Movable Span Bridge Study

Volume 2: Bascule and Swing Span Bridges

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Appendices

6. Bascule bridges

6.1 Description of bascule bridges

The term “bascule” originates from the French language and translates as ‘a balance’ (Waddell, 1916). They are defined as those bridges which operate by raising one side and lowering the other. This action can be achieved through considerable variations in geometry, mechanisms and operation leading to a great diversity of designs. Notwithstanding this, components common to all bascule bridge designs include: leaf spans which pivot, variable force counterweights, locks and gearing.

The bascule bridge design is utilised when there is a need for infinite headway at a river crossing. This was often the requirement on coastal rivers where masted vessels were frequent users of the waterway (Dare, 1904). Further advantages of the design include the speed of operation and keeping the river passage free from pier obstructions as is the case with the central pier of swing bridges (Waddell, 1916).

Due to the complexity of the evolution in bascule bridge designs, particularly in North America, the descriptions of these bridges are laid out in detail within the following sections.

6.2 European origins of bascule bridges

6.2.1 Drawbridges

The bascule bridge is an evolution of the common medieval drawbridges that were utilised mainly as military devices. They would prevent the passage across a channel or moat thus providing protection to inhabitants (Hovey, 1926). It appears that the size of the spans was originally limited due to the reliance on manual haulage to operate the bridges. This led to the eventual introduction and evolution of counterbalanced systems to provide mechanical advantage.

Cover Image: The two Swansea bascule span bridges shown in the raised position in 2004.

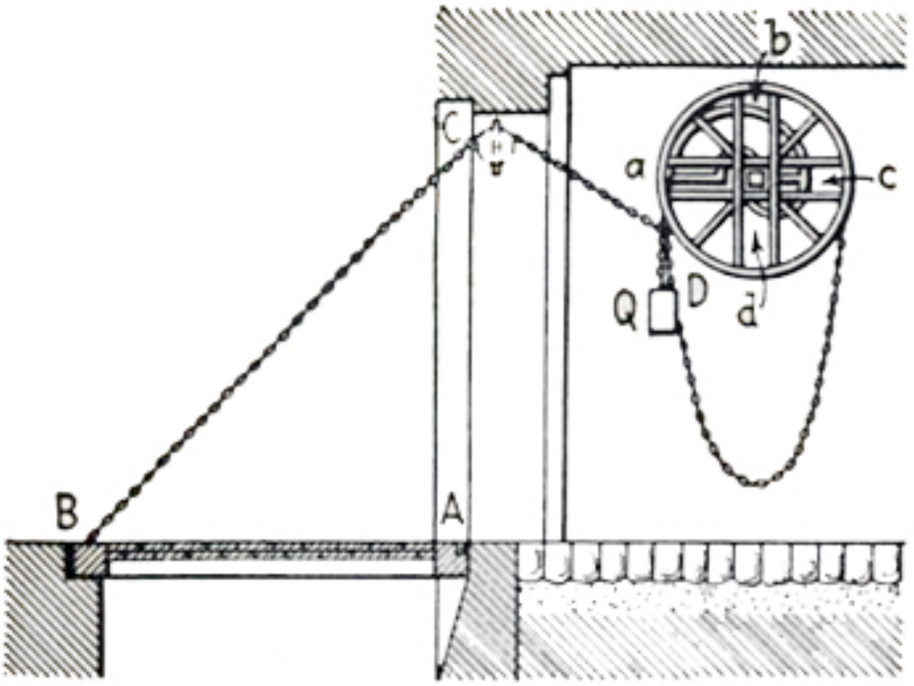


Figure 6.1 **Typical medieval castle drawbridge operated by a compact pulley and chain attached to the entrance wall**

The mechanical advantage of this arrangement means that the force required to lift the span dissipates as it reaches the top of its motion. However, if the counterweight force is constant the span will accelerate into the support tower with the subsequent difficulty of lowering and closing the unbalanced span (Fraser, 1985).

This problem has been solved by various mechanisms that ensure the variation in driving force is matched with a variation in counterweight force. Early attempts consisted of seesaws, complex lever arrangements, rollers and draw pits. This led to the eventual introduction and evolution of counterbalanced bascule systems to provide the required varying mechanical advantage.

At wider crossings drawbridges were constructed in two leaves. The leaves could be drawn-up from support posts or frames by chains, or alternatively by the Dutch method of overhead beams (Price, 1879). Figure 6.2 shows this style of movable bridge.

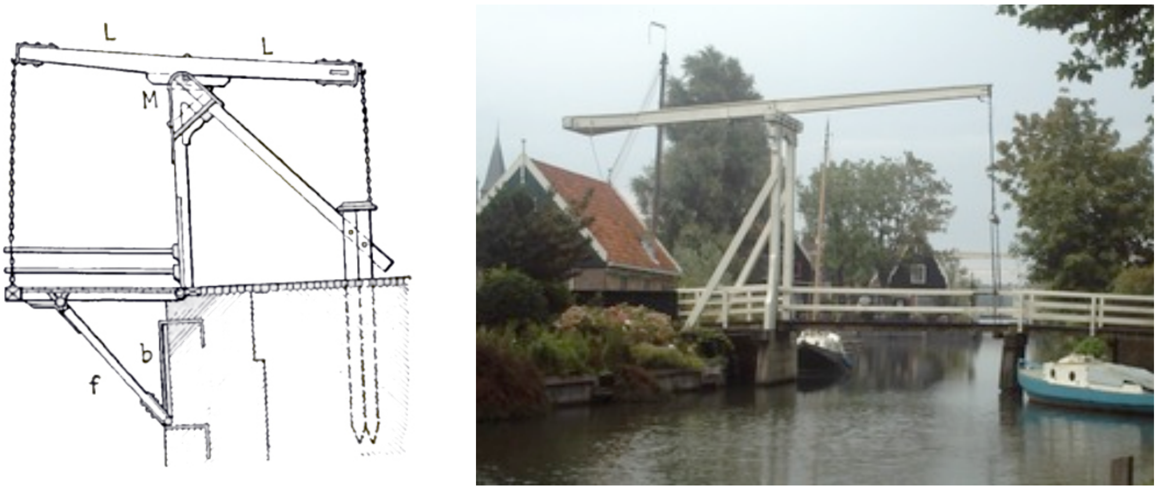


Figure 6.2 Dutch draw bridge (Source of Drawing: Hovey, 1926)

Figure 6.3 A modern Dutch bascule bridge at Yarmouth, England

6.2.2 Origins of the Bélidor bascule

An ingenious alternative system was devised to replace the conventional drawbridge arrangement by adopting a counterweight that rolled down a rear curved track. This was originally used exclusively for military fortresses. The fortress of Bonifacio in Corsica is cited as the earliest known example of this style (Hovey, 1926).

Credit for the first analysis of the system has attributed to the French mathematician Guillaume de l'Hôpital, in correspondence with the Swiss mathematician Johann I Bernoulli during the late 16th century. This correspondence from l'Hôpital contained the curve equations which were published in Latin by Bernoulli in 1695, who recognised the equation as that of a cardioid (Barpi & Deakin, 2012).

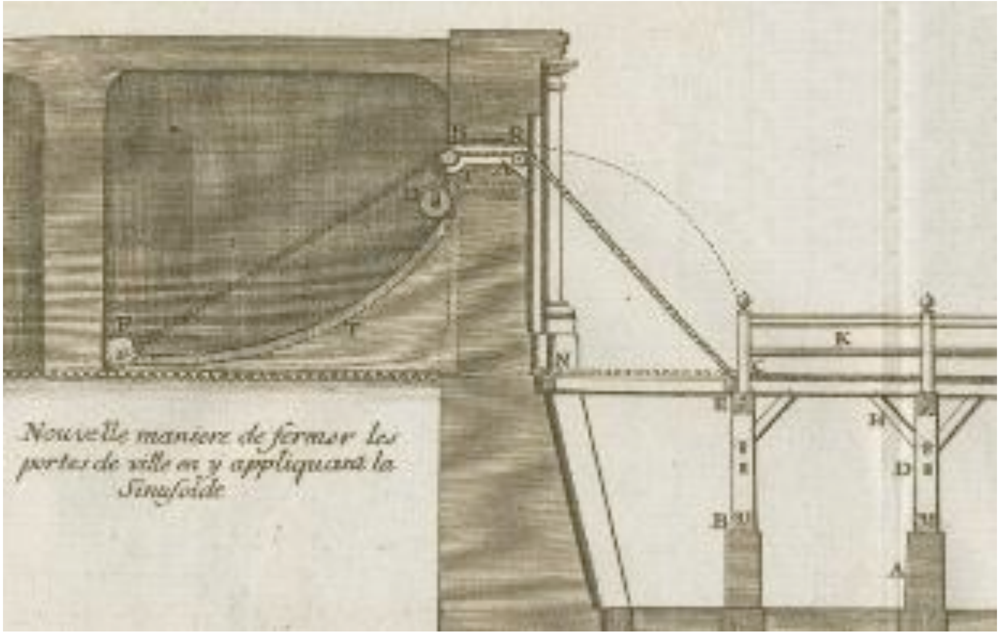


Figure 6.4 **Sketch of early Bélidor type bridge detailing its usage as a castle drawbridge (Source: La Science de Ingenieurs, 1754)**

Subsequent French publications resulting from the work of Bernard Forest de Bélidor became influential, with the publications also including sketches of these designs (Figure 6.4).

There are a considerable number of bridges with this design built in the 1700s with examples including; the Königstein fortress in Germany, the Exilles in Italy, the Esseillon in France and the Fort l'Écluse also in France (see Figure 6.5). The list is not exhaustive and further examples have been earmarked as possible Bélidor designs by Barpi & Deakin, 2012.

Figure 6.5 **Fort l'Écluse, gate downstairs (Source: Barpi & Deakin, 2012)**

6.2.3 Trunnion bascule

The next evolutionary development was the trunnion bascules. These are distinct from previous bascule designs with the introduction a heavy counterweight mounted on a frame at fixed end of the span. The bridge rotates around a fixed pivot point and as the span is raised the counterweight swings down.

Due to crude arrangements of counterweights and the lack of ample and convenient power for operating, the bascule remained in its primitive state until the early 1800s. Designs of bascule bridges continued to develop through this period and a number of types began to emerge with most of the early types rotating about a fixed axis (Waddell, 1916). One of the earliest recorded trunnion type bascule bridges (Figure 6.6) was built at Selby England in 1839 and was noted to provide practical service as a rail bridge (Price, 1879).

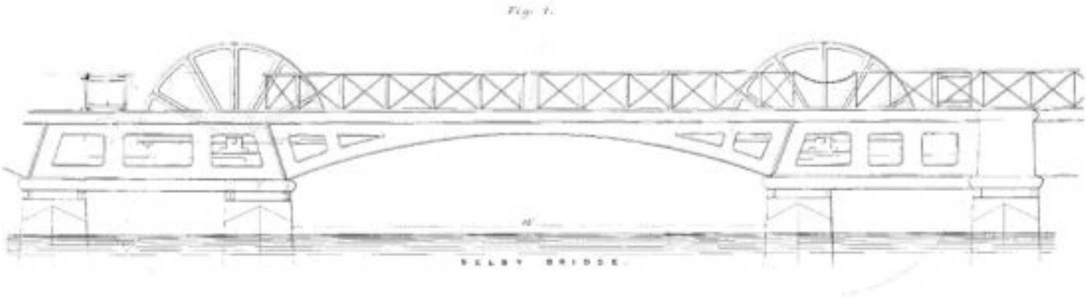


Figure 6.6 Bascule Bridge, Selby, England (Source: Price, 1878)

The best known bascule bridge in the world is the Tower Bridge over the Thames River in London completed in 1894 which is a roller-bearing trunnion type (WisDOT).

Figure 6.7 Tower Bridge, London

6.3 North American influences

The adoption and development for bridges blossomed in the USA during the 19th century. So many bridges were required in America that bridge building became a profitable industry for bridge designers (Fraser, 1985). In comparison to the relatively slow development recorded in Europe, the intense competition that took place in the USA to have patents led to an explosion of sub-types of bascule bridges being developed with extensive variations of mechanisms and geometry between the 1890s and 1920s.

6.3.1 Adaptation of the Bélidor bascule

The potential of the Bélidor Bascule as an elegant and energy efficient movable bridge design was described in an influential 1896 paper in *the railroad gazette*, by Assistant Chief Engineer of American Bridge Company, Otis E. Hovey (1926). Hovey's comprehension and knowledge of the Bélidor bascule was pivotal in the successful adaption of the design to road and rail bridges. He designed a number of these bridges in America displaying their practical advantages (Figure 6.8 and Figure 6.9).

Two examples of Hovey's designs built in 1896 include the Bridge across the West Branch of the Chicago River and the Berry's Creek Bridge on the Erie Railroad.

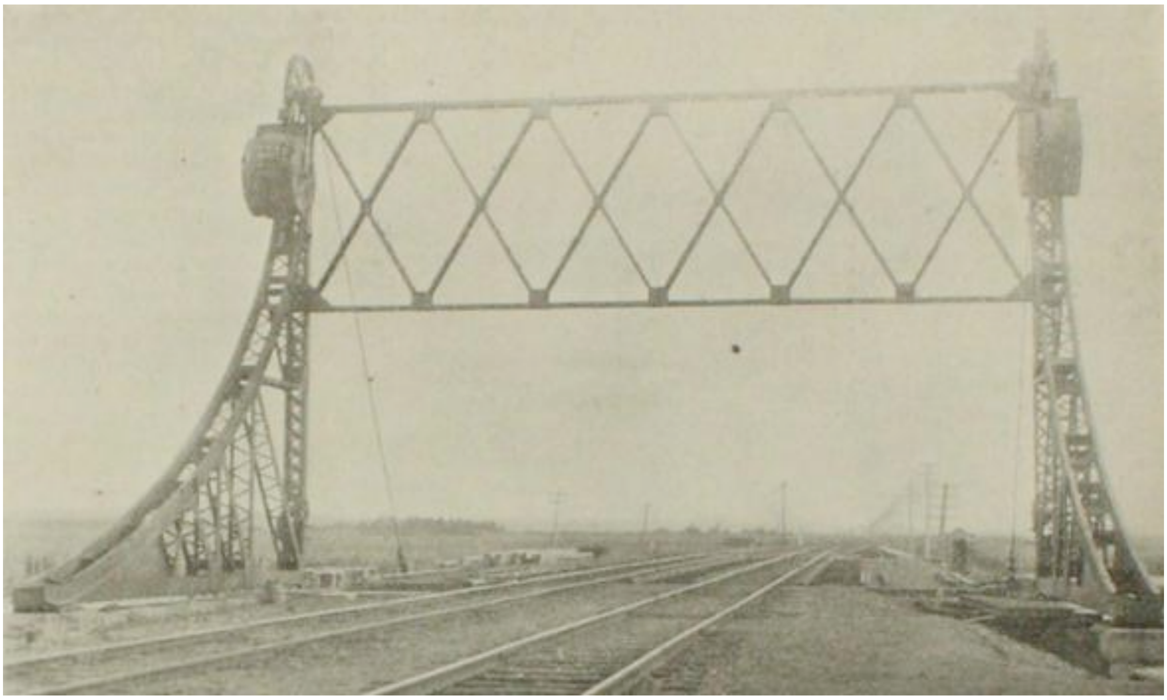


Figure 6.8 Berry's Creek Bridge on Erie Railway, New Jersey USA (Source: Railroad Gazette, Nov. 27, 1896)

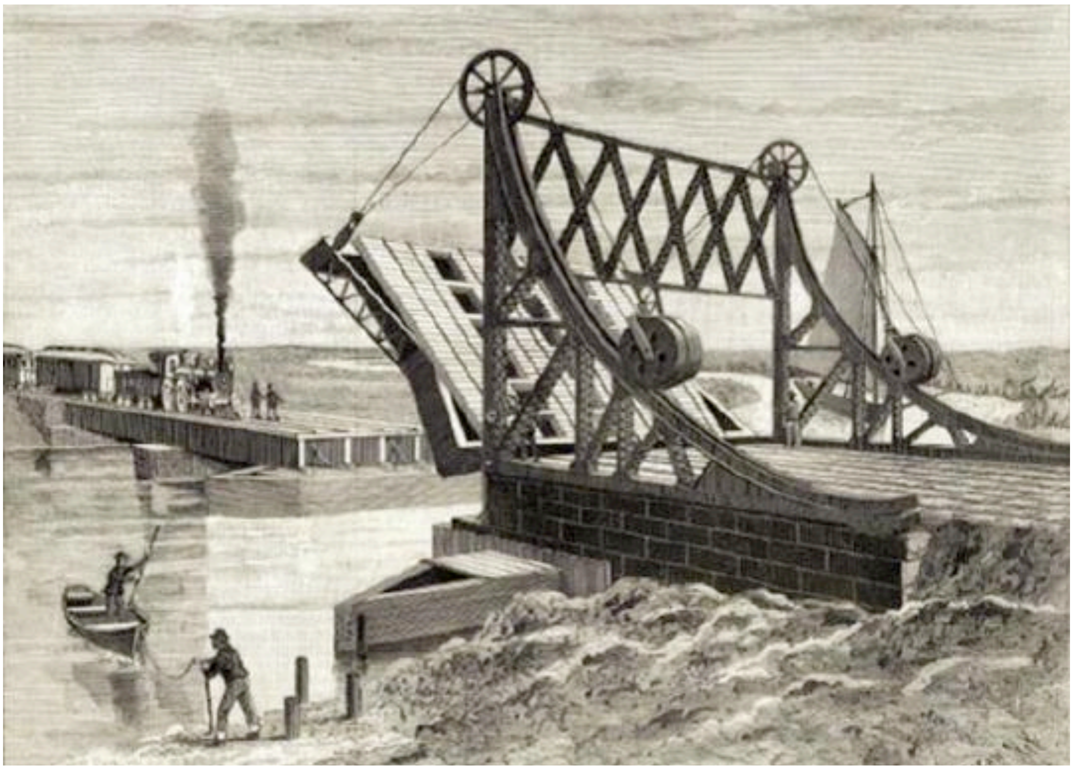


Figure 6.9 From Scientific American, November 28, 1896

The key feature of the design is the curved rear counterweight track. As the counterweight travels down the curved track the vertical force component dissipates to compliment the reduced force required to raise the span. This arrangement ensures that the span is balanced in all positions of the operation.

The Bélidor bascule bridge design (or cardioid curve) operates by the principle that the rolling counterweight provides maximum lifting force when it is vertical and at its peak or maximum height. From here the counterweight rolls down the curve, and where the curved track radii increases so that the vertical load of the counterweight decreases to keep in balance with the rising centroid of the bascule span (Figure 6.9 and Figure 6.10).

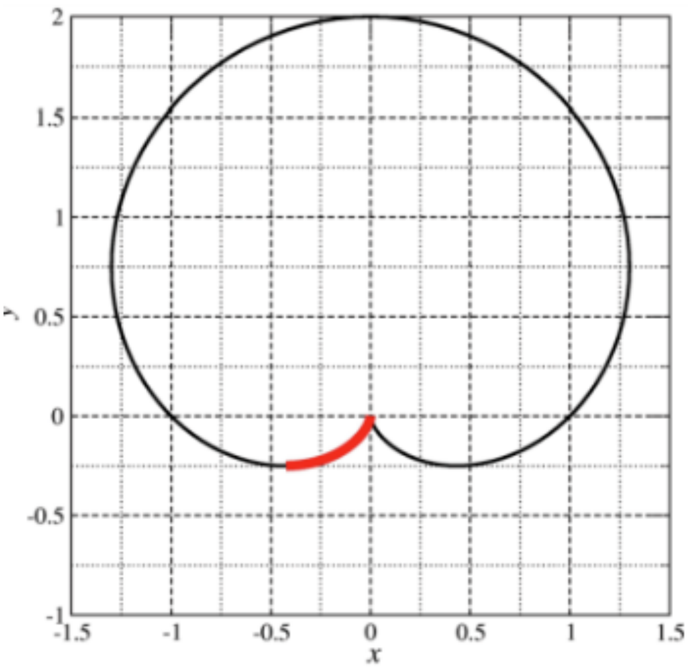


Figure 6.10 The cardioid in the orientation required. The track occupies only the broad red line section (Source: Barpi & Deakin, 2012)

In contrast to the relatively slow development in Europe, further bascule bridge developments continued in the USA, often taking the European designs as a starting basis. However, American bridge engineers continued to innovate in three distinct basic types; simple trunnion, rolling lift and articulated counterweight bascules.

6.3.2 Simple trunnion bascule

The simple trunnion type was an evolution of the Selby Bridge (UK design) described above with the key feature of a fixed pivot point (Figure 6.11). Early North American adaptations were built in New York, Washington D.C. and Benton Harbor, however the well-known simple trunnion bascule is attributed to Mr. John Ericson and Mr. Edward Wilmann, who were Chicago City bridge engineers in early 1900s. Various simple trunnion bridges were subsequently built in Chicago City, owing to the reason that these bridges are sometimes referred to as Chicago type bascules (Hovey, 1926).

Simple trunnion bascule bridges exhibit various common characteristics. The trunnion shafts are on a common centre line, and mounted in trunnion bearings fastened to the piers. The forward end of the bascule leaf extends over the water and is much longer than the opposite end, referred to as the tail end. Power to operate a trunnion bascule is transmitted to pinions located on each side of the span. The pinions engage curved racks on the bottom of the leaf. The pinions rotate in one direction to open the leaf and reversing the rotation of the pinions closes the leaf.

A few trunnion bascule bridges have machinery mounted on the counterweight end of the movable leaf, with curved racks fixed on the pier.

As the pinions rotate, they move around the racks to open and close the span (WisDOT, 2011).

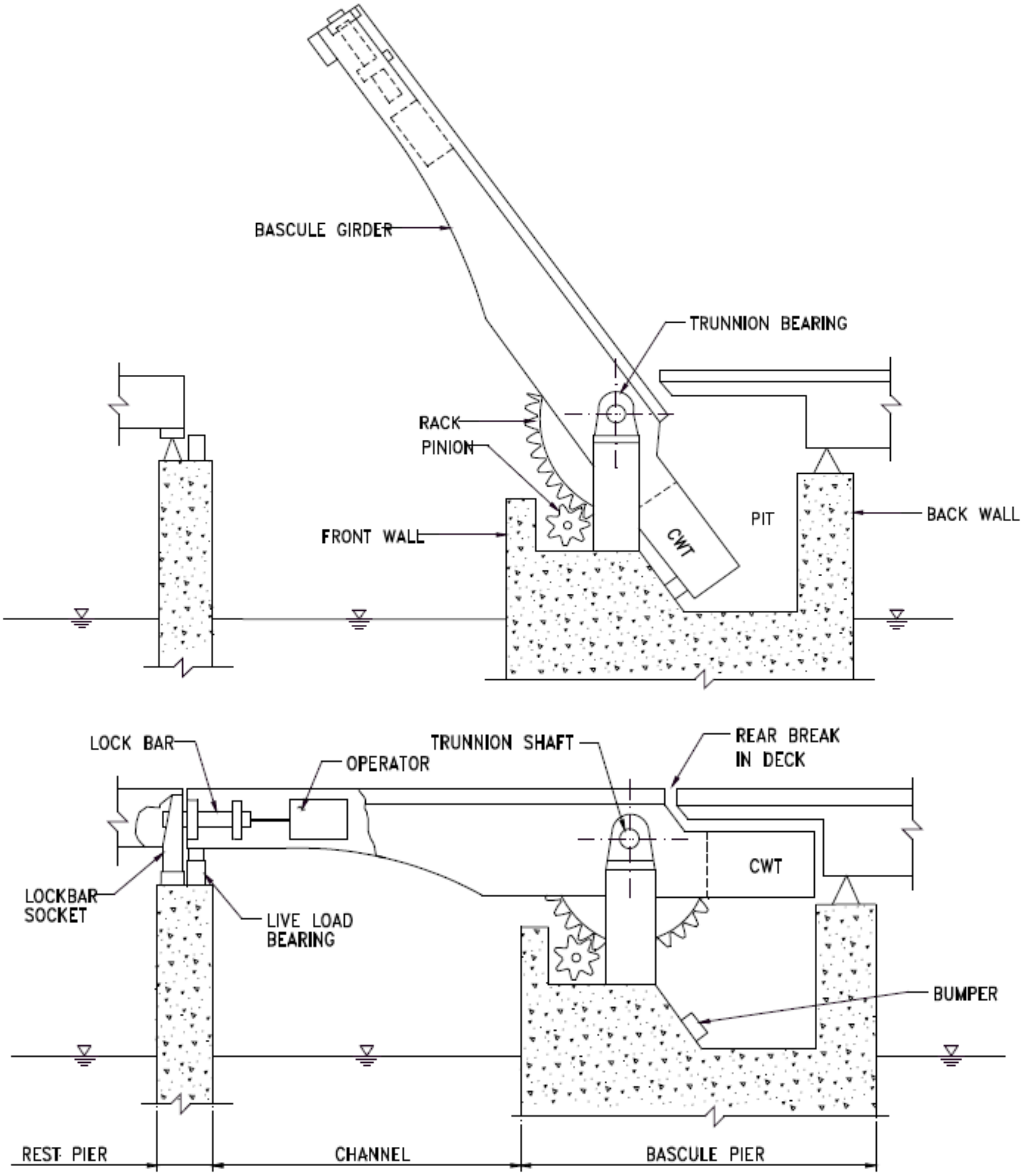


Figure 6.11 Single leaf showing open and closed positions of a simple trunnion bascule bridge and components (Source: Wisconsin Department of Transportation, 2011)

The final significant development in trunnion bascule bridges was the evolution to a hydraulically actuated trunnion bridge.

The design was first patented in America by George G. Mooney and Earnest C. Driver. The American patent number was 3308496 and it is titled 'Hydraulic Operating System for Opening Bridges'. As noted in the patent:

"Operating systems for pivotally elevating and lowering the span sections of (bascule) bridges have been of the mechanical gear driven type. In accordance with the present invention however, the mechanical gear driven systems are to be replaced by a hydraulic system and reversible hydraulic motors" (US Patent 33084946). Figure 6.12 shows the patent drawing submitted in 1967.

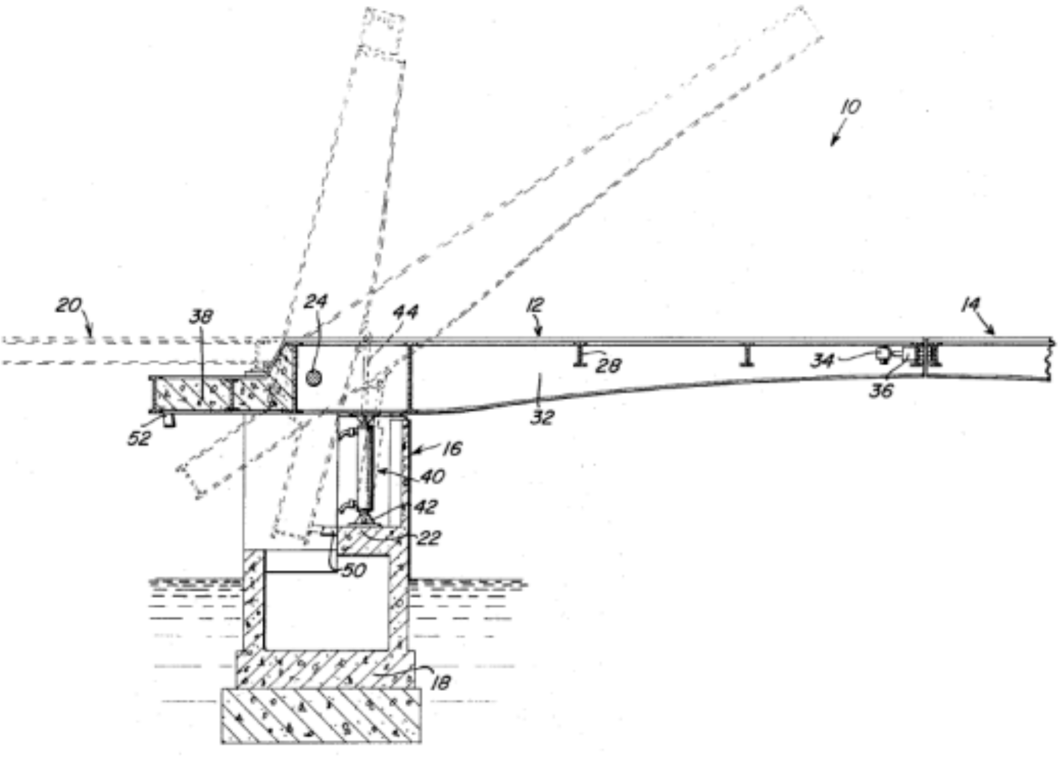


Figure 6.12 Simple trunnion type bascule bridge with hydraulic system (Source: Patent 3308496)

This patent appears to be the first implementation of such a system and is therefore the likely source of the Swansea Bridge (1989). Comparisons between both drawings sets show a number of similarities.

6.3.3 Rolling lift bascules

Rolling lift bridges are distinctly different in operation to other bascule bridges as the movable span does not pivot about a fixed point. Essentially, operation of the bridge is achieved by rolling the entire span backward on curved extensions of the bridge girders or on large rollers. As it does this, the leaf rises and the counterweight drops. The fixed counterweight makes this movable bridge type very economical to operate.

The US rolling lift bascules had two important forerunners; these were the 40 ft. track girder built at Le Havre, France, before 1824 and another rotating on a wheel built at Bregere and documented by Waddell (1916). These designs were later built upon by American engineers, with the two most common designs being that of the Scherzer and Rall types.

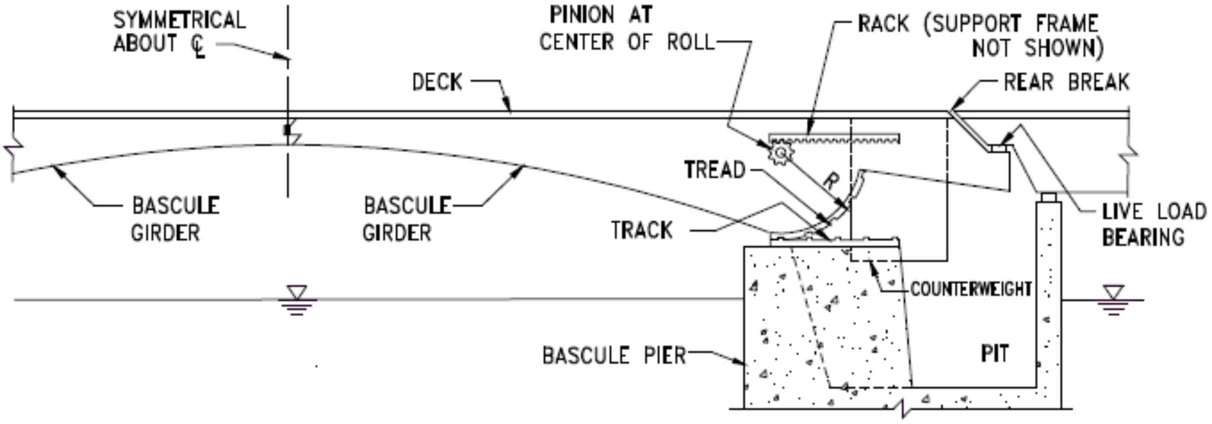
Scherzer type

The Scherzer design was the most common rolling lift bridge design adopted in the USA. The Scherzer Bridge was first developed in 1893 by William Scherzer of the Metropolitan West Side Elevated Railroad Company of Chicago. The bridge design was patented, vigorously advocated and widely used in the US and several cases in other countries. The type was popular on account of its simplicity and the small power required for operation (Hovey, 1926).

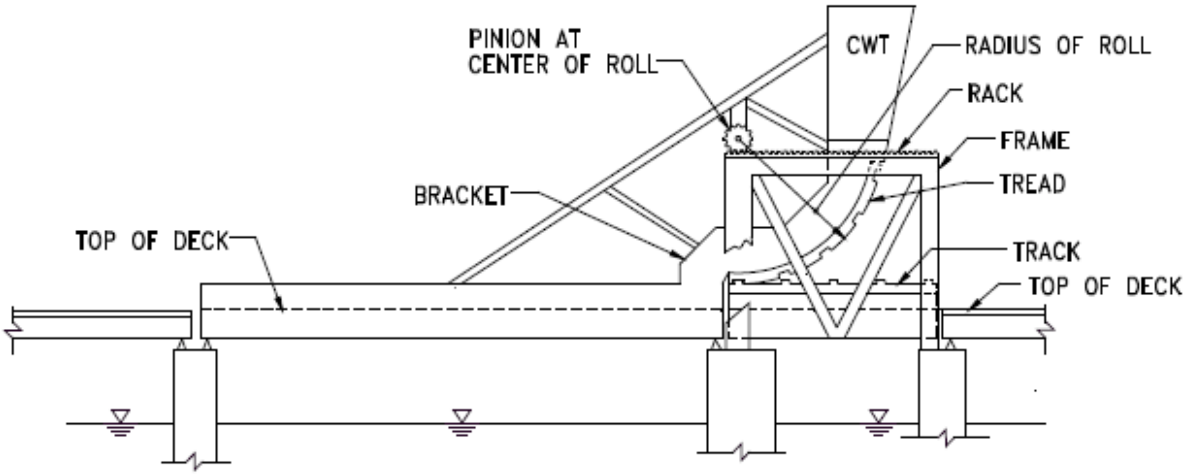
Rolling lift bascule bridges of the Scherzer type are characterised by cylindrically curved parts of the bascule girders or trusses at the ends over the bascule piers. Due to their large size, the girders or trusses of the early Scherzer bridges were assembled from segments and subsequently titled “segmental girders”. During operation, the type of motion is best described as a rotation about an axis that translates. The segments of the girder may be viewed as a segment of a wheel, as the wheels roll away from the channel along the tracks, the bascule leaf rotates open or closed. Slippage between the segmental girder treads and the running tracks is prevented by teeth that mechanically engage sockets within the girder segment (WisDOT, 2011).

Three common types of Scherzer bascules include the deck double-leaf, the half-through single –leaf and the through single-leaf (Figure 6.13).

- Deck double leaf



- Half-through plate girder (pony) single leaf



- Through truss single leaf

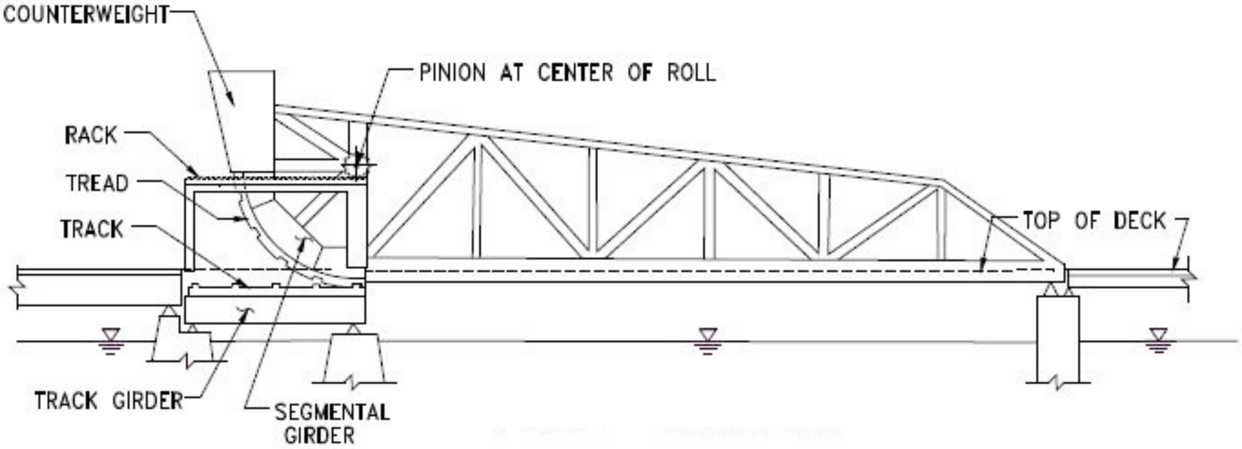


Figure 6.13 Scherzer rolling lift bascule types (Source: WisDOT, 2011)

Rall type

The Rall bascule bridge is an interesting variant of the rolling bascule type. The design seems to have arisen in part as a way around the patents held by the Scherzer Bridge Company. The design was developed and patented by Mr. Theodore Rall and was controlled by the Strobel Steel Construction Company of Chicago.

Contrasting to the Scherzer type bridge, which rotates back on curved girders, the Rall patent involves large moving rollers that are utilised to achieve both the translation and rotation of the bridge. The driving force for the bridge is provided by a pinion and rack system, as the pinion works on a rack the bridge is drawn back from the channel. Tension struts located beneath the roller are then engaged, causing the span to rotate and open.

The most significant bridge built to this specification was the Broadway Bridge across the Willamette River in Portland, Oregon opened in 1913.

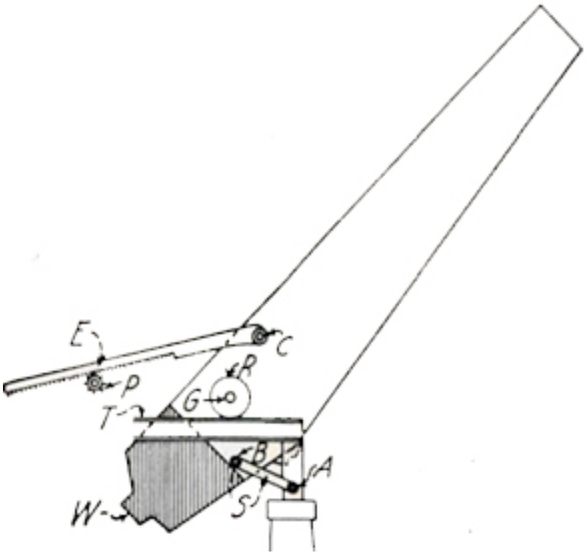


Figure 6.14 Rall bascule bridge mechanism (Source: Wilson, 2005)

6.3.4 Articulated counterweight bascules – Strauss type

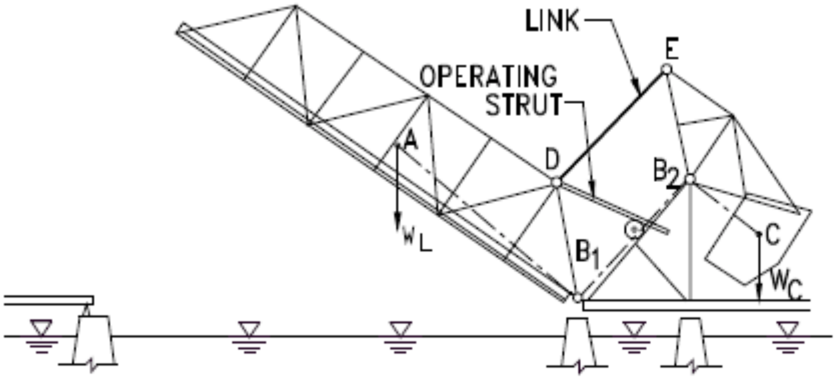
Joseph Strauss developed a number of other variants of the bascule bridge in the early 1900s. These designs were patented by the Strauss Bridge Company of Chicago and were constructed throughout the USA and other countries. The patent was granted on the concept of a remote counterweight system that would indirectly connect to the tail end of the leaf span. Bridges with his specific counterweight arrangements are often called Strauss bascules.

There have been more bascule bridges built from the Strauss designs than any other single type of bascule. This series comprises designs of three common types including the heel-trunnion type, the underneath counterweight type and the vertical overhead counterweight type.

Strauss heel-trunnion (first Spit Bridge)

The Strauss heel-trunnion has the distinguishing feature of an overhead rotating counterweight frame, as shown in Figure 6.15. The geometrical figure B1DEB2 is a parallelogram and the centre of gravity of the counterweight at C is located so that the line B2C is parallel to the line between the centre of gravity of the leaf at A and the heel trunnion B1. This arrangement is implemented to ensure that the ratio between the leaf dead load moment about B1 and the counterweight moment about B2 remains essentially constant during rotation of the leaf (WisDOT, 2011).

The leaf span rotates about the heel-trunnion B1 in response to a force transmitted to the leaf by the operating strut which is hinged at the top chord joint D and engages the output pinion of the span drive machinery mounted on the counterweight support frame. The trunnions B1 B2 and D E are heavily loaded during motion. The reaction at the heel trunnion B1 may reverse direction, depending on the proportions of the structure, and this effect should be considered in evaluation of the heel trunnion bearings (WisDOT, 2011).



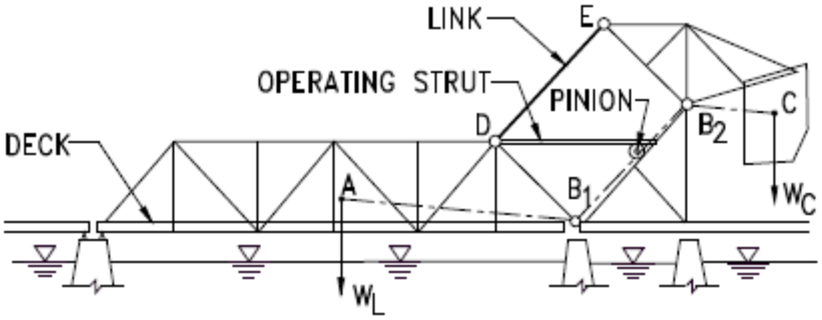


Figure 6.15 Strauss heel-trunnion type (Source: WisDOT, 2011)

Strauss underneath counterweight

The single leaf Strauss trunnion bascule with an under-deck counterweight is depicted in Figure 6.16. The counterweight hangs from two trunnions and the direction of the vertical axis C-E of the counterweight is maintained by the link between the counterweight and the trunnion tower. The need for this link has often been questioned. One argument is that at a small angle of opening the friction in the counterweight trunnion bearings may not permit the hanger to rotate such that the axis C-E remains vertical. As the angle of opening increases the moment applied to the bearing would increase and when it exceeded the bearing friction moment the counterweight would swing free. This motion would cause a dynamic load on the leaf which may interfere with control of the moving leaf (WisDOT, 2011).

Excessive friction in the counterweight trunnion bearings is often due to improper lubrication. The bearing friction induces a bending moment in the counterweight hanger, which produces repetitive bending stresses for which the hangers were usually not designed. Hangers on some bridges have failed in fatigue, resulting in collapse of the leaves (WisDOT, 2011).

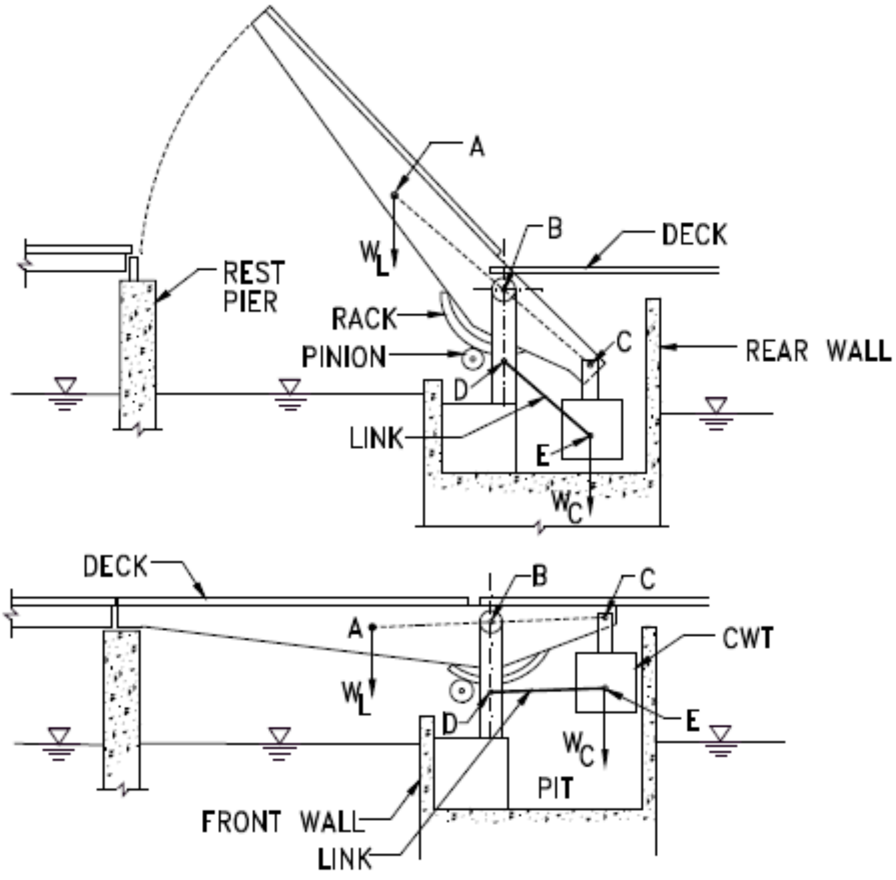


Figure 6.16 Strauss underneath counterweight type (Source: WisDOT, 2011)

Strauss vertical overhead counterweight (Menindee Bridge type)

The vertical overhead counterweight type designs position the counterweight above the road/railway, as shown in Figure 6.17. This is advantageous at sites where the road profile is located close to the high water level in the channel and the bascule pier cost must be minimised. The principle of maintaining a balance during operation is achieved by matching the centre of gravity of the leaf at A with that of hinge C, the pivot point is taken in reference to the trunnion axis B. Line C-E will remain parallel to B-D if the line D-E is parallel to B-C (WisDOT, 2011).

Vertical overhead counterweight type Strauss bascules were built across small rivers in remote areas where appearance was not a primary consideration. Operation is usually by rack and pinion with drive machinery mounted on the pier or, at sites subject to flooding, at the deck level bracketed from the approach structure (WisDOT, 2011).

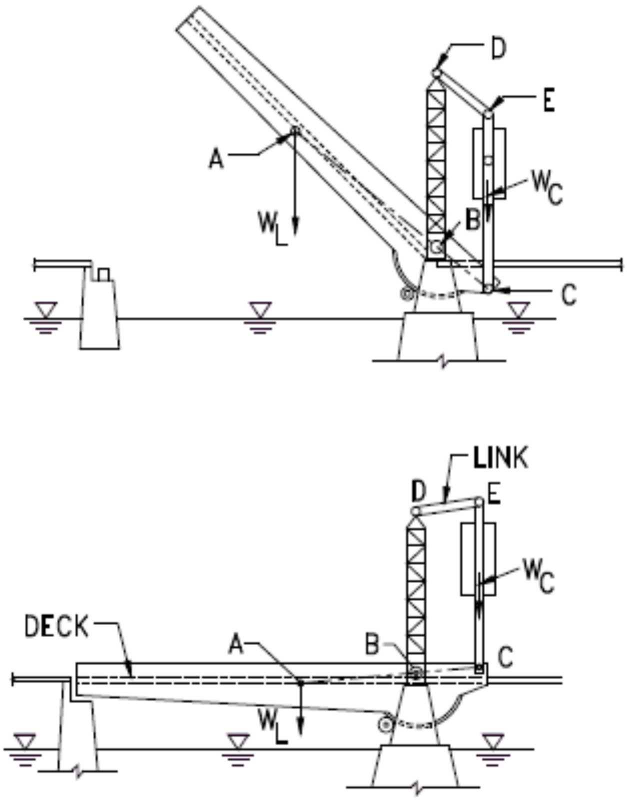


Figure 6.17 Strauss vertical overhead counterweight type (Source: WisDOT)

6.4 NSW bascule bridges

6.4.1 First generation: Drawbridges

In NSW the earliest bascule bridges were constructed in the 1890's according to designs by J. A. McDonald (Fraser, 1985). These designs consisted of an entirely timber structure encompassing a lattice tower, longitudinally orientated sheaves and counterweights hung inside the tower cavity. The span was raised at one end by a cable which passed over the sheaves and onto the counterweights. Tower stability was provided by tie rods from the top of the tower restraining it to the side spans (Figure 6.18).

Allan (1924) noted that the stiffness of the towers was not adequate to prevent excessive deflection during opening and closing however the design still met the overall operational requirements. This type of bridge was constructed at four locations, namely the Belmore and Camden Haven Rivers both built in 1891 and over Shea's Creek and Kinchela Creek built in 1892 and 1893 (Table 6-1). For the purpose of this study these are known collectively as the “Drawbridge Type” bridge.

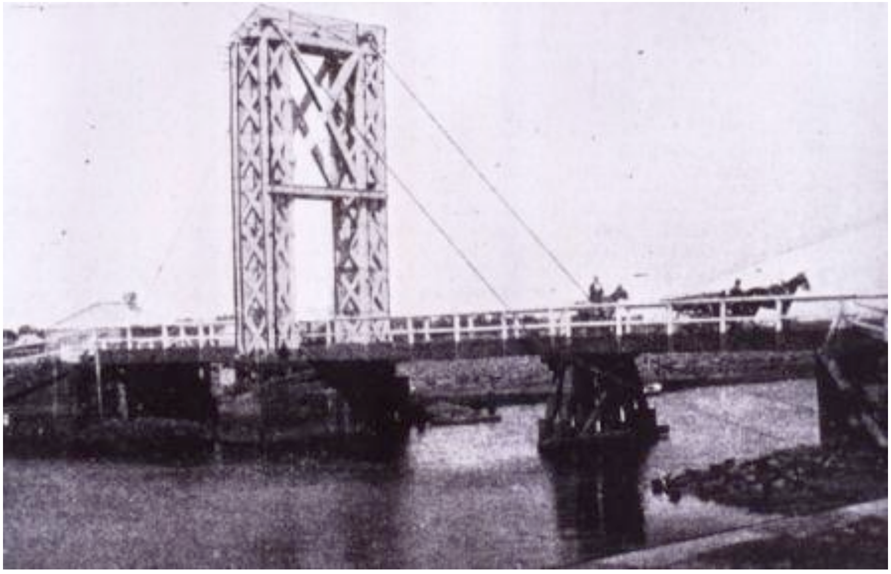


Figure 6.18 Shea's Creek Bridge (Source: Don Fraser collection, RMS archives)

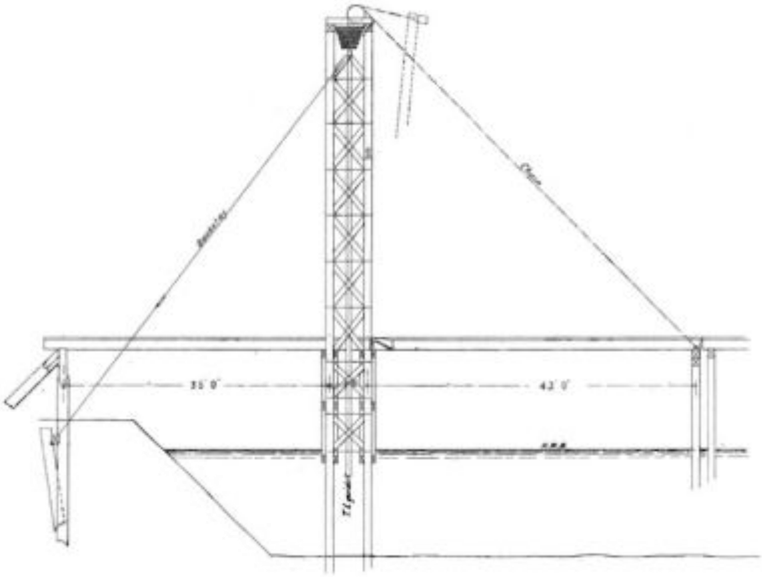


Figure 6.19 First generation bascule bridge – essentially a drawbridge (Source: Dare, 1896)

One interesting feature of these first generation designs was the method adopted for retaining a balance of the lift span during operation. J A McDonald used a set of metal disc weights of decreasing diameters to balance the opening span as it rose. The discs were picked off by matching sized lugs inside the tower and provided the correct amount of active counterweight balance against the position of the opening span. The counterweights can just be seen in Figure 6.19 at the top of the tower.

Table 6-1 Bascule type 1 - Drawbridges

DRAWBRIDGE type	Built	Status	Opening span length
Gladstone Bridge, Belmore River	1891	Replaced 1984	12.2 m
Camden Haven River Bridge	1891	Replaced 1940	12.2 m
Shea's Creek Bridge, Canal Road, St. Peters-Alexandria	1892	Replaced 1937	12.2 m
Kinchela Bridge, Kinchela Creek	1893	Replaced 1925	12.2 m

6.4.2 Second generation: Bélidor type

The early drawbridge designs were informed by British engineering technology (Fraser, 1985). However the adoption of the "Bélidor Type" bascule design is a display of the turn towards adopting American engineering technology. The Bridge over the Wilson River named Telegraph Point was designed by Harvey Dare in 1902 and he noted that the bridge was designed on a principle applied in several structures in the United States (Dare, 1904).

The inherent complexity of bascule bridges is how the mechanical advantage, centre of gravity and load continually varies during operation. As the lift span is raised the weight of the span and centre of gravity is shifted towards the pivot and consequently the lever arm is reduced requiring less force from the lifting mechanism as the lift span rises.

The solution adopted by Dare at McFarlane was the Bélidor curved balance counterweight track. Here the counterweight rolls down the track and the vertical component of force diminishes as the track levels out. The changes in force are matched to ensure that there is minimal weight differential during the entire lifting operation. This was achieved by increasing the radii (or diameter) of the curved track as the rolling counterweight approaches the base. Dare was already using the graphical method from America to set out the cardioid geometry as shown in Figure 6.20 and represents the design of one of the first bascule bridges built in NSW.

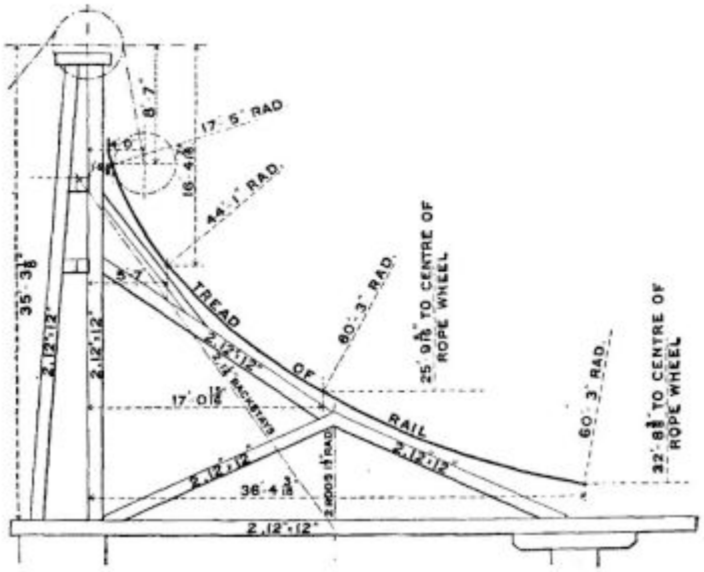


Figure 6.20 Telegraph Point Bridge Track Curve (Source: Dare, 1904)

Berry's Creek Bridge, shown in Figure 6.8, was published in an American Railroad Gazette in 1896. The description contains significant engineering details of the bridge and it is likely that the articles would have informed Harvey Dare in his designs which appears to be supported by the clear similarities between the two designs. He changed to a practical piece of curve fitting using sections of circular curves to closely match the progressively changing radii of the true cardioid in a period where metal fabricators were familiar with shaping metal components to fit circular curves.

The Telegraph Point Bridge was of timber construction with a curved track incorporated into the adjacent fixed span. The counterweight travelled along the track during operation and as noted previously this results in a varying counterweight force that retains the balance in the system (Figure 6.21). The Swansea Channel was also bridged by a similar design in 1909 which remained in service for 46 years (Figure 6.22). The two bridges form part of the "Bélidor Type" bascule bridge.

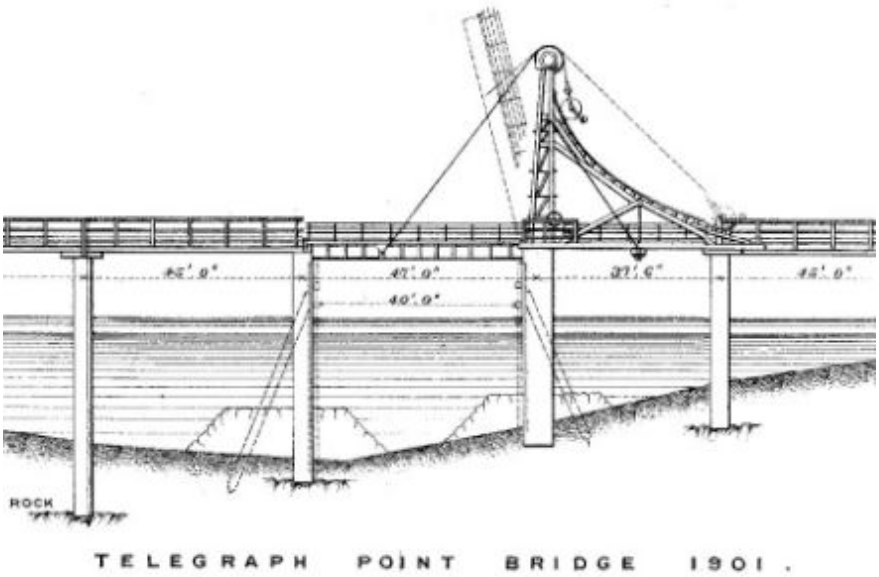


Figure 6.21 Telegraph Point Bridge drawing 1901

Figure 6.22 First Swansea Bridge replaced in 1955 (Source: Digital Hunter, Newcastle Library)

The Telegraph Point Bridge bascule span was relatively short and therefore the use of a timber tower was adequate. The later “Bélidor Type” bridges designed by Dare needed to span greater distances and hence metal was required (Dare, 1904). The Coraki Bridge was the first of this type and was completed in 1905. It was designed on the same principle however the scale was increased with the tower and adjacent truss subsequently reinforced with additional diagonals. Five other bridges of this type were completed to Dare’s designs, including the Darling Point Bridge built in 1905, the McFarlane Bridge over the South Arm of the Clarence River built in 1906, the Kyalite Bridge over the Wakool River built in 1912, the Carrathool Bridge over the Murrumbidgee River built in 1922 and the Shea’s Creek rail bridge built in

1925. These bridges collectively complete the “Bélidor Type” bascule bridge subset, with some of these bridges shown in Figure 6.23 to Figure 6.27.

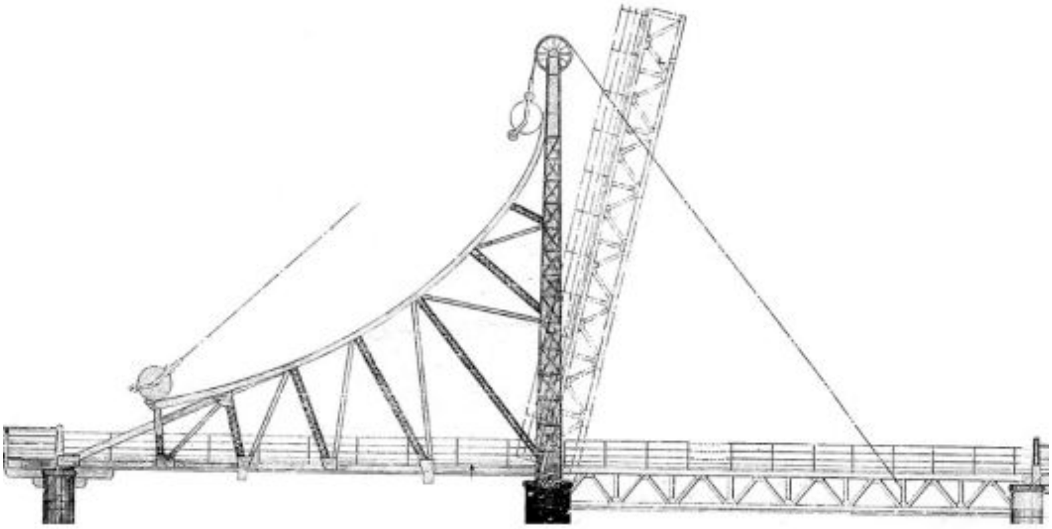


Figure 6.23 Profile view of track and lift spans of McFarlane Bridge 1906

Figure 6.24 Lift span half raised on Darlington Point Bridge over the Murrumbidgee River (undated). Note operators on landing near top of track span (Source: RMS photographic archives)

Figure 6.25 Following its replacement the Darlington Point Bridge track span was reconstructed at the entrance to Darlington Point Caravan Park (Source: Fraser, 1990)

Figure 6.26 View of Wakool River Bridge in 1967, replaced in 1981 (Source: DMR - DN 649)

Figure 6.27 Shea's Creek railway bridge, Alexandria replaced in 1985 (Source: SRA Archives)

Table 6-2 Bascule Type 2- Bélidor type

BELIDOR type	Built	Status	Opening span width
Telegraph Point Bridge over Wilson River, near Port Macquarie	1902	Replaced 1974	12.2 m
Glebe Bridge, North Arm of Richmond River at Coraki	1905	Extant	18.6 m
Darlington Point Bridge, Murrumbidgee River	1905	Replaced 1975	18.6 m
McFarlane Bridge, South Arm of Clarence River at Maclean	1906	Extant	18.6 m
Swansea Bridge, Lake Macquarie	1909	Replaced 1955	18.6 m
Kyalite Bridge, Wakool River	1912	Replaced 1981	18.6 m
Carrathool Bridge, Murrumbidgee River	1922	Extant	20.2 m
Shea's Creek Railway Bridge	1925	Replaced 1985	12.2 m

The construction period in NSW between 1905 and 1925 was relatively brief. The story did not end there though as was evidenced by the winner of a design competition for the Portsmouth Harbour Millennium Scheme in 2011. The pedestrian and Cycleway Bridge built is of the rolling span bascule type with the notable innovation that the two separate counterweights have been fused into a single roller as shown in Figure 6.28.

Figure 6.28 The 2011 Forton Lake Bridge, Portsmouth, UK (Source: A Torn Construction website)

6.4.3 Third generation: “Modern bascules”

The third generation bascule bridge designs are primarily categorised as those derived from US designs patented between the period 1896 to 1967. These are distinctive through the sophistication of their mechanical and operational systems and relatively large size.

Strauss bascules – Heel trunnion

In 1924 the first Spit Bridge over Middle Harbour was completed and the design adopted was a double-leaf Strauss heel-trunnion bascule as shown in Figure 6.29 and Figure 6.30. This design positions the trunnion at the top of the tower where the driving force rotates the counterweight and lever arm which effectively raises the span. This bridge is the first design that forms part of the “Strauss Type” subset of bascule bridges.

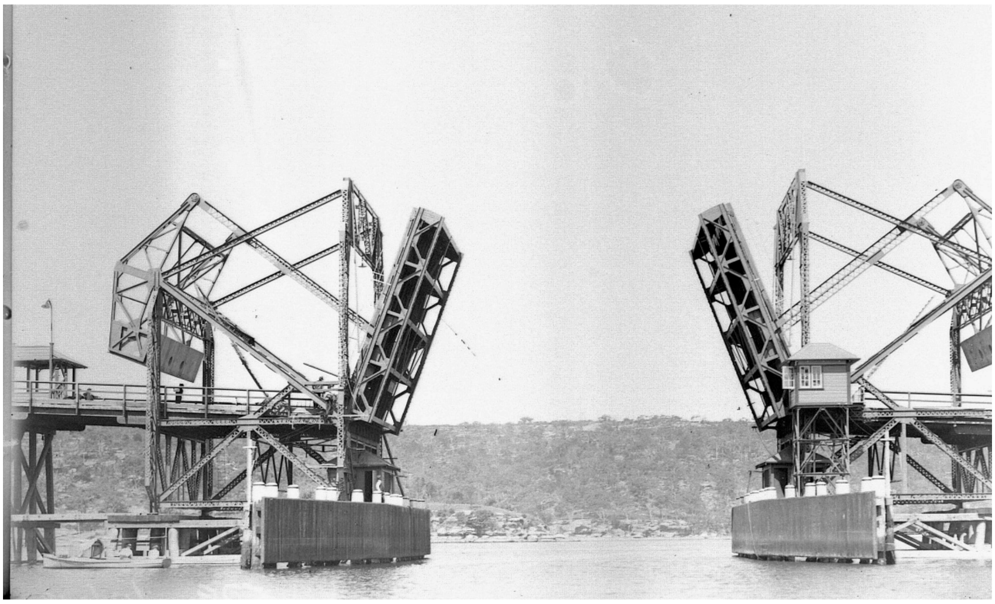


Figure 6.29 **View of the first Spit Bridge raised looking east in November, 1924 (Source: MSBSR 579, RMS photographic archives). The controller's cabin can be seen on the southern side**

Figure 6.30 **Elevation of the Spit Bridge 1924 (Source: Sydney Harbour Trust NRA Archive)**

Strauss bascules – Vertical overhead counterweight

The bridge over the Darling River at Menindee (Figure 6.31 and Figure 6.32) was the first vertical overhead counterweight Strauss Type Bridge built in New South Wales. The Bridge was completed in 1927 and the design consists of a counterweight supported laterally by a rear tower. The driving force of the bridge is provided by a rack and pinion mounted at the rear of the span. This design was also adopted for the bridge over the Wagonga Inlet at Narooma built in 1931, the bridge over the Lansdowne River at Coopernook built in 1934 and the Barneys Point Bridge built in 1936. These bridges collectively complete the "Strauss type" subset of bascule bridges.

Figure 6.31 Menindee Bridge - counterweight lowered and bascule span raised, undated. The counterweight and tower were removed in 1970 (Source: SRA Archives)

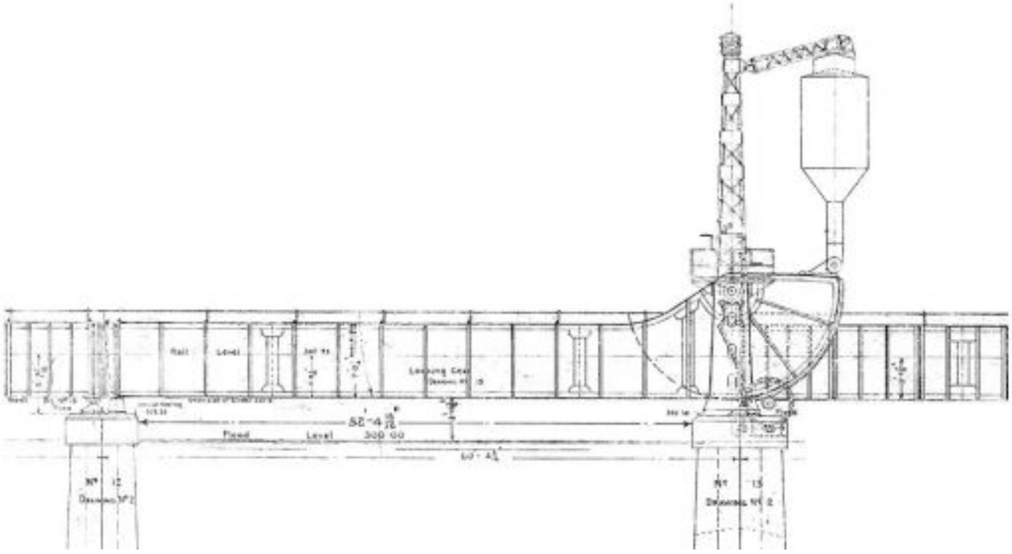


Figure 6.32 Menindee Bridge 1927

Figure 6.33 Lansdowne Bridge, replaced in 1987 (Source: RMS photographic archives)

Figure 6.34 Portal frame of the Lansdowne Bridge erected in a park in Coopernook near the former bridge site

Figure 6.35 **Barneys Point Bridge, replaced in 2000 (Source: RMS photographic archives)**

Table 6-3 Bascule Type 3 – Strauss Type

STRAUSS type	Built	Status	Opening span length
Spit Bridge over Middle Harbour	1924	Replaced 1974	18.2 m
Menindee Railway Bridge	1927	Extant	18.2 m
Narooma Bridge	1931	Extant	18.2 m
Landsdowne River Bridge at Coopernook	1934	Replaced 1987	18.2 m
Barneys Point Bridge	1936	Replaced 2000	18.2 m

The Rall Bascule

The Grafton Bridge completed in 1932 was a unique design for New South Wales. It is based on the Rall type bascule bridge (Figure 6.36 to Figure 6.37). Key features include the mechanism which rotates and traverses horizontally on a large roller during operation and the truss bascule span. The bridge has a double deck and is designed to provide passage for both road and rail traffic. This bridge forms the sole entry of the "Rall Type" bascule bridge subset.

Figure 6.36 Trial assembly of Grafton Bridge

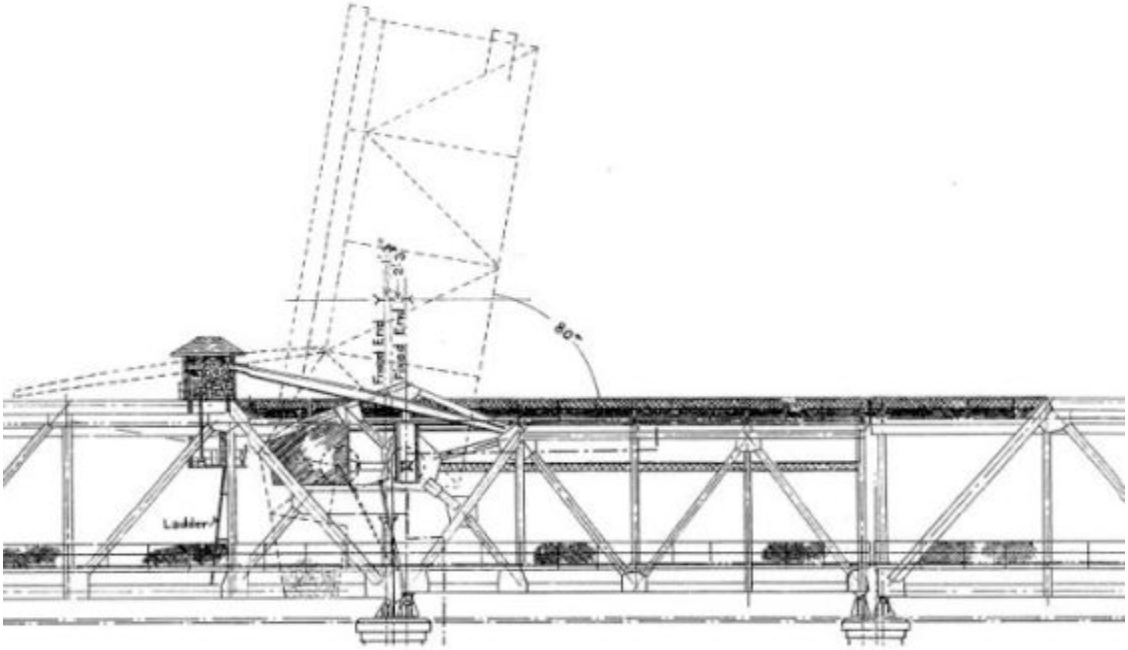


Figure 6.37 Grafton Bridge 1932

Table 6-4 Bascule Type 4 – Rolling lift bascule - Rall Type

RALL type	Built	Status	Opening span length
Grafton Bridge over the Clarence River	1932	Extant	18.2 m

Simple trunnion bascules

In 1955 the “Bélidor Type” bascule bridge over the Swansea Channel was replaced with a trunnion type design shown in Figure 6.38. This type of bridge is electro-mechanically driven, with electric motors operating a rack and pinion mounted on the rear quadrant of the span. The 1958 Spit Bridge was also designed on a similar principle. These two bridges collectively form part of the “Simple Trunnion Type” bascule bridge subset.

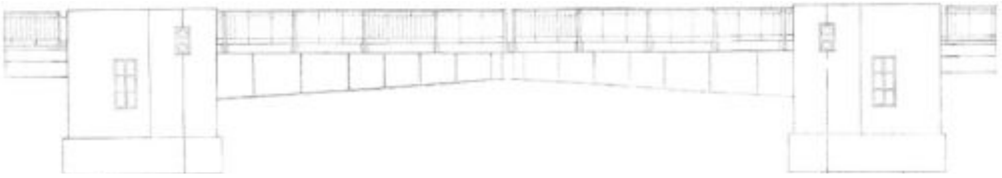


Figure 6.38 Swansea Northbound Bridge elevation 1955

In the 1950s bascule and lift spans were the two options used by the DMR to meet requirements on main roads. The bascule was preferred to the vertical lift span due to its generally superior appearance, especially if there was room for the counterweight below the deck. The vertical clearance of a bascule span is unlimited. However, unless rock was present the foundations were costly because the counterweight was two or three times as heavy as the moving span. Vertical lift spans were the preferred type where foundation conditions were not especially favourable, and this was a frequent condition on New South Wales’ coastal rivers (DMR, 1953:40).

The Swansea Bridge built in 1989 (Figure 6.39) is similar in many respects to the adjacent 1955 design however there is a progression in the operating mechanism. The driving force is provided by hydraulic luffing cylinders that are mounted near the trunnion of the spans. This type of movable bridge is considered as a hydraulically actuated trunnion bascule and the design was published in a 1967 American patent by G. Mooney and E. Driver.

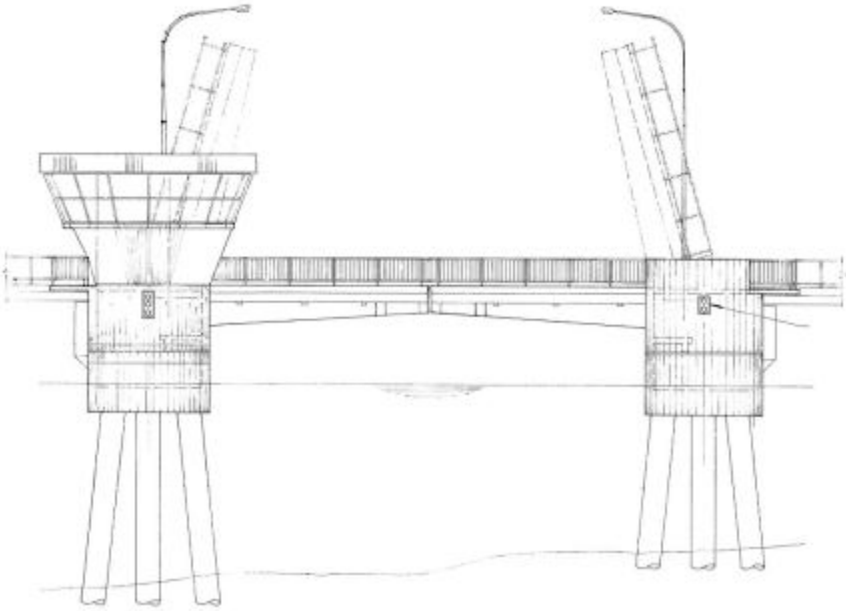


Figure 6.39 Swansea Southbound Bridge elevation 1989

The application of hydraulics to a bascule bridge was also adopted in the design of Broadwater Bridge over the Richmond River (Figure 6.40). Broadwater Bridge lift span is a reused and relocated bascule span from Barneys Point Bridge (Figure 6.41) and the decisions leading to the adoption of a hydraulic driving system by Richmond Valley Council is not clear.

The bridge consists of a steel plate web girder and the span pivots on a reinforced concrete pier that is founded on concrete piles. The pier construction and bridge relocation was completed in 2005. As gates were not fitted to the bridge to stop traffic during lifting, three operators are required to attend every opening: two to flag down traffic and a third to operate the bascule span. These two bridges collectively complete the “Simple Trunnion Type" bascule bridge subset.

Figure 6.40 General view of Broadwater Bridge

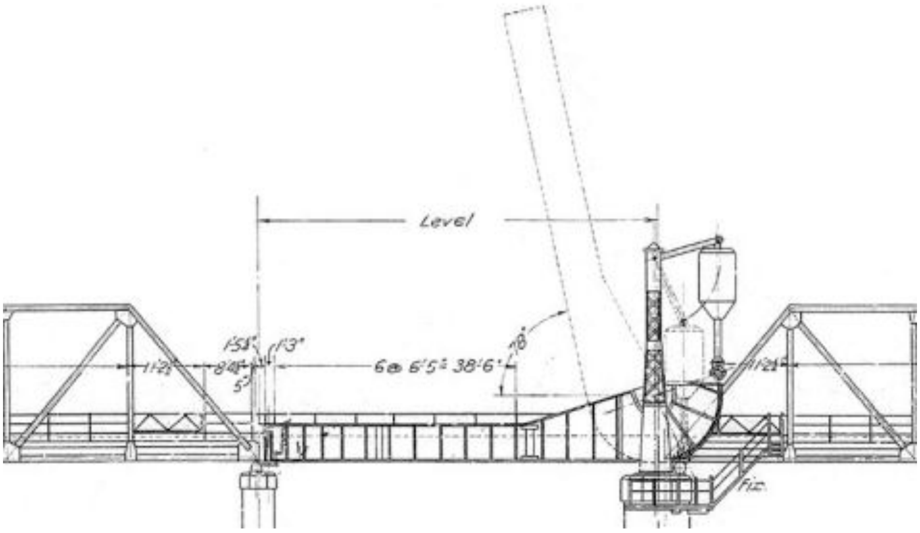


Figure 6.41 Elevation of bascule span at Barneys Point Bridge prior to relocation

Table 6-5 Bascule Type 5 - Simple Trunnion Type

SIMPLE TRUNNION type	Built	Status	Opening span length
Swansea Bridge, Lake Macquarie	1955	Extant	18.0 m
Spit Bridge over Middle Harbour	1958	Extant	24.4 m
Swansea Bridge, Lack Macquarie	1989	Extant	18.0 m
Broadwater Bridge over Richmond River	2005	Extant	18.2 m

7. Bascule bridge entries

7.1 GLEBE BRIDGE

(Bélidor Type, built 1905)

7.1.1 Description of the Bridge

The bridge over the Richmond River at Coraki named Glebe Bridge is of the bascule type which consists of a steel single leaf opening span with length 61 ft., a steel tower span with length approximately 60 ft., one compound timber beam span of 45 ft., six timber approach spans 30 ft. in length.

The upper framework of the bridge generally consists of a riveted steel lattice tower structure which is integrated into the supporting piers. The single leaf span is a steel Warren type truss arrangement which pivots about the base of the tower. Finally the superstructure is founded on iron cylinder piers at the tower, with the adjacent support piers either side being concrete Monier cylinders.

Figure 7.1 General view of Glebe Bridge

Development of roads and transportation in the Coraki region

The history of the Coraki region is closely tied with the exploration of the Richmond River during the early 1840s. The exploration of the area was for the purpose of "cutting the finest specimens of cedar" and it was conducted under the employment of a Mr Small who was the owner of a timber yard down south (SMH, 1842). This was the commencement of the cedar industry in the area. From this time onwards the number of cedar camps continued to grow. However, these camps were nomadic in nature and followed the cedar resources.

The first known permanent European settler to the area was William Yabsley who obtained a lease for Brook Station in 1849. This settlement was the beginning of the Coraki town and the entrepreneurship of Yabsley's was the continual driver of the growth. Over the year Yabsley was responsible for building a shipyard, general store and conducting a school. As settlements continued to increase a street plan was drawn up for Coraki in 1866 and by the late 1880s the town was booming with its own police station, post office and hotels. However following this period the river trade declined and Coraki gradually became a quiet town off the Richmond River (SMH, 2004).

The Richmond River crossing at Coraki was previously provided by a ferry service, until the community began to request that a bridge be built to reduce the travel distance from Grafton to Ballina (*Clarence and Richmond Examiner*, 1866). The fight for the bridge was said to undertaken by local member Mr R. Pyers. It is noteworthy that in the past the bridge was often cited by locals as the Pyers Bridge as recognition to Mr Pyers for his contribution in securing the bridge for the community.

Design and construction

The design of the Glebe Bridge was completed by Henry Harvey Dare and was based on similar bridges constructed in America. This bridge represents the initiation of the steel "Bélidor Type" bridges which were built in NSW. Finally tenders for the construction of the bridge were called for on the 27th of July 1903 and the bridge was completed in early May of 1905.

The Commissioner for Roads undertook a final inspection on the bridge in order to take possession from the contractor and it was noted that an official opening would take place in about three weeks (*Richmond River Herald and Northern Districts Advertiser*, 5th May 1905). However there is no evidence of an opening occurring and furthermore, there are reports in the local paper that the community was generally dissatisfied with the bridge due to poor approach roads and the low headway provided for shipping when closed (*Richmond River Herald and Northern Districts Advertiser*, 25th May 1905). Although the bridge was a technical success, reports have noted that the bridge was only ever fully opened on one occasion and was therefore not utilised to its full capability (Curby, 2006).

The name Coraki was originally adopted for Glebe Bridge, however due to a second bridge being constructed in the early 1990s necessitated the need for a new name to distinguish between the bridges. As noted in the 1905 Public Works Annual Report, this bridge represents the “second bridge completed in the State with an opening span on the bascule principle having a rolling counterweight. Glebe Bridge was also an improvement of the Telegraph Point Bridge, noted as the first built, as the tower superstructure was built with steel opposed to ironbark timber.

It is also noteworthy that compression loads in the tower verticals are higher than at McFarlane Bridge because of the heavier original counterweights and cable force.

Operational History

At the time the Glebe Bridge was built, Coraki was still an important river port with ocean-going vessels docking regularly. Here goods to be taken up the South Arm to Casino were trans-shipped into small shallow draught river “droghers”. Twisting, turning and unpredictable, the South Arm was a constant navigational nightmare and, but for regular dredging and snagging operations, would never have remained open. Although there is evidence that in the late 19th century ocean steamers continued to operate, the South Arm is reported to have very little river traffic.

Only one instance is recorded of an ocean-going vessel travelling up the South Arm. In 1910 the *Friendship* was tasked with delivery of a load of boilers to the Casino Butter Factory and its masts required the full opening of the bascule span for the first and only time (Curby, 2006).

In 1931 it was noted that the water traffic on this branch of the Richmond River at Coraki is very small and under ordinary circumstances there is no traffic necessitating the opening of the lift span. In flood time, however, it is found that the motor boat which carries the cream supplies to Lismore cannot get under the bridge, requiring opening. While this vessel was operating it was necessary to maintain the opening span of the bridge to allow the vessel to operate during rises of the river. This vessel ceased operation in early 1974.

The last recorded opening for the passage of a vessel was 23rd September 1959, subsequent lifts were for maintenance purposes only - last of these was on 8th December 1969.

The bridge was permanently closed on March 1979 following agreement from the Maritime Services Board. Vertical clearance above Mean High Water was maintained at 6.2 m.

A file note from 1978 records:

"it is considered that no action should be taken to remove any parts of the operating mechanism. As the bridge could be required to be opened in unforeseen circumstances at short notice, it is felt that the lifting mechanism should remain in a condition that it can be opened without the delay that would be occasioned by reassembly of stored parts particularly so if the opening should be needed in flood time" (*RMS* File 389.61 part 3).

Figure 7.2 Glebe Bridge with lift span half raised (Source: Town and Country Journal 27/11/1912)

Maintenance History

In February 1927 flooding led to increased demands on the lifting of the bridge which became jammed shut for several days. As a consequence there was a great loss to the dairy farmers through the boats not being able to collect the cream for the factory in Lismore.

In February 1929 after raising the lift span the bridge caretaker "found it necessary to chop away some of the decking in order to get the lift span down on to the seating" (*RMS* File 389.61 part 1). A subsequent inspection identified that the whole of the structure on the Coraki side of the river had moved out into the stream about 4 inches causing the track span to lean forward with the result that the lift span could not open and close effectively.

Steps taken to remedy the jamming of the lift span included:

1. Tying back with cables of the abutment on the Casino side to two short lengths of bed log buried in the road approach.
2. The attachment by cables of the superstructure of the bridge to two driven piles set on either side of the roadway 25 ft. back from the abutment, the cables including turn-buckles in their length. The turn buckles enabled the bridge to be pulled back 1 inch and it was decided to leave the cables permanently in position, thereby enabling any further adjustment to be made should this be required in the future (attached photo shows these cables in place on bridge in 1952).

Figure 7.3 Image of Glebe Bridge with tie-back cables (Source: RMS bridge file)

In June 1932 the bridge caretaker Mr J. Phali reported to Divisional Engineer that "while no difficulty was experienced in opening the span, great difficulty was experienced in closing it, and it would appear that some of the counter weights required adjustment or removal" Further investigation revealed that "the trouble with lift span is only in the balance weights and moving parts being a little bit stiff on account of infrequent use".

In October 1933 the Divisional Bridge Engineer reported that:

"the rolling weights on the bascule span did not roll and considerable difficulty was met in getting them to roll instead of slide during recent repairs. Also the hinges at the attachment of the ropes to the lift span were tight".

It was noted that each counterweight consists of nine cast iron sections bolted together and keyed to a spindle. The spindle is intended to rotate in the cradle by which the counterweight is attached to the ropes. If an oil hole were provided in each cradle boss, the lubrication of the spindles would be facilitated.

The corrective action was to bore a 1/8 inch oil hole in the top of the boss of each bearing of the counterweights (4 holes in all) and through to the centre of the pin and another hole to meet it bored longitudinally through the pin. The pin is then to be slightly rotated and the hole pressure-filled with grease. These repairs seemed to have had the desired result as no further difficulties are reported in the maintenance files.

In 1966 following complaints from local residents repairs were undertaken to the cover plate over the bascule pivot were undertaken to remove excessive noise caused by traffic driving over it. In 1970 the Post Master General's Department attached telephone conductor cables to the bridge.

In 2006 Ospreys commenced nesting on the track span tower of Glebe Bridge and the nearby Harwood Bridge. As Ospreys are listed as "vulnerable" on the *NSW Threatened Species Conservation Act* the bridge operators adopted a "do not disturb" policy, leaving the birds in peace during their breeding season. A steel nesting basket was subsequently attached to the eastern (downstream) side of the bridge at the top of the northern tower, since Ospreys have a tendency to search for the highest possible location in the area to nest. An Osprey pair continue to use the basket each year and it ensures minimal disruption of the bird nests as well as ongoing protection of the road and pedestrians using the walkway on the upstream side of the bridge.

7.1.2 Statement of significance

Historically, the Bridge is significant due to its early date of construction for the 'new' American adaptation of movable span bridges in the state. This 1905 bascule-type bridge in its completeness and sound condition demonstrates the influence of American bridge design across NSW and Australia.

The "Bélidor Type" design of a bascule bridge is a significant example of the creative and technical force behind early bridge engineers and designers in NSW and Australia. This Bridge is understood to be the one of the oldest surviving bascule type bridges in NSW (Fraser 1985) and one of five ever built.

The Bridge is also representative of one of the first steel rolling weight bascule bridges in NSW (Dare 1903).

Source: RMS s170 Register

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Not listed
OEH Heritage Division State Heritage Register	Not listed
Richmond Valley Local Environmental Plan, 2011	Listed
NSW National Trust Register	Listed
RTA s.170 Heritage and Conservation Register	Listed

Evolution of modifications

Glebe Bridge was a further evolution on the proceeding Telegraph Point Bridge, which was the first to adopt the Bélidor bascule design. Although the concept was identical, the design represents a significant evolution through the implementation of a steel riveted lattice superstructure and bascule to achieve a greater lift span length.

Table 7-1 Glebe Bridge – Summary of modifications

Preceding Designs	Issues with Design	Evolution of Glebe
Timber construct	Limitations on the span length that could be achieved	Steel superstructure, with additional bracing
Smaller size of structure		Increased tower height and adjacent track span
Web plate girder lift span	Limitations on span length that could be achieved	Increased length of bascule span

7.1.3 Description of lift span mechanism components

Movable span and track span

The form and fabric of the movable span and track span components are EXCEPTIONAL significance.

The superstructure arrangement consists of two towers which in essence are braced into the fixed adjacent span. The towers are made up of a steel riveted lattice construct that are also braced in the transverse direction with steel rods with some portal frame action at the base. As made evident by Figure 7.5, the truss span is integrated into the tower thus providing longitudinal bracing and subsequently the lateral strength required to resist the span operation loadings.

The fixed span adjacent to the tower also incorporates the curved track for the rolling counter weights to travel along during a span lift. This curve is the defining feature of this type of bascule bridge and has often been described as a good approximation of the cardioid arc. The curve is instrumental in the operation of the lift span and is discussed further with the lifting mechanism. The base of the tower is supported by Iron Cylinder piers with the piers either side of the tower being of the concrete Monier type.

The lift span of the Glebe Bridge consists of steel Warren type truss arrangement. The primary longitudinal members support steel truss cross girders which support timber stringers and finally the timber deck. The entire span pivots about the base of the tower during operation. The pivoting is enabled by a cast iron steel hinge connection at the tower end of the single leave lift span.

Figure 7.4 Top of tower span of Glebe Bridge with Osprey nesting basket shown at right

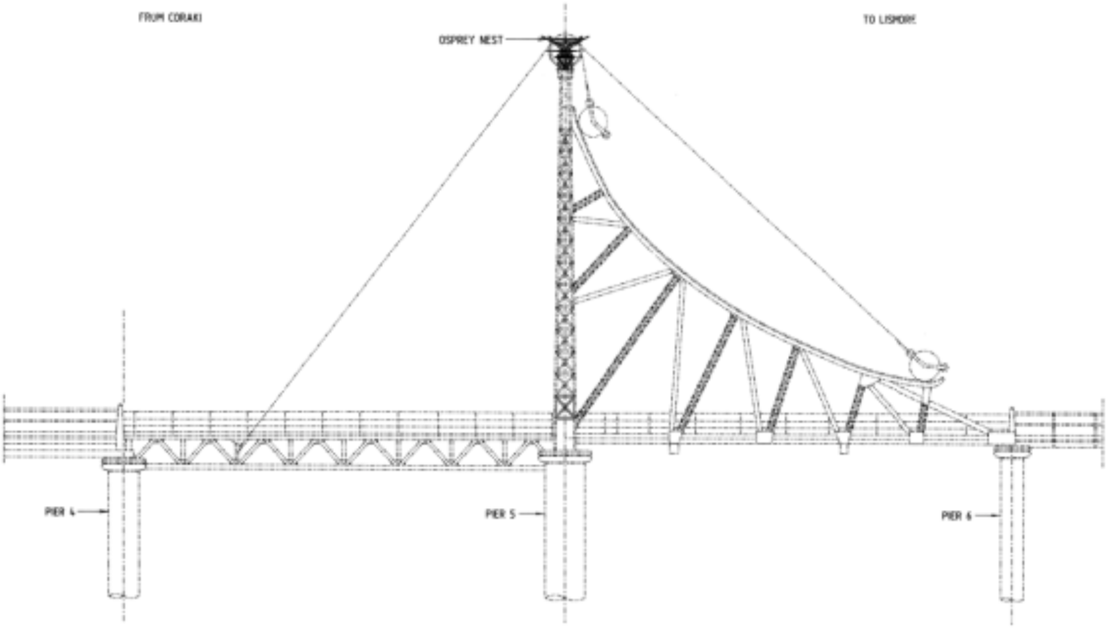


Figure 7.5 Elevation of bridge (Source: RMS)

Rope wheel

The form and fabric of the rope wheel component is EXCEPTIONAL significance.

The rope wheels consist of a spoke arrangement of wrought iron rods keyed into a cast iron rim (Figure 7.6).

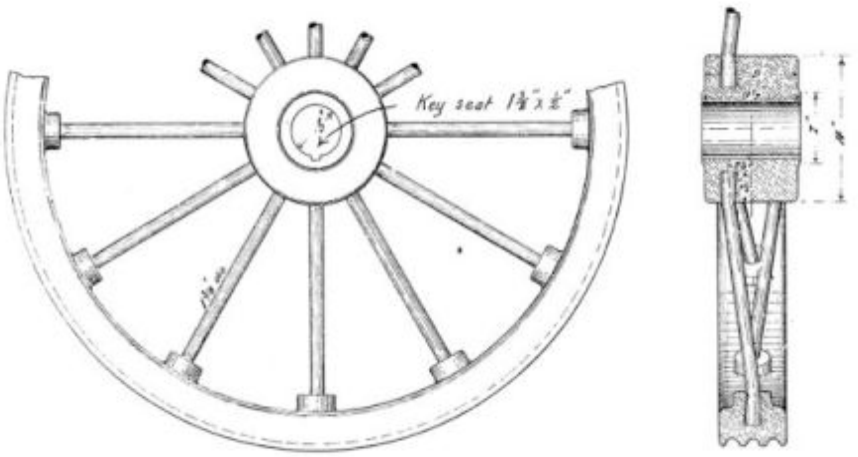


Figure 7.6 Drawing of Glebe Bridge rope wheel

Ropes

The form and fabric of the rope components are MODERATE significance.

The wire rope arrangement remains unchanged.

Operator work station

The form and fabric of the operator work station component is HIGH significance.

The bridge was originally built with a platform and shelter adjacent to the winch wheel (Figure 7.7). Since the bridge has been locked the winch wheel and shelter have been removed from the structure, however the platform remains.

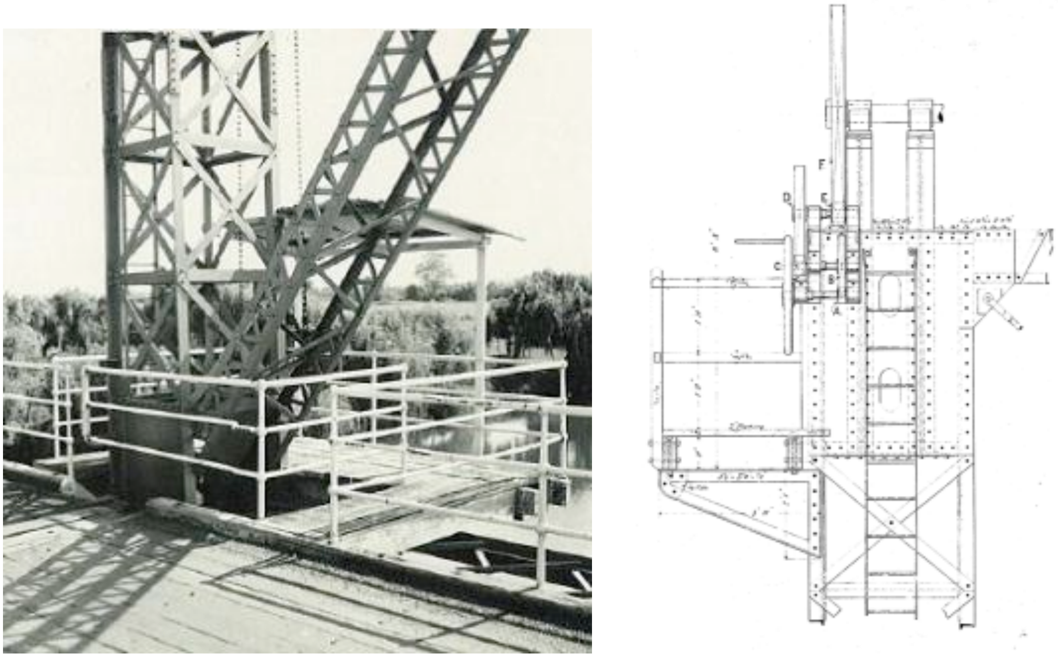


Figure 7.7 View of operating platform in 1966 and plan of winch mechanism

Counterweights

The form and fabric of the counterweight and rope component are of EXCEPTIONAL significance.

The balance weights that are implemented on Glebe Bridge consists of a cylinder made up of nine cast iron sections bolted together and keyed to a spindle (Figure 7.8). The spindle is intended to rotate in the cradle by which the counterweight is attached to the ropes. The balance weight cradle also has an allowance for changes in span dead weight with points for four smaller weights to be hung on the system.

The cylindrical shape of the balance weight allows it to travel smoothly down the curved track, which is fitted with a small rail to prevent the balance weight coming off the curve during operation. The wire ropes are connected to the balance weight by means of the end being spliced round a cast iron thimble at the balance weight cradle.

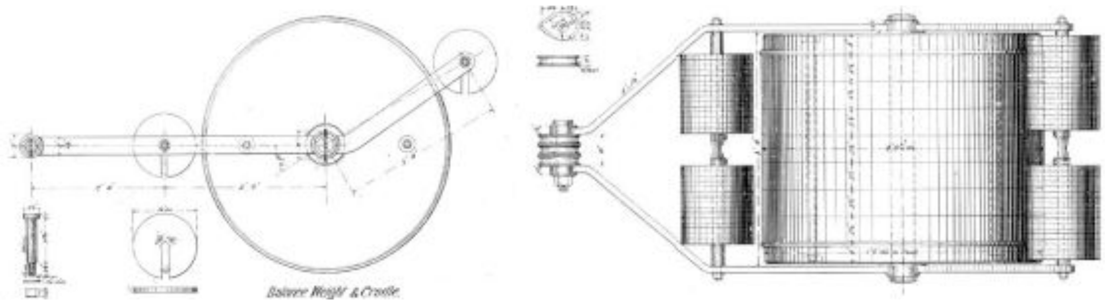


Figure 7.8 Glebe Bridge counterweights

Mechanical components

The form and fabric of the mechanical components are of EXCEPTIONAL significance.

The mechanical components consist of the winch handle, fly wheel, gearing and shafts (Figure 7.7). The driving force of the mechanism is provided by a fly wheel and gearing located at the top of the tower. The rotation is transferred through a number of gears before gaining sufficient mechanical advantage to rotate the longitudinally oriented sheaves. The rotating sheaves act to lower the balance weight and raise the span. The three wire ropes in the mechanism simply pass from the lift span over the sheaves and onto the balance weight. Small locking gears are utilised to secure to the movable span in the closed position.

Vehicle and pedestrian barriers

NO significance.

Gates were formerly mounted on the bridge approaches, these have been removed.

Motors and electrical

NO significance.

Motors and electrical components were never installed on Glebe Bridge. It remained manually operated throughout its serviceable life.

Actions required in order to restore the bridge to lifting operation:

- Replace wire ropes.
- Overhaul mechanism.
- Re-deck movable span.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-2 Glebe Bridge – Summary of heritage significance

Bridge Component	Significance Grading
Movable span and track span	EXCEPTIONAL
Rope Wheel	EXCEPTIONAL
Ropes	MODERATE
Operator work station	HIGH
Counterweights	EXCEPTIONAL

Bridge Component	Significance Grading
Mechanical components	EXCEPTIONAL
Vehicle and pedestrian barriers	NO
Motors and electrical	NO

7.2 McFARLANE BRIDGE

(Bélidor Type, built 1906)

7.2.1 Description of the Bridge

The bridge over the Clarence River South Arm named McFarlane is a bascule type bridge which consists of a steel single leaf opening span with length 67 ft., a steel tower span with length 68 ft., one compound timber beam span of 46 ft., twelve timber approach spans 45 ft. in length and another two 30 ft. approach spans.

The upper framework of the bridge generally consists of a riveted steel lattice tower structure which is integrated into the pier 10-11 span. The single leaf span is a steel Warren type truss arrangement which pivots about the base of the tower. Finally the superstructure is founded on iron cylinder piers at the tower, with the adjacent support piers either side being concrete Monier cylinders.

Figure 7.9 General view of McFarlane Bridge

Development of roads and transportation in the Maclean region

The history of the Maclean region adjacent to the bridge is linked in with the history of the Clarence River Valley. The region was discovered by the escaped convict Richard Craig in the early 1800s. Soon after Craig arrived in Sydney, information regarding cedar deposits in the region was conveyed to timber yard owner Thomas Small and this led to the first expedition to the area. This was the beginning of the cedar trade that would boom until the 1840s when the resource became scarce. The land was also utilised as pastoral grounds and as settlements continued to increase this eventually led to the creation of a township (Maclean Shire, 2006).

Figure 7.10 The newly completed McFarlane Bridge (Source: PWD Annual Report: 1906)

The Bridge replaced an earlier ferry which had operated for many years across the South Arm. In 1901 the Maclean and District Progress Association resolved to lodge a request through Mr McFarlane to the Works Department due to increased traffic over the South Arm. This was partly the result of the operation of Woodford Quarry which necessitated an improved crossing (*CRA* 5/4/1906).

Design and construction

Government funding was secured for the Bridge as early as 1902. McFarlane, in a letter later published in the *Clarence River Advocate (CRA)*, announced that he had:

Much pleasure in stating that a sum for the construction of a bridge over the South Arm has passed parliament. £4000 has been voted. This will be a sufficient sum for the year ending June 30 (CRA 16/12/1902).

The *Advocate* then reminded readers that:

It [was] only a short time since the claims of the district to this bridge were put before the people by the ADVOCATE, and the first formal request for its erection made by the Maclean and District Progress Association. It is pleasing to find that the efforts of those working locally for this bridge have been so successfully backed up in Sydney by Mr McFarlane (CRA 16/12/1902).

The NSW *Government Gazette* first advertised for tenders for the "construction of Bascule Bridge over the South Arm of the Clarence River, Maclean" on the 17th of April 1903 and the 3rd of July 1903. In September 1903 the tender of Mountney and Company, for £11,732 was accepted. There had apparently been some delay in getting to this stage, and a public meeting was held to urge the Government to take action. The official Government estimate for the work was £15,000 (CRA 5/4/1906).

In common with the Glebe Bridge at Coraki, the McFarlane Bridge is a bascule-type moveable span bridge. It was completed shortly after the Glebe Bridge and both were constructed by Mountney and Co.

A 1904 article in the *Richmond River Herald* records a visit to Coraki by a Mr Marsland "manager for Messrs Mountney and Co." who:

Said that the reason for beginning work at Coraki first was because the ironwork for that bridge, which was made by the Government was ready, while his firm had not had the time since the acceptance of their tender to complete the ironwork for Maclean Bridge. The sinking of the cylinders is to be proceeded with at Coraki first, and when they are brought above water level the plant will be transferred to Maclean. The approaches of the Maclean Bridge are being commenced at once, and for these 2000 cubic yards of earthwork will be required on the Maclean side, and about 4000 yards on Woodford Island. Mr Marsland assured the Maclean people that their bridge would be finished on time (RRH and NDA 13/5/1904).

Earth was taken from River Street, Maclean where Mountney and Co. received permission to "cut down [the street] to a depth of 5 feet on the hill between the Presbyterian Manse and the old school site" (McFarlane 1980).

Some delays were encountered during the construction of the Bridge when it was found that the iron piles could not be sunk by means of water jet as had been outlined in the contract specifications, but rather had to be put down to the rock by means of excavations made in airlock casings (*CRA* 3/4/1906).

A number of men who had completed their work on the Glebe Bridge arrived by steamer from Coraki to commence working on the McFarlane Bridge in March of 1905 (McSwan 1992:316).

The *Annual Report of the Department of Public Works* for the year ended 30/6/1905 mentions the McFarlane Bridge as one of "several important bridges [then] in progress". It was given the following description:

This bridge will consist of a steel bascule span upon cylinder piers, similar to that in the Coraki Bridge, together with thirteen timber approach spans. A roadway 20 feet wide and two footways of 5 feet each have been provided for the new structure (DPW 30/6/1905).

The Bridge was officially opened on Monday the 9th of April 1906. The opening, according to an announcement in the Clarence River Advocate was "to be celebrated by a basket picnic and other attractions on the Showground". In addition, children's sports were to be held, a procession formed and entertainment would be found at the pavilion at the conclusion of the addresses. The announcement urged that:

The Public are requested, by their attendance, to make this function the success that it deserves to be, and the day a “red-letter” day in the history of the Clarence district (CRA 6/4/1906).

To ensure that all could attend the event, public schools within a 10-mile radius of Maclean were to close on the day and businesses within the town decided to close at 1pm. A long account of the opening appeared in the same paper on the 10th of April. Some 1000 people are thought to have taken part in the festivities and there was much toasting of Mr McFarlane who “had been largely instrumental in obtaining [the Bridge] for [the people of Maclean]” (CRA 10/4/1906). McFarlane himself noted on the day that “he may be liable to the imputation of being a “roads and bridges member” but, he said that:

this was said by city people. If some of those made themselves better acquainted with the requirements of the country districts, they would see the necessity of roads and bridges to develop the country (CRA 10/4/1906).

Since the bridge was completed Maclean has become an important North Coast residential settlement area, a bastion of Scottish cultural heritage and a growing tourist destination with links to the popular coastal settlements of Iluka, Yamba and Angourie. The bridge is held in very high esteem by the community who turned out in their hundreds to take part in the centenary celebrations of the bridge opening in April 2006 (see below). As part of the celebrations a plaque was erected at the bridge site by the Engineers Australia Heritage Committee to display its importance as a Historic Engineering Landmark.

Figure 7.11 Members of the McFarlane Clan marching across bridge during Centenary celebrations in 2006 (Source: RMS photographic archives)

Operational history

One of the principal areas of sugar growing was Woodford Island opposite Maclean and in easy reach of the Harwood Mill. The frequency of water traffic, particularly at harvest times with many high-funnelled steam tugs, meant that when a bridge, the future McFarlane Bridge between Maclean arid Woodford Island, was being considered, it had to include an opening span, even though some tugs had hinged funnels for laying back in the horizontal position. Such innovations and the changeover to low profile diesel tugs eventually led to the redundancy of the opening span. The number of lifts undertaken was not recorded though it is thought to be less than Glebe Bridge. The lift span was locked in position in 1962 by extending the timber decking over the joints in the movable span (McSwan 1992).

Maintenance history

No records are available of the lift span operation so it is unclear whether it was subject to the same jamming experienced at Glebe Bridge. A Load Capacity Assessment Report prepared by RTA in 2010 determined that the approach spans of McFarlane Bridge were under strength for current traffic loads and that upgrading was required.

Since 2012 all corroded cross girders have been removed and timber stringers which support the timber decks laterally have been replaced with steel stringers fabricated to the same dimension. In 2013 a bitumen seal was placed on the timber decking to improve durability and safety for motorists.

7.2.2 Statement of significance

The bridge reflects the primacy of river navigation in the transport history of the region. It is important in enhancing north-south road communications in the Clarence area and more generally. Its presence is testimony to the efforts of long serving Clarence MP, John McFarlane, who is commemorated in the naming of the bridge.

The construction of the Bridge was important in the development of the town of Maclean. Massive quantities of clean fill needed for the Bridge approaches came from within the town, creating the decreased level of River Street between Church and Cameron Street.

It is one of three remaining bridges from the original eight which used an unusual type of bascule. It is a valuable part of Australia’s engineering heritage because of its design and its association with the work of Harvey Dare who had a long and distinguished career in the NSW Public Works Department (*North Coast REP Draft Amendment* No.3: 55).

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Not listed
OEH Heritage Division State Heritage Register	Not listed
Clarence Valley Council Local Environmental Plan, 2011	Listed
NSW National Trust Register	Listed
RTA s.170 Heritage and Conservation Register	Listed

Summary of modifications

McFarlane Bridge was essentially an adoption of the Coraki Bridge design, with no significant variances evident. The original drawings of Coraki Bridge note the other four Bélidor bascule designs built in NSW (Darlington Point, Maclean, Wakool and Carrathool), suggesting that the designs were all undertaken within a close period of time and only minor modifications to match local site conditions were implemented.

7.2.3 Description of lift span mechanism components

Movable span and track span

The form and fabric of the movable span and track span components are EXCEPTIONAL significance.

The design of the McFarlane Bridge was completed by Henry Harvey Dare and was based on similar bridges constructed in America. This bridge represents the second “Bélidor Type” bridge built in NSW. It is noteworthy that the plans for the McFarlane Bridge were completed before those of Coraki Bridge, however due to circumstances surrounding the status of the ironwork not being ready, Coraki Bridge was built first (Richmond River Herald 13/05/1904).

The superstructure arrangement consists of two towers which in essence are braced into the fixed adjacent span. The towers are made up of a steel riveted lattice construct that are also braced in the transverse direction with steel rods with some portal frame action at the base. As made evident by Figure 7.12, the truss span is integrated into the tower thus providing longitudinal bracing and subsequently the lateral strength required to resist the span operation loadings.

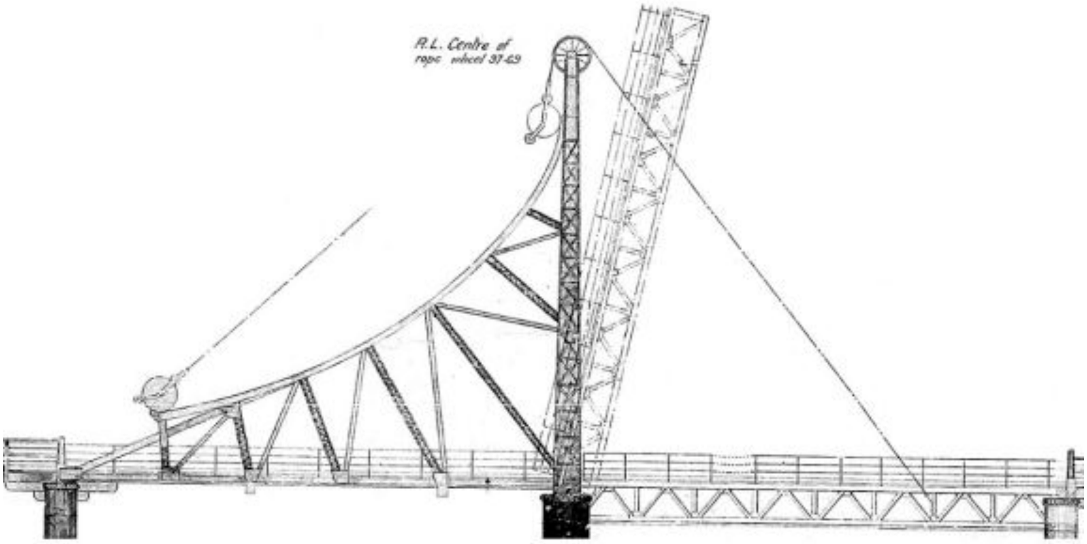


Figure 7.12 Elevation of McFarlane Bridge

The fixed span adjacent to the tower also incorporates the curved track for the rolling counter weights to travel along during a span lift (Figure 7.13). This curve is the defining feature of this type of bascule bridge and has often been described as a good approximation of the cardioidal arc. The curve is instrumental in the operation of the lift span and is discussed further with the lifting mechanism.

The base of the tower is supported by Iron Cylinder piers with the piers either side of the tower being of the concrete Monier type.

Figure 7.13 View of McFarlane Bridge along deck

The lift span of the McFarlane Bridge consists of steel Warren type truss arrangement. The primary longitudinal members support steel truss cross girders which support timber stringers and finally the timber deck. The entire span pivots about the base of the tower during operation.

Figure 7.14 McFarlane Bridge lift span

The pivoting is enabled by a cast iron steel hinge connection at the tower end of the single leave lift span. As evident by Figure 7.15 the hinge is riveted into the back of the span.

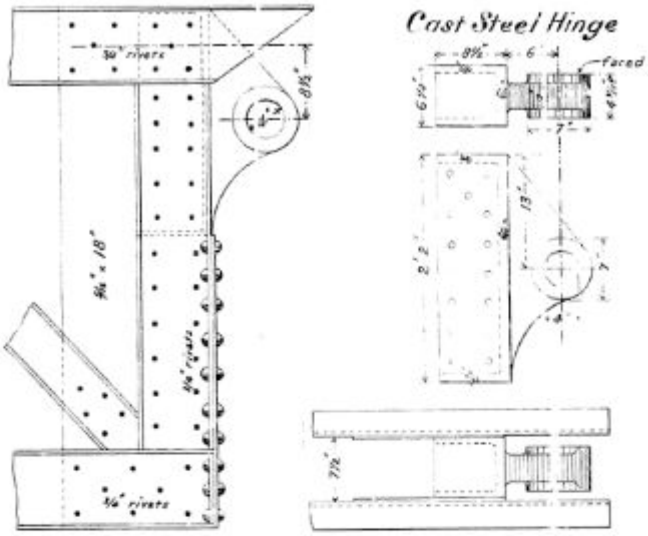


Figure 7.15 Pivot connection for McFarlane Bridge

The wire ropes are connected to the lift span by way of an attachment component as shown in Figure 7.16. This rope attachment transfers the load from the three wire ropes into another bracket mounted on the span.

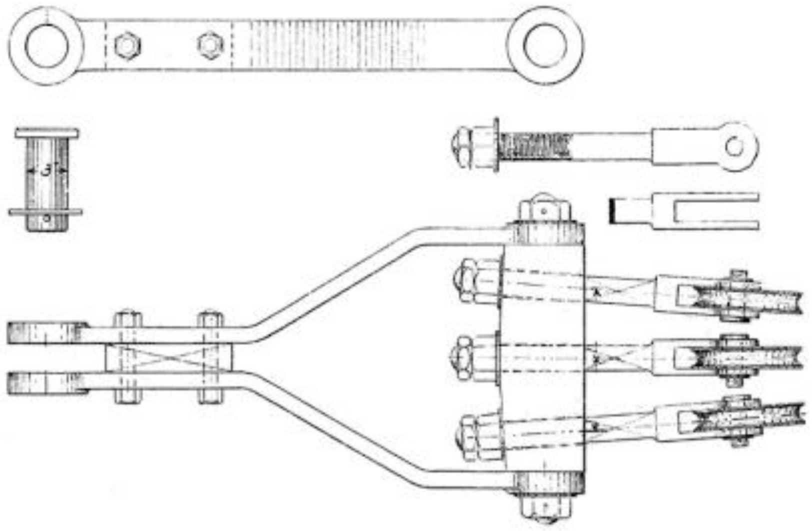


Figure 7.16 McFarlane Bridge wire rope to lift span attachment

Rope wheel

The form and fabric of the rope wheel component is of EXCEPTIONAL significance.

The sheaves are 5 ft. in diameter and are made up of cast iron spoke wheel arrangement (Figure 7.17).

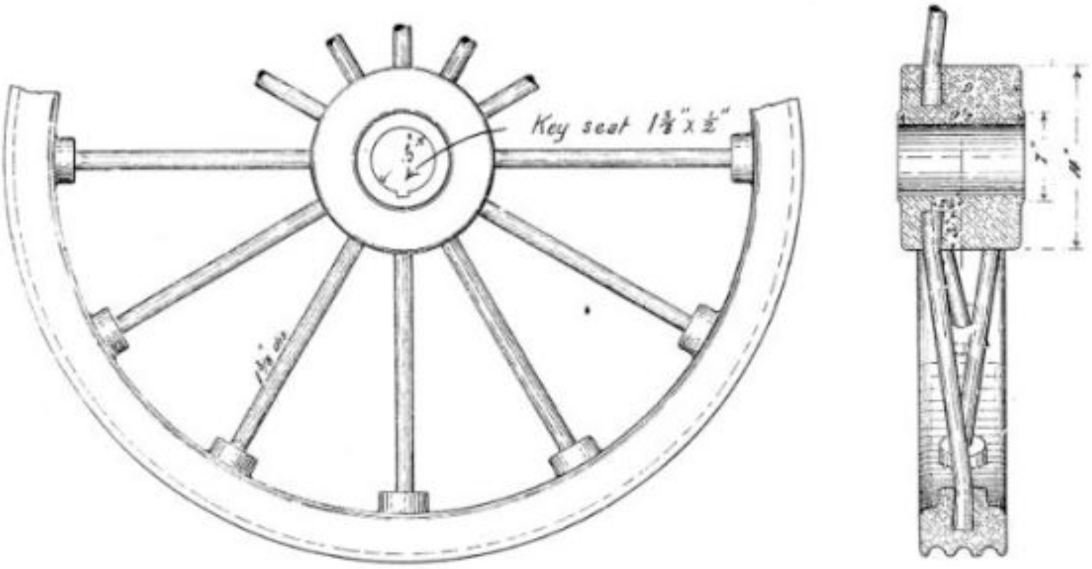


Figure 7.17 Rope Wheel Design for McFarlane Bridge

Ropes

The form and fabric of the rope components is of LOW significance.

The wire ropes consisted of wire strands wound around a hemp core.

Operator work station

The form and fabric of the operator work station component is HIGH significance.

Originally the operator station was mounted at the top of the curved track. Modifications made in 1916 added a mid-level and bottom level workstation to the bridge. The driving mechanism was altered to suit.

Counterweights

The form and fabric of the counterweight and rope component are EXCEPTIONAL significance.

The balance weights that are implemented on McFarlane Bridge consisted of a cast iron cylinder with a diameter of 4’ 6¾” and width of approximately 5’ 9”. The balance weight cradle also has an allowance for changes in span dead weight with points for four smaller weights to be hung on the system.

The cylindrical shape of the balance weight allows it to travel smoothly down the curved track, which is fitted with a small rail to prevent the balance weight coming off the curve during operation. The wire ropes are connected to the balance weight by means of the end being spliced round a cast iron thimble at the balance weight cradle. The balance weight arrangement is shown in Figure 7.18.

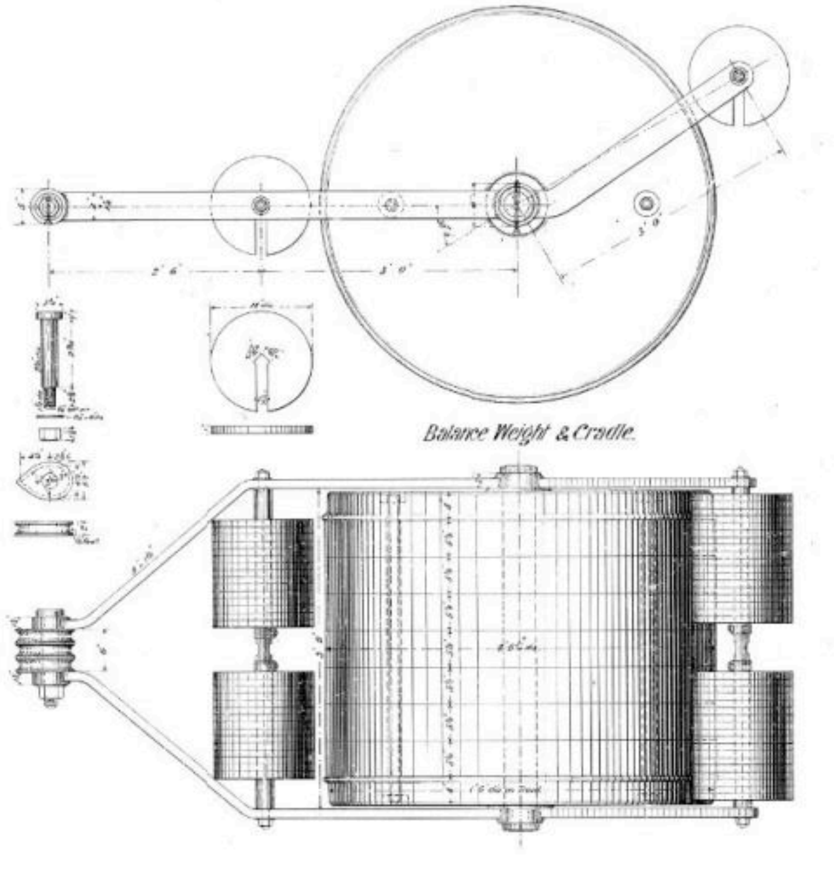


Figure 7.18 Balance weight and cradle for McFarlane Bridge

Mechanical components

The form and fabric of the mechanical components are EXCEPTIONAL significance.

The lifting mechanism on McFarlane Bridge comprises of a combination of longitudinal sheaves, gearing, balance weights and a winch (Figure 7.19).

The driving force of the mechanism is provided by a fly wheel and gearing located at the top of the tower. The rotation is transferred through a number of gears before gaining sufficient mechanical advantage to rotate the longitudinally oriented sheaves. The rotating sheaves act to lower the balance weight and raise the span. The three wire ropes in the mechanism simply pass from the lift span over the sheaves and onto the balance weight.

It is noteworthy that it was originally intended to use a worm-gearing system at deck level that would turn a vertical shaft into a horizontal shaft fixed to the sheaves. However it was found that there was excessive friction in this mechanism and it was abandoned in favour of the above arrangement.

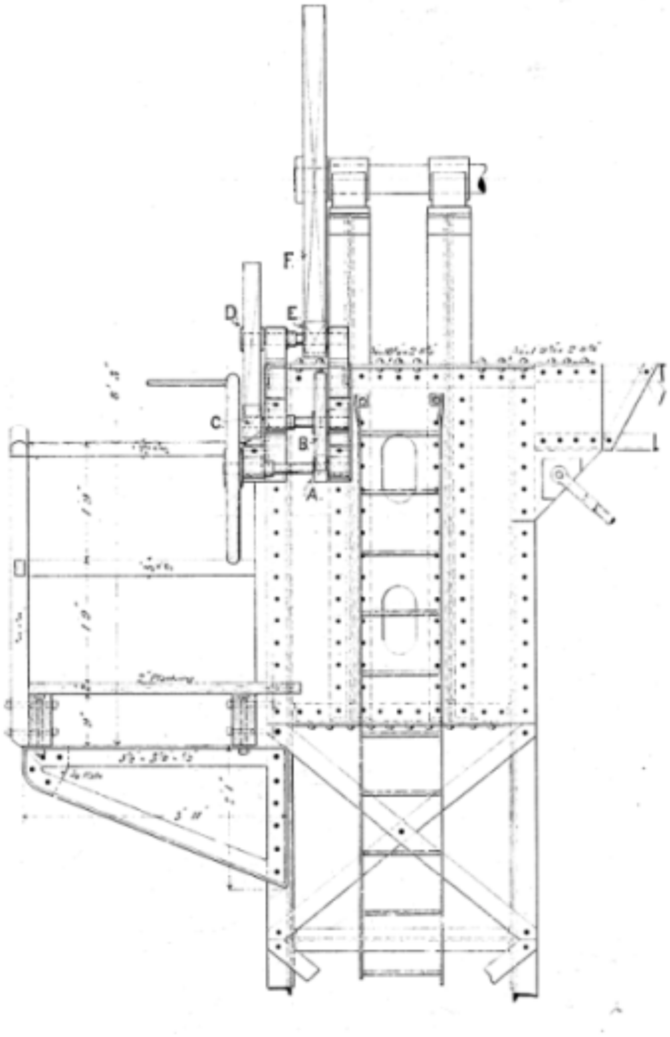


Figure 7.19 McFarlane Bridge Operating Mechanism

Vehicle and pedestrian barriers

NO significance.

Motors and electrical

NO significance.

Motors and electrical components were never installed on McFarlane Bridge. It remained manually operated throughout the initial period of its operation.

Actions required in order to restore the bridge to lifting operation:

- Replace wire ropes.
- Overhaul mechanism.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-3 McFarlane Bridge - Summary of heritage significance

Bridge Component	Significance Grading
Movable span and track span	EXCEPTIONAL
Rope Wheel	EXCEPTIONAL
Ropes	MODERATE
Operator work station	HIGH
Counterweights	EXCEPTIONAL
Mechanical components	EXCEPTIONAL
Vehicle and pedestrian barriers	NO
Motors and electrical	NO

7.3 CARRATHOOL BRIDGE

(Bélidor Type, built 1922)

7.3.1 Description of the Bridge

The bridge over the Murrumbidgee River at Carrathool is a bascule type bridge which consists of a steel single leaf opening span with length 66 ft., a steel tower span with length 68 ft., two Allan type timber truss spans of 71 & 72 ft. and four timber beam approach spans 25 ft. in length.

The upper framework of the bridge generally consists of a riveted steel lattice tower structure which is integrated into the pier 6-7 span. The single leaf span is a steel Warren type truss arrangement which pivots about the base of the tower. Finally the superstructure is founded on iron cylinder piers at the tower, with the adjacent support piers either side being similar cylinders with a smaller diameter.

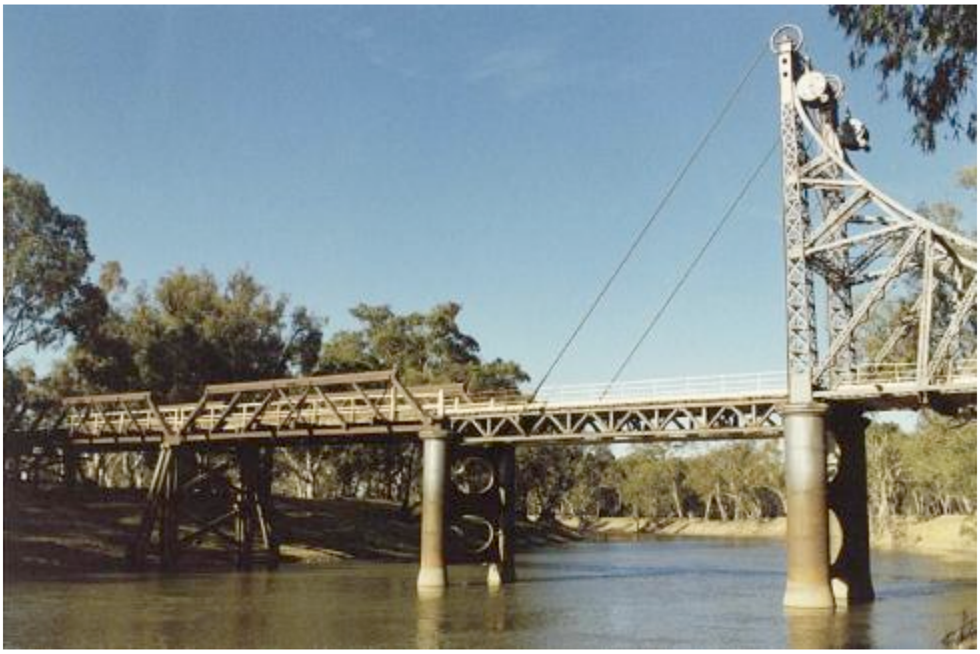


Figure 7.20 General view of Carrathool Bridge

History of transport on the Murrumbidgee River

The European exploration started in 1829 with Charles Sturt travelling along the Murrumbidgee River (Merrylees, 1983). From this time onwards the waterfront land began to utilised by pastoralists. However the occupation of the waterfront land interfered with the traditional way of life of the Wiradjuri people and a number of incidents occurred. These ranged from Aboriginals hunting the land owners cattle to retaliations with local tribe members killed. Eventually the continued spread of pastoralists forced the local Aboriginals to leave the river areas and seek employment in other towns or stations (Heritage Office, 1996:132).

Carrathool was the location adopted for crossing the Murrumbidgee River and it the regions above Carrathool to the main western route travelling towards Wagga Wagga. The township was established in 1865 with the listing of the Carrathool Parish in the NSW *Government Gazette* and the subsequent sale of fourty allotments in the same year.

There was a reasonable river trade which supplied the smaller towns off the Murrumbidgee. However it wasn't until the arrival of a railway line that the town really boomed. Carrathool West was established to service the railway and there was rapid growth as it became a shipping centre for wool, wheat, timber, livestock and copper to be transferred to rail. This boom would last until 1916 when a new railway line to Griffith was opened and it diverted a large amount of Carrathool's trade (Merrylees, 1983). Resettlement schemes for returned soldiers helped open up the irrigation areas around the Murrumbidgee and new crops began to be grown onwards from this time.

The crossing was originally provided by a hand operated punt, however this was deemed insufficient. According to newspaper reports of the time, joint lobbying or the construction of the bridge by the Carrathool and Murrumbidgee Councils had commenced as early as 1913. Initially the request was rejected on the grounds that the amount of traffic then using the hand operated punt ferry crossing did not justify the construction of a bridge (*The Riverine Grazier* 19/7/1924). The ferry had operated at this crossing for 35 years (*RDPW* 30/6/1922), and had a reputation for being somewhat unreliable (Merrylees 1983: 12). Mr Henry Webb commented on the opening of the bridge that when the ferry was in operation "he had heard more bad language over the crossing than he had heard anywhere" (*The Riverine Grazier* 29/7/1924).

Design and construction

Lobbying for a bridge continued and the two councils, in an unusual move, agreed in 1915 to jointly fund half of the cost of the bridge work and £6,000 was set aside as a fixed deposit. It was not until 1921, however, that an agreement between the Government and the Councils was formed. The willingness of the Councils to partly fund the bridge would seem to indicate the importance of the structure to the local community.

A bascule-type lift bridge with an opening of 60 feet in the clear was settled on as the agreed design. The councils had rejected an earlier proposed plan for "a lift span similar to those already installed on the Murray River bridges and elsewhere in New South Wales…which [have] a limited headway" (*RDPW* 30/6/1922).

Three tenders were received for the construction of the bridge in October of 1921: Poole and Steel Ltd submitted the winning quote of £26,700 10s for a bridge of either iron cylinders or concrete piers. Approaches to the bridge were not covered by either the quotation or the agreement entered into by the councils and the Department of Public Works (*The Riverine Grazier* 14/10/1921).

The construction of the approaches appears to have been an ongoing problem for the councils, the Department of Public Works did not consider the expenditure warranted despite the tendency for the low-lying land on the north side of the bridge to flood. In the opinion of *The Riverine Grazier*, however, "it [did] not require an engineer to see that a long approach to the Carrathool bridge is essentially required if the traffic is to be able to use the bridge in all seasons" (*The Riverine Grazier* 3/4/1923). Building and funding of the approaches was left to the Shires (*The Riverine Grazier* 29/7/1924).

The construction of the bridge itself ran a year over time, partly as a result of some unfavourable conditions caused by flooding (*The Riverine Grazier* 12/10/1923); the original contract stipulated that the work should be finished by May 1922 (*The Riverine Grazier* 20/11/1923). The delay caused some inconvenience to the local community and to pastoralists in particular. The punt ferry, which served at the crossing, was in such poor condition by October of 1923, that the Carrathool Shire was forced to ban the use of the punt for those wishing to put cattle across the Murrumbidgee (*The Riverine Grazier* 20/11/1923).

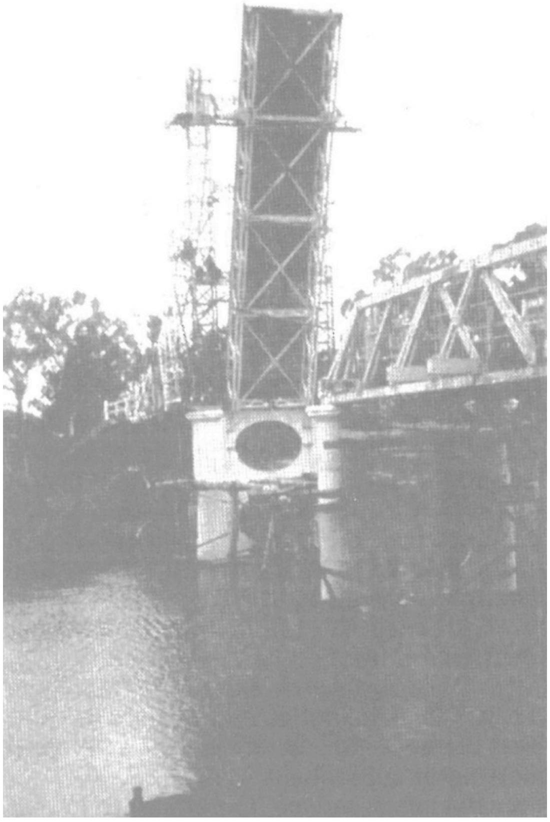


Figure 7.21 Carrathool Bridge bascule span under construction in 1924 (Source: Hay Historical Society)

When the bridge was officially opened the approaches had not yet been finalised. On the north side of the bridge a temporary ramp had been constructed to allow use of the bridge; the approach bridge itself was not yet complete. Nor, on its opening day, could the lift span of the main Carrathool Bridge be opened as a caretaker had not yet been appointed to the job (*The Riverine Grazier* 29/7/1924).

These problems do not appear to have dampened the mood of the opening day. According to *The Riverine Grazier*, a good crowd was on hand for the event, a number of speeches were made and two ribbons, which had been stretched across either end of the lift span, were cut by Mrs Varcoe, wife of the president of the Carrathool Shire and by Mrs Campbell, wife of the Murrumbidgee Shire president.

As soon as the ceremony was over there were rushes for pieces of ribbon as souvenirs...An adjournment was then made to the Carrathool side where afternoon tea and other refreshments were served by Mrs Campbell and Mrs Varcoe, assisted by a number of ladies and gentlemen. The children were regaled with an abundance of sweets and fruit. In a very short time a number of vehicles and motor cars had crossed the new bridge (The Riverine Grazier 29/7/1924).

The final cost of the bridge, not including the cost of the approaches, was £29,002 15s 11d (Merrylees 1983: 12).

The Riverine Grazier was full of praise for the new structure, describing the bridge as:

"...a very handsome one, its lines being very graceful, the tower with its curved support adding to its appearance. The lift span is seventy feet long, and the tower is as high as the lift is long...The work has been well carried out, and in its new white paint, picked out very sparingly with black, it certainly makes a fine picture against the background of the green river timber."

Carrathool Bridge is one of three "Bélidor Type" bascule bridges surviving in New South Wales, and the only one having a timber truss approach.

Operational history

Following the opening of the Carrathool Bridge, the former puntman, William Henry Le Fevre, was appointed to the position of bridge caretaker (*The Riverine Grazier* 10/10/1924); the caretaker was provided with a two-roomed cottage (possibly formerly the puntman's cottage on the southern bank of the river adjacent to the bridge along with grazing and farming rights to 170 acres nearby. Tenders were again called for the position in January though Mr Le Fevre remained in this role until 1942 and raised his family of 6 children at the site.

There is no record of when operational lifts took place, though test lifts were undertaken at regular intervals. Other than this his role was to sweep the bridge clean after the regular stock crossings and any routine repainting as required. In 1929 at his prompting netting was added to the railings of the bridge because during stock crossings "sheep often fell through into the river" (RTA file 80.66 part 1).

The Riverina Grazier of 16 January 1942 noted that the caretaker had resigned and advertised the position thus:

"Allowance to cover Caretaking duties will be at the rate of £26 per annum. Preference will be given to Returned Soldier applicants particularly those residing within the Carrathool Village."

The successful applicant's name is not recorded though on 29 December 1942 he made a request to the Divisional Engineer to purchase a 14ft boat for the purpose of freeing debris from the bridge in flood time. This was rejected on grounds it would be a hazardous task and that the work could be best done with a long pole from the bridge deck or banks.

The lift span was last raised in 1961 following the decline of river traffic. By the 1970s it was considered unlikely that the span could be opened; the hinges had seized and the lift span and fixed span deck sheeting butted up to one another without the necessary gap. Requests to ready the bridge for a final opening during the Carrathool Centenary celebrations of 1983 were rejected as to the estimated price of $10,000 was considered to be too high to justify the work (RTA file 80.66 part 3). The winching system for the lift span has been decommissioned, although the rollers remain in place.

Maintenance history

In 1961 a semi-trailer crossing over the bridge broke through the decking and slid into the river, causing injury to two bridge maintenance workers; following this new decking and girders were required in bridge spans 7 and 8 (RTA file 80.66 part 2). In 1993 the southern abutment was reconstructed in front of the original abutment.

In 2006 it was determined that the existing stringers and girders on the track span were not of the required capacity to safely carry modern truck loadings, and also were susceptible to deterioration as they were located under the bridge in an area where maintenance is difficult. In 2007 then all timber stringers which support the timber deck longitudinally on the track span were replaced with steel stringers. The timber railings were replaced with visually similar steel barriers at this time also.

7.3.2 Statement of significance

Completed in 1922, the Carrathool bridge is an Allan type timber truss road bridge, and has a rare Bascule type lift span to allow river craft to pass. In 1998 it was in good condition.

As a timber truss road bridge, it has strong associations with the expansion of the road network and economic activity throughout NSW, and Percy Allan, the designer of this type of truss.

Allan trusses were third in the five-stage design evolution of NSW timber truss bridges, and were a major improvement over the McDonald trusses which preceded them. Allan trusses were 20 per cent cheaper to build than Mc Donald trusses, could carry 50 per cent more load, and were easier to maintain.

The Bascule lift span is a rare feature, and has associational links with the historic river trade, and has much to reveal about late 19th century civil engineering and manufacturing technology.

In 1998 there were 38 surviving Allan trusses in NSW of the 105 built, and 82 timber truss road bridges survive from the over 400 built.

The Carrathool Bridge is a representative example of Allan timber truss road bridges, and is assessed as being State significant, primarily on the basis of its technical and historical significance.

Source: RMS s170 Register

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Listed
OEH Heritage Division State Heritage Register	Listed
Carrathool Shire Council Local Environmental Plan, 2012	Not listed
NSW National Trust Register	Listed
RTA s.170 Heritage and Conservation Register	Listed

Evolution of modifications

Carrathool Bridge was essentially an adoption of the Coraki Bridge design, with no significant variences evident. The original drawings of Coraki Bridge note the other four Bélidor bascule designs built in NSW (Darlington Point, Maclean, Wakool and Carrathool), suggesting that the designs were all undertaken within a close period of time and only minor modifications to match local site conditions were implemented.

7.3.3 Description of lift span mechanism components

Movable span and track span

The form and fabric of the movable span and track span components are EXCEPTIONAL significance.

The design of the Carrathool Bridge was completed by Henry Harvey Dare and was based on similar bridges constructed in America. This bridge represents the third “Bélidor Type” bridge built in NSW.

The superstructure arrangement consists of two towers which in essence are braced into the fixed adjacent span. The towers are made up of a steel riveted lattice construct that are also braced in the transverse direction with steel rods with some portal frame action at the base. As made evident by Figure 7.22, the truss span is integrated into the tower thus providing longitudinal bracing and subsequently the lateral strength required to resist the span operation loadings.

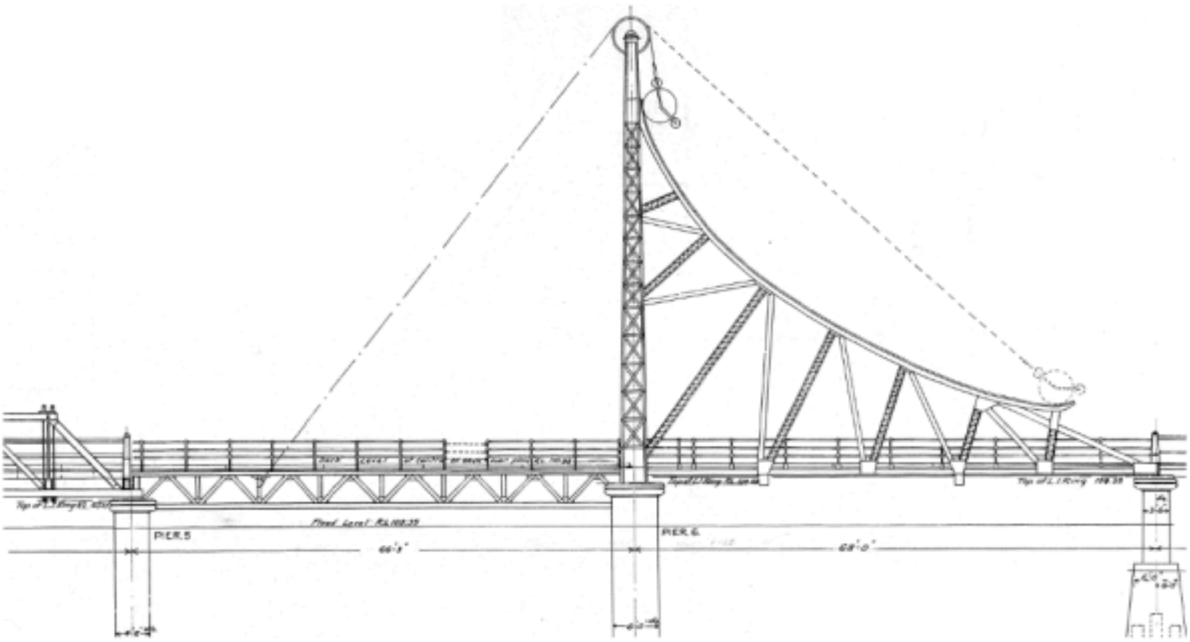


Figure 7.22 Elevation of Carrathool Bridge

The fixed span adjacent to the tower also incorporates the curved track for the rolling counter weights to travel along during a span lift (Figure 7.23). This curve is the defining feature of this type of bascule bridge and has often been described as a good approximation of the cardioidal arc. The curve is instrumental in the operation of the lift span and is discussed further with the lifting mechanism. The base of the tower is supported by Iron Cylinder piers with the piers either side of the tower being of the concrete Monier type.

Figure 7.23 Image of Carrathool Bridge

The lift span of the Carrathool Bridge consists of steel Warren type truss arrangement (Figure 7.24). The primary longitudinal members support steel truss cross girders which support timber stringers and finally the timber deck. The entire span pivots about the base of the tower during operation.

Figure 7.24 Carrathool Bridge Bascule Span

The pivoting is enabled by a cast iron steel hinge connection at the tower end of the single leave lift span. This hinge is riveted into the back of the span.

The wire ropes are connected to the lift span by way of an attachment component as shown in Figure 7.25. This rope attachment transfers the load from the three wire ropes into another bracket mounted on the movable span.

Figure 7.25 Carrathool Bridge wire rope to lift span attachment

Rope wheel

The form and fabric of the rope wheel component is EXCEPTIONAL significance.

The sheaves are 5 ft. in diameter and are made up of cast iron spoke wheel arrangement (Figure 7.26 and Figure 7.27).

Figure 7.26 Sheaves and counterweights – with figure for scale

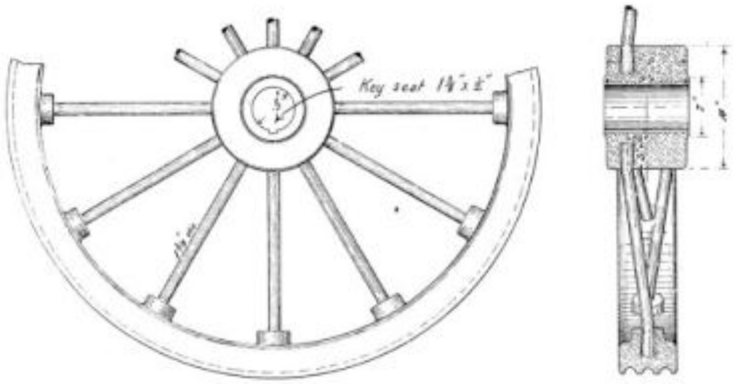


Figure 7.27 Typical rope wheel design

Ropes

The form and fabric of the rope components are LOW significance.

The wire ropes consisted of wire strands wound around a hemp core.

Operator work station

The form and fabric of the operator work station component is HIGH significance.

Originally the operator station was mounted at the top of the curved track. Modifications made after its construction added a mid-level and bottom level (Figure 7.28) workstation to the bridge. The driving mechanism was altered with to suit.

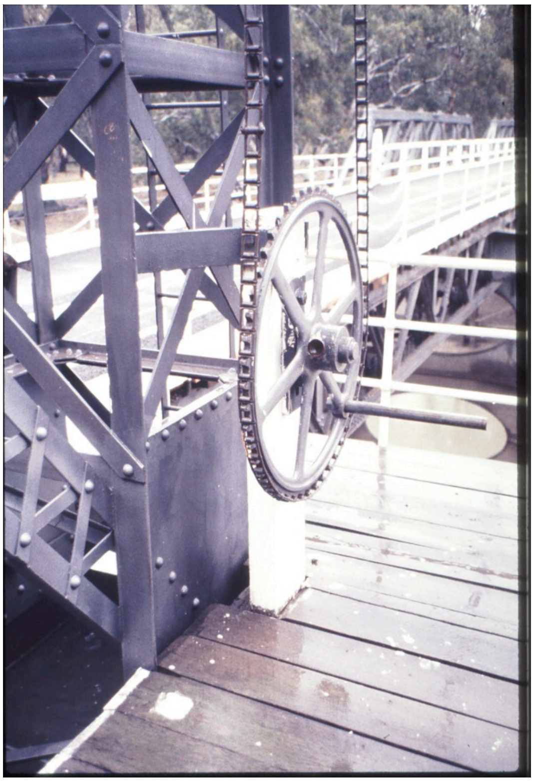


Figure 7.28 View of bottom operating platform

Counterweights

The form and fabric of the counterweight and rope component are of EXCEPTIONAL significance.

The balance weights that are implemented on Carrathool Bridge consisted of a cast iron cylinder with a diameter of 4’ 6¾” and width of approximately 5’ 9”. The balance weight cradle also has an allowance for changes in span dead weight with points for four smaller weights to be hung on the system.

The cylindrical shape of the balance weight allows it to travel smoothly down the curved track, which is fitted with a small rail to prevent the balance weight coming off the curve during operation. The wire ropes are connected to the balance weight by means of the end being spliced round a cast iron thimble at the balance weight cradle. The balance weight arrangement is shown in Figure 7.29.

Figure 7.29 Balance weight and cradle for Carrathool Bridge

Mechanical components

The form and fabric of the mechanical components are EXCEPTIONAL significance.

The lifting mechanism on Carrathool Bridge comprises of a combination of longitudinal sheaves, gearing, balance weights and a winch.

The driving force of the mechanism is provided by a fly wheel and gearing located at the top of the tower. The rotation is transferred through a number of gears before gaining sufficient mechanical advantage to rotate the longitudinally oriented sheaves. The rotating sheaves act to lower the balance weight and raise the span. The three wire ropes in the mechanism simply pass from the lift span over the sheaves and onto the balance weight.

It is noteworthy that it was originally intended to use a worm-gearing system at deck level that would turn a vertical shaft into a horizontal shaft fixed to the sheaves. However it was found that there was excessive friction in this mechanism and it was abandoned in favour of the above arrangement.

Vehicle and pedestrian barriers

NO significance.

Gates were originally position on the embankment approaches. However these have since been removed.

Motors and electrical

NO significance.

Motors and electrical components were never installed on Carrathool Bridge. It remained manually operated throughout the initial period of its operation.

Actions required in order to restore the bridge to lifting operation

- Replace wire ropes.
- Overhaul mechanism.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-4 Summary of heritage modifications

Bridge Component	Significance Grading
Movable span and track span	EXCEPTIONAL
Rope Wheel	EXCEPTIONAL
Ropes	MODERATE
Operator work station	HIGH
Counterweights	EXCEPTIONAL
Mechanical components	EXCEPTIONAL
Vehicle and pedestrian barriers	NO
Motors and electrical	NO

7.4 NAROOMA BRIDGE

(Strauss Type, built 1931)

7.4.1 Description of the Bridge

The bridge over the Wagonga Inlet at Narooma is a Strauss type bascule bridge which consists of a steel single leaf opening span with length 62 ft. and two Pratt type truss approach spans with lengths 160 ft. and 161 ft. respectively.

The single leaf bascule span generally consists of dual fabricated steel plate web girders. These main girders support steel cross girders and stringers before supporting the timber deck. It is noteworthy that the timber deck was replaced by steel grating in September 1980. The superstructure of the mechanism is a lattice portal frame that assists in guiding the counterweight during operation. The bridge finally bears on reinforced concrete piers that are founded directly onto rock.

Figure 7.30 General view of Narooma Bridge with former ferry ramp in foreground

Development of roads and transportation in the Narooma region

The Narooma region was originally occupied by the Yuin people. The first European settlement occurred in 1839 when Francis Hunt arrived in the region and took up residence on a property he named ‘Noorooma’. The township of Narooma was later named after his property, with the spelling error attributed to the local post office printing an incorrect stamp label (Narooma District Chamber of Commerce & Tourism).

The initial settlement by Hunt resulted in the area being utilised for pastoral grounds however following the discovery of Gold at Mount Dromedary in the 1860s the population increased with the arrival of prospectors. This drove development at the Wagonga Inlet as it became a port servicing the nearby gold town of Nerrigundah. Following the decline of the gold rush, timber became the dominant resource in the area with several sawmills being established (Narooma CMP).

Crossing of the Wagonga Inlet was originally provided by a hand propelled punt that was installed in 1894. As the town continued to grow into the 19th century a need for a bridge began to arise. The temporary solution of an old petrol driven punt taken from Batemans Bay was adopted however with the establishment of the Main Roads Board in 1925, the improvement of the Princes Highway was of a high priority and a bridge over the inlet was proposed (NSW Heritage).

The construction of the bridge commenced in 1929 with two contracts awarded for the components of the work. The majority of the steel was produced by BHP in Newcastle with Morrison and Bearby being responsible for the fabrication works. The contract for the foundations was awarded to the State Monier Pipe and Reinforced Concrete Works and the project was completed in 1931 (Narooma CMP).

The final cost of the structure was approximately £42,267 (NSW Heritage). The opening ceremony was held on the 20th of June 1931 and it was well attended with a noted 1800 individuals present (Narooma CMP).

Design and Construction

The Bridge consists of two concrete girder spans (7.5 m each), two fixed steel truss spans (48.77 m each) and a steel girder bascule lift span (19.20 m) for a total length of 131.98 m. It was the first bridge in Australia with a cantilever bascule-lifting span that could be worked by a single operator if kept well greased. The opening span is a single leaf bascule that is hinged with a counter-balance and timber was originally used on the deck to reduce dead weight. It is 6.1 m wide between kerbs and has a 2.6 m wide footway and the deck level is approximately 4.25 m above the waterline at high tide.

The substructure consists of reinforced abutments and piers, the northern abutments being founded on rock, which required heavy cutting. The southern abutment is established on timber piles driven 35 feet into the sand. The piers in the water are carried down to rock about 26 ft. below low water, with 12 ft. of overlying sand.

The Main Roads Board, judging by a report in the Board's journal *Main Roads*, designed the bridge. The report titled "The Bridge over the Wagonga Inlet at Narooma" was written by F. Laws, B.E. who was titled "Assistant Designing Engineer". The drawings are signed by the Chief Engineer, Mr D. Gaig and the Bridge Engineer, Mr Dennis.

The construction work for the Bridge was carried out under two contracts. Most of the steel was made by BHP. However, the large steel plates in the bascule span and cross-girders, and the two nickel steel shafts and the ball and roller bearings for the bascule operating mechanism had to be imported from Germany. The fabrication and fitting was completed by Morrison and Bearby, of Newcastle with the total cost equating £12,267 2s. 6d.

The Bridge was assembled in Newcastle one section at a time (Figure 7.31), then taken to pieces and brought to Narooma by the steamer *Kianga* in three shipments. The steel was unloaded at the receiving wharf and hauled to the bridge site by bullocks.

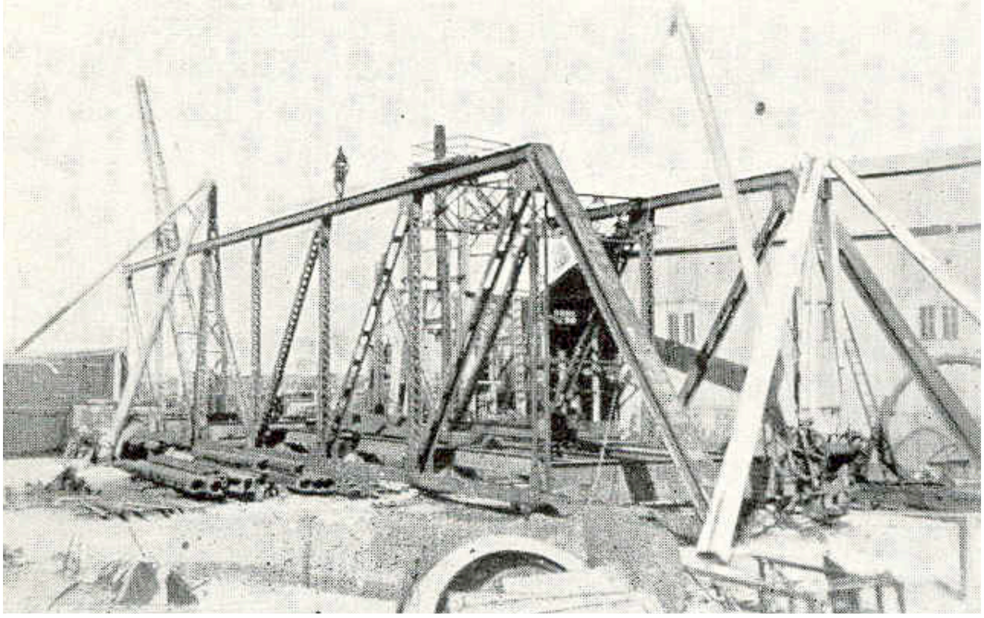


Figure 7.31 View of a truss in the course of assembly at Walsh Island Dockyard and Engineering Works, Newcastle (Source: DMR, 1929:20)

The State Monier Pipe and Reinforced Concrete Works won the contract for construction of the foundations, approaches and the erection of the steel work for the sum of £29,495 16s 7d. The final cost was a little higher than these figures at £42,267 7s 6d as the rock under the piers was found to be less substantial than ascertained by the geotechnical investigation. It was therefore necessary to sink the northern pier 5 feet and southern pier 8 feet further into the ground. State Monier Pipes also built Tom Ugly's Bridge across the Georges River, Sylvania in 1929.

In the speeches at the opening recorded by the *Moruya Examiner*, the following people involved in the Bridge's construction received an honourable mention:

Mr Stephens, Manager, State Monier Pipe Works; Mr Harold Renshaw, Supervising Engineer; Mr Logan, Clerk of Works and Mr Thirlwall, Bridge Builder.

The steamer *Kianga* which had been integral to the Bridge's construction was to be used in a demonstration of the bascule span during the Bridge opening ceremony but unfortunately had run aground at Bingie Point the night before. The story of the wreck is in the *Moruya Examiner* adjacent to the description of the Bridge opening. The irony of this tragedy is that the construction of the highway and the Bridge were largely responsible for the decline in importance of coastal shipping.

Apart from specialist tradesmen, most men who worked on the Bridge were locals, which was important for the community during a period when unemployment was high. This led Mr. Stephens, Manager, State Monier Pipe Works to note that "the great majority of men employed have always been local residents, and I have not any reason to regret that". Mr. Mark Morton, MLA Wollondilly, at the opening, related the issues of the bridges cost and the cost of unemployment by stating that "it is remarkable to me the small amount that this bridge cost, and when you recognize that the amount it did cost £42,000, that is only equal to what the Government is spending every three days for men on the dole" (*Moruya Examiner*).

The Opening

The opening of the Bridge on 20 June 1931 was a major public event for Narooma and the far south coast and 1800 were present to witness it. Speeches were made by C. Mitchell, President of Eurobodalla Shire Council, H.J. Bate, MLA, the local Member of Parliament and Mr. H.H. Newell; Chairman Main Roads Board whereupon Mr Bate declared the bridge open and Mrs. Bate cut the ribbon.

Figure 7.32 Narooma Bridge with bascule and tower wrapped with bunting at the formal opening (Source: RMS photographic archives)

Before the proceedings could start, H.J. threw a dart to decide who would have the privilege of being the first person to walk across the Bridge after the official opening. All proceeds from the draw went to the Narooma Soldiers

Memorial Hall. The winner was local resident Mr. Don Southam, head sawyer at Mitchell's Mill. He was followed by a crowd, which was followed by some cars. Amongst the speeches made at the ensuing reception C. Mitchell noted:

"this is the day which the Narooma people, the public of the Far South Coast, and the traveling public generally, have been looking forward to for the past 25 years. ... (Moruya Examiner)"

Concerning the need for the bascule span the following comments were made:

"The design is a simple one and it was decided upon for the reason that it is safer against damage than the ordinary span. ... It was the requirements of the Navigation Department that necessitated the provision of an opening span."

(Mr. H. H. Newell, Chairman Main Roads Board in *Moruya Examiner*)

Other significant statements recorded at the occasion include:

"I was struck by the beauty of this spot here. I think the Bridge you have just built is going to be a wonderful adjunct to this district. (Mr. G.F. Ardill, MLA Yass in Moruya Examiner)."

The final word on the importance of the Narooma Bridge is given to the reporter from the *Moruya Examiner*

"Saturday, 20th June, 1931, was an epoch in the history of Narooma, and in fact of the whole Far South Coast, as on that day the bridge across the Wagonga River was officially opened to traffic thus linking together the northern and southern area of the pretty tourist resort and giving modern facilities to travelers on the beautiful Princes Highway."

Operational history

Commercial fishing commenced in the 1930s and a fish cannery opened on the banks of the Wagonga River in 1940 requiring the bridge to be opened frequently.

There has been a reduction in shipping in the area since the 1960s. Bridge opening records between May 1961 and October 1967 revealed an average of 3 openings, with a maximum of 14 openings in October, 1962. March to May is the busiest period with 4 – 10 per month reducing to 1 – 2 per month during the rest of the year.

At present the average number of openings per month is between 6 and 12 (for trawlers and pleasure boats) except in October when up to 30 openings may take place. This is attributable to vessels traveling from Ulladulla which are dry docked at Fosters Bay to the west of the bridge for inspections.

Figure 7.33 Image of bridge during opening (Source: RMS photographic archives)

Maintenance history

In 1963 a footway was provided on the eastern (downstream) side of the Bridge and the abutments were reinforced. The footway consists of hardwood beams and planking over mild steel stringers, angles and plates.

In 1967 it was reported by the caretaker that the downstream locking pin was regularly jamming. This was attributed to the poor balancing in place on the bascule span. The locating hole for the pin was modified as required.

In 1981 a contract was let for $76,000 to Max Pearce Engineering, Bega to supply a steel grille to replace timber deck on lift span. The work of replacing the timber deck with the steel grating deck was undertaken in December 1982.

On October 19, 1999 part of the safety railing was damaged as a result of a truck overturning while traveling on the northern approach of the Bridge. Had the truck continued sliding, the cabin would have struck one of the bridge principals, possibly resulting in a fatality. This accident served to highlight issues with the road curvature of the northern approach which has been signposted accordingly (RTA bridge files: 1/145.131 Parts 1, 2 and 3).

Figure 7.34 **View of the overturned truck on the northern approach in October 1999 (Source: RTA Bridge File)**

7.4.2 Statement of significance

The Narooma Bridge, completed in 1931, is of State significance. It has is representative of an important period of development of the Princes Highway and was the first major bridge constructed on the highway by the Main Roads Board as part of its efforts to develop the highway. The bridge represents this period of development in a readily interpretable physical way. Opening span bridges are important in NSW because they are a reminder of the time when river transportation was more common. The design of bascule span used on the Narooma Bridge represents a simple, practical and economical solution to the problems posed by the competing needs of navigation and road transport. The Narooma Bridge has State technical significance because it represents a significant and rare variation of the bascule opening span which is an important type of bridge in NSW.

There is only one other bascule span in NSW which has a similar design and that other bridge is currently threatened with demolition.

Source: RMS s170 Register

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Not listed
OEH Heritage Division State Heritage Register	Not listed
Eurobodalla Shire Council Local Environmental Plan, 2012	Not listed
NSW National Trust Register	Not listed
RTA s.170 Heritage and Conservation Register	Listed

Evolution of modifications

Narooma Bridge was essentially an adoption of the vertical overhead counterweight Strauss type bridge design. The bridge is derived from the American patented design and therefore is not the result of a sequential evolution in Australian designs.

7.4.3 Description of lift span mechanism components

Tower

The form and fabric of the tower component is of EXCEPTIONAL significance.

The Narooma Bridge lift span is a Strauss type bascule which has the defining feature of the counterweight being mounted off the short arm of the span. For the arrangement considered herein only one tower is implemented in the superstructure, with the purpose of guiding the movement of the counterweight during operation and providing the support for the trunnions which uphold the lift span (Figure 7.35).

The lift span tower consists of dual lattice columns restrained by a portal frame system. The base of each column is boxed by plates in the longitudinal direction and this increase in stiffness for the towers assists in minimising deflections (Figure 7.36).

The portal frame brace members are made up of dual equal angel struts that are restrained by tie plates at regular intervals.

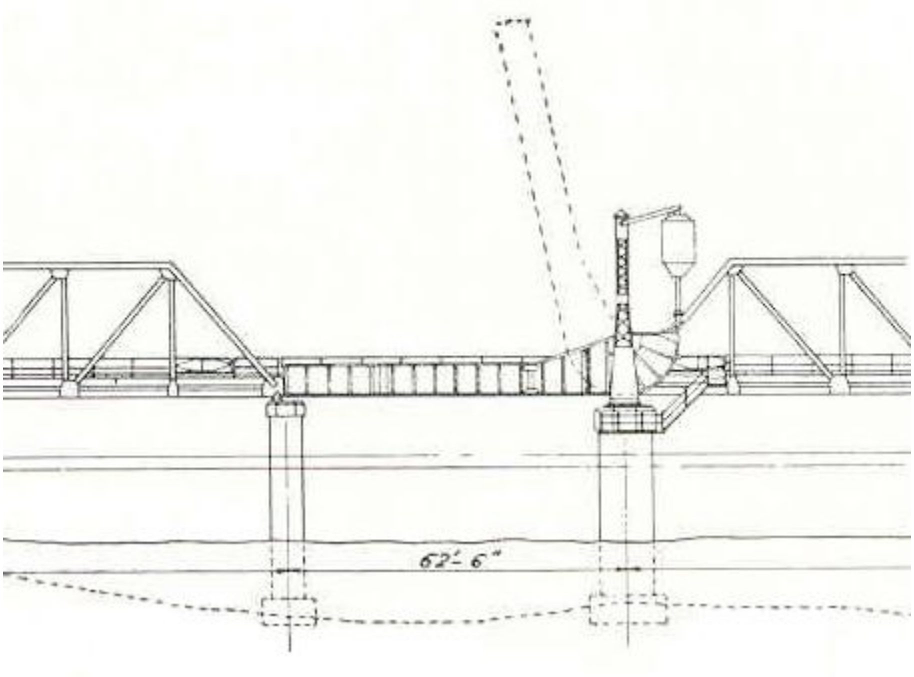


Figure 7.35 Elevation of Narooma Bridge

The steel connections between the individual components of the tower were achieved through riveting with the primary bolt usage only being adopted for the hold down bolts in the tower to pier connection.

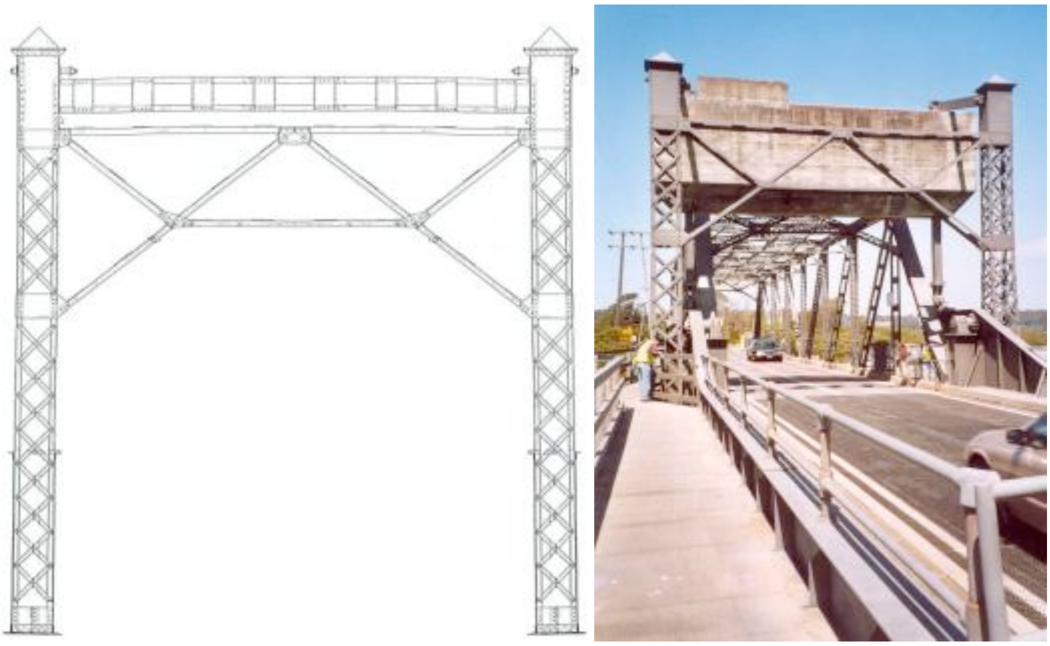


Figure 7.36 Elevation of Narooma Bridge Tower

Operator work station

The form and fabric of the operator work station component is HIGH significance.

The operation of the bridge was originally undertaken by hand operation through the two-speed gearbox (or since 1996 operate the motor). The Bridge would be raised using the low gear and lowered using the higher gear.

Operators would stand on a platform adjacent to the tower where the turning screw was located as shown in Figure 7.37.

Figure 7.37 Location of operator work station and turning screw (Source: RMS)

It is noteworthy that when operated manually, the force required would be excessive, Figure 7.38 shows four men winding down the span at high gear in 1967.

Figure 7.38 View of four men winding down the span at high gear in 1967

Movable span

The form and fabric of the movable span component is HIGH significance.

The movable span of the Narooma Bridge consists of two primary plate web girders which deepen toward the trunnion of the span. The quadrant at the tail of the span is curved and fitted with a rack for the mechanism to key into and cause motion.

The primary girders support cross girders and rolled steel stringers before originally supporting the 5 inch thick hardwood planks that made up the deck (Figure 7.39).

Figure 7.39 Original timber deck of bridge

From 1966 onwards recommendations were made to replace the timber deck with a steel grille deck as to reduce the dead weight of the span. Hence the deck was replaced in September 1980 at a cost of $76,000. The upgrade was also a response to the significant number of complaints of local residents regarding the noise pollution arising from the loose timber decking that subsequently was continually being tightened. Furthermore, the timber deck made the steel components susceptible to corrosion as the timber would retain water. The footway was also added to the inland side of the bridge in 1963 (Narooma Bridge CMP).

Counterweights

The form and fabric of the counterweight component is MODERATE significance.

The counterweight adopted for the Narooma Bridge is a reinforced concrete block with an upper void to allow for either iron or lead weights to be added or removed depending of fluctuations of the span mass and future bridge modifications (Figure 7.40). The entire counterweight is mounted on a vertical steel arm that attaches to the tail end of the lift span. Secondary steel arms attach to the top of the weight and provided horizontal stability for the mass during operation. The key feature of the arrangement is the ability for the counterweight to move horizontally towards the pivot point as it travels downward. This ensures that the spans centre of mass remains constant throughout the lift and subsequently the force to cause motion of the spans also remains constant.

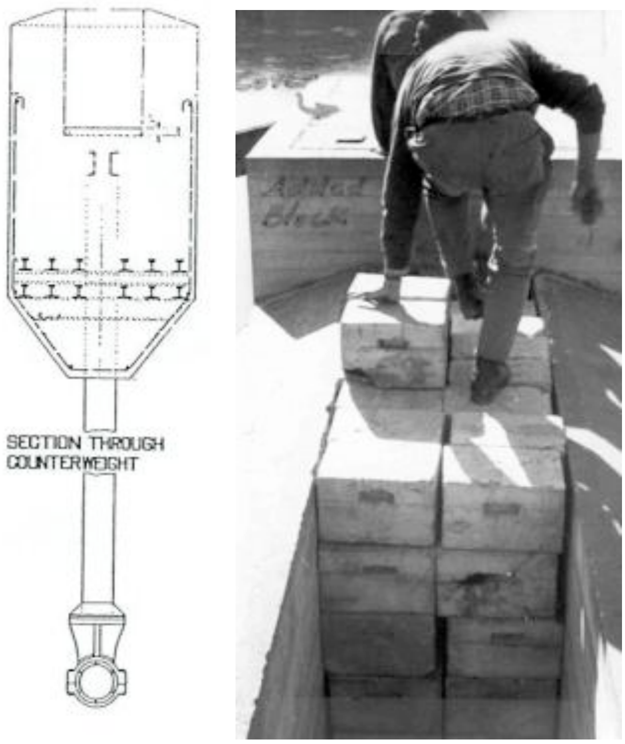


Figure 7.40 Counterweight for Narooma Bridge and Ballast block void looking east in 1966. Existing pig iron ballast blocks are seen being shifted while new blocks are added

The span was initially lifted by a single operator and this highlights the importance of accurately balancing the span with the counterweight. With the addition of the walkway in 1960 this balance was for a time lost and as a result a single operator was no longer sufficient.

Mechanical components

The form and fabric of the mechanical components is EXCEPTIONAL significance.

The lifting mechanism on Narooma Bridges generally consists of the manually operated handle, a number of gears and shafts along with the cast steel rack bolted to the quadrant at the tail end of the span (Figure 7.41).

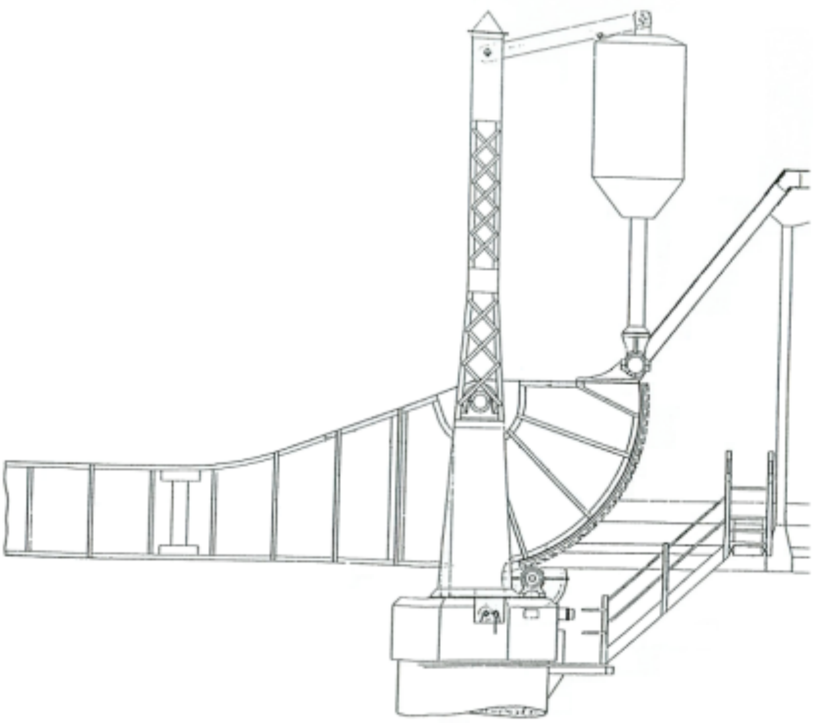


Figure 7.41 Narooma Bridge Original Drawing of Lift Mechanism

As noted, the driving force of the mechanism is provided by a manually operated handle which drives a transverse shaft into a worm gear. The worm gear transfers mechanical advantage into a second transverse shaft that is fitted with a pinion at either end. These pinions are keyed into the racks on the quadrant of each girder and their rotation causes movement of the span. The trunnions of the mechanism, which support the bascule span, are mounted on the tower and provide the pivot point for the span to rotate about. Figure 7.42 shows a number of these components.

Figure 7.42 View of the trunnion end of the bascule span detailing the machine-cut racks on the curved ends of the plate girders

The rack, pinion trunnion and quadrant are key components of the mechanism and Figure 7.43 provides a detailed elevation of these components.

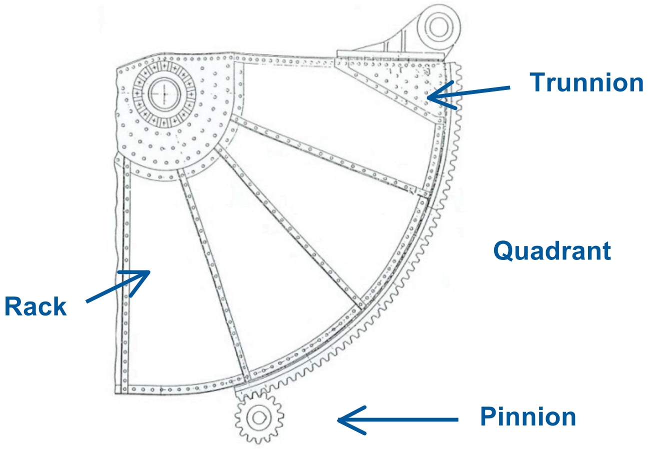


Figure 7.43 Narooma Bridge Pinion to Rack Arrangement

Roller bearings have been provided for the gearing, the transverse shaft and the bearings secured to the top flanges of the bascule plate girders which carry the concrete counter-weight. In this manner, frictional resistance was reduced sufficiently to enable the movable span to have been operated by one man without distress.

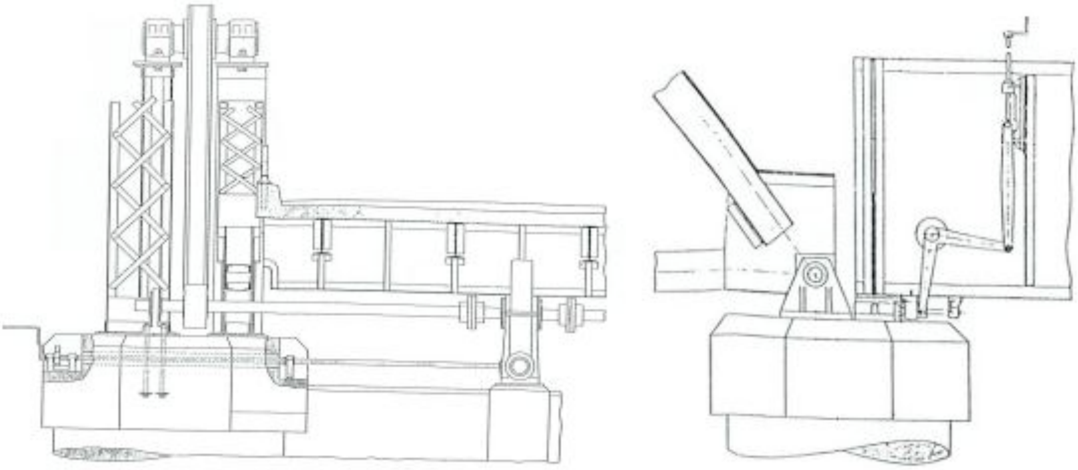


Figure 7.44 Narooma Bridge operating mechanism and forward bearing lock mechanism

The firm end bearing of the span is achieved by a steel block and subsequent locking mechanism. The locking mechanism consists of a hand operated gearing that rotates a lever thus extending a pin into the cavity of the steel block (Figure 7.45).

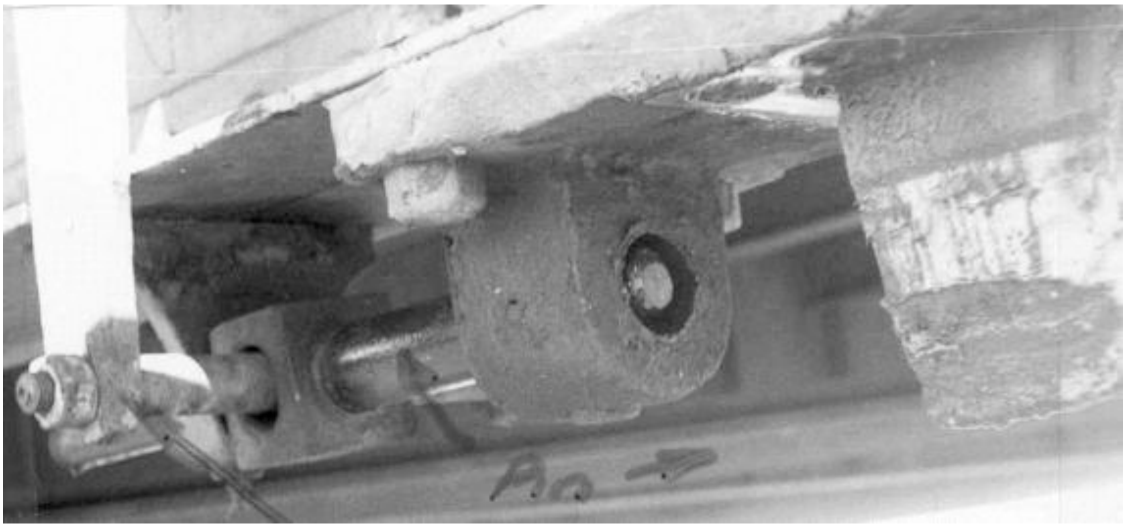


Figure 7.45 View of locking pin and centering wedge retracted

Vehicle and pedestrian barriers

The form and fabric of the vehicle and pedestrian barrier components is HIGH significance.

The Narooma Bridge is fitted with the safety feature of gates at either end of the bascule span. The gates are manually operated and are closed to prevent traffic from continuing whilst the bridge is being operated.

Motors and electrical

The form and fabric of the motors and electrical components is LOW significance.

The driving power for the bridge was originally provided by a handle into a gear box, thus gaining sufficient mechanical advantage to raise the bridge. From the 1970s a portable drill was used to operate the bridges, however this to was superseded by an electric motor drive system that was installed in 1994 (Figure 7.46). The new motor consists is a three phase electric motor that is connected to a 90 degree reduction gear box and finally coupled to the drive shaft of the bridge. New brakes were also fitted to the drive shaft. Operation of the electric motor is achieved by a pendent hand control device at the end of a 20 m long cable. The device can be easily detached from the control board. The original driving components are still operable and act as a secondary control. Should the electric system fail the bridge can be lowered by a portable drill or hand winch with approximately 360 turns required to open the bridge.

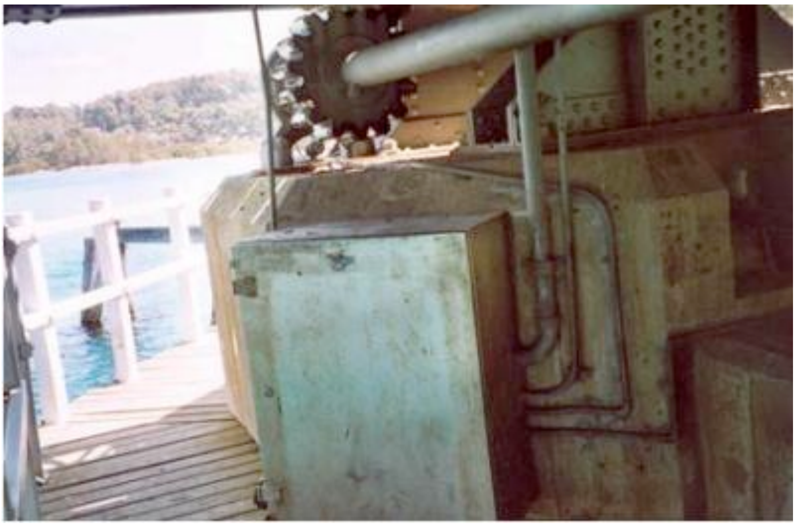


Figure 7.46 View of electric motor in steel casing located on the operating platform. The intermediate machinery drive can be seen above

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-5 Narooma Bridge – Summary of heritage significance

Bridge Component	Significance Grading
Tower	EXCEPTIONAL

Bridge Component	Significance Grading
Operator work station	HIGH
Movable Span	HIGH
Counterweights	MODERATE
Mechanical components	EXCEPTIONAL
Vehicle and pedestrian barriers	HIGH
Motors and electrical	LOW

7.5 GRAFTON BRIDGE

(Rolling Lift – Rall Type, built 1932)

7.5.1 Description of the Bridge

The bridge over the Clarence River at Grafton is a double decked bridge that caters for both a road and railway. The structure consists of a Rall type steel bascule lifting span with length 90 ft., five steel Pratt type trusses with lengths ranging from 243 ft. to 245 ft., and two approach spans at either end. The approach spans are effectively split into two separate structures, with the upper road way approach consisting of a 100 ft. truss span and the railway approach being a 66 ft. steel plate web girder.

The upper framework of the lifting span generally consists of a single leaf bascule truss. The truss pivots on the concrete Pier 2 support with the lifting mechanism and associated housing mounted on the adjacent span.

Figure 7.47 General view of Grafton Bridge looking south

Development of roads and transportation in the Grafton region

The history of the Grafton, like many other towns in the region, is strongly linked to the Clarence River. The original inhabitants were the Bundjalung tribe that capitalised on the Northern Rivers for their marine life, vegetation and land animals. Early explores noted the dense Aboriginal population in the area. European settlers began to occupy the area from 1838 onwards when cedar getters were attracted to the area following reports of their presence.

The first expedition was completed under the direction of Parramatta timber yard owner, Mr Thomas Small. Cedar was not the only resource available, the surrounding region was also utilised as pastoral grounds. The Aboriginal population suffered greatly due to the European settlement, with the occurrence of disease and massacres reducing the number of inhabitants. Towards the 19th century reserves were created to assist the local Aboriginal community in re-establishing itself (Statement of Heritage Impact, 1996).

The township of Grafton began as a cedar port, where timber was floated down stream to the port where it was subsequently loaded on to vessels for transportation to Sydney and other destinations. Ship building was also prominent until the 1900s onward, when the railways began to dominate overland transportation.

As the population of Grafton continued to grow and a railway line between Brisbane and Grafton was completed, the need for a river crossing was realised. Vehicular passage was originally achieved by a punt, and a ferry was utilised for transporting trains across the river. The passengers had to get off the trains and travel across on one of the ferries (they were given priority for places on the ferry), whilst the train carriages were transferred across two, three or four at a time on a barge. Two train barges were used for this purpose, the “Induna” and the “Swallow”. The “Induna” still exists on the southern bank of the river just west of the bridge and is now an overgrown, rusting hulk.

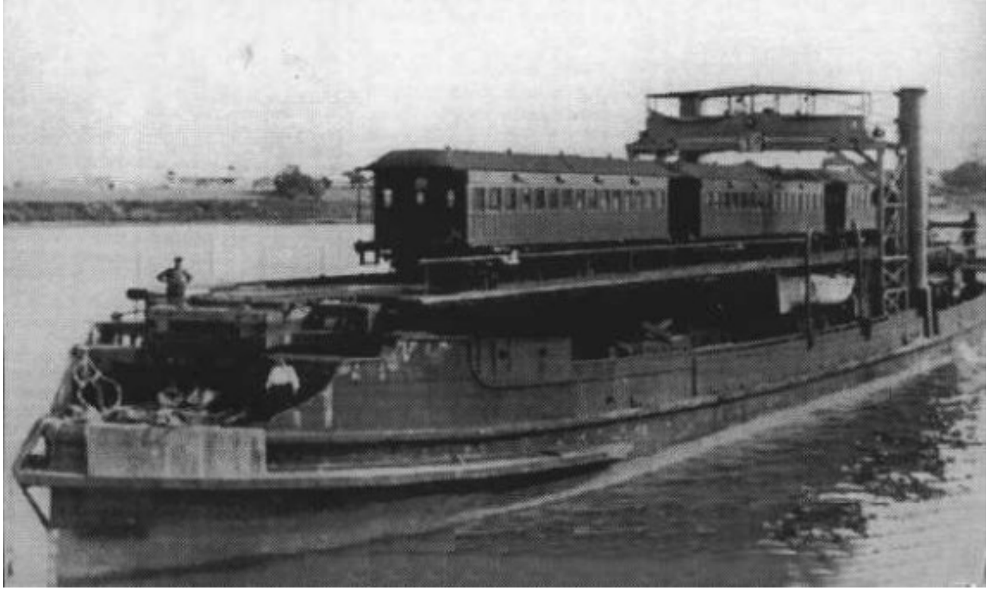


Figure 7.48 The “Induna” train barge in operation over the Clarence River in 1931 (Source: RMS photographic archives)

The high volumes of rail and vehicle traffic resulted in long delays across the river and the inadequacy of such an arrangement was noted in 1910 when the Chief Commissioner of NSW Railways wrote to the Department of Public Works in order to bring to attention the need for a bridge over the Clarence River at Grafton (NSW Heritage).

Preliminary plans and designs were completed a number of years before the bridge was to be built, however World War I forced the bridge to be placed on hold. Following the war, and after a number of site investigations, a final design was chosen which combined the road and rail bridge into a single crossing as this was deemed the most cost effective design (NSW Heritage: Grafton Bridge).

Design

The bridge is a series of Pratt trusses as modified and standardised for use on the NSW Government Railways (NSWGR) by PWD engineer James Waller Roberts. When the decision to construct the North Coast line from Maitland to South Grafton was taken in 1906, the intention was that “the track will be of first class character, capable of carrying the heaviest traffic and at the maximum speed”. This included such details as track geometry and bridges.

Roberts’ truss bridges have proved to be an enduring and important design and 22 of these bridges were opened on the North Coast line between 1911 and 1924. J.J.C. Bradfield supervised the drawings for the bridges and the railway as a whole, his last project before he devoted his life to the Sydney city railway and Harbour Bridge.

The truss spans of the Clarence River Bridge were generally based on Roberts’ earlier designs for North Coast bridges, although it also included a double-deck opening bascule span. So far as can be ascertained, this is the only bascule span on a heavy railway bridge with a road on the upper deck in the world. While the principle of the span is based on the 1901 US patent of Theodore Rall, it was designed and built by the NSWGR’s own engineers. The Rall patent involves moving rollers and is therefore suitable for a double deck bridge. Its most significant previous use was in the Broadway Bridge across the Williamette River in Portland, Oregon, USA, opened in 1913.

Figure 7.49 Broadway Bridge in Portland with double-leaf bascule span open (Source: Wikipedia)

The Broadway Bridge was a truss bridge and so essentially it was on two levels – the top and bottom of the truss. Therefore it needed the moving rollers to enable the truss span to open. The Clarence River Bridge took the design one stage further and to a new level of complexity by including a road laid across the top of the trusses. Apparently the only other double deck opening rail and road bridges in the world are in Chicago. These are basically road bridges, whereas the Clarence River Bridge is basically a railway bridge. The railway in the case of the Chicago bridges is a lightly engineered elevated suburban line and is above, not below, the road deck. In fact, the Chicago elevated is only slightly heavier in construction than a tram line. Therefore, the engineering challenges presented by the Chicago bridges were far more modest than those presented by the bridge at Grafton (EHA, 2009).

Construction and opening

Tenders for the bridge were requested with a closing date of 15 June 1926 and it was stipulated that only Australian steel was to be used. Only two tenders were received for the Clarence River Bridge: one from Dorman Long and Company, then building the Sydney Harbour Bridge, for £484,190; the other from John Grant and Sons for £499,250. As these were well in excess of the £400,000 Public Works Department estimate it was decided to undertake the works in house. The first rivet in the caissons of the bridge was driven on 11 June 1928. It was to cost £529,000, of which £83,650 was for the roadway. Clyde Engineering secured the contracts both for the caissons and the superstructure, to cost £22,000 and £144,500 respectively. Clyde had agreed to deliver all the steelwork by July 1930 and its opening was then expected sometime in 1931.

The upper (car) deck of the bridge was incomplete when the trains began to use the bridge in May, 1932. The Bridge was officially opened by Governor

General Sir Isaac Isaacs on Tuesday 19 July 1932. “Deafening cheers” followed Isaacs’ cutting of the ribbon, aeroplanes flew overhead, Grafton was bedecked with flowers, and crowds surged to walk over the bridge’s roadway (*Canberra Times*, 20 July 1932). Isaacs spoke expansively of the achievement, emphasizing the bridge’s national significance as the completion of the Grafton Bridge was the final link in not only the Brisbane to Sydney railway line, but it also completed the rail network from Cairns to the city of Perth *(The Argus*, 20 July 1932).

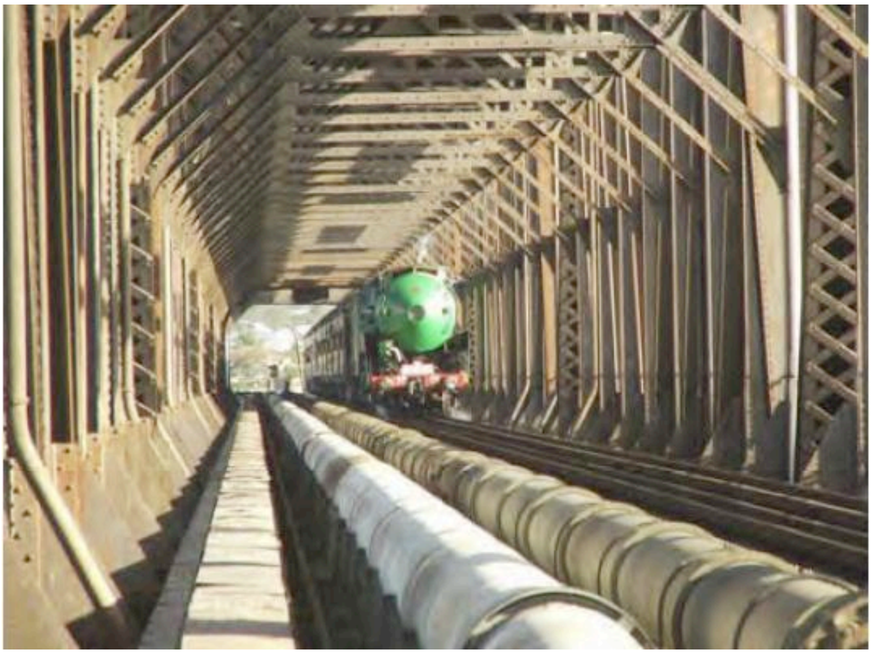


Figure 7.50 A special train hauled by Locomotive 3801 crosses the bridge in October 2005. The bridge was designed for two tracks, but the second track space is used for water mains (Source: Greg Mashiah)

Operational history

Prior to the construction of railways into Grafton it was a busy operational centre for coastal shipping which ran timetable services to and from Sydney and other coastal centres. Ships of the North Coast steam Navigation Company continued to operate in Grafton until 1954 when, largely as a result of the several phases of post-war shipping industry restructuring, the company went into voluntary liquidation.

Photos showing the bascule span open are rare; the image below is thought to date from the 1940s. Openings were complicated by the need to first disconnect water pipes and telephone cables that were installed on the lower deck which made for a lengthy process. No records are available of the lift span operation though the last known opening took place in the 1970s for a naval vessel (EHA, 2009).

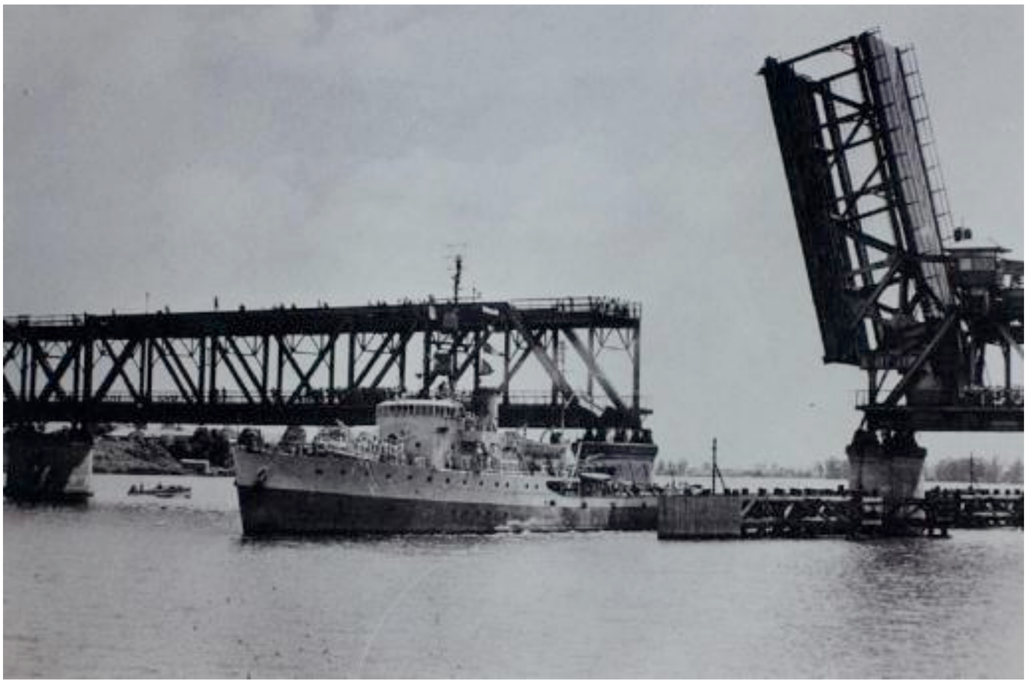


Figure 7.51 A RAN Corvette passes through the opened bridge, probably in the 1940s (Source: SRA Archives)

The Broadway Bridge in Portland Oregon, built in 1912, still opens on occasion. It is not popular with motorists as opening takes at least 20 minutes (Tilly, 2002).

Maintenance history

The bridge has bends at each end of the upper deck to allow the trains on the lower deck a straight path on and off the bridge. The bends were not considered a problem in 1932 considering the speed, size and number of cars and trucks around at the time, but because of the volume of traffic that now crosses the bridge, many consider the bends a nuisance and the bridge has come to be known by locals as the “Bendy Bridge”.

Semi-trailers often have to swing out wide to get around the bends, so drivers must be cautious when approaching them, in case they have to give way to an oncoming semi. In order to address this potential traffic hazard planning studies have been underway since 2004 to identify the location for a new bridge that would eliminate traffic risks on the Bridge by making it one-direction only.

More recently some of the concrete piers on the southern approach have undergone repairs. Minor cracks noted are due to by ground movement and differential settlement at the base of the piers. The installation of ground tie beams at the pier bases and stress bars in the headstocks have served to ensure that they are not compromised by further ground movement and subsidence in the future.

Figure 7.52 **View of concrete railway viaduct extending straight from the truss spans. The road approach span piers are angled or "bent" at deck level leading on to the truss spans**

7.5.2 Statement of significance

This bridge is a double-deck road/rail structure, the only one of its type in NSW and is acknowledged as significant to the State. It has a lift span to allow passing of river traffic but this is no longer used. It presents a commanding visual reminder of rail and road to residents of Grafton and is historically significant and its opening in 1932 completed the North coast standard gauge line between Sydney and Brisbane, avoiding the winding road route via Tenterfield. The viaduct along with the wharf remains are important relics of the development of the north coast railway. The viaduct is representative of similar structures constructed at a range of locations, many of which have been replaced. This bridge is a double-deck road/rail structure, the only one of its type in NSW. There is a lift span to allow passing of river traffic (no longer used). It presents a commanding visual reminder of rail and road to residents of Grafton. Opening of the bridge in 1932 completed the North coast standard gauge line between Sydney and Brisbane, avoiding the winding route via Tenterfield. The viaduct along with the wharf remains are important relics of the development of the north coast railway. The viaduct is representative of similar structures constructed at a range of locations, many of which have been replaced.

Source: NSW State Heritage Register

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Listed
OEH Heritage Division State Heritage Register	Listed
Clarence Valley Council Local Environmental Plan, 2012	Listed
NSW National Trust Register	Listed

Evolution of modifications

Grafton Bridge was essentially an adoption of the Rall type bascule bridge design. The bridge is derived from the American patented design and therefore is not the result of a sequential evolution in Australian designs.

7.5.3 Description of lift span mechanism components

Control cabin

The form and fabric of the control cabin component is EXCEPTIONAL significance.

The control cabin is mounted at deck level of the side of the of the approach truss (Figure 7.53). It is highly visible to the travelling public and provides a point on interest on the bridge.

Figure 7.53 Image of Grafton Bridge control cabin

Movable span

The form and fabric of the movable span component is EXCEPTIONAL significance.

The Grafton Bridge is a unique design which accommodates for both road and rail traffic. The railway is carried within the truss spans, with a road deck placed on top of the bridge. The movable span consists of a double decked cross section (Figure 7.54). Both decks are mounted off the same primary longitudinal Modified Warren type trusses as distinct from the fixed span approaches which are all Pratt Type trusses. The upper roadway then consists of a transverse Warren type truss supporting steel stringers and finally the timber deck.

The lower railway deck consists of a transverse plate web girder that supports steel stringers and finally the timber rail transoms.

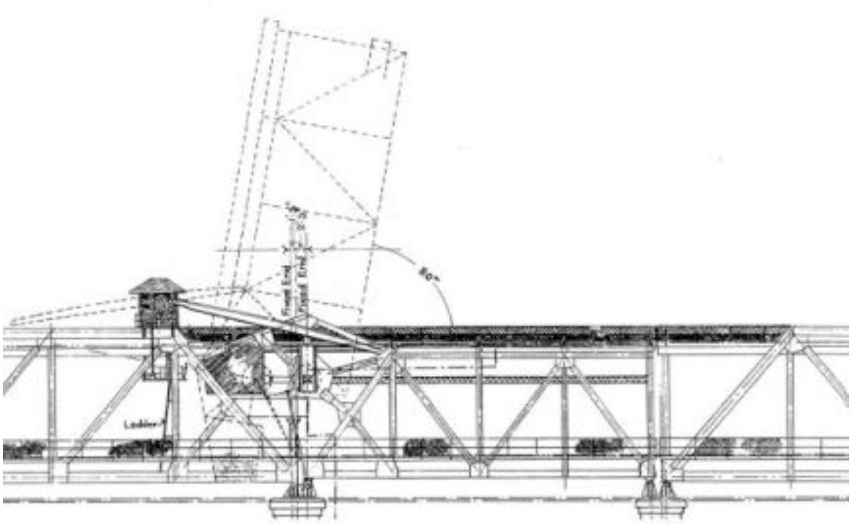


Figure 7.54 Elevation of Grafton Bridge

Counterweights

The form and fabric of the counterweight component is EXCEPTIONAL significance.

The counterweight utilised on Grafton Bridge consists of a number of segmented cubes that are stacked into a steel support frame and capped with armour concrete (Figure 7.55). The counterweight is fixed to the end of the lift span and acts to reduce the amount of force required to raise the bridge (Figure 7.56).

The counterweight is also fitted with a hinged leaf mechanism which effectively locks the counterweight in position when the movable span is in the closed position.

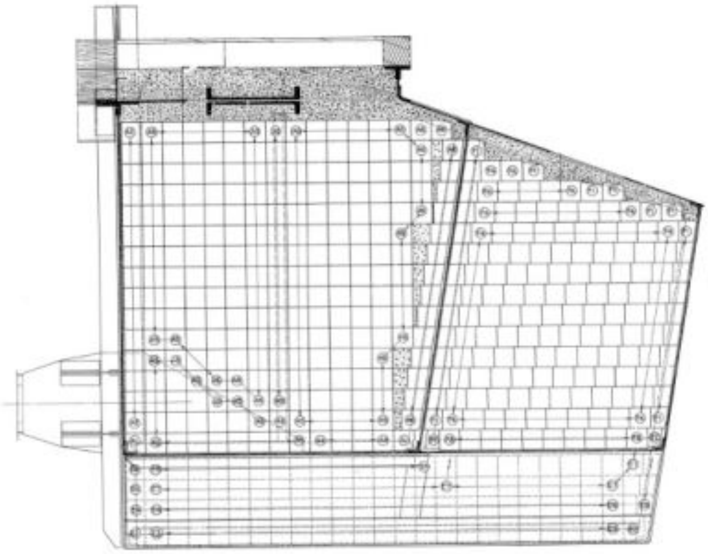


Figure 7.55 Grafton Bridge counterweight

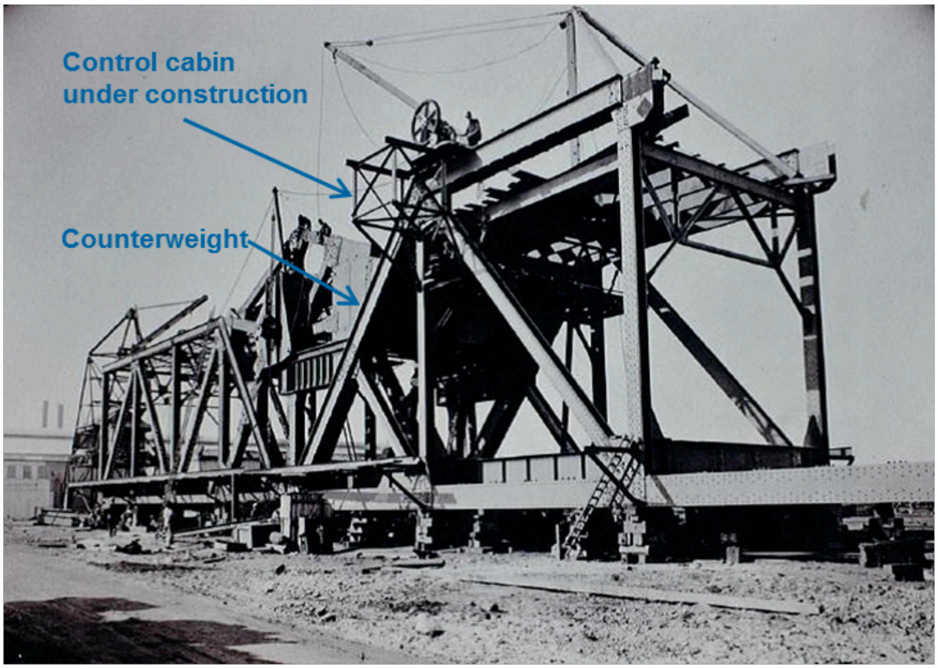


Figure 7.56 Trial assembly of bascule span and machinery for road/railway bridge at Grafton c1930 (Source: SRA Archives)

Mechanical components

The form and fabric of the mechanical components are EXCEPTIONAL significance.

The lifting mechanism implemented at Grafton is an interesting feature of the bridge. The main components of the mechanism consist of a steel beam with rack, rollers, electric motors, gears and shafts (Figure 7.57).

The driving force is provided by electric motors located underneath the control house. The electric motors transfer rotation through a number of shafts and gears before sufficient mechanical advantage is achieved to turn the final pinion. This pinion is connected to the rack on the main driving beam and as it turns it pulls the rack through the mechanism.

As the rack beam is drawn through the gearing mechanism the initial span movement is only horizontal, however the link, acting as a lower control arm, attached at the rear of the span becomes engaged and this new fixity results in the span pivoting and thus raising. The main weight bearing of the lift span is achieved by "Rall" wheels, acting as a large roller, which travel along a stiffened member on the adjacent fixed span. The main components of the system are notated in Figure 7.58 and Figure 7.59.

The rolling track is located at high level, supporting the structure directly at its centroid through the "Rall" wheels (Figure 7.60). As the bridge opens it both rolls and pivots on the Rall wheels, with the actuating arm and a lower control arm acting against each other to cause the deck to rotate upwards as it rolls back from the clear opening.

It is noteworthy that four guide wheels are mounted at the pinion to rack connection to prevent the rack lifting off during operation. Also a hinged leaf mechanism was designed to effectively lock the counterweight in position when the movable span was in the closed position.

Figure 7.57 Grafton bridge mechanical components

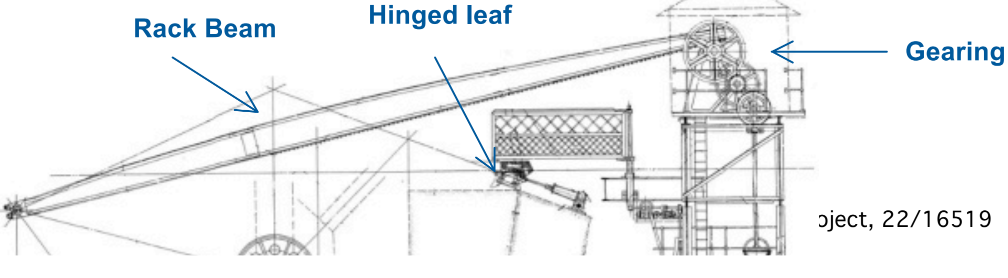


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Figure 7.58 Notated elevation of Grafton Bridge lifting mechanism

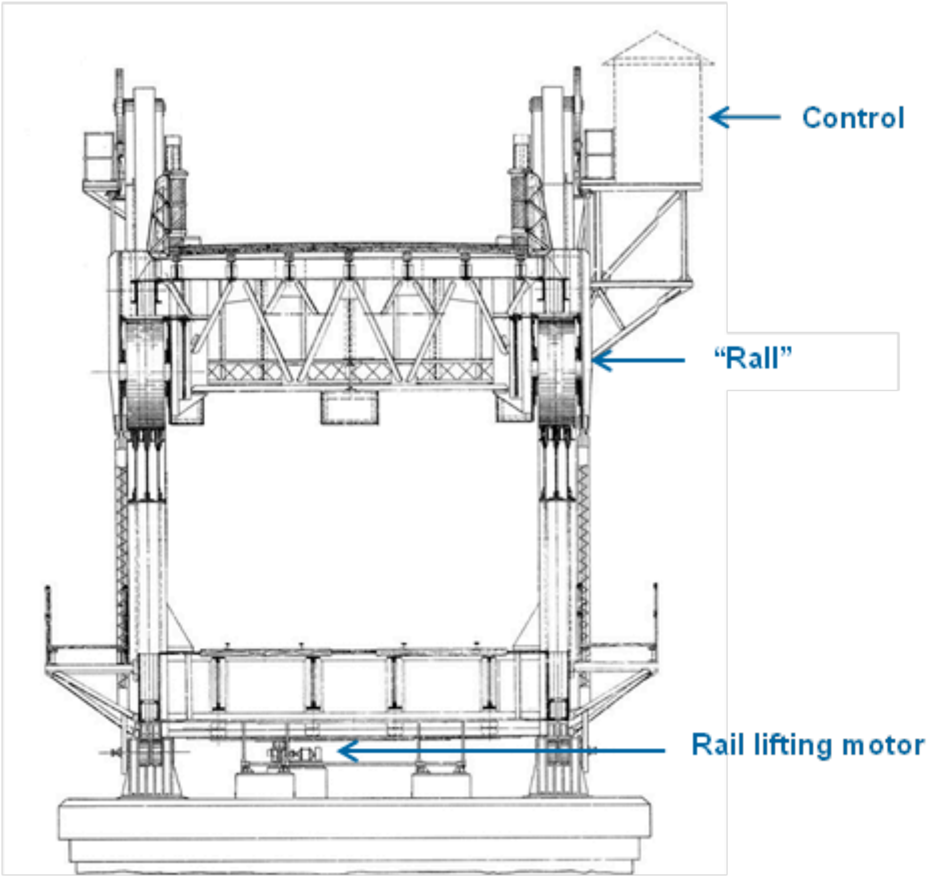


Figure 7.59 Notated cross section of Grafton Bridge lift span

Figure 7.60 One of the Rall wheels on Broadway Bridge (Source: Tilly). The deck is suspended from this wheel

Vehicle and pedestrian barriers

The form and fabric of the vehicle and pedestrian barrier components is HIGH significance.

The Grafton Bridge is fitted with the safety feature of gates and traffic lights at either end of the movable span. The gates are electro mechanically operated and are closed to prevent traffic from continuing whilst the bridge is being operated. When in the open position the gates are recessed into the lattice hand rail that is continuous along the bridge deck, see Figure 7.53 of cabin image above.

Motors and electrical

The form and fabric of the motors and electrical components are HIGH significance.

Grafton Bridge was operated by a sophisticated network of motors (

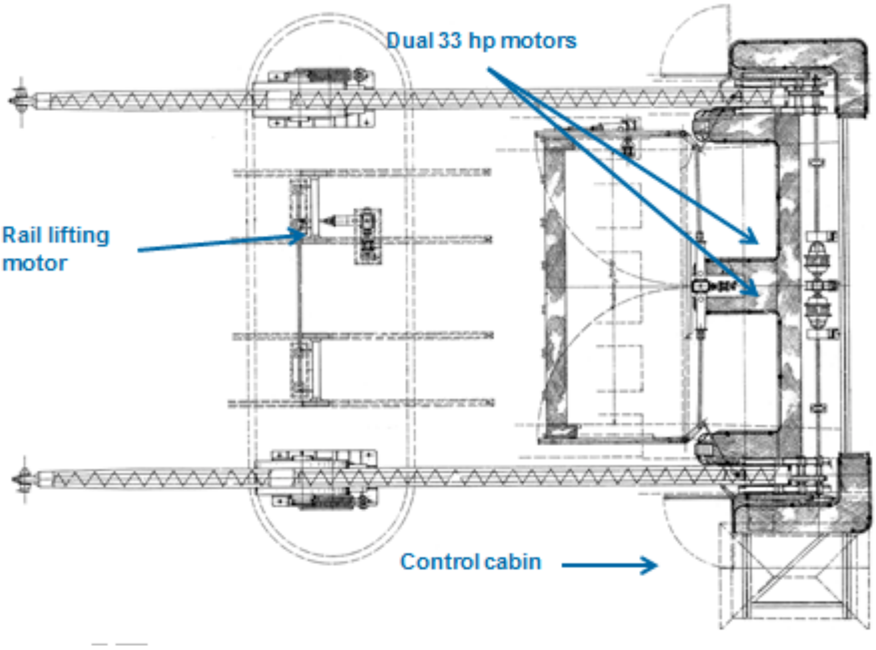


Figure 7.61).

The movable span was principally operated by dual 33 hp electric motors that are positioned below the centre line of the road deck. Additional sequential operating and braking motors facilitated the lift by:

- Closing the northern gates
- Closing the southern gates
- Open the railway track on the lower deck
- Open the hinge leaf to release the counterweight

To close the bascule the order was reversed.

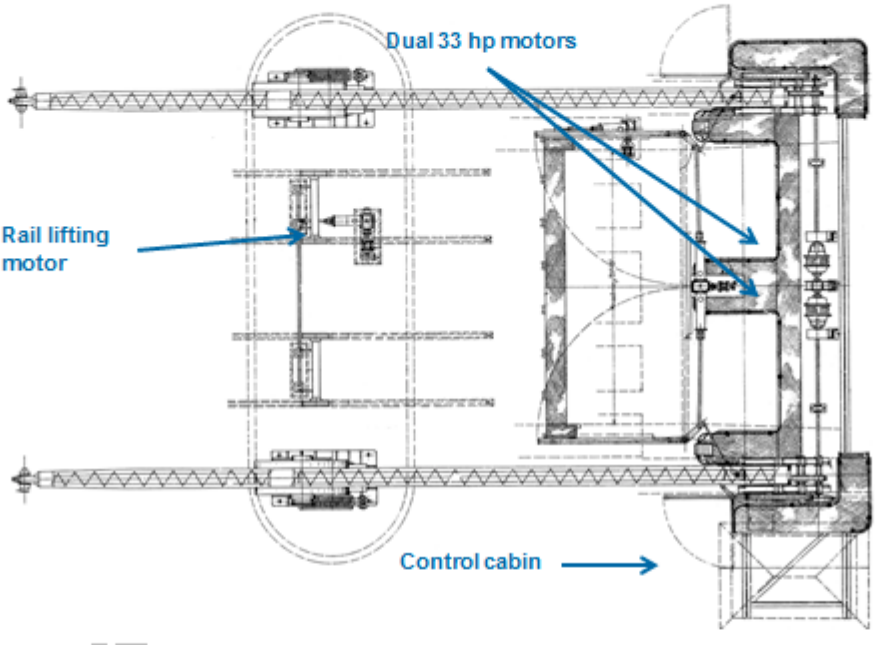


Figure 7.61 Motors on Grafton Bridge

Actions required in order to restore the bridge to lifting operation

- Inspect and overhaul:
- All electrical components and motors.
- Reinstate electrical control systems including traffic barriers and signalling.
- Movable span operating mechanism, counterweights and structure.
- Disconnect services including water and sewer mains.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-6 Grafton Bridge – Summary of heritage significance

Bridge Component	Significance Grading
Tower	EXCEPTIONAL
Control cabin	EXCEPTIONAL
Movable Span	EXCEPTIONAL
Counterweights	EXCEPTIONAL
Mechanical components	EXCEPTIONAL
Vehicle and pedestrian barriers	HIGH
Motors and electrical	HIGH

7.6 SWANSEA BRIDGE

(Simple Trunnion Type, built 1955)

7.6.1 Description of the Bridge

The bridge over Lake Macquarie at Swansea is a bascule type bridge which consists of a steel double leaf opening span each with clear lengths 29 ft. and twelve 40 ft. steel beam approach spans supporting reinforced concrete decking.

The double leaf span of the bridge generally consists of a specifically fabricated steel plate web girder which tappers towards the centre of the span. The supporting piers are integrated into the bridge and act as machinery housing for the lifting mechanism. The piers are a reinforced concrete construct that is founded on concrete piles.

Figure 7.62 The two Swansea Bridges raised for a charter fishing boat in 2013. Swansea Bridge (1955) is in the foreground

Development of roads and transportation in the Lake Macquarie area

The Swansea Channel is the entrance to the Lake Macquarie area which was discovered by mistake in 1800 when Captain William Reid entered the lake thinking it was the Hunter River. The area became known as Reid’s Mistake until 1826 when the name was changed in honour of Governor Lachlan Macquarie (NSW Heritage: Swansea Bridge).

The area surrounding the Swansea Channel was intended to be used as an Aboriginal reserve, however this was unsuccessful and the after the 1860s settlers began taking up portions of land on the northern side of the channel. The subsequent township was originally known as Kahibah. On the southern side of the channel a small settlement named Pelican Flat was established before the post office was finally renamed Swansea in 1887, with suggestions that the choice of name was due to the Welsh miners that had settled in the area (NSW Heritage: Swansea Bridge).

Swansea Channel was first bridged in 1881 as a passage for transporting stone form the local quarry on the southern shore of the lake to the break wall. Even this early timber bridge was fitted with a draw span to allow the passage of vessels. In 1909 this bridge was replaced with a timber bascule bridge shown in Figure 7.63.

Design and construction

This bridge served the Swansea area for 46 years before it was considered too deteriorated and also unable to cope with the traffic frequencies and higher loadings. Hence plans were made for a new bridge to be constructed. The solution adopted was a steel bascule bridge with the lowest possible deck level to reduce the approach span costs. The counterweights were also hung underneath the structure in this design (NSW Heritage).

Figure 7.63 Swansea Bridge 1909 (Source: The Bert Lovett / Norm Barney Collection and Cultural Collections at the University of Newcastle)

At the first calling of tenders for the work, no acceptable tenders were received. When fresh tenders were invited, the contract for the manufacture, supply and delivery of metalwork and machinery was awarded to Maschinenfabric Augsberg-Nurnberg of West Germany in late 1950. Although tenders for the erection of the bridge were invited on several occasions in Sydney and interstate, no tenders were received, and the Department undertook construction of the bridge by day labour, work commencing in 1952. The Department also constructed the approaches to the bridge.

The sourcing of materials overseas and the lack of contractors tendering for the construction of the bridge was symptomatic of post-War conditions where material shortages made contractors unwilling to bid for work. The new bridge was officially opened by the Hon. E. Wetherell, M.L.A., Minister for Transport on 14 December 1955. The final cost of the bridge was £280,000 and was wholly provided from Main Roads funds (DMR *Main Roads*, March 1948, p.74; March 1951, p.93; March 1956, pp. 68-69).

Maintenance history

In 2009/10 a new lift induction motor and gearbox were installed allowing smooth raising and lowering operation.

Operational history

Over the last 6 years the number of lifts has remained largely unchanged when viewed on an annual basis. The opening requirements are seasonal with the majority taking place during the warmer summer months. The lifts for 2011 exceeded those recorded at Spit Bridge making it the highest usage opening bridge of all those in the study at present. The single busiest month recorded is January in 2007 and 2010 when 275 lifts were logged.

Table 7-7 Record of lifts of the Swansea Bridge opening span between 2006 and 2011.

Lifts	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2011	246	110	157	199	126	100	127	130	124	168	144	191	1822
2010	275	163	164	209	124	117	134	103	128	162	161	205	1945
2009	251	158	166	151	112	122	129	127	124	159	160	207	1866
2008	240	144	224	140	155	120	116	117	119	174	137	198	1884
2007	275	190	164	193	163	70	89	121	134	155	138	214	1906
2006	243	167	136	179	127	102	118	132	129	142	155	213	1843

7.6.2 Statement of significance

The Swansea Bridge is of State historical, aesthetic and technical significance. Crossing Swansea Channel at the entrance to Lake Macquarie, the site and its associated history demonstrates the development of bridge building technology over a period of more than 100 years and contains some physical evidence of earlier crossings. The 1955 bridge, a double leaf bascule opening span steel and reinforced concrete structure, reflects the economic conditions of the period in which it was constructed, the metalwork being fabricated overseas and construction carried out by day labour due to the post-WWII shortages of labour and materials. Its design demonstrates the response to the need for a low-cost, low level bridge that allowed for the passage of water transport as well as road traffic. It is associated with the development of the Pacific Highway, the major coastal route between Sydney and Newcastle. Its history is also associated with the development of the coal and related industries in the area, which provided an important impetus for upgrading and improving road infrastructure. As a double leaf bascule span, the bridge is rare and a number of design features were used for the first time by the Department of Main Roads in this bridge's construction, making it aesthetically and technically significant. Its location across an important waterway - the Swansea Channel and entrance to Lake Macquarie – at the edge of Swansea town centre gives it a prominent position in the locality as a link connecting communities on the north and south of Lake Macquarie and as a popular recreational site for locals and visitors.

Source: RMS s170 Register

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Not listed
OEH Heritage Division State Heritage Register	Not listed
Lake Macquarie Local Environmental Plan, 2013	Not listed
NSW National Trust Register	Not listed
RTA s.170 Heritage and Conservation Register	Listed

Evolution of modifications

Swansea Bridge (1955) was essentially an adoption of the trunnion type bascule bridge design. The bridge is derived from the American patented design and therefore is not the result of a sequential evolution in Australian designs.

7.6.3 Description of lift span mechanism components

Operator work station

The form and fabric of the operator work station component is NO significance.

The operator work station for Swansea Bridge (1955) is built integrally within the southern bascule pier. This arrangement was adopted as a means of mitigating the aesthetic impact of the crossing. The work station consists of a reinforced concrete structure which also contains the lifting mechanism and span bearing points. The structure is founded on a number of concrete piles.

As part of the duplication works in 1989, the operator work station was relocated to the southern bascule control tower of the new south bound bridge. Consequently this bridge features no independent operating controls.

Figure 7.64 Swansea Bridge (1955) twin leaf bascule spans

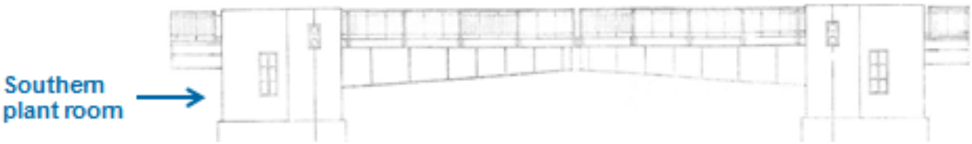


Figure 7.65 Western elevation of Swansea Bridge

Movable span

The form and fabric of the movable span component is EXCEPTIONAL significance.

The movable span of the Swansea Bridge consists of two leafs meeting at the centre. The leaves consist of primary plate web girders which taper at one end to a centre lock, with the pier end of the leaf consisting of a quadrant. Cast steel racks are attached to each quadrant. Each girder is strengthened by transverse web stiffeners. The primary girders support cross girders and rolled steel stringers before finally supporting the steel grate deck. Figure 7.66 shows the components of the movable span.

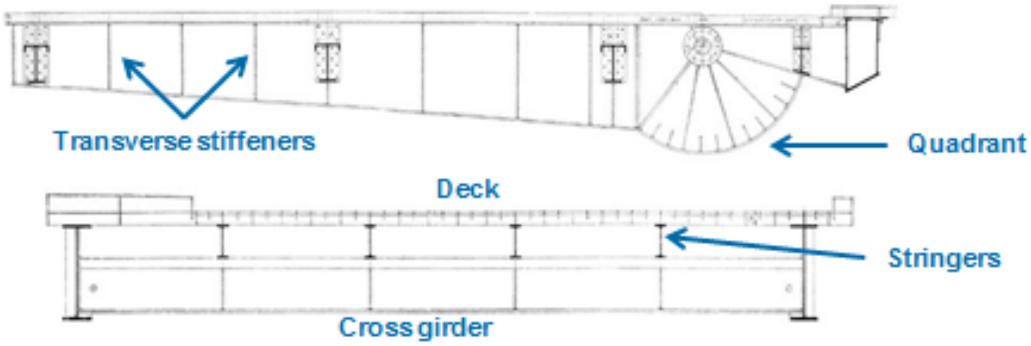


Figure 7.66 Swansea Bridge single leaf elevation and Cross Section

Counterweights

The form and fabric of the counterweight component is EXCEPTIONAL significance.

Typical of the "Simple Trunnion Type" bascule bridges is the placement of the counterweight below deck level. This is the first time this was implemented in NSW and it marks a significant safety improvement to motorist. It also provides unimpeded overhead access for vehicles. The counterweight consists of a large reinforced concrete block. The arrangement and trapezoidal shape of the counterweight also ensures that as the span is raised the difference between the span self-weight and counterweight centre of masses is maintained as both pivot about the same point during operation.

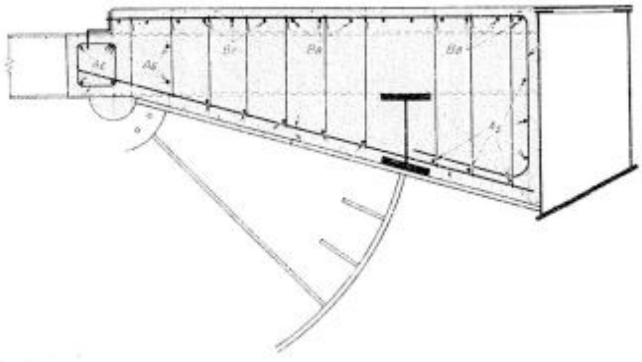


Figure 7.67 Counterweight for Swansea Bridge 1955

Mechanical components

The form and fabric of the mechanical components are MODERATE significance.

The post war technologies employed in bascule machinery are significantly more sophisticated and complex than those seen in the Narooma type bridges.

The mechanical components on Swansea Bridge consists of an electric motor, a number of gears and shafts along with a cast steel rack bolted to the quadrant of the movable span girder (Figure 7.68).

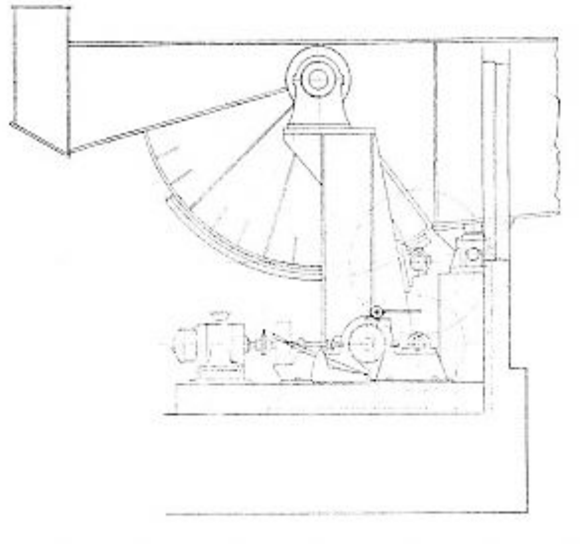


Figure 7.68 Swansea Bridge lift mechanism

As noted, the driving force of the mechanism is provided by an electric motor which drives a number of gears into a horizontal shaft. This transfers the rotation into the gear box before gaining sufficient mechanical advantage rotate the common drive shaft. At the end of the drive shaft is mounted a pinion which is keyed into the rack teeth of the quadrant. Thus when the pinion works on the rack the quadrant rotates and the span rises (Figure 7.69).

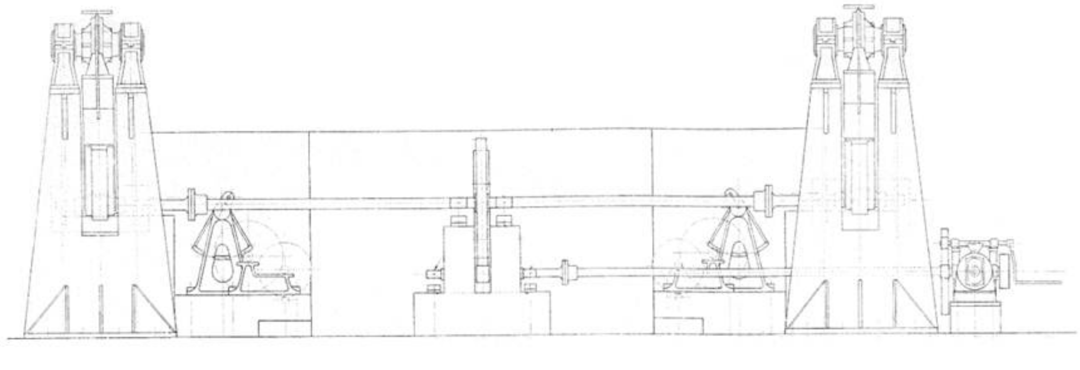


Figure 7.69 Swansea Bridge elevation of operating mechanism

The braking mechanism for the operation consists of a spring-on-off thruster brake which was originally operated by a lever and cast iron brake drum mounted on the side of the gear box (Figure 7.70).

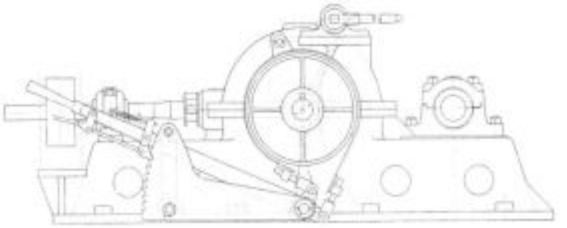


Figure 7.70 Swansea Bridge drawing of Brake Mechanism

Since the bridge is a double leaf bascule there is a lack of end support where to two spans meet in the centre. The design for Swansea Bridge adopts two mechanisms to achieve a firm support when the spans are closed. The first is the forward bearing component located at the start of the span. As evident in Figure 7.71, when closed this component compresses onto the V shaped block bolted to the underside of the girder. This ensures that an even and secure bearing is achieved.

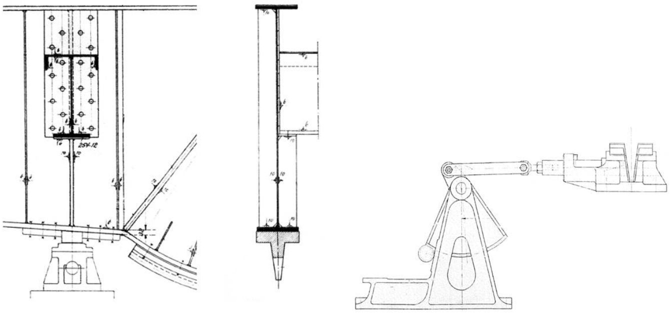


Figure 7.71 Forward Bearing Mechanism for Swansea Bridge

The second mechanism used is the centre lock. As evident by Figure 7.72 the centre lock consists of a gravity actuated system, whereby as the span is lowered the weighted actuator link causes the lock to engage, thus completing the closing operation.

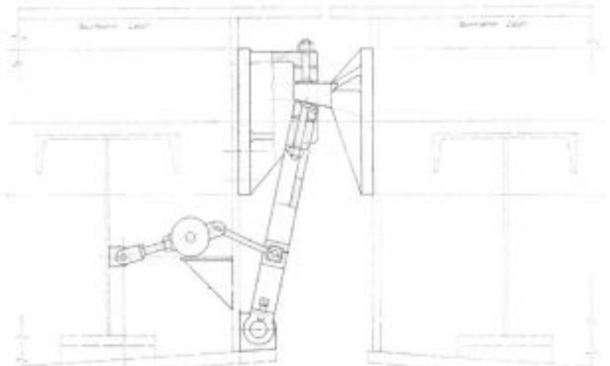


Figure 7.72 Centre Locks for Swansea Bridge

Vehicle and pedestrian barriers

The form and fabric of the vehicle and pedestrian barrier components is LOW significance.

The original gates were positioned either side of the movable span (Figure 7.73), however these have since been removed.

Swansea Bridge (1955) was later fitted with the new gates and traffic lights at either end of the bridge approaches. The gates are electro mechanically operated and are closed to prevent traffic from continuing whilst the bridge is being operated.

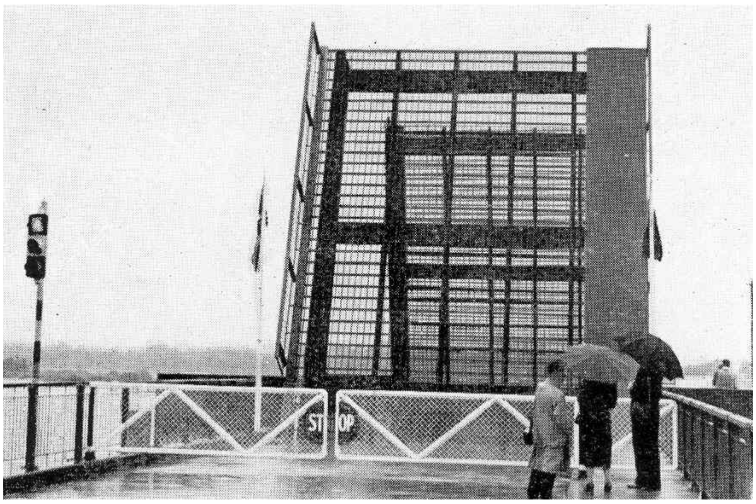


Figure 7.73 Swansea Bridge (1955) in raised position

Motors and electrical

The form and fabric of the motors and electrical components are LOW significance.

There are a number of electric motors integrated to operate the Swansea Bridge (1955) movable span. They consist of the primary driving motor and secondary forward bearing mechanism motors.

Over time the trunnions had become worn allowing excessive ‘play’ and dynamic loads on the lifting mechanism especially when breaking the span during the opening. This raised serious concerns regarding the possibility of damaging the quadrant, rack teeth and associated mechanisms. Such an event would result in the bridge being out of operation for extended period. Therefore in 2009/10 a new lift induction motor and gearbox were installed allowing smooth raising and lowering operation.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-8 Swansea Bridge – Summary of heritage significance

Bridge Component	Significance Grading
Operator work station	NO
Movable Span	EXCEPTIONAL
Counterweights	EXCEPTIONAL
Mechanical components	MODERATE
Vehicle and pedestrian barriers	LOW
Motors and electrical	LOW

7.7 SPIT BRIDGE

(Simple Trunnion Type, built 1958)

7.7.1 Description of the Bridge

The Spit Bridge over Middle Harbour can be described as a steel and concrete girder bridge with a bascule lift span (Figure 7.74). Spit Bridge comprises 7 spans of a total length of 745 feet 6 inches (227.28 m), has 4 traffic lanes (44 feet or 13.41 m wide) and a pedestrian walkway of 5 feet (1.5 m) on either side.

There are three spans at either end of the opening span. Each of the six fixed spans have four welded plate girders as the main members, with cross girders, but without stringers or horizontal bracing. The concrete deck is dowelled to the steelwork.

Figure 7.74 Spit Bridge with bascule span in the open position in 2002 (Source: RMS photographic archives)

The two footways are of concrete on the fixed spans, and steel on the bascule span. The piers either side of the opening span are flanked by fenders, and when the bridge is in the open position a navigation channel of 80 feet wide is created.

The main pier which supports the bascule span is Pier 4 (Figure 7.75). It rests on four cylinders taken down to sandstone bedrock at a depth of between 45 to 75 feet which is 75 to 105 feet below mean sea level. The pier is box-like and supports all machinery for the operation of the bascule, including the operator's cabin.

Figure 7.75 Pier 4 – Western end – This is the main pier that supports the Bascule Span (Source: Austral Archaeology Pty Ltd 2002)

Development of roads and transportation in the Mosman area

Prior to the construction of permanent bridge crossings, large areas of Sydney Harbour could only be traversed by boat. The establishment of defensive works at Georges Head helped to open up the headland beyond Mosman. In 1829 Barney Kearns applied to the Government for a licence to operate a ferry service across Middle Harbour, to travel between Chinaman's beach and Clontarf (McLaren 1978:48). By 1832 a track was established from North Sydney to Middle Harbour, following a route roughly in line with Military and Spit Roads. Apparently it was developed specifically to provide overland access to the ferry, thus linking travellers to Manly and Pittwater (Sturrock 1982:16). The path was considered to be quite rugged and is shown on some early maps of the suburb. Nearby a long narrow sand spit jutted out into Middle Harbour. The formation is unique within the Sydney area and was called Burrabra by the Cammeragal but was known more simply as the Sand Spit by European settlers (Sturrock 1982:32).

One of the earliest historically recorded attempts to cross Middle Harbour from Clontarf back to the western shores around The Spit occurred in July 1789. A party led by Captain Hunter which had ventured north to explore Pittwater and Broken Bay reached Clontarf on their return before a boat had arrived to meet them. A first attempt by one of the party to cross using a small bark canoe found lying on the beach failed as the craft capsized and sunk. They then built a raft which also proved useless and eventually two men volunteered to swim the distance of approximately 500 metres to reach Parriwi Point before continuing on foot to the *Sirius*.

The nearby Spit was effectively one of the narrowest harbour crossing places, and a punt is first thought to have been operated in 1849 by Peter Ellery (and later his son). Hand-powered, it ran along cables and remained in used until its replacement by Government steam driven punt (McLaren 1978:48).

According to some sources a crude manual punt was in operation earlier than 1849 but no further detail is known (Sturrock 1982:16). An account of the wreck of the *Dunbar* dating to 1857 makes reference to a location known as “Hillery’s Spit”, around which bodies and cargo had washed up. This is thought to have been a corruption of Ellery’s surname, showing that as the sole occupant, the Spit was referred to by his name (Sturrock 1982:32).

As settlement expanded it followed that transportation requirements increased to service the area. Richard Harnett, who had helped to establish regular ferry services to the northern shores, was also instrumental in initiating road transport in the form of horse-drawn omnibuses (McLaren 1978:64). They ran from Milson’s Point to Middle Head and remained in service until the commencement of tram services (Sturrock 1982:61). In 1871 road widening was being carried out along Military Road and Manly residents were hopeful that the improvement programme would extend north thus allowing:

...the inhabitants... to be able to drive to Sydney (a distance only the same as that from the South Head), by connecting manly with the approaches to the punt now being completed by the Government at Middle Harbour... (from Champion and Champion 1998:131)

In February 1871 an advertisement offering the lease for a Government ferry at the Spit was placed in the Government Gazette but it is unclear whether Peter Ellery or his son continued to work as its operator. Various dates have been suggested for the commencement of operation of the Government ferry, but most suggest this was sometime during the 1880s (McLaren 1978:48; Sturrock 1982:37). At this time, as a safety precaution, the sand spit was built up and fenced off with brush, but was still very narrow. Even as late as 1900 when the trams ran up to the punt, water and sand often reached the level of the tracks (Gamble 1976:24).

In 1893 electric trams ran between North Sydney and Spit Junction with services extending to the Spit by 1900. Cheap transportation allowed the suburbs to be further opened up and a period of home building in the Mosman area followed the arrival of the trams (McLaren 1978:65).

By 1891 the Spit still seems to have been largely undeveloped. There were three stone houses at the foot of Spit Hill to accommodate the punt operators, but no boatshed was in place. The punt that serviced Seaforth was steam driven and ran from a jetty on the south-eastern shore.

Most of the activity at the Spit itself was associated with sailing and recreational activity. Boatsheds and private moorings were built some time after 1891 and from 1903 the Middle Harbour Aquatic Clubs would conduct regular fundraising events for the North Shore Hospital (Phelan 1993:109).

The first Spit Bridge crossing at Middle Harbour

From as early as 1861 plans for a bridge crossing over Middle Harbour were considered (Souter 1994: 184). A high level structure near Clontarf was ruled out mainly for financial reasons, but by 1881 the Government realised that the punt would eventually need to be replaced by a permanent structure. The punt was thought to be:

> *…acting as a check on the proper expansion and prosperity of the Manly district and [it was considered] that something should be done to relieve the intolerable traffic congestion then prevailing* (Bickford 1927:3).

A plan for a low-level opening bridge at the Spit was proposed in 1888 but was rejected. At this stage most traffic would still be using ferries and punts elsewhere on the harbour so plans were put on hold (Souter 1994: 184). The first bridge was intended to provide a temporary solution to the growing traffic demands and congestion at Spit Junction in the early 1920s. Weekend road traffic on the northern beaches was growing along with local users, and with news that a large bridge would soon be built over Sydney Harbour, plans for Spit Bridge could go ahead. At this time the New South Wales Government was encouraging local councils to finance their own bridges rather than rely on the Department of Public Works to undertake such projects. As a result the Manly Council was keen to build a fairly utilitarian structure in a short space of time to alleviate immediate problems (Bickford 1927: 4). Permission was granted in State Parliament for the Sydney Harbour Trust to design and build a low level bridge (Souter 1994:185).

Certain physical constraints affected the design of the bridge and the approaches. A new alignment for Spit Road was constructed and on the northern side a road was cut through the rock face to help eliminate dangerous hairpin bends that had characterised the northern route to the punt. The road level on the rocky northern shore now sat around 10 metres above the sand spit and the Bridge was built with a different gradient either side of the opening span (Bickford 1927;40. The road on the southern side was prone to landslides and was considered unfit for increased traffic. To solve this problem work was started in 1923 on a new road on the west of the hill (towards Pearl Bay). This was named Spit Road and the old alignment was renamed Parriwi Road, meaning eastern point (Phelan 1993; 110).

Borings into the harbour bed at this time also showed that a deep deposit of sand and clay lay over the bedrock making the construction of foundations for a more substantial structure difficult and more expensive than could be met with the available funds (Bickford 1927: 3). The navigation channel is located towards the Spit side sands where the rock bed falls away. The cheapest option for the required opening was to build a bascule span and with the underlying sand as a foundation it was necessary to spread the load over a double-opening (Bickford 1927: 8).

Work commenced in May 1924 when the first pile was sunk, and was carried out by the Sydney Harbour Trust in conjunction with manly Council. By the 23rd of December the same year it was open to traffic (RTA 279.167). The completed structure was mainly a timber beam span construction with piers, walings and braces sheathed in wrought iron. The opening span consisted of a double leaf bascule (Bickford 1927: 4-8). Trams could not be accommodated on the bridge and tram passengers would have to alight and walk across under a covered walkway (Figure 7.78) (Souter 1994:185).

Figure 7.76 First Spit Bridge under construction in 1924 (Source: MSB 4881, RMS photographic archives)

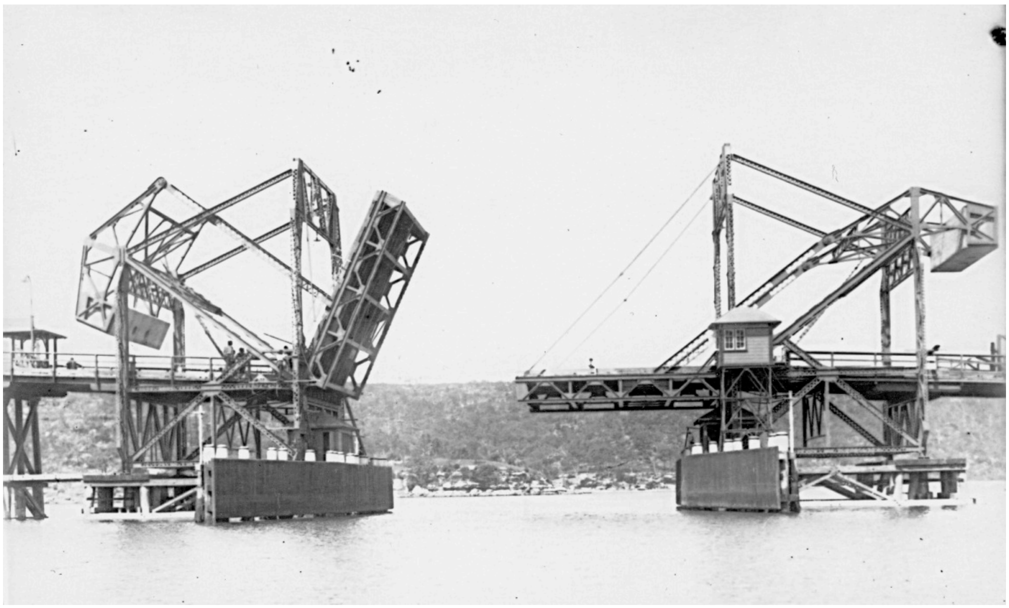


Figure 7.77 View of the first Spit Bridge during opening trials in September, 1924 (Source: MSB 4842, Graeme Andrews collection, RMS photographic archives)

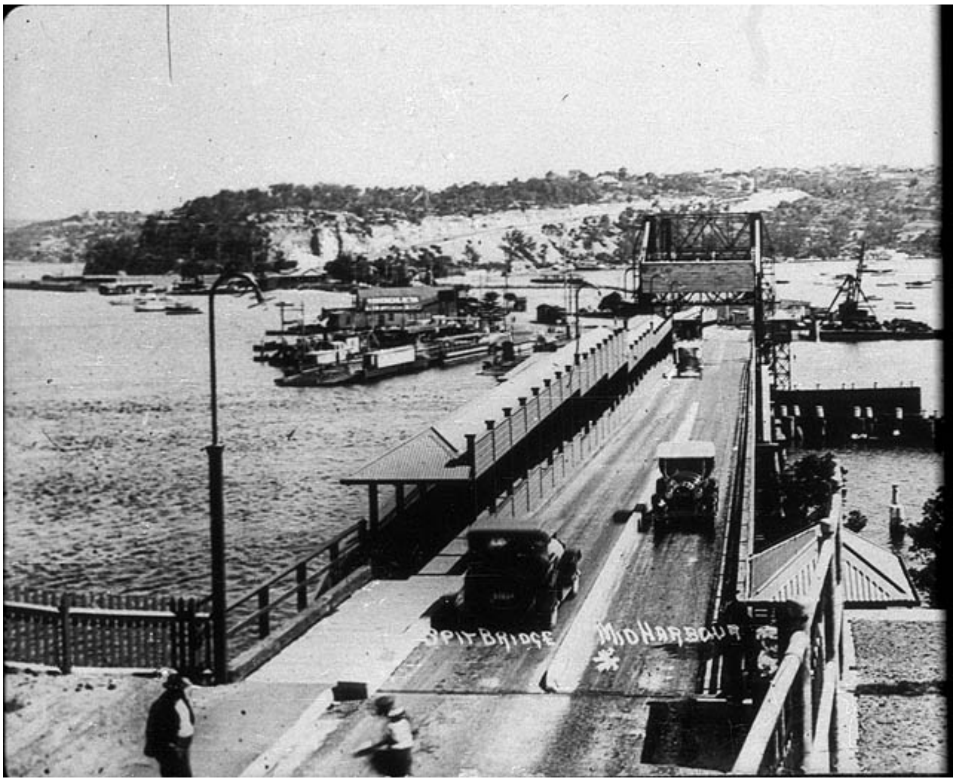


Figure 7.78 View of the first Spit Bridge looking south in 1940 (Source: State Library of NSW). The covered pedestrian walkway is at left

The new wooden bridge was opened on December 23, 1924 by Premier Sir George Fuller, even though the Manly Council had outlaid the full £60,000. The outlay was recompensed by a toll and so busy was the traffic that the bridge become toll free in 1930. On January 1, 1929, 8,677 vehicles made the crossing.

An operator was employed to open and close the bridge to maritime traffic and ensure that it was properly maintained. The operator of the lift-span had a set of red and green lights which he could use to hold vessels up on one side to allow others through first. Whichever side had the public ferry on it always got the first green light.

The Second Spit Bridge

As early as 1927, only three years after the first bridge was completed, it was noted that the amount of traffic using the bridge was higher than expected and the subsequent revenue from tolls providing a financial boon. Use of the bridge had risen by 60% over that of the punt for the year prior to the bridge opening, but with this improved access came problems of a different kind. It was noted at the time that:

> *While the bridge solved a traffic problem which existed prior to its construction, it has created a traffic problem of its own, because of the facility it provides for people desirous of travelling to Manly and the many beaches to the north* (Bickford 1927:13).

In 1934 a proposal was put forward to widen the existing bridge. At a public meeting held at Manly one year later, it was moved that the Government be approached to build a new bridge. Congestion from increasing traffic, particularly at the weekends, was the reason put forward (RTA 279.167). Four years later the Manly Council and Manly-Warringah Chamber of Commerce again called for a replacement but were informed by the Minister for Transport that:

> *…there was no immediate possibility of any action being taken to widen the bridge, or to provide a new bridge* (RTA 279.167).

However not all parties wanted a new bridge to go ahead. The Warringah Direct Transport League campaigned against further bridge works at the Spit, preferring instead that a new Middle Harbour bridge be built further west connecting Sugarloaf Point and Seaforth, thus leaving the current bridge to deal with local traffic only (*Daily Telegraph*, 7/7/39).

Road users weren't the only ones to find fault with the bridge. The line of the navigation channel meant larger vessels, such as the Showboat "Kalang", experienced difficulty in squaring up to the bridge opening as they passed from the upstream side. A rocky projection extends into the channel requiring vessels to change their line of approach causing additional delays not experienced by smaller craft (RTA 279.1122).

In 1940 the Main Roads Board commissioned a survey of the Spit and its surrounds for the purpose of building a new bridge with an improved road alignment. Construction could not go ahead until after the end of World War II but preliminary designs had been developed by 1944 (RTA 279.1122). As plans proceeded for another low-level bridge, deputations from councils and community groups continued to push for the erection of a high-level bridge, but to no avail. In 1948 the response from the Department of Main Roads maintained that a high-level bridge would best be placed further up Middle Harbour, serving a larger number of communities. Given this, and the constraints of local topography, it was felt that:

> *…the high cost of building a high level bridge and the resultant spoliation of The Spit area for recreation purposes would not be warranted* (RTA 279.1122).

By 1949 the Government officially acknowledged that the old bridge had become inadequate to meet the demands of traffic. Frequent openings for marine vessels were causing long delays and the matter was receiving unfavourable publicity. Due to the coverage given to one particular delay an Alderman for the Mosman Council was led to pose a "Question Without Notice", suggesting that the matter of bridge delays be further raised at the next Committee Meeting (*TD*, 1/6/49).

Shortly afterwards the announcement was made that a new bridge was to be built. It would be slightly higher than the old one, requiring an opening span for large vessels to pass through. Most community groups and local residents remained unconvinced that a new bridge of this nature would alleviate any traffic problems.

> *Owing to excessive cost in erecting a structure sufficiently high to avoid the necessity for an opening span, there will still be traffic hold-ups – improved mechanical devices for opening the bridge will no doubt, reduce the duration of these, but some nuisance will still be caused* (*TD*, 17/6/49).

The number of road users was considerably higher than that of marine craft and the paper further added that:

> *Attention should be given to the possibility of reducing the extent and frequency of these hold-ups by restricting the hours… during which water transport may pass under the bridge. It seems rather absurd that one small craft may at will hold up possibly hundreds of vehicles on the road* (*TD*, 17/6/49).

Details of the new design, including an artist's impression of the finished structure, were published in December 1949. This described the bridge as being of a more substantial nature than its predecessor (concrete construction), twice the width and of better appearance (*Main Roads*, 1949: 48-50).

In May 1950 the first advertisements were placed calling for tenders (both Australian and international) for the construction of a low-level, opening span bridge at the Spit. The closing date was in October 1950, but at the request of some international companies, an extension of six weeks was granted to allow time for their engineers to visit the site (RTA 279.1122).

The successful tender, announced in early 1951, came from an English firm, The Cleveland Bridge and engineering Company, Darlington. Two contracts were let, the first of which was for the manufacture, supply and delivery of the metalwork and machinery for the proposed steel and reinforced concrete bridge, while the second was for its construction. Most parts of the bridge were to be prefabricated in England and the value of Contract No.1 was £173, 361 in pounds Sterling. The second contract, for construction was for £384, 981 in Australian pounds (*Main Roads*, 1951:125). Due to the position of the bridge both Mosman and Manly Councils were listed as the local municipal authorities.

The new bridge was to be built downstream of the existing wooden structure, and would be higher and wider, carrying four lanes of traffic and two footways. Designed by the DMR the bridge would be of concrete and steel with seven plate girder spans and one opening span, a total of 745 feet in length. The opening span would be an electrically driven single-leaf bascule that would allow marine traffic to pass through. The entire superstructure was to be steel, while the substructure was concrete. Depending on the position of the piers some foundations would sit on bedrock (up to 100 feet below the water) and the rest on concrete piles. Once finished the bridge would need an operator, housed in a control cabin with views over both harbour and road traffic. It was anticipated that opening the span and letting water traffic through would take no longer than three minutes (*DMR*, 1949:48-50). In addition, work was also to commence on improving the road approaches, finally eliminating the steep one-way roads with hair-pin bends that were still in use on the Manly side (*Sunday Herald*, 19/8/51).

Construction of the second Spit Bridge

Work on the bridge site was carried out under the supervision of DMR Metropolitan Engineer, Mr. L. Hawley in conjunction with the contractor, The Cleveland Bridge and Engineering Company (CBEC). As noted above most materials were to be supplied from England. All steelwork was to be prefabricated and finished in England, minimising the amount of work to be done on site (*DMR*, 1959:81). Construction work commenced in September 1952 and almost immediately problems arose which were to be the start of many in the years ahead. Minor complaints were received from residents protesting about excessive smoke from the cranes and the company worked on alleviating such problems (*Sydney Morning Herald*, 13/12/52). By 1954 the first of numerous disputes between the workers and the company had arisen.

In February 1954 the Australian Workers Union wrote to the DMR asking them to make more land available near the bridge to build amenities for workers. The employer had been unable to provide adequate facilities due to the limited space and this had caused:

> *Much discontent…among members of this union because of the inadequate provision of washing facilities, dressing rooms etc*. (RTA 279.1188)

During the year problems over labour intensified. A crane-driver was sacked, leading to a month long strike. Disruptions to progress were attributed to union “go-slow” tactics and rolling strikes and the Australian spokesman for the company was quoted as saying that:

> *In forty-five years of bridge building I’ve never seen as much trouble as I’ve seen in the eighteen months I’ve been on this job* (RTA 279.1226).

In a communication with the DMR, Mr Clinch, Chief Bridge Engineer, summed up the delayed progress of works as resulting from a combination of factors including industrial troubles, lack of suitable plant and delays in getting an active start on the contract (RTA 279.1226). In January local supplies of cement were no longer available and the company had to import 1000 tonnes from England, again causing delays. The industrial dispute from 1954 involving crane-drivers led to a ruling from the Federal Conciliation Commissioner ordering all three unions involved in bridge works to attend a compulsory conference on the dispute and for those still on strike to return to work (RTA 279.1226).

Another problem from the employers was what they considered to be high rates of absenteeism. Cleveland Bridge and Engineering again wrote to the DMR in May 1955 stating that considerable delays had resulted from an accumulated loss of work hours. To combat the problem they proposed that an additional one hour of overtime be worked each day. They also introduced a “bonus” scheme whereby those workers who took no sick leave in a 12 month period, would at the end of a year’s service be paid for the five days instead (RTA 279.1188).

By November, realising that the bridge could not be completed within the stated time, the CBEC officially requested an extension of the contract period to July 1958 (RTA 279.1188). This obtained they continued, despite further setbacks. Poor weather and industrial strife had delayed work on the foundations and again in 1956 there were more problems. A strike by 12 men over pay rates halted all work on the bridge. As they were already receiving above award rates of pay, their claims were not viewed favourably.

The weather also contributed to delays. Floating pontoons were used to move materials about the site and to lift bridge components into place; large swells and windy conditions on the harbour often made it impossible to carry out these operations. When, in August 1956, the contractor was ready to lift the bascule into place, the weather was so bad that the task was delayed until mid-October (RTA 279.1188). Some two years later it was still not in position. Finally in June 1958 another attempt to place it went forward. The trials of the project were followed with great interest in the press and the *Sydney Morning Herald* carried the story of the impending lift. The Titan, the largest floating crane on the harbour with a capacity of 120 tonnes, would attempt to lift the bascule from the nearby span where it had been assembled. Taking a few hours to complete this time it was successful (*SMH*, 17/6/58). The bridge was then closed to shipping for two weeks while final adjustments were completed.

As the July 1958 deadline approached bridge work was again behind schedule. To speed up progress the CBEC introduced a night shift in early June (RTA 279.1188). Other problems were now to force delays, this time in relation to the roads. Continued campaigning by local residents and Mosman Council helped to gain a last minute reprieve for recreational land on the Reserve forming part of the intended alignment for the southern approach. At this late stage the DMR agreed to change their plans, saving a larger portion of the Reserve and reducing considerably the number of pine trees that were to be removed (*TD*, 13/6/58).

On Wednesday afternoon, on the 19th November 1958 the new bridge was finally opened to traffic for the first time, but with no official opening ceremony. Only Sydney-bound traffic could use the bridge until a temporary connection with the northern approach was completed (*DT* 19/11/58). Scheduled to open at 3:00pm, the opening actually took place some fifty minutes earlier, disappointing numerous onlookers, and some guests, who arrived at the well publicised later time. As one man commented:

> *I've been waiting seven years for this day and the show kicks off early* (*DT*, 20/11/58).

The first to cross the bridge were two young cyclists who raced ahead of the waiting cars. At 4:00 pm foot traffic was allowed onto the bridge and a Miss Dorothy Riddle was reported as the first pedestrian. Apparently Miss Riddle had promised her father (deceased ten years earlier) that when a new bridge opened she would cross in his place. Mr. Riddle had apparently built the first house at The Spit in the 1880s when only the hand operated punt was in use. He had attended the earlier bridge opening in 1924 as a guest of honour (*Sunday Telegraph*, 23/11/58).

The final cost of the bridge was approximately £1,100,000, well over the budget projections. The bridge had taken four years longer to complete than anticipated and it was reported that during construction a total of 12 months had been lost due to 33 separate industrial disputes while difficulties in building the foundations had also caused delays (*DT*, 20/11/58). Work was continuing on the road approaches and would be finished sometime in early 1959.

Even as late as November 1958 some residents still hoped that the old bridge would be retained to carry additional traffic over the narrow waterway. *The Daily* ran a story at this time noting that the old bridge was to be put up for sale. Mosman Council had decided against keeping the structure and it was now to be offered for sale by the builders. They suggested that it was worth £15,000 “on the spot” or else it could be broken up and delivered.

After its first morning in operation a small news item was carried in the *Sydney Morning Herald* under the caption “Bridge Opening Delays Traffic” (*SMH,* 21/11/58). A barge scheduled to travel under the bridge at 6:45 am had been delayed and when the opening span was lifted only half an hour later city-bound traffic was stalled stretching back over a mile. Senior traffic officers and police stated however, that the opening had gone very well and expected traffic to run more smoothly in the future (*SMH* 21/11/58). Some minor teething problems were experienced with getting the bascule to close smoothly over the next few weeks and some modifications were carried out (RTA 279.1188).

A local paper was a little more enthusiastic in its coverage of the bridge’s opening. A piece entitled “At Last! New Spit Bridge is opened” also ran on November 21st. Although the northern approaches were not completely finished the bridge was finally opened to through traffic (*TD*, 21/11/58).

It was now possible to start work on the demolition of the old bridge, expected to take up to five months (*SMH*, 27/2/59).

Approximately 4 years after the expected completion date and at a total cost of £1,100,000 the bridge was finally opened to the public on the 19th of November 1958. Figure 7.79 shows the bridge soon after its opening in 1958, it also shows the first Spit Bridge still in operation.

Figure 7.79 Spit Bridge soon after opening in 1958 (Source: RTA File 279.167 pt 3)

Operational History

The Spit Bridge has the highest level of usage of all of those in this study. Soon after its opening it was noted that the bascule span worked about twice as quickly as had the first Spit Bridge which averaged around 600 lifts annually (RTA 279.1188).

Table 7-9 records the number of lifts for the Spit Bridge for a year from each decade since it opened in 1955. While incomplete the trend appears to be of increased usage until the 1980s that has tapered back since. This may be due to a reduced number of boats wanting to pass through the channel or better regulation by operators in ensuring that lifts take place only at listed times (so restricting informal lifts) or a combination of both these factors.

The highest recorded month was in December 1995 with 380 separate lifts.

Table 7-9 Record of lifts of the Spit Bridge opening span

Lifts	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2011	182	151	148	146	117	116	123	117	140	153	150	175	1718
2005	251	196	201	199	178	170	171	171	174	196	204	246	2357
1995	286	224	229	244	190	178	210	202	204	231	245	380	2823
1983	347	277	276	256	267	211	205	270	244	272	309	330	3264
1974	249	257	214	236	241	168	190	146	222	217	237	248	2625
1964	219	171	167	127	150	99	103	144	131	155	151	178	1795
1956	162	100	101	120	86	78	101	101	122	141	120	148	1380

Lifts	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1955										139	106	132	377

Maintenance History

Table 7-10 Summary of works undertaken on the Spit Bridge

Year	Nature of works
1961	Replacement of No. 4 Gate on opening span after accident.
1968	Alterations to lift span controls.
1969	Work undertaken on the braking system for bascule span.
1977	Repairs to bascule span locking mechanism, some new steel required.
1979	Non-skid surface on steel grid of bascule span was renewed.
2006	Bascule span bearings replaced.
2012	Supply, fabricate and install components for Spit Bridge upgrade. All new opening mechanisms and platforms within Pier 4.

7.7.2 Statement of significance

The Spit Bridge, completed in 1958, is of State significance.

It is a substantial landscape feature that has played a crucial role in allowing the development of the northern beaches suburbs to occur over the last 44 years. The Bridge is also extremely rare as it is the only lift bridge still operational on a major arterial road. As such, the Spit Bridge is representative of all the major lift bridges that were once a common sight throughout NSW. The relative lack of modification to the original design of the Bridge also contributes to its level of significance. Historically the Bridge has a high level of significance developed primarily through being part of an important local transport route that has been in operation over a large period of time in several different guises.

The Spit Bridge Cultural Landscape also contains the remnant features and locales of the former bridge and punt crossing and the remains of other transportation links such as the tramways. These additional items add to the significance of the Bridge through their ability to add to contextualise the current bridge as a single element of the crossing points colourful history.

Source: RMS s170 Register

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Not listed
OEH Heritage Division State Heritage Register	Not listed
Manly Local Environmental Plan, 2013	Listed
Mosman Local Environmental Plan, 2012	Listed
NSW National Trust Register	Not listed

Evolution of modifications

Spit Bridge was essentially an adoption of the trunnion type bascule bridge design. The bridge is derived from the American patented design and therefore is not the result of a sequential evolution in Australian designs.

7.7.3 Description of lift span mechanism components

Operator work station

The form and fabric of the operator work station component is EXCEPTIONAL significance.

The control tower offers 360 degree views at the operator's level to best enable the monitoring on marine and road traffic. It forms a significant element of the vertical profile of the Bridge and is a source of interest and curiosity to the general public (Figure 7.80). The manner in which the Control Tower is integrated within Pier 4 is a marked improvement over previous lift span bridge designs as it allows safe and unobstructed access for the operator into the machinery level by means of a fully enclosed spiral staircase. Early examples of control cabins used at the first Spit Bridge are essentially add on arrangements as were the engine house/ control cabins used on the early vertical lift bridges. Figure 7.81 shows an operator in the work station in 1958.

Figure 7.80 Control tower for Spit Bridge

The only alterations to the Control Tower since construction include the introduction of a split system air conditioner for operator comfort and modern electrical equipment fitted into a button operated control panel along the western side of the cabin for the machinery of the bascule span, traffic signals, navigation lights and gate mechanisms. The original control panel has been refitted twice and is shown in the three separate configurations below.

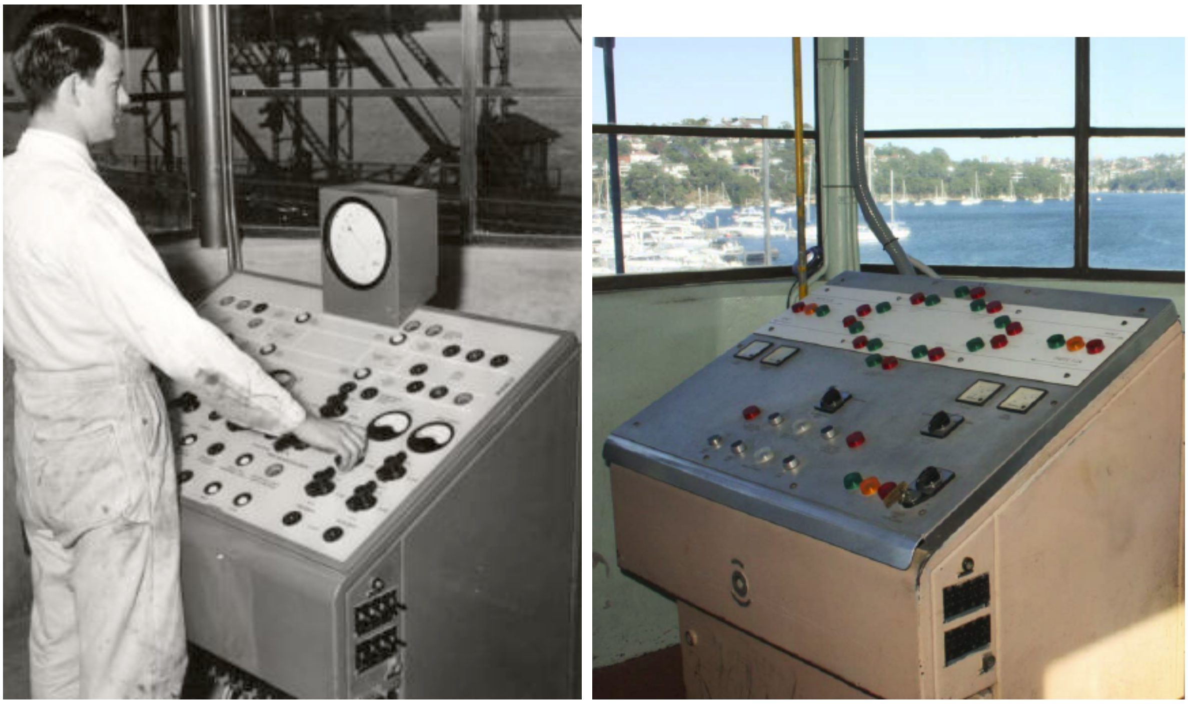


Figure 7.81 **Operator inside control tower with original and remodelled work station (Source: RMS photographic archives 1955 + 1998)**

Figure 7.82 **Operator using new touch screen controls installed as part of 2012 upgrade**

Movable span

The form and fabric of the movable span component is EXCEPTIONAL significance.

The lift span is a single-leaf bascule type and forms Span 4 of the Bridge (Figure 7.83). The lift span consists of two main longitudinal girders, supporting cross girders and stringers that finally support a light-weight open mesh steel deck. The deck has been surfaced with a coating of epoxy compound, in order to increase its adhesiveness and prevent vehicles skidding whilst on the Bridge deck. The steel deck is less than half the weight of a comparably sized concrete deck allowing for a reduction of the size of all the operating machinery and counterweight.

Figure 7.83 Open steel deck looking south

Counterweights

The form and fabric of the counterweight component is MODERATE significance.

The counterweight consists of a large reinforced concrete block. The arrangement and trapezoidal shape of the counterweight also ensures that as the span is raised the difference between the span self-weight and counterweight centre of masses is maintained as both pivot about the same point during operation.

The counterweight is placed below deck level which was a design favoured on aesthetic grounds. It is also a significant safety improvement for motorist as it eliminates the possibility of a counterweight dropping onto the deck. Another advantage is the unimpeded overhead access for vehicles. This design was previously used on the second Swansea Bridge completed in 1955 which is still in operation.

Mechanical components

The form and fabric of the mechanical components are MODERATE significance.

The method of operation of the bascule span machinery is distinctly different to that in place on the remaining intact Strauss bascule bridge at Narooma Bridge due to the variation in the placement of the counterweights. Many similarities exist with the machinery in place on the second Swansea Bridge though it is on a considerably smaller scale with an alternate arrangement. The bascule span machinery at the Spit Bridge is therefore assessed as a unique and exceptionally significant item of engineering heritage.

A general view of the bascule span stripped down and undergoing tests at Darlington, England prior to dispatch to Australia can be seen in Figure 7.84.

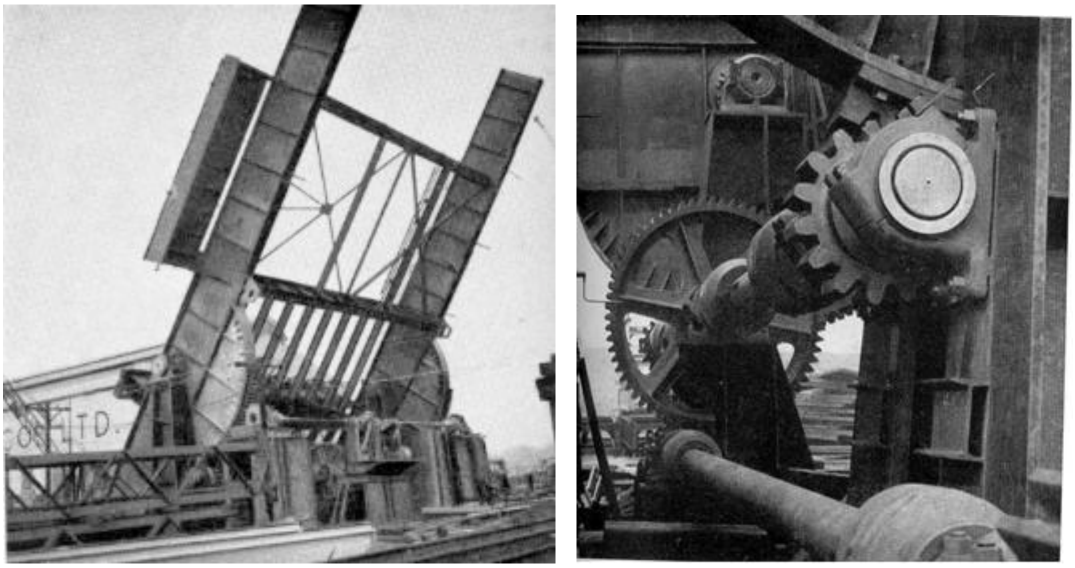


Figure 7.84 View of the trunnion end of the bascule span detailing the machine-cut racks on the curved ends of the plate girders

The driving force of the mechanism is provided by an electric motor which drives a number of gears into a horizontal shaft. This transfer’s rotation into the large centre gear thus gaining sufficient mechanical advantage rotate the common nickel steel drive shaft. At the ends of this drive shaft are mounted pinions which are keyed into the rack teeth of the quadrants. Thus when the pinion works on the rack the quadrants rotate and the span rises. The entire counterweight and span pivot about trunnions which are supported in bearings mounted either side of the girders. Components of the mechanism are given in Figure 7.85 to Figure 7.86.

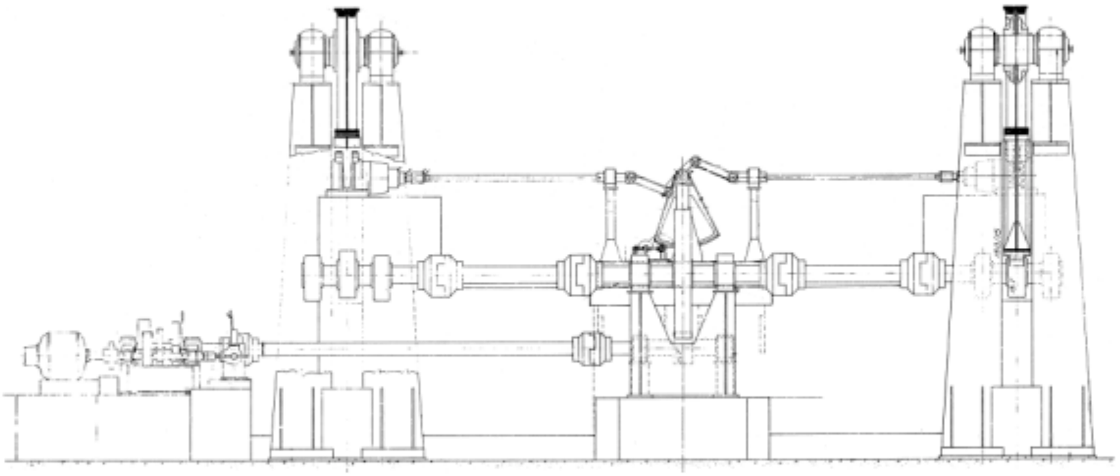


Figure 7.85 Spit Bridge elevation of operating mechanism

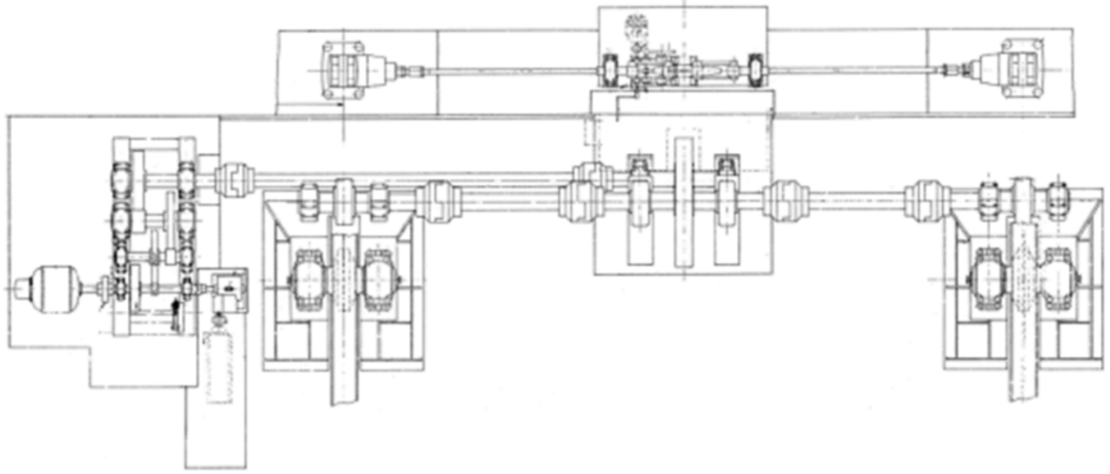


Figure 7.86 Spit Bridge plan of operating mechanism

As noted previously, the scale of the machinery adopted on the Spit Bridge is extremely impressive. Figure 7.87 depicts a worker undertaking maintenance on the center gear and the image gives an appreciation of the size of the mechanical components.

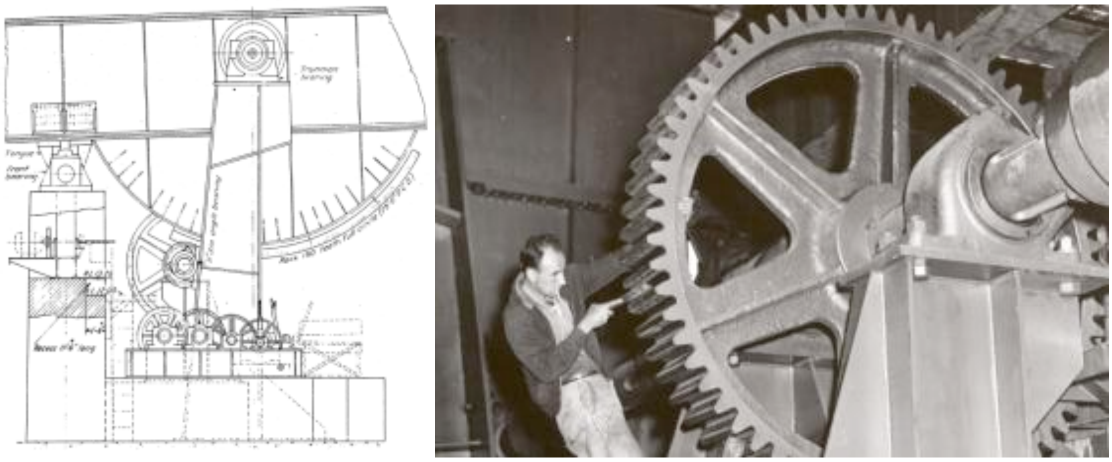


Figure 7.87 Elevation of mechanism and image of maintenance being undertaken on Spit Bridge centre gear (Source: DMR HO 8617, Oct 1958)

Figure 7.88 Centre gear, shafts and trunnion prior to 2012 upgrade

When in the closed position the movable span bearing upon two support mechanisms located adjacent to the quadrant and the other at the span end. The first support consists of a front bearing mechanism with a v shaped block that sits within a v shaped clamp that is compressed to maintain a firm bearing. Locking of these clamps is achieved electro-mechanically. The span end rest on pier and bearing is achieved through the interlocking of a tapered wedge that projects from the top of the bearing pad with an opening on the underside of the bascule span encasing this wedge when closed (Figure 7.89).

Figure 7.89 Detailed view of tapered wedge and opening on underside of bascule span (Source: 2006 Spit Bridge SOHI)

Vehicle and pedestrian barriers

The form and fabric of the vehicle and pedestrian barrier components is LOW significance.

The original vehicle barriers consisted of a retractable barrier that sunk into the road deck (Figure 7.90). These barriers are no longer utilised with modern vehicle barriers having now been added. The pedestrian barriers are a simple gate and these are still in place.

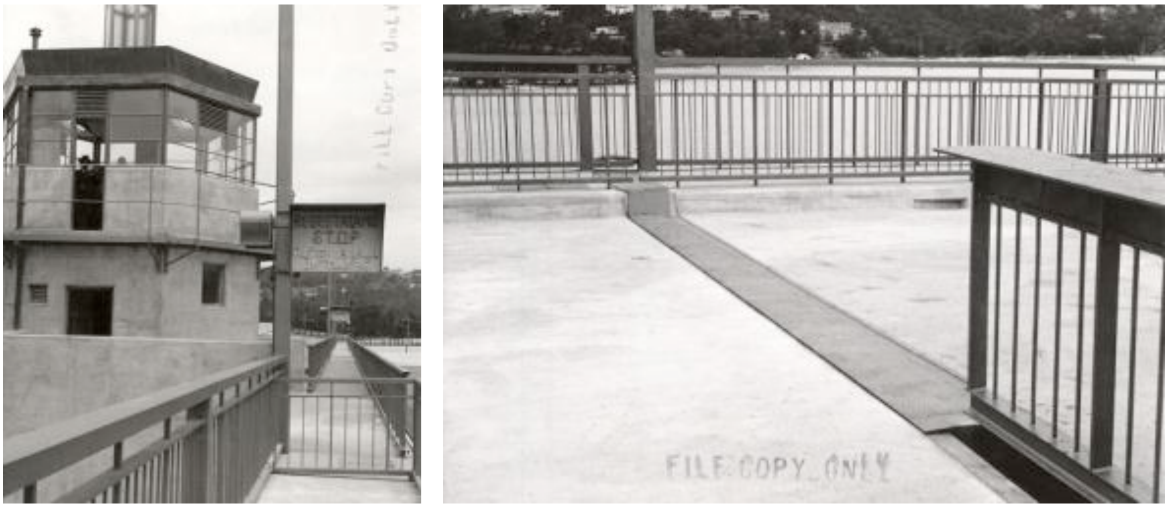


Figure 7.90 Spit Bridge pedestrian and vehicle barriers (Source: DMR HO 8685 & 8686, Oct 1958)

Motors and electrical

The form and fabric of the motors and electrical components are LOW significance.

There are a number of electric motors integrated to operate the Spit Bridge movable span. They consist of the primary driving motor and secondary forward bearing mechanism motors.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-11 Spit Bridge – Summary of heritage significance

Bridge Component	Significance Grading
Operator work station	EXCEPTIONAL
Movable Span	EXCEPTIONAL
Counterweights	MODERATE
Mechanical components	MODERATE
Vehicle and pedestrian barriers	LOW
Motors and electrical	LOW

7.8 SWANSEA BRIDGE

(Simple Trunnion Type, built 1989)

7.8.1 Description of the Bridge

The 1989 bridge over Lake Macquarie at Swansea is designed a duplication of the previous bascule type bridge built in 1955; however there are still a number of differences between these bridges. The Swansea Bridge (1989) consists of a steel double leaf opening span, each with clear lengths of approximately 9 m and twelve approach spans with lengths ranging from 12.2 to 12.7 m.

The double leaf span of the bridge generally consists of a fabricated steel plate web girder integrated with a reinforced concrete deck. As with the 1955 Swansea Bridge, the supporting piers are integrated into the bridge and act as machinery housing for the lifting mechanism. The piers made of reinforced concrete are founded on concrete piles and the control cabin for the structure is mounted on Pier 3. The separate components that make up the bridge are shown in Figure 7.91 and Figure 7.92.

Figure 7.91 General view of Swansea Bridge (1989)

Figure 7.92 Aerial view of the two Swansea Bridges (Source: Jenkins and Tilley, 2011)

Development of roads and transportation in the Lake Macquarie area

As noted previously, the Lake Macquarie area was discovered by mistake in 1800 by Captain William Reid when he entered the lake thinking it was the Hunter River. The name Reid's Mistake was adopted for the area until 1826 when the name was changed in honour of Governor Lachlan Macquarie (NSW Heritage: Swansea Bridge).

Swansea was originally settled as Pelican Flats until 1887 when the post office was given its current name. The choice of name has been linked to the Welsh miners that had settled in the area (NSW Heritage: Swansea Bridge).

The Swansea area was an attractive location for early industry, with the region being utilised for fishing and cultivating the land for vegetation. By 1863 well established fisheries were producing up to 70 tons of cured fish per year. Coal loading, storage depots and ship building were also among the early industries that continued to push development in the area (Swansea Chamber of Commerce).

The first known bridge across Swansea Channel was constructed in 1881 and it provided a passage for transportation of stone form a local quarry. It is noteworthy that even this early timber bridge was fitted with a draw span and it highlights to importance of the channel and shipping in the area. In 1909 this bridge was replaced with a timber bascule bridge which implemented counterweights on a curved track as the lift mechanism. The bridge was operational in Swansea area until 1955 until it was deemed unacceptable to cope with the higher traffic volumes and greater loadings. The 1955 Swansea Bridge was thus built, it was a different type of bascule bridge that was designed with the lowest possible deck level to reduce the approach span costs (NSW Heritage: Swansea Bridge).

By July 1969 plans were initiated to build a second bridge over the Swansea Channel as a means of upgrading the Sydney-Newcastle Freeway. However these plans were not realised until 1989 when the duplicate bridge was built. The design was completed by Rankine & Hall Pty Ltd Consulting Engineers and the Bridge was officially opened on the 21st of May 1989 by the Hon. Peter Morris M.P and the Hon. Robert Webster M.P (Swansea Chamber of Commerce).

Operational History

For lifts – see previous Swansea Bridge entry.

Maintenance History

Between 2002 and 2012 a significant amount of rehabilitation and maintenance work was undertaken including the following major activities:

- All four luffing cylinders overhauled.
- Centre locking cylinders overhauled.
- Centre lock rollers overhauled.
- Hydraulic lifting circuit modified back to original design intent.
- Control panel upgrade including PLC and SCADA.
- Control cabin upgrades.
- New fenders and dolphins.
- Deck re-sealed with MMA.
- Impressed current cathodic protection installed to all piers.

7.8.2 Statement of significance

The Swansea Bridge (1989) is of local historical, aesthetic and technical significance.

A double leaf bascule opening span steel and reinforced concrete structure it largely mirrors the form of the adjacent 1955 bascule bridge forming a unique complex of twinned opening bridges in NSW. It is distinguishable from the 1955 bridge as it features a control tower which is a significant element of the vertical profile of the Bridge and is a source of interest and curiosity to the general public.

It is associated with the development of the Pacific Highway, the major coastal route between Sydney and Newcastle. Its location across an important waterway - the Swansea Channel and entrance to Lake Macquarie – at the edge of Swansea town centre gives it a prominent position in the locality as a link connecting communities on the north and south of Lake Macquarie and as a popular recreational site for locals and visitors.

Heritage Listings

Listing	Status
Australian Heritage Database (formerly the Register of the National Estate)	Not listed
OEH Heritage Division State Heritage Register	Not listed
Lake Macquarie Local Environmental Plan, 2013	Not listed
NSW National Trust Register	Not listed
RTA s.170 Heritage and Conservation Register	To be listed

Evolution of modifications

Swansea Bridge (1989) was essentially an adoption of the hydraulically actuated trunnion bridge design. The bridge is derived from the American patented design and therefore is not the result of a sequential evolution in Australian designs.

7.8.3 Description of lift span mechanism components

Operator work station

The form and fabric of the operator work station component is EXCEPTIONAL significance.

The operator work station on the Swansea Bridge (1989) is located within a control tower built integrally with pier 3 (Figure 7.93 to Figure 7.94). The control tower offers 360 degree views at the operator's level to best enable the monitoring on marine and road traffic. It forms a significant element of the vertical profile of the Bridge and is a source of interest and curiosity to the general public.

The station is a reinforced concrete structure which is finally founded on a number of concrete piles. The machinery is encased inside the piers either side of the clear span. These piers are constructed with a number of chambers allowing for the lifting mechanism and associated equipment to be housed.

Figure 7.93 Control tower of Swansea Bridge (1989)

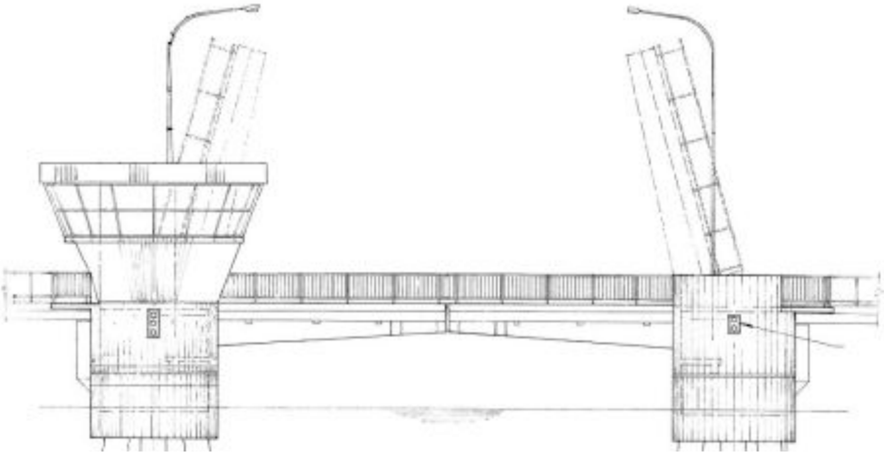


Figure 7.94 Original Elevation of Swansea Bridge (1989)

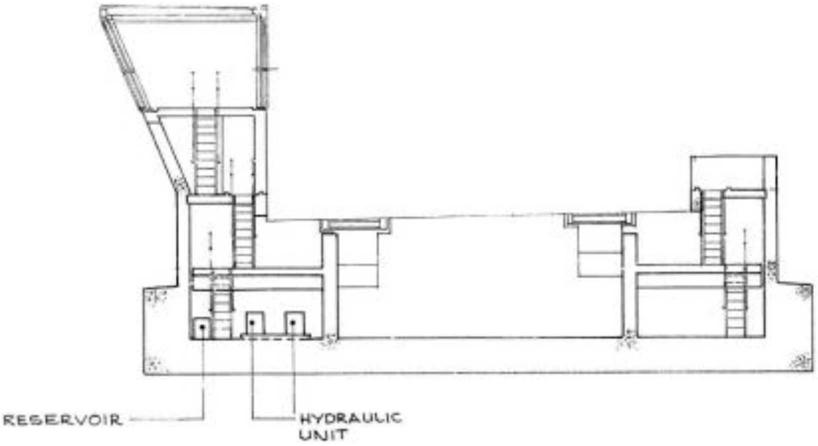
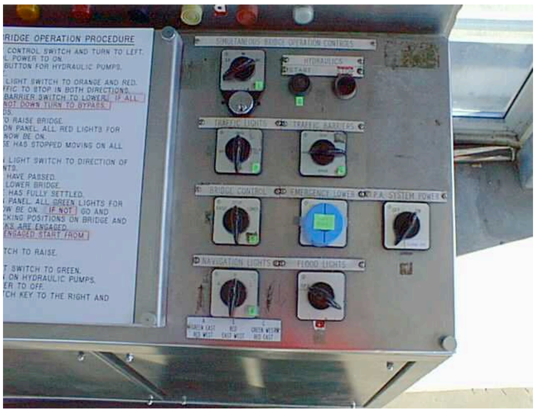


Figure 7.95 Section of Swansea Bridge (1989) Pier 3



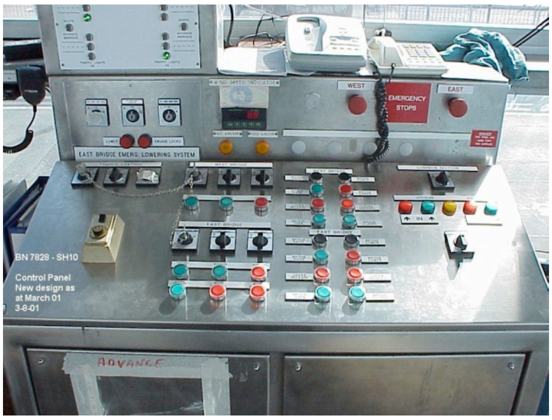


Figure 7.96 The evolution of the Swansea Bridge Control Panel. At top left the original panel from 1989, in 2001 after the first upgrade, and then at base in 2009 following the most recent upgrade

Movable span

The form and fabric of the movable span component is EXCEPTIONAL significance.

The movable span of the Swansea Bridge consists of two primary plate web girders which tapper towards the centre of the span. The girder is strengthened by isolated transverse web stiffeners. The primary girders support cross girders and rolled steel stringers before finally supporting the reinforced concrete deck (Figure 7.97).

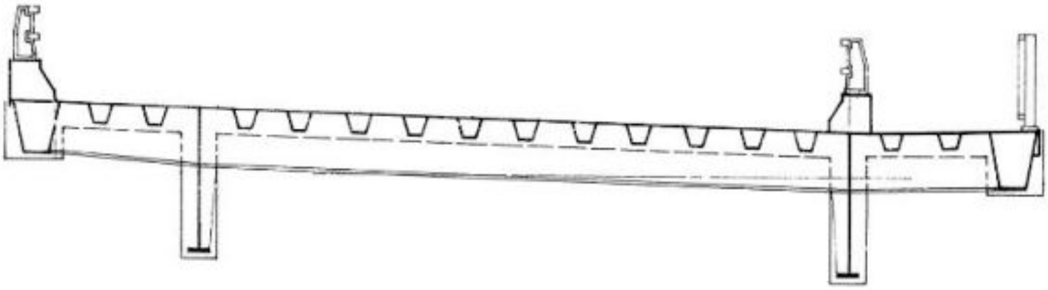


Figure 7.97 Swansea Bridge (1989) movable span cross section

The lifting mechanism attaches to the pier end of the spans by a bracket welded to the underside of the beam. The lifting force is provided by a hydraulic luffing cylinder attached at this point.

Counterweights

The form and fabric of the counterweight component is MODERATE significance.

The counterweights consist of a reinforced concrete block encased in a steel frame (Figure 7.98). Voids are built into the frames to allow for lead blocks to be added if there is a variance in the span self-weight or future modifications are made to the bridge.

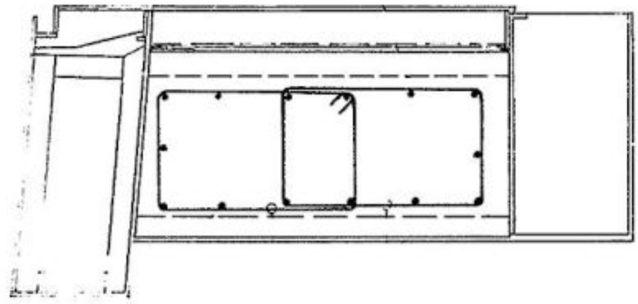


Figure 7.98 Counterweight for Swansea Bridge (1989)

Mechanical components

The form and fabric of the mechanical components are MODERATE significance.

The components of the Swansea Bridge (1989) lifting mechanism consist of electrically driven hydraulic pumps, luffing cylinders and counterweights. The main hydraulic luffing cylinders are mounted in front of the spans pivot point. As the cylinders extends the span is raised as shown in Figure 7.99 to Figure 7.100.

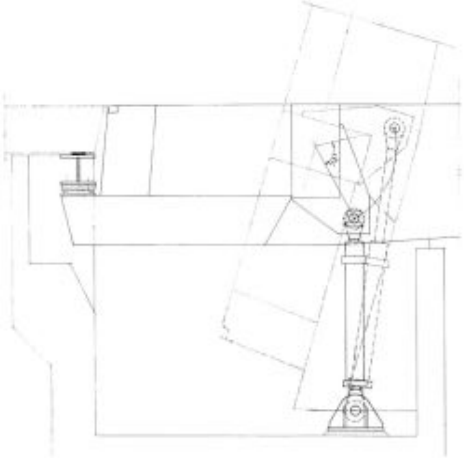


Figure 7.99 Swansea Bridge (1989) drawing of lift mechanism

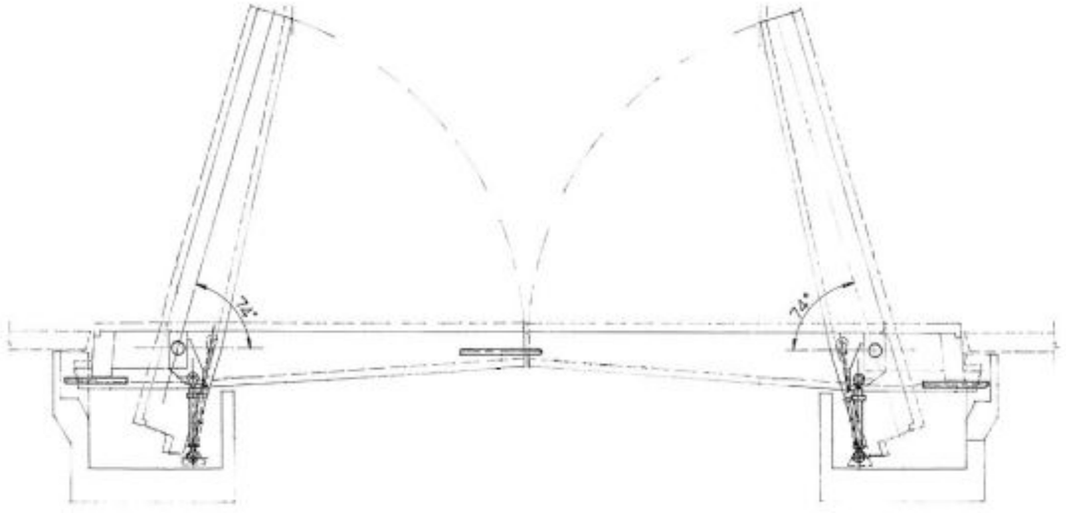


Figure 7.100 Swansea Bridge (1989) elevation of raised spans

The hydraulic luffing cylinders are 2400 mm long and extend to 3576 mm when the span is in the raised position.

Figure 7.101 Hydraulic luffing cylinder on Swansea Bridge (1989) in poor condition (Source: Jenkins and Tilley, 2011)

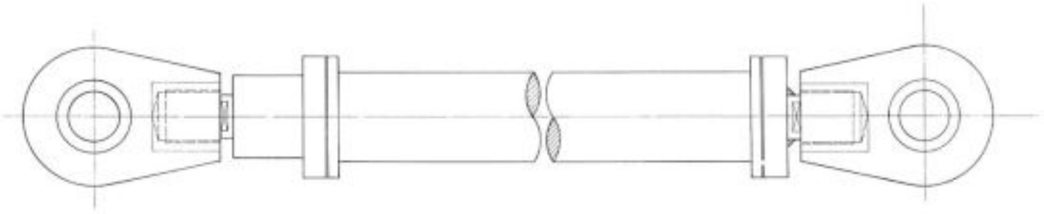


Figure 7.102 Swansea Bridge (1989) Hydraulic Luffing Cylinder

As the bridge has a double leaf bascule span there is a subsequent lack of support in the centre of the channel. This creates a tendency for the span to deflect excessively if left unrestrained and therefore the bearing arrangement for the lift spans is paramount. The design for 1989 Swansea Bridge adopts a rear reaction bearing and a number of hydraulic locks to achieve this restraint. The reaction bearing consists of a beam mounted at the rear of the span which catches the counterbalance end once the bridge has been lowered (Figure 7.103).

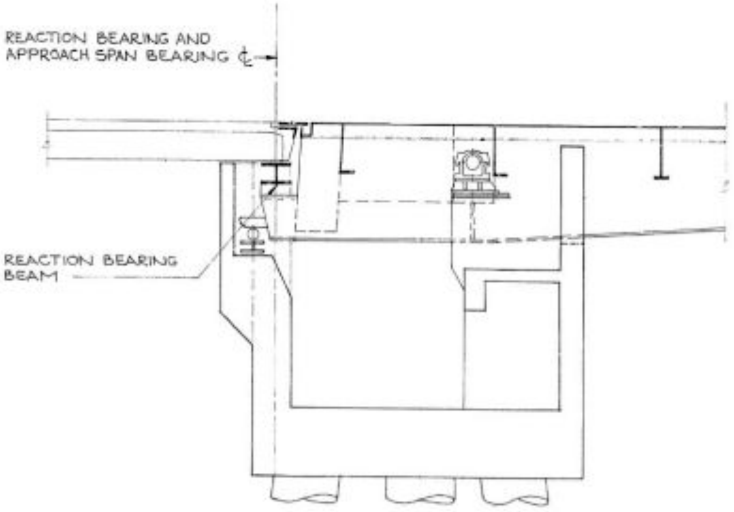


Figure 7.103 Reaction Bearing for Swansea Bridge (1989)

The second mechanisms used are the hydraulic locks. These locks are mounted at both the rear and centre of the span and are also operated by a hydraulic cylinder (Figure 7.104). The cylinder pushes a steel rod into a cavity and secures the span when not in use.

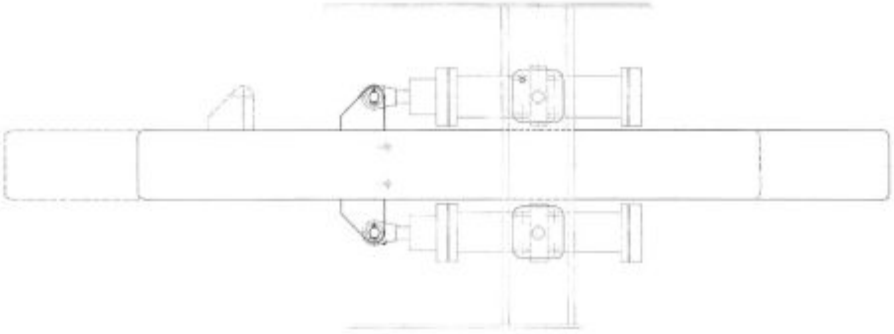


Figure 7.104 Hydraulic Centre Locks for Swansea Bridge (1989)

Vehicle and pedestrian barriers

The form and fabric of the vehicle and pedestrian barrier components is LOW significance.

The original vehicle barriers consisted of a boom gate located in close proximity either side of the movable span. These boom gates have since been replaced with modern equivalents mounted at the start of the bridge approach spans. The pedestrian barriers remain unaltered.

Motors, electrical and hydraulics

The form and fabric of the motors, electrical and hydraulic components are LOW significance.

There are a number of electrical and hydraulic components on Swansea Bridge (1989). They are implemented in conjunction to effectively operate the lifting mechanisms, locking systems, both road and water traffic signalling and access gates.

Summary of heritage assessments

The significances of each bridge component are summarised in the table below.

Table 7-12 Summary of heritage significance

Bridge Component	Significance Grading
Operator work station	EXCEPTIONAL
Movable Span	EXCEPTIONAL
Counterweights	MODERATE
Mechanical components	MODERATE
Vehicle and pedestrian barriers	LOW
Motors, electrical and hydraulics	LOW