Design and construction of a bascule bridge

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Design and Construction of a Bascule Bridge

Etude et construction d'un pont basculant

Entwurf und Erstellung einer Klappbrücke

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SUMMARY

The design and construction of a new bascule bridge is described. The bridge is a single-leaf overhead counterweight frame type, spanning 20 meters, carrying a roadway and a sidewalk. The factors affecting design are discussed, and the changes in design philosophy to effectively provide a structurally redundant deck are described. Restrictive conditions during construction are discussed together with problems experienced during the fabrication and construction stages.

RESUME

L'article présente le projet et la construction d'un nouveau pont basculant. Cet ouvrage comporte un portique à contre-poids suspendu, d'une portée de 20 mètres, supportant une chaussée carrossable et un trottoir. Les auteurs exposent les facteurs admis dans le calcul ainsi que l'évolution survenue dans la philosophie de l'étude en vue de parvenir effectivement à une structure du tablier redondante. Ils fournissent en outre les conditions restrictives admises pendant la construction et les problèmes survenus durant les étapes de fabrication et de mise en œuvre.

ZUSAMMENFASSUNG

Entwurf und Erstellung einer neuen Klappbrücke werden beschrieben. Die Brücke weist eine Klappe von 20 m Spannweite mit Fahrbahn und Gehweg und obenliegendem Gegengewicht auf. Die Hauptfaktoren für den Entwurf und die Bemessungsphilosophie, welche zu einem redundantem Tragsystem führte, werden erläutert. Die einschränkenden Randbedingungen während der Erstellung sowie Herstellungsprobleme werden ebenfalls beschrieben.

1. INTRODUCTION

1.1.1 The Oswego River Flows through a rural area with minor industries, and has a dam with tainter gates across at the village of Phoenix. Navigation is maintained by means of a Canal Lock System between the appropriately named Lock Island and the right bank of the river.

1.1.2 There used to be a factory on the Island and access to the island was provided by means of two heel trunnion type Bascule Bridges, one each at Culvert Street and Bridge Street. Access from Phoenix to the left bank of the river was obtained by means of a double leaf trunnion bascule type bridge at the extreme southern tip of Lock Island connected to a five span concrete encased steel arch structure, all known as the Lock Street Bridge.

1.1.3 The factory has long gone, and the Lock Street Bridge had become so deteriorated that the sidewalks had been closed to pedestrian traffic in 1985. The main structures and machinery had become so bad that it was decided that rehabilitation was impractical. A full feasibility study was commissioned by New York State Department of Transportation, (NYSDOT) to investigate the needs of the community, consider alternative options for replacement, and to undertake the necessary environmental impact study.

1.1.4 Because the existing bridge was the only crossing within a radius of 5km, it was a vital link between the communities of Phoenix and West Phoenix, New York and the new bridge needed to be constructed before demolishing the old one.

2. DESIGN

2.1 Options For The New Bridge

2.1.1 Three low level options with movable span and two high level fixed span designs were considered. The high level fixed spans were rejected as creating a detrimental impact on the area, from greater visual intrusive appearance and a greater property and land use requirement. The three low level options were

a) Reconstruction on the Lock Street Alignment;
b) Reconstruction just to the south of the existing alignment but entering Phoenix at Church Street.

Both these alternatives were above the dam.

c) Realigning the west approach to the river crossing and constructing the bridge below the dam and entering Phoenix at Culvert Street.

2.1.2 After holding local meetings NYSDOT issued its final transportation project report recommending the adoption of the third option -- the Culvert Street Alignment.

2.1.3 This finally adopted alignment for the bridge provided for a crossing of the Oswego River and navigation canal in two distinct elements. The first portion was a 192m long fixed bridge over the river from the left bank to Lock Island, below the dam in a position of much less visual impact than the existing Lock Street Bridge. Because of the decision to construct at a low level a movable span was therefore required to continue the roadway from Lock Island to the East Bank, to permit passage of river traffic.

2.2 Selection of Movable Bridge Arrangement

2.2.1 The selection of the type of movable bridge to be utilized was governed by a number of factors, not the least of which was the overall appearance of the bridge. A bascule bridge had already been tentatively assumed to be the type of movable bridge required, as being the most economical, and the design options considered were a rolling lift bridge, a simple trunnion bridge and a heel trunnion bridge.

2.2.2 The simple trunnion bridge was the type in use at the existing Lock Street Bridge, and even though it creates the least visual impact, the additional cost of constructing the counterweight pit and the potential maintenance problems of a pit below water level were considered to outweigh the advantages. The rolling lift, with overhead counterweight is possibly the least attractive movable bridge, aesthetically, and is subject to possible instability of the bascule piers. The heel trunnion type, with overhead counterweight was therefore recommended, particularly as the existing Culvert Street Bridge was of this type, and would thus result in little visual change overall in the area.

2.3 Detail Design Of Bridges

2.3.1 The decision to use a heel trunnion arrangement having been made, it was considered that the bridge should be made as redundant as possible. The normal practice with structures of this type is to have two edge girders with the hanger links connected at approximately 2/3 of the distance from the heel trunnion to the toe. The deck is then supported on cross girders between the edge girders. With this arrangement the hangers will be transmitting fluctuating deflections to the counterweight frame as vehicles move across the span.

2.3.2 It was decided to revise the usual sequence of support, by supporting the deck on multiple underdeck beams. These beams are themselves supported by the heel trunnion beam at the pivot pier, and a toe beam at the rest pier. The hanger links are connected to the toe beam directly over the rest-pier bearings. The main trunnion bearings are mounted on the ends of the heel trunnion beams.

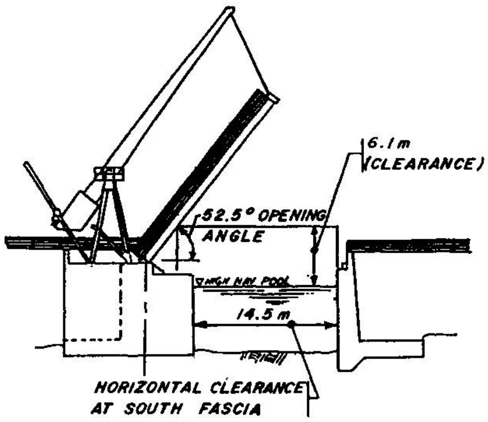

Fig. 1 Elevation with bridge open

2.3.3 The advantages of this arrangement are three fold. First, the rest pier is only supporting the live load from the bascule leaf. All dead load is supported by the overhead counterweight, but no live load is transmitted through the hanger links to the operating machinery. Second, the bascule leaf is effectively redundant, as there are eight primary load supporting beams spanning the canal, instead of the usual two through-deck girders. Finally, the longitudinal members never undergo stress reversal as is the case when the hangers are connected to the interior of the span.

2.3.4 The deck itself is a concrete-filled steel grating spanning across the stringers with haunches to provide for the final deck elevations. The Contractor was given the option to form these haunches in concrete or to provide steel fillers, and he elected to supply tapered steel sections. The deck is designed to act as simply supported panels to carry all dead load, but acts compositely with the stringers to support the live loads.

2.3.5 The counterweight boom arms were designed as tapered box sections, and were treated as free cantilever arms laterally connected at the tip. The counterweight box provides full torsional stability at the rear end, but the tip is effectively free except for the transverse strut connecting the two tips. It was for this reason that the box section was selected, in order to obtain the maximum lateral-flexural stability.

2.3.6 The A-Frame towers provide support to both the main counterweight boom trunnions, and also to the pivot of the main operating struts. Each leg was designed as an unbraced I Section, stabilized laterally only at the top junction position.

2.3.7 The link arms are not vertical, but crank in 787mm from the boom center lines to the center line of the live load shoe bearings. This arrangement was selected because of the necessity to position the A-Frames outside the roadway line, to eliminate eccentricity on the counterweight boom trunnions, these being the most heavily loaded moving elements of the entire structure, and to keep the overall length of the toe beam to a minimum. The horizontal load components of these links are resisted by the tip strut, which itself is laterally stabilized by a 45^{o} K-brace back to the 1/3 points of the counterweight booms.

2.3.8 The counterweight was designed as a steel box to contain balance concrete. This resulted in a larger box than would have been necessary if cast iron counterweights had been used, but the proportions are similar to those utilized with the existing Bridge Street bascule span and concrete is more economical. The shape of the counterweight box resulted from trimming off the bottom outer corner at the same angle as the raised span - 52.5^{o}.

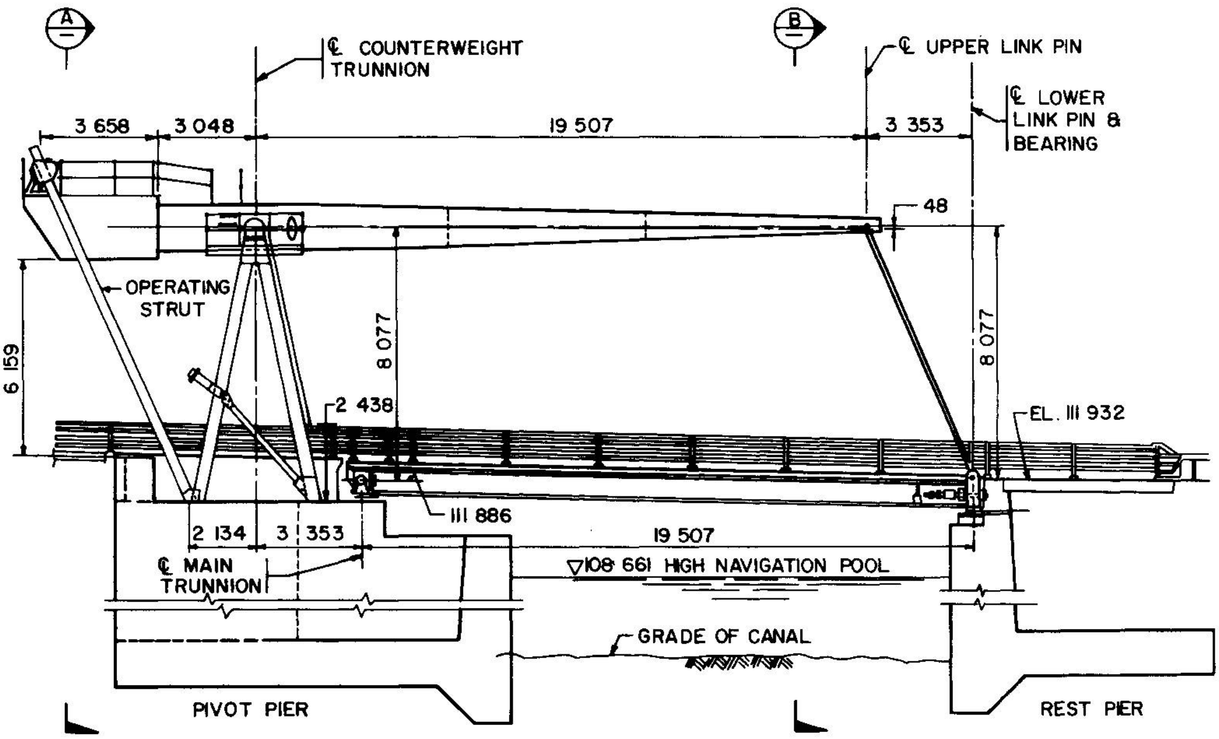

Fig. 2 Lock Street Bridge Replacement-South Elevation

2.4 Mechanical and Electrical Components

2.4.1 The decision to use an electric drive mechanism with rack and pinion operating machinery was made as a result of the need to keep maintenance of mechanical and electrical items down to a minimum. This need arises from the location of the bridge in an area subject to severe winter weather, within the New York State "Snowbelt". Canal traffic does not operate from early December through mid-April, during which period the bridge is down, and is unattended. Electric drives with direct operating mechanical components were selected as being more robust than hydraulic systems, and the entire drive system was mounted on top of the counterweight box, inaccessible to the public. The drive system consists of a 15kw motor operating through a 120:1 speed reducer via 178mm diameter shafts directly coupled to the pinions engaging the toothed racks on the operating struts. Emergency operation is through a hand crank mounted at the top of the South A-Frame tower at the maintenance platform.

2.4.2 When the bascule leaf has been lowered into the closed position, the span is fixed in place by span locking bars mounted on the outer face of the fascia girders and operating through the toe beam over the rest-pier bearings. These locking bars are operated by electrically driven linear actuators.

2.4.3 All trunnion and link arm bearings are lubricated bronze shells with steel shafts or casings. This bearing type was selected for simplicity, and to keep maintenance to a minimum.

2.4.4 The remaining item of interest is the counterweight stop block which is positioned to prevent overrun of the opening mechanism, and thus also to protect the A-Frame towers from being hit by the counterweight. Any such inadvertent impact forces will be transmitted directly to the foundations.

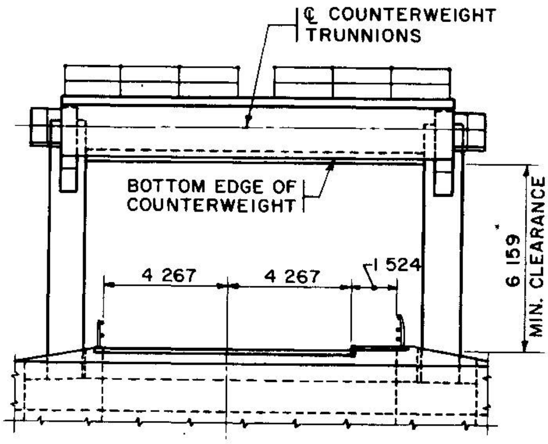

Fig. 3 Section A (Bridge Closed)

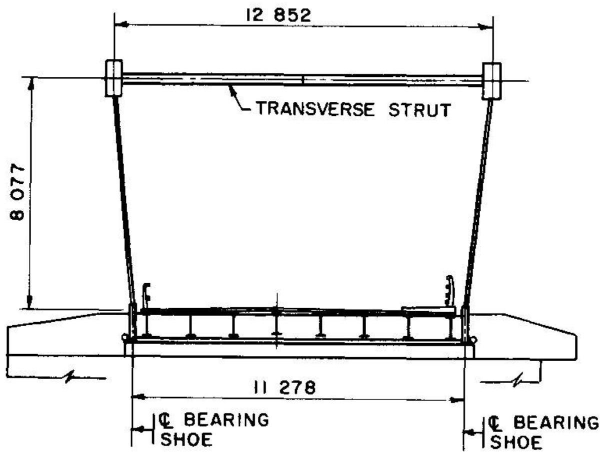

Fig. 4 Section B

3. CONSTRUCTION

3.1 Foundations

3.1.1 The primary restraint on the construction of both the fixed and bascule spans was the necessity to limit any sediment producing operations to an absolute minimum during the fish spawning season. This resulted in a prohibition of any work operation in the river that was not directly protected by coffer dams in the months of April to September. The pivot and rest pier foundations of the bascule bridge were designed as shallow spread footings on rock with transverse keys for lateral forces. They were constructed by means of providing a sheet piling cofferdam around the footing outline, excavating to bed rock and dewatering the cofferdam, placing reinforcement and filling with concrete to the top of the spread footing. This provided an effective seal to the sheet-piling and the new pier construction could be continued inside the cofferdam with no effect on the river water. The sheet piling was cut off at canal bottom level after the completion of the pier construction. This final operation was undertaken outside the spawning season.

3.2 Superstructure of the Bascule Bridge

3.2.1 All structural steelwork was fabricated at New Castle, Pa, all mechanical components made in Birmingham, Alabama, and everything was shipped by roadway to the job site. Installation of all items was undertaken using a mobile crane on the Lock Island, or on the Phoenix side of the canal lock.

3.2.2 A problem occurred during the assembly of the counterweight boom trunnion shaft to the boom hub, as a result of a failed weld, which resulted in cracks forming in the trunnion hub and boom webs. The Contractor elected to repair this area using a bolted splice detail instead of welding, as a result of a combination of time constraints, and concern over the effect of excessive welding in the vicinity of the trunnion hub. Extreme care had to be taken in the analysis of this section of the booms, as it is the point of maximum stresses for both bending and shear, and all these forces had to be accommodated in the bolted splice details, prepared by Steinman.

3.2.3 The sequence of erection was initiated by the positioning and tie down of the combined grillage bases for the main trunnion bearings and A-Frame towers. These bases allowed for a small amount of adjustment in the positioning of the A-Frames and main trunnion bearings, but still required very exact positioning.

3.2.4 The installation of all deck leaf steelwork was then undertaken. The concrete fill to the deck grating was placed in winter, and a full curing operation was undertaken to ensure that the temperature of the concrete was maintained above 7°C. This consisted of positioning a pontoon barge underneath the deck span to cover the full width of the canal, providing heavy duty plastic sheeting to close the gap from the pontoon barge to the fascia girders, covering the deck concrete with insulated blankets after placement, and then operating space heaters in the volume between the pontoon barge and the deck for the full curing period. This very effective method was only possible because the canal is normally shut down during winter.

3.2.5 The A-Frame towers were constructed independently of the deck installation. The counterweight booms had their bearings fitted to the shafts and were lifted into place with the tips supported on temporary shoring. The link arms were then installed with the bearings fitted top and bottom, and at the same time the counterweight box was assembled on top of temporary heavy-duty shoring. After all connections had been made, the counterweight concrete was placed inside the steel box. The machinery was then installed, and tested.

3.2.6 Final balancing of the overall structure was undertaken first by means of calculation of the theoretical requirements for transverse and overall balance. After installation of the necessary balance blocks, direct reaction load readings were taken at the toe beam for the closed position, to obtain the correct lateral balance, and final longitudinal balance was determined by torque figures obtained from strain gauges fixed to the main drive shafts. These readings were taken during opening and closing of the span as the exact balance was required between 35° and 45° open position, with an approximately 18kn "heavy" state at the toe beam required when the bridge is closed.

3.3 Barrier Gates

3.3.1 A final item of interest is the provision of the barrier gates designed and installed to prevent automobiles from driving into the bridge or canal when the span is raised. These are cable net gates of the energy dissipation type, which operate on a similar principle to the arrestor wires on a naval aircraft carrier. A net is stretched across the traffic lanes. If a vehicle drives into the net, the attachment bars at the ends of net pull through a series of circular rollers, and the kinetic energy of the vehicle is dissipated in the bending and straightening of the attachment bars, as they pass through the rollers. These barriers are designed to halt a 2 050 kg vehicle travelling at 110 kph in less than 8m.

3.3.2 The net, is normally parked at a clear height of 6.25m above the roadway, and is only lowered to roadway level immediately before the raising of the bascule span.