Concrete Beam Bridges

Heritage Study of Pre-1948 Concrete Beam Bridges (Sydney, South West and Southern Regions)

2005

HISTORY OF CONCRETE BEAM BRIDGES IN NSW

1.1. History of Reinforced Concrete

The first report prepared by BRW and HAAH detailed the development of concrete and then reinforced concrete for use in bridges[1]. To enable this current report to be used as a stand-alone document, those sections of the previous report are replicated below, incorporating some amendments as more information emerged through this current study.

1.2. Timeline of Reinforced Concrete

The following timeline summarises the history of the material now referred to as reinforced concrete up to 1918. Its path to the form used in bridges in New South Wales up till 1948 represents one of the successes of the industrial age by bringing together physics, chemistry, engineering and innovation to produce a product that has given excellent service to the community. The timeline, of course, did not stop at 1918, and this report also records what has happened to the various bridges since then, and their current role in the infrastructure of the state. However, the major technical advance in concrete, the introduction of prestressing, is outside the scope of the current study and is thus omitted.

REINFORCED CONCRETE TIMELINE TO 1918

12,000,000 BC	Reactions between limestone and oil shale during spontaneous combustion occurred in Israel to form a natural deposit of cement compounds. The deposits were characterized by Israeli geologists in the 1960's and 70's.
3000 BC	Egyptians used mud mixed with straw to bind dried bricks. They also used gypsum mortars and mortars of lime in the pyramids.
7th to 2nd C BC	Chinese used cementitious materials to hold bamboo together in their boats and in the Great Wall.
800 BC	Greeks, Cretans & Cypriots used lime mortars which were much harder than later Roman mortars.
300 BC	Babylonians & Assyrians used bitumen to bind stones and bricks.
300 BC - 476 AD	Romans used pozzolana cement from Pozzuoli, Italy near Mt. Vesuvius to build the Appian Way, Roman baths, the Colosseum and Pantheon in Rome, and the Pont du Gard aqueduct in south France. They used lime as a cementitious material. Pliny reported a mortar mixture of 1 part lime to 4 parts sand. Vitruvius reported a 2 parts pozzolana to 1 part lime. Animal fat, milk, and blood were used as admixtures (substances added to cement to improve the properties.) Many structures still exist. Bronze cramps were used to reinforce masonry in the Colosseum.
1200 - 1500 The Middle Ages	The quality of cementing materials deteriorated. The use of burning lime and pozzolan (admixture) was lost, but reintroduced in the 1300's. Gothic builders in Northern France used iron ties and cramps. Damage due to rust spalling led to abandonment of the method.
17th	Claude Perrault used armature of embedded iron for long span architraves in his colonnade in

[1] Study of Heritage significance of Pre-1948 RTA Controlled Concrete Slab and Concrete Arch Bridges in NSW by Burns and Roe Worley Pty Ltd in association with Heritage Assessment and History, February 2004

Century	the Louvre.
1678	Joseph Moxon wrote about a hidden fire in heated lime that appears upon the addition of water.
1779	Bry Higgins was issued a patent for hydraulic cement (stucco) for exterior plastering use.
1780	Bry Higgins published "Experiments and Observations Made With the View of Improving the Art of Composing and Applying Calcareous Cements and of Preparing Quicklime."
1793	John Smeaton found that the calcination of limestone containing clay gave a lime which hardened under water (hydraulic lime). He used hydraulic lime to rebuild Eddystone Lighthouse in Cornwall, England which he had been commissioned to build in 1756, but had to first invent a material that would not be affected by water.
1796	James Parker of England patented a natural hydraulic cement by calcining nodules of impure limestone containing clay, called Parker's Cement or Roman Cement.
1802	In France, a similar Roman Cement process was used.
1812 -1813	Louis Vicat of France prepared artificial hydraulic lime by calcining synthetic mixtures of limestone and clay.
1812-1824	The world's first unreinforced concrete bridge was built at Souillac, France by Louis Vicat.
1824	Joseph Aspdin of England invented Portland cement by burning finely ground chalk with finely divided clay in a lime kiln until carbon dioxide was driven off. The sintered product was then ground and he called it Portland cement named after the high quality building stones quarried at Portland, England.
1828	I K Brunel is credited with the first engineering application of Portland cement, which was used to fill a breach in the Thames Tunnel.
1836	The first systematic tests of tensile and compressive strength took place in Germany.
1849	Pettenkofer & Fuches performed the first accurate chemical analysis of Portland cement.
1849	Joseph Monier of France commenced producing concrete tubs for orange trees using wire reinforcing.
1851	A beam consisting of brickwork reinforced with hoop iron was displayed at the Great Exhibition.
1854	Patent 2293 by W B Wilkinson of Newcastle, England for concrete floor with network of flat iron bars or wire rope sagging near centre of span. Not significantly commercialised.
1862	Blake Stonebreaker of England introduced jaw breakers to crush clinkers.
1865	Mass, unreinforced concrete used for multiple arch Grand Maitre Aquaduct to convey water to Paris
1867	Joseph Monier of France patented reinforced concrete portable containers.
1867-72	Patents issued to Monier for reinforced concrete pipes and bridges.
1875	First reinforced concrete bridge (of four beams with composite deck) built by Monier at Chateau de Chazelet, Indre, France
1884-1891	Wayss & Freitag acquired patent rights and built a claimed 320 reinforced concrete arch bridges with spans to 40m.

1887	Wayss published "Das System Monier", incorporating theory developed by K Koenen
1894	Experimental Monier arch on Parramatta Road, Burwood as culvert.
1896	Aqueducts over Johnstons and Whites Cks at Annandale by Carter Gummow & Co.
1896	Unreinforced arch bridge over Black Bobs Creek near Berrima by J W Park
1899	The first reinforced concrete bridge built in Victoria: Anderson St Bridge, by Carter Gummow & Co
1900	The first reinforced concrete Monier arch bridge built in New south Wales: Reads Gully near Tamworth, by Carter Gummow & Co
1905	Bridge over the Hawkesbury River at Richmond using Monier arches
1907	First reinforced concrete beam bridge in New South Wales, at Rockdale
1918	First continuous beam bridge, Fullers Bridge, Lane Cove

Prime references:[2],[3].

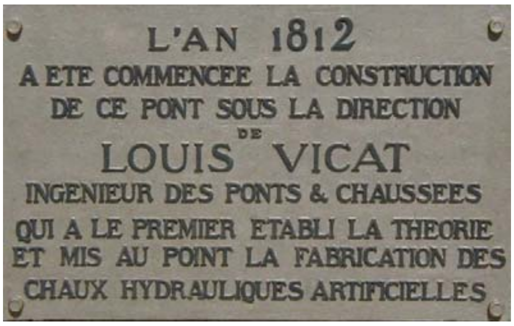
1.3. The Evolution of Concrete Technology – International Context.

The timeline above demonstrates the long path from the earliest uses of cementitious materials to the application of steel and concrete for the construction of bridges. Two keys were required to unlock the door: strong cements, and the means to carry tensile forces.

The Romans had used a cement sourced from the Italian town of Pozzuoli, mixed with lime, sand and water c.400BC – 476AD. This material was used as a binder in piers and arch spandrels, but also in mass footings.[4] In the following centuries the use of cement was largely lost although lime mortars (made by burning seashells for example) were common.

Louis Vicat in France, an engineer (Ingenieur des Ponts et Chaussees) initiated scientific studies of natural cements to reveal for the first time an understanding of the chemical properties of hydraulic (meaning it would set under water) cement. Between 1812 and 1824 he supervised the construction of a seven span unreinforced concrete bridge over the Dordogne River. Known as Pont de Souillac or Pont Louis Vicat, it has a total length of 180 m and utilised his artificial hydraulic lime.[5]

Pont de Souillac by Louis Vicat 1812-1824



Plaque on Pont de Souillac (source www.structurae.de)

[2] "The History of Concrete" Materials Science and Technology Teachers Workshop, University of Illinois. Website //matse1.mse.uiuc.edu/~tw/concrete/hist.html

[3] International Database and Gallery of Structures www.structurae.de

[4] "Context of World Heritage Bridges" A Joint Publication with TICCIH, 1996 by Eric DeLony www.icomos.org/studies/bridges

[5] International Database and Gallery of Structures www.structurae.de

In 1824 an artificial Portland cement was developed in England by Joseph Aspdin using a mixture of clay and limestone, calcined and finely ground. The use of these materials began to extend through the building industry as their utility became better appreciated. In 1828 Isembard Kingdom Brunel was credited with the first application of hydraulic cement to repair a breach in the Thames Tunnel which his father had designed.[6]

By 1865 unreinforced concrete had been used in France to build a mass concrete arch aqueduct, continuing to use the compressive strength of the concrete in exactly the same manner as stone which has been used in arch bridges for at least two thousand years. In this instance, it was used for a multiple arch aqueduct (Grand Maître Aqueduct), conveying water from the River Vanne to Paris.[7]

However, this use still reflected the limitations of masonry, which was its inability to carry tensile loads. Even when using stones with good tensile strength, the joints between blocks would not pass any dependable tensile forces. This shortcoming of masonry had been addressed in a variety ways over the centuries but with insufficient success to permanently change the way materials were used. China's oldest surviving bridge, of open spandrel arch construction, is the Zhaozhou Bridge (c AD 605), attributed to Li Chun and located in Hebei Province south-west of Beijing. Its thin curved stone slabs were joined with iron dovetails so that the arch could yield without collapsing.[8] This articulation allowed the bridge to survive the movements of abutments bearing on spongy, plastic soils, and also the effects of moving traffic loads. In Europe, bronze cramps had been used by the Romans in stone masonry in such structures as the Colosseum in Rome.[9] From the 12th Century, gothic builders used iron ties and cramps in cathedral construction. Unfortunately, damage in the form of rust spalling led to the abandonment of the method. In the 17th Century, Claude Perrault depended on an armature of embedded iron to achieve the long span architrave of his colonnade in the Louvre, Paris. The French-born engineer and innovator Marc Isembard Brunel (1769-1849) experimented with reinforced brickwork in 1832; and a beam of hoop-iron reinforced brickwork was displayed at the Great Exhibition of 1851. However, none of these approaches addressed the problem of corrosion of iron which increases its volume by a factor of 6 (causing bursting or spalling of material around it), not to mention the loss of strength as the iron turns to iron oxide (rust).

Joseph Monier 1823-1906
(source www.structurae.de)

The solution to this problem came from an unexpected source. In 1867, a French gardener, Joseph Monier was granted a patent for cement flower pots strengthened by iron-wire mesh embedded in the concrete and moulded to curvilinear forms. He had begun making such pots in 1849.[10][11] During this period to 1867 several other patents were granted to other innovators including: in 1848 for a reinforced concrete boat; in 1855, for the use of iron in combination with cement as a substitute for wood; and in 1854, for a concrete floor with a network of flat iron bars or wire rope.

While Monier was thus not the first to put cement and steel together, he was the first to trigger its use in bridges. He lodged a patent extension on 13 August 1873 for the construction of bridges and footbridges

---

[6] "The History of Concrete" Materials Science and Technology Teachers Workshop, University of Illinois. Website //matse1.mse.uiuc.edu/~tw/concrete/hist.html

[7] "The History of Concrete" Materials Science and Technology Teachers Workshop, University of Illinois. Website //matse1.mse.uiuc.edu/~tw/concrete/hist.html

[8] "Context of World Heritage Bridges" A Joint Publication with TICCIH, 1996 by Eric DeLony www.icomos.org/studies/bridges

[9] "A note on the history of reinforced concrete in buildings" by S.B. Hamilton HMSO London 1956

[10] "A note on the history of reinforced concrete in buildings" by S.B. Hamilton HMSO London 1956

[11] "Joseph Monier et la naissance du ciment armé" by J-L Bosc et al,Editions du Linteau, Paris 2001

made of iron reinforced cement.[12] In 1875 he built the world's first reinforced concrete bridge, a four beam footbridge of 13.8m span and 4.25m width at the Chateau de Chazelet, Indre, France.[13]

(By way of context, in the same year patents were taken out for the electric dental drill and blasting gelatin!) As he was not an engineer in a country which had a strong engineering heritage, (the Ecole Nationale Des Ponts et Chaussées was established in 1747) he was not permitted to design or build bridges for general public use. He therefore on-sold his patents in 1884 to German and Austrian contractors Wayss, Freitag and Schuster.

Bridge at Chateau de Chazelet, France (photos Sid French)

Underside of bridge showing four curved beams and retrofitted central prop to allow tractors to cross the bridge

Interestingly, the history of Wayss[14] suggests that they obtained the patent rights gratis, perhaps evidence of a lack of business acumen which ultimately led to Monier dying a pauper in 1906. Wayss, Freitag and Schuster built the first commercial reinforced concrete bridges in Europe: the Monierbrau footbridge of 40 m span in Bremen in Germany, and the Wildegg Bridge with a span of 37 m in Switzerland. It is reported that by 1891 they had built 320 arch bridges.[15] (A somewhat questionable claim for such new technology in only seven years)

As part of the process of developing reinforced concrete design, Wayss initiated strength testing of this new combined material, and had K Koenen develop a system of computation. This was published in 1887 as "Das System Monier", and incorporated the following principles:

- Steel alone took the tensile loads
- Transfer of force to the steel from the concrete took place through adhesion
- Volume changes in both materials due to temperature could be assumed to be approximately equal
- For calculations of bending, the neutral axis was assumed to be at the mid-depth of the section

In 1890, Prof Paul Neumann, Professor at the Technical School of Brunn published a memoir on calculation using Monier construction in which he corrected the location of the neutral axis. This basically put the design of reinforced concrete into the hands of general civil engineers. This remained the theoretical basis for design until the middle of the 20th Century, when design based on ultimate strength criteria began to displace elastic design principles.

Whilst the bridges of Wayss et al were the first of the genre, the period saw a proliferation of patents and applications for reinforced concrete. These took advantage of improvements in available cements and

[12] Additif au brevet No 77 165 : "Application a la construction des ponts et passerelles de toutes dimensions"

[13] International Database and Gallery of Structures www.structurae.de

[14] International Database and Gallery of Structures www.structurae.de

[15] "A note on the history of reinforced concrete in buildings" by S.B. Hamilton HMSO London 1956

delivered structures considered to have enhanced features including fire and corrosion resistance, and freedom of form. Reinforced concrete began to be widely used in construction of civil works, domestic and then commercial buildings.

Pont Camille de Hogues (Pont de Châtellerault) 1899-1900 First notable reinforced concrete bridge.

Plaque on bridge (photos Sid French)

The first firm to market reinforced concrete bridges internationally was formed by Frenchman Francois Hennebique who also held various patents for improvements to the art. His bridge at Châtellérault in 1900, listed as having potential to be considered as a World Heritage Bridge, remains one of the first notable reinforced concrete arch bridges in the world, with a central span of 52m and two side spans of 40m.[16]

Outside Europe the reinforced concrete bridge began to spread, but sporadically. The first known reinforced concrete bridge in the USA was an arch built in Golden Gate Park, California in 1889.[17] New Zealand built several small footbridges in the Otepuni Gardens in Invercargill in about 1899 before their first road bridge in George Street Dunedin was constructed in 1903.[18] The bridge claimed to be the oldest in the UK is Chewton Glen near Milton in Hampshire, built in 1900.[19]

Otepuni Gardens footbridge c1899 (source Bridging the Gap by G Thornton)

---

[16] "Context of World Heritage Bridges" A Joint Publication with TICCIH, 1996 by Eric DeLony www.icomos.org/studies/bridges

[17] "A Survey of Non-arched Historic Concrete Bridges in Virginia Constructed Prior to 1950" by A.B. Miller et al Virginia Transportation Research Council July 1996

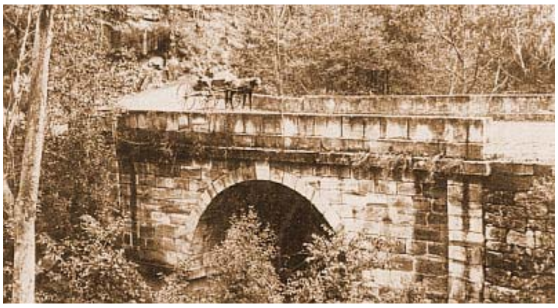
[18] "Bridging the Gap Early Bridges in New Zealand 1830-1939" by G. Thornton, published by Reed

[19] www.hants.gov.uk/environment/bridges Bridges in Hampshire of Historic Interest

1.4. The History of Reinforced Concrete Bridges in the Context of New South Wales

1.4.1. Introduction

Bridging streams was one of the first public works carried out in the fledgling penal colony of Sydney. The Tank Stream was spanned by a bridge made from local timber, in the first year of European settlement. At the time, it was noted that *"a gang of convicts were employed in rolling timber together to form a bridge over the stream at the head of the cove"*.[20] This set a pattern which was to continue into the twentieth century – of using the strong, plentiful, straight local hardwoods for bridge construction over streams. Larger rivers were forded or crossed by punts or ferries.



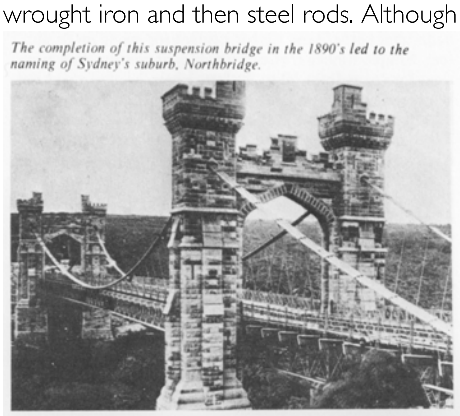
Lennox Bridge 1880s
(Source Mitchell Library scanned from Pictorial Memories Blue Mountains)

Although during the 1810s Governor Macquarie set his sights higher, and triggered a period of excellence in public works, no bridges of his period remain, largely because of a dearth of artizans skilled in bridge construction. The oldest surviving bridges are of stone arch construction over Lapstone Creek in 1833 and over Prospect Creek at Lansdowne in 1836, both by David Lennox. However, the vast majority of bridges built over the following eighty years were of timber. These were initially simple structures using timber for piers and abutments, with round logs forming the stringers of the deck, and topped with timber planking, all connected using iron bolts and spikes.

1.4.2. The Colonial Period

During the nineteenth century the need to span larger crossings, and to avoid piers in the water which degrade quickly and form an obstruction to flood debris, led to the development and adoption by the 1850s of a range of truss designs. These were typically named after the designers who developed their geometry, immortalising Allan, Warren, McDonald, Pratt and Howe amongst others. While Percy Allan was an Australian (Chief Engineer for National and Local Government Works, Public Works Department), they were not all local engineers (Pratt was an American for example). Information on the latest bridge design tended to spread fairly rapidly through the worldwide engineering community. Adoption of new ideas was, however (and remains) a slower process, being driven by a diverse set of constraint including cost, material availability, site suitability and various pragmatic issues such as individual preferences, resistance to change, and the cost of preparing new designs.

As the century wore on, iron in its various forms became more available and its use in bridges increased. Its ability to carry tensile loads led to truss forms wherein timber in the truss tension diagonals was replaced by wrought iron and then steel rods. Although complete iron bridges had been built elsewhere from the late



Northbridge (source The Roadmakers)

; not till 1851 that an all metal superstructure was erected in New
Subsequent bridges included the Prince Alfred Bridge over the
aving three continuous wrought iron spans, the Denison Bridge
0 using iron from the Fitzroy Iron Works at Mittagong, and Iron
ey in 1882 and c1883 respectively. Complexity of metal structures
: opening spans becoming common, and with wrought iron
rial was also applied successfully to suspension bridges (Hampden Bridge, Kangaroo Valley 1898 and Northbridge 1892).[21] Concrete saw its first role in bridges in New South Wales through the "back door". It was found to be a suitable material for filling the insides of cast iron pier caissons and the like, providing a filling which was not only

[20] The Roadmakers A History of Main Roads in New South Wales, Department of Main Roads New South Wales, 1976

[21] The Roadmakers A History of Main Roads in New South Wales, Department of Main Roads New South Wales, 1976

strong and stable but also protected the iron from corrosion due to its alkalinity. It also began to make cameo appearances in the form of mass concrete for abutments. This actually revived a role concrete had filled for the Romans two thousand years earlier.

With the dominance of German speakers in the commercialisation of reinforced concrete bridges in the late nineteenth century it is not surprising that this link brought the technology to Australia. W J Baltzer, a German immigrant working for the New South Wales Public Works Department maintained contact with his brother in Germany, and through that link, awareness of the emerging technology. In 1890 he travelled to Germany to gather information on this new form of bridgebuilding. However, on his return he was unsuccessful in interesting his superiors in the technique and ultimately joined several businessmen to obtain licences through Wayss to cover the Australian Colonies.[22]

Their company, Carter Gummow & Co, built several small trial structures, apparently one of these being a culvert under Parramatta Road at Burwood in 1894.[23] Unfortunately, it is unclear if this structure is still extant. The current main crossing has a flat soffit and the semi-arched connection to an upstream circular pipe is of rough construction unlikely of a trial structure built to impress potential users.

Entrance to culvert under Parramatta Road Burwood

Arched connection from slab culvert to circular pipe under footpath

Carter Gummow & Co subsequently obtained contracts to build two large arched sewage aqueducts over Johnstons Creek and Whites Creek in Annandale.[24] Completed in 1896 they remain as probably the earliest reinforced concrete bridge-like structures in Australia.

Johnstons Creek Aqueduct, Annandale

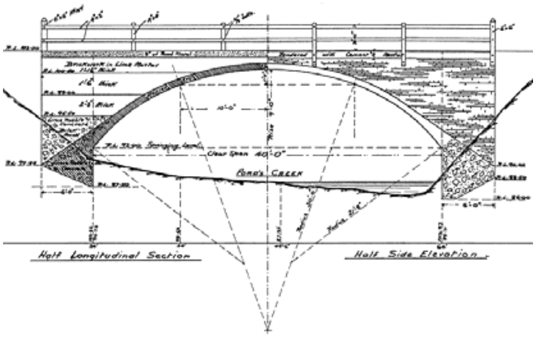
Whites Creek Aqueduct, Annandale

22 **John Monash Engineering Enterprise Prior to** World **War I Introduction of Monier concrete to Victoria,** Australia http://home.vicnet.net.au/~aholgate/welcome.html

[23] Some Notes on the History of Concrete Bridges in N.S.W. by L.H. Evans Unpublished manuscript, stamped March 1986, held by RTA library, Parramatta

[24] John Monash Engineering Enterprise Prior to World War I Introduction of Monier concrete to Victoria, Australia http://home.vicnet.net.au/~aholgate/welcome.html

Baltzer became the Chief Engineer of Carter Gummow and in this role began promoting the technology. He spoke in 1897 to the Engineering Association of NSW, and the company held a stand at the Engineering and Electrical Exhibition in Sydney, gaining coverage in the Building Mining and Engineering Journal.



Monier arch, Fords Creek, Victoria(http://home.vicnet.net.au/~aholgate)

Monier arch construction, Victoria. (Source:State Library of Victoria)

In the same year Gummow and W C Kernot, Professor of Engineering at the University of Melbourne jointly mounted an exhibition on the subject in Melbourne. The partnership of John Monash and Joshua Anderson, which had formed in 1894, obtained from Gummow sole rights to the Monier patent in Victoria. In 1899 Anderson St Bridge was built by Carter Gummow & Co and then the Monash/Anderson partnership constructed two Monier arch bridges, at Fyansford and Wheelers Creek in 1900. Several others followed. In 1901 one of their bridges, Kings Bridge at Bendigo, collapsed whilst being load tested,[25] ultimately bringing the partnership down with it, but not before they had built a total of 15 bridges in the period 1899-1903. The Bendigo bridge was a heavily skewed arch. It collapsed under an unusually severe test load of a steamroller back to back with a steam traction engine, killing one man. The partnership was exonerated by the coroner when Professor Kernot of the University of Melbourne showed that accepted theory (as set forth in W J M Rankine's texts) greatly underestimated the stresses in skewed arches - by a factor of as much as four. Monash went on to establish the Reinforced Concrete and Monier Pipe Company, and progressively moved into beam type bridges rather than the arch concept which had proved so troublesome.

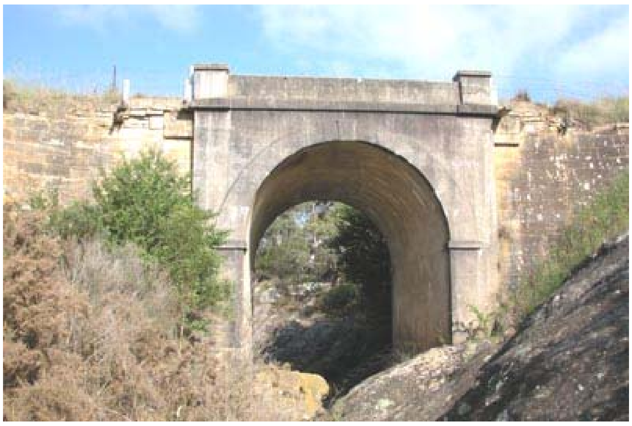
Kings Bridge collapse during load test by steam and traction engines – both visible (source http://home.vicnet.net.au/~aholgate/jm/)

Returning to New South Wales, the oldest existing concrete road bridge was constructed for the Public Works Department by J W Park of Gladesville in 1896 over Black Bobs Creek on the Hume Highway near Berrima.[26] Like the Pont de Souillac, it was unreinforced, having a 9.14m span and a width of 8.84m. It remained in service until the Highway was rerouted in 1971, despite the concrete having been made from low strength sandstone aggregate. It has been said in the RTA that the bridge was, in fact, detailed with the appearance of exposed stone to avoid problems from those who were nervous about the new technology of concrete.

---

[25] John Monash Engineering Enterprise Prior to World War I Introduction of Monier concrete to Victoria, Australia History of King's Bridge Bendigo http://home.vicnet.net.au/~aholgate/jm/texts/kingshist.html

[26] Some Notes on the History of Concrete Bridges in N.S.W. by L.H. Evans Unpublished manuscript, stamped March 1986, held by RTA library, Parramatta

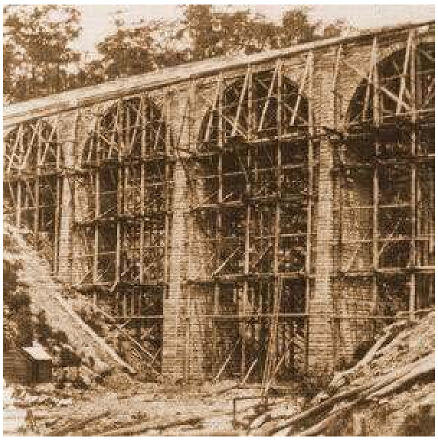


Black Bobs Creek Bridge, old Hume Highway alignment. Unreinforced concrete arch

Although this bridge is no longer in service and has passed to the care of the local council, there are current plans to improve its accessibility from an adjacent rest area, and install appropriate interpretive signage.

Whilst on the issue of unreinforced arches (i.e. the form leading to reinforced concrete arches) it should also be mentioned that brick and stone arches were also a very significant bridge form, not so much for road bridges as for rail. The spread of an extensive rail network throughout New South Wales saw a large number of brick and stone arches built, ranging in size from modest culverts to large multispan structures such as those visible west of Lithgow. One of these which has come into the RTA's portfolio is the sandstone multi-span arch over Knapsack Gully at Glenbrook. Originally built in 1865 as part of the centre leg of a zig-zag rail link up the eastern escarpment of the Blue Mountains, it consists of 7 arches, reaching a height of 38m at the centre. It was designed by John

Lapstone masonry arch bridge (RTA Bridge No 967) (Photo NPB Photographics)



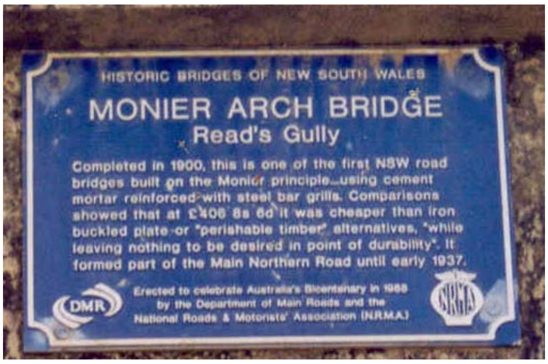
Lapstone Bridge during construction (source http://info.mountains.net.au/rail/lower/lapstone.htm

Whitton, engineer-in-chief of the Railways, and referred to as his masterpiece.[27] Abandoned in 1913 when the rail line was rerouted to avoid the delays of the zig-zag, it was widened and reopened in 1926 to carry the Great Western Highway. Another arch structure still in the RTA inventory was a brick arch built in 1840 over Duck Creek at Granville, servicing the Great Western Highway. A number of other masonry arches from the late nineteenth century are also still in service, including the Battle Bridge (RTA Bridge No 40) sandstone arch over the Hawthorne Canal at Petersham.

In 1900, six years after the trial culvert at Burwood, a Monier reinforced concrete arch was erected over Reads Gully on the Main Northern Road near Tamworth (presumably by Carter Gummow & Co who held the patent rights) at a cost of £406.8.6. The bridge served until it was replaced during a realignment of the New England Highway in 1937. It is now in the care of Parry Council.

[27] The Roadmakers A History of Main Roads in New South Wales, Department of Main Roads New South Wales, 1976

Reads Gully Bridge, Tamworth 1900



Plaque on Reads Gully Bridge, Tamworth

The Assistant Engineer for Bridges, Mr E M De Burgh mentioned in the Public Works Department Annual Report for 1900 that the Monier arch system would have been used more often if there had been more suitable sites.[28] Such a site was soon found at Richmond where the existing timber bridge was prone to damage during the frequent floods which submerged it, often with heavy loads of floating debris. Professor W. H. Warren of Sydney University acted as a consultant to the Public Works Department on the design which consisted of thirteen Monier style arches, two of 15.84m span and eleven of 16.45m. With a total length of 214.6m this 1905 structure was the longest reinforced concrete bridge in New South Wales for the next 25 years.

Bridge over Hawkesbury River at Richmond 1905 (RTA Bridge No 429)

1.4.3. Developments in the Twentieth Century

In support of the move to use reinforced concrete for local structures, Professor W.H. Warren, Challis Professor of Engineering at Sydney University and President of the Royal Society of NSW undertook research into the strength and elasticity of reinforced concrete utilizing local materials. Results of these investigations were published in the Journal of the Royal Society of NSW in 1902, 1904 and 1905.[29] Despite this supportive work, the number and scale of concrete bridges built in New South Wales over the next decade was small.

The first concrete beam bridge built in New South Wales was a small bridge over Muddy Creek on the Princes Highway at Rockdale in 1907 (deck now replaced and widened). The oldest extant slab bridge is over Muttama Creek at Cootamundra (RTA Bridge No 6438), built in 1914 whilst the beam bridge over American Creek near Figtree, built in the same year has now been replaced, as has a similar bridge over Mullet Creek,

---

[28] Some Notes on the History of Concrete Bridges in N.S.W. by L.H. Evans Unpublished manuscript, stamped March 1986, held by RTA library, Parramatta

[29] W.H. Warren, " Investigations in regard to the comparative strength and elasticity of Portland Cement Mortar and Concrete when reinforced with Steel Rods and when not reinforced'. *Journal of the Royal Society of NSW*, Vol. XXXVI, 1902, pp.290-313; "Further Experiments on the Strength and Elasticity of Reinforced Concrete', *Journal of the Royal Society of NSW*, Vol. XXXViiI, 1904, pp.140-189; "Reinforced Concrete, Paper III', *Journal of the Royal Society of NSW*, Vol. XXXIX, 1905, pp.49-64.

Dapto of 1916 and concrete beam bridges at Throsby Creek Wickham and Shark Creek, Maclean. Extant from the same year is the slab bridge over Surveyors Creek at Walcha (RTA Bridge No. 3485).

Muttama Creek Cootamundra 1914 (RTA Bridge No 6438)

Surveyors Creek Walcha 1916 (RTA Bridge No 3485)

These structures, with deck geometries having either flat soffits or beams cast monolithically with the deck, represented a logical step forward in the use of reinforced concrete from the first spate of arch bridges, and actually reverted to the style used by Monier in his first bridge. The concrete arch did not in fact, efficiently utilise the freedom of geometry that reinforced concrete was able to offer. In the traditional masonry arch, avoidance of collapse was achieved by keeping the line of compression within the curved masonry. With a reinforced arch the same thinking initially applied, but with the advantage that the reinforcement could accommodate some local bending effects (such as from concentrated loads from heavy wheels) by using the tensile capability of the reinforcing in the concrete. However, these structures were still faced with placing filling on top of the arch to build an almost level surface for traffic, and this meant an overall heavy (and thus somewhat inefficient) structure. Once designers of reinforced concrete began to use the material in a manner which took advantage of its tensile capabilities, lifting the underside of the superstructure close to the top of the deck, design efficiency began to improve. Up to a span of several metres, flat slabs were efficient. Beyond that, by having a thin deck to carry the local wheel loads across to beams with steel reinforcement concentrated near the bottom, deck structures of up to 15 m were ultimately achieved.

The next step was to make the composite beam systems continuous over their supports. By making the deck continuous at the piers, adjacent spans effectively assisted each other by spreading a load on any one span along the bridge. In a typical span, by changing from simply supported to continuous, the bending moment due to self weight at midspan drops from M to M/3, whilst the moments at the supports go up from zero to -2M/3. There is thus a 33% net reduction in the bending moment to be designed for, and the peak occurs at the piers where extra beam depth can be provided efficiently. Placing the reinforcing steel predominantly in the bottom of the slab at midspan, and bending it up into the top over supports (where the bending effect is reversed) designers were able to place the steel effectively where the tension forces occurred. The bridge described as "the first true continuous girder reinforced concrete bridge" was Fullers Bridge across Lane Cove River, completed in 1918.(RTA Bridge No. 105)[30]. This has spans of 9.14 m. It is interesting that this continuous bridge has outlived all the simply supported span beam bridges erected before it.

Fullers Bridge (Bridge No 105) Note curved beam soffit, continuous over piers, providing deeper beams where the bending moments are greatest

[30] Some Notes on the History of Concrete Bridges in N.S.W. by L.H. Evans Unpublished manuscript, stamped March 1986, held by RTA library, Parramatta

The conceptual logic contained in these early bridges was to persist with relatively modest changes until the introduction of prestressing in the 1950s. (As beam bridges are the core topic of this study, their design, numbers etc are more fully explored in Section 3.)

By the end of World War I there was the prospect of a substantial increase in both bridge building in general and in reinforced concrete in particular. In 1914 the Director General of Public Works stated that *"the increasing cost and difficulty in obtaining timber of suitable quality and dimensions for the large highway bridges determined me to adopt steel and ferro-concrete construction wherever practicable".* [31] In contrast with timber, the raw materials for reinforced concrete bridges: coarse aggregate, sand, cement and steel bars were becoming readily available.

The other driver was the explosion of private car ownership and the dramatic growth in truck transport of goods, with the weight of trucks growing continuously.

Croobyar Creek Bridge (Bridge No 730) Note curved deck with crossfall to suit high speed curve

The style of roads and bridges which had sufficed during the nineteenth century, wherein the road alignment and surface was subservient to the surroundings, was no longer acceptable for the higher vehicle speeds now emerging. Road design became a science in which the design speed dictated the minimum radius of vertical curves as well as horizontal ones. These were predicated on principles of safe stopping sight distances, and on limiting the lateral forces on vehicles. Previous rules, such as that mandated by the railways, that all overbridges must be at right angles to the rail line (to minimise soot effects from steam trains) began to be overturned, as were rules of thumb such as minimising the cost of bridges by making them straight and of minimum length (for example over rivers). Other parameters to evolve progressively during the Twentieth Century included the design weight of vehicles, the width of lanes, the provision of width to provide continuity with the shoulders of the roadway, and rules for impact resistance of railings. All of these have had their impact, not only on the design of new bridges but also on the continued appropriateness of existing structures and the need to modify them to maintain their level of service.

1.5. The Role of Government in Road and Bridge Expansion in NSW.

1.5.1. The Colonial Era

Prior to the granting of responsible government in the 1850s all authority and responsibility was exercised by the Crown's representative in the Colony of New South Wales, the Governor. Roads and bridges were constructed by decree of the Governor on the advice of his staff. These were the officers of the Colonial Architect's Branch of the Surveyor-General's Office. This system evolved at Federation into a structure containing three tiers of control: Federal, State and Local. Interfacing with this hierarchy was free enterprise, the entrepreneurial companies of which variously built roads and bridges for contracted amounts or were licensed to carry out works and collect tolls. The course of change through this process has been well documented in such works as *The Roadmakers*, and *Vital Connections.* During the period of interest for this current study, viz 1905 to 1948, many changes occurred. Leading to the period in question (and covering some of the earliest reinforced concrete works), the Department of Public Works (created in 1859) was put under the control of R Hickson as Commissioner in 1889 who separated the State into six divisions, each with its own Resident Engineer who reported to Divisional Engineers operating from Sydney

[31] Some Notes on the History of Concrete Bridges in N.S.W. by L.H. Evans Unpublished manuscript, stamped March 1986, held by RTA library, Parramatta


David Lennox, first Superintendent of Bridges, 1833-1843.

David Lennox

In 1895 the Roads, Bridges, Harbours and River Branches were placed under the control of one officer with the title of Engineer-in-Chief for Public Works, and Hickson was appointed to this position. In the following year he was also made Under Secretary for Public Works.

1.5.2. The Twentieth Century

With the turn of the century, significant political change occurred. The States combined (with the blessing of the Crown) to form a new country, the Commonwealth of Australia, in 1901. The increase in population also led to further pressure for decentralisation of power, and the 1906 Local Government Act transferred to shires and municipalities the responsibility for care and maintenance of local roads and other public works. This was funded partly by council rates which were based on the unimproved capital value of land, and topped up by grants from the State and Federal governments under a variety of funding arrangements. As a result of the handover, the greater part of the state's 48,500 miles of roads and bridges were passed over to the care of local government, and in 1907 the position of Commissioner for Roads was discontinued. Unfortunately, this change led to a decline in the amount of money actually spent on roads in general, and main roads in particular, although a proportion of roads and bridges were declared National Works and were maintained by the Department of Public Works.

By the end of the First World War, the NSW roads were in a poor state with even national roads badly underfunded. In 1924, after years of haggling and politicking, the Main Roads Bill was introduced into the New South Wales Parliament and subsequently the Main Roads Board of New South Wales was created in 1925 with the powers to function as a State road authority, and with 12,840 miles of roads to care for. Within a year the Board was swamped with requests from councils eager to offload their road responsibilities, the cost of which had been escalating. Early planning reviews not only allocated funding to established roads, but also set in train plans for a dozen new roads linking areas of the state not well connected by the road system which, until then, had grown like the proverbial Topsy. These new roads required new bridges, a number of which form part of the present study.

It was not until 1927, after almost three years of wrangling between the Main Roads Board and the Department of Public Works that a clear definition of the lines of responsibility was achieved. The Department of Public Works took charge of roads and bridges in the Western Division, and the Main Roads Board took responsibility for Main and Developmental Roads in the Eastern and Central divisions of the State. Matters relating to other roads, including interfaces with the councils, were placed with the Department of Public Works.

To rationalise the system of road classifications, all roads were reviewed in 1928 and new classifications of State Highways, Trunk Roads and Ordinary Main Roads were introduced. These changes had substantial implications for funding of the various roads, and thus of the councils who carried out much of the work. In the same year the Main Roads Board decentralised its road design and construction activities to regional headquarters in Glen Innes, Tamworth, Parkes, Queanbeyan, Wagga Wagga and Sydney. While it was feasible to set up road design teams in these offices, the high level of professional skill required for bridge design (and the more peaky nature of the workload) was seen as justification for keeping the bridge design team together in Sydney, at the Board's offices in Castlereagh Street.

More political machinations and funding skirmishes saw the Main Roads Board dismantled in 1932 and replaced by the Highway and Roads Transportation Branch of the Department of Transport. In the aftermath of a dogfight between the State and Federal governments (during which the funds of the State were garnisheed by the Commonwealth), the Department of Main Roads was created in 1933, a bureaucratic arrangement which lasted until 1989. These organisational changes occurred during (and perhaps because of) confronting times of economic depression and high unemployment.

From 1932, motor vehicle registrations grew at the astonishing annual rate of 48% in a period of 4% population growth and with a depressed economy. As the motor vehicle moved from being an unreliable and relatively slow contrivance to an essential high speed means of transport, new concepts for roads began to emerge, including multilane roads, grade separated intersections, speed limits, removal of level crossings, and, in the country, separation of roads from stock routes. Thus the focus changed from making the roads passable to making them safe and efficient. By 1938 the total length of roads covered by the Department was 24,643 miles. This was a boom period for the construction of simple, functional concrete bridges which embodied the new standards, to replace decrepit timber structures or flood prone open crossings on roads controlled by the Department. (Whilst not part of this study, the same pressures were also being felt at the local government level with respect to bridges on local roads. However, with lower levels of funding their inventory of bridges typically lagged behind).

The prospect, duration and aftermath of World War II meant that defence priorities overshadowed civic factors in the development of roads and bridges over the final 10 years of the period under study. The decisions regarding which roads would be built and which bridges built or upgraded were made on defence criteria ahead of general traffic management issues. Key issues included the ability to move troops and military hardware rapidly from military facilities to strategic defensive locations. North-south lines of communication were seen as particularly important, with potential invasion expected from the north. Further downsides of the war included the diversion of funds and personnel away from non-strategic infrastructure. Contractors with bridges already committed to construction found difficulty getting tradesmen and materials to complete their works, and the Department was asked for extensions of contract times in many cases.

Coming out of the War, there was another hiatus as the community and bureaucracies refocussed. This meant another difficult period of limited access to equipment, materials and personnel even for urgent works, some of which had been held over from prior to commencement of hostilities. The War had seen a further jump in motor vehicle technologies and with it a new era of road planning began to implement more of the ideas regarding traffic management conceived in the 1930s, but not brought to fruition. The late 1940s thus closed out an era, to be replaced by a new world of freeways and prestressed concrete.

1.5.3. Key Bridge Design Personnel

The following table identifies many of the key engineers involved with the design or design management of bridges in NSW, with particular reference to the period under study. The list is provided to help readers understand the flow of engineers and managers who drove the design processes of the road bridge network. Where information has been available to link individuals to bridges, this has been identified. Unfortunately, in the majority of the bridges under study, little remains in the RTA files to identify the actual designers. Where original drawings (or copies thereof) are on file, the initials of designers are sometimes discernable and these have been acknowledged in the inventory. However, the practice of not including the designer's full name on the drawings, and giving him recognition on the bridge itself, all conspire to hide the identity of the individuals who created the original designs.

Having said that, it should be recognised that bridge design, like many other areas of human endeavour, is generally not the work of one person alone, but the progressive total of those who have gone before in developing earlier designs, of field personnel who gather data necessary for proper assessment of foundations, waterways etc, of peers carrying out design checking and drafting, and of management who ensure that all aspects are orchestrated efficiently and within overall budget constraints.

In the instance of slab and beam bridges in particular, the modest scale of most crossings has meant that designs became more or less standardised, with individual bridges being created by use of standard spans, piers and abutments. These standard designs tended to stay in use for some years until the march of progress, in the form of increased traffic design loads or improved material properties (such as concrete strength) meant that revision was warranted, leading to an updated standard design.

TABLE 2.5.3.1 KEY NAMES IN BRIDGE DESIGN, NSW[32]

Title	Name	Start Date	End Date	Significant Work
First *Superintendent of Bridges*	David Lennox	June 1833	1843	Lennox Bridge Lansdowne Bridge
Commissioner and Engineer-in Chief for Roads	W.C. Bennett	1862	1889	
Engineer-in-Chief for Public Works	R. Hickson	1889	1901	
Professor of Engineering, Sydney University	Prof W.H. Warren	1883	1925	Northbridge suspension bridge, Richmond Bridge
Bridge Modeller & Bridge Computer	H.H. Dare			Richmond Bridge
PWD Engineer	John A. MacDonald			MacDonald truss bridges
Chief Engineer for National and Local Government Works	Percy Allan	?	46 years	Allan truss bridges; Associated with more than 550 bridges
Chief Engineer, Sydney Harbour Bridge and Metropolitan Railway Construction, PWD	Dr J.J.C. Bradfield 1867-1943	1891 (Started with PWD) 1912	1932	Sydney Harbour Bridge
Supervising Bridge Engineer	E.M. De Burgh	1891 (?)	1900?	De Burghs Bridge, Lane Cove
Bridge Engineer (Transferred from Public Works)	Spencer Dennis	1928	1951	Promoted use of Reinforced concrete
Bridge and Designing Engineer	H.M. Sherrard	1926	1928	
Assistant Bridge Engineer	F.W. Laws	1935	1942	
Assistant Bridge Engineer	C.A.M. Hawkins	1944	1946	
Assistant Bridge Engineer	R.A.J. Thompson	Jan 1946	Nov 1946	
Assistant Bridge Engineer	A.J.Clinch	1946	1953	
Bridge design engineer	Vladimir Karmalsky	1930s	1950s	Bow-string arches

[32] The Roadmakers A History of Main Roads in New South Wales, Department of Main Roads New South Wales, 1976

Title	Name	Start Date	End Date	Significant Work
Bridge design engineer	A.T. (Sandy) Britton	1930s	1950s	Shark Ck, Hillas Creek (bow-string arches)
Bridge design engineer	A Halvorseth	1930s	1950s	Tuena River (through girder) Galston Gorge Bridge and others

1.6. The Reinforced Concrete Bridge as an Element of Public Infrastructure

1.6.1. Introduction

Despite the arduous process required of Baltzer and others to get reinforced concrete bridges accepted as a valid medium, the social, economic and environmental impact of these bridges during the twentieth century has been immense. From a standing start at the turn of the century, they achieved the status of preferred bridge form for small to medium spans, and were seen as providing the flexibility that would allow the greatest spans to be contemplated. They are now a ubiquitous part of the landscape, generally providing many years of troublefree service to the community and representing a substantial part of the bridge infrastructure of the state. Bridges built to variations on the beam design are found in a great range of natural and cultural landscapes, and facilitate social and economic life in a great range of communities across NSW.

1.6.2. Bridges as Infrastructure

The bridges comprising the study group are all under RTA-control by virtue of being located on main roads, and in the context of this study, in the Sydney, Southern and South West Regions. Several of the great highways of NSW are represented. Almost one third of the seventy-eight bridges in the study group are located on the Princes Highway, spread out between Wollongong and the Victorian border. Three of the bridges are located on the Great Western Highway, and two on the Hume Highway. Approximately one third of the bridges in the study set are located in the Sydney area, on main roads such as Pittwater Road in the north or Woodville Road in the west. In the south western part of the State the Sturt Highway and Olympic Highway are among the transport conduits of which bridges in the study set form a part. Many of these routes have long and rich histories which are intimately related to the patterns of economic, social and environmental history in the regions or suburbs they traverse. The roads on which the bridges are situated are the context for the bridges' planning, construction and use, and provide much of the historical context and landscape context in which they are located.

Several of the bridges in the study group cross major waterways – the Hawkesbury River, Lane Cove River, and the upper reaches of the Wonboyn, Woronora and Wollondilly Rivers. Here the bridges have played a major part in the development of important routes, replacing punts or less reliable lower level bridges. In doing so they have also become dominant features in the landscape and are perceived as important infrastructure items by the community. For example, Fullers Bridge across the Lane Cove River when constructed in 1918 formed the first bridge link across the river linking the Willoughby and Lane Cove municipalities via Fullers and Delhi Roads. The bridge is an impressive structure which has retained a dominant place in the landscape and has excited continued interest in the community from the early stages of its planning in 1898, when a meeting of the Lane Cove and Willoughby Councils[33] discussed the siting of the bridge, to the present.

While most of the bridges in the study group are more modest structures crossing more minor waterways, their value as infrastructure on the State's major transport conduits should not be underestimated. The

[33] Willoughby Mayor's Minute Book; record of meeting of Willoughby and Lane Cove Councils, 5 September 1898

crossings are characterised typically by various combinations of steep gullies, bogging sands, rapidly rising freshes or persistent flooding, and have the potential to form considerable obstacles to traffic.

The bridges in the study group were predominantly built in the period 1925-1948, by which time the vast majority of the routes which form today's main roads were well established transport conduits, often on generally the same alignment presently followed. These roads had developed as tracks and stock routes through the early to mid twentieth century, many likely to have followed Aboriginal pathways, and been formalised and improved through the mid to late nineteenth century under colonial administration, the Department of Public Works and local government administration from 1906. The majority of bridges in the study group therefore replaced a previous bridge, generally timber, on the same site, or were built on short deviations which improved the alignment of an existing route across the waterway in question. In several cases, the concrete bridges in this study were constructed to replace timber structures which were on the point of collapse, or which had done so already, having served sixty years or more. The timber bridge crossing Cattai Creek in the Hawkesbury region, for example, met its demise through attack by teredo worms[34], and was replaced by the current concrete beam bridge in 1946. The more usual story along the Princes Highway was severe damage or even complete destruction of timber bridges by flood. In other cases on the South Coast, bridges constructed in the late nineteenth century were just no longer appropriate for the traffic demands being placed upon them.

The bridge over Sheas Creek, otherwise known as the Alexandra Canal, in the Botany area was constructed to replace a lift span bridge built in 1895. Canal Road - Ricketty Street on which the crossing is located had become a busy thoroughfare by the mid 1930s as industry in the Botany area continued to grow, and the bascule lift span of the 1895 track span type bridge had a narrow carriageway, only capable of accommodating a single lane of traffic. As visibility on the approaches to the bridge was poor, traffic crossing the canal from either direction frequently met on the bridge, necessitating the backing up of one of the lines of vehicles.

The historical significance of some of the bridges in the study group is enhanced by physical evidence of older structures. The remains range from a few cut-off timber piles, such as those directly under the Poisoned Water Holes Creek Bridge on the Sturt Highway, to more substantial remains, such as the two abutments and one pier footing adjacent to the Mummel Brudge over the Wollondilly River on the Goulburn – Grabben Gullen Road.

Mummel Bridge (RTA Bridge No 6677) Old abutment

Concrete pier footing with base timber

A small group of bridges within the study set combine reinforced concrete beam decks from the period 1920-1948 with abutments and piers of an earlier era. The Hawkesbury River Bridge at Windsor was initially opened in 1874, consisting of iron piers filled with mass concrete, with a timber deck supported by hardwood girders. The deck was raised eight feet in 1896, with the extension of the iron piers. In about 1920 the current concrete beam deck was added. Thus the history of that bridge is a lot longer than the history of reinforced concrete beam bridges in NSW.

[34] RTA General File 91.1537, Correspondence 5-31 December 1935


Hawkesbury River (RTA Bridge No 415) Cast iron caissons


Yellow Rock Bridge (RTA Bridge No 790) Mass concrete wall piers


Bowning Creek Bridge (RTA Bridge No 6474) Stone wall pier

Yellow Rock Creek Bridge at Albion Park [RTA Bridge No. 790] currently has a concrete beam deck, constructed in 1940, supported on mass concrete piers constructed in the late nineteenth or early twentieth century, which earlier supported a timber deck. The Bowning Creek Bridge at Bowning [RTA Bridge No. 6474] similarly incorporates stone abutments and pier constructed in the 1880s and a concrete beam deck of c1930. Through their form as composite structures, this small group of bridges has the ability to demonstrate changing needs and standards through the adaptation of the older structure for continued use.

For the majority of bridges in the study group, their construction was associated with upgrades of state-managed roads under the Department of Public Works and subsequently the MRB and DMR. As stated above, most were constructed on or near the site of the previous crossing, but in some instances the logical development involved the construction of deviations which necessitated the replacement of a number of crossings. The Cockwhy deviation on the Princes Highway, for example, which contains the concrete beam bridges over Stephens, Cockwhy, Hapgood, Higgins, Middle and Backhouse Creeks (RTA Bridge Nos 737, 738, 739, 740, 741, 742), was constructed in the 1930s to improve travel time and safety on the Princes Highway between Termeil and the area to the north of Batemans Bay, and was the longest and most ambitious of the deviations on the Princes Highway at the time[35].


Woronora River (RTA Bridge No 152)

Against the general trend, a small number of the bridges in the study group were constructed on entirely new roads built for purposes related to the political or economic climate of the twentieth century. During World War Two priority was placed on providing and upgrading road links seen as strategically significant for military purposes. Harris Creek Bridge and Woronora River Bridge, were constructed under this imperative as part of the Heathcote Road link between the Holsworthy Army Reserve and the Princes Highway at Heathcote.

The newer, more flexible bridge technologies embodied in the study set provided higher speed alignments, smoother surfaces and wider carriageways; the character of the State's roads were changed. The beam bridges in the study group along with road improvements facilitated comparatively reliable, safe, comfortable and speedy travel which revolutionised motor transport in local areas, regions and, cumulatively, the State as a whole.

History has not stopped since the bridges in the study group were constructed. Traffic volumes and speeds have continued to increase across the 20th century and expectations of road infrastructure have continued to

[35] DMR, 1976, pp 160-161

rise. These trends have had an impact on the number, form and status of beam bridges constructed in the period 1907 –1948. The growth in vehicle weights and increases in lane and shoulder widths have meant that many bridges built of reinforced concrete in the 1907-1948 period have already been replaced. It is therefore testimony to the success and resilience of the subject bridges that they still exist. That many have been widened or duplicated is a reflection of their flexibility to be incorporated in upgrades. Of those which have not been changed in width, many have had their original pipe or concrete railings replaced with guardrailing which has a better safety record in redirecting impacting vehicles. The bridges with all original features intact have thus become a minority, and one that is under pressure, particularly those outside urban areas where high transit speeds and narrow bridges compromise road safety.

Broughton Creek Bridge (RTA Bridge No 704) Widened two span bridge composite with abutment

Stapletons Bridge Albion Park (RTA Bridge No 881) showing original frames, centre, and widening frames

Of the bridges that have been widened, some have been done in a way which is visually sympathetic to the original structure and preserves opportunities for the viewing and interpretation of the original bridge, whereas other widenings have paid scant attention to issues of aesthetics or sensitivity to the original structure. The widening of Broughton Creek Bridge on the Princes Highway, seen above, is an example of a sympathetic widening, using cantilevers attached to the existing three beam bridge, as is the widening of Stapletons Bridge Albion Park where additional beams of similar form to the original were used for the widening.

1.6.3. The Bridge Planning, Design and Construction Process.

Many roads in the first decades of the Twentieth Century were susceptible to quick degradation during rain, and stream crossings were even more vulnerable. The priorities of the Public Works Department , Main Roads Board and then Department of Main Roads were set by a combination of long term goals for infrastructure improvement and the responses necessary to flood events and the like and to community action for improved roads. Community action was directed to achieving all-weather roads and bridges on locally essential routes. This action usually took the form of written dialogue with the local representative of the Department of Main Roads (or its predecessors), and in some cases, via Members of Parliament.

Several of the bridges in the study group were constructed due to pressing local needs, and at times under the pressure of energetic community lobbying. For example, the Cattai Creek Bridge, completed in 1946 was constructed partly in response to community agitation for a new, higher level bridge over Cattai Creek, which began in the mid 1930s, with the Cattai District Progress Association writing to the Department. The Sydney Morning Herald of 2 March 1938 ran a short article noting that when the low level timber bridge was submerged in flood, farmers were forced to take their milk supplies to the factory across the creek by boat. The timber bridge was also dilapidated and planning for the current bridge was commenced prior to 1940, but, according to the RTA file, was delayed by World War Two. Safe pedestrian use of bridges, particularly those providing access to schools has also been a significant issue in the planning of bridges, with decisions as to whether to provide a footway (and who should pay) and retrofitting of footways being well represented in the correspondence in the MRB and DMR files.

Once the need for a new crossing was established, the site was surveyed, soil investigations undertaken and the catchment area measured. This work was typically undertaken by DMR personnel or contractors working for them. Bridges were typically designed by the Bridge Section in Sydney, with construction being undertaken through divisional offices. Construction was either by the Department's own work force (so-called day labour) or let out by tender to private contractors. Many local contractors were engaged. Irrespective of contractual arrangements, the majority of input was labour and the supply of materials, much of which was available locally – all assisting the local economy.

Bridge building is a specialised and highly skilled trade. Several generations of bridge builders were involved in the construction of the bridges in the study group. Construction in the period under study had certain salient features that made the builders a particular kind of community in an unusual workplace. The workers were often accommodated in camps due to the on-site pouring process which, when concrete was mixed by hand, was a slow, labour-intensive activity, and one which could not be suspended at convenience but which had to reach pre-designed construction joints. The study period saw an increasing mechanisation of the road and bridge construction process with petrol driven mixers replacing hand mixing of concrete for example.

Concrete mixer 1947 – Cockle Creek railway bridge (Photo Max Broadbent)

The construction of bridges often necessitated the bridge gang setting up camp in the neighbourhood. Mrs Jessie Johnston (nee McGregor) of Brogo remembers crossing the bridge over Alsops Creek every day to get to school. She remembers the construction of the new concrete bridge in 1929, chiefly because the bridge gang is suspected of poisoning her much loved old dog, which used to visit their camp and eat any unguarded food.[36]

The elaborate construction process was vulnerable to interruption by flood, and the economic exigencies of the time. More than one contractor was forced to relinquish the contract with the bridge still incomplete. The construction of Middle Creek Bridge No. 1 on the Wakehurst Parkway in Sydney's north by contractor Peter Koshemakin of Ulladulla was initially delayed by the difficulty of obtaining requisite materials on time and "the acute shortage of labour', due to the shortages of the early years of World War Two. At the end of March 1942, with footings prepared and at least one abutment completed, floodwaters washed away the timber falsework in place for construction of the bridge, and due to the losses incurred thereby, the contractor found himself financially unable to complete the work. The Department approached A.T.B. Anderson & Sons, who had just completed the construction of the nearby No. 2 bridge over Middle Creek and had also won the contract for the Deep Creek Bridge further to the north, to finish the job.[37]

Entire routes were constructed in the aftermath of the Depression in order to stimulate the economy and generate employment. Unfortunately, even the Board was affected by the economic woes in the depths of the Depression and unemployment relief works which carried 2000 people in 1929 (out of a total workforce of 4000) was curtailed completely by 1931, leaving only 1000 in jobs. By 1933 the number employed by the Board was back up to 3000, and in the mid 1930s relief works aimed directly at using unemployed labour included sections of the Princes Highway including the Cockwhy Range deviation, which contains the bridges over Stephens, Cockwhy, Hapgood, Higgins, Middle and Backhouse Creeks (RTA Bridge Nos 737, 738, 739, 740, 741, 742).[38]

[36] **Correspondence, Bega Valley Historical Society, 2004**

[37] **RTA File 479. 1351, RTA File 479. 11736**

[38] The Roadmakers A History of Main Roads in New South Wales, Department of Main Roads NSW, 1976 pp160-161

1.6.4. The Construction Process and Visual Evidence of Construction in the Fabric of the Bridges

All of the bridges in the group bear evidence of the construction processes characteristic of their period. They are all cast-in-situ structures, involving the pouring of the concrete into a mould (formwork) supported on a scaffolding of falsework on the construction site. The majority of the bridges in the study group used timber formwork, which was eventually phased out by large sheets of formply. These developments left their imprint on the finished work. The beam design required complex formwork, particularly where the beams incorporated tapered or curved profiles, and where the bridge was built on a curve or a skew. Therefore, a team of skilled carpenters was necessary for the construction of each bridge.

Middle Creek No 1 (RTA Bridge No 146) Complex shapes using timber formwork

Middle Creek No 1 Remnant timber piles used for formwork support

Falsework used to support the formwork was originally made from timber, with concrete footing pads for this still visible under some bridges. (While this timber falsework was eventually replaced by standardised steel frames, there is no evidence of the transition). Within the concrete, the reinforcing steel had to be supported above the formwork to provide sufficient cover of concrete to prevent corrosion of the steel. This has been achieved by a variety of means over the years, with most work of the period being supported on small cubes of concrete referred to as Aspros. The marks of many of these can be seen on the undersides of bridges in the study group. Later, bar chairs were made from steel wire, then tipped with plastic, and finally made completely from plastic. These changes have reflected sometimes poor performance of these systems which, when they allowed the ingress of moisture to the steel, triggered corrosion.

Wandandian Creek (RTA Bridge No 723) This sturdy high level structure was erected in 1929 replacing a set of three low level timber bridges vulnerable to flood. As well as motor traffic, the bridge was used by bullock teams dragging logs to the Wandandian Sawmill

1.6.5. Relationships with Communities – using the bridges, and their place in the social and economic landscape.

Bridges represent a substantial and an essential part of the assets of the community. Of the bridges in the current study, the majority are on routes carrying high levels of goods and services, and their disappearance would bring much of the State to a halt. The cohort of bridges comprising the study group have a diverse set of relationships with the community. Some are in suburban Sydney or Wollongong, others in regional centres or small towns and some on long stretches of highway. As evidenced by replies from local historical societies, some bridges have been created and satisfactorily performed a function while remaining almost totally unnoticed, or have been simply experienced as part of general road improvements. Others provided much relief to locals at the time of construction, alleviating the stress of being stranded in floods or having part of the town cut off.

Burrangong Creek Bridge, Young (RTA Bridge No 6427).Shopping precinct in background and Information Centre on right

A small number of bridges in the study set have been connected to a community's sense of pride or identity. Burrangong Creek Bridge, now the Sarah Musgrave Bridge at Young is one such. The "Young Chronicle" gives an account of the opening of the bridge in early November 1932. The Mayor, Ald. Prescott presided over the proceedings, welcoming the Minister for Local Government, Mr Jackson, Commissioner for Transport, Mr Newell, and dignitaries from surrounding centres. The new bridge was heralded as a symbol of Young's progressive spirit and wise administration by Mr Jackson who said that, "the spirit of progress was exemplified by their doing away with the old and supplanting it with the new". The Minister cut a ribbon at either end of the bridge with a pair of gilt scissors. The opening was attended by a "huge crowd" who were eager to cross the bridge on foot and souvenir pieces of the ceremonial ribbon [39]. The first car to cross after the ribbon had been cut was a Chevrolet driven by Mrs Cyril Robertson of "Barwang", with her two children and the Town Clerk, Mr G S Sparks as passengers. The *Young Witness* newspaper noted that the main girders and piers were of heavy construction and would withstand great weights and great pressure from floods respectively, and that everybody in the town for the opening was full of admiration for the strength, durability and attractive finish of the newly completed bridge[40].

1.6.6. Visual Impact in the Landscape

A large proportion of the bridges in the study group are, by the nature of their scale and design, inconspicuous and unobtrusive, particularly from the roadway. Many are only discernable to the passing motorist by the presence of a signpost identifying the waterway, and a length of guardrail protecting the drop on either side. The bridges in the study group which retain their original steel pipe or concrete handrailings are much more visually distinctive from the roadway, the railings indicating their vintage.

[39] **The Young Chronicle, Municipal Jubilee Number, 4 November 1932**

[40] **Young Witness Newspaper, 13 January 1932**

Haslams Bridge (RTA Bridge No 307) Original reinforced concrete railings

Harris Creek Bridge (RTA Bridge No 500) Pipe railings with concrete endposts

Croobyar Creek Bridge (RTA Bridge No 730) Retrofitted Thrierail guardrailing

In contrast to steel or timber and truss bridges which enclose the motorist and declare their structural form above deck level, for many bridges in the study group it is necessary to leave the carriageway and in some instances climb fences before the actual structure of the bridge can be viewed. An exception is the Tuena River Bridge, with a through-girder design, featuring edge beams which also form the bridge parapet or sidewall. The girders are robust structural members with enlarged top flange areas, thinner side walls with vertical ribs aligning with the cross beams, and bottom flange enlargements. The girders of the two central spans have an attractive curved profile.

Tuena River (RTA Bridge No 6401)

Ten Mile Creek, Holbrook (RTA No 5444) In town centre with model rail track beneath.

Hawkesbury River (RTA Bridge No 415) Viewed from riverbank parkland

A small number of bridges in the study group, however, have settings facilitating views of the bridgeworks. For example, Prouts Bridge in Canterbury has public parkland adjacent on both sides, and a cycleway passing underneath the bridge. Similarly, Burrangong Creek Bridge and Ten Mile Creek Bridge have public areas adjacent to, and underneath them. All three bridges have landmark qualities, forming gateways to the localities to which they facilitate road access, to Canterbury centre, and to the regional centres of Young and Holbrook respectively. Some of the bridges in the study group are impressive in scale and facilitate views to the waterways and valleys they cross. The Hawkesbury River Bridge at Windsor and the Woronora River Bridge are the longest bridges in the study group at approximately 143 metres and 125 metres in length respectively.

Both have landmark qualities because of their size and place in the landscape, the Hawkesbury River Bridge crossing the most impressive watercourse in the Sydney area, and the Woronora River Bridge soaring across a steep rocky gully in spectacular sandstone woodland country. The Hawkesbury River Bridge, Fullers Bridge and Lane Cove River Bridge (Northbound) both crossing the Lane Cove River, cross navigable watercourses and form landmarks from the water as well as the road.

Diggers Creek (RTA Bridge No 6201) Simple curved soffit

Croobyar Creek (RTA Bridge No 730) Complex curvature

Concrete beam bridges in general are the outcome of a process which has maximised function by minimising the complexity of form, resulting in simple clean construction lines. However, the study group includes a great range of minor variations on the basic beam designs, and a substantial proportion of the study set demonstrate some attention to aesthetic considerations on the part of the designers. The curved beam profile characterising many of the bridges has a simple but pleasing effect on both the small scale and larger bridges. The curved beam soffits of the single span Diggers Creek Bridge, present a modest but appealing form sympathetic to the spectacular Snowy Mountains landscape in which the bridge is situated. Croobyar Creek Bridge on the Princes Highway makes extended use of curved forms in its beams, crossbeams and headstocks, the entire bridge is built on a curve and crossfall, which emphasises the curved form further.

Many of the bridges enhance the simple, clean lines of the beam form with detailing of a broadly classical, art deco or modernist style. Such detailing renders these bridges visually distinctive as structures from the first half of the twentieth century. The advent of prestressing in more recent decades has resulted in the commodification of the smaller classes of bridges to the point where prestressed concrete planks are ubiquitous, and detailing of decks incorporates standard details, leaving bridges with little individuality. Paradoxically, prestressing, particularly in the form of post-tensioning, has also opened freedoms in design never available in reinforced concrete, and there are many newer structures of this form bearing testament to the ongoing concern of designers with aesthetics, at least on larger scale and visible projects (of which footbridges are a good example).

Middle Creek Bridge (RTA Bridge No 147) Post art deco endpost

Wonboyn River Bridge (RTA Bridge No 6012) Bold straight and curved lines

Couria Creek Bridge (RTA Bridge No 5978) Individualised pier framing