THE EVOLUTION OF

# VERTICAL LIFT BRIDGES


By

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EVANSTON, ILL.


*Author of Mill Building Construction, 1900 ; Concrete Bridges and Culverts. History of Bridge Engineering. Mill Buildings. Artistic Bridge Design, etc. etc.*


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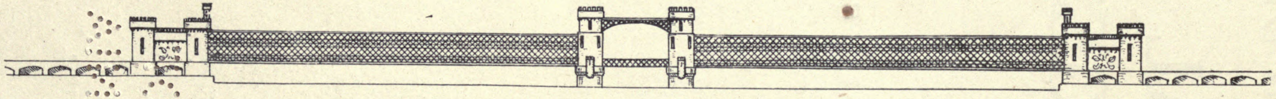
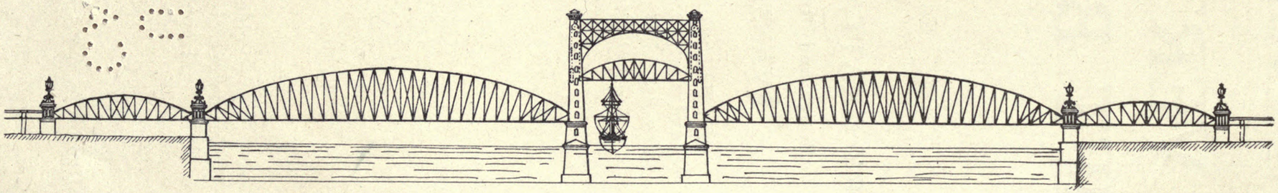


Design made in 1850, by Captain W. Moorsom, for a bridge over the Rhine at Cologne.



Design for a proposed bridge over the Scheldt at Antwerp made by M. H. Matthyssens in 1878.

# THE EVOLUTION OF
# VERTICAL LIFT BRIDGES

Hew down the bridge, Sir Consul,
  With all the speed ye may,
I, with two more to help me,
  Will hold the foe in play.

And Fathers mixed with Commons,
  Seized hatchet, bar and crow,
And smote upon the planks above,
  And loosed the props below.

But meanwhile axe and lever
  Had manfully been plied,
And now the bridge hangs tottering
  Above the boiling tide.

And with a crash like thunder
  Fell every loosened beam,
And like a dam, the mighty wreck
  Lay right athwart the stream.

The development of constructive types forms an interesting study and usually shows that the designs for many recent works are based upon earlier and often very unpretentious ones, modified to suit local requirements. It is only by following these developments that it is possible to appreciate the degree of merit or originality which any new creation may contain. Movable bridges have been used for many centuries, some writers contending that the bridge over the Euphrates River at Babylon (B.C. 783), built under the direction of Queen Nitocris, was arranged with movable platforms, which could be withdrawn at night to prevent thieves from entering the city. Pons Sublicius (B.C. 621) over the Tiber at Rome, is described by some historians as having been of the same type, but the description of its removal, as given by Lord Macaulay, does not indicate that it contained any parts that are easily moved, some of his references being quoted above.

Though the accuracy of these early traditions will probably remain shrouded in mystery, it is well known that movable bridges of the bascule type were very common during the Middle Ages, especially at the approaches to castles and walled cities, and quite elaborate drawings of such bridges are still extant, exhibiting a degree of inventive skill that has not been surpassed even in our own time. Indeed, most of the patented inventions of the last twenty years are merely revivals of earlier ones which were studied out or built during previous centuries, and many features of modern bridges, originality for which is claimed by recent proprietors, are found to have been in use long before the advent of the present generation. There is, therefore, no branch of engineering in which a knowledge of history is more essential.

Movable bridges of the direct lift form are, however, of more recent origin, one of the first appearing previous to 1840, in the wooden trestle of twenty-three spans, over the Danube River at Vienna, the floor over one 30 foot opening being arranged to lift 6½ feet. There was also, in 1846, on the Amsterdam and Rotterdam Railway, over the Poldervaart—a canal on the Polders—a bridge with two side openings of 21 feet and a center one of 13 feet, the last capable of being lifted about 5 feet vertically, by means of a crab and screw worked by hand power. It was a small structure, only 55 feet long and 10½ feet wide, with floor less than 10 feet above water. Piers were on a slight skew and were founded on piles. The next vertical lift bridges appeared in England, two being placed over the Grand Surrey Canal at London (1848), under the direction of Robert J. Hood, to carry the Thames Junction branch of the London, Brighton and South Coast Railway. These bridges crossed the canal and tow path and the larger one had a span of 35 feet between tower faces, though the channel opening was only 21 feet. It was 83 feet wide with a rail-track on one side. The moving platform, weighing 12¾ tons, was suspended by wire ropes over sheaves on top of four disconnected cast iron towers, and the 12½ tons of counterweight descended into underground cast iron cylinders. It could be lifted by two men on a hand winch, the greatest rise being only 5 feet. The other bridge over the same canal was 12½ feet wide and 31½ feet long, the upper end of towers being connected by braces with curved bottom cords. Chains were used for the suspenders instead of ropes, and the rear tower faces were curved, giving them a graceful appearance. The total cost of the latter was $6,500. These two bridges over the Grand Surrey Canal, were probably the first properly constructed ones of the vertical lift type, and for more than sixty years have served as prototypes for many later and larger ones.

Following these, there appeared at least four fine designs which have hardly been excelled, and certainly not in artistic merit. The first was in the international competition of 1850 for a bridge across the Rhine at Cologne, which brought forth no less than sixty-two competitive plans, one of which by Captain W. Moorsom, of London, contained a centre lifting span 100 feet long, between 600 feet through side lattice girders. Provision was made for a 25 foot street and two railroad tracks, with footwalks on an upper floor. The under clearance of the bridge when down, was 50 feet, and 104 feet when at its highest position. The first prize in the competition was awarded to J. W. Schwedler, of Berlin, for a three span bridge with a central double bascule, somewhat similar to that afterwards used for the Tower Bridge at London. But Captain Moorsom's design was notable for being the first important one of its kind, being used even now as a model for succeeding ones. Its estimated cost was $1,184,000. In 1867 a design was made by Oscar Roper of Hamburg, for a bridge over a wide river, containing a 300 foot lift span, which could be raised to allow ocean sailing ships to pass under it. Another large bridge was proposed in 1872 by T. E. Laing, for carrying a railroad over the River Tees at Newport near Middlesbrough, England. The centre lifting span had a width of 200 feet, and under clearance of 50 feet when down, and 90 feet when raised. The principals were heavy plate girders 200 feet long—very bold indeed for the time—rising between stone towers which had recesses for the counterweights. Provision was made for a variation in the counterweight by adding or withdrawing water, supply tanks for the purpose being placed high up in the towers. To lift the bridge, water would be run into the tanks on the counterweight, when it would automatically rise, and to lower it again, the water was withdrawn until the balance weights were lighter than the span, causing it to descend. Sand glasses were proposed for gauging the amount of water needed. Another elaborate design for a lift bridge appeared in 1878, in a bridge of five spans to cross the Scheldt at Antwerp, the work of M. H. Matthyssens. It had two shore openings of 178 feet (59 meters), two over the main channel of 472 feet (150 meters), and a central lift with clear width and height of 131 feet (40 meters). All trusses had curved upper chords, and multiple web members, there being provision for a 19 foot road, two rail-tracks and double sidewalks. The towers were carried out in stone the tops being connected in both directions by struts with curved lower members. The fixed spans and the centre one when down, had an under clearance of 43 feet, sufficient to pass all ordinary craft. These four designs for lift bridges at Cologne, Hamburg, Newport and Antwerp made with masonry towers and before the days of structural steel, are the prototypes for many important and later ones, and contain much of artistic merit.

Going back a few years to France, it is found that a lift bridge of unusual design over the Ourcq Canal at Paris, on a slight skew, was completed in 1868 to carry a line of railway, the height of which was only 14 inches above the surface of a 28 foot channel. A lifting platform was suspended between two brick arches 28 feet apart, having a clear span of 66 feet and 21 feet rise, and when raised, the under clearance beneath the platform was 16½ feet. The brick arches were 6½ feet wide and 3½ feet thick at the crown, and brick pillars at each end with guide grooves for the counterweight supported the 4 foot sheaves and the shore ends of lattice girders. The weight of moving platform was 22 tons, which was balanced by an equal amount of counterweight, suspended by chains over sheaves, on the face of which were depressions to prevent the chains from slipping. Stairs at each end led up to an elevated foot walk which was always accessible. The platform remained up at all times excepting when wanted down for the passage of a train, after which it was raised again. It was operated by hand power. Another lift bridge somewhat similar to the last, was placed over the Rhine-Marne Canal in 1872, overhead girder supports being used instead of brick arches. The canal had a width of only 12 meters, but the distance between the approaches, including the two tow paths, was 24 meters, and the over-all length 29 meters. Suspenders attached to the ends of brackets on the main girders, passed over sheaves on the upper framing, and were attached to counterweights at the ends. The framing lacked rigidity, as it was braced transversely only by the stairs leading up to the upper level.

One of quite different design was erected in 1873 at Dublin to carry a line of railway over the Royal Canal entrance at Spencer Dock, on a skew of 25 degrees. It is described as weighing 14 tons, the bridge being balanced with counterweight consisting of tanks filled with water, the tanks when empty being one ton lighter than the bridge, and when loaded with two tons of water, one ton heavier. It could be raised by hand power to a height of 7¼ feet, which left room enough beneath for barges. The width was 12 feet and the lattice girders were 40 feet long, though the water opening was only 14½ feet. It was the first bridge on the site, and has since been replaced.

After completing the Erie Canal in 1825, elevated fixed bridges similar to those in England and France, had been used, with approach grades of 7 to 8 per cent., the grades being afterwards reduced and lengthened, with slopes not exceeding 4 to 5 per cent. A few swing bridges with center piers were then tried but none of them were satisfactory. The need of more efficient ones became evident, and in 1872 Squire Whipple began his investigations for commodious ones. He found that a center pier was too great a hindrance to navigation in a canal only 60 feet wide, and to place a turn table on one side, would obstruct valuable wharfage and business property. He therefore designed a vertical lift bridge on which a patent was granted to him in 1872. The first bridge at Hotel Street, Syracuse, was completed in 1874, and in 1907 was still in service. The platform, 60 feet long and 18 feet wide, was the only lifting part. It was suspended by rods 10 feet apart, from the fixed overhead trusses supported on end towers, the rods moving up inside the hollow columns of the trusses. The bridge crossed the canal and tow path, the total length of trusses being 72 feet. The counterweight consisted of twelve long cast iron boxes nine inches square, filled with pig iron, six of them hanging on each side, and weighing when empty 800 pounds. The whole moving weight, including counterweight, was 20 tons. A tread wheel 9 feet in diameter was used for raising two weights, one of which was for lifting and the other for lowering the bridge, both of which merely to overcome friction, were twice as large as actually needed. Their movement was regulated by a ratchet wheel like that on a clock. The rope sheaves were 3 feet in diameter for ¾-inch rope, turning on 2¼ inch axles. In the same year (1874) a patent was granted to A. J. Post of Jersey City for a "vertical sliding bridge guided by columns at the four corners, operated by flexible connecting belts between the towers, driven by a windlass and crank." It was counterweighted by heavy blocks hanging in the towers.

Many other lift bridges began to appear in the principal towns along the Erie Canal, among them being the Allen Street lift at Rochester (1878), which was somewhat similar to that at Utica, having overhead girders on corner towers with a suspended counter-weighted platform. Instead of hand power, it was operated by hydraulic motors, which transmitted power to an overhead shaft with pulleys. Other similar ones were soon afterwards built in the same city.

Benefiting by the experience of American engineers, a lift quite similar in principle to those at Utica and Rochester was erected in 1878 at Calcutta, India, with a span of 116 feet over a tow path and 110 feet waterway. The principal difference in the designs was in the corner towers, which at Calcutta were of stone, giving a much finer and more substantial appearance than the lighter ones of metal used in America. The two lines of trusses were 18 feet deep, and from them, a platform was suspended which could be raised about 13 feet, providing a head room of 20 feet at high water. The counter-weight was two tons heavier than the suspended platform causing the bridge to rise and remain open, but the addition of about 4 tons of water to the platform tanks reversed the overbalance and caused the platform to descend, the required overbalance being just enough to overcome the friction. In this respect it was similar to the one of 1873 over the Royal Canal at Dublin. It carried a single line of railway and cost $51,500., the maintenance cost being $450. per year. W. D. Bruce was engineer. Another very fine European design appeared in 1883, the work of J. Pitt Bayley, for crossing the Thames near the Tower of London. The plans showed four deck arches of 175 feet span, and a centre lift between a pair of great metal ribs, the clear width and height of the open passage being 70 and 90 feet respectively. Its width was 54 feet, and length 880 feet, the estimated cost with machinery and approaches being 500,000 pounds sterling.

In the same year (1883) the city of Rochester erected another hydraulic lifting bridge over the Erie Canal, at Lyell Ave. quite similar to the one of 1878. The platform was 78 feet long, 18 feet wide with a projecting 5 feet walk at each side, and the overhead bridge spanning the canal and tow path at one side on a slight skew, was 94 feet long. Another of 1884 over the canal at Syracuse, carries two tracks of the West Shore Railway, and it is on a skew, having a length of 104 feet, but it is different to the last, in that the whole bridge rises and not simply the floor. The trusses are 23 feet with double web systems, and are suspended by wire rope passing over sheaves 7½ feet in diameter. The counterweight boxes are 6 feet by 6 feet by 9 feet, filled with pig iron, the weight of the bridge being 146 tons and counterweight 140 tons more. Previous to this time, the floors were the only lifting parts of railroad lift bridges on the Erie Canal. The towers of the last bridge were 36 feet high, and the span can be raised 13 feet between them. Albert Lucius was engineer. The Salina Street hydraulic lift bridge near-by is similar to the one in Utica, with a crossing angle of 56 degrees, and a span length of 83 feet. It is 25 feet wide, with two 6 foot walks, the floor weight of 60 tons being counter-balanced by semi-cylinder troughs filled with pig iron, suspended by eighteen wire ropes three-quarters of an inch in diameter, over 24 inch pulleys, the floor being capable of rising 9 feet.

The most elaborate system of navigable inland canals anywhere in the world is in France, where not less than 3,000 miles of such waterways are operated under government direction. But, as previously described, France and England generally used fixed overhead bridges with graded approaches, instead of movable ones. Departures from the usual custom were, however, introduced in France at the cities of Paris and Dijon, a very attractive little bridge being completed in 1886 in the reconstruction of Bassin Villette-Canal St. Denis—in Rue de la Crimee, Paris. A lift bridge was preferred to a rotating one, as the tail end of the swing span would have interfered with existing approaches. The canal is 30 meters wide, but the opening at the site is narrowed to half that width, making the bridge 20 meters long, and leaving space at each side of the canal for boats at the docks. The bridge is 7½ meters wide and the maximum lift 4½ meters, but at one side is an elevated fixed foot bridge with a 79 foot span, approached at the end by steps. The main supports are lattice girders and the platform is suspended by means of chains with 2¼ inch links passing over 8 foot sheaves at the top of independent corner towers which are 25 feet high and 27 to 33 inches in diameter. The counterweights descend into pits, the motion ceases when they reach the bottom. It is operated by hydraulic pistons under the center of the end floor beams, and is provided also with hand power machinery, with pinions working on vertical racks placed against the towers. At each corner are safety ratchets which would engage teeth on the towers if the suspenders should fail. Its total weight is 241 tons, and cost 5,000 pounds sterling. It replaced the one of 1868 in which a platform was suspended between brick arches.

Another bridge at Larrey in the city of Dijon, erected 1890 over the Burgundy Canal, replaced an old stone arch of 1800. The span is 32 feet, crossing a 20 foot canal and two tow paths, and it is lifted 4 feet by hydraulic cylinders, the under clearance when raised being slightly less than 8 feet. The pavement is one, peculiar to the canal bridges of France, and consists of old discarded collier ropes of 1½ by 7 inch flat manilla, laid crosswise over the plank flooring. It is said to wear well, but absorbs a lot of water and causes the weight to vary, seriously affecting the counterbalance.

At each end are steps leading up to platforms from which the bridge is accessible when raised, so that predestrians may cross at all times. A highway bridge 184 feet long in three spans, crossing an arm of the Danube at the Alt-Ofen Dockyard, has a centre lifting span of 68 feet. The road is 17 feet wide and the lattice side girders are 7 feet deep, moving between braced metal towers at each corner, which extend 28 feet above the floor. The counterweight of 44 tons is hung by chains over pulleys, and the whole can be raised 13 feet by a windlass and hand power near the span centre, giving a clear headroom of 42 feet above low water. It was erected under the direction of Peter Remel, and cost 5,648 pounds sterling.

During the year 1890 a design appeared in Europe for a long bridge with a succession of cantilevers, in one span of which a lift bridge replaced the usual suspended part. Towers were supported above the deck on the ends of the adjoining cantilever arms, and the counter weights hung inside of the two near-by river piers which were 60 meters apart, similar designs with bascules instead of lifts, being patented in America, some years later. In the same year a patent was granted in the United States to J. F. Alden, for a vertical lift bridge with counter-weighted platform hung by rods, the whole being worked by electric motors.

The greatest impetus to the design of movable bridge in America began in 1892 with the competition for a bridge over the channel at Duluth, one of the twelve designs submitted being a patented one by Dr. J. A. L. Waddell for a lift bridge of 250 feet span, rising to a clear height of 140 feet above water, the total estimated cost being $125,000. The trusses were shown 25 feet apart for a line of steam railway and two walks, and outside the trusses were 13 feet roads on cantilever brackets for carriage and trolley travel. The suspended weight was about 500 tons, which was counterbalanced, making the moving mass 1,000 tons. Provision was made for raising and lowering it again by electric power, all in the space of five minutes. Sheaves were 15 feet diameter for forty-eight 1½ inch ropes loaded to only one tenth of their capacity. Towers were not connected at their tops as were those of Cologne, Newport and Antwerp, but stood independent of each other. The prize in this competition was awarded on a double retractile design, but as its cost was excessive, the lift bridge was recommended and accepted, though a bridge of another form was finally built.

On June 30, 1892, the South Halsted Street swing over the East Fork of the South branch of Chicago River in Chicago, completed twenty years before, was demolished by collision with a steamer, and as it was a principal thoroughfare, immediate action was taken for its restoration. Encouraged by the favor shown for a lifting bridge at Duluth, the engineers of that project submitted to the city of Chicago a modification of their former plans, which were accepted, and a contract was awarded to the Pittsburg Bridge Co. on a tonnage basis and estimated quantities, revised plans being prepared by the engineers in less than thirty days. The length of lifting span is 130 feet, crossing a channel of 118 feet on a slight skew of 10 degrees. Trusses are 40 feet apart on centres, leaving a clear roadway of 36 feet, outside of which are 10 foot walks at each side, making a total width of 60 feet. It was proportioned for a live load of 4,500, and a dead load of 4,000 pounds per lineal foot. The towers at each side are 40 feet square at the base and 200 feet high, the top of pole being 217 feet above water. Rear tower legs have adjustment to provide against any possible settlement of foundations, each leg having a ball and socket bearing with 10 inch screws. Comparison made at Duluth showed that no saving would result from using an elevated fixed span, with suspended floor, and the whole span is therefore lifted 140 feet, leaving a clear under height of 155 feet above water. It rises at a maximum velocity of 4 feet per second, the whole weight of bridge and platform weighing 290 tons, being suspended by thirty-two wire cables, 1½ inch diameter, eight at each corner, the power for moving being applied by a seven-eighth inch wire rope. The suspension cables pass over 12-foot sheaves turning on 12-inch axles at the top of towers, and are balanced by cast iron counterweight blocks 10 by 12 inches by 9 feet, moving between vertical angle guides, the whole weight of moving parts being 600 tons, the cables and counterweight chains weighing 20 tons. Beneath the floor are four water ballast tanks having a capacity of 19,000 pounds, for the purpose of regulating an exact balance, and in case of failure of the machinery, the bridge can be operated by water-weight supplied from a reservoir on the top of one tower, filled by pumps in the engine room, all water tanks having steam coils to prevent their freezing. The original design called for the use of two 65 h.p. electric motors, but the city of Chicago required a steam engine plant of 115 h.p. instead. As a steam plant in the towers would have caused too great vibration, the engine room was placed under ground. The cost of the steam power operation and maintenance, however, was found to be excessive, and in 1907 electric motors were substituted for steam. Operation by steam had required the services of three engine men, two signal men, four police and one coal shoveller, or ten men all together, their combined wages being $1,000 per month. In addition to this there was $170. per month expended for coal, the boilers being kept going at all times, whereas the cost of electric power for intermittent service proved to be only $50. per month, with the services of only one tender while two had formerly been needed with steam. Altogether the change to electric power resulted in a saving of $3,240. per year in the operating expenses. The bending of the cables consumed in itself no less than 6 h.p. The comparison just given, is, however, hardly fair, for it was found that 26 tons of sand that was placed under the pavement to crown the road, had not been counterweighted, and this had to be lifted at each operation, in addition to overcoming inertia and friction. Buffer cylinders 12 inches in diameter and 4 feet stroke are provided, glycerine being used to avoid freezing, but the upper bumpers are ineffective as the over head girders where they strike the tower framing have for several years been bent and battered, greatly injuring the appearance.

The itemized cost of the bridge is as follows:—

| | |
|---|---|
| Substructure | $84,600 |
| Superstructure | 81,400 |
| Machinery and engines | 50,000 |
| | $216,000 |

It is claimed by the designer that the bridge could be reproduced at a cost of $50,000 less than that of the above figures, while Mr. W. W. Curtis, the resident engineer in charge, reported that it need not cost again more than $175,000. The use of steam power with engines greatly increased both first cost and maintenance, though in any case the lifting of a whole span to so great a height would consume a large amount of energy. The weight of metal in the span is 250 tons, and the whole weight with counterweight is 675 tons. When inspected recently by the writer, it had no street gates or guards of any kind.

Soon afterwards (1894) the same engineers made plans for a somewhat similar bridge over the Missouri River at Kansas City, using the piers of the proposed Winner Bridge which had been abandoned. Piers were to be cut off 52 feet, making it a low level bridge, and provision was made for two railroad tracks on each deck with trusses 32 feet apart, and double wagon-ways and walks on the upper deck, the total width being 65 feet. Metal towers are pierced above piers No. 4 and 5 near the south side, with an elevated fixed span, and suspended lifting floor weighing 925 tons, all of which is counterweighted at every panel with cast iron blocks supported by one hundred and twelve 1¼-inch steel wire cables, over fifty-six cast iron sheaves 5 feet diameter. The deck can be lifted 45 feet and can be worked by eight men. The hangers which support the lower deck will rise through the main posts of the fixed overhead span when the deck is lifted, as was done on those over the Erie Canal in 1874.

In 1894-95 several new lift bridges were placed over the Erie Canal at Rochester and Syracuse. Two adjoining overhead fixed bridges at Rochester were removed in 1875, and a single swing substituted, but in 1889 it was replaced by two lifting spans. Bridge service on the canal was still unsatisfactory, and in 1894, before rebuilding the West Main St. bridge at Rochester, the state of New York sent a representative to Europe to investigate similar conditions there, special attention being given to the bridges in Holland where canals are abundant. The old Dutch Portal bridge with overhead balance beams was found to be the prevailing type, though some of the newer bridges were being built as double bascules. Returning to America, this representative reported quite fully on European bridges as he found them, and improvements that were appropriate for American canals were adopted. The Emerson St. lift at Rochester, finished 1895, was then the longest span over the canal, the distance between end columns being 112 feet, and the floor only is raised, like Whipple's first one of 1874 at Utica. A very serious accident happened to another one at Rochester in November

1896 when the whole movable structure of the Caledonia Avenue bridge fell from its highest position upon a passing canal boat, fortunately without loss of life. It was to prevent such an accident as this, that safety appliances were added to the Ourcq Canal lift at Rue de Crimee, which was previously described. On March 7, 1898, another bridge over a dry bed of the Erie Canal at Whitesboro St., Utica, failed, killing one person. It weighed about 50 tons and is said to have been built forty years before, but had been condemned and closed for a year. It is interesting here to note the heroic measures used at Watervliet, N.Y., to meet operating expenses. The draw was raised and left up until the two adjoining towns paid the bridge tenders' wages which were a year in arrears.

The second important event in America to cause progress in the design of movable bridges was the competition for one over Newton Creek at Vernon Avenue in 1896, when among many others, a lifting design was submitted by F. S. Williamson, similar to that at Halsted Street, Chicago, with an estimated cost of $200,000. A contract was awarded to the King Bridge Company for its construction at a price of $418,000, which agreement was afterwards cancelled.

No lift bridges worthy of notice had been erected or proposed in other countries since the completion of those in France in 1886 and 1890, until 1896, when a small one was placed over Murray River at Swan Hill, Australia, between New South Wales and Victoria, with a 14 foot highway and a 58 foot span. The whole bridge weighed 34 tons and cost only $44,500, and is operated by one man hand power. There are no masted ships on the river and the maximum lift is, therefore, only 30 feet. The design was the work of Mr. Percy Allen.

In the four years following 1899, five other lifts were placed over the Erie Canal at Utica, Lockport, Rochester, and Canajoharie. On the Schuyler St. lift at Utica (1899) with a span of 84 feet, the floor only is raised. The Lockport lift, 111 feet long and 32 feet wide, is worked by hydraulic power from the city mains under pressure of 90 pounds per square inch, the piston rod being attached to a cast steel rack gearing with an 8 inch pinion, all machinery being below the floor, but it is equipped also for hand power. The towers are 24 feet high, supporting cables of cast steel rope, supporting the cast iron counterweight. One at West Avenue, Rochester (1902) with a span of 139½ feet, is the longest over the canal, and air-tight pontoons are used instead of counterweight, similar to that used the same year for a direct lift over the Elbe-Trave Canal at Launenburg, Germany, and at Wattrelos, two years later. Other similar bridges are at Plymouth Avenue, Rochester, 1903, and Church St., Canajoharie, 1904. The lift bridge over a street subway at Friedrichstrafse, Dresden, is quite different from the usual forms, the upper road being lifted about 5 feet by means of levers to which segments are attached, on which hand-operating pinions are worked by winches.

Another important American waterway, the Miami and Erie

Canal, which is used for barges only, had for many years been equipped with automatic closing swing bridges, mostly of the "Smith Bridge Co." type, but in 1900 a new form was erected at Middletown, Ohio, 34 feet long and 66 feet wide, crossing the canal and tow path, the floor being raised about 9 feet for the passage of boats. The moving part weighing 46 tons, is balanced by two counterweights of 23 tons each, lifted by an electric motor beneath the floor, the maximum armature speed being 1,100 revolutions per minute. Another, and very economical design of lift bridge for small waterways, was prepared by the writer in 1904 in the competition for one to cross the same canal at New Bremen, Ohio. The bridge has a 28 foot roadway and two 6 foot walks, with plank floor and steel joist. It consists of an ordinary deck plate-girder highway bridge suspended and counterweighted by means of wire ropes passing over sheaves at the four corners, the counterweights moving up and down inside the towers. The fixed end of the rope is attached to the overhead lattice girder, and produces bending therein. The bridge is raised and lowered by means of four pinions working on racks attached to the corner towers. These pinions are connected through a series of shafts and gears to a 10 h.p. electric motor placed beneath the floor, the motors and machinery being enclosed and protected from the weather. For oiling or inspection, it can be reached through a movable panel in the floor. The controller is placed against the railing and is likewise enclosed, electric current being taken from the street wires. The quantities of material in the superstructure are as follows:—

| | |
|---|---|
| Riveted steel work | 37 tons |
| Machinery | 5 " |
| Counterweight iron | 20 " |
| Steel joist | 6 " |

Electric motor and equipment.
Lumber, 6,000 feet b.m.
Estimated cost, $5,300.

Generally, all forms of lift bridges require expensive counterweights. In this case, the cost of counterweights alone is about 20 per cent. of the entire cost of the superstructure. In nearly all other forms of lift bridges, the cost of counterweight greatly exceeds this amount. In South Halsted Street lift bridge at Chicago, the total weight of metal in the structure is 675 tons, and of this amount, 290 tons, or 43 per cent. is counterweight. This expensive feature applies not only to direct lift bridges, but also to all forms of bascule bridges, which are counterweighted to a greater or less extent. Swing bridges over canals with only one waterway, have either one half of the bridge over the land where it is not required excepting for a counterbalance, or have one short arm loaded with cast iron or concrete, either of which arrangements are expensive. The retractile draw similar to that at Summer St., Boston, which rolls back on a track at an angle of 45 degrees to the canal, is likewise expensive, inasmuch as a large part of the bridge must be built over the land, in order to give room for mounting it on trucks. The trucks and track, and the excavated recess for the bridge when it is rolled back into its open position, all add to its cost. Swing bridges with small roadways, such as commonly used over waterways, are not suitable for wide roadways with sidewalks. The ordinary drawbridge over the Miami and Erie Canal through the rural districts, has a roadway 12 to 16 feet in width, and is a bob-tail swing. It is opened by the pressure of the boat against it, and after the boat or barge has passed, the bridge swings back again automatically into its closed position. A bumping timber backed with springs is bolted to the side of the bridge to receive the blow of the barge as it strikes the bridge and opens it. These bridges are very common along the canal, and are satisfactory for rural districts and light travel. But where wide roadways and walks are needed to accommodate city travel, they are then no longer practicable.

The normal width of the Miami and Erie Canal is 50 feet, allowing three boats each 15 feet wide, to pass each other. But at crossings, the canal is frequently narrowed to about 32 feet, and the cost of the draw bridge reduced accordingly. The estimated costs of other forms of opening bridges for the same location, are as follows, and in each case the estimate is based on providing a fifty foot clear waterway. A double leaf bascule with leaves meeting at the centre, and towers at each side, with a platform 60 feet long, would cost $5,700. A single retractile draw, similar to that at Summer Street, Boston, would cost $7,300. In this case the length of platforms required is 75 feet on one side and 115 feet on the other. A bob-tail plate girder swing, with sand counterweight, would cost $5,400. The length of platform in this case would be 90 feet. A revolving truss swing with equal arms, and a platform 140 feet long, would cost $6,700. Comparative estimates are therefore as follows:—

| | |
|---|---|
| Tower direct lift bridge.................. | $5,200 |
| Double leaf bascule...................... | 5,700 |
| Single retractile draw...................... | 7,300 |
| Bob-tail plate girder swing............... | 5,400 |
| Revolving truss swing, equal arms........ | 6,700 |

The bridge was designed to open by electric power in one minute, and it appears to fulfil all the requirements for the given location. Gates should be used at each end of the bridge, to be lowered or closed before the bridge is opened.*

The forty-one movable railroad bridges in New York State were examined in 1907 by engineers, under the direction of the State Board of Railroad Commissioners, with a view to making such changes as might be necessary to insure public safety, and the conclusions and report of this board contain many valuable provisions. (*Engineering Record*, July 10th, 1907).

Several comparatively small lifts in other countries are those at Haslar, Nyasaland, and Edinburgh, all other ones of any importance

*Lift Bridges for Small Waterways. H. G. Tyrrell in *Electrical Review*, Dec. 31st, 1904.

being in America. That over the entrance to Portsmouth Harbor, at Haslar, England, is a small affair of less than 28 feet span, with towers framed in reinforced concrete, though the floor, which is only 7 feet wide, has steel frame. It forms an opening through the harbor jetty and is probably the only one of its kind. A lift over Shire River—a branch of the Zambesi—at Nyasaland, designed by Sir Douglas Fox, has a 100 foot opening, and a clear height above water of 30 feet. The lifting span rises between disconnected towers, supporting the sheaves, and when open, the counterweight descends and lies across the track, forming a substantial barricade. Openings are of rare occurrence, and hand power only is supplied, so it can be opened in 25 minutes by eight men. The weight of steel in the lift span is 55 tons, in tower 31 tons, and in counterweight shells 8 tons. The towers stand on 30-inch cast iron cylinders. The small lift bridge over Union Canal, at Fountainbridge, Edinburgh, has a 25-foot road and steel trough floor. The canal is only 13 feet wide, and the maximum lift is 8½ feet. It has an elevated foot walk at one end, reached by steps, similar to the bridge at Dijon.

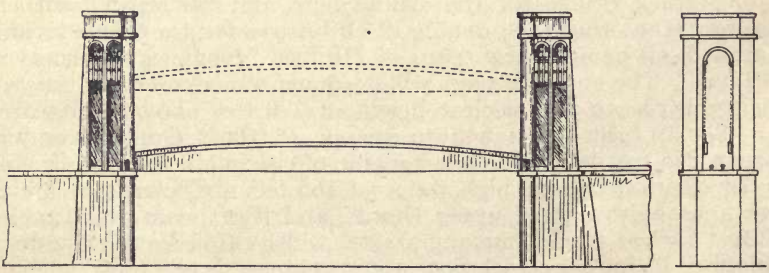
A patent was issued in 1908 to Eric Swenson of Minneapolis, for his "gyratory lift bridge" designed for crossing the Narrows at Lake Minnetonka, the counterweight being so placed as to keep the centre of gravity in the centre of rotation, and the towers were to be covered with ornamental iron.

Other important designs for direct lift bridges during the last three or four years are the work of Waddell and Harrington, civil engineers, several patents having been granted to them during the summer of 1908 for bridges at Keithsburg, Chicago, and Portland. One for the Iowa Central Railroad over the Mississippi River at Keithsburg, will not contain a draw of the usual form, but a novel lifting arrangement instead. Several spans are so arranged that towers can be placed at their ends, with their rear legs on the adjacent fixed spans. The 230 feet intermediate span between the towers can then be lifted 45 feet, thus providing for a shifting channel. Comparative tenders received, showed the arrangement to cost about $39,000 less than an ordinary swing. Three other lifting spans over Calumet River, Chicago, were begun in January, 1910, one being a four track bridge for the Lake Shore and Michigan Southern Railway, the other two, double track bridges for the Pennsylvania Railroad, all having skew spans of 210 feet, crossing a waterway of 140 feet. The concrete piers will go down to rock and the moving span will rise to give a clear height of 120 feet above high water.

The lift bridge at Hawthorn Avenue, Portland, Oregon, contains a span 245 feet long, which is capable of rising 110 feet, leaving an under clearance above high water of 165 feet. The trusses are 23 feet apart with curved upper chords, and floor beam overhanging 19 feet for car tracks, making a total width of 63 feet. The total weight of lifting span with floor and machinery is 885 tons, which is counterweighted with concrete blocks 21 feet by 37 feet by 6 feet 10 inches. Towers are 170 feet high, each one weighing

128 tons. The cost of substructure is $100,000, and superstructure $350,000. The other lift at Portland, for the Oregon Railway and Navigation Company is the largest of the kind ever attempted and adjoins a swing bridge built from plans by George S. Morison in 1889. It contains two decks, the lower one only, being lifted 52 feet for ordinary craft, which includes about 90 per cent. of all the river travel, although the whole span and both decks can be lifted between the towers for masted ships, leaving a clearance of 135 feet. The approach trusses are through spans with a railroad on the upper deck, and highway 70 feet wide on the lower one, which is locked down when in service. The highway is paved with blocks on plank supported on cross ties, all wood being creosoted. Its total cost is reported to be $1,650,000. The method of providing two decks, both of which are movable, is somewhat similar to that used in 1891 for the elevated railroad at Liverpool, England, where the double bacsules of the lower deck are lifted for small boats, while for larger ships, the whole bridge with lower platform suspended from the upper one, can be revolved open on turntables at each side. Other direct lift bridges are in Idaho, Washington, and Arkansas, and another over the Miami and Erie Canal at Mohawk Place, Cincinnati.

It appears therefore, that the chief progress during seventy years, in the design and construction of direct lifting bridges, has been in the use of steel towers instead of cast iron and stone, and in the substitution in some cases, of floating buoys instead of counterweight, a method which was successfully used by M. Vescovali in 1893, in the Tiber River bascule near Rome. Compensating chain weights have also been used in some recent works, modifications of those invented by Poncelet, and used on bascules in France, prior to 1847. In only one case—at Kansas City—has the length of lifting span exceeded 300 feet, as proposed by Oscar Roper, of Hamburg, in 1867.



Proposed Lift Bridge over the Tees at Newport, the design by T. E. Laing in 1872