Timber Beam Bridges

Study of Relative Heritage Significance of RTA Controlled Timber Beam Road Bridges in NSW

2000

HISTORY OF TIMBER BEAM BRIDGES IN NSW

1.1 Introduction

Timber beam bridges, in the form of fallen tree trunks across streams, are probably the oldest types of bridges used by humans. The focus of this report is on the use of timber beam bridges in New South Wales, for roads. Some historical references are also made to their parallel use for railways.

Timber beam bridges and timber openings, or TOs, as they are called in the railway organizations, were the foundation structures of the road and railway networks of land transport in NSW. The two forms of construction for the road and railway bridges are very similar as they were based on traditional examples in Britain and Europe and because engineers in the Department of Public Works (PWD) dealt with both types until around 1920.

Typical timber beam road bridge, Br No 2769

Typical timber beam railway bridge

The growth of the settlement of Sydney and the later expansion of settlement west of the coastal strip, depended on the effective and economical use of roads, and later on the railways. This dependence grew from the limitations of the coastal and inland shipping and the consequent necessity for improved land communication.

Within Sydney Town a log bridge was built over the Tank Steam in October 1788, six months after settlement. It was replaced by a stone arch bridge in 1803, giving rise to the name of today's Bridge Street (DMR 1976).

Further afield, a timber bridge was completed over Duck River (Granville) in 1797. In 1805 the Governor's Road Committee listed 10 bridges on the Parramatta Road, 'as this road was a vital food supply route', from Johnston's Creek (Annandale), to A'Beckett's Creek (Parramatta), to the following specification

> 16 feet wide with Four Sleepers of at least a foot and a half in diameter, either of ironbark or blue gum, bedded on timber of the like dimensions, to be covered with three inch planks, 16 feet long and properly secured by treenails of 1 ½ inch diameter (DMR 1976).

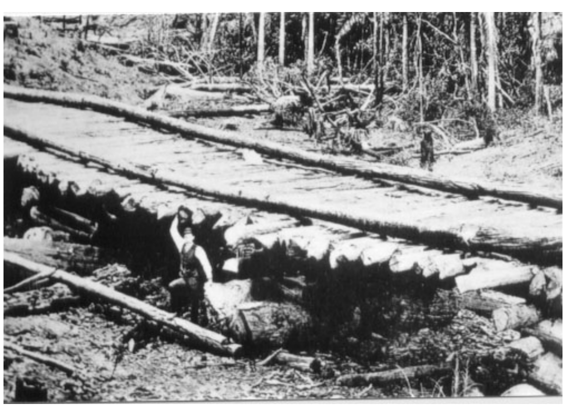
In 1808 Lt-Governor Joseph Foveaux mentioned 'framing log bridges' when referring to repairs for High George Street in Sydney (DMR 1976).

By 1790 the settlement of Parramatta had been established at the head of navigation of the Parramatta River where the width made it possible to build a bridge for the road to the Hawkesbury River. Major Francis Grose is credited with the building of a timber bridge over the river in 1794, but it was not stable and was swept away by floodwater in 1795. A more durable timber bridge on stone piers took its place in 1802 (DMR 1976).

Between 1813 and 1821, during Governor Macquarie's term, William Roberts was contracted to undertake many road works including 28 bridges on the Windsor and Liverpool Roads. The building of these bridges 'rendered incalculable benefits to the settlers' (DMR 1976).

Following the trail blazed by Blaxland, Wentworth and Lawson over the Blue Mountains in 1813, William Cox's team of 30 completed a 'road' to Hartley in January 1815. The road included bridges over the Lett and Cox's River using 'pieces made from an oak tree with a girth of up to 9 feet' (DMR 1976).

All these bridges were of a timber beam type, but neither exact details nor sketches are available. However, more is known of an earlier form of log bridge, the corduroy bridge, because some of the late survivors were photographed around the 1880s. Large longitudinal logs were topped by smaller transverse logs with side logs, acting as kerbs. The ride over the transverse logs was, of course, rough and sometimes the decks were covered with soil and turf, to make the crossing easier for drays and more comfortable for coach passengers. Later the transverse logs were replaced by planks, which further improved the riding surface.



Corduroy bridge

A turf covered beam bridge

1.2 Department of Public Works

During the 1840s and early 1850s building Infrastructure was the responsibility of the Colonial Architect. However, following the impact of the Gold Rush, the demand for public-oriented works exceeded the capacity of the Colonial Architect's Office and a new government agency, the Public Works Department (PWD), was established in 1859. In 1861 William C. Bennett began a 30-year tenure as Commissioner and Engineer for Roads and Bridges. He had already gained wide experience in both areas, particularly in the construction and maintenance of laminated timber arch bridges during the late 1850s.

Capt. B H Martindale, an Officer of the Royal Engineers, was Commissioner for Railways and for Internal Communications from 1858 to 1861. Under the direction of the Minister for Lands he journeyed around the colony of New South Wales and produced four Reports on Internal Communications, 1857,1858,1859 and1860. The reports are all contained in the *Votes and Proceedings* of the New South Wales Legislative Assembly.

The Reports dealt with all manner of aspects of road and rail transport as well as communications by electric telegraph. In summary, they reported on the contemporary status of land transport and made many recommendations on how to improve it. He drew attention to:

> the want of bridges suspends inter-communication steep and sliding banks of creeks would be obviated by very ordinary bridges of simple construction
>
> bridges urgently required at Singleton, Aberdeen, Murrurrundi and Bendemeer
>
> labour cost are three times those in England
>
> inhabitants of Gundagai are inconvenienced by creeks along the flats and submergence when the Murrumbidgee floods
>
> the principles for carrying out road works, first, to bridge the creeks and rivers which habitually stop traffic in times of flood, second, improve the places along the roads (Martindale 1857 to 1860).

In Martindale's report there are lists of bridges being built or recently completed and many are 'simple beam' bridges (Martindale 1857 to 1860).

Petitions for bridges were regularly published in the newspaper, for example in the *Sydney Morning Herald* (SMH):

> Petition to Sir William Denison includes figures for the stock crossing the Murray River each year, 400,000 sheep, 30,000 cattle and 4,000 horses. Condemnation of ineffective action from centralized governments (*Sydney Morning Herald* 1/10/1856).

Community frustration due to the lack of bridges being built was published in the *Sydney Morning Herald* and the *Newcastle Chronicle*:

In the Edwards River District private individuals are prepared to build a bridge at Deniliquin (Sydney Morning Herald 1/10/1856).

City folk don't appreciate the importance of bridges to the interior *(SMH* 14/1/1856).

Money spent on bridges is money put to good use (*Newcastle Chronicle* 5/7/1870).

The need for road bridges had been established early. As for knowledge about road and bridge building, it was scarce in the young colony. However there was a substantial body of knowledge in Britain and Europe from whence most arrivals had come and among whom there were experienced military engineers and tradesmen. There was a great deal more engineering and scientific knowledge in the hands of a group of competent bridge engineers in the PWD by the 1890s.

By the time the PWD was established, timber was the dominant building and construction material, even though some notable stone arch bridges had been constructed under the supervision of David Lennox (Selkirk 1920). For example, in 1836 the Landsdowne Bridge over Prospect Creek and in 1839 the Bridge over the Parramatta River at Church Street Parramatta. The North Coast districts were yielding their abundance of cedar for furniture, doors, windows and other house fittings, and various hardwoods for structural uses. Wrought iron was not used as much as timber as it was an expensive import from England, even though it may have been more suitable in some applications.

The dominance of timber for bridges, wharves, interiors of building and other structural uses was further strengthened in 1861 when the Government decreed that local materials (stone, bricks and timber) had to be used in preference to wrought iron. This action was largely designed to curb John Whitton (Engineer-in-Chief for Railways) following his lavish spending to build two wrought iron bridges over the Nepean River at Menangle (1863) and at Penrith (1867). Their combined weight of iron was 2,035 tons and the combined completed cost was £194,562, an enormous sum for the still fledgling colony.

John Whitton

The 1863 Menangle railway bridge, extra piers 1905

The government move was partly effective because Whitton went on to use timber beams, arches, trusses, and some magnificent stone arch viaducts for the railway extensions through the Great Dividing Range. However, for major river crossings he successfully asserted the need for large, high-level iron bridges to stay above maximum flood levels, and to carry the heavy steam locomotives. This was particularly so in the boom years of the 1880s when roads were seen as feeders to the railways and were allocated less funding. Consequently, road bridges were dominated by the cheaper timber construction.

High-level flood-free structures were not the case for most road bridges so they were built either at a low level to let floods pass over or somewhat higher so as to pass moderate floods only. The slower, lighter road traffic could make do with timber bridges, mostly 30-foot (10m) span timber beam bridges and timber trusses up to 90 feet (27m) spans.

In order to meet the growing need to span the numerous creeks and rivers to move rural produce, goods and passengers clear of river fords, timber beam bridges offered the cheapest and quickest solution. This is because they used the abundant local hardwoods and they involved simple construction details. Thousands of these bridges were built, mostly as independent structures. Many were also built as approach spans to major bridges so as to reduce the overall project construction costs.

The most spectacular example of timber beam bridge construction is the long timber viaduct across the Murrumbidgee flood plain at Gundagai. Originally completed in 1869 it was replaced by a new viaduct in 1896, which, although out of service, is extant and is now the responsibility of Gundagai Historic Bridges Inc.

Commissioner Bennett's 1865 and 1870 Reports to the Colonial Governments contain lists of bridges for the Southern, Northern and Western Roads (Highways), and shows that a large majority were timber 'beams on piles' (Bennett 1865, 1870).

The clearest evidence of the role of the timber beam bridges in the developing road network is given by successive PWD Roads and Bridges Branch Annual Reports from 1892 to 1902 (PWD 1892 to 1902). The reports show that the total number of bridges built steadily increased from 2,700 to 3,700 with the larger bridges, timber trusses, masonry arches, iron girders and iron trusses being specifically identified and described. The latter averaged only around 13% with timber beam bridges as 87% of the total number of bridges at the beginning of the 20th century.

Timber beam bridges were cheap and represented good value for the restricted finances of the colony of NSW. But in the long term, the total price was high taking into account the accumulated maintenance costs, many times greater than the initial cost of construction. There has also been a steady depletion of the hardwood forests, which now makes the supply of good timber a critical factor in maintenance of timber beam and timber truss road bridges.

1.3 The Timber Beam Bridge

The best descriptions of the construction and uses of timber beam bridges are those contained in papers by Harvey Dare in 1904 (Dare 1904), Percy Allan in 1924 (Allan 1924) and Frank Laws in 1931 (Laws 1931).

William C. Bennett

Percy Allan

Harvey Dare

Collectively they confirm that the timber beam bridge was the most common type of road bridge, due to the simple form and the myriad of minor crossings of creeks and small rivers. This situation persisted into the 1950s when steel production recovered after World War II and prestressed concrete was introduced. Thereafter, very few new timber beam bridges were built, and a great many have been replaced by steel beams or precast prestressed concrete units, or stripped of their infamous planked decks and covered by a slab of reinforced concrete.

The bridges can be classified into two design phases:

- pre–1894 traditional design; and
- post–1894 when the design was improved to make the bridges cheaper, stronger and requiring less maintenance.

These bridges may be classified according to the following types:

- low-level where the superstructure is submerged by most floods; and
- high-level where the superstructure is above the design flood level.

1.3.1 Pre-1894 Timber Beam Bridge Construction

The construction details from the period of 1840 to 1894 consisted of a series of timber trestles each with 3 to 5 piles of 14-18 inch (360-460mm) diameter driven into the bed of the waterway. The piles were capped directly over their tops by a 12 inch x 12 inch (300 x 300mm) headstock. A headstock is a single piece of timber sitting over the tops of the piles. To replace it required raising the whole superstructure to obtain clearance. The piles were then braced on the outsides by opposite inclined 10 inch x 4 inch (250mm x 100mm) planks to form cross bracing.

Pre-1894 detail at top of trestle

For a low-level bridge, the cross bracing would be omitted whereas for a high-level bridge there could be two levels of cross-bracing separated by a pair of horizontal wales, one on each side of the piles, and with another pair just above ground level.

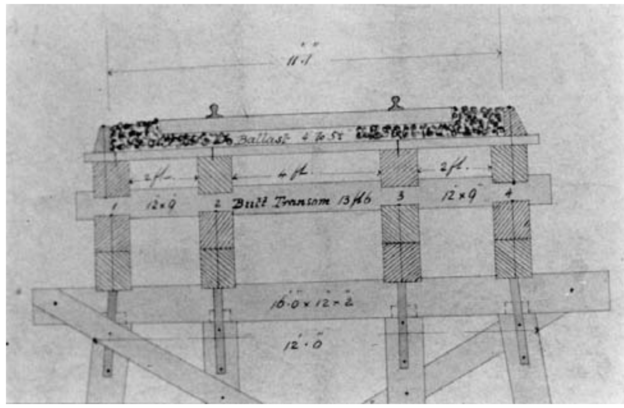
Supported on the headstock, and at right angles to it, would be a set of short (8-12 foot) 12 inch x 12 inch timbers, called corbels. Their number and location would be the same as the main longitudinal beams that were usually 12 inch x12 inch dressed or 15 inch (380mm) logs dressed only at their ends to sit flat on the corbels. Both 12 inch x 12 inch beams and 15 inch round beams were used in timber beam road bridges. The most common arrangement was for the dressed or squared timbers to be on the outside for appearance sake and the round logs with their bark attached "hidden" in the interior. The lengths of these beams would be either equal to the distance centre to centre of the trestles when cut square or longer if overlapping scarfing was used over each support. On top of the main beams were the 3 inch (75mm) thick transverse deck planks.

For railway bridge spans longer than 35 feet (11m), compound beams were used whereby two 12 inch x 12 inch timbers, one above the other, would be locked together by a combination of vertical bolts and wooden keys, in precut slots, across the interface.

1.3.2 Post – 1894 Timber Beam Bridge Construction

In 1894 Percy Allan began his redesign of both the timber beam and timber truss bridges (Allan 1924). His purpose was to greatly simplify construction and maintenance and to minimise the amount of timber used. In terms of the latter, Allan was aided by Professor Warren who conducted extensive research into the strengths of Australian hardwoods (Warren 1890).

A typically costly maintenance item was the replacement of headstocks that were attached to the tops of the piles by a combination of internal mortise and tenons, and external strap bolts. The whole superstructure at that trestle had to be raised by the height of the tenon so the headstock could be raised and withdrawn.



Cross-section of a rail timber beam bridge prior to 1894.
Note the mortise and tenon joints between headstock and piles which were typical of those used on road or rail timber beam bridges.

Allan's solution to this problem was simple. A pair of half-headstocks or capwales was checked into the piles at their tops, one on each side, and cross-bolted. They could be replaced without raising the superstructure. The time consuming carpentry required to make the mortise and tenons, and the use of the strap bolts were eliminated.

Furthermore, the lengths of the corbels were reduced, scarfing of the main beams over the trestles was eliminated and simple squared butt ends introduced and the number of shear keys for compound beams was reduced. Full-length piles were eliminated and were cut off just below ground and covered by a concrete sill or capping beam, then an independent trestle structure was built on top of the sill. This system could not be applied to the abutments due to the effects of lateral earth pressure, so full height piles were retained at the abutments. The deck was changed from a single layer of 3 inch (75mm) cross planks, to two layers of 2 inch (50mm) planks, one cross layer with a longitudinal layer over the top. This practice continued as circumstances dictated until formalised in the 1950s as standard for all timber decks.

The overall effect of the changes was to reduce the initial cost of construction by 20% and reduce maintenance costs as well as extending the service lives of these bridges.

A development in the 1920s was the use of spiking planks under the deck between the beams. It had become clear that the wear and tear and impact on the deck planks was severe. A beam outlives several decks and this led to an excessive number of spike holes in the beams with successive decks. The holes allowed the penetration of water into the beams, which is the bane of all exposed timber construction. Spikes were installed into the spiking planks rather than the beams, thereby reducing this problem.

Improved detail at top of trestle

The 1894 timber beam road bridge

First layer of cross planks on the girders

Second layer of longitudinal planks

The differences in details between the pre- and post- 1894 timber beam bridge designs generally assist in identifying the era of a timber beam bridge by site inspection, although two factors can lead to an incorrect decision. Firstly, there was a transition period after 1894 before the wholesale change over to the new design. Consequently, bridges of either type were built during the late 1890s. Secondly, despite the 1894 design becoming the new standard, site visits have revealed many younger timber beam bridges from the 1920s and 1930s, which have old style details such as single member headstocks across the tops of the piles of the trestles. Why the reversion to outmoded practices occurred is not known or recorded.

1.3.3 Low-Level and High-Level Timber Beam Bridges

Percy Allan effectively summarised the situations governing the use of low-level bridges:

> Many of the New South Wales rivers carry little water in dry seasons but are subject to very high floods of great width and carrying large quantities of drift timber. In some cases the floods are short duration whilst others remain at a high level for months. Experience and judgment are consequently required to determine whether, with small traffic to be served, a low level bridge available for most of the year can be safely adopted, or should a high level bridge be adopted above flood level (Allan 1924).

There is always a large risk with the height of a low-level bridge. These bridges need to be placed at a certain height above normal water level. This height was determined such that the bridge was available for traffic in times of small floods, yet was low enough to be submerged to a sufficient depth to allow drift timber to pass safely over in a major flood. The deck of such bridges seldom exceeds 2 metres above normal water level.

Some low level bridges were built at higher levels than designed due to an agitation being started by locals to raise the deck following the authorisation of the bridge. Many failures have occurred in the State with low level bridges due to their being built at a higher level than originally contemplated by the engineer with consequent exposure to damage by drift timber which was not allowed for in the original design.

For high level bridges, the criterion is to maintain traffic flow over all likely levels of flooding. The decks were usually placed 0.6 metres clear of the highest known flood. However, there is a limit to this ideal when the trestles become as tall as the spans are long, and where the whole structure is quite long. With excessively tall trestles the larger proportion of costs is in the substructure and the forest of relatively closely spaced trestles can present a serious obstacle to drift timber during flooding. The conventional solution was to increase the spans of the superstructure using timber trusses, steel beams or iron lattice spans, with fewer but sturdier timber trestles, masonry or cylindrical iron piers.

Solutions beyond the limits of timber beam bridges,
left, timber trusses on concrete piers over the Clarence River at Tabulam,
right, iron lattice trusses on cylindrical iron piers over the Snowy River at Dalgetty.

1.4 Summary

The timber beam road bridge, in its four forms of pre- and post-1894 and low and high-level, was the mainstay of road bridges in New South Wales from the time of European settlement at Sydney Cove in 1788, through to the end of World War II in the late 1940s. At peak usage they numbered in excess of 4,000 (including those forming approach spans to major bridges), and represented around 80% of the total road bridge population controlled by the Department of Main Roads.

These bridges played a significant part in the development of land transport, road and rail, during the second half of 19th century in colonial New South Wales.

Over the years their shortcomings have been exposed. These are:

- Low strength for the heavier and faster modern traffic
- High maintenance costs
- Construction details that allow penetration of water and hence deterioration of members
- Lower durability due to the declining quality of available hardwoods for replacement elements
- Overall superiority of steel and concrete bridges.

As a class of bridge the timber beam bridges served the Colony and State of NSW well for 150 years as a cheap 'temporary' structure to get the movement of goods and people 'out of the mud'. These temporary structures often become permanent with the renowned durability and strength of the Australia hardwoods being tested to the limit.

During the second half of the 20th century the replacement of timber beam road bridges has occurred at such a rate that their current population (excluding a larger number of similar bridges on the railway system) is approximately 4,000. About 110 are under the control of the Roads and Traffic Authority, around 800 are controlled by the State Rail Authority and approximately 3,000 are controlled by Councils.

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