

FOOTBRIDGES

A Manual for Construction at Community and District Level



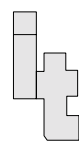
SUPPLEMENT A: CASE STUDY

Construction and Installation of a Modular Steel Truss Footbridge



Prepared for the
DFID Department for
International
Development,
UK.

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June 2004

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“This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID”.

1. INTRODUCTION

1.1 BACKGROUND

A manual has been produced on the selection, design, construction and installation of footbridges¹. As part of the preparation of the manual a test programme was carried out with three main objectives:

1. To test the design of a modular steel truss footbridge developed by the project
2. To test the clarity and content of the sections of the manual dealing with planning, construction and installation of footbridges and to make improvements in presentation where needed
3. To provide a case study to illustrate the construction and installation of the steel truss footbridge and to provide useful information for the installation of other types of footbridges.

This report gives details of the case study and its findings. It provides a practical example of some of the guidelines contained in the manual.

A suitable partner to carry out the test programme was found in Sri Lanka where ITDG (Intermediate Technology Development Group) S.E. Asia were already involved in footbridge installation and were able to identify a site where there was an immediate need to provide a footbridge to improve access for local communities.

The steel truss footbridge was designed to cover the span range of 10 to 20m where there are limited alternative design options. Below 10m there are a number of design options including timber and reinforced concrete footbridges. Above 10m these types require intermediate pier supports which is not always possible or desirable. Above 20m spans, cable suspension bridges are an option up to spans of 150m or more.

Standard designs of steel truss footbridges are available from Nepal. These involve the accurate manufacture of individual members in a workshop and then assembly by bolting on site. They are particularly suited to hilly areas where parts may have to be carried to site on mountain paths and tracks. However, there are many situations where it would be more appropriate to construct truss footbridges in modular form to reduce the difficulties and time of manufacture and assembly. No standard designs were found for this type and therefore a design was developed as part of the preparation of the manual to increase the options that are applicable to community and district implementation.

The design involves the manufacture of panels in a workshop and then transport to site where they are bolted together. The advantages of the design are considered to be:

- It can be readily be manufactured in a medium sized workshop and assembled on site by the community with some technical assistance

¹ “ FOOTBRIDGES – A Manual for Construction at Community and District Levels”: produced by IT Transport for the UK Department for International Development, June 2004.
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- It requires much less drilling and accurate lining up of holes than assembling individual members
- It avoids the use of piers up to 20 to 25m and above this span range requires less than half the number of piers needed by timber and reinforced concrete footbridges
- The steel sections needed, angle of 40 x 40 x6mm to 60 x 60 x6mm, are readily available in most countries
- The overall cost is likely to be similar to a sawn timber footbridge and less than a reinforced concrete footbridge. Also the availability of good quality timber is tending to decrease and costs to increase in some countries
- The life of a properly maintained steel footbridge should be at least 40 years, which will be considerably longer than a timber footbridge.

The modular steel truss footbridge is a valuable addition to design options for construction at community and district level, particularly for spans in the range 10 to 20m. It is mainly suited to flat to undulating terrain where panels can be carried to site by 2 to 4 persons. The maximum weight of a panel will be about 100kg.

1.2 CONTENT

These guidelines follow on from the manual in providing a practical example of the construction and installation of a modular steel truss footbridge in Sri Lanka.

Step-by-step instructions for the manufacture of a footbridge are contained in a separate document (Supplement B) for use by a workshop. The working drawings are presented mainly in 3-dimensional form with short notes of explanation so that they do not require an understanding of engineering drawing conventions. A set of drawings in A3 size is included for ease of use by a workshop.

The guidelines cover the following aspects of the bridge construction and installation:

- Section 2* - describes the findings of a site survey to identify the specifications of the footbridge
- Section 3* - outlines the step-by-step procedure of manufacturing the footbridge. It is illustrated by photographs of specific features of the procedure. The assembly and testing of the footbridge in the workshop is also described. Details of the design of the footbridge are contained in Supplement B which is identical to Appendix B of the manual in order to link it directly to the manual.
- Section 4* - describes the installation of the footbridge, covering construction of abutments, transport of panels to site, construction of a cable-way to install the bridge and the installation procedure.
- Section 5* - Summarises the findings and conclusions of the case study.

2. DETAILS OF SITE

2.1 GENERAL

The site is shown in Figure 2.1. The river is in a valley in an area of undulating terrain. There are paddy fields on both sides of the river. The river is about 12 to 15m wide. A well-used footpath crosses the river at the site, the present crossing of the river being by a ford. In the dry season the water is about knee high but in the rainy season the river is often impassable. This constrains the access of people to various facilities including preventing about 50 children from attending school. There is, therefore, an urgent need for a footbridge.

The crossing is about 400m from a motorable gravel road. The final 30m is by concrete steps dropping down the bank to the river.

2.2 SITE SURVEY

The site survey followed the method presented in Appendix A of the manual. It gave the profile of the river crossing shown in Figure 2.2. The maximum water level shown is the reported highest flood level expected over a 5-year period. The site survey located the footbridge abutments as shown in the figure, giving a required span of about 17m. The soil on the bank was classified as 'shale and soft sandstone'. The maximum slope of the banks is about 30° so that there was no constraint on placement of the abutments and they could be located to give the least span.

Traffic surveys gave the following data on potential users of the footbridge:

Pedestrians - up to 200 per day, maximum of 10 to 15 on bridge at any time

Bicycles - up to 8 per day

Livestock - up to 10 cows/oxen per day

Footbridge specifications: based on the site survey data the specifications were identified as follows –

Width – 1.4m (It could be less based on present users but it was considered that an allowance should be made for possible future use by carts and 3-wheeler motor scooter based vehicles)

Span – 17.1m



The site where the footbridge was located with women crossing at the ford. Note the steps leading down to the river.

Figure 2.1: Site for the Footbridge

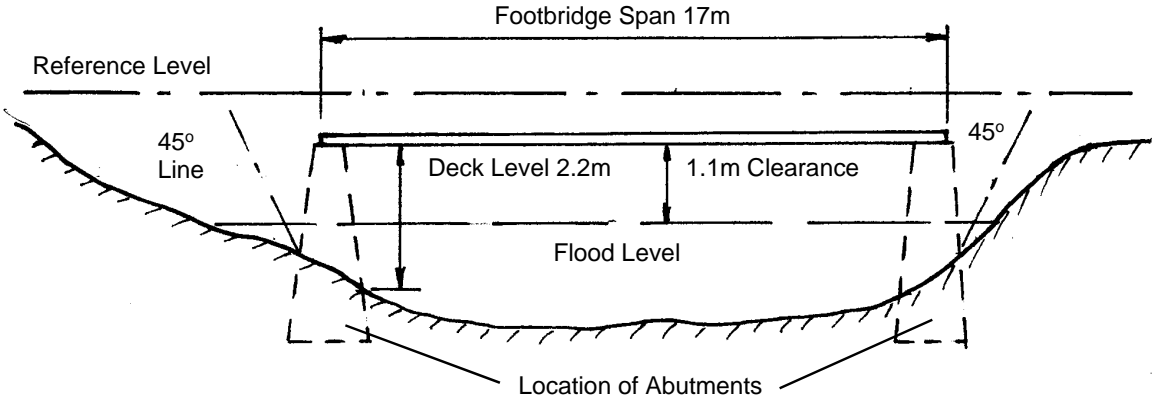


Figure 2.2: Profile Across River Crossing
(Note that the vertical scale is 2 x the horizontal scale to clarify detail)

3. MANUFACTURE OF FOOTBRIDGE

3.1 DETAILS OF DESIGN

The steps in the manufacture of the footbridge are explained by the working drawings and instructions set out in Appendix B of the Manual and in Supplement B. The details of the design are given in Section B2 of the Appendix.

From Table B1 the Module Length for a 17m span footbridge is 1.9m. The height of a 1.4m wide footbridge is 1.5m giving Side Panel Verticals (SVL and SVR) of 1.45m. The footbridge therefore comprises the following components;

Side Panels (SL and SR):	8 Panels of Type A, with diagonal top left to bottom right; (See Figure B3); 8 Panels of Type B, with diagonal bottom left to top right All Panels are of length ML = 1.9m and H=1.45m (Figure B3)
End Panels (EL and ER):	4 Panels (2 pairs) of length ML/2 =0.95m and H = 1.45m (Figure B5)
Base Panels (B):	9 panels of length ML = 1.9m and Width 1.5m (Figure B7)
Joining Brackets (J):	9 Brackets EACH side, total 18
Stiffening Braces (Fig. B17):	9 sets, 1 for each joint between modules

3.2 MANUFACTURE OF THE PANELS

Instructions for the manufacture of the panels are given in Section B3 of the Appendix (and Supplement B) – Stages 1 to 5. Various steps are clarified in the photographs on the following pages.

- Figures 3.1 and 3.2 show steps in the manufacture of the Bottom Longitudinals for the Side and End Panels
- Figures 3.3 and 3.4 show the templates and drilling procedure for the bolted joints between the footbridge modules
- Figures 3.5 to 3.7 show the assembly of Bottom, End and Side panels in an assembly jig.

3.3 ASSEMBLY AND TESTING OF THE FOOTBRIDGE IN THE WORKSHOP

The footbridge was assembled in the workshop (Stage 6 of Section B3) to make sure that all the panels bolted together satisfactorily and any corrections needed could be carried out before transporting the bridge to site. The drilling and assembly procedures used for the panels proved very satisfactory and no problems were found in bolting the modules together. *This confirms the need to follow the procedures set out in Stages 4 and 5 of*

Section B3 and in particular to clearly identify all the panels and brackets as they are assembled.

- Figures 3.8 and 3.9 show steps in the assembly of the footbridge

After assembly, the footbridge was tested in the workshop to make sure it performed satisfactorily and to check the design. Ideally this should be done with crowd loading but this was not found possible and 6 small vehicles were used instead. This gave a live load of about 22% of the design load, but well above the expected maximum service load of the footbridge.

Testing – the set up is shown in Figure 3.9. Electrical resistance strain gauges were attached at critical locations of the panels to check stresses. This is NOT part of the normal requirement for testing but was carried out to check the design analysis in order to confirm the design concept for the modular truss footbridge. The measured stresses were at least 10% lower than those from the analysis. The central vertical deflection of the bridge was measured as 4mm giving a predicted deflection at the design load of 20mm which is much below the allowable deflection of 68mm for a 17m span footbridge. The tests therefore confirmed that the design concept is satisfactory.

3.4 PAINTING THE FOOTBRIDGE

To prolong its life the footbridge needs to be thoroughly painted to protect the steel from corrosion. This may be done at the workshop or on site. If at the workshop, care is needed not to damage the paintwork during transportation, and any damage should be repainted at site.

- Figure 3.10 shows the panels being prepared for painting. All welds should be cleaned up, preferably by grinding, and all weld splatter removed. All surfaces were wire brushed to remove loose scale and rust and then degreased with petrol-soaked rags. 2 coats of paint were applied, a primer and a top coat of anti-corrosive paint. Ideally a second top coat should have been applied. The figure shows the use of paint soaked rags to thoroughly paint inside the spaces between the channels of the Bottom Longitudinals. This was also done for the spaces between the angles of the Diagonals.
- Figure 3.11 shows the clear labelling needed for each panel and member to ensure they are in the correct order for assembly on site.



3.1 Welding of channels for the Bottom Longitudinals. Note the chalk marks across all the pieces showing the position of the stitch welds. The weld is between each pair of chalk marks.

Welding is still in progress.

The procedure is similar for the End Panel Longitudinals and Base Panel Longitudinals.



3.2 A pair of channel sections being aligned and clamped together to form a Bottom Longitudinal.

A gusset (G1 or G4) can be seen facing downwards i.e. the Longitudinal is resting upside down.

The procedure is similar for the End Panel Longitudinals.

Figure 3.1: Manufacture of Side Panel Members (see Figure B4)



3.3 First step in welding up End Panel Bottom Longitudinal (EB) as in Figure B6, Step 1.2. Note 6mm space left around gussets for welding



3.4 Completed welding of End Panel Bottom Longitudinal as in Figure B6, Step 1.3.

Figure 3.2: Manufacture of End Panel Bottom Longitudinal



3.5 Joining bracket with bolt holes drilled. Note the 3mm thick stiffeners welded on the top and bottom surfaces.



3.6 Template for drilling pilot holes in the joining brackets.

Figure 3.3: Details of Joining Bracket and Drilling Template (see Figure B9)



3.7 Drilling template for Side Panel Verticals (Figure B10.3)



3.8. Drilling template for Base Panel Cross Members (Figure B10.4)



3.9 Drilling holes for joining the Side Panels (Figure B11.5). Note the Joining Bracket is tack welded inside the joining Side Panel Bottom Longitudinals. Similarly the Base Panel Longitudinal is tack welded in the opposite side.

Figure 3.4: Drilling Procedures



3.10 Checking the lengths of the diagonals in constructing the assembly jig (see Figure B12(i)). Note that jig is being set up on a flat floor area.



3.11 A base panel being assembled in the jig (see Figure B13). (Note that the lower frame resting on the floor is the jig). Note the bolting together of the joints between the Side Panel Bottom Longitudinals and the Base Panel Longitudinals.

Figure 3.5: Construction and Use of Assembly Jig



- 3.12 Fitting the Base Panel Cross-members in position (see Figure B13). This is at the joint of adjacent Base Panel Longitudinals which are inside the channel section of the Side Panel Bottom Longitudinals.



- 3.13 A completed base panel still set up on the jig and ready to be removed for final welding

Figure 3.6: Construction of Base Panel



- 3.14 Joining Bracket bolting together 2 Bottom Longitudinals (SB) to fit Side Panel Verticals (SV) (see Figure B14).

Note: there is a problem here in that the Verticals are resting on the Gusset Weld so that the gap between the Verticals and the Bottom Longitudinals is too large for welding. It is **essential** that the bottoms of the verticals are welded all round. The gusset weld, therefore, needs to be ground to reduce the gap to 1 to 2mm to allow welding of the Vertical to the Bottom Longitudinal.



- 3.15 End Panel (E1.L) and Side Panel (S1.L) assembled in the jig (see Figure 14 Step 1). The End Panel is ready to be removed and completed by adding the Deck Side Diagonal and fully welding the joints.

Figure 3.7: Assembly of Side and End Panels



3.16 Beginning assembly of the Panels at the Left Hand end of the footbridge. Note the Base Panel Longitudinal (BL) fitting inside the Side Panel Bottom Longitudinal (SB)



3.17 Lining up the holes at the bolted joint between adjacent side panels. Note the Joining Bracket fitted inside the channel of the Bottom Longitudinal.

Figure 3.8: Assembly of the Footbridge in the Workshop



3.18 Assembly in workshop almost completed.



3.19 6 Bajajs (3-wheel taxis) loaded on the footbridge to test it in the workshop. This gave a total load of about 2 tonne, only about 22% of the design load but well above the maximum load expected in service. Ideally the footbridge should have been tested with a crowd load. However, strain gauges were attached at critical points to predict the effect of larger loads.

Figure 3.9: Assembly and Testing of the Footbridge in the Workshop



3.20 Preparation for painting using wire brushes to remove loose scale and rust. All welds need to be cleaned up and weld splatter removed. Degrease all surfaces with petrol soaked rags before painting.



3.21 Using a paint soaked rag to paint inside the space between the channel sections of the Bottom Longitudinals. This also has to be done for the diagonals.

Figure 3.10: Preparation and Painting of the Panels



- 3.22 Note that all panels and brackets must be clearly identified at the stage of manufacture and assembly in a manner that remains clear after painting. This is essential to ensure that parts are correctly matched for the assembly on site.

Figure 3.11: Marking of Panel Members

4. INSTALLATION OF THE FOOTBRIDGE

4.1 CONSTRUCTION OF ABUTMENTS

The abutments were designed by the site supervisor to a standard local design. This comprised a reinforced concrete abutment built on a concrete footing. The reinforcing steel allows a thinner cross section and therefore less concrete is used. The comparison of cost depends on the relative cost of concrete and steel. A masonry abutment would give the lowest cost and be the preferred design, but the reinforced concrete design is the type commonly used in the area.

- Figure 4.1 shows the preparation for the footing of an abutment, involving clearing and excavation. The average depth of excavation was about 1.2m for a footing of about 0.5m thickness. The work was carried out by local paid labourers
- Figures 4.2 and 4.3 show stages of the construction of the abutments. The construction was carried out by 2 or 3 persons with experience of building this type of abutment assisted by local labourers.

4.2 ERECTION OF THE FOOTBRIDGE

Because of limited space and lack of a flat area on the banks to assemble the footbridge it was decided to assemble the bridge in stages, pushing each module out over the river as it was assembled. Two methods were considered:

1. To build a temporary platform over the river supported by piers and to push the footbridge over this (Section 7.4.2 of the manual)
2. To build a cable-way with a travelling pulley block and hoist to support the end of the bridge (Section 7.4.3 of the manual).

It was considered that the first method would require considerable work and might be difficult because of the depth of the water. It was felt that the second method probably involved less effort although more skills, and because it was more widely applicable to a range of situations it would offer the best experience for the case study. It was therefore adopted.

The method involved building towers behind the abutments on each bank to support a cable on which a pulley block could travel to support the end of the footbridge. Materials needed were:

- Wooden poles to construct the towers
- Ropes to bind the poles and also for guys to stabilise the towers against being pulled over
- A cable of suitable strength and length. It was estimated that the weight of the bridge frame was about 2.5 tonne and that taking into account the sag of the cable it should be capable of carrying at least this load. A minimum 10mm cable was therefore needed, (see Section 7.4.3 of Manual). A 16mm cable was used.
- A pulley block with a winch to allow lifting and lowering of the end of the bridge
- Ropes from the bridge to each bank to control the pulling of the bridge over the river

All materials were either purchased or hired locally. The cost is shown in Section 5 of the report.

The sequence of steps in erecting the footbridge is shown in the following figures.

- Figures 4.4 and 4.5 show the erection of the towers for the cable-way. The overall details of the cable-way are shown in later photographs
- Figure 4.6 shows panels being carried from the road to the site, a distance of 300 to 400m
- Figure 4.7 shows the panels stacked at site and the construction of a platform on which the footbridge was assembled
- Figure 4.8 shows the beginning of the assembly of the footbridge modules at the left hand end of the bridge. This was carried out by about 4 technical staff from the workshop assisted by members of the local community
- Figure 4.9 shows the first modules pushed out over the river and supported by the pulley block and hoist
- Figures 4.10 and 4.11 show the continuing assembly of the footbridge and further details of the erection equipment and procedure
- Figure 4.12 shows the fully assembled footbridge supported above the abutments at each end. The casting of the bearing caps on the abutments was completed at this stage in order to simplify the correct location of the bolts and pins fixing the footbridge on the abutments
- Figure 4.13 and 4.14 show the completion of the bearing caps and the bearing arrangement for the footbridge on the abutments. Note that the bridge is fixed by bolting at one end and allowed to slide longitudinally at the other to cater for changes in length caused by temperature variations

4.3 CONSTRUCTION OF THE DECK (see Stage 7 of Section B3)

The deck is constructed from hardwood planks. Since the cross-planks are only supported at their ends on the Bottom Longitudinals, a span of 1.4m, they need to be at least 75mm thick for adequate strength. It is therefore cheaper to use longitudinal runners of 150 x 50mm supported on cross-members spaced about 600mm apart than to have a continuous deck of 75mm thick planks. 8 runners are used. Kerbs are also made from 150 x 50mm planks.

Timber decks have a relatively short life and need to be treated as effectively as possible with a preservative.

- Figure 4.15 shows some of the planks after treatment with a bituminous preservative. It is noted that the treatment should also have included the end grain and have been repeated a number of times to get reasonable penetration
- Figures 4.15 and 4.16 show the arrangement of the decking planks and the methods for fixing them in position

- Figure 4.17 shows the completed footbridge. The approaches to the bridge still have to be constructed by the community.



- 4.1 Start of preparation for the abutments. The far bank has been cleared and leveled and excavation for the abutment footing has been started.



- 4.2 Excavation of the footing for an abutment. The depth of the excavation is below the water table. Note the suction pipe for a pump to extract the water during the construction of the footing.

Figure 4.1: Preparation of Footings for Abutments



4.3 Details of the footing for the abutment. The local technical person supervising the installation decided to use a standard design of reinforced concrete abutment that they were familiar with. The footing is a concrete slab of 3 x 1.2m in area x 0.5m deep (approximately)



4.4 Construction of the abutment on the steeper bank of the crossing. The shuttering is supported by poles and is moved upwards as each layer of the concrete is cast. Each layer of the concrete is about 600mm thick. The overall size of the abutment is 2.4m long x 0.6m wide x 2.4m high.

Reinforcing bar is 20mm diameter at a spacing of 200mm around and about 50mm inside the outer walls.

Figure 4.2: Construction of the Abutments



4.5 Mixing and pouring the concrete for construction of an abutment.



4.6 Tamping the concrete to make sure it is densely spread. Larger stones collected by the community are spread over the central section to reduce the volume of cement needed.

Figure 4.3: Concrete Work in Constructing the Abutments



- 4.7 Fitting foot of tower pole into an excavated hole. The hole should be at least 0.5m deep. The pole is about 120mm in diameter



- 4.8 Tower poles erected up the bank from the abutment and stabilized with guy ropes tied to adjacent trees. Note the poles between the abutment and tripod which are the beginning of the support structure for the platform on which the footbridge is to be assembled.

Figure 4.4: Erection of Tripod for Installing the Footbridge (see Figure 7.14 of Manual)



4.9 Completion of a tower for supporting the cable for the installation of the footbridge. The support beam for the cable is about 6m above the ground on this lower bank of the river. The cross-members bracing the poles are about 50mm in diameter.



4.10 Details of the support beam for the cable. This is 120mm in diameter. It is important that the cable runs in a straight line from anchor at one bank, over the cross-members on the two towers to the anchor at the other bank, in order to minimize side-ways forces on the two towers.

Figure 4.5: Details of the Construction of the Cable-Way



4.11 Carrying a Side Panel down the steps to the site.



4.12 Carrying a Base Panel to Site.

Figure 4.6: Community Members Carrying Footbridge Panels from the Road to the Site



- 4.13 Construction of a platform on which to assemble the footbridge modules. This comprises planks that are supported by logs that rest on the abutment at one end and the bank at the other end. The platform is 4m long x 3m wide.



- 4.14 The panels are stacked ready for assembly of the footbridge. Note also the joining brackets on the right hand side. Panels and members should be stacked carefully with separating spacers to avoid contact and damage to the paintwork. Panels and members should be stacked in the correct sequence ready for assembly.

Figure 4.7: Preparations for Assembly of the Footbridge



- 4.15 Start of assembly with End Panels E1.L and E1.R and Base Panel B1. Note that the Base Panel rests on wooden planks that are supported on log rollers. It is important that the Base Panels do not rest directly on the rollers as this would damage the paintwork. The rollers are approximately 100mm in diameter x 2m long.



- 4.16 Assembly of Side Panels S1.L and S1.R and bolting of the joints with Joining Brackets J1.L and J1.R. This set of bolts should not be tightened until the next set of panels has been added so that holes can be lined up. Assembly was carried out by technicians from the workshop together with help from members of the community.

Figure 4.8: Start of Assembly of the Footbridge



- 4.17 The assembled part of the footbridge is pushed out over the river on the rollers to make space for the next module. The end of the bridge is supported by a pulley block and chain hoist that rolls along the cable.



- 4.18 Details of the pulley block. The chain hoist enables the level of the end of the footbridge to be adjusted and the end to be lowered onto the abutment. Note also the ropes and pulley used to pull the bridge across the river. A pulley is also used at the anchor end so that passing the rope around the pulleys gives a mechanical advantage of 3 : 1, i.e. the pulling force on the bridge is 3 x force applied by the pullers but the movement is only 1/3.

Figure 4.9: Pulley Block Arrangement



- 4.19 Overall arrangement of the cable-way used for installing the footbridge. The cable passes over the cross-beams at the tops of the 2 towers. The angle of the cable is roughly the same on both sides of the tower to balance the horizontal force components and therefore minimize the force tending to pull the tower over. Note in the background the cable is anchored to the centre of a log wedged behind 2 trees.



- 4.20 Side panels 1, 2 and 3 have now been assembled. Note that during the initial installation the pulley traveler runs downhill. A steadying rope is therefore needed to control the forward movement of the footbridge. The person at the top left is applying the steadying force. The force is fairly low due to the relatively high friction at the rollers.

Figure 4.10 Arrangement of Cable-Way for Supporting the End of the Footbridge



4.21 Bolts being tightened at Joint 3 as Joint 4 has been assembled and bolts fitted. The set of bolts at a joint should be fitted before the previous set are tightened.



4.22 As the pulley block passed half-way it begins to travel “up-hill”. The triple pulling rope is then needed to pull the bridge across the river together with persons pushing at the assembly end. Note the pulling ropes are initially nearly horizontal. As the end of the bridge approaches the abutment the ropes have to be inclined upwards from the bridge to get a more effective pull.

Figure 4.11: Continuing Assembly of the Footbridge



4.23 Fully assembled footbridge supported above the two abutments. Note that the pulling rope is now passed over the cross-member at the top of the tower in order to pull at an upward angle on the bridge



4.24 Assembled footbridge supported on packing at each abutment. Note that the pulley block is now supporting the centre of the bridge.

Figure 4.12: Fully Assembled Footbridge



4.25 Shuttering set up around the top of the abutment to cast the concrete bearing cap.



4.26 The end of the footbridge supported on the shuttering with the fixing bolts hanging from the bearing foot.

Note at the other end reinforcing steel pins (NOT BOLTS) are fitted in a similar manner allowing the end of the footbridge to slide to allow for expansion and contraction with temperature change.

Figure 4.13: Embedding the Fixing Bolts and Pins in the Concrete Bearing Cap



4.27 Completing the concrete bearing cap



4.28 Bearing foot at the Fixed End of the footbridge. Note the rubber sheet used to support the foot.

Figure 4.14: Bearing Feet Arrangement



4.29 The deck planks were treated with a bituminous wood preservative before installation. It is seen that the ends, the most susceptible surface, have not been adequately treated. At least 2 coats are needed on all surfaces.



4.30 Arrangement of decking. Cross-beams of 125 x 75mm rest on the Bottom Longitudinals at a spacing of 600mm. 8 runners of 150 x 50mm are screwed on the top of these with 75mm brass screws. Note the holes being drilled for the screws. Kerbs are also 150 x 50mm. The use of screws was a local decision. It is a better option than galvanized nails but more costly.

Figure 4.15: Fitting the Decking



- 4.31 Cross-members are attached to the kerbs with 60mm long brackets of 50 x 50 x 6mm angle. At junctions of the kerbs, 120mm long brackets are used to join the kerbs together.

The cross-members are bound to the Bottom Longitudinals with 2mm galvanized wire fitted in plastic tubing to prevent damage to the paintwork.



- 4.32 The arrangement of the deck showing the longitudinal runners supported by the cross-beams. Although it is recommended to overlap the joints of the runners, this is not a significant issue.

Note in the background an excellent example of the need for the footbridge with two young children apprehensively crossing at the ford on their way to or from school.

Figure 4.16: Assembly of Deck



The opening ceremony for the completed footbridge. The community still has to complete backfilling the areas behind the abutments to form the approaches to the footbridge.

Figure 4.17: The Completed Footbridge

5. FINDINGS FROM CASE STUDY

5.1 COST OF FOOTBRIDGE INSTALLATION

The breakdown of costs for the installation of the footbridge is shown in Table 5.1 below.

Table 5.1: Breakdown of Footbridge Installation Costs (USD)

ITEM: Material or Labour	Material Cost (\$)	Labour Cost (\$)	Total Cost (\$)
1 Manufacture			
1.1 Steel – 18 lengths 60x60x6 mm angle; 66 lengths 50x50x6mm angle; 15 lengths of 40x40x6mm angle; 4 lengths 60x6 flat bar	1,395		
1.2 Timber – 48m of 125x75mm plank; 180m of 150x50mm plank	864		
1.3 Bolts, screws, paint, wire	396		
1.4 Workshop charge – labour and supervision – 150 work days +overhead etc.		1,800	4,455
2 Transport – from workshop to site	315		315
3 Installation			
3.1 Abutment materials – cement, sand, reinforcing bar	360		
3.2 Materials for erection – timber for platform, cable, rope, pulleys, hoist	48		
3.3 Skilled labour for abutments – 40 work days		360	
3.4 Unskilled labour for abutments – 50 work days		225	
3.5 Skilled labour for erection – 25 work days + overhead		230	
3.6 Labour for erection – 75 work days		338	
3.7 Site supervision – 40 work days		1,152	2,713
TOTAL COSTS	3,378	4,105	7,483

The overall cost was \$7483, equivalent to \$312/m². Because of the nature of the project some of the labour costs were high, particularly for the workshop. For an actual installation, labour costs could probably be reduced by at least 20%, reducing the overall cost to about \$275/m². This is at the low end of the reported costs for footbridges and low-volume road bridges shown in Table 3.1 of the manual.

5.2 MANUFACTURE OF THE FOOTBRIDGE

- A medium-sized workshop mainly involved in the manufacture of door and window frames had no significant problems in manufacturing the footbridge. However, a competent supervisor is needed to interpret the working drawings from Appendix B and instruct the workshop staff. This needs to be a person who has experience of a wider range of engineering manufacture than just for the domestic market
- The workshop equipment needed was an arc welder, a drill with a capacity up to 17mm (22mm for a 2.1m wide footbridge), an angle grinder, and a power-saw for steel (in this case an abrasive cutting-off machine was used)

- The workshop needs a flat surface, preferably concrete, of at least 3.5 x 2m for the manufacture and use of the assembly jig for making up the bridge panels
- The procedure used for drilling and welding up the panels as instructed in Appendix B proved very satisfactory. The sequential procedure and clear marking of parts ensured no problems with assembly of the panels and modules either in the workshop or on site

5.3 INSTALLATION OF THE FOOTBRIDGE

- *Transport* of the panels from the road (nearest access point for vehicles) to site was not a problem. 4 persons carried the heavier Side Panels along a footpath and down steps and 2 persons the lighter Base Panels. However, transport might be a problem on steeper mountain paths where there is only width for a single person (single file)
- No problems were experienced with the *construction of the abutments*. A sketch was provided giving overall dimensions needed but no instructions for construction. This was an area where local technical staff had good experience. This is likely to be the case in many situations
- For *assembly of the footbridge*, it is best to have 2 or 3 persons from the workshop that manufactured the footbridge to direct the work and assemble the joints. Alternatively a technical person familiar with the design could direct local mechanics. Members of the community can be used to handle and position the panels
- The *erection of the footbridge* was found the most challenging part of the installation, largely because of the lack of practical guidelines on this. However, a technical person following the guidelines of Section 4.2 above should have no problem in directing this work. The important factor is that a small group of persons with experience in building is given clear instructions on the procedure to be followed and no other persons are allowed near the abutments in order to avoid any safety risks.

5.4 OVERALL CONCLUSIONS

- The case study showed that the modular steel truss footbridge is a feasible option for use at district and community level. The design concept was proven by the testing and the approach of manufacturing the footbridge in panels in a workshop and transporting them to site for assembly proved very satisfactory. It is considered that the modular approach has significant advantages over manufacturing and assembling individual members where access to site is suitable for transporting the panels.
- The steel truss footbridge has considerable advantages over timber and reinforced concrete bridges in the span range 10 to 20m because intermediate piers are not needed. Above 20m only half the number of piers are needed

- The total unit cost of the modular steel truss footbridge proved to be at the lower end of the range of unit costs reported for equivalent sawn timber and reinforced concrete bridges
- The case study has covered the use of the following sections of the footbridge manual:
 1. Site survey and planning of the footbridge installation (Chapter 2 and Appendix A)
 2. Construction of a modular steel truss footbridge (Chapter 5 and Appendix B)
 3. Construction of abutments (Section 7.2)
 4. Erection of a footbridge (Section 7.4)

Although the case study involved the installation of a modular steel truss footbridge, Sections 1, 3 and 4 are applicable to any type of footbridge. The case study was, therefore, valuable in testing the clarity of presentation of these sections. The photographs obtained and presented in these guidelines will considerably enhance the clarity and content of these sections, particularly Section 4 on the erection of a footbridge using a cable-way.