# 8. Swing span bridges

## 8.1 Description of swing bridges

Swing bridges in broad terms consist of bridges that rotate about a vertical axis to provide a clear opening for the passage of vessels. Typical components of a swing bridge include a large centre pier and drum which the deck bears upon and some form of pivot point. The swing bridge design has often been considered as the most desirable of all movable bridges, provided that site conditions warrant their use (Hovey, 1926). The major advantages include:

- The mechanism is inherently low friction and thus doesn't require high levels of maintenance or lubrication.
- Stress on the mechanical components is minimal when bridge is in the closed position as end bearing mechanisms raise and essentially turn the bridge into a fixed structure.
- There is no need for counterweights in the design of most swing bridges.
- High efficiency as the power required to move than span is less than other movable bridge types.
- Provides an even distribution of loads onto the centre pier.

Despite the above advantages there are still two major disadvantages with this type of bridge design. Firstly, the centre pier usually needs to be built in the deepest part of the waterway and this can result in a number of navigational hazards and engineering challenges along with the excessive costs associated with such works. Secondly, the bridge cannot be readily upgraded or duplicated to cater for traffic volume increases as there are large clearances required when rotating the bridge (Main Roads, 1953).

As a testament to the durability of the swing bridge design, both the Pyrmont Bridge and Glebe Island Bridge were built in 1902 and 1903 respectively and after over 100 years of service both bridges are still fully operable.

**Figure 8.1 Pyrmont Bridge (Source: NSW Department of Commerce)**

**Figure 8.2 Hay Bridge opened to allow passage of the steamer Ulonga with barge in tow in 1932 (Source: Brown Collection, Hay Historical Society)**

Swing bridges are categorised according to the type of pivot bearing. If all the dead load is supported at the centre, the swing span is said to be centre bearing. If the majority of the dead load is supported by a large-diameter ring of rollers concentric with the pivot axis, the bridge is termed rim bearing (WisDOT, 2011). Table 8-1 provides a notation for the schematic item numbers within Figure 8.3 and Figure 8.4.

**Table 8-1 Schematic component number description for Figure 8.3 and Figure 8.4**

| Item | Description | Item | Description |
|---|---|---|---|
| 1. | Swing span | 11. | Distribution framing |
| 2. | Pivot pier | 12. | Deflected position (wedges withdrawn) |
| 3. | Rest pier | 13. | Drum girder |
| 4. | Centre bearing | 14. | Tread plate |
| 5. | Track | 15. | Tapered roller |
| 6. | Balance wheel | 16. | Track plate |
| 7. | Pinion | 17. | Pivot post |
| 8. | Rack | 18. | Live ring |
| 9. | End wedges (extended) | 19. | Spider |
| 10. | End wedges (Withdrawn) | 20. | Draw pivot bearing |

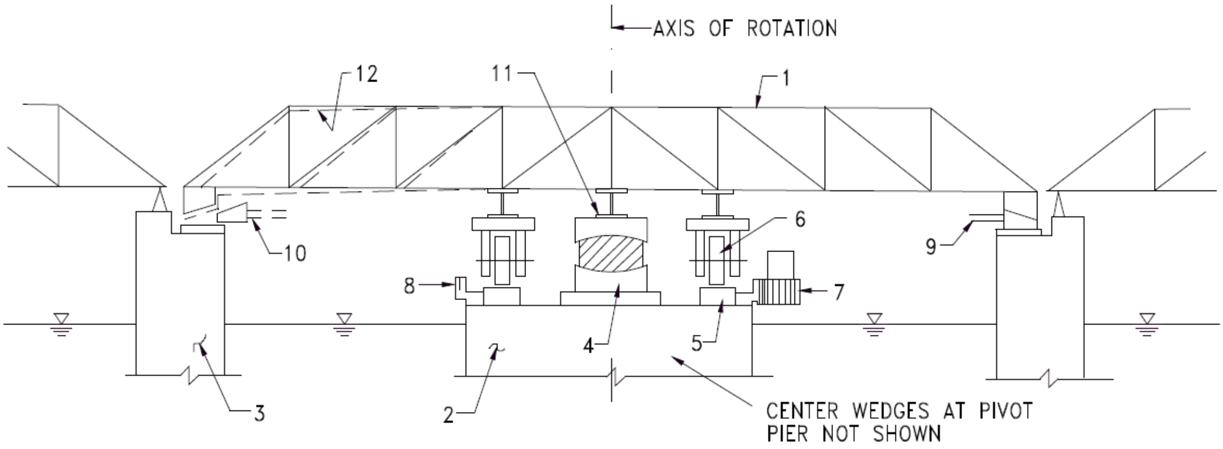

**Figure 8.3 Centre bearing swing bridge (Source: WisDOT, 2011)**

### Centre bearing swing bridges

Figure 8.3 presents a schematic of an equal-arm centre-bearing swing bridge. The spanning member is shown as a truss, however girders are another common variant. The span weight is balanced on the pivot bearing, which is mechanical in the figure, but could be hydraulic. To prevent the span from tipping under unbalanced loads, such as wind, balance wheels are provided that roll on a large-diameter circular track concentric with the pivot bearing. The design intent is that the centre bearing supports all of the dead load when the span is open. The live load on centre bearing swing bridges is usually supported by centre and end lift devices which are actuated when the span is returned to the closed position. They provide the load path for the free ends of the girders and also provide a firm intermediate live load support for the girders at the pivot pier.

Rotation of the span is achieved by means of mechanical or hydraulic machinery. When the mechanical span drive is mounted on the draw one or more downward extending pinion shafts engage a rack mounted on the pivot pier and rotate the span (WisDOT, 2011).

### Rim bearing swing bridges

The rim bearing swing bridge is characterised by the way in which the dead load of the superstructure is supported by tapered rollers when the span is in the open position (Pyrmont Bridge). The superstructures of rim bearing swing bridges are supported by a minimum of two longitudinal spanning members. Figure 8.4 shows the way in which the tapered rollers run on a circular track whose diameter is usually about the same as the transverse spacing of the outer swing span trusses or girders. Tapered rollers are necessary because the distance travelled by the outer end of a roller is longer than that travelled by the inner end, for the same angle of bridge rotation. When the bridge is closed, the rim bearing supports both dead load and live load. Rim bearings are used for wide heavily-loaded swing bridges. Special load-equalising framing is provided to transfer the loads from the bridge trusses to the circular drum girder at a number of points around the circumference of the centre drum so that it is uniformly loaded along its length. The load is transferred through the drum girder to a tapered tread plate supported by tapered rollers. Rotation of the span is achieved by the same means as for the centre-bearing swing bridges (WisDOT, 2011).

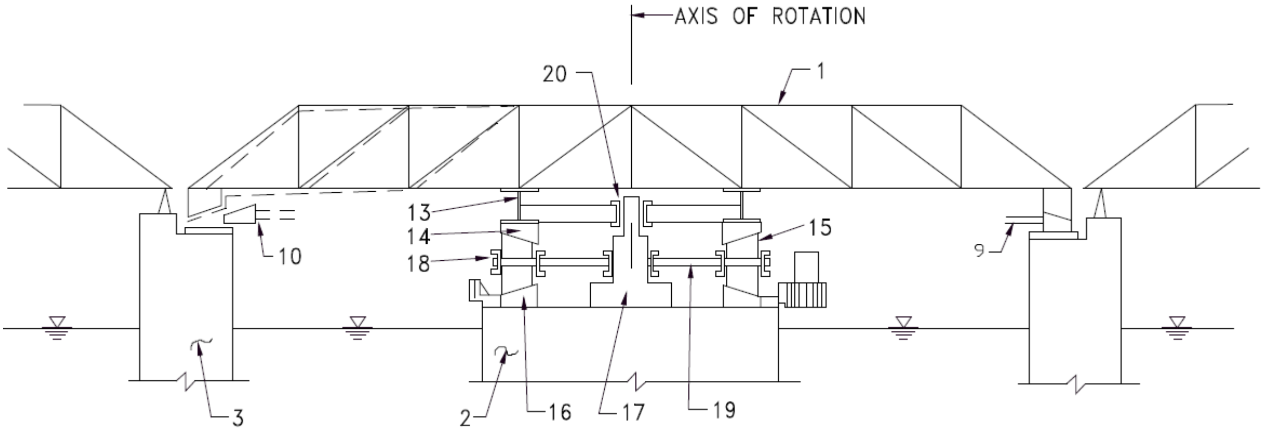

**Figure 8.4 Rim bearing swing bridge (Source: WisDOT, 2011)**

## 8.2 European origins

Swing bridges are a later development in movable bridge engineering than bascule bridges, however their origins still date to the early 1600s with accounts of two swing bridges contained in French engineering papers written by M. Bélidor (Hovey, 1926). The first is a description of a dual timber swing bridge with a centre pivot and the second is described as centre bearing swing bridge as depicted in Figure 8.3. Later eras in swing bridge design continued to develop in both England and America throughout the mid-

1800s. The 1856 Rush Street Bridge (Figure 8.5) across the Chicago River is one of the first built in this era and several subsequent swing bridges were built from this time onward (Hovey, 1926).

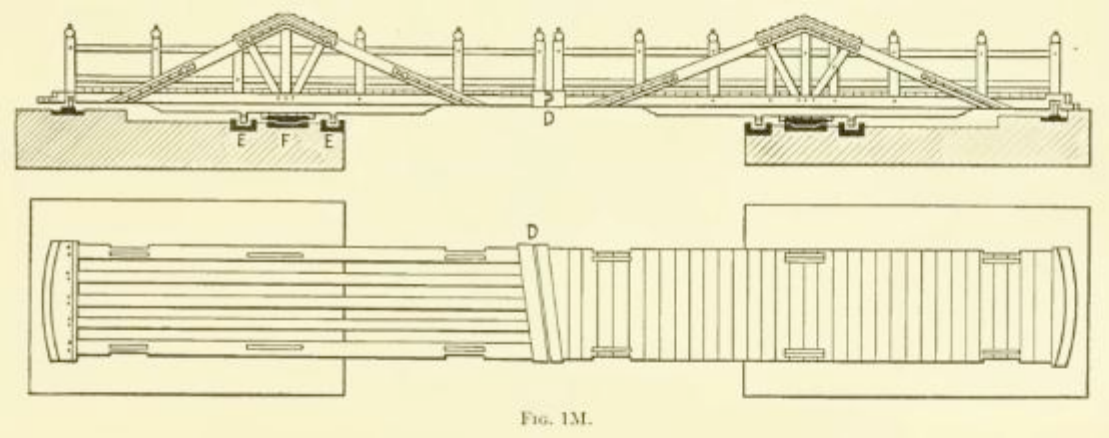

**Figure 8.5** **The 1856 Rush Street Bridge across the Chicago River (Hovey, 1926)**

## 8.3 NSW Swing bridges

The history of swing bridges in New South Wales most likely commenced in Sydney, with it being noted that the earliest swing bridges in the colony were those erected at Wentworth Park, Pyrmont and Glebe Island in 1850, 1857 and 1862 respectively (Dare 1896, *Main Roads* 1973). The Pyrmont design consisted of a lattice deck which pivoted about a central pier and the Glebe Island design consisted of a single opening swing span mounted on the bridge abutment (Figure 8.6).

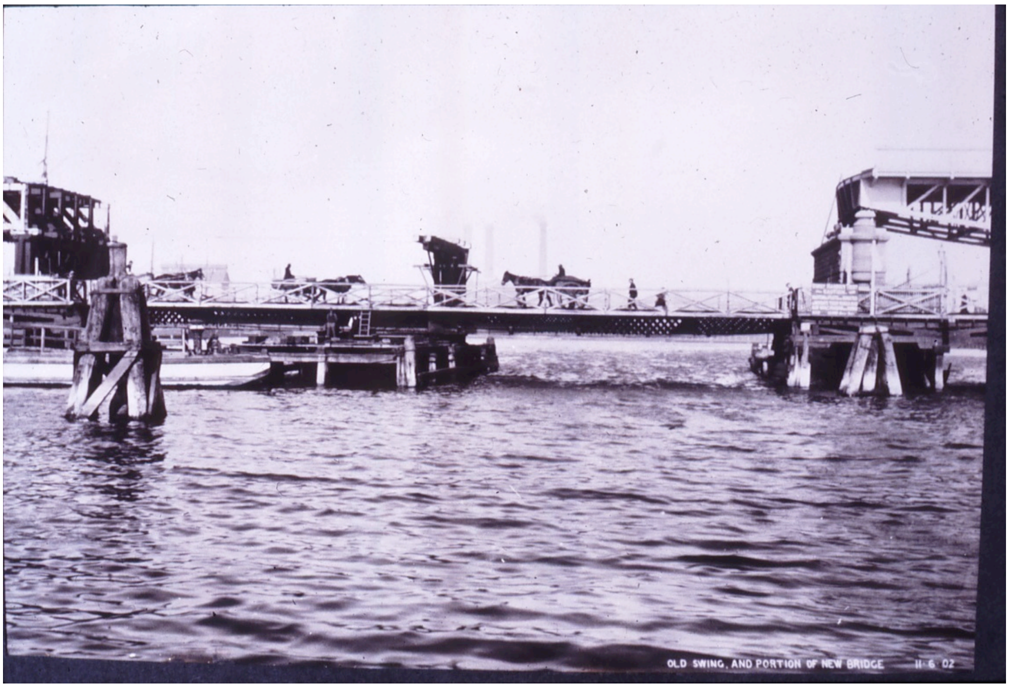

**Figure 8.6** **First Pyrmont Bridge built 1857, swing span at Pyrmont end, photo taken during construction of the 1902 bridge (Source: RMS, Government Printer)**

The next development in swing bridge design was apparent on the Hay Bridge completed in 1873. The design consisted of lattice girder span supporting timber decking and the bridge was operated by hand. The drum was a composite of cast and wrought iron that was finally founded on a centre pier. It was noted by Mr G. S. Mullen, past Resident Engineer, that the Hay Bridge was operating satisfactorily with the frequency of openings being over times per annum in the 1880s (*Main Roads*, 1973). The swing span was locked shut in 1937 and the bridge was demolished in 1973 with the turntable relocated to Lions Park, Hay.

**Figure 8.7 Hay Swing Bridge in closed position, undated (Source: Hay Historical Society)**

This type of bridge design was also adopted for the swing span on the Gladesville Bridge over Parramatta River completed in 1881, with reports that the operation was also satisfactory. Figure 8.8 is an elevation of this type of swing bridge design.

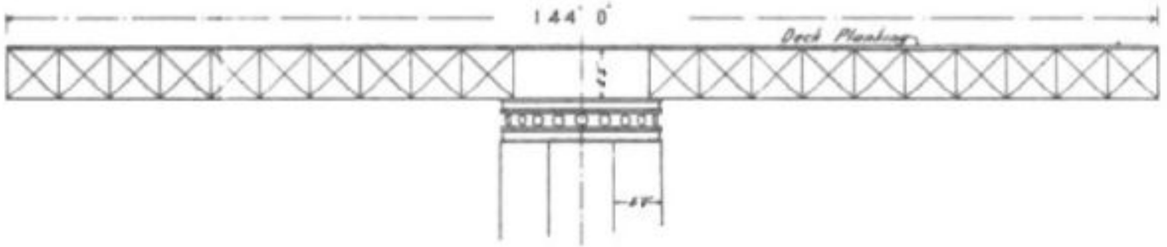

**Figure 8.8** Hay Bridge and Parramatta River Bridge type elevation (Source: Dare, 1896)

**Figure 8.9** Turntable from demolished Hay Bridge shown with footway on right. This forms part of the Bidgee Riverside Trail near Lions Park, Hay

**Figure 8.10 Gladesville Swing Bridge built 1881 (Source: RMS photographic archives)**

In 1885 a different type of swing bridge was constructed on the Fig Tree Bridge over the Lane Cove River (Figure 8.11). The swing span was a bob-tailed design which consisted of a shortened rear span. This type of bridge is usually adopted due to limited land availability. In order to balance the resultant differential in span masses a counterweight is mounted on the shorter span. There are some minor consequences for this type of design, namely the asymmetric wind loads that are experienced, however these can be catered for by strengthening the bridge where necessary (Waddell, 1916).

Dual plate web girders are the main components of the bridge superstructure and they taper from 6 ft. at the abutment to 2 ft. at the pier. It is noteworthy that this design was also manually operated by a handle on deck level which passed through a number of gears before transferring rotation to the structure.

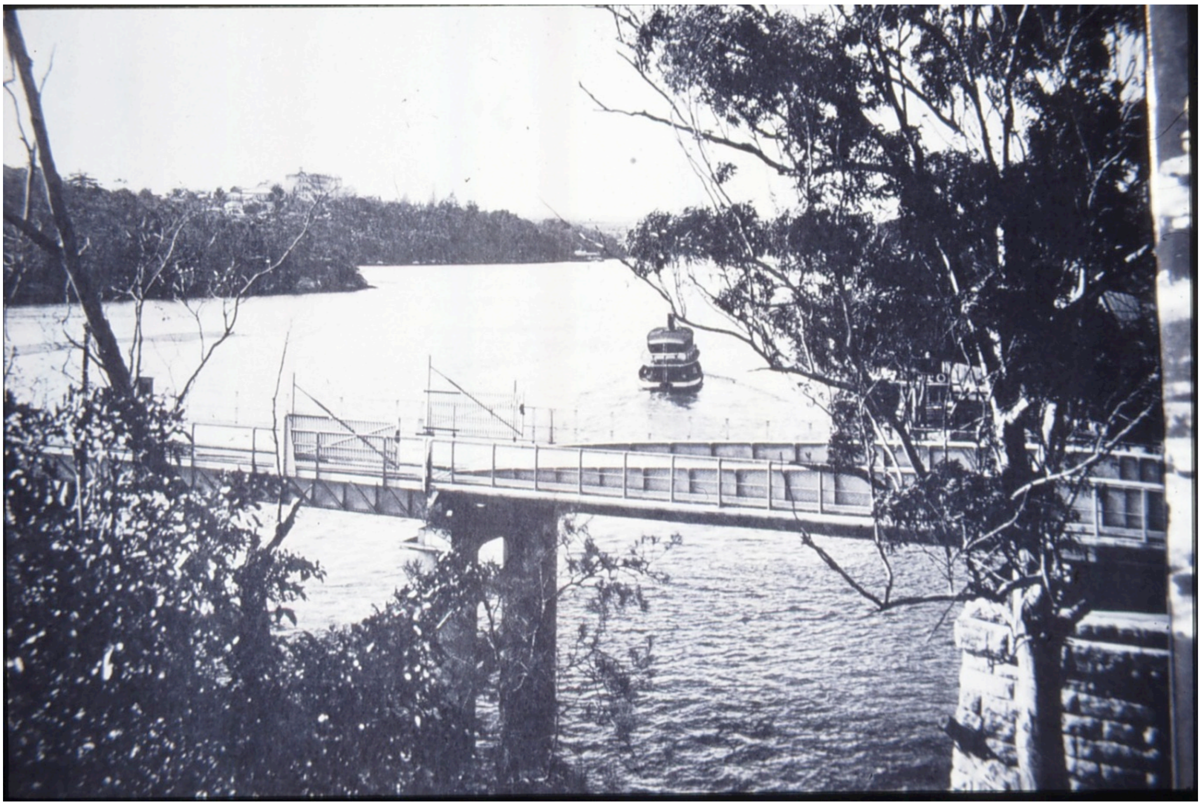

**Figure 8.11 Fig Tree Bridge over Lane Cove River in the 1920s detailing swing span and pedestrian gates, replaced in 1960s (Source: RMS photographic archives)**

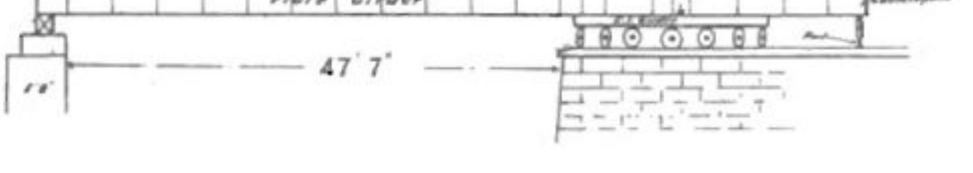

**Figure 8.12 Lane Cove Bridge at Figtree type elevation (Source: Dare, 1896)**

In 1892, John MacDonald prepared a design for a swing bridge to be built on the North Coast, over Coldstream River a tributary of the Clarence River near Maclean. The intention was that it would provide access for the tugs and barges associated with the sugar industry between the farms and the mill at Harwood (Fraser 1985).Only a small line drawing survives in MacDonald's calculation books; the design is unusual in that it consists of a lattice trussed central pivoting span with what appear to be plate girder approaches. It would have been similar in some regards to the Sale Bridge in Victoria built in 1883 (see section 8.4).

Possibly as a result of the considerable expense involved, or potentially due to a lowering of demand from river traffic, this bridge was never built; a single lane timber beam bridge was erected at the crossing instead.

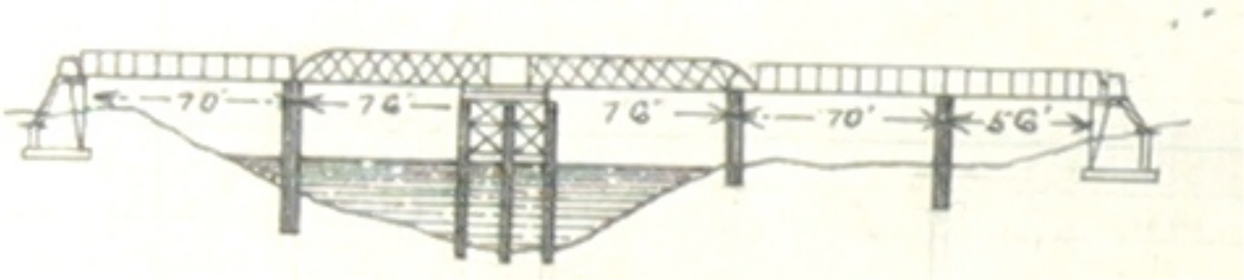

**Figure 8.13 John MacDonald's design for the Coldstream Swing Bridge which was never built**

The completion of the Pyrmont Bridge in 1902 and the Glebe Island Bridge in 1903 represented a significant milestone in the Australian swing bridge design evolution. The designs are often cited in engineering literature as being at the forefront in the world for swing bridges at their time due to their electrical operation and large size (*Main Roads* 1953, Allan 1924, Fraser 1985).

The bridges are both the rim bearing type, where the deck is supported on a large steel drum and numerous cast steel conical rollers are situated at the drum to pier interface to provide an even bearing. These conical rollers run along circular tracks that also allow the bridges to rotate with minimal friction. One of the major features is that the driving force is provided by electric motors. This has proved to be a highly efficient design as after 21½ years of service, there was only a single stoppage due to a mechanical fault (Allan 1924).

Pyrmont Bridge was closed to traffic in 1981 following the construction of new concrete bridges over Darling Harbour. It was intended to demolish Pyrmont Bridge to provide expanded wharfage in upper Darling Harbour. Campaigns for its conservation by the Lord Mayor of Sydney and the Institution of Engineers Australia ultimately led to its conservation and it underwent extensive restoration in time for the National Bicentenary celebrations in 1988 (Trueman, 1988).

Other noteworthy comments on the bridges include their high speed of operation and energy efficiency with only £392 being expended over a 22 year service with 130,521 openings (Fraser 1985).

**Figure 8.14 Pyrmont Bridge in closed position**

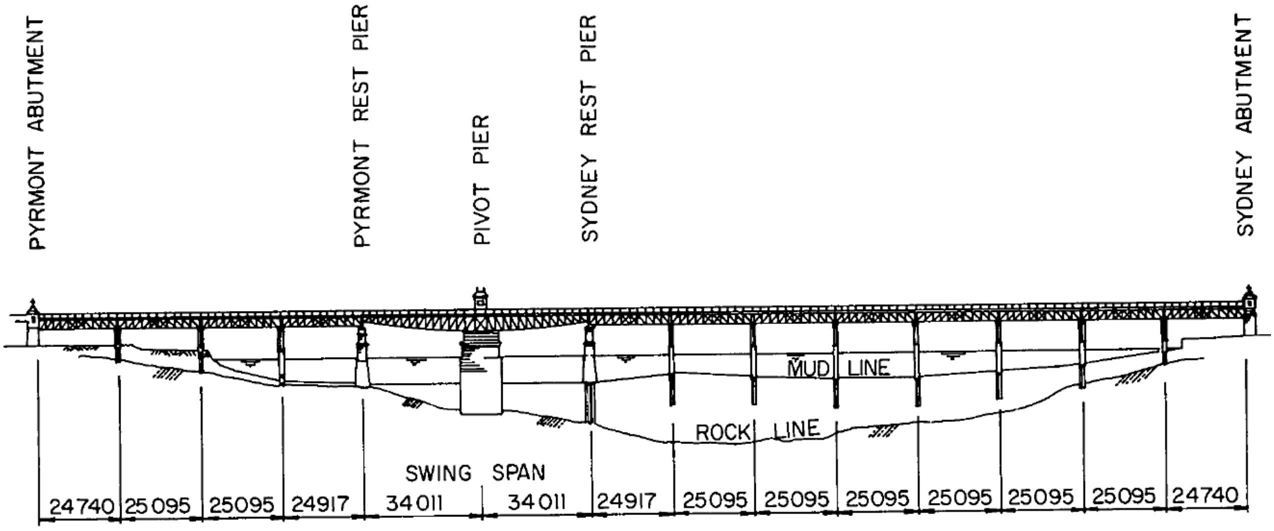

**Figure 8.15 Plan of Pyrmont Bridge with its 12 Allan truss approach spans**

## 8.4 Other Swing Bridges in Australia

There have been at least ten sites in Australia where swing bridges have been erected. In Sydney Harbour there are two; Pyrmont and Glebe Island Bridges, four in Tasmania, two in Port Adelaide and one each in Queensland and Victoria. In several cases, when an early swing bridge reached the end of its service life, it was replaced by another.

The 1874 Bridgewater Bridge carried the Tasmanian Main Line Railway across the Derwent River. The swing span was supported off-centre to maximise the width of the navigation channel. A separate road bridge was opened in 1892 with a swing span designed for conversion to railway use. This was later converted to dual road and rail use in 1908 because the turntable of the road bridge was supported on timber piles and gave endless trouble. The existing bridge was opened in 1942 and carries both road and rail in separate corridors and has a lift span.

The Institution of Engineers Australia placed a Historic Engineering marker on the remnants of the Jervois Swing Bridge which carried road vehicles, rail, trams and pedestrians across the Port River in Port Adelaide. It was built in 1878 and demolished in 1969.

Similarly to Pyrmont Bridge, several other swing bridges have been refurbished or restored and remain in existence. The 1883 road bridge at Sale, Victoria is restricted to foot traffic but is swung regularly at advertised times. The Victoria Bridge in Townsville built in 1889 was returned to use as a major community asset after restoration in 2001 by the Townsville City Council.

Two more modern swing bridges in Tasmania remain in full service, at Victoria Dock in Hobart (built 1960) and across the Denison Canal in Dunalley built in 1965 (Cole 2013).

**Figure 8.16 Sale Swing Bridge, Victoria in closed position**

(Source: http://en.wikipedia.org/wiki/Sale_Swing_Bridge)

# 9. Swing span bridge entry

## 9.1 GLEBE ISLAND BRIDGE

### 9.1.1 Description of the bridge

The bridge over Johnston Bay at Glebe Island is a swing type bridge which consists of a rotating centre span with length 191 ft., two fixed approach spans with lengths 81 ft. and two substantial stone causeways.

The swing span of the bridge generally consists of a steel Howe deck truss with curved bottom cord. This deck is mounted on a steel drum that is designed to rotate on the centre pivot pier. The pivot pier is a concrete and stone cylinder founded on 97 timber piles. The separate components that make up the bridge are shown in Figure 9.1.

**Figure 9.1 General view of Glebe Island Bridge in 1993 (Source: RMS)**

#### Development of roads and transportation in the Glebe area

Glebe and the surrounding area were first surveyed in 1790 by Augustus Alt under the direction of the NSW Governor Arthur Philip. The survey was for the purpose of assigning land for church and Crown usage. Approximately 400 acres was surveyed and control was given to Reverend Richard Johnson. It was noted that the land was covered with large trees and Johnson was unable to obtain convicts to clear the land and thus considered it to be worthless. The area therefore remained largely untouched for a number of years until private settlements of the very wealthy occurred.

As industries began to develop it also allowed lower socio-economic individuals to settle in the area and what started as a small town on the edge of Sydney by 1841 had become Sydney's largest suburb (Glebe Island Bridge CMP, 2004).

The first Glebe Island Bridge was opened in 1862 and consisted of a primarily timber structure which was fitted with a one sided swing span (Figure 9.3). After 41 years of service the old Glebe Island Bridge was deemed as having excessive deterioration by E. M. De Burgh, due to damage caused by white ants and underwater worm borers. It was also noted that repairs would only slightly lengthen the life expectancy of the bridge hence it was decided in 1894 by the Public Works Committee to replace the bridge as soon as possible (Glebe Island Bridge CMP, 2004).

Following the review of a number of proposed solutions, a select committee was unfavourable towards all of them and it was decided that the Public Works Department would be responsible for designing the new bridge. This design was completed by Percy Allan and a swing bridge was chosen for the crossing (Glebe Island Bridge: NSW Heritage).

**Figure 9.2 Driving pigs to the abattoirs – an early morning scene on Glebe Island Bridge (Source: Town and Country Journal, July 25, 1906)**

The construction contract was awarded to H McKenzie & Sons with work on the causeway commencing in April 1898. The construction process involved a number of exemplary techniques, with a noteworthy example being the coffer-dam which was understood to be the deepest single-wall dam ever constructed in the world. The bridge was completed at a cost of £112,500 with the opening ceremony held on the 1st of July 1903 (PWD AR, 1903).

It is noteworthy that the Glebe Island Bridge has often been considered as a sister bridge to the Pyrmont Bridge and both bridges were considered to be at the forefront of swing bridge engineering upon their completion (Main Roads, 1953).

## The first land grants

Governor King granted the land on the Pyrmont side of what was to become Glebe Island Bridge, to Surgeon John Harris, a Northern Irish Officer in the New South Wales Corps, on 31 December, 1803. Harris also obtained the whole of Five Dock and Drummoyne, a total of over 600 hectares in another grant of land from King in 1806. The so-called Ultimo Estate remained in the Harris Family until they divided it up in a ballot in 1860 (Matthews, 1982, pp. 9-14). The land for the Glebe Island Bridge and approach roads was resumed from the John Harris Estate in the late 1850s and in 1896 (RTA Aperture Card 9004847). The land on the Glebe Island appears never to have been alienated from the Crown, and passed from the Public Abattoir to Sydney Harbour Trust.

## Early Harbour crossings

The first bridge over the reaches of the Harbour was one built in the first half of the nineteenth century at the head of Blackwattle Bay, where a large swamp was covered at high tide. The Bridge, which was of timber with an opening span, was erected at about the present site of Wentworth Park, and was the prelude to the filling in of the swamp. The swing span in the centre was to allow the passage of punts laden with fill (Main Roads, December, 1954).

The earliest Pyrmont Bridge opened in 1857 and was a toll bridge. It was the first of four swing bridges to open in Sydney and it helped to ease the congestion on Parramatta Road. In 1884 the Government purchased it from its private owners and abolished the tolls.

The first Glebe Island Bridge, which opened in 1862, was Government built and had a one sided swing span balanced by a counterweight next to the Pyrmont side. These two swing bridges (Pyrmont and Glebe Island) were followed by two more, the 1881 Bridge over the Parramatta River from Drummoyne to Gladesville and the Figtree Bridge of 1885 over the Lane Cove River, these completed the roads to Ryde and beyond and to the North Shore. The Pyrmont and Glebe Island swing bridges were replaced in 1902 and 1903, and new Gladesville and Figtree Bridges were completed in the 1960s (Fraser, 1985; Main Roads, September 1951). Thus the Glebe Island Bridge played an important role within the northern and western Sydney bridge networks as part of several transport arteries. This in turn had a significant bearing on the economic and social development of greater Sydney.

**Figure 9.3 1862 Glebe Island Bridge taken in 1870 (Source: Government Printer No.SH620, RTA No.32108)**

Figure 9.3 above is looking north from Pyrmont. The single sided swing span with counterweight is on the lower left and the abattoirs are on the upper left. Glebe Island is yet to be cut down for the causeway and for reclamation.

From 1890, replacement of the original Glebe Island and Pyrmont Bridges were before the NSW Parliament, however, the Public Works Department was not in favour of a new Pyrmont Bridge, preferring the option to fill Darling Harbour to Bathurst Street. This was not popular in the Parliament and the matter was referred to the Public Works Committee in 1894.

The evidence at the hearing from Engineer for Bridges, E. M. De Burgh detailed the damage to the tops of the piles and the girders from white ants and to the walings by the underwater worm borer, ‘cobra’, noting that the piles under water were sound. The Bridges would remain open during repairs, but would not last more than three years before requiring renewal; the repairs would cost £4,000. The Committee recommended that both Pyrmont and Glebe Island Bridges be replaced as soon as possible (NSWPP 1894).

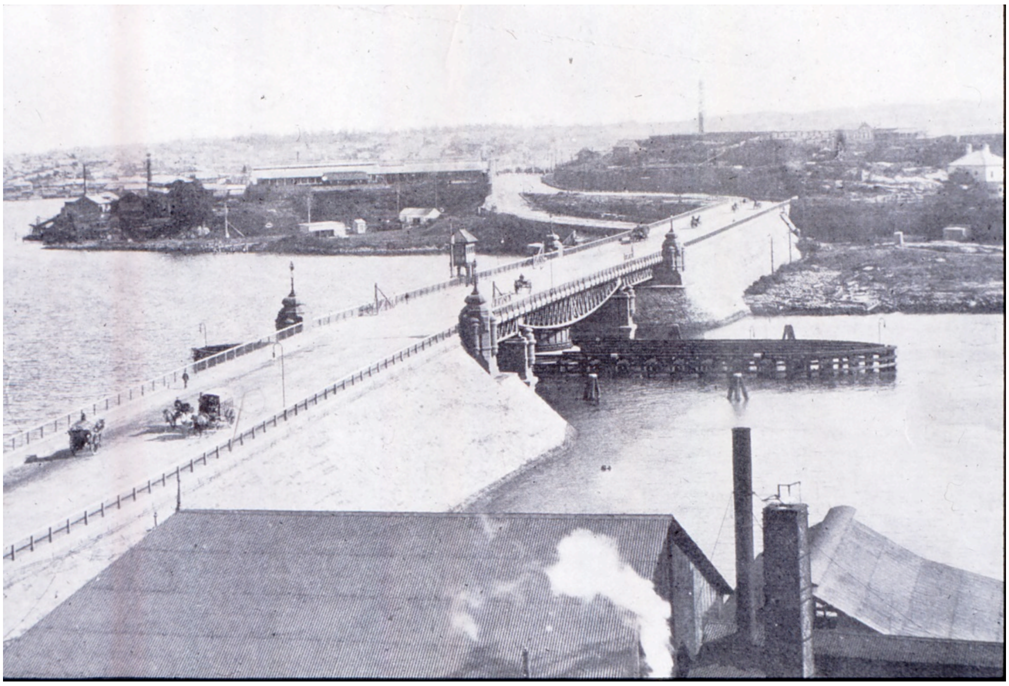

**Figure 9.4** **Glebe Island Bridge circa 1913 (Source: RMS photographic archives)**

## Glebe Island Bridge design

The Glebe Island Bridge of 1903 was designed by Percy Allan, Engineer in Charge of Bridge Design in the Bridges Branch of the New South Wales Public Works Department, working under the Assistant Engineer for Bridges, E.M. De Burgh. It was decided that, given the amount of rock, which was available at Glebe Island and the land that could be reclaimed by removing it, a stone causeway was an economical proposition. The swing and approach spans were to be of steel. Following test bores in 1899, and given the depth to rock and the presence of an overlay of stiff clay, it was decided that the pivot pier would be founded on piles driven to rock within a cofferdam, the top layer of mud being removed and replaced by concrete. The rest piers were to be formed by dredging off the mud, driving piles to rock and depositing the concrete through the water from specially designed hoppers (PWD Annual Report 1903).

The 1903 Glebe Island Bridge has two fixed steel truss spans 24.7 metres long and 2.7 metres deep. The central swing-span is an inverted arch truss, which varies in depth from 2.7 metres at the ends and 4.3 metres at the centre and is 58.3 metres in span, giving two 18.3 metre clear waterways. The length of the Bridge is 107.7 metres, the width of the roadway is 12.2 metres and of the two footways, 1.5 metres each (PWD Annual Reports 1899- 1904; Godden, 1987).

The swing-span is mounted on a steel roller track on the cylindrical pivot pier and is swung by a 600 volt DC motor fed through a 415 volt modifier operated from the Bridge control cabin above the western footway (Godden, 1987). The cabin, controller and wiring was burnt out in a fire in 1982 and has been replaced by a reconstruction of the cabin and a more modern electrical arrangement than the original tram type controller, which is still in use on Pyrmont Bridge (Main Roads, June, 1983 pp. 52-3; Fraser, 1992). The Bridge is moved by a pinion bearing on a crown wheel, which is part of the roller track. During a power failure the Bridge can be moved manually.

The ends of the span move at 6 km/hour and have a 25 mm clearance where they meet the fixed trusses (Godden, 1987). The Bridge was designed to swing in 46 seconds and the delay to be from 4 to 7 minutes.

The design of Glebe Island Bridge swing span is smaller than that of Pyrmont, but is similar, in that they are both made up of a steel truss of a variable depth, from 13 feet to 5 feet (3.96 metres to 1.52 metres) in the case of Glebe Island and 15 feet to 5 feet (4.57 metres to 1.52 metres) in the case of Pyrmont. Both bridges have N shaped panels, 20 for Glebe Island and 24 for Pyrmont, both have cross-braced central panels and plated end panels.

The difference in design between Pyrmont and Glebe Island Bridges lies in the fact that the fixed spans of Pyrmont are of timber and more numerous, and at Glebe Island they are of steel supplemented by stone causeways (Allan, 1907; Fraser, 1985 & 1992).

### Glebe Island Bridge construction

During 1899, when the dredging of the 11 metres of mud from the clay was complete along the route of the Bridge, stone was quarried on Glebe Island and at Pyrmont and was tipped to form the causeway. At the same time 97 piles were driven into the clay to rock and were surrounded by the cofferdam to form the pivot-pier. Within the cofferdam, the concrete base was laid. It was thought at the time that the cofferdam was the largest single wall dam in the world, being subjected to a pressure of water 12.5 metres deep, without appreciable leakage. The pivot pier is faced with rock-faced sandstone blocks, and is protected with a timber fender.

The rest piers at either end of the swing-span were constructed on the monolithic principle with the concrete being deposited through the water with specially designed skips, continuously day and night, until the work was completed. They are faced with sandstone and capped with trachyte. They are each equipped with timber fenders and 4 dolphins.

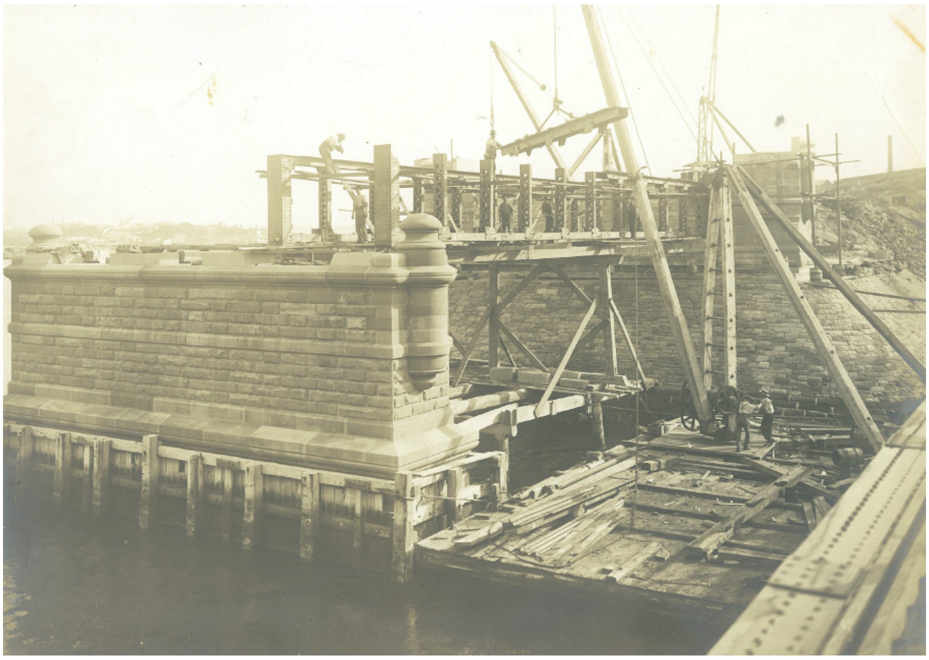

**Figure 9.5** **Rozelle side rest pier and approach span under construction in 1902 (Source: RMS photographic archives)**

The causeway is over 21 metres high and over 68 metres wide, and contains over 168,202 cubic metres of stone. Almost 5 metres of mud, weighing over 101,600 tonnes was dredged to form a firm foundation. The filling was obtained by cutting down Glebe Island so that 13 acres (5.3 hectares) of railway yards and 2,800 feet (853 metres) of deep water frontage were formed. The section on the Pyrmont side had to be left to last in order to let the water traffic through the swing-span of the old Bridge. The new Bridge was provided with a small trestle until the causeway was complete (PWD Annual Reports 1899 - 1903).

On the night of 5 August, 1899, a slip in the stone causeway demolished 365 feet (111.2 metres) of the old timber bridge next to the swing. No loss of life occurred, but it was necessary to hurriedly rebuild the old Bridge 6.4 metres wide and piles as long as 70 feet (21.3 metres) were brought from Wyong by rail. A quantity of 9,300 superficial feet (219.5 cubic metres) of timber was used from the Departmental stockpile at Cockatoo Island. The accident occurred at 3 a.m. on 5 August, and was restored at 8 a.m. on 19 August, 1899, or in 14 days, 5 hours, work being carried out by day and night in very stormy weather. The work cost 2,946 pounds 2 shillings and sixpence or 8 pounds three shillings and eight pence per foot run, a small sum even in those days (PWD Annual Report, 1899).

The rapid and intensive response to this incident evidences the importance of having a working crossing, not only during construction of the new Bridge, but to serve as part of the inner west’s transport infrastructure.

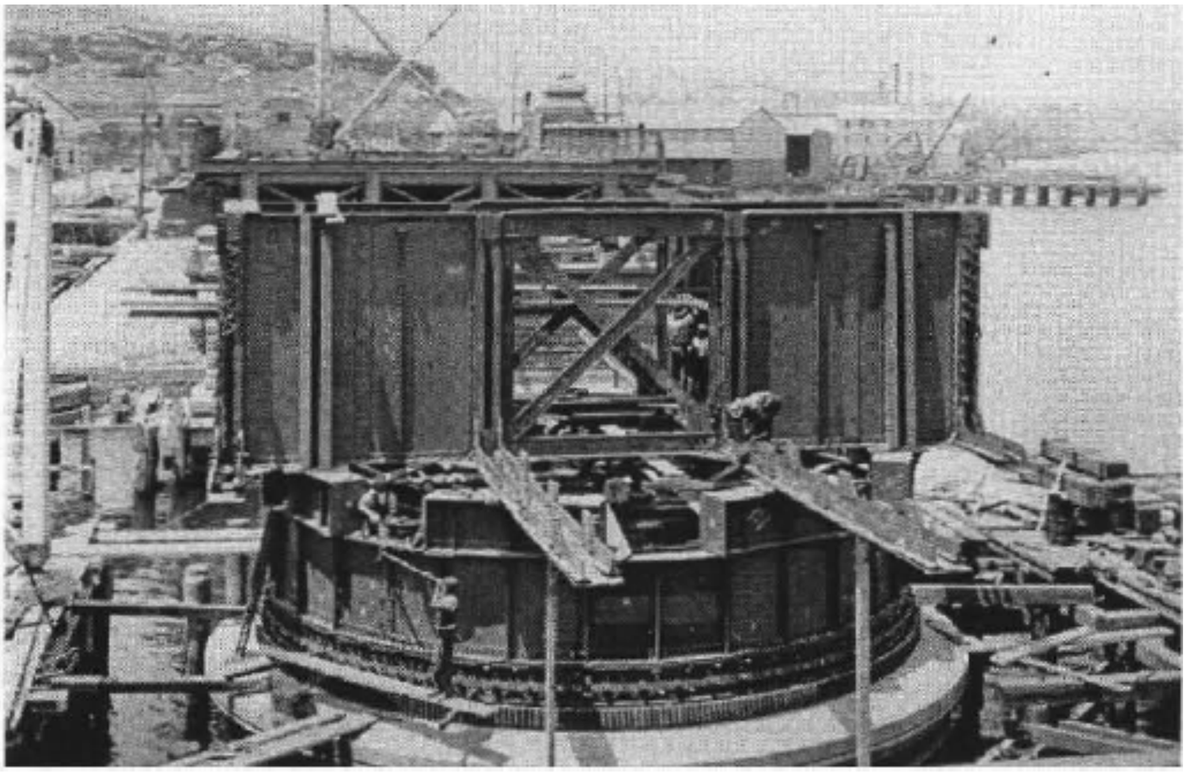

Figure 9.6 Swing span under construction (Source: RMS photographic archives)

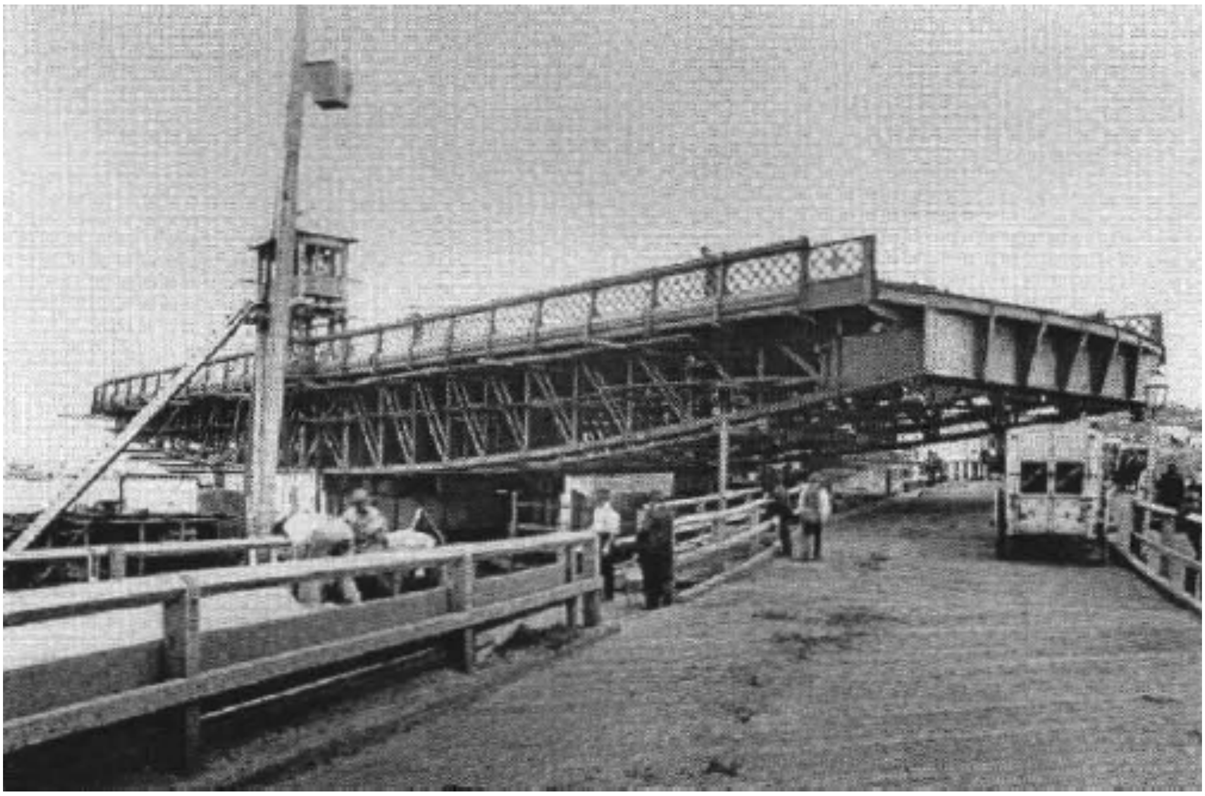

Figure 9.7 Swing span completed in 1902 as seen from the 1862 bridge prior to its demolition (Source: RMS photographic archives)

## Operational History

The bridge was designed to swing open in 46 seconds and the delay to traffic while in use from 4 to 7 minutes. The bridge was reported to have opened 5,499 times in 1903-04 (PWDAR, 1903-04). There are no accurate records available of the operational lifts made on the bridge though it remained in continual and frequent operation up until 1995. On at least ten separate occasions vessels collided with either the fender or rest piers which would appear to reflect some inherent difficulty for larger boats in navigating through the channel. After 1995 the bridge has remained in the open position and was operated and used for access by cyclists in the annual Spring Cycle in October until 2008. Since that time the bridge has been closed on average 3 times a year to test the swing span mechanism.

**Figure 9.8** **View looking north of the bridge with swing span in open position, fender in foreground and rest piers lining the channels to each side**

## Maintenance History

### Table 9-1 Summary of works undertaken on the Glebe Island Bridge

| Year | Nature of works |
|---|---|
| 1923 | Collision of S.S. *Malachite* with dolphins and fixed span on the Balmain side. |
| 1923 | Replacement of obsolete resistance boxes by Department of Tramways. |
| 1923-28 | Vehicular collisions with gates – complaints from motorists about signals. |
| 1924 | Collision of S.S. *Audrey D.*, owned by R.W. Miller & Co., with swing span fender. |
| 1924 | Collision of S.S. *Malachite* with Balmain dolphins and fixed span. |
| 1927 | Tug *Delilah* towing a large steam crane abreast got jammed in the channel between fender and rest pier. |
| 1928 | Collision of S.S. *Sir Arthur Dorman* with swing span fender. |
| 1936 | Underpinning of abutments. |
| 1959 | Power changeover to AC with Sydney City Council from DC from White Bay Railways Power Station, mercury arc rectifier installed. |
| 1969 | Pivot pier wiring connections modified to include 54 trailing cables. |
| 1972 | Relocation of electric meter box. Swing span fender piles replaced.<br>M.V. *Burwah*, owned by Howard Smith, hit the swing span damaging the counter lever under the footpath and a fence post. |
| 1974 | Roadway expansion plates replaced.<br>Tug *Boorawang* and pile driving barge with crane hit the eastern rest pier fender fracturing one pile and breaking off the southeast dolphin. |
| 1977 | M.V. *Burwah*, towed by tug *Brigand* hit steelwork of the swing span. *Lisa Miller* hit the south east dolphin and speared into the Pyrmont rest pier fender.<br>M.V. *Burwah* and tug *Barbary* collided with the Pyrmont rest pier fender. |
| 1978 | On 3 January the Pyrmont fixed span was jacked 25 mm back to its proper position.<br>On 5 May M.V. *Goliath*, owned by Union Bulkships, collided with the lift pedestal and bearings were broken on the Pyrmont fixed span which was found to have moved 22 millimetres,<br>Rest pier stonework was broken and fender timbers fractured. Repairs were undertaken. |
| 1980 | VHF radio in use between Bridge Operator and ships following award agreement. |
| 1982 | On 26 November Bridge control cabin destroyed by fire and replaced with modern electrics. |
| 1982-3 | Fenders rebuilt. |
| 1989 | Request to dismantle fender rubbing strip to permit entrance of dredge W.H. Goomai, owned by WestHam Dredging Pty. Ltd. for foundations of new Glebe Island Bridge. |
| 1991 | Request to allow passage of *Golden Bay*, 16.64-metre beam vessel, owned by CSR. |
| 1995 | Old Glebe Island Bridge decommissioned following the opening of the new cable-stayed Anzac Bridge. |
| 2001 | Fender repairs. |
| 2010 | April 10, vessel impact caused damage to corner of bridge deck and handrail. Repairs were undertaken. |

Source: Heritage Design Services, 2000

## Underpinning the Abutments in 1936

The foundations of the abutments of the Glebe Island Bridge, like the pivot and rest piers, were made up of piles driven through clay to rock and were capped with concrete, but differed in that the concrete did not extend below water level. By 1928 it was noted that there was movement and cracking of the abutment walls and terminal pillars of the Bridge. The Public Works Department had already found it necessary to cut back the outer faces of the abutments and to reset the roller bearings, which supported the ends of the fixed spans of the Bridge. It was thought that the placing of the causeway on clay had set up the stresses that had moved the abutments and it was later discovered that the piles were leaning inwards with a slope of about 1 in 18. In 1933, when the newly formed Department of Main Roads took over responsibility for main road bridges, the first step was taken to see how serious the problem was with the foundations of the abutments.

Two shafts and galleries were dug alongside the eastern abutment and it was found that the tops of the piles and the ironbark headstocks were eaten away by white ants or destroyed by dry rot. The weight of the abutments and sandstone terminal pillars, of a similar pattern to Pyrmont Bridge, was being carried on the fill alone.

It was decided that the weight of the stone terminal pillars, the capstones of which weighed about 7 tons, would have to be removed before the abutments could be underpinned with concrete. Hardwood frames were constructed to lift the terminal stones for loading onto trucks, while leaving enough room for the passage of trams and other traffic. The sandstone terminals were eventually replaced by smaller hollow concrete structures.

Trenches were dug around the sets of piles, in succession, while removing the outer stone work and supporting each section on timber setts, driving fox wedges on sole pieces bedded onto the fill. Teams of four men each side worked to remove all unsound timber and pack all spaces to form concrete beams, which were finally grouted in under pressure.

The concrete mix was 4 of metal to 2 of sand to 1 of cement and the grout was 2 of cement to 1 of sand. The total quantity of concrete used was 250 cubic metres and the total excavation amounted to 917 cubic metres. The work took 8 men about 15 months and cost approximately $5,200 (*Main Roads,* February, 1936).

## Electrical Modifications

Major electrical modifications were made to the Glebe Island Bridge in 1959, when the Sydney County Council took over the White Bay and Ultimo Power Houses from the Railways, which had operated their whole system on D.C. A new set of wiring diagrams were drawn for the installation of a 28.6 KW mercury arc rectifier to handle the A.C (R3D/30, ND) input. In addition, the lighting was converted from the old arc lamps to standard roadway lighting. The electrical meter box was relocated in 1972 (EBM/165/34, 1972).

The emergency bridge maintenance records of the Glebe Island Bridge before 1923, have not as yet been found. However the present Bridge Electrical Foreman, Alan Cairns, remembers the modification of the pivot pier cable connections to include 54 trailing cables on the pier, in 1969 and 1970 and he holds a current set of 10 electrical drawings. According to the records, the 13 submarine cables were replaced in 1974, and again in 1978, following a failure, leaving only one cable intact. In 1994 tenders were called to bury the cables in a trench, but it is not clear if this work was done (EBM/165/34, 1972).

A fire broke out in the Control Cabin of the Glebe Island Bridge on Friday 26 November 1982, damaging the control equipment that operated the Bridge. The cause was thought to be electrical. Electricians from Five Dock DMR Works Office removed the controls from the then disused Pyrmont Bridge, and installed them temporarily below deck level on the Glebe Island Bridge. Meanwhile a new Control Cabin was built at the Department's Central Workshop, retaining the design characteristics of the old Control Cabin and the Pyrmont Bridge control equipment was returned. While the Bridge had only been opened during daylight during the emergency, it was returned to normal day and night operation on Wednesday, 22 December, 1982 (*Main Roads*, June, 1983; Alan Cairns - Electrical Foreman; EM 534, 1983).

### 9.1.2 Statement of significance

The Glebe Island Bridge across Johnstons Bay has significance because:

The current structure has been an important item of infrastructure in the history of Sydney and the inner western suburbs for over 90 years, and its history, going back to 1862 is intimately bound to the development of Sydney in the middle of the 19th century.

It is an impressive structure sited in the middle of a wide waterway,

Technically, it is a complementary structure to the already acclaimed Pyrmont Swing Bridge and has all the significant features,

It contributed significantly to the social and commercial development of Sydney and its inner western suburbs, and was a vital component of the "short cut" route from the city to the Great Western Highway,

It, and its neighbour the Pyrmont Bridge, are rare examples of this type of bridge in New South Wales and are still operated by electrical power in the manner designed by Percy Allan.

Source: RMS s170 Register

Glebe Island Bridge is an exceptionally significant example of a Percy Allan designed steel swing Bridge. The exceptional level of significance is generated by the way the Bridge addresses the assessment criteria as a whole. In particular, Glebe Island Bridge's significance lies in the integrity of its fabric and the preservation of its original design style. These factors give the Bridge exceptional levels of technical significance because of its ability to demonstrate its design excellence and all of the defining aspects of an innovatively designed steel swing bridge. The technical and research potential of the Glebe Island Bridge is embodied in a number of individual design elements which are not common on most swing bridges. These elements include the electrical operating mechanisms, relatively long and massive sandstone approaches and the fact that it is one of only two electrically powered swing bridges to be built.

The electrically operated swing span is an incredibly rare feature, having been utilised on only one other bridge at Pyrmont. Glebe Island Bridge has associational links with the historic harbour trade, and has much to reveal about late nineteenth / early twentieth century civil engineering and manufacturing technology, material and attitudes.

Source: Heritage Design Services, 2000

### Heritage Listings

| Listing | Status |
|---|---|
| Australian Heritage Database (formerly the Register of the National Estate) | Listed |
| OEH Heritage Division State Heritage Register | Listed |
| Leichardt Local Environmental Plan, 2012 | Listed |
| NSW National Trust Register | Listed |
| RTA s.170 Heritage and Conservation Register | Listed |

### Evolution of modifications

The design of the Glebe Island Bridge swing span is smaller than that of Pyrmont, but is essentially similar, in that they are both made up of a steel truss of a variable depth, from 13 ft. to 5 ft. (3.96 m to 1.52 m) in the case of Glebe Island and 15 ft. to 5 ft. (4.57 m to 1.52 m) in the case of Pyrmont. Both bridges have N shaped panels, 20 for Glebe Island and 24 for Pyrmont, both have cross-braced central panels and plated end panels.

Pyrmont Bridge swing span is 223.2 ft. (68 m) in length and 54 ft. (16.45 m) wide for a total deck area of 12,053 sq ft. (1119.76 sq m). Glebe Island Bridge by comparison is 187.7 ft. (57.2 m) in length and 50 ft. (15.25 m) wide for a deck area of 9,385 sq ft. (871.9 sq m). Pyrmont bridge swing span weighs 800 tons while Glebe Island Bridge weighs 650 tons. Both bridges are electrically operated and can swing open in 46 seconds.

The difference in design between Pyrmont and Glebe Island Bridges lies in the fact that the fixed spans of Pyrmont are of timber and more numerous, and at Glebe Island they are of steel supplemented by stone causeways (Allan, 1907).

## 9.1.3 Description of lift span mechanism components

### Operator work station

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

The Glebe Island Bridge consists of the interaction of a number of mechanisms however a feature of the bridge is that it can be operated by a single individual. The operator is positioned in the control cabin mounted at the centre of the swing span (Figure 9.9).

The control cabin sits above the parapet at the centre of the south side of the span. It is 4.36 m long, 1.68 m wide and 2.56 m floor to ceiling. It is supported on eight cast-iron columns and a heavy timber frame about 2.8 m above the bridge deck. There are decorative cast-iron friezes spanning between the columns and a decorative pressed-steel fascia in the same design covering the timber frame.

The cabin is reached via a relatively new spiral staircase, which leads to a door in the west end. Originally a ladder led to a trapdoor in the floor of the cabin but in 1945 a staircase was built and a new door cut into the Glebe Island end of the cabin.

The lower part of the timber-framed cabin is clad with weatherboard with exposed timber posts and the upper section is a series of sixteen windows giving a 360 degree view over the road approaches. The hipped roof was originally clad with copper slates and there are two decorative sheet metal vents, one at each end of the ridge. The cabin was completely rebuilt after a fire that destroyed it in 1982, to the original specifications, except for new electrical gear (*Main Roads*, June 1983).

The only innovations were the introduction of a split system air conditioner for operator comfort and modern electrical equipment fitted into a control panel along the north side of the cabin for the bridge opening mechanism utilising crane type joy sticks was installed.

The roof shingles were replaced with corrugated iron in 2000 and lead flashing was installed between the weatherboard and the pressed metal fascia to prevent water penetration.

**Figure 9.9 Glebe Island Bridge control cabin (Source: DPWS, 2000)**

**Figure 9.10** View inside the control cabin in 1995 (Source: RMS photographic archives)

### Movable span

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

The movable span on the Glebe Island Bridge consists of four steel Howe type trusses with curved bottom chords. The bottom chords of the trusses are linked transversely by lattice girder tie beams and cross bracing (Figure 9.12).

**Figure 9.11** Detail of swing span in open position

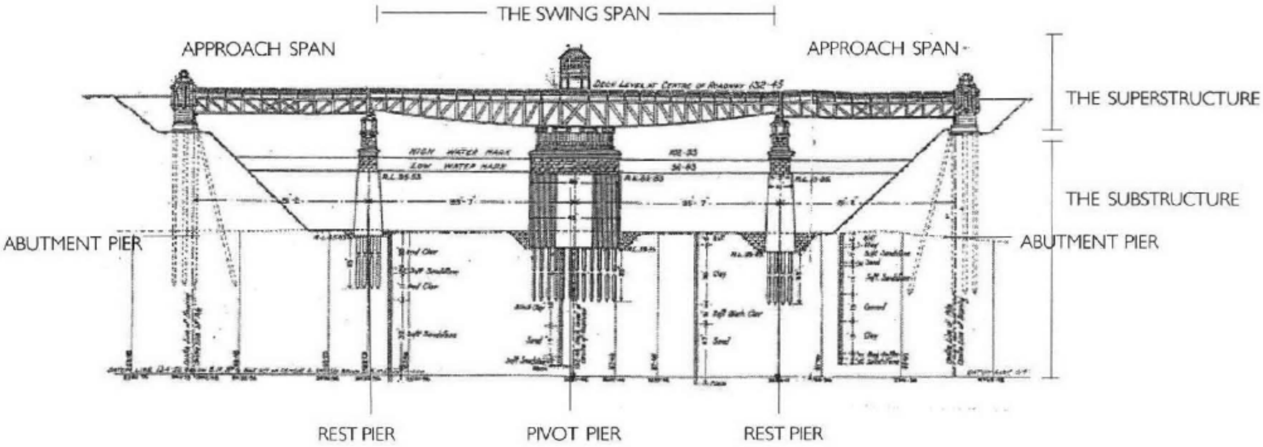

**Figure 9.12 Elevation of Glebe Island Bridge**

The main longitudinal trusses support plate web cross girders and rolled steel stringers before finally supporting steel buckled plates and subsequent road deck.

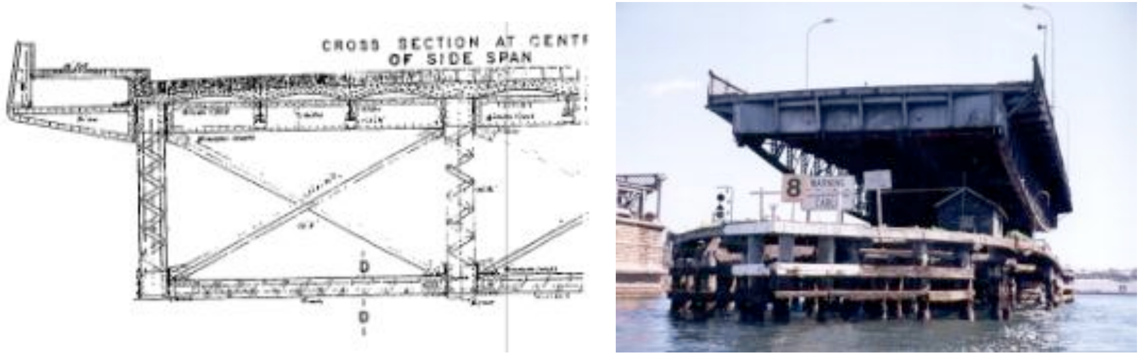

**Figure 9.13 Section and image of opened Glebe Island Bridge swing span**

The entire swing span is mounted on the main pivot drum by means of considerable distribution girders which bear on the top rim of the steel drum (Figure 9.14).

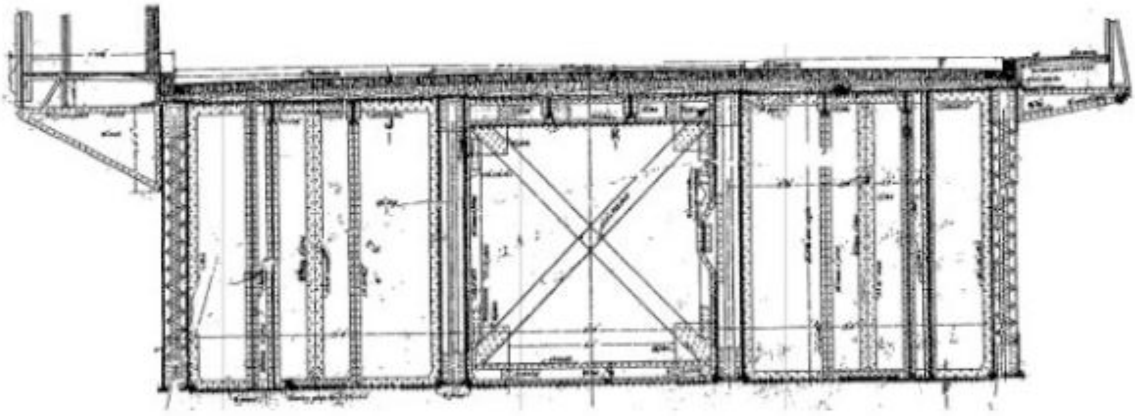

**Figure 9.14 Section of swing span over drum on Glebe Island Bridge**

### Mechanical components

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

The swing span mechanism implemented on the Glebe Island Bridge consists of a number of components including: electric motors, gearing, rollers, racking, shafts and rail tracks.

Dual electric motors are mounted in the centre of the span above the pivot and they drive motion through a number of gears and into a horizontal shaft. This shaft is fitted with a bevelled pinion that is keyed into a vertical shaft at either end. The vertical shaft has a lower end pinion which rotates on a fixed rack at the pier deck thus causing motion.

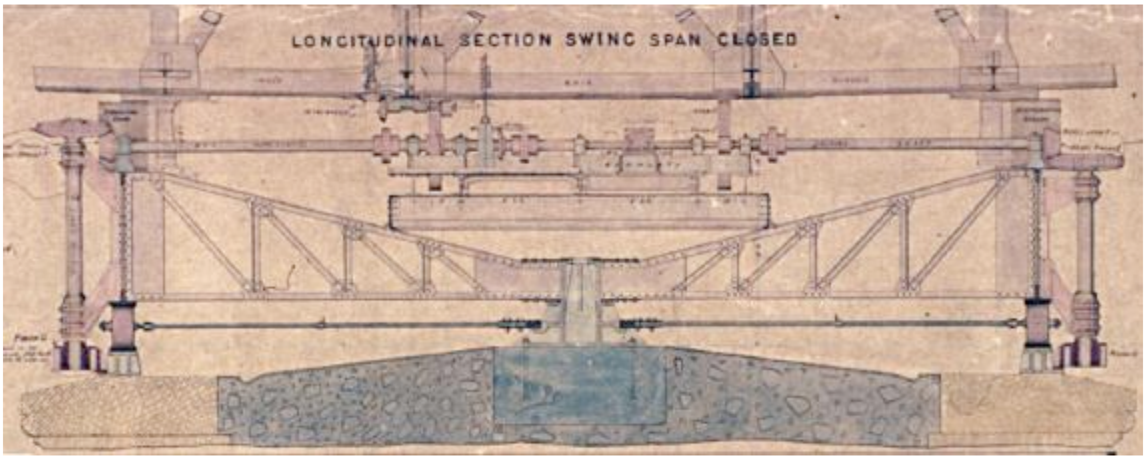

**Figure 9.15 Glebe Island Bridge swing mechanism**

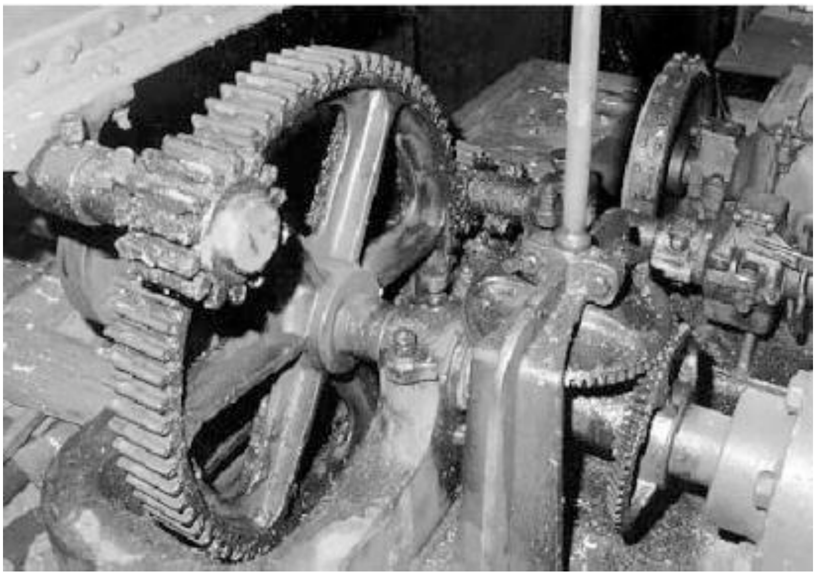

**Figure 9.16** **The slewing motors and the spur wheel mounted on the main slewing shaft**

The bearing of the drum on the pier is achieved by steel conical rollers which are contained between a track fixed to the underside of the drum and a second track fixed to the pier. As the drum rotates, the rollers allow for the smooth continuous bearing during motion. These components are shown in Figure 9.17 to Figure 9.18 below.

**Figure 9.17** **Glebe Island Bridge swing span drum. The main girders rest on the distributing girders and the drum pivots on the cast steel rollers**

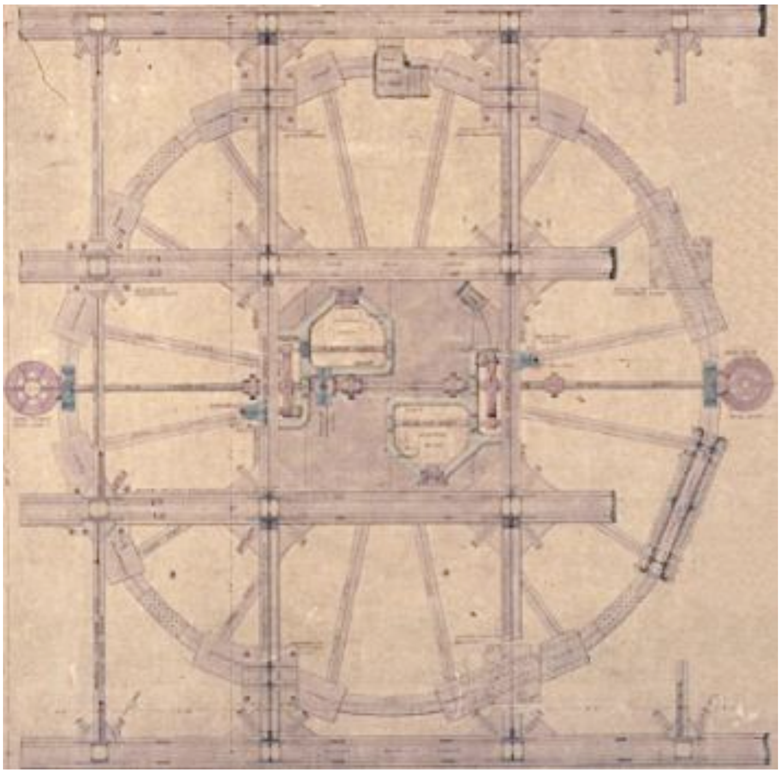

**Figure 9.18 Plan of swing mechanism for Glebe Island Bridge**

As the span returns to its closed position near the rest piers, a braking mechanism consisting of a ‘latch and catch’ is engaged. The latch component is essentially a bracket and wheel mounted on the swing span. The catch is a triangular piece with a centre void. As the span approaches the rest position, wheels on the latch transverse up the incline of the catch thus slowing motion before falling into the opening (Figure 9.19).

Once the span is in its rest position and motion has been stopped by the latch and catch mechanism, four end lifts are raised to provide a firm bearing at the ends of the span. These end lifts are also operated by electric motors, gearing and shafts mounted on the swing span.

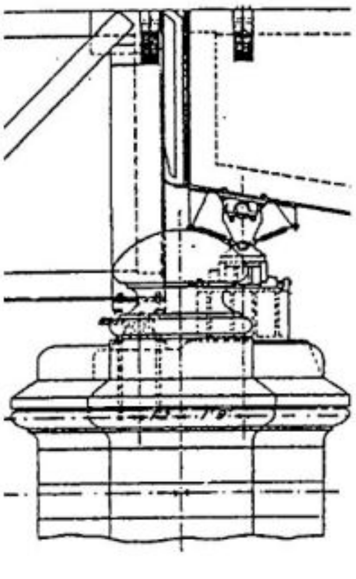

**Figure 9.19 Glebe Island Bridge end lifts**

## Fender

The form and fabric of the fender is of MODERATE significance.

The fender is a massive timber pile, headstock and beam construction, rectangular in form with pointed ends that encloses the pivot pier and is founded on driven timber piles. The rectangular section is approximately 16 m wide and 50 m long with the pointed ends being a further 14 m long each, giving the fender a total length of 78 m.

The purpose of the fender is to protect the pivot pier from impact with large vessels passing beneath the swing span, which might otherwise threaten the integrity of the structure.

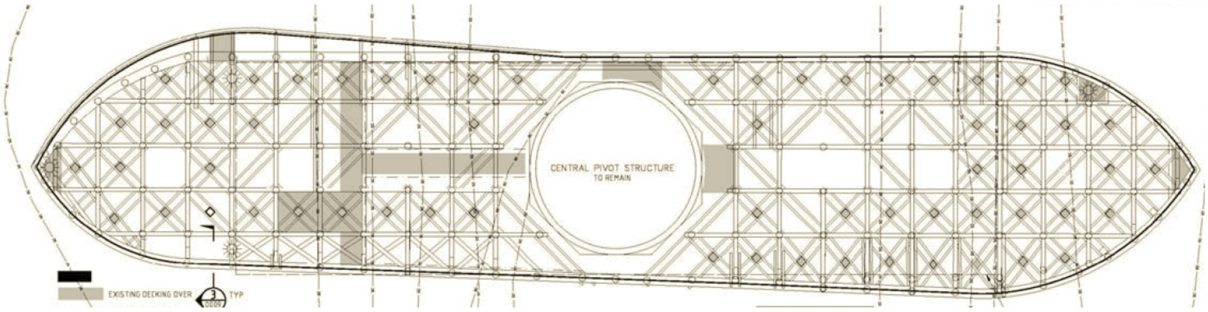

**Figure 9.20 Plan view of fender with pivot pier at centre**

**Figure 9.21 View of the southern end of the fender in 2012 prior to repair works**

### Vehicle and pedestrian barriers

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

There are four sets of combined traffic and pedestrian gates located on the approach spans. The gates are timber framed, with three rows of horizontal steel rods, and are strap hinged for stability to a decorative cast iron column (Figure 9.22).

The outer ends of the traffic gates were originally stayed by a steel rod/strap, which was attached to a collar near the top of the cast iron columns. The steel rod/strap has been replaced by a timber stay and the gates appear to have been rebuilt since the Bridge was opened.

The pedestrian gates are simply cantilevered off the hinge post of the traffic gate. The original pedestrian gates, which were of timber and steel, have been replaced by steel framed gates with mesh covering.

Each set of gates was operated by its own motor. The motors were made by General Electric, Schenectady, New York.

**Figure 9.22 Glebe Island Bridge vehicle and pedestrian gates**

### Motors and electrical

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

There are a number of electrical components on Glebe Island Bridge. They effectively operated the swing mechanisms, bearing systems and gates. An important historical feature of the bridge opening mechanism is that the two 600 volt DC motors are powered from mains via a 600 volt Mercury Arc Rectifier (MAR).

The electrical operation of the swing span was made possible by the opening of the Ultimo Power House in 1899, generating 600 volts Direct Current power for the newly instigated electric tramway system in Sydney. The motors driving the swing span are similar in arrangement to the motors used in the electric trams of this era and the original control gear of the bridge was based upon electric tramway technology.

By 1912, Ultimo Power House had ceased generating DC current and had converted the original DC Engine Room to a Substation equipped with rotary converters, converting AC current to DC current for distribution to the tramway lines in the vicinity. More remote sections of tramway were supplied by high-voltage AC current to local substations, in which rotary converters were installed to produce the Dc current required for the tramlines.

This change had little impact upon Glebe Island Bridge, as it picked up its DC supply from the tramway network. It wasn't until the late 1950s when the tram system was being dismantled throughout Sydney that the electrical supply to the Glebe Island Bridge required reorganisation. The last tram ran over the Glebe Island Bridge on 22 November, 1958 and Ultimo Power House ceased full-time generation in May 1960, closing permanently in December, 1963.

Reorganisation involved obtaining a 415 Volt AC supply from the local reticulation network in Pyrmont operated, at that time, by Sydney City Council. This power supply was led into a new electric services hut installed on the north side of the eastern abutment, in which a MAR and associated switchgear was installed during 1959. The installation has operated reliably since that time.

**Figure 9.23 Electrical services hut (circled), seen from the Pyrmont abutment (Source: Brassil, 2011)**

Steel tank MARs (of the type used at Glebe Island Bridge) were developed In the 1930s and were once a common piece of equipment used in electricity generating stations, electric sub-stations, electro-plating works, theatres, railways and tramway systems and in a variety of large workshops where large quantities of DC current were required. By the 1950s, solid-state rectifiers had largely equalled their performance and had the advantage of needing little supervision, with a high degree of reliability; by the 1970s, MARs were superseded in virtually all applications by semi-conductor technology.

Between the 1970s and the end of the 20th century, most MARs had been taken out of service, both because of the decline in the use of direct current as a motive power source (with AC motors now providing virtually all the same qualities) and through the progressive replacement of glass-bottle rectifiers with their compact, maintenance-free, solid-state equivalent.

In NSW, this occurred relatively rapidly, as the closure of the tramway system occurred during the 1960s (trams had been the major user of DC power) and external facilities utilising DC via the tramway system were typically converted to AC at that time. By the 1980s, other existing MAR installations from the 1930s and 1940s were reaching the end of their operating life and were typically replaced by “modern” equipment in that decade.

The Glebe Island Bridge MAR then is an excellent, single, unitary example of a historically significant electrical technology which is one of the last examples in Australia still performing the function for which it was installed. It is a key functional component within the operating system for the State-significant Glebe Island Bridge and is historically associated with the cessation of electrical tramway operations in Sydney (Brassil, 2011).

**Figure 9.24** The Mercury Arc Rectifier Cabinet, with the door open and the glass bulb upper right with reactors, wiring and relays at the base. Manufactured by Lancashire Dynamo Coates Pty Ltd, of Goodwin Street, Richmond, Victoria. A silicon rectifier unit is mounted on the wall adjacent (Source: Brassil, 2011)

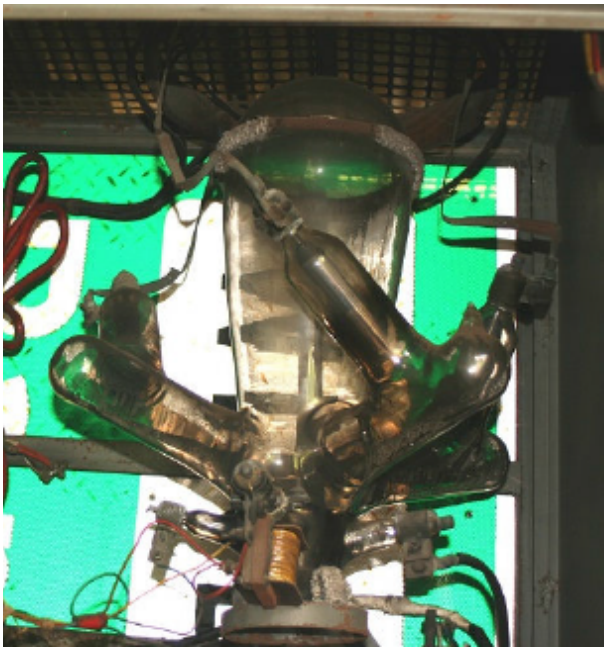

**Figure 9.25** Detail view of the glass bulb of the MAR. It glows white when in use (Source: Brassil, 2011)

## Summary of heritage assessments

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

**Table 9-1 Glebe Island Bridge – Summary of heritage significance**

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

# 10. Management strategies

## 10.1 Technical resources

There are a number of documents for advice with respect to the design, construction, specification, management and maintenance of movable bridges and we would recommend the following documents as the first reference resources for:

- **Past practices.** The use of "Movable Bridges" by Otis Ellis Hovey 1926.
- **Current practices.** The use of "Movable Bridge Inspection, Evaluation and Maintenance Manual" and "Movable Highway Bridge Design Specifications" by the American Association of State Highway Officials (AASHTO) 2nd edition 2012.

## 10.2 Operational nature

Movable bridges by their very nature are complex multi-discipline structures that have greater maintenance requirements and ongoing costs than fixed structures, typically:

1. Vertical lift bridge
- Tower
- Power and control systems.
- Mechanical driving machinery, motors, gearbox, brakes.
- Winch drums, ropes and sheaves.
- Hoist and counterweight cables.
- Counterweights.
- Locks.
- Table
- Power and control systems.
- Hydraulic motors, accumulators, filters, controls and cylinders.

2. Bascule bridge
- Power and control systems.
- Driving machinery, motors, pumps, accumulators.
- Hydraulic or electro-mechanical drives.
- Trunnion bearings.
- Front and/or rear bearings.
- Locks.

3. Swing bridge

- Power and control systems.
- Central or rim bearings.
- Locks.

4. Additional common issues

- Access.
  - Traffic and pedestrian control.
  - Emergency procedures, especially lowering.
  - Isolation procedures.
  - Operating protocols.

Consequently conservation led maintenance strategies requires a wider range of skills, knowledge and multi-disciplined engineering. It can be seen that there are common engineering disciplines that run through the different bridge types and can be broadly defined by the following areas:

- Operational.
- Electrical.
- Control.
- Mechanical.
- Hydraulic.
- Civil and structural.

## 10.3 Strategies

Nevertheless, the management strategies can generally be categorised as follows:

- Maintain.
  - Established maintenance practices.
  - Inspection.
  - Assessment and evaluation.
- Repair.
  - Like for like repairs.
  - No design, material or technological changes.
- Rehabilitate.
  - Reconstruction.
  - Modified design, materials and technologies but reversible.
- Upgrade.
  - Enhancement and betterment to current design safety standards.
  - Permanent improvements in design, materials and technologies.
  - Load carrying capacity or operational speed.
- Replace.
  - New bridge.

- Or permanently fix or re-use the bridge.

For the purpose of this report we will examine each bridge type for the following two maintenance strategy categories only:

1. Maintenance and repairs.
2. Rehabilitation and upgrades.

The purpose is to provide conceptual strategic treatments only and does not cover common, general or specific bridge type problems as this is outside the scope of this study.

## 10.4 Maintenance and repairs

Maintenance and repairs require a broader range of skills than for fixed bridges. It is essential to develop and use well proven techniques to assess and undertake any work. On an operational opening bridge it is good practice to keep a set of critical spare components.

The activities described below should be covered by existing maintenance practices and current AASTHO documentation.

### 10.4.1 Vertical lift span bridges

**Table 10-1 Vertical lift span bridges typical maintenance and repairs**

| Component | Maintenance and repair activity |
|---|---|
| Power | Ensure regular testing (Mega test) and inspection of supply, distribution boards and motors (induction or imperial). Rewire and bake brush motors every ten years. Ensure adequate spares. |
| Control | Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Mechanical components | Ensure moving parts are inspected and serviced regularly, including greasing and non-destructive testing as required. Gears, shafts, gearboxes, brakes, etc should be overhauled typically every 5 to 10 years. |
| Rope winch drums and sheaves | Ensure the winch drum and sheaves are in good condition including valley wear and rope alignment. |
| Hoist and counterweight ropes | The ropes should be inspected annually and carefully lubricated regularly. This includes the rope connections including metalling sockets and swages. |
| Counterweights | Connection pins, saddles and bars should be inspected regularly. Their balance should be checked typically every 2 years. |
| Locks | The engagement locks and lift span hold down should be checked monthly and any adjustment undertaken as required. |
| Lift span and towers | Subject to the same maintenance activities as fixed bridges. |

### 10.4.2 Table bridge

**Table 10-2 Table bridge typical maintenance and repairs**

| Component | Maintenance and repair activity |
|---|---|
| Power | Ensure regular testing (Mega test) and inspection of supply, distribution boards, etc. Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Control | Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Pump motors and accumulators | Inspect and test regularly. Re-charge the nitrogen bladder in the accumulators as required. |
| Hydraulic machinery | Ensure regular inspection and testing (including oil samples). Replace hoses and worn components on a regular basis. |
| Front and/or rear bearings | Inspect and maintain regularly. Adjust play and level as required to ensure smooth running deck surface and joint. |
| Locks | The engagement rear and centre locks should be checked monthly and any adjustment undertaken as required. |
| Control tower and rooms | Subject to the same maintenance activities as fixed bridges. |

### 10.4.3 Bascule bridges

**Table 10-3 Bascule bridge typical maintenance and repairs**

| Component | Maintenance and repair activity |
|---|---|
| Power | Ensure regular testing (Mega test) and inspection of supply, distribution boards and motors (induction or imperial). Rewire and bake brush motors every ten years. Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Control | Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Drive machinery | Ensure moving parts are inspected and serviced regularly, including greasing and non-destructive testing as required. Gears, gearboxes, brakes, etc should be overhauled typically every 5 to 10 years. |
| Hydraulic machinery | Ensure regular inspection and testing (including oil samples). Replace hoses and worn components on a regular basis. Re-charge the nitrogen bladder in the accumulators as required. |
| Trunnion bearings | Inspect and maintain as recommended by the manufacturer. Adjust play and repair as required. |
| Front and/or rear bearings | Inspect and maintain regularly. Adjust play and level as required to ensure smooth running deck surface and joint. |
| Locks | The engagement rear and centre locks should be checked monthly and any adjustment undertaken as required. |
| Control tower and rooms | Subject to the same maintenance activities as fixed bridges. |

### 10.4.4 Swing bridge

**Table 10-4 Swing bridges typical maintenance and repairs**

| Component | Maintenance and repair activity |
|---|---|
| Power | Ensure regular testing (Mega test) and inspection of supply, distribution boards and motors (induction or imperial). Rewire and bake brush motors every ten years. Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Control | Test controls and barriers under normal and emergency operations. Ensure adequate spares. |
| Mechanical components | Ensure moving parts are inspected and serviced regularly, including greasing and non-destructive testing as required. Gears, gearboxes, brakes, etc should be overhauled typically every 5 to 10 years. |
| Central or rim bearings | Inspect and maintain as recommended by the manufacturer. Adjust play and repair as required. |
| Locks | The engagement locks and lift span hold down should be checked monthly and any adjustment undertaken as required. |
| Control tower and rooms | Subject to the same maintenance activities as fixed bridges. |

## 10.5 Rehabilitation and upgrades

Rehabilitation and upgrades require extremely careful planning and design including often complex new material and machinery selection. Only highly experienced personnel should be involved in this work as the risks of making unintentional mistakes by not fully understanding the movable span constraints in the design or execution are great.

In general major upgrades similar to those taken at Swansea Bridges, Hexham, Wardell and Harwood Bridges have involved significant and costly temporary works designs to facilitate the rehabilitation and upgrade. This usually involved complex work, often at height over a waterway or busy road at night during bridge closures with limited working hours.

### 10.5.1 Vertical lift span bridges

**Table 10-5 Vertical lift span bridges typical rehabilitation and upgrades**

| Component | Rehabilitation and upgrades |
|---|---|
| Power | Secure power source and uninterrupted power supply (UPS). Upgrade wiring, control panels to current standards and IP rating. |
| Control | Control systems including PLC and SCADA to meet current operating, safety of machinery and isolation procedure standards. |
| Mechanical components | Overhaul or replace gears, shafts, gearbox, brakes, etc. Requires design and material selection to Australian Standards. Different approaches are likely for longitudinal and transverse sheave operational improvements. |
| Rope winch drums and sheaves | Overhaul or replace winch drums and sheaves to current standards. New sheaves may be cast using spheroidal cast iron. |
| Hoist and counterweight ropes | Replacement using pre-stretched fibre core ropes. |
| Counterweights | Replace pins, saddles and bars to current standards and factors of safety as required. |
| Locks | Redesign to secure the bridge and form part of the locking control protocols. |
| Lift span and towers | Strengthen and upgrade as required. Stairs and landings overhauled to make access and working at heights easier. |

### 10.5.2 Table bridge

**Table 10-6 Table bridge typical rehabilitation and upgrades**

| Component | Rehabilitation and upgrades |
|---|---|
| Power | Secure power source and uninterrupted power supply (UPS). Upgrade wiring, control panels to current standards and IP rating. |
| Control | Control systems including PLC and SCADA to meet current operating, safety of machinery and isolation procedure standards. |
| Pump motors and accumulators | Replace with dual pump motors. Replace and upsize accumulators. |
| Hydraulic machinery | Fabricate one new luffing and locking cylinder then replace and overhaul each one in turn, keeping the last cylinder as a spare. Overhaul the hydraulic circuits design to current standards and ensure manufacturer compatibility and future proofing. |
| Front and/or rear bearings | It is unlikely these will require replacement during their lifespan but again careful design and staging will be required depending on their in-service performance. |
| Locks | May require redesign or modifications to secure the bridge. |

| Component | Rehabilitation and upgrades |
|---|---|
| Control tower and rooms | Strengthen and upgrade as required. |

### 10.5.3 Bascule bridges

**Table 10-7 Bascule bridges typical rehabilitation and upgrades**

| Component | Rehabilitation and upgrades |
|---|---|
| Power | Secure power source and uninterrupted power supply (UPS). Upgrade wiring, control panels to current standards and IP rating. |
| Control | Control systems including PLC and SCADA to meet current operating, safety of machinery and isolation procedure standards. |
| Drive machinery | Overhaul or replace gears, shafts, gearbox, brakes, etc. Requires design and material selection to Australian Standards. |
| Hydraulic machinery | Fabricate one new luffing and locking cylinder then replace and overhaul each one in turn, keeping the last cylinder as a spare. Replace and upsize accumulators. Overhaul the hydraulic circuits design to current standards and ensure manufacturer compatibility and future proofing. |
| Trunnion bearings | Very difficult in general to overhaul and replace. Replacement means lifting an entire bascule. Seek specialist bearing advice. |
| Front and/or rear bearings | It is unlikely these will require replacement during their lifespan but again careful design and staging will be required depending on their in-service performance. |
| Locks | May require redesign or modifications to secure the bridge. |
| Control tower and rooms | Strengthen and upgrade as required. |

### 10.5.4 Swing bridge

**Table 10-8 Swing bridges typical rehabilitation and upgrades**

| Component | Rehabilitation and upgrades |
|---|---|
| Power | Secure power source and uninterrupted power supply (UPS). Upgrade wiring, control panels to current standards and IP rating. |
| Control | Control systems including PLC and SCADA to meet current operating, safety of machinery and isolation procedure standards. |
| Mechanical components | Overhaul or replace gears, shafts, gearbox, brakes, etc. Requires design and material selection to Australian Standards. |
| Central or rim bearings | Very difficult in general to overhaul and replace. Replacement means lifting the entire swing span. Seek specialist bearing advice. |
| Locks | May require redesign or modifications to secure the bridge. |
| Control tower and rooms | Strengthen and upgrade as required. |

## 10.6 Common issues

As highlighted previously there are common maintenance and operational issues found on all opening bridges:

### 10.6.1 Access

Access is a major issue for nearly all movable bridge types:

***Vertical lift span – old type.*** On the old type there is often limited or no suitable safe access to the top of the towers and bracing girders to maintain the working components like sheaves and open gears. Access was typically using open ladder rungs attached to one tower at each pier (Figure 10.1).

Recommendation: This could be mitigated by reversible temporary bridge access ladders and platforms but would require careful design and consultation.

Alternatively, and probably preferably access requirements could be greatly reduced by significant overhauls of the lifting system with modern equipment largely out of sight of the existing machinery which would be retained.

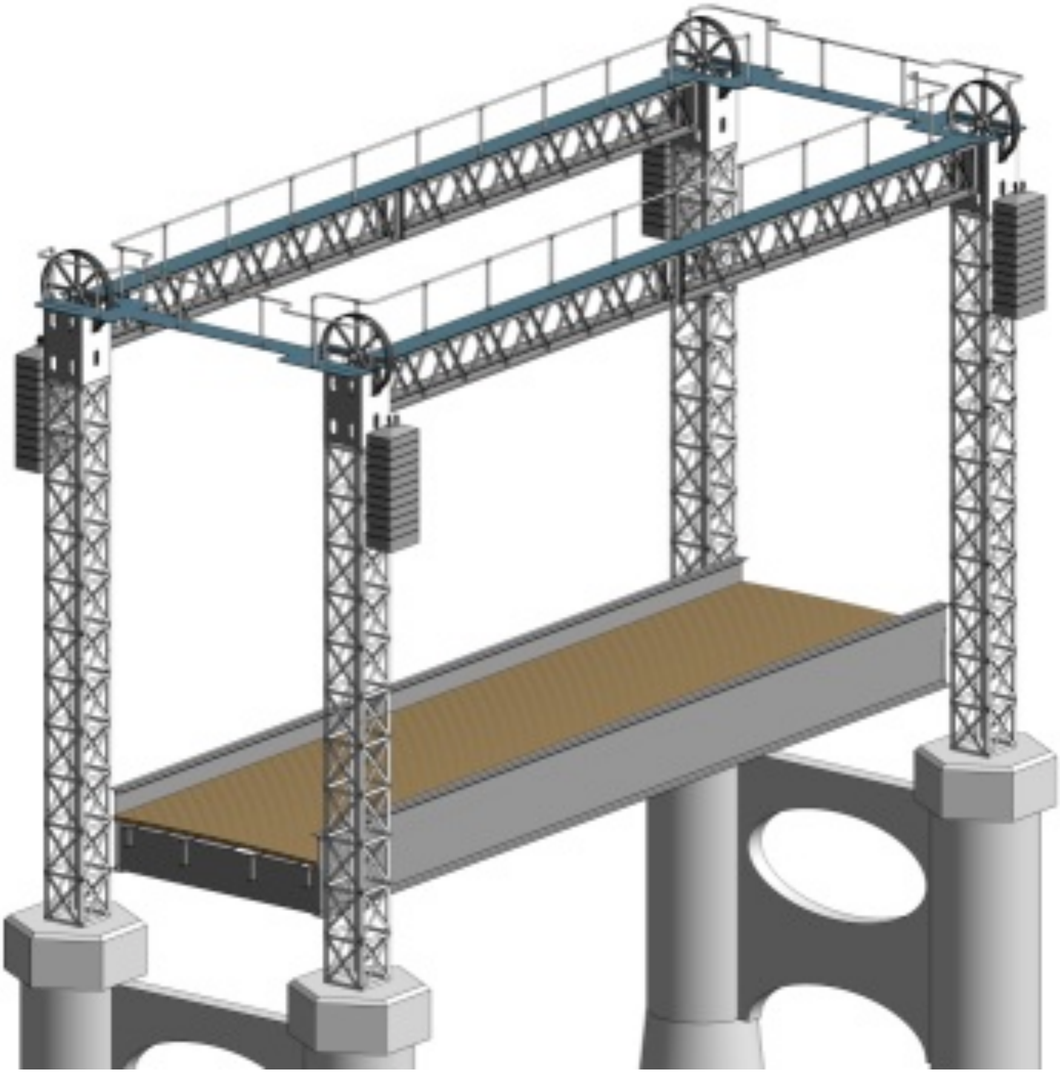

**Figure 10.1 No modern day access was provided to the top of the towers (Source: GHD)**

***Vertical lift span – new type.*** On the new bridges there is little ability to lift any bulky or heavy inspection or maintenance gear around or to the top of the structure. During major overhaul works, like Harwood Bridge, Alimak cranes were attached to the towers for men and machinery access.

Recommendation: Upgrade the existing ladders, stairs and platforms over time with minimal visual impact on the existing bridge span and towers (Figure 10.2).

***Table bridge.*** There is inadequate access to the lifting cylinder bases and associated operating and control machinery with numerous confined space and lighting issues within the bridge piers.

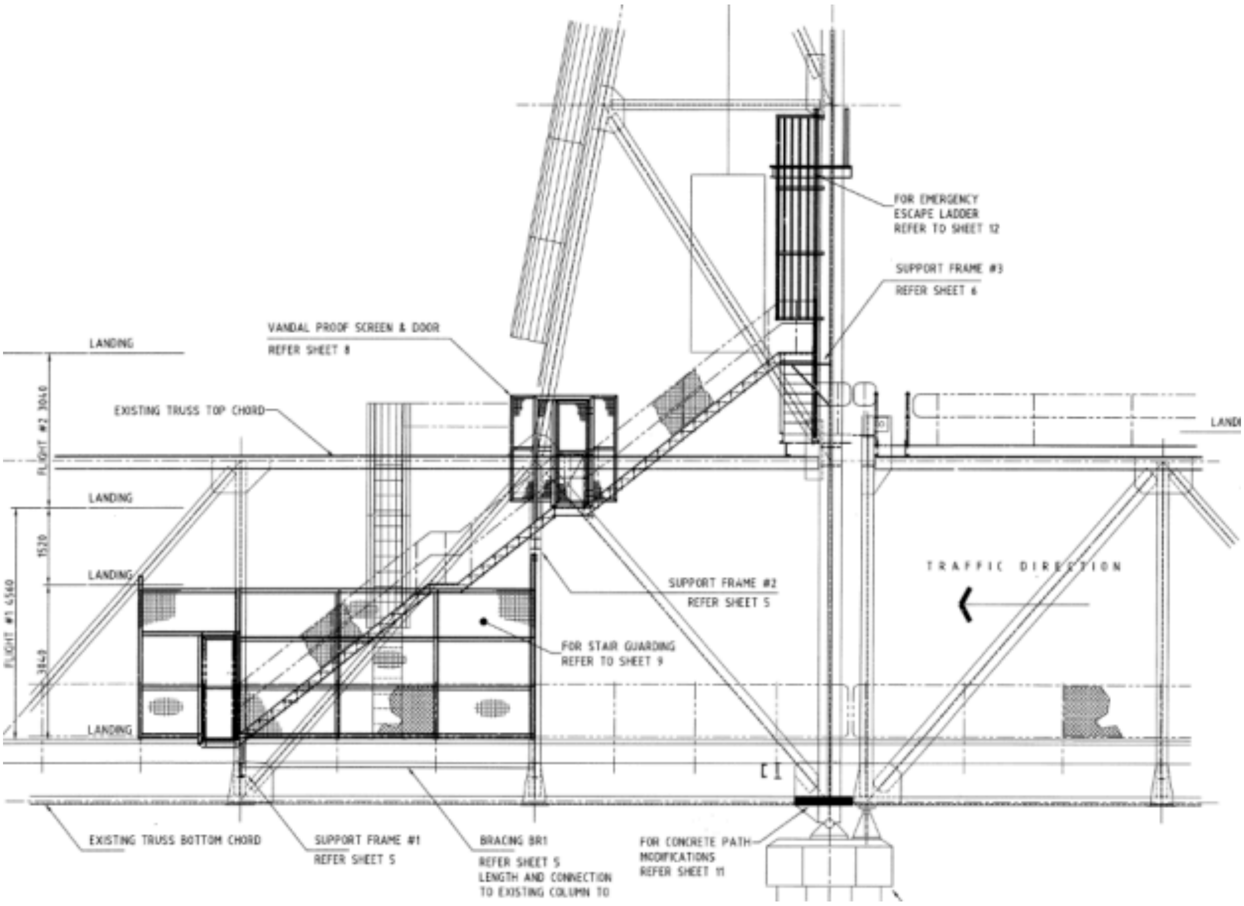

**Figure 10.2 Typical retro-fitted access stairs, platforms and gates**

***Bascules – old type.*** Again there is no access to the top of the towers.

Recommendation: All the old type bascules are no longer functioning opening bridges. We would recommend that the old counterweights are lowered, de-weighted and left atop the running rail at the lowest section of track at deck level.

***Bascules – new type.*** One of the major modern day safety considerations is working in confined spaces. Even in the recently designed bridges, like

Swansea Bridge southbound, there was inadequate appreciation of adequate ventilation and exit strategies during an emergency or accident.

Recommendation: Implement access and ventilation improvements on a bridge by bridge basis to remove or improve confined space access.

***Swing bridge.*** Again there is very limited access for inspection and maintenance.

Recommendation: Implement access improvements as required.

Recommendation: Implement access, lighting and ventilation improvements.

The approach to solve and mitigate all the numerous access issues with each and every bridge type is beyond the scope of this report. In addition bridges like Hexham Bridge use Jomy safety ladders for emergency access which should probably be mandatory.

### 10.6.2 Traffic and pedestrian control

All movable span bridges have to cater for vehicular and pedestrian traffic. Some bridges designs do this better than others. However, commonly the traffic barriers are susceptible to wind and traffic impact damage.

The older barrier designs also tended to be less reliable, especially if not operated frequently. Many of the older type vertical lift and bascule bridges have no safety barriers for vehicles, pedestrians or operators which should be rectified.

### 10.6.3 Emergency procedures, especially lowering

Emergency controls and procedures, including testing of the pony motors, hand winding mechanisms, back-up generators, etc. Emergency traffic control plans should be available for the fourteen operational bridges.

In addition the operators should be trained and practice the emergency lowering procedures at least once a year typically.

### 10.6.4 Isolation procedures

Site inductions, isolation, lock-out (see Figure 10.3) and tag-out procedures should be developed for all operational bridges. This is vital and should be mandatory when numerous multi-discipline personnel are working at the same time on the bridge, often during shutdowns, at night and over water.

**Figure 10.3 Danger lock out tags front and back**

### 10.6.5 Operating protocols

Good operating protocols can vastly improve the safety and speed of an opening and reduce operational incidents.

In addition modern day control panels can ensure operate error is virtually removed from the lifting and operating sequence (see Figure 10.4).

**Figure 10.4 Control panel upgrade Swansea Bridge**

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