



# Pre-1930 Metal Bridges

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Study of the Heritage Significance of Pre-1930  
RTA Controlled Metal Road Bridges in NSW

1998

## HISTORY OF METAL ROAD BRIDGES IN NSW

### 1.1 Historical Review

The chronological list of metal bridges supplied with the Brief provides a convenient framework for this historical review for which there are the following principal papers:

- *The First 60 Years of Metal Bridges in New South Wales* (Fraser D.J. 1986);
- *Moveable Span Bridges in New South Wales prior to 1915* (Fraser D.J. 1985);
- *Curved-tracked Bascule Bridges in New South Wales and their relationship to the Cardioid* (M A B Deakin and D. J. Fraser 1995);
- *The Roadmakers* (Department of Main Roads New South Wales 1976);
- *Bridge Building in New South Wales 1788-1938* (Department of Main Roads New South Wales);
- *All About Bridges* (Department of Main Roads New South Wales 1970);
- issues of *Main Roads* (Department of Main Roads New South Wales);
- *Highway Bridge Construction. The Practice in New South Wales* 1924 six-part series (Percy Allan 1924).

Other references are cited where they are relevant.

However, the supplied list does not indicate what type of bridge each entry is (arch, truss, girder/beam or moveable span), nor the material used (cast iron (CI), wrought iron (WI) or steel). This limits the ability of the list to convey a historical overview or to give any evidence of trends in the use of each type of bridge. This is shown in Table 3.1 below.

Table 3.1

Types, Materials and Eras of the Bridges

Arches	1		1889	CI
Trusses	27		1865 – 1930	WI then steel
Including:	14	Lattice Trusses	1874 – 1893	WI
Girders and Beams	16	Plate Web and Rolled	1867 – 1928	WI then steel
Moveable	7		1888 – 1906	WI then steel
Including:	4	Lift	1888	WI
	1	Swing	1903	Steel
	2	Bascule	1905 – 1906	Steel



*The Albury arch*



*Typical lattice truss*



*Overhead braced truss*



*Nepean girder, Penrith*



*Steel beams at Wallarah Creek*



*Lift bridge at Brewarrina*

*An example of the different types of metal bridges.*

In addition to the principal 51 bridges, the RTA supplied details of 32 similar metal bridges, under the control of other agencies such as the Rail Access Corporation and local councils, which are for comparative purposes in assessing the heritage rankings of the 51 bridges. These other bridges are included, where relevant, in the historical review.

This review is not simply a presentation of dates and technical facts, it is a component of a broader history in which politics, economics, social inputs, personalities and technical innovations are just as important as the technical history, and more so on occasion.



*Glebe Island swing bridge*



*Bascule bridge at Coraki*

For example, the most common form of road bridge in colonial New South Wales was the timber beam bridge (Cardno MBK 2000). Based on the availability of high quality local hardwoods, such as ironbark, these bridges were cheap and easy to build. Although their long-term maintenance costs were to prove high, they became the foundation bridge structure for the developing network of roads (and railways) and by 1900 represented 87% of the road bridge population (PWD Annual Reports). Timber truss bridges, in contrast, comprised approximately 10%.

The cause for this dominance of timber was formalised by government decree in 1861 when the enormous costs of John Whitton's imported wrought iron railway bridges at Menangle, Penrith and Goulburn had the potential to bankrupt the fragile economy of New South Wales. Only metal bridges with essential technical merits were approved and only during the boom years of the 1880s was there a significant use of major metal bridges, particularly the lattice trusses. The depression of the early 1890s further restricted the use of metal bridges until the economic recovery began around 1895 by which time steel, also an expensive import, had displaced wrought iron.

Despite the establishment of a steelworks at Lithgow in 1908 followed by the BHP steelworks at Newcastle in 1916, local production did not begin to meet local needs until the mid-1920s. In the case of the railways, an extensive programme of brick arches compensated for the limited supply of steel for bridge construction.

Consequently, there was a general lack of locally produced wrought iron and then steel up to about 1930. Typically, steel for the 1929 Tom Ugly's Bridge over the Georges River at Sylvania was supplied by Cargo Fleet, England. But then, metal road bridges in the 60 years from 1867 to 1927 were a very small percentage of the total population of road bridges, even though they dominated the major bridges. For most of this time, the Annual Reports of the Department of Public Works indicated a bridge population steadily increasing to around 4,000 with metal bridges accounting for less than 3%.



*Dorman Long (England)*



*Cargo Fleet (England)*



*Shelton (England)*



*Hallside (England)*

On 1 January 1907 the Local Government (Consolidation) Bill came into operation whereby an administrative system of Municipal and Shire Councils came into being. The councils were to be responsible for a wide range of local activities hitherto managed by the previous colonial governments and the recent State governments. Councils could finance these activities by levying rates on the populations (ratepayers) and properties within their boundaries. But it was recognised that councils could not generate enough income to fund expensive works programmes previously carried out by the PWD (1906-07 Annual Report).

Therefore, in the 1906-07 PWD Annual Report under local government there appeared the following:

*In accordance with the Provisions of the Act a number of bridges have been declared to be national works, and so exempted from the control of the councils. Only such works as, by reason of their size, cost, and extra-local importance, are such as the local councils cannot reasonably be expected to maintain, have been declared to be "national".*

Two schedules were published in the Government Gazettes of 31 December 1906 and 27 March 1907 proclaiming the listed bridges to be National Works. These lists included such bridges as Vale Creek, Perthville; Murrumbidgee River, Gundagai; Shoalhaven River, Nowra; Hunter River, Luskintyre; Orara River, Bawden; Nepean River, Penrith; Bungambrawatha Creek, Albury; A'Beckett's Creek, Parramatta; the bascule bridges at Coraki and Maclean, and so on.

A total of 258 bridges were listed to be National Works, including timber truss bridges and some iron beam bridges. Most of the older metal bridges reviewed in Section 4 were so proclaimed, which attests to their size, importance and significance.

Therefore, the bridges in this study represent a very significant group of survivors in terms of heritage significance.

## 1.2 Deck, Half-Through and Through Bridges

These are important technical terms about bridges because they relate to the appearance of bridges and how they carry their loads to their supports. All three categories are represented in the bridges in this study. The simplest definitions are:

- **Deck bridges** have the whole of their superstructures below the level of the deck, that is, the deck sits on top of the bridge.



*Beam bridge at Oxley*



*Manilla lattice truss approach*

*Two examples of deck bridges: beam and lattice truss.*

- **Half-through bridges** have a cross-section that is U-shaped. The deck spans between the bottom levels of the supporting superstructure and traffic passes between or through a shallow depth bridge.

Note that the top of the superstructure is open so that nothing joins the tops of the side bridging elements (it would be a barrier to traffic), hence the term half-through bridge.

A piece of bridge vernacular, occasionally used in Australia, is the American term “pony bridge” or “pony truss” for the half-through bridge, because it is too small to have overhead bracing like a “fully grown” bridge.



*Girder bridge, Penrith*



*Bawden lattice bridge*

*Typical half-through bridges.*

- **Through bridges** are usually taller trusses having bracing between the tops of bridging elements such that the traffic drives through the bridge like a spatial tunnel.



*The Luskintyre trusses are a good example of a through bridge.*

It is worth noting that for pre-1930 bridges in New South Wales:

- Beam bridges, old or recent, are usually deck bridges;
- Girders (beams which are fabricated because they are deeper than “off the shelf” rolled steel beams and can range from one to three metres deep) and trusses of modest depth (the lattice trusses), during the second half of the nineteenth century, usually made half-through bridges. However, such bridges have a degree of structural inefficiency and eventually reach their limits of application;
- Then in the first quarter of the 20<sup>th</sup> century, with better structural design and the steady increase in the spans of bridges, the taller through truss began a dominance that lasted another 50 years.

### 1.3 Iron and Steel Trusses with Overhead Bracing

In Section 3.2 attention was drawn to three types of trusses and the illustrations of them. They were the deck truss (wholly beneath the traffic), the half-through or “pony” truss (the

traffic drives between the trusses and large vehicles are taller than the trusses) and the through truss (trusses tall enough to be cross-braced overhead, above the tall vehicles, such that all traffic drives through the bridge like a spatial tunnel).

The approach spans to the 1886 Manilla bridge (No3655) are examples of deck trusses; the family of colonial lattice bridges exemplify the half-through or “pony” truss; and the 1881 Whipple trusses at Nowra (No 713) are through trusses. The first example of a post-colonial through truss is at Luskintyre, in the Hunter Valley, so a brief explanation of its development follows.

The development of through trusses was essentially an American innovation. Although some early examples appeared in Britain and Europe, bridges in the Old World were dominated by the half-through bridges, girders and trusses. Even when overhead bracing was used, it was generally applied to a half-through structure as shown in the two photographs below.



*European style half-through bridge with overhead bracing at Bathurst*



*1914 Goodiwindi trusses, axis view*

Through bridge construction began with the American covered bridges as early as the 1840s. There were various types of patented timber truss configurations but all were tall enough to be completely enclosed by a protective “skin” of timber boards along the sides plus a roof. The unlit interior really did make driving feel like being inside a tunnel, truly a through bridge.

The American iron industry grew rapidly from the 1860s and metal bridges, particularly those used for the heavier railway loads, began to replace timber bridges and were usually the first choice for new lines. Many of the metal bridges were half-through, particularly for girder bridges where span limitations automatically meant girders of shallow depth, without requiring overhead bracing.





*One American enclosed through bridge was the covered timber bridge which became an open spatial arrangement in metal.*



*Early American through truss*



*Steam loco and train on half-through girder bridge*

As the spans of bridges increased, the metal truss quickly emerged as the ideal structure. The greater the span, the deeper (taller) the side trusses, and very soon through construction from the covered timber bridges became standard. With the inclusion of pinned joints (see photographs of the Nowra Bridge deck in Section 4.7) and the change over from iron to steel around 1880, the large pin-jointed steel truss came to symbolise American bridge technology.

A new generation of engineers educated at Sydney University, J J C Bradfield and Harvey Dare to cite just two, were well aware of the technical merits of American trusses but it was not until the retirement of long serving Chief Engineers John Whitton (Railways) and William Bennett (PWD) that American bridge technology took hold in New South Wales. Following their successful use in 1894 on the Lismore to Murwillumbah Railway, American style trusses (with large diameter pins now being replaced by riveted joints) became standard for all major rail and road bridges through to the advent of welded girders and developments with pre-stressed concrete box girders in the 1960s.

The application of American steel trusses to major road bridges in New South Wales began with two bridges over the Hunter River at Luskintyre and Singleton (see Section 4.16).

## 1.4 Buckled Plate Floors

Iron was an expensive import during the colonial period (refer Section 3.5) to the extent that its use was restricted to the main structural components of bridges, that is, the piers of the substructures and the beams and trusses of the superstructures. The usual cost saving device was the use of timber for the approach spans and for the decks.



*Typical timber beam bridge deck,  
its log girders and plank deck.*



*Elevation of timber approach.*

However, with low initial costs, timber decks had high long term costs due to their need for replacement approximately every 20 years.



*Typical timber deck on a lattice bridge at Forbes and the use of buckled plates*

Buckled plates were a form of decking support which provided a rigid connection between beams and cross girders and gave a permanent smooth riding surface. The term 'buckled' is something of a misnomer because it implies collapse whereas the plates were simply dish-shaped and attached, dome upwards, to the tops of the beams or cross girders to form a waffled iron floor. This was then covered with concrete or a similar material to form the road surface.



*The distinction between rough, exposed timber decks and smooth surfaces provided by buckled plates.*

The buckled plate floor has proved to be a cost-effective component of bridge decks and its use, or some variants, has been continued through to modern times even though types of temporary reusable formwork units between beams have been developed. For example, the 1929 Tom Ugly's Bridge has a buckled plate floor with a concrete running surface (refer Section 4.26).



*Underside of concrete slab exposed after temporary formwork has been removed.*

## 1.5 Iron and Steel

Iron is the most important of the industrial metals. Its basic alloys, cast iron, wrought iron and steel, are the world's cheapest and most useful metals. They are the key to the development of our modern civilisation, particularly since the start of the industrial revolution over 200 years ago. From bridges to railways, ships, motor vehicles, machinery, canned foods, knives and forks, even reinforced and pre-stressed concrete, iron and steel have played a fundamental role.

Iron is a generic term that can be applied to the pure element, iron, or to its alloys, particularly cast iron and wrought iron, but not generally to steel because it has proved to be "something different" and is by far the more important and dominant metal. Steel bridges are usually referred to as metal bridges, not iron bridges, such is the important distinction between the two.

The three basic iron alloys consist almost entirely of two elements, iron and carbon, with iron usually in excess of 95% and carbon at a maximum of 4%. Special alloys have other elements added, usually at the expense of the iron, in order to achieve particular characteristics. For example, non-corrodible stainless steel has 12–30% chromium and some nickel, whereas manganese imparts hardness and long wearing qualities.

When viewed through a microscope, iron appears as a collection of grains. Pure iron has a useful strength (equal in tension and compression), is easily worked into shapes by rolling or forging (it is malleable) and is weldable. When overstressed, it deforms by a large amount before breaking (it is ductile), but it is relatively soft and so is easily abraded. Wrought iron is almost pure iron but it is the result of an expensive manufacturing process.

The introduction of carbon changes all these basic characteristics, initially for the better then gradually for the worse. As little as 0.25% creates mild steel, which is a much stronger metal than wrought iron because the carbon lodges between the iron grains causing a locking action that resists deformations. However, malleability, ductility and weldability remain good. Being readily rolled into plates, bars, wire and a large range of structural shapes, it is the most widely used steel. Its manufacturing process, incorporating large open hearth furnaces, allows huge quantities to be made much more cheaply than wrought iron.

As the amount of carbon increases, it continues its locking action but begins to push the iron grains apart. The introduction of 0.45% carbon creates high strength steel with a doubling of strength but at the expense of a significant loss of malleability, ductility and weldability. Loss of ductility means an increase in brittleness, hence high strength steels are susceptible to fatigue failure in which variations of internal stress cause minute cracks to progressively increase until fracture.

By the time the percentage of carbon reaches 1%, strength is still high but the other characteristics are unsuitable for structural use, such as bridges. However, the steel is very hard and is therefore widely used for machine parts and tools.

At 2%, all these characteristics have disappeared and cast iron is the result. It has useful compression but negligible tensile strength. It cannot be rolled or worked but has improved fluidity suitable for casting into moulds, hence the name cast iron. Under load, particularly in tension, it fractures without signs of distress as it is now brittle (a dangerous condition) and so it cannot be welded. It has become a niche product suitable for particular applications such as columns in buildings and trestles for bridges.

At 4% carbon the metal is useful only where sheer mass is desirable, such as engine blocks for motor vehicles.

Historically, steel and high strength steels have been used for two thousand years but mainly in weaponry, particularly for swords. The high costs of labour intensive production and the small quantities produced meant that steel was not available for general use, such as for bridges. But cast iron was well known and widely used. It was cheaper to make and large quantities could be produced.



*Ironbridge, the first metal bridge over the Severn River, England*

The first metal bridge, the 1779 Ironbridge in England, was an open, lightweight arch, a basic compression structure, for which cast iron was ideal and affordable.

Concurrently, ironmakers were experimenting with methods to refine cast iron, as had been done by blacksmiths for centuries, but in economic quantities. The most successful method was developed by Henry Cort in England in 1783. His “puddling” process raised a quantity of cast iron to a spongy white-hot mass that was beaten under a forge hammer (it was wrought or worked or shaped) such that the impurities and the carbon were oxidised and squeezed out as a slag. The process was repeated a number of times until a uniform mass of near pure iron was obtained. It was malleable and was able to be worked into many forms, merchant bars or structural sections. This was wrought iron.

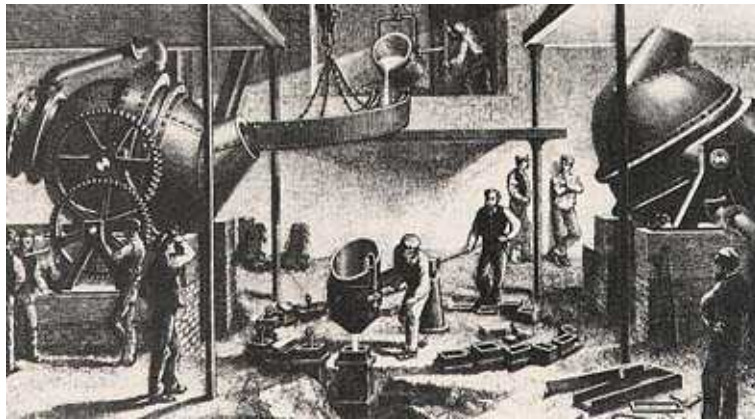
It was an outstanding contribution to iron technology and increased production from one ton per day to 15 tons per day. This process provided the means for making pure iron of reasonably uniform quality and in quantities needed for the great industrial expansion of the early 1800s. Wrought iron became the major civil engineering material for railways and bridges where the brittleness of cast iron made it unacceptably dangerous. However, when appropriately used, a mix of cast iron and wrought iron elements could create useful bridges in which compression members are cast iron and tension members are wrought iron. There are some 150 year old examples still in use in England and Europe.

The quest to further improve wrought iron continued. Experience had shown that small amounts of carbon could increase strength, but the manufacturing process beat it all out again. A new process was required.



*The labour intensive effort of producing wrought iron.*

The breakthrough came in 1856 when Henry Bessemer invented his converter, basically an iron pot with holes at the bottom by which air could be blown through a molten mass of cast iron to oxidise the impurities in only about 20 minutes. The resulting pure iron could then be transferred to another furnace where pre-determined amounts of carbon, or any other alloying material, could be added. An economical process for the production of steel had been invented. It led to the mass production of uniformly reliable, low cost steel which was stronger than wrought iron, was equally strong in tension and compression, was malleable, ductile and tough – a wonder material.



*Two Bessemer converters in use.*

Two aspects of civil engineering benefited enormously from the availability of this new metal. Railway networks were built in countries all around the world and very large bridges were built across waterways that had been hitherto considered impassable, except for ferries and punts. The famous Firth of Forth railway Bridge is a classic example.



*The famous 1890 Forth Bridge, Scotland.*

In New South Wales, industrial development, including railways and bridges, took place in the second half of the nineteenth century. The only local iron industry was the Fitzroy Iron Works at Mittagong, started in the 1850s, which only refined cast iron into merchant bars. It did, however, supply the cast iron cylindrical rings for the piers of the 1867 Prince Alfred Bridge at Gundagai. Local cast iron was also used to a limited extent for structural purposes. There are some cast iron floor girders in some old buildings in Sydney's CBD and the King Street Bridge over the railway at Newtown has cast iron beams made in 1892 by Hudson Brothers (Clyde Engineering).



*An 1892 cast iron beam at King Street, Newtown and the maker's name.*

New South Wales was dependent on wrought iron from England, an expensive import. Despite this, some splendid iron bridges, road and rail, were built between 1873 and 1893, of special note being the lattice truss bridges with spans up to 160 feet (49 metres).



*An 1884 sturdy British lattice bridge and the 1901 American Pratt trusses.*

Economic quantities of structural steel did not begin to arrive until the 1890's which coincided with the change from British to American bridge technology. The most notable change in the bridges was visual, from the sturdy somewhat heavyweight British lattice

bridges made from larger quantities of the weaker wrought iron, to the lightweight American trusses made from the stronger metal, steel.

This advantage was first demonstrated on a large scale with the 415 foot (126 metre) steel trusses of the first Hawkesbury River railway Bridge, completed in 1890.



*The largest bridge in colonial New South Wales, the American designed Hawkesbury River railway Bridge.*

By 1900, steel had displaced wrought iron, virtually world wide, and its dominance in civil and structural engineering has continued ever since. Larger buildings and larger bridges are clear evidence of its superiority.



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