

Crossing the Nepean River on the Western Line between Penrith and Emu Plains.

The Hawkesbury – Nepean River reaches in a wide arc around the whole of the metropolitan area of Sydney. There is no way out of Sydney, except for a narrow strip of land between its headwaters and the coast above Wollongong, that does not cross it. The planners of the early NSW railways, whose intended destinations were Goulburn and Bathurst faced the river crossing as their largest single constraint, at least until they tried to cross the Blue Mountains.

The early railways kept to the watersheds between river valleys to avoid river crossings, but the Nepean could not be avoided. At one stage the point at which the South line would diverge from the West line was placed west of the Nepean near Emu Plains, so as to allow a single crossing to serve both lines. The South line would have been routed through Silverdale and The Oaks to Thirlmere. This was circuitous and didn't really solve any problems for it just introduced a crossing of the Warragamba River. This 'tributary' is in fact the major contributor to the flow of the Nepean at Penrith and would have required a significant bridge.

So the decision was made to cross the Nepean twice – at Menangle for the Great Southern Railway and at Emu Ford for the Great Western Railway. Although the Emu Plains crossing opened four years after Menangle it had taken longer to build as recurring floods disrupted work on the piers. The two bridges were more or less built at the same time, work at Emu Plains was in hand in 1862 well before Menangle opened.

As is widely recognised the Colonial Governments were anxious to minimise the cost of the railways and had decreed that only local stone or timber could be used for bridges. Iron had to be imported and its great cost was largely expended out of New South Wales. Whitton designed Menangle in iron, was forced to redesign in timber but a fortuitously timed flood made it apparent that the timber bridge was a folly. The iron bridge was built. The loss of two timber road bridges, just upstream of the site of the Penrith rail bridge reinforced this decision. Nevertheless both railway bridges only had iron spans for the central section over the river *per se*; the approaches would be timber. This was proven to be a false economy at Penrith, even before it opened.

The first designs for the western line bridge had a trestle approach on the east and a pair of laminated timber arches on the west. The arches were not built. A longer trestle was used instead.

Both Menangle and Victoria (as the Penrith – Emu Plains bridge was named) are TUBULAR GIRDERS. They are the only tubular girder bridges on the NSW railways. It is sometimes suggested that the central longer span of the two iron viaducts over the Wollondilly River to the north of Goulburn were also tubular girders. Although initially designed as girders which could be considered as tubular, they were in fact never built to that design.

The problem facing engineers as they evolved designs for the use of this new material – iron – was to find the best way to use it. The earliest examples used it as if it were wood, albeit a very strong form of wood. Their designs were limited by the capacity of iron works to produce, cast and then work the iron into useful shapes which could be assembled into bridges. Their rolling mills did not have anywhere near the power to form the material into very large "I" beams which might be the ideal bridge building section in later years and electric welding, which could fabricate large plates into gigantic "I" beams, did not exist yet. They had small plates and angles, which they could only join by riveting, and they had to figure out a way to make something which could span 150 or 200 feet.

It should also be emphasised that the material was IRON, not STEEL. Iron at this time was described as WROUGHT Iron. The wrought term refers to the hammering and rolling used to get the ingot from the furnace, shaped into a useful thing. Wrought Iron is basically pure iron, and that is not

particularly strong. There are inclusions of slag and carbon, like a plum pudding, and they become flattened by the working, but they play no part in strengthening the iron. Steel, on the other hand has no slag or carbon inclusions, but rather has the carbon dissolved in the iron. It is an alloy of iron and carbon. The small number of carbon atoms in the iron crystals snag as the iron tries to deform under load so the material is stronger and has many other useful properties which make it ideal for building bridges. But steel was not 'invented' until 1869 by Henry Bessemer, and by then Victoria Bridge had been in service for two years.

The great insight of TUBULAR bridges was that by fabricating the small pieces of iron into square tubes a strong and rigid girder could be produced. The tubular girder of all tubular girder bridges was the Britannia Bridge over the Menai Straits built by Robert Stephenson in 1850. It was so large , twice the span of Victoria, that trains actually travelled inside its closed tube, but the important design similarity to Menangle and Victoria is the multiple small tubes which at Britannia form a roof and floor and at the NSW sites form the top and bottom 'flanges' of the girders. Tubular girders were used in other structures in NSW. The roof of the Australian Museum in College Street is formed of them.

In any girder bridge (That is not an arch or a suspension bridge) the engineer must place the heavy and expensive iron in such a way that it does the maximum work at the least expense. Generally this means that most of the material is at the top and the bottom, in the so called 'flanges' and only a lesser amount is used in the central part of the girder. This part, the WEB, does the job of keeping the flanges apart and working together. The classic "I" beam is a good illustration.

In both Menangle and Victoria the top and bottom flanges are formed of a pair of square tubes about 450mm (18") square. The square is important for it makes the flange capable of resisting buckling. Near the centre of a span the top flange is being compressed as the bridge bends down under the weight of a train. A piece of paper has virtually no capacity to support a load. Formed into a round (or square) tube it is quite strong.

Both Menangle and Victoria Bridges are continuous over their three spans so the bending behaviour is more complex, sometimes the bottom cells are in compression, so both top and bottom 'flanges' need to be tubular.

The great limitation of tubular girders is the size of the tube. It is too small for access both in the initial building and for maintenance. Look at the tubes as we cross the bridge. Men worked inside them in 1866 placing and holding rivets while other men closed them with swinging hammers. Boys scurried up the tubes with red hot rivets which they passed to the "Boilermakers Holder Up".

After Victoria, Whitton built no more tubular bridges. The new design was the lattice girder. Structurally it was very similar, but the solid plates of the webs became lattice and the closed tubes became three sided things. They still resisted buckling, but they were accessible for work.

The Wollondilly spans were designed with a tubular top flange only. As they were both single span the bottom flange was always in tension and thus buckling was not an issue and a simple plate, or several sandwiched together would do. As single track bridges (hence less load) and of a bit shorter span the tubes were even smaller than Victoria. Too small for men to do reliably good work, said John Fowler in England and so he did away with them and designed an elaborate system of brackets to make the webs work with the simple plate flanges to prevent buckling.

Victoria is not a replica of Menangle. The most important difference is the span. Menangle is 150 feet. Victoria 192 feet 4 inches. Whitton's reason for the increase is unknown. Was he trying to get across the wide stretch of water with just three spans, not four. Whatever his reason the span was never repeated. All the twelve lattice girders are the same 150 feet span as Menangle.

The other design change is the curved top plate for the top tubes. Probably designed to shed rain water, it does no harm to the buckling resistance of the section. It does require obtuse angle sections for its fabrication and this will become an issue twenty years later during the Bridges Royal Commission.

The two girders, one on either side of the bridge span between the piers, but don't offer anywhere for the train to run. The bridge needs a floor. In later steel bridges, like the 'new' 1907 bridge at Emu Plains, the tracks are carried on relatively long stringer girders between substantial cross girders at each PANEL POINT of the truss. (The Panel point is the intersection point of each triangle of the truss). These may be 30 feet apart. At Menangle and Victoria we see the earlier way of making a floor. Cross girders are close together, only 3 feet apart. The track is supported on them with heavy timbers spreading the load from the train over the cross girder directly under the wheel and those adjacent. Victoria's floor is very close to original, save for the concrete road surface required now that it is a road bridge. Since Menangle is still in service as a rail bridge, and has had to have been strengthened to allow it to continue to be that, it has had a second set of cross girders added between cross girders of the old floor, so it is hard to see how it was originally. At Victoria how it is now is how it always has been.

The piers in the river were initially contracted by Tyler, but a series of floods so disrupted the work that he abandoned the task. They were completed by Watkins, who had the good fortune to be able to work without any more floods. The iron girders were fabricated in the United Kingdom by Peto Brassey and Betts. Timber falsework was erected between the piers and upon this floor the components were assembled. Once they were capable of supporting their own weight the timber work was removed.

Two timber road bridges just upstream had been erected in the years immediately preceding the work on the railway bridge. Both had brief lives as they were washed away by floods. Pending the completion of the new iron bridge, which would carry a single line of rail and a single lane of road, punts were used to make the crossing. With the railway just about ready to open another flood descended in June 1867, swept the punts away, wedging them against the western approach spans. The river swirling around them scoured the bank around the trestles. Plans exist showing the eastern bank armoured with timber to prevent scour. It was realised that the western trestle would not last and it was replaced with the different, shorter and smaller girder we see today. The railway opened a month after the flood so the trestle must have been repaired. Substantial iron girders weren't available in Sydney, and to get one from the UK would take at least a year. In October plans were drawn for a substantial stone pier supporting the same timber arches as had been first considered. Exactly when the fourth western span arrived is not known to this author. Evidence before the 1884 Royal Commission suggests that the bridge was not finished until about a year later

A wonderful insight into the construction of the bridge is given in evidence to the 1884 Bridges Royal Commission. Whitton built new lines, but once they were in the hands of the Railway authorities their maintenance was the responsibility of the Engineer for Existing Lines, George Cowdery. Cowdery thought the bridges were badly built; Whitton said they were fine. Cowdery said there were loose rivets. The agreed method of finding loose rivets was to tap them with a hammer. Whitton said that Cowdery was using too big a hammer and that if you hit rivets with a hammer that big they would all become loose. The Minister had no idea so he called a Royal Commission, which among other competent members included the Professors of Engineering at both Sydney and Melbourne Universities.

Joseph Dunn, a boiler-maker's holder-up who had worked on Victoria gave evidence as to how the work was done:

“Before you got the trolley into the boom you had to crawl on your hands and knees; you had to get in on your face and hands and then you had to lie on your back. Before the rivet came it was passed to the boy and before it was used it was nearly black hot. It ought to have gone in nice and hot. I have worked at riveting from a lad and have been a holder-up all my lifetime, and in the work that I have done I have always done good work.

Question 529: How long did you stay in the box at one time? Answer Well, I went in at a quarter to nine and come out at 11. Of course I am an exception as I am a small man.

Question 530: You must have found it pretty hot? Answer: I did; I have come out ringing wet. In fact I have not had a shirt on my back, many a time.”

The Royal Commissioners did a thorough job. They caught Whitton out when he gave them the old, wrong, plans of the Wollondilly spans. His excuse – he had forgotten the Fowler had changed the design. At Victoria one of their number was drawn through the tubes on a trolley taking notes as he went.

Alfred Williams, who was resident engineer for Peto, Brassey and Betts did not know of this thoroughness when he testified about the quality of the work which the contractors had done. Having committed himself so deliberately he has no answer when the Royal Commissioner’s log of his journey through the tube shows that deep inside, where no inspector or Royal Commissioner would ever reach, the special obtuse angle had run out and ordinary square angle, suitable bodgied up with filler had been used. It was an ICAC telephone intercept of an earlier century.

The Royal Commission largely exonerated Whitton, though he was directed to co-operate more with Cowdery and to give him copies of the plans of what had been built to help him maintain the structures.

As the nineteenth century closed, the traffic on both the South and the West lines had grown to the point where the river crossings needed to be made double track. Both bridges had been designed for two tracks though only one was needed initially. At Menangle the road crossing of the river had remained on a low level insignificant bridge and the possibility of having a flood free road route on the high iron bridge never pursued, so the space was still there for the duplication, even though the girders would need strengthening to accommodate heavier trains which half a century of development had produced.

The same option was not undertaken at Emu Plains. Was it too hard to found the extra piers which could have halved the spans as at Menangle? A new and significantly large bridge would be needed for the road in any case, so perhaps the best option was seen as a new bridge for the railway and the old shared bridge given over to road only.

By the early 1900s bridge design had moved on. The preferred option was now a steel truss. The span lengths would be the same as the old bridge so as to avoid restricting flood flows with two sets of piers at different spacing. The ‘new’ bridge (It is 108 years old) has three spans corresponding to the three original tubular spans, the western most span is the same length for uniformity’s sake, and the space which was bridged by the eastern trestle work is spanned by a short truss of the same overall height for the sake of appearance.

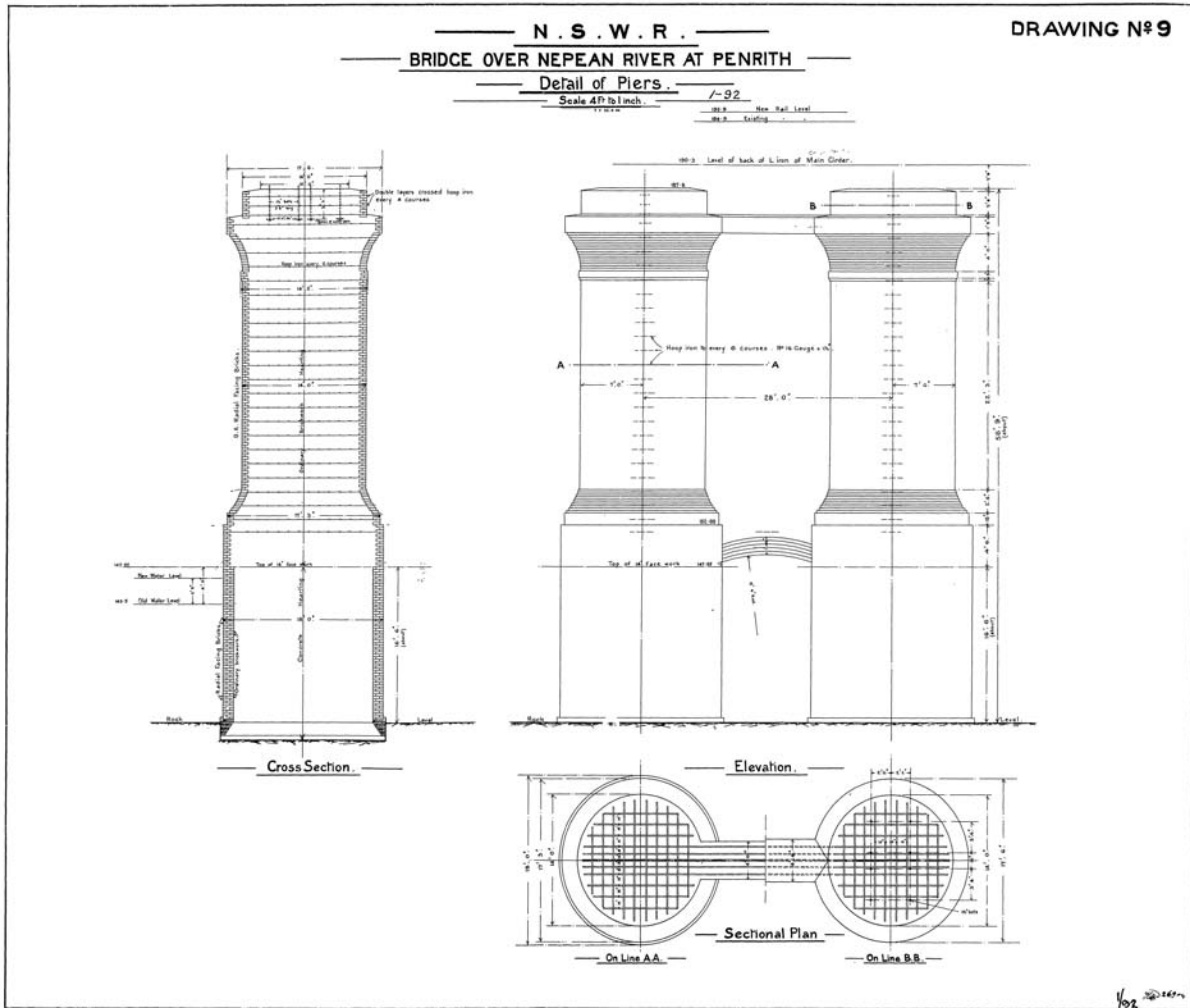
The new piers are brick and a wonderful example of the capacity of that material and the skill of those who worked with it. Below water level the brick face is filled with concrete, but the above water parts are nothing but brick reinforced with flat strips of steel (hoop iron) in every sixth bed joint. The piers are two cylinders with a connecting wall. To form the curved face the bricks are made as sectors with a curved face and tapering sides. Since the work is Flemish Bond with some courses laid as headers, two types of brick were made – with the curve on the long or short sides.

The bridge was fabricated and erected by the Tulloch company. Its relatively modern structure with a truss formed of only a few widely spaced members, cross girders at every panel point and stringers between those girders under the track has already been described. An important improvement in bridge design had been to increase the height so as to allow effective cross bracing against buckling and wind loads above the space allowed for the passage of the trains. The 1867 Victoria bridge has no cross bracing and the twelve lattice trusses have cranked girders joining the tops of the main load carrying side members at a few points.

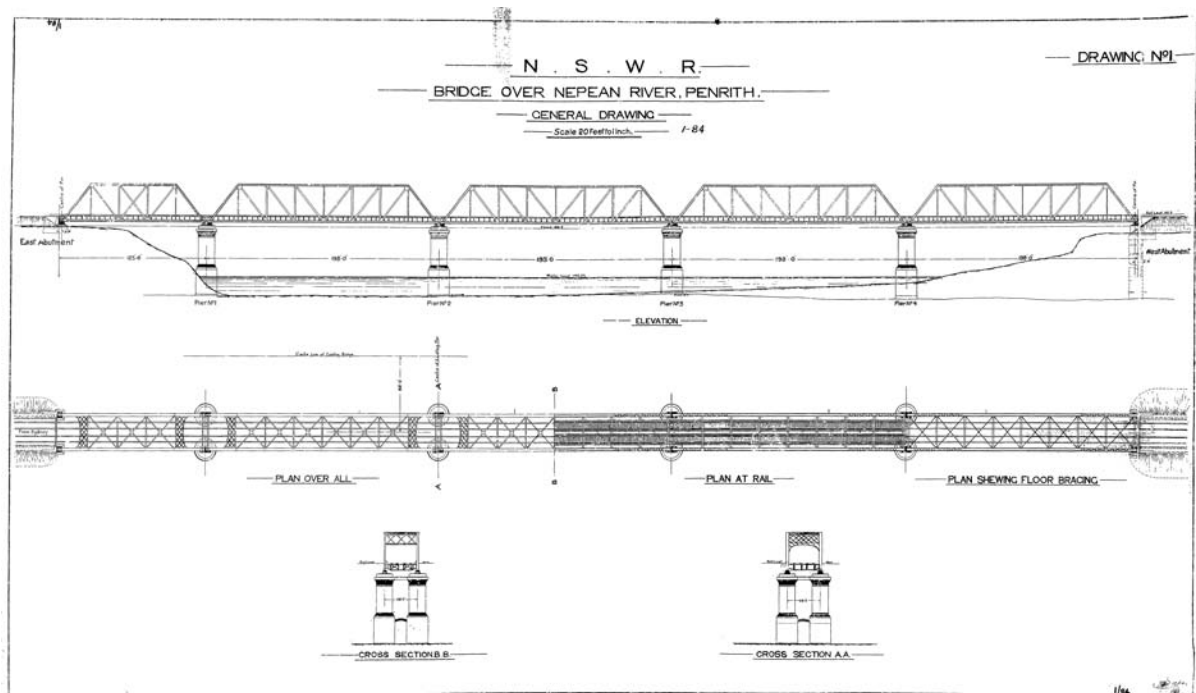
Also more visible in the 'new' bridge is the provision for expansion of the steel with heat and load. The load of the truss is transferred through a single pin to a strong and rigid plate which rolls on a set of cylinders. The old bridge has a race of rollers working between cast iron plates without the single pin bearing to share the load equally among the rollers. Originally Victoria's (and Menangle's) bearings sat on heavy timbers and then the stone of the piers. What is there now, out of sight to any ground level inspection, is unknown.

The unsatisfactory nature of the pedestrian walkway on the bridge has long been noted. Without it on the bridge the road lanes could be widened. In 1951 plans were approved for a walkway outside the main girders on brackets, but this scheme was never proceeded with. The current RMS proposal, and it would seem likely to proceed, is for a separate pedestrian bridge well upstream so as not to detract from the appearance of the old bridge. It has two right-angled bends at midspan. You can do that sort of thing with computer designed structures, modern materials and joining techniques. It will be a creature of its age, just like John Whitton's and John Fowler's 1867 old bridge.

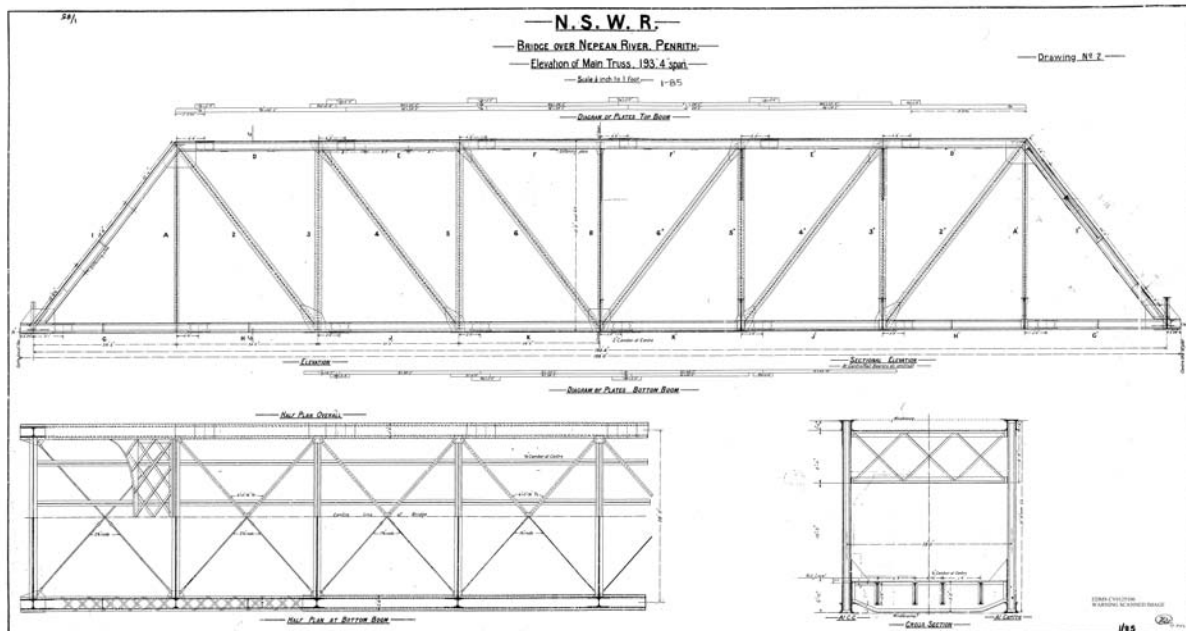
Captions



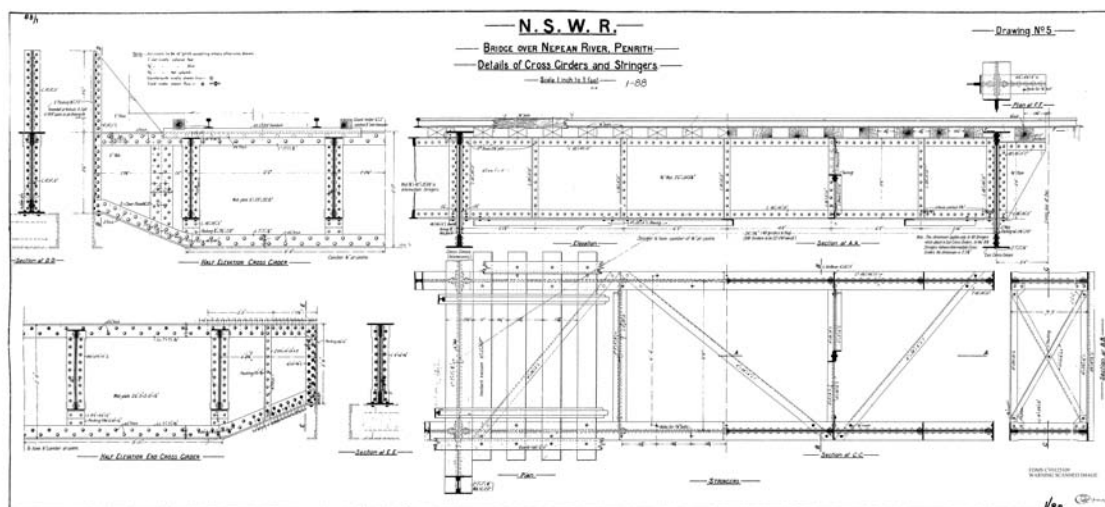
Plan 1 The brick piers of the 1907 bridge. Note the relatively shallow water and depth to good rock for bearing. The piers are concrete filled to water level and then solid brickwork for the rest.



Plan 2 General arrangement for the 1907 bridge. The eastern span is excessively high for its short span, but is made uniform with the others.



Plan 4 General arrangement of a truss of the 1907 bridge. The members are numbered and lettered. Since the span is symmetrical the left and right ends are 1 and 1A, D and D' etc. The lower drawing shows the cross bracing above the trains and the stringer girders under the track.



Plan 7 The cross girders. As they may bear the weight of two heavy locomotives they are very deep and strong. Even in 1907 they are fabricated from angles and flat plates riveted together.

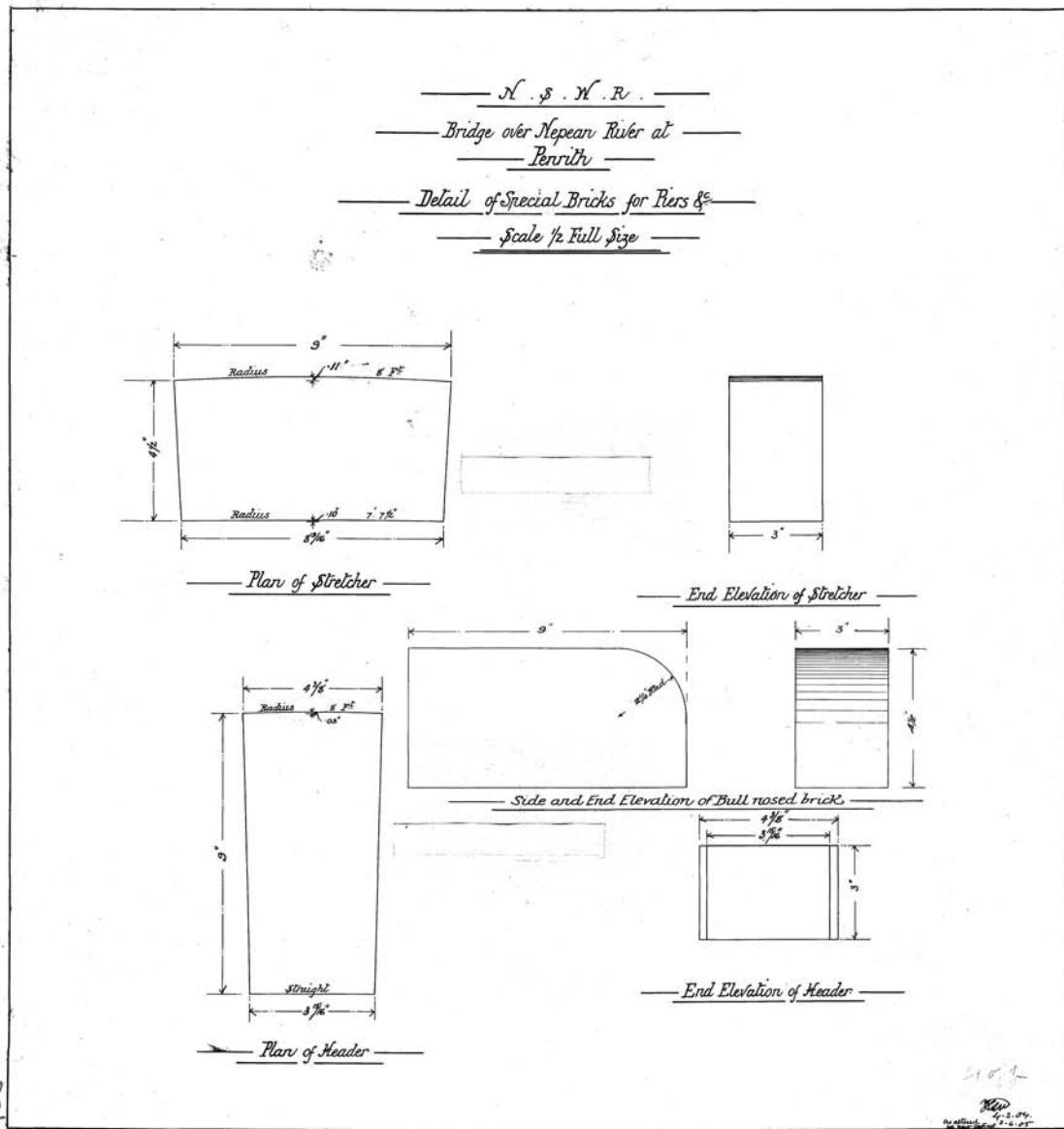
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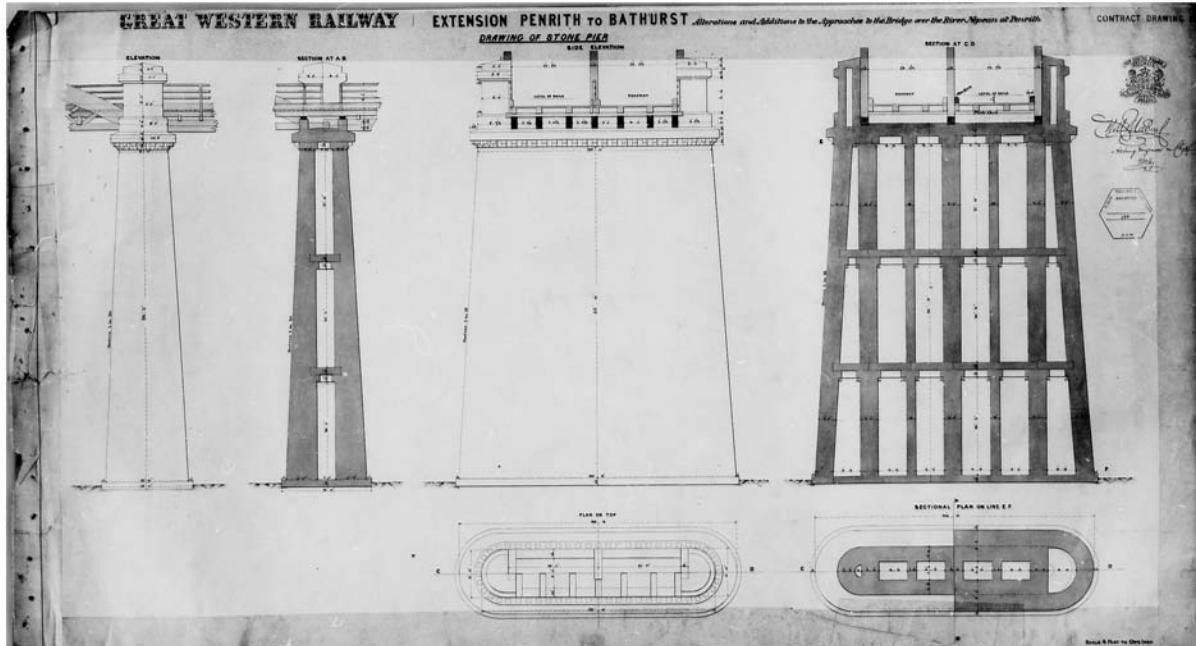
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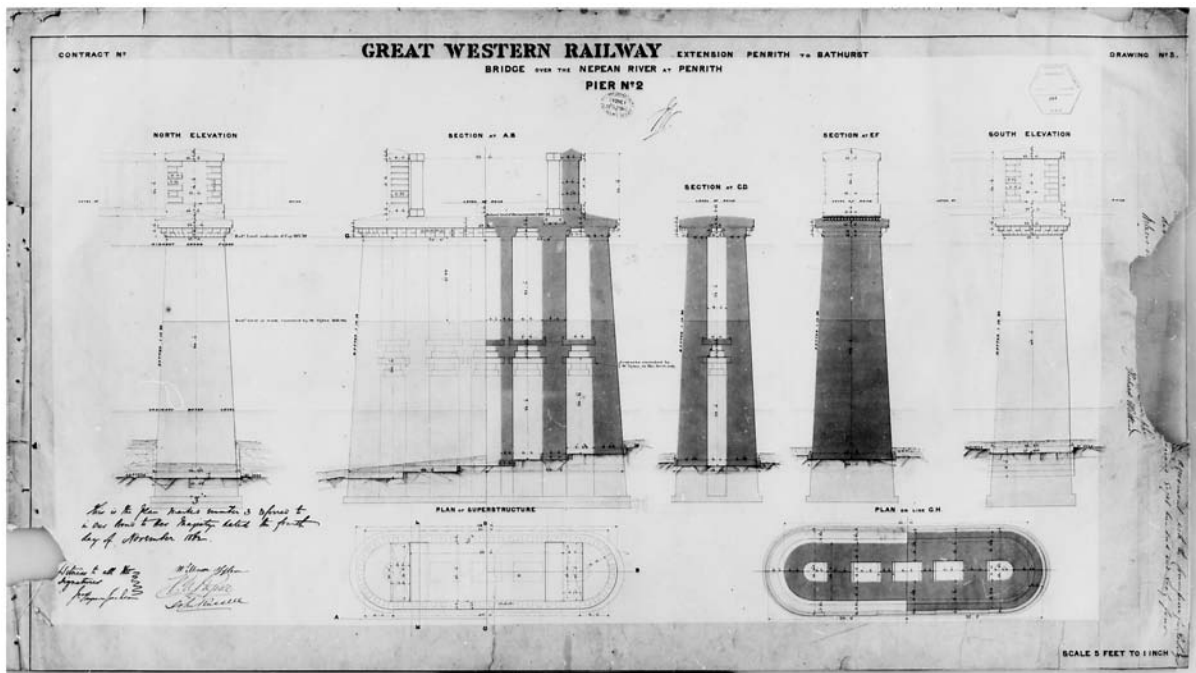
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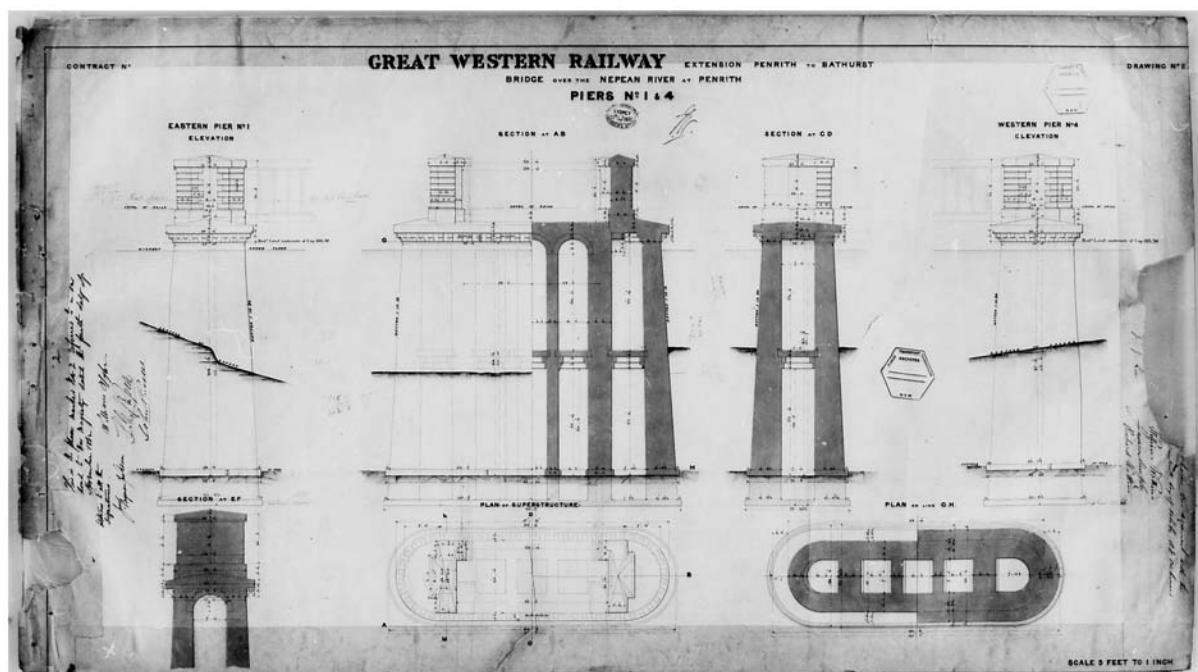
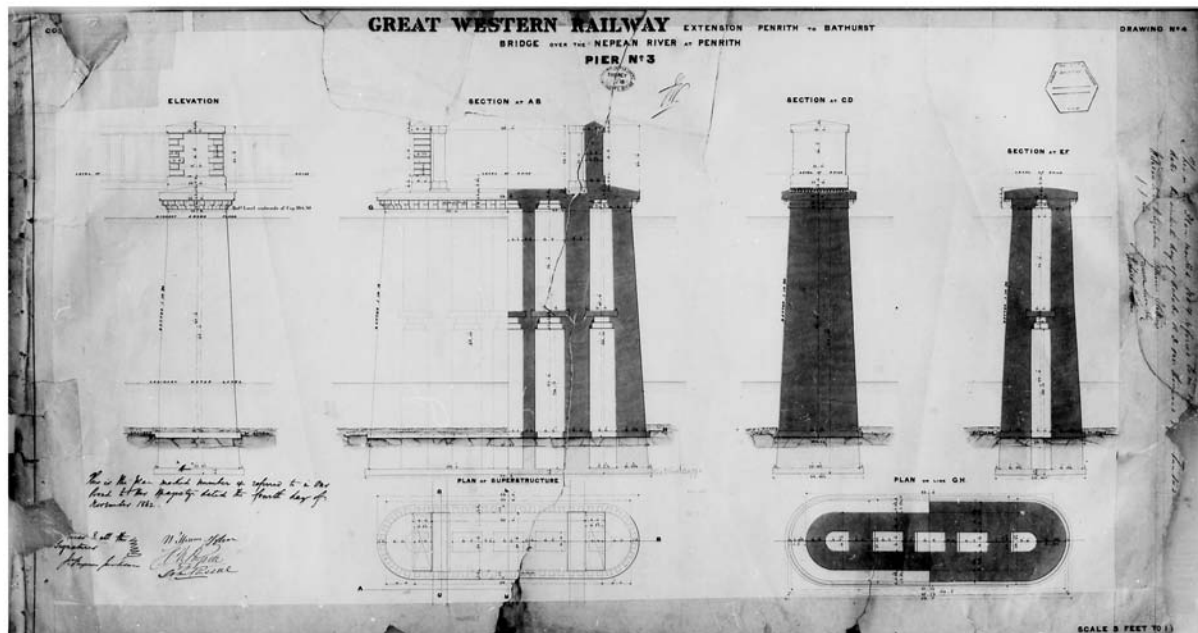
Plan 20 The special tapered and curved bricks to form the cylindrical piers.

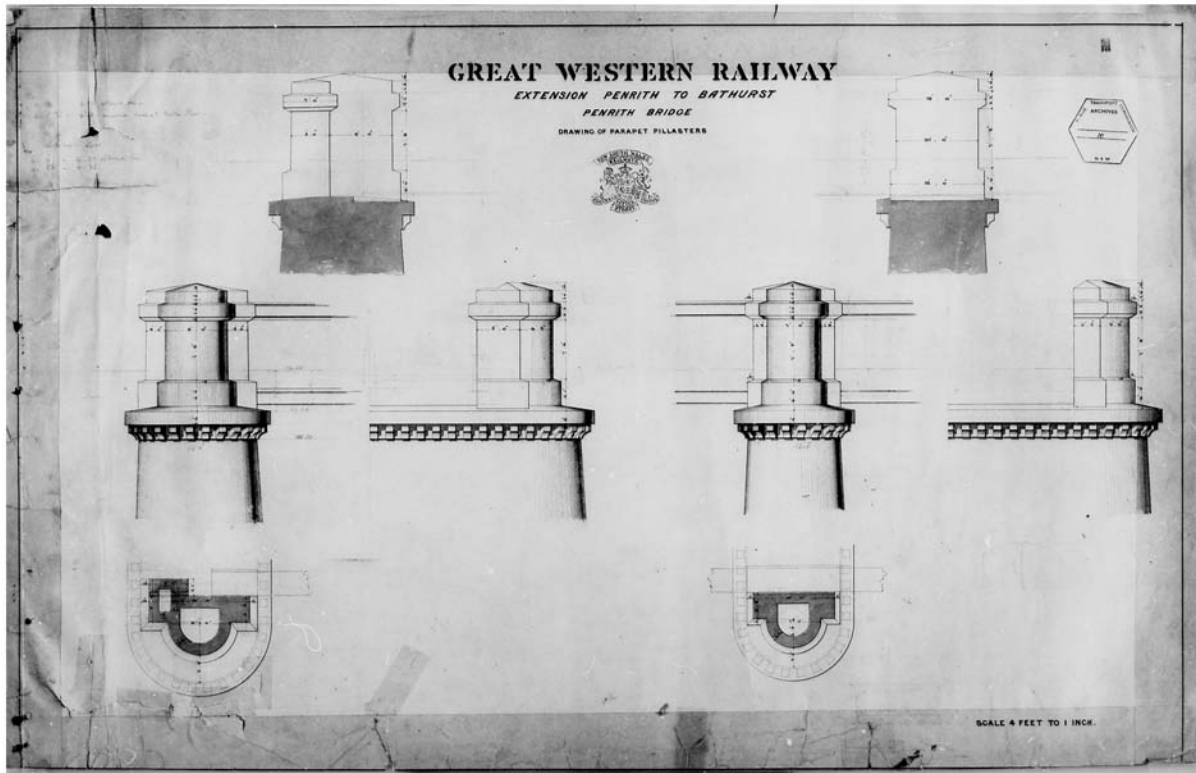


Plan 21 The extra stone pier designed in October 1867, when the remedy for the damage to the western trestle was a timber arch and more trestles

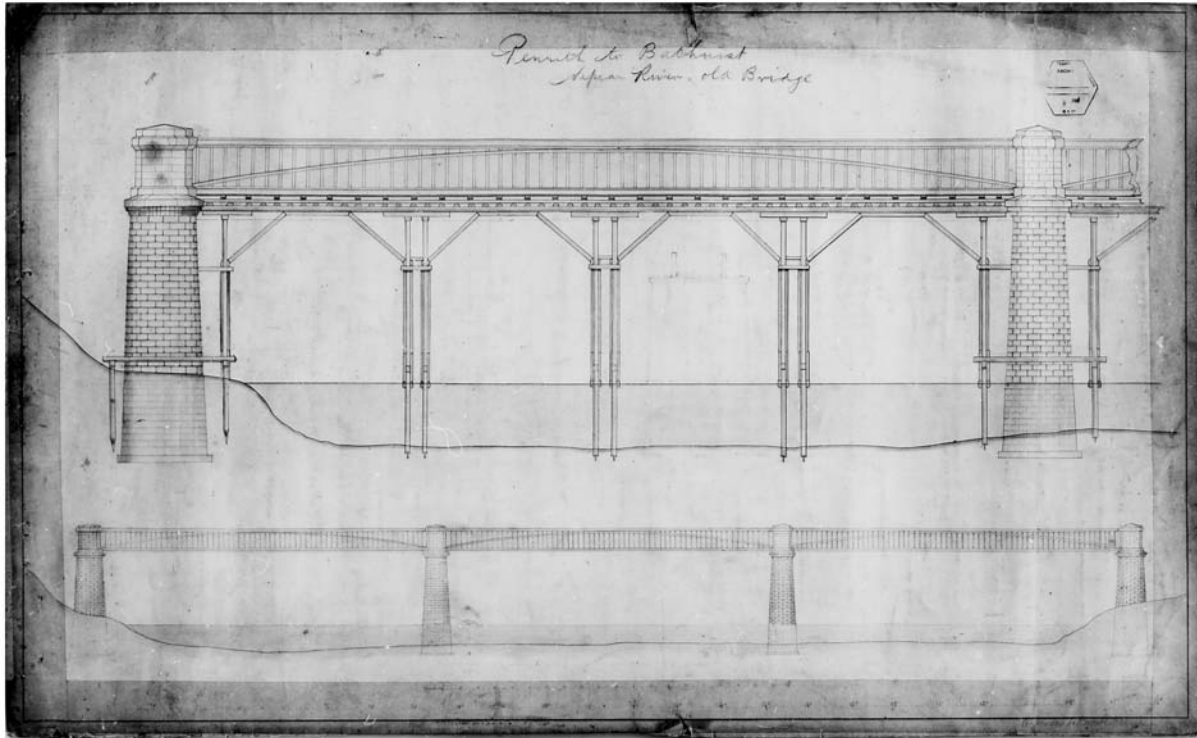


Plan 22 The 1862 plan for pier 2

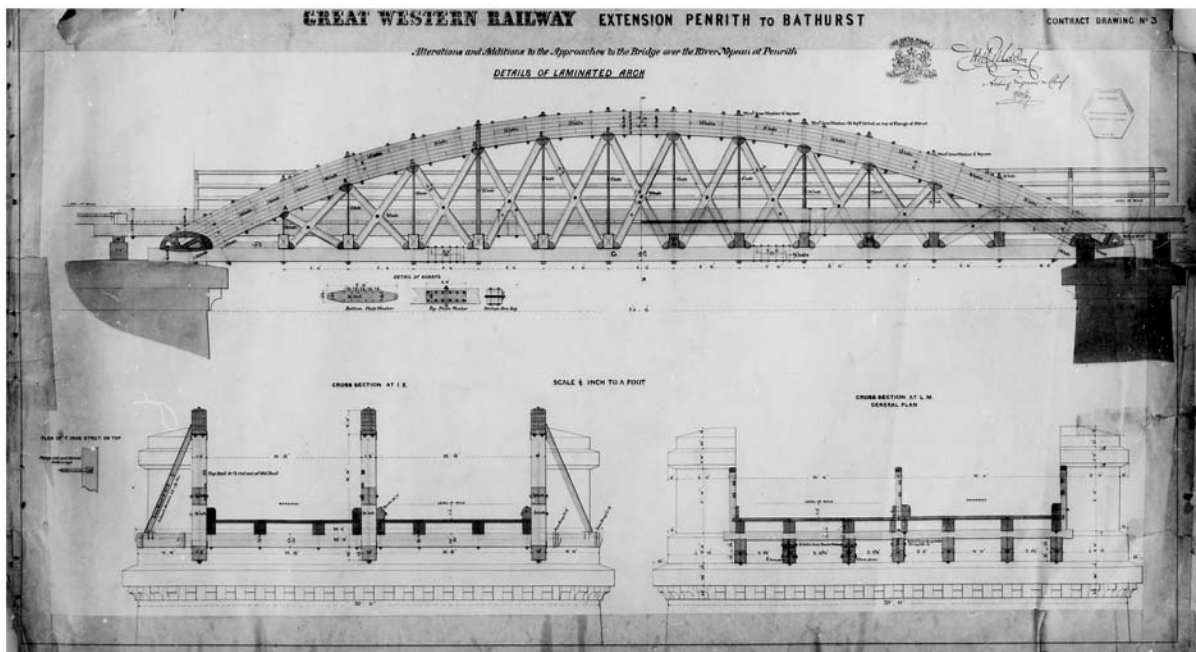




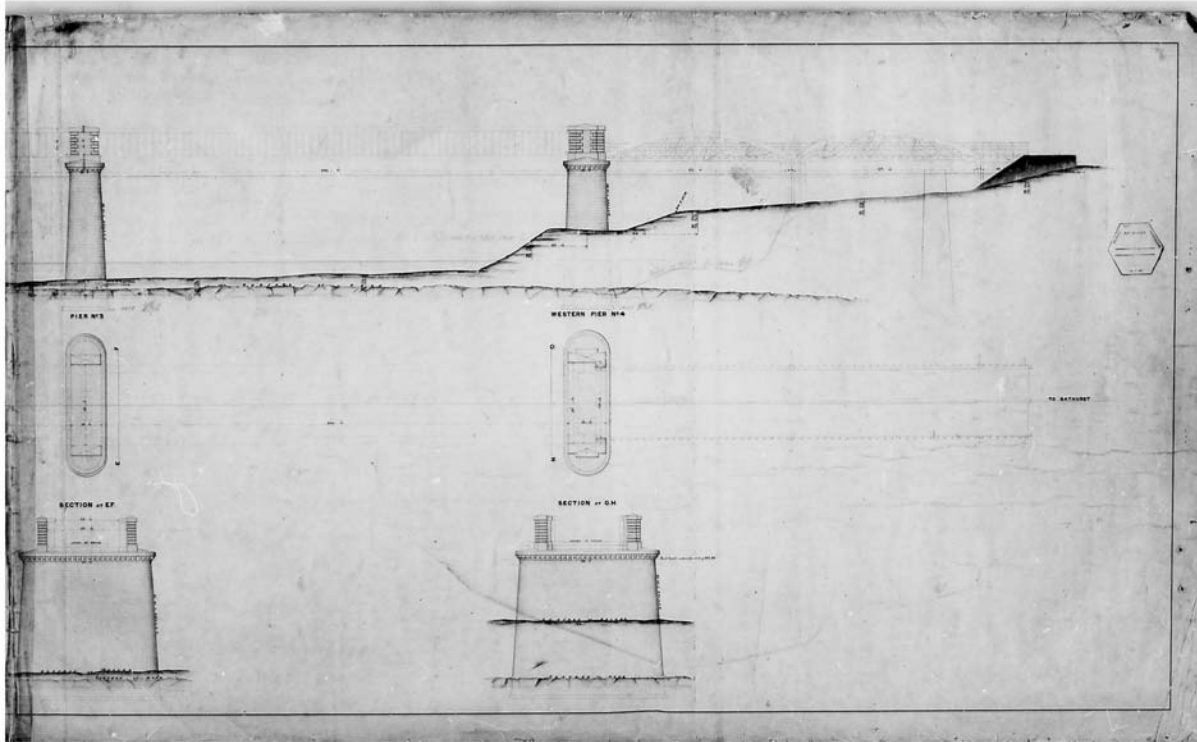
Plan 25 The detail of the parapet and pilasters



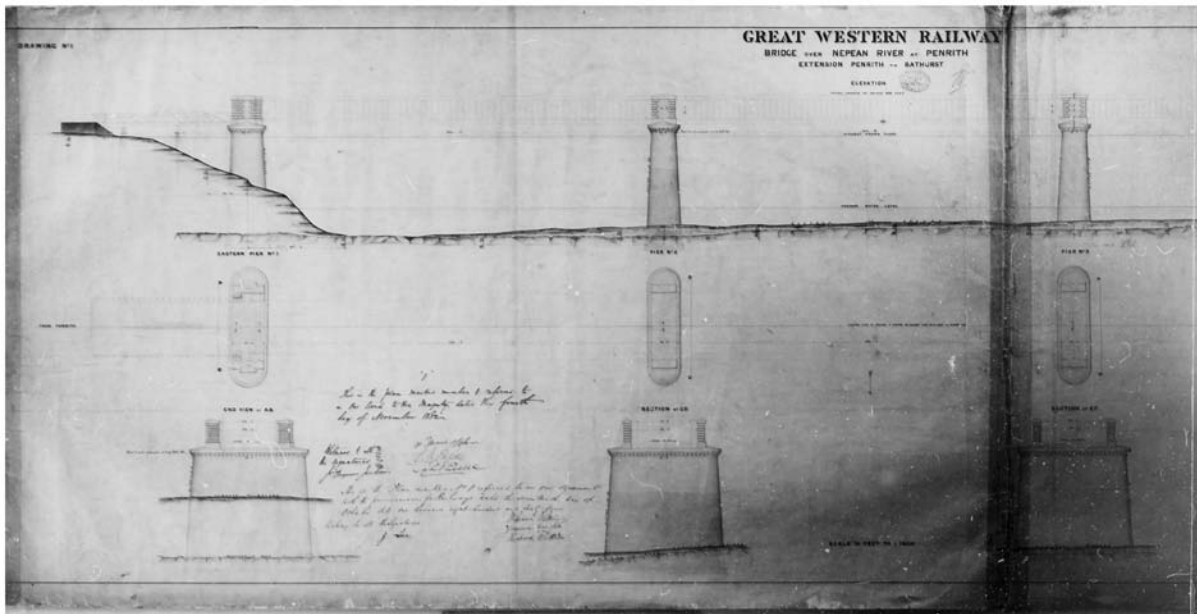
Plan 27 The method of erection of the tubular girder. Since the water was shallow a frame could be erected to carry the parts until they were connected and became self supporting.



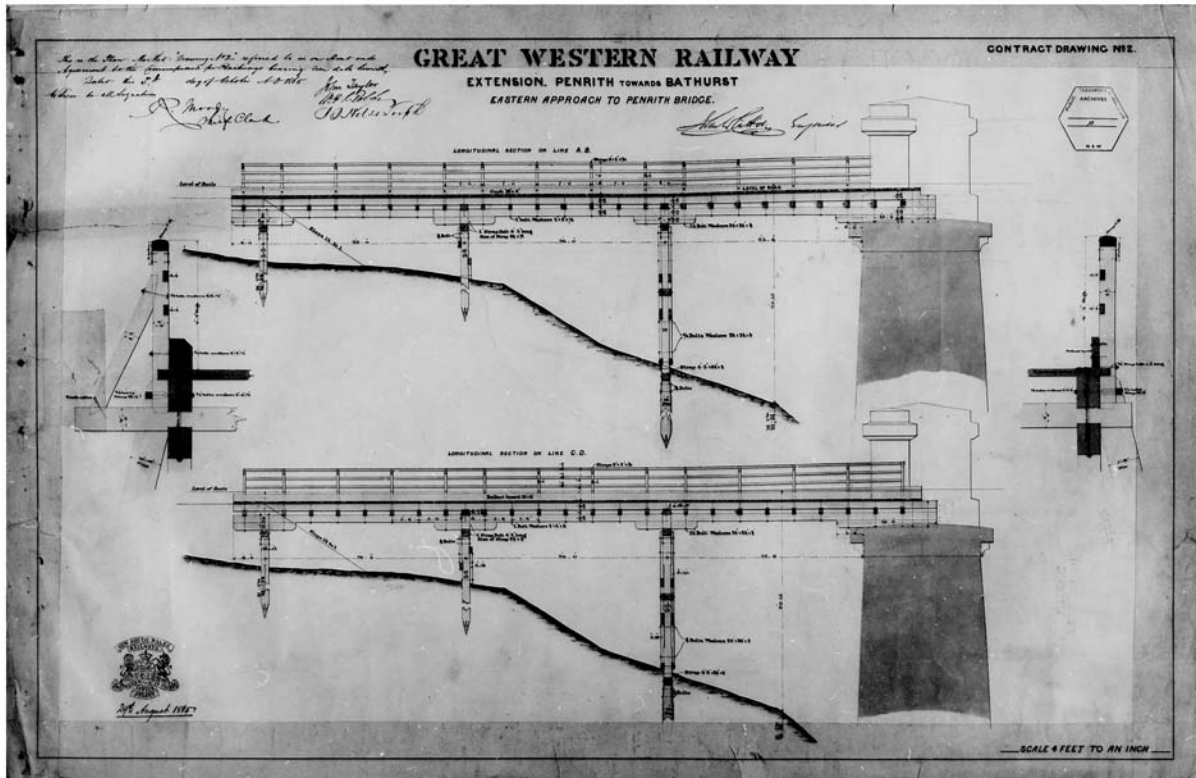
Plan 28 Once the western trestle was damaged the old wooden arch was planned. This plan is dated in October some 4 months after the damage in the flood. In the event the arch, the pier nor the trestle beyond was built. Another iron girder was procured.



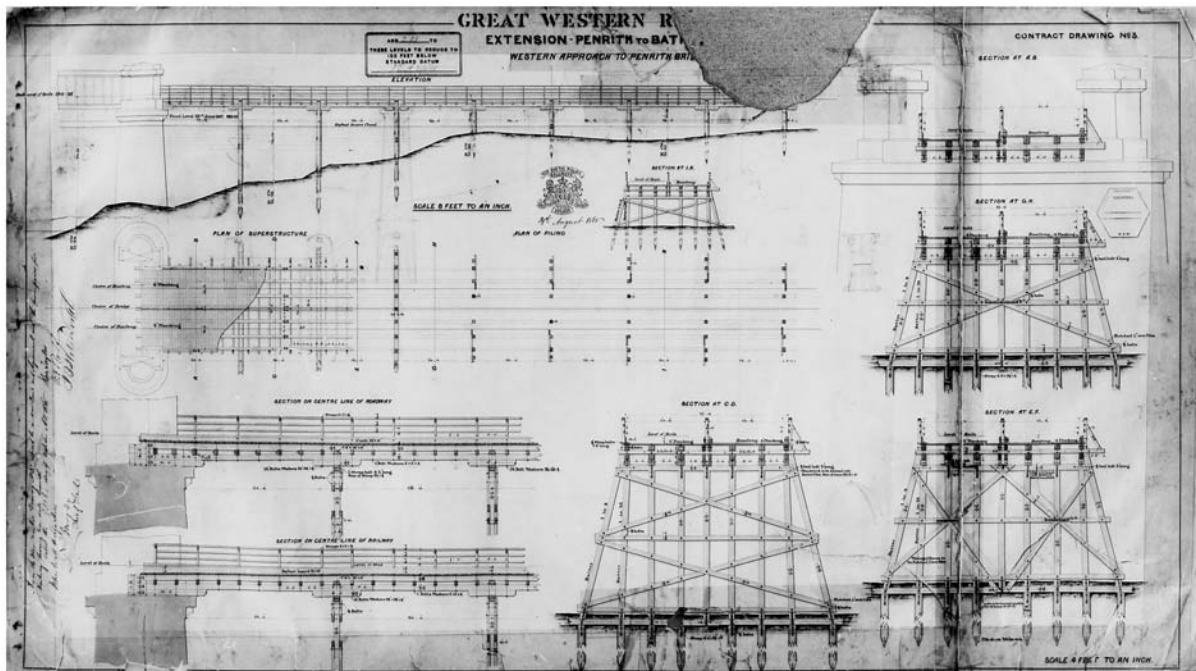
Plan 29 The westernmost pier now stands well out into the river, but this plan suggests that it was actually built into the bank as it existed. There is a faint line which indicates how much of the bank was scoured by the flood rushing around the road ferry punts. This 1862 contract plan shows the use of two laminated timber arches at the Emu Plains end.



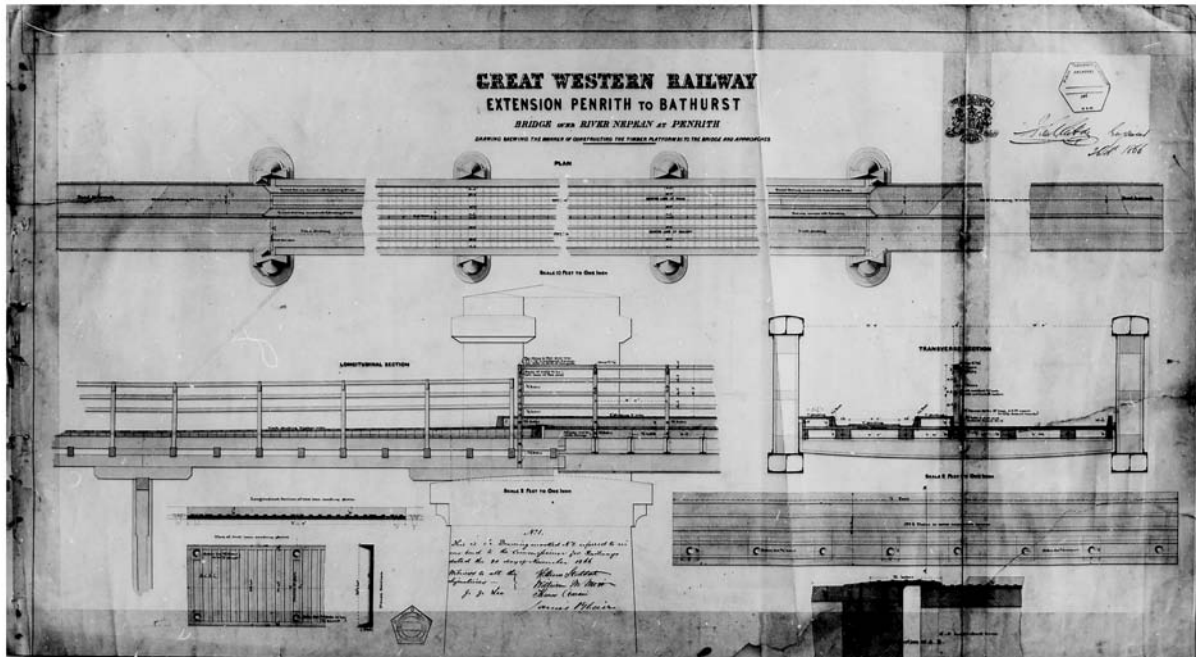
Plan 30 The other half of the 1862 plan. It probably exists in the roll plan holdings of NSW State Records, but these scans come from aperture cards which were produced in the 1980s. Long plans were often scanned in several parts at that time as that was the best the technology could do.



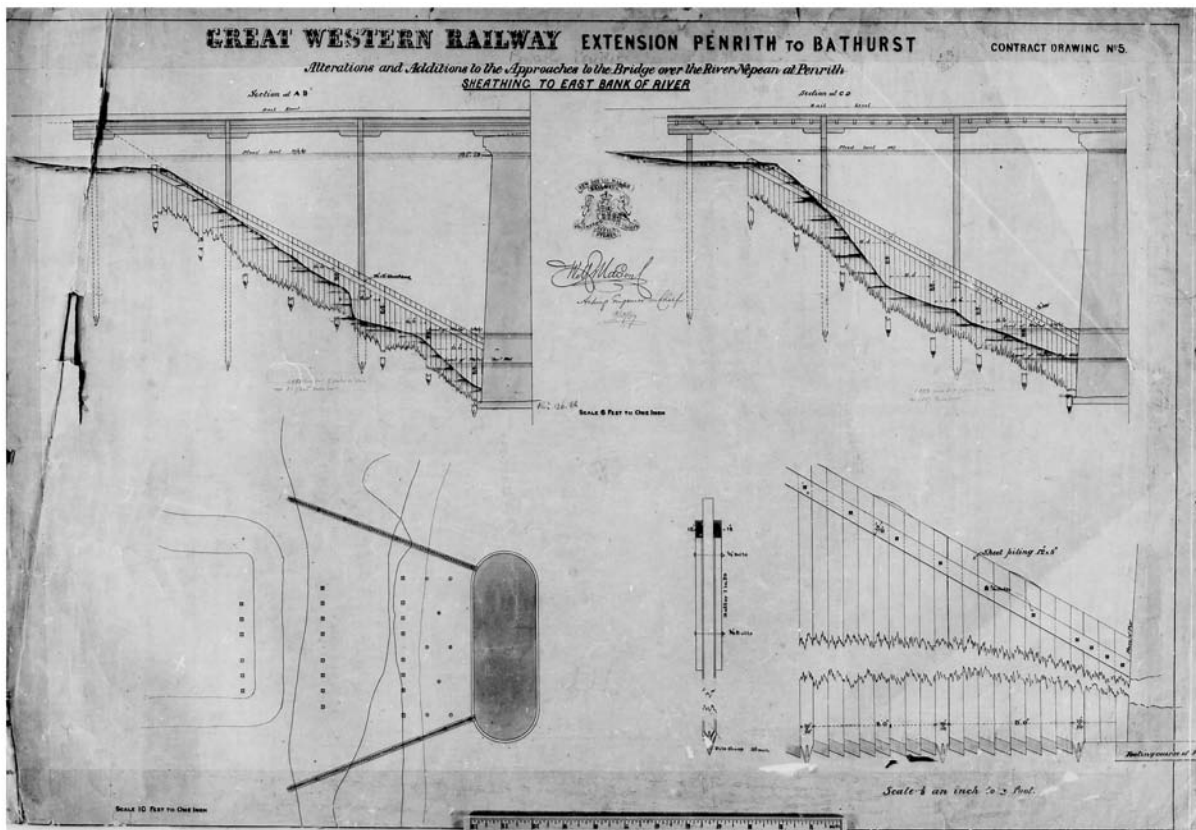
Plan 31. The eastern approach as built in 1867



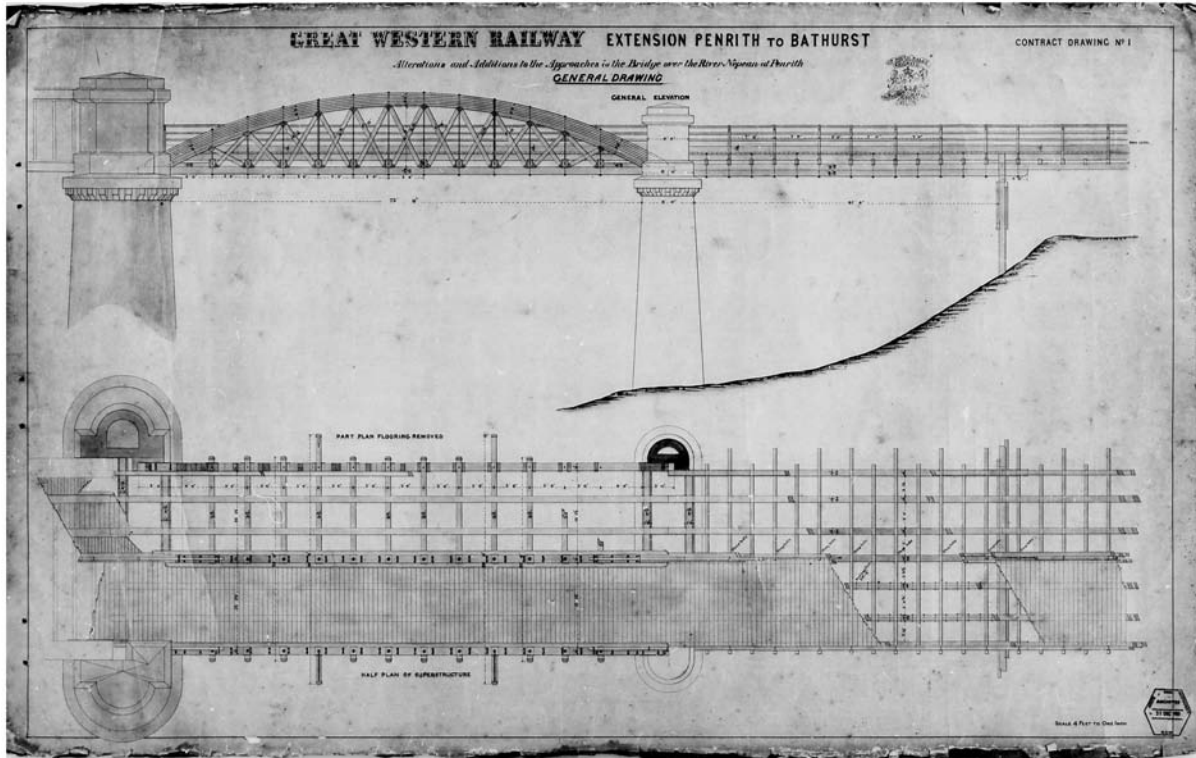
Plan 32 The western approach as originally built.



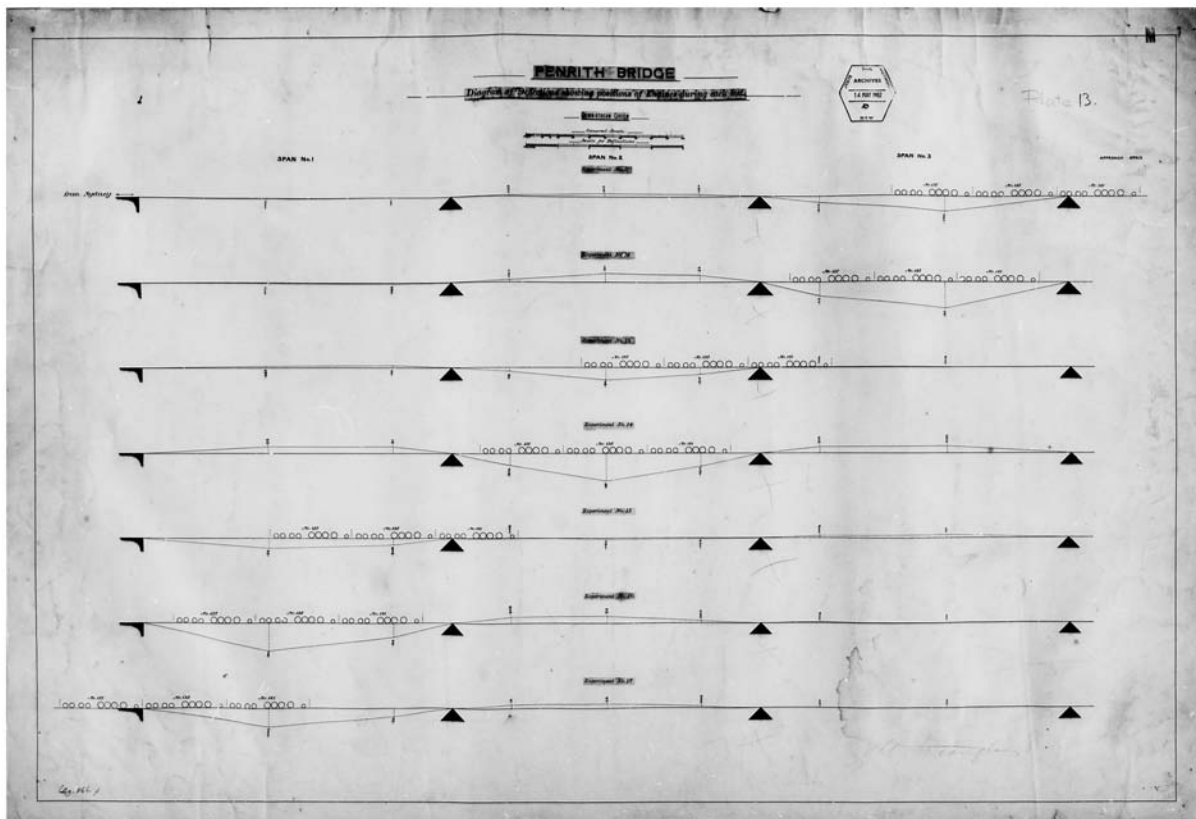
Plan 40 The 1866 contract plan for the timber deck. Note the curved top to the upper tubes of the main girders. There was a fence between the road and rail sections



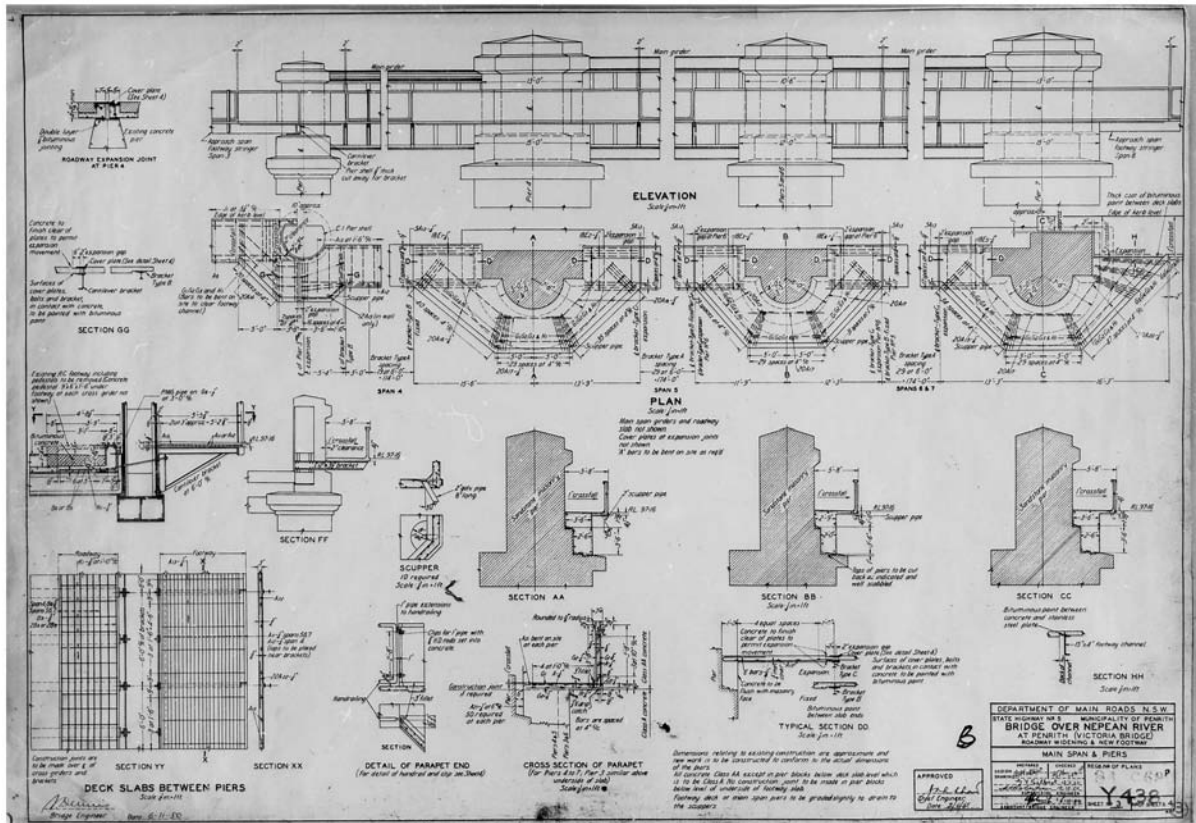
Plan 41. In the aftermath of the flood the eastern bank was sheathed in timber to prevent scour.



Plan 42. A detailed plan of the laminated arch and trestle from October 1867. Before it could be built a new plan for a single iron girder was devised.



Plan 43. Deflection diagrams from the 1884 Royal Commission report. The load, represented by the locomotive wheels approaches from the right and the thin line graphs and exaggerated deflection. Really the movements would be too small to show on a plan of this scale. Note that because the bridge is continuous and the span where the locomotive is placed moves downwards, the adjacent spans move upwards, thus helping the loaded span and reducing its deflection.



Plan 48 A 1951 proposal for a pedestrian path off the main deck, cantilevered on the outside of the girders.

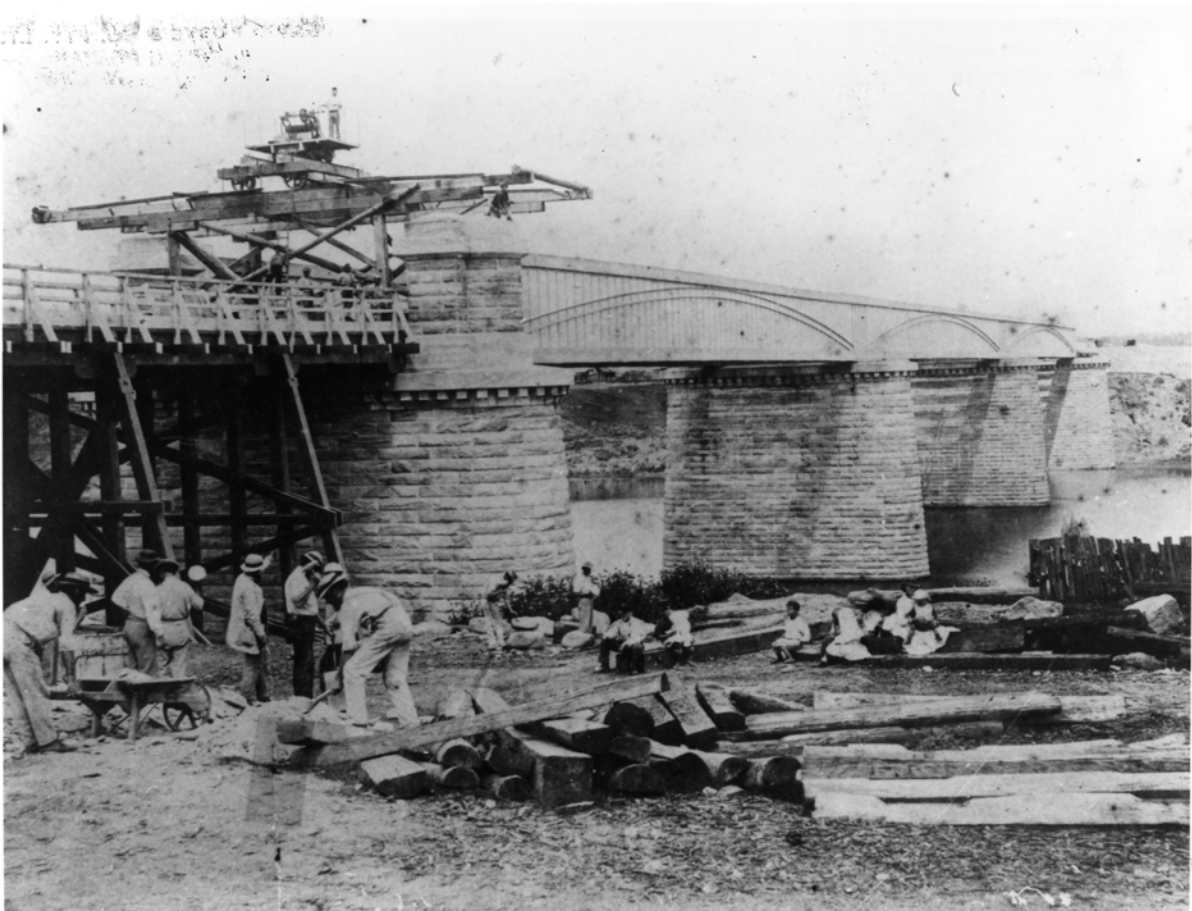


Photo 9377. The 1867 bridge under construction



Photo 34277. The method of assembling the ironwork on timber staging is evident in this early image.

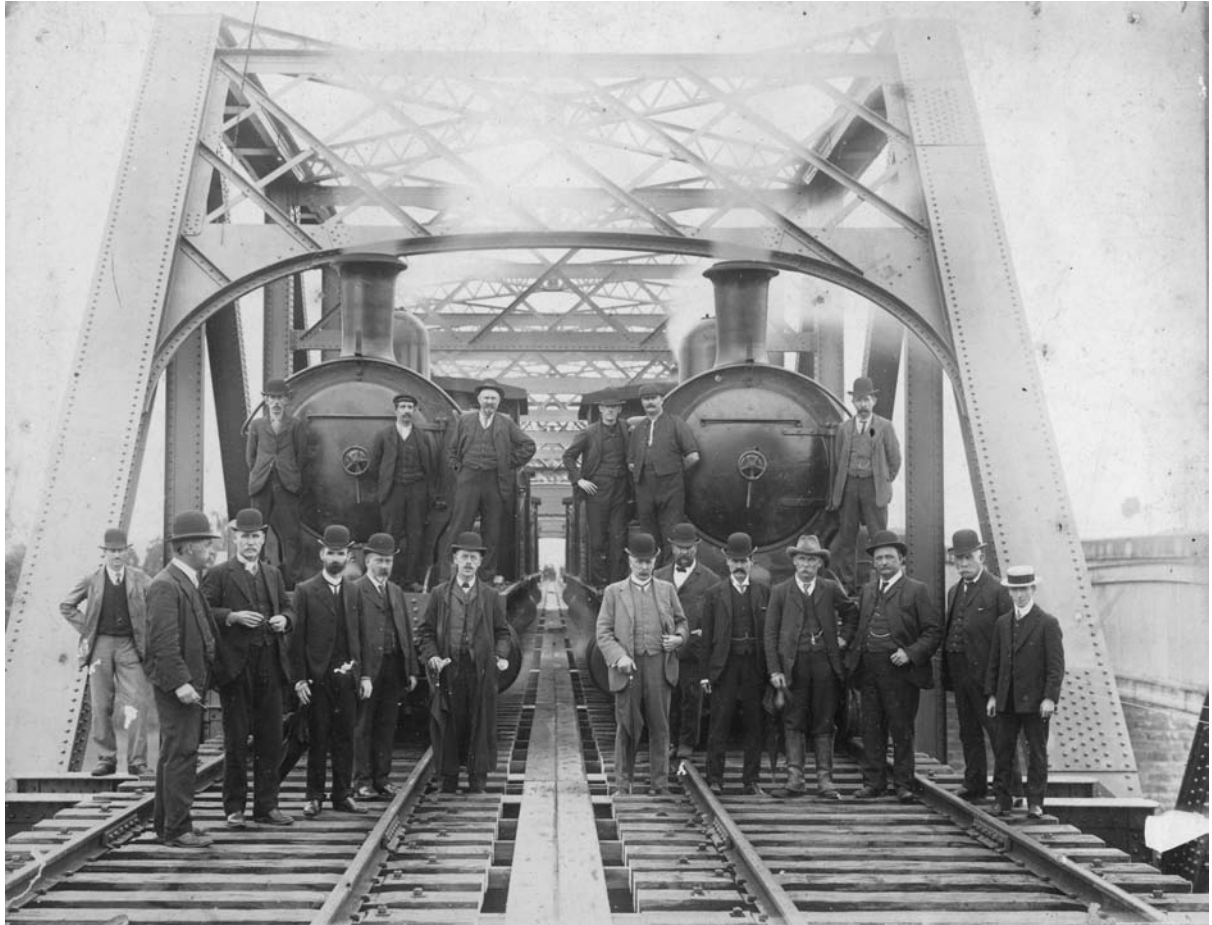


Photo 48000. The opening of the 1907 bridge