Path Bridges

planning, design, construction and maintenance

Produced by the Paths for All Partnership with support from Scottish Natural Heritage and Forestry Civil Engineering

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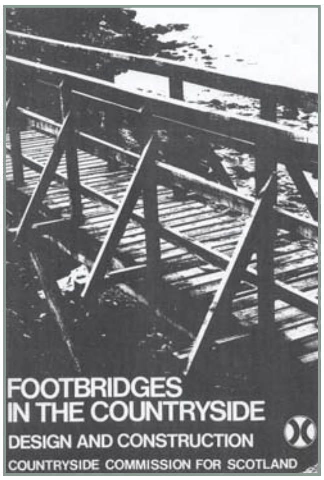

Design matters

Bridges are an integral part of paths. They are needed in many different ***settings***, to perform a range of ***functions*** and cater for a variety of ***users***. Crossing roads, railways, rivers or burns each bridge poses a different set of design issues. A bridge carrying a low-usage recreational path is a different proposition to one carrying a high-usage route for people to get to school, work or shops. Pedestrians, cyclists and horse riders and those passing under bridges each have their specific needs.

Recent legislation has changed the ***context*** within which bridges will be built in the future. Under the *Disability Discrimination Act 1995* (DDA), service providers may break the law if they treat a disabled person less favourably because of their disability. Designers and managers will have to consider on a case-by-case basis if it is reasonable to install a bridge which is not fully accessible. *The Land Reform (Scotland) Act 2003* (LRA) gives people in Scotland the right of non-motorised access to most land and water as long as they exercise that right responsibly. This is likely to increase the number of multi-use bridges that are installed and stimulate new designs that satisfy a broader range of users.

Bridges tend to be costly, so each one must be ***fit for purpose*** and not a barrier that unreasonably limits path use. Knowing who the users will be and what their needs are is the first crucial step to getting your bridge design right.

In 1979 the Countryside Commission for Scotland (CCS) published *Footbridges in the Countryside*. It has remained the definitive (and only) guide to path bridge construction. Scotland, and much further afield is peppered with the designs it promoted - a legacy to the quality of the publication. This guide builds on the CCS publication, offers new designs evolved from the experience of the intervening years and hopefully takes account of the needs of today's bridge users, designers and builders.

Introduction

Using the guide

The guide is designed to help you negotiate the complex factors involved in planning, designing, constructing and maintaining bridges, whether you have a technical background or not.

If you have no technical knowledge, these factors can be daunting. However, the guide will help you to:

(i) think through the options available for undertaking a project,
(ii) decide the key design parameters, and
(iii) determine whether you need professional engineering input.

In particular, it will help you to select a suitable design from the guide, or an 'off the shelf' proprietary span, to use a contractor for construction or to prepare a brief for a consultant to design a more complex structure.

Those who do have some technical knowledge and experience will be able to use this guide in accordance with their level of competence and the scale of the project. The guide gives a number of Standard Designs for which some simple calculations will be required. Where longer and more complex bridges are needed, experienced designers and engineers will find information that will help shape their design solution.

The guide has been designed to help people gain a rounded understanding of path bridges. To aid this process much of the technical detail and background information has been kept separate from the main text and can be found in the Technical Sheets. There is much to be gained from real examples and so a range of Case Studies have been included to both inspire and provoke.

Technical Verification - The technical information in the guide, including the Standard Designs, has been verified by Dr Geoff Freedman, Head of Design, Forestry Civil Engineering. Health and Safety advice has been endorsed by John Morris, Health and Safety Advisor to the Paths for All Partnership (PFAP).

To help draw attention to particular items you will find the text punctuated with the following symbols.

Practical tips

Key information

References have been coloured to aid navigation throughout the document.

Introduction

Now over to you...

Bridges are a serious business. The designer is responsible for the health and safety of the bridge builders and users. Always be aware of your own abilities and how they relate to the type of structure you are planning. The designs provided in this guide have been used in many different situations across the United Kingdom. However, every situation has its own specific issues, all of which cannot be adequately covered in a guide such as this.

If you have any doubt about the requirements of a particular site, seek specialist engineering advice - it is readily available. Where there is a British or European Standard covering either an element of bridge design or a material, it is listed in the guide. It is up to the designer to look up the listed Standard and make sure of the recommendations.

Bridge design is continuously developing. New designs and materials are being tried and tested to find more efficient, appropriate and sustainable solutions. Recycled materials are becoming increasingly common, and local sourcing is being encouraged. Wherever possible, the guide takes account of these trends.

Designing and building bridges is an exciting part of developing paths and improving access. We hope this guide will help you understand more about the process….and get out there building bridges that look good and make the outdoors more accessible to more people.

Thanks

The production of this document has only been made possible with the help and support of a number of people to whom sincere thanks are due. They include the following members of the focus group which helped to steer the project.

- Frank McCulloch - Forestry Civil Engineering (Scotland)
- Bridget Jones - Loch Lomond and Trossachs National Park Authority
- Brenda Clough - Perth and Kinross Council
- Rowena Colpitts - Sustrans
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- Rob Garner - Scottish Natural Heritage
- Ron McCraw - Scottish Natural Heritage

Many other people have contributed comments, ideas and material. These have been much appreciated and have helped make the document what it is.

Special thanks go to

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Consider the Options

There are several different ways of going about a bridge construction project. Consultants, contractors, in-house staff and volunteers all have potential roles to play. Choosing the best combination will depend on the complexity and size of the project and your own experience, skills, resources and confidence. Your choice will influence the work you have to do and the level of responsibility you have to carry. In making a decision, it is useful to break the project down into different stages (set out below) and to work out where you might need help. The guide itself will act as a more detailed checklist of the tasks and responsibilities involved.

- Planning and permissions
- Site survey and assessment
- Bridge design
- Bridge construction
- Certification

Although the options and permutations for organising a bridge project are more extensive than can be listed here, there are broadly three main choices to consider and these are discussed below. But don't forget, no one size fits all, so use the resources you have and the expertise you need to best advantage, not only to get a good job done but also to build capacity and skills within your own organisation.

Do It Yourself

If your bridge is a short span with low levels of risk and complexity, the DIY option might be perfectly feasible. Carrying out all of these tasks 'in-house' brings the greatest control over the project and you will be most likely to get the bridge you want at a reasonable cost. Practical expertise may be available within your own organisation (some Countryside and Ranger Services have developed a lot of bridge construction experience) so always check what help you might be able to garner from within. Alternatively, you might wish to involve local volunteers in the construction. Although these projects may be less expensive financially, they can be very time consuming, so don't underestimate the amount of time you will need to commit to supervising volunteers or organising other people. Involving local people brings its own rewards in terms of community ownership.

Use contractors

Contractors can be involved in a bridge project in a variety of ways. A good option is to select and survey a suitable site following the advice in this guide, use a Standard Design, draw up a tender, get it checked by a civil engineer and select a contractor. If you work for a local authority, there may be a civil engineer in your transportation department who may be willing to do this for little or no cost. Relatively inexperienced people will be reliant on the contractor doing a good job without too much in the way of supervision. In view of this, it is a good idea to use a contractor recommended by other access practitioners. As you build experience, you will start to get a feel for the difference between a good and a bad job, and will be able to be more proactive in contract management.

Some contractors provide proprietary spans (bridges built to their own design and with their own certification) and will construct a bridge as a design and build contract based on survey information supplied by the client. Sometimes it makes sense to consider abutments separately. They can be put in as part of the proprietary span, or they could be built 'in-house' or a separate contractor engaged.

Hand it over to consultants

Using consultants to do the whole lot is likely to be the most expensive method, and will still take time to manage. For a small bridge project done in isolation, the consultants' costs could be prohibitive. If the bridge project is part of a larger path construction project, however, then the consultants' fees for the bridge design will simply be a small addition to their overall fee. Large or specialist bridge projects justify the use of consultants more, as overall costs will be high anyway and there will be higher risks to accommodate as well as more complex design requirements. Use the advice in this guide to steer the consultant in the direction you require.

Long spans or complex situations will always require professional help

Consultation - getting it right first time

Working closely with land managers

Early consultation and agreement with the land manager is essential. Try to work closely together throughout the project. As well as getting permission to build the bridge you should also discuss in detail how and when the work will be done to minimise impact on land management operations. Furthermore, you should discuss the land manager's own access needs in relation to the new structure. Often, making a bridge accessible to land managers' vehicles increases costs by a surprisingly small amount. Where liability for the bridge will lie must be clarified at an early stage (see 1.3).

Land managers can provide invaluable site information when undertaking the site survey, saving time and money. The LRA and proposed changes to land management incentives mean that land managers are likely to be increasingly proactive in planning access to the ground they manage. The Scottish Rural Property and Business Association's publication *Managing Access - Guidance for Owners and Managers of Land* gives useful advice.

Meeting needs

Bridges are part of path infrastructure - often the most expensive part - and likely to last many years once installed. It is important to get it right first time and to ensure that any new construction does not introduce an unreasonable barrier to legitimate users, now or in the future. Ensure any path consultation process covers bridge proposals. Consulting all user groups will determine the desired use and help you get the best solution for the intended purpose.

Horses have a significant effect on bridge design. The large point loads they impose require careful consideration. In the recent past, most path bridges were not designed to carry horses; in some cases they were used to control and restrict equestrian access. However, under the LRA, equestrian use can no longer be disregarded. Bridges need to be as accessible as they reasonably and practicably can be for the widest range of non-motorised users. It is likely that where a new bridge cannot be used by horses a reasonable alternative should be available. As access rights also extend to inland water, care must be taken to ensure that bridges or other crossings do not unreasonably impede access along water courses.

1.3 Permissions and Legalities

Planning Permission and Building Warrant

The *Town and Country Planning (Scotland) Act 1997* and the *Building (Scotland) Regulations* apply to bridges. Whether planning permission and/or building warrant will actually be required in any given case depends on a number of factors that call for a professional judgement. If a bridge that is to be repaired or modified is 'listed' as being of architectural or historic interest, a special kind of planning permission known as 'listed building consent' may be required. These approval procedures all take time. The planning and building control staff in the local authority or National Park Authority should therefore always be consulted, and the sooner the better.

Highways, railways and waterways

Consent from a Highways Authority is required to span a road, and from Network Rail to span a railway line. Trunk roads are managed by the Scottish Executive and all other highways by the relevant local authority. To span a river or canal, consent must be sought from those with navigation or fishing rights and from the Scottish Environment Protection Agency (SEPA).

Designated Areas

Scottish Natural Heritage must be consulted at an early stage about proposed works on Sites of Special Scientific Interest, Special Areas of Conservation, Special Protection Areas, National Scenic Areas, National Nature Reserves and Natura 2000 sites.

Environmental protection

SEPA will also be interested in whether a bridge may have a detrimental effect on the flow of a watercourse, especially in flood, and in the materials proposed for construction. The *Water Environment (Controlled Activities) (Scotland) Regulations 2005* cover almost any work that could affect the water environment. Some activities do not require formal approval from SEPA, as long as they are carried out in accordance with the regulations, but others do: it is important to check. The *Nature Conservation (Scotland) Act 2004* and the *Wildlife and Countryside Act 1981* need to be considered in project planning.

Permissions and Legalities

Liability and insurance

Legal Position

The legal position on liability is largely based on the *Occupiers' Liability (Scotland) Act 1960* and common law. Under the 1960 Act, an occupier has a duty to take reasonable care to make sure that people entering the land that is under their control will not suffer injuries or damages arising through negligence. For any case to succeed under the 1960 Act, it must be shown that:

- the person who allegedly caused the injury or damage owed a duty of care to the person who was injured or whose property was damaged;
- this duty was breached by a failure to take reasonable care; and
- the failure caused the injury or damage.

Under Section 5(2) of the LRA, the extent of the duty of care owed by an occupier towards people on their land is not affected by the Act or its operation.

An introduction to liability law in relation to public outdoor access is provided in the SNH publication, *A Brief Guide to Occupiers' Legal Liabilities in Scotland*. This highlights relevant statutory and common law for land managers, including health and safety legislation.

Management Responsibility

If you are undertaking a bridge project, it is vital to clarify who will have responsibility for the safety and management of the structure and individuals at all stages. During and following construction, and until a completion certificate is signed (see over), a contractor will normally have responsibility for the bridge and will be liable for any defects or accidents. Following formal completion, any structure generally becomes the legal property of the landowner, regardless of who built it and, *unless specified otherwise,* the landowner will be responsible for exercising the occupier's duty of care towards its users. It is therefore good practice to agree from the outset who will be the *agreed manager* and therefore liable for maintenance and for addressing any claims arising from accidents associated with the bridge. If not the owner, this *agreed manager* might be the Access Authority (Local Authority or National Park Authority), a countryside trust or a conservation body. This will need to be agreed in writing - perhaps for instance through a path agreement under the LRA - if the access authority is to be the agreed manager.

Permissions and Legalities

The agreed manager should be satisfied that the bridge was designed and built to a suitable standard and, to this end, must keep a record of all design and contract details, and the completion certificate in the Construction Health and Safety file (see Section 5.1). The agreed manager should undertake a risk assessment to identify all risks, and devise and implement a programme of safety inspections, monitoring and maintenance to ensure safe use and to create a record of all risk management activity (see Section 5.6).

Completion Certificate

Following construction and **before use**, a bridge should be certified by a Chartered Civil Engineer to ensure the bridge has been suitably constructed to fulfil its requirements. It is vital to plan how this will be achieved at the start of a project - at the end you might not find anyone willing to give a signature.

If you use a proprietary span the manufacturer will generally issue the certification. Bridges constructed from the Standard Designs in this guide still require certification and a suitable consultant or in-house engineer should be contacted early to determine how certification will be achieved.

Some organisations choose not to formally certificate some very short span bridges where the risk of accident is low. This decision must be firmly based on risk assessment and on a competent person ensuring that the bridge has been built to specification. A competent person can be thought of as someone with experience of implementing the planning, design and construction principles contained in this guide.

Permissions and Legalities

Insurance

Insurance will be required for the different phases of the bridge construction and management.

The **contractor** will require insurance for the site, employees and the public during the construction phase, and will require cover for the period of defects liability. Where voluntary labour is involved, volunteers should either be directly insured or be covered by other arrangements for the overall project.

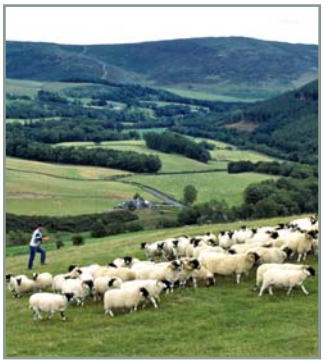
The **designer** will require Professional Indemnity insurance to protect against compensation sought by a client because of mistakes or negligence in design.

The agreed **manager** will require insurance for public liability and other risks of loss or damage arising within the manager's responsibility. Sometimes organisations (and many local authorities do this) choose to 'self insure' structures. In these cases the organisation bears the cost internally, and includes the structure within its broader insurance coverage in case of any liability claims.

1.4 Design Parameters

Working through the issues discussed in this section will help you to assemble a list of design parameters for a bridge. This involves working out what functions a bridge will perform so that a structure can be chosen or designed to do its job. These functions will of course include consideration of the people and vehicles that will use the bridge but function goes beyond that. The design parameters might also include the sort of 'look' you want to achieve or what contribution the bridge should make to the landscape.

Clearly setting out design parameters is particularly important when commissioning a fresh design. You must be clear on what you want and set the boundaries for the designer or engineer to work within. Giving insufficient thought to this at the outset can result in a lot of misdirected effort, disappointing results and wasted money.



Path users and numbers

Determining who will use a bridge, and in what sort of numbers, will probably - through the loads they impose - have the biggest influence on bridge selection and design. Deck width, handrail height and strength, and approach ramp design will all vary with user types. Consider the following:

- Pedestrians (tourists, experienced walkers, local people, commuters)
- People with disabilities
- People with pushchairs
- Children and older people
- Horse riders or stalking ponies
- Cyclists (commuters, mountain bikers)
- Livestock
- Farm or forestry machinery
- Authorised vehicles
- Unauthorised vehicles
- Path construction and maintenance plant
- Emergency vehicles
- Watercourse users

Design Parameters

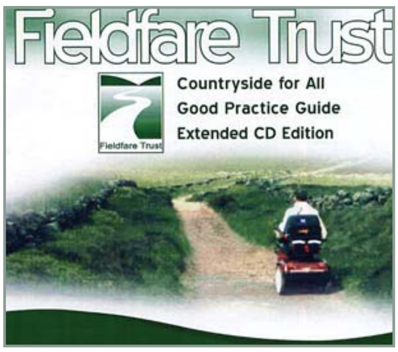
Volume of traffic is an important consideration, especially in determining the load that a bridge must carry and therefore the load class it must be built for. A bridge in a remote upland glen may not get large numbers crossing at one time, whereas a busy commuter route can be expected to be crowded at some times of the day. Section 3.3 explains loads and their assessment in more detail.

Access for All

The Disability Discrimination Act (1995) or DDA makes it unlawful for people who provide goods, services and facilities to the public to discriminate against disabled people. The overriding principle of the DDA is that these service providers take reasonable measures to provide access. A service provider may break the law if they treat a disabled person, because of their disability, less favourably than they treat someone else. Potential 'service providers' unsure of their status should contact the Disability Rights Commission.

Remember that a bridge may represent the biggest restriction to access on a route. Even if the path on either side of a bridge is very inaccessible at the time a new bridge is planned, building an inaccessible bridge just adds another barrier. Once you have decided to install a bridge, the extra cost required to make it accessible may be minimal, whereas you may never have another opportunity to upgrade or replace a restrictive bridge.

The Fieldfare Trust's *Countryside For All Good Practice Guide* identifies the levels of accessibility (including minimum widths and gradients, handrail heights) that are satisfactory for the vast majority of disabled people. Deck width and design, plus the nature of the approaches, are key elements that affect accessibility.



In situations where it is not reasonable to construct a fully accessible bridge, the principles of '*least restrictive option*' should always be applied, that is, by removing or minimising barriers, providing access for the widest range of people. **Make every bridge as accessible as you can**.

Design Parameters

The Land Reform (Scotland) Act 2003 - the right to responsible access

The LRA gives a right of non-motorised access to most land and inland water provided the right is exercised responsibly. The *Scottish Outdoor Access Code* provides details of what constitutes responsible behaviour. Always consider if a new bridge may unreasonably discourage or prevent legitimate access under the LRA. Details of the Code are available on **www.outdooraccess-scotland.com**

Unauthorised users

It is essential to consider who may wish to use the bridge, regardless of the designer's intention. So, for example, although you may not permit unauthorised vehicles along a route, you must assume that at some point they may try. You must either design the bridge to withstand such use or else take positive measures to prevent it.

What does the bridge cross?

You must consider what will pass underneath the bridge. If it is a traffic route (road, rail or river), clearances and safety measures are required. Statutory considerations apply to both road and rail. Watercourses may require clearances for canoeists, fishermen, sailing boats or commercial traffic. Contact Network Rail, the Local Authority Transportation Service, SEPA or British Waterways as appropriate (see Section 1.3).

Landscape fit

A bridge must be appropriate to its surroundings, whether that's a city centre, lowland farmscape or mountainside. Well designed and placed bridges can enhance landscapes and add to people's experiences; ill-conceived ones can ruin a place.

Think about the following:

Design Parameters

Location

Site selection plays an important role in fitting a bridge into the landscape. If you wish the bridge to be unobtrusive, try to select a site which is in a dip or hollow so the bridge will not be sky-lined. Existing or new planting can be used creatively to either hide a bridge or reveal it from a desired vantage point.

Approaches

Think of the path on either side as integral to the bridge itself. Make the approaches work for you. If you wish the bridge to make a statement or showcase an attractive design, consider routeing the approach paths to give good views of the bridge. The path, approaches and bridge itself should all link together as seamlessly as possible.

If you are placing a bridge on an unmade path or an open-access area (for example, a park) remember that wear will be concentrated at the bridge approaches and short sections of constructed path may be required. Consider the effects of bridge construction plant to the area adjacent to the bridge. Sensitive landscapes may preclude the use of heavy plant and so a lightweight, easily portable bridge may be the only solution. Always allow for repairs and regeneration works to the land adjacent to the bridge.

Materials

Choose materials that are appropriate to the setting and to the functions the bridge will perform. Section 4.6 contains more details about the properties and uses of materials. The colour of materials affects their visual impact; for example, dark colours will make large wooden beams appear less obtrusive. However, for the same strength of structure, steel components are smaller and can produce a much lighter-looking bridge. Remember that a bridge can be an uplifting structure in its own right and can have a dramatic effect on a location - so do not be afraid to be creative where it is appropriate.

Design Parameters

An interpretive tool

Bridges can present great opportunities for provoking interest and fostering understanding. Often in interesting locations, they are places where people naturally pause and take stock, offering good opportunities for getting messages across.

This attractive little bridge may not be fully compliant but in terms of design and sense of place it is food for thought

Site access

Access to the construction site will influence the type of bridge you can install. Ideally, a complete bridge will be brought to site and lifted into place in one go. This may require heavy cranes and transport lorries, and so you must assess if the site can accommodate them. If this is not possible, bridge elements can be brought in separately and built on site. This requires plenty of space to lay out and assemble the components, so expect increased disturbance to the adjacent ground as a result and always ensure remediation is carried out. In remote locations helicopters may be used, bringing their own access requirements.

Anticipate future needs

If you are planning path construction in the future, consider if a bridge will restrict plant access. Maintenance plant may also need to cross a bridge if an alternative access is not available and in some cases emergency vehicles may need to cross.

Design Parameters

Cost

Cost is, of course, a factor that influences design. It might, for example, have an impact on the materials used or alter the way a bridge is constructed. But using cost limitations as the primary reason for, say, installing a pedestrian bridge without taking into account the needs and aspirations of other potential users, is unacceptable. If the bridge you need cannot be afforded now it might be better to wait until it can, rather than spend money on a bridge that does not do what it should.

Maintenance

Ongoing maintenance is a key consideration. Factors including robustness and durability, ease of access to the structure and replacement of components must all be thought through. When commissioning designs consideration of how ease of maintenance will be accommodated in the structure should always be included in the brief.

Sustainability

Including sustainability as a key design parameter will ensure that environmental cost is considered from the outset. This will impact not only on the choice of materials and the way construction is undertaken but also on the expected life span of the bridge, the impact of its eventual replacement and the way maintenance is carried out.

Initial Assessment

This section will help you to find the best site for your bridge. In some cases there may be only one suitable location. Usually though, there is flexibility and it is useful to keep an open mind, so investigate several potential locations as part of an initial assessment before selecting one or two for more detailed survey.

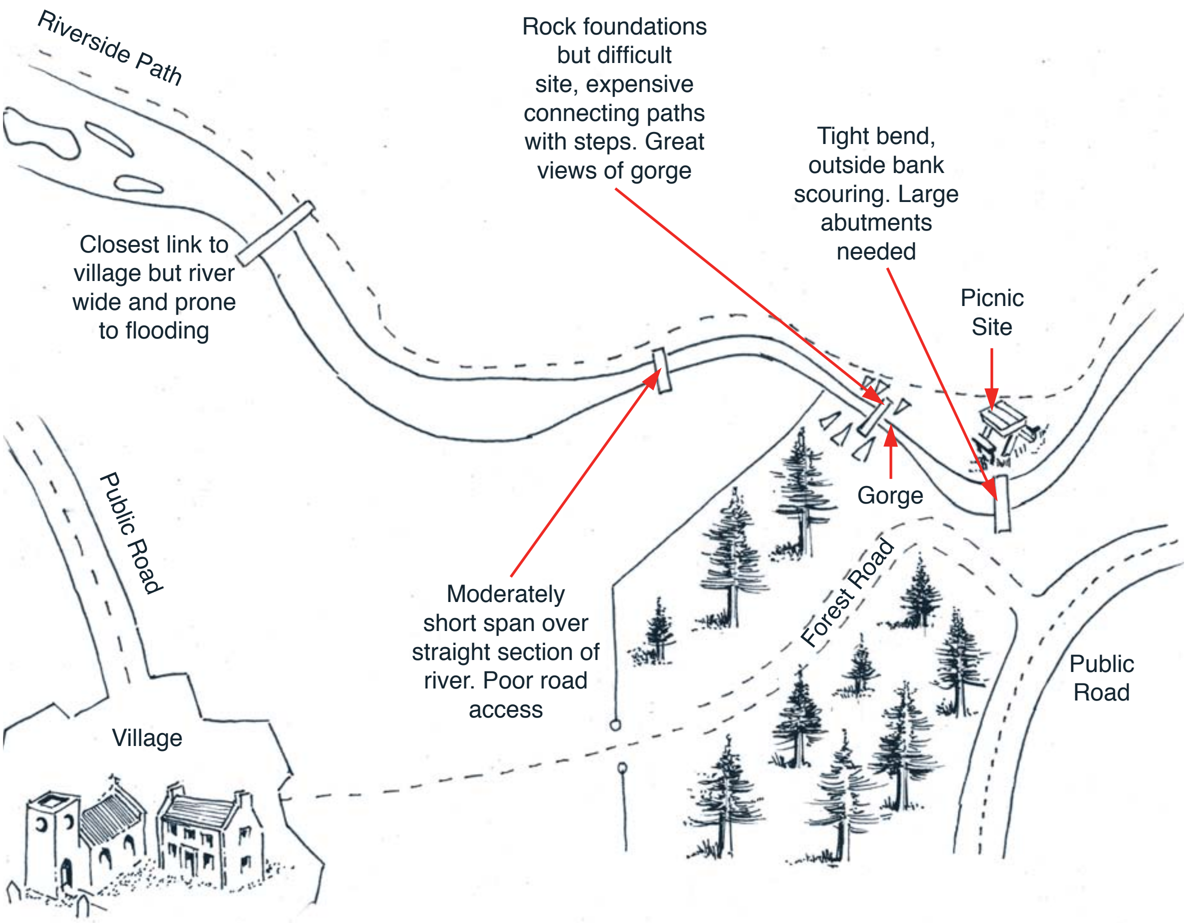
2.1.1 Identifying potential sites

The checklist below will help to assess possible bridge locations.

- **the length of the gap to be crossed -** try to minimise this.
- **ground conditions -** ideally find firm, well drained ground or bedrock for bridge foundations.
- **proximity to the existing path line -** will the bridge location require an existing route to be moved?
- **areas subject to flooding -** try to avoid or find the best clearance.
- **site accessibility for plant and materials -** the easier the access, the lower the cost and the greater choice of designs and construction methods, and subsequent maintenance.
- **site hazards -** minimise these, both for staff constructing the bridge and for users.
- **river shape and dynamics -** bends are often dynamic areas where banks are liable to change. Straight sections are usually more problem free.
- **height of gap -** allow good clearance for water and debris. It affects safety of construction, handrail requirements and perception of danger.
- **bank levels -** try to find banks that are level to minimise abutments and a big drop to one side.

Initial Assessment

Fully satisfying all of these criteria rarely occurs, so you need to make a judgement about where you can compromise and where you cannot. While funding levels inevitably have a strong influence, always consider the long-term benefits of a site which may be more expensive initially but will serve a wider range of users or impact less on the environment in the long run. A more expensive structure may turn out to be better value long term.



Sketching out possible locations for providing a crossing point and listing the pros and cons will help with site selection where there is a choice. In the above example local people have asked for a link to a riverside path on the opposite bank. Constructing a matrix that sets out the advantages and disadvantages of potential bridge locations can help in coming to a decision.

2.1.2 Is a bridge the right solution?

Having gathered the background information and before moving on to a detailed site survey, it is useful to stop and think, ‘do we really need a bridge?’ An alternative solution may be possible. For example, in remote, undeveloped areas, a judgement must be made. Will the intrusion into the landscape of a new man-made artefact be justified by the extra convenience and safety it will provide?

Initial Assessment

Always consider whether an ***alternative route*** could be chosen to avoid using a bridge at all or whether an existing bridge could be used or upgraded. Some rivers and burns can be crossed by ***fords*** or ***stepping stones***. In some cases a ford for vehicles and horses can be combined with a light bridge for walkers and cyclists to avoid the need for a large bridge to serve everyone. Remember though that people must be able to cross safely at all times of year.

Fords can offer useful alternative crossings for horses and vehicles

It may also be possible to install a pipe or box culvert instead of a bridge. These have a high load-carrying capacity and can be comparatively cheap. They may also be useful on sites with poor access or where vandalism is a repeated issue. Pipe sections are easily transported and back fill can sometimes be sourced on site. The downside is that they readily cause scour downstream and there is increasing concern about their impact on the movement of fish and other wildlife. Details of culverts and fords can be found in the *Lowland Path Construction Guide* and the *Upland Pathworks Guide*. SEPA should be approached for advice. The restriction of water access rights should be considered for any bridge alternative.

Vented causeways (sometimes referred to as Irish bridges) are easily overtopped by water and are not recommended. Serious scour can occur downstream giving rise to undercutting and failure of the structure.

The Water Environment (Controlled Activities) (Scotland) Regulations 2005 cover almost any work that could affect the water environment, including the alternatives to bridges discussed here. See Section 1.3.

2.2 Detailed Site Survey

Once you have narrowed down potential sites to one or two, a more detailed survey is needed. Be prepared to reject a site that was initially promising on the strength of the information revealed. Most of the tasks required are no more complex than normal path surveying. However, bridges cross rivers, roads, railways and canals - locations that can pose serious hazards to the surveyor. These hazards need to be anticipated, risks assessed and appropriate safety measures taken.

Useful Survey Equipment...

- ✓ **Tape Measure** - long enough to do the job!
- **Clinometer** - for gradients and levels
- **Ranging Staff** - for use with above
- **Engineers Level** - for precise calculation of levels
- **Notebook and Pencil** - ideally waterproof
- **Camera** - for recording potential positions and landscape settings - this helps a lot with design
- **Assistant** - to hold one end of the tape, particularly useful when crossing gorges
- **Spade/Trowel** - to dig trial pits for ground condition assessments
- **Pointed Stick or Cane** - to gauge depth of soft ground

Detailed Site Survey

The information you need to gather is summarised in the checklist and discussed in more detail below.

Survey checklist

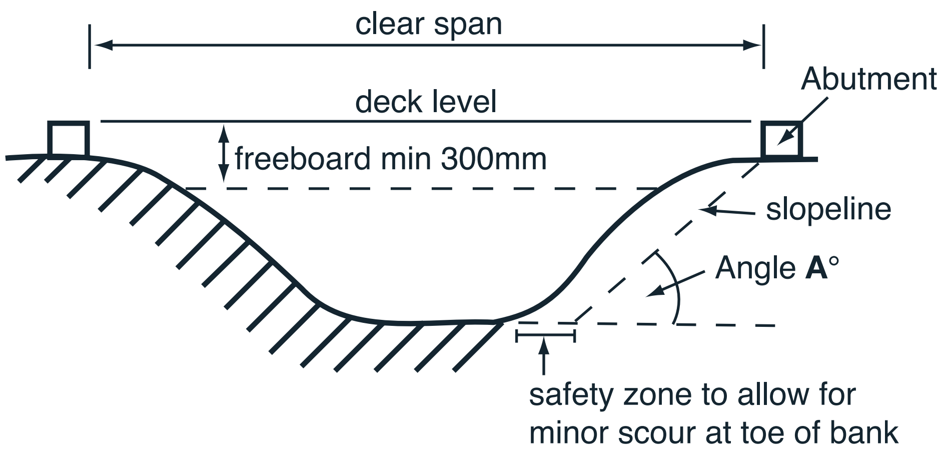
- **span** (exactly the distance you need to cross)
- **ground levels** (on both sides of gap)
- **water levels** (maximum and minimum)
- what is **upstream** that may be likely to come down, e.g. big trees
- **ground conditions** (at bridge site and approaches)
- position of any **obstacles** (trees, large rocks, fences etc.)
- position of any **hazards** (power lines, underground services, potential unstable slopes)
- **site access** details
- **laying out space** for construction
- **general site awareness**
- **sense of place**
- tie-in for **link paths**

2.2.1 Span

You will need to establish how long the bridge needs to be, that is the distance between abutments. Remember to include any extra length in the span, for example to avoid eroding banks or boggy areas. Difficult abutments can cost more than a longer deck so minimising span is not always the cheapest option. A short span is usually measured with a measuring tape. In difficult locations like gorges or uncrossable rivers, ask an assistant to go round to the other side (this can often be a major challenge itself and may require a substantial walk). Throw the end of the tape across and get them to hold it where required. Alternatively, use a Distomat - an electronic device that attaches to a theodolite and accurately measures distances. Low cost lasers are now readily available for the same purpose.

Detailed Site Survey

When using a tape to measure long spans, attach the end of the tape to a line with a weighted end (a stone, for example) and throw this across first, pulling the tape through afterwards. It will stop your tape getting snagged in the river.



It is important to consider the stability of the banks when choosing the locations for the abutments. The toe of a bank is particularly vulnerable to scour. If it is actively eroding, seek advice.

The abutments should lie **outside** a slope line of Angle **A**°, which will depend on soil conditions. For example,

- for stable rock. **A** can be up to 60°
- for firm soil. **A** should not exceed 45°
- for loose sand, gravel and soft soil. **A** should not exceed 35°

Based on *Footbridges: A Manual for Construction at Community and District Level*.

When it comes to specifying a bridge it is important to recognise the different ways in which span can be measured and to have these in mind when undertaking the survey work.

Clear span - the distance *between* abutments (see 4.1.1).
Effective span - the full length of the beams from bearing to bearing (see 4.2.3).
Deck length - may be longer than effective span if the deck extends further.

Detailed Site Survey

2.2.2 Levels

To enable you to determine the dimensions of approach ramps and bridge abutments, you will need to measure the difference in level between each side of the gap. An engineer's level or theodolite (and someone who knows how to use it) is the quickest and most accurate way of doing this. If this is not possible, a clinometer, tape, ranging staff and some ingenuity will suffice. For river crossings, you also want to measure the difference between the normal water level and the bank level to determine what clearance is available under the bridge for navigation. Accurately determining levels will be crucial for calculating the height of abutments required and understanding how the bridge will sit in the landscape.

2.2.3 Flood water and scour

As our climate changes, becoming wetter and more unpredictable, a careful assessment of flood water is crucial to planning bridges - and minimising the chance a bridge will be washed away. Local land managers and fishermen are often a valuable source of information. Visit the site after heavy rainfall; look for evidence of previous floods: lines of debris, sandbanks above normal water level, flattened vegetation and erosion; inspect other bridges on the same watercourse; contact SEPA,

The impact of a 1-in-200 year flood, where a burn changed course completely

River levels can rise alarmingly - always over-estimate flood prediction

Detailed Site Survey

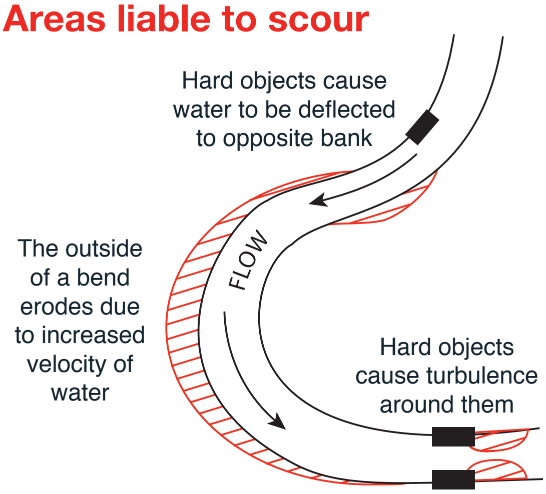
the local planning service or flood appraisal group if it exists. It is possible to estimate potential flood water for small catchment areas using the information given in Technical Sheet 6.2. Estimating floods mathematically can be said to be something of a 'black art' but it will give some sort of indication of the volumes of water that can be expected. Floods are classified by their return period, that is the time interval in which it is predicted that a flood of a given size will occur. It is predicted therefore that a 'one-in-ten year flood' will occur only once in ten years. Designers use return period as a design parameter - bridges built to withstand a 1-in-50 year or a 1-in-100 year flood might be very different structures.

The Centre for Ecology and Hydrology has a National Water Archive database and publishes a *Flood Estimation Handbook* that enables the calculation of flood levels anywhere in the UK. Go to **www.ceh.ac.uk** for more information.

The best way of dealing with flood water is to avoid it. Trees and other water-borne debris can cause immense structural damage, so aim for a bridge where the deck is kept above water and the abutments far enough back to be dry at all times. As a general rule, the freeboard (distance between the underside of the beams and water under flood conditions) should be 300mm minimum. However, total avoidance is not always possible. In these cases bridges must be particularly firmly attached to their abutments, which must in turn be protected against water scour. See Section 4.1.6.

Damage to the watercourse is often caused by the bridge structure restricting or altering the flow. Upstream, water backs up, flooding and eroding banks. Downstream, increased speeds and forces can result in scour, bank failure and bed movement, which can be harmful to fish, particularly in spawning areas. Any hard object introduced into flowing water will change the flow and cause scouring somewhere - often on previously undisturbed sections of bank. Always try to anticipate this and minimise any effects the bridge may have on the watercourse.

Areas liable to scour



Detailed Site Survey

2.2.4 Ground investigation

This is an important element of survey that is often overlooked for small bridges. Ground investigation should:

- reveal the soil structure or bedrock under the topsoil
- determine the level of water table
- help make informed decisions about the type and position of abutments

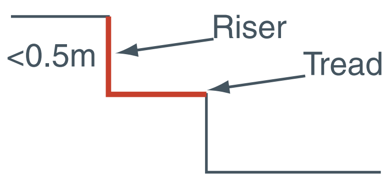
Before starting, make a general inspection around the site. Riverbanks, existing excavations, road and rail cuttings all slice through the ground and so yield valuable information. Look out for settlement of any surrounding structures and try to gather information about conditions from adjacent landowners or local authorities.

Locating bedrock or a firm subsoil layer is important as this will support the bridge abutments plus the weight of the bridge and its users. Abutment height is calculated from this point. Hand auger bores are a good way of investigating down to 3m.

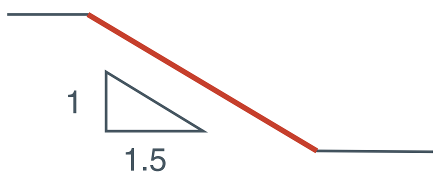
Trial pits are a simple and inexpensive form of ground investigation. They can be carried out in all soil types, giving a clear *in situ* picture of the ground conditions. Always dig pits in the vicinity of proposed foundations. If appropriate, service drawings from the statutory authorities and utility companies should be sought. Hand dig trial pits carefully or use a CAT scanner to ensure any services present will not be damaged.

If trial pits deeper than 500mm are needed, the sides of a trial pit must be stepped or sloped to a safe angle to prevent collapse, as outlined below. Seek specialist knowledge for pits deeper than 1m.

Digging safe trial pits



Where steps are used, riser height should equal tread and be 0.5m or less.



Slopes, depending on water content of soil, should be 1in1.5 at least.

If no firm mineral sub soil layer can be found, it is possible to float the bridge abutments on a geotextile, (see Section 4.1) or to drive piles down to a firm subsoil or bedrock level (it will be down there somewhere!). Both of these techniques will add to the cost of the bridge and require more materials, which will have to be brought onto the site. This cost must be factored into your choice of bridge site.

Detailed Site Survey

2.2.5 Obstacles and hazards

Electricity or telephone pylons/poles must be identified and marked along with any underground services. While they may not be affected by the bridge itself, they may dictate the use of certain installation techniques. Many bridges will cross rivers that are deep and fast flowing, sometimes over a gorge or ravine. These features can present extra hazards for installation, maintenance and possibly also the bridge users themselves.

Remember the golden rule of site hazard management - avoid or remove or manage.

2.2.6 Landscape fit

During the survey take pictures of proposed locations from different angles. Potential bridge designs can be superimposed or sketched on to help assess landscape impact. If not available in-house, this service is available from specialist companies. See Section 1.4 for more details on landscape fit.

An artist's impression helps to visualise the finished product

2.2.7 Site access and working space

As well as surveying the bridge site, you will also have to survey likely site access options. These will influence the type of bridge you can build and the way you can build it. Try to gain access to both sides of the gap to avoid plant crossing watercourses as this poses additional hazards and an increased risk

Detailed Site Survey

of environmental damage. You will need to assess the carrying capacity of the site access routes and what sort of vehicles, if any, could get to the site.

Land managers can provide valuable knowledge about where you can and cannot drive vehicles - they do it as part of their daily business! Check approach roads for weight limits, height restrictions and width restrictions. These are generally signed but if in doubt contact the local Transportation Department for more information. Consider how the bridge might be maintained and what access will be required. In some inaccessible locations, consider using a helicopter for delivering bridge components to site.

Delivering long beams to site can require access for large vehicles

The luxury of adequate space to lay out components and carry out construction work (working space) is not always available so thinking through the practicalities of construction at an early stage is important in selecting a design. Sections 5.3 and 5.4 deal with this in more detail.

2.2.8 A sense of place

A bridge may be more than a crossing point. It can give access to views from each side, maybe a pool beneath (for looking at fish), rapids close by, or a waterfall in sight. It can provide a place for interpretation and extending understanding. Always ask yourself if the bridge can perform other functions as well as getting people from A to B and put it in the best place to capitalise on them.

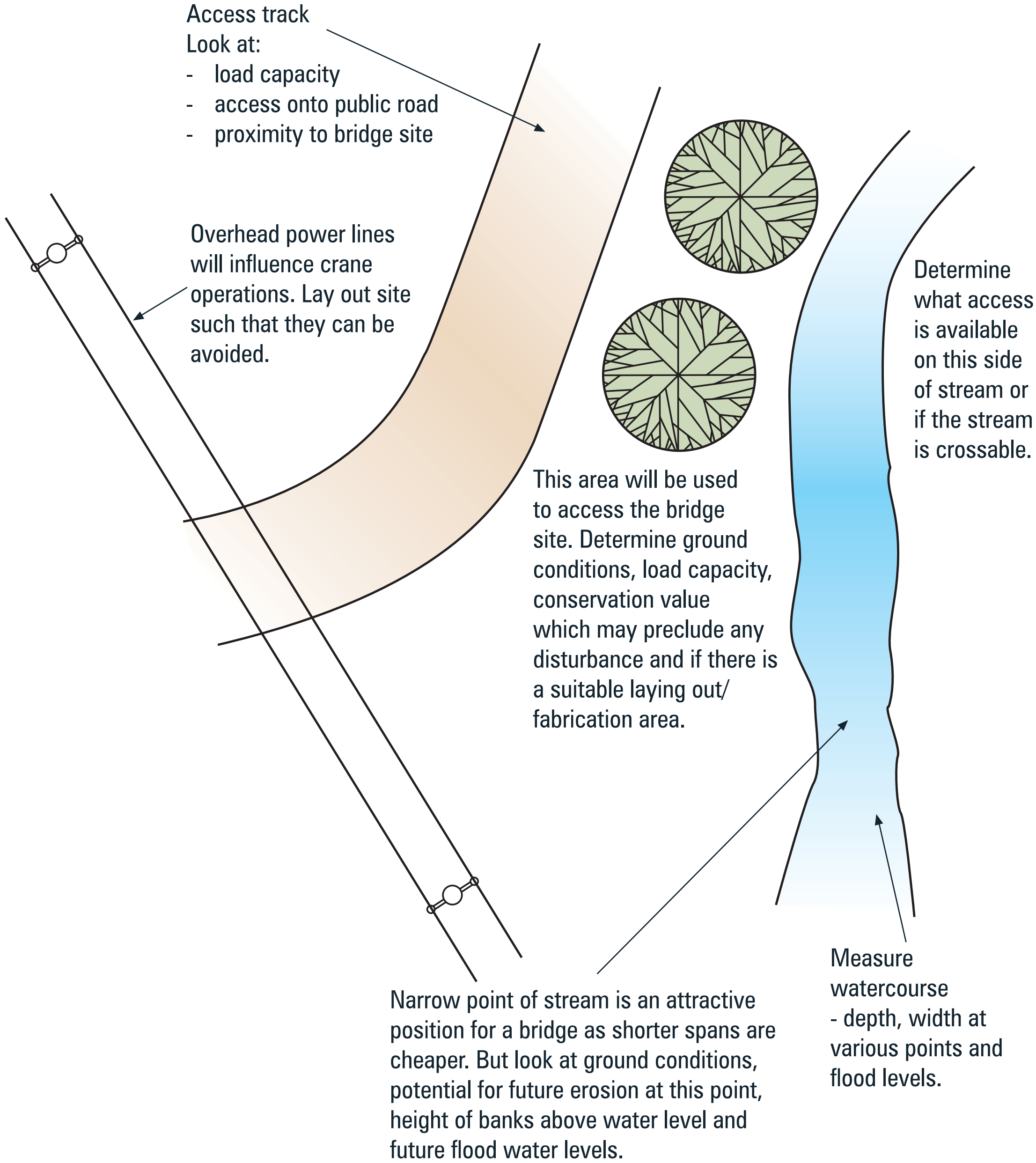
2.2.9 General site awareness

It is important to take account of the general character of the site. For example, evidence of vandalism or misuse should influence choice of construction materials and design. In some situations, urban sites overlooked by housing or close to public roads are likely to be better 'protected' by being visible than those in more secluded locations.

Detailed Site Survey

2.2.10 Survey recording

It is best to record the information using scale drawings and annotated maps and sketches. A global positioning system (GPS) can be useful in recording the precise locations of, for example, proposed abutments. A survey should include longitudinal and cross sections of the gap and a plan covering at least the same area. Accurate recording is vital as the detailed survey will be used in designing and drawing the bridge, its foundations and approaches, and in planning the construction.



Producing accurate diagrams is a crucial prerequisite to designing and planning construction. See Technical Sheet 6.1 for examples of the detailing required.

The Basic Bridge

The diagram on the opposite page shows the components of a basic simply supported beam bridge.

The **substructure** includes the elements that transfer the weight of the bridge to the ground at either end and comprises the following elements.

Abutments 1 are the bridge foundations and must be able to support the weight of the bridge and the users. The abutments will also determine the bridge level. This may have to be adjusted to provide clearance under the bridge for vehicles, boats, floods or debris.

An abutment is sometimes formed to include an **upstand** 2 which allows a gap for heat expansion and air circulation, and can be extended to create **wingwalls** 3 that support an approach ramp.

A **bearing** 4 lies between a beam and an abutment and transfers the load evenly. It holds the beam in place while allowing it to expand and contract in response to temperature.

Piers are used to provide intermediate supports for multi-span bridges.

On top of this sits the **superstructure**.

The main **beams** 5 are the structural heart of the bridge. These must be capable of supporting the loads of the users as well as the weight of the bridge itself.

The **deck** 6 provides a safe surface for users and transfers their weight to the main beams.

Handrails 7 prevent users falling off the bridge. In some designs they are also an integral part of the load-carrying structure.

Bridge Types

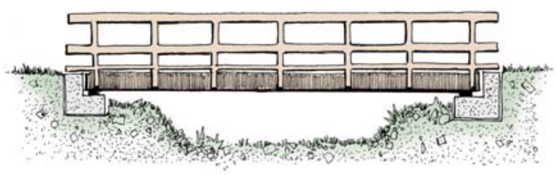
A wide variety of options and designs are available to put a bridge across a gap. Although there are many different types of bridge that could be used, most situations encountered will require a simple bridge of a short single span. Wide gaps and awkward locations may need a more complex solution, and in these situations specialised engineering input will be required to design a suitable structure.

This section will help to broadly identify the types of bridge you may encounter and to understand which bridge may be suitable for a given site. This understanding should be of assistance in working in a more informed way with engineers and designers.

Some of the main types of bridge are:

Simply supported beam bridges

These are the simplest and cheapest bridges and the ones that will 'do' for nearly all of the situations you will encounter. A railway sleeper placed across a burn is the most basic of simply supported bridges - one solid beam supported at each end, acting as a deck and beam in one.

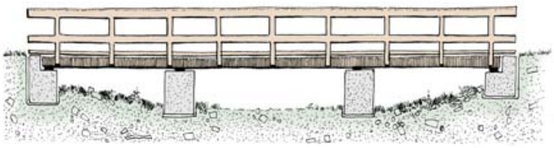


Green oak construction - a creative approach to a simply supported beam bridge

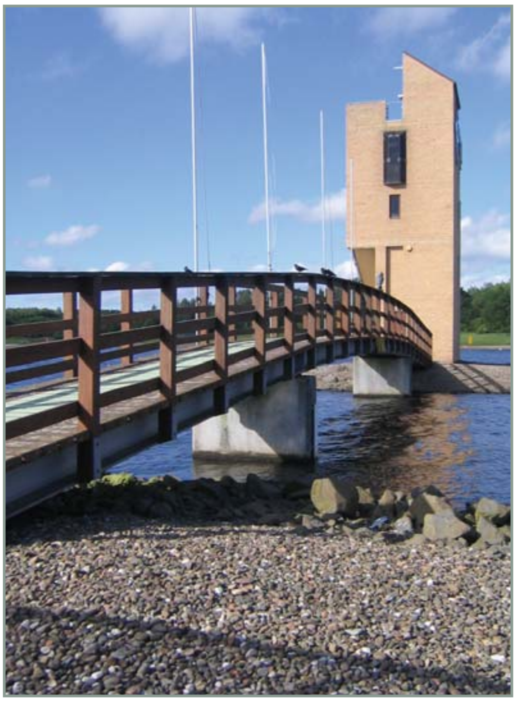
Most simply supported beam bridges have solid beams (either steel or timber) supporting a deck made up of timber boards or steel grids or plates with some form of handrail. All types are supported at either end on a simple pad foundation or abutment. Bridges of this type are available for spans up to 25m where an alternative to a solid beam is used. A common 'off the shelf' design for these long-span structures is a Warren Truss. Composed of a lightweight lattice of steel members, these specialist constructions allow large spans to be built while minimising materials and weight.

Bridge Types

Multi span bridges



These are similar to simply supported beams with one or more central supports (piers) in addition to the end abutments. They allow longer overall spans to be achieved or can be used to reduce beam sizes. However, there must be somewhere to place the piers and in rivers this is fraught with difficulties. Piers on river beds give rise to scour and should be avoided. They are better placed on bedrock. Even so, there is an increasing tendency to opt for a longer single span over a multi-span. These bridges should always be left to the experts.



Arch bridges

Once very common, they are now rarely built, apart from the new generation of timber arches, discussed later. For the path builder, arch bridges still have a place, particularly in rural areas. Loads from the deck are transferred around the arch into the abutments. Solid foundations are required and good stonework skills are needed to build them. British Trust for Conservation Volunteers' (BTCV) *Dry Stone Walling* has details of traditional stonework techniques. Achieving accessible gradients is sometimes difficult. You can make a 'cheat' arch by using a liner (either a section of plastic pipe or specialist galvanised corrugated steel) and then covering it with mass concrete. Stone work is then added purely for aesthetic purposes. Span range is up to 3m, unless you have a big budget and expert guidance.

Bridge Types

Suspension and cable stay bridges

Designing a suspension or cable stay bridge is complex and very solid foundations to bedrock are required. They can span big gaps without intermediate piers and are often extremely elegant and dramatic structures.

Suspension bridges are not uncommon on paths, but engineering input is essential.

Stress laminated timber arch bridges

This type of bridge is an efficient form of construction in terms of material and cost, and can be very attractive. At the moment, these must be designed and constructed by professionals but as the science develops, construction will simplify and relatively low levels of skills will be needed to carry out all operations.

Bridge Types

It makes use of small lengths of sawn timber vertically laminated. The laminations are stagger lapped and compressed together using high tensile steel rods. Because of the arch construction the timber is used in compression, which is its best property. This accounts for the efficiency and has led to spans between 60 and 100 times the timber depth. Care is required to design out steep gradients at either end to meet accessibility standards. Stress laminated timber arches are also available with flat decks. See Case Study 8.6.

Aerial mast bridges

Invented by the Forestry Commission, this design uses factory produced triangular steel truss units, 3m long, which are bolted together on site to form beams of lengths up to 26m. Beam units are laid side by side to give a bridge of the desired width and they are linked laterally using steel angles 'U' bolted to the top and bottom tubes of the mast sections. A timber deck is fixed to the top of the beams and handrails are attached to the lateral steel angles. They can be used for simply supported beam or multi-span designs. With very long spans horses can refuse because of the relatively low natural vibration frequencies that are set up. See Case Study 8.2.

Standard Designs

This guide gives designs for simply supported beams only. The other types of bridge illustrated in this section are beyond the scope of this guide and will require specialist knowledge. The bridges shown in the Standard Designs can be used in those situations where a single short span of 9m or less is suitable and there are no other complications.

3.3 Loadings

Understanding and accurately quantifying loads is an essential part of bridge design. In designing 'one-off' bridges, qualified engineers calculate these loads from first principles and specify the bridge accordingly, ensuring the structure is both 'fit for purpose' and safe.

The Standard Designs offered in Section 7 are relatively simple and do not require complex calculations. Normally you will need to specify a span, determine a load class, and a design to 'fit the bill' should be available. Alternatively, component sizes can be taken from tables in Technical Sheets 6.6, 6.7 and 6.8.

However, regardless of your technical 'know-how', it is still important to understand the impact loads have on structures and the next section provides an insight. The loads which may affect a bridge are covered by British Standards (BS), Approved Codes of Practice and Department for Transport (DfT), Memoranda and Eurocodes (see 4.6.8). An explanation of loads relevant to path bridges can be found in Technical Sheet 6.3.

Loads and their impact on bridges

Loads can be classified as:

Dead Load

The weight of the bridge itself. It is relatively easy to calculate knowing the construction materials and their dimensions.

Live Loads

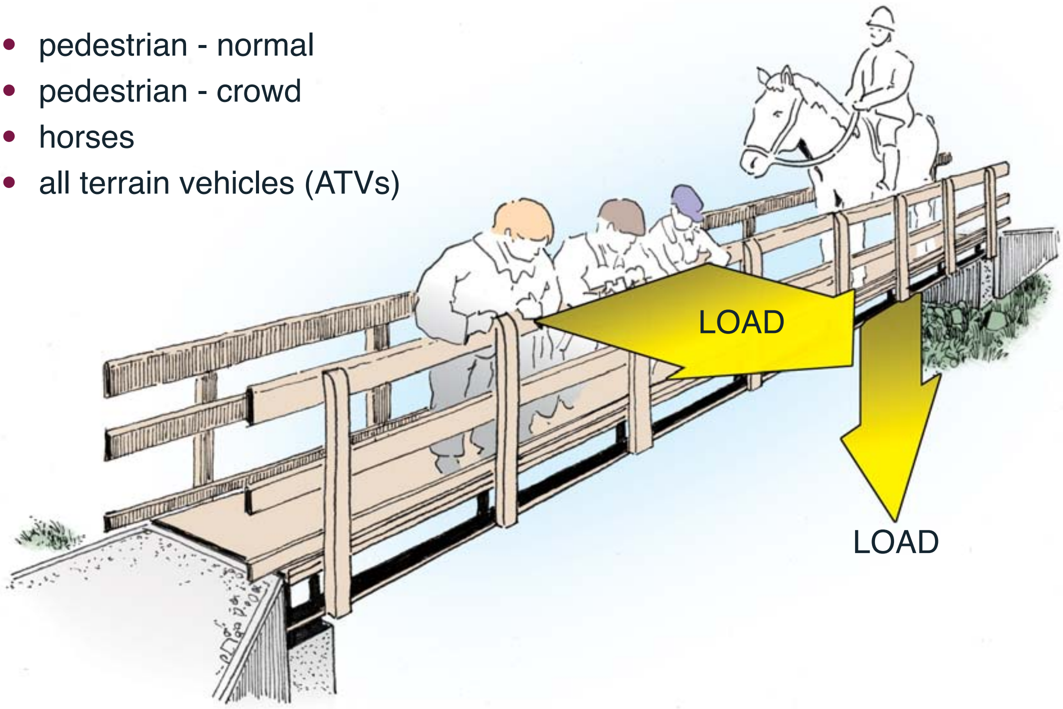
These are imposed on the bridge from external sources. The main types of live loads are:

Users: Users can impose both static loads and dynamic loads. A horse standing on a bridge exerts a weight vertically downwards - a *static* load. When it moves, the *dynamic* load imposed through its hooves is much greater but localised. Users leaning against a handrail will impose horizontal loads in the same way.

Loadings

User loads are categorised according to both type and volume of expected use by *BS5400*. These loads influence not only beam size but also the specification of decks and handrails. The load tables in Technical Sheets 6.6, 6.7 and 6.8 give options for the following BS load categories:

- pedestrian - normal
- pedestrian - crowd
- horses
- all terrain vehicles (ATVs)



Heavily used bridges in urban areas may have to accommodate 'extreme crowd' loading, in which case expert help should always be sought. Occasionally Highways Agency (formerly Department for Transport) Standard *BD 29/04* may override the requirements of the *BS5400* series. *BD 37/01* is also relevant.

Wind: Wind mainly imposes horizontal loads but may also cause suction over a flat surface leading to vertical loading. For most simple bridges, wind loads need not be considered separately.

Snow: Snow and ice will provide a static, vertical load. Factors of Safety (see over) will accommodate this on a simple bridge and it does not need to be considered. Usually when there is lots of snow, few people will use the bridge.

Flood Water: Flood water can give rise to all kinds of loads, often from unexpected directions. The water itself will provide large horizontal loads on the bridge structure, abutments and piers; upwards vertical pressure loads can cause the bridge to literally float away; floating debris in flood water can impose dynamic loads.

Loadings

Predicting flood loads is complex. The Standard Designs in this manual detail fixing-down methods that will cope with moderate inundation.

The designer of this bridge was anticipating flood conditions: the beams and handrails are designed to let water pass through

Deflection: A structural element can bend significantly while still being well within its maximum allowable load. However, bridge users will feel unsafe if a bridge moves alarmingly when they cross it. The beam sizes given in the Standard Designs and the tables in Technical Sheet 6.7 will limit deflection to an acceptable amount.

Every structure vibrates with a fixed *natural frequency*. If a varying force with a frequency equal to the natural frequency *(in phase)* is applied to such an object the resulting vibrations are known as resonance and they can become violent. For example, sometimes the action of wind or a group of people walking in-step will cause a structural member to oscillate or 'drum' in time with the steps. Dealing with this *dynamic deflection* is complex and its potentially catastrophic effects were experienced in 2000 with the Millennium Bridge over the Thames in London. Fortunately, this only needs consideration in the design of long slender spans.

Horses are very sensitive to vibration laterally and only very stiff bridges will be suitable for all horses. Current estimates of suitable frequencies are over 5Hz and work is on-going to improve understanding of horses' specific requirements.

Factors of Safety

When determining the magnitude of loads imposed on a structure, an engineer will always include a factor of safety to accommodate unforeseen circumstances. This will vary depending on how accurately you can quantify the load and the strength of the element it acts upon. For example, the Factor of Safety for ground loads is usually 2.0 because determining ground strength is difficult. So the total load, live and dead, imposed by the bridge on the ground is multiplied by 2 to determine the size and strength of the foundations required. Factors of Safety are covered in the various codes of practice relating to bridge design noted on the previous page.

Abutments

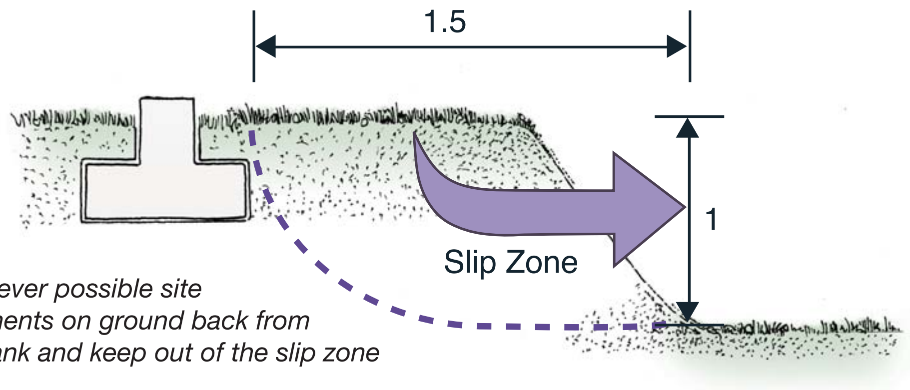
4.1.1 Specifying abutments

Abutments are the foundations of the bridge and have a number of functions. They must:

- safely transfer all of the bridge loads into the ground
- provide sufficient clearance under a bridge
- secure the bridge from being washed away if flooding is a possibility
- be robust enough not to be damaged by water
- provide an anchor for wingwalls if they are used

This means that they can often be substantial constructions that will have a major effect on the cost of a project. Every effort in siting the bridge to limit the work required on the abutments is worthwhile.

Wherever possible, set the abutments back from the bank edge. This may increase the length of bridge required but will keep the foundations away from the potentially unstable 'slip zone' of the bank slope and from potential scour. Scour at the toe of a bank should be anticipated unless bedrock is present. It is the most common cause of abutment collapse. One method of calculating the span of a bridge is given in Technical Sheet 6.1.

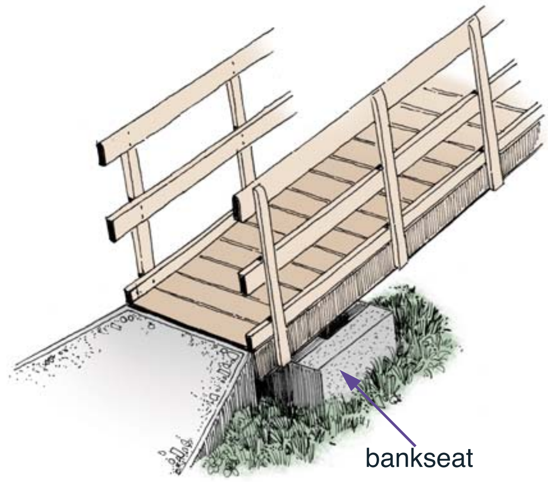


Whenever possible site abutments on ground back from the bank and keep out of the slip zone

These substantial abutments are required for a short span bridge because they lie in the slip zone; the alternative would be smaller foundations and a larger span

Abutments

The simplest abutments are called *bankseats*. These are basic concrete pad foundations and are suitable for use on the top of bankings (i.e. not in the slip zone). The bridges shown in the Standard Designs carry comparatively light loads. For this reason the *width* of bankseats used with them can be restricted to 500mm wider than the bridge itself. *Height* (minimum 150mm) is then determined by the required level of the bridge.



The ability to increase the height of an abutment above the required minimum is an important design consideration both for accessibility and landscape fit. Technical Sheet 6.4 gives some abutment design details for bankseats and more complex constructions. Constructing upstands on abutments provides attachment for wingwalls and will retain the path material.


Simple concrete bankseats being formed

Where tall abutments are constructed or steep slopes are created, protective handrailing may be required.

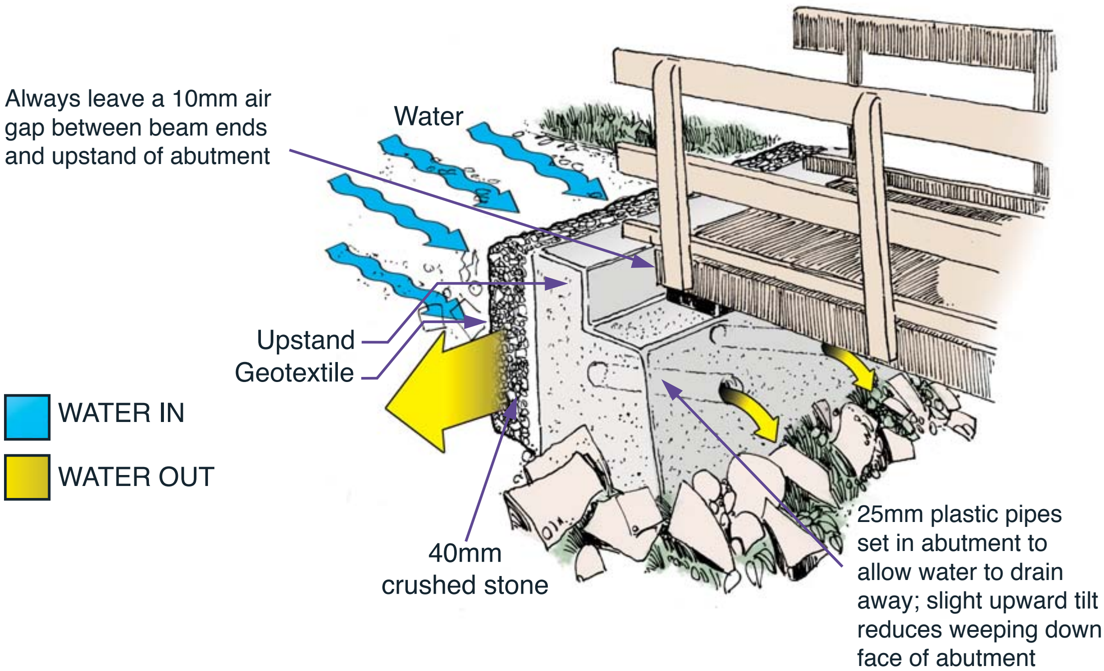
4.1.2 Soil conditions

Ideally, abutments are founded on the firm mineral subsoil layer below the topsoil, or better still attached to bedrock. On peaty soils or those with high clay content it is possible to 'float' abutments on a geogrid. A multi-layered 'sandwich' of geogrid and aggregate can substantially spread and support the load. Construction details can be found in Technical Sheet 6.4. but need careful detailing by an engineer.

Soil strength can be assessed in detail to calculate its bearing capacity so that abutments can be accurately designed to cope. However, abutments for a simply supported bridge of 9m and less will accommodate a minor amount of settlement and calculation is unnecessary. In these circumstances the overall stability of the riverbank and the effect of scour are far more important factors to be considered.

Abutments

If an abutment is also going to retain soil behind it, drainage for the soil must be provided. This is best achieved by putting a layer of single size 40mm crushed stone or gravel between the abutment and the soil, separated by a geotextile. If the abutment is going to retain soil behind it to a depth of over 500mm careful detailing is required and expert help should be sought.



Any upfilling or material behind an abutment should be well compacted and provision should be made for leading water away (see diagram). Compaction is best achieved by building up the fill material in thin layers (about 225mm) and using a vibratory roller or plate compactor to consolidate each layer. In remote areas a hand-held timber dolley or 'heeling in' by boot could be sufficient. Despite this, some settlement of unbound material should be expected.

4.1.3 Preparing foundations

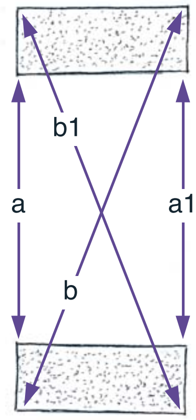
It is important that abutment foundations are kept as dry as possible during construction, as water can affect the structural integrity of the surrounding (and supporting) soil. If you have to excavate an abutment foundation in wet conditions, the hole may fill up with water as you dig it. Usually a line of sandbags around the hole will help to prevent this but you may also need a pump to keep it dry. The bearing capacity of saturated soil is about 50 per cent of the same soil in a dry state. Water seeping in to the foundation below the water table can substantially weaken the soil resulting in the hole collapsing; a serious health and safety concern.

To prevent collapse of side walls, dig foundations as recommended for trial pits in Section 2.2.4.

Abutments

4.1.4 Setting out

It is essential that abutments are accurately placed, level and parallel. Fitting beams or a complete bridge to badly measured or inaccurately constructed abutments can be an expensive and unpleasant experience. Emphasising their careful construction (including any allowable tolerances) on tender documents and designs is worthwhile.



Measure abutments carefully; if abutments are in line and parallel then a=a1 and b=b1

4.1.5 Construction materials

Abutments can be made from a variety of different materials, the most common of which are discussed below. A more extensive discussion about materials can be found in Section 4.6.

Concrete is a material that can be mixed to precise specifications. It can be tailored to meet the needs of different situations and used for a wide variety of different abutment designs. Care is needed when pouring concrete near to watercourses. Unset (green) concrete must not get into the water as it has a high pH (alkali) and may harm aquatic life as its fine particles block fish gills. Use of a gelling agent will reduce this and is standard practice, insisted on by some authorities. *SEPA's Pollution Prevention Guidelines (PPGs) 5 and 6* apply.

If the abutment is to be placed in the watercourse or if it may be subject to floodwater, a stronger concrete mix than standard is advised to resist scour and impact damage. The main downside of concrete is one of aesthetics. If your abutment needs to be large and visible above ground then consider hiding or cladding it. If you are simply using a small pad foundation then concrete is ideal. Concrete foundations should always be left to cure for one week before loading. See Technical Sheet 6.5 for mixing concrete.

Certain soils can have deleterious effects on the materials used to construct foundations. For example, ground with a high sulphate content (burnt shale waste, for example) will attack and decompose concrete. Any unusual soil conditions should therefore be tested prior to construction.

Abutments

Concrete abutments are usually constructed by pouring concrete into a shape preformed by shuttering. In most cases the shuttering is constructed from wood which is removed after hardening. Sometimes permanent shuttering is built from brick or stone and left in place as facing. Pour heights for concrete should be limited to 750mm if permanent shuttering is used.

Coating the inside face of wooden shuttering with 'shutter oil' will allow the shuttering to be easily removed when the concrete has cured. Release (loosen) shuttering after 24 hours and remove after 3 days.

Concrete sleepers (reclaimed or new) make an excellent simple bankseat. Use the existing holes in them to bolt down the bridge. It is essential to use them flat side down as they are reinforced to be loaded in this direction only.

Concrete sleepers can also be stacked up to face high abutments and retain approach ramps as well as to provide scour protection. This type of construction is called a crib wall. The crib wall is built up in layers with rows of sleepers overlapping each other. Steel pins driven through the rail bolting down holes tie the wall together. Gaps between the sleepers will allow vegetation to grow out of the wall, aiding stability and reducing visual impact. A diagram can be found in Technical Sheet 6.4. Construction of retaining walls presents a number of hazards which need careful management. For walls greater than three sleepers high (about 500mm), an engineer must be consulted and careful design is essential.

Proprietary precast concrete sections are also available specifically for crib wall construction.

Stone abutments are strong, long lasting and particularly appropriate for upland and other rural settings. The difficulty with stonework is finding stone of a suitable size, quality and shape to form an even topped abutment that will support the bridge beams. Also, the load bearing capacity of the available stone is unlikely to be known. Skilled stone masons may be needed to select and shape stone. Stonework may be laid dry but be aware of the effect of flood water, which may wash out pinning stones, causing abutments to settle or even collapse. Stone can be used to face a concrete abutment to reduce the visual impact.

Abutments

In the past, gabion baskets have been used for bridge abutments. However, they can be unsightly and susceptible to vandalism. Contrary to popular belief the wire baskets should not be simply filled with stone, rather the wire net should provide an outer skin on what is effectively a dry stone construction within. To be totally effective as bridge abutments they require as much skill to build as normal masonry. Always keep bearings (See Section 4.2.3) well back from the face of the gabion to ensure safe spread of load.

Timber, particularly a single large section can make a simple but effective bankseat for a short span bridge. Reclaimed railway sleepers or sections of telegraph pole have been used on many small bridges with great success. While these will not last anywhere near as long as stone or concrete, they can be very cheap and easy to install. If your site has poor access for machinery, timber may be a favourable option due to its relative ease of transportation. Ideally use a hardwood such as oak heartwood.

European Larch may also be used but will be even less durable. Elm will last almost indefinitely when placed in water or below ground level, although it is not durable if exposed to air.

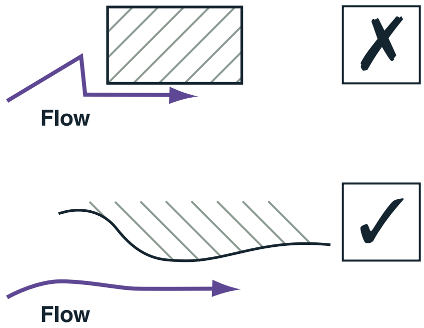
Timber can also be used for piled abutments. This is effective on soft ground, where piles are driven down to a hard subsoil or bedrock. They can simply be driven to refusal (driven in until they won't go any further) if no hard sub layer is present. They are often used in sand on beaches where they are vibrated into place.

Crib wall abutments (See Section 4.1.6) are also possible with timber, (often railway sleepers) and can be used to face abutments constructed from local materials, such as the earth abutments described below:

Earth can be utilised to create earthwork abutments from sub soil sourced on site. These are usually reinforced with a geotextile and / or geogrid. The geogrid is wrapped around successive layers of compacted soil and pinned firmly in place. Friction between the soil and the grid is very high, substantially eliminating settlement and erosion. Side slopes of the abutment can be made up to as much as 60°. It is critical that the soil type is suitable and the earthwork is carefully designed and detailed by an engineer.

Abutments

4.1.6 Scour protection



Try to avoid introducing hard edges into the watercourse

Designing for scour protection should only be necessary where a bridge abutment may be in potential contact with a watercourse. It is very much a last resort. (See Section 2.2.3). If it is necessary, the base of the abutment should be founded at least 350-500mm below bed level. Acute angles introduced into the flow will cause more problems than obtuse ones. So the choice of technique and the way the protection is designed are both important.

Conventional approaches to scour protection include:

Rock armouring or 'rip-rap' - This is a skilled job where rocks are interlocked over the face of a bank. Rock armouring should divert the river flow smoothly around the abutment without any obstructions. A small area of damaged 'rip-rap' soon enlarges causing total collapse, so monitoring and early repair is vital. Extracting stone from the river itself may require statutory consent. The rocks used should be as large as possible and locked together tightly.

Timber revetments - These must be substantial, of durable timber and tied well into the bank behind.

Stone-filled wire gabions - See Section 4.1.5.

Planting and geotextiles - A number of techniques for resisting scour have been developed by the River Restoration Centre and some of these may be useful when considering design of abutments and bank stabilisation. The *Manual of River Restoration Techniques* can found on the website **www. therrc.co.uk**.

Timber revetments such as this crib wall must be robust and well constructed

4.1.7 Approaches

The design and construction of the approaches are key to ensuring a safe transition from path to deck but also have a crucial role in tying the bridge into the landscape. Often bridges are set higher than the surrounding ground level and a ramp or steps will be needed to make the connection with the path surface. In most cases a ramp will be the most accessible choice but in some situations steps are unavoidable. Refer to the *Countryside for All Good Practice Guide* for advice.

The choice of approach path line and associated landscaping strongly influence how well a bridge sits in its landscape

Path wear is increased at a bridge and a path surface which is adequate elsewhere may not suffice for the approaches. The designer must consider how this will be managed; for example, by improving drainage and building to a higher specification at these locations. People tend to slow down, linger and congregate at bridges. Widening the approach paths and extending handrails can make the bridge safer and more comfortable to use.

Steps and ramps are affected by river flow under flood conditions and they can have their own impact on river dynamics. As far as possible they should be orientated parallel to the line of flow to minimise resistance. Where this is not possible and they are at right angles to the river, consider installing culverts beneath them.

Main Beams

Structurally, the main beams are the most significant part of a simply supported beam bridge. They will generally be the largest element, increasing in section size as span lengthens. If you are transporting a bridge to site in pieces, the main beams are likely to present the biggest challenge.

A beam of a simply supported bridge is mainly loaded in bending - it will increasingly deflect downwards the greater the load added to it. Beams have to be strong enough to carry these bending loads without breaking, but also be stiff enough to not bend to any significant degree under normal loading. Increasing beam depth increases stiffness and load carrying capacity, but it also increases weight. Reducing the width of a beam will help to reduce weight (and cost); however, there is now a danger that the beam will twist sideways as it is loaded. This is called buckling and the main beams must also resist these deflections. The specification of beams therefore depends on managing these two variables while minimising the material required. Precambering (see Technical Sheet 6.3) will help resist deflection and can add an elegance to a long span bridge structure.

Generally path bridges will have two or more beams. Using more beams allows smaller section sizes to be specified. They may be easier to transport onto site and can reduce the distance the deck boards have to span, but levelling them as a platform for the deck may be more difficult. As a rule, the greater the number of beams, the greater the weight of the bridge, so exploring a site to minimise span can sometimes reduce this. See Section 2.2.

4.2.1 Beam materials

As the main structural components of a bridge, beams have a big visual impact. The material and its final colour should be chosen with care.

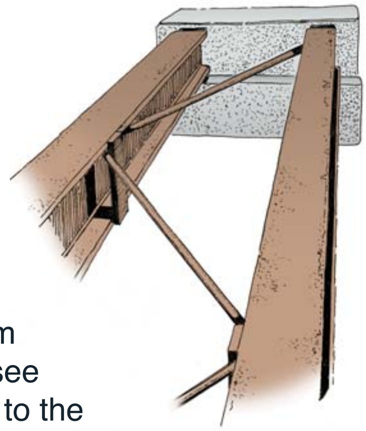
Steel bracing helps prevent both timber and steel beams from twisting

Timber

Rectangular timber beam sections are stiff and resist buckling very well. However, timber beams are expensive and very heavy at large sizes. This makes getting them on site a potentially difficult operation. Sometimes smaller section timbers can be laid next to each other and bolted together on site to make bigger beams - useful in difficult locations. Introducing a DPM (damp proof membrane) between beams and abutment helps prevent rot and extends the life of the timber. See Section 4.6.1 for more information on timber.

Main Beams

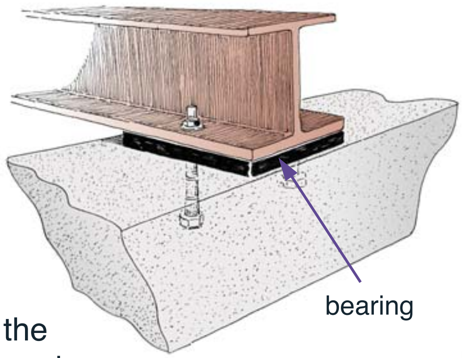
Steel



Structural steel can be specified in a variety of different sections. Most bridges are built with ‘I’ beams. These are structurally the most efficient, i.e. the stiffest beam for the least weight. Long span steel beams can lack rigidity, so providing additional cross bracing allows the beams to resist twisting and buckling. This bracing can take the form of small steel angle sections in a ‘zig-zag’ pattern (see diagram) or more substantial braces at right angles to the beams as in the Glentrool bridge (see Standard Design 7.4). In this case the angles can be extended to attach handrail posts. Steel ‘I’ beams are lighter than timber of an equivalent size (load carrying capacity) so they are a good choice for sites with poor access. However, the visual impact must be taken into account. See Section 4.6.2 for more information on steel.

4.2.2 Specifying sizes

The Standard Designs give a range of beam dimensions to match both the chosen effective span (see 2.2.1) and loading category for each design up to a maximum span of 9m. The tables in Technical Sheet 6.7 give more options. Designing spans that exceed this are likely to require the assistance of an engineer, making use of *BS 5400* which gives design rules for different loads and spans.



4.2.3 Bearings

Where superstructures rest on the abutments and piers, the load is transferred through a bearing. For long spans the bearing must allow the bridge to expand and contract under temperature or moisture changes and should let the ends of the beam flex slightly as they are loaded and unloaded. Short span bridges below 10m expand very little so special bearings are not required. Movement of the abutment or some tolerance in the structure will take account of expansion so bridges can be bolted to both abutments.

Rubber matting supplied for use in horse boxes can be cut to size to make bearing pads.

Deck

This will provide fixity for flood, wind and live load. Industry recognised materials for bearings are available for the purpose.

Choice of deck design will depend largely on the expected users. It is an important consideration not only in the construction of a new bridge but also in refurbishing existing bridges or extending their accessibility to new user groups by placing a new deck on existing beams. A variety of materials may be used but a few issues need to be considered before making a choice:

4.3.1 Key factors

Grip - In all weathers the deck must be non-slip. A number of options are available. Timber deck boards can be grooved to provide a reasonable grip but these collect detritus and invite rot if not regularly cleared. Chip or bauxite grit coatings using either tar or epoxy resin as a binder can be laid onto timber or steel. Alternatively, self-adhesive strips of non-slip material are available. These are effective and easily applied to the deck boards. Both methods require dry conditions and materials for application. Strips of non-slip material are inset in some proprietary decks. Glass reinforced plastic (GRP) panels with stone chips set into them are also available. Steel decks can be textured (e.g. 'chequer plate') or open grill panels can be used. The maintenance and installation implications need to be taken into account when choosing the best 'grippy' surface for a bridge. Don't be tempted to use chicken wire - it will always need a lot of looking after and may form a trip hazard.

Non-slip treatment of deck boards

Strength - The deck must support the impact loads of feet (particularly horses) without excessive deflection. Technical Sheet 6.6 gives typical timber section sizes for different combinations of deck widths and users.

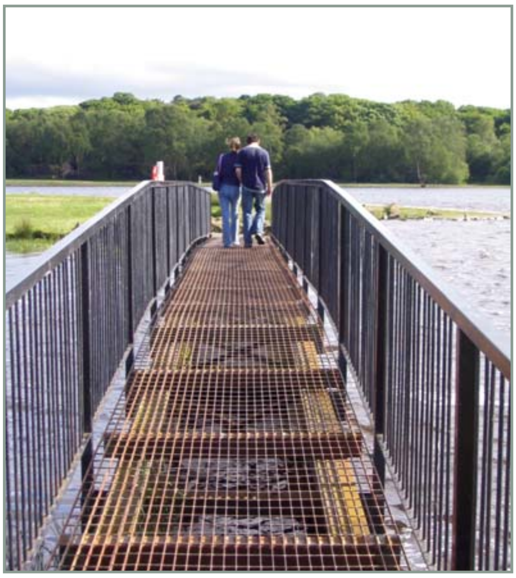
The depth of a timber deck reduces with wear and this is particularly noticeable where shod horses cross. Consequently the lifespan of a deck will be affected by the intensity and type of use. Always make an allowance for wear and rot.

Deck

Gaps - Gaps between deck boards or panels affects accessibility and maintenance. Keeping gaps to below 12mm is good practice and will allow bikes and wheelchairs to cross without problems. Similarly, gaps must be kept to 12mm if sheep may be driven across the bridge. Small gaps (under 6mm) trap material inducing rot. Open lattice steel bridges can sometimes frighten dogs or horses and can also be awkward for wheelchair users to cross. In some cases the addition of textured steel strips along one or both edges can help alleviate these problems.

Large gaps may drain well but they are not accessible

Noise - The noise produced by hooves on some steel decks or echoing off solid parapets can alarm horses.



Open lattice decks can be alarming for users; dogs often refuse

4.3.2 Deck materials

The common options are discussed below but a range of proprietary surfaces are also available.

Timber is lightweight, easy to work on site and is often the preferred choice. In most cases timber deck boards are laid across the bridge. It is possible to lay the deck along the length of the bridge (useful for putting a wider deck on existing beams), although access for any wheeled vehicles can be dangerous because of tram lining. Visually the effect is unnerving so longitudinal deck boards are usually a last resort.

Wet timber, particularly where algae is allowed to grow can be very slippery without some sort of non-slip treatment.

Deck

The top surface of timber decks wears in use, so consider using a board thickness greater than required purely for strength for a longer lifespan, particularly where horses are involved. The large point loads (see Technical Sheet 6.3) imposed by horses' hooves will require the standard life expectancy of timber decks to be reviewed and hardwood may be a more robust option. See Section 4.6 for more information on specifying timber.

Bauxite grit non-slip treatment will extend the life of deckboards subject to equestrian use. Plywood decking with non-slip surfaces pre-applied is available from specialist suppliers. See Case Study 8.2.

Grooved decking is available off the shelf or can be grooved in the workshop.

Always lay deck boards heart down

Metal decks can be cheap, easy to install and durable (particularly where vandalism is a problem). Steel and aluminium are both well suited giving a light, strong deck with a long lifespan. In most cases proprietary deck systems are used. Manufacturers will supply details, costs and advice on suitability for different situations. Bare metal decks are generally unpopular with horse riders.

Recyled plastic has a longer life expectancy than timber and there are occasional examples where it has been used for decking. However, it is heavier than timber, currently more expensive and more flexible. There are no industry standards that apply at the present time, so load carrying capacity is not certified. In wet weather it can be less slippery than timber (see Section 4.6.5).

4.3.3 Choosing deck width

A number of organisations have recommended minimum useable deck widths to suit different users and circumstances. These are shown in the table below.

User Group	Recommended minimum width	Source
Wheelchair users	1.2m	Fieldfare Trust Countryside for All
Horses	1.5m (up to 3m span) 1.5 –2m (up to 8m) 4m (for longer road/river crossings)	British Horse Society (BHS)
Pedestrian Normal	900mm	BS5400
Pedestrian Crowd	1.2m	BS5400
Cycles	2.0m	DfT BD 29/04
	As for horses (see above) but 2.5m over 10m	Sustrans

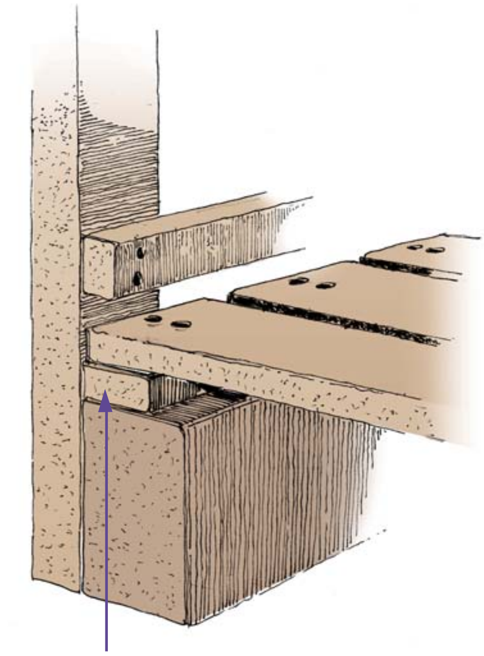
However, choosing a width of deck can sometimes be a compromise between what is recommended and what is structurally possible, affordable or visually acceptable. That choice must always be firmly based on risk assessment. As a rough guide 1.2m should be a minimum width. For multi-use 1.5 - 2.0m will be required. Deck width must also take account of span and the volume of users. A longer span is likely to require a wider deck to allow passing. The Standard Designs have a maximum deck width of 1.8m. Where a wider deck is required, engineering input will be required.

Technical Sheet 6.6 sets out deck sections and widths for different load classes. It is particularly useful for assessing and upgrading the deck on existing beams. If there is any doubt over the load carrying capacity of existing beams, an engineer should be consulted.

Deck

4.3.4 Attachment

It is common just to nail or screw timber deck boards direct to timber beams; however, nail and screw holes are a haven for decay, and removing boards for cleaning and maintenance is awkward. These problems can be lessened by nailing deck boards to secondary *nailing strips* or *runners* strapped directly to the beams, or screwed on from below. Hardwood or recycled plastic are popular choices of material for the nailing strips because of their long life and resistance to decay. In reality a nailing strip of 50 x 100mm will be adequate for most situations.



It is possible to prefabricate deck sections in the workshop. This simplifies assembly on site and allows these sections to be easily removed for maintenance. Sections can be delivered on pallets cutting down on handling and reducing the number of components to be assembled.

Handrails and Toeboards

Handrails not only prevent users from falling off a bridge, they also have an important function in giving support to people crossing it. Some wheelchair users use them as a means of propulsion. A basic handrail will have uprights, a top rail and one or more intermediate rails. The top rail should have a smooth and rounded section offering an easy, comfortable grip. Where the top rail is too high for wheelchair users to grab and use, the rail for assisting people should be positioned and finished at an appropriate height. Mesh panelling can be added for extra safety if necessary. Take care to ensure that the view from the bridge is not unreasonably impaired - do not forget, some people have to look through, not over, the handrail.

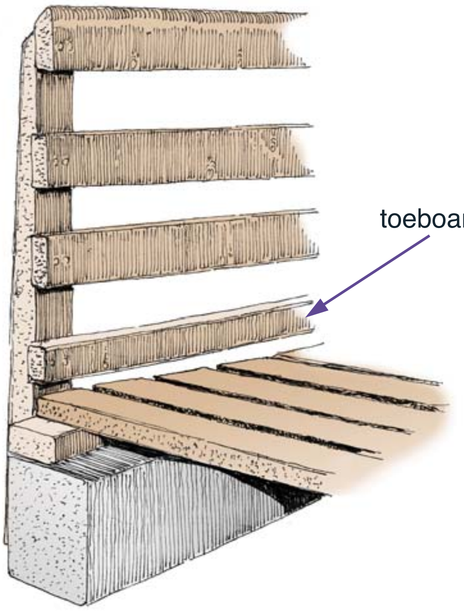
Handrails can have a significant visual impact, which you may wish to either minimise or exploit. Slender, open handrails reduce intrusion, as can vertical rails or horizontal wires. Vertical handrails are becoming increasingly popular; offering an elegant solution, they deter people from climbing on them and should be seriously considered in all locations where high use is expected or where the drop is substantial. Forestry Civil Engineering now only use horizontal handrails on short, low spans or deep in the forest. Alternatively a hefty handrail can make a striking visual feature in an appropriate place.

This handrail detail gives a high degree of safety for users while allowing wheelchair users and smaller people to enjoy the view

The curved detailing lends an elegance to the tops and outside edges of these substantial handrail posts

Handrails and Toeboards

Toe boards are planks or strips just above deck level which prevent pets or small children slipping under the handrail, while providing a tapping rail for people with visual impairments and security for wheelchair users. They are particularly important on bridges that horses will cross and must be close enough to the deck to prevent a hoof from slipping between. Up to 50mm should always be left between toeboard and deck to prevent rot and allow maintenance. BHS recommend a solid toeboard of minimum 250mm.



The steel toeboard and handrails pictured here bring a contemporary feel to a wooden path bridge

4.4.1 Choosing handrail height

Selecting handrail height can be a thorny issue. British Standards exist and some organisations have recommended heights for their own particular interests, as shown in the table overleaf. However, in some situations the visual intrusion presented by say, a 1.8m high handrail, is not justified by the modest increase in risk to users by lowering it to, a more visually acceptable 1.4m. Similarly, being confined by very high handrails could ruin the experience of being in that location. It is all a matter of risk assessment. Occasionally bridges have removable handrails, which can be dismantled when flooding is likely, preventing them from being torn off and damaging the rest of the bridge structure. For example, the Forestry Commission now remove the rails from a wide road bridge by the River Affric before winter arrives, having suffered a number of episodes where the handrails had been swept off in flood conditions. This is only an option for wide decks. Whether the bridge can remain open at these times will depend on assessment of risk.

Handrails and Toeboards

A horizontal load applied to a tall handrail exerts a much greater force on the fixing between the handrail post and the beam than is the case with a lower rail. Essentially a load applied further from the fixing exerts more leverage and a stronger fixing is required to withstand it. This usually means that beams have to be deeper and handrail posts of a larger section size - adding substantially to cost and increasing design difficulties. This effect on the fixing increases exponentially with the load and so providing adequate fixings for a 1.8m handrail suitable for equestrian use is structurally challenging. For this reason handrail heights in the Standard Designs are limited to 1.6m. Should a taller handrail be required, seek professional help.

A number of organisations have recommended minimum handrail heights to suit different users and circumstances. These are shown in the table below.

User Group	Recommended height	Source
Wheelchair users	1000mm	Fieldfare Trust Countryside for All
Horse with rider	1800mm (1500mm acceptable depending on drop) 1800mm	British Horse Society (Equestrian Factsheet) DfT BD 52/93
Pedestrian Normal	1100mm	DfT BD 52/93
Pedestrian Crowd	1100mm	DfT BD 52/93
Cycles	1400mm	DfT BD 52/93
Pedestrians (over 5m drop)	1250mm	FCE
Pedestrians (under 5m drop)	1000mm	FCE

* where bridge is in an area of high prevailing winds or with headroom under bridge of over 10m

Handrails and Toeboards

Try to keep handrail height to the minimum required to do its job and think creatively about the problem when height conflicts strongly with other issues.

Selecting handrail height is not always a clear cut decision. You must take into account all of the factors, including type and volume of users, busyness or remoteness of the site, the span, the drop and the consequences of a fall. It is a choice that must be firmly based on risk assessment. A table in Technical Sheet 6.8 gives some handrail height suggestions for a variety of situations.

Here horse riders are asked to dismount, and mounting blocks are provided at each end, which allows handrail height to be minimised. Look at **www.ride-uk.org.uk** *for a mounting block design.*

Bridges crossing a highway or railway line will have minimum standards set by the Highway Authority or Network Rail that must be followed. In other cases a risk assessment on a case-by-case basis is the most logical approach for determining handrail height.

4.4.2 Construction options

Detailing handrails

Choosing suitable handrail section sizes and distances between posts is dealt with in Technical Sheet 6.8. This information is particularly useful for tying in the handrails on approach paths and in awkward situations. Handrails may need to be strengthened to withstand large horizontal loads particularly if the bridge could be flooded.

The gap between rails under 1000mm in height is covered by UK Building Regulations and DfT memoranda, which state that a sphere over 100mm diameter (a baby's head) should not be able to pass through. Detailing a more open handrail must be based on risk assessment. However, there are other considerations, too. For example, where sheep may cross, gaps between lower rails should be 200mm maximum.

Handrails and Toeboards

Materials

Choice of handrail material will depend on cost, location and function. Steel or aluminium in small section allows 'light-looking' bridges to be built, but the handrails will need to be prefabricated. Tensioned wire cables perform a similar function but are assembled on site. Wood is easily worked and can be cut to size on site if required. However, the post section sizes required to withstand some loads can be considerable and then fixing them to beams becomes challenging.

Attaching posts to beams

The attachment of handrail posts to the bridge has long been, for the aforementioned reasons, the weakest part of bridge design. Many older designs have been dropped because of the difficulties in successfully creating these joints and ensuring that they last over time. Bolting posts directly to beams weakens the beams and can reduce lifespan through rot. So other ways of attachment have been explored. Many designs employ the use of transoms. These supports, fixed at right angles between main beams, provide a handrail post attachment, add stiffness and resist twisting. Sometimes they form part of the deck.

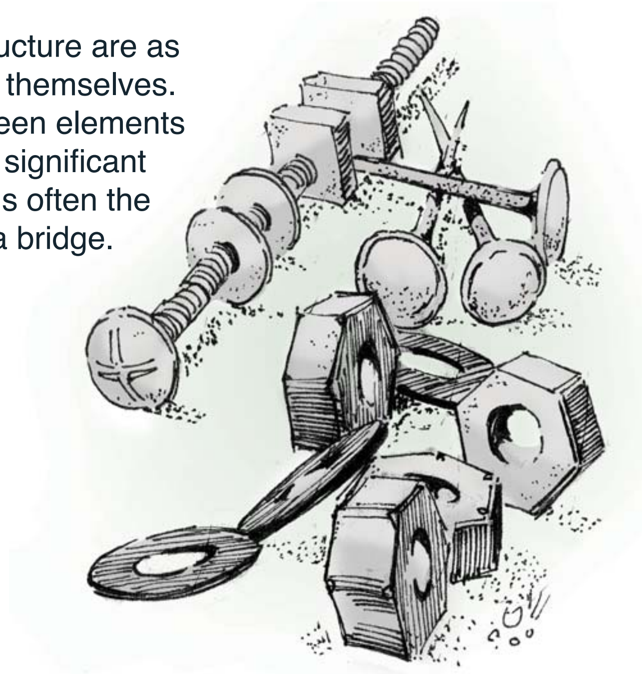
Solid post attachment on a Glentrool Bridge

In recent years a patented design, the torsional restraint system, has been developed by Forestry Civil Engineering that tackles this issue. Evolved from the Galloway Bridge, the torsional restraint system takes the form of a galvanized steel angle above and below the beams, fixed to the beams or clamped around them, while their extension provides the support for the posts. This structure forms a mid span torsional restraint which resists twisting and stiffens the bridge while giving a strong support to the posts.

Handrails and Toeboards

The beams are prevented from twisting by rigid steel frames, which also give strong handrail post attachments. A series of wooden wedges can be used to take up any tolerance between the beams and steel frames (See Standard Design 7.5).

Joints and Fasteners



The integrity of joints in a bridge structure are as important as the separate elements themselves. Each joint must transfer loads between elements without weakening them or causing significant additional stresses. Detailing joints is often the most challenging part of designing a bridge. This section looks at the different methods of joining parts of a bridge together, their suitability for use with a range of materials and some of the points to watch out for when specifying them.

As a basic premise, drilling through elements to joint them together weakens them. So for designers of complex bridges, careful thought is required to determine the most effective and efficient type of joint. However, for the majority of simple bridge structures the factors of safety introduced into the design will easily ensure that the section sizes will accommodate the weakening impact of joints.

Common types

The most common ways of creating joints are outlined below with details for specifying and using them in Technical Sheet 6.9.

Nails are the most basic of fasteners. Choice of lengths and thickness (gauge) is important, depending on the size of timber section used.

Screws are used to join small timber sections to each other or to a larger element (for example, to join a handrail to a post). In recent years screw technology has come on in leaps and bounds. Most now have their own drill point and can be driven without pilot holes. There are many specialised applications. Consult manufacturers' information for advice.

Coach screws are a larger type of screw. They are used for bigger joints, e.g. attaching handrail posts to the side of a timber main beam where drilling for a normal nut and bolt may be difficult due to site access. A square head is standard - hexagonal heads must be specified.

Joints and Fasteners

Nuts and bolts form the most commonly used joint on the majority of footbridges - the bolted connection. Parts of a bridge are clamped firmly together as a nut tightens down on a bolt through a pre-drilled hole. Pre-drilling bolt holes weakens bridge elements. As a result larger sections are specified to take account of this.

Studding is sometimes necessary for long connections (over 200mm). A length of threaded rod with a nut and washer at each end is used.

Welds join steel or aluminium sections, making very strong, rigid joints. If done well there is minimal loss of material strength around the joint. A welded joint is permanent - you will not be able to dismantle it for maintenance.

While it is possible to weld effectively on site, it is not an ideal situation. The weather needs to be dry and still, and it must be possible to bring the equipment right up to (and often on to) the bridge. Provision of a safe working platform is absolutely critical for welding operations, far more so than simply inserting and tightening nuts and bolts, for example. This may be an expensive option if a remote bridge is needed to cross a large gorge. On-site welding will also destroy any protective coating - galvanised or painted. Any ‘touching up’ of the affected area will never be as good as the original finish and so corrosion can be expected sooner than would otherwise be the case.

Glued joints can be used for timber and metal but is generally only used on specialist designs. In principle, glue transforms a pinned (potentially moveable) bolted or screwed joint into a rigid one.

Clamping bridge elements together using a variety of straps, hangers and glands with bolted fastenings is sometimes used. These avoid the need to drill holes in sections, which maximises strength and durability.

Mortise and tenon or doweled joints can also be used, but require skilled timber workers to manufacture and are always susceptible to weathering. They must only be formed in a joiner’s shop.

Rivets are now rarely used but once were very common on steel bridges of all sizes. You may encounter rivets on disused railway bridges. Specialist advice should be sought in these instances.

Joints and Fasteners

Choosing the best joint or fastener

Given the above variety of joint types and the different types of fasteners available, choosing the right one can seem a bewildering task. Joint choice is influenced heavily by how a bridge is to be constructed and installed. If the bridge is to be manufactured in a factory, transported complete to site and installed in one operation, then it is easier to provide more complex joints that allow the materials' properties - strength, appearance, etc. - to be maximised. For example, an all-welded Warren Truss bridge will look considerably smarter than one involving a lot of bolted joints with all of the associated flanges and gusset plates visible. It will also be lighter, more efficient and cheaper.

If, however, the site has poor access and the bridge needs to be assembled on site, then you need to specify joints that are easy to create. This is especially the case if your bridge is to be installed by unskilled labour or volunteers. Even a specialist contractor can struggle to make a tricky joint in a howling gale and torrential rain!

As a general guide, any on-site assembled joints should be bolted, screwed or nailed. Any other joints should be constructed in a factory or workshop. It may be possible to bring in the bridge in prefabricated sections, such as a complete handrail assembly, which is factory-made with more complex joints. The 'prefab' sections are then bolted together on site. The Ekki hardwood bridges found on the A9 cycle route were constructed like this. Galvanised fasteners are still the 'norm' but stainless steel is being used increasingly and should be considered.

Materials

In choosing materials for a bridge, suitability for the required purpose will be the most important consideration. However, where there is a choice, cost, visual appearance and environmental impact should be considered.

Cost can, of course, be measured purely in terms of installation. However, it is perhaps more useful to consider whole life costs. Whole life costs are the sum of:

- Acquisition costs - planning, design and construction.
- Operational costs - those incurred during the operational life of the bridge (maintenance, predicted repairs and renewals) and the length of that life.
- End life costs - associated with disposal and/or replacement.

4.6.1 Timber

Timber is used extensively for large scale bridge construction around the globe and its potential in the UK has not been fully realised. There is much interest and research being undertaken to fill this void, which is best accessed through InTEC (Innovative Timber Engineering for the Countryside) via **www.forestry.gov.uk**.

Timber has a number of advantages: simple designs usually demand low levels of skill and materials are readily available locally; small span timber bridges are usually cheaper than other alternatives; it is chemically stable - especially useful in marine environments - and easy to dismantle compared with steel and concrete at the end of its life.

Aside from sawn timber and round log, timber is available in other forms for use in bridge construction, glulam (glue laminated timber) and mechlam (mechanically laminated timber) being two examples. New constructions and composites are likely to be developed to better utilise short section and ‘waste’ materials.

Some tropical hardwoods offer strong and durable solutions. However, their sustainability credentials are not always reliable. Fixing can be difficult and in some cases splinters are toxic. Homegrown oak, European larch and Douglas fir all have useful roles to play in bridge construction.

Materials

Whether you want a bridge that makes a statement or a bridge that is low cost and unobtrusive, timber can fit the bill. It is a natural material which is generally light, strong and easily worked, and a renewable construction material with favourable 'green' credentials, especially when compared with concrete and steel. Timber weathers sympathetically; it can be shaped in a huge variety of ways giving great scope for designers.

Strength grading and classification

Timber quality is affected by the soil and climatic conditions in which the parent tree has been grown, the care the forest has received during the growing period and the way in which the tree has been felled, sawn and seasoned.

Put at its simplest, strength grading, formerly known as stress grading, is a method of determining the strength of a piece of timber destined for structural use. It is essential that the timber used for bridge building is up to the job, and acquiring the correctly specified timber will ensure this. Strength grading is carried out by either visual or mechanical methods.

Visual grades are a broad brush measurement, giving a few different categories of timber, namely:

General Structural (GS) and *Special Structural (SS)* for softwoods
Hardwood Structural (HS) for hardwoods

Grading depends on growth rates, number of knots, fissures and general timber condition. Certified visual grading is carried out by qualified graders under *BS 4978*. A short interpretation of visual strength grading softwoods for decking can be found in Technical Sheet 6.10, this is only for use by people experienced in assessing timber qualities.

Mechanical grades confirm the minimum strength of the piece of timber. They are species specific, for example Douglas Fir spans strength classes C14 - C24, where larch can make C27 if the quality is good enough. Hardwood grades are prefixed with a D. Grading is governed by *BS EN 519*. It is only possible to mechanically grade for small sections, hence most beams are visually graded. In general, Scottish softwood timber tends to be strength graded at C16. Higher strength classes are generally supplied from imported timber, though small quantities may be available from Scottish sources.

Equipment is available to carry out non-destructive testing of timber strength on site, which allows accurate assessment of locally sourced timber for construction and the evaluation of the status of existing structures. Alternatively, a qualified timber grader can be brought in to visually assess locally sourced material. The Scottish Timber Trade Association, **www.stta.org.uk** can advise.

Choosing suitable species

Home-grown oak or European larch bridges are becoming more common and offer strong, long-lasting timber constructions that require no chemical treatment. Imported species such as Ekki are readily available but their sustainability credentials are not always reliable. Always ensure that all timber comes from sustainable sources through a recognised certification scheme e.g. Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certificate (PEFC). Hardwoods are used for high quality decking because of their resistance to wear and decay but they are more difficult to work than softwoods and all fixing holes must be predrilled. Some tropical hardwoods have toxic splinters. Hardwoods are also used for beams because of their strength and resistance to decay.

Materials

Home-grown timber may be obtained from the Forestry Commission, local sawmills and estates. Imported timber will be obtained from a timber yard. The Yellow Pages Directory will show those available in any area.

Increasingly, mobile equipment is available for milling timber on site. This can enable low-cost bridges to be constructed in difficult locations with minimal transportation of construction materials. See Case Study 8.4.

Durability

The natural durability of timber is due to the anatomy of the wood and in some cases to the presence of naturally occurring chemicals which are toxic to wood-destroying organisms. Durability is species specific. It is classified according to the table below and applies only to heartwood. In the construction of bridges it is advisable to use only timber which is 'moderately durable' or better. In terms of home-grown timber, only European larch (moderately durable) or European oak (durable) meet that advice.

Durability Category		Approximate life in ground contact
VD	Very Durable	More than 25 years
D	Durable	15 - 25 years
MD	Moderately Durable	10 - 15 years
SD	Slightly Durable	5 - 10 years
ND	Not Durable	Less than 5 years

Good design should minimise the opportunities for water to become trapped in the structure - this is what causes rot. Much can be achieved in terms of increased durability by improved detailing. Some very old structures (up to 1000 years old!) have incorporated sacrificial wooden boarding or a drip moulding to protect structural elements from moisture. These are replaced when necessary. Covering bridges with protective roofs is common practice in some countries. Technical Sheet 6.9 details the susceptible parts of a timber bridge and some ideas for improved detailing.

For further information go to the Timber Research and Development Association (TRADA) website **www.trada.co.uk**. This details the range of timber species available and gives their uses, density, working qualities, durability, treatability, sizes available and relative costs. The Scottish Timber Trade Association site **www.stta.co.uk** is also useful. *EN 460* applies.

Materials

Timber treatment

Preservative treatment will be necessary only if the natural durability of a timber is insufficient to meet the required service life.

The most common form of timber treatment is Copper Chromium Phosphate (CCP). Through pressure application this can extend the natural life expectancy of some timbers. However, it should never be a substitute for good detailing and species selection.

Increasingly, the active ingredients in traditional preservatives are coming under environmental scrutiny. Concerns over the environmental impact both where treated timber is used and in the vicinity of the treatment plant have led to the following recent changes:

- Amendment to the EC Marketing and Use Directive limits Copper Chromium Arsenate (CCA), which was previously widely used to a few derogated uses, including bridge decking.
- Creosote was withdrawn for public/domestic use in 2003, but is still available for industrial uses including bridge decks.

Timber treatment restrictions are likely to become more stringent and it is important to keep abreast of changes.

As a general principle try to minimise use of treated timber as all treatments have some environmental impact. As an alternative to treated softwood, it is usually possible to source relatively locally produced European larch or oak, both of which have reasonable durability without treatment. Douglas fir can also be used untreated if sections are large enough. Any wood in contact with the ground will rot more quickly and treatment should be considered.

Always ensure protective gloves are used when working with wood treated with CCA or creosote. CCA treated off-cuts should not be burnt in an open fire as the toxic preservative elements will be released.

Materials

Timber Sections

Timber sections will be supplied sawn or processed. In both cases the actual dimensions of the timber you receive may vary from the stated size.

A ***sawn*** 50mm x 150mm will measure 50mm x 150mm within a tolerance of -1mm to +3mms on the thickness and -2mm to +6mms on the width.

A ***processed*** 50mm x 150mm (cut from a larger section) will have a minimum size of 46 x 144mms.

These variations and processing allowances in section sizes must be considered when determining the strength of members.

4.6.2 Steel

In terms of durability and vandal resistance, steel is probably the best material to use for a bridge. In many situations, it is common practice to have a composite bridge marrying steel beams with a timber deck and handrail, for example the Glentrool Bridge shown in Standard Design 7.4.

While stainless is the most durable steel, it is very expensive. It is often used for very ornate bridges (for example the Millennium Bridge in London). In most cases plain mild structural steel is adequate.

Structural steel

Steel can be obtained in different grades of uniform quality, each grade having its own characteristic mechanical properties. *BS 7668* gives the current standards for steel grades. S275 is normal for short-span bridges. Low temperature ductility grades must always be used to withstand frost conditions.

Steel is available in a wide range of sections, the choice of which has a key influence on the inherent strength and potential use of the material. For example, an ‘I’-beam is much more efficient (strength for weight) than its corresponding box section which in turn is more efficient than a tubular section of the same dimensions. Technical Sheet 6.12 gives more details of what is available.

Materials

Structural steelwork should be obtained from a competent steelwork fabricator who will be responsible for the standard of workmanship being in accordance with *BS 5950*, and who will also prepare the steel and apply the protective coatings. *BS 5400: Part 2* applies to bridge loadings, and *BS 5400: Part 3* to design. *BS 5950* is a general building code, which is very useful for simple bridge construction unless an authority demands the use of a more specific code. The fabricator may also erect the steel, but if this is not the case the erection should be supervised by an experienced and competent person.

If steel beams are required that need no fabrication other than being cut to length, they can be obtained direct from a steel stockist, but preparation and painting of the steel will then be the responsibility of the purchaser.

Attachments for handrail posts have been welded to the beams before galvanising

Protecting mild steel

To increase the durability of mild steel, it should be galvanised, and then painted if required. One of the most effective painting methods is to use powder coating. This provides an extremely tough coloured finish which is highly resistant to knocks and scrapes. It must be done after any drilling or cutting, otherwise water will get under the coating and cause rust, which may not be visible until it is very severe. It is common for powder coating to be applied post-galvanising for maximum durability and for a better colour. The success of all coating systems depends on the method and thoroughness of the preparation of the steel surface. The Forestry Commission galvanise all steel and leave unpainted - in time it dulls down.

Treat galvanised components with care and try not to chip them. Touch up any disturbed galvanising with galvanising paint - it will give some degree of protection.

Dirt and grease must always be removed for priming coats and all subsequent coats, and the surfaces must always be dry. Blue mill scale is formed on the surface of steel during the hot rolling process. As it is not a suitable base for paint or metal coating, it and any associated rust must be thoroughly cleaned before application. A variety of cleaning methods are available, including hand cleaning, blasting with grit and pickling.

Zinc is the main metal used in galvanising. Some metals (including zinc) are not compatible in connection with some others (i.e. copper) giving rise to accelerated rates of corrosion at the join. Any unusual combinations of metals in contact with each other must be researched first.

4.6.3 Aluminium

Aluminium structural sections have some advantages over other materials. Alloys of aluminium can be as strong as steel, weigh around one-third as much and be highly resistant to corrosion. However, aluminium has a high coefficient of expansion and low modulus of elasticity, both of which give rise to large movements in a structure. It can also react when in contact with other materials such as copper and steel. A variety of structural sections are produced but only the smaller sections are readily available and it is a fairly

Aluminium bridge in Tillicoultry Glen. Twelve years old and no rust!

expensive material. Its light weight makes it attractive for areas which are inaccessible to normal transport, but an experienced designer should be employed to ensure that the correct alloy is used and the proper allowance is made for the difficulties mentioned above. Aluminium is particularly useful as a lattice girder solution, which can span long gaps (up to 30m) and which allows the structure to be transported in small sections for assembly on site.

Aluminium profiles are fabricated by the extrusion process which allows many varied hollow shapes to be formed, so that aluminum structures can often be more elegant than those of steel. Aluminium profiles can be a popular choice for bridge parapets because they need no protective paint. Information on the use of aluminium is given in *BS 8118: Parts 1 and 2*.

4.6.4 Concrete and mortar

Concrete is made from sharp sand (fine aggregate), gravel (coarse aggregate), Portland cement and water. A suitable mix for general use is 1 part cement: 2.5 parts sand: 4 parts gravel, by volume. Fresh water from the public supply or clear watercourses should be used. Sea water should never be used; nor should sea sand.

Concrete sets by a chemical reaction which takes 1-2 hours so never mix more concrete than can be laid. Concrete will take at least seven days to harden completely. During this period exposed surfaces must be protected from frost damage with polythene sheeting. Drying out too quickly must be avoided and the concrete should be kept wet in dry weather.

Aggregates and cement are sold by builders merchants. Concrete may be mixed by hand or machine. Ready-mixed wet concrete can be delivered by specialist firms, but is usable only where vehicle access is available. Jaegers (ready mix lorries) carry $6m^3$ or $3m^3$. Extending chutes are available and ready-mix can be poured some distance from a delivery lorry.

Relevant standards are in *BS 5328*, *BSEN 206-1* and *BS 8500*. Technical Sheet 6.5 contains basic details about concrete specification and mixing. *Concrete Practice* by GF Blackledge is a useful publication. More information about working with concrete can be found at **www.concrete.org.uk**.

Materials

Mortar is used to join and point brickwork and masonry. It can be made from builders sand, cement and water or for small jobs prepacked dry mortar mixes can be bought from builders' merchants. White Portland cement should be used if a colour additive is required to match mortar to brick colour.

Increasingly, lime mortar, a traditional material, is being reintroduced for building and pointing stone structures. This is particularly successful if used in conjunction with sandstone where the 'softness' of the mortar allows some movement of the stone where a cement mortar, being 'stronger' than the sandstone, could cause the stone itself to fail. Water is often trapped behind hard pointing, preferentially eroding the stone whereas water can escape through the lime joints and the stone does not 'frost out'. More details are available from the Scottish Lime Centre Trust website **www.scotlime.org**

4.6.5 Recycled materials

Over the last few years some use has been made of recycled plastics as timber substitutes for some bridge components. They have an advantage of being totally inert and rot proof. At present there is no strength classification or design standard for recycled plastic timber and this will prohibit its use where Building Standards regulations are enforced. Hence, any use made of the material must be with these issues firmly understood.

At present, sections suitable for beams are not available, although it has been used occasionally for decking, handrails and nailing strips. Recycled plastic burns readily once alight, unlike timber which can form a protective charred coating in certain circumstances. It is a more flexible material than timber and has a tendency to sag over time unless well supported.

Manufacturers of recycled plastic should be able to advise on its use and specification. Details are available from **www.wrap.org.uk**.

4.6.6 Aggregates

Sometimes it is possible to win appropriate materials on or close to the construction site from borrow or gravel pits. Although unsuitable for concrete due to lack of grading, aggregates won this way can have a useful role in backfilling. This reduces transportation costs to site. It is crucial to ensure that the material is fit for purpose and to obtain any relevant consents for its extraction.

4.6.7 Glass reinforced plastic (GRP)

Bridges can be built from moulded or extruded GRP. They are specialist designs which can be strong, lightweight and versatile. Their design is complex, however, and beyond the scope of this guide.

4.6.8 Material standards (BS and EN)

British Standards (BS) published by the British Standards Institution (BSI) have been a familiar part of construction for over a century. Since 1988, however, a new set of European Standards called EN (for *Europaischen Normen*) has begun to make its appearance. The idea is to give firms equal opportunities to compete throughout Europe by harmonising technical requirements between countries.

These new standards are mandatory in the sense that national standards bodies, of which BSI is one, are required to officially withdraw their national standards when an EN is created with the same scope of application. The fact that BSI and the other national bodies publish EN does not, however, compel people to use them. Only when suppliers and customers fully accept and understand the EN standards will that actually happen.

Nevertheless, EN standards are bound to become more common as time goes by, and it will be important to keep abreast of developments in this field. **www.bsi.co.uk** has up-to-date information.

Health and Safety

Above all other considerations, the safety of people involved in the construction of a bridge as well as members of the public is of paramount importance to the construction project manager. Compliance with the *Health and Safety at Work Act (1974)* is a legal requirement. Even if you are putting the whole project out to a consultant, as a client you still have a responsibility to ensure any consultants or contractors used are competent to carry out their duties. In general, the path construction industry has a good health and safety record. This reflects the generally safe environments and scale of operations encountered in the majority of path construction projects. Bridge construction is, however, an area of path creation that can pose significant hazards. These hazards must be managed effectively to ensure the health and welfare of all involved or affected by the project.

Health and safety is the responsibility of everyone involved with a project

Section 1.3 covers the liability and insurance issues involved with a bridge project. It is important to be very clear about where liability lies during each phase of a project and after completion.

5.1.1 Risk assessment

Risk assessment is the essential building block on which health and safety management is built. It is a requirement of both the *Management of Health and Safety at Work Regulations 1999* and the *Construction (Design and Management) Regulations 1994* to identify hazards and assess the attendant risks for all working environments. Risk assessment is a powerful tool for hazard management and an essential part of bridge construction. It is also a fundamental part of bridge design and will influence choices of, for example, handrail height, materials, location and installation method. Undertaking a risk assessment is not a complex process and full details of how to prepare one are given in *PFAP Factsheet 5.5 Hazards and Risk Assessment in Path Construction*.

5.1.2 CDM - get into the habit

The *Health and Safety at Work Act (1974)* and the construction specific regulations including the *Construction (Design and Management) Regulations 1994* (CDM Regulations) define safe working practices on construction sites. *PFAP Factsheet 5.3 'Health and Safety in Path Construction'* details the relevant legislation and explains what it means. *Upland Path Management* also has a very comprehensive section on health and safety.

In terms of overall project safety management, the CDM Regulations define roles, responsibilities and lines of communication. The CDM Regulations do not apply to all projects - it depends on project duration, number of people on site and other variables.

Working safely requires a team effort. The CDM Regulations are fundamentally about improving communication between all of those involved in a construction project so that all parties are considering health and safety issues. To this end, the Regulations set out clearly defined roles, each having specific responsibilities.

Role in CDM regulations	Key responsibilities
Client	Appoints competent Designer and Planning Supervisor, usually maintains final build.
Designer	Assesses and designs a structure that is fit for purpose, safe to use and safe to construct.
Planning Supervisor	Ensures Health and Safety Plan is prepared and that Health and Safety procedures are implemented on site and are effective. Ensures communication between other parties, notifies HSE if required.
Principal Contractor	Controls site. Prepares method statements, risk assessments, ensures safe working on site and competence of site personnel.
Health and Safety Executive (HSE)	Legal enforcer may have to be notified of a project (depending on its duration), provides advice, may carry out inspections and issue improvement or prohibition (stoppage) notices.

Health and Safety

For uncomplicated short span projects most of the duties may be available 'in-house', and it is often the case that more than one role is taken on by one person or organisation. More complex projects and longer spans will require professional help.

A Health and Safety Plan is required for every project. If a contract is being tendered the plan is in two parts, the Pre-tender Health and Safety Plan and the Construction Phase Health and Safety Plan.

At the end of the project a Health and Safety file must be prepared. This document is a permanent record of how a project was designed and built. It should be prepared and passed onto the Client before the Principal Contractor leaves the site. The Health and Safety Plan is included, along with any amendments and additions. The purpose of this document is to provide all health and safety information to anyone who will be carrying out maintenance work, repairs, upgrading works, extensions or removal/ demolition on the project.

The CDM Regulations are sometimes portrayed as extra bureaucracy, and people have been known to 'tweak' projects to fall outwith their jurisdiction. However, the procedures outlined in the CDM Regulations are all about sound project management. *Even if your project is too small to register for the CDM Regulations, the process is a good habit to get into - it will help with planning, working out who is responsible for what, and minimising the chances of things going wrong.*

The PFAP Factsheet 5.4 'A Guide to the Construction (Design and Management) Regulations (1994)' has details of when and how these regulations apply. Note that if you are replacing an existing bridge with a new one, removal of the old bridge could be classed as demolition and the CDM Regulations always apply to demolition, regardless of project duration and number of people on site.

If a project takes more than 30 working days or 100 person days, it is notifiable to the HSE using form F10.REV. Bridge construction cannot be separated from the adjoining path construction to try and squeeze the project under 30 days. It is always better to phone the Health and Safety Executive Infoline on 0845 345 0055 or go to **www.hse.gov.uk** if you are in any doubt about compliance with the CDM Regulations.

The CDM Regulations are under revision at the time of printing. It is therefore important to keep abreast of any changes. See **www.hse.gov.uk**.

5.1.2 Method Statements - keeping projects safe

The best way of planning project safety is by using a 'method statement'. This management tool ensures that:

- the whole operation can be planned taking safety into consideration at every step.
- everyone involved in the bridge construction understands the method required to build the bridge safely, the risks and hazards involved and the measures required to control if not mitigate their effect.

The main headings within a method statement are shown below (not in order of importance), but there can be others.

Method Statement

- **Site location** and **access arrangements**
- **Site conditions** and **accessibility**
- **Chain of command** (with contact details)
- **Method of working**, including type of plant, equipment and resources required
- **Risk assessment table**, listing all known hazards, level of risk and measures to control the risk
- **COSHH*** sheets for the materials used
- **Environmental** considerations
- Nearest **medical** facilities
- **Accident** procedure
- **Site welfare**

* Control of Substances Hazardous to Health Regulations 2002

Health and Safety

Some of the typical hazards are as follows, but always be aware of what is important on your own site:

- Underground and overhead services
- Working over water
- Working at height
- Working in poor weather conditions
- Working with corrosive/hazardous substances
- Slips, trips and falls
- Manual handling
- Spillages
- Vehicle movements
- Lifting operations

Bridge construction may involve the use of specialist plant such as cranes, winches and even helicopters. This kind of equipment poses specific hazards to operators and members of the public and is regulated very strictly to ensure safe working practices. Whether you are a project manager, designer, contractor or all of the above, you must be aware of regulations governing plant use and how they will affect the project and construction method. As you plan your project, you should consider what plant is available and base your construction method on using the safest operations.

Site selection (see Section 2.1.1) can be crucial to health and safety management. Be prepared to reject a site if it poses hazards that are unmanageable.

Health and safety also applies to site surveys and maintenance. Many bridges will be installed in remote sites and hazardous terrain. If possible take someone with you both to help with the survey and to raise the alarm in the event of an accident.

A summary of the key health and safety regulations follows overleaf:

5.1.3 Summary of key health and safety regulations

The Health & Safety at Work Act 1974
The key principle of the Health & Safety at Work Act is that all parts of a work force should be involved in improving health and safety. There is a duty of care for employers to protect their employees and the public, and to provide a safe system and place of work. The involvement of employees is a key component.

The Construction (Health, Safety & Welfare) Regulations 1996
These Regulations are ***specific*** to the construction industry and aim to protect persons working on a site. They require that a construction site should have the following provisions:

- Adequate shelter for site staff which is clean, dry and suitably heated when required
- A supply of drinking water
- Washing facilities
- Toilet facilities
- Fire prevention measures
- Safe access and egress to and from the site
- Managed and safe traffic routes around, to and from a site
- Provisions to prevent earthworks or excavations collapsing
- Provisions to prevent falls, both in terms of people falling and objects falling on people

The Management of Health & Safety at Work Regulations 1999
These regulations relate to ***all*** working environments. The key issue is the requirement to identify hazards and assess the attendant risks to employees in the work place through risk assessment. Measures should then be taken to avoid, remove or reduce the hazard.

The Reporting of Injuries, Diseases & Dangerous Occurrences Regulations (RIDDOR) 1995
These regulations require that an accident which kills a person, or injures them causing them to be off work for more than three consecutive days, must be reported to the relevant authority (HSE, Police etc depending on the nature of the accident).

Health and Safety

Control of Substances Hazardous to Health (COSHH) Regulations 2002
These Regulations are designed to protect people from injury or illness caused by substances and materials used in the work place. Every potentially hazardous material or substance used should have a COSHH assessment form which highlights the hazards that material or substance presents, and what precautions must be taken.

The Manual Handling Operations Regulations 1992
These Regulations cover all aspects of manual handling of loads in all working environments. The Regulations require that all manual lifting operations be assessed prior to carrying them out and are presumed to be a last resort when mechanical handling is not possible.

The Provision and Use of Work Equipment Regulations (PUWER) 1998
These Regulations cover all plant, machinery, or tools that will be used on a site. They require that any equipment is designed for its intended purpose, to a recognised British Standard. They also require that equipment or plant is maintained to a suitable standard and stored in a safe and secure manner.

The Personal Protective Equipment (PPE) at Work Regulations 1992
These Regulations cover all types of safety or protective clothing and equipment. They state that employers have a duty to provide all necessary equipment to protect their work force.

The Construction (Design and Management) Regulations 1994 (CDM)
These Regulations form a framework on which health and safety management of the construction site is based. Their aim is to ensure that any construction project is designed and managed such that hazards to both site employees and the public are minimised (see Section 5.1.2).

The Working at Height Regulations 2005
These Regulations apply to all work at height where there is a risk of a fall liable to cause personal injury. A place is ‘at height’ if a person could be injured from it, even if it is at or below ground level. A safe working platform must be provided.

Health and Safety

Duty holders must ensure that:

- All work at height is properly planned and organised
- Account of weather condition is taken
- Those involved are trained and competent
- The place where work at height is done is safe
- Equipment is properly inspected
- Risks from fragile surfaces are controlled
- Risks from falling objects are controlled

The Lifting Operations and Lifting Equipment Regulations (LOLER) 1998
These Regulations require that lifting equipment provided for use at work is:

- Strong and stable enough for use and has SWL (Safe Working Load) indicated
- Positioned and installed to minimise any risks
- Used safely, i.e. planned, organised and performed by competent people subject to thorough examination and inspection by competent people

Construction Options

The decision over who will construct the bridge - either contractors, in-house staff or volunteers - will depend on the complexity of the task, availability of resources and the skills of the available workforce. It is useful to think about construction of abutments, beams and superstructure separately. For example, work on the abutments and beams could be undertaken by a contractor and fitting the deck completed by well-supervised volunteers, or it could all be constructed by one company. Whichever way is chosen, good supervision is always required. The options available are:

Standard Designs - for spans of 9m and under with no site difficulties or special requirements, the designs in this manual offer several possibilities

There is a great deal of engineering expertise within local authority Roads and Transportation services. In some cases local authorities have come up with their own in-house solutions to small bridges.

Proprietary Spans - many companies offer pre-designed bridge solutions and a range of services from survey to installation. The Endat Standard Indexes **(www.endat.com)** are updated annually and list a wide variety of suppliers of proprietary spans.

Specialist Design - in particularly testing situations or where a ‘one-off’ solution is required, an engineering/specialist designer will be needed. In some situations artists working with a structural engineer have successfully combined art and functionality - often much cheaper than might be imagined.

Art and engineering combined

Construction Options

In all situations good workmanship is vital. Without it, maintenance will be more onerous and the bridge may not be well enough built to receive a completion certificate. Common failings are:

- Fixings - mainly failure to use galvanised fixings where specified, or the use of nails where screws are required.
- Joints - badly made joints cannot be concealed with mastic or filler, the timber will move and the joints open up.
- Finishing off and tidying up - painting can be left unfinished, particularly in less accessible parts and on concealed surfaces which need to be treated before assembly. Waste materials can be left around the site instead of being taken away to a licensed waste disposal facility. Ensure all timber surfaces exposed to contact are smoothed off.

Installation Techniques

There are a number of ways of getting a bridge across a gap. Which one you choose will depend on the size and type of bridge and the ease of access to the site. Small bridges could be transported in bits by quad or power barrow and assembled by hand. Where vehicles cannot be used, ponies may be useful although the loads must be kept small. Sometimes there is no alternative but to carry all the components in by hand. Large loads can be successfully handled by good teamwork but good planning and safe practices are essential. Helicopters are also an option. Careful planning and a slick operation on the day is essential to keep costs down as helicopters charge highly by the hour.

Large bridges may need large haulage plant to bring onto site and a crane to install. Potentially, this is probably the most hazardous operation of a bridge construction project. Careful planning of the installation operation is essential. (See Section 5.1.2)

5.3.1 Cranes

Cranes come in many sizes. The lifting capacity quoted for a crane is its absolute maximum. As a crane extends its boom its load capacity drops, so a 1 tonne bridge may need a 20 tonne crane if it has to be lifted to the limit of the crane's reach. There are a number of crane companies around and they can be found in the Yellow Pages. They will provide advice and guidance on what size of crane is required for a given bridge and will advise on access requirements. This is generally done free of charge as the companies will want your business. If you are installing the bridge yourself, the best way to manage the crane lift is to treat it as a small contract. This puts the onus on the crane company to provide a suitable size crane and to ensure it is capable of accessing the site. This may cost more than doing it by simply hiring a crane and driver but there will be less chance of disaster. Any power lines within reach of the full extension of the boom anywhere in its 360° swing must be switched off.

All lifting is covered by the *Lifting Operations and Lifting Equipment Regulations (LOLER)1998 (SI 1998 No 2307)*. Always ensure that contractors have appropriate and current certification and adequate up-to- date insurance.

5.3.2 Using tracked excavators

Tracked excavators, normally used for earthworks, can also be used to lift or drag small bridges or beams into place. It should be noted from the outset that effectively using an excavator as a crane means that LOLER applies just as for cranes (see Section 5.1). LOLER requires the excavator boom to have suitable lifting points, to be rated for a load limit and to have all of the safety features found on a crane. Inform the plant hirer/operator of your requirements and they should advise on a suitable machine. Access to the site must be carefully assessed. Although tracked excavators are capable of negotiating rough and boggy terrain, they can still get stuck. Freeing them can be extremely difficult, hazardous and expensive.

With prior permission from SEPA excavators can work within a river. However, there must be no risk of oil or fuel leakage. Restrictions may apply in SSSIs and other protected areas. Excavator operators must be competent and be able to prove it with suitable certification. In the hands of a skilled operator, 360 excavators can make light work of small bridge installation.

5.3.3 Winching bridges into place

'Tirfor' or similar manual winches can be used to literally drag a bridge into place. A secure anchor point is essential. The great benefit of a winch is its portability, so this is often a useful option for a remote site. Winches must be tested and certified annually, as must any slings or chains you will use. Care must be taken to secure slings to the bridge such that they do not break part of the bridge or slip off. If you are lifting in beams separately, attach slings tightly so they grip the beam more the harder they are pulled.

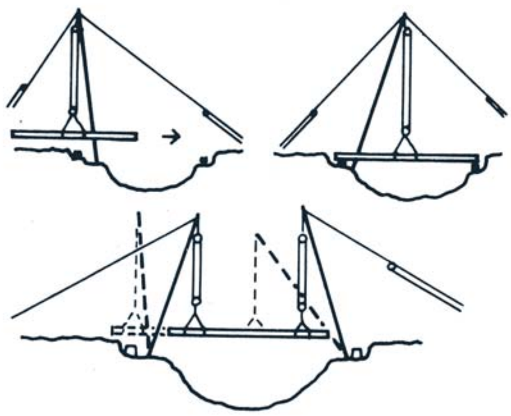
Installation Techniques

Scaffolding can allow easy access to both sides of a gap and provide a safe working platform for assembly.

If the bridge is a substantial weight ensure a winch is also attached to the rear of the structure (as well as the front). This will help to support and control the bridge as it is being manoeuvred into place and will stop it running away if a slope is involved. (*Upland Pathwork* has more information about using winches). Small beams can be winched and manually handled without any other assistance. Larger beams will need to be launched across a scaffold erected across the gap. If the gap cannot be scaffolded, you can counter balance the beams using weights, (NB do not use people for this), to keep them horizontal as you drag them across the gap.

Launching a bridge is technically challenging and a potentially very risky operation. It is not for the inexperienced or unskilled. Some options for supporting while winching are shown below. All require competence and experience.

Shear legs and spars



Shear legs and spars may be used for moving beams into position with chain blocks lifting the load and guy ropes, fastened to dead end anchorages, allowing controlled luffing either by a sheaved pulley section with ordinary sisal rope or using pulling devices such as Tirfors with a wire rope.

The longer the bridge span the longer the shear legs or spar required, and it may be difficult to transport these to site. Although the loads are not large, a knowledge of rigging blocks, pulley sheaves and guy ropes is essential for anyone attempting this method of erection. The sketches indicate different stages in the operation.

Installation Techniques

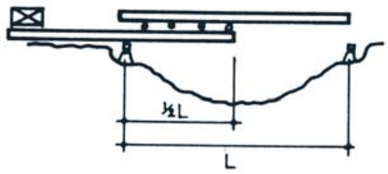
Temporary supports

Where temporary supports can be provided in the gap the structural members may be rolled into position.

The supports should be well braced to ensure that they are not knocked over. Normally the beam will be well above bearing level after launching in this way. It can be lowered onto the bearing either by the use of relatively short shear legs and chain blocks or by staged jacking with hydraulic or screw jacks and with packing in front of the bearing and on it. The timber deck members can be used for this operation.

Cantilevering

Beams can be cantilevered over the gap using one of the other beams. Care must be taken to keep the system suitably counterweighted. Once the beam is over the bearings, it can be picked up with shear legs and chain blocks or progressively jacked up until it sits on the bearings as described above. The remainder of the beams can be rolled over the top of the first beam.



Site Planning

Good planning of a bridge construction site is essential to ensure everything goes according to plan. You may have a number of people on site at one time trying to do several different tasks. Bridge sites are usually small, so it is very easy to end up with everybody getting in each other's way. Before the project goes on site, draw up a plan of action with dates and timings so that you can co-ordinate all of the operations effectively. The aim is for one operation to follow straight on from another with no time lost waiting for an operation to finish and without different contractors getting under each other's feet. If you are planning to drop the bridge in place in one go, then you won't need much working space on site. If access permits, crane the bridge straight off the delivery lorry and onto its abutments. Assembling the bridge on site requires an area to store the components, space to work on them (if holes need to be drilled etc.), and a clear lane to move them onto the abutments. Every site has its own distinctive problems, but some common areas of difficulty include:

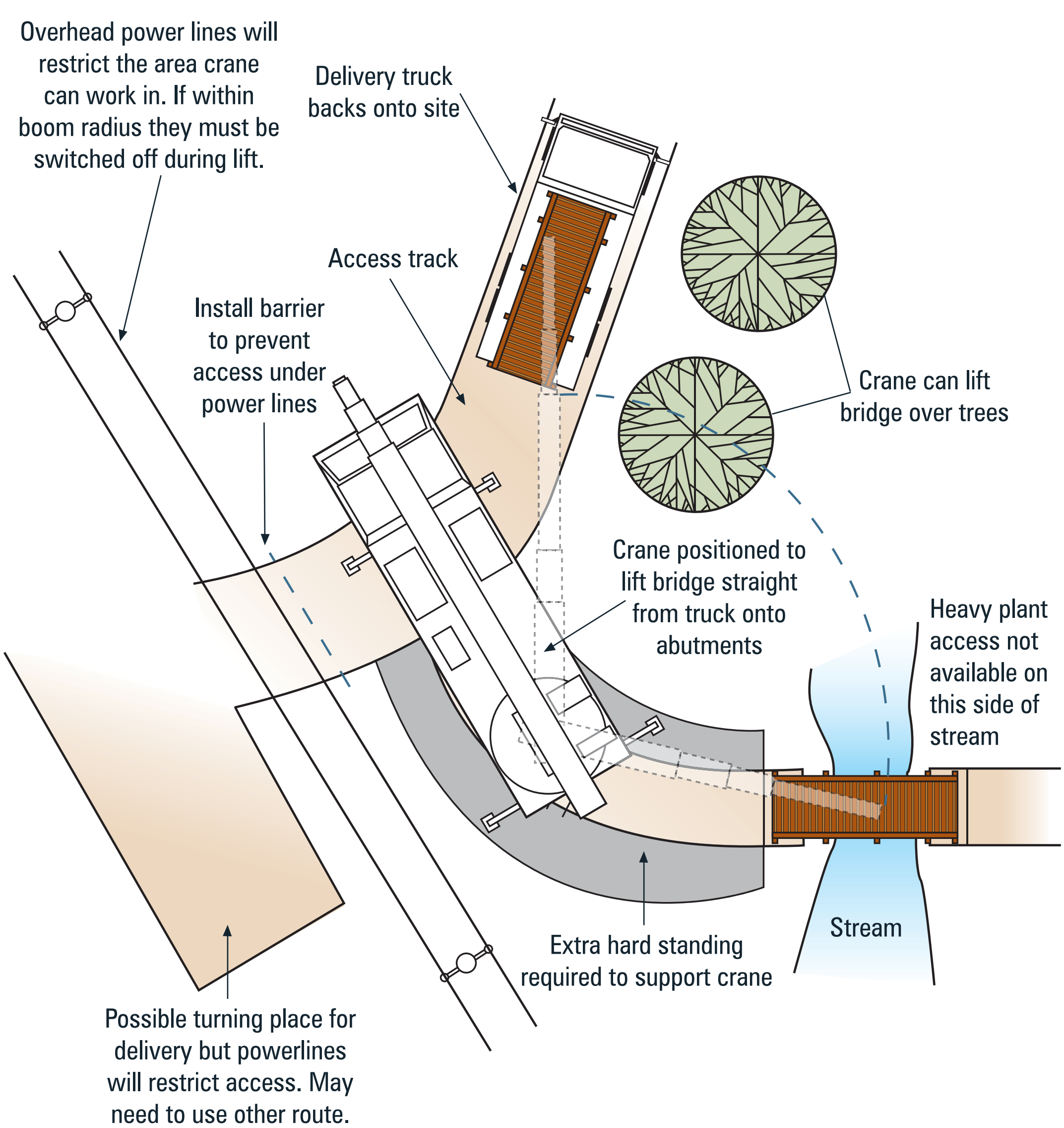
- Access to the site for materials, plant and labour
- Power for small tools
- Lack of suitable areas for fabrication
- Placing the bridge across the gap
- Coping with dangerous working conditions
- Deep water
- Overhead power lines
- Underground services

Planning should also include consideration of probable weather conditions. Certain times of year may favour or preclude elements of the work required.

The illustrations on the following two pages show how drawing plans of a site can help in sequencing and managing a build.

Site Planning

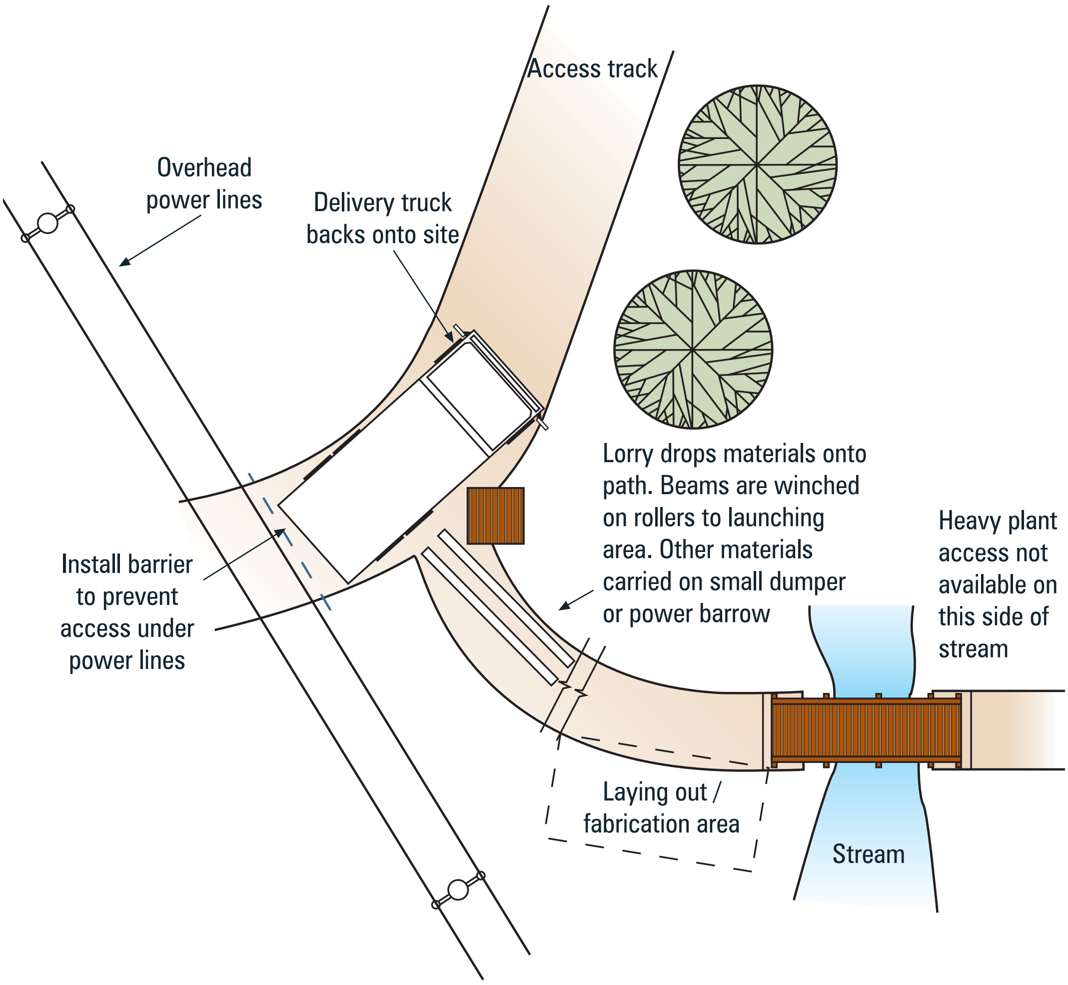
CRANE ACCESS - Site layout if crane access is available



Notes

1. Site may need extra hard standing to allow crane to set up in required position.
2. Access track must be able to carry crane.
3. Cranes must be booked at least a week in advance so careful planning is required to ensure abutments are constructed and concrete has time to cure.
4. If bridge is not pre-assembled then crane can be used to lift main beams into place.
5. If crane cannot lift bridge straight onto abutments, then this option is not cost effective.
6. Service companies will advise on minimum clearances and procedures for working in the vicinity of power lines.

NO CRANE ACCESS - Site layout if heavy plant cannot get to bridge site



Notes

1. Beams can be winched using a hand 'Tirfor' winch along path to site and then onto abutments. Alternatively, a small excavator can be used to drag them. Use steel tube rollers (e.g. sections of scaffold pole) to assist this operation.
2. A laying out and fabrication area will be required beside the path at the bridge site - typically around 2 x 5m. This need not be hard standing but must be firm and well drained.
3. This method is generally more labour intensive as extra personnel are needed to guide beams while winching and for general manual handling tasks.
4. Careful considerations of how the main beams will be winched into place and how the rest of the super structure is added is essential if this method is to be used.

Site Planning

It is vital to plan the sequencing of activities carefully. The following list gives a run-down as an example of a bridge construction project using a timber bridge on concrete abutments. A linked bar chart (on the next page) is a useful way of expanding this information to determine critical paths and identify which operations depend on others.

Phase 1 - Project planning

- Consultation
- Initial survey
- Further consultation
- Detailed survey
- Design
- Consents
- Contractor selection
- Produce project plan

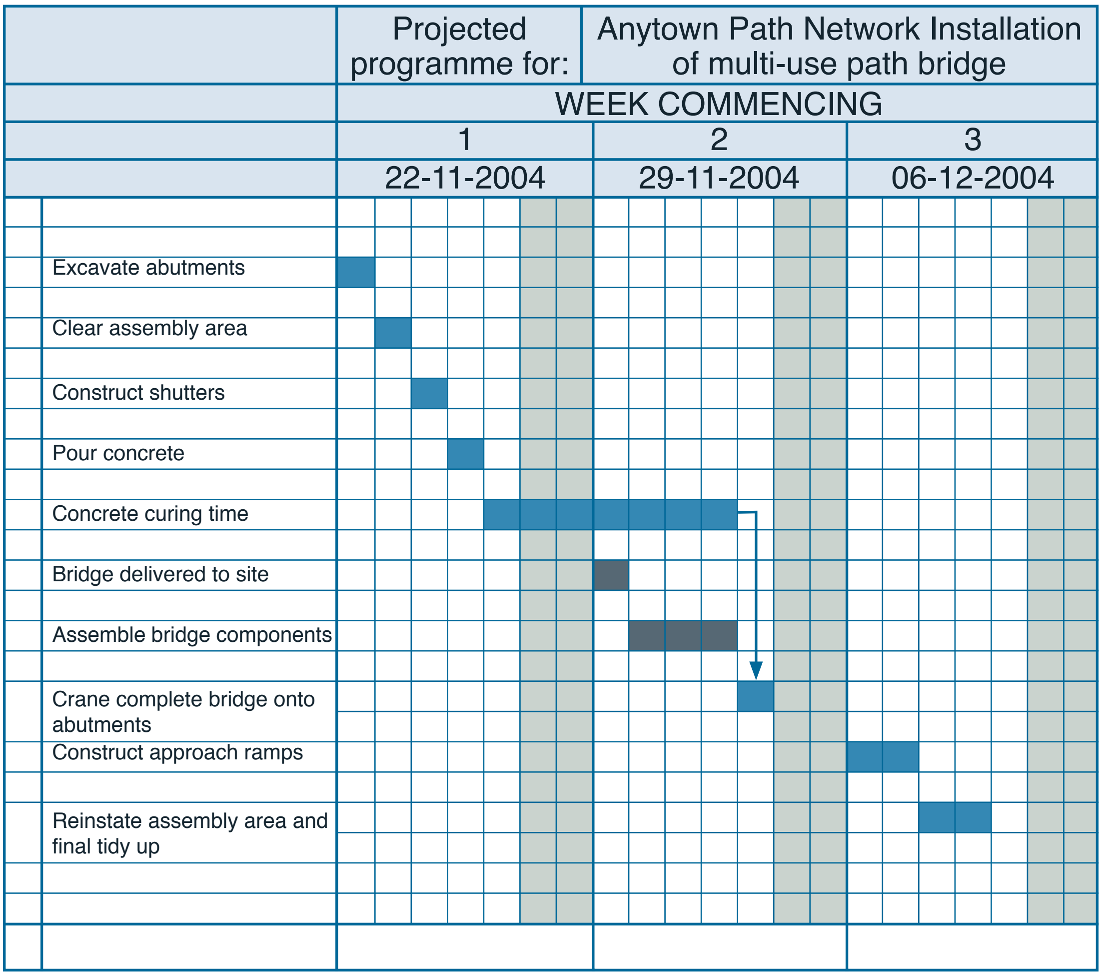
Phase 2 - Construction

- **Site clearance - clearing unwanted vegetation etc.**
- **Set out abutment locations and profile markers**
- **Excavate abutment foundations**
- **Construct and install shutters, including any reinforcement**
- **Pour concrete into shutters, compact and allow to cure**
- **Add bearers to abutments**
- **Lift in main beams**
- **Bolt on nailing strips and transoms**
- **Attach deck boards**
- **Bolt on handrail uprights**
- **Attach handrails and approach rails**
- **Treat or paint any cut timber if required**
- **Construct approach ramps**
- **Clear site and landscape any disturbed areas**

Phase 3 - Ongoing maintenance

- Visual check of deck and handrails quarterly
- Full visual inspection of bridge annually
- Check bolt tightness annually
- Clean deck boards annually
- Replace damaged timbers as required
- Lift deck, inspect and clean/re-treat main beams and transoms every 5 years
- Engineer’s inspection every 5 years

Site Planning



Example of a linked bar chart used to plan a construction project

5.5 Contract Management

In many cases a contractor will install the bridge. As with any construction project careful selection and management of a contractor is essential to ensure best value and a high quality job. The principles of contractor selection and management are discussed in detail in *Upland Path Management*. Many organisations (including local authorities) have procedures for selecting contractors and it is important to be aware of these and to conform to them. *PFAP Factsheets 2.3 and 2.4* give more details on contract management.

To varying extents, bridge construction is a specialist field of civil engineering, and there are specialist contractors whose expertise may be important for you. For example, if your bridge is going into a remote upland site an upland path contractor might be a good choice. They will be used to getting materials into remote sites and will be fully aware of the environmental issues relating to upland areas. That said, for a simple bridge, most mainstream civil engineering contractors will be suitable.

Path bridges tend to be relatively small contracts and picking the correct conditions of contract that will suit the small contractor is important. For projects like this, big contractors may not give competitive prices and small contractors can be frightened off by complex contracts. Use simple conditions which are fair and preserve the interests of the client along with close supervision. As an example, contract documentation used by Forestry Civil Engineering for these types of project can be found in Technical Sheet 6.13.

Maintenance

As with all structures, once a bridge is installed it will require regular maintenance throughout its design life. Choice of materials will greatly affect the life span of a bridge and its maintenance requirements. However, no bridge can be completely 'maintenance-free'. The key aim is to 'design in' minimal maintenance. To reduce a bridge's maintenance requirements think about the following:

- Easy cleaning
- Use durable timber. Treat if required
- Steel work should be galvanised (and painted if required) to a suitable specification
- Fasteners should be galvanised and threads greased for ease of future dismantling
- In marine environments any steel should ideally be stainless
- Make the deck easily 'unboltable' to allow inspection and maintenance of main beams
- Consider how any maintenance plant can access the bridge site
- Inaccessible parts of a bridge should be 'maintenance free'
- Simple designs need simple maintenance

Technical Sheet 6.11 gives more information about reducing maintenance through design on timber bridges. Refer to the *Lowland Path Construction Guide* for information on maintenance planning and implementation. All maintenance work must be carried out safely using a risk assessment and in accordance with *SEPA PPG 23: Maintenance of Structures over Water*.

Inspections

As part of on-going risk management and maintenance, bridges must be routinely inspected to ensure that they are safe and free from damage. The frequency of inspection will vary between structures depending on the use, location, design and age of each bridge. A bridge nearing the end of its expected lifespan may need inspecting more frequently than the same structure early in its life. The key issues are that inspections are carried out when they are supposed to be, they are rigorous and are properly recorded. Bridge inspections must be carried out by people who understand what they are looking at and are in a position to make an informed judgement about its present condition, i.e. someone with the relevant training and/or experience to do the job. The same issues that determine frequency of inspection may also have a bearing on who is seen as competent to inspect each structure. Each inspection must be signed off by a **qualified signatory** - a suitably competent person who may not have undertaken the inspection themselves but is able to make a decision based on the report about the safety of the

5.6 Maintenance

structure and any action that is required. Experienced bridge inspectors are best placed to spot deterioration or hazards. Every five years the inspection should be carried out by a qualified bridge engineer.

Managing bridge inspections can happen in different ways. For example many local authorities carry out the inspections ‘in-house’. Sustrans, by contrast, employ students to inspect bridges in the summer holidays. Inspection results are recorded on laptops backed up by digital photographs. These are then seen by the qualified signatory who decides if any action is needed. Spot checks are carried out to ensure the standard of inspections is maintained. Increasingly organisations are using computerised path management systems which can include the bridge inspection process.

Useful Inspection Equipment...

- ✓ Bridge Inspection and Maintenance Record Sheet
- Construction Drawings
- Past Record Photographs
- Knife - for assessing timber decay
- Chalk - to mark areas for repair
- Torch - for dark spots
- Camera - to record condition
- Brush - to clear decking
- Screwdriver and Spanner - to allow fixings to be checked and tightened
- Mobile Phone / Radio

Maintenance

An inspection record sheet (see Case Study 8.5 for an example) should be used to record all inspections. This acts as a checklist to ensure everything gets inspected. Important points to look out for during inspection include:

- Scouring of river bed and abutments
- Damage to banks and adjacent land
- Unsafe trees close to the bridge
- Muddy or worn paths, steps and ramps
- Decay in timbers, particularly at holes, joints and checks
- Loose components, joints and fasteners
- Water lying on surfaces and in joints
- Rust

Many problems are very simple to rectify but may have public safety implications; for example, broken deck boards or splinters on a timber handrail. The location of a bridge may affect the prioritisation of repairs and also the frequency of inspection - it all comes back to risk assessment.

Take a basic toolkit with you on inspections. Using a surform to smooth a rough edge at the time of inspection removes the need for a return visit.

On-site structural testing for timber

It is possible to purchase or hire portable equipment for testing the structural integrity of timber. This is particularly useful in detecting unseen rot and weakness (timbers sometimes rot from the inside, out). Being assured of the strength of old beams, in particular, may extend the life of a bridge well beyond its projected life expectancy. Although the equipment is expensive, it might be a worthwhile purchase for an organisation with a lot of timber structures to maintain.

There are three types of portable testers - sonic, micro-bore and impact. All are available in the UK from Forestry Civil Engineering.

A screwdriver is a vital inspection tool for revealing pockets of rotten wood.

5.7 Upgrading Existing Structures

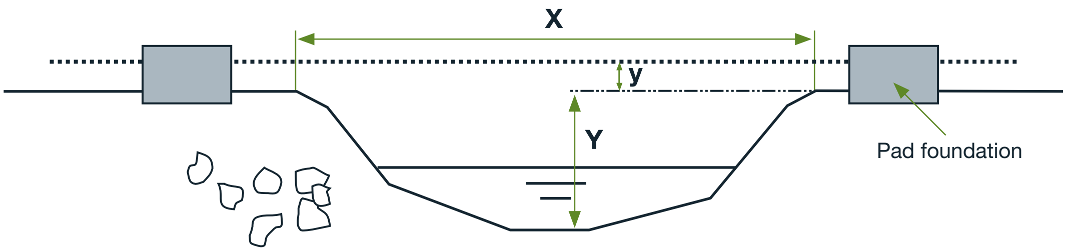
You may often be faced with the need to use and adapt an existing bridge. For example, it may be necessary to adapt a bridge to allow access by a wider range of users, or a bridge on a disused railway being converted into a path may need modifications to allow safe access. In some cases it may be possible to lift out the old bridge in one piece and use it elsewhere where its design is still suitable. It is not possible for this guide to cover all eventualities that existing bridges may present but here are some basic principles:

- Carry out a structural assessment of the bridge - can it take the extra loading the change of use may create?
- Find out when the bridge was built - if it is approaching the end of its design life, it may be better to replace it and the expense may not be much greater.
- Will the additions to the bridge compromise its structural integrity? For example, simply bolting a taller handrail onto a pedestrian bridge to allow use by cyclists can be a very dubious prospect. The longer handrail will impose greater twisting loads on the main beams, as well as increased dead weight.
- If the modifications require additional joints and holes, these will not have been allowed for in the original design - think carefully before you act.
- Railway bridges are designed to carry many hundreds of tons but may have no, or very low, handrails - how easy will it be to add a new and suitable handrail? If the beams have been neglected for several decades, they may well be so corroded that the bridge is seriously unsafe.
- The tables included in Technical Sheets 6.6, 6.7 and 6.8 give guidance on the load carrying capacity of decks and handrails for different users to assist in fitting a suitable new superstructure to existing beams.

Most often, upgrading existing structures will require the services of a qualified engineer.

Site Survey Example

Cross section: Survey dimensions required to be taken to design bridge



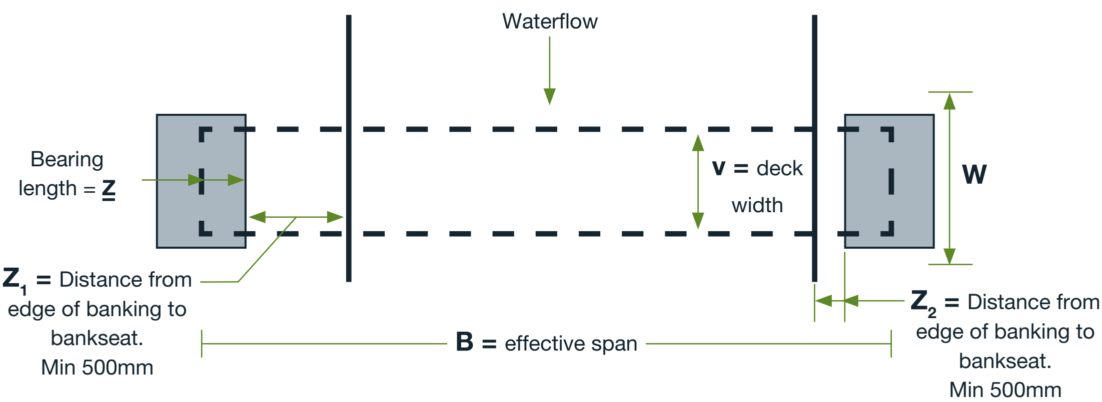
When siting a bridge over, say, a watercourse the main consideration is to design the bridge dimensions so that the new structure does not interfere with the normal water flow in any way. The sub-structure needs to be far enough away from banking edges to avoid the slip zone and the underside of the bridge deck requires to be above frequent flood levels by a minimum of 300mm.

X - Span distance between top of banks

Y - Height of top of bank above bed

y - Height of flood water **above** top of banking from local knowledge or calculation

Plan of a new bridge



V - Overall width of bridge deck required - see next note below.

W - Ensure there is sufficient width on the ground to accommodate the bridge foundations. (**W** min = **V** + 1m)

- Stability of banking and ground conditions will determine the distance the bankseat will sit from the edge of the top of banking (**Z_1** and **Z_2**). This value may be different for the two bankseats. Minimum = 500mm. (Scour can occur at the toe of a bank altering slip zone significantly.)
- Therefore, the overall length of bridge is **$B = X + Z_1 + Z_2 + 2\underline{z}$**

  where **Z_1** or **Z_2** = Distance from edge of banking to bankseat and **$\underline{z}$** is the bearing length of the bridge on the bankseat.
- **A simple pad foundation for a bankseat may not be appropriate at all locations due to physical/ground constraints. If this is the case then professional design help may be required.**

NATIONAL CYCLE NETWORK	Sustrans 16A Randolph Crescent Edinburgh EH3 7TT Tel: 0131 539 8122	TITLE: Survey dimensions for bridge siting	DATE SCALE DRAWN BY DRG No.:	23-08-05 NTS RMJC Drg 1 Rev 03

Flood Level Estimation

It is essential to estimate the maximum flood level of a watercourse to be crossed by a bridge. This is typically done for a 1-in-100 year flood. It is possible to calculate a level analytically using the following method:

- The *Rational Formula* calculates the quantity of flood water that will arrive at a bridge site using the area of the catchment and the expected rainfall for the 'design' storm. This method relies on assessing the geology and drainage characteristics of the catchment and determining a coefficient which reflects this. It is regarded as being a fairly approximate method of flood calculation but may be useful for small catchments which have uniform terrain.

- Using the flood water figure generated, the *Manning Equation* can be used to calculate the flow depth in a given channel, the parameters of which (i.e. size, gradient and roughness) need to be assessed and quantified.

Further details of both these calculations are beyond the scope of this guide. The complex nature of natural watercourses makes use of the Manning formula particularly difficult and suitable for experienced hydrologists only. Alternatively, the Centre for Ecology and Hydrology (**www.ceh.ac.uk**) publishes the *Flood Estimation Handbook* which can be used to calculate flood levels anywhere in the UK. They also produce a software package which has catchment, rainfall and water course data built into it and can give accurate flood water flows across the country.

All of these ways of estimating flood levels require specialist input and sound judgement. Various websites describe the derivation and uses of both the Rational formula and Manning's equation.

In many cases flood water levels can be estimated sufficiently using local knowledge and site observations.

- Speak to local land managers and ask them to describe flood levels as far back as they can remember.

- Look at the level of other bridges on the same watercourse.

- Look at debris from previous floods and measure its level. Note that debris may only be from a recent flood, which may have been a lot lower than a 1-in-100 year flood.

Flood Level Estimation

What method you use to determine the flood level at a bridge site should be done by risk assessment. Assess the consequences of the bridge being flooded – the risk to users, the likelihood of damage and the cost of repairs or replacement. Assess the availability of local knowledge on historic flood levels. In general, areas subject to severe floods will be well known and easily identifiable. If local knowledge is not sufficient it may be wise to utilise the services of a consultant hydrologist to assess and calculate flood levels and flow depths.

Loads

This sheet explains how the loads used in path bridge design have been derived and calculated. The load table that follows quantifies these loads in terms of their impact on the main bridge components.

The calculation of user loading

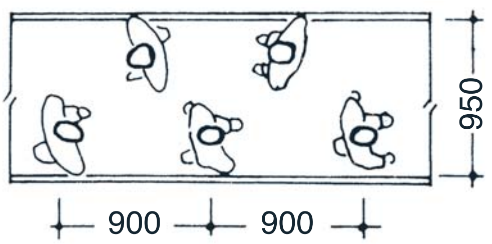
The user loading suggested in the current British Standards (BS) and Codes of Practice (CP) were evaluated in the context of major structures in heavily trafficked urban situations. Most path bridges will be of restricted width (900 to 1800mm) and located in areas where it is unlikely that extreme crowd loading or other extraordinary loads will be encountered. Therefore, loadings for such structures were derived from consideration of their likely uses and included in *'Footbridges in the Countryside'* in 1981. These have proved to be adequate and have become standard reference figures. The basis on which they have been calculated is shown below. It is important to understand the distinction between point loads and uniformly distributed live loads.

Point load - best illustrated by a stiletto heel acting on a bridge deck. The full weight of a person impacts through one particular point.

Uniformly distributed load (UDL) - the sum of point loads considered over the length of a bridge. Usually expressed as kN/m².

Pedestrian Loading

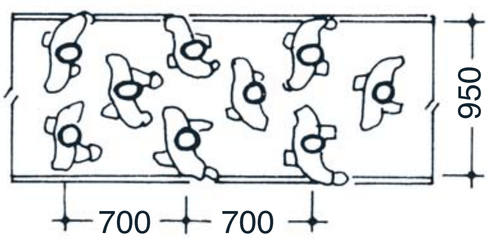
Pedestrian Normal



= person weighing
90.7kg (200 lbs)
Impact factor 1.12

2.3 kN/m²

Pedestrian Crowd



= person weighing
72kg (160 lbs)
Impact factor 1

3.2 kN/m²

Main beams and girders - a uniformly distributed live load (UDLL) over the whole span equivalent to that shown in the sketches for Pedestrian Normal and Pedestrian Crowd Loading respectively.

Loads

Deck members - as for Crowd Loading on the previous page. However, where the deck is of small individual units, such as deck boards, consider as alternatives either a fully loaded person running with their whole weight on one foot (a point load of 1.8kN) and an Impact Factor 1.25 - or a line of people of mass 112kg at 650mm centres along the member with an Impact Factor of 1.

Horse and rider/cattle loadings

Main beams and girders - horses and riders in single file at 1.5 horse length spacings with an Impact Factor of 1.3 or cattle two abreast in a 1400m width at 2200mm centres with an Impact Factor of 1.125.

Deck members - where the deck is of small individual units, such as deck boards, consider as an alternative the full weight of a moving animal transmitted through one hoof. For a horse this load will be on a 175mm square and for cattle on a 120mm square with an Impact Factor of 1.25.

Load Table for path bridges

900mm - 1800mm wide

The table opposite summarises the intensity of the different types of loading applicable to path bridges. The horizontal loadings given for handrails are similar to those given in the relevant British Standards and Codes of Practice and DfT Memoranda as are the wind speeds. Snow loads and wind loads are included for information but the assumption is generally that if the bridge is affected by either in extreme conditions significant numbers of pedestrians will not use it at the same time.

Loads

MEMBER	LOAD TYPE	LOADING		REMARKS
		UDL	POINT LOAD	Use BS 5400
Main Beams	Pedestrian - Normal	2.3kN/m^2		For urban or wide bridges use BS 5400
	Crowd	3.2kN/m^2		
	Horse Cattle Sheep	5kN/m^2		
	Quad Bikes		10kN	Could be greater
Short span Deck Boards	Pedestrian - Normal Crowd Sheep		1.8kN point load	
	Horses & Rider		7kN point load	
	Cattle		7kN point load	
Horizontal Handrails	Pedestrians - Normal	0.74kN/m 1.1m above deck		
	Crowd	1.4kN/m 1.1m above deck		BS 5400 normal
	Horse & Rider Cattle	1.3kN/m 1.25m above deck		Handrail heights are not the same as height of load application
	Cycles	1.4kN/m 1.15m above deck		
	> 3m drop below bridge deck	1.4kN/m 1.1m above deck		
All Members	Snow	0.4kN/m^2		
	Wind	1.4kN/m^2 loaded 0.7kN/m^2 unloaded		Consult engineer for long spans
	Collision		50kN @ 3m high	

Loads

Deflections

The deflection of the individual structural members and the main beams and girders under full loading should be limited to 1/240th of the span. Clearances at all parts of the structure should be checked to ensure that this deflection does not cause other problems.

Where possible, structures should be built with a precamber which should be at least equal to the dead load deflection. The appearance of bridges is improved by making this precamber substantial. Between 10mm and 35mm per metre of total spans is a suitable range. The top end of this range results in a deck gradient of about 1 in 15, which is reasonable for pedestrian traffic, is wheelchair accessible and will be suitable for horses as long as the deck has grip.

Dynamic deflection

Longer span (over 15m) bridges should be checked for their response to dynamic loading and to excitation by wind. The bridge design should avoid structures whose primary natural frequency coincides with the frequency of pedestrians' pace i.e. approximately 2.0 cycles per second or several people jumping on the bridge at 2.5 cycles per second. Horses require stiff bridges of a minimum 5 cycles per second.*

The calculation of frequency of vibration of a structure is complex and requires a great deal of judgment. As these calculations will apply to the longer spans an experienced designer must be employed.

Where bridges are found to be susceptible to vibration this can be dampened in a variety of ways, including the use of rubber bearings and side guys to suspension spans.

* Work on this is on-going. Hence this figure is an estimation.

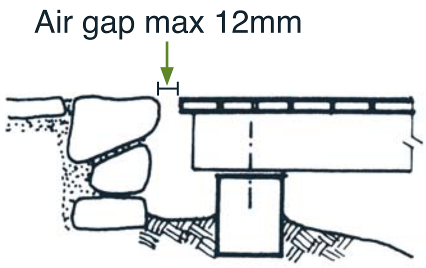
Abutment Design Options

General principles

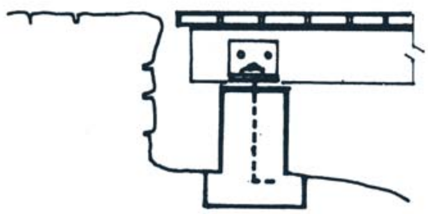
Constructing abutments and forming approach paths can be a substantial part of the overall cost of a bridge project and every effort in siting the bridge to limit the work required on them is worthwhile.

However, sophisticated abutments are rarely necessary for narrow bridges. Often plain mass blocks built in concrete, brick or stone are sufficient and the most economic. Even these simple abutments will need to accommodate a variety of situations, the most common of which and their suggested solutions are illustrated below:

Keep beam ends dry and free from encroachment of fill material by providing a good **air space** and adequate drainage at the bearing area. Maximum gap 12mm.



Bridges can be light structures and their deadweight may not be sufficient to hold them in position under vibrating live loads, flooding etc. **Bolt or clamp beams** to the abutments if necessary.

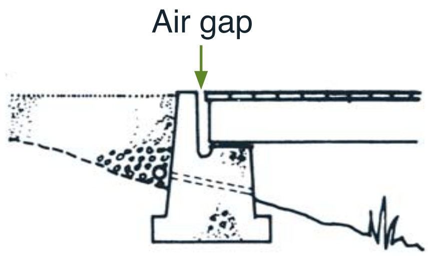


The simplest abutment is a **bankseat**, where the bridge superstructure meets the ground at its natural level on a stable area of suitable bearing capacity. In this case, a concrete strip foundation will do. Try to avoid steps.

Timber bankseats can be used but these will have a limited life. Timber must be durable or pressure treated. A tile drain is necessary.

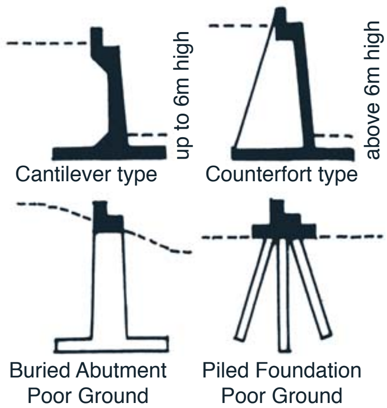
Abutment Design Options

Where the bridge deck level is above natural ground level, a **mass abutment** can be constructed and the upfilling used to ramp the path allowed to spill naturally around it.



On steep slopes it may be necessary to retain the upfilling for the path by widening the abutment or providing **wingwalls**.

Where high abutments (over 3m) are required, or if poor bearing capacity demands a light structure, more sophisticated solutions can be designed in **reinforced concrete**, or **piled foundations** can be adopted. In all these cases, the advice of an experienced designer should be sought.



Bearing pressure of soils

Some examples from *BS 8004*

Substrate	Presumed allowable bearing value kN/m²
Hard rock	10,000
Strong limestone and strong sandstone	3,000
Dense sand and gravel	>600
Loose sand and gravel	<200
Stiff boulder clay	300 - 600
Soft clays and silts	<75

Abutment Design Options

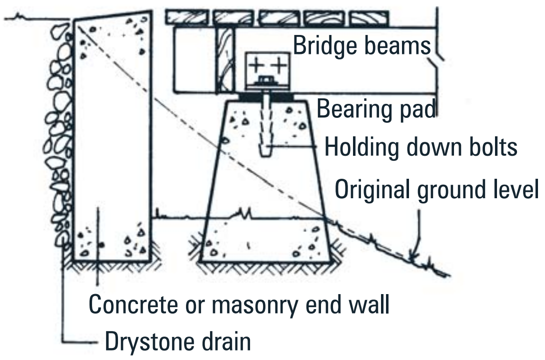
Typical end bearing details

Bridge beams must be:

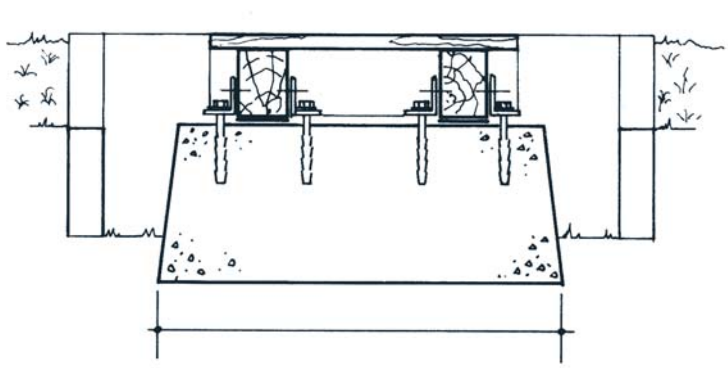
- *Supported* - bearing pressure within permissible limits
- *Held down* - holding down bolts required. Bearing must have sufficient weight
- *Restrained against lateral and longitudinal movement* - holding down bolts required

Junction of the bridge and the path must be constructed:

- by building an *end wall* retaining fill (as shown)
- by constructing a *ramp* from the deck to the natural ground level
- by installing *steps*. Try to make this approach a last resort to maximise accessibility



SECTION - ALONG DECK



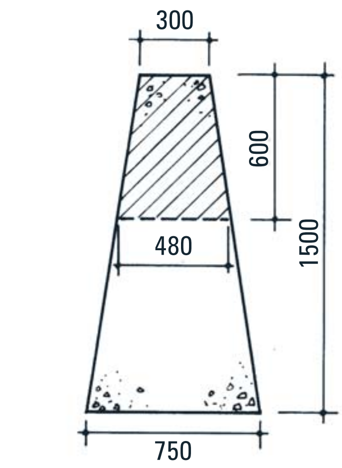
Abutment Design Options

Typical support piers

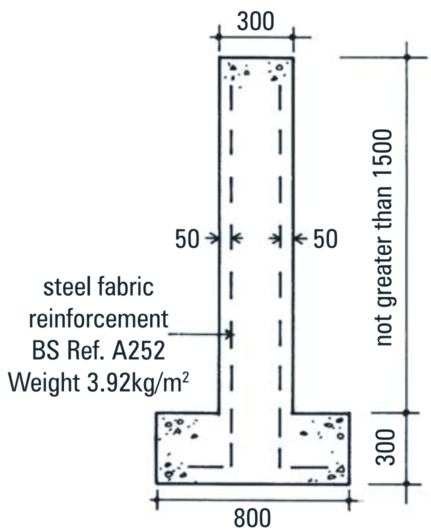
Separate support piers -

- Allow circulation of air and keeps bearing dry
- Are not required to retain fill
- Reduce complication of constructing an end wall as part of the abutment

1. **Timber beam bridges** under 10m span fixed at both ends.
   For smaller piers use hatched top of section as shown.

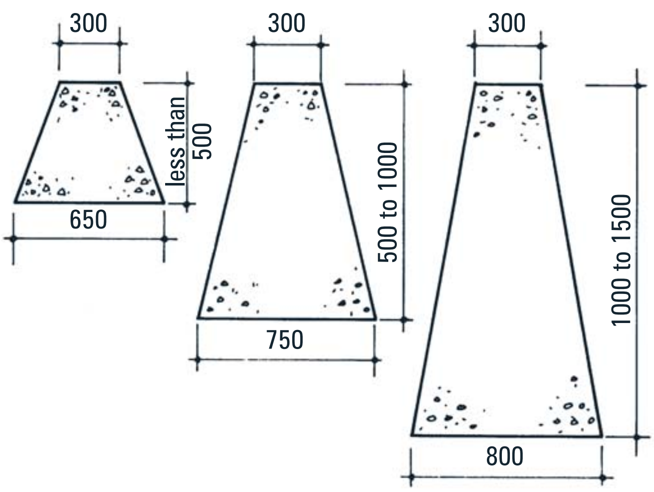


Mass Concrete - 1:2:4 mix
Max. bearing pressure 115 kN/m²

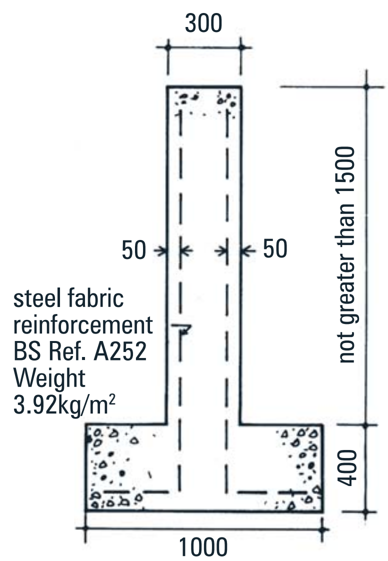


Semi Reinforced Concrete - 1:1½:3 mix
Max. bearing pressure 132 kN/m²

2. **Steel beam bridges** under 10m span. Fixed at one end and free to
   expand at the other.



Mass Concrete - 1:2:4 mix
Max. bearing pressure 112 kN/m²



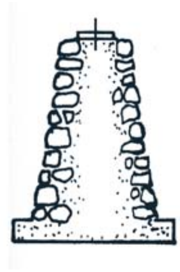
Semi Reinforced Concrete - 1:1½:3 mix
Max. bearing pressure 90 kN/m²

For concrete mixes refer to Technical Sheet 6.5.

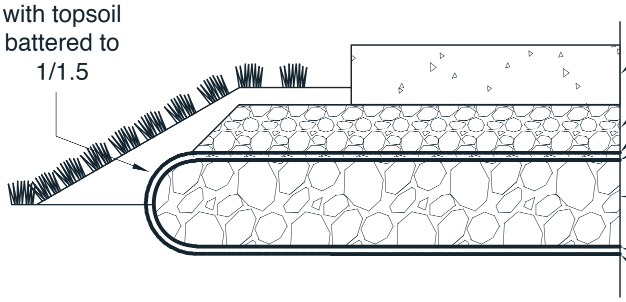
Abutment Design Options

Mass piers and walls - masonry and brick

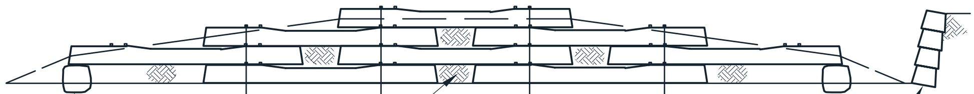
Mass work can be built solid in stone or engineering-quality brick with solid mortar bed and joints, or used as face work to a mass concrete infill. Care must be taken to make the face work strong enough to withstand the pressure of the wet concrete.



Floating geogrid construction

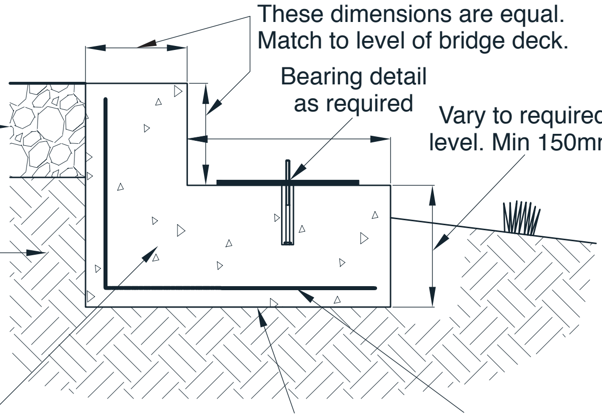


Sleeper crib wall



Sleeper arrangement can be varied to suit different situations. For example, outer sleepers can be angled back into wingwalls.

Typical simple concrete bankseat with integral end wall



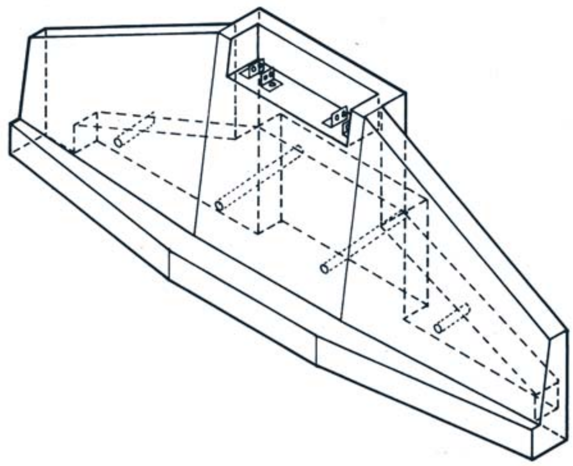
Width to be bridge deck plus 500mm min. Increase to ensure path verges are adequately retained as required.

Can be shuttered and poured as one complete unit or in two parts - pad and end wall.

If end wall retains more than 300mm depth of sub-soil, include drainage gravel layer and weep holes.

6.4 Abutment Design Options

Typical mass concrete abutment and wingwalls retaining granular fill



Experienced joiners and concrete workers are required.

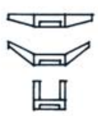
For heights of 3m and above or where foundation conditions are doubtful engineering advice should be sought.

Concrete:

1:2:4 mix (21N/mm^2) using up to 40mm aggregate.

Bearing area should be drained.

A drainage layer should be formed behind the wall with single size stone and water released thro weepholes and at the ends of the walls.

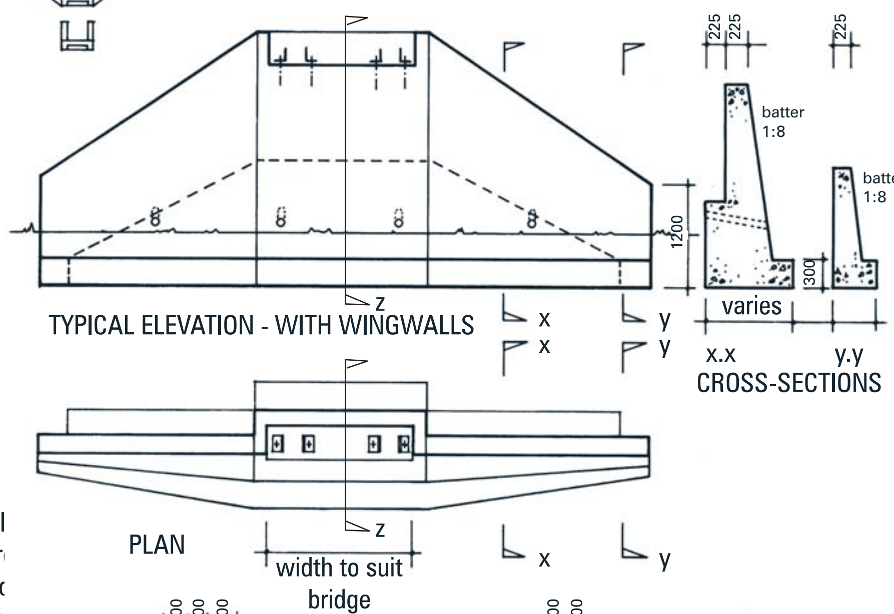


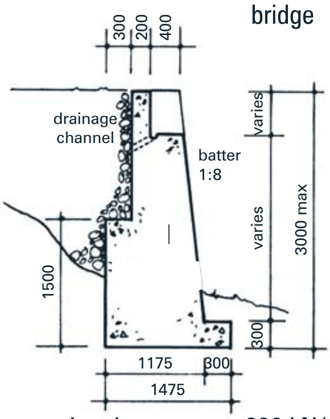
Wingwalls may be:

- as shown
- inclined to the line
- of the abutment
- parallel to the path

Fill should be spread and compacted in thin (150mm to 225mm) layers. Soft clays, peats etc. should not be used for filling.

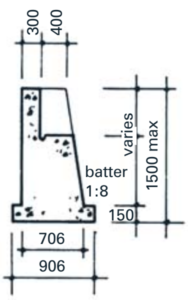
Concrete facework can be straight from the shutter. Alternativel it can be bush-hammere or point tooled to provic a variety of finishes. Th original concrete face must be sound and free from blemishes and a hard stable aggregate must be used if this is to be successful. Concrete facework may also be painted.





max. bearing pressure 239 kN/m^2

CROSS-SECTION Z-Z



max. bearing pressure 170kN/m^2

SIMPLE SECTION FOR SHALLOW ABUTMENTS

Using Concrete

Concrete is usually made from the following components:

- Sharp gritty sand usually termed concreting sand (fine aggregate)
- Gravel (coarse aggregate)
- Portland cement
- Water

Ratio of I part cement: 2½ parts sand: 4 parts gravel by volume.

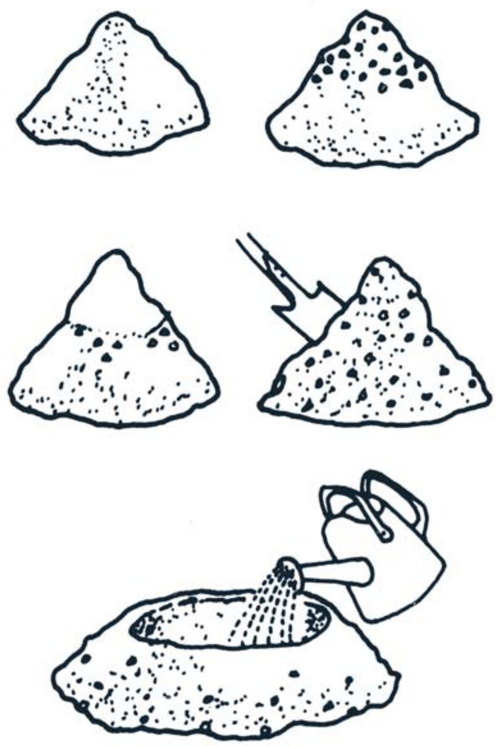
Sea sand and sea water must never be used. Small quantities of concrete can be mixed by hand or machine.

Machine mixing

Load half the gravel and half the water first; then all the sand; allow a thorough mix; then add the cement, and the remainder of the gravel. Mix and add enough water to make a workable mix. Mixing should continue for at least two minutes after adding the cement. The proportion of water is important. Too little means that the concrete will not set properly; too much weakens the concrete and shortens its life. Half a bucket of water per bucket of cement is a good guide. The concrete mix should be like very stiff porridge.

Hand mixing

Use the sequence illustrated here - pile up sand, then aggregate, then cement, mix thoroughly, form a hollow and add water. Mix to correct consistency. A good rule is to turn the batch three times dry and three times wet or until an even colour is achieved.



Using Concrete

Laying and compacting

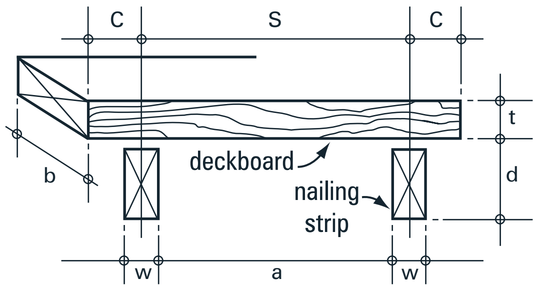
Concrete is best compacted by means of a vibrating poker which encourages settlement and expels air bubbles from the mix. It should be laid in layers. Each layer should be vibrated at about 450mm centres until no more air bubbles rise to the surface. If no vibrator is available concrete can be consolidated by podging with metal bars and tramping in by people wearing wellington boots. In this case, the concrete must be placed in thin layers. The concrete next to any shuttered face requires particular attention if it is not to remain honeycombed. The top surface of concrete should be tamped with the edge of a board and then trowelled smooth with a wooden trowel. Over-trowelling must be avoided. It causes a cement-rich layer to form on the surface which will quickly deteriorate and spall off during frosty weather.

Concrete will take at least three days to set completely and seven to develop its full strength. Strike or loosen any shuttering after one day and remove after three. Prevent exposed surfaces from frost damage or drying out too quickly with polythene sheeting and keep wet in dry weather.

Specifying Timber Decking

The table overleaf shows the timber sections that are required to construct safe decks for a variety of bridge widths and user types using different timbers. For all tables refer to the diagram below and the associated key.

KEY	
Deckboards	
Span	= S or a+2t, whichever is the shorter
Cantilever	= C
Width	= b
Thickness	= t
Bearers	
Width	= w
Depth	= d



All dimensions given in mm

Specifying Timber Decking

The table below gives the maximum span and cantilever for a variety of deckboard sections, timber strength classes and user groups.

	Pedestrians * and cyclists						Livestock, horses and ATVs					
Strength Class	C16		C24		D50		C16		C24		D50	
Size t x b mm	Span	Cant	Span	Cant	Span	Cant	Span	Cant	Span	Cant	Span	Cant
36 x 100	-	-	-	-	750	200	-	-	-	-	-	-
36 x 125	-	-	-	-	925	250	-	-	-	-	-	-
36 x 150	-	-	-	-	1100	300	-	-	-	-	-	-
50 x 100	500	150	700	200	1400	350	-	-	-	-	-	-
50 x 125	625	175	850	230	1500	450	-	-	-	-	-	-
50 x 150	725	200	1000	270	1575	525	300	100	360	130	570	185
75 x 100	1050	300	1450	400	2050	890	-	-	-	-	-	-
75 x 125	1300	350	1800	475	2225	960	420	150	520	175	900	270
75 x 150	1550	400	2000	550	2350	1000	470	160	590	190	1060	300
75 x 200	1900	525	2200	725	2600	1125	560	185	730	225	1350	380
100 x 150	2275	700	2675	950	-	-	700	220	960	270	-	-
100 x 200	2500	900	2950	1275	-	-	875	260	1160	330	-	-

For an explanation of timber strength classes See Section 4.6.1

* includes Pedestrian Normal and Pedestrian Crowd

Specifying Beams

Sawn timber beams (strength class C24)

	Pedestrian Normal 2 Beam		Pedestrian Normal 3 Beam		Pedestrian Crowd 3 Beam		Horses 3 Beam	Horses 5 Beam	ATV 5 Beam
Effective Span (m)	1m deck 0.7m crs	1.2m deck 0.9m crs	1.2m deck 0.45m crs	1.5m deck 0.7m crs	1.2m deck 0.45m crs	1.5m deck 0.7m crs	1.8m deck 0.8m crs	1.8m deck 0.45m crs	1.8m deck 0.45m crs
3	150 x 75	250 x 100	150 x 75	200 x 75	200 x 100	200 x 75	250 x 100	200 x 75	250 x 150
4	200 x 100	250 x 100	200 x 100	200 x 100	200 x 100	250 x 100	250 x 100	250 x 100	250 x 150
5	250 x 150	250 x 150	250 x 150	250 x 150	250 x 150	250 x 150	300 x 225	250 x 150	300 x 225
6	250 x 150	300 x 225	250 x 150	300 x 225	250 x 150	300 x 225	300 x 225	300 x 225	300 x 225
7	250 x 150	300 x 225	250 x 150	300 x 225	250 x 150	300 x 225	350 x 250	300 x 225	300 x 225
8	300 x 225	350 x 250	300 x 225	300 x 225	300 x 225	300 x 225	-	300 x 225	350 x 250
9	300 x 225	350 x 250	300 x 225	350 x 250	300 x 225	350 x 250	-	350 x 250	350 x 250

beam dimensions shown as depth x width

Specifying Beams

Mild steel beams

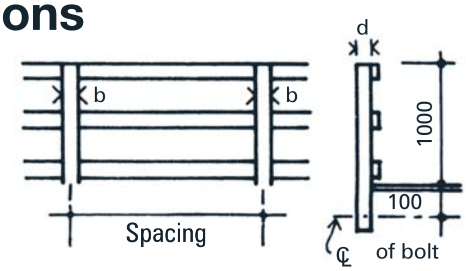
	Pedestrian Normal 2 Beam		Pedestrian Normal 3 Beam		Pedestrian Crowd 3 Beam		Horses 3 Beam	Horses 5 Beam	ATV 5 Beam
Effective Span (m)	1m deck 0.7m crs	1.2m deck 0.9m crs	1.2m deck 0.45m crs	1.5m deck 0.7m crs	1.2m deck 0.45m crs	1.5m deck 0.7m crs	1.8m deck 0.8m crs	1.8m deck 0.45m crs	1.8m deck 0.45m crs
3	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17
4	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17
5	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	203 x 133 x 25	203 x 133 x 25	203 x 133 x 25
6	152 x 89 x 17	203 x 133 x 25	152 x 89 x 17	203 x 133 x 25	152 x 89 x 17	203 x 133 x 25	203 x 133 x 30	203 x 133 x 25	203 x 133 x 25
7	152 x 89 x 17	203 x 133 x 25	203 x 133 x 25	203 x 133 x 25	203 x 133 x 25	203 x 133 x 25	254 x 146 x 37	203 x 133 x 30	203 x 133 x 25
8	203 x 133 x 25	203 x 133 x 25	203 x 133 x 25	203 x 133 x 30	203 x 133 x 25	203 x 133 x 30	254 x 146 x 37	203 x 133 x 30	203 x 133 x 30
9	254 x 146 x 30	254 x 146 x 30	203 x 133 x 30	254 x 146 x 30	203 x 133 x 30	254 x 146 x 30	305 x 165 x 40	254 x 146 x 37	254 x 146 x 37

N.B. when specifying steel the figures give dimensions and mass.

For example 152 x 89 x 17
(depth in mm) x (width in mm) x (kg/m of beam)

Handrail Specification and Fixing Details

Calculating handrail dimensions



The tables below allow sizes for suitable handrails and supporting posts to be calculated for a variety of situations.

An accompanying table giving suggested handrail heights is overleaf.

Post dimensions and maximum spacing for handrails (mm)

Post size (mm) (b x d)	Loading	Height (m)	Spacings		
			C16	C24	D50
75 x 75	Normal	1.0	550	800	1700
	Crowd	1.0	300	400	900
	Livestock	1.25	0	400	850
	Cycles	1.4	0	400	850
	Horse & Rider	1.6	0	0	500
75 x 100	Normal	1.0	1000	1400	2000
	Crowd	1.0	525	750	1600
	Livestock	1.25	500	700	1500
	Cycles	1.4	500	700	1500
	Horse & Rider	1.6	300	400	900
75 x 125	Normal	1.0	1575	2000	2000
	Crowd	1.0	825	1175	2000
	Livestock	1.25	800	1125	2000
	Cycles	1.4	800	1125	2000
	Horse & Rider	1.6	450	660	1400
75 x 150	Normal	1.0	2000	2000	2000
	Crowd	1.0	1200	1700	2000
	Livestock	1.25	1125	1625	2000
	Cycles	1.4	1125	1625	2000
	Horse & Rider	1.6	675	950	2000
100 x 100	Normal	1.0	1350	2000	2000
	Crowd	1.0	700	1000	2000
	Livestock	1.25	675	950	2000
	Cycles	1.4	675	950	2000
	Horse & Rider	1.6	400	550	1200
100 x 125	Normal	1.0	2000	2000	2000
	Crowd	1.0	1100	1575	2000
	Livestock	1.25	1000	1500	2000
	Cycles	1.4	1000	1500	2000
	Horse & Rider	1.6	600	875	1875
100 x 150	Normal	1.0	2000	2000	2000
	Crowd	1.0	1600	2000	2000
	Livestock	1.25	1525	2000	2000
	Cycles	1.4	1525	2000	2000
	Horse & Rider	1.6	900	1250	2000

6.8 Handrail Specification and Fixing Details

Suggested handrail heights above deck

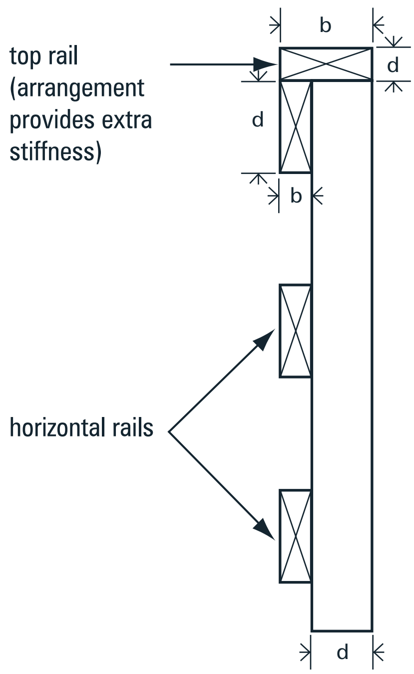
1.0m	Normal and Crowd Loading for deck heights up to 3m and dismounted cycles.
1.25m	Livestock, cycles for deck heights up to 5m and dismounted horses (with low risk).
1.4m	Cycles over roads, dismounted horses (high risk) and deck height over 5m.
1.6m	Mounted horses (low risk).
1.8m	Mounted horses (high risk). Not covered in this guide.

Maximum spans for rails and vertical infill (mm)

RAIL	Size (mm)	C16	C24	D50
Horizontal (Intermediate) Rail	75 x 50	1150	1370	2000
	100 x 50	1330	1580	2310
	150 x 50	1630	1940	2830
Top Rail	30 x 100	1460	1750	2530
	30 x 150	2190	2600	3800
Vertical Infill	35 x 35	-	-	770
	40 x 40	440	570	1080
	50 x 50	750	1000	2000

Also note that:

- all rails designed for crowd loading
- for horses maximum span is always 1250mm
- horse parapet as BHS recommendations with top rail at 1250 and 1600mm. Use horizontal rails rather than vertical infill and a kickboard of minimum height 250mm.



Handrail Specification and Fixing Details

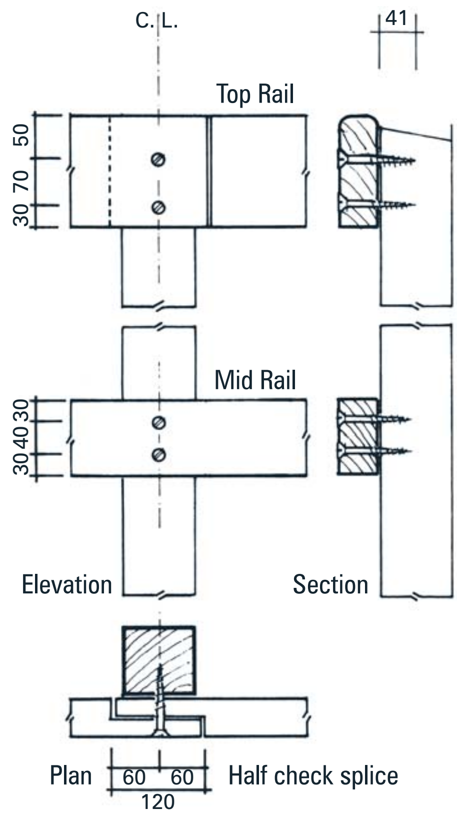
Fixing details (all dimensions in mm)

Fixed to face of post

Galvanised steel countersunk screws to be No. 12 (5.6 dia) penetrating the post not less than 41mm.

Predrilled holes.

Fixing at half-checked splice shown. Fixing for continuous rail is similar.



Spliced joint

Only one rail to be spliced at any one post.

Treat all cut edges with preservative if the wood is treated

Half check joints not located at a post seriously weaken the horizontal strength of the handrail.

Top rail over post

76 x 64 x6.2mm galvanised steel angles drilled and countersunk for screws. Screws No 12 x 50 long for normal loading or No 16 x 63 for crowd loading.

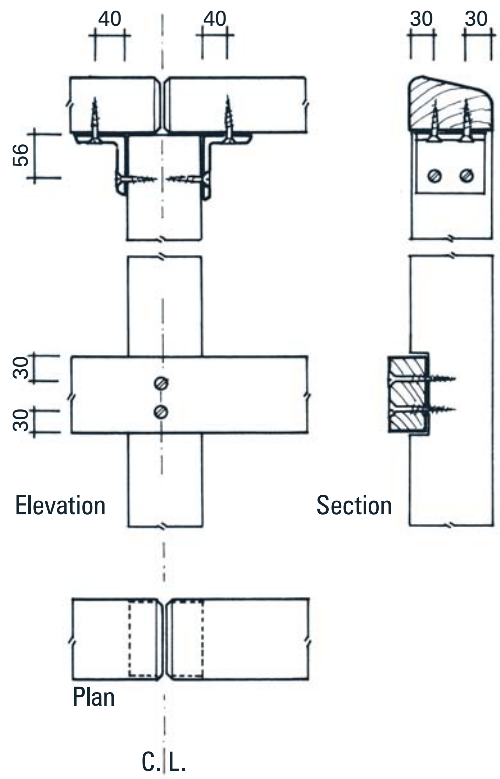
Pre-drilled holes.

Mid rail

Half checked into post. Fixed with 2 No. 12 screws penetrating the post not less than 41mm.

Butt joint

Top rail over the post.
Cut ends treated with preservative, if the wood is treated.



Nuts, Bolts and Other Connectors

Nails

Nails are commonly used for attaching deck boards to beams or deck bearers. They can be used to attach handrails to posts but this is less effective than using screws. Nail guns are now available, making for rapid construction with minimal disturbance of the pieces being joined. The nails are stronger and slimmer and their use is very accurate. Smooth and ridged nails are available. Nail guns require training for their safe use.

With larger nails, a predrilled hole of 0.6-0.8 times the diameter of the nail and 0.9 of its length is required to prevent timber splitting. With smaller nails hammer a flat onto the nail point and it will chisel its way into the wood without splitting it.

- Always use galvanised nails to reduce corrosion
- Remember that it is very difficult to remove a nail once it is hammered in
- If you need to remove a section for maintenance then use a screw or bolt

The chart below will help in choosing the right gauge of nail for the job in hand. Remember that:

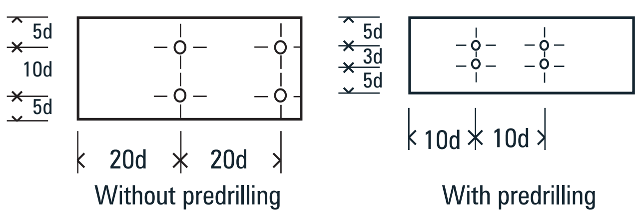
- When working with softwoods over half of the nail length should penetrate the main member of a joint
- In hardwoods a minimum of 2/5 of the length should be in the main member

The table allows the correct gauge to be chosen once the length has been determined.

Nail Length (mm)	**Standard Wire Gauge** (diameter in mm)								
	12 (2.65)	**11** (3.0)	**10** (3.35)	**9** (3.75)	**8** (4.0)	**7** (4.5)	**6** (5.0)	**5** (5.6)	**4** (6.0)
50	✓	✓	✓	-	-	-	-	-	-
75	-	-	✓	✓	✓	-	-	-	-
100	-	-	-	-	✓	✓	✓	-	-
125	-	-	-	-	-	-	✓	✓	-
150	-	-	-	-	-	-	-	✓	✓

To take its full design load the penetration of the nail should be in accordance with Table 57 of BS 5268 and should comply with the minimum spacing and edge distances shown right.

Minimum spacing and edge distances



Predrilled holes should not be greater than 0.8 times the diameter of the nail.

Nuts, Bolts and Other Connectors

Screws

The technology of screws has shown huge developments and the materials and coatings from which they are now made give them an extremely wide application – even if choice can be bewildering. Always refer to the manufacturers' specifications.

Many screws now cut their own thread without the need for pre-drilling and can be easily driven with battery operated screwdrivers. Steel is strong but it must be galvanised or sheradised (nickel plated) to prevent them from corroding. Brass screws do not corrode and so are better for marine or very wet environments. They are essential for oak as steel will cause black stains in the wood.

Drill pilot holes (if required) of 0.4-0.6 times the diameter of the screw and 0.9 the length. The drilling size is usually given on the box the screws are supplied in.

You can calculate the correct length and gauge of screw for a job using the table below. To do this you need to know the standard penetration of a given screw, that is, the depth to which a screw must be driven into the main member to give sufficient strength to a joint.

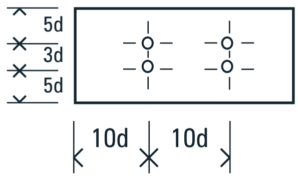
Length of screw required	=	thickness of piece being attached to main member	+	standard penetration

Screw length (mm)	**Screw Gauge** (diameter in mm)					
	10 (4.9)	**12** (5.6)	**14** (6.3)	**16** (5.0)	**18** (7.7)	**20** (8.4)
50	✓	✓	✓	-	-	-
60	✓	✓	✓	✓	-	-
75	-	✓	✓	✓	✓	✓
89	-	✓	✓	✓	-	-
100	-	✓	✓	✓	✓	✓
Standard Penetration (mm)	**34**	**39**	**44**	**49**	**54**	**59**

Nuts, Bolts and Other Connectors

Predrilling - the hole for the shank should be equal to the shank diameter and the hole for the threaded portion should be 0.4 to 0.6 times the diameter at the root of the thread adjacent to the shank depending on the density of the timber - see Clause 42.1 of *BS 5268*. The hole should be drilled to 0.9 of the total screw length.

Minimum spacing and edge distances



To reduce friction (and arm ache) screws should be dipped in linseed oil before driving.

Coach screws

All coach screws should be galvanised or sheradised (nickel plated). Some common sizes of square head coach screws are given below:

Length (mm)	Diameter (mm)			
	6.5	8.0	10.0	12.0
75	✓	✓	✓	✓
100	-	✓	✓	-
125	-	-	✓	-
150	-	✓	✓	✓

Longer lengths and larger diameters can be obtained to order. Spacing and predrilling are as for wood screws.

Bolts

Bolt holes in timber structures tend to rot much faster then other parts. This is usually due to water getting into the hole and not getting out. Careful sealing of bolt holes in timber sections is therefore essential - *use silicon sealant*.

Specify large flat washers under bolt and nut heads to spread out stresses and prevent localised crushing of timber.

Holes for bolts should be slightly oversized to take account of manufacturing tolerances. About 1-1.6mm oversize is generally fine, depending on the size of the bolt. Any more will affect the strength of the joint.

6.9 Nuts, Bolts and Other Connectors

Drilling holes on site will make lining up of holes easier, but a site-drilled hole cannot be pressure treated (or galvanised on a steel structure) and rot or rust will be a problem. Using predrilled slots instead of holes can make site construction easier as a little room for movement (or error) is introduced when fixing members together.

Coat threads of bolts with copper grease to prevent them rusting solid. This will greatly assist future maintenance if sections of the bridge need to be unbolted.

Stainless steel nuts and bolts are the best option but will usually need to be specially ordered. Zinc plated bolts are most usually used. Plated black bolts will only resist rusting for around 5 years and untreated black bolts should be avoided. These days nearly all bolts will be metric and various diameters and lengths are available. Bolts are specified as M (for metric) followed by the diameter in millimetres. So M12 is a metric, 12mm diameter bolt.

Choosing the right bolt for the job

As a useful 'rule of thumb' the length of bolt ordered must allow for the thickness of the timbers jointed plus a washer under both head and nut and the thickness of the nut with at least 5mm protruding. For complex situations bolt sizes are an engineering calculation.

As a general guide M10 joins rails to posts, M16 joins nailing strips to steel beams and M20 would be used to join a handrail post to a transom.

Bolt diameter (mm)	Nut thickness (mm)	Washer	
		Size of square or diameter (mm)	Minimum thickness (mm)
10	8.5	50	3
12	10.5	50	3
16	13.5	65	5
20	16.5	65	5
24	19.7	76	6

Washers

Washers used for joining timber tend to be larger that those for fastening metal elements together to resist the greater potential of wood to be crushed. Washers should have a nominal diameter of at least three times and a thickness of at least 0.25 times the bolt diameter - see BS 5268 Part 2: 1984 Clause 43.1.

Pre-drilling - Holes for bolts should be drilled not more than 1.6mm larger than the bolt diameter.

Visual Timber Stress Grading

The following FCE specification can be used to identify suitable pieces of home grown softwood timber which have not been machine graded or visually stress graded to *BS 4978*. This identification technique is ultimately a short cut visual grading which is relevant for timbers used for path bridge decks, but **not** for structural members.

The information contained in this sheet should only be used by people experienced in assessing timber.

Permitted timber species

Species	Grade
Pine	GS
Larch	GS
Douglas Fir	GS

Rate of growth

Average width of annual rings no greater than 4mm.

Fissures

(Resin pockets and bark pockets)
Codes permit up to ½ way through the thickness anywhere and all the way through for a restricted length. This specification takes a conservative approach and allows only up to 25mm deep splits for a 500mm length.

Slope of grain

Not steeper than a gradient of 1 in 6.

Growth ring distribution

No fully boxed heart permitted

Visual Timber Stress Grading

Wane

¼ of width for full length of a timber is acceptable or ⅓ of the width for a distance of 300mm.

Knots

Knot area at any cross section not greater than ⅕ of total cross sectional area.

Distortion

Bow	Maximum 10mm over 2m	(ends up)
Spring	Maximum 5mm over 2m	(sides out)
Twist	Maximum 8mm over 2m	(corners up)
Cup	Maximum 4mm	(bow across section)

Worm holes

There shall be no wasp holes but pin worm holes are permitted in small numbers, which will not affect the wood strength.

Fungal decay

Reject any piece with any decay.

Sapstain

This is not a defect.

Abnormal defects

Abnormal special defects, e.g. compression wood, which would weaken the plank below its serviceability are grounds for rejection.

Timber Bridges: Susceptibility and Detailing

The table shows susceptible parts of timber bridge structures, with examples of common detailing weaknesses and suggested improvements

Part of the structure	Examples of poor detailing	Examples of better detailing
End grain of members in general e.g. beams	Exposed end grain leads to fissures, is unattractive and ultimately a seat of decay	Protected end grain, e.g. by attaching other timber members having side grain, or by ventilated capping/ sealing
Upper edges of exposed members e.g. beams and handrails	Flat upper edges where water lies and which trap dirt, especially when weathered/ fissured	Chamfered and sloped upper edges which freely drain Edges protected by ventilated capping
Joinery details e.g. handrails, parapet to beam connections	Details which trap moisture in mortises, fixing holes, recesses etc.	Freely draining, ventilated flush details Raise parapet above splash level with a separate drained kerb
Decking and its attachments	Deck which is tight jointed or with a sealed surface but which merely traps moisture Attachments to beams which form traps	Deck which freely drains, laterally and longitudinally even when worn Drip mouldings beneath deck boards DPC between deck and beams
DPC between deck and beams	Intersection points can easily form moisture/dirt entrapment regions	Not easily avoided, but detail for maximum ventilation and drainage, e.g. by drilling/arranging gaps
Member intersection points, column bases, especially with steelwork	Intersection points can trap moisture and remain damp	Design steelwork to allow drainage and ventilation. Avoid details which allow the collection of water
Bearing points, supports, bank seats etc.	Poorly ventilated susceptible to silting up, dirt and debris entrapment	As well raised from surroundings, e.g. by masonry and supporting steel, as possible.

Taken from *Timber Bridges and Foundations*

Steel Specification

Structural Steel

Steel can be obtained in different grades of uniform quality, each grade having its own characteristic mechanical properties. *BS EN 10025* defines the various grades of which Grade S275 is ordinary mild steel.

Structural steel is supplied in a variety of sections:

BS EN 10056 - 1:1999
Angles - leg sizes vary from 20mm to 200mm in a variety of metal thicknesses and equal and unequal legs.

BS4:2005

Channels - sizes vary from 76 x 38mm to 432 x 102mm.

Tees - sizes vary from 38 x 38mm to 127 x 254mm.

I-beam or Universal Beam - sizes vary from 127 x 76mm to 914 x 419mm.

Universal Column or H beam - sizes vary from 152 x 152mm to 356 x 406mm.

BS EN 10219:2006 or *BS EN 10210:2006*

rectangle

square

Rectangular Hollow Sections - sides from 20mm to 450mm and with a variety of wall thicknesses.

BS EN 7768:2004

Circular Hollow Sections - outside diameter 21mm to 457mm and with a variety of wall thicknesses.

Structural steelwork for bridges should be obtained from a competent steelwork fabricator who will be responsible for the standard of workmanship being in accordance with *BS 5950* and who will also prepare the steel and apply the protective coatings.

Steel Specification

Specifying Steel

Steel is specified in different ways depending on the section chosen.

I-beams, **universal columns** and **channels** are specified as

depth (mm)	x	width (mm)	x	mass (kg/m)

Angles, **tees**, **rectangular** and **circular hollow sections** are

depth (mm)	x	width (mm)	x	wall thickness (mm)

Contract Documentation

An example of simplified contract documents follow. It is used by Forestry Civil Engineering (FCE) for small bridge construction projects.

FCE use the ICE Minor Works Contract issued by the Institution of Civil Engineers. These are fronted with the 4 pages that follow and are used to control rural jobs and sign agreements simply, which make contractors feel at ease. The introductory clauses vary slightly according to the job.

The simplified documents have been developed over many years of experience by Geoff Freedman (FCE). They provide a good example of how complex contract documentation can be honed down to a more simple and usable set of agreements.

It must be stressed that this is for example purposes only and simplified documents will need to be tailored to meet the needs of your own organisation and the project concerned.

Using the Designs

The designs offered in this guide have been chosen for their robustness and ease of construction on site. They all offer options for a range of user groups. The designs in *Footbridges in the Countryside* have mainly been replaced because of their complex construction or their reliance on glued timber joints. If not accurately cut and assembled in a workshop these joints have proved points of weakness, either because of water ingress or poor fit. They have mainly been superseded by designs that can be more reliably assembled on site by unskilled labour under appropriate supervision.

Each design includes a general layout and some notes for construction. To simplify the process of choosing the correctly sized components, a table (like the one shown below) accompanies each design and gives suggested solutions for different load classes. Long spans for certain load classes are not safe for some of the designs and the appropriate boxes on the tables have been hatched out.

User Category		**Span (m)**						
		2	**3**	**4**	**5**	**6**	**7**	**8**
Pedestrian Normal usable width handrail height handrail post section (b x d) handrail section (d x b) deck section (t x b) no. beams	**beam section (d x b)**						(hatched)	(hatched)
Pedestrian Crowd usable width handrail height handrail post section (b x d) handrail section (d x b) deck section (t x b) no. beams	**beam section**						(hatched)	(hatched)
Horses usable width handrail height handrail post section (b x d) handrail section (d x b) deck section (t x b) no. beams	**beam section**				(hatched)	(hatched)	(hatched)	(hatched)

7.1 Using the Designs

The suggested combinations of components will not always produce exactly the bridge you need. For example, you may wish to vary the handrail arrangements or choose a wider deck or to alter the number of beams. In these situations, or if you wish to use timber other than C24 (See Section 4.6.1), use the tables in Technical Sheets 6.6, 6.7 and 6.8 to specify the components individually and ensure the bridge fits your exact requirements.

Note that 'Pedestrian Normal' also includes occasional cycle use and 'Pedestrian Crowd' includes normal cycle use. For 'Crowd Cycle' use the 'Horse' specification.

Designs for horse use with a 1.8m handrail are not included. Safe attachment of 1.8m handrail posts is difficult and the services of an engineer will be required.

Different handrail arrangements are shown on each of the designs. If required, the handrailing details may be interchanged between the Sawn Timber (7.3) and Glentrool (7.4) designs to give a greater variety of options. The appropriate load class must be adhered to.

Log Bridge

Log specification

Logs to be species Douglas fir, European larch, Scots pine, Oak or telegraph poles.

They should be straight and of the minimum diameter specified within the middle ⅓ of the log length. Excessive taper will affect the amount of cutting required to achieve a level deck. 10mm/m on each side is acceptable.

Branches to be removed but not trimmed flush. Bark to be removed and the butt ends sealed soon after felling.

Timber to be rejected if it has:

- Knots larger than 100mm diameter
- Signs of fungal decay or other serious defects
- Marked spiral grain slope
- Severe checking or fissures. Maximum width of surface cracks at felling to be 0.2mm and after seasoning to be 3mm. The total depth of all fissures must not exceed ⅓ of the log diameter.

Logs should be placed to achieve a level deck and a straight line of handrail with the minimum of cutting.

User Category		**Span (m)**						
		2	**3**	**4**	**5**	**6**	**7**	**8**
Pedestrian Normal usable width 1.0m handrail height 1.0m handrail post section 75mm x 100mm @ 1400 crs handrail section 100mm x 50mm deck section 50mm x 100mm 2 logs @ 0.7crs	**Minimum log dia (mm)**	250	250	300	350	350		
Pedestrian Crowd usable width 1.2m handrail height 1.25m handrail post section 100mm x 125mm @ 1475 crs handrail section 100mm x 50mm deck section 50mm x 150mm 3 logs @ 0.45 crs	**Minimum log dia (mm)**	250	250	300	350	350		
Horses usable width 1.8m handrail height 1.6m handrail post section 100mm x 150mm handrail section 150mm x 67mm deck section 100mm x 150mm 5 logs @ 0.45m crs	**Minimum log dia (mm)**	300	350	400				

Note that widths can be increased by simply adding another log of the same section for a given span.

Glentrool Bridge - Steel

User Category		Span (m)						
		3	4	5	6	7	8	9
Pedestrian Normal usable width 1.0m handrail height 1.0m handrail post section 75mm x 100mm @ 1400 crs handrail section 100mm x 50mm deck section 50mm x 100mm 2 beams @ 0.7m crs	**beam** section (mm) (kg/m)	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	203 x 133 x 25	254 x 146 x 30
Pedestrian Normal usable width 1.2m handrail height 1.0m handrail post section 75mm x 100mm @ 1200 crs handrail section 100mm x 50mm deck section 50mm x 100mm 3 beams @ 0.45m crs	**beam** section (mm) (kg/m)	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	203 x 133 x 25	203 x 133 x 25	203 x 133 x 30
Pedestrian Crowd usable width 1.5m handrail height 1.25m handrail post section 100mm x 100mm @ 1000 crs handrail section 100mm x 50mm deck section 50mm x 100mm 3 beams @ 0.7m crs	**beam** section (mm) (kg/m)	152 x 89 x 17	152 x 89 x 17	152 x 89 x 17	203 x 133 x 25	203 x 133 x 25	203 x 133 x 30	254 x 146 x 30
Horses usable width 1.8m handrail height 1.6m handrail post section 100mm x 150mm @1250crs handrail section 100mm x 67mm deck section 100mm x 150mm 5 beams @ 0.45m crs	**beam** section (mm) (kg/m)	152 x 89 x 17	152 x 89 x 17	203 x 133 x 25	203 x 133 x 25	203 x 133 x 30	203 x 133 x 30	254 x 146 x 37

Bedfordshire's Crash Barrier Bridges

Since 1992 Bedfordshire County Council has constructed a number of bridges for their public Rights of Way network based on standard crash barrier sections. Currently two designs have been developed, one using a closed section barrier for beams, the other using the open section barrier familiar on motorways. These have been used at over 20 locations and have proved easy to install, robust and low maintenance. Crash barriers and many of the other steel components used in the bridges are standard materials already manufactured and galvanised to a very high specification. The barriers are available in large quantities and at reasonable cost either new or secondhand.

Closed box section Bridge

This footbridge at Arlesey Common has been designed by NAT Bridges and is a 6.4m single span over the River Hiz. A minimum soffit height requirement was imposed by the Environment Agency to maximise the clearance between the river and bridge in this flood plain location. This could have resulted in the bridge deck being much higher than the surrounding land, adding the need for ramped or stepped approaches – so the thin (200mm x 100mm) crash barrier beams seemed like an excellent solution. To reduce the depth of the bridge still further, the deck was fixed to a rail attached to the inside face of the beam. Conventional 'I' beams would have been much deeper and required a deck support board between beam and deck. The handrail post brackets were prefabricated and galvanised before being bolted to the beams. The end post brackets were incorporated into the anchoring system that attaches to existing jointing holes in the crash barrier.

The bridge is in a location prone to vandalism so tubular steel handrails were fitted. KeyKlamp is a versatile galvanised tubing system used for cow stalls, milking parlours and many other applications. It is readily available in 6.4m lengths with threaded ends. End-to-end jointing with external threaded collars makes longer runs simple to achieve. The three upper rails pass through holes in the posts and are secured by external locking collars slid along the rails. The ends are finished with threaded caps. Stainless steel fixings are used throughout.

Bedfordshire's Crash Barrier Bridges

The toe rails are separate sections attached between the post brackets. They do not pass through the posts as a 42mm diameter hole so close to the fixing point could lead to the post fracturing under severe side loading or impact. With their many fittings, this proved an expensive option compared to a simple wooden rail but was specially requested by the client (Arlesey Conservation for Nature). The deck comprises 50mm thick grooved softwood decking, supplied by a local timber merchant. Stainless steel fixings were used throughout.

Due to the lightness of the construction all assembly was done on site without the aid of any lifting gear.

There are many careful design features but particularly note the handrail post bracket with upright flange added to stop rainwater, shed from the deck, soaking into the wooden post.

Bedfordshire's Crash Barrier Bridges

Open box section bridge

The open section bridge transfers the shape of the beam into the rake on the handrail. This type of crash barrier is readily available in 4.8m and 2.4m standard lengths and can be joined using internal fishplates. For use as a footbridge the beam is rotated through 90 degrees from its usual roadside orientation and any joints are reinforced with an additional brace. The wooden handrail posts are simply bolted through the wall of the box. The deck is screwed to a thin (37mm) board which seals the top of the open box. This design has been used for clear span footbridges up to 8.4m in length.

In this remote location a handrail on one side was considered adequate.

No longer needed at its present location this 7.2m footbridge was removed using a farm forklift for reuse on another of Bedfordshire's paths.

Bedfordshire's Crash Barrier Bridges

General comments

Bedfordshire County Council has developed these solutions instead of I-beam constructions for some locations for the following reasons:

- The bridge beams are thin in section and less 'chunky looking' than I-beams.
- They are more likely to get approval by bodies such as the Environment Agency or local drainage board because they present less of an obstacle to flood water.
- Material costs are likely to be less, the bridges are lighter and therefore much cheaper and safer to construct.
- They are less likely to require ramps or steps and are therefore more likely to conform to the requirements of the DDA.
- The bridges are long lasting and low maintenance.

Both crash barrier designs have been used with wider, thicker decks for bridleways. For equine use a third beam (barrier) is added down the centre. (an odd number of beams are always a good idea with horses as they usually walk down the middle of a bridge).

For more information contact Chris Nicol **chris.nicol@bedscc.gov.uk** or Adrian Fett (NAT Bridges) **adrian.fett@hotmail.com**

Dollar Glen Aerial Mast Bridges

Background

In the 1980s six timber footbridges were built by the Army through a number of Military Aid to the Civil Community (MACC) schemes, allowing access up the precipitous and scenic gorge of Dollar Glen. By 2001 the timber beams had failed and the sloping walking surface had become very slippery due to the damp nature of the site. The potential courses of action were both difficult; either to replace all of the bridges, construct new ones and replace a section of land-slipped path; or close a popular site permanently.

Dollar Glen (an SSSI) is extremely steep and access to the site is by path only. All materials would have to be carried into and out of the Glen by hand. Taking the first option was therefore a challenging job.

Forestry Civil Engineering were employed to

- Survey the bridges
- Come up with a design & specification tailored for this site, that would provide safe access up the steep Glen, offer visitors a real 'gorge experience' and deal with the inevitable 'slippy walking surface' problem
- Act as Planning Supervisor for the contract

Action Environment Ltd won the contract and the work was completed in July 2002.

The solution

A series of 6 new Ranger footbridges (a Forestry Commission design) were erected in the Glen linked by improved sections of path. The construction consisted of 3m aerial mast sections bolted together to form the main beams, hardwood runners fixed to the beams and Rocol Acme panels screwed on to form the deck. These panels, 1000 x 900mm marine ply, were designed to contain 2 integral steps to form a slope of 1 in 4 up the Glen. To form a lasting non-slip surface, the panels were dipped in resin after being holed for screws and the surface dusted with bauxite chips. Hardwood posts were then bolted to the mast sections and treated softwood handrails attached. Some additional pathwork and handrails were also carried out. The total cost of the project was around £80k.

Dollar Glen Aerial Mast Bridges

Construction and contract

Health and safety requirements are so central today that jobs as dangerous as this can easily be ruled out on grounds of cost. There is always debate about what a safe working platform is and so the trick is to design a solution with a method statement that a contractor will believe in.

This job entailed the manual carrying in of every item and carrying out of every piece of demolition material. The designer must make this as easy as possible to ensure safety, high morale and low cost. In the Glen all construction was carried out using winches operated by men in full harness, hanging on double-anchored safety lines. Any fall would have been fatal, so a secure feeling was necessary not only to meet health and safety requirements but also to ensure good morale. This sometimes requires measures greater than are required for safety alone. For example, forming the bearings on rock outcrops minimised the volume of concrete that had to be carried and hauled in, reducing the strain, effort and anxiety of the workers on site.

The secret of success for a difficult job is a good practical design which operatives can identify with and will believe in its 'buildability'. If builders criticise a design or method statement the job starts on the wrong foot. Difficult jobs need good design.

For more information contact Christopher Cassels **ccassels@nts.org.uk** or Dr. Geoff Freedman **geoff.freedman@forestry.gsi.gov.uk**

Puck's Glen Bridges

In the mid 1980s a walk through the steep-sided glen near Dunoon in Argyllshire, with waterfalls and spectacular scenery, was opened to its full potential with the construction of 10 short span bridges. They were of timber construction and without adequate preservative treatment. When an inspection in 2002 condemned 8 of the bridges Forestry Civil Engineering (FCE) were asked to replace them with budget bridges while creating some structural interest. The glen is about 1km long with a severe gradient only suitable for fit, experienced walkers. There was access from a forest road at the top and similarly from the bottom. Every item of material had to be carried to its site.

Design

FCE were developing a new form of construction known as mechanical stress lamination of timber (SLT) for bridges. This has been used successfully in the USA for 25 years and in Australia and Europe for 15 years, but never in the UK. FCE began a programme of assimilation of the techniques for UK species and construction practice. They also decided to develop an arch to utilise timber in compression as that is its strongest property. To utilise the opportunity to the full, a flat SLT deck was proposed as well as an arch and a tied arch. The other 5 bridges were designed as standard Glentrool footbridges.

Glentrool

This design was developed so that unskilled labour could build a bridge which would never be unsafe. It comprises 2 small steel beams diaphragmed together using steel angles welded to the top and bottom flanges at intervals coinciding with the position of the handrail posts. This diaphragm arrangement provides an excellent fixing for the posts - which is precise and permits a good flow of air to keep the timber dry and avoid rot. (See Standard Design 7.4)

Puck's Glen Bridges

Stress lamination

Stress laminated flat deck

Stress-lamination of timber is a form of construction where sawn sections of timber are placed on edge and compressed together by high tensile steel or carbon fibre bars or strands. The bars are passed through pre-drilled holes in the wide face of the timber sections and are anchored to the deck edges using bearing plates. The tensile force introduced into the bars, by a hydraulic jack, compresses the timber sections (laminations) together forming a solid load-bearing timber plate or deck. A large arched version is described in Case Study 8.6.

Loading and materials

Each bridge was designed for a rural crowd loading of 3.2kN/m^2 and a standard handrail loading of 0.74kN/m run.

All timber was C16 pressure treated FSC approved. The steel was grade 275N/mm^2 ultimate strength and galvanized.

Construction

Because of the restricted site conditions and poor access, prefabrication was important, but weight had to be restricted to what could be manhandled. The Glentrool frames were fully fabricated and arrived with all angles welded to the beams. They weighed up to 300kg and were carried in a 4-person lift with special shoulder harnesses, distributing the load evenly.

The existing abutments were re-used but some new concrete was required. This was kept to an absolute minimum. The SLT technique was fully appreciated by the operatives as the materials were light and easy to carry and, in effect, the deck was also the structure because there are no beams. There was a boast that one 5m deck was constructed in one hour!

Conclusion

Difficult access demands careful design and lightweight materials. The standard Glentrool provides a robust suitable solution but the SLT bridges will become the future solution when fully developed.

For more information contact Dr. Geoff Freedman
geoff.freedman@forestry.gsi.gov.uk

On-site Conversion of Log to Bridge

Reduce, Reuse, Recycle - a sustainable solution for Callander

Setting

Callander Lower Wood Walk is managed by Stirling Council Countryside Service. As part of Callander's path network it is well used by both local people and visitors. In 2001 when a concrete surfaced bridge spanning a gorge mid-way along the path became unsafe, how to replace it became a challenging issue.

The bridge lay right in the middle of the woodland at the highest point on the path. The nearest and, indeed the only feasible access, was along a steep, metre-wide path with many tight bends - so no access for machinery. A bridge demolition and replacement solution was therefore required that minimised bringing in and removing material.

The solution

Following local consultation a plan was developed that met a number of local objectives in one go. Long overdue woodland thinning, path infrastructure improvements and the bridge replacement were rolled into one project funded by a Woodland Improvement Grant. The scheme involved recycling much of the existing bridge and building a new one from the trees growing on site. A 6.5m oak bridge was designed for the purpose.

Construction

Work commenced with felling two large oak trees next to the old bridge, improving the views to Loch Venachar and letting light in for bank revegetation. The main beams (6.5m x 300mm x 120mm) and deck boards were milled from these using an Alaskan Lumbermill - a guide which clamps onto a chainsaw bar allowing material to be cut on site. Handrails were prefabricated at the Countryside Service workshops, from air-dried oak taken from other Council-managed areas.

On-site Conversion of Log to Bridge

Before demolition work commenced, the new beams were winched across the old bridge. Foundations were dug into the top of the banks by hand and rubble concrete from the demolition work used as a base for a shuttered 200mm concrete pad, reinforced with reused metalwork from the demolition process. The rubble was compacted with a vibrating plate. Concrete mixed in a Belle mixer was transported down the narrow path in a tracked powered wheelbarrow. When required, the vibrating plate and concrete were ferried across the gorge via an aerial ropeway constructed through creative use of a Tirfor winch, a pulley, a shackle, two lengths of thin rope and a bucket!

The beams were lifted onto the pad foundation, aligned and secured using prefabricated clamps and threaded rod epoxy, grouted into the concrete. Drilling for bolt holes and pilot holes was powered by petrol generator. The approaches were finished by casting a concrete sill at either end of the bridge to prevent the path slumping and prematurely rotting the new beams. Arisings from the excavation of the foundations were graded and compacted, to provide a new path surface.

Project evaluation

- Bridge was constructed with little new or foreign material being imported to the site.
- Virtually all of the old structure was reused and recycled.
- Achieved multiple aims agreed by the Stirling Countryside Service, the local community and the Forestry Commission.

For more information contact
Richard Barron
barronr@stirling.gov.uk

Forestry Commission Inspection Regime

These examples of a bridge record sheet and bridge inspection sheet are taken from the Forest Civil Engineering Handbook

Bridge recording, inspection and maintenance

1. All bridges and large culverts (i.e. those greater than 1.5m span or diameter) should have a Record Form such as the example shown at the end of this section.
2. It is advisable to create an inspection schedule of all bridges and large culverts. The schedule should contain the required minimum frequency of inspections recommended by a competent engineer.
3. Inspections should be carried out by a competent person. The inspector should make use of an Inspection Form such as the example shown at the end of this section.
4. Inspection periods are a matter of considerable importance. When deciding on the frequency of inspection of a particular structure, points to bear in mind are:

- Type of structure
- Age
- Position (i.e. level of public access)
- Use
- Stream characteristics (if appropriate)
- Known history

5. Advice on inspection periods can be obtained from the Design Engineer. It is likely that these periods will range from 6 months for temporary or unstable structures to a maximum of 3 years for stable, reliable structures. However, there will be cases where even 6 months is too long.
6. Where the competent person inspecting a bridge has any reason to suspect a change in structural characteristics (e.g. serious cracking), a Chartered Engineer should be called in to carry out an assessment.
7. Should the assessment lead to the imposition of a weight restriction, the Forest District Manager must be informed immediately. Advice on weight restrictions can be obtained from the Design Engineer.
8. All the inspections and remedial works should be recorded. The Service Level Agreement will dictate the information to be passed to Forest District Managers.
9. Records of inspections should be retained for at least 5 years. However, there is scope for the use of an Inspection and Maintenance Record if desired. An example of such a form is shown at the end of this section. The FCE database is, however, the main method for storing this information.

8.5 Forestry Commission Inspection Regime

FORESTRY CIVIL ENGINEERING BRIDGE RECORD

FCE Area……………………………………

Forest District……………………………….

Location[1]…………………………………….

OS Map Reference[2]………………………....

Bridge No. & Name…………………………..

Bridge Type[3]………………………………….

Road Category[4]……………………………….

Owners/Users[5]………………………………..

Clear Span(s)[6]…………………………………………

Effective Span(s)[6]……………………………………

Height Deck to Bed (U/S)[7]……………………………

Waterway Area………………………………..

Catchment Area[8]……………………………....

Bed Gradient @ Bridge[9]……………………….

Load Capacity…………………………………………

Weight Restriction[10]…………………………………..

Completion Date……………………………………….

Cost[11]……………………………………………

Services[12]……………………………………...

Drawing Nos[13]…………………………………..

BEAM/SLAB SUPERSTRUCTURE

Main Beams…………………………………No.
Type[14]…………………………………………..
Sizes…………………………………………….

Diaphragm

Type[14]………………………………………..
Size……………………………………………..

Deck

Type[14]………………………………………

Thickness……………………………………
O/A Width…………………………………..
Width for Traffic…………………………….
Kerb Sizes…………………………………...

Abutments/Bank Seats[15]

Type………………..L……………………R
Height……………...L……………………R

Wing Walls[16]

Type…………………………………………
Length……………………………………….
Piers(s)……………………………………..No.
Type…………………………………………

CULVERT/IRISH BRIDGE

Type[14]……………………………………….
Diameter……………………………………..

Cover………………………………………

Head Walls

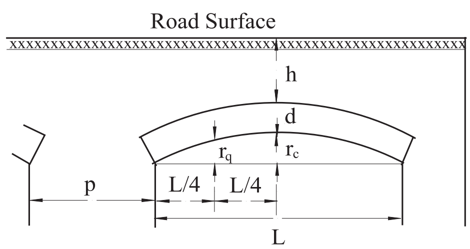
Type…………………………………………
Height……………………………………….

Tail Walls

Type ……………………………………………

Height ……………………………………….

ARCH SUPERSTRUCTURE



Span(s)
L……………………Show other Dims. Over.
Bridge O/A Width…………………………
Width for Traffic…………………………..

Parapets

Type…………………………………………
Thickness……………………………………
Height above Road…………………………

Material Types[17]
Arch Barrel…………………………………..
Arch Ring……………………………………
Spandrel Walls………………………………
Wing Walls…………………………………..
Arch Fill……………………………………..

Wing Walls[16]

Length………………………………………..

FOUNDATIONS[18]

L Abut/Headwall……………………………...
R Abut/Tailwall………………………………

Piers…………………………………………..

Foundation Subsoil……………………………………

Date of Record…………………………………

…………………………………FCE Engineer

Forth and Achray Stress Laminated Timber Bridges

Background

In 2003 a number of path improvements in Queen Elizabeth Forest Park were proposed. These included 4 new bridges with spans between 15m and 20m. Coincidentally, Forestry Civil Engineering (FCE) and Napier University had already begun to develop a new form of timber structure using short sections of timber - the Stress Laminated Timber Arch - but so far had not built one 'for real'. Two 20m span arches over the Achray Water and the River Forth were planned - they would be the first structures of their type in the world and probably the longest non-truss timber spans ever, being 100 times the depth of the structure. The structures would be a shop window for the capacity of short, low-strength timbers used to span great distances.

The two sites are spectacular and deserved an investment to create a feature rather than just build a bridge. The client showed great courage to try something new.

Testing and research

Research testing was carried out at Napier University to provide the design, and finally a 20m test arch was built and put through its paces in Glentress Forest. Surprisingly, the vibration frequency of the bridge became the main design issue, not the low strength of fast-grown Scottish timber which, because of the arch structure, was being used in compression - the best load bearing characteristic of the product.

Design

The design was finalised using C16 timbers (2m long and 200mm deep) cut identically with holes and cuts made before pressure treatment. Bridge design parameters included; loading rural crowds and horses, minimising barriers and handrail heights and strengths designed for livestock at 1250mm and 1.4kN/m run.

Stress laminated timber arches rely on the strength of timber in compression. The most critical aspects of the design are the friction between timbers, the moisture content of the timbers, the types of stressing bars and their tensions. The combination of these remain the subject of a PhD thesis which has led to a design code.

Forth and Achray Stress Laminated Timber Bridges

Construction

There was much debate about building the bridges at the river edge and lifting them into place or building them *in situ*. The final decision was to erect a full scaffold and build *in situ*, providing the best harmony between cost and safety. The scaffold to support the builders could also be used to support the construction. As the bridge took shape the arch would become self supporting. An initial narrow arch was formed and widened out to the finished dimensions. The technique lends itself to building a splayed structure of 3m width at abutments and 2m at mid span.

Good foundations were necessary to take the lateral thrust from the arch. The Achray bridge had good rock at each bank which made matters easier. One side of the Forth bridge required a substantial amount of concrete because the ground was poor.

The building technique was highly dependant on accuracy and tolerances. Hole diameters need tolerance and end cuts had to be exact to result in the butt ends transferring compression. The deck was placed, allowed to settle and then stressed *in situ* using a hand pump. The external timbers were of hardwood in order to sustain the high local pressures.

Forth and Achray Stress Laminated Timber Bridges

Finishing

The deck was covered with 40mm of dense bitumen macadam to stiffen it, waterproof it and provide a safe wearing surface. It was profiled to provide the all ability gradients necessary. When complete the natural frequency was measured to ensure it was above the vandal frequency of 2.5Hz thus avoiding any risk of resonance.

Conclusion

This form of construction has a great future because of aesthetics and sustainability, once the construction difficulties are fully resolved. There is only 11m^3 of fabricated timber and some steel bars in the materials with a total cost of about £6000 (2004 figures). The square area of deck is 50m^2. The staff hours, scaffold and foundations are approximately the same cost as the materials so a unit cost of £500 per m^2 represents a teasing target to be improved on by innovative construction techniques. Achieving gradients that meet accessability standards at either end of the bridge remains a key challenge.

8.6

Forth and Achray Stress Laminated Timber Bridges

For more information contact Dr. Geoff Freedman
geoff.freedman@forestry.gsi.gov.uk

Drummuir 21 - A Creative Low-cost Solution

Drummuir 21 is a community group near Dufftown comprising of a number of partners including the local estate and the Community Council. In 2002 they sought funding to replace the long-since disappeared bridge over the River Isla. Historically the bridge had linked the village to the railway station and had always been popular with those using the line. Since decommissioning, the bridge had fallen into disrepair and eventually failed.

Remains of the wooden footbridge that once linked Drummuir village with Drummuir railway station

Subsequently Keith and Dufftown Railway Association restored the line between Dufftown and Keith, with a stop at Drummuir. More recently Drummuir 21 has worked tirelessly to develop a community woodland adjacent to the line and a network of paths on the local estate. A new bridge was seen by the group as a missing link that would allow visitors using the line to explore the area.

Drummuir 21 - A Creative Low-cost Solution

Financing the project

The proposed 2m by 15m bridge would cost in the region of £10,000. In partnership with the local estate, Drummuir 21 secured 50% of the costs from Forestry Commission Scotland as the bridge lay within the woodland boundary. Finding a 50% match required some creative thought and the group set about identifying cost-effective ways of building and designing a bridge. The Cambridge Officer Training Corps (COTS) agreed to design and build the bridge as a training exercise if they were supplied with accommodation, materials and their activities were indemnified. Coupled with this, the estate agreed to supply some materials, labour and access to machinery. Putting a monetary value on these contributions allowed the group to match the FCS grant.

Building the bridge

The Services have built many bridges around Scotland as training exercises. They design and build, and like a challenge.

The bridge is primarily timber supported by two steel beams. These were lowered onto concrete abutments by a crane borrowed from the railway group. Once these where in place the bridge was then built *in situ*. It is a simple construction but was specifically designed for the location by the army. Initial concerns that the bridge was over-designed have been laid to rest as the bridge has withstood a recent spate of damaging floods much to the relief of the community. Planning permission was required but through the community council Drummuir 21 were able to get a discount and save money - partnership in action!

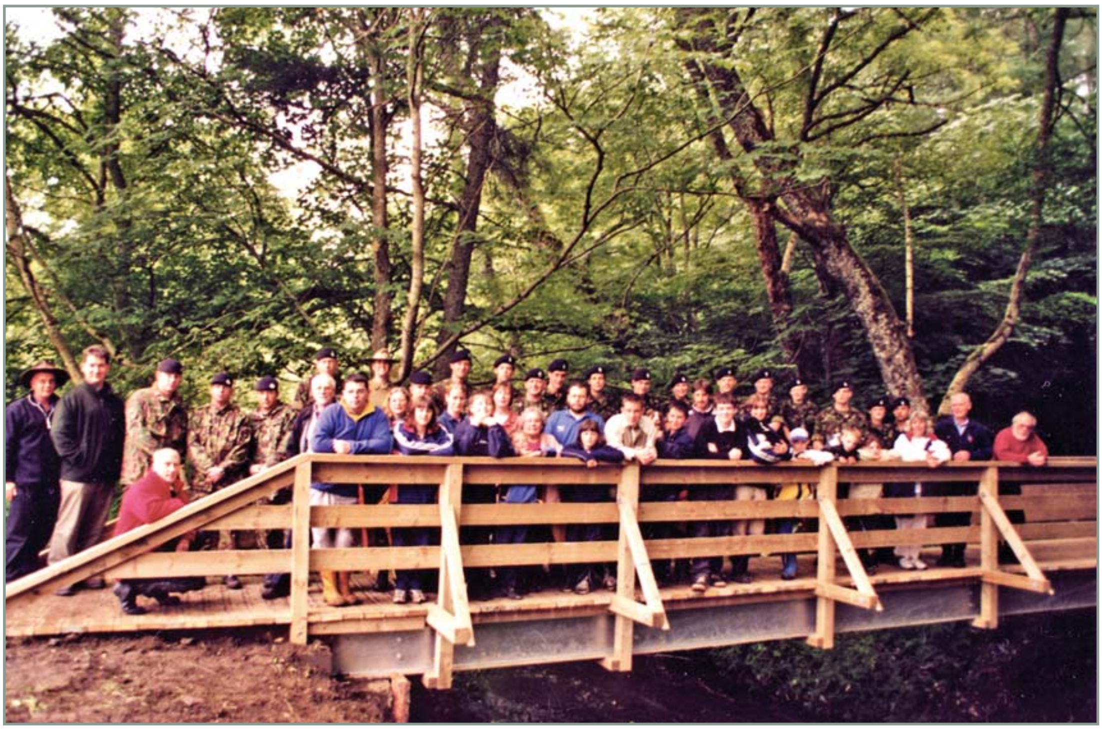
Drummuir 21 - A Creative Low-cost Solution

Pros and cons

Would the group have done it differently? They felt it made a substantial saving using the army, which solved two vexing problems of design and construction. Using the army also meant they could support the local community by sourcing accommodation for them locally, spreading more of the benefit. If they were to choose one aspect of the project that had worried them, it would be the health and safety side and in particular the CDM Regulations and their role as a client. It was also a serious cost for them to indemnify COTS while on site.

The future

The inspection of the bridge is carried out by the estate free of charge. Planned maintenance in the future will be sourced out of the development for the community woodland. The bridge has been well received by the community. It is heavily used and provides a valuable link to the path network. In fact, it has opened up the opportunity for further development including the possible construction of a visitor centre.



Handover time. The community takes possession of its new bridge

For more information contact **www.botriphnie.org.uk**

Glossary

abutments	foundation/end support for a bridge, either stone, concrete or timber
bankseat	simple pad abutments suitable for the top of bankings
batter	to form a slope between two levels
borrow pits	place where fill (as dug) material is sourced for use elsewhere on a site
BS	British Standard
BSI	British Standards Institute
CAT scanner	hand-held device for detecting live electricity cables
chamfer	a narrow flat surface at the corner of a beam or post etc.
checking	minor cracking along the grain of timber/cut or slot in timber section
coefficient of expansion	the fractional change in length, area or volume per unit change in temperature at a given constant pressure
conditions of contract	legally binding conditions between client and contractor that cannot be altered without the consent of both
culvert or Irish bridge	multiple culverts laid side by side with a concrete deck allowing flood water to flow over
dead weight	the intrinsic and permanent self-weight of a structure, exclusive of its load
deflection	the movement of a structure or a part of a structure when it is bearing a load
detritus	debris
distomat	piece of equipment for measuring distance

Glossary

DPC	damp proof course, usually waterproof plastic material used to keep certain bridge components dry to help resist rotting
dynamic load	moving load
EN	Europaischen Normen - European Standards
flange	horizontal component of a steel cross-section
frost out	the action of freeze/thaw which causes structures to degrade
gabion baskets	a rectangular wire mesh basket filled with graded rock which can be used as a revetment or bridge abutment
geogrid	woven or moulded mesh, usually plastic, used to reinforce slopes or provide support for material on soft ground
geotextile	water-permeable woven sheet used to support foundations or fill materials on soft ground or as a filtration membrane for drains
glulam	glue laminated timber
hand auger	hand powered drill for taking soil cores and assessing soil conditions
hanger	usually a simple steel fastening that allow one piece of timber to be suspended from another without the need of timber joints
IDB	Internal Drainage Board
impact factor	factor applied to an imposed load that impacts on a structure. For example, a stationary person will impose a load through their feet onto a bridge deck. The impact factor will assess the extra force from that person running over the deck.
jaegers	ready-mix concrete lorries
lateral shear	horizontal spreading of material due to vertical loading

Glossary

level (engineer's)	adjustable telescope mounted on a tripod with a spirit level to allow precisely horizontal sights to be taken. Measurements can be read off a graduated staff which is moved around a site such that height differences between points can be noted to allow calculation of gradients and spot heights
luffing	to move the jib (of a crane) or raise / lower the boom (of a derrick) in order to shift a load
mechlam	mechanically laminated timber
modulus of elasticity	the force on an elastic body is proportional to the ratio of the body's extension to its original length: the constant of proportionality is called the modulus of elasticity
mortar	a mixture of sand, water and cement or lime that becomes hard like stone and is used in building to join and hold bricks and stones together
piles	foundations (usually concrete, steel or wood) that are driven into the ground mechanically or by hand
podging	agitating concrete to expel air
point load	the load exerted at a discreet point, i.e. the load through a horse's hoof on a bridge deck
pointing	the visible mortar between the bricks or stones in a wall
poker vibrator	a tool (usually powered by compressed air) used to dispel air from concrete prior to setting
precamber	setting a curve into a structural element prior to construction
proprietary	standard or 'off the shelf' manufactured item
revetments (retaining walls)	general term for all types of retaining structures, timber walls, stone walls, gabions or other commercial retaining walls used to stabilise or retain a slope

Glossary

rip-rap	rock armouring
shakes	cracks (sometimes substantial) along the grain in timber developed in the standing tree, at felling or in seasoning
shear legs	a device for lifting heavy weights consisting of 2 or more spars lashed together at the upper ends from which a lifting tackle is suspended
slip zone	the area of a bank liable to collapse due to inherent instability of the bank material
SLT deck	mechanical stress lamination of timber for bridges
soffit	the underside of a part of a building or a structural component, such as an arch, beam or stair
spall	flaking and breaking up of the surface of stone or concrete often due to action of frost
spar	a bracing or supporting strut
standard wire gauge	measurement of wire diameter
static load	a stationary imposed load
superstructure	collectively all parts of a bridge except the abutments
surform	a rasp used to smooth timber
tamping	manually compressing and consolidating material (usually aggregate) by repeated tapping
theodolite	instrument that allows precise measurement of angles between points or 'stations' on a piece of land
TIRFOR	manufacturer of a manual winch
torsional restraint	resists twisting and stiffens the bridge
transoms	supports fixed at right angles between main beams to add stiffness and resist twisting; sometimes they form part of the deck

Glossary

truss	a roof, bridge or other elevated structure supported or strengthened with a network of beams and bars
u-bolted	linked laterally using steel angles bolted to the top and bottom of a tube
wane	the defective edge of a timber board caused by remaining bark or a beveled end
web	vertical component of a steel cross-section
wingwall	attached to an abutment, it contains and supports a splayed ramp onto a bridge

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[Download from www.pathsforall.org.uk]

ESI External Works. Endat Standard Indexes.
[Download from www.endat.com]

Fact sheet 2.3 Writing briefs for Consultancy Work. Paths for All Partnership (2004) [Download from: www.pathsforall.org.uk]

Fact sheet 2.4 Choosing and Managing Consultants. Paths for All Partnership (2004) [Download from: www.pathsforall.org.uk]

Fact sheet 5.3 Health and Safety in Path Construction - an overview. Paths for All Partnership (2002)
[Download from www.pathsforall.org.uk]

Fact sheet 5.4 A Guide to the Construction (Design and Management) Regulations 1994. Paths for All Partnership (2002)
[Download from: www.pathsforall.org.uk]

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Pollution Prevention Guidelines, Working at construction and demolition sites: PPG6. Scottish Environmental Protection Agency [Download from www.sepa.org.uk]

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10.2 Relevant Standards and Codes of Practice

BS 4:2005. Structural steel sections. Specification for hot rolled sections.

BS 729:1995. Quality requirements for welding.

BS 1706:1990. Method for specifying electroplated coatings of zinc and cadmium on iron and steel.

BS 4360:1986 Specification for weldable structural steels.

BS 4848: Part 2: 1975. Specification for hot-rolled structural steel sections.

BS 4978: Specification for visual strength grading of softwood.

BS 5268: Structural use of timber.

BS 5328 - 1:1997 Concrete - Guide to specifying concrete.

BS 5400:1978. Steel, concrete and composite bridges.

BS 5756:1997 Specification for visual strength grading of hardwood.

BS 5950: Structural use of steelwork in building.

BS 7668:2004. Weldable structural steels. Hot finished structural hollow sections in weather resistant steels specification.

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BS 8118 - 2:1991 Structural use of aluminium.

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BS EN 10025:2004. Hot rolled products of non-alloy structural steels various properties for flats and plates.

Relevant Standards and Codes of Practice

BS EN 10056:1999. Specification for structural steel equal and unequal angles.

BS EN 10210:2006. Hot finished structural hollow sections of non-alloy and fine grained steels. Various properties, specifications and requirements.

BS EN 10219:2006. Cold formed welded structural hollow sections of non-alloy and fine grained steels. Various properties, specifications and requirements.

EN 460: Durability of wood and wood-based products.

The following extracts from the Highway Agency publication *Design Manual for Roads and Bridges* are relevant to path bridge design:

BD 29/04 Design criteria for footbridges

BD 37/01 Loads for highway bridges

BD 52/93 The design of highway bridge parapets

10.3 Contacts

British Standards Technical Indexes Limited
Willoughby Road, Bracknell,
Berkshire, RG12 8DW
Tel: 01344 404429
www.bsoline.bsi-global.com

Centre for Ecology and Hydrology
Hill of Brathens, Banchory,
Aberdeenshire, AB31 4BW
Tel: 01330 826300
www.ceh.ac.uk

Endat Standard Indexes Ltd
Ochil House, Springkerse Business
Park, Stirling, FK7 7XE
Tel: 01786 407000
www.endat.com

Forestry Civil Engineering
Greenside, Peebles, EH45 8JA
Tel: 01721 720448
www.forestry.gov.uk

Forestry Commission Scotland
Silvan House, 231 Corstorphine Road,
Edinburgh, EH12 7AT
www.forestry.gov.uk

Health and Safety Executive
Rose Court, 2 Southwark Bridge,
London, SE1 9HS
Infoline: 0845 345 0555
Publications: 01787 881165
www.hse.gov.uk

Paths for All Partnership
Inglewood House, Tullibody Road,
Alloa, FK10 2HU
Tel: 01259 218888
www.pathsforall.org.uk

Scottish Lime Centre Trust
Charlestown Workshops, Rocks Road,
Charlestown, Fife, KY11 3EN
Tel: 01383 872722
www.scotlime.org.uk

Scottish Natural Heritage
Great Glen House, Leachkin Road,
Inverness, IV3 8NW
www.snh.gov.uk

Scottish Timber Trade Association
Office 14, John Player Building,
Stirling Enterprise Park,
Springbank Road, Stirling
Tel: 01786 451623
www.stta.org.uk

SEPA Corporate Office
Erskine Court, Castle Business Park,
Stirling, FK9 4TR
Tel: 01786 457700
Fax: 01786 446885
www.sepa.org.uk

SUSTRANS
16a Randolph Crescent,
Edinburgh, EH3 7TT
Tel: 0131 539 8122
www.sustrans.org.uk

The Concrete Society
Riverside House, 4 Meadows
Business Park, Station Approach,
Blackwater, Camberley, Surrey,
GU17 9AB
Tel: 01276 607140
www.concreteinfo.org.uk

The Fieldfare Trust
67a The Wicker, Sheffield,
South Yorkshire, S3 8HT
www.fieldfare.org.uk

Timber Research and Development Association
Stocking Lane, Hughenden Valley,
High Wycombe, HP14 4ND
Tel: 01494 569600
www.trada.co.uk

WRAP (The Waste and Resources Action Programme)
The Old Academy, 21 Horse Fair,
Banbury, Oxen
Tel: 0808 100 2040
www.wrap.org.uk

Image Locations and Credits

Introduction

Glamis Burn - Strong Bridges

Ekki Bridge on A9 cycle route - PFAP

Shaky Bridge, Comrie - PFAP

River Ayr suspension bridge - East Ayrshire Access Project

Section one

Urquhart Wood, Drumnadrochit - Strong Bridges

Land manager consultation - PFAP

Ben Wyvis information cairn - SNH

Cyclists - PFAP

Sheep - SRPBA

Path construction machinery - Stirling Council

Carrie Footbridge, Tay Forest Park, Rannoch - Strong Bridges

Peckham Rye Common, South London - Strong Bridges

Strathnaver - PFAP

Fish bridge Kidston Mill near Peebles - Jeremy Cunningham

Section two

Dalvreck Ford, Crieff - PFAP

Craigvinnean, Dunkeld - Perth and Kinross Council

Falls of Leny, Callander (photomontage) - Forestry Commission Scotland

Bridge delivery lorry - North Lanarkshire Council

Section three

Green oak bridge, Luss - Loch Lomond and Trossachs National Park

Strathclyde Park - PFAP

Stone arch bridge, Strathclyde Park - PFAP

Brick culvert - Bedfordshire County Council

Image Locations and Credits

River Ayr suspension bridge - East Ayrshire Access Project

Stress laminated timber arch, Achray - FCE

Aerial mast bridge - FCE

Darn Road Bridge, Dunblane - Stirling Council

Section four

Glentrool bridge, Penfield Loch, Dumfries and Galloway - PFAP

Bankseat construction - Perth and Kinross Council

Concrete abutment, Broadwood Loch - North Lanarkshire Council

Timber abutments - Fife Council

Sluggan Bridge, Inverness-shire - PFAP

Drumpellier Country Park - PFAP

Broadwood Loch, Cumbernauld - North Lanarkshire Council

Broadwood Loch, Cumbernauld - PFAP

Deck Boards and wheelchair - Ali Hibbert

Drumpellier Country Park - PFAP

Grooved deck boards - PFAP

Bridge construction in workshop - Perth and Kinross Council

Vertical handrail, Achray - FEC

Curved handrail posts, Broadwood Loch, Cumbernauld - PFAP

Tubular handrail - Bedfordshire County Council

Mounting Block, Tillicoultry - PFAP

Handrail post attachment, Glentrool bridge - PFAP

Glentrool timber bridge in workshop - FCE

Haselbury New Bridge, (artists - Andrew Hutchins and Paul Hately) - River Parret Trail

Handrail post attachment, Strathclyde Loch - PFAP

Tillicoultry Glen - Clackmannanshire Council

Image Locations and Credits

Section five

Throwing a Stone over a Torrent - The Bridge Builders by William Heath Robinson - Reproduced by permission of Pollinger Limited and the proprieter

Bridge construction, River Turrett, Crieff - Perth and Kinross Countryside Trust

Dyfi Millennium Bridge, (Artist - Jon Mills, *Engineer* - Bruce Pucknell) *Photo credit* - Cywaith Cymru. Artworks Wales

Lochwinnoch Calder Bridge - Sustrans

Mini-excavator - Drummuir 21

Bridge winching - FCE

Scaffolding construction platform - FCE

Section eight

8.2 All images - National Trust for Scotland

8.3 All images - FCE

8.4 All images - Stirling Council

8.6 All images - FCE

8.7 Cambridge OTC on Drummuir Bridge - John Lyne

Drummuir old bridge - Priscilla Gordon Duff

Drummuir handover - John Lyne

Short Description of Works

All Permanent and Temporary Works in connection with :-

Construction of a 6 new footbridges, overlay deck of one footbridge, new footpaths and new handrails for access through Dollar Glen.

Form of Tender

To **Forestry Civil Engineering**
Greenside
Peebles
EH45 8JA

Gentlemen,
Having examined the Drawings, Conditions of Contract, Specification, Bills of Quantities and Schedules for the construction of the above mentioned works (and the matters set out in the Appendix and Contract Schedule hereto) we offer to construct and complete the whole of the said works in conformity with the said Drawings, Conditions of Contract, Specification, Bills of Quantities and Schedules for the sum of :-

£ (amount in words) **all excluding VAT**

If our Tender is accepted we will, if required, provide security for the due performance of the contract as stipulated in the Appendix hereto.

We undertake to complete and deliver the whole of the Permanent Works comprised in the Contract within the time stated in the Appendix hereto.

Unless and until a formal Agreement is prepared and executed this Tender together with your written acceptance thereof, shall constitute a binding contract between us.

We certify that this is a bona fide tender, and that the sums have not been disclosed to anyone except as necessary for financial guarantees.

We understand that you are not bound to accept the lowest or any tender you may receive.

We are, Gentlemen

Your faithfully,

Signature

Address

Date

6.13

Section six | Technical Sheets | Contract Documentation

Forestry Civil Engineering

FORESTRY CIVIL ENGINEERING
is part of
FOREST ENTERPRISE
an executive agency of
FORESTRY COMMISSION

Name of Tenderer

Address & Tel

CONSTRUCTION OF FOOTBRIDGES, FENCING AND PATHS AT DOLLAR GLEN

Job No FCE/0202

NATIONAL TRUST FOR SCOTLAND

TENDER DOCUMENTS

Tenders to be returned by 2pm on Friday 22nd February 2002

Anticipated start date of Works : 1st March 2002

Engineer for the Works:	Planning Supervisor	Resident Engineer
Mr G. Freedman	Geoff Freedman	Geoff Freedman
Forestry Civil Engineering		
Greenside		
Peebles		
EH45 8JA		
Tel 01721 720 448		
Fax: 01721 723 041		

Path Bridges - planning design construction and maintenance
Produced by the Paths for All Partnership with support from Scottish Natural Heritage and Forestry Civil Engineering

November 2006

Contract Schedule

(list of documents forming part of the contract)

1 Letters of invitation and acceptance
2 The Contractor's Tender on the Form of Tender(excluding any items introduced by the Contractor)
3 Instructions to tenderers
4 Conditions of Contract
5 Appendix to the Conditions of Contract
6 Modifications, additions and exclusions to the Conditions of Contract.
7 The following letters
from... to...
dated..............
from... to...
dated..............
from... to...
dated..............
8 Appendices to documents. Drawings Nos FCE/0202/01,02,03
Specifications for New Bridge Works and Deck Overlay
Specification for Footpath
Specification for Basic Pollution Control Kit
Bills of Quantities
Draft Method Statement
Draft Health & Safety Plan
Draft Risk Assessment document
Location maps. (showing authorised access routes)

Appendix to The Conditions of Contract

1 Description and of Works - The Contractor will demolish and remove from site the equivalent of 6 footbridges and construct 6 new footbridges and overlay the deck of one existing footbridge. The abutments are generally existing with some reconstruction and new concrete necessary. The Contractor will carry out new path-works where rock is protruding through existing paths. The Contractor will provide all of the labour and materials except for aerial mast sections which will be delivered to site for him to assemble.

- **The Glen is a Site of Special Scientific Interest therefore all demolished materials will be removed from site and no damage to the fabric of the site will be tolerated.**

2 Location and description of Works - The site is located just north of Dollar Village which is on the A91 between Kinross and Stirling. Site OS References NS 963 990. Access is by a minor public road to a car park area and a 300m walk to the first site, Junction bridge. There is also access from the North at the castle along a steep footpath approximately 200m long. The site is very dangerous with steep drops at the work areas. Access for materials may be possible by polypropelene chute from the public road. There will be sufficient storage and working space in this area. Mobile phone communication is liable to be limited for reception.

3	Method of Payment (Clause 7.2)	Measure & value using the priced Bill of Quantities
4	Engineer (Clause 2.1)	Mr G Freedman
5	Resident Engineer (Clause 2.2)	Mr G Freedman
6	Starting Date (Clause 4.1)	1st March 2002.
7	Period for Completion(Clause 4.2)	10 weeks.
8	Liquidated Damages (Clause 4.6)	£200 per week
9	Defects Correction Period (clause 5.0)	6 months
10	Rate of Retention (Clause 7.3)	5% , 2.5% for Defects Correction Period
11	Minimum interim certificate (Clause 7.3)	£5 000.
12	Insurance of the Works (Clause 10.1)	£100,000
13	Minimum amount of third party liability (Clause 10.6)	£5,000,000
14	Planning Supervisor (Clause 13.1(b))	Mr G Freedman
15	Principle Contractor (Clause 13(1)(b))	....
16	Performance Bond - value	£5,000

STANDARD CONDITIONS OF CONTRACT FOR FORESTRY CIVIL ENGINEERING CONTRACTS

Instructions to Tenderers

- The Contract will not include a price fluctuation clause. The rates and prices will remain fixed for the duration of the Contract. If the Tender is altered or qualified in any way it will be disqualified. ·
- The Contractor will return the Form of Tender and the Bills of Quantities only. They will be completed and signed in ink.·
- Before work commences on site the Contractor must provide the Engineer with the following:

  Health & Safety Plan,

  Risk Assessments for all tas

  Proposed programme of work & method statement,

  Assurance that SEPA/EA have been informed,

  A CIS 5 or 6 or equivalent to permit full payment of invoices without deduction of tax,

  A performance bond as required.(see appendix to Cdt of Cont)·
- If any errors occur between the rates and the extensions, the rates will be taken as correct. The Engineer will make the necessary corrections and the Contractor will confirm or withdraw his Tender.·
- The Engineer will inform the losing Tenderers within 7 days of the opening of the tenders. The name, together with a list of the tendered sums, may be issued if the Engineer thinks fit.
- Tenders to be submitted to the Engineer by the time and date marked on the front page. It will be returned in the envelope provided. It may be faxed through a third party and delivered sealed.
- Late tenders will not be considered.
- A site visit can be arranged by contacting the Engineer during the tender period.
- While working on FC land the Contractor will ensure that he is acquainted with the booklet "Forestry Commission Bylaws". A copy is held at the Forestry Enterprise District Office.·
- The Contractor will familiarise himself with the work site and the authorised access. The use of the access routes will be at the Contractor's own risk. The Engineer will not be liable for any damage or injury which may occur while using the access.
- On completion of the works the Contractor will repair any damage to the access routes to the satisfaction of the Engineer.
- The National Trust for Scotland's objectives include encouraging recreational use of their properties while conserving the environment. The Contractor will take special care at all time to ensure these policy objectives are upheld. This will entail making provision for the public and ensuring that the plant and wildlife are not harmed.
- The Contractor will hold a basic pollution control kit (see Specification for Basic Pollution Kit in Appendix) on site. In event of a major incident he will call the SEPA office in Stirling to locate full and adequate facilities to deal with the incident.
- If there are other activities close by or through routes adjacent the site boundaries will be marked on the plans.
- Site huts will be erected in a position agreed with the Engineer. This will be combined with the siting of the storage yard for materials. Toxic chemicals and oils will be kept in double skinned containers or bunded storage so they cannot spill into a watercourse. All stores and lagoons for washing out to be a minimum distance of 25m from the watercourse.
- The Contractor will ensure that other authorised users of Dollar Glen are adequately warned of any dangers created by the contractor. Access will not be severed without notice and agreement.
- The Contractor is not permitted to light fires in the Glen for any reason whatsoever.
- The Contractor will provide his operatives with full harnesses while working at height. Those moving with the aid of ropes are to be adequately trained

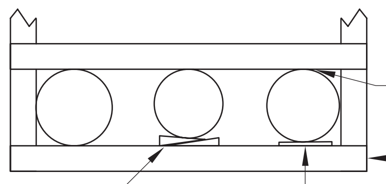
Conditions of Contract

The Conditions of Contract governing this contract shall be the ICE Conditions of Contract for Minor Works 2nd Edition 1995 incorporating the Amendments to the ICE Conditions of Contract Minor Works 2nd Edition, to take into account the Housing Grants, Construction and Regeneration Act 1996 (Part ||) Ref ICE/MW2/HGCR/March 1998, as published by the Institution of Civil Engineers, The Association of Consulting Engineers and The Civil Engineering Contractors Association and incorporating the modifications and additions as noted hereunder:-

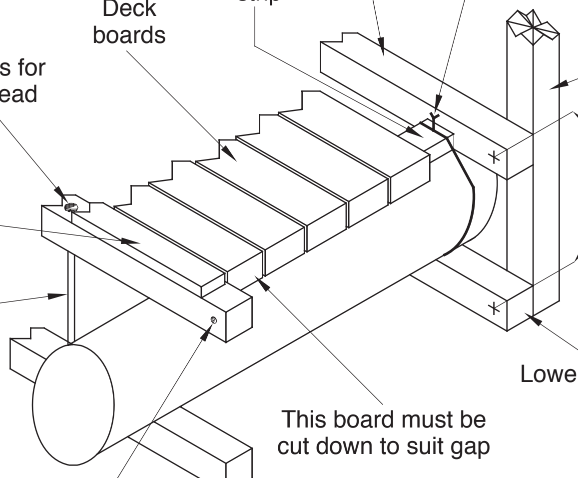
Modifications and additions

- Insert Clause 3.2 (4) The Contractor will ascertain by inspection the existence of any overhead High Voltage Cables which could constitute a hazard to working. If any are found he will notify the Engineer and the Electricity Company and take action as recommended by them before commencement of the works.
- Insert Clause 3.2 (5) The Contractor is responsible for detecting the existence of any underground services or hazards. He will then take all measures required by the Local Authority or Utility to protect the pipe, cable or equipment. The contractor will make good any damage caused as a result of his operations.
- Clause 3.8 Delete this clause. The Contractor takes all responsibility and prices the tender accordingly.
- Insert Clause 3.10 The Contractor will have a sighting level, staff and tape on site for the use of the Engineer.
- Clause 4.4 Delete sub paragraph 'c' relating to clause 3.8
- Insert Clause 7.10 The Contract will be fixed price and no variation will be allowed except in respect of a quantity in the Bill of Quantities provided it has been agreed by the Engineer.
- Clause 9.1 Renumber this clause to read 9.1 (a)
- Insert Clause 9.1 (b) **Health Safety & Welfare**
- The Contractor will notify the Health & Safety Executive (HSE) unless the project can be completed in less than 30 days with less than 5 men.
- The Contractor will always notify the HSE if demolition works are involved
- The Contractor will comply with the following Acts and Regulations
  Health and Safety at Work Act 1974
  Management of Health and Safety at Work Regs. 1999
  Construction (Design and Management) Regs. 1994
  Construction [Health Safety and Welfare] Regulations 1996
- The Contractor will take specific precautions to protect the Public in the same way as employees. Specific actions will include fencing off dangers and notifying of excavations etc. These precautions will be especially relevant if there are workings on roads or if there is likely to be large numbers of public nearby.
- The Contractor's attention is drawn in particular to the following relevant regulations:
  The Lifting Operations and Lifting Equipment Regs. 1998
  The Construction (Head Protection) Regulations 1989
- The Contractor's operators will show a CTA certificate on demand.
- The Contractor accepts the minimum standards relevant to the work as defined and promulgated by Construction Industry Training Board Publication PSN 01.
- Insert Clause 9.4 The Contractor will comply with the requirements of 'The Forests and Water Guidelines' (Forestry Commission 2000 copy at FDO), SEPA/EA guidance for Civil Engineering Contracts and UKWAS certification standards. This will not be to the exclusion of other requirements. Particular attention will be given to prevent silting, erosion or pollution of rivers, streams, waterways, watercourses, water supplies, groundwater, lakes and the likes or cause injury or death to animal, fish or plant life.
- Insert Clause 9.5 The Contractor shall safeguard all water supplies and indemnify the employer against all losses and claims whatsoever in respect of the Contractor's failure so to do.

Log Bridge



Detail showing method of packing out beams and transoms



Log bridge 3D

Notes:-

1. End handrail posts to be screwed to both beams and end faces of bankseats with M20 x 200 coach bolt into suitable predrilled holes.
2. Lay self adhesive textured strips or similar non-skid treatment onto each deck board.
3. Telegraph poles to be laid such that top surface is level and outer faces are parallel.
4. Screw deck boards to nailing strips in sections or ‘pallets’. Lay pallets on beams, loosely attach with wire ties and line up. Tighten until pallets firm. Pallets can be removed for maintenance or replacement by simply cutting ties.
5. Recessed holes on transoms to be filled with clear silicon sealant after tightening of bolts.
6. Deck board thickness plus nailing strip must equal top transom depth.

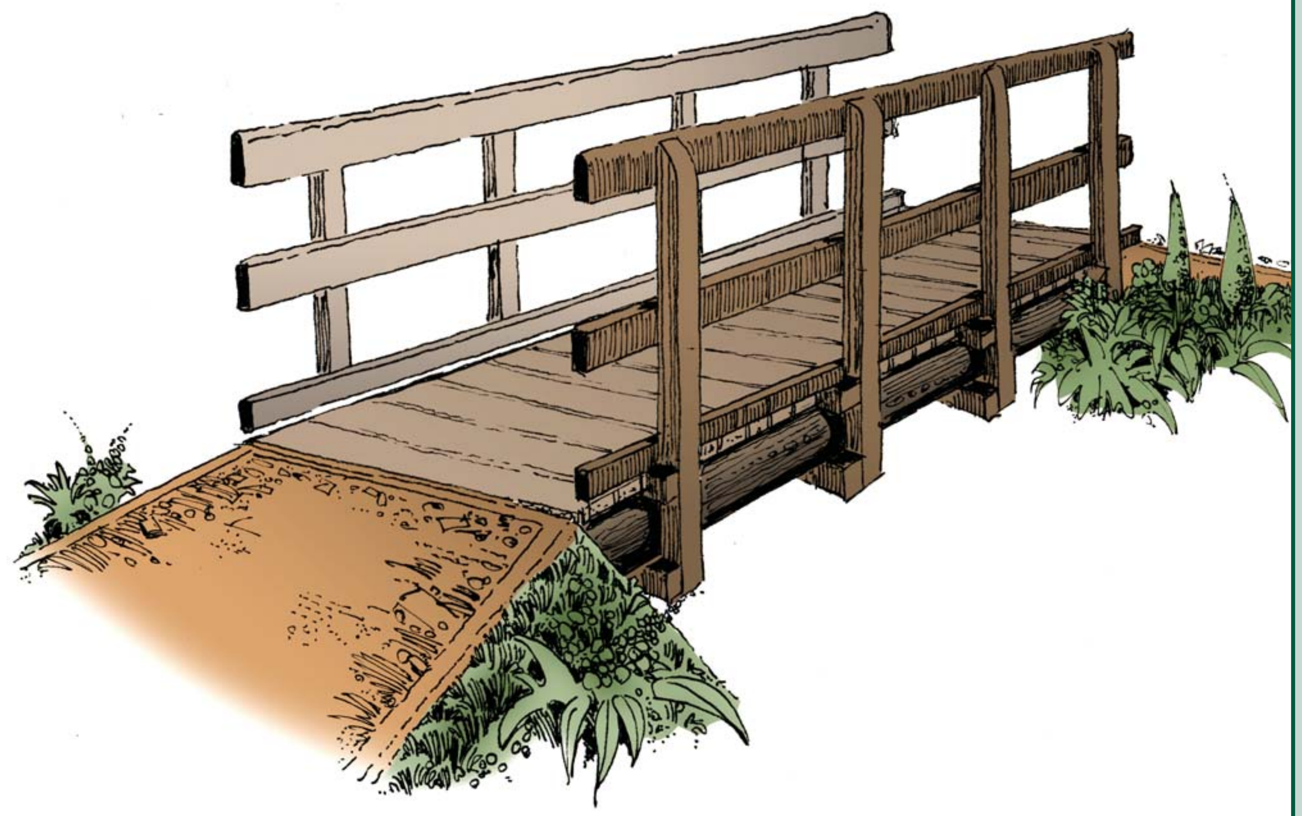
Log Bridge

7.2

The log bridge is designed to present a cheap and short-term option. It will have application where logs are available at sites where importing standard beams might be difficult. It can be built from readily available components that do not require prefabrication.

However, the fact that it is difficult to grade the log beams and, therefore guarantee their structural integrity, means that not only are the loads the bridge can accommodate kept to a minimum, **the bridge cannot be expected to last for more than 5 years**.

Particular care is needed in cutting and bolting the handrail posts to the transoms (See Section 4.4). This is the most likely point of weakness, and accurate construction is imperative.

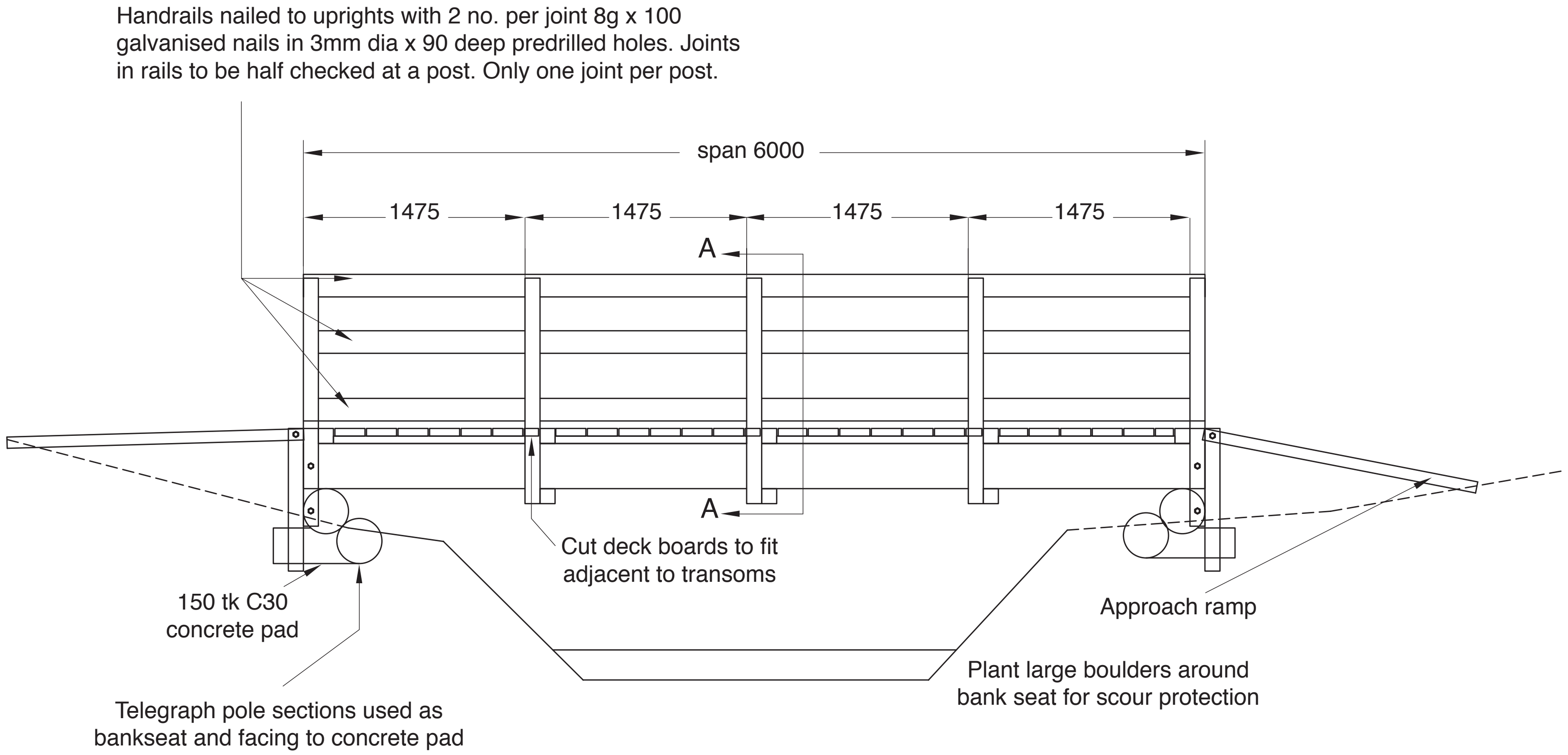


Section seven | Standard Designs | Log Bridge

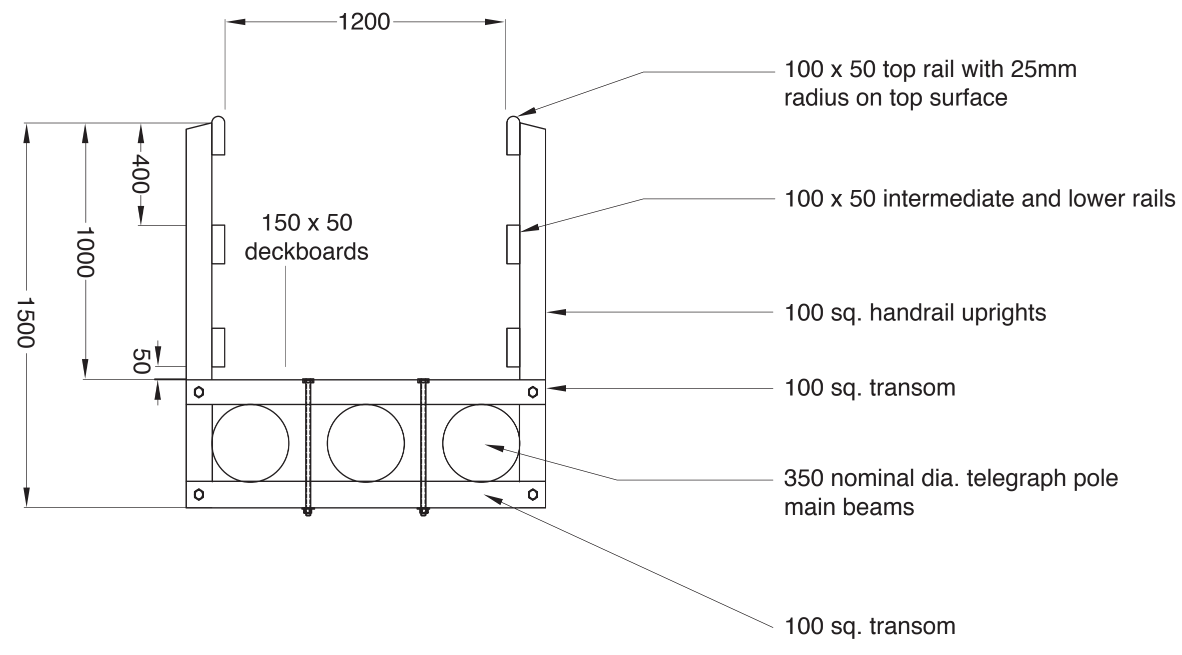
November 2006

Log Bridge

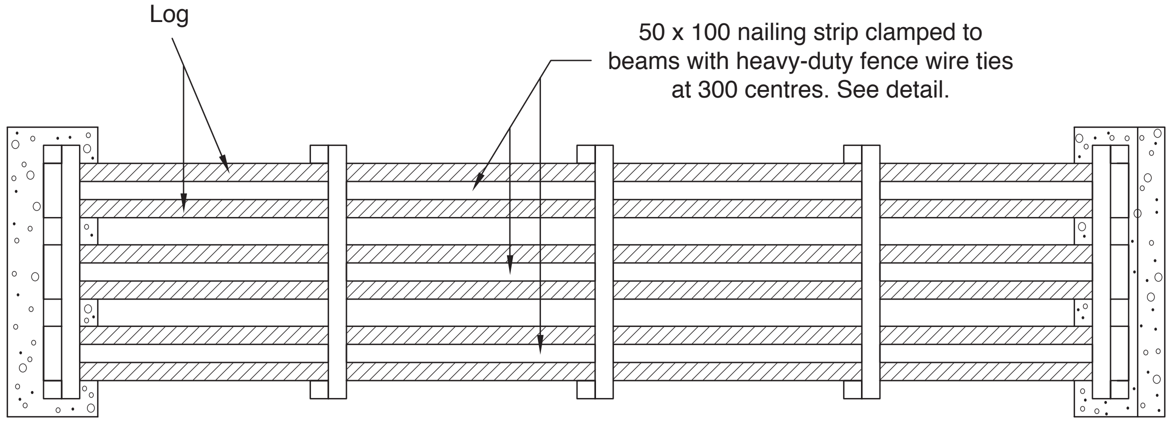
7.2



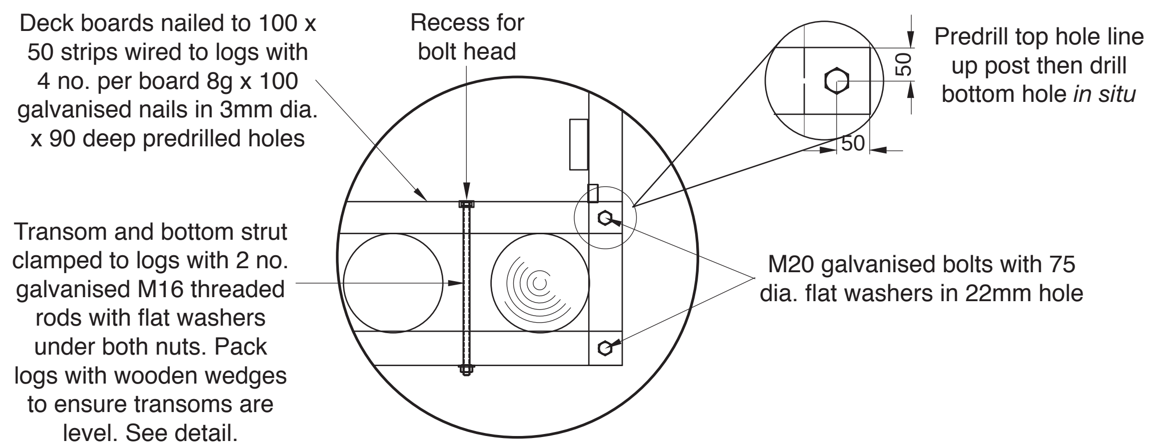
Side elevation



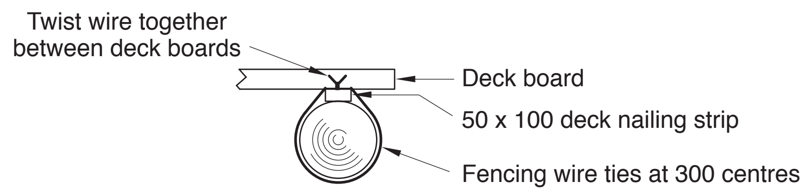
Section AA



Plan view
(deck and handrails not shown)



Handrail and deck fixing detail



Deck/Bearer fixing detail

Example shown is 1.2m Pedestrian Normal NOT TO SCALE

Sawn Timber Bridge

User Category		Span (m)						
		3	4	5	6	7	8	9
Pedestrian Normal usable width 1.0m handrail height 1.0m handrail post section 75mm x 100mm @ 1400 crs handrail detail refer to drawing deck section 50mm x 150mm 2 no. beams @ 0.7m crs	**beam** section d x b (mm)	150 x 75	200 x 100	250 x 150	250 x 150	250 x 150	300 x 225	300 x 225
Pedestrian Normal usable width 1.2m handrail height 1.0m handrail post section 75mm x 100mm @ 1400 crs handrail detail refer to drawing deck section 50mm x 100mm 3 no. beams @ 0.45m crs	**beam** section d x b (mm)	150 x 75	200 x 100	250 x 150	250 x 150	250 x 150	300 x 225	300 x225
Pedestrian Crowd usable width 1.5m handrail height 1.25m handrail post section 100mm x 150mm @ 1500 crs handrail detail refer to drawing deck section 50mm x 100mm 3 no. beams @ 0.7m crs	**beam** section d x b (mm)	200 x 75	250 x 100	250 x 150	300 x 225	300 x 225	300 x 225	350 x 250
Horses usable width 1.8m handrail height 1.6m see handrail details - Glentrool table (vertical infill not advised) deck section 100mm x 150mm 5 no. beams @ 0.45m crs	**beam** section d x b (mm)	200 x 75	250 x 100	250 x 150	250 x 225	300 x 225	300 x 225	350 x 250

Note: Deck board thickness plus nailing strip must equal top transom depth.

Path Bridges - planning design construction and maintenance
Produced by the Paths for All Partnership with support from Scottish Natural Heritage and Forestry Civil Engineering

Sawn Timber Bridge

7.3

This design uses timber throughout and is suitable for a range of spans depending on the availability of timber sections for main beams. A key principle of the design is to avoid drilling or nailing into the main beams in order to minimise timber decay. Please note:

- For wider decks refer to tables for beam numbers and sizes
- Structural timber to be Strength class C24. Visually graded to Forestry Commission specification
- Drill transom/handrail post connecting holes *in situ* to ensure tight fit around beams. Tighten transom clamping bolts to refusal
- Nailing strips to be attached to beams using galvanised fencing wire ties. Deck boards may be screwed to nailing strips prior to transportation to site for ease of installation
- Plane smooth all handrail sections to remove splinters
- Use self-adhesive textured strip or similar non slip coating on deck boards
- Fasteners to be galvanised. Grease all threads prior to installation

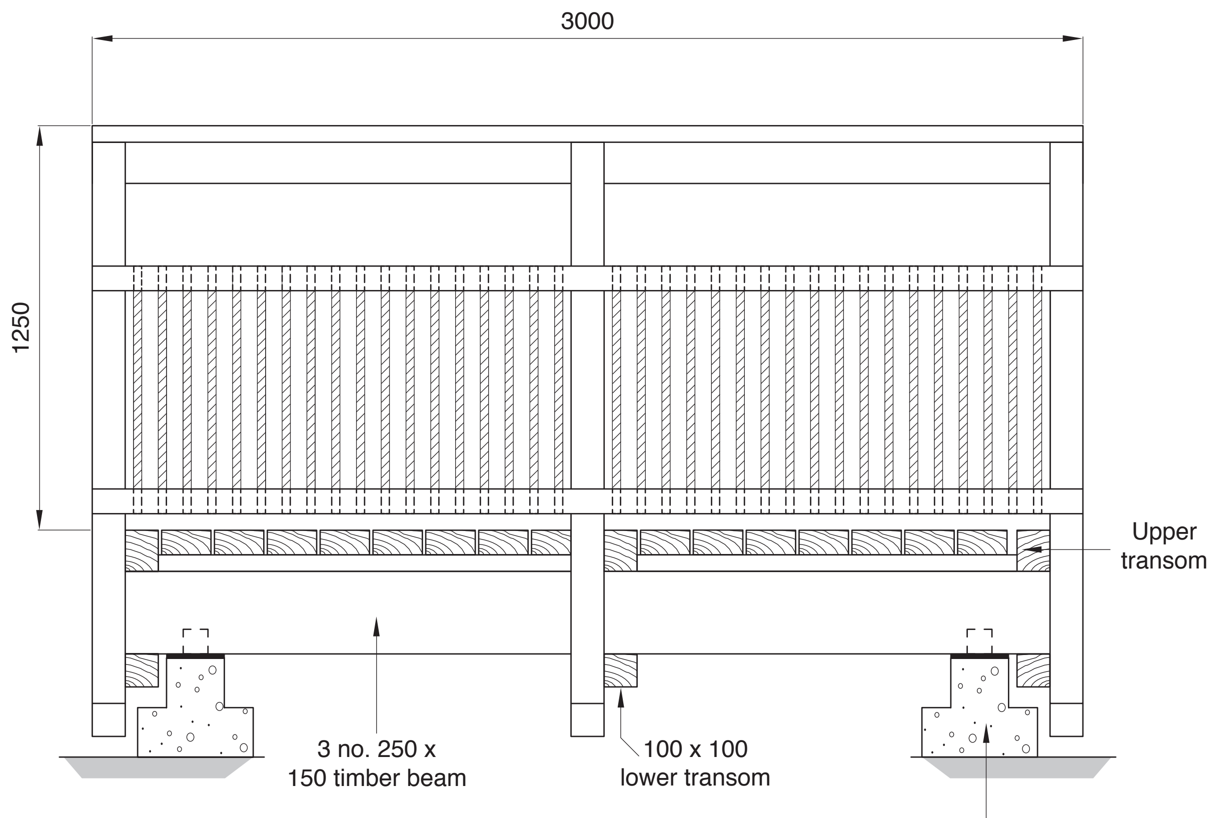
Section seven | Standard Designs | Sawn Timber Bridge

Path Bridges - planning design construction and maintenance
Produced by the Paths for All Partnership with support from Scottish Natural Heritage and Forestry Civil Engineering

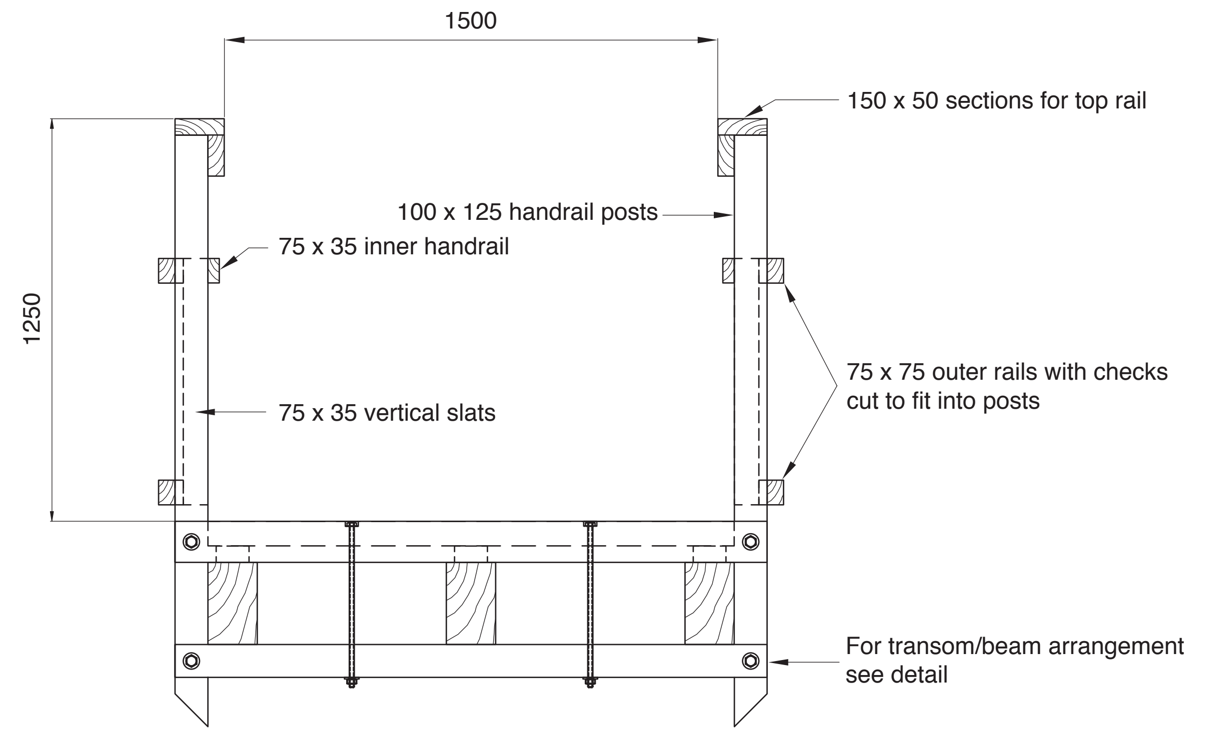
November 2006

Sawn Timber Bridge

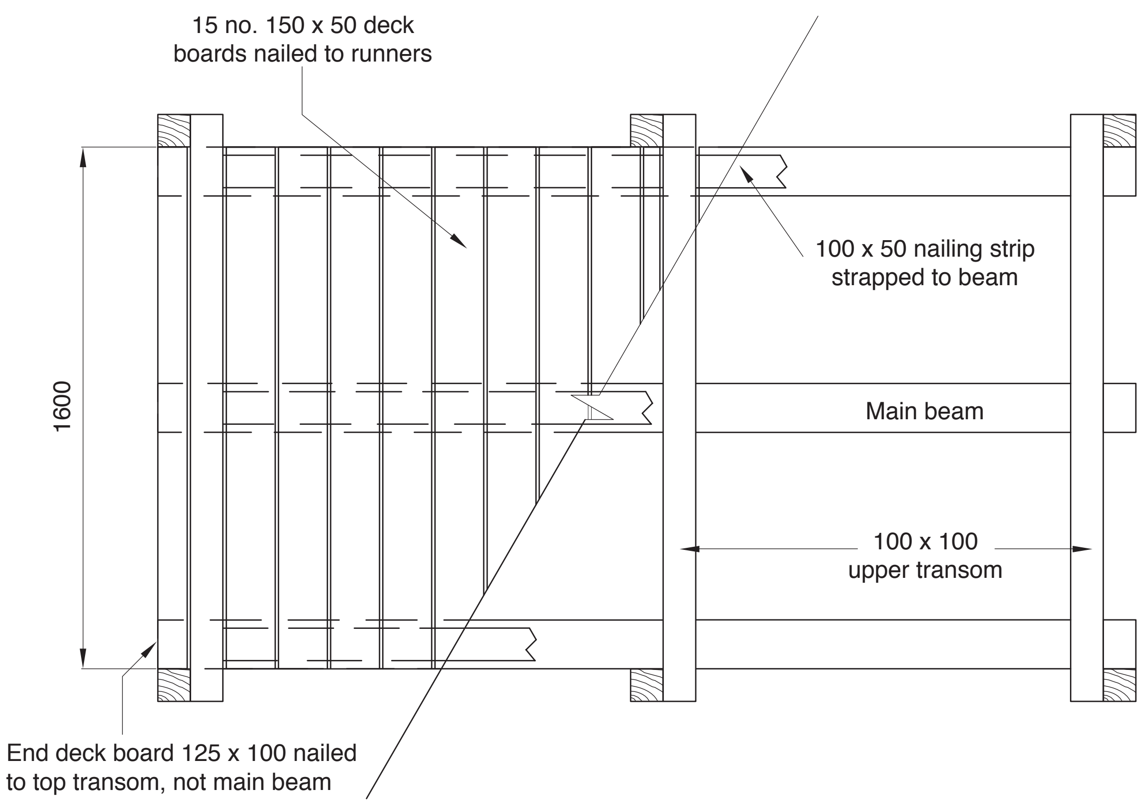
7.3



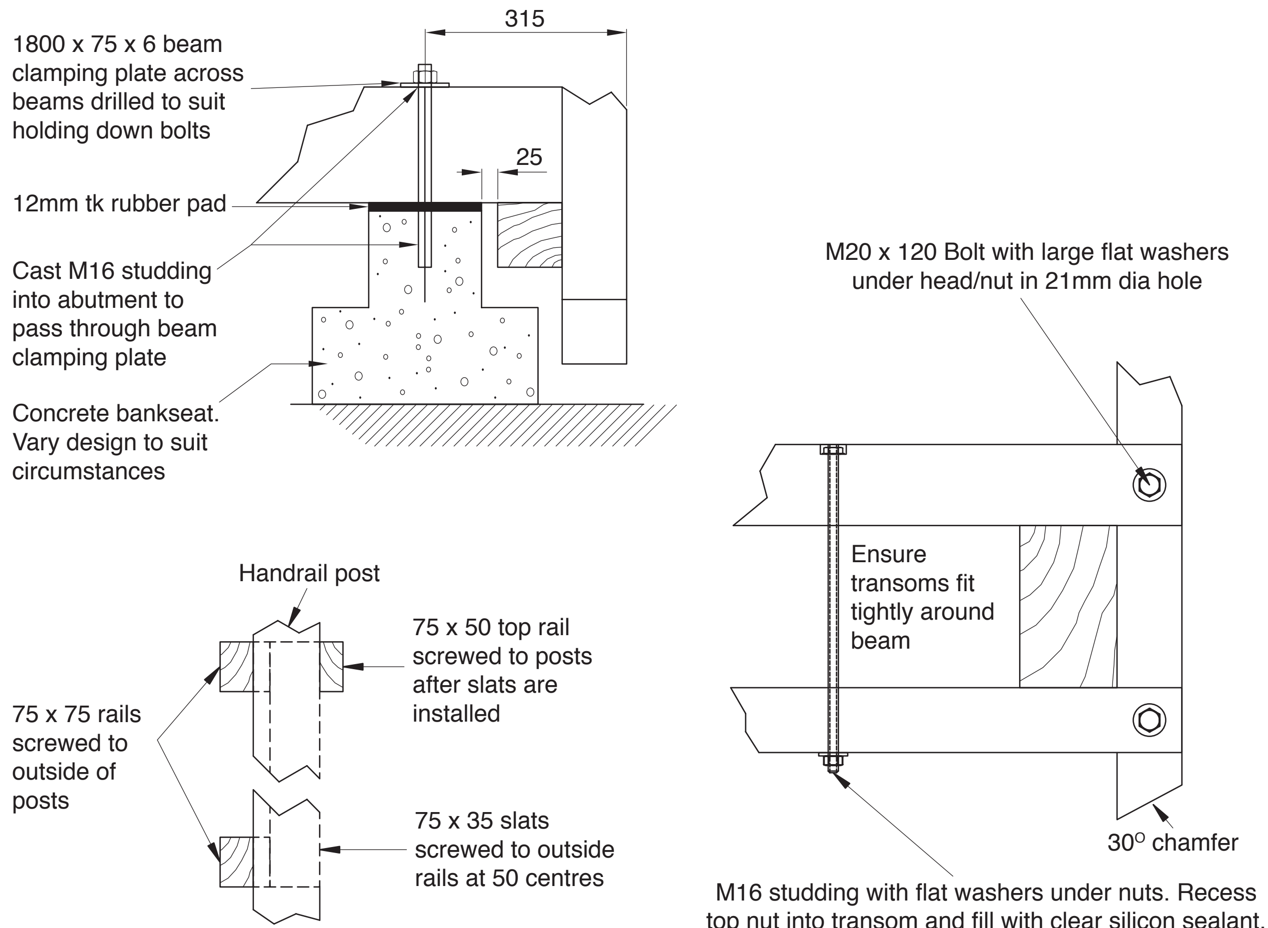
Side elevation



End elevation



Plan



Details

Example shown is 1.5m Pedestrian Crowd NOT TO SCALE

Glentrool Bridge - Steel

1. Typical span shown for pedestrian/cycle use. Determine beam sizes and numbers depending on required span and use. Extra beams may be added to beam/angle frame as required.

2. Beam/angle frame to be fabricated in factory, including base plates. Bolt holes are drilled as required and then whole frame is galvanised. All base plates must sit flat to within 5mm or less post-galvanising. Frame to be delivered on site and installed as one unit.

3. Holding down bolts can be changed to M20 expansion bolts for attaching to existing abutments.

4. If a more secure handrail is required add galvanised weldmesh or use vertical timber strip infill.

5. Construction sequence as follows:-

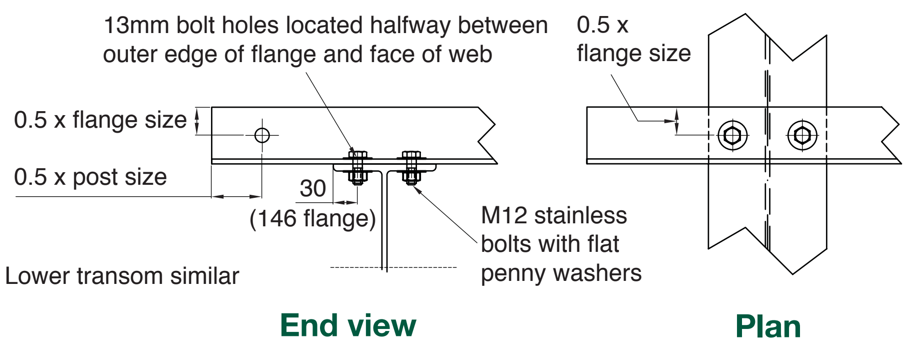
- Construct abutments and approaches
- Lift in and bolt down steel frame
- Bolt on nailing strips (note, if bridge is spanning inaccessible gap such as a deep gorge, the nailing strips should be bolted before frame is lifted in)
- Nail down deck boards
- Bolt on handrail posts
- Screw on handrails

Note handrail/deck members can be progressed together across the bridge if gap is inaccessible. An adequate lifting device will be required. Provide a safe working platform and plan lift carefully.

Frame Construction

The steel frame can be either:

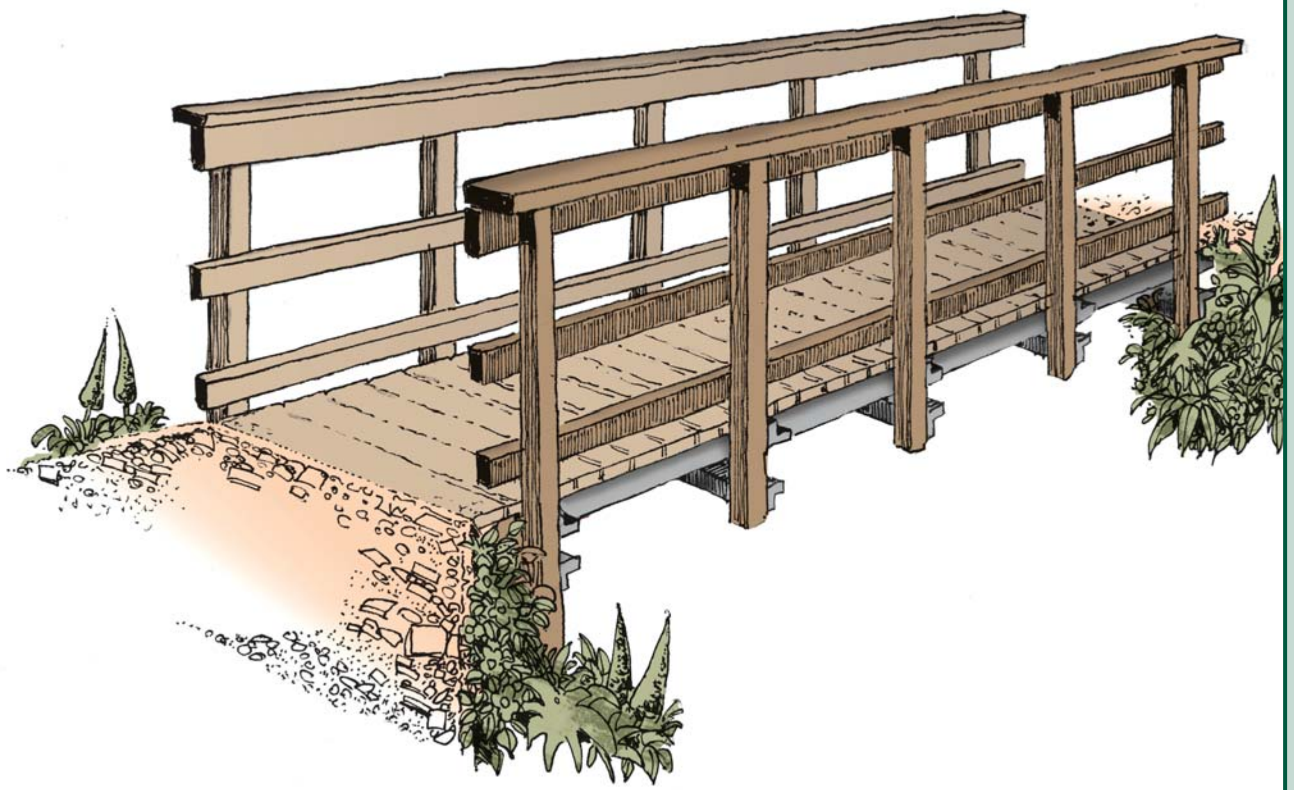
1. Welded together and galvanised (as shown in drawings) and transported to site as one unit.
2. Bolted together on site. In this case the angles and beam flanges must be predrilled and then galvanised. For bridges of 9m or less, use M12 bolts and drill holes centrally.



Transom bolting detail

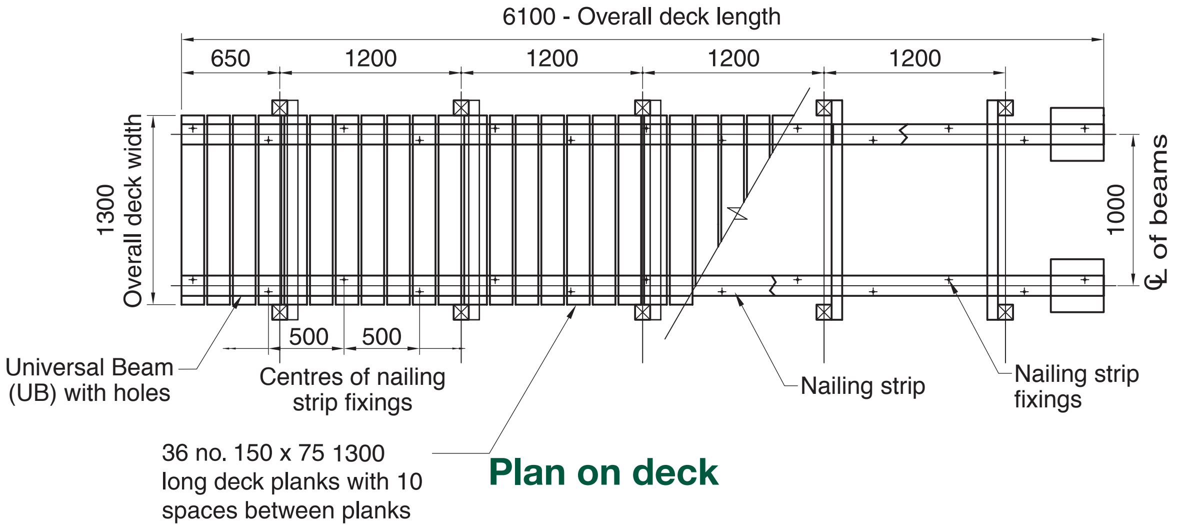
Glentrool Bridge - Steel

This is a simple bridge design developed by Forestry Civil Engineering and has been used in many situations. It is seen as a replacement for the Galloway timber and steel bridges, being simpler to construct and more durable. It utilises steel main beams and angle transoms with a timber deck and handrail. The steel beam/angle frame is fabricated in a factory, galvanised and then delivered to the site as one unit. Good access is therefore essential for this design. This bridge is suitable for all users and a range of spans.

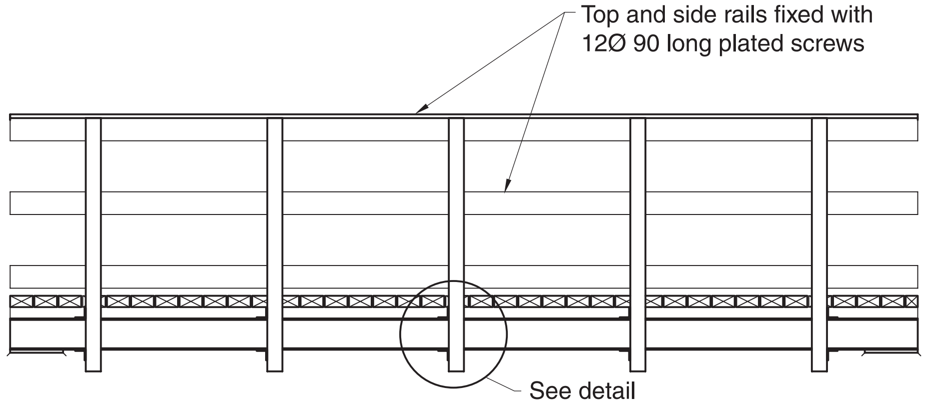


Glentrool Bridge - Steel

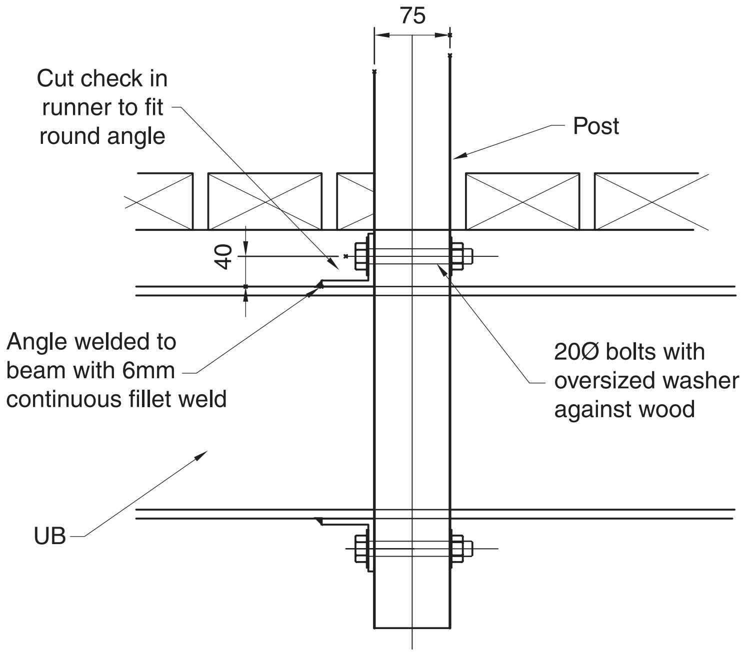
7.4



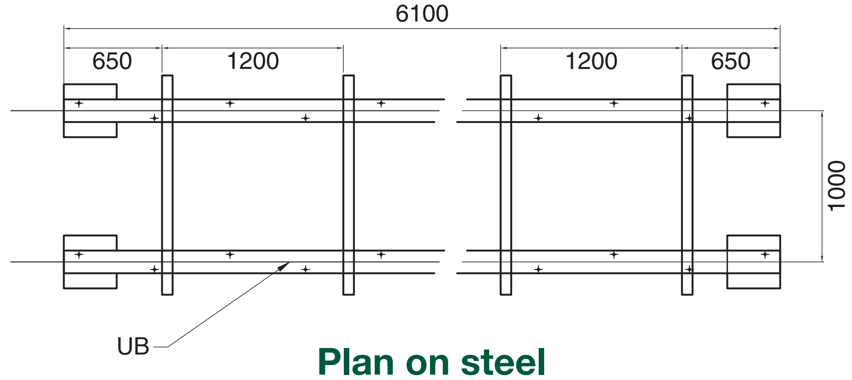
Plan on deck



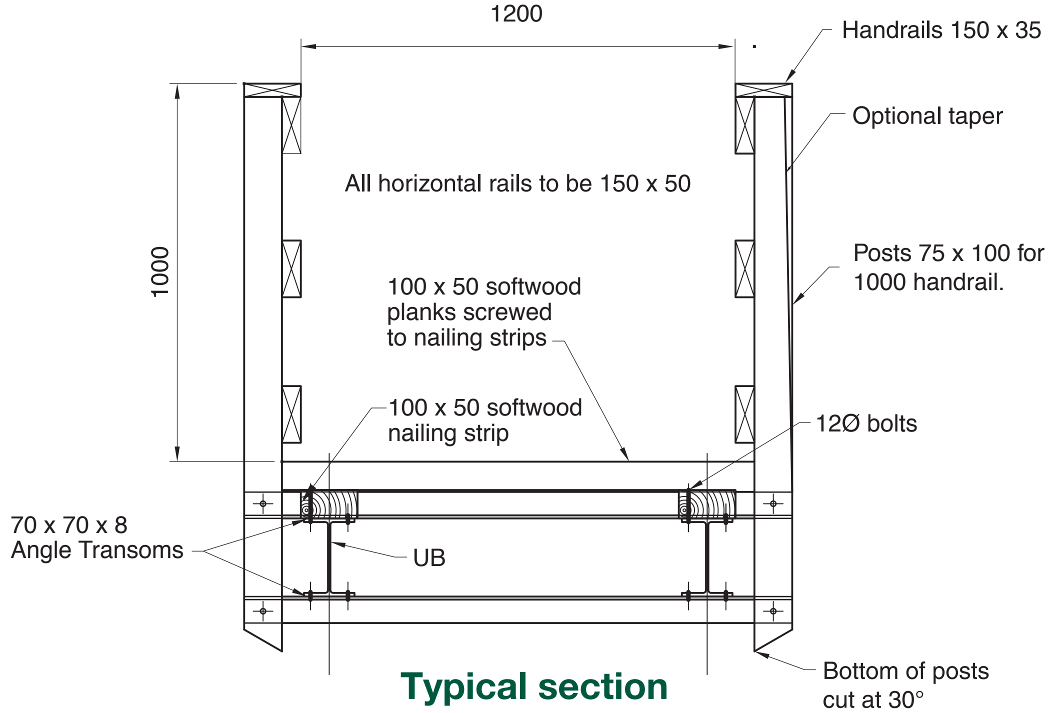
Elevation on bridge



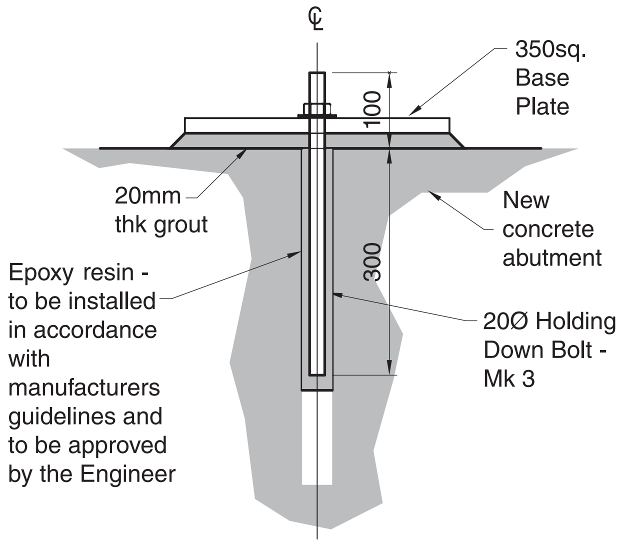
Angle/Beam connection detail



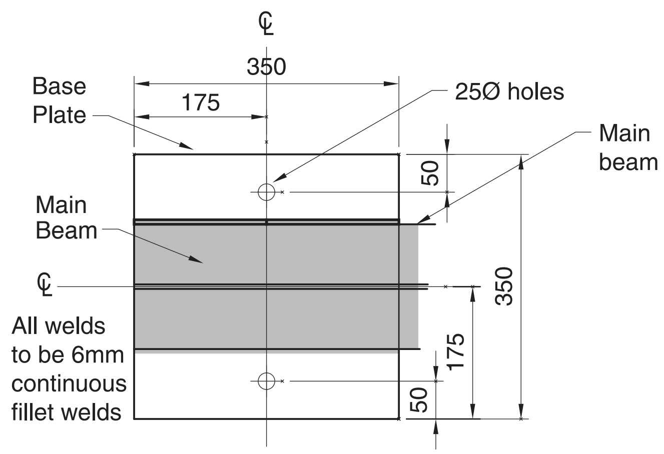
Plan on steel



Typical section



Holding down bolt detail



Base plate detail

Example shown is 1.2m Pedestrian Normal NOT TO SCALE

Glentrool Bridge - Timber

NOTES:
1. All dimensions are in millimetres unless stated otherwise.
2. Structural timber - As schedule and visual graded to Forestry Commission specification by others. All timber to be provided from a sustainable source, i.e. an FSC registered supplier or equal and approved.
3. Timber finishes - sawn except for rails, which are to be sawn and sanded *in situ*.
4. Handrail joints must not be adjacent. Rails cut on site.
5. Back fill to abutments to be free draining granular material. Back fill not to be taken above beam bearing level until beams are fixed.
6. Coach screws to be dipped in light oil before use.
7. Steel beams and end plates must be made from grade S275 steel. All steel to BSEN10025.
8. All beams and end plates to be hot-dip galvanised in accordance with BS729:1986.
9. All bolts, screws and washers to be zinc plated in accordance with BS1706:1990, Classification Code Fe.Zn25.
10. Epoxy resin for holding down bolts to be approved.

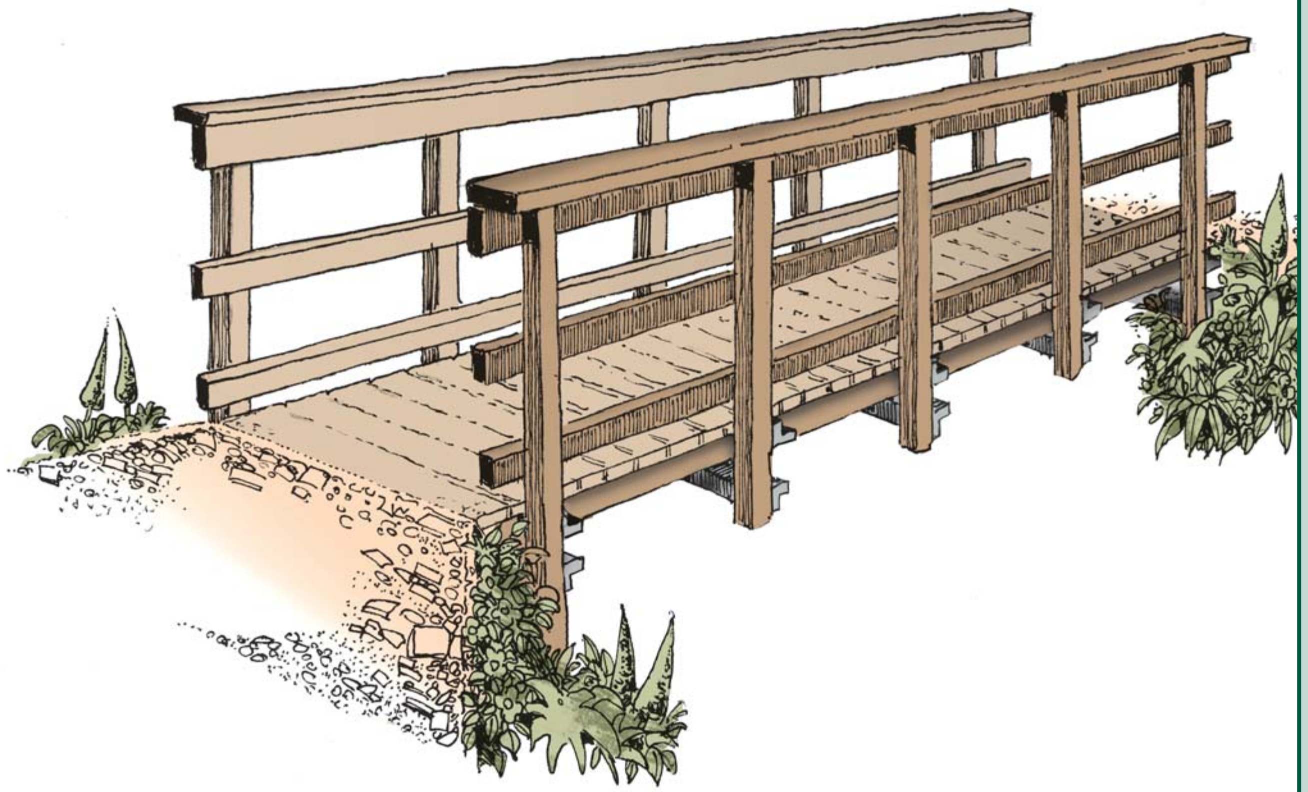
User Category		Span (m)						
		3	4	5	6	7	8	9
Pedestrian Normal usable width 1.0m handrail height 1.0m handrail post section 75mm x 100mm @ 1400 crs handrail section 100mm x 50mm deck section 50mm x 100mm 2 beams @ 0.7m crs	**beam** section d x b (mm)	150 x 75	200 x 100	250 x 150	250 x150	250 x 150	300 x 225	300 x 225

The order of erection is as follows:
1. Lay abutments
2. Position timber beams with steel frame at either end (with welded angle and holding down bolt) on abutments, and fix with holding down bolts.
3. Position internal steel frames and wedge beams with timber wedges if necessary. Fix posts.
4. Lay runners and deck.
5. Attach handrails.

Glentrool Bridge - Timber

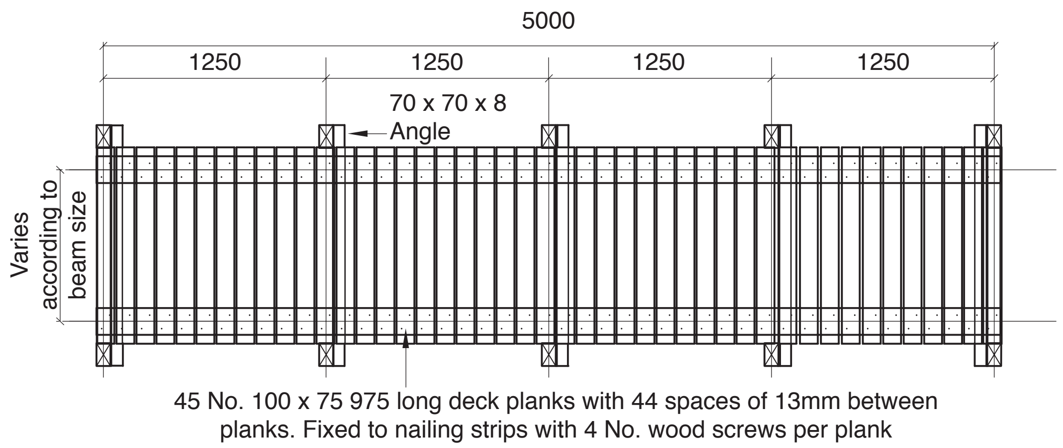
This version of the Glentrool uses timber beams in conjunction with a series of steel frames which both restrain the beams and act as attachments for the handrail posts. Unlike the steel beam version, this bridge can only accommodate pedestrian normal loads as the design restricts the number of beams to two.

The table below suggests a combination of components and beam sizes but these may be altered as needs dictate by referring to the tables in Technical Sheets 6.6, 6.7 and 6.8.

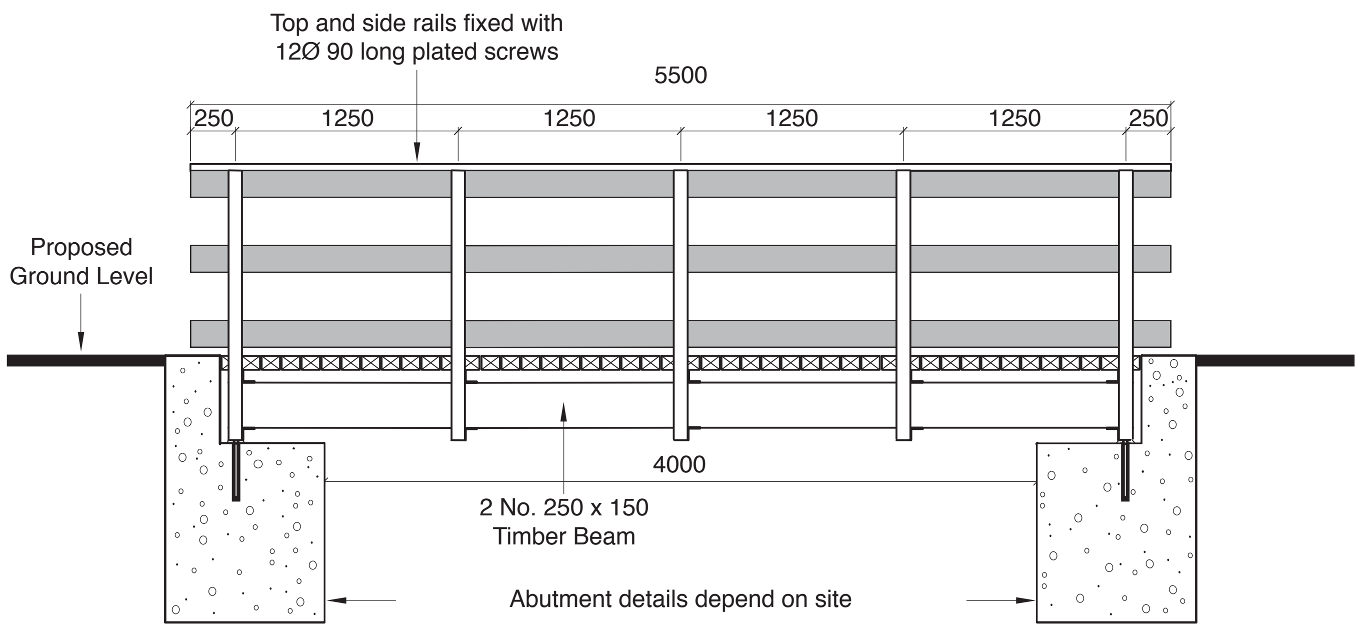


7.5 Glentrool Bridge - Timber

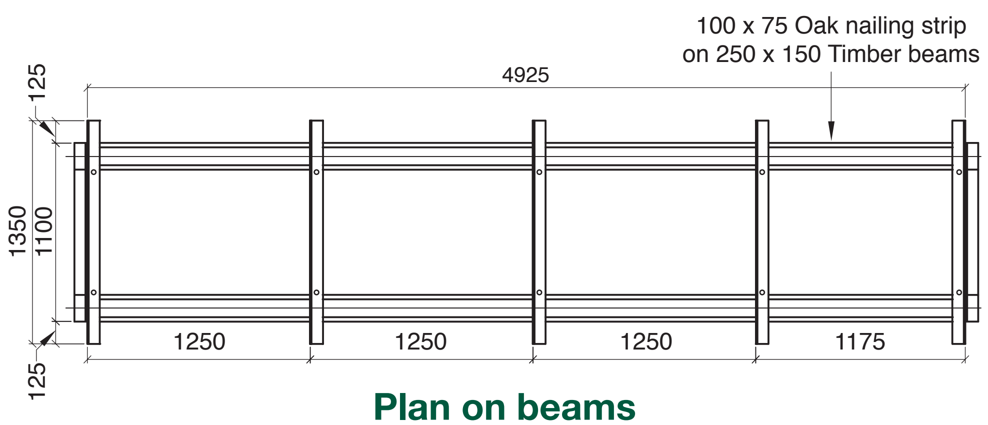
7.5



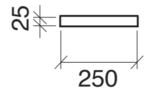
Plan on bridge



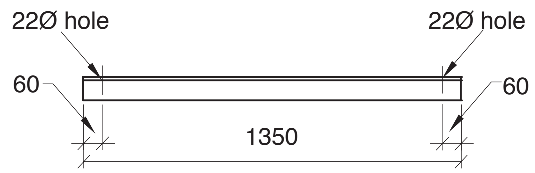
Elevation on bridge



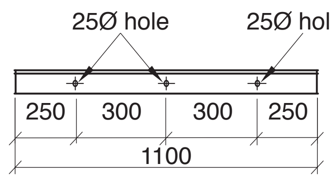
Plan on beams



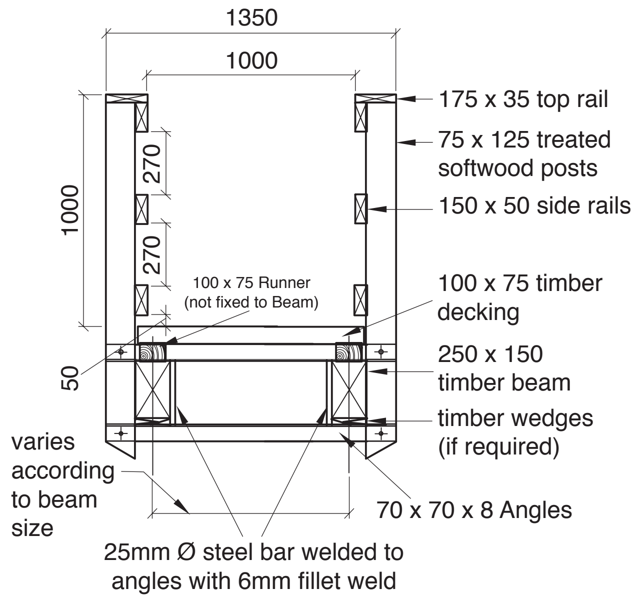
Plan on vertical steel rod



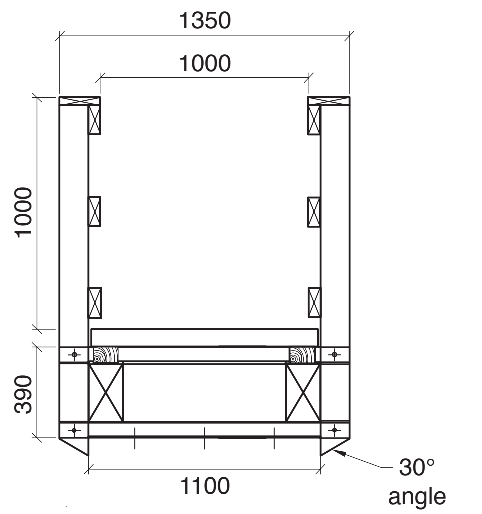
Plan on post angle



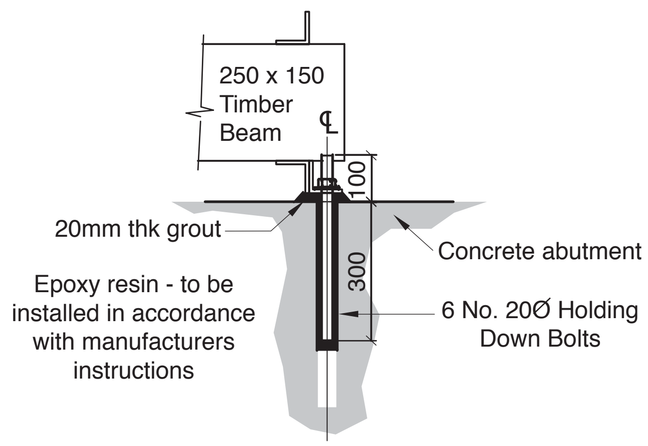
Plan on bearing angle



Section through bridge



Section through bridge at support



Holding down bolt detail

Example shown is 1.0m Pedestrian Normal NOT TO SCALE

FORESTRY CIVIL ENGINEERING
INSPECTION AND MAINTENANCE RECORD

FCE Area………………………………..
Forest District……………………………
Location………………………………….
OS Map Reference……………………….
Structure No & Name……………………..
Structure Type…………………………….
Road Category…………………………….
Owners/Users……………………………..

Inspection Date	Defects Noted	Maintenance and Remedial Work Done	Date Completed

NOTES

1. This could refer to a forest block, river name, local area name etc.
2. OS survey reference: 2 letters, 6 digits.
3. Arch, RC slab, PSC beams and insitu infill, composite steel and concrete, tramrail, steel beam with timber deck, aerial mast, Bailey, large culvert, timber footbridge, suspension, etc..
4. This should refer to the current classification i.e.

   A Arterial Route: **B** Spur Road **:C** Other Road: **D** Footpath
5. This refers to joint ownership or joint maintenance agreements or multiple users. Entry to show FE's percentage liability and names of partners.
6. Dimensions in metres and hectares for short record and millimetres for detailed record below. (Imperial units used where necessary for old sections.)
7. Approximate dimension.
8. Area and description of topography, vegetal cover etc.
9. Average within 50m up and downstream of bridge and an indication of flow characteristics – sluggish, torrent, meandering etc.
10. This will probably be the same as load capacity, but for certain (possibly non-engineering) reasons, it may differ.
11. This should be total cost i.e. construction plus overhead / design cost.
12. Electricity, water supply or other services attached to deck.
13. Construction and survey drawings if any.
14. Metal members to have their protective coating detailed under type e.g. UB painted, tramrail waxed etc.
15. Left and right bank looking downstream. U/S = upstream; D/S = downstream.
16. Where necessary, distinguish between L & R, U/S & D/S walls.
17. Descriptions to accord with Tables 3.1 and 3.2 of BA 16/97 i.e. as for MEXI assessment.
18. Depths required from fixed points on structure to underside of foundation. Foundation subsoil e.g. gravel, clay, bedrock etc.

Sketch and/or photograph

Forestry Commission Inspection Regime

FORESTRY CIVIL ENGINEERING BRIDGE INSPECTION REPORT

FCE Area…………………………………………	Bridge No. & Name…………………………………..
Forest District………………………………………..	Road Identity[2]…………………………………………
Location[1] ……………………………………………	Owners / Users [3]………………………………………
Map Reference………………………………………	Date of Inspection……………………………………..

Condition Report[4] Extent Severity

Overall =

		A	B	C	1	2	3	4	5
1.	Foundations								
2.	Invert/Apron								
3.	Piers								
4.	Abutment Left[5]								
5.	Abutment Right[5]								
6.	Wing Wall Left U/S[5]								
7.	Wing Wall Right U/S[5]								
8.	Wing Wall Left D/S[5]								
9.	Wing Wall Right D/S[5]								
10.	Retaining/Revetment								
11.	Approach Embankments								
12.	Bearings								
13.	Main Beams								
14.	Transverse Beams								
15.	Diaphragms/Bracing								
16.	Concrete Slab								
17.	Kerbs								
18.	Metal Deck Plates								
19.	Deck Timbers								
20.	Arch Barrel								
21.	Arch Ring								
22.	Spandrels								
23.	Bwk/Masonry Pointing								
24.	Tie Rods								
25.	Service Ducts								
26.	Expansion Joints								
27.	Parapets/ Handrails								
28.	Paintwork/Prot. Coating								
29.	Culvert/Pipe Arch								
30.	Scour Below Structure								
31.	Scour of Bed								
32.	Erosion of Banks								
33.									

Details of Maintenance Work Since Last Report

Details of Defects[8]

Weight[9] Restriction	Required ?						Yes/No
	GVW Tonnes	3	7.5	17	38	41	44
	Signs up?						Yes/No

Maintenance Work Recommended[6]	Est. Cost

Inspector[7]……………………………………………..

Date……………………………………………………

ACE's Comments[10]

Maintenance Category[11] **A / B / C**

Next Inspection By[12] ……………………………….

Work Authorised:……………………………..

Date………………………………………………

NOTES

1. This could refer to a forest block, river name, local area name etc..
2. This should refer to the current classification i.e.

   A Arterial Route
   B Spur Road
   C Other Road
   D Footpath
3. This refers to joint ownership or joint maintenance agreements or multiple users. Entry to show FE's percentage liability and names of partners.
4. The 'Condition Report' is the assessment of defects. The following system of scaled descriptions must be used. Number 'Overall' box, and tick other boxes as appropriate.

   Extent

   A Slight, up to about 10% of area/length affected
   B Moderate, 10% to about 50% affected
   C Extensive, over 50%

   Overall & Severity

   1 Very good, no defects

   2 Good, minor defects of non-urgent nature.

   3 Minor defects, requiring attention within 2-3 years.

   4 Poor, defects of an unacceptable nature which should be included for attention within the next annual maintenance programme.

   5 Urgent, severe defects where action is needed within the present financial year. (These should be reported immediately to the client.)
5. Left and right bank when looking down stream. U/S = upstream, and D/S = downstream.
6. The requirement for the work should be obvious from the comments above. An estimated cost should be provided for the ACE.
7. Unless another system is agreed, a copy of the form should be sent to the ACE for authorisation. The following year's report will show details of work carried out.
8. 'Details of Defects': Provides for expansion of the description of the extent and severity beyond ticks in the boxes. Photographs should be considered. The defect number from the 'Condition Report' should always be used.
9. This refers to the current status of the bridge capacity.
10. 'ACE's Comments': ACE to agree or disagree work recommended, and estimated costs. There may be other, non engineering reasons, why repairs are not to be carried out as recommended. If so, the ACE should report here.
11. 'Maintenance Category': Allows for ACE to comment on the urgency / timescale of the proposed work

    A Urgent – < 3 months
    B Medium term – 3/6 months
    C Long term - > 6 months
12. ACE to insert latest date for next inspection (maximum 3 years).