The Eleven Bridges of Long Cove.

The First Bridge

Long Cove is a place that now only exists in railway folklore. The watercourse, constrained as a concrete storm water drain, is now known as the Hawthorne Canal and the bay which the stream becomes as it enters Sydney Harbour is Iron Cove, but once it was Long Cove and it required the construction of the only substantial engineering structure on the original 1855 Sydney to Parramatta Railway.

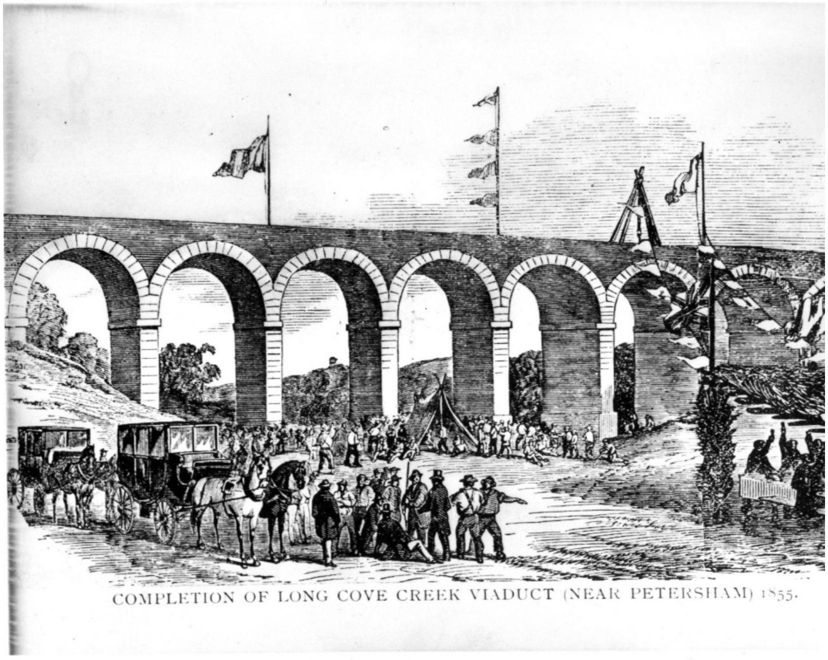

Figure 1 A contemporary drawing of the opening of the original stone and brick viaduct. RRC 8158

Perhaps it was something of a folly brought about by the too high standards which the first designers of the fledgling railway adopted. An acceptance of a less ideal vertical alignment, with grades either side of a shorter timber bridge might have been more sensible, but the standards and the costs of the railway were high and it was a tall bridge of eight stone arches which was provided. Unlike the stone arches which would be built in the next fifteen years at Picton, Knapsack, Zig Zag, Lithgow and Wallerawang, which were totally sandstone, Long Cove had stone piers and arch rings, but brickwork for its upper parts. It was built for double track, although for a very short time it carried only a single line. The other two double track stone arches, at Picton and James Street in Lithgow still carry main line trains, apparently without concern by the engineers who manage them or with only minor modifications since new. The single line stone arches have been bypassed though they are otherwise sound.

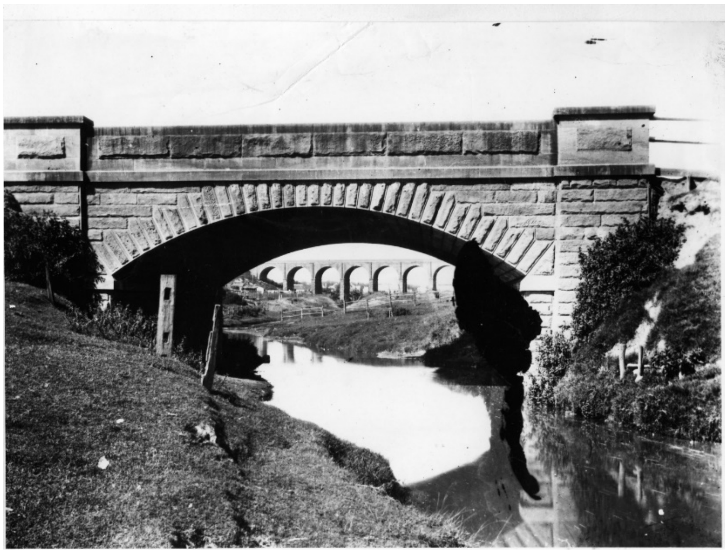

Figure 2 Long Cove Viaduct seen from the western side, and beneath the stone Parramatta Road bridge. RRC 4767

Long Cove does not seem to have been so trouble free. In his extensive Report on the Origins and Progress of the Railways from 1846 to 1864 John Rae stated: ”Very extensive repairs were completed to Long Cove viaduct just before I took charge of the lines (July, 1862) and these, up to the present time, have effectually prevented any further signs of failure in this structure. At the present moment (and it is daily watched) it is perfectly safe.

There was no particular reason of alignment or width why the arches should have been replaced, but in 1886 the bridge was taken down, replaced by a wrought iron truss.

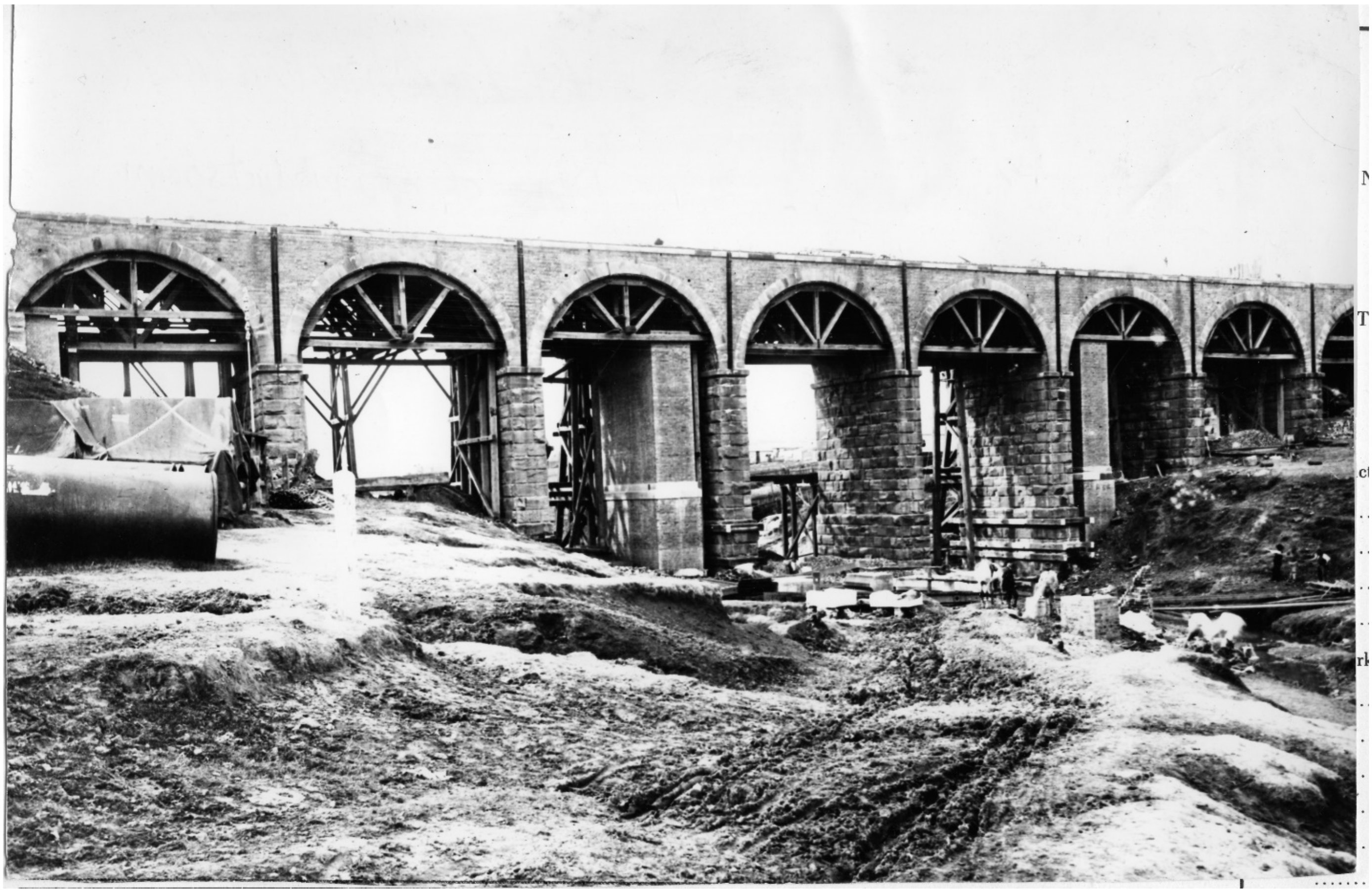

Figure 3 Work beginning on removing the stone bridge. The brick piers for the new iron bridge are complete and formers have been made under every arch to hold them as they are dismantled in a reverse building technique. RRC 5138

The Second Bridge

The replacement process was remarkable in its own way, and the trusses themselves very rare examples of a construction technique long past. Newspaper reports attribute the design to Max Thompson, a railways' employee. Rather than build a new bridge beside the old, as would seem the sensible thing to do and a method often used in other locations, the 1880s engineers decided to build the new bridge exactly in the place of the old arches. The new spans, only three instead of eight, were assembled on timber towers on either side of the old bridge in turn and with the trains running on them, diverted from the true alignment by a short reverse curve. Half of the stone bridge was demolished, fairly carefully one might imagine so as to not bring down the other half, and the new spans slid across onto the old alignment onto new brick piers which had been brought up under the third and sixth arches. The process was repeated on the other side. The demolition of the old stone arches was difficult as it had to be construction in reverse or the whole lot would come crashing down catastrophically, perhaps taking out the new brick piers too. One wonders why the old bridge was not just left unused. The impositions which the constructors of the new bridge placed upon themselves are even more difficult to understand when it is realised that another bridge, carrying third and fourth tracks was built just seven years later, beside the replaced first bridge. Why have the temporary piers and the sliding across when four bridges were needed anyway?

Figure 4 One track has been slewed into its final location, while trains run on the new bridge temporarily supported away from its final alignment. Once the masons have removed the old bridge, the trusses will be slid into their final location. RRC 34497

Figure 5 A commuter train traverses the new bridge, perched high on timber trestle towers. The Down bridge can be glimpsed, already in place with the stone arch still partly in existence between the two parts of the new work. RRC 432465A

Figure 6 The bricks from the old bridge were evidently salvaged and cleaned for re-use. RRC 432464B

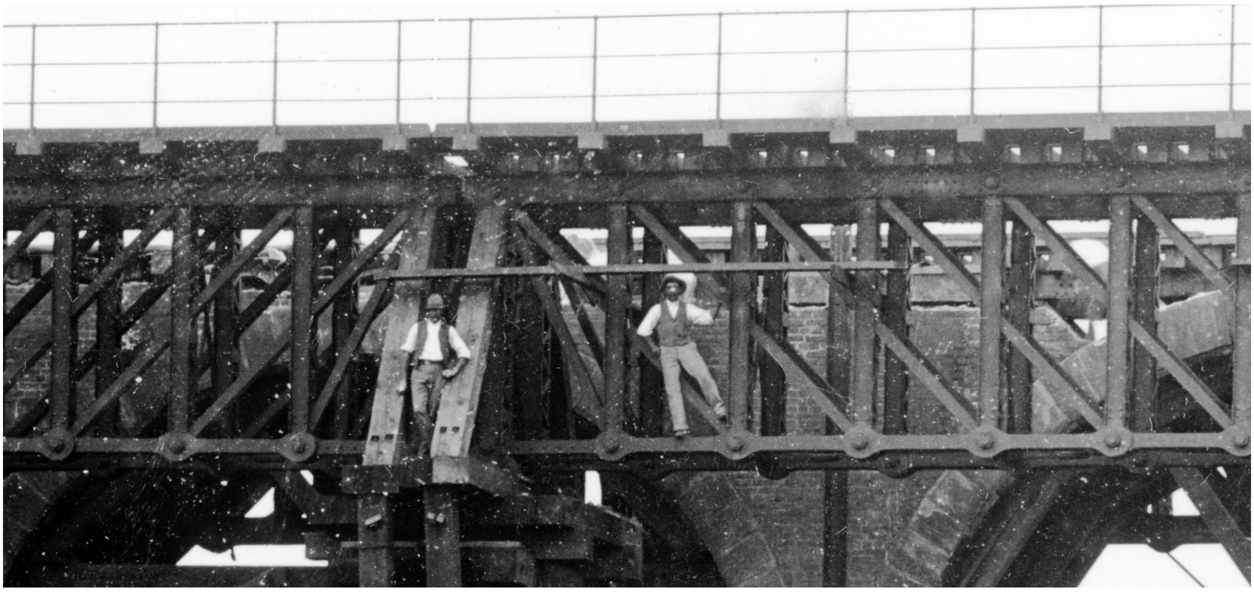

Figure 7 Workers pose for the photographer high on the new bridge. RRC 432464C

Figure 8 Like all work in the 1880s and beyond there was little mechanical aid and no obvious means as to how these heavy timbers could be moved. RRC 432464D

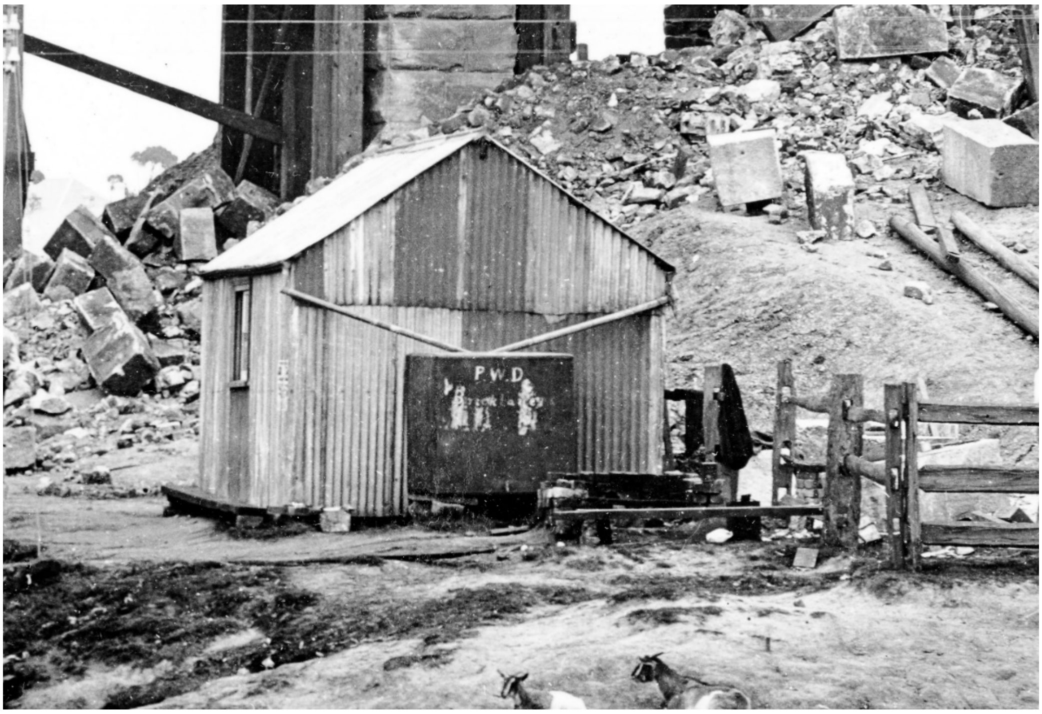

Figure 9 The new bridge was built by the Existing Lines Branch, rather than the Railways Section of the Public Works Department, so the "PWD" on the water tank is unexpected. RRC 432465C

Whatever the reasoning, the new iron bridge was a wonder in itself. It was probably fabricated in Sydney by Royce and Company. No firm statement of this fact has been found, but they certainly were the 'contractors' for the work, whatever that meant, and there is no record of the importation of a bridge or its components in the relevant years. Royce had submitted a tender for the much more substantial Hawkesbury River Bridge in 1884, in partnership with the Butterley Company in the UK, so they apparently had the know-how to make a bridge. There was certainly capacity in Sydney to do such things as Morts Dock had readily manufactured from scratch some substantial components of the Hawkesbury River Bridge which had been short delivered from Glasgow.

Figure 10 The bronze plaque placed by Engineers Australia to mark the bridge's significance. It is high on the brick pier, out of harm's way but difficult to read.

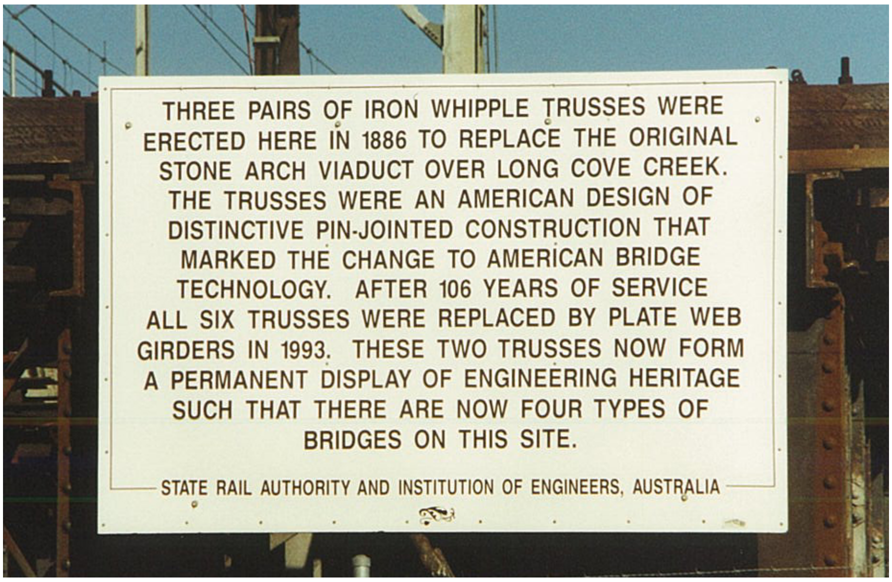

Figure 11 An interpretative sign originally mounted on the trusses, but in 2017 noted lying face down in the grass.

The replacement bridge's claim to fame is that it is pin-jointed. There have only ever been four pin-jointed bridges in NSW. The grandest of them all by far was the Hawkesbury Railway Bridge, but it was demolished in 1947 and is another tale in itself. The iron span over the river channel of the long Murrumbidgee Viaduct at Gundagai is pin-jointed. It still stands, though the timber spans around it are rotting and collapsing. The amazing road bridge across the Shoalhaven at Nowra is not only the oldest of the four, but it is still in service as the southbound carriageway of the Princes Highway. Planning is beginning with a view to take it out of service, but it seems likely that it will be retained in some public use.

The spans at Long Cove (and at Nowra) are usually described as Whipple trusses. Squire Whipple (and Squire was his given name) was an American who developed the first rational understanding and method of analysis of trusses. Like many other structures, people had been building them for a while but relied as much on intuition and experience as sound calculation to design them. For an engineer the design of a bridge is not a matter of making a drawing of something that looks good, but rather a rigid mathematical calculation of the forces in every component and then the provision of enough material, often iron or steel, to safely bear those forces. Whipple's insight and one which more or less required the pin-joints, was that at every joint in the frame, because of the pin, the forces in the pieces meeting there could only be axial within themselves, and they all had to balance. Isaac Newton had said that when he made his oft quoted but often mis-understood law "that to every action there is an equal and opposite reaction". The other great attraction of the pin-joints was that in the field all the work was just Meccano. The precision work was all done in a workshop with big machines, comfortable working positions and without wind and rain. Assembly at the site could be quick and accurate. We don't know how quickly the Long Cove trusses were built, but they were only 90 feet long. At Hawkesbury River, three years later, a span 415 feet long – as long as four spans at Lewisham and two-thirds again – was made and placed in 18 days. The trusses could have been assembled in just a day or two.

The Whipple trusses lasted for more than 100 years at Long Cove, and fortunately when they came down in 1993, one pair, of the three, was left on site as a heritage item and it can be seen up close to understand what it looked like and how it was made. The defining geometry of a Whipple truss is that the diagonals cross two panels, except for the first bay which is crossed by a diagonal at a much steeper angle. These diagonals and the eye-bars which form the bottom chord must have been very carefully made as they all fit. With the diagonals crossing two bays the structure in highly redundant. A structure made of only triangles always fits together, even if the bits are a little bit wrong in length. With the long diagonals and the bottom chords covering two panels with a single component, small errors make for big problems, but Royce seems to have been good enough to avoid that.

The two trusses under each road are braced together across the bridge, and the two pairs of trusses are braced together in the 'six-foot'. Expecting all those parts to be so precisely made, and for them all to go together despite the heat or cold of the day or the weight of other components pressing on them, would be too much, so all of the diagonals are made with turnbuckles. A turnbuckle is a long nut with threaded rods in both ends. The trick is that one end is a right-handed thread and the other left handed. Turn the nut one way and the threads go into the nut; turn it the other way and they come out – you can adjust the length of the diagonal cross member by tiny amounts.

To lift the span out of the bridge to its present exhibition place the contractors oxy-cut the long nuts and have never repaired them.

Pin-jointed trusses didn't catch on and no more were built after the four. The most telling illustration of the limitation of the pin-joint was the Hawkesbury Bridge. Trains became heavier. The deck of the bridge, which was riveted, was upgraded by removing a few rivets at a time, adding more plates and replacing the rivets. The main trusses with one and only one huge pin at every joint couldn't be upgraded because the bridge wouldn't stay up while the pin was removed to fit a bigger, harder, one. The theoretical concept of the pin-joint became crucial however – it's just that they weren't made that way. Engineers still 'assumed' that the joints in a truss were pinned in many cases, even if they were riveted or bolted. The assumption allowed them to use Newton's laws of statics to analyse bridges. They realised that the difference between pinned and not pinned was a rotation in the joint so small that no joint could be so rigid. But then there were welded joints and then there were computers which could do the calculations in a second that no human brain could do in a lifetime.

When track centres were widened for the new suburban rolling stock in the 1920 the two parts of the old bridge were moved apart. I wonder how they did that – new diagonals, longer nuts?

Figure 12 When track centres were widened the straight across members of the bracing between the two tracks were clearly cut and lengthened. The diagonals do seem a little more bent than the corresponding members between the trusses directly under the tracks. The large "C" shaped bracket to which the strut is pinned may be a nut on the end of the pin of the joint. Bill Phippen photo

A bridge this long expands and contracts about an inch (25mm) for every hundred feet (30m) of its length, and the spans at Lewisham are 90 feet (27m) long. If it can't expand it tears at the brick abutment and piers. Imagine how much force it might tale to press on both ends of the iron work you see in front of you and shorten it by 3/4" (20mm) and that's the force that would be pulling on or pushing against the brickwork every day or every night, and under every train which passed – irresistible. To save the brickwork, iron bridges have roller bearings. These bearings for the Whipple trusses were at the other end, and weren't kept for the preserved span. The new spans, of the Local and Suburban lines, have neoprene rubber bearings, which work quite well, but their action isn't as obvious as a roller. The 1927 Warren trusses under the Main Lines, now the oldest bridges over the creek, still have their rollers, but in a most peculiar arrangement. The Down bridges have the fixed bearing at the Sydney end and the expansion bearing at the Parramatta end, while the Up bridges have them the other way around. It is allegedly something to do with the way the trains run, but it may be just a clever idea which has no real value in practice. Cleaning and greasing them more often would probably be more useful.

Figure 13 The bearings under the Warren trusses. The nearer pair are fixed and at the Sydney end of a Down truss and the moving bearing is at the Parramatta end. The farther two are rolling bearings and are at the Sydney end of the Up track. Bill Phipen photo

By 1993 the Whipple trusses were well over a hundred years old and they were tired. Engineers don't say tired, they say fatigued and to engineers fatigue has a very specific meaning. The material in a bridge, say steel, might have an ultimate strength of 30 tons per square inch – that is if you have a rod of one square inch and pull on it with a force of 30 tons it breaks. A component in a bridge would never be loaded to near 30 tons per square inch – the design stress might be 7 tons per square inch. It should be safe. Insidiously however repeated loadings, even much less than 30 tons and much less than 7 tons each do an infinitesimally tiny amount of damage, but there are tens of millions of these load cycles. Between 1886 and 1993 47,262,865 carriages and wagons, and 2,480,898 locomotives had crossed the old Whipple trusses. We know the number because in 2015 the Railway Resource Centre was commissioned by Sydney Trains to count trains across the Local bridge across Old Canterbury Road, also built in 1886.

Sophisticated analysis and microscopic inspection lead to a decision to replace the spans designed by Thompson and fabricated by Royce. The new spans are clean plate web girders. They are steel, because wrought iron was superseded not long after the old bridge was made. They are different because in 1993 plates of steel were available in sizes which Royce could not imagine and electric welding can join two plates as if they were one. In 1993 engineers had sophisticated computer based ways of calculating stresses in large plates without resorting to Squire Whipple's 'trick' of the pin-joint.

The Third Bridge.

By the 1890s EMG Eddy had been installed as Commissioner and he is deemed responsible for the decision to increase the main Suburban Line to four tracks, so two more lines were needed at Long Cove. Although the pin-jointed Whipple trusses were only a few years old they were not repeated. Riveted wrought iron lattice girders were used. The last of the 'big' lattice girders had been built at Meadowbank in 1886. The Long Cove spans were much less loaded with the shorter span. The new spans were placed on the northern side of the existing bridge. They too lasted more than 100 years until 1998 when fatigue fears – and who could be certain that a 106 year old bridge didn't have a hidden crack ready to let go under the next crush-loaded Tangara? – lead to a replacement with welded plate web girders over a Christmas close down. A sample of that bridge was not kept, but the technology is well represented at Meadowbank and Como, as well as several still in service at country locations.

Figure 14 The lattice girders, before they were obscured by the later mainline bridge. RRC18356

Sometimes these lattice bridges are called girders and sometimes trusses. What's the difference? To a 2017 engineer the difference is not much as she has the immense power of computers to analyse any structure, but to the nineteenth century engineer making the structure conform to a mathematical model which he could analyse with pencil and paper arithmetic was inescapably necessary. "Beam Theory" had been developed and things that looked like "I" beams could be designed with confidence. The flanges (The horizontal part) took the bending forces and the plate web (The vertical part) kept the flanges apart and made them work in partnership – in engineering-speak they carried the shear forces. A bit of seat-of-your-pants experience, a few experiments, a few failures and web-stiffeners meant that beams were able to be designed. Whipple had shown the world with his pin-joints how to analyse a truss. The calculations were tractable. The lattice girder/truss was somewhere between. It had more or less continuous flanges like a beam and it had a large number of diagonal web members a bit like a plate web with a lot of holes in it. There were far too many web members, and far too many intersections to do a proper calculated analysis, certainly in 1890! They really should be described as lattice girders.

The Fourth Bridge

The Forth bridge has claim to be the greatest bridge ever built, but unfortunately it is in Scotland and not suburban Summer Hill, so our interest will have to be limited to the fourth bridge on the site – a more modest thing.

The rapid growth of Sydney and the major investment in urban rail transport in the 1920s lead to the provision of a third pair of lines on the Main Suburban. Although at Long Cove the new lines were always built towards the Up side, this is not always true at every location. At other locations the newer bridge or track is on the Local side.

Figure 15 The Mainline Warren Truss bridge. In 2018 this 1927 span is the oldest superstructure component remaining over Long Cove Creek. RRC19269

Fortunately for those interested in rail history, the building of the new bridge in 1927 was documented in the *Staff* Magazine. The brick piers were readily made from below, and the new Down trusses assembled on the approach embankments. From there they were carried and lifted down by two steam break-down cranes running on the Up Suburban. The Up bridges were built and lifted in the same way from the now complete Down Main. The 1927 bridges remain in place and in service.

The style of the fourth bridge is termed a **Warren** Truss. Warren trusses are easy to identify as the internal members form the letter "W". They were named for Captain James Warren, an Englishman, and not William Warren the founding and long term professor of Engineering at Sydney University. Warren's partner in the patent was Monzani, so they could have been called Monzani trusses, but then the internal members would look like "M", but be the same. It is fortunate that Warren was Warren and not of a name starting with any other letter!

In any truss, at least those of simple span, the top chord (the horizontal bit) is in compression and the bottom chord (another horizontal bit) in tension. The bits in between – the diagonals and posts – do much the same job as the plate web of a beam, or the lattice of a lattice beam – they keep the chords apart and make them work together. In a Warren Truss, the diagonals slope alternate ways and they are therefore in compression or tension alternately. A pure Warren Truss doesn't need vertical posts at all as elementary statics shows they carry no force. In practice the long chords do need support against buckling, and deck loads do need to be carried to the nearest panel point, so vertical members are provided. They are often very light (see the Harbour Bridge approach spans) and take no part in the truss action.

Figure 16 The approach spans of the Sydney Harbour Bridge well illustrate the action a Warren truss. The obviously substantial members are the diagonals, and the top and bottom chords. The vertical posts at positions 1, 3, 5, &7 do support the deck but have no role in the spanning effort of the truss. The vertical posts at positions 2, 4, & 6 don't support the deck and don't act as part of the truss so are very light. The cross girders which support the deck are trussed, and all the posts, including 2, 4, & 6 DO have a role in that action. The centre pair of diagonals carry less load, so they are noticeably lighter than the others. The end panels of the top chords have no role at all so that while the four centre bays of the top chord are solid the bays at either end are light laced members only.

The Fifth Bridge

When the Second Bridge (the Whipple Truss) became tired in the late twentieth century, it was replaced by welded plate web girders as we have already seen. We should also recognise that it was only the spans which were replaced. The foundations and the brick piers go on regardless. Good engineering economy dictates that the best bridge for a site is the one where the cost of the foundations equals the cost of the superstructure. This might not have been achieved exactly at Long Cove, but whatever the figures, a good part of the 1886 bridge is still there, at work.

The Sixth Bridge

The replacement for the lattice girders under the Suburban Lines came in 1998, though once again only the superstructure was replaced.

The Seventh Bridge

Hiding demurely, just Up from the ostentatious Lewisham Viaduct, is the humble Old Canterbury Road bridge. It may seem to be just another steel simple span double-track bridge over a two lane road, but it is more than it seems. It is not steel at all – it is wrought iron. It is not a simple span as it has supporting columns at the kerb line, added about 1930, shortening its span from 17m to 13m. That may not sound like much, but it is a lot for bridge which is more than 130 years old. It is as old as the Whipple truss. Sydney Trains are aware of its heritage. They thought about replacing it, but it is to remain for the present, closely monitored. It may be the oldest working metal bridge on the system, at least within Sydney, apart from the Grand Old Lady at Menangle.

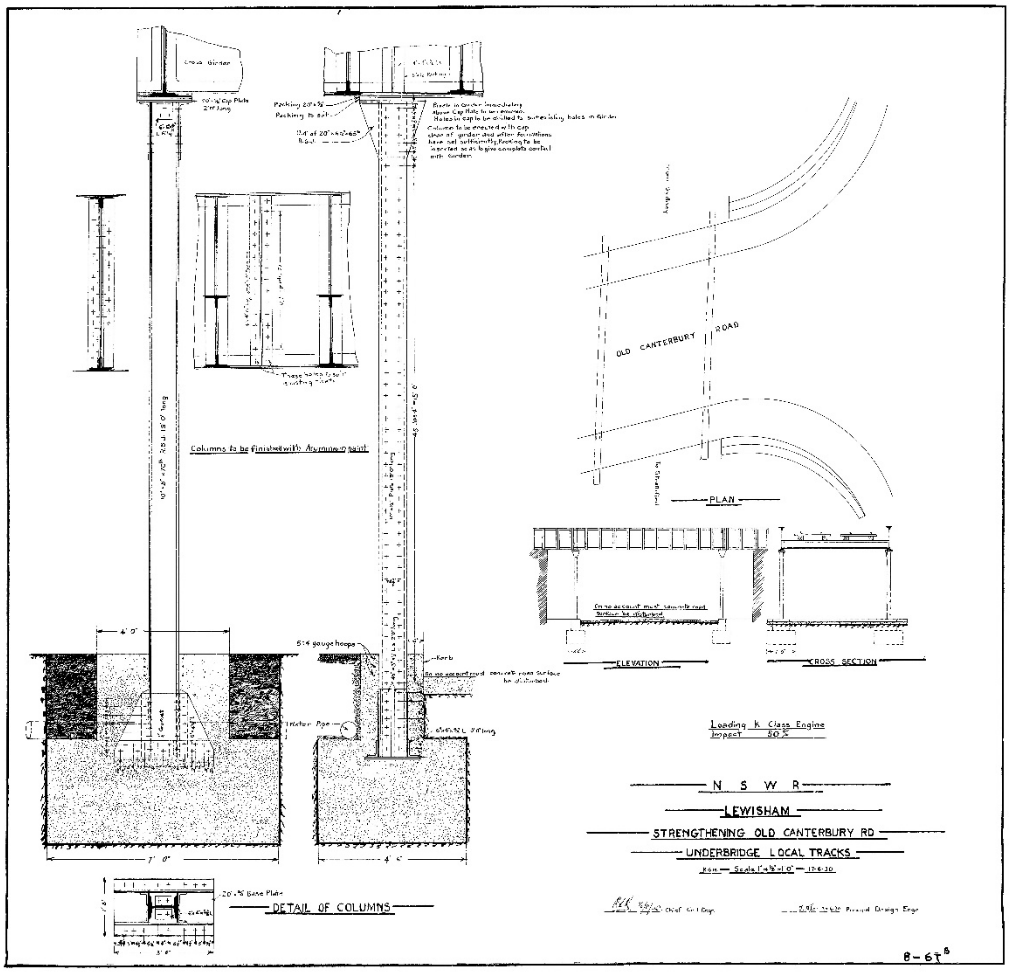

Figure 17 The 1930 addition of posts on the line of the kerbs to reduce the span of the 1886 bridge. RRC Collection.

Figure 18 This sign adorns the western abutment wall, beneath the 1886 Old Canterbury Road bridge. It is clearly a railway sign for 6.377km is the correct chainage from Sydney. Is it a plea for motorists to ring the railways if something looks wrong with the bridge? All underbridges with low clearance, and therefore a risk of accidental damage, seem to carry a similar sign.

In 2015 the Railway Resource Centre estimated that since 1886 63,000,000 carriages and 2,600,000 locomotives have crossed this bridge, in each direction.

The Eighth Bridge

The Suburban Line bridge over Old Canterbury Road was first built in 1892. It is a peculiar thing in that the two girders (and there were only two originally) are of different sizes. The northern one is much taller (7ft 6in) with therefore less iron used in the flanges. The southern one is shorter (5ft) with much thicker flanges. Engineers would say that both sections have the same Moment of Inertia, but that is just technical-speak for saying that less tall girders have to be chunkier to do the same work.

Figure 19 Viewed from Lewisham platform the markedly different sizes of the girders of the Suburban bridge is obvious. The left most girder of the 1886 bridge, then the three of the modified 1892 bridge and then the girders of the 1927 bridge. The three girders seem to be heavily cambered, but this may be partly an illusion created by the extra plates in the flange at the middle of the span. Bill Phippen photo.

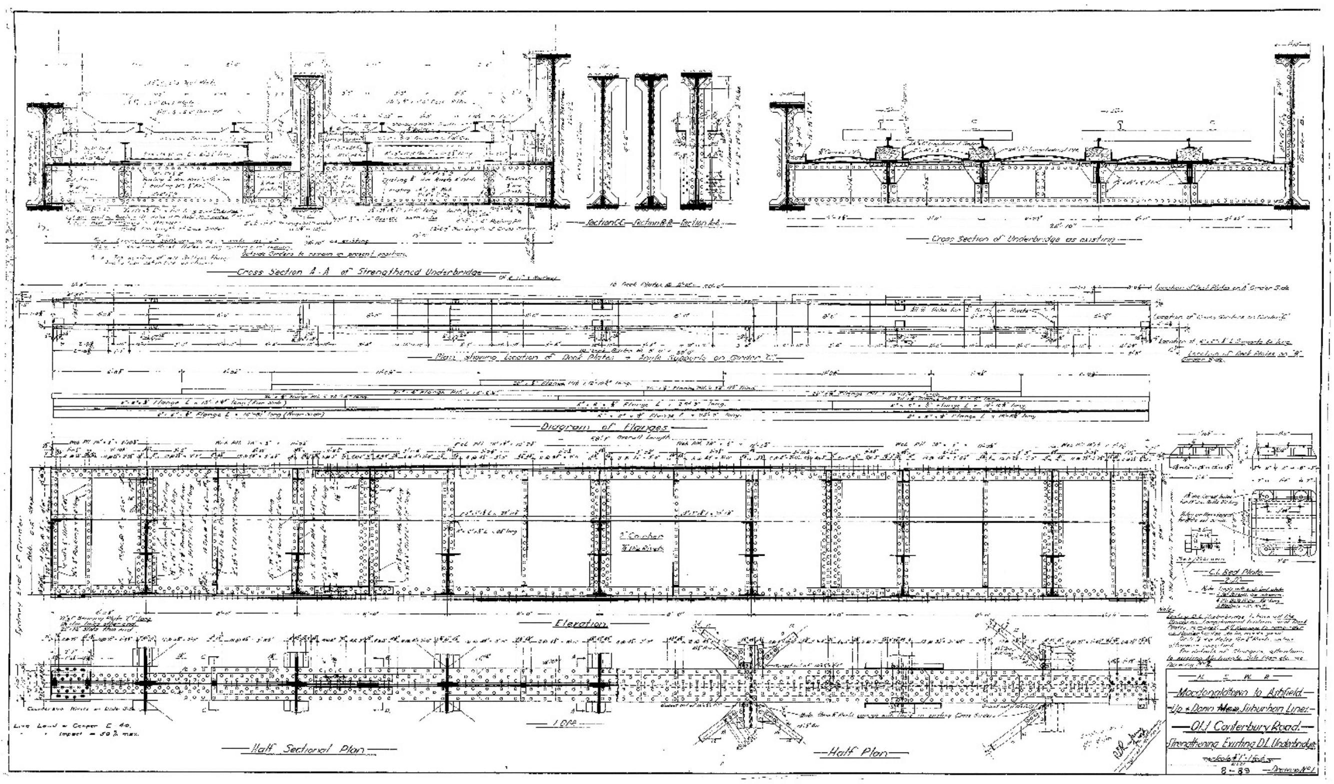

Figure 20 The 1927 strengthening, using a third girder between the Up and Down roads. RRC Collection

There is no obvious cause for this design feature. As might be expected, it needed upgrading to cope with later loading standards and was heavily modified in about 1927. Rather than shorten the span by the provision of columns at the kerb line, a third girder was positioned between the two tracks. In keeping with the 'odd' design of the existing bridge this new girder was of intermediate height. The technique of strengthening bridges by inserting a third girder was well established having been used at six bridges over Solitary Creek near Tarana and on the five bridges north of Goulburn. The difference at Old Canterbury Road was that there was no clearance below, so the cross girders had to be cut and the new girder fitted higher up. This required the bridge to be taken out of service, so the Suburban Line was slewed onto the then new but as yet unused Main Line bridge for a time. The new work would have been in steel, though just what the older parts are made from – wrought iron or steel – would be open to question.

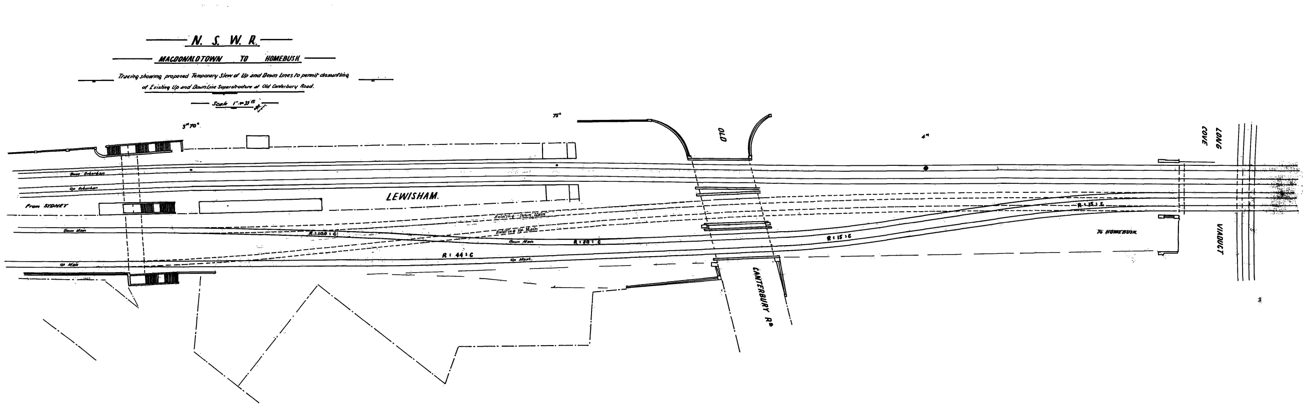

Figure 21 The temporary use of the new mainline bridge to carry the Suburban tracks while the old bridge was strengthened. RRC Collection

The Ninth Bridge

The Main Line bridge over Old Canterbury Road was built in 1927, to the higher loading standards of the time. Before the Main Line was operational the Suburban Line was slewed onto the Main Line Bridge to allow upgrading work on the older bridge. The two older bridges are skewed because the road below does not cross the railway on the square. The last two cross girders at both ends of the 1886 bridge are supported on the abutment wall, not the opposite girder. There are no short cross girders in the 1893 bridge, but the cross girder over the bearing meets the opposite girder well out into the span. The 1927 bridge is not skewed at all. It is simply made longer with the point of support for one of the girders at each end well behind the abutment wall.

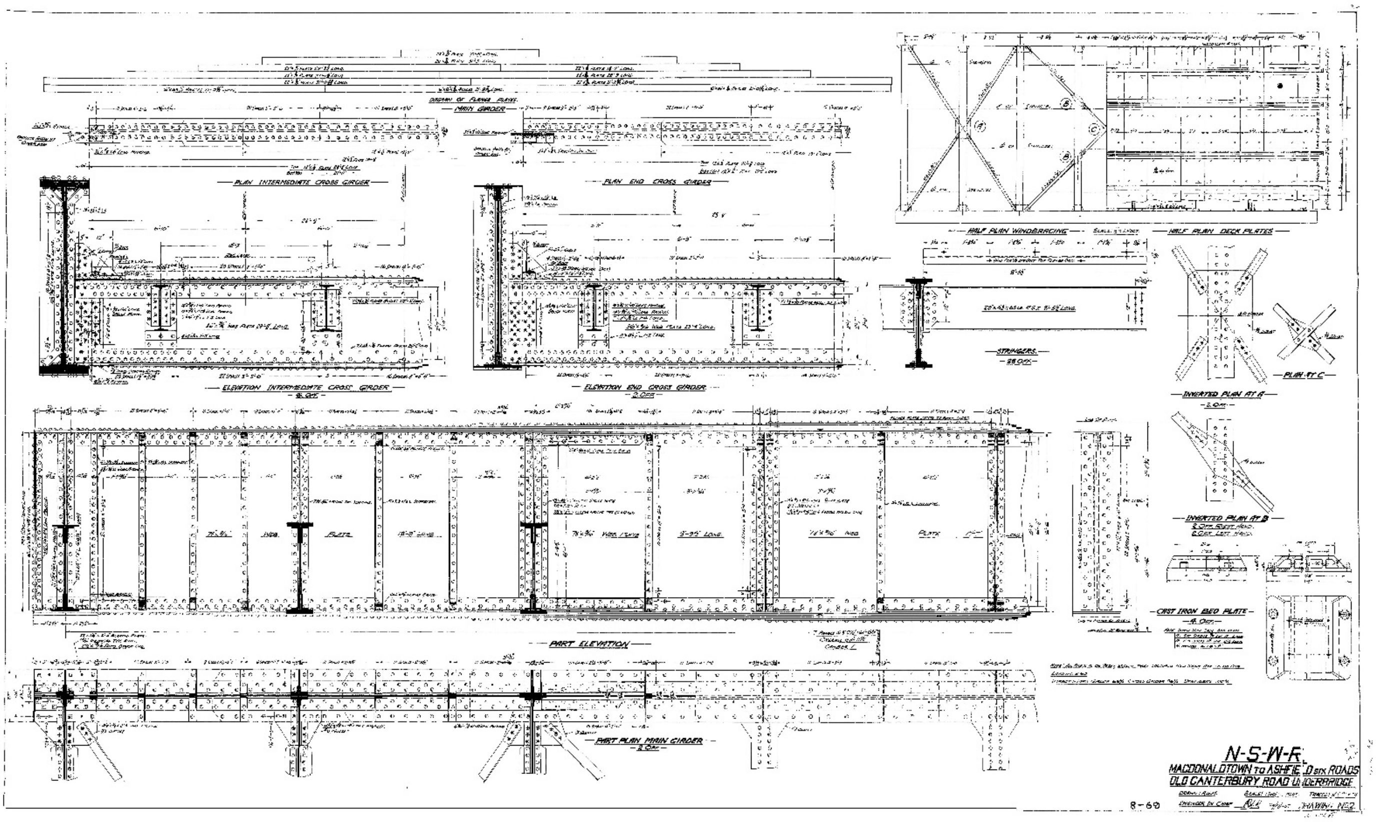

Figure 22 The third bridge over Old Canterbury Road. RRC Collection

The Tenth Bridge

For completeness the overbridge carrying Longport Street over the Rozelle Goods Line should be mentioned. Designed in 1912 it is formed of closely spaced rolled joists with the spaces between filled with brick jack arches.

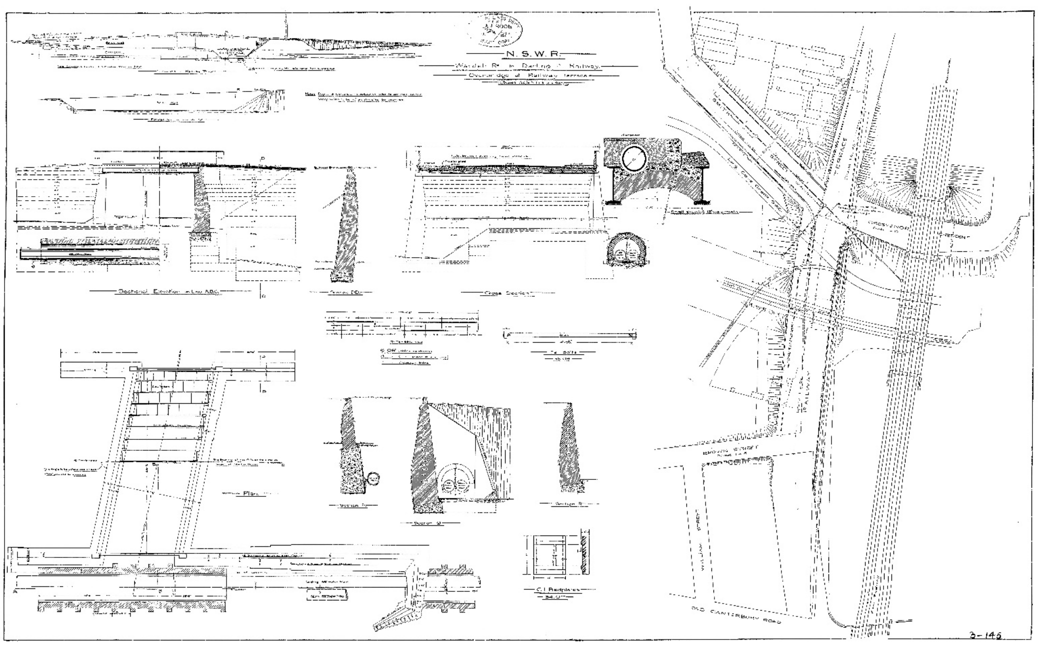

Figure 23 The Longport Street over the Goods Line. Note that on the site plan only four tracks exist on the Main Suburban above. RRC Collection

The Eleventh Bridge

When you leave for home, towards Sydney, look carefully on the Up side of Lewisham as your train passes under West Street. There are two skew brick arches in the overbridge. They might be of only 4.4m span but they are things of wonder and amazing skill to construct. They are also impossible to photograph, from the platform, from the road or from a moving train.

Figure 24 A distant view of the skew brick arch under West Street Lewisham, Bill Phippen Photo

Bill Phippen 2018