Meadowbank Bridge.

The Meadowbank Railway bridge is a six span wrought iron lattice girder bridge, spanning the Parramatta River on the Main North Line, between Rhodes and Meadowbank. Its use as a railway bridge ended in May 1980 when it was superseded by a parallel box girder bridge, but it has not been demolished and is now used as a pedestrian and bicycle crossing of the river.

Line History

The North to South, Homebush to Waratah, Junction Railway was a relatively late link in the trunk lines of New South Wales. The difficult topography of the route and the very large and technically demanding crossing of the Hawkesbury estuary somewhat to the north of Meadowbank, are the obvious explanations for the delay in connecting the two largest population and industrial centres in the colony. The connection was completed on 1st May 1889 at Hawkesbury River, but the line though Meadowbank had been opened about three years before, on the 17th September 1886. The bridge was built for double track and while initially it only carried a single line of rails, the second track was provided in 1891.

The contract for the construction of the whole section from Homebush to Hawkesbury River, including Meadowbank Bridge, was undertaken by Andrew and Robert Amos. The casings for the piers were made by Stockton Forge and the lattice spans by Andrew Handyside and Company, both located in Britain.

Major Bridges before Meadowbank.

Generally railway routes in colonial NSW were positioned to travel along watersheds to avoid major bridges if at all possible. Stone and timber were the first choice, especially where the government prevailed to avoid expenditure of scarce funds out of the colony.

Metal bridges were used when necessary. The most notable predecessors of Meadowbank are the Tubular Girder bridges at Menangle and Penrith, and the earlier lattice girder bridges. Menangle, and all of the lattice girders had nominal spans of 150 feet. Penrith was perhaps an attempt to increase the span of the already built Menangle design and was stretched to 186 feet, but this development was not pursued.

The only other metal bridges of significance apart from the tubular girders and the lattice girders were the two central river spans of the Wollondilly viaducts just north of Goulburn. At 140 feet span they were comparable to Menangle and Penrith, but only single track. Although designed as tubular girders they were not built as such probably because the just acceptable access restrictions for construction and maintenance on the two earlier larger bridges were impossible on the smaller bridges. There were many shorter (60 foot) plate web girders in the series of five bridges at Goulburn and among the seventeen bridges on the descent of Solitary Creek to Tarana on the West.

The Emerging Use of Iron in Bridges

The development of railways, and the bridges which would carry them across rivers was occurring simultaneously with the development of metallurgy and the technologies which produced iron components which could be fabricated into large structures. All of these early bridges, including Meadowbank, use wrought iron. The availability of steel, in the large quantities needed for a bridge, was still in the future. The first steel railway bridge in NSW was Hawkesbury River, completed in 1889.

Wrought iron is a cruder structural material based on the element iron. The technology to produce the better material, steel, was undeveloped. Wrought iron has a relatively high proportion of carbon, present as discrete grains in the product as it emerges from the furnace. When the ingot is hammered and rolled (hence the term wrought) the carbon grains become elongated and the material has a laminated internal structure, something like plywood.

Steel on the other hand has no carbon grains, but a small percentage of carbon alloyed with the iron, that is, dissolved within it, and this produces not only a stronger material but one with superb engineering properties including extraordinary ductility.

The wrought iron production was also limited by the capacity of the furnaces and power of rolling mills. Not all structural sections which are well used today were available in 1860 or 1880. Flat plates, bars, rods and angles and “T” s seem to have been the products in the catalogues.

By the time of Meadowbank channels (C shaped sections) seem to have been developed.

Looking at the new Meadowbank Bridge, fabricated from plates several metres wide, many metres long and of immense weight, and then joined into a single steel object as long as the span by electric welding, the designers of the 19th Century bridges are to be admired for their ability to achieve the same result with many small components, only connected by rivets.

Menangle and Penrith

These very similar bridges are assembled from plates and angles into enclosed tubes. The structural action is sound (both bridges survive in service) but the assembly is awkward and maintenance difficult. To fit a rivet, a man has to be inside the tube to place the rivet and hold it while the boilermaker forms the head by hammer blows. The red hot rivet is brought to him by a boy slithering up the tube which is only 450mm or 18 inches square, and several hundred feet long. It could be done and it was done, but a better way was needed. The other limitation of the sealed tubular girder was that the cross girders which form the floor of the bridge and carry the tracks can only be riveted to the sides of the bottom of the main load carrying girders by angle cleats, fixed by the same unsatisfactory riveting technique.

The Lattice Trusses

No further tubular girders were built after Penrith. The leap forward was the lattice girder. By replacing the solid side plates (known as webs) with a close spaced lattice array, the same structural affect was achieved but access for fabrication and maintenance was easy. The closed box of the top and bottom cells was replaced with a fabricated “U” section and virtually no rivet was inaccessible. It was easier to assemble and more likely to be assembled well.

There were twelve lattice wrought iron railway bridges and Meadowbank is among the last. The earlier ones had closer spaced lattice and the cross girders were still framed into the side of the bottom of the main member. The later lattice bridges had a wider lattice spacing which was carefully designed to allow the regular placement of the cross girders between the lattice members on top of the main bottom chord members. In that way the load was carried directly from cross girder to lattice girder. All the few rivets had to do was keep the whole assembly from rattling and vibrating out of position.

Of the twelve similar bridges, Meadowbank is the largest. Only one other, at Albury across the Murray River, is double track, and only one other, at Como across the Georges River has six spans, but it is only single track.

The Span of the old Bridges.

More modern bridges, at least until the advent of neoprene bearings, are supported on a single bearing pin, which allows for rotation as the bridge deflects under load. The centre to centre distance between the pins at either end of the bridge is the span, without much confusion. The span of older bridges seems to have been defined as the clear distance between the thick supporting piers. Thus while Menangle is normally quoted as having 150 foot spans, they sit on a 12 foot long nest of rollers atop the 12 foot thick piers. Similarly the 150 foot spans at Meadowbank, are actually longer if the centre to centre distance between the piers is measured.

Continuity

From the beginnings of the development of engineering theory, the benefits of making a series of bridge spans into a single girder spanning across several piers was realised. When a heavy locomotive is near mid-span, not only is the bridge girder carrying that load by bending within itself, if it is rigidly attached to the girders in the adjacent spans then they are contributing to the effort by acting as cantilevers. Meadowbank is constructed as two adjacent sets of three spans continuous within themselves. Over piers 2 and 3, 5 and 6, the ironwork has no gap; Over pier 4 there is a gap. Imagine making a saw cut right through span 3. The half toward the centre of the whole bridge will fall into the river as its mate in span 4 can’t hold it up. The part of the cut span closer to the shore will stay up as its can hang off span 2.

All of the spans are possibly not continuous as a set of 6 as that perhaps would concentrate too much thermal expansion at a single location.

The new bridge adjacent is not continuous. It is five stand alone ‘simple’ spans. The design of a bridge is a complex set of trade offs between economy, build-ability, initial cost versus ongoing maintenance costs, and other considerations. Perhaps the designers of the new bridge were willing to pay the price of the extra steel which a continuous design would have avoided, for the ease of placement .

The Structural Action of a Girder

In simple terms, and ignoring the continuity mentioned above, a bridge girder acts, when a load is placed at midspan, by the bottom flange being put into tension and the top into compression. The parts of the girder away from the supports experience the greatest load. Notice how the flanges are built up with more and more layers of plate near mid-span, because that is where the greatest force is, and without more iron, the pressure, called stress by engineers, will exceed the material’s capacity.

For the top and bottom flanges to work together as a bridge and not just two independent and weak strips of iron, they must be connected and this is what the lattice webs are for. Engineers say they carry the ‘Shear Force’. Imagine cutting through the whole bridge quite close to the end support.   The rest of the bridge will want to slide straight down along the saw cut into the river. Shear force is greatest near the supports and that is why the lattice members are larger near the supports than at midspan.

The floor of the bridge forms a girder in its own right to resist sideways wind loads. It is a sort of truss formed by panels of crossed tension rods. At some stage early in the 20th Century the original design must have been thought inadequate and a second set of rods placed.

The top flanges of the main load carrying side girders are typically in compression and under compression buckling becomes an issue. Because the girders are not high enough to provide a proper framed ‘roof’ they are connected by curved bracing members. These had to be raised to give clearance for electrification.

The next development of steel bridge design was the truss in which the web members are few, and capable of being given a calculated design because they are so few and engineering theory could cope with the arithmetic by that time. Longer span truss bridges are typically tall enough to allow a rigid portal structure at both ends above the train to stabilise the trusses, and a properly triangulated frame between the top chords to resist wind loads and any tendency of the main trusses to buckle.

Cross Girders

The purpose of a bridge is to allow a heavy object – a train – to be carried high in the air. The weight of that train has to be transmitted from one component of the bridge to the next, until it is borne by the earth beneath the foundations. The wheels of the train bear on the rails, and these span between the sleepers, which carry the force into the bridge proper. Older bridges like Meadowbank tend to have closely spaced cross beams which carry the weight to the main girders, which then transmit it the bearings into the piers and to the ground. The cross girders are small bridges, which have to obey the same principles as the main girders. Bending action is greatest near the centre of their span, so they are taller there. To keep the track level as low as possible the cross girders taper near their ends where the bending moments are less. In earlier bridges the cross girders are close enough together that a heavy timber is strong enough to span between them and transmit the load from the sleepers. At Meadowbank this is achieved with short, iron, stringer girders between each pair of cross girders.

A truss, such as either of the Hawkesbury bridges can only accept load at the intersection points of its component members, known as panel points. These are a long way apart, perhaps 10 metres or more, and the load from the train is carried first on long stringers, directly beneath the track, to large cross girders at each panel point.

Bearings

The attached drawing shows roller bearings under the girders at the abutments and centre piers with fixed bearings at the intermediate ones. Any bridge is continually changing length as its temperature changes, and the considerable force generated by the weight of a train stretches the iron or steel. The longest spans at Hawkesbury would shorten and lengthen by about 100mm from the coldest day, unloaded, to the hottest day fully loaded. If this movement cannot be accommodated it becomes a force pushing against whatever is restraining it. Imagine taking the full three span length of Meadowbank and pushing on the end of it until it was compressed by 100mm. The force required would be hundreds of tons. This is the same force as would be generated if the bridge were locked cold between rigid abutments and then allowed to warm up.

Method of Construction

The Parramatta River at Meadowbank is reasonably shallow with silt overlying rock. Timber piles were driven into the riverbed and a falsework platform was created upon which the iron spans were assembled in their final locations.

Replacing the Bridge

With increasing train weights many older bridges needed to be either strengthened or replaced. Just after the Second World War a plan was formed to quadruplicate the Main North and replace the 1889 bridge at Meadowbank. The design called for 5 truss spans, with the piers lined up with the old wrought iron tubes. At a little more than 150 foot span these trusses would have been replicas of the shortest spans at Hawkesbury River, just completed. A double track bridge was to be built upstream of the old, and once this was in use, the old bridge demolished and another, identical, double track truss bridge built in its place. The work got as far as the piers in the river, and their design is identical to Hawkesbury River, before work stopped in the early 1950s, not to resume until the 1980s.

By 1980 the age of the large steel truss bridge had passed. Fabrication and maintenance costs were high, and the development of electric welding meant that large box girder bridges were feasible. With the bridge now fully below track level, the four proposed new tracks could be placed quite close together, without the truss on the outsides. A small increase in the width of the piers, by provision of a concrete headstock, meant that all four tracks could be accommodated on the existing set of piers, and the second bridge did not need to be built.

As a first stage only two of the tracks were provided, to replace the existing ones, the others to be built when required, and this is yet to occur.

The New Bridge

The new bridge is comprised of 5 simple composite steel and concrete box girders. They act in the same way as the old lattice girders. With the main load carrying member directly beneath the track there is no need for cross girders. The tension component of the girder, the bottom flange, is a heavy steel plate. Note that it is thicker near the middle of the span as that is where the bending moment and the force the plate has to bear is greatest. The compression component, the top flange, is a composite of steel and concrete. Concrete is good for compression as it is bulky and unlikely to buckle. The box girder does have a steel plate top as well as the concrete, and to ensure that these two components act together, the top steel plate has many large steel studs welded onto it and these are deeply embedded in the concrete, which is placed only after the steel girder has been positioned. Without these 'shear studs' the two components would act independently, sliding over each other as they deflected under a train load. Locked together they act as one girder, the compression in the concrete complementing the tension in the steel lower flange to produce a very strong beam.

The side plates of the box, still called the webs, act, as does the lattice in the old bridge, to connect the heavily loaded top and bottom flanges and make them work together as a single bridge. These webs, being so large and relatively thin, could be prone to buckling, but this is avoided by having closely spaced stiffeners welded on the inside. Such stiffeners are often seen on plate web girders serving the same purpose. The beauty of the box girder is that all the complications, and hence maintenance requirements for avoidance of water ponding, vermin infestation, cleaning and painting , are sealed on the inside. The exterior surface is plane and easy to maintain. The contrast between the maintenance requirements of the complicated riveted lattice truss, and the more modern bridge is obvious.

Building the New Bridge

The ten box girder spans were fabricated at Chullora and brought to Meadowback by rail as out-of-gauge loads. A temporary span was placed between the northern abutment and the first pier, and upon this the wagon carrying the girder was shunted until the girder could be lifted by a large pontoon with hoisting towers. Each girder was then moved by this pontoon into its correct location and lowered into place. The first 163 tonne girder was placed on the 30th July 1978 and the last in January 1980.