The History and Service of Timber Howe truss Bridges in Australia

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Abstract The Howe truss was patented in USA initially in 1840 and again in 1850 and went on to become one of the primary timber truss designs used in North America. The adaptation of the Howe truss in NSW into the two distinct forms known as the "Allan" and "Dare" trusses is well documented, though its usage elsewhere in Australia is largely ignored. This paper will briefly describe the extent of this usage and suggest the manner in which some of the bridge engineering knowledge required for their construction was transmitted.

The Howe truss in North America

The adoption and development for bridges blossomed in the USA during the 19th century. So many bridges were required in America that bridge building became a profitable industry for bridge designers. There were many types of bridges patented of which the Howe was prominent.

William Howe of Massachusetts was granted his first truss patent in 1840 and extended the patent with improvements in 1850. His 1850 patent used metal rods as the vertical members of what was otherwise a simple timber parallel-chord, cross-braced truss. This was the first truss patent granted with some major structural components made with metal. The configuration used easy-to-erect and readily prefabricated components that could be assembled on site and adjusted via threaded connections at the rod ends (US DOT, 2005). Little skilled labor was involved in assembling and erecting this truss type, and it became an immediate success (see **figure** 1).

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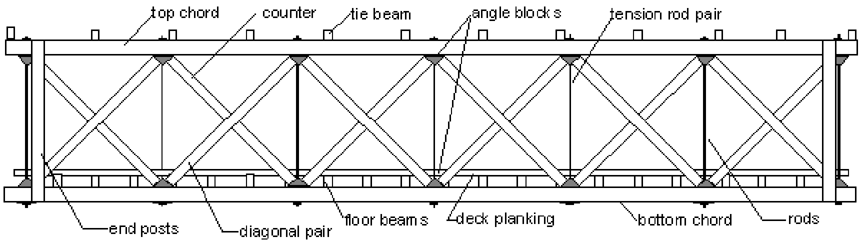

Fig 1. Diagram of Howe truss based on patent issued in 1850 (US DOT, 2005).

Another factor in the success of Howe's truss type was his inclusion of a mathematical stress analysis with the patent application. Up to this time, the selection of member sizes, materials, and overall geometry, was generally left to the judgment of the individual bridge builder.

The initial Howe truss bridges had wooden blocks cut to fit at the connections at the ends of the diagonal members against the chords. Later versions converted to the use of cast iron angle blocks. These blocks were simple to construct and install, and they were a major factor in the popularity of this configuration.

The suitability of the Howe truss for heavy duty bridge spans led to it being adopted by the railroad industry where it found its greatest usage (Steinman, 1957). Builders could use multiple panels to increase the length of the bridge as required.

With so many designs patented and, in a highly competitive market, the alternatives were peddled around the country by the designers and builders like any commercial product with catalogues, sales talk and guarantees (Fraser, 1985).

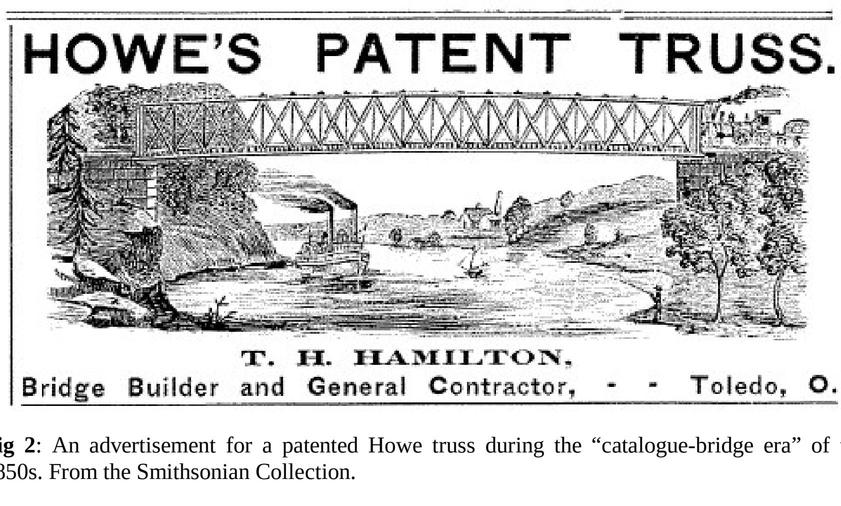

Fig 2: An advertisement for a patented Howe truss during the "catalogue-bridge era" of the 1850s. From the Smithsonian Collection.

In the period between 1850 and 1930 the Howe truss underwent a number of refinements in the United States, and three forms were developed. These included the “Through” truss, known in Australia as an “Overhead-Braced” Truss; the “Half-Through” truss and the “Deck” Truss (see **figure 3**).

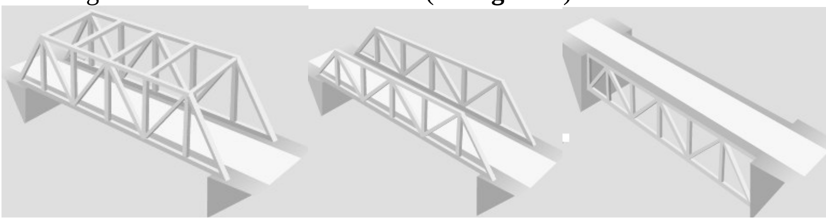

Fig 3: Names for different truss-deck arrangements were developed in the United States; “Through”, “Half-through” and “Deck” trusses. From Lichtenstein Consulting Engineers, Inc., 2000.

The Through truss was the most widely produced of these forms in North America. Of the extant covered timber bridges in the United States, there are about 143 bridges supported by a Howe truss, or about 15 percent of all covered bridges (US DOT, 2005). One of the last extant Through Howe truss Bridges in North America is the old Adam’s Coal Mine Bridge at Alberta, Canada, built in 1907 (**figure 4**).

Fig 4: Adam’s Coal Mine Bridge at Alberta, Canada. From www.pbase.com/martinbunting/images_of_alberta

Squirrel Creek Bridge, Idaho (figure 5) was an example of the relatively small number of half-through Howe trusses that were built in the U.S. with sloping end posts or “principals” rather than the previous square ends. These sloping principals enabled ease of maintenance on multiple span bridges as well as saving timber by eliminating the upper triangle of timber above the sloping ends. This bridge featured three 60ft Howe half-through trusses (known in the U.S. as “Pony” trusses) and was built in the 1930s as part of an unemployment relief program.

Fige 5: Squirrel Bridge, Fremont County, Idaho, USA (Idaho Department of Transport)

Other distinct differences between **figure 5** and **figure 1** are that the cross girders are hung below the bottom truss chord and are located at the nodal points only as distinct from distributed along the entire bottom chord. The sway braces are of timber rather than the iron or steel angles found on the earlier designs.
Deck Howe trusses were built in several states in Australia, though these are not discussed in this paper.

Early Howe Trusses, NSW

The majority of early bridge designs in NSW had been prepared by architects in the Colonial Architects Office, and not being engineers they were apt to use any established bridge design. The year 1858 was the changeover from Department of Lands and Public Works to the Department of Public Works (PWD). All timber truss bridges built in NSW up to this date had been of the King Post or Queen Post form (**figure 6**), with an increasing interest in exploring the potential of the form of the laminated timber arch.

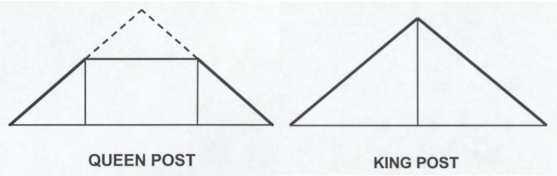

Fig 6: Profile view of the simple forms of the King Post and Queen Post truss adapted from house roof construction for use as bridges.

It was a notable development that in this year of changeover plans were prepared for two Howe Trusses in NSW bearing the signature of the Commissioner Benjamin H Martindale of the former Department of Lands and Public Works. These were Vacy Bridge over Paterson River (**figure 7**) and a second similar bridge built over Falbrook Creek at Camberwell in 1859 and replaced in 1882. The similarities between Vacy Bridge and the patent developed by Howe are unmistakable and, given their very early usage, it would be reasonably expected that royalties would need to be paid to secure the use of the relatively recent 1850 patent.

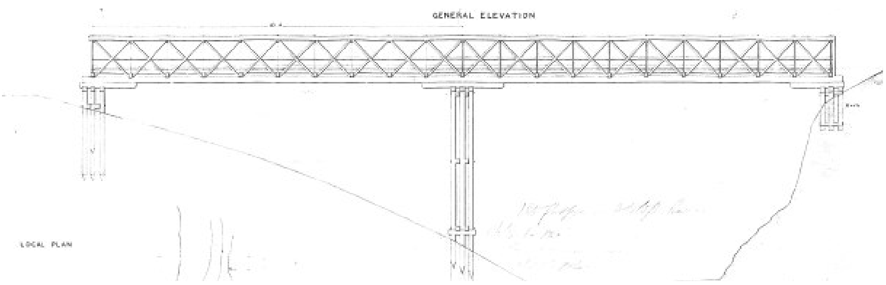

Fig 7: Plan of Vacy Bridge over Paterson River, Vacy built 1858 replaced 1898 (RTA Plans Archive).

Whether or not Martindale had envisioned utilizing the Howe truss design more widely is unclear, and the manner in which he abruptly left office in 1860 meant that the simple design listed in Howe's 1850 patent was never taken up further in NSW.

Allan truss, NSW

Percy Allan was Appointed Assistant Engineer for Bridges in NSW Public Works Department in 1895 and was promote to Engineer-in-charge of bridge design in 1896. He was strongly influenced by the work of his former mentor Professor W

H Warren at Sydney University. Not only did Warren promoted, through his lectures and technical papers, a more scientific approach to structural design, but his research work, using all the local hardwoods (and some imported softwoods for comparison) also yielded results which could be used to apply those design principles to timber trusses (Warren, 1890, 1893).

It is just possible that Allan had the benefit of seeing one of the earlier NSW Howes intact. If so, these may have been one of the many influences (along with Warren's work) that compelled him to revisit the Howe truss design and make it his own.

One of the features of the modified Howe truss developed by Allan (and subsequently named the "Allan" truss) was the use of paired timber elements throughout, which allowed any component to be replaced while the bridge remained in service, without the need to temporarily prop the trusses from below (**figure 8**). Furthermore, cast-iron shoes at all joints ensured proper truss action and a good transfer of member forces at the joints.

Fig 8. Nunnock Creek Bridge, near Bega, NSW (built 1897) detailing duplicate principals and diagonals (RTA Photo Archive).

Allan's design was lighter and more economical than the McDonald truss it replaced. They were also designed to be more accessible for painting and repair, and to use shorter lengths of timber which were much easier to obtain and to manoeuvre during construction. Another distinct benefit, as identified by Allan, was that this design enabled footways to be built outside the truss (Allan, 1924).

Through his experience of maintaining truss bridges in service, Allan was aware of the problems found in splices in bottom chords in tension, and developed a testing machine for those at Pyrmont. He reported that his splice detail was adopted in North America which, while difficult now to prove, marks the extent to which he was able to improve on the basic Howe design. For all his improvements

however, he wasn’t able to solve the flitch problem entirely, as these joints have been described as the major causes of problems in the trusses (DMR, 1962).
There can be little doubt that Allan saved his highest regard for his series of 6 overhead-braced trusses he had built between 1895 and 1900. He presented a paper to the Institution of Civil Engineers, London on the “The Wagga Wagga timber bridge, N.S.W.” which was the first of these designs (Allan, 1907). In writing at the twilight of his career, he nominated his bridge over the Macleay River Kempsey, NSW as “the most important timber bridge in NSW” (Allan, 1924). It featured the longest (non-composite) timber spans in Australia, each of 153ft (**figure 9**).

To ensure that the length of ironbark timber he needed for the bottom chords was available, Allan had a young engineer by the name of J.J.C. Bradfield go out with a theodolite to estimate the height of solid timber in the standing trees (Raxworthy, 1989).

Fig 9. Macleay River Bridge at Kempsey, NSW (built 1900 replaced 1959) featured four 153ft timber spans (RTA Photo Archive).

Dare truss, NSW

Harvey Dare, in 1903, when in charge of highway bridge design in the NSW PWD, developed a composite truss of the Howe type which built on and improved the serviceability of the Allan truss. The main feature distinguishing Dare’s truss design from that of Allan’s was its steel bottom chord, effectively removing the issue of the timber flitches in the Allan truss and these were superior designs as a result. In addition it had a much simplified bottom chord joint with diagonals and principals– the steel lower shoes were built in (**figure 10**).

Top quality ironbark suitable for the critical tension bottom chord of an Allan truss was becoming harder to obtain, due partly to large scale exports of ironbark timber that was so prized by overseas engineers. Ironbark had long been recognized in Europe as an excellent timber for shipbuilding (Chambers, 2006).It is interesting to note, that despite the improved Dare Truss design being available, the basic Allan Truss continued to be built and enjoyed a late surge in the 1920s (see **Table 1**).

Fig 10. New Buildings Bridge over the Towamba River, near Wyndham, NSW (built 1921) has the characteristic steel bottom chord of a Dare composite truss (Author's collection). Note the principals and diagonals are no longer splayed as in the Allan truss.

Railway Bridges, NSW

Railway bridges were initially designed by a group in the PWD Railway Branch under John Whitton. In 1889 there was an extensive reorganisation which saw the formation of the NSW Government Railways responsible for all new work for and operation of the existing working railways including replacing bridges.

By 1892 the trunk-line network had been established though it was still necessary to fill in between the branch/ feeder lines. Nearly all the Branch lines were located in the flat open country west of the Great Dividing Range in the wheat belt. Henry Deane (Whitton's successor) advocated the American practice of building cheap developmental lines, known locally as Pioneer Lines (Fraser, 1995).

Despite the policy of no significant bridges on these lines, to keep costs down, important rivers still had to be crossed. The cheapest form of crossing would have been timber viaducts but the large volumes of flood water and tons of debris carried by the inland rivers ruled out this option, at least over the main channels. In order to achieve reasonable waterways for the main channels, the design engineers adapted the successful Howe Timber Truss Bridge to railway needs. (Fraser,1985).

The Half-Through truss developed (**figure 11**) is similar in appearance to the Allan truss road bridge though not as sophisticated. Web layout and details show the influence of Allan with the chords in pairs making maintenance and replacements simpler, though that is where the similarities end. Significant differences are evident in that the top chord has timber notched for principals and diagonals without shoes being used. The cross girders are suspended beneath the bottom chords and triple hanger rods are in place at each panel point. The rails were further supported by under-deck bracing in timber (**figure 12**).

Fig 11. View of Two Mile Creek Bridge at Walgett, NSW (built 1908) photo courtesy of Don Fraser. Note the principals and diagonals (now parallel) are duplicated for ease of maintenance.

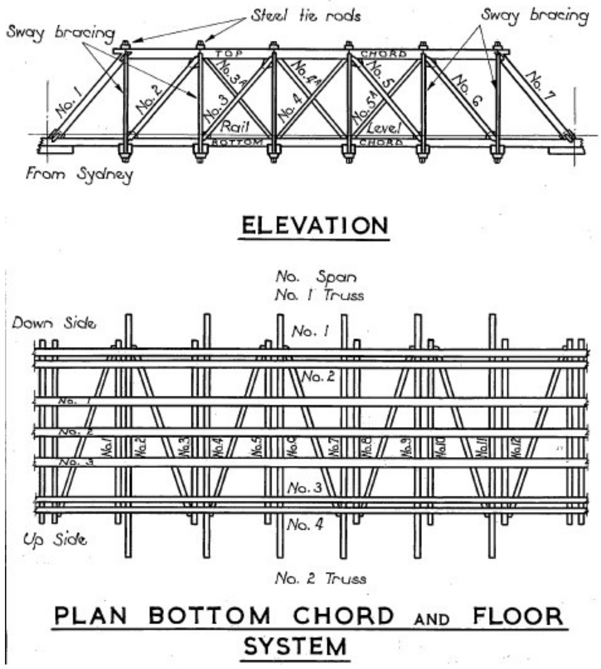

Fig 12. Plan of "NSW Government Railways, Standard Type 60ft timber truss bridge", Railcorp NSW Archives.

It is interesting to note that, through a clear lack of integration between NSW Government Branches, several significant innovations devised by Allan to assist with ongoing maintenance were not carried over into the development of these railway bridges. A parallel can be found in the design differences between the sophisticated deck Howe spans developed by Allan for his Pyrmont Bridge built in 1902 as compared to the relatively simple deck Howe trusses built by the NSW Government Railways between 1902 and 1915.

Early Howe truss bridge at Keilor, Victoria

In the 1850s, the Colony of Victoria was buoyant on the back of numerous and high yield gold discoveries. The massive amounts of traffic generated by the Bendigo and Ballarat goldfields in particular meant that Mt Alexander Rd carried more traffic than any road in England at the time yet had no permanent means of crossing the Maribyrnong River. An early crossing of the Maribyrnong River for traffic to the north west, west and south west was at Keilor. A ford 300m upstream of the old Calder Highway was initially used, though a temporary wooden bridge was erected in 1848, but this was washed away in a flood in 1852 (Biosis,2003).

In 1851, when Samuel Brees was appointed Acting Colonial Engineer, he took control of the Mt Alexander Rd and was soon after given control of the whole Roads and Bridges Department, Central Road Board. Brees was a noted British railways authority since the 1840s having helped several prominent British railway engineers on major construction projects, and having played a significant part in the designing of the London to Birmingham Railway. His big construction manuals featured many examples of British railway bridges including the laminated timber bowstring arch. It is reported that it was his initial intention to use a timber arch at the crossing of the Maribyrnong River at Keilor but he was unable to proceed due to a lack of skilled labour coupled with the need to reduce the use of supporting piers due to flood risk (Chambers, 1996).

With few options open to him and immediate action needed, Brees (possibly by virtue of a catalogue and/or salesman) settled on a very recent design that was then hardly known outside the United States. In 1853, after paying the necessary royalty, Brees arranged for the construction of an overhead-braced through Howe truss which received world acclaim for spanning 135ft. The trusses were actually 160ft long, 17ft high and weighed over 50 tons. A central truss was used to give two lanes of traffic (**figure 13**).

Although expected to last at least 30 years if properly maintained this bridge was soon damaged by frequent floods and replaced with a new structure in 1854. It was subsequently repaired in 1857, 1860 and 1866, but remained close to collapse and was demolished soon after (Biosis,2003*)*.

Fig 13. Keilor Melbourne 1856 (State Library of Victoria, Accession No: H17072).

Later Howe truss bridges, Victoria

Until the formation of the Country Roads Board (CRB) just prior to World War 1 (and for some time thereafter) Victorian road and bridge construction and maintenance was very haphazard, largely dependent on the relative wealth and efficiency of local municipal authorities, and their success at securing a portion of the meager government subsidies for main roads. During this period Victorian bridge design had much more variety than that seen in NSW, because bridge design largely depended on local municipal engineers. The limited service life of Brees Bridge at Keilor took away the opportunity for other bridge designers to gain familiarity with the capabilities of the Howe Truss form.

Gippsland has provided many of Victoria's major road and bridge engineering problems. It possesses some very difficult river-valley terrain, riverbanks subject to sudden large-scale erosion, and numerous wet areas where it was historically difficult to achieve firm bridge foundations. To address these challenges, in 1919 CRB engineers designed elaborate plans including simplified Howe Truss designs for Gippsland waterways (Chambers, 2006).

These plans took the form of standard drawings for a Howe truss that bears many similarities (along with distinct differences) from those built in NSW (see **figures 14** and **15**). Instead of cast iron bearing blocks found on Allan and Dare Trusses, almost all bearing blocks are of timber (except for connection between principal and top chord). The cross girders are hung below the bottom chord (as seen in NSW railway bridges) and single thickness principals and diagonals were used. In some instances Ironbark was shipped from NSW for their construction, though Gippsland Grey Box was also used (Chambers, 1996). The fragmented nature of the CRB, when compared to the NSW PWD, makes it very difficult to trace the influence of individual designers in the preparation of these standard drawings.

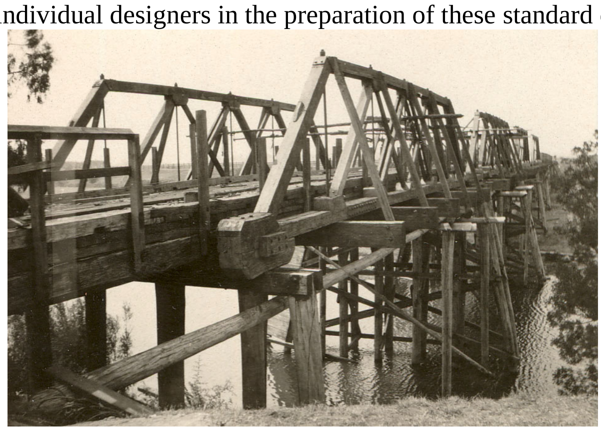

Fig 14. Bushy Park Bridge over the Avon River, west of Briagalong, Victoria under construction in 1926 (VicRoads Archives).

Genoa River Bridge opened in 1928 is the largest surviving Howe truss bridge in Victoria and features 3 truss spans. A curious example of a Howe truss built to the standard Victorian design has come to light over the Mill Creek at Gunderman, NSW (Jordan, 2010). The Mill Creek Bridge was built in 1930, and has been previously incorrectly identified as a Dare Truss (MBK, 1998). It is probable that this bridge was designed by an ex-CRB engineer or at the least someone familiar with Victorian bridge building processes.

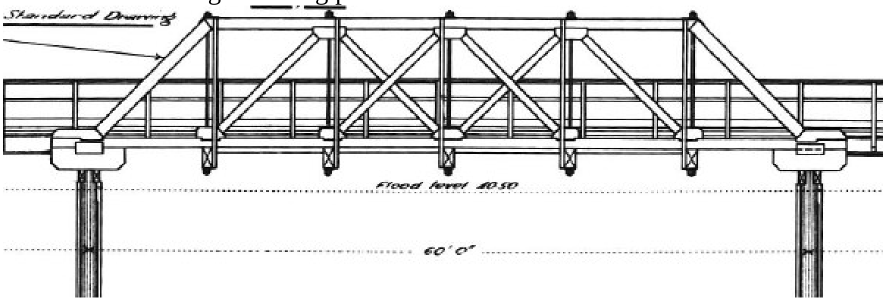

Fig 15. Plan of Bridge over Broken River, Victoria built 1928 (VicRoads Archives).

O'Connor truss, Western Australia

From 1886 when the convict system was disbanded, until 1926, when the Main Roads Department was formed, construction of bridges on public roads in Western Australia was the responsibility of the Public Works Department (Palmer, 1979).

Charles Yelverton O'Connor was one of the outstanding engineers in New Zealand in the period from 1865 to 1891. In 1891 he left to take up the position of Engineer-in-Chief of the small PWD in Western Australia, where his two great achievements were the Fremantle Harbour and the Coolgardie Water Supply.

In order to facilitate these works however, he contributed considerable design input into the roads and railways. In this task, he drew on his experience while an engineer on the West Coast, South Island of NZ where many such bridges were in service. The Howe Truss had been adopted in NZ as early as 1874, and many of those built after 1881 featured Australian ironbark in the truss (Thornton, 2001).

The chief use of timber trusses in Western Australia was in the railways and these featured relatively short spans of 30 to 40 feet length with low Half-Through Trusses. The bottom chord was a 14 x 14 inch member of unspliced length, the top chord being 12 x 12 inch member, the entire truss being made of Jarrah timber.

Figure 16 details a Howe Truss rail bridge being demolished in 1957 and none of these now survive.

Fig 16. Workers demolishing the Belmont Railway Bridge, East Perth in 1957 (Battye Library, WA, Call # BA1218/13). Note the principals and diagonals are solid, heavy members.

The NZ influence on these bridges is further confirmed when the bridge builders are taken into account. A tender was called for the construction of a timber Howe Truss road bridge at Mandurah in 1894. The successful tenderer was Matthew Price who had much experience in bridge building having worked for the Railway Branch of the Public Works Department in New Zealand (Reynolds, 2009).

The term "O'Connor truss" for these WA Howe Trusses was first coined, confusingly enough, by Colin O'Connor (O'Connor, 1982). While it has not been widely used since, it provides a useful distinguisher for the purposes of the current paper.

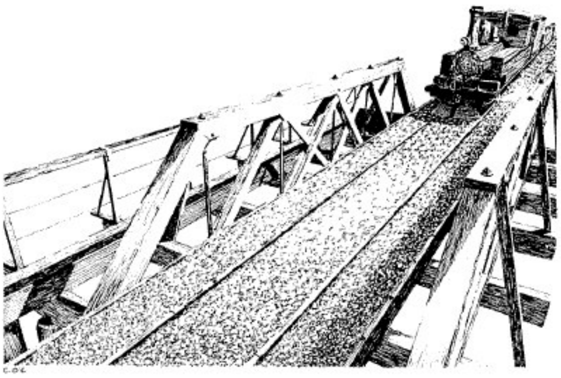

Fig 17. The Bridge on the Canning River, Gosnells built in 1893 from original engineer's drawings (O'Connor, 1985).

Howe truss bridges, Tasmania

Only two Howe truss road bridges have been identified in Tasmania but they are certainly distinctive. At the opening of one of these, the Second Huonville River Bridge in 1926, a commemorative booklet issued for the event reveals some interesting details about its design. The bridge it replaced was a major structure featuring five laminated bowstring arch spans which incorporated a drawbridge. Broad consideration was given to its replacement with the ultimate design selected being attributed to a Mr William Moore, then Minister for Lands, who had had wide experience of bridge building in Canada in his youth (Anon, 1926).

Mr Moore's design featured eight Howe trusses the top chords of which sat low in relation to the deck level (**figure 18**). In many regards the trusses appear similar to the previously mentioned O'Connor truss, perhaps indicative that they were both ultimately derived from early North American models (e.g. **figure 3**) with no further modification.

While no plans are available for the Second Huonville Bridge to allow for its deeper investigation, plans have been located for a significantly earlier Howe truss built over the Derwent River at Plenty in 1892. This is in itself quite remarkable as instead of a timber bottom chord, it features a wrought iron bottom chord in a hollow boxed section, making it the earliest composite truss of the Howe type to be built in Australia. The previously mentioned Dare Truss in NSW, was first built in 1903 and the bottom chord consists of steel channels placed back to back so as to resemblance an I-girder. The design for Plenty Bridge (**figure 19**) shows the diagonals slotted into wrought iron bottom chords while the cross girders rested above. These cross girders are attached to saddle brackets riveted to the bottom chords.

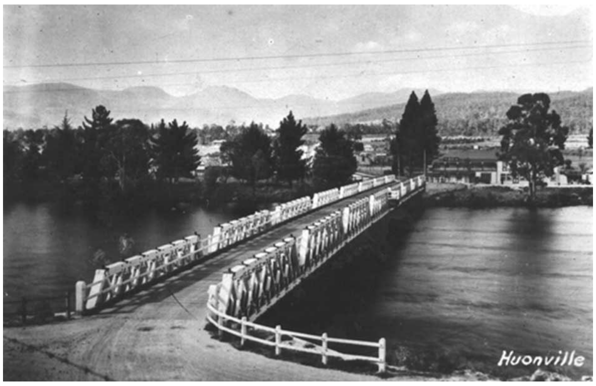

Fig 18. Second Huonville Bridge over the Huon River, Tasmania built in 1926 (Postcard-Author's collection).

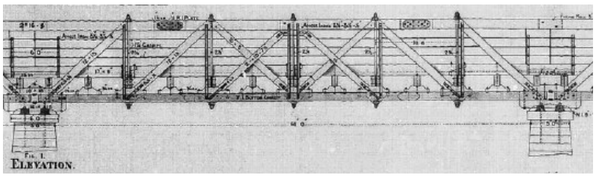

Fig 19. Plan of the Bridge over Derwent River at Plenty, Tasmania built 1892 (Tasmanian Archives Office).

Howe Truss bridges, Queensland

In the period between 1934 and 1936 three similar steel and timber truss bridges were constructed in southern Queensland at Tenthill Creek near Grantham on the Warrego Highway, at Cash’s Crossing on the South Pine River and at Teviot Brook near Dugandan on the Boonah-Rathdowney Road. (O,Connor,1985). The last two of these were through trusses with overhead bracing (**figure 20**).

While merely described as “A” Class bridges on the plans, the use of a steel bottom chord makes them directly comparable to the NSW Dare, though none of these were built with overhead bracing in NSW.

As the last Dare truss was built in NSW in 1936 (Minneys Creek Bridge at Tabulum), it is tempting to suppose that the designer of these three truss bridges in Queensland was ex-NSW PWD or at least strongly influenced by their work, and then took the design a further step forward.

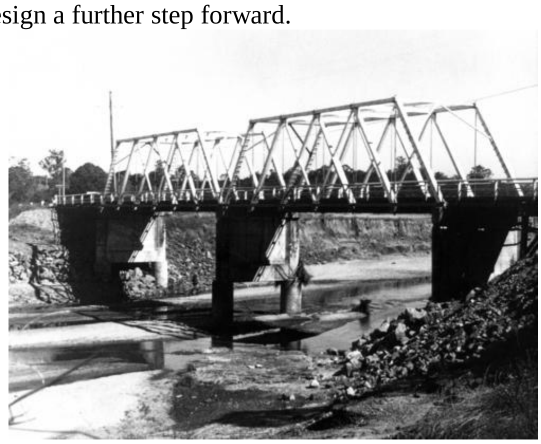

Fig 20. Cash’s Crossing Bridge, Albany Creek, Queensland in August 1974 (State Library of Queensland).

Closing remarks

Howe truss bridges were built in all states and territories of Australia, with the exception of the Northern Territory. Table 1 below marks the author's efforts to catalogue the number of bridges and the period over which they were built.

Table I: Howe truss bridge construction in Australia by state and decade. Table does not include Deck Howe trusses.

STATE	**1850**	**1860**	**1870**	**1880**	**1890**	**1900**	**1910**	**1920**	**1930**	**TOTAL**
NSW (Howe)	2									2
NSW (Allan)					50	15	5	34		104
NSW (Dare)						13	15	12	8	48
NSW Railway					2	10	2			14
Victoria					1	1	5	19*	1	28
Western Australia					7	6				13
Tasmania					1				1	2
Queensland									3	3
South Australia								1	1	2

* Indicates date of construction is approximate. Total number shown is correct.

In examining the manner in which the Howe truss was utilized in each state an interesting picture emerges as to bridge engineering knowledge required for their construction was transmitted. In Victoria and NSW for example, very early uses can be attributed to the "catalogue era" of the 1850s, while subsequent appearances derived from an interest in pushing the structural design of the Howe to its furthest development. The "O'Connor" trusses in WA owe their origins to New Zealand models, while the two Howe bridges in Tasmania may be based on forms developed in Canada. Finally, it is highly probable that the Dare-type trusses built in Queensland are the work of a displaced NSW PWD engineer, while a similar scenario (this time involving a Victorian CRB engineer) may have resulted in the construction of the highly curious bridge at Mill Creek, NSW.

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