BRE

digest

Timber bridges

Digest 481

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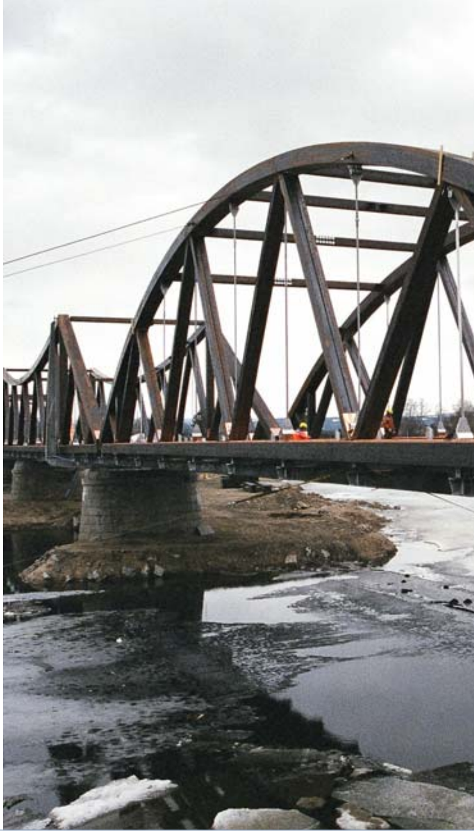
Timber is a highly versatile construction material, strong and lightweight, with tremendous ease of handling and workability. It is both attractive in its appearance and in its environmental credentials. Correctly selected it has good durability, particularly in relation to de-icing salts. Bridges made from wood also tend to exhibit a natural empathy with the landscape. For the bridge designer, using timber offers a multitude of possible bridge forms ranging from simple beams to glue laminated arches, trusses and space frames. Timber can also be used in conjunction with other materials such as natural stone, stainless steel and glass.



Flisa Bridge, Norway. The world's largest timber highway bridge at 182 m overall length (Photo courtesy of TRADA)

Worldwide, timber is experiencing a major revival for constructing vehicular and pedestrian bridges. Recently there have been major programmes of timber bridge building in north America and northern Europe. In the US there are 41,700 road bridges of over 6 m span that are made of timber; while in Finland about 700 timber bridges are owned by the Finnish Road Administration. Bridge clients and designers are beginning to become aware once more that bridges using this traditional material can be designed, fabricated and constructed in interesting new ways, as well as being created in forms sensitive to past traditions. Developments such as new, efficient connection techniques, modern wood based composites and stress laminated decks are further encouraging the use of timber for bridge building.

History and modern examples

Timber is a traditional bridge building material, with examples dating in authenticated records to as long ago as 600 BC. The Romans built large timber structures crossing both the Rhine and the Thames. One of the largest and best documented of the Roman timber bridges was built over the Danube in 104 AD. Known as Trajan's Bridge, it consisted of 20 piers up to 45 m high, each joined by a semi-circular timber arch of about 52 m span. At Putney, a timber bridge consisting of 26 arches once crossed the Thames. This bridge lasted, albeit with periodic repairs, from 1726 until 1870. In the 13th century the Normans built a timber bridge across the River Wye at Chepstow. The oldest timber bridges that still exist in Europe date from the late mediaeval period. Many of these are covered bridges, owing their longevity to this simple structural protective device. Several examples of these ancient bridges are in Lucerne (eg the Kapell and the Spreuer Bridges). During the 18th century, very long timber bridge spans

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were achieved through the use of arched trusses. Typical European examples include a Rhine bridge of overall span 119 m constructed in 1758 by Hans Ulrich Grubenmann.

Timber played a major role as a construction material in the development of north America. Timber trestles were used extensively to span gorges and rivers for the transcontinental railways. The Colossus Bridge over the Schuylkill River at Philadelphia was constructed in 1812 by Lewis Wernwag, and had a remarkable free span of 340 feet (102 m). The laminated arch elements each comprised six 6 x 14 inch (150 x 350 mm) heart-sawn baulks of softwood linked together with iron bands and threaded rods. Another impressive timber bridge was constructed in 1936 at Sioux Narrows in Kenora, Ontario, where large, incised and creosote preservative treated Douglas fir members were arranged in a box-Howe truss pattern. At 64 m main span, this was for many years the world's longest single-span highway traffic bridge (Figure 1), although in 2002 it was downgraded to single lane use.

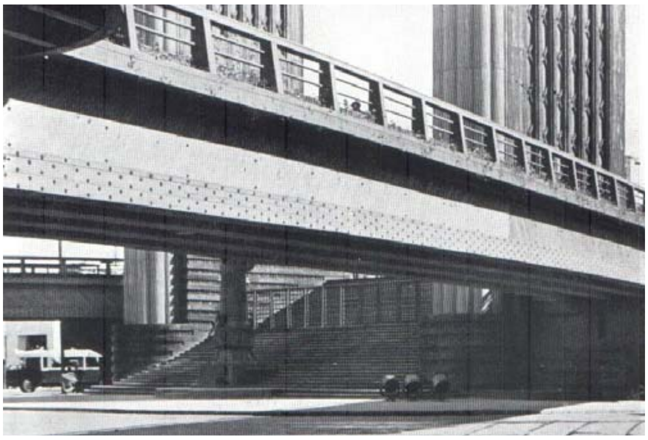
Figure 1 Sioux Narrows Bridge, Ontario, Canada built in 1936 (Photo courtesy of Ben J Haight)

In Britain, Isambard Kingdom Brunel made extensive use of timber for many railway viaducts which were built across the valleys of south west England and south Wales. Brunel built 43 viaducts in Cornwall alone which spanned a total of 8 km. The last of these types of bridge were only dismantled in 1930s as the lines were upgraded for heavier traffic. At Barmouth estuary in north Wales, a timber railway viaduct designed and constructed according to similar principles remains in use today, with pitch pine piles having been replaced by extremely durable greenheart timber. Two impressive mechanically laminated timber bridges designed by Solotareff were displayed at the 1937 Paris Exhibition (Figures 2 and 3).

Fischer (1995) in *Timber Engineering STEP 2* illustrates several modern examples of timber bridges. These include a foot and cycle bridge over the River Neckar, Remseck, Germany (Figure 4), consisting of an innovative triangular space frame of glued laminated timber spanning 80 m; and at Wennerbrücke over the river Mur, a two lane highway bridge consisting of four parabolic glue laminated timber arches, each 360 x 1200 mm in section, with clear spans of 45 m.

The Nordic Timber Bridge Programme (NTC, 1999), involving Denmark, Finland, Norway and Sweden, has resulted in the erection of several hundred timber bridges during the last decade, many of which are vehicle carrying. These include a five-span, glulam bowstring truss bridge, with an overall length of 180 m, with a stress laminated deck; and a three-span, glue laminated, king post truss bridge with each truss spanning 42 m at Vihantasalmi, Finland (Figures 5 and 6). A variety of other forms of bridge were also constructed including glulam arches with suspended decks, truss beams, arched trusses, stressed timber box beams, and cable stayed timber decks.

Although timber bridges in the UK tend to be short span, there are nevertheless a few noteworthy examples (Figures 7, 8 and 9), including an innovative stress laminated arch bridge with a 15 m span at Northwich (Figure 10).



Figures 2 (left) and 3 Wooden bridges displayed at the 1938 Paris Exhibition

Figure 4 Bridge across the River Neckar, Remseck, Germany (Photo courtesy of the Nordic Timber Council)

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Figures 5 and 6 Vihantasalmi Bridge, Finland. Glue laminated timber trusses, each spanning 42 m (Photos courtesy of the Nordic Timber Council)

Figure 7 Black Dog Halt Bridge, Wiltshire

Figure 8 Timber bridge over the River Thames at the Trout Inn, Oxford

Figure 9 Oak bridge at Ealing, west London

Figure 10 Timber arch bridge near Northwich, Cheshire

Basic forms of timber bridge

Beams, including bowed types; no arch action

Beam bridges range from a single, simply supported span to multiple spans and cantilever arrangements. Where practicable, intermediate support can be provided by struts. Pre-camber and slightly bowed forms (without expressly designed arch action) are quite common in laminated construction. Span ranges for beam bridges may be from as little as 3 m for a very small solid timber footbridge, to about 24 m in bowed laminated construction. Bowed beams are used to provide sufficient clearance for traffic passing under the bridge.

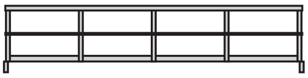


Figure 11 Simple beam bridge

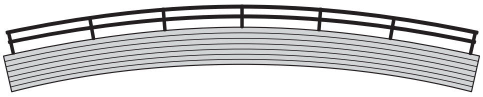


Figure 12 Bowed beam bridge

Arches

Site, terrain and clearance considerations may lead to the choice of an arched form, which, architecturally, is very striking. Much larger spans are possible with true arches than with beams, in the order of 12 to 70 m being feasible. Various deck arrangements and positioning levels can be provided including suspending the deck via cables.

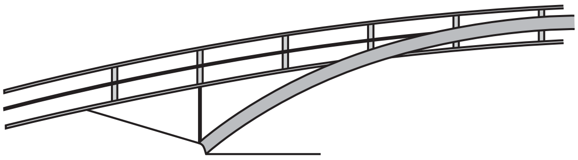


Figure 13 Arched bridge

Girder beams and trusses

Trussed girders provide greater load carrying capacity and stiffness than simple beams, together with efficient use of materials. Various trussing arrangements are possible, with common types being Howe, king and bowstring. Girders are often formed from several lines of trusses. These require to be cross-linked with bracing, and the design may involve other lateral members such as transoms. Deck levels may also be varied with the trusses forming parapets. Camber and light curvature are often applied. Individual spans for bridges formed from girders of this type are likely to range from about 9 to 45 m.

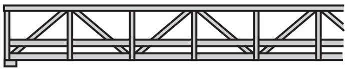


Figure 15 Trussed girder bridge

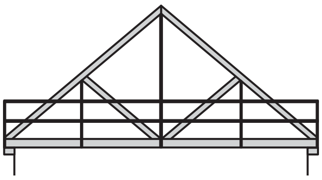


Figure 16 King truss bridge

Lift and swing bridges

There are several moveable bridge forms in timber. These include bascule bridges (which can be lifted by tilting) and swing bridges. Either traditional or contemporary architectural styles are possible. Spans for this type of bridge tend to be fairly modest, with those in excess of about 24 m being uncommon.

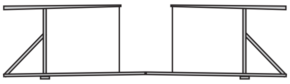


Figure 17 Bascule bridge

Cable stayed and suspension types

The provision of intermediate supports allows very long spans to be achieved for timber deck and beam bridges. Steel cables can be strung from single or twin towers, parallel masts or A-frames.

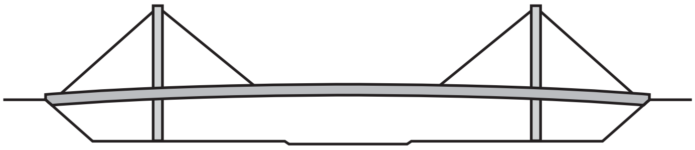


Figure 14 Cable stayed bridge

Materials

Sawn timber

British Standard BS 5268-2 lists the strength class values for the three temperate hardwood (TH) grades of oak plus twelve tropical hardwoods. Typical examples of the latter group are iroko (strength class D40); keruing (D50) ekki (D60) and greenheart (D70). Information on the availability of certified tropical hardwoods can be obtained from the Forest Stewardship Council (FSC). Specifiers and users of timber also need to be aware of the Convention on Internal Trade in Endangered Species of Wild Fauna and Flora (CITES) and can obtain information on sustainable and legal sources of timber from organisations such as Greenpeace (see 'Websites' on page 8). British softwoods and hardwoods can offer a viable alternative to imported material for bridge building. Softwoods listed in BS 5268-2 include Scots pine which has good preservative retention, and larch which has a good degree of natural durability. British grown Douglas fir is available in comparatively large sections (up to 500 mm square and 12 m long), and may also be preservative treated.

Timber in round and pole forms

Using round timber in construction facilitates a variety of interesting forms and connection techniques, while retaining the natural strength of the tree form itself. Poles are also used as the main beams for small or medium span footbridges and occasionally for small masts. There are, however, no formal grading rules for roundwood timber given in either BS 5268-2 or DD ENV 1995 (Eurocode 5: *Design of timber structures*), although grading rules for transmission poles exist.

Glued laminated timber (glulam)

Glulam bridge elements are manufactured to BS EN 386, and other supporting standards. Strength classes for glulam are contained in BS EN 1194. Both softwood and hardwood laminations are used for bridges. Glulam bridge beams are possibly more common in iroko than in any of the softwoods. This timber has found favour for its combination of durability, the ability to be bent and glued, and its good joinery properties. Where laminated softwoods are specified, European redwood rather than whitewood is preferred for external structures. There is virtually no limit to the section size possible, and beams greater than 1.5 m depth are quite common.

Other structural timber composites (STCs)

The major advantages of STCs are that large dimensions are available, with higher characteristic strength values than those of the raw material itself as a consequence of defect dispersal within the manufacturing process. These products are manufactured at low timber moisture content; their dimensions are accurate; and, when installed, moisture related movements (eg shrinkage, twisting and warping) are virtually eliminated. Types of STC include laminated veneer lumber (LVL), parallel strand lumber (PSL) and laminated strand lumber (LSL).

The design of elements and components using STCs may, in general terms, be undertaken in accordance with the rules given in BS 5268-2, or with those in the European pre-Standard, Eurocode 5 (DD ENV 1995-1-1).

Mechanically laminated timber (mechlam)

The modern manufacturing process of mechlam was developed in Germany and has been used quite extensively there and in the Netherlands. Numerous examples of bridges containing members of this type are to be found, ranging from simple, short span beam bridges to the more ambitious types such as arches and cable stayed structures.

Timber durability

Timber, when suitably selected and protected, can be remarkably durable and may, in certain conditions, outlast other materials such as metals, brick, stone and concrete. It is resistant to salt water, either from sea spray or de-icing salts, and freeze–thaw action. Preservative treatment is necessary when the natural durability of a timber is insufficient to meet the required service life. The biological natural durability of timber is due to the presence of naturally occurring chemicals within the heartwood, and in some cases the anatomy of the timber species. Even when the detailing is as good as possible for an exacting, fully exposed application of timber such as a bridge, it is advisable to consider using a timber which falls into a natural durability category which is rated moderately durable, unless preservative treated.

Natural durability classifications are given in BS EN 350 for all of the better known construction timbers, both softwoods and hardwoods, including all of those listed in BS 5268-2. Again, specifiers need to be aware of the restrictions for using certain species referred to in the previous section, ‘Materials’. Many of the tropical hardwoods listed in Table 1 below are not currently available with FSC or other certification but the information can be used for purposes of comparison or as a guide for existing bridges.

Table 1 Natural durability classifications listed in BS 5268- 2

Timber (standard name)	Region of origin	Natural durability
Balau	SE Asia	Durable
Ekki (Azobe)	W Africa	Very durable
Greenheart	Guyana	Very durable
Iroko	W Africa	Very durable
Jarrah	Australia	Very durable
Kapur	SE Asia	Very durable
Karri	Australia	Durable
Kempas	SE Asia	Durable
Keruing	SE Asia	Moderately durable
Merbau	SE Asia	Durable
Opepe	W Africa	Very durable
Teak	SE Asia	Very durable
Oak	Europe	Durable
Sweet chestnut	Europe	Durable
Douglas fir*	N America	Moderately durable
	UK	Non-durable
European larch*	Europe	Moderately durable
Scots pine/European redwood*	Europe	Non-durable

* May be preservative treated

Preservative treatment

For timber bridge members the principal chemical preservative treatments usually considered are either copper-chrome-arsenic (CCA) or creosote, both applied under pressure. There are alternatives, included proprietary formulations with equivalent performance. Amendment to the EC Marketing and Use Directive for arsenic will limit CCA to a number of derogated uses, but these include bridges. Creosote has been withdrawn from the DIY market (effective June 2003), but is still available for industrial applications such as utility poles and bridges. Both CCA and creosote treated timber are unsuitable for applications where there is a risk of frequent skin contact (eg handrails and parapets).

In general, most of the hardwoods usually favoured for bridge construction either do not require treatment or are difficult to treat due to poor permeability. Most softwoods are treated since they are at best only moderately durable. Some hardwoods such as beech are perishable, but may be creosote treated and the sapwood of oak can also be preservative treated. BRE Digest 429 (1998) gives guidance on both natural durability and resistance to preservative treatment. Incising of softwood timber prior to treatment facilitates greater penetration of preservative into the wood section. All cutting and drilling of bridge members should preferably be carried out before preservative treatment. Where less well protected material is exposed by site fabrication, these parts need to be liberally reapplied with preservative.

Many newer preservative products have been developed over the last 10 years that provide alternatives to CCA. A number of these have focused on removing the arsenic compound from the preservative formulations, such as CCB systems that use boron. There are also systems available that are both chromium and arsenic free where azole based preservative, usually in combination with copper and boron, have replaced those ingredients.

Selection system for timber bridges

Selecting an appropriate system for timber bridge components should follow the European Standards below:

1. Design the bridge.
2. Assess the hazard class of the timber component (BS EN 335-1). For example, a timber in freshwater contact is Hazard Class 4. Out of ground contact timber is Hazard Class 3 and is a less challenging environment for the timber component.
3. Select wood species and assess natural durability (BS EN 350-1.
4. Determine whether the wood species has a natural durability sufficient for the performance required for the Hazard Class. (BS EN 460 links durability to Hazard Class).
5. If the species has insufficient naturally durability, then select and specify the preservative (BS EN 599-1) and required treatment result (BS EN 351-1 and DD 239).
6. Make sure the timber is certified and comes from a sustainable source.

An alternative specification philosophy is given in BS 5589 and BS 5268-2 with specification based on preservative treatment schedules applied to particular timber species being fit for purpose.

Detailing

Bridges are a particularly exacting application, and ensuring that the timber members have adequate durability is a vital consideration. However, much can also be achieved in terms of increased durability by means of correct detailing for water shedding, circulation of air and avoiding dirt and water traps. Modern water repellent finishes offer a considerable measure of protection to exterior timber structures. The prevention of weathering of the timber surface itself has an important role in this respect.

Connections

One of the principal advantages of timber as a construction material is the ease with which connections can be made. Connection systems range from simple nails and screws for small members such as parapet components, to bolts with spiked tooth plates and split ring connectors for principal members. Arrangements of concealed plates are common for glulam members. Other types of connection involve using steel hangers, framing brackets and splice plates. Splices can also be facilitated by bolted scarf or lap joints. A variety of node connection systems are available for roundwood structures and space frames. Mortice and tenon joints are used on traditionally styled hardwood bridges.

Mechanical fasteners and connectors for bridge structures are either of galvanised steel or stainless steel. Where flitched or spliced joints involve using steel plates, these are usually specified with a thickness of not less than 6 mm, following steel bridge design practice.

Parapets and handrails

The choice of parapet depends on the following:

- the type of footbridge user (eg pedestrians only, or equestrian use);
- the nature of the site and locality (eg whether it is a rural or urban location, and whether it passes over a main road, railway or a stream).

For bridges over trunk roads, motorways and railways, consideration must be given to the avoidance of objects being accidentally kicked, or deliberately dropped, onto the highway, rails or traffic. In applications such as these, authorities will invariably stipulate the required dimensions of enclosure that will normally prevent an open solution in the bridge design. In rural areas, bridge parapets may be more open. However, consideration must be given to preventing climbing of parapets.

Both softwoods and hardwoods are used for handrails. Particular hardwood species are preferred for durability and smoothness to touch. Most, if not all, of the smoothest-to-touch timbers used in joinery are of tropical origin. External weathering tends to aggravate splinter pick-up in open grained species.

Decks

Sawn timber

The commonest form of simple one way spanning, non-diaphragm deck uses spaced sawn planks. These are usually laid transversely, but are sometimes placed longitudinally or in a herringbone pattern. Two-layer plank decks are also possible. Timber can be softwood or hardwood, with certain hardwoods preferred for maximum wear and durability. Softwood decking planks can be specified as either GS (general structural) or SS (special structural) grade to BS 4978. Treated Scots pine/European redwood, Douglas fir and larch are suitable. Hardwood decking planks are usually from a naturally durable species (eg oak, iroko, jarrah or ekki) and are specified as HS (hardwood structural) grade to BS 5756.

Where foot grip is especially important, profiled decking planks provide a good solution. Edge grain planks are more resistant to wear than flat grain planks. Where flat grain planks are used they should be fixed with the surface closest to the heart of the tree uppermost so that in the event of cupping, water is shed rather than collected. Edges should be provided with a radius so that water is encouraged to run off by surface tension. The gaps between simple decking in rural footbridges should not be less than 5 mm, in order that water, dirt and debris can pass through the deck and to allow air to circulate.

Timber–concrete composite (TCC) decks

Timber and concrete composite decks have been used in New Zealand and north America for decades. Early systems comprised nailed laminated decking with unreinforced concrete and a thin asphalt surface. More recently, thicker reinforced concrete layers and shear connectors have been added, giving greater composite action (Figure 17). Some design rules for this form of construction are given in Eurocode 5, DD ENV 1995-1-1, while supplementary rules are contained within prEN 1995-2.

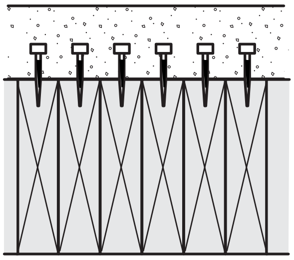


Figure 18 Section through a timber–concrete composite deck

Laminated decks

Laminated decks fall into two main categories:

- longitudinal or transverse nail-laminated (LNL/TNL) decks (Figure 19);
- longitudinal or transverse stress laminated (LSL/TSL) decks (Figure 20).

In longitudinal laminated decks, the timber laminations are orientated parallel to the direction of the traffic, whereas in transverse laminated decks the laminates are orientated at 90° to the direction of the traffic flow.

Nail laminated decks consist of planks of timber laid on edge side by side. The laminations are nailed together to form a slab. Nails are driven through the faces of the planks to fix them together laterally. Stress laminated decks, capable of carrying heavy vehicle traffic, have been a significant development particularly in the USA, Canada and Australia where they are in common usage. Post-tensioning is applied using steel bar to facilitate load transfer across the width of the deck (Figure 21). Edge members are often made of hardwood or steel in order to avoid damage due to high bearing stresses at 90° to the grain at the prestressing points.

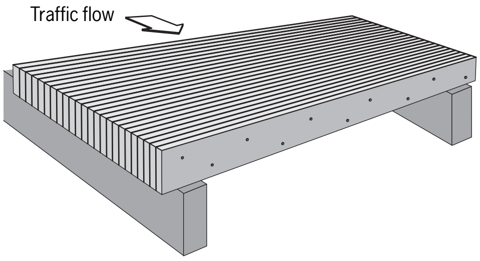


Figure 19 Transverse nail laminated deck

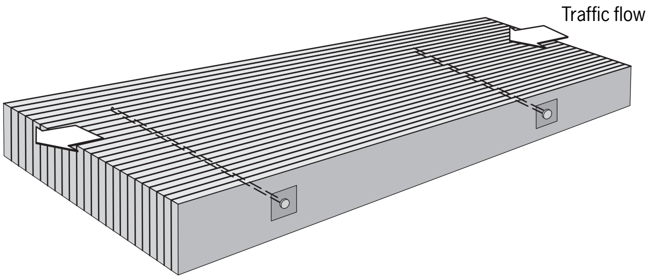


Figure 20 Longitudinal stress laminated deck

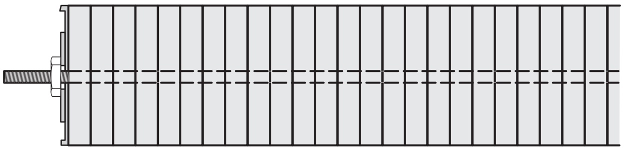


Figure 21 Tension bar detail for stress laminated deck

Deck design

Although still in draft form, Eurocode 5 Part 2 (CEN/TC 250/SC 5: N197) contains the following simplified (conservative) design approach for laminated decks subjected to concentrated loads, demonstrating the relative effectiveness of each type of system. For purposes of design, deck plates may be replaced by one or several beams in the direction of the laminations with effective width b_{ef} calculated as follows:

$$b_{ef} = b_{w\,middle} + a$$

where $b_{w\,middle}$ is shown in Figure 22 and Table 2 (below) and a is taken as detailed in Table 3:

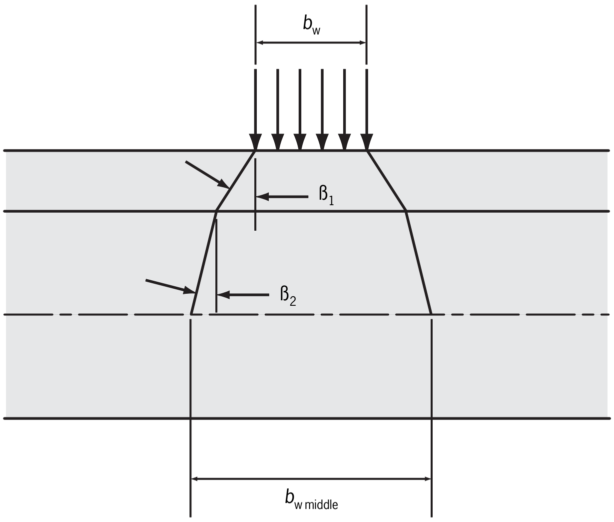


Figure 22 Deck load distribution

Table 2 Distribution angles $ß_1$ and $ß_2$ of concentrated loads in different directions and materials

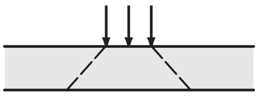
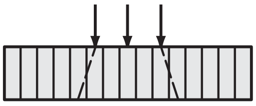
	$ß_1$ or $ß_2$
Pavements, boards and planks	45°
Laminated deck plates, in the direction of the laminations 	45°
Laminated deck plates, in the direction of the laminations 	15°
Plywood and cross-laminated decks	45°

Table 3 Value of '*a*' for determining effective width of a beam

Deck plate system	*a* (m)
Nail-laminated deck plate	0.1
Stress-laminated deck plate	0.3
Composite timber–concrete	0.6

It is clear that the effect of both nail laminating and stress laminating is to spread the concentrated load over a wider section of the deck plate than would otherwise be possible. Stress laminated decks need to be subjected to a re-stressing routine. Laminated decks can take the form of single decks with extended webs, or cellular integrated decks using two deck layers joined by webs of laminated veneer lumber (LVL) for greater load carrying capacity.

Eurocode 5 Part 2 also contains a more rigorous design approach. Further guidance is also given by Crews (1995).

Wear surfaces for vehicle-carrying bridges

Plain timber does not have sufficient friction when wet to be used as a wear surface for vehicular traffic. For tracks and forest roads, using heavy steel mesh or grills is one option. Timber bonds well with asphalt, although heavily creosoted timber should be avoided as this may cause the wear surface to loosen. The timber substrate should be dry and treated first with a tack coat. The timber–concrete composite deck (Figure 18), with reinforcement, is one alternative. Drainage needs to be detailed so that rainwater can flow freely away from the bridge deck and avoid penetration into the support structure.

Bridge design practice

In the case of road bridges or bridges over roads, the Highways Agency (part of the Department for Transport) has produced a number of Departmental Standards which occasionally override the requirements of the BS 5400 series. The HA Standard, BD29/03, gives directions to engineers on how to design footbridges, including timber types.

An outline procedure for the design of timber footbridges over roads or in urban areas

The procedure may be considered in three stages, as follows.

1. Establish the general arrangements for the bridge, noting the requirements for layout and minimum dimensions given in Highways Agency Standard BD29/03.
2. Evaluate the loads acting on the bridge using the unfiltered loads of BS 5400-2, unless these are made more onerous by an HA Standard.
3. Design the members of the bridge in accordance with BS 5268-2 which is a permissible stress code used principally for timber members in buildings. BS 5268-2 does however contain sufficient basic materials properties, fastener design information and member design procedures for simpler types of timber bridge, as explained above in the earlier section, 'Materials'. Alternatively design the bridge members in accordance with Eurocode 5.

An outline procedure for the design of timber footbridges in suburban or rural areas

Many engineers specialising in timber bridges consider the BS 5400/Highways Agency provisions for minimum dimensions and loading too severe for lightly trafficked footbridges in suburban and rural areas. For these footbridges, typical alternative procedures are exemplified as follows.

1. Establish the general arrangements for the bridge, noting the minimum dimensional recommendations given in publications such as *Footbridges in the countryside*: *design and construction* published by the Countryside Commission for Scotland; or for equestrian bridges, British Horse Society recommendations.
2. Evaluate the loads acting on the bridge using the unfactored loads of BS 5400-2, or consider making them less onerous on the basis of recommendations given in publications such as those above.
3. Design the bridge members in accordance with BS 5268-2 or Eurocode 5.

Table 4 Deck widths for different bridge types and locations

	From HA Standard BD29/03 Urban area (mm)	From Countryside Commission for Scotland (1981) publication Accessible rural area (two-way traffic) (mm)	Inaccessible rural area (one-way traffic) (mm)
Pedestrians only	2000	1200	900
People with disabilities	2000	1700	1200

Table 5 Imposed loadings for different bridge types and locations

	From BS 5400-2 Urban area (kN/m^2)	From Countryside Commission for Scotland (1981) publication Rural area (kN/m^2)
Vertical imposed uniformly distributed load on bridge deck	5.0	2.3 – 3.2
Horizontal load per metre (kN/m) to handrail	1.4	0.74 – 1.4

Examples of less onerous minimum dimensions and loadings recommended by the Countryside Commission for Scotland (CCS) in its publication *Footbridges in the countryside: design and construction* are given in Tables 4 and 5.

The Highways Agency (HA) Standard BD29/03 stipulates several further criteria relating to the layout of footbridges over highways. These include height clearances, widths for different types of bridge, ramp gradients, stairs, parapets and handrails.

Equestrian bridges

For equestrian bridges or bridges spanning bridleways, guidance on widths and clearances is available from the British Horse Society. For example, bridleway bridges are normally 2.7 m wide and minimum parapet height is 1.4 m. Minimum clearance (headroom) for a horse and rider is 3.4 m. The loadings given for equestrian bridges in the CCS publication are 3.2 kN/m^2 uniformly distributed load (UDL) and 8.12 kN on a 175 mm square for point load. Bridge surfacing should be non-slip and non-echoing(eg rubber matting).

Evaluation of loads using BS 5400-2

Timber footbridges are designed using the unfactored nominal loads of BS 5400-2.

The following types of nominal load relating to footbridges are considered.

- **Permanent loads**
  Dead-weight of structural elements
  Superimposed dead loads – road surfacing etc

- **Live loads from pedestrian traffic**
  Nominal vertical live load
  Nominal load on pedestrian parapets

- **Wind loads**
  Transverse
  Longitudinal
  Vertical

- **Loads from temperature effects**

- **Erection loads**

BS 5400-2 suggests that in most cases snow loads can be ignored. This is logical since the full pedestrian design load is improbable under heavy snow falls of the duration likely to be experienced in the UK.

The maximum wind gust speed is evaluated by applying gust factors to mean hourly wind speeds extracted from a map of isotachs. The magnitude of the gust factor depends on the height of the bridge and on the horizontal wind loaded length. For footbridges only, BS 5400-2 allows the following reductions in wind load.

- The mean hourly wind speed is reduced by 0.94, which is a conversion factor to obtain 50-year return period values from 120-year return period values.
- A reduction in the gust factor where the bridge is located in urban areas or a rural environment with many windbreaks.

Service classes and load durations

To use BS 5268-2 for the design of bridge members, the designer has to decide on the service conditions for the bridge. This mainly involves deciding the exposure and duration classes that are appropriate for the member concerned. Experience has shown that designers are usually on the conservative side when choosing to design members using wet exposure stresses. For a vertical imposed uniformly distributed load (UDL) which represents a crowded bridge, designers usually select medium term duration. This is also the duration class used with BS 5268-2 for snow loading in the UK. Horizontal loads on handrails or parapets are usually designated as short term. This is the same load duration class as that arising from the case of a man standing on a roof member.

Deflection limits

The limited guidance given in BS 5268-2 for deflection limit is of little relevance to the design of bridge members. Indications are that a static deflection limit of span/200 under imposed load is often used for beam members. The CCS publication recommends a tighter limit of span/240 under total loading. Lightly pre-cambered, glulam bridge beams are often designed using a deflection limit for live load only which is permitted in principle by BS 5268-2.

Vibration and dynamics are important considerations for bridge designers. Guidance is available in Eurocode 5.

Eurocode 5

Eurocode 5 offers a number of advantages over BS 5268-2. It provides the opportunity to design with a wide selection of materials and components. The use of characteristic values for materials, based directly on test results, means that new materials and components which have achieved suitable technical approval can be assimilated more easily, therefore facilitating development and innovation. Eurocode 5 provides more guidance on the design of built-up components than BS 5268-2; it also provides a unified design and safety basis for laterally loaded dowel-type joints (nails, staples, screws, bolts and steel dowels). DD ENV 1995-1-1 contains no information on the design of joints using connectors such as toothed plates, shear plates and split rings, but a procedure is being developed through other sponsored research programmes. Interim guidance on the design of these joints is contained in the UK National Application Document.

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