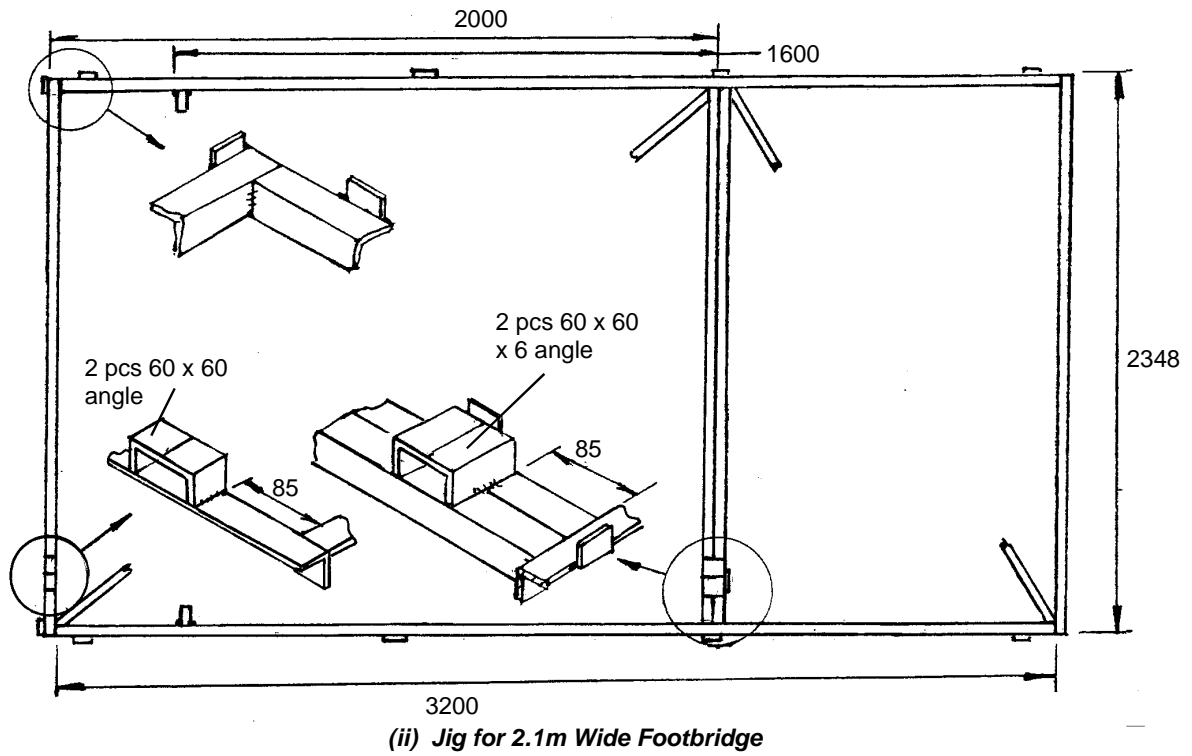


Figure B12 (Sheet 2): Details of Assembly Jigs

**STAGE 5.1: Assembly of Base Panels****STEP 1: Assembly of Base Panels B1 and B2 (Left Hand End)**

- 1.1 Bolt together: Left Side – SB1.L, SB2.L, J2.L, BL1.L, BL2.L  
Right Side – SB1.R, SB2.R, J2.R, BL1.R, BL2.R
- 1.2 Clamp the Left side and Right side assemblies on the jig, accurately lining up the joint between SB1 and SB2 on the joint position on the jig on each side.
- 1.3 Bolt together the joining Cross Members for Base Panels 1 and 2 (BC1.R, BC2.L). Position accurately in the jig at the joint of the Base Panels and tack weld both in position on their respective base frames.
- 1.4 Position Cross Member BC1.L (undrilled member) at left hand end of Base Panel 1 and tack weld in position.
- 1.5 Unbolt joints to remove Base Panel 1 and Side Bottom Longitudinals SB1.L and SB1.R.
- 1.6 Measure, cut and fit diagonals for Base Panel 1 and complete welding up. All joints must be fully welded.

**STEP 2: Assembly of Base Panels B2 and B3**

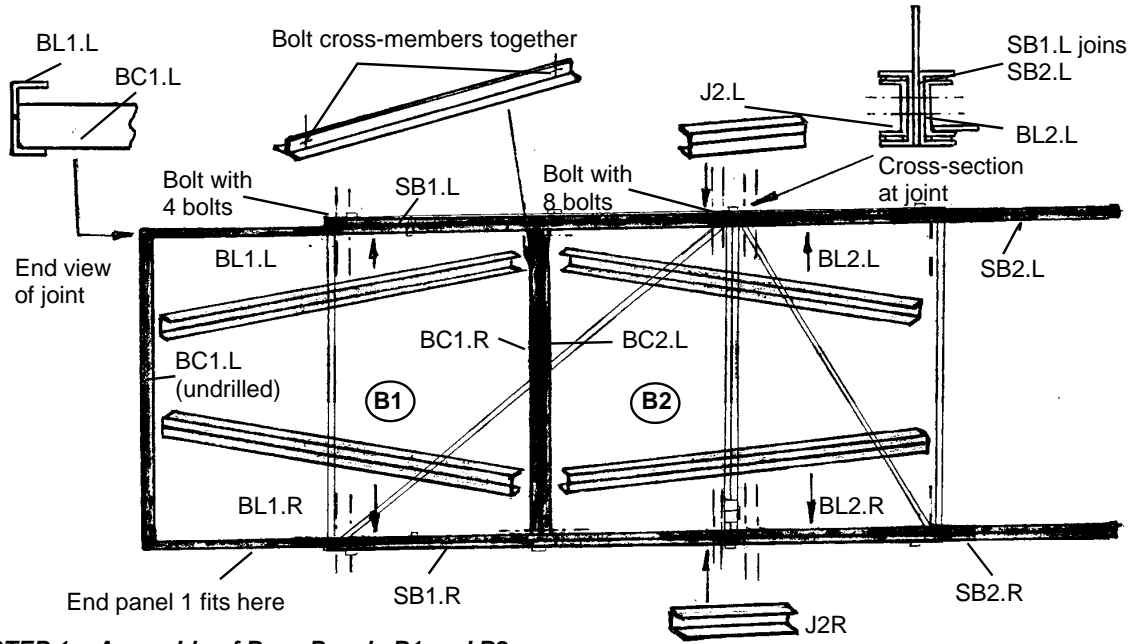
- 2.1 Bolt together: Left Side – SB2.L, SB3.L, J3.L, BL2.L, BL3.L  
Right Side – SB2.R, SB3.R, J3.R, BL2.R, BL3.R
- 2.2 Clamp Left and Right assemblies on jig, accurately lining up joints between SB2 and SB3 on the joint positions on the jig.
- 2.3 Bolt together Cross Members BC2.R and BC3.L. Locate accurately in position and tack weld them to their respective Base Frames.
- 2.4 Unbolt joints to remove Base Panel B2 and bottom longitudinals SB2.L and SB2.R.
- 2.5 Fit diagonals and complete welding up Base Panel B2.

**STEPS 3 to 9 Assembly of Base Panels B4 – B9 (If there are 10 Side Panels).**

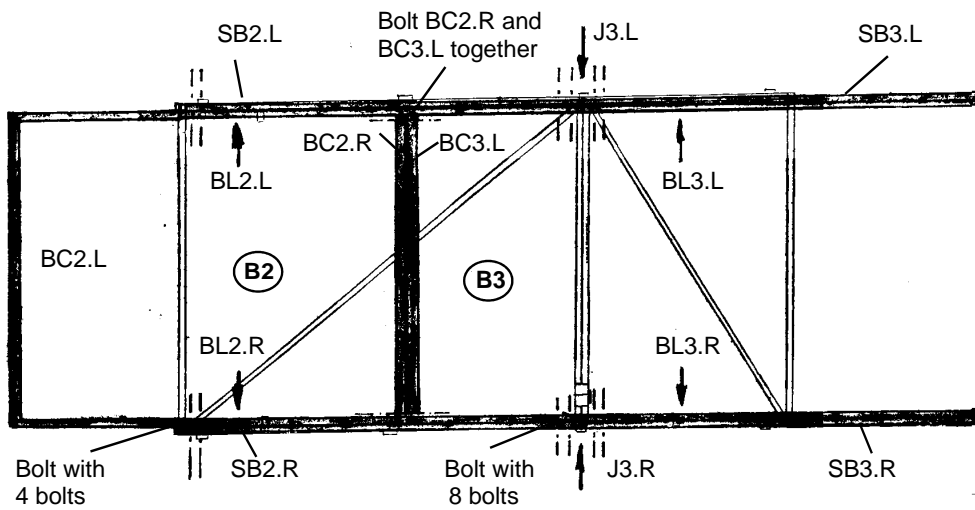
Repeat Step 2 for each joint in sequence to the right hand of the bridge.

**STEP 10: Assembly of Base Panels B10 and B11 (Right Hand End)**

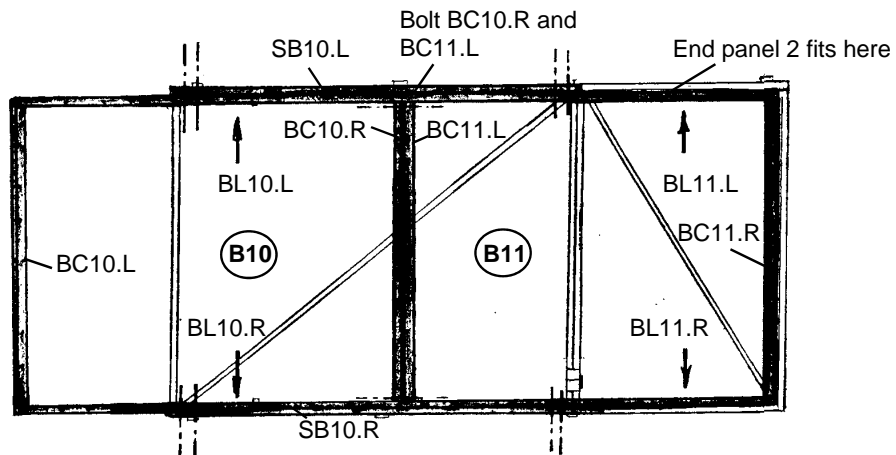
- 10.1 Bolt together: Left Side – SB10.L, J11.L, BL10.L, BL11.L.  
Right Side – SB10.R, J11.R, BL10.R, BL11.R.
- 10.2 Clamp Left and Right assemblies on jig.
- 10.3 Bolt together Cross Members BC10.R and BC11.L. Fit in position and tack weld them to their respective base panels.
- 10.4 Fit end Cross Member, BC11.R, (undrilled) and tack weld in position.
- 10.5 Unbolt joints, measure and cut diagonals for the 2 base panels. and complete welding of Base Panels B10 and B11.



**STEP 1: Assembly of Base Panels B1 and B2**



**STEP 2: Assembly of Base Panels B2 and B3**



**STEP 10: Assembly of Base Panels B10 and B11**

**Figure B13: Assembly of Base Panels**

**STAGE 5.2: Assembly of Side Panels (Left Side)****STEP 1: Assembly of End Panel E1 (Left End)**

- 1.1 Bolt together EB1.L, J1.L and SB1.L.
- 1.2 Clamp on the jig with the joint between EB1.L and SB1.L accurately located on the joint centre-line of the jig.
- 1.3 Bolt together verticals EV1.L and SVL1.L and locate on jig. Tack weld EV1.L to EB1.L and SVL1.L to SB1.L.
- 1.4 Measure and cut the outside face diagonal ED and tack weld in position on the End Panel gussets.
- 1.5 Unbolt joint and remove End Panel E1.L. Fit deck-side diagonal and complete welding of all joints.

**STEP 2: Assembly of Side Panel S1**

- 1.1 Bolt together Side Panel Longitudinals, SB1.L and SB2.L with Joining Bracket J2.L.
- 1.2 Clamp on jig with joint accurately located on the joint centre-line.
- 1.3 Rest Top Longitudinal ST1.L on the raised supports on the jig with the gussets resting on the supports and the mitre joint with the left side vertical aligned for welding.
- 1.4 Bolt together verticals SVR1.L and SVL2.L. Locate on jig with lower end lined up with the joint of the bottom longitudinals and the top end lined up for the mitre joint with the top longitudinal. Tack weld all the joints.
- 1.5 Measure and cut the outside face diagonal SD and tack-weld in position. Note that the upper end rests on the gusset and has a short length of 40 x 40 x 6 angle to link it to the angle pc of the Top Longitudinal.
- 1.6 Unbolt joint and remove Side Panel S1.L. Cut the deck-side diagonal noting that this fits directly against the angle piece of the Top Longitudinal. Fit in position and fully weld all joints.

**STEPS 3 to 9: Assembly of Side Panels S2 to S9**

Repeat procedure of STEP 2 for each pair of Side Panels in sequence working towards the right hand end.

**STEP 10: Assembly of Side Panel S10.L and End Panel E2.L (Right Hand End)**

- 10.1 Bolt together Bottom Longitudinals SB10.L and EB2.L with Joining Bracket J11.L.
- 10.2 Clamp on jig with the joint accurately positioned.
- 10.3 Locate Top Longitudinal ST10.L in position on supports, aligning mitre joint with SVL10.L.
- 10.4 Bolt together Verticals SVR10.L and EV2.L and locate on jig lining up joints to top and bottom longitudinals. Tack weld bottom ends to their respective Bottom Longitudinals. Tack weld verticals for Panel S10 to Top Longitudinal.
- 10.5 Measure and cut outside face diagonals SD10 and ED2 and tack weld them in position on the Side and End Panels respectively.
- 10.6 Unbolt joint. Complete Side Panel S10.L and End Panel E2.L by fitting deck-side diagonals and welding up all joints.

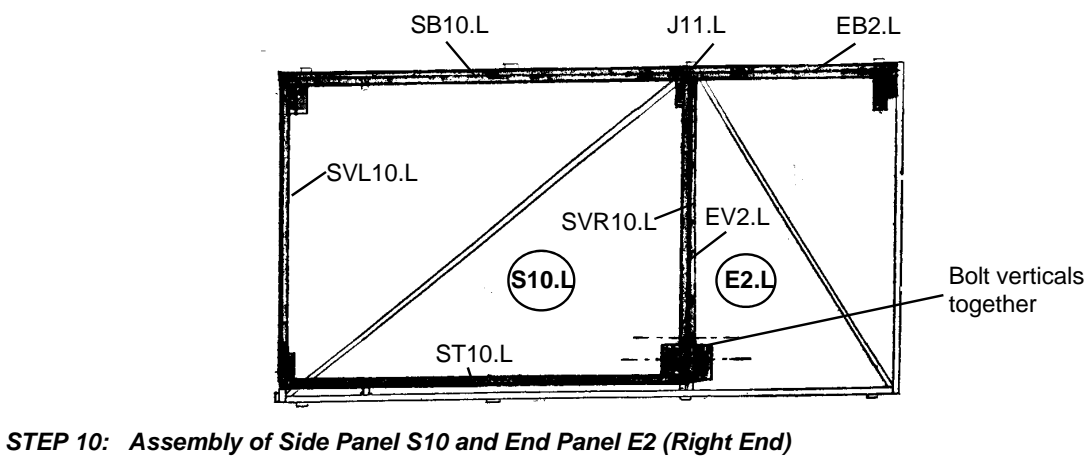
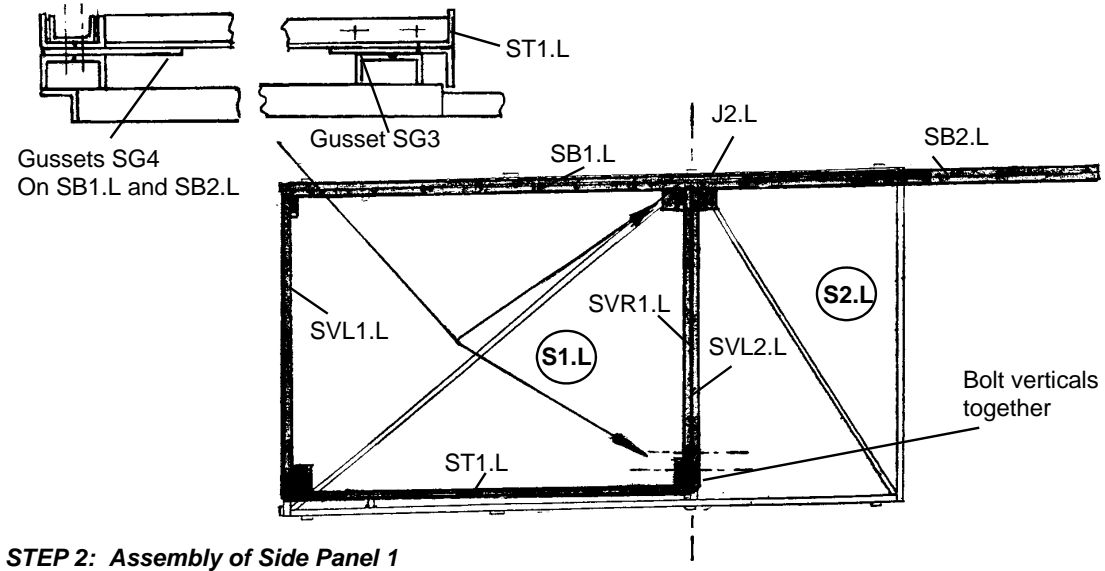
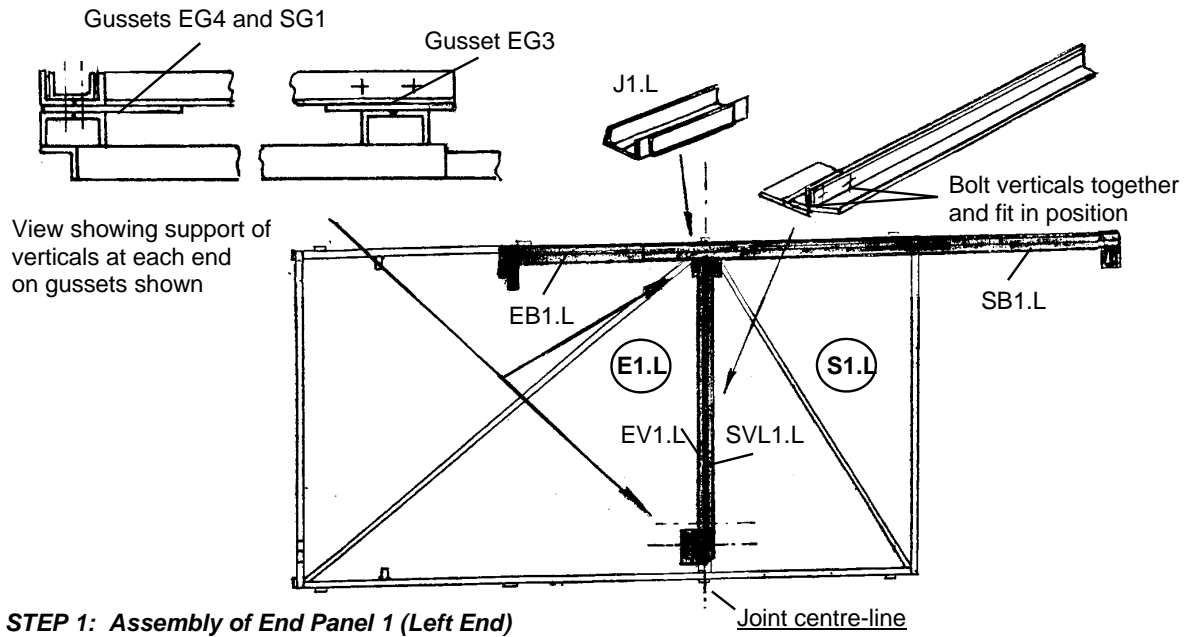


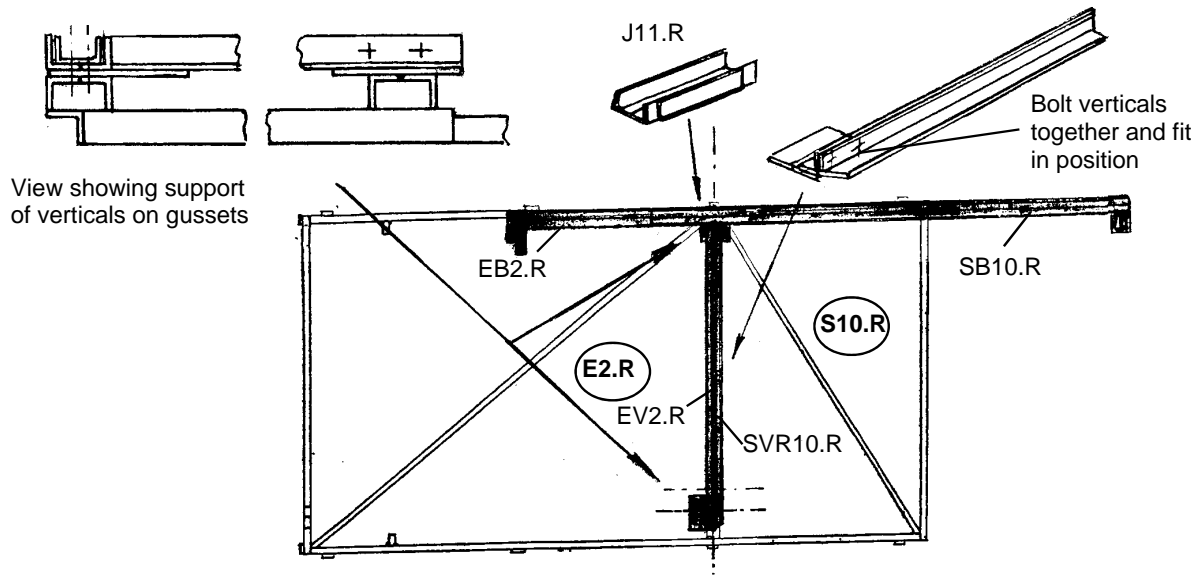
Figure B14: Assembly of Side Panels (Left Side)

**STAGE 5.3: Assembly of Side Panels (Right Side)**

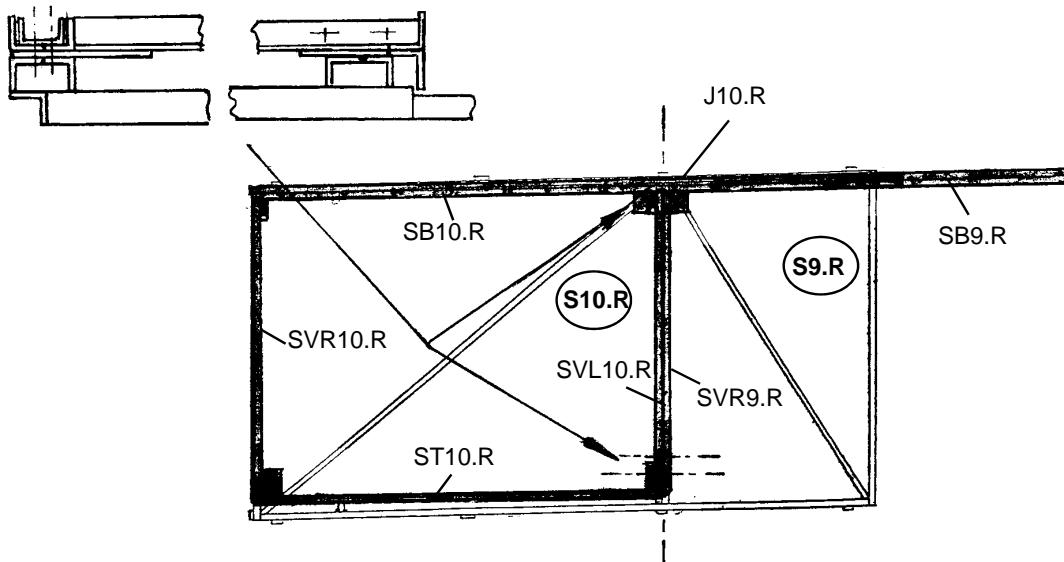
This follows the same procedure as for the Left Side panels but starting from the Right Hand end and then working in sequence to the Left Hand end.

Therefore STEP 1 is the assembly of the right hand End Panel 2 and Step 10 the assembly of Side Panel 1 and Left hand End Panel 1.

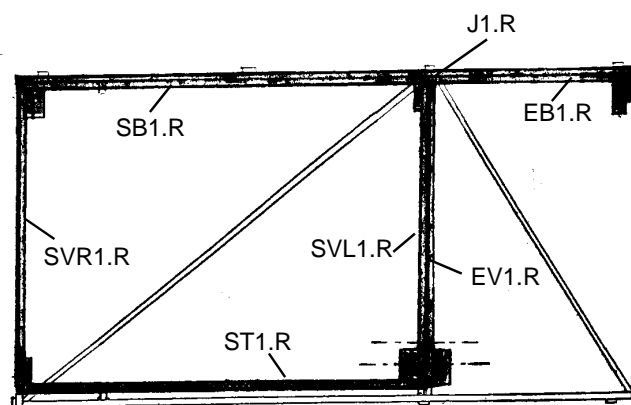




**STEP 1: Assembly of End Panel 2 (Right hand end)**



**STEP 2: Assembly of Side Panel 10**



**STEP 10: Assembly of Side Panel 1 and End Panel 1 (Left Hand end)**

**Figure B15: Assembly of Side Panels (Right Side)**

## **STAGE 6: Assembly and Testing of Footbridge**

When all panels have been completed the footbridge should be fully assembled at the workshop. This has three purposes:

1. To ensure that all panels bolt together before transporting the footbridge to site.
2. To complete the construction of the footbridge by adding the bearing feet at each end and the stiffening braces for the verticals.

The bearing feet are best fitted when the bridge is assembled to ensure that they sit evenly on the ground. The stiffening braces are best fitted after proof testing so that they are not in the way of the footbridge deflection whilst testing.

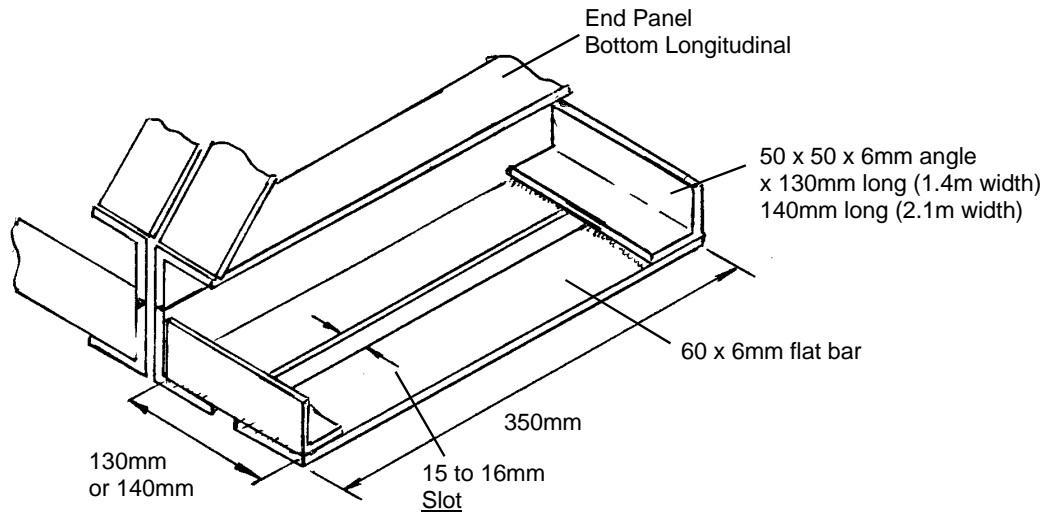
3. To proof test the footbridge (see Section 5.2.7)

### **6.1 Fitting Bearing Feet**

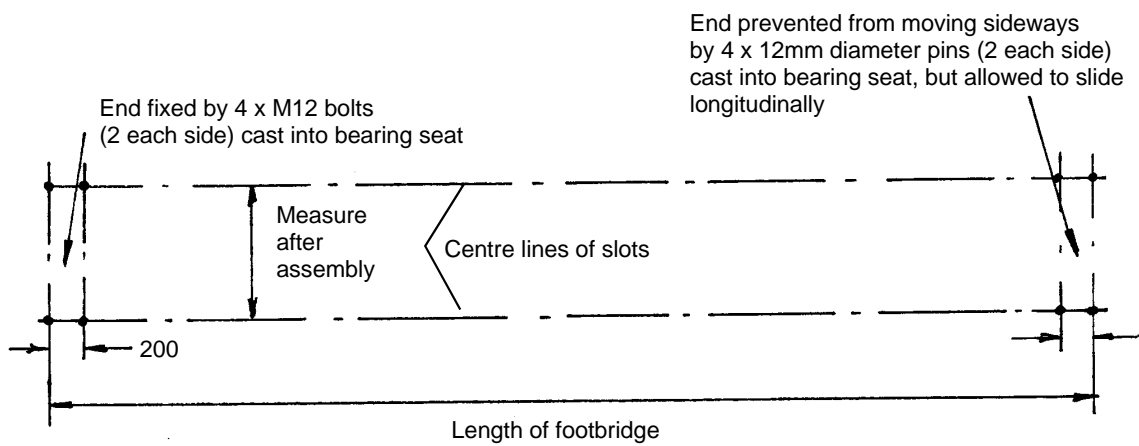
The construction is shown in Figure B16. A bearing foot is required at each side at each end of the bridge, 4 in total.

### **6.2 Fitting the Stiffening Braces for the Verticals**

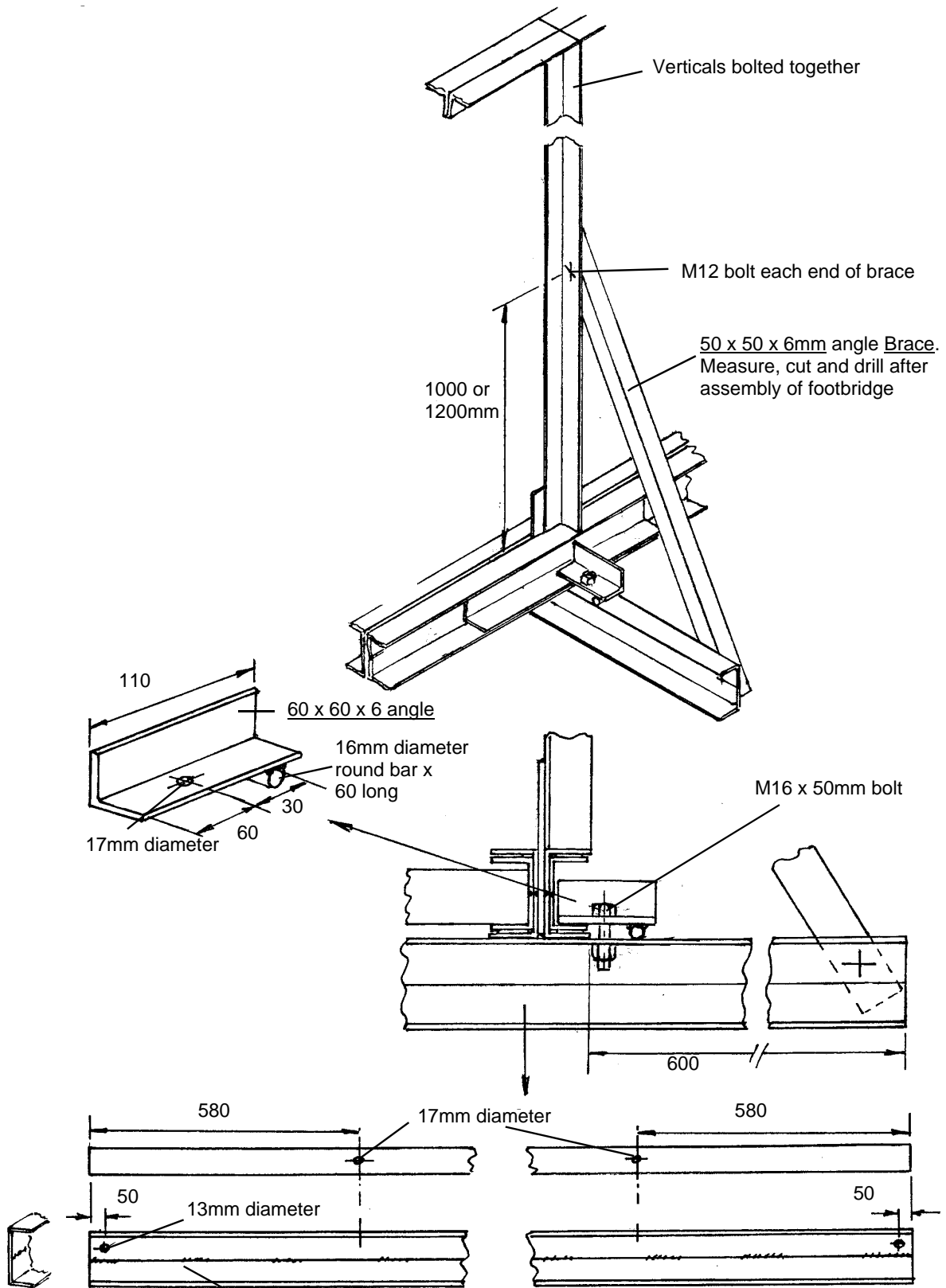
The details of the Stiffening Braces are shown in Figure B.17. At each module joint a cross-beam is clamped under the bottom longitudinals to which are bolted angle braces to the Verticals on each side of the footbridge. The braces provide sideways support to the pair of verticals that are bolted together at each joint.



**Bearing Feet at each end corner of bridge**



**Figure B16: Bearing Supports and Anchors for Footbridge**



Channel made by stitch welding together 2 pcs of 60 x 60 x 6mm angle. Measure and cut after assembly of bridge. Note: it protrudes 600mm each side of bridge.

**Figure B17: Details of Stiffening Braces for Verticals**

## **APPENDIX C**

### **CONSTRUCTION OF A FOOTBRIDGE USING A SCRAP TRUCK/BUS CHASSIS<sup>3</sup>**

Figure C1 shows the details of a footbridge that uses 2 scrap truck chassis as the support beams for the deck. The footbridge has a total span of 21.7m with a central concrete pier where the chassis meet.

Figure C2 shows a typical scrap chassis. They are reasonably common in some countries and can provide low-cost steel beams for construction of a cost-effective footbridge. The depth of the beams needs to be at least 180mm with a metal thickness of 8mm for a span of 10m.

A chassis may need some straightening and repair or replacement of cross-members to make it suitable for a footbridge.

The basic construction of the footbridge of Figure C1 is shown in Figure C3. The deck and guard rails are supported by 150 x 75mm timber cross-beams resting on the chassis at 1m intervals. The cross-beams need to be fixed on the chassis. Figure C3 shows one method in which angle brackets are welded to the chassis and the beams screwed to the brackets. Other methods are possible.

The deck comprises sheets of 3mm thick steel that rest on the cross-beams. The joints are sealed by 50 x 25mm strips of treated timber nailed to the cross-beams through holes drilled in the sheet.

---

<sup>3</sup> Information and photographs provided by the Kisii Training Centre, Kenya.



**Figure C1: Footbridge Using a Scrap Truck Chassis for the Beams Supporting the Deck**



**Figure C2: Typical Scrap Truck Chassis**

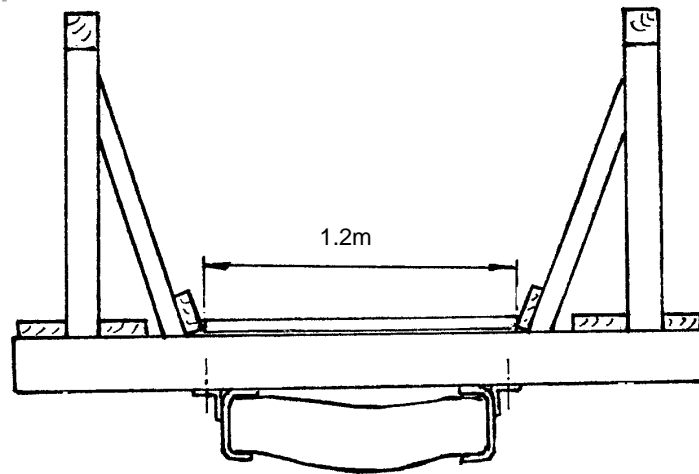
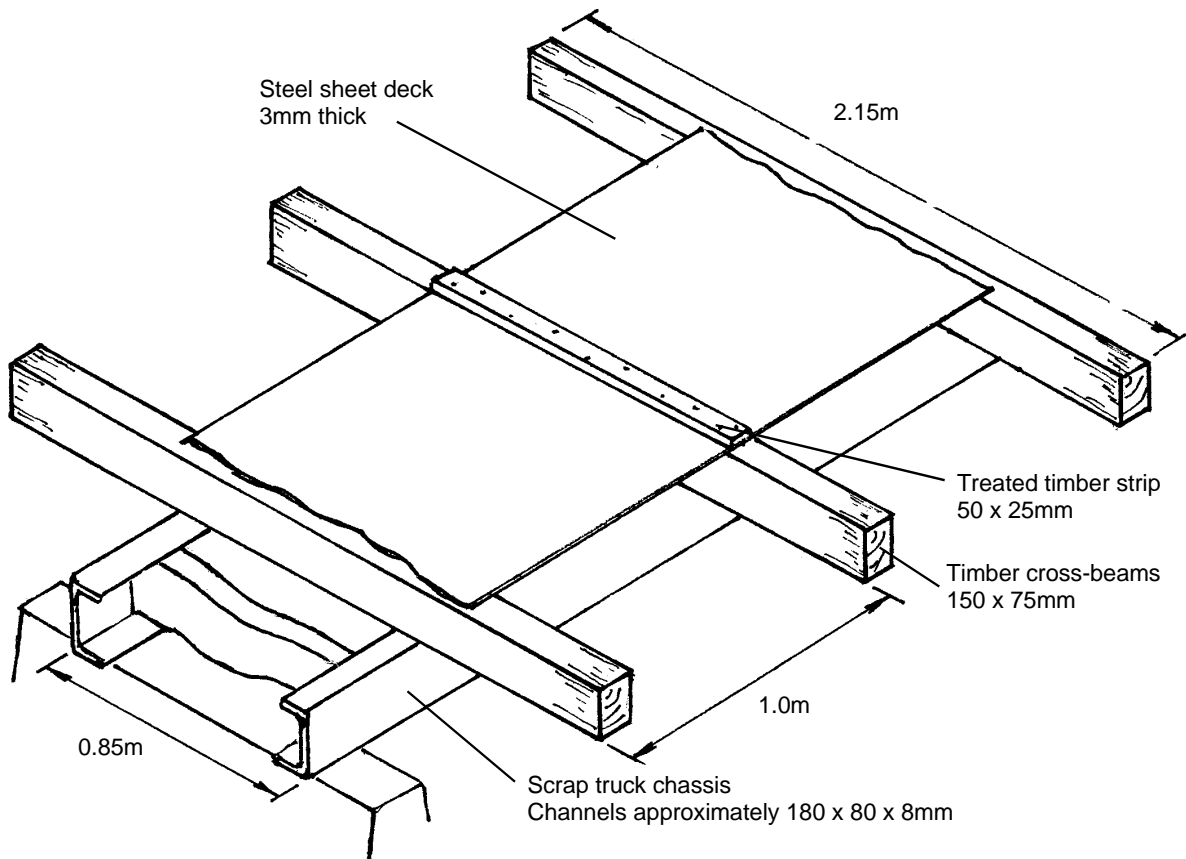


Figure C3: Construction Details of Footbridge with Scrap Truck Chassis Beams





## APPENDIX D

### CONTACT DETAILS OF SOURCES OF FURTHER INFORMATION

- ***American Institute of Sustainable Science and Technology Inc***

211-TIC Oakdale Research Campus, Iowa City, 1A 52242-5000, USA  
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- ***Bridges to Prosperity, Inc.:***

1674 Cuba Island Lane, Hayes, Virginia 23072 – 3910, USA  
Web - [www.bridgestoprosperty.org](http://www.bridgestoprosperty.org); Email - [kfrantz@bridgestoprosperty.org](mailto:kfrantz@bridgestoprosperty.org)

- ***Countryside Commission of Scotland:***

Perth, Scotland  
Web - [www.snh.org.uk](http://www.snh.org.uk); Email - [pubs@snh.gov.uk](mailto:pubs@snh.gov.uk)

- ***Developing Technologies:***

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- ***ILO/ASIST:***

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Email – [KTC@form.net.com](mailto:KTC@form.net.com); Tel/Fax: 254 381 21634

- ***Outdoor Structures Australia:***

Old College Road, P.O. Box 517, Gatton Q 4343, Australia  
Web - [www.outdoorstructures.com.au](http://www.outdoorstructures.com.au); Email - [Timber.Tek@uq.net.au](mailto:Timber.Tek@uq.net.au)

- ***SKAT Foundation:***

Vadianstrasse 42, CH-9000 St. Gallen, Switzerland  
Web - [www.skat-foundation.org](http://www.skat-foundation.org); [www.skat.ch](http://www.skat.ch); Email - [foundation@skat.ch](mailto:foundation@skat.ch)

- **Trail Bridges in Nepal:**

His Majesty's Government of Nepal, Ministry of Local Government, Department of Local Infrastructure and Agricultural Roads, GPO Box 8975, EPC 797 Kathmandu, Nepal  
Email - [tbs@nepaltrailbridges.org](mailto:tbs@nepaltrailbridges.org)

TBSSP (Trail Bridge Sub-Sector Project), HELVATAS Nepal, Swiss Association for International Cooperation, P.O. Box 688, Kkathmandu, Nepal  
Web - [www.helvetasnepal.org.np](http://www.helvetasnepal.org.np); Email – [tbssp@helvetas.org.np](mailto:tbssp@helvetas.org.np)

- **TRADA Technology Ltd:** (Timber information)

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- **TRL (Transport Research Laboratory):**

Crowthorne House, Nine Mile Ride, Wokingham, Berkshire, RG40 3GA, UK  
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