RTA

Masonry Bridges

Heritage Study of Masonry Bridges in NSW

2005

HISTORICAL BACKGROUND TO MASONRY BRIDGES IN NSW

1.1 History of early bridges constructed in NSW

Bridges constructed prior to the 1830s were relatively simple forms. The majority of these were timber structures, with the occasional use of stone piers. The first bridge constructed in NSW was built in 1788. The bridge was a simple timber bridge constructed over the Tank Stream, near what is today the intersection of George and Bridge Streets in the Central Business District of Sydney. Soon after it was washed away and needed to be replaced. The first "permanent" bridge in NSW was this bridge's successor. This was a masonry and timber arch bridge with a span of 24 feet erected in 1803 (**Figure 1.1**). However this was not a triumph of colonial bridge engineering, as it collapsed after only three years' service. It took a further five years for the bridge to be rebuilt in an improved form. The contractor who undertook this work received payment of 660 gallons of spirits, this being an alternative currency in the Colony at the time (*Main Roads*, 1950: 37)

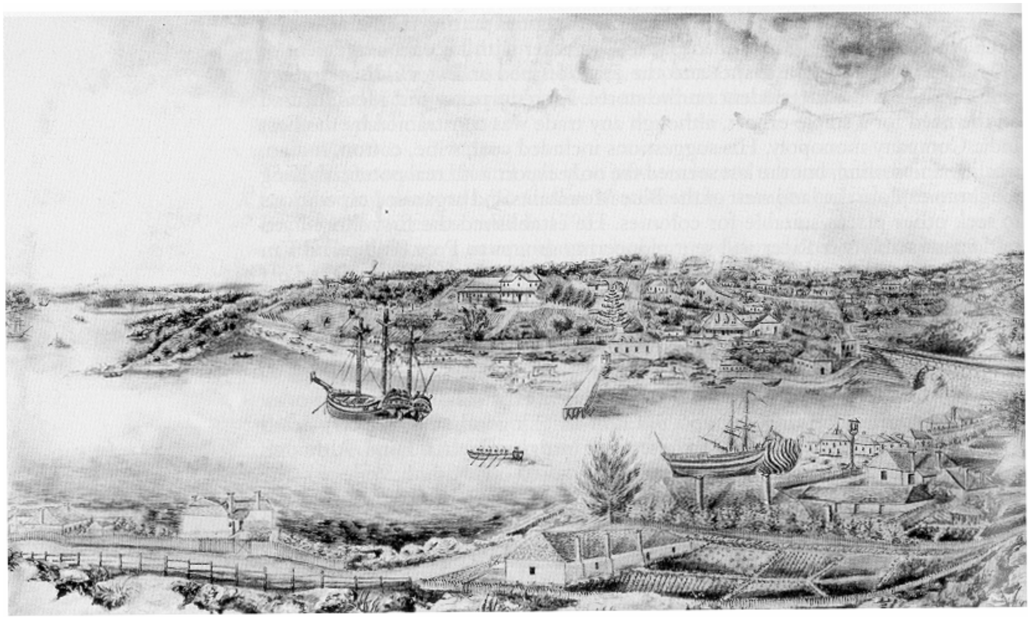

Figure 1.1 "View of Sydney from The Rocks, 1803", by John Lancashire (Dixson Galleries, SLNSW). The masonry bridge over the Tank Stream can be seen on the right.

Other early bridges consisted of timber including one in Parramatta, built by Major Grose in 1794, washed away in 1795 and replaced by a second bridge built a few years later and repaired in 1802. The Duck River Bridge, between Parramatta and Sydney was completed in October 1797. This was later destroyed by fire in 1839.

Prior to the arrival of David Lennox in the Colony in 1832, NSW was without expert knowledge in bridge design and construction. The earliest masonry bridge extant in NSW is the Horseshoe Bridge on Mitchell's Pass, near Lapstone (**Figure 1.2**). Completed in 1833, it is located on Mitchell's Pass and part of the Great Western Road. It was David Lennox's first project following his appointment as Sub-Inspector of Roads on 1 October 1832. This bridge marked the introduction of modern bridge engineering technology in NSW, earning Lennox the description of the "first "scientific" bridge builder in the colony".

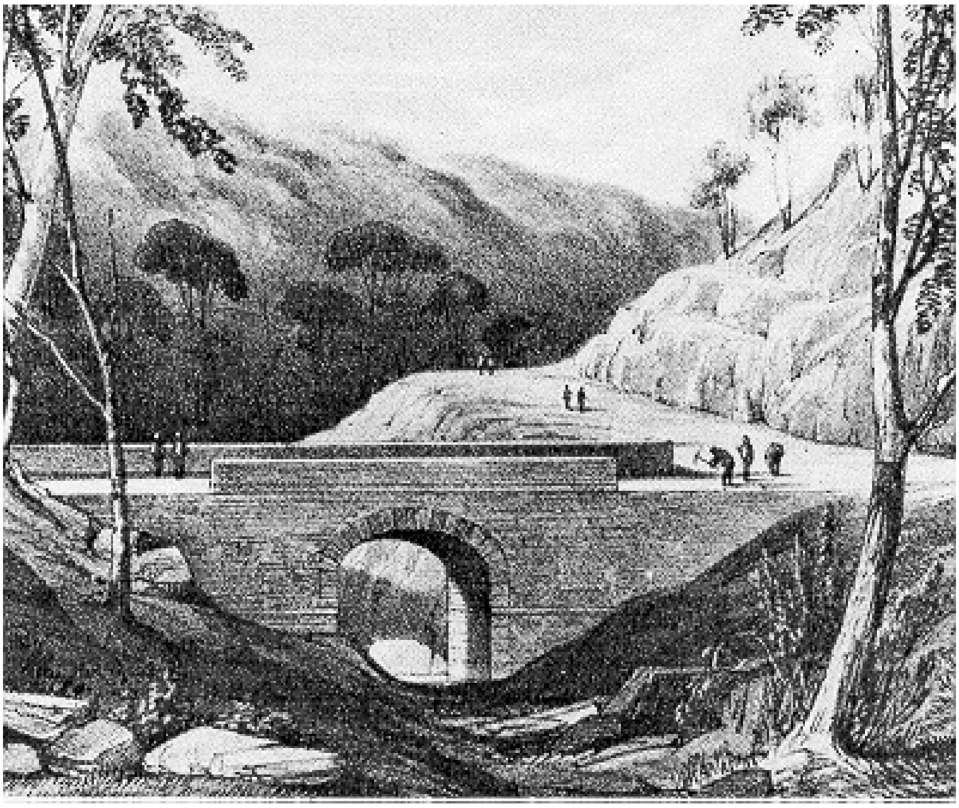

Figure 1.2: Early print of Lennox Bridge, Lapstone (DMR, 1976:27).

During the first 60 years of the Colony, the majority of bridges were built from stone or timber, in the same manner as bridges being constructed in Britain and Europe. Stone was the bridge building material of choice in NSW, with construction costs kept low by the use of convict labour. However, with the cessation of convict transportation in the 1840s and subsequent rise in labour costs, bridge designers were forced to explore the use of other materials in bridge construction, leading to the eventual adoption of timber as the economical alternative. The size and quantity of readily available Australian hardwoods in the 1800s allowed the design and construction of efficient timber truss bridge designs reaching respectable spans.

1.2 History of masonry bridge design

The colonial application of bridge construction techniques was based on imported knowledge from Britain which in turn had been based on knowledge that went back to Roman times. The bridge building techniques employed by Lennox were not innovative. The main problem in New South Wales was the lack of skilled persons in the colony, knowledgeable in this area prior to Lennox's appointment. The development of major roads in New South Wales coincided with a flurry of road and bridge works in Britain. In 1838 alone, £46,000 was spent on bridges by county authorities. The development of the macadamised system of road building by John MacAdam, and Telford's successful improvement of the highway between London to Holyhead raised the public profile of road engineering. Henry Parnell's account on Telford's Holyhead Road in 1833, was the first of a large body of technical manuals on road engineering to be published during the nineteenth and early twentieth century (**Figure 1.3**). A copy of Parnell's work was sent to Governor Bourke in 1835 by Lord Glenelg, Secretary of State for England.

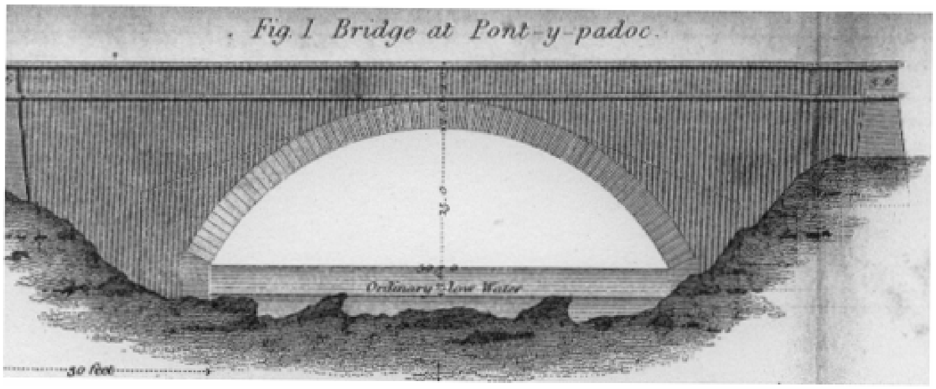

Figure 1.3: Parnell's account of Telford's Holyhead Road included drawings of the various bridges and tollbars (Parnell, 1833:9).

Bridges constructed in New South Wales prior to 1833 consisted mainly of simple span structures. In his manual for the construction of roads, Gillespie wrote that:

> *The most simple and natural form of a bridge consists of two timber beams, laid across the stream, or opening, which is to be passed over, and covered with a plank to form the roadway. Walls should be built to support each end of the timber, and are named the abutments* (Gillespie, 1868: 173).

Such simplistic constructions were only suitable for bridging short widths of waterway. For greater lengths, supports from the base of the opening such as piers, upright props or timber shores were used. These were supported on piles if the foundations were insecure. This method was not recommended for deep openings, or across rapid watercourses. In such situations, the use of bolsters, struts or a straining-piece was used (**Figure 1.4**).

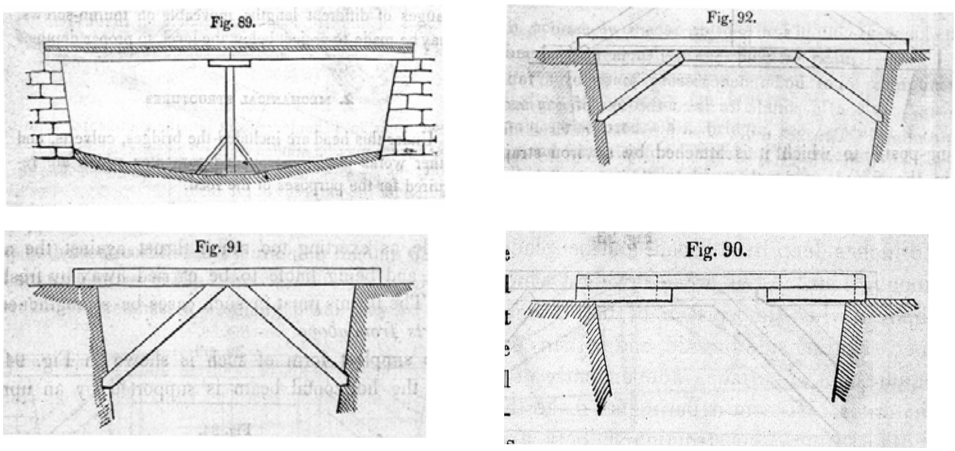

Figure 1.4: Simple bridge construction methods using timber planks (Gillespie, 1868:174-5).

In Britain and Europe, the technical design of masonry bridges reached new levels of sophistication from the late eighteenth century and into the nineteenth century. In Britain, the design of masonry bridges underwent three major developments in the first part of the nineteenth century. This included a lengthening of the spans of the largest arches, impact of French practices on bridge form and architecture, and improvements in foundation work (Ruddock, 1979: 46). Construction of long spans was spurred mainly by desires to construct record spans. During the nineteenth century, bridges were often prepared as part of design competitions.

The value of theoretical mathematics and physics to building applications was first recognised in France. Such sciences remained primarily academic pursuits until the seventeenth century. The formation of the Academie de Sciences as a school for the natural sciences by Colbert in 1666, established France at the forefront in the development of engineering sciences. Road and bridge construction was centralised in 1720, when the Corps des Ingenieures des Ponts de Chaussees was formed from the corps of military engineers. The first engineering school was founded in Paris, opening in 1747. Jean-Rodolphe Perronet was the first head of the school and later became the Premier Ingenieur of the Corps. He developed a style of arch bridge that was applied extensively throughout France and later adapted to British designs.

Perronet's style was characterised by three main elements, see **Figure 1.5**. First, there were pointed cutwaters, rounded at the shoulders. They extended up the spandrels, continuing above the springings of the arches, but not as far as the parapet. The spandrel faces were plain and vertical. The interior was usually filled with masonry.

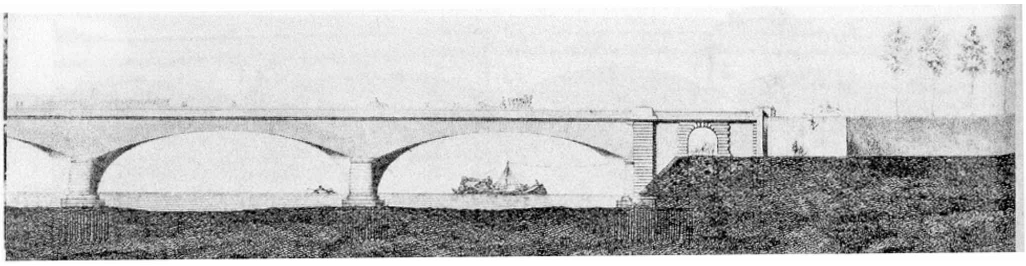

Figure 1.5: Half of Pont de Neully (from Perronet 1783 in Ruddock 1979).

The second characteristic related to the arch curves. These were either circular segments or ellipses. Earlier masonry bridges mainly consisted of a three-centred curve, producing a limited arch span. With Perronet, the segments of a greater radius circle was applied, allowing the bridge to have greater waterway clearance. The arch profile was also very low. By applying findings of structural and material analysis to design, Perronet reduced the vertical distance from the springing line to the crown to a value of 1/12, a value rarely exceeded in present designs. Perronet first applied this design element to Sainte-Maxene Bridge over the Oise.

With a low profile arch, the abutments were designed to carry most of the horizontal thrusts, with the piers designed only to support the vertical load. This enabled the piers to be unusually narrow. Previous to Perronet's designs, the customary ratio of pier width to span width was 1/5. This ratio was reduced to between 1/10 to 1/12. This method of design required the centering of all the arches to be erected at once and the support work could not be removed until all the arches were built (Ruddock, 1979: 63).

The third characteristic related to the lines of the road and parapets. These were generally horizontal in contrast to the majority of which were rounded to let rainwater run off the roadway easily. While assisting traffic flow this could however lead to water pooling on the bridge.

In addition to the three main elements, Perronet incorporated a fourth feature that was used occassionally. This involved chamfering the edges of the arches, which appeared as tapering crescents on the elevations (Ruddock, 1979). This characteristic was known as cornes de vache (cow's horns) or the splayed arch.

Its more streamlined form provided hydraulic benefits by lessening the flat surface opposed to the current of the river whenever it was in flood. Cornes de vache were used prior to Perronet, but became widely recognised through his application of the technique on the Perronet bridge of Neuilly, near Paris.

This fourth characteristic is of particular interest, because it was used by Telford for the design of the Over Bridge near Gloucester. Lennox, who had overseen the construction of this Bridge, later used this design as the basis for Lansdowne Bridge over Prospect Creek in New South Wales.

In 1783, Perronet published *Description des projets*, which included 67 plates showing all the details of his bridges. This publication provided British engineers with details of the French designs and the influence of this soon began to appear in British works.

Masonry arch bridge design was further improved in Britain during the nineteenth century. In particular, pier foundations were advanced to provide more stable and durable bridges. The construction of Westminster Bridge from 1738 to 1750 included the first use of open caissons. These consisted of open-ended boxes, which were pre-formed before being floated out to the pier location and sunk. The top of the box remained above water level, allowing the masonry work to be constructed within the caissons before they were removed. Caissons were used in conjunction with cofferdams to allow greater protection to the pier foundation. While the use of caissons provided an effective means of pier construction, it took several decades to refine the technique. With Westminster Bridge, problems with its foundations finally led to its demolition less than a century after its completion (Steinman & Watson, 1941:103-4).

John Rennie introduced new techniques to bridge construction, which marked a departure from French designs. In 1809, Rennie was invited to review the design of a new bridge intended to connect the Strand with the Surrey side of the Thames and was to be known as Waterloo Bridge. In the course of his review, Rennie recognised it was based on Perronet's bridge at Neuilly. Since its completion, the Pont de Neuilly had experienced problems with the settlement of the arches and unstable foundations. Rennie prepared new plans, including one for a bridge consisting of nine semi-elliptical arches, which was approved in favour of the original design submitted. Construction of Waterloo Bridge commenced in 1810, with Rennie as the chief engineer (**Figure 1.6**). The use of cofferdams allowed greater certainty in driving piles and laying foundations on the dry riverbed within these dams. The successful usage of cofferdams was also due to Rennie's application of steam power to drive the pumps. This effective use of cofferdams made caissons obsolete.

1.3 Lennox's work in New South Wales

The mammoth task of surveying the whole colony from 1828 to 1831 had resulted in the growth of the Surveyor General's Department to over thirty staff members. Directing his attention to establishing a road system, Mitchell wrote in 1833:

> *...have now completed the marking of the great roads throughout the Colony according to one general system; when they will be made God knows* ("Papers of Sir Thomas Livingstone Mitchell Vol.II" Mitchell Library).

Many colonial engineers and surveyors, such as Assistant Surveyors Elliot and Lambie had worked with Telford and MacAdam, and were knowledgeable with road construction techniques. There was however a notable gap in bridge engineering within the Department, particularly in regard to masonry walls.

In 1832, Mitchell had a chance encounter with David Lennox whilst walking along Macquarie Street. Lennox was employed as a mason at the Legislative Council Chambers and was busy shaping a coping stone for the dwarf wall. Mitchell was so impressed with his workmanship that he inquired of his experience. Mitchell later recalled:

> *Mr David Lennox, who left his stone wall at my request, and with his sleeves still tucked up – and trowel in hand -, came with me to my office, and undertook to plan the stone bridges we required, make the centering arches, and to carry on such works by directing and instructing common labourers then at the disposal of the Government. Thus originated all the bridges this colony possesses worthy of the name.*
>
> ("Papers of Sir Thomas Livingstone Mitchell Vol.VIII" Mitchell Library)

The Surveyor-General lost little time in submitting Lennox's credentials to the Governor, describing him as "a very well qualified person recently arrived in the Colony." Acting on Mitchell's recommendation, Governor Bourke provisionally appointed Lennox as a Sub-Inspector of Bridges on 1 October 1832 at a salary of £120 per annum. In June 1833 the position was confirmed by London as Superintendent of Bridges.

David Lennox was born in 1788, at Ayr in Scotland. Following his wife's death in 1828, he migrated to New South Wales arriving in Sydney on August 11, 1832. Lennox gained his experience in Britain, working for 17 years on public works funded by the British government. When applying for a salary increase in 1835, Lennox wrote:

> *I have recommendations from the best qualified persons in Europe to give such recommendations, - From that late Thomas Telford Esq Civil Engineer F.R.S.P.S.E. without whose advice the British Government advanced no money upon Public Works in the Engineer Department…* (Bundle 38/7385, Mitchell Library)

In Britain, Lennox had worked in different capacities on two key bridges, both designed by Telford. These were the Menai Suspension Bridge, connecting the Isle of Anglesea on the northwest coast of Wales with the mainland, where he worked as a stonemason from 1819, and the Over Bridge at Gloucester (**Figure 1.6**) in the west of England where he worked as Foreman, with three others, during its three year construction (Selkirk, 1920: 204). Completed in 1827, the bridge consisted of a single span of 150 feet with a rise of 35 feet above the waterline. Telford had adopted the design from Perronet's Neuilly Bridge over the Seine (**Figure 1.5**).

Figure 1.6: Over Bridge, Gloucester, 1827. (Image courtesy of Gloucester City Council).

David Lennox's first project following his appointment as Sub-Inspector of Roads on 1 October 1832 was the Horseshoe Bridge on Mitchell's Pass, near Lapstone (see **Figure 1.2**). It was This bridge marked the introduction of modern bridge engineering technology in New South Wales, earning Lennox the description of the "first "scientific" bridge builder in the colony".

His greatest bridge was the Lansdowne Bridge across Prospect Creek, between Parramatta and Liverpool, completed in January 1836 (**Figure 1.7**). During its construction he made regular tours of inspection to several bridges under his direction on the Great Road South. He completed two other bridges later in 1836.

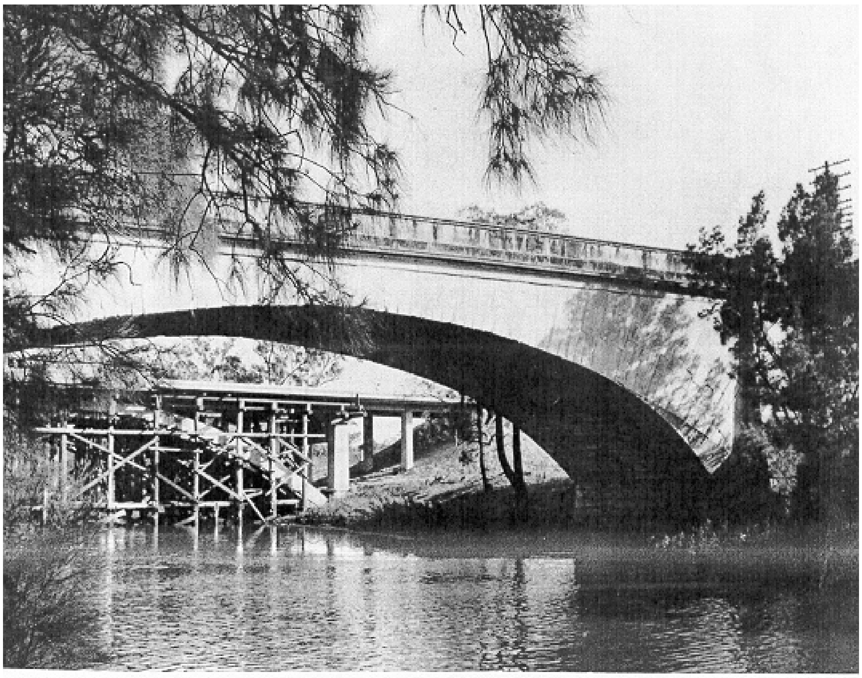

Figure 1.7: View of Lansdowne Bridge looking south in 1957. The new bridge for westbound traffic is under construction in the background.

In 1833 Lennox received instructions to construct a bridge across the Wingecarribee River at Berrima, and although there was some delay in the commencement of the work it was completed in June, 1836. It was designed along the lines of the Lansdowne Bridge, but it was smaller with a span of 15.2 metres (50ft) and a width of 27ft, including parapets and without the bevelling of the arches (**Figure 1.8**). It was damaged by flood in 1858, and then destroyed in February 1860 (Main Roads, 1950: 40).

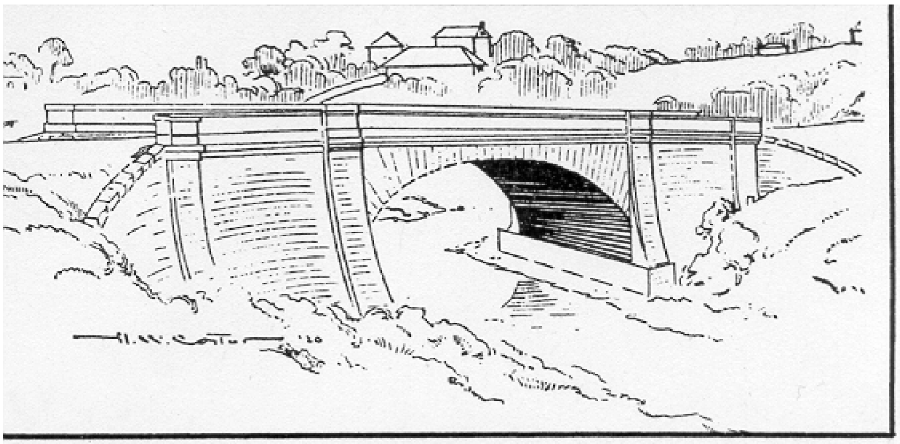

Figure 1.8: Sketch of Berrima Bridge (*Sir Thomas Mitchell's Field Book* C.53 ML SLNSW).

On 23 January 1834, Lennox reported having laid out the site of a bridge on the main southern road at the crossing of Medway Rivulet, three miles south of Berrima. For this crossing a wooden bridge supported by three masonry piers 20 feet apart was designed. In 1835 the Surveyor-General reported that the bridge had been completed. This was destroyed by floodwaters in 1860 and later replaced.

Again in 1834 Lennox laid out the site of a bridge at Crawford's or Black Bob's Creek, 7.5 miles south of Berrima. The span of the bridge was 9.1m (30ft). Although the bridge was open to traffic in April 1836, it was not completed until early 1837. The Surveyor-General reported that the piers and walls were of excellent stone resting on a solid mass of rock, and that the bridge was constructed of strong beams, supported by a brace. It was built on the same design as a number of bridges constructed by Lennox on the Gloucester-Berkeley Canal This was replaced by the Public Works Department in 1896 with a mass concrete arch built between the sandstone abutments. It is the oldest existing concrete bridge in NSW (Evans, 1987: 3).

The last bridge which Lennox designed and built in NSW was over the Parramatta River in Church Street, Parramatta. Originally designed in 1835 as a single elliptical arch of 90 ft span, it was built, after much controversy, as a simple stone arch spanning 80ft and having a width of 39ft. Construction began in November 1836, using the centering from the Lansdowne Bridge, adjusted to the new span, and was completed in 1839. The Bridge was named Lennox Bridge by the Parramatta Council in 1867.

From January 1, 1837, the construction of roads and bridges passed from the Surveyor-General to the Royal Engineers under Colonel Barney, to whom also Lennox was transferred. Duck Creek Bridge on the Parramatta Road, originally designed by Lennox as a timber structure on stone piers, was built about 1840 as a semicircular brick arch of 9 m (30ft) span with brick abutments. This had a total length of 25.50 metres (83 ft) and provided a 10.80 metre (35ft) wide roadway (**Figure 1.8**).

Figure 1.8: View of the Duck Creek Bridge at Granville looking north.

The keystone of the arch on the downstream side bore the Masonic symbol of a pair of compasses open upon the segment of a circle. In Freemasonry this has a Scottish significance, and is no doubt a Master Mason's mark, providing strong evidence that Lennox supervised the work (Selkirk, 1920: 228). In 1937 the bridge was widened under the direction of the DMR, by the addition of a 30ft span concrete arch to the downstream side of the bridge. There is another small bridge at Towrang with a span of the order of 5metres. One of the keystones is inscribed 1839, and it is believed that the bridge was built by Lennox (**Figure 1.9**). It is located on the original south road between Berrima and Goulburn, immediately east of the turn-off to Carrick.

Figure 1.9: Towrang Bridge built in 1839.

In November 1842, Lennox was appointed as District Surveyor to the Parramatta District Council on the recommendation of a Board of Examiners. The Board spoke in the highest terms of his qualifications in bridge building of the best construction, construction of roads, canals, dams, and most other descriptions of public works, which they considered should be sufficient recommendation to any District Council.

Lennox held this office for only one year before taking up a position as Superintendent of Bridges at Port Phillip, Victoria. In this capacity he was responsible for the construction of all roads, bridges and wharves. He is said to have built over fifty bridges in the state, however many were of timber and none have survived. Severe flooding in May 1852 washed away his bridge at Geelong, and severely damaged those at Batesford, Inverleigh and Cressy. Lennox's greatest Victorian work was the Prince's Bridge spanning the Yarra with a single stone arch of 150 feet. Completed in 1850, this structure was demolished when the river was widened in 1888 (Selkirk, 1920: 238).

In 1855, on his return to New South Wales from Victoria, Lennox settled in Parramatta, living firstly in Macquarie Street while he designed and built a cottage in Campbell Street. This cottage, which is still standing and is listed by the National Trust, was where he spent the remaining years of his life.

David Lennox died at his home on 12 November 1873 aged 85, and was laid to rest in the vault of his son-in-law Mr CW Rowling, in old St. John’s Cemetery. By some strange oversight no inscription was placed upon the stone which marks his grave, so that some uncertainty exists as to where he is actually buried.

It has been said of the renowned 19th century engineers Telford and Rennie:

> *Here were Scotsmen of humble origin who applied their remarkable gifts in an age that offered opportunity to men of vigour and intelligence* (de Mare, 1975: 117)

The same could be said of Lennox.