Timber Truss Bridges

Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW

1998

HISTORY OF TIMBER TRUSS BRIDGES IN NSW

1.1 GENERAL

During the first fifty years of the colony of New South Wales, 1788 - 1838, settlement was confined to the narrow coastal strip between the Pacific Ocean and the Great Dividing Range. The scattered communities were well served by ships plying the east coast and its many navigable rivers.

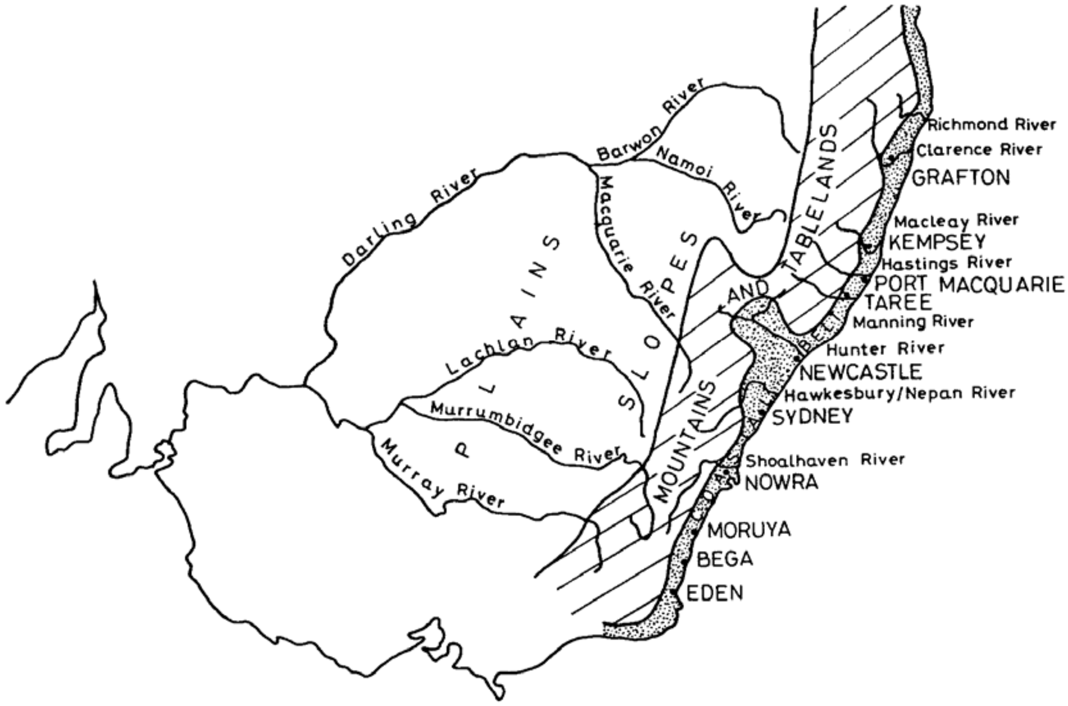


Figure 1.1a: Settlement of early colonial NSW. Shaded areas are settled.

In Governor Macquarie's time between 1810-1822, a number of good roads were built, but despite his efforts and those of the subsequent Governors Darling and Bourke, and of road builders George Evans, William Cox and Thomas Mitchell, the road system and its associated bridges could only be described as primitive. Many roads and bridges were financed through public subscriptions or as private ventures, particularly where tolls could be levied.

The first significant improvement to this situation occurred in late 1832 when Surveyor-General Mitchell observed a competent stone mason working on a wall in front of the Legislative Council Chambers in Macquarie Street. It was David Lennox[R3]. He was appointed Sub-Inspector of Roads on October 1, 1832 then Superintendent of Bridges on June 6, 1833. His first project was to span a gully for the newly formed Mitchell's Pass on the eastern side of the Blue Mountains. This bridge survives in part as a facade concealing a newer concrete structure.

Lennox's crowning achievements are the surviving stone arch bridges at Lansvale over Prospect Creek (opened by Governor Bourke on January 26, 1836) and for Church Street over the Parramatta River (1839). The former carries the heavy northbound traffic of the Hume Highway and the latter carries suburban traffic through the commercial heart of Parramatta. Their permanency, durability and high initial costs were in marked contrast to the more common and less costly timber beam structures. At the time most rivers were crossed at a ford or by a toll-charging punt.

By the 1840s with its economic slump, only the highly priced wool clip could sustain the slow and costly journeys from west of the Great Dividing Range to Sydney.

These were the conditions for land transport in New South Wales prior to the 1850s. Eliminating the worst features of this unsatisfactory situation proved to be a slow process. However, a succession of political, economic, social and technical factors starting in the 1850s, generated a steady flow of improvements.

1.2 HISTORY

History has shown that for progress to take place there must be the simultaneous occurrence of three factors, NEED, KNOWLEDGE and RESOURCES. So it was for the development of bridges in New South Wales over 60 years from 1860 to the 1920s. The principal events of the 1850s are shown in Figure 2.3a.

DATE		EVENT
1850	Aug	Separation of the colony of Victoria
	Oct	Cessation of convict transportation
1851	May	Discovery of gold
1852	June	First timber arch bridge, at Maitland
1853	Aug	First paddle steamer journey on the Murray River
1855	July	Responsible Government granted to New South Wales
	Sept	Railway opened to Parramatta
1856	Jan	First timber truss bridge at Carcoar
	May	First New South Wales Parliament
	Aug	Department of Lands and Public Works created
1857	Mar	First swing bridge, at Pyrmont
		The four Reports of Capt. Martindale on the Internal Communications of the Colony
1859	Oct	Department of Public Works created
	Dec	Separation of the colony of Queensland.

Figure 1.2a: Events

It is not within the brief of this Survey of extant timber truss bridges to elaborate on these events except to say that politics (new colonies, new Parliament), economics (the gold rush, labour shortages), social conditions (the needs identified in Martindale's reports) and technical (the two types of timber bridges) were important factors.

1.2.1 The need for bridges

At the beginning of the second half of the 19th century in colonial New South Wales, the NEED for better road transport had become urgent. Trade and commerce in commodities other than wool was being stifled and goods damaged at the prevailing river fords. Travel generally too was slow, uncomfortable and potentially dangerous, and the movement of people had dramatically increased with the Gold Rushes of the early 1850s. The New South Wales Government also saw a need for a better road system because, beginning in the mid-1850s, a significant amount of its rural wealth was being exported via the inland river system through the rival ports of Melbourne and from Goolwa in South Australia.

Capt. Martindale's reports were published in the Votes and Proceedings of the Legislative Assembly between 1857 and 1860[R4]. In them he draws 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, Burrurrundi 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."*

These are a sample of the official recognition of the need for bridges and it was also echoed strongly in the newspapers. Petitions for bridges were regularly published, for example,

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

and community frustration due to lack of building bridges

> *"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* "
> (Sydney Morning Herald 14/1/1856)

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

followed by expressions of appreciation when bridges were built

> "*as a public convenience, more especially to the residents in the neighbourhood, the Hawick and Russel Street bridges are already much appreciated*"
> (Sydney Morning Herald 11/3/1856)

> "*it would be impossible to describe the intense joy of the inhabitants and travellers generally when they are able to cross the rivers to and fro at any time without hindrance .... it was like a new era*"
> (Anonymous)

> "*bridges present good evidence of the progress of civilization in this country*"
> (Town and Country Journal, April 3, 1880, p648)

and even into the twentieth century the appreciation continued:

> "*several fine new bridges have recently been constructed in inland districts of New South Wales by the Public Works Department ....they will supply a long felt want and give easy communication to people living on both sides of the river*"
> (Town and Country Journal, June 30, 1909, p37)

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

1.2.2 Agriculture and transport

The impact of poor roads and lack of bridges has been indicated in the previous section, and the contemporary evidence is explicit. In his First Report, Capt. Martindale told the Government that

> "in*wet weather rivers are impassable, lives are lost bullock teams make only 3 - 4 miles per day produce rots on the ground for want of transport*"

and in his Fourth Report he

> "*earnestly recommends more Government money for the road program. If improvements stop, dissatisfaction prevails.*"

Punts were not a solution because "*frequently hundreds of teams and horses were waiting to cross*" and the tolls at each of the punts used on a long journey added significantly to the cost per ton-mile.

In the Riverina, the regions was the cheaper bulk transport of the River Trade but this diverted the rural wealth to Melbourne and to Goolwa in South Australia. For the huge area of Western and North-Western New South Wales, access to markets was very poor and settlement on the land was at a low level.

Engineering technology was however about to change all that. The greatest impact came from the railways, particularly once they crossed the Great Dividing Range after 1870. As early as 1855 the developments in timber road bridges were recognised as having long term benefits when, concerning a new bridge over the Belubula River at Carcoar, the Sydney Morning Herald of December 31 remarked

> *"the bridge is on the main road from Bathurst and Western Districts to the Southern Road and will afford the utmost assistance opening up valuable land."*

This did not come to pass until 1861 when Premier Sir John Roberston's Crown Lands Alienation Act provided for free selection of crown lands. New South Wales was gradually transformed from a land of semi-wilderness and large sheep runs into areas of closer settlement including permanent towns and villages.

1.2.3 Rail - road relationship

In the twenty years 1860 to 1880, the adjoining colonies of Queensland, Victoria and South Australia were siphoning off much of the wealth from those border areas of NSW so distant from Sydney. Successive New South Wales governments saw railways as the way to reach those districts and redirect the goods and trade through Sydney. Huge amounts of borrowed capital were invested in the expanding railway network, significant worse for roads and associated bridges was that railway construction absorbed as much as 80% of the Public Works budget[R5]. By the 1880s the political decision had achieved its goals and railways had reached Hay in the Riverina in 1882, Albury in 1883, Bourke in 1885 and Wallangarra in 1888. The fast, all-weather, low-freight-cost railways "killed off" the River Trade and the subsequent spread of branch lines made it possible to economically transport rural produce and opened up the western plains to previously unprofitable crops such as wheat.

The role of the roads was seen to be as feeders to the nearest railway yard where hundreds of men were employed in loading bales of wool and bags of wheat into rail wagons. Even so, the roads had to be suitable for heavily laden drays, particularly in the boggy black-soil country, and the waterways had to be crossed by bridges. The full extent of the branch lines was not achieved until the 1920s so there were large areas between the main railway lines where, given better roads and satisfactory bridges, it was just as easy to use the trunk roads and highways.

The need for road bridges did not decrease despite the dominance of the railways. Instead, the railways generated so much freight and public travel in wide corridors parallel to the early railway lines that roadworks and the construction of bridges proceeded at a pace. In that same twenty years of railway expansion 147 large timber truss road bridges were built together with hundreds more of the smaller span timber beam bridges.

1.2.4 Political landscape for bridges

RESOURCES required were various, with the key element being money. As early as the late 1850s it became obvious that New South Wales was not generating anything like the revenue from gold that Victoria was.[R6] The relative advantage to Victoria was in the order of 4 to 1 and Victoria was only a quarter the size of New South Wales. This meant that the larger colony had to rely more heavily on British capital to pay for its public works programs than did Victoria, with the consequential repayment of large interest bills. New South Wales governments could therefore ill-afford to be lavish with their spending and yet for political and financial reasons they had to ward off the "poachers" on its borders and this required large investments in infrastructure, particularly for railways.

One measure to ease the pressure on the limited financial resources was to avoid labour-intensive masonry arches and to heavily restrict expensive imports such as iron for structural uses, hence the edict of 1861 that local hardwoods were to be used as much as possible. Only John Whitton, Engineer-in-Chief for Railways, had the strength of personality and technical knowledge to defy the edict and build some remarkable, but very expensive railway bridges. The 1863 iron girder bridge at Menangle and the 1867 stone arch viaduct at Picton are still in use. Eventually, however, financial constraints forced him to build many kilometres of timber girder bridges, some laminated timber arches and a few timber truss bridges[R7].

For the Roads and Bridges Branch of the Public Works Department (PWD) there was no such opportunity. Their relatively small budget could not allow for grand designs, so for spans greater than the 35 feet (10 metres) limit of the timber beam bridges they initially, in the 1850s, chose the laminated timber arch which could span up to 90 feet (27 metres). Notable examples were built at Yass, Bathurst, Queanbeyan and Bendemeer. The Bendemeer bridge is shown at Fig 1.2.4a. These structures were difficult to build and proved to have expensive maintenance problems. A better timber bridge was needed and it was the timber truss.

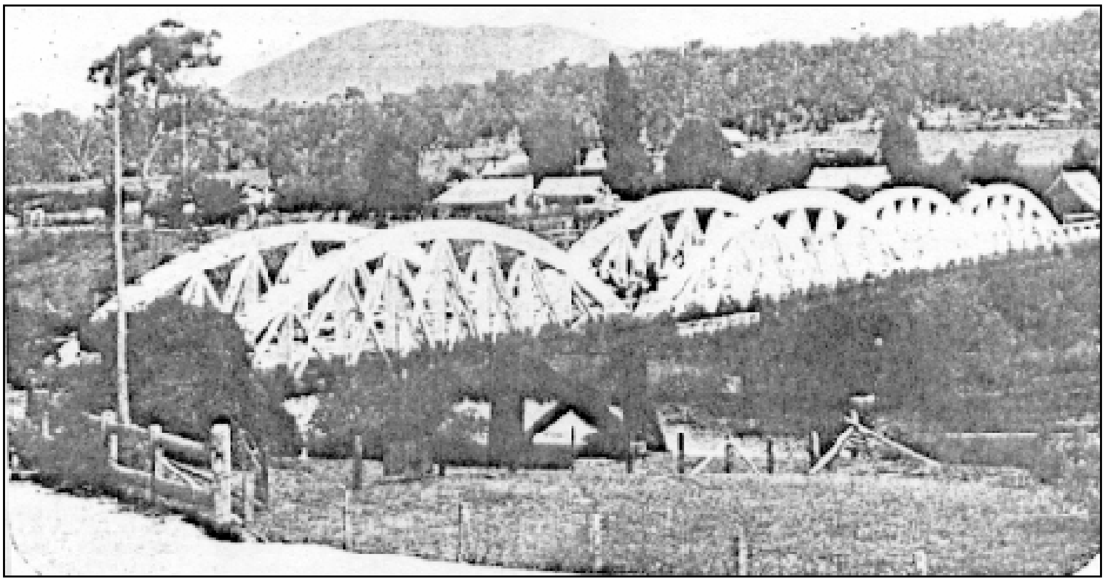


Figure 1.2.4a - 1874 laminated timber arch bridge at Bendemeer.

1.3 THE TIMBER TRUSS BRIDGE, TECHNICAL BACKGROUND AND DESIGN EVOLUTION

1.3.1 Introduction

The evolution of timber truss road bridges in New South Wales from 1860 to 1905 saw a change from traditional, virtually non-scientific, British and European structures to scientifically engineered structures based on developments in America.

Starting in the mid-1850s, the Colonial Architect began to use a European style of timber truss based on the 16th century work of Italian architect Andrea Palladio[R8] with large-span roof trusses. Typical truss details of the 17th and 18th centuries are shown in Figure 1.3.1a. Palladio showed that large roof structures could be assembled economically from relatively small sections of timber. The extension to bridges soon followed. Sketches of some of his trusses are shown in Figure 1.3.1b.

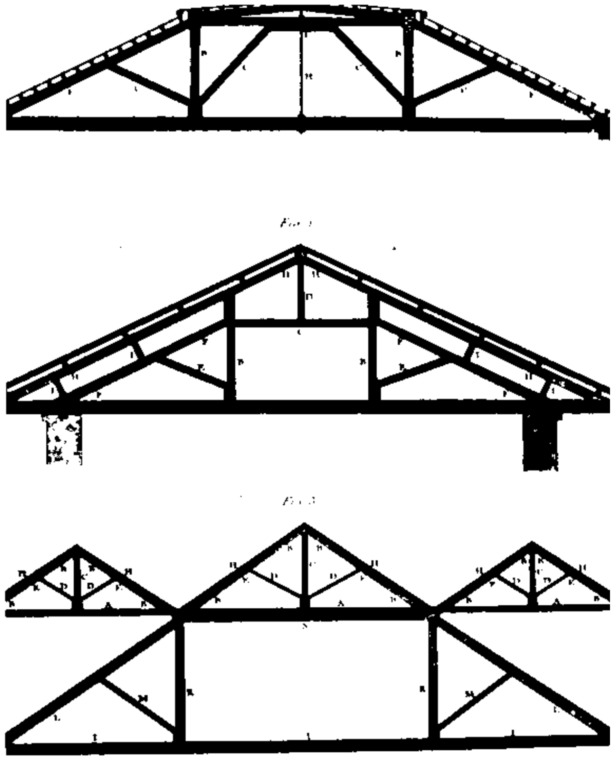


Figure 1.3.1a – 17th & 18th Century roof trusses.

A popular form of roof truss was the Queen Post which eliminated the tall central post of the King Post truss and placed two shorter posts equidistant from the centre which allowed for a horizontal top to the truss as distinct from the apex of a King Post truss. The inner rectangle of the Queen Post truss provided a readily useable space within the roof structure.

When applied to bridges, the Queen Post truss provided a longer shallower profile than a high-peaked King Post truss of the same span and, importantly, inner queen trusses could be incorporated to meet the strength required for longer spans. The Queen Post truss is in fact a simple segmental tied arch, the two sloping end members and the top horizontal providing the compression arch and the bottom horizontal member, being the tie, takes the thrust of the compression arch and holds the segmental arch in place. The combination becomes an internally self-supporting structure that simply rests on piers, trestles or abutments without applying the horizontal thrust at the abutments associated with a traditional arch.

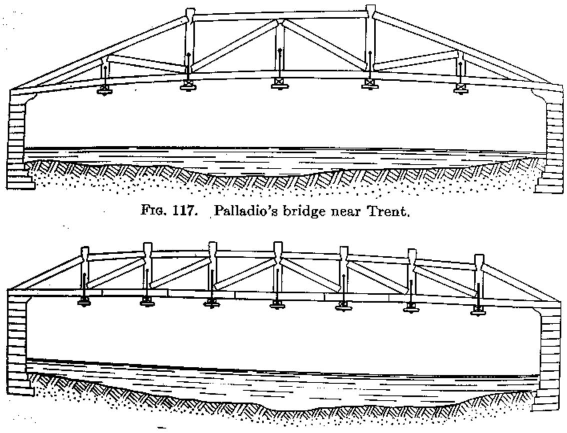
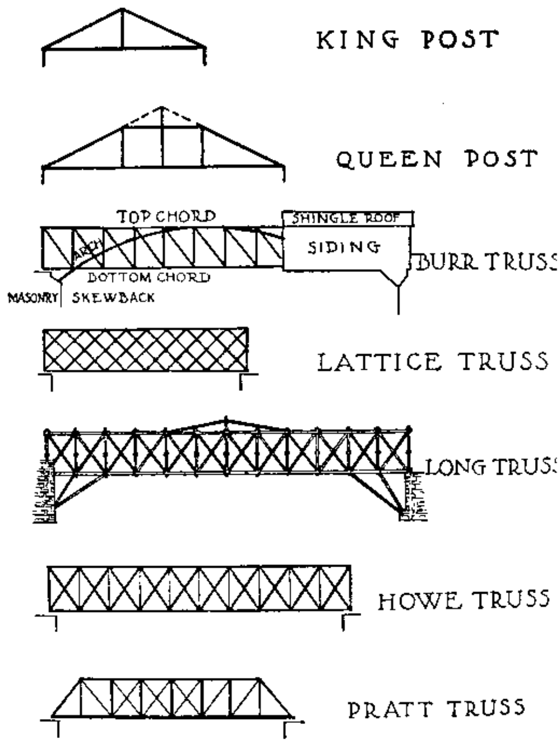


Figure 1.3.1b – Palladio's wooden trusses of the mid 1500's – Timoshenko's History of Strength of Materials page182.

In America, in the 1840s, the indigenous carpenters experimented with and patented many forms of timber truss bridges[R9]. Early examples of their designs are shown in Figure 1.3.1c,d &e. With steady scientific improvements and in-service performances, the two most successful were the Howe and Pratt trusses which, after 1894, became the dominant truss forms in New South Wales both for road and rail bridges.



Types of Timber Trusses

Figure 1.3.1c – Early trusses of the USA.

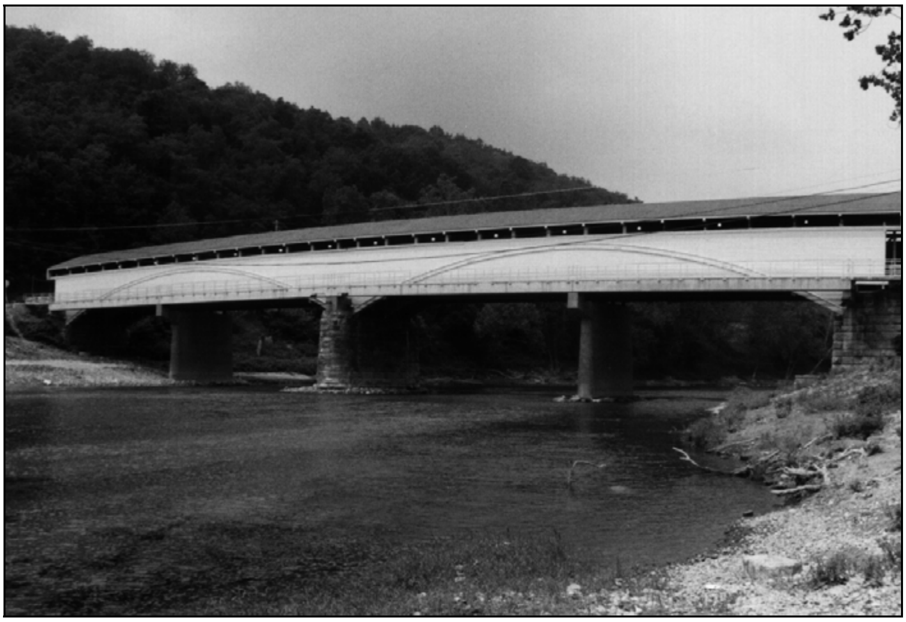


Figure 1.3.1d – Typical American covered timber bridge, the Philippi Bridge, West Virginia

Figure 1.3.1e – A typical Burr truss exposed during restoration work, Barrickville, West Virginia

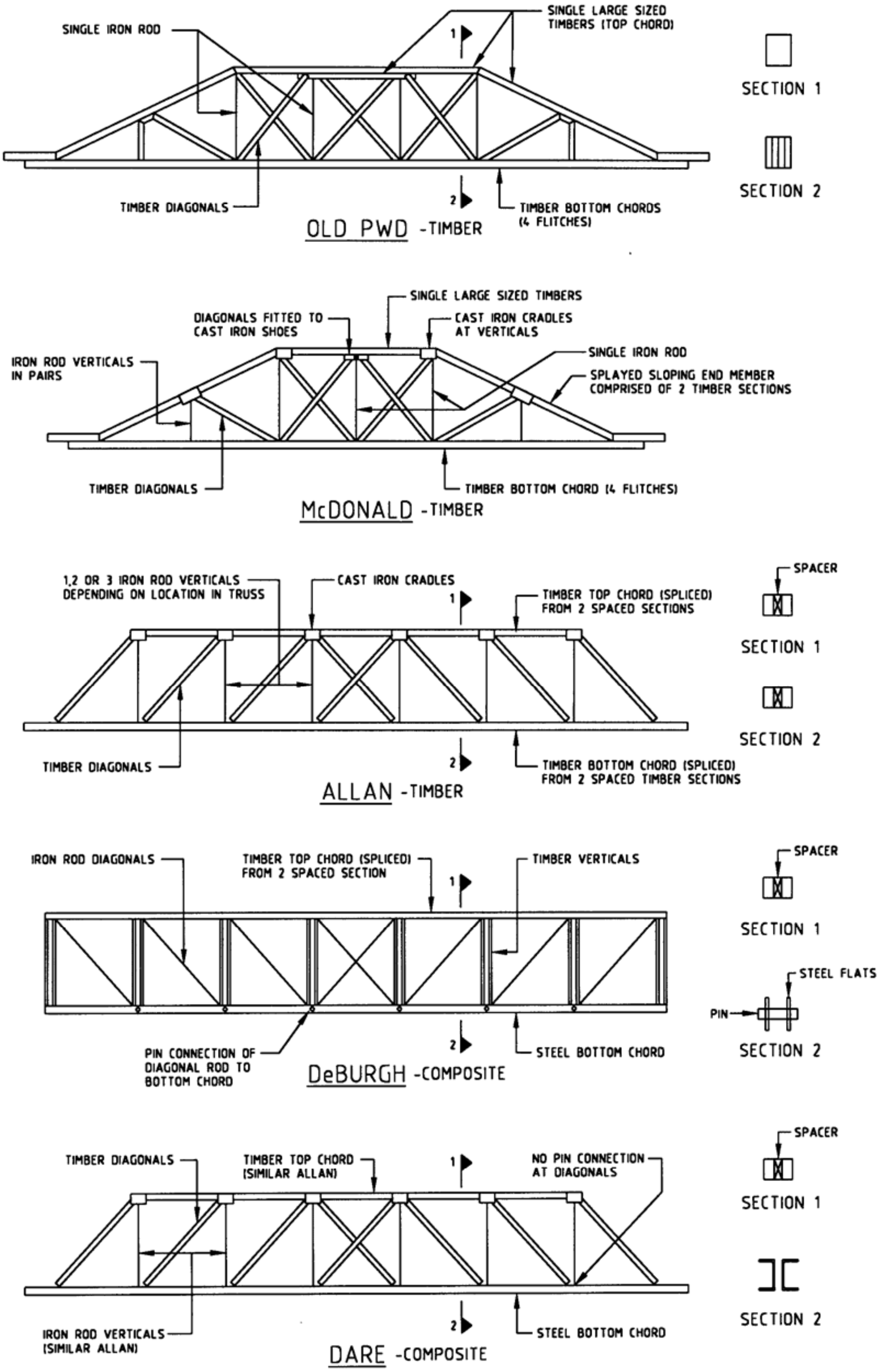


Figure 1.3.1f: Diagrams of truss types used in NSW timber truss road bridges.

1.3.2 The Old PWD Truss

In 1860, Capt. Martindale, shown in Figure 1.3.2a, recorded in his *4th Report on Inland Communications* that there were seven Queen Post truss bridges, with spans ranging from 35 to 68 feet (10 - 21 metres). But it was under William C Bennett, Commissioner for Roads and Bridges (Public Works Department) 1862–1889 (Figure 1.3.2b), that large improvements were made. During his tenure in office and despite the lion's share of the PWD budget going to the railways, he oversaw the construction of 6,000 miles (9,600 kms) of main roads and 4,000 miles (6,400 kms) of other roads and the building of 40 miles of bridges, mostly timber beam bridges and a few iron lattice bridges[R10]. The bridges also included timber truss spans, ranging from 55 to 100 feet, at 147 sites representing an average construction rate of 5 per year. This timber Queen Post truss bridge, so favoured by the PWD from 1860 to 1886, has become known as the OLD PWD truss. A typical truss of this design is shown in Figure 1.3.2c.

Figure 1.3.2a – Captain Benjamin H Martindale.

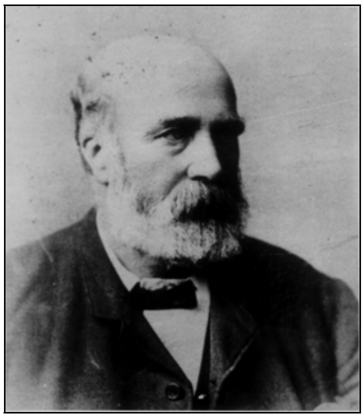


Figure 1.3.2b – William Christopher Bennett, Commissioner for Roads and Bridges (PWD) 1862 – 1889.

Figure 1.3.2c – Typical Old PWD truss
(Monkerai Bridge over the Karuah River)

The benefits to both trade and travel were enormous and the building of bridges, particularly in and near towns, and the subsequent opening ceremonies were regularly reported in the contemporary newspapers and weekly journals. There was less political controversy associated with the roads and bridges program than with the expansion of the railway system. The road network was regarded by successive governments as a feeder network to the nearest railway station or navigable river port. The technical benefits of the OLD PWD truss were limited because there was little engineering science in their design and little practical input into cost-effective maintenance[R11]. Faults were soon recognised, the major ones being as follows:

- the segmental arch components of the truss were all made from single large-sized timbers which were both hard to obtain and difficult to handle and install. Figure 1.3.2d shows a deck view of the Monkerai Bridge over the Karuah River which utilises these large sections.

Figure 1.3.2d - Deck view of the Monkerai Bridge over the Karuah River which has large timber sections typical of the Old PWD design

Figure 1.3.2e – Typical interior view of an Old PWD Truss with an inner truss at mid-span.

- it was extremely difficult to renew such members, particularly the lower inner piece of the top chord in long spans (see Figure 1.3.2e), because taking the defective member out immediately destroyed the structural integrity of the truss so it had to be temporarily supported or even taken out of service until the work was completed. This could impose great inconvenience to road traffic where the next available bridge was many miles away.
- the vertical iron rods connecting the top and bottom horizontal timbers were comprised of single rods installed through the middles of these timbers as shown in

Figure 1.3.2f. Had the theory of structures been applied, it would have shown that loads applied to the rods are larger near the ends of each truss. It is not surprising then that there were frequent breakages of the single rods which seriously weakened the truss span and incurred unexpected and recurring repair costs.

Figure 1.3.2f – View of truss showing single rods all of which are the same size

Figure 1.3.2g –Four flitch bottom chord - View from underside

- the bottom chords were made from four flitches or planks placed side by side on edge and cross bolted together (see Figure 1.3.2g). This was equivalent to vertical rather than the horizontal laminations applied at the earlier arch bridges. The same flaw existed for each arrangement of laminates, in that when the inner laminates deteriorated, it was extremely difficult to renew them and a completely new assembly of flitches was required.

- shrinkage of the local hardwoods caused joints to open up such that the truss developed excessive sag or deflection. Packing at the bottom chord joint as shown in Figure 1.3.2h alleviated the problem but required regular adjustments as the shrinkage continued over many years.

Figure 1.3.2h – Packing at bottom chord was used to help counter the effects of shrinkage.

Consequently, although the 147 OLD PWD truss bridges served their function well, with their average life being 54 years with 26 in service from 80 to 117 years, they were both expensive to build and maintain. There was scope for improvement.

1.3.3 The McDonald Truss

Throughout this period, the engineers who progressively joined the Public Works Department were mostly expatriate Britishers or Europeans and consequently, infrastructure design was dominated by British or European technology. When John A McDonald joined the Department in 1879 he was one of the first bridge design specialists and was to become Engineer for Bridges from 1889 to 1893. Almost immediately after joining the Department he set about designing a new timber truss bridge that would be easier to build and maintain and which could carry loads significantly greater than the OLD PWD designs, in order to provide some allowance for future increases in vehicle loads. The design has become known as the McDONALD TRUSS, following Percy Allan's 1924 reference to the "McDonald style" truss. Figure 1.3.3a is of the Junction Bridge at Tumut, typical of McDonald's design.

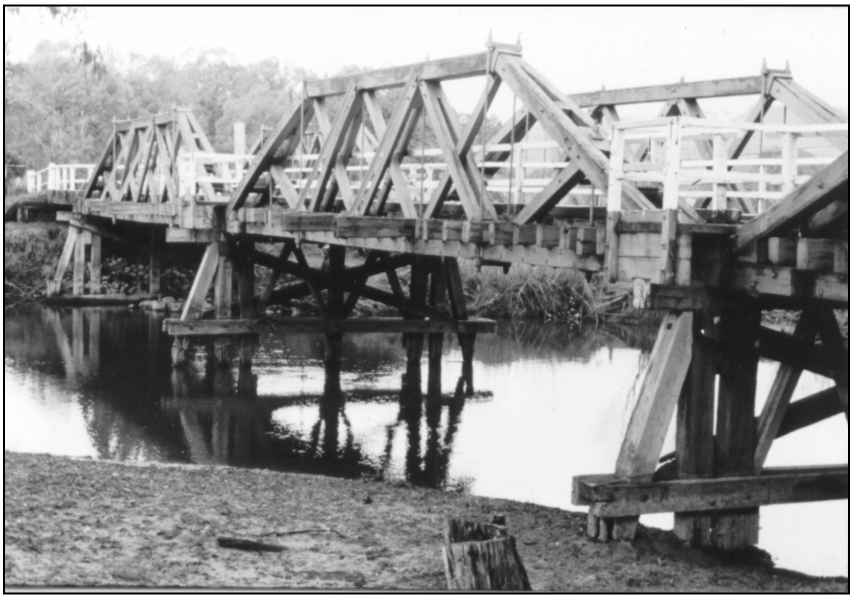


Figure 1.3.3a – McDonald Truss - Junction Bridge at Tumut remains in use to this day.

McDonald's design was still based on the European type of bridge truss so they look similar to the OLD PWD trusses, but there were important technical improvements, such as:

- elimination of the double thickness top chord for the longer span trusses (see Figure 1.3.3b).

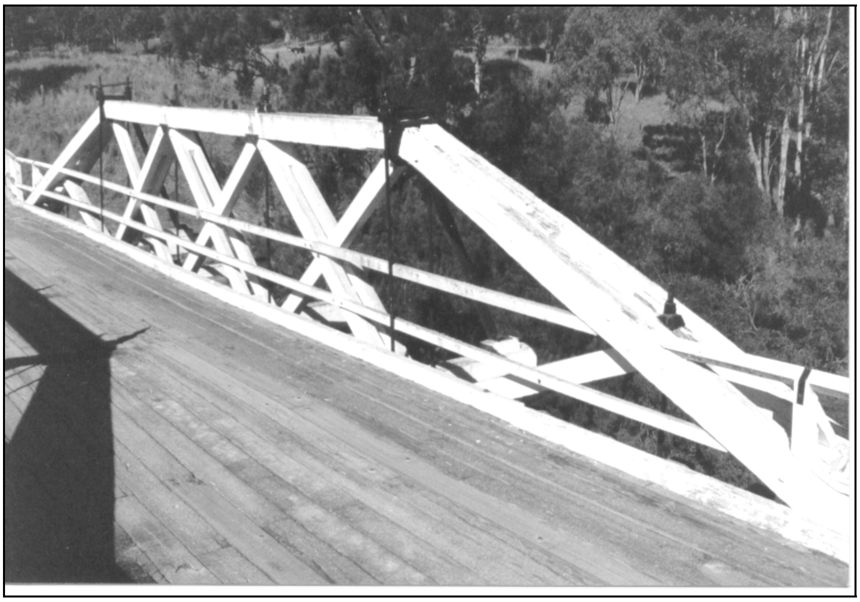


Figure 1.3.3b – The single thickness top chord was part of McDonald's improvement to the OLD PWD trusses.

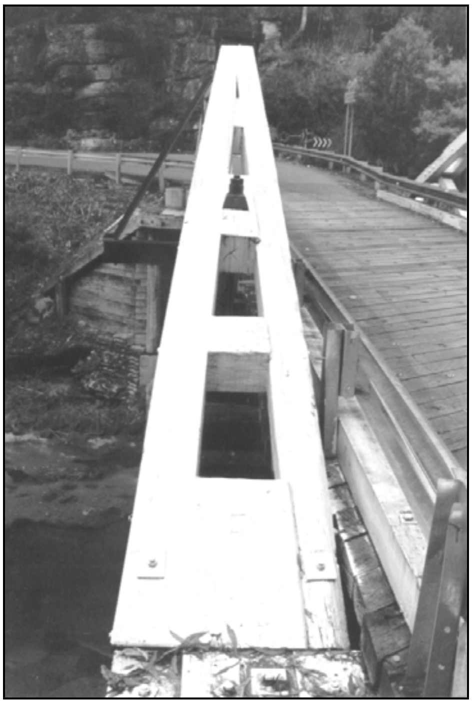


Figure 1.3.3c – Splayed end members increased the stability of the truss.

- the splaying of the sloping end member so as to increase stability of the compression top chord which was prone to buckling. (Figure 1.3.3c)
- the vertical rods at the ends of the his trusses were placed outside the chord timbers and held in place by cast iron cradles as in Figure 2.3.3d. This eliminated the need to drill through the chord members so the number of rods was doubled and larger sizes could be easily incorporated and kept tight.

Figure 1.3.3d – Vertical rods placed outside the truss faces eliminated the need to drill through the top chord.

Figure 1.3.3e – Connection of diagonals to top chord via cast iron plates provided a superior transfer of force.

- the diagonal timbers were fitted into cast iron plates (refer Figure 1.3.3e) at their junctions with the top chord timbers so as to give good force transfer at the joints.

- where the diagonal timbers met the bottom chord joints, opposing steel "fox" wedges were installed (see Figure 1.3.3f) so that regular hammering would keep the shrinkage gap filled, thereby reducing long-term deflections.

- methods were devised whereby combinations of chains and a minimum of temporary timber supports (see Figure 1.3.3g) could be used to create an alternate internal load path thereby relieving a defective timber of load. This allowed its easy removal and replacement without taking the bridge out of service and with little interference to traffic. After WWII the Bailey bridge largely superseded these methods of temporary support, see Figure 1.3.3h.

- the use of sawn timber from heartwood which was of similar quality to the hewn timber, was less costly and more readily available.

McDonald's crowning achievement, however, was his pioneering of the new technology of composite trusses where timber and steel were used to their best purposes. The bulky and relatively lower-strength timbers were best suited to members in compression, hence the top chord, end sloping members and the diagonals were timber members. The higher strength of steel made it more suitable for slender tension members, the verticals and the bottom chord. In his design for the 3-spans trusses over the Lachlan River at Cowra in 1893 he demonstrated the potential for composite construction with a span of 160 feet, almost double the previous longest span of 100 feet. The bridge served 93 years and was replaced in 1986. One span was saved and is on display in a nearby riverside park (see Figure 1.3.3i). Note that typical McDonald trusses had timber bottom chords.

Figure 1.3.3f – Steel fox wedges were used to counter shrinkage effects and provided a simple means for regular adjustments.

(iv) ***To remove top chord.***

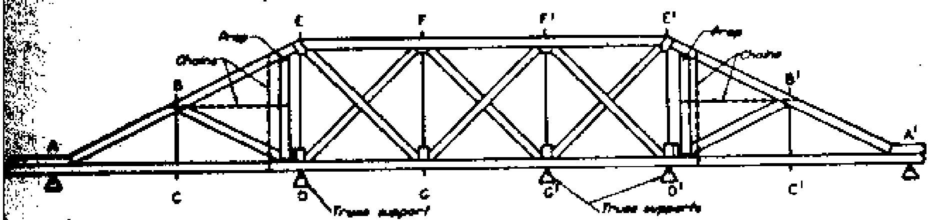


FIG. 9

(a) Place props between tops of principals and lower chord at panel points **D** and **D'** and securely tie with chains and union screws to ends of **truss,** say panel points B and B'.

(b) Tie tops of principals to lower chord with chains and unions.

(c) Support bottom chord at panel points D and D' and alternate ones.

(d) Place props between tops of principals and kerb on opposite side of **bridge.**

(e) Tie tops of principals across bridge.

(f) Brace all diagonals to maintain alignment.

(g) Remove and replace top chord.

(h) Dismantle in order (*f*), (*e*), (*d*), (*b*), (*a*) and (*c*).

Figure 1.3.3g – Removal of top chord was made possible with the creation of alternative temporary load paths.

Figure 1.3.3h – Bailey Bridges became the preferred method of temporary support during maintenance and rectification works.

Figure 1.3.3i – A span of the original Lachlan River Bridge at Cowra on display at a nearby riverside park. The bridge utilised steel tension members and timber compression members in an early example of composite design.

In the short period, 1886 - 1893, McDonald truss bridges were built at 91 sites at an average rate of 13 per year, a remarkably productive though short-lived boom despite the onset of a severe economic depression.

1.3.4 The Allan Truss

In 1890, as the economic depression began to grip New South Wales, the 29-year old chief draftsman and engineer, Percy Allan[R12] (see Figure 1.3.4a), began a complete revision of the timber truss bridge to incorporate the proper engineering science of the structural behaviour of trusses, and to use the reliable strength data of Australian hardwoods obtained from Professor Warren's testing program at Sydney University in order to reduce the costs of construction and maintenance.

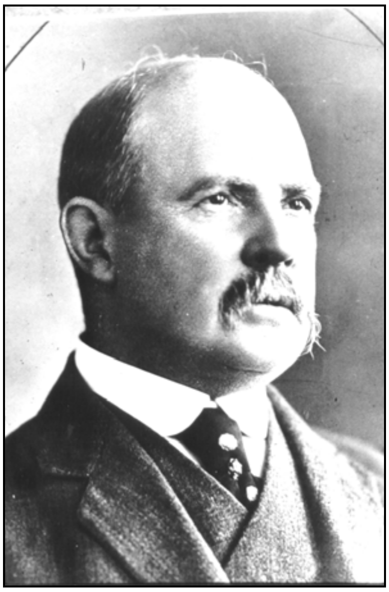


Figure 1.3.4a - Percy Allan.

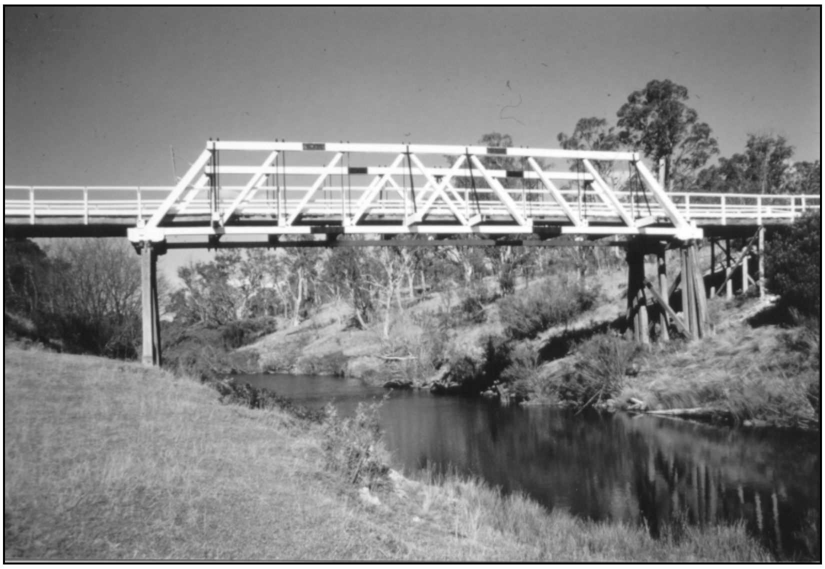


Figure 1.3.4b – The simple lines of a typical Allan truss.

In 1893 Allan introduced his new design based on the American Howe truss (see Figure 1.3.4b). It was not however, a composite truss as foreshadowed by McDonald because only the verticals were iron rods while the bottom chord, despite being a tension member, was still all timber. The new truss featured a much simpler arrangement of triangulations and incorporated many improvements and innovations, derived from his design and practical experience, that made this truss a more cost-effective structure than its predecessors. The PWD Annual Report for 1893-94 had these comments,

> *"The type of design for truss bridges in use since 1884 has been superseded by a truss of more modern design, the principal features of which are: the use of marketable lengths of timber, the adoption of open chords and braces always accessible to the brush, and the ease with which any defective timber can be replaced."*
>
> *"In each of the new 90-feet spans there is a saving of 450 cubic feet of timber and it carries 10 feet more roadway than the old truss. There is also a saving in effort owing to the shorter lengths of timber employed and the greater ease of framing. Altogether the saving is on the average 20 per cent."*
>
> *"The introduction of the large timber truss adopted at Wagga Wagga will now permit the economical bridging of those rivers which cost had hitherto rendered prohibitory."*

Then in the next Annual Report it is stated that

> *"One of the most important matters in connection with the work done has been the introduction of the new form of truss which is proving to be cheaper in construction and promises to lessen the cost of maintenance."*

Figure 1.3.4c – Parallel pairs of members held apart by timber spacers were used to improve load characteristics, aid painting and prevent the collection of water.

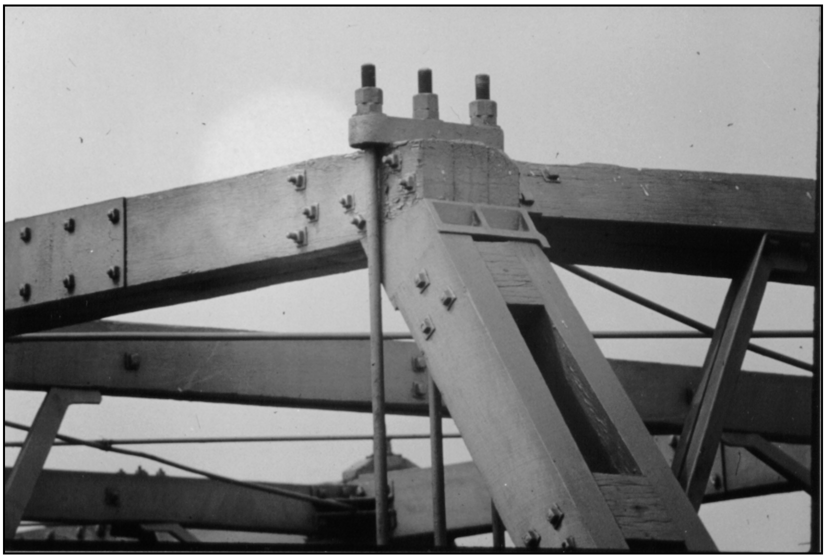


Figure 1.3.4d – The simple truss shape allows tightening via the nuts on the top chord to combat shrinkage effects. One, two, or even three vertical rods were possible due to the separated members.
The cast iron shoes allowed good transfer of forces at truss joints.

This timber truss, which could carry 50% more load but with 20% less material, has become known as the ALLAN TRUSS. Allan designed three sizes, the 70 and 90 feet spans in the conventional "pony or half-through" style and the 110 feet spans which were "through" trusses, tall enough to accommodate horizontal sway bracing above the traffic.

In his 1924 series of papers[R13], Percy Allan summarised the important aspects of his achievement as:

- all timber members were assembled from relatively smaller and shorter sizes, spliced at regular intervals for the top and bottom chords, laid parallel in pairs but held apart by spacer timber blocks. This allowed rain water to fall through, gave easy access for painting and for the compression members it increased their buckling strengths (see Figure 1.3.4c).

- external iron clamps at the joints meant that the vertical rods could be placed within the space between the top and bottom chord timbers or outside these members. One, two or three vertical rods could be accommodated depending on the magnitude of the shear force at the member (see Figure 1.3.4d).

- cast-iron shoes at all joints ensured proper truss action and a good transfer of member forces at the joints (see Figure 1.3.4d).
- the simple triangulations, mostly without crossed diagonals allowed the truss to be kept tight simply by applying large spanners to the nuts at the vertical rods along the top chord (see Figure 1.3.4d).

- any member could be renewed without temporary staging from below and without taking the bridge out of service.

- These above are improvements in the details of construction and maintenance, but Allan's REAL INNOVATION was the concept of building two parallel half trusses and bolting them together to form a complete truss, one on each side of the deck. Member replacements in effect only involved half members, making repairs easier and quicker to do, and yet enough of the structural integrity of the truss was retained to keep the spans in use.

Figure 1.3.4e – Hampden Bridge, Wagga Wagga.
The first of Allan's large overhead through truss bridges
with 3 truss spans, each of 110ft (33.5m).

Figure 1.3.4f – Morpeth Bridge. The oldest serving over head timber truss bridge recently celebrated its centenary (opened 1898).

The immediate success of Percy Allan's design was good news for colonial governments of the late 1890s wrestling with the financial, social and unemployment consequences of the economic depression. The improved economics of Allan's design assisted Governments in implementing public works programs to both relieve unemployment and achieve more infrastructure for the meagre funds available. The rate of construction was, however, not as intense as for the McDonald period.

The transition year was 1894 with the last of the McDonald truss bridges and the first of the Allan truss bridges being completed. The latter was over Glennies Creek at Camberwell just north of Singleton, opened for traffic on 13 August 1894. The first of the large overhead-braced truss bridges was built a year later over the Murrumbidgee River at Wagga Wagga, comprised of three 110 feet spans and opened for traffic on 11 November 1895 (see Figure 1.3.4e). In 1998 it was extant but out of service. The largest of these projects was over the Macleay River at Kempsey where four 154 feet spans were opened for traffic on 5 April 1900. This bridge was replaced by steel trusses in 1959. Currently, the oldest serving large trusses are those at Morpeth opened on 15 June 1898 (see Figure 1.3.4f).

13.5 The DeBurgh Truss

The technical merits of composite construction, utilising timber for compression and steel for tension, and pioneered by J A McDonald in 1893 at Cowra were not lost on the brilliant team of engineers in the PWD at the end of the colonial era. They included the senior engineer E M DeBurgh[R14] (see Figure 1.3.5a) and three young top graduates from Sydney University, Harvey Dare, J J C Bradfield and J W Roberts.

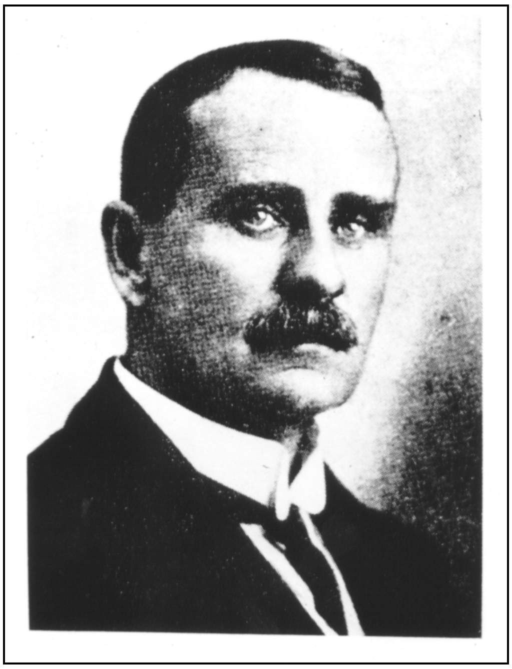


Figure 1.3.5a – Ernest M. DeBurgh

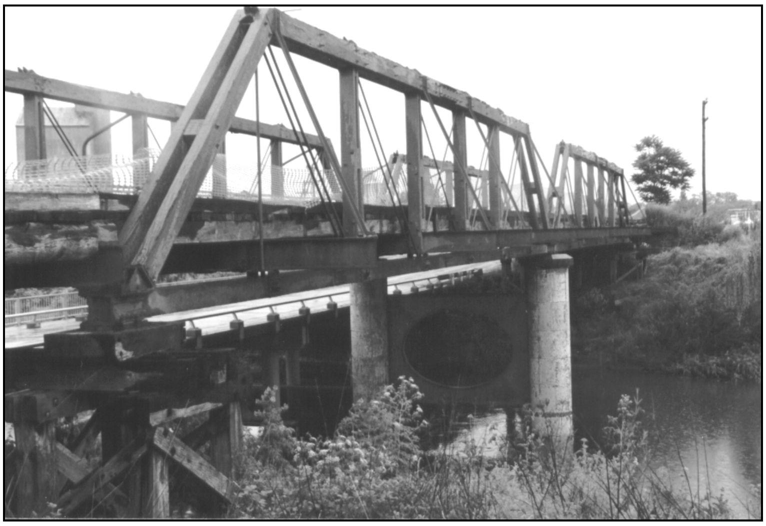


Figure 1.3.5b – The bridge over the MacIntyre River at Inverell was one of DeBurgh's early Pratt trusses with sloping end members.

Ernest McCartney DeBurgh was among the last of the expatriate British engineers of the colonial period having joined the PWD in 1885 and he was involved in both the design and construction of bridges. His first composite truss bridge was built over the Queanbeyan River at Queanbeyan. It replaced the 1878 OLD PWD truss bridge known as the Queens Bridge, and was opened on 16 March 1900. The Annual Report to 30 June 1899 stated

> *"This bridge is rapidly nearing completion and is of considerable interest because the Pratt style of truss, with vertical posts and inclined tension members, has been adopted in lieu of the Howe type. The superiority of steel over timber in tension, and the great cost of replacing the timber chords, points to a great economy in maintenance."*

Percy Allan, in his 1924 series of papers added that

> "*the bottom chords are of steel and are connected to the diagonal rods by turned pins."*

This first composite Pratt truss bridge was replaced by a prestressed concrete structure in 1975 but an example of its type with sloping ends is extant over the MacIntyre River at Inverell (see Figure 1.3.5b). It provided access to the railway yard nearby but is out of service next to a new concrete bridge.

Figure 1.3.5c – The square ends that are typical of the DeBurgh truss.

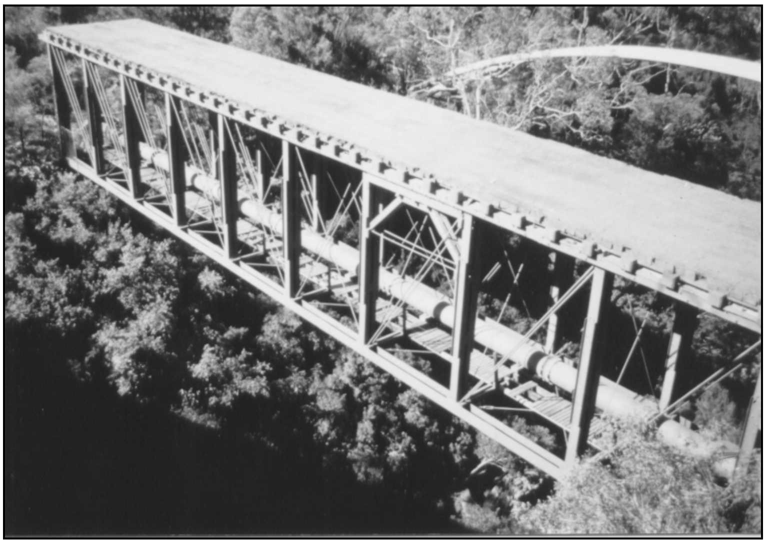


Figure 1.3.5d – The 1901 DeBurgh Bridge over Lane Cove River. DeBurgh's greatest achievement with a 165ft (50.3m) deck span was damaged in the 1994 bush fires.

A minor technical change was subsequently made whereby the sloping end members were replaced by a conventional rectangular Pratt panel. Henceforth all DeBurgh trusses have had the familiar squared ends (see Figure 1.3.5c). In 1998 there are nine of these bridges in service. His greatest achievement was the 165 feet deck span over the Lane Cove River on the North Ryde to Gordon Road pictured in Figure 1.3.5d. It was opened on 20 December 1900 and officially named the DeBurgh Bridge on 23 February 1901. Unfortunately it was destroyed by the bush fires of January 1994.

Figure 1.3.5e – Pins along the bottom chord facilitated speedier construction but later lost favour due to the difficulties experienced in maintenance and strengthening works.

DeBurgh incorporated all the improved features of Percy Allan's revision but changed some details to suit the inclusion of the steel bottom chord. The overall result was a stiffer, structurally superior truss for which member replacement was quite easy. However, the inclusion of pins (see Figure 1.3.5e) along the bottom steel chord was a carry-over of the American system which, although it allowed rapid construction, was a hinderance to certain aspects of maintenance and future strengthening. Local engineers were aware of this through experience with the 1889 Hawkesbury River railway bridge. Consequently, the DeBurgh trusses were only constructed for the relatively short period between 1900 and 1905.

13.6 The Dare Truss

This was the most successful composite truss, having a construction period from 1905 to 1936. In 1903 the 36-year old bridge designer, Harvey Dare, was in charge of highway bridge design and took the opportunity to change the composite truss. He returned to the Howe truss arrangement of the Allan truss but substituted a pair of steel channels for the timber bottom chord (see Figures 1.3.6a & b) and redesigned the bottom chord joints to eliminate the pins of the DeBurgh truss. He achieved further simplicity in member replacements thereby creating the most cost-effective timber truss, at the end of this evolutionary process. The Dare truss bridges have the highest survival rate, 24 are extant in 1998 of the 44 built. In fact the first one, completed in 1905, is extant over the MacDonald River at Bendemeer being used as a footbridge.

Figure 1.3.6a – Bulga Bridge over Wollombi Brook is typical of Dare's design.

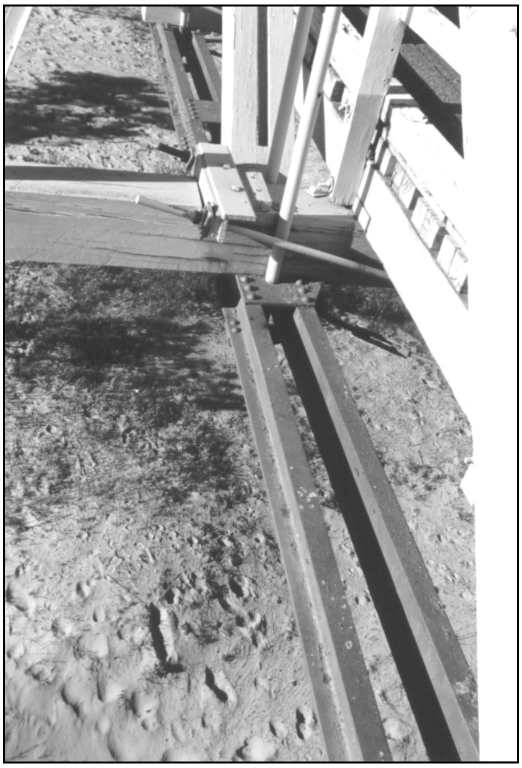


Figure 1.3.6b – The pair of steel channels that made up the bottom chord utilised the tension characteristics of steel along with the compression characteristics of the timber.

1.3.7 Summary

The timber truss, from the OLD PWD (1861) to the DARE (1936), was the mainstay of large span bridge construction in New South Wales for 60 years until, in the 1920s when the BHP steelworks at Newcastle began to supply steel to the local market and reinforced concrete became the new technology for road bridges.

There were in excess of 400 timber truss bridges built in NSW, as shown on the following distribution table, whereas other colonies and states did no better than 10% of this figure or even none. Travellers into New South Wales dubbed it the "timber bridge State".

Unfortunately, these bridges had a number of faults:

- they were designed for loads much less than those applied by modern heavy trucks;
- they were built as single lane bridges, an inconvenience to modern traffic densities;
- the decking, cross girders and timber bottom chords were designed for traffic travelling much slower than today, so impact and fatigue effects are greater. But the new technology of Stress Laminated Timber decks is showing encouraging signs of prolonging the lives of the surviving timber truss bridges;
- water has been the greatest scourge, despite Percy Allan's details designed to shed as much water as possible, and has led to considerable rotting of the timbers. Fortunately, many timber members are being protected by metal sheeting and there are cost-effective chemical treatments now that suitable available hardwood pieces have become progressively more difficult to purchase;
- maintenance costs, particularly for the three all-timber truss types, have continued to be relatively high because much of the work is labour intensive.

All of these factors were mentioned at various times in the PWD Annual Reports as early as around 1900. Despite the many new timber truss bridges built during the first twenty years of this century, replacements in steel and concrete has produced a steady decline in the population of timber truss bridges. No timber truss bridges have been constructed since 1936. It has been possible to monitor the decline since 1940 and this is shown in the Figure 1.4b.

The situation has been reached in 1998 where the surviving 82 represent only 19% of the total constructed and it is likely to be lower by the year 2000 as some new bridges come into use and the old timber trusses are demolished.