Heel Trunion Bascule Bridge

THE JOHNSON STREET BRIDGE

Details of Construction Methods and Comparative Costs of the Johnson Street Bridge in Victoria, B.C.

F. M. Preston, A.M.E.I.C.
City Engineer, Victoria, B.C.

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In 1919 after many years of discussion the three parties interested in the building of the Johnson Street bridge, namely: the provincial government, the E. and N. Railway Company and the city of Victoria signed an agreement which called for the building of the bridgeby the city of Victoria with contributions from the parties interested. These contributions included $100,000 from the E. and N. Railway Company and $200,000 from the provincial government.

The final cost of the work was 21.7 per cent higher than the estimate and this has brought home to me that in future the right thing to do, when, as was the case of the Johnson Street bridge, no money is available for preliminary plans and estimates, is to put a by-law before the people asking authority to spend the necessary amount on preliminary work, and after these preliminary plans and estimates are prepared, to again submit to them a construction by-law.

The estimate as used for the by-law was based upon one prepared by the Strauss Bascule Bridge Company, and although it was prepared for two individual Bascules the dimensions of the approach spans and details of substructure differed from that finally constructed. After the by-law was passed, work was immediately commenced upon the actual design; the substructure and approach spans being designed in the city engineer's office and the bascules by the Strauss Bascule Bridge Company of Chicago

The original intention was to erect the Bascules on large cylinder piers sunk to rock, but upon the advice of the Canadian Pacific Railway bridge department this was changed to practically solid concrete piers carried on piles driven to the rock. Objection was taken at the same time by the Canadian Pacific Railway bridge department to the location of the main trunnion pier in close proximity to the cylinders carrying the turntable of the existing swing bridge, and it was therefore decided to take advantage of the fact that the city had provided for a railway loading on their side of the bridge, (for the purpose of giving the British Columbia Electric Railway Company opportunity for handling railway freight cars with electric locomotives, during certain periods of the night). It was decided to first construct the greater part of the substructure, except the northerly quarter of the main trunnion pier and the northerly half of the east abutment, and to then erect the highway steel work, diverting the E.& N. Railway over it when it was completed, and to then remove the old swing bridge and finally erect the railway portion of the new bridge.

Tenders were called for the substructure towards the end of 1920, and the city engineer was also instructed to put in an estimate for carrying out the work by day labour. Opportunity was given for bidding both on a lump sum and a schedule basis. No tenders were received upon the former and the city engineer's estimate being the lowest it was decided to carry out the work departmentally.

Comparative and Unit Costs

The engineer's estimate on the schedule was $177,376. and he would have been paid on the final schedule, supposing he were a contractor, $189,873: the actual cost being $207,897. If the work had been let to the lowest contractor, the latter would have been paid $237,632., approximately $30,000 more.

It will be noted that the actual cost above the day labour schedule cost was approximately $19,000 and nearly $17,000 was dropped on the rest pier. An additional [illegible] can also be accounted for through unavoidable delay, and for which no doubt a contractor would have been paid and no allowance for this has been made in the engineer's actual cost as given above.

The following individual costs on various sections on the substructure may be of interest. The first cost given in each case being the estimated cost; the second the actual cost and the third the amount that would have been paid to the next lowest tenderer.

East abutment	$14,156	$17,563	$19,235
Counterweight trunnion pier	$64,315	$66,089	$69,319
Main trunnion pier	$43,827	$43,401	$44,558
Rest pier	$35,778	$52,527	$64,067
West abutment	$31,796	$28,316	$40,453

The unit costs for excavation under water, including the cost of the caissons or sheet piling were:

East abutment	$3.40
Counterweight trunnion pier	$23.23
Main trunnion pier	$38.21
Rest pier	$23.08
West abutment	$ 5.53

Concrete laid under water averaged approximately $13.27 per cubic yard, and the balance of the concrete on piers $12.70 and $16.00 per cubic yard, averaging about $14.60. Piling averaged 82 cents per lin. foot of pile in place.

In all of the above costs, allowances have been made for rental of equipment amounting to about $16,000. The labour cost on the first portion of the substructure was 35.5 per cent of total and on the second part 43.8 per cent.

Details of Construction

The west abutment and a portion of the east abutment were founded on rock most of which was bare at low water and presented little difficulty in construction. The excavation for the counterweight and main trunnion piers was carried out by open dredging inside timber caissons which were built upon the ways of one of the old ship-yards. These caissons were carried up to their twenty-fourth course and they were then launched and floated around to their correct position. Their seams were not caulked in the ordinary way but between each course two layers of jute rope were laid about five inches apart, and an asphalt mixture poured between them, before the next coarse was laid. A strip of canvas 5 inches wide, held in place by a 1 x 3" batten, was also spiked over the side of the joint. This method was found extremely satisfactory and cheap.

Before the caissons were launched a collapsible bottom was built 5 feet up from their lower edges, for the reason that the depth of water at the ends of the wayswas insufficient, and pontoons consisting of old steel water pipe were also strung along their outside edges at about their approximate water line to give them the necessary stability after they were launched. Each caisson took a heavy list when it entered the water, and after the first caisson was launched, and to insure the others listing in a certain direction in order that they might not foul existing obstructions, they were weighted with lumber, which automatically fell free when the desired list was obtained. Each launching was carried out successfully and it was found that this false bottom leaked slowly enough to enable the caissons to be towed into deep water before they had reached their natural flotation level. The caissons were then towed into position and held there by pile stagings, and the balance of the work on them completed. Compressed air for drills and hammers was used freely on all timber work.

The excavation was done by a clam-shell bucket with the assistance of divers and high pressure water jets. The caissons were sunk by means of weighting at their upper edges with sand boxes. When they had reached their correct position washborings were taken and the piles cut off to their finished length, which allowed a five-foot projection into the concretebase of the pier. These piles were driven with a steam hammer using sliding leads and a follower. At times it was found necessary to submerge the hammer, and rather to our surprise, with no evil consequences to it.

Pouring Concrete under Water

After the piles were driven the bases of the piers were poured with concrete under water using a special bucket. The method used was developed by the city engineer and was afterwards patented. The concrete used was a 1: 2: 3 mix, which was deposited into a water-tight cylindrical bucket. Its upper door was then closed and the bucket lowered into place under sufficient air pressure to balance the water pressure outside. When it had reached its correct position the bottom door of the bucket was tripped from the surface and it then emptied by gravity, the concrete being displaced by air instead of water. The bucket was held in position by rope and a brake and it worked in sliding leads like a pile hammer. A long spout at the end of the bucket enabled the material to be placed accurately around the pile heads. The resulting concrete, after pumping the caissons out in about 20 days time was found to be excellent, 12 yards per hour can be laid with a one-yard bucket. About 13 feet in depth of under-water concrete was placed by this method. Additional frames weighted with concrete blocks were then slid into place and wedged into position. All the caissons were then pumped out with no difficulty. A small amount of caulking with oakum and shingles making them watertight, and each one was landed within a few inches of its correct position. After the caissons were dry the pier forms were built inside them and the balance of the concreting done in the dry.

While sinking the largest caisson the lower edge encountered a thin crust of hardpan and one side broke through unexpectedly and within a few minutes the caisson assumed an angle of 15 degrees to the vertical. This accident although spectabular was easily righted by cutting away the sand boxes on the lower side, excavating under the high side, and using pontoons on the low side; and in spite of the racking it had received this caisson was as watertight as any of the others, which is a strong recommendation for the methods of caulking that were used.

All the concrete was mixed on a floating plant, the mixer scow carrying a one-yard steam driven mixer and hoppers for sand, gravel and cement erected about it, with cement sheds at either end. The sand and gravelwere fed by means of a clam-shell bucket operated by the derrick scow, and the cement was raised from the sheds to the level of the hopper by means of air pressure.

The sinking of the caisson for the rest pier proved to be the most difficult operation of all. This was floated into position and a row of sheet piling driven around it to the rock, the caisson being then sunk inside the piling, no attempt being made to bring the caisson itself to the rock bottom. The rock on the northerly one-third of the site was 12 feet higher than that on the south end, with a cliff between, and allowances were made for this in building the caisson.

After excavation had been commenced an unexpected hard layer of material, chalk like in character, which the original wash borings had not shown, from 3 to 4 feet in thickness, was found immediately upon the rock and after trying several methods for its removal without success a solution was found in the use of a 2-inch water jet made out of hydraulic pipe having a nozzle flattened to 3/4 inch. This was suspended from a derrick and operated below by a diver. The water at a 100 pounds pressure at thenozzle was found to break up the material sufficiently to allow the clam-shell bucket to remove it. Before concreting a very accurate scalle model of the rock was made in order to determine if the foundation was safe against sliding.

The balance of the substructure for the completion of the highway portion was carried out in much the same way, except that the balance of the east abutment was constructed in cofferdams. During this part of the construction the only serious accidents during the work occurred. In the first place the walls of the cofferdam spread, the tie bars parting at the welds, but this was rectified by new tie bars and dumping clay on the outside. Then the concrete mixer scow was sunk through settling with the falling tide on a floating pile stump. It was carrying a load of 500 sacks of cement at the time, and was blocked on three sides from all possibility of approach and therefore considerable difficulty was experienced in raising it. The northerly portion of the main trunnion pier is practically an independent unit, only being steadied by a key way. It was carried up independently and the key portion poured to below low water separately. Careful records of the levels of the substructure have been kept and show no settlement to date.

The contracts for the superstructure were both let to the Canadian Bridge Company, and the spans consist of two 112-foot plate girder deck spans, 45-foot tower spans, 150-foot Bascule spans, and 73-foot plate girder spans. Both of the Bascules were erected in the open position and for this purpose the Canadian Bridge Company built a special steel derrick with boom consisting of six 30-foot sections of lattice girder, all of which, with the exception of the two end pieces, were interchangeable, and the connections were bolted so that it was possible to carry anything requiring a 60-foot to a 180-foot boom. The derrick was capable of carrying 6 tons at 120-foot radius using the full length of the boom, and 20 tons at a 75-foot radius using a 90-foot boom.

The 112-foot approach span, the girders of which weighed about 54 tons, was first erected by means of jacking the main girders into place from flat cars on a temporary track laid alongside. The large derrick was then erected on this span and the Bascule constructed in the open position. The top cords of the movable leaf were temporarily anchored to the diagonal posts of the tower span, and the bottom of the vertical posts to the 112-foot approach span, and in this way the approach span was

was used as a counterweight during the erection.

The forms for the concrete counterweight were supported directly by the counterweight trunnion pier and by piles especially driven, no portion of the weight being taken by the steel until the concrete had set. Cavities were left in the counterweight for taking balance blocks, these blocks were made of different weights by the addition of steel punchings for an increase of weight, or cinders for the opposite purpose. The cubic foot weights of the concrete in the counterweight vary; being approximately 142 pounds per cubic foot for the upper, and 156 pounds for the lower portion. The counterweights were afterwards painted with a waterproof paint, and the points at which steel entered caulked with a plastic composition of red lead, asbestos fibre and tallow. The weights are 867 tons for the highway and 550 tons for the railway bridge.

After the concrete was finished, the ties and rails for the two street car tracks, the centre freight track and the subflooring of creosoted lumber were laid while the bridge was still in the vertical position. This work was both difficult and dangerous. The bridges were then lowered and in each case came within a small fraction of an inch of their correct seats. The balance of the work upon them was then completed.

On the highway portion, the operating machinery consists of two 3-phase, 75-h.p., electric motors geared through a differential to the main driving shaft. A 50-h.p., gasoline engine for emergency use is also coupled to the same shaft. The end locks are operated by a 5-h.p., motor, and the entire control for both bridges is centralized in one operator's house. The Bascules can be raised or lowered in just over one minute using electric motors and six minutes using the gasoline engines. The electrical operation is so tied together that before the bridge motors can be started the signals have to be put at danger and the end locks withdrawn.

There are two sets of electrically operated brakes to each bridge as well as a hand emergency brake and these electrical brakes can cut in by the automatic cutting off of the current at certain points of travel, both up and down, and do so unless they are held off by means of a finger operated button. The idea is that if the operator is suddenly incapacitated his finger would leave the button, and the automatic operation would stop the bridge.

The main trunnion bearings on the highway Bascule are 22 inches in diameter and the counterweight trunnion bearing 38 inches. The upper portion of the bearings are babitted and the lower phosphor bronze. Naturally the lining up of these has to be very carefully carried out.

The old bridge was also removed by the Canadian Bridge Company. It consisted of two pin connected trusses constructed of wrought iron. All of these pines were frozen into place so they adopted a method of cutting it with an oxygen-acetylene torch.

The main pier consisted of four steel cylinders, each cylinder having eight piles driven inside it and the spaces filled with concrete. The average length of these piles was 90 feet of which about 60 were penetration. The cylinders themselves were about 40 feet long. The steel and concrete was cut away from the piles above low water. The balance of the work was of considerable difficulty until the following method was used: Holes were drilled longitudinally down the piles with hand augers and a stick of dynamite was exploded at the bottom of each hole; the effect of this was to force the cylinder open and loosen up the concrete around the piles but the explosion was not sufficient to break the piles themselves. The piles were then pulled by means of tackle carried by a frame erected upon the nose of the derrick scow, giving a pull on the pile of approximately 80 tons.

The railway bridge was designed with Coopers E-50 loading, with 50 per cent impact allowance. The highway bridge for 25-ton motor trucks and Class A electric car loads on each car track, with Coopers E-50 on the centre track only, plus the impact allowance for highway bridges, Engineering Institute of Canada, and 80 pounds per square foot on the sidewalk.

The total cost of the bridge amounted to approximately $918,000; substructure $251,153, highway Bascule $213,172, railway Bascule $173,390, higway approach spans $59,000, railway approach spans $38,000. These include inspection and the Strauss Company's fee. The Strauss Company's fee for designing and royalties amounted to $34,125, or 10 per cent of the final Bascule costs. The city engineer received $2,400 for extra work.

The weight of the highway Bascule is 1,602,490 pounds, representing a cost of 13.3 cents per pound. The original estimate was for weight 1,074,000 pounds, at an estimated cost of 16.7 cents per pound. The railway Bascule weighs 1,066,700 pounds, and cost 15.6 cents per pound. The estimate was 820,000 pounds at a cost of 15.5 cents per pound.

The weight of the highway approaches is approximately 629,565 pounds at a cost of 9.4 cents per pound; the railway approaches 404,700 pounds at a cost of 9.4 cents per pound.

The highway flooring on the Bascule span consists of long leaf yellow pine creosoted 3-inch wood blocks, laid on a creosoted 4-inch sub-floor. These blocks are held in place by 2" x 2" galvanized angles laid every twelfth row of bocks, and upon three layers of single-ply felt. The flooring on the approach spans is of reinforced concrete laid with only longitudinal joints.

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SUPERSTRUCTURE OF JOHNSON STREET BRIDGE, VICTORIA

(Layout consists of two separate bridges resting on the same piers - Work introduced a number of interesting structural problems - Movable portion of single leaf Strauss Bascule type - Highway section completed)

By F. H. Allwood - Resident Engineer

There appeared an article by Mr. Allwood in the June 6 issue of "The Canadian Engineer", in which was illustrated and described the substructure of this bridge. The present article deals more particularly with the superstructure.

The first stage of an engineering work of great interest has just been completed, namely, the highway portion of the new Johnson Street Bridge, which spans the waters of the Inner Harbor at Victoria, B.C., and which is being jointly built by the city, the Provincial Government and the Esquimalt and Nanaimo Railway.

General Layout

The general layout consists of two separate steel bridges resting on the same piers and abutments, one of these bridges to be for railway use exclusively and the other for highway purposes. Owing to the proximity of the old Esquimalt and Nanaimo Railway swing span it was found necessary to build the highway span first, designing it for railway loading; to then divert the Esquimalt and Nanaimo Railway on this new span, demolish their old bridge and finally erect the railroad portion of scheme.

The first or highway section is now completed and in use, the substructure having been erected by the city engineering staff and the steelwork by the Canadian Bridge Co. of Walkerville, Ont.

Erection Details

The erection of the steelwork gave rise to many interesting problems, a brief resume of which might be of interest.

The bridge consists of from east to west:

(1) 112-ft. plate girder deck span.
(2) 45-ft. tower span.
(3) 150-ft. movable leaf.
(4) 75-ft. plate girder deck span.

The movable portion is of the single leaf Strauss bascule pattern. Owing to the constant use of the harbor by shipping it was found necessary to erect the movable leaf in its fully open position which was 80 degrees to the horizontal and to do this a special derrick boom was designed by George Davies of the Canadian Bridge Co. This boom consisted of six 30-ft. sections of lattice girder, all of which with the exception of the two end pieces were interchangeable. The connections were bolted so that it was possible to carry anything requiring a 60-ft. to a 180-ft. boom. The derrick was designed to carry 6 tons at 120-ft. radius using the full length of the boom and 20 tons at a 75-ft. radius using a 90-ft. boom. The lengths used during construction were 90 ft. and 180 ft. The 112-ft. approach span was first erected by means of jacking the main girders into place from flat cars on a temporary track laid alongside a 20-ton derrick car working from this same track. The long boom derrick was then erected on this span and the vertical and diagonal posts of the tower span were put in place. The main trunnion was then lined up and the end posts of truss erected. The top chords of the movable leaf truss were anchored to the diagonal posts of the tower span and the bottom of the vertical posts of the tower span anchored to the 112-ft. approach girders. In this way the approach span was used as a counterweight for the main leaf during erection. The bracing of the tower span was then put in place and the machinery enclosure constructed. The erection of the moving leaf was then carried to completion after which the counterweight truss was erected and preparation made for the actual pouring of the concrete counterweight.

The forms for the concrete were supported directly by the counterweight trunnion pier and by piles specially driven, no portion of the weight being taken by the steel until after the concrete had set. These temporary supports were then removed and the counterweight truss allowed to take up the entire weight.

Cavities were left in the counterweight and a number of 1-cu.ft. concrete blocks of different weights made for the correct adjustment of balance after the span was lowered. Variation in the weights of these blocks was achieved by the addition of aggregate of steel punchings for increasing or of cinders for decreasing their weight. While the concrete for the counterweight was being poured, the ties and rails for two street car tracks and one electric freight track were placed on the moving leaf as was also the sub-flooring of creosoted lumber. This was all done while the bridge was in a position of 80 degrees to the horizontal which made the work both difficult and dangerous.

Operating Machinery

The operating machinery was then installed consisting of two 3-phase 75-h.p. motors differentially geared to the main shaft. There is also an auxiliary 42-h.p. gasoline engine geared to the same shaft for use in emergencies. A 5-h.p. alternating current lock motor is installed at the end of the moving leaf and interlocked with the main motors. The entire electrical control is centralized in the operators room which is built on the side of the bridge. The average time taken to elevate or lower the bridge from its locked position to its full open position or vice versa is 1 min. 5 sec. using the motors, and 6 min. using the gasoline engine.

On completion of erection the anchor connections between the top chords of the moving leaf and the batter posts of the tower span were removed, and it was found that the bridge was balanced so perfectly that the bolts could be taken out by hand. The span was then lowered by electric power and pronounced satisfactory in all respects, landing on its bearing on the rest pier absolutely true.

Wood blocks were used for the surfacing of the roadway and these were laid after the bridge was lowered as were also the wooden sidewalks; the added weight on the span being taken care of in the counterweight by the addition of the requisite number of concrete blocks in the pocket left for this purpose.

The temporary track for the diversion of the Esquimalt and Nanaimo Railway had already been constructed so it was possible to test the bridge within a few days of its being lowered. This was done with a train of heavily loaded gravel cars and as no weak spots developed the order was given for the complete diversion of the railroad.

Great credit is due to George Davies, the Canadian Bridge Co.'s representative engineer on the works and Mr. O'Brien, their superintendent, for the accurate and expeditious manner in which this rather intricate work was carried out.