South Dock Bridge
Goole

An Historical Audit

Milepost Research
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Contents

1 SUMMARY

An historical audit of South Dock Bridge was carried out for Associated British Ports, Goole, to assess the historical importance of the bridge in local, regional and national terms. Historical document sources were inspected and the opinion of industrial and technical history experts around Britain sought, together with information which they could supply regarding swing bridges. The report presents a general introduction to swing bridges, with reference to other surviving examples, particularly in Yorkshire. The history of South Dock Bridge is considered, together with the technical aspects of the bridge and its mechanism.

In conclusion the importance of the bridge is discussed, and a series of recommendations made as to the possible conservation and interpretation of South Dock Bridge.

View of South Dock Bridge from the south west, looking across the passageway opened in 1910. On the right is the fixed plate-girder bridge over the passageway.

One of the few remaining wood-framed Leeds & Liverpool swing bridges, typical of early swing bridge technology. This one is at Apperley Bridge, near Bradford. Note the steel stay bars supporting the ends of the bridge from a cast iron fitting on the top of the side rails at the centre of the bridge.

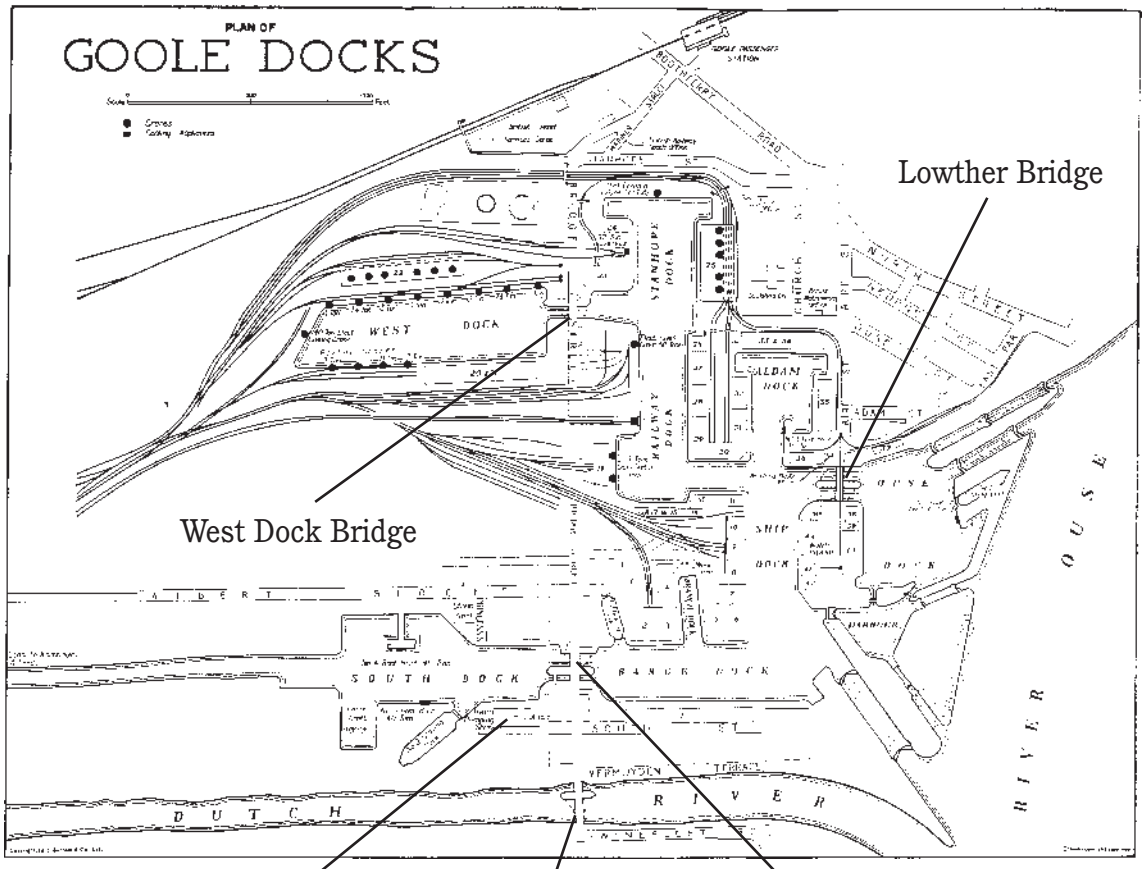
2 INTRODUCTION

2.1 Background

South Dock Bridge is a listed Grade II structure. It was built in 1897-8 and is a water-hydraulic powered swing bridge. Agreement for its upgrading to cope with increasing axle weight regulations by the construction of a new bridge structure has been obtained, though the existing abutments will be retained. This historical audit looks at the history of swing bridges in general, and South Dock Bridge in particular. Other surviving swing bridges were identified, though this part of the survey was restricted to bridges built prior to the Second World War and, to some extent, those in the Yorkshire area. The problems of conserving and interpreting the bridge deck are considered, and recommendations made for future action with regard to the bridge. The audit was undertaken by Mike Clarke of Milepost Research.

2.2 Organisation of Report

The report first considers the design, development and use of the various types of swing bridges. The development of hydraulic power, with particular reference to Goole, is then reviewed, followed by notes on the sources used during research for the report. The history of South Dock Bridge is then considered both chronologically and technically. The report closes with a discussion and appraisal of the significance of South Dock Bridge with recommendations for conservation and interpretation.



Goole Docks in 1961 showing the location of swing bridges and the hydraulic pumping station

3 SWING BRIDGES

3.1 Draw bridges and bascule bridges

The earliest opening bridges were draw bridges in which one end of the bridge is hinged and the other end is raised, the power needed to raise the bridge being reduced by a counter balance. The simplest design is the traditional Dutch type of bridge where the counter balance is carried on an overhead beam. Recent examples can be found on the New Junction Canal. This design developed into the bascule bridge where the counter balance is under the tail of the bridge. A pit is required to accommodate the counter balance when the bridge is raised.

3.2 Swing bridges

Swing bridges became popular in the eighteenth century, particularly for canals and docks. The weight of the bridge is either taken by a centre bearing or by a rim bearing where rollers run around a circular track. On some centre bearing bridges, a rim bearing is provided with light loading to stabilise the bridge when in motion. The benefits of swing bridges are their low power requirements, minimal bearing wear, absence of deep pits for counter weights and small variation in road level. Their disadvantages are that they are longer than bascule bridges and side recesses are needed when the bridge is open to water traffic.

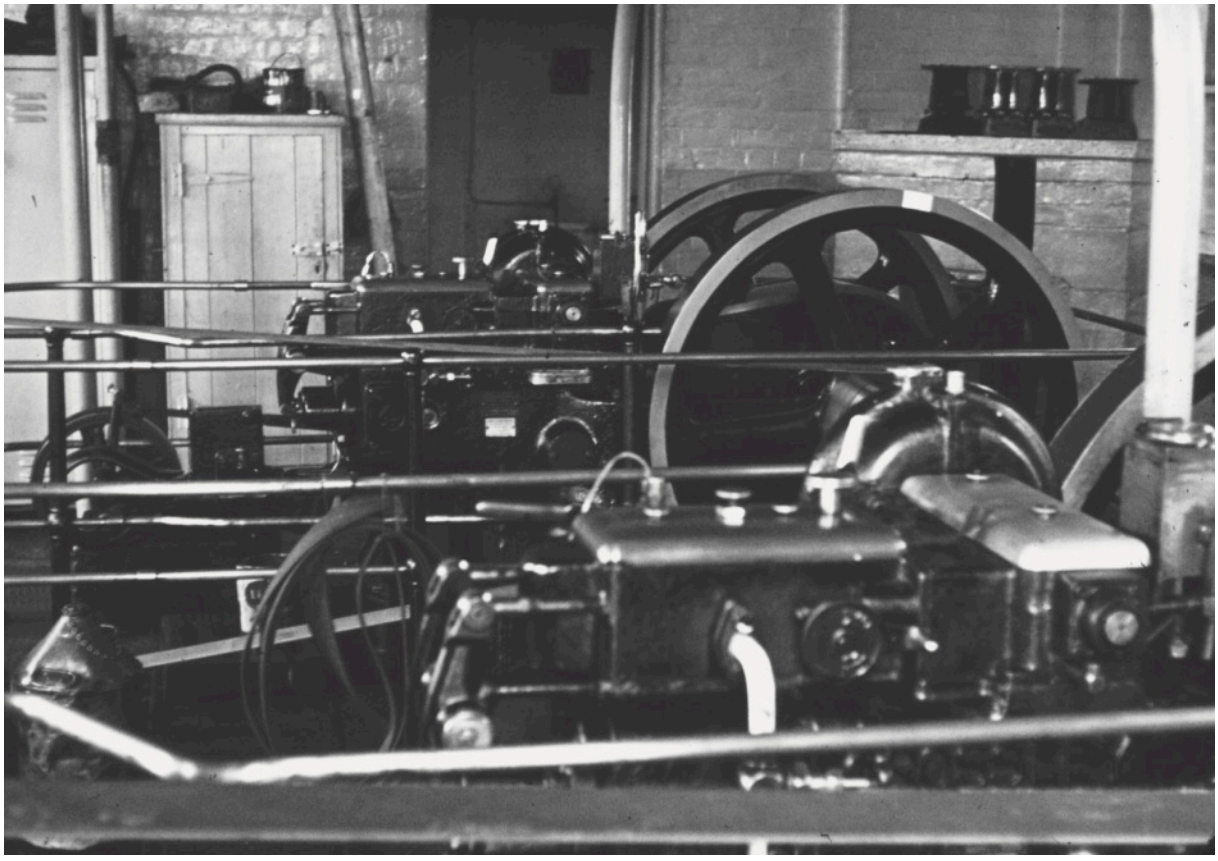
The earliest swing bridges were built from wood, usually with iron stays and bearings. They seem to have had rim bearings, possibly in an effort to reduce point loading. It must have been difficult to keep the bearing track free from stones and dirt on these early bridges. The Leeds & Liverpool Canal Company began replacing swing bridges with stone bridges in 1784, just ten years after the canal had opened, probably because of difficulty in opening them. In the same year they sent one of their engineers to look at the swing bridges on the Sankey Navigation, ordering him to build a similar one on their canal. Could this design have incorporated a centre bearing? Certainly more recent small canal swing bridges all have such bearings. These are much easier to keep free from dust and stones, thereby reducing wear and increasing ease of operation.

A simple steel swing bridge over Sykehouse Lock on the New Junction Canal. Design work for this canal was carried out by the Aire & Calder Navigation, so reflects their working practice.

By the mid-nineteenth century, cast iron was being used for the main bridge structure of many dock bridges, those at Albert Dock, Liverpool, being a good example of this type. They date from 1843. However, cast iron is not the ideal material for bridge construction as it is poor in tension. As a result, wrought iron was used for dock and navigation bridges as the increasing size of vessels demanded greater bridge spans. Technological problems restricted the size and shape of the wrought iron sections which could be rolled, resulting in the need to fabricate complex bridge girders from simple plates and angle sections by rivetting. Consequently, late-nineteenth century bridges are either plate girder or open lattice girder construction. With the introduction of steel and the improvement of rolling technology around the turn of the century, bridge girder design concentrated on the open lattice. This allowed spans to be increased while restricting the overall weight of the bridge and consequently reducing loading on the bridge bearing.

On simple swing bridges, the load of the bridge deck and traffic passing over the bridge is taken directly by the bridge bearing. As clearance is needed for the bridge to move, the deck will tend to rock as a vehicle passes across, and this can cause excessive bearing wear. This is overcome on larger bridges either by raising the bridge off its bearings or lowering the bearing when the bridge is in its closed position. In the former case wedges are then introduced for the bridge to sit on and this stops the bridge from moving as traffic passes over it. In the latter case, the bridge is lowered onto fixed supports to stop movement.

Manual power is sufficient for many swing bridges, with hydraulic power being used for those in docks where such power was available. From the 1890s, hydraulic power was available more widely with individual internal combustion engines driving hydraulic pumps to operate the bridge. The swing bridges on the Manchester Ship Canal were good examples of this. As electric power became more widely available, it became the standard power source, either directly via electric motors, or by electrically driven hydraulic systems.



The diesel powered hydraulic pumps at Old Quay Swing Bridge, Runcorn, on the Manchester Ship Canal. Operation of the bridge has now been converted to electrically generated hydraulics.

4 HYDRAULIC POWER

4.1 General introduction

Hydraulic power has a long history, hydraulic engines being applied to pumping as far back as the mid-eighteenth century. In Britain, Joseph Bramah developed hydraulic presses towards the end of the eighteenth century, Hull being an important centre for their use in seed and oil mills.

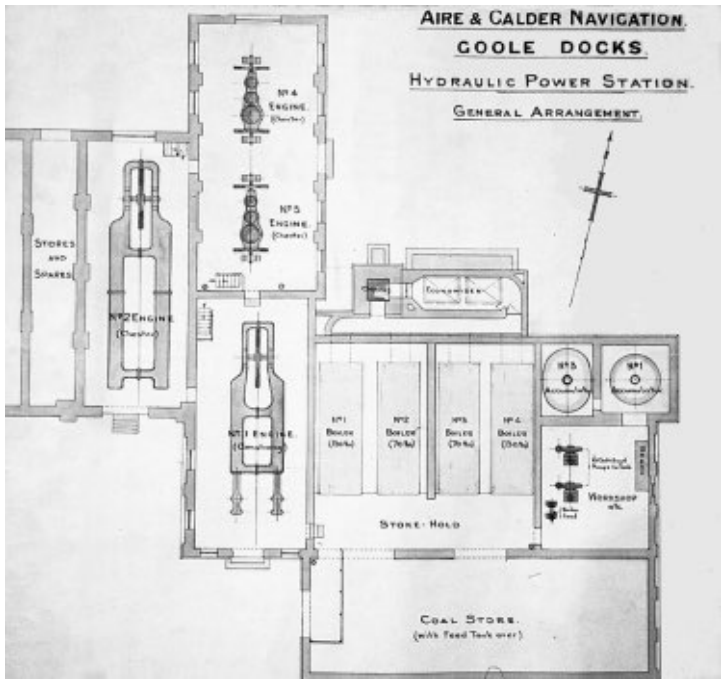
The earliest use of hydraulic power for opening bridges was in Manchester, where a bridge over the Rochdale Canal was lifted hydraulically circa 1825. It is uncertain what type of bridge this was, but J.M.Rendell's bridge over Bowcombe Creek in Devon was certainly a bascule bridge. Opened in 1831, the bridge was operated by a toothed rack, moved by a hand pump extending a hydraulic ram. The rack turned a drum through a pinion, and a chain wound around the drum opened the bridge.

William Armstrong successfully exploited hydraulic power when he used water pressure from Newcastle's water supply to operate a crane in 1845. Chains were placed around pullies at either end of a cylinder and ram which was then extended by water pressure, the chains being connected to a load which was thus raised. Steam driven water pumps were soon introduced to make the power source independent. Originally these pumped water to a high-level reservoir, the best known being the tower at Grimsby Docks dating from 1849-50. This was an expensive solution to the problem of providing a constant high pressure supply, and in 1851 Armstrong introduced the accumulator. This was a weighted ram in a vertical cylinder. When no machinery was being used on the hydraulic system, the steam driven pumps raised the weight, thus providing a reserve for use later.

Although first introduced for operating cranes, Armstrong soon adapted the system to operate lock gates. By 1858, hydraulic lock gates were installed at Sunderland Docks, and Victoria and West India Docks, London, and were being installed in Liverpool.

4.2 The system at Goole

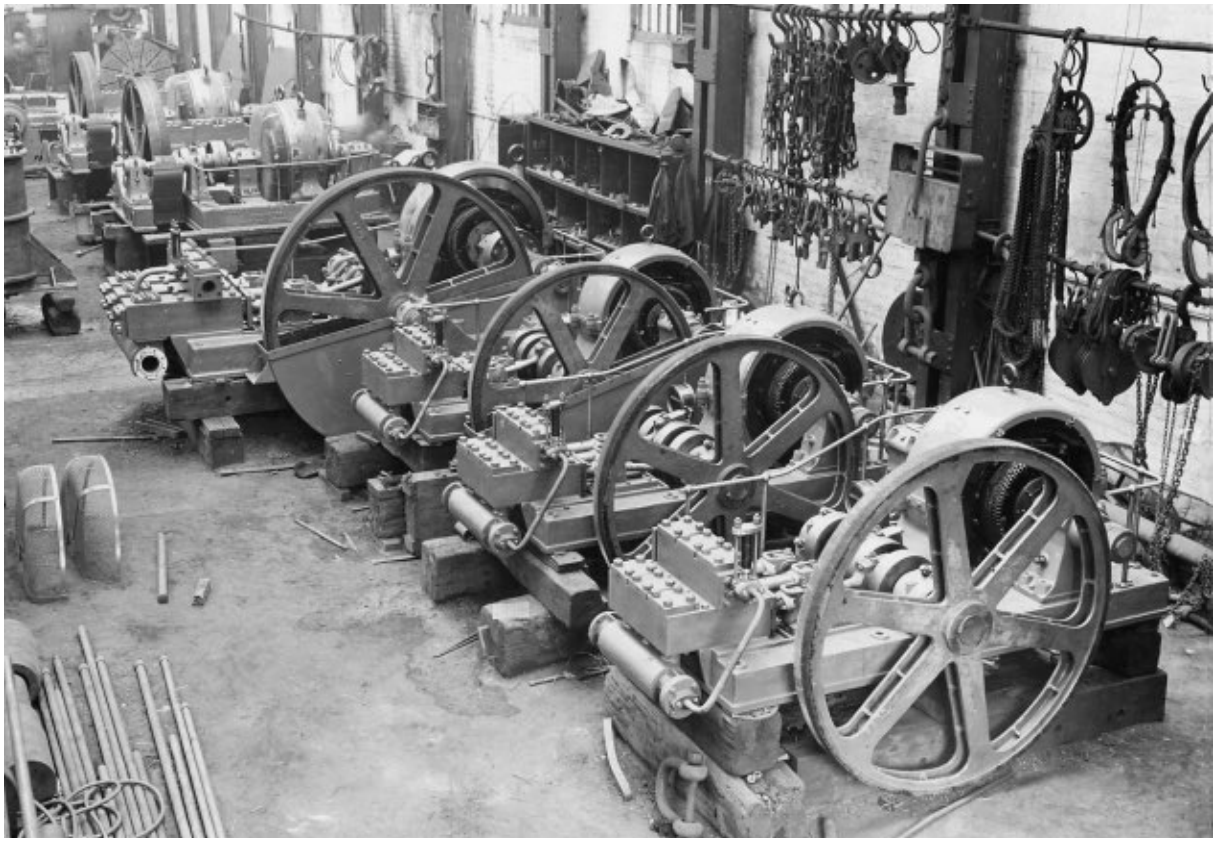
A hydraulic system at Goole was authorised on 14 Jan 1862 for working the gates of the lengthened Steamship (Ouse) Lock and the new boat hoist. Sir William Armstrong & Co. supplied an horizontal tandem steam pump with an 8 feet dia flywheel. A Cornish boiler supplied the steam for the engine. At first the system operated at 750 lbs/sq.in, then it was increased to 825 lbs/sq.in, finally reaching 900 lbs/sq.in. An accumulator was installed soon after opening of system to even out pressure fluctuations. The steam pump was compounded in 1888, when three Lancashire boilers were installed. A second engine was supplied in 1890, followed by two vertical engines, capable of supplying 300 gals/min at 1000 lbs/sq in., from the Chester Hydraulic Engineering Co. in 1906. The engine house was on the corner of the island between Ouse Dock and the Harbour.



A plan of the steam powered hydraulic pumps prior to the system being converted to electrical power.

The pumps circulated high pressure water through mains which fed all areas of the docks. The water was taken from the docks, and after use it ran to waste into the docks. Hydraulics were not just used for working lock gates and operating the boat and railway hoists, but also worked many of the dockside cranes and jiggers in the warehouses. Some ten accumulator towers were located on the mains around the docks, ensuring that the operation of hydraulic equipment did not cause too great a fluctuation in operating pressure. Pumping was electrified in 1934 when electric pumps were supplied by Hodgart & Barclay Ltd, Vulcan Works, Paisley. They were installed in a new pumping station in South Dock, close to the gas works. The system closed circa 1986 following the ending of coal export shipments which used the boat hoists and railway tips.

The development of electric power led to a decline in the use of water-hydraulic power after the First World War. However, there are still many bridges and dock gates operated by water-hydraulic power, but, as at Goole, the hydraulic pressure is now generated by electrically-powered pumps nearby instead of at a centralised hydraulic pumping station.



The electric pumps in the works of Hodgart & Barclay prior to installation at Goole.

4.3 Hydraulic operation

The ram and cylinder remained the main-stay of hydraulic power applications, but in the early 1870s the hydraulic motor was introduced to provide rotary motion. When operated by hydraulic power, opening bridges tended to use rams, though Scherzer (rolling bascule) bridges often used hydraulic motors.

Swing bridges were usually worked by two horizontal cylinders situated to one side of the swing bridge bearing. A chain or wire rope from the end of the piston passed partway around a circular pulley concentric with the bearing and underneath the swing bridge. The chain from one cylinder passed around the left hand side, and from the other cylinder around the right hand side. By working either cylinder individually, the bridge could be turned in either direction.

5 METHODOLOGY AND SOURCES

5.1 The range of evidence

The terminology describing opening bridges varies from place to place and, although there are accurate descriptive terms, these are not widely known or understood. Consequently, it is difficult to access information about opening bridges from the database held by the National Monuments Record Centre at Swindon. The descriptions there are also written, in the main, by architectural historians and give little or no detail of the type or method of operation of opening bridges. The Civil Engineering Department at the Science Museum was contacted and their database consulted in order to identify opening bridges. This and the database at the Institution of Civil Engineers are the main sources for information on the location of swing bridges in Britain.

Associated British Ports at Goole have their own archive of drawings and other records which go back to around 1900, and these were checked for details related to South Dock Bridge. The Aire & Calder Navigation records, held at the Public Record Office, Kew, were inspected, in particular the directors minutes and engineering reports related to South Dock Bridge, formerly known as Goole Canal Bridge.

Opening bridges have always been a specialist subject within the wider scope of bridge building. Consequently there are few technical books which cover the subject. Histories of bridge building have tended to concentrate on fixed bridges, with opening bridges being covered by just the odd page or two of text.

5.2 Technical sources consulted

The Library of the Institution of Civil Engineers was visited and the Librarian, Michael Chrimes, provided information regarding opening bridges from the manuscript he is preparing on the history of bridges. Several papers in the Minutes of the Proceedings of the Institution contain information about opening bridges, perhaps the most important being that of Price, in which the various types of bridge are discussed, and some of the most important listed. Most technical books relating to opening bridges are American, the best being by Hovey. Cunningham considers bridges where they were used on docks and gives a good overview of the technology at the time South Dock Bridge was built. Articles in periodicals are usually about specific bridges. Wilson gives a good overview of swing bridges. McNeil provides background information about the supply and use of hydraulic power.

5.3 Contemporary sources consulted

The records and archives of ABP, Goole, were examined and the drawings held listed. These, together with the records of the Aire & Calder Navigation in the Public Record Office (RAIL800) provided most of the information needed to draw up a chronology of events related to South Dock Bridge. Most important were RAIL800/131 which contains the contract documents for South Dock Bridge, including a sketch of the original proposal. Other information was found in the relevant Aire & Calder Navigation Acts (1889, 1895 and 1908) and in the records held by British Waterways, some plans related to Goole remaining in their archive at Dock Street, Leeds.

Information about previous bridges on the site was difficult to obtain. The best source proved to be a drawing of the canal to the west of the bridge in ABP's archive, from which it was possible to deduce that this bridge had been of bascule construction.

5.4 Secondary sources consulted

There are several histories of the Aire & Calder Navigation, ***The Canals of North-East England*** by Charles Hadfield providing the most complete information about the period related to South Dock Bridge.

6 THE HISTORY OF SOUTH DOCK BRIDGE

6.1 Bridges in Goole Docks

Goole Docks were first opened in 1826. Over the following ninety years, bridge and materials technology developed, resulting in a wide variety of bridge types being built around the docks. Most have been replaced at least once, so individual sites may have had two or three different bridge types. Where headroom was not important, overbridges were used, but most bridges needed to be opened to allow vessels with fixed masts to pass through.

At one stage there was a sliding bridge over the passage between the Harbour and Steamship (Ouse) Dock. For many years, the largest bridge was the Iron Bridge, a cast iron double leaf bascule bridge on the site now occupied by Lowther Swing Bridge. West Dock Bridge, opened 1912, was another swing bridge. The original designs for this bridge were for a bascule bridge, two different types being proposed in 1908. One was produced by the Strauss Bridge Company of America, possibly the result of the visit to America in 1881 of the Aire & Calder's Engineer, William Bartholomew.

6.1.1 Other opening bridges on the Aire & Calder Navigation

There were other opening bridges on the navigation. The Aire & Calder Directors' Minutes (RAIL 800/15) for the 8 August 1881 state:

> *Leeds Chamber of Commerce suggest making Leeds a port. Proposed raising bridges and widening waterway, not less than two bridges per year.*

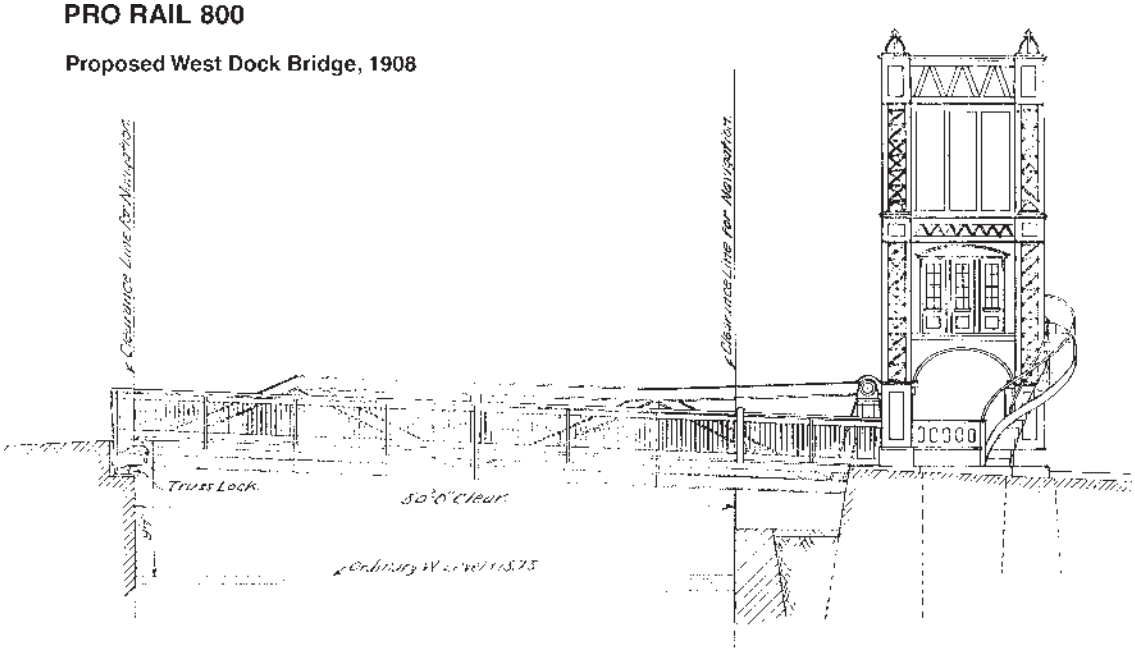
This was at the time when the Manchester Ship Canal was being promoted, and there were schemes for ship canals to both Leeds and Sheffield suggested at various times over the following decades. When the Hunslet Railway was built across the Aire & Calder Navigation just below Thwaite Lock in the 1880s, a swing bridge of a size suitable for a ship canal was erected. Later, in 1912, when the Hull & Barnsley Railway bridge below Pollington Lock was built, a Scherzer rolling lift bridge was installed. Neither had operating machinery and neither were ever opened. As part of the general improvements to the navigation, other bridges were widened. The Aire & Calder Directors' Minutes (RAIL 800/15) for the 4th December 1882 authorise the span of swing bridges on the Goole Canal to be increased to about 27 feet. Swing Bridge No.3, close to Pollington Lock, still remains as built at this time, though the other four swing bridges have now been removed.

No. 3 Swing Bridge, situated just below Pollington Lock. This type of open lattice girder swing bridge was originally proposed for South Dock Bridge in the 1880s.

The Iron Bridge at Goole, a cast iron bascule bridge which later was replaced by Lowther Swing Bridge. From 1864 to 1897, a single leaf bridge of this type may have been used on the South Dock Bridge site.

PRO RAIL 800

Proposed West Dock Bridge, 1908



ELEVATION.

The proposed Strauss bascule bridge for the bridge over the entrance to the new West Dock.

6.2 South Dock Swing Bridge

6.2.1 Previous bridges

South Dock Swing Bridge was originally known as Goole Canal Bridge. When first built in 1826, it was a stone arch bridge. Any sailing vessels passing under the bridge would need to have had their masts removed or lowered. By the 1860s, traffic at the docks was increasing. Further dock space was required, and as a cheap alternative it was decided to convert the stone bridge into an opening one, allowing wider vessels and those with fixed masts to reach wharves in what is now known as South Dock. The Aire & Calder Navigation's Director's minutes (RAIL 800/15) for 1 June 1863 record:

> *Mr Bartholomew having explained the plan upon which the canal bridge at Goole might be converted into a swing bridge and that the probable cost would be £1500. Resolved that any decision on the matter be postponed until the directors visit Goole.*

The Engineers Report (RAIL 800/61) given to the Annual Meeting 3 August 1863 state:

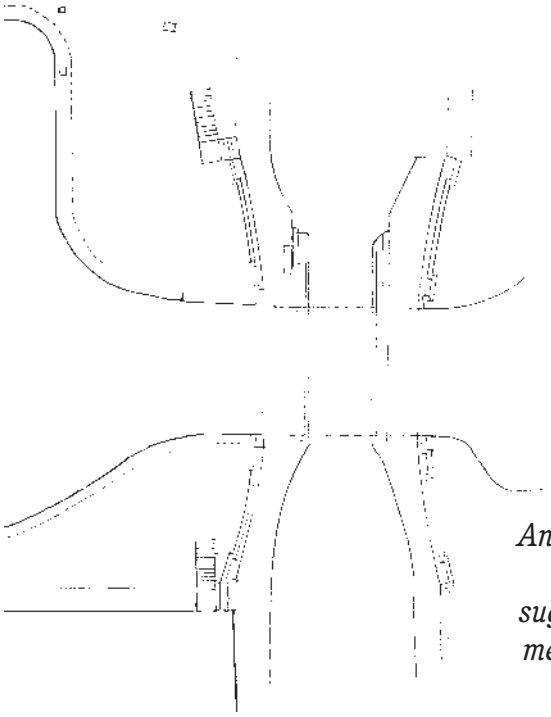
> *...and the conversion of the existing stone bridge at Goole into an opening one in order to afford access to further wharfage space, more particularly for the landing of stone. The whole of these works have made some progress and I expect will be competed by the end of October.*

The following year, on 1 August 1864, the Report gave the cost of:

> *...widening and converting Goole Stone Bridge into an opening one £1439.*

Finally, the Reports by Chief Officers (RAIL800/31) for the 1st August 1864 state:

> *The increase of traffic at the Port of Goole owing to the extension of the Steam Trade has been such that every wharf & berth have been fully occupied, and there is every reason to conclude that some additional Dock accommodation will be shortly required. In anticipation of this it has been thought desirable to remove the Arch of the Stone Bridge and convert it into a Hoist Bridge, so as to allow for the passage of Ships up the Canal, and it is in contemplation to widen & deepen the Canal thro' the whole extent of the Navigation Estate, for the accommodation of the Stone and Coasting Traders & with the view of relieving the present deep water Docks and postponing the construction of an additional Dock.*



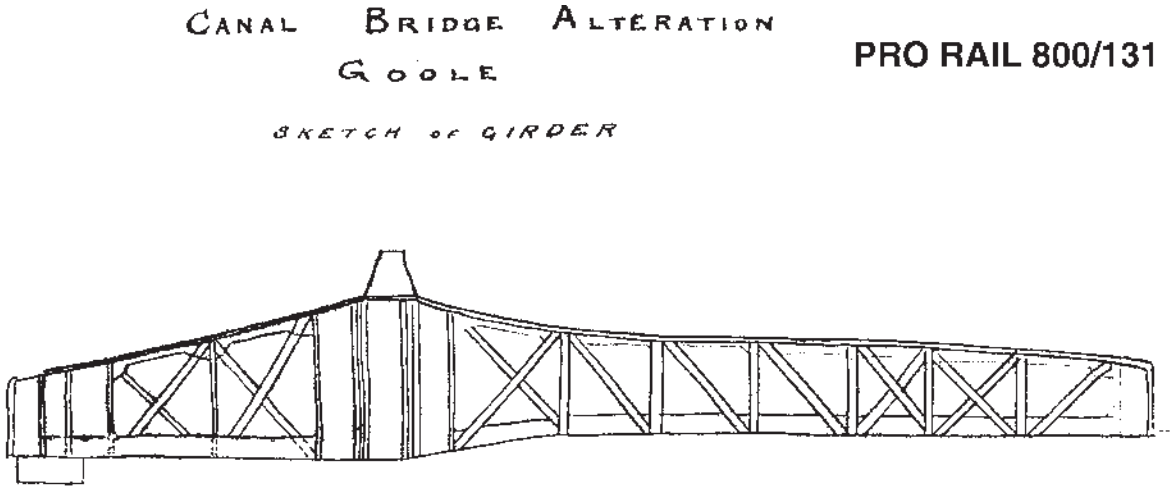
An 1880s plan of the area around South Dock Bridge. The details shown on the north side of the bridge suggests that this was a bascule bridge. The operating mechanism would have worked on an extension of the bridge deck on that side of the bridge.

No detailed information about this bridge has been discovered, but a plan of developments around the bridge c1880 suggest that it was a single leaf bascule bridge. Given the date of construction, 1864, it is suggested that the bridge had cast iron beams and was similar, though with just a single leaf, to the Iron Bridge over the passage between Ouse and Aldam docks. As built, it would certainly have had manual operation, but it may have been converted to hydraulic operation at a later stage.

6.2.2 Planning and construction of the present bridge

By the 1880s, the volume of road traffic around Goole was increasing and this may have led to the reconstruction of the Dutch River Bridge by the Manchester, Sheffield & Lincolnshire Railway in 1886. Certainly Old Goole had become an important residential area for dock workers and shipyard men, and the time taken to operate older bridges, such as that over the Dutch River, was becoming more significant, particularly as these men made their way to and from work. If the Goole Canal Bridge was still manually operated, this could also have caused delay. There was also a demand for an increase in dock space, and for improvements to allow larger vessels to use the navigation, as seen in the enlargement of the swing bridges between Goole and Whitley Bridge.

In the early 1880s, plans were formed for widening Goole Canal Bridge. A drawing in the ABP archive dated 18 June 1883 shows a new bridge with a passageway 32 feet wide at water level, with a roadway 12 feet wide and two footpaths 5 feet wide. The existing bridge passageway was 25 feet 6 inches wide at water level.



A sketch of the original design for South Dock Bridge.

In Estimates for Improvements, 1884-1914 (RAIL800/129), the cost of the alterations to the opening bridge at Goole are given as £7,083-5-0. Authorisation for rebuilding the bridge was obtained in the Aire & Calder Navigation's 1889 Act, and by this time the width of the passageway had been increased to 50 feet and the clearance increased from 13 feet to 14 feet 6 inches. The Reports on the 1889 Bill (RAIL800/60) state:

> *The Bill provides for the construction of an opening bridge of wider dimensions over Bridge Street which would open out the land beyond for dock purposes.*

Although authorisation had been obtained, work did not commence, and an extension of the time for completion of the work had to be included in the Aire & Calder Navigation's 1895 Act. Planning work began again in 1897, the Director's Minutes (RAIL800/16) for 5 July 1897 state:

> *It was reported that seven firms had been asked to tender for the ironwork for the new opening bridge at Goole and that only one firm: Messrs Butlers of Stanningley, had sent in a tender. It was further reported that the amount of this tender was*

£3,850, whereas the estimate for the work, made in 1889, was £2,500. It was resolved that certain other firms be asked to tender including Messrs Armstrong of Newcastle, and that the committee be empowered to deal with the question as they think best.

William Bartholomew obviously wanted to get the work under way with as little delay as possible and at the next meeting on 6 August 1897 it was reported that:

Mr. Bartholomew explained that the details of construction of the new bridge over the canal at Goole had been reconsidered and that he had entered into a contract with Messrs. Butler & Co. for the construction of the bridge according to the amended design at prices which would reduce the cost to about £2,600. It was resolved that the acceptance of this tender be confirmed.

From the tender documents in RAIL800/131, the alterations in design can be clarified to some extent. A drawing with the original tender shows a bridge with open lattice girders, whilst that as constructed has plate girders. Other alterations to the contract covered delivery - to Leeds instead of to Goole - and the navigation may have undertaken more of the erection work than at first proposed. The cost of the bridge from the navigation's accounts came to £4,419, though this was probably just for work undertaken by the navigation's men such as foundation work and erecting. If the £2,600 quoted by Butlers is added to this, the final amount comes to £7,019. This is slightly less than the 1888 estimate of £7,083-5-0.

South Dock Bridge seen from the south east across the passageway opened in 1910. The bridge swings over the two arches, the operating mechanism being on the north western side of the bridge.

6.2.3 Maintenance

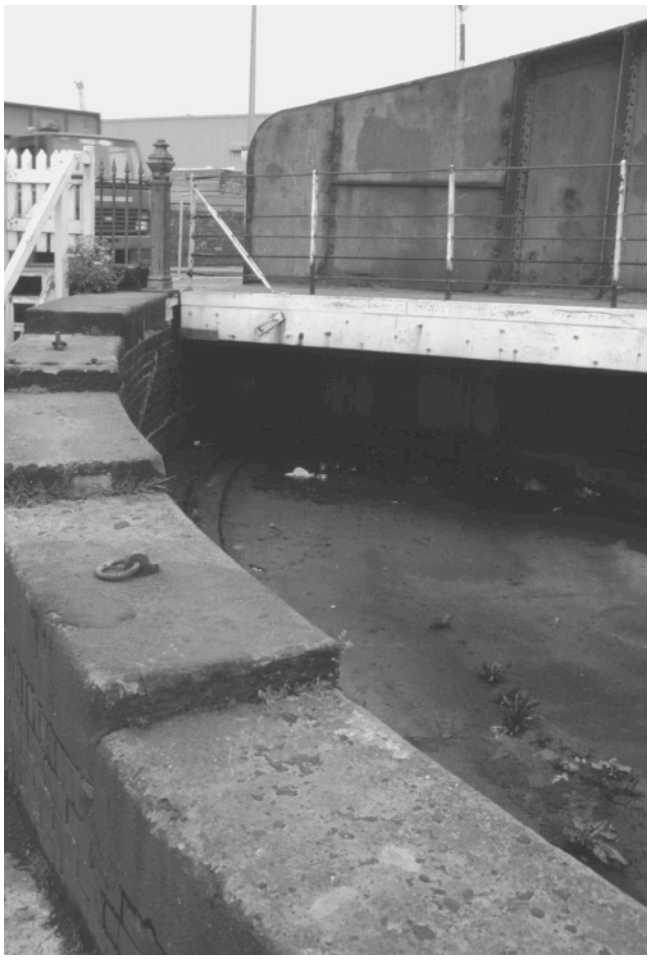
There were problems with the bridge fairly soon after opening, the local engineer reporting to Mr. Fitzgibbon, the successor to William Bartholomew, in May 1903:

This bridge is again on the move, either the centre is flattening or the bridge is sliding on the centre till it jams at the long end between bridge and the abutment plates. I am getting the bolts altered so that we can move plates in case of need $^{1}/_{2}$ inch further on to abutment.

South Dock Bridge seen from the north west. The hydraulic pump is situated in the building on the right of the picture, the operating platform being behind this building.

In 1910, a "drivers' lobby for Goole Canal Bridge" was erected, and the plate inspector's lobby (one of several on the navigation for people who ascertained the weight being carried by boats) was moved from the south side of the new passageway to the east side of the centre pier. Such work was part of the construction of South Dock, part of which included the construction of a new fixed bridge to the south of the swing bridge.

South Dock was formed by widening the canal to the west of the swing bridge, Barge Dock being widened in a similar fashion around the same time. To allow barges to pass between the two docks without having to swing the bridge, a fixed bridge was built with a passageway between the southern extensions of the two docks. At the same time Bridge Street was to be improved and the West Dock entrance and swing bridge constructed, permission for the work being granted in



The bridge well with the quadrant rail just visible on the inside of the wall. The jacks and wedges were located here under the tail of the bridge. The hooks in the wall are for manual operation of the bridge in case of an hydraulic failure.

the 1908 A&CN Act. Estimates for the work in 1908 (RAIL800/129) amounted to £2,489-3-1 for altering the levels of Bridge Street in the South Dock area and £4,447-8-2 for building the cut beneath Bridge Street.

Work had started by 11 July 1909 when traffic on Bridge Street was diverted over a temporary bridge. The bridge must have been virtually complete by 3 October 1909 when traffic was allowed to use the western half of the new bridge. The bridge itself is a simple plate girder bridge resting on stone and brick abutments. The passageway opened in May 1910, a letter of 21 May 1910 stating:

> *…traffic was diverted through the above on Thursday last and already the compartment boats are damaging the stop grooves.*

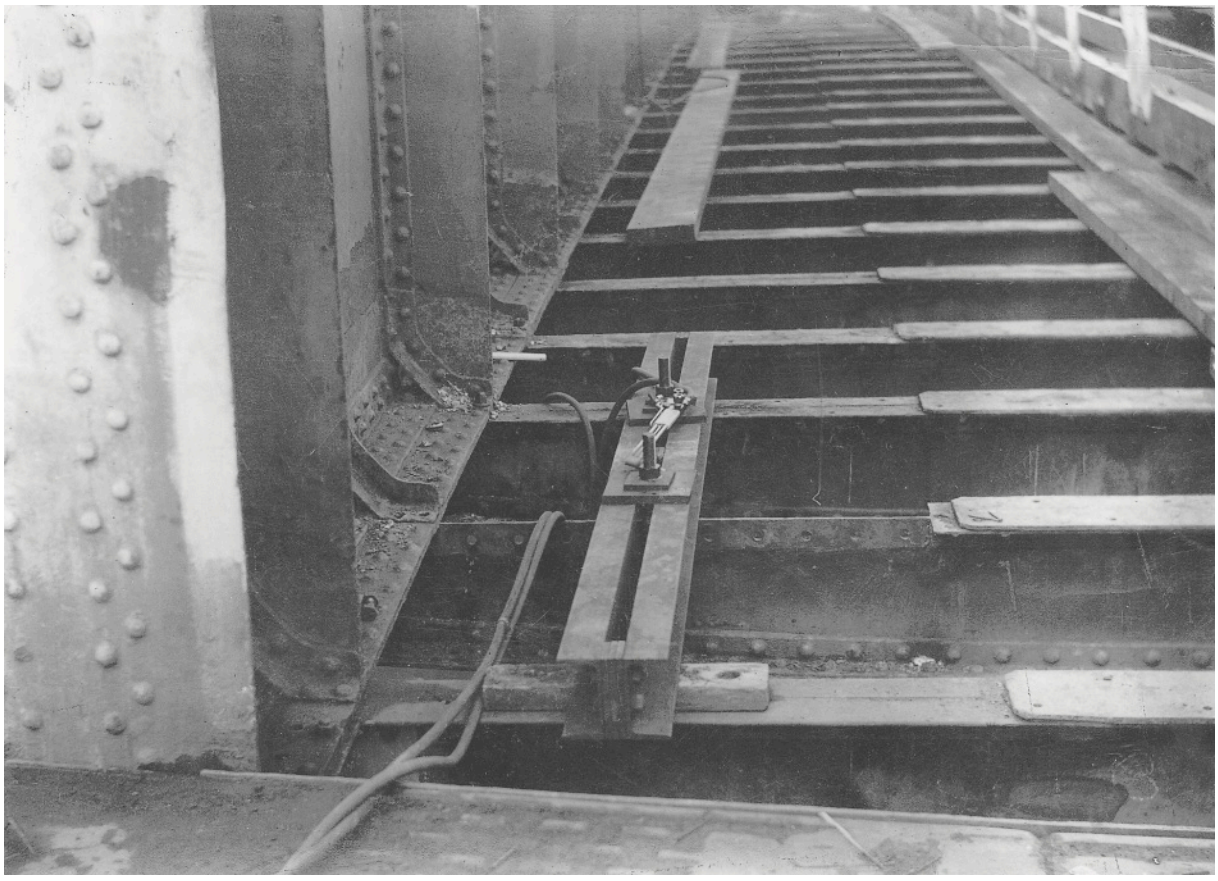
The following February it was decided to call the new dock 'South Dock' and a letter of 22 January 1912 from the navigation's Engineer stated:

> *Be good enough to note that the bridge at the west end of the Barge Dock hitherto called the 'Canal Bridge' is in future to be known as the 'South Dock Bridge'.*

By 1912, the swing bridge needed redecking, the 2 inch thick planking having become worn. Jarrah timber was used. Fifteen years seems to have been fairly standard between redecking, further work being undertaken in 1927 and 1938/9. In 1960 the planking was again relaid, this time with 2 inch thick planking laid on edge and glued and spike together. A variety of different surfaces were then tried as part of an experiment by the Road Research Laboratory to find the best hard-wearing non-slip surfacing.

The roadway from the north in 1999 showing the wearing surface applied to the wooden deck covering.

The old flat wooden deck planking pictured before replacement in June 1960.



The deck girders being repaired after the removal of the wooden decking.

The replacement vertical planking during installation.

The non-slip wearing surface being applied to the new deck planking, June 1960.

6.2.4 Operation

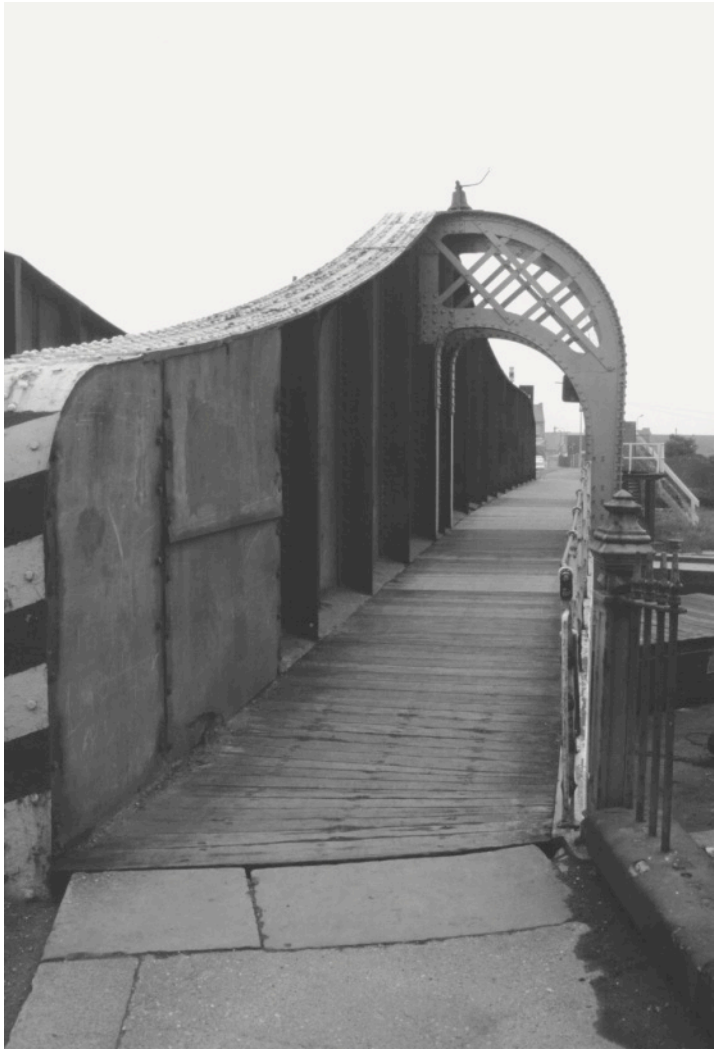
When the bridge was first used, there was a bridgeman and one bridge boy, soon increased to two bridge boys, to operate it. A hand-operated warning bell, still fitted to the bridge, was rung for five minutes prior to the bridge being swung. The bridge boys then placed chains across the roadway and checked that all was clear under the bridge. The bridgeman then raised the end of the bridge, removed the chocks and lowered the bridge onto the quadrant rail before allowing the bridge to turn. (see section 7.2 for details of hydraulic operation) After the vessel had passed, the bridge was swung back, the wedges inserted and the chains removed to allow traffic to resume.

Problems sometimes occurred with wood left under the bridge interfering with the lowering. The were also occasional problems with the hydraulic valves, usually the result of the bridgeman not returning them to the fully closed position. In this event the tail of the bridge could fall, resulting in a step down onto the bridge at the northern end and a step up from the southern abutment.

The opening of West Dock Bridge in March 1912 resulted in problems with co-ordination of opening of the bridges. Workmen were often held up on their way to or from work. Stevedores who lived in Old Goole sometimes lost a day's work because they could not get to the docks in time for taking-on. Agreement as to five quarter-hour periods during which the bridges would not be opened was finally reached with Goole District Council in September 1913.

The chains across the roadway also proved troublesome. Originally they were just two feet from the edge of the bridge pit, but were moved back about ten feet in 1913. They must have been difficult to see as on two occasions motorcyclists ran into them, though fortunately without serious consequences. Lifting barriers were considered as far back as the 1920s, and these have now been installed.

Shipping also had problems with seeing the position of the bridge at night so, in 1926, signal lights were fitted and instructions for their use circulated. The bridge has been hit by shipping on a fairly regular basis.



The footway on the western side of the bridge. Note the warning bell on the top of the curved strengthening over the footpath and the cast iron fence post.

A general view of the bridge from the road on its southern side.

Old ballast being removed during refurbishment of the bridge in June 1960.

7 TECHNICAL DESCRIPTION

7.1 The bridge - civil engineering

South Dock Bridge is a swing bridge with plate steel riveted girders. (see drawings in the ABP archive and the tender document in the Appendix for full details of construction) The roadway is supported by cross beams fitted to the underside of the main girders. There are footpaths on the outside of the main girders supported by extensions to every alternate cross beam. To strengthen the bridge around the bearing, the outer end of the footpath beams in this area are connected to the top of the main girders by curved iron frames. The bridge bearing is offset such that the longer end of the main girders cross the 50 foot wide waterway. The shorter end contains a counter balance which ensures that the bridge does not tip when being swung. When being swung, the tail of the bridge is supported by cast iron wheels which run on a cast iron quadrant located in the bridge well.

The bridge foundations are constructed from brick and stone. The platform over which the bridge swings when open is supported on two arches which have been infilled with wooden partitions to create a covered storage area.

When the bridge is being swung, the road is closed by lowering barriers of recent construction. The original barriers were simple chains hooked to posts on either side of the road. A warning bell, originally rung prior to the bridge being turned, is still fitted to the strengthening over the western footpath.

In 1969, British Railways bridge engineers undertook a bridge assessment to ascertain the permitted axle loading for vehicles passing over the bridge. The assessment gives a very complete description of the engineering structure of the bridge and can be found in the ABP records for the bridge.

The new ballast inside the ballast box at the tail of the bridge. This extra weight ensures that the bridge does not tip whilst being swung.

7.2 The hydraulics

The bridge is operated by three levers which open and close valves in the hydraulic system and thus control jacks, wedges and turning cylinders. When closed, the bridge sits on bearing plates, two each located on both the southern abutment of the bridge and close to the edge of the northern abutment. Contact is made with these bearing plates by jacking up the rear of the bridge and inserting wedges, the bridge pivotting on its bearing. Both actions are undertaken hydraulically.

To open the bridge, the rear end is raised using jacks, and the wedges are then removed. The rear of the bridge is then lowered such that the cast iron wheels engage with the quadrant rail, stabilising the bridge whilst being turned. Two horizontal hydraulic cylinders are used for turning the bridge, one for opening, the other for closing. For each cylinder, a wire rope is fixed to one end of a horizontal quadrant on the bridge. The other end of the wire is wound round pulleys fitted to the ends of the cylinder and piston creating a four-fold purchase. As hydraulic pressure is applied, the piston is pushed outwards, lengthening the path of the wire around the pulleys, pulling the end of the wire towards the cylinder and thus turning the bridge.

7.3 The hydraulic supply

Originally the hydraulic supply for the bridge came from the main dock system. The first pumping station was on the corner of the island between Ouse Dock and the Harbour. When the system was electrified in the 1930s, the pumping station was moved to the south side of South Dock, next to the gas works.

By 1960, the use of hydraulic power was declining, though the pumping station had to be manned day and night so that the locks and bridges could be operated at tide time. The main user of hydraulic power were the compartment boat hoists and railway hoists which were normally only in use during the day time. To reduce costs, individual electrically-powered hydraulic pumps were installed at the locks and bridges, the central pumping station then just being used for the hoists. Ocean Lock and South Dock Bridge were converted in 1963.

The new Hydraflow pumps were built by Tangye and supplied water at 900 lbs/sq.in. There were two sizes delivering 25 or 40 gallons/minute, an electric motor driving an oil pump, the high-pressure oil then working a duplex water piston in a horizontal cylinder. Unlike the earlier system, where the hydraulic water ran back into the dock, the new pumps operated on an enclosed system with a header tank fed from the town mains. The pump at South Dock Bridge is fitted within a brick building close to the valves used to operate the bridge.

8 DISCUSSION AND APPRAISAL OF SOUTH DOCK BRIDGE

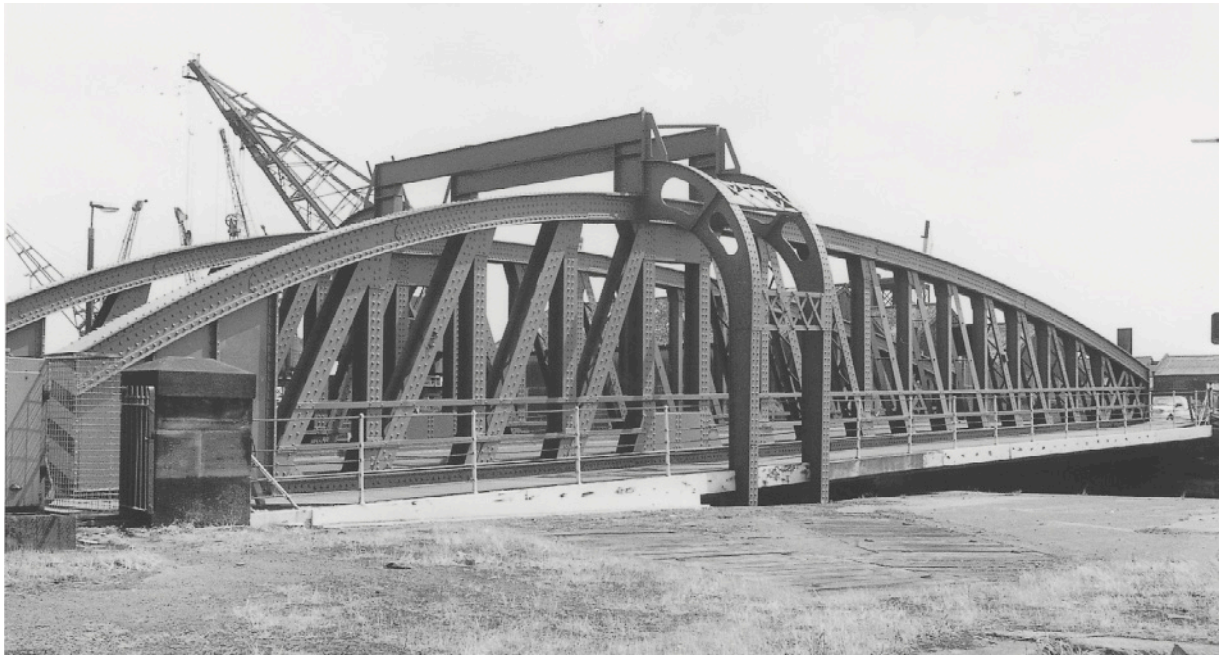
There are still many swing bridges built before the Second World War in operation, with at least ten surviving in Yorkshire. South Dock Bridge is of fabricated plate girder construction, other similar examples being the road bridge at Sculcoates, Hull; the railway bridges at Selby and Goole; Whitby Harbour road bridge; and the Dutch River Bridge, Goole. The fabricated plate girder is typical of bridges built in the second half of the nineteenth century, and was used for swing bridges with a limited span up to the First World War. Several of the fixed bridges over the Aire & Calder Navigation use this type of construction.

The railway swing bridge over the Ouse at Selby.

The railway swing bridge over the Ouse at Goole.

The swing bridge over the Dutch River at Goole.

The change in the design of South Dock Bridge, from open lattice to plate girder, was the result of the need to reduce costs, flat plate being cheaper at the time than rolled sections. Improved production of rolled sections and the widespread introduction of Bessemer steel in the early twentieth century reduced material costs, making the open lattice bridge the economical solution for swing bridges. It reduced the weight of the deck structure, thus allowing greater spans to be constructed and reducing the power needed for swinging the bridge. The open lattice girders of No.3 Swing Bridge, on the Aire & Calder Navigation at Pollington, is very similar to that originally proposed for South Dock Bridge, though of smaller dimensions. Other open lattice girder swing bridges in the area are the West Dock and Lowther bridges in Goole; Boothferry road bridge; and Cawood road bridge.



West Dock Bridge, Goole.

Lowther Bridge, Goole.

Boothferry Bridge.

Cawood Bridge.

The hydraulic operation of South Dock Bridge is typical. The opposed cylinder system, with wire ropes connected to a quadrant under the bridge, was found on the majority of hydraulically operated swing bridges. The control system, with removable levers, is also typical of hydraulic bridge operation. The continued use of water hydraulics is to some extent unusual as the trend is towards the use of suitable hydraulic oils. Scott Street Bascule Bridge in Hull has conventional water hydraulic cylinders, but has been converted to oil as a working fluid.

South Dock Bridge is fairly standard in design, though it was beginning to be out-dated at the time of its construction. Only two major alterations have been made to it; the construction of the wooden deck has been strengthened and the hydraulics have been changed to a separate pump and enclosed system. Other than this, alterations have been minor in character; the lighting of the bridge has been altered at various times, and the safety chains have been removed and folding barriers fitted instead.

The bridge is well documented, with a good selection of drawings, the history of the bridge being reflected in these. There are two sets of undated A&CN drawings. One could be from the original design with lattice girders, the second set being as altered to plate girders. Some details could have been common to both designs resulting in two distinct sets of drawings. The A&CN numbered their drawings from No.1 for each specific job. The majority of the remaining drawings show the alterations undertaken in the 1950s and those related to the conversion of the hydraulic system in 1963.

There are also a fairly comprehensive set of files related to the operation and maintenance of the bridge. These date back to 1903. Further information can be obtained from the files and drawings related to the construction of the passageway, bridge and service subway to the south of the swing bridge, and from those related to the enlargement of Barge Dock and the 'Dockising' (the term used by the A&CN) of the canal, better understood as the construction of South Dock.

The Old Quay Bridge over the Manchester Ship Canal at Runcorn. The tower for the hydraulic accumulator and the pump house are on the left.

9 RECOMMENDATIONS

9.1 The New Bridge

It is suggested that the original warning bell, still surviving on the old bridge, be refitted to the new bridge, together with an engraved plaque giving brief details of the bell and the history of the bridge, docks and navigation. Attention could be drawn to the original swing bridge abutments, as their conservation has already been agreed.

9.1.1 Retention of Deck Structure

The current proposal is for the retention of the bridge deck structure at some point within the South Dock area. The interpretation of this isolated part of the bridge for members of the general public will be extremely difficult as they will have problems in visualising the bridge's operation. A model would provide a much better solution for explaining the design of the bridge and its operation to the public.

Although old swing bridges are becoming rarer, South Dock Bridge is not that unusual. At the time of its construction, the plate girder was being replaced by the lattice girder, so it displays, to some extent, outdated technology. Also, Dutch River Bridge is just 100 metres away, and though its main girders are underneath the roadway, the method of construction is similar. There are several other plate girder swing bridges surviving within an hour's drive from Goole.

For the technical historian, South Dock Bridge is well documented, the original plans and the 1963 weight calculations being sufficient for most research purposes, while the operational files provide information for the social historian. Consequently it is recommended that the retention of the whole bridge deck is unnecessary. However, it may be worth keeping a small part of the bridge such as the one of the curved frameworks over the footways. A suitable location for its preservation and its incorporation as part of a themed display should be discussed with the Waterways Museum.

9.1.2 The Hydraulic System and the Interpretation of the Bridge

Perhaps the most interesting and historic feature of South Dock Bridge is that it is still operated by water hydraulics. It is suggested that at least one of the pumps, operating cylinders and parts from the controls, jacking and wedging mechanism should be retained for display at the Compartment Boat Hoist site, adjacent to South Dock. They would then form part of a display related to hydraulic power as used throughout the dock system.

Such a display would cover the opening bridges in the docks. A painting of the current South Dock Bridge could be commissioned, together with artist's impressions of the two former bridges. These could then be used to illustrate not just the bridges, but also the increasing size of vessels using the docks and navigation.

9.2 Documentary Evidence

The plan stores maintained by ABP, Goole, contains many historic drawings of structures now no long existent as well as current ones. The older files relating to the docks, many dating from the A&CN period, are stored in poor conditions nearby. These should be moved to the plan store and their contents listed. The whole archive should be sorted and those which are no longer of operational use deposited in a local archive, the new extension to the Waterway Museum being the best place when this is completed.

9.2 Publication

In view of the limited number of published sources related to the history of opening bridges, it is suggested that this report be re-written and published as an article in a suitable journal. A copy of the report should also be deposited in the library at the Institution of Civil Engineers and at the Waterway Museum, Goole.

SOURCES

Public Record Office, Kew, RAIL 800, the Aire & Calder Navigation records.

16 Directors Minutes 1887-1898

17 Directors Minutes 1899-1912

60 Reports on the A&CN Bill 1888-1889

61 Annual Reports from the Engineer to the Shareholders 1838-1899

129 Estimates for Improvements 1884-1914

131 Various specifications, including swing bridges at Goole, tender documents for South Dock Bridge, proposals for West Dock Bridge, etc 1872-1920

305 Engineers Monthly Reports 1887-1895

306 Engineers Monthly Reports 1899-1904

314 Abstract of Accounts 1864-1867

ABP Goole, Drawings for South Dock Bridge and files relating to the bridge.

BIBLIOGRAPHY

Cunningham, Brysson, ***A Treatise on the Principles and Practice of Dock Engineering***, 1922

Hadfield, Charles, ***The Canals of North East England***, 1973, ISBN 0 7153 5975 4

Hovey, Otis Ellis, ***Movable Bridges***, Vol.1, Superstructure, 1926.

McNeil, Ian, ***Hydraulic Power***, 1972, ISBN 0 582 12797 1

Price, James, Movable Bridges, ***Min. of Proc. Inst. Civil Engs.***,11 March 1879.

Pugh, B., ***The Hydraulic Age***, 1980, ISBN 0 85298 447 2

Robinson, Henry, The Transmission of Power to Distances, ***Min. of Proc. Inst. Civil Engs***., 13 April 1877

Wilson, George, ***Opening Bridges***, Manchester, 1896

APPENDICIES

1. The relevant sections from the 1889 Aire & Calder Navigation Act.
2. The relevant sections from the 1895 Aire & Calder Navigation Act.
3. A list of some of the swing bridges in Britain arranged chronologically.
4. The listing for South Dock Bridge.
5. South Dock Bridge drawings held by ABP
6. Original tender for South Dock Bridge, 1897. (PRO RAIL800/131)
7. Specifications for South Dock Bridge as built. (PRO RAIL800/131)
8. Various papers, arranged chronologically, related to South Dock Bridge.

together with a widening of the said canal on the south side, under the said bridge, and for a distance of about thirteen yards on each side thereof;

Cold Hiendley Bridge.

(10.) An alteration of the bridge and the approaches thereof in the parish of Felkirk, in the county of York, known as the Cold Hiendley Bridge, which carries the Cold Hiendley Common Lane over the Barnsley Canal in that parish, such alteration commencing at a point about nine yards northward of the south-west corner of the western parapet wall of the present Cold Hiendley Bridge, and terminating on the south side of the canal, about fourteen yards south-eastwards from the said south-west corner of the said parapet wall; together with a widening of the said canal on the south side, under the said bridge, and for a distance of about six yards on each side thereof;

Oakenshaw Bridge.

(11.) An alteration of the bridge and the approaches thereof in the parishes of Crofton and Sandal Magna, in the county of York, known as the Oakenshaw Bridge, which carries the Oakenshaw Lane over the Barnsley Canal in the parish of Crofton, such alteration commencing on the north side of the canal, about thirty-eight yards north-eastward from the north-west corner of the western parapet wall of the present Oakenshaw Bridge, and terminating on the south side of the canal, about seventy-one yards southward from the south-west corner of the said parapet wall; together with a widening of the said canal on the north side, under the said bridge, and for a distance of about one yard on each side thereof;

Bridge at Goole.

(12.) An alteration of the opening bridge and approaches thereof at Goole, in the said parish of Snaith, carrying Bridge Street over the Knottingley and Goole Canal, such alteration commencing on the northern side of the canal, at the junction of Victoria Street with Bridge Street, and terminating on the southern side of the canal, at a point about forty-six yards northward from the junction of Doyle Street and South Street with Bridge Street aforesaid; together with a widening of the said canal on the north side, under the said bridge, and for a distance of about ten yards on each side thereof;

Walton inclines.

(13.) A cut or canal (hereinafter called Cut No. 1) in the parish of Sandal Magna, commencing by a junction with the Barnsley Canal, at a point about fifty yards northward from the bridge carrying the road from Walton to Walton Hall across the said canal, and terminating near the northern end of the third lock on the Barnsley Canal below such bridge; and an inclined

wise interfere with, either temporarily or permanently, canals, rivers, streams, watercourses, drains, culverts, sewers, flood gates, flood banks, sluices, cloughs, staiths, jetties, landings, wharfs, gas and water mains and pipes, telegraphic, telephonic, electric and other wires, pipes and apparatus and other works, so far as may be necessary or desirable for the purposes of the works by this Act authorised, the Undertakers providing or causing to be provided a proper substitute before interrupting the flow of water or sewage in any of the premises, and in the exercise of any of such powers the Undertakers shall do as little damage as may be, and shall make full compensation to all parties entitled thereto for any damage by them sustained by reason of the exercise of such powers, the amount thereof to be determined in the manner provided by the Lands Clauses Consolidation Act, 1845, for settling cases of disputed compensation: Provided that the Undertakers shall not remove, alter, or in any way interfere with any telegraphic apparatus belonging to or used by the Postmaster-General, except in accordance with and subject to the provisions of the Telegraph Act, 1878: Provided also that nothing in this section shall extend to or authorise any interference with any works of any undertakers within the meaning of the Electric Lighting Act, 1882, to which the provisions of section fifteen of the said Act apply.

Power to carry railway across new road in Goole on level.

6. Subject to the provisions contained in the Railways Clauses Consolidation Act, 1845, and in Part I. (relating to the construction of a railway) of the Railways Clauses Act, 1863, in reference to the crossing of roads on the level, the Undertakers may, in the construction of the Railway No. 1 by this Act authorised, carry the same, with not more than four pairs of rails, across and on the level of the new road in Goole by this Act authorised to be constructed in substitution for St. John Street: Provided that the Undertakers shall at all times provide a substantial footbridge over the said railway at the site of such level crossing.

Provisions as to opening bridge at Goole.

7. The bridge at Goole, carrying Bridge Street across the Knottingley and Goole Canal by this Act authorised to be altered, may be made and thereforth maintained by the Undertakers as an opening or swing bridge, with an opening span of not more than fifty feet, and such opening or swing bridge shall at all times be worked by or at the expense of the Undertakers: Provided that no unnecessary interference or delay shall be occasioned at any time to the traffic using Bridge Street, and that the said bridge shall at all times be kept closed across the canal, except when required to be opened for the passage of vessels through the same, or for necessary repairs.

Appendix 1

The relevant parts from the 1889 A&CN Act

company were transferred to and vested in the Great Northern Railway Company and it was provided that such company should discharge and fulfil all liabilities and obligations of the Hunslet Railway Company under the Hunslet Railway Act 1893 and under all contracts and agreements entered into by them or on their behalf in reference to the Hunslet Railway or connected therewith: A.D. 1895.

And whereas it is expedient in connexion with improvements now being made on the navigation of the Undertakers between Wakefield Leeds and Goole that the Undertakers should be authorised to alter the bridges and widen the waterways thereunder and construct the new overflows or byewashes and other works herein-after mentioned:

And whereas by the Aire and Calder and River Dun Navigations Junction Canal Act 1891 the Undertakers were empowered to make a new canal from the River Dun Navigation to join their Knottingley and Goole Canal and to widen a portion of the last-mentioned canal and by the Aire and Calder Navigation Act 1893 the powers granted to the Undertakers by the said Act of 1891 for the compulsory purchase of lands for the purposes of the new canal authorised by that Act were extended until the expiration of two years from the 28th July 1894 and it is expedient that such powers should be still further extended: 54 & 55 Vict. cap. clxx. 56 & 57 Vict. cap. xlvii.

And whereas by the Aire and Calder Navigation Act 1889 the Undertakers were empowered to alter the opening bridge and approaches thereof at Goole carrying Bridge Street over the Knottingley and Goole Canal and to widen the canal under such bridge and it is expedient that the period limited by that Act for the completion of those works should be extended: 52 & 53 Vict. cap. xxxii.

And whereas it is expedient that the rates or dues leviable by the Undertakers in respect of their docks at Goole should be in some respects varied and that the Undertakers should be authorised to take and recover the rates and dues herein-after specified and to make charges for the use of their graving and floating docks and repairing slips and gridirons:

And whereas it is expedient that such further powers and provisions as are in this Act contained should be conferred upon the Undertakers or be made with respect to their undertaking:

And whereas plans and sections showing the lines and levels of the works by this Act authorised and a book of reference to such plans containing the names of the owners and lessees or reputed owners and lessees and of the occupiers of the lands required or which may be taken for the purposes or under the powers of this Act were duly deposited with the clerk of the peace for the west

A.D. 1895.

Extending period for completion of alteration of Goole Bridge and Canal widening.

47. The period limited by the Aire and Calder Navigation Act 1889 for the completion of the alteration of the opening bridge and approaches thereof at Goole carrying Bridge Street over the Knottingley and Goole Canal and of the canal widening under that bridge is hereby extended for three years that is until the 24th day of June 1899.

Undertakers may retain lands required for purposes of their undertaking.

48. Notwithstanding anything contained in the Acts relating to the Undertakers or in this Act the Undertakers may (subject to the provisions of the Lands Clauses Acts relating to the sale of superfluous lands so far as such provisions may apply to any such lands or buildings) retain any lands or buildings which shall not for the time being be wanted for the use of the navigation and which the committee may from time to time deem it expedient to retain for the purpose of widening deepening improving or maintaining their navigation property and works or for other purposes connected with their undertaking.

Amendment of Acts as to power of sale and demise.

49. Notwithstanding anything in the Acts relating to the Undertakers or in this Act the committee may (subject as in the last preceding section mentioned) sell or demise any lands or buildings which shall not for the time being be wanted for the use of the navigation as aforesaid and it shall not be necessary upon any such sale or demise that the Undertakers or the trustees should first offer to re-sell the property to the person or persons from whom the same shall have been purchased or who would then have been entitled thereto in case such lands or buildings had not been purchased by the Undertakers or the trustees.

Trustees may carry out sales and leases.

50. Any such sale or demise may be carried out and the necessary deeds and documents executed by the trustees and no purchaser or lessee or intending purchaser or lessee shall be bound or concerned to inquire whether the trustees are duly authorised in that behalf or be affected by any irregularity or want of authority.

PART IV.—DOCK CHARGES.

Alteration of dock charges in 9th Geo. IV. for remaining in dock.

51. The provisions of section 61 of the Act of the 9th year of the reign of King George the 4th cap. xcviii. that for every ship or vessel coming into the docks or basins therein mentioned to be laid up there shall be payable for every ton the sum of one penny per week and the provisions of section 65 of the same Act that all ships or vessels going into the docks basins or cuts therein mentioned or any of them shall and may lie there to unload on paying the rates therein referred to for the space of six weeks to be computed from the time of going into the same and that from and after the expiration of the

Appendix 2

The relevant parts from the 1895 A&CN Act

Appendix 3

A list of some British swing bridges. Some are demolished, those in bold are known to be listed.

Location	*Date*	*Type*	*Channel width*
Selby Canal, originally built 1778, road			
Gravesend, road	1824	timber/CI, stayed	
Liverpool Albert Dock, double leaf, road	**1843**	**cast iron**	**44.75 feet**
Bristol Cumberland Basin, road	1849		
Leith Docks, road, double leaf	1850c	cast iron	34 feet
Hull, Victoria Dock	1852		45 feet
London, Surrey Docks	1855		
Birkenhead, possibly replaced by Scherzer type bridge	1860		100 feet
Hull, South Bridge, demolished	1860		100 feet
Liverpool, Waterloo Dock, removed	1860		60 feet
Goole, River Ouse, railway	1869	plate girder	100 feet
Skelton Bridge	1869		
Naburn, railway	1870c		
Cawood, road	1872	truss	53.5 feet
Hull, Sculcoates, road	1873	plate girder	56.5 feet
Rochester, River Medway	1873		48.5 feet
Birkenhead, Morpeth Dock, replaced by Scherzer	1874		70 feet
Leith Docks, road/rail	1874	open lattice	120 feet
Newcastle-upon-Tyne, road	1876		110 feet
Glasgow, Queen's Dock	1877		100 feet
Grimsby, New Cut	1877		52 feet
Hull, Albert Dock	1879		80 feet
Liverpool, Canada Dock	1879		80 feet
London, Blackwall Basin	1879		38 feet
London, Milwall Dock	1879		80 feet
London, SW India Dock	1879		55 feet
Penarth Dock	1879		60.5 feet
Oxford railway SB over canal; ancient monument	**1880?**		
Aire & Calder Navigation, swing bridges Nos. 1-5	1880c	open lattice	
Boston Haven	1884		
Goole, Dutch River, MSLR road bridge	1886	plate girder under roadway	
Hawarden, rail	1889	truss, 287 feet	140 feet
Cardiff, Clarence Bridge	1890		72 feet
Weaver Nav'n, Vale Royal Lock swing bridge, grade II	**1890c**		
Selby Railway Bridge	1891	plate girder	
Ramsey, IOM, road	1892	truss	36 feet
Manchester Ship Canal, Barton Road	1894	bowspring lattice	75-120 feet
Manchester Ship Canal, Chester Road	1894	bowspring lattice	75-120 feet

Manchester Ship Canal, Knutsford Road	1894	bowspring lattice	75-120 feet
Manchester Ship Canal, Manchester Docks, rail	1894	bowspring lattice	75-120 feet
Manchester Ship Canal, Moore Lane	1894	bowspring lattice	75-120 feet
Manchester Ship Canal, Northwich Road	1894	bowspring lattice	75-120 feet
Manchester Ship Canal, Old Quay	1894	bowspring lattice	75-120 feet
Manchester Ship Canal, Trafford Road	1894	bowspring lattice	75-120 feet
Neath; on curve and skew (unique?), rail	1894	truss, 170 feet	
Sutton, River Nene, road/rail	1897		
Goole, South Dock Bridge	**1898**	**plate girder**	
Weaver Navigation, Hayhurst, road, grade II	**1899**	**bowspring lattice**	
Weaver Navigation, Town, road, grade II	**1899**	**bowspring lattice**	
Bristol, Ashton, road/rail	1900		
Bristol, Vauxhall	1900		
Castletown Harbour, IOM	1903	open lattice	30 feet
Crowle Swing Bridge, River Axholme	1903		
Regent Swing Bridge, Aberdeen, hydraulic	1904		
Hull, Stoneferry, road	1905	open lattice	
Reedham, rail	1905	plate?, 139 feet	55 feet
Somerleyton, rail	1905	plate?, 139 feet	55 feet
Avonmouth	1906		
Oulton Broad, rail	1907		
Whitby, road	1909	plate girder under roadway	
Goole, West Dock Bridge, road	1913	bowspring lattice	
Goole, Lowther Bridge, road	1914c	bowspring lattice	
Bristol, Cumberland Swing Bridge, hydraulic	1924		
Milwall Dock, London, hydraulic	1928		
Goole, Boothsferry	1929	open lattice	127 feet
Weaver Navigation, Acton, road	1930c	bowspring lattice	
Weaver Navigation, Sutton Weaver, road	1930c	bowspring lattice	
Kincardine Railway Bridge	1936		

Appendix 4

The listing for South Dock Bridge.

SE 72 SW	GOOLE	BRIDGE STREET
10/57		Goole Bridge
GV		II

Road swing bridge. 1864. Wrought iron or steel, ashlar abutments with cast-iron railings; brick starling with ashlar dressings. Roadway flanked by walls of plate girders ramped up to a central pair of transverse arched girders forming portal over roadway and outer pedestrian walkways. Original railings to north abutment have square-section principals with ornate finials, plain bars with pointed finials above a single top rail. Bridge rotates on circular drum housed on a starling with rounded ashlar plinth and coping, and pair of segmental-arched openings to east end. Kelly's Directory of West Yorkshire, 1867.

From this report it can be seen that this listing is incorrect. The 1864 date refers to the earlier bascule bridge. The arched girders do not form a portal on South Dock Bridge, but they do on West Dock and Lowther Bridges. The contract specification shows that the bridge should have been made from steel and that wrought iron was not used.

Appendix 6

Original tender document for South Dock Bridge, 1897

Appendix 7

Specifications for South Dock Bridge as built

Appendix 8

Various papers related to South Dock Bridge arranged chronologically