

LIGHT Bridge Manual



**Outdoor
Structures Australia**
Practical solutions that enhance community design projects

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Kitashi Moura bridge - Japan

Introduction

The need to provide convenient and safe pedestrian access is considered more important than ever. It may be part of a community's infrastructure providing access to education, shopping and work or simply a recreational track in the country. But, all too frequently, a simple footpath will not do because of flooding or proximity to a busy roadway or the potential of a shorter route over otherwise difficult ground. Then a footbridge may provide an appropriate link, spanning both natural and man-made obstacles.

The bridge may be utilitarian and plain, fulfilling its role without fuss. In other locations it provides a viewing platform encouraging the passerby to linger. In yet another spot, the bridge may itself be the landmark or frame a vista, urging the designer to create something out of the ordinary to enhance a traveller's enjoyment.



Covered bridge Einbunkin Lagoon, Sandgate - Owner: Brisbane City Council

Timber is a versatile material for these styles of bridges. It may be covered in muted colours or simply oiled and left to grey gracefully in the bush. Alternatively it may have fine details, often associated with buildings, since it is enjoyed at a leisurely pace in contrast to road bridges. It may have its frame painted boldly, just asking to be seen. It is a material that is readily worked, adapted and maintained. It presents great opportunities for the creative designer to create elegant and long lasting footbridges.

Outdoor Structures Australia also offers a range of metal framed bridges with hardwood decks that compliment and extend their range of light bridges. Regardless of the style or material, every bridge is fabricated with the particular site in mind so the finishes, materials and handrailing are appropriate.

Why Prefabrication?

Life is so much easier for designers and constructors if bridges can be prefabricated rather than built on site.

This relieves designers of the need to:-

- undertake specific structural design in materials often unfamiliar to them (although some in-house design would be necessary in choosing from the wide range of options and styles).
- recruit bridge carpenters (assuming they are available)
- inspect timber species, treatment and grade conformance
- order ancillary materials that are not normal hardware lines (& the delay that it brings)
- inspect the various stages of construction, the details of which are unfamiliar to many.
- the disturb the site, considering many workplace health & safety measures, security compound installation, nuisance effects on neighbours.
- make major provision for bad weather especially in and around waterways
- finely plan expenditure. Costs can be contained with fixed price and no hidden extras. Easy to order and store until appropriate installation time.
- provide continuity of employment for bridge workers
- implement quality assurance as this is implemented by OSA's QA system.

The use of prefabricated bridges allows speeding up the construction process and, consequently, reducing job overheads. Risk is also reduced as prefabrication is carried out on a secure site without the risks of flood or theft.

OSA can provide Engineering certification of the specific design as well as Certification of the superstructure prefabrication. Typically substructure and bridge installation is inspected by local Consulting Engineers as the distribution of OSA's bridges is Australia wide.

The Manual

This Manual is about pedestrian bridges but it includes bridges carrying bicycles, golf cars and the occasional light vehicle load such as light mowers and maintenance vehicles. All the structures built by Outdoor Structures Australia have exposed hardwood decking (without asphalt or any other surfacing) and this gives them their distinctive appearance and pedestrian scale.

The manual offers general advice on the appropriateness, siting and types of footbridges. It guides the specifier on loadings, structure, foundations and handrailing. Suggestions are also offered on installation and maintenance practices developed to promote a long lived asset.



OSA's Log Bridge 2 span with central corbel - Owner: Ipswich City Council

This booklet cannot but touch on principles of footbridges in a general way and is far from complete. The reader is directed to books, references and standards throughout this text. The booklet does not substitute for an experienced designer especially in the areas of foundations, and the consequences of floods or vehicle impacts. Naturally, with the larger spanned bridges, experienced supervisors are necessary, if only for a short period. Outdoor Structures Australia can provide assistance on request. This booklet considers relatively small span structures (less than 30m), leaving designers of more challenging bridges to seek information in more specific texts.

Bridge Structures

Bridges consist of two major parts - superstructure and substructure. The superstructure is the fabrication above the supports that we would normally think of as the bridge itself. The substructure is, as the name implies, below the bridge consisting of abutments (at the beginning and end of the bridge making the transition to the pavement) as well as the piers (that provide intermediate supports for bridges of more than one span). Abutments and piers sit on foundations appropriate to the loads and the ground conditions. Common foundations include driven piles and strip footings.

Bridge Types

OSA produces bridges in timber, aluminium and steel to suit a variety of appearance and circumstances. Also designs can be undertaken to suit the unique characteristics of a particular site. The aluminium and steel bridges all have hardwood decking and can also be furnished with other timber elements such as railings and balustrading. This booklet is primarily concerned with the timber bridges but much of the information is relevant to the metal framed bridges as well.



Demountable bridge with 'Barrup' Truss - Owner: Brisbane City Council

Timber bridges are of the following types

- log girder (the mainstay of OSA's production)
- sawn girder (for small spans to 5m; and beyond when supported by a 'Barrup' style truss)
- laminated girders
- arched laminated girders (in three pinned arrangement where the foundation can take the lateral thrust without yielding)
- covered trussed bridges from modern to European & North American styles.

The limit to prefabrication is often the handling and transport considerations. 3.5m width and 18m length

are the usual limits for road transport in Australia without extensive escort requirements. Exported products must fit within a standard 40' container. Of course, the actual bridge site may dictate additional restrictions on size such as crane reach, obstructions and support locations.



Parallel Flange Channel Girders Bridge - Owner: Logan City Council

OSA's Boardwalks Design Guide gives guidance for the geometrics for pedestrian and cycleways such as minimum widths, grades and handrail requirements. Single span bridges curved in plan are normally not possible for OSA's standard bridges because of torsional effects and handrail logistics. However multispan bridges may be built following a gentle horizontal curve as a series of chords (like a boardwalk).

Sometimes footbridges are installed as a temporary solution prior to a major upgrade such as road widening. Because of their versatility, OSA's bridges can easily be relocated to another site.

Frequently the distance between the deck level and the underside of the structure needs to be minimized to provide more waterway or headroom or to minimize approach works or grades. Then arches or truss elements below the deck cannot be used, but trusses forming the handrail system (through truss) are satisfactory for bridges above flood level.

Bridging

When optimizing the cost of a bridge, a balance needs to be struck between the cost of the superstructure and the substructure. Multiple spans reduce the vertical loads carried by the foundations as there are more points of support. But on the other hand these intermediate supports (called piers) may cost disproportionately more. Additional expense is incurred for foundations in water, foundations in swiftly flowing water, piers to resist flood flow, poor ground and tall piers in deep gullies. So, while long span superstructures cost more, they may be justified on total project cost alone because of the demands of the site making the piers expensive.

Common locations for OSA's bridges have been over small creeks, gulleys and drains in bushland dedicated as park as part of land development. The ground is frequently low strength; often unconsolidated sediment and quite susceptible to erosion. Access for construction is often poor due to tree cover and the topography, while the location makes the site susceptible to short term flooding. The use of prefabricated bridges partly reduces this construction risk by reducing the time on site.

Once in service, bridges can be inundated by flooding and this fact is important in the design of these structures. Road bridges are considered to provide an 'essential' service so the public expectation is that they have a high level of availability (depending on the importance of the road) so that they are rarely closed for repair, maintenance or flood. On the other hand, pedestrian bridges may be unavailable for short periods without too much concern as there are other means of access, albeit less convenient or pleasant. So while road bridges (and pedestrian facilities beside them) may need to be immune from all but the most infrequent of floods (e.g. 1 in 100 occurring on average once in one hundred years), small span pedestrian bridges may be designed for much more frequent submergence. This is because they are not the only access and, in small catchments, the storm makes them impassable for only a short time (hour or so). During and immediately after a storm are not pleasant times to walk anyway.

Obviously bridges cost more than footpath construction so the bridge lengths are kept to a minimum. This can mean crossing a stream at right angles rather than skew.

Forces

Decking design is typically controlled by concentrated loads such as those imposed during construction or light wheeled vehicles while girders and substructure are sized in response to the uniformly distributed loads.

Austroroads Bridge Design Code 1992 specifies quite a high Load Combination Factor (2) for Live Load and makes no reference to timber at all. While there may be some debate about the severity of the combination factors and the loading intensity of the Austroroads requirement for many pedestrian bridges, OSA designs to these requirements unless requested otherwise by the client.

Uniformly Distributed Live Load

A Distributed Live Load for stand-alone pedestrian bridges of 5 kPa is specified by Austroroads Bridge Design Code. In reality, this is a severe crowd loading as well as corresponding to a wheeled trolley during maintenance. OSA bridges are designed for 5kPa as a matter of course, but for relatively isolated locations this may be reduced to 4kPa or even 3 kPa (Walking Tracks: Infrastructure Design Code).

Concentrated Live Load

A 20kN concentrated load is specified in Austroroads where there is a likelihood of park tractors and livestock. Even heavier loads can be exerted by trucks. These are quite significant imposts for the decking so realistic values should be used provided there is some means of control of the vehicles using these bridges (e.g. bollards, narrow deck). Otherwise the decking cost becomes disproportionate as normal pedestrian bridges can have a 35mm thick deck but those carrying wheeled vehicles may require up to 125mm thick decking.

There is no concentrated load specifically for pedestrians themselves. OSA's bridge decks are normally designed to a 4.5kN load distributed over 150mm x 150mm unless otherwise requested. This corresponds to the wheel load of a typical trolley in a commercial building (AS 1170.1 Appendix B) and that is slightly worse than the situation of a heavily loaded person running (1.3kN x 1.25 impact factor) on a 70mm wide board (the narrowest used by OSA for decking).

Timber decking spans only one way and there is normally no connection with the adjacent decker (as there would be if it were tongue & grooved). The decking design is sensitive to both the concentrated load and the area over which it is distributed. Accordingly the concentrated load must be specified if it is feasible for it to be above 4.5kN.

Bridges with decks wider than 2m should provide either Load Limit signs, or positive measures such as bollards, grids or chicanes to prevent unplanned use (e.g. vehicles or stock). Restricting the speed of cyclists on shared use bridges may be achieved with narrower planks and this also provides an audible warning of approaching bikes for pedestrians.

Other Loads

In general wind loads are not a major design factor for short span bridges but it is recommended that the superstructure and substructure be checked for a lateral load equal to 10% of the vertical live load to duplicate movement of a crowd of people, earthquake or braking load from a light vehicle.



Golf Car Bridge - Owner: Pelican Waters Golf Club

If any part of the structure goes under water, additional loads are imposed. These include :-

- buoyancy caused by a tendency of the structure to float. This is not a particular problem for OSA's hardwood log bridges as they are just heavier than water, having a density of about 1100 kg/m^3 . Further, the open nature of the decking means that pockets of air are not trapped.
- stream flow. The pressure is proportional to the square of the stream velocity acting over the surface area of the members facing the flood.
- the additional drag caused by catching debris including branches, mown grass and crops on the piers, girders and, most importantly, the handrailing system.
- log impact. It is not usually designed for as it is an unlikely event and it greatly prejudices the design of light pedestrian bridges. One would think that rogue logs would not be found in urban waterways, but that is not always the case.
- submersible bridges are not preferred but, if required, a robust log or stress laminated bridge should be adopted. The railings should be sacrificial, demountable or omitted (if the consequences of falling from the bridge are not significant).

Additional loads, fastening, movement or access requirements have to be considered where bridges have to carry services. Footbridges are frequently used to hide ugly gravity sewer lines crossing gullies.

The project designer (or the design consultant) should determine these loadings and advise OSA of the specific requirements, as, unless advised to the contrary, the bridge will be designed for nominal loads with no immersion.

Light pedestrian bridges can be sensitive to resonance under the dynamic load of synchronised foot-fall, and this is the reason soldiers are ordered to break step crossing damaged bridges. These people-induced vibrations are usually within the range from 1 to 2 Hz (cycles per second). For this reason OSA's bridges (with the exception of cable supported systems) are engineered so that their first natural frequency of vibration is greater than 5 Hz.

Stiffness

OSA's decking is sized so that relative movement between decking boards is kept to comfortable limits for foot traffic (See Boardwalks Engineering Guide). Additionally the bridge girders themselves are kept robust so that deflection under the full crowd load is less than span/180 so people feel safe.

Hydraulics

Bridges over watercourses require more detailed consideration than other locations. Firstly to what height and how fast does the flood water flow? Generally flows are expressed in terms of Q_{10} , Q_{50} , Q_{100} being the flow in cumecs (Cubic metres/sec) corresponding to a flood of that severity or worse occurring every 10 years, 50 years, 100 years etc. These calculations may also have to consider the effect of the bridge and any embankment approaches blocking off part of the waterway. This may cause a significant rise in waters upstream. This has more severe consequences in urban areas in raising the flood levels in adjacent properties.

Depending on the characteristics of the catchment and the stream itself, there may be little difference in height and cost of a bridge to satisfy the Q_{100} compared to Q_{50} . In other locations, a bridge may be inundated once a year in a pathway following a creek. Provided the bridge is designed for the flood forces, it should not prove to be a problem. The flood forces have to be assessed for the design event and the elements designed to resist this e.g. the piers only or the whole bridge - depending on the flood depth in relation to the bridge.

A consulting engineer experienced in hydraulics can assess the likely stream flows as well as the influence of the structure on any upstream properties. Information required for this assessment includes contour maps,

catchment boundaries and on-site appraisal of the flow characteristics of the stream. This can be supplemented by flood maps and local knowledge as well as traces of debris from previous floods. In many urban catchments, hydraulic modelling reports may already be available as part of a 'catchment wide' assessment.

The very act of building a bridge blocks off sunlight, especially with low bridges. The protective vegetation dies leaving the stream bed and banks susceptible to erosion. For this reason protective rip-rap may be needed under and near the bridge. Also it is prudent to anticipate some soil loss and bury the footings further or drive piles deeper.

Trussed, suspension and cable stayed bridges should not be used if there is a possibility of even part of them going underwater as they are very susceptible to lateral forces. Log or stress laminated bridges with limited railings are the most robust for submersible bridges.

Revegetation should be provided for at the budgeting stage to allow for the disturbance caused by the construction process, regrading of the approaches and change in the environment caused by shading by bridge deck. This can be done together with erosion control measures.

Scour protection can be achieved in a variety of ways:-

- Stone pitching (either grouted or ungrouted) with stone size based on the force of the flow or concrete-grass pavers.
- Mattresses can be stone filled wire baskets (gabions), stone filled plastic cells or cement grouted fabric mattresses
- Erosion control mats, possibly supplemented by planting
- Seeded grass (spray grass) with a temporary protection in the form of quick growing grasses and/or emulsion/fixative.
- Turfing with erosion resistant grasses provided they will not provide a maintenance problem with mowing, fire etc.
- Training walls or wing walls to direct the flood flow. These can be timber, reinforced concrete or concrete 'link block'

In all cases care should be taken to prevent water from scouring under these elements. A geofabric can be useful in achieving this.

In salt water locations bridge superstructures should be located above the effects of the sea. This means placing them above the HAT (highest astronomical tide) plus some allowance for wave action. Consideration of storm surge (local increase in water

level due to lowered atmospheric pressure during cyclones) and even a potential rise in average sea levels due to the greenhouse effect due to thermal expansion of the sea and melting of the polar ice caps, could be given, especially for important bridges. Of course small bridges can be easily re-located or raised if there is a problem.

Design Process

Some guidance is necessary for the design brief for the footbridge. Consideration has to be given to the users and to specific site factors.

Users

The anticipated users dictate some requirements to the designer.

User	Possible requirement
Crowd	Extra rail loadings, extra width
Bushwalker	Reduction in many aspects of design, e.g. load, width, handrailing
People with disabilities	Reduction in grades, rest platforms, reduced gaps in decking, easier to grip handrails, friction coating on decking
Horse riders	Much higher railing, screening from road traffic, high concentrated decking loads
Stock	High concentrated decking loads
Bicycles	Higher rails, rubbing rails rather than balusters, wider decking for better ride
Motor bikes	Steel continuous railing
Golf cars	Wider decking for better ride
Unaccompanied children	Full barrier type railing, no footholds for climbing
Fisherman	Widenings for fishing positions, top handrail for resting on, visibility through rail for fishing
Services	Provide support and access for installation & inspection

There may be the occasional unplanned use and maybe some specific measures have to be taken to prevent this e.g. bollards to prevent vehicle use, or signs prohibiting horse riders or a grate or more widely spaced boards to exclude stock.

Consideration must be given to what is passing under the bridge

Passing	Possible requirement
Sailing boats	Height and span requirements for tacking, consider tidal range
Canoes	maintain height during flood & no projections to scalp canoeist
Roadway	Legal height limit, designated high load route, high rails with screen to prevent throwing objects onto passing traffic
Railway	High screen over electrified wires
Occasional boat traffic	fenders to protect piers from boat impact, height and width of navigation span, lighting, commercial or recreational fishing, sailing, rowing, canoeing, adjacent riverbank land use.
Flood	fenders to piers to deflect logs, robust log bridge

The controlling authority (local council, road/rail/ waterways authority) of an existing facility is certain to have specific requirements. OSA's footbridges are comparatively light and may be modified to open to let high boats pass.

Location

In choosing a site, the following may have to be considered:-

- shortest span
- best foundation conditions (or choose the bridge style to suit the foundation conditions)
- best location for freedom from flooding
- best location for alignment especially for a cycling bridge or one for people with disabilities
- least clearing, obstructions and best access for construction plant.
- least hazards in terms of construction safety and to mitigate handrailing requirements
- most harmonious with the existing topography and presenting the best viewing opportunities
- security for users
- privacy issues for adjacent properties
- soil stability, bank/slope stability
- stability of the stream, scour and sedimentation, avoid locations vulnerable to scour.

Site Survey

A site survey is necessary as a design aid and to properly locate the structure within the landscape. This is necessary from an aesthetic and practical point of view as, generally, OSA does not build on site but prefabricates the superstructure. They do not have the luxury of building to fit the actual site - only the representation of the site - so the site plan must be as complete as possible so that the structure fits both the site and its landscape setting.

The first source of information may be an ortho-photo that often includes contours. A detailed contour survey extending 50m up and 50m downstream is usually the best way of presenting the information together with a survey of the possible connections to the pathways. This should also include top of bank, existing water levels, tidal range, observed tide, relationship to AHD or tidal datum. Debris marks, flood levels, evidence of soil scour or siltation are all important.

Obstacles should be located on this plan including services (underground and overhead), pits and valves, signs, property boundaries, trees (including type, girth and root buttressing), roads, paths, fences barriers etc. Sufficient recovery marks including temporary benchmarks should be installed at this stage to enable future set-out. This work is best done by engineering surveyors with the output direct to CivilCAD or Land Development Desktop. OSA and their Consultant require any plans sent electronically in AutoCAD 2000 or DXF format.

The hydraulic consultant may also need information on upstream properties that could be affected by any damming effect of construction.

Information on heavy vehicle access for construction, storage areas and site photos are also required.

Geotechnical Investigation

In comparison to typical civil engineering and building work, OSA's footbridge foundations are lightly loaded. Working bearing pressure on standard footings has been kept to 50kPa, acknowledging that the locations are often unsuitable for housing where 100kPa is the 'norm'. Working loads on piles are typically less than 100kN - an order of magnitude less than 'conventional' piling (1000kN). This means that light plantation pine piles are frequently used, making for economies in handling and driving. Piles may not have to be driven to rock by using skin friction to carry most of the load.

While the ground loadings for typical OSA's bridges are quite small, they still need to have adequate foundations. All bridges require a geotechnical

investigation to determine the nature of the founding material so that economical foundations can be designed to adequately withstand the anticipated loadings.

Usually where we bridge creeks, the ground is poor, unconsolidated, erosion prone, waterlogged and susceptible to flooding during construction. In that situation small capacity driven timber piles are the foundation of choice. Where the ground is stronger (50kPa allowable bearing pressure or better), consolidated (will not compress with time), erosion resistant, and above the watertable, a strip footing is the preferred option.

More sophisticated bridges like arches or suspension bridges impose considerable horizontal forces and so require good foundations. Simple bridges with small spans and free from inundation are the other end of the spectrum and are both versatile and adaptable.

The minimum geotechnical requirements are for a borehole at each abutment and pier position. In each bore SPT's (Standard Penetration Tests) or undisturbed tube samples should be taken at regular depth intervals as a means of establishing soil strength. These bores should be supervised by an appropriately qualified professional. Bore depths would typically be 2-4m deep on good 'residual soil' sites (strip footings) and 5-9m or deeper on 'soft soils' or 'alluvial sites' (driven piles). In cases where access for the drilling rig is limited, DCP's (Dynamic Cone Penetrometer) can be taken adjacent to the SPT and then at the other (hand augered) boreholes where the drilling rig cannot reach. SPT's are preferred as they are universally available and correlate better with driven pile resistance.

Bridge Arrangements

General

From an aesthetic point of view, bridge spans should be odd numbered (1,3,5...) This leaves a central span with more vertical clearance and this can be increased by arranging the spans to conform to a vertical curve. In a stream situation, the flood velocity is fastest at the middle of the stream and so any piers here obstruct the flow and accumulate debris build-up. The water is deepest here so it is more difficult to construct foundations for these intermediate supports. For these reasons, spanning the obstruction in one leap is preferred. However, while this approach eliminates the cost of the pier, it requires a stronger superstructure and so total project costs may remain unaltered.

Superstructure types

Typical Span range m	System
2-5	sawn girder
4-7	sawn girder with 'barrup' truss
5-10	log girder
10-15	double log girder
3-9	stress laminated timber slab bridge
6-12	laminated girder
6-20	3 pinned arch laminated girder
5-24	covered timber bridge
5-12	steel girder PFC's
10-20	steel Girder UB's
8-24	steel tubular warren truss
6-14	steel tubular Vierendeel girder
10-40	steel cable stayed
5-18	aluminium tubular warren truss

Limit single span bridge lengths by:-

- crossing at a natural, but stable, channel
- using a projecting abutment (providing streamflow is not adversely affected)

Increasing the span requires more expensive solutions as girder bridges deflect in proportion to the fourth power of the span.

All these systems may be continued in multiple spans. All have exposed timber decks except for the stressed laminated slab bridge which has a deck wearing surface of asphalt that protects the timber against rain and ultra violet radiation.

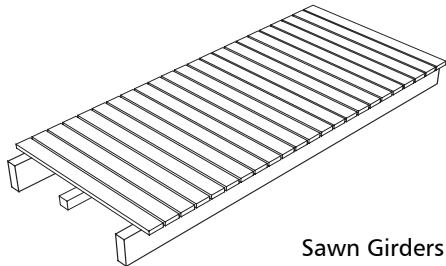
For multispan bridges, a better appearance is often achieved when spans are equal. The handrail posts look best when they are some sub-multiple of the span. In general almost any handrailing system can be used provided that they meet the structural and functional requirements.



Short span bridge - Owner: Robina Dales

Sawn girder

These are simple small span bridges limited to the sawn sections available. They can be threaded through the forest to form a boardwalk and can be completely pre-fabricated or assembled on site in the more sinuous alignments. Loads on the foundations are low. Depending on the spans, handrails can be located at the supports, providing integration with the piers. For spans greater than 3 metres, intermediate handrail posts are required. Bracing of these intermediate posts can be difficult to detail well.



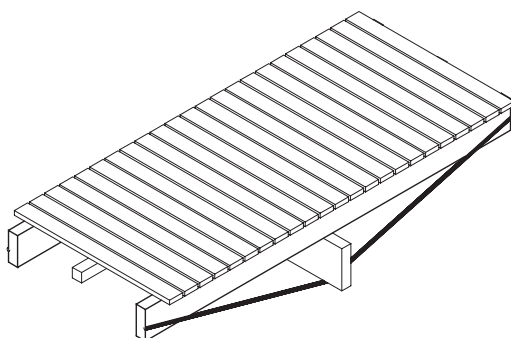
Sawn Girders



Sawn Girder bridge - Owner: North Lakes

Sawn girder with 'barrup' truss

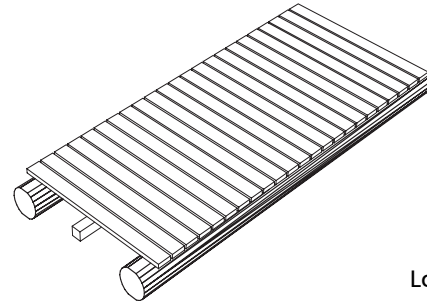
An underslung steel truss extends the spanning capabilities of sawn girders. The arrangement reduces headroom underneath and may catch debris during a flood.



Barrup Truss

Log girder

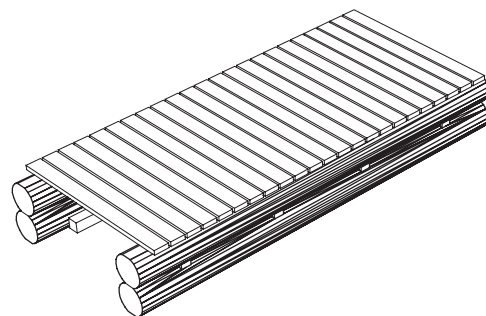
An un-sawn log uses timber in its strongest sense and with minimal waste. The log has the same strength in bending vertically and horizontally and so is an excellent choice for bridges that may submerge. The logs lend a rustic, robust feel to the bridge.



Log Girders

Double Log girder

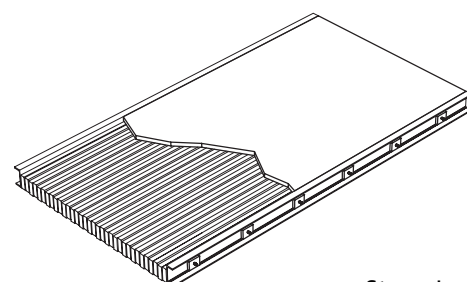
Very large logs are expensive and somewhat wasteful of the forest resource. OSA has developed a system of mechanically laminating two logs to extend the span range.



Double Log Girders

Stress-Laminated timber slab Bridge

Stress laminated bridges are a new innovation. They virtually form a slab of timber spanning between supports. The elements are vertically laminated and held together by prestressed bars. Concentrated loads are transferred between timbers by friction and so are



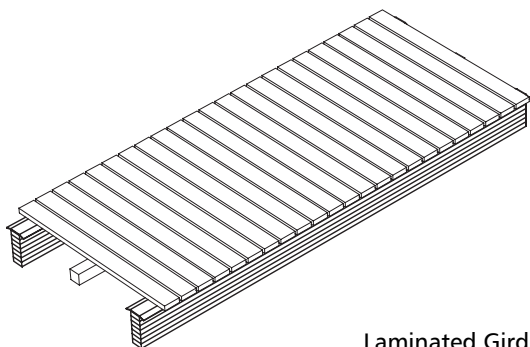
Stress-Lam Bridge

quite suitable for vehicles. As is typical with timber design, deflection controls so some end lapping of members may be used to make up the span or to provide continuous spans. The timber surface is a series of boards with no gaps and is irregular so a surfacing of flexible asphalt is required to provide a suitable riding surface, as well as waterproofing the timbers below.

This system is quite suitable for cycleways or for bridges where a low profile is necessary. The asphalt can be coloured or painted as required.

Laminated girder

Laminated girders can be produced to substantial depth compared to sawn timber. They have a pre-camber (upwards hog) and so can be used for relatively large spans. OSA use a system of flashing and battens to keep rain and sunlight off the beams so that they are not subjected to stress caused by differential moisture fluctuations.

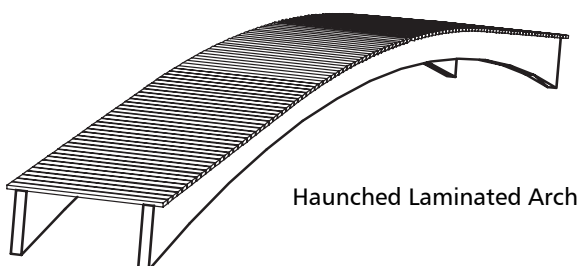


Laminated Girder

3 Pinned Arch Laminated girder

Laminated beams can be bonded to conform to an arch so timber can be used in a more efficient way by using it substantially in compression rather than bending. While the structural efficiency of the system improves as the radius reduces, this increases the deck's steepness. In extreme cases, either steps have to be employed or the deck has to be supported by a secondary structure to reduce the travelled grade.

Some Codes of Practice with respect to maximum grades for ramps and stairs as given in the following table.



Haunched Laminated Arch

Maximum grades for ramps & stairs

Ramps

Maximum Grade	Grade %	Reference
1:14	7	AS 1428.1 Design for Access and Mobility
1:8	12.5	BRIDGE DESIGN CODE Austroads - 1992 & BCA
1:4	25	AS 3962 Marinas (gangways)*

Stairs

Maximum Grade	Grade %	Reference
1:3	33	BCA (minimum slope)**
1:1.3	77	BCA (maximum slope)**
1:1.6	62	BRIDGE DESIGN CODE Austroads - 1992

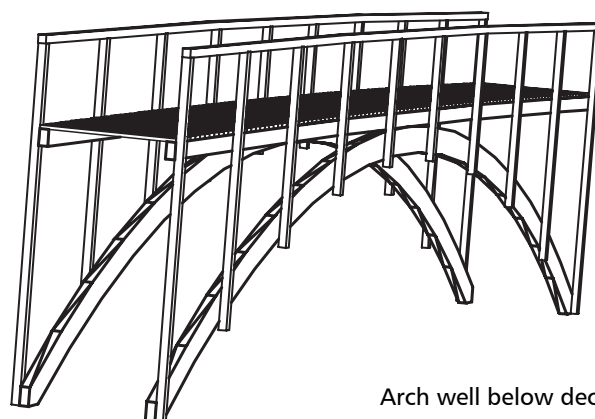
* these surfaces need extra measures to prevent slipping e.g. cleats

** stairs have also to be within the range 700 to 550 for 2 x rise + going

While the arch can be arranged to project above the travelled surface (as in a through arch), there is less opportunity to protect laminated timber from the weather, so that option is only useful for colder climates.

The only arrangement used by OSA is with the arch located below the deck to give some measure of protection to the laminated beams. The three pinned system, in particular, allows more constructional tolerance, improves handling and accommodates small movements of the abutments in service without damage compared to arches without a central joint.

Regardless, true arches produce horizontal thrusts on the ground many times the weight of the bridge and pedestrians. Consequently good ground conditions are necessary for this form of construction. As a rough guide, the horizontal thrust relative to the vertical load supported is in inverse proportion to the slope at the start of the bridge i.e. an arch bridge with a maximum grade of 1:10 at the abutments has lateral thrusts 10 times greater than the bridge weight and traffic loading combined.

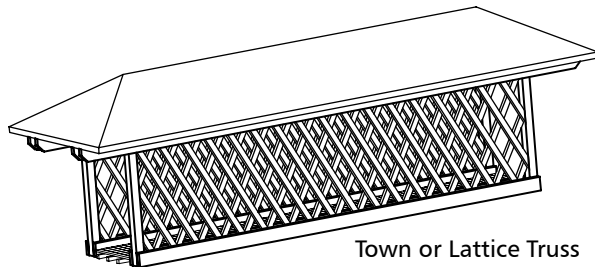


Arch well below deck

Covered Timber Bridges

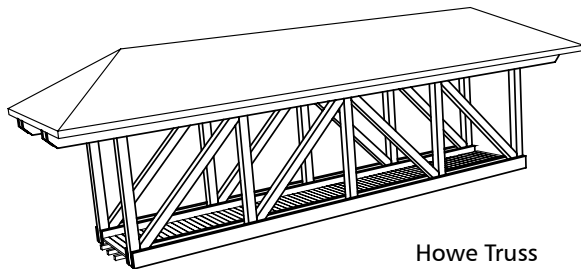
TRADAC's (www.tradac.org.au) Colin MacKenzie's often heard mantra; ".....long lived timber structures have three requirements:-

- keep them dry
- don't let the rain get to them
- don't let them get wet"



Town or Lattice Truss

A covered bridge achieves this by having a roof to keep much of the rain and UV away from the timber framework and deck. There are many examples of long lived covered bridges. Well known examples include Lucerne and those in New England region of the USA in Lancaster and Madison Counties. The roof facilitates the use of many structural arrangements without the severe dictates of wet joints. The beauty of these structures can become destinations in themselves. There is even a web site devoted to the covered bridges of the world (www.atawalk.com) and how to get to each one.



Howe Truss

A covered bridge provides cover from sun and storms for the users as well and this makes them at home on golf courses as well as at tourist attractions where they provide refuge from sudden storms.

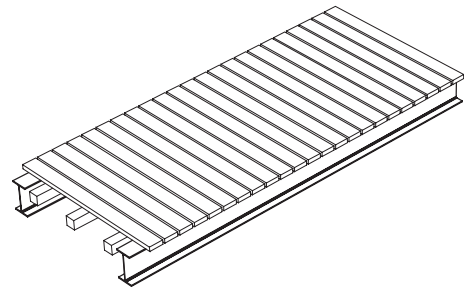
Steel girder PFC's

Parallel flange channels are used as girders around the perimeter. Flanges are turned inwards and, being under the decking, are not visible. The flush web exposed to view may then be painted a discrete or flamboyant colour. Alternatively the elements can be hot dipped galvanized before assembly. In fact, the use of galvanizing in conjunction with an industrial paint system results a synergy where the protection system's life is better than the sum of the individual systems.

This PFC system results in clean lines and facilitates almost any handrail system. While the standard system uses pre-cambered beams, a more pronounced curve can be rolled in (at some additional cost) to produce a more recognisable arch profile. In that situation, the beams are still designed as beams so no horizontal thrust is imposed on the foundations due to 'arch' action.

Steel girder UB's

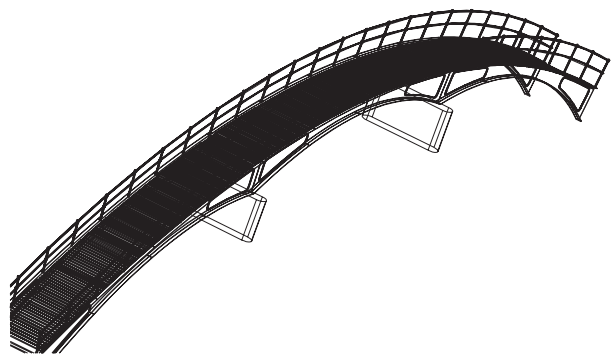
Universal beams are used as girders again around the perimeter. Flanges are exposed so the steel is obvious. While the usual arrangement has the girders totally under the decking, variations can be arranged so the bridge becomes a 'through' type with the users walking between the girders. In long bridges, this means part of the girders forms the handrail providing more clearance underneath. While girders can be spliced to facilitate transport, it is preferred not to for appearance purposes so that the clean sweep of the beams remains uninterrupted.



Steel Universal Beams as Girders

Steel welded beams

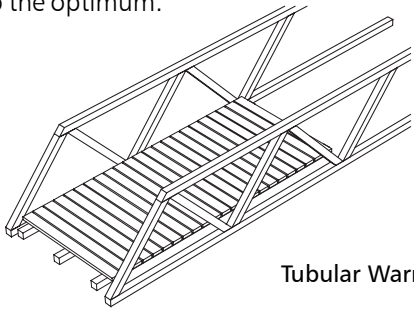
Steel can be worked and welded into a variety of shapes. A welded steel beam is often the answer when a significant curvature is required or for spans beyond the limits of Universal Beams. At the same time there is the opportunity to make holes and additions to shape the bridge in sympathy with surrounding buildings and bridges or to echo a historic style. These bridges are site specific and so preliminary costs can be indicative only.



Steel tubular warren truss

A warren truss is a regular triangulated framework constructed in rectangular hollow sections. Typically they are supplied in un-spliced spans. They are a 'through' girder type with the truss forming the major members for the handrailing. Additional railing and balustrading can be added in either timber or steel.

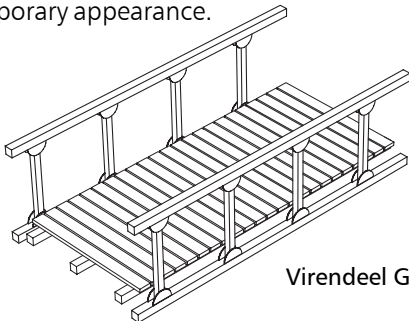
The fabrication is fully welded tube so the sheer size and the venting requirements does not facilitate hot dip galvanizing. In its place, a premium industrial painting system is used. The web arrangements are such that bridge lengths are multiples of a two metre module. While other lengths can be catered for, some additional costs apply as the members are not being used to the optimum.



Tubular Warren Truss

Steel Viendeel girder

Again the OSA system is comprised of fully welded rectangular hollow sections forming a through frame characterised by gussets at rigid joints. There are no diagonal members but the verticals are more frequent facilitating handrail installation. While the system is not as efficient as a truss, it may be chosen for its more contemporary appearance.



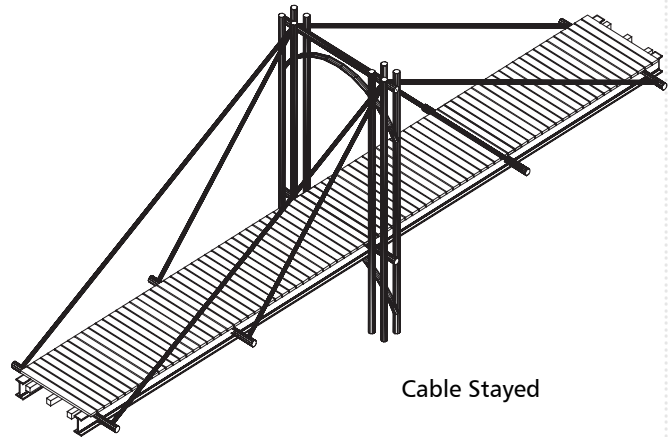
Viendeel Girder

Aluminium tubular warren truss

The aluminium truss is similar to the steel option but is used for severe corrosion locations like marine environments. Sometimes they are chosen for appearance only such as over swimming pools etc. Typically the aluminium is left unpainted and contrasts well with oiled timber. This system can also be used for gangways linking to pontoons where a reeded finish to the deck surface may be more appropriate on the steep grades caused by a large tidal range. Gangways are designed for different load intensities, fixings and tread requirements than bridges. For the extremes of grade (pontoon at low water), cleats may be used to give a better foothold.

Steel cable stayed

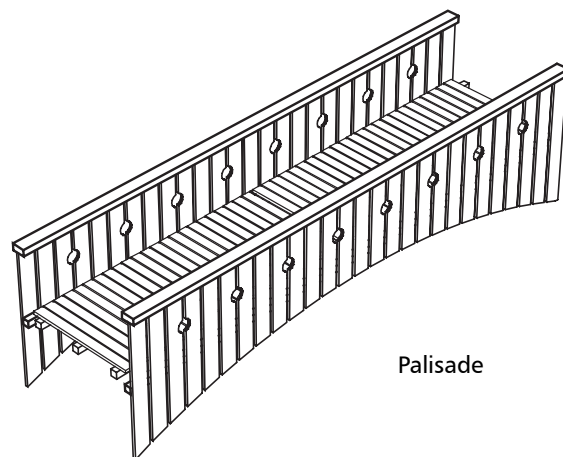
Cable stayed designs use cables from masts to increase span. Both masts and girders are steel while the decking is timber. Most of the reactions associated with the use of cables are taken within the deck system and so do not require expensive ground anchors associated with suspension bridges. Often the minimum deck width is governed by providing a horizontal wind girder to ensure lateral stiffness. These designs are always site specific.



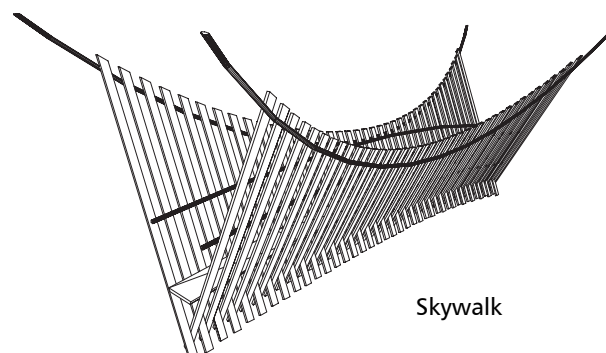
Cable Stayed

Whimsical Bridges

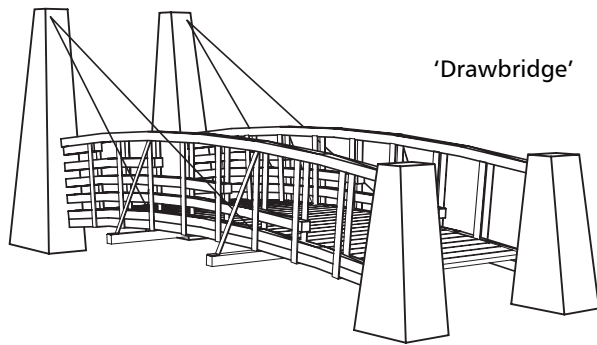
All manner of bridge designs can be designed and fabricated by OSA. These can be based on your own architectural concepts or can be developed in conjunction with engineering consultants.



Palisade



Skywalk



Decking

All timber decking in OSA's bridges are laid across the width of the bridge. This is consistent with design principles for the visually and mobility impaired as well as for bicycles. The exception to this is the range of rolled steel girdered bridges where the decking is arranged at 45°. This provides a smoother ride as well as lateral bracing. Unless noted otherwise by the client, the average gap between decking in the long term (after reaching equilibrium moisture) is set at about 12mm. Obviously larger gaps will shed leaves easier and could be specified where there is less risk to users. Gaps over 40mm do not promote user confidence as one can see too much through the deck.

Deckwood is a product exclusive to OSA and has been developed through years of experience with exposed timber decks. It is a premium open forest hardwood product, virtually clear from defects on the exposed face. Any sapwood is protected by the pressure preservative treatment to H3 hazard level by a non chrome, non arsenic based preservative. The unique profile has been derived to reduce maintenance costs and to reduce development of edge splinters. The system is fixed with stainless steel screws. Detailed information is contained in the Deckwood Brochure or available from our web site.

OSA uses its hardwood Deckwood exclusively for all of its decking, it does not have confidence in the long term performance of pine or plywood decking for these applications. There may be some situations where other decking systems (steel grating, aluminium extrusions or GRP) may be required by the designer and OSA would endeavour to accommodate these alternative materials into a design. These other systems are a lot more open than typical timber decking. They may provide entrapment for tiny feet, discomfort in walking on narrow metal grating bars in bare feet, as well as the visual unease of see-through deck.

Footpath approaches to bridges should rise a little before reaching the abutment so that surface water and debris are not carried onto the timber deck but rather diverted safely away from the structure.

In many situations a footbridge provides an opportunity to linger and this can be encouraged by making the deck wider than the approach path. Viewing platforms associated with the bridge may also be an option.

Substructure

Between the bridge superstructure provided by OSA and the ground there is the substructure which is normally constructed by the purchaser. The bridge is fixed to the substructure which itself fixed to the earth by piles or embedment. The abutments and piers that comprise the substructure should provide good air circulation to the bridge, be free of rubbish and soil and facilitate drainage.

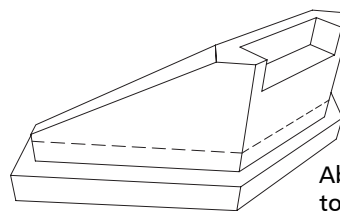
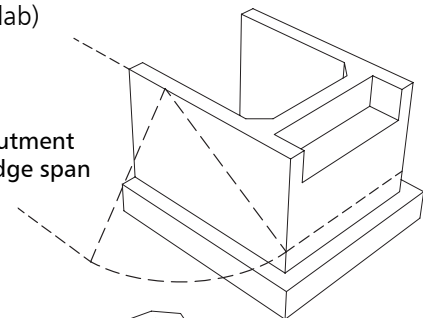
Abutments

Abutments are required at both ends of the bridge.

Abutments:-

- form the transition from the timber deck to the paving
- support the last spans of the bridge
- direct the flow of the stream often by the use of wingwalls
- act as a retaining wall supporting the fill or cut
- anchor the superstructure to the ground resisting lateral and uplift loads
- carry a the pavement away from the bridge (relieving slab)

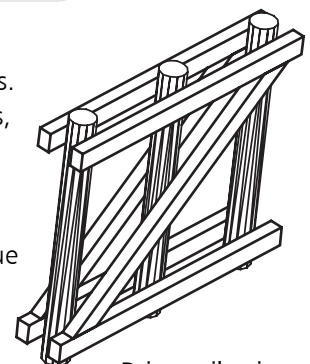
Projecting abutment to reduce bridge span



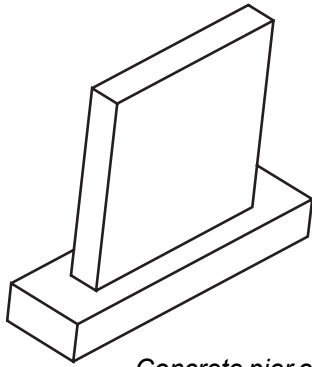
Abutment with wing walls to streamline flood flow

Piers

Piers are the intermediate support for the bridge spans. Because of their slenderness, they are often vulnerable to lateral loads caused during construction (in placing the bridge) or during service (due to floating log impact or vehicle impact).



Driven pile pier



Concrete pier on strip footing

Where practical, piers should not be located in the middle of the stream. This is where we expect the maximum velocity of flow and the navigable span for boats. This is partly the reason bridges crossing a stream look most pleasing if they have an odd number of spans (1, 3, 5...).

As previously mentioned, the centre of a stream presents difficulties in construction being usually in the deepest water, the worst foundation condition, the most inaccessible location and the most vulnerable to flooding. Where a high pier is required, in say a gully location, its cost can be disproportionate. For these reasons a single span is often desirable.....but large spans cost more and present handling problems on restricted sites.

Handrails

Handrails provide support and confidence in bridge users and assist in arresting a trip from becoming more serious. Also a user can be forced to one side by other users or a high wind. Once barriers are provided, users lean against them so they must meet the required structural standards.

Handrails look best if the verticals (stanchions) are spaced from 1.5 to 2 times the rail height. For pedestrian and cycle requirements, this rule results in handrail stanchions at 2m centres. This is the maximum requirement for post spacings of AS 1657 (Access Code). Additionally the stanchion spacing needs to relate to the bridge span as well. This is one of many reasons the spans of the steel bridges by OSA are preferred in 2m increments.

Lighting poles or other fixtures should also relate to the stanchion locations.

Handrail Heights Austroads

- 1.1 m pedestrians
- 1.3 m where cyclists permitted.

Walking track structures AS 2156.2

- typically 1.0m high type A & B barriers
- 0.9m type C & D barriers

Types of barrier relate to type of track (users & user's expectations), effective fall height and consequence of falling.

Access & Mobility AS 1428.1

typically 0.87m to 1.0m for steadying on ramps (i.e. steeper than 3%) (barrier may extend higher than grabrail).

Building Code of Australia

1.0m high barrier when fall height greater than 1.0m

Horse Riders

A higher handrail (parapet) may be required for horse riders and there may be a need for a visual barrier as well so the horse does not get spooked by adjacent road traffic. For this and other reasons, a more prudent approach may be for a bridge to be signed for the rider to dismount before crossing. Alternatively see the recommendations of the UK Department of Environment, Transport and the Regions (DETR) (parapets from 1.8m to 1.2m depending on the situation). They also recommend additional friction surfacing on top of timber such as rubber matting or a sprayed bituminous/epoxy seal on timber decking.

OSA

A handrail height of 1.1 m is a reasonable compromise based on these Codes where cyclists are excluded and 1.3m otherwise. *These heights present a viewing issue for wheelchair bound adults.*

OSA has adopted **1.3m** as its **standard** rail height unless specifically directed otherwise.

Handrail (top) loadings of **0.75kN/m** are adopted on all designs unless noted otherwise.

Other loadings can include

- remote bridges (refer Walking Track Infrastructure Design) 0.36kN/m
- those with crowd loadings (Austroads/Building Code of Australia) 3kN/m.
- submerged bridges subject to flood flows depending on velocity and debris mat.

Infill loadings currently adopted are those contained in the proposed revision to AS 1170.1 and are 1kPa horizontally and 0.5 kN (this last value may be low for horizontal rails subjected to vandalism). These are increased to 1.5kPa & 1.5 kN for areas likely to have crowd loading.

Handrail construction

Handrails (the top rail) can be made from many materials but generally need to be stiff enough to inspire confidence. So a wire or rope handrail is only appropriate in a low risk situation. There are two options; the rail is the dominant line or is punctuated by the vertical stanchions. The former may be more suited to cyclists and those with a mobility disability while the latter offers more opportunity for creative designers.

In the special situation of a bridge steeper than 3% frequented by people with a mobility disability, the handrail needs to be small enough to grip and that handhold must not be broken (can not have penetrations of the stanchions for instance) Refer to AS 1428.

Arched bridges or bridges on grade provide their own difficulties in the barrier arrangements and this may limit certain types of construction.

Infills

The space between the handrail and the deck needs to provide restraint from falling through, consistent with user expectations.

This balustrading may consist of several types. In order of effectiveness (and cost):-

- solid infill (Type A) †
- vertical balusters * (Type A) †
- horizontal wires* (Type B) †
- horizontal rails * (Type B) †
- mid rail & kerb/rail (Type C) †
- mid rail (Type C) †
- no infill (Type D & E) †

* indicates spacing between all elements less than the 125mm sphere representing a child head.

† Types as defined in Walking Track Infrastructure Design.

If the barrier geometry will prevent a child under 6 from climbing over, then that system may be classified barrier type A in terms of Walking Track Infrastructure Design. A solid infill may be expanded metal, solid boarding, plywood or glass/plastic.

A very low bridge over a benign fall surface (less than 1 metre effective fall height) may need no handrail at all, on one side only or rail type D or E. Typically though, a balance has to be struck between safety and the impact of the handrail infill. The infill may catch flood debris and may be visually obtrusive and is often a disproportionate cost in small span bridging.

OSA bridges suit almost the complete range of handrail options including steel, aluminium, stainless steel wire rope and timber; either by themselves or in combinations.

Fixing Bridges

Bridges need to be fastened to the substructure so they remain in place. Things that tend to displace bridges include:-

- temperature changes (not especially applicable to timber bridges)
- shrinkage/swelling with moisture content changes
- flood forces including debris, hydrodynamic, log impact
- buoyancy for submerged bridges
- vehicle impact, braking, mooring (boats)
- foundation movement
- wind, extreme people movement

The superstructure needs to be fixed at abutments and this is usually done by 'chemset' bolting after the bridge has been positioned.

For the metal bridges, thermal expansion needs to be accommodated otherwise the bridge could buckle (like railway lines on a very hot day). This expansion is even more pronounced with aluminium bridges due to even larger expansion. Movement is facilitated at the 'free' end by elastomeric ('rubber') pads supplied by OSA. They are also used at the fixed end to allow some rotation. The fixing at the 'free' end is also by bolting but through a slot to enable the bridge to move along its length as the temperature changes.

Access need to be provided for inspection at supports as the lack of airflow often makes this a problem area for all bridges. In some situations decking timber can be removed for inspection from on top.

Maintenance

All construction deteriorates with time and bridges are no exception. As with all public assets, regular inspection and care can extend their useful life. And the need and ease of maintenance depends on the design and construction.

OSA in the design of the superstructure adopt materials and installation methods that promote a long life and facilitate adjustment, inspection and replacement. In the installation and substructure the arrangement should allow visual and physical access to clean, inspect, tighten and maintain the structure especially at abutments and piers. Photographs taken during construction and retention of these with the plans will assist in future programmed maintenance. A six monthly inspection should be normal with more frequent visits if the site warrants it (vandalism, public expectation, condition of the structure, severe environment).

Some points to observe with field inspections of these bridges and approaches include:-

Approach paths	Overgrowth, lighting, slippery conditions (mud, moss), potholes, abrupt Changes in level, approach railing
Access restriction device	Presence, condition and visibility of bollards, gate, chicane, grid
Embankment	Scour, overgrowth, fire hazard, stability
Stream Bed	Scour, debris
Abutments	Access, litter, holddowns
Piers	Holddowns, stability
Wingwalls	Stability, scour, revertment condition
Girders	Corrosion, decay, splitting, distress
Bracing	Fastening, tightness, corrosion
Cross beams	Fastening, corrosion, decay
Decking	Fastening, decay, surface condition, litter, preservative oil & emulsion coating
Handrail & Posts	Compliance, fastenings, Surface condition, Paint system

A typical maintenance reporting and action sheet is included in the Appendix.

APPENDIX A - OSA

TIMBER BRIDGE DESIGN BRIEF SHEET

Owner _____

Postal Address _____

Contact Name _____

Position _____ Fax _____

Telephone _____ Mobile _____

Fax _____ Email _____

Bridge Type Sawn Log Double Log
 StressLam Laminated Other (drawing/sketch attached)

Location
Creek/park
Street
UBD grid

Bridge over Creek Open SW drain Swamp
 Road Dry gully Other (drawing/sketch attached)

Soil Testing* Attached Pending

Scour potential* Yes Possible No

Hydraulics‡ Attached Pending Girders above (Q50 event)

Site photos Attached Pending N/A

Long. Section (AHD) Attached Pending N/A

Nominal Span(s) _____ m

Clear Width between rails _____ m

Use
Loads Pedestrian Walking Track >type 2
 Cycles Golf car
 Tractor (specify GVM) Special (specify)

Handrail type Cruiserline Timber + balusters Rural look
 Kerb only none Other (drawing/sketch attached)

Handrail height 1.3m (std) 1.1m Other (specify)

Finish
Decking CN Oil Stained Painted ends & Oil

Handrail Intergrain Painted Other (specify)

‡ Velocity of stream, Q50 height, Debris load, impact log size (if any)

* Required if foundations are to be designed by us

Copy this form and Fax to 07 5462 4077 to more efficiently communicate your requirements to OSA.

APPENDIX B - OSA

STEEL BRIDGE DESIGN BRIEF SHEET

Owner _____

Postal Address _____

Contact Name _____

Position _____

Fax _____

Telephone _____

Mobile _____

Fax _____

Email _____

Steel Bridge Type Girder Arch Warren Truss
 Other (drawing/sketch attached)

Location

Creek/park
Street
UBD grid

Bridge over Creek Open SW drain Swamp
 Road Dry gully Other (drawing/sketch attached)

Soil Testing* Attached Pending

Scour potential* Yes Possible No

Hydraulics‡ Attached Pending Girders above (Q50 event)

Site photos Attached Pending N/A

Long. Section (AHD) Attached Pending N/A

Nominal Span(s) _____ m

Clear Width between rails _____ m

Use

Loads Pedestrian Walking Track >Type 2
 Cycles Golf car
 Tractor (specify GVM & wheel load) Special (specify)

Handrail type Cruiserline Timber + balusters Rural look
 Kerb only None Other (drawing/sketch attached)

Handrail height 1.3m (std) 1.1m Other (specify)

Finish

Decking CN Oil Painted ends & Oil Stained
Girders Galv.† PSX Galv. + top coated +
Handrail Intergrain Painted Other (specify)

‡ Velocity of stream, Q50 height, Debris load, impact log size (if any)

* Required if foundations are to be designed by us

† Not offered with Trussed Bridge

Copy this form and Fax to 07 5462 4077 to more efficiently communicate your requirements to OSA.

APPENDIX C - OSA

RECOMMENDED MAINTENANCE PRACTICE

It is difficult to generalise for maintenance practice on OSA's bridges considering the huge range of options. The following shows items in a typical check list.

Bridge Name	Rusty Creek	Inspection Date	12/2/01
Suburb	Burbank	Inspected by	RS Green
Location	Gnome Rd	Remedial work completed date	25/4/01
UDB Ref	235 M-6	Remedial work carried out by	P Grenville
<i>Element</i>	<i>Condition</i>		<i>recommend action</i>
Approach paths	overgrown		✓
Access restriction device	bollard missing		✓
Embankment	good		
Stream Bed	debris, logs		✓
Abutments	rubbish around Seats		✓
Piers	scour		✓
Wingwalls	good		
Girders	good		
Bracing	not applicable		
Cross beams	good		
Decking	4 loose boards, 1 split board rubbish		
	between boards, needs re-oiling, needs		
	CN emulsion on ends		✓
Handrail & Posts	loose bolts on 2 posts, need repainting		✓

Photos Taken Yes/No

Action required

Clear grass from concrete approach path, waterblast moss from path, Replace bollard, remove large debris from stream bed, Clean out abutments at girder ends, place extra rip-rap around central pier, tighten decking screws, replace 1 board, blow out between boards, oil all boards with CN Oil, CN Emulsion to all end grain of girders and decking, Tighten 2 posts, Sand, prime where necessary and paint timber handrail system with Intergrain D-W-D.

Remedial work done

All work above done plus tightened hold down bolts.

References

BOARDWALKS DESIGN GUIDE
Outdoor Structures Australia - 1998

BOARDWALKS ENGINEERING GUIDE
Outdoor Structures Australia - 1998

BRIDGE DESIGN CODE
Austroads - 1992 (& proposed revision 2001)

**BRIDGESCAPE -
THE ART OF DESIGNING BRIDGES**
Fredrick Gottemoeller
John Wiley & Sons Inc - 1998

DECKWOOD SELECTION GUIDE
Outdoor Structures Australia - 2000

**FOOTBRIDGES IN THE COUNTRYSIDE -
DESIGN & CONSTRUCTION**
Countryside Commission for Scotland - 1981

GUIDE TO TRAFFIC ENGINEERING PRACTICE
AP-11.13/95 PART 13: PEDESTRIANS
Austroads

GUIDE TO TRAFFIC ENGINEERING PRACTICE
AP-11.14/93 PART 14: BICYCLES
Austroads

PROCEEDINGS OF 1992 TIMBER BRIDGES CONFERENCE
University of Melbourne -1992

THE ARCHITECTURE OF BRIDGES
Elizabeth B. Mock -
Museum of Modern Art New York 1949

**TIMBER DECKS - COMMERCIAL
INDUSTRIAL & MARINE**
Timber Datafile Timber Manual NAFI - 1989

TIMBER IN LANDSCAPE
Timber Datafile Timber Manual NAFI - 1989

**TIMBER STRUCTURES PART 1: DESIGN METHODS AS
1720.1 - 1997**



Kitashi Moura Bridge - Japan

Compiled by James Pierce & Associates, Consulting Engineers,
for

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The information and recommendations contained in this Manual have been prepared with due care. They are offered for the purpose of providing useful information to assist in the specification of light duty bridges. Outdoor Structures Australia reserves the right to change or, cease to manufacture, any of the bridges represented in this Manual.

Whilst every effort has been made to ensure that this Manual is in accordance with current practice, it is not intended as an exhaustive statement of all relevant information. As successful design and construction depends upon numerous factors outside the scope of this Manual, Outdoor Structures Australia and James Pierce & Associates accepts no responsibility for errors in, or omissions from the Manual, nor on designs or work done, or omitted to be done, in reliance on the Manual.