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STRUCTURAL AND CONSTRUCTION FEATURES
BURLINGTON NORTHERN RAILROAD VERTICAL LIFT BRIDGE 5.1
OVER THE WILLAMETTE RIVER IN PORTLAND, OREGON

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Introduction

The purpose of this paper is to present some of the structural and construction features that were encountered for the design and construction of the Burlington Northern Railroad's vertical lift bridge No. 5.1 over the Willamette River in Portland, Oregon. The new lift span is 516 feet long and weighs 3,940 tons. The span provides a horizontal navigation clearance of 497 feet and a vertical clearance of 200 feet. The lift span is the longest and heaviest double track vertical lift railroad bridge in North America.

History

On June 21, 1906, the War Department approved the final plans for construction of the original swing span structure. The piers were constructed by the Railway Company's own forces, as was the custom in that era, and the superstructure contract was awarded to American Bridge. The original design was by Ralph Modjesky for the Northern Pacific Railway Company. The bridge is a double track center pivot swing 521 feet center to center of end bearings. The original structure provided unlimited vertical clearance and 200 feet of horizontal clearance in the two channels. All original river piers, which were founded 82 feet below the water, were built with pneumatic caissons. The rest piers at the ends of the swing span were constructed with granite blocks backed with concrete. The center pivot pier is solid concrete and topped with two courses of granite. The original swing was operated with a 270 horsepower motor or by a standby gasoline engine for emergency conditions. Ten men could also manually swing the bridge 90' in approximately twenty minutes.

The original bridge was open to service on November 5, 1908, twenty-six months from the date the first caisson construction began. Regular service was inaugurated on November 17, 1908. The cost of the original pivot pier and the swing span super-structure was $405,000. Today, approximately twenty-five trains operate over the structure each day.

The most damage to the bridge occurred on Halloween night, 1978. A freighter, the Marie Bakke, moving upstream, hit the swing span in the open position. The impact moved the swing span approximately five feet upstream and caused it to drop approximately eighteen inches vertically as the span was pushed off of its center pivot support. The bridge was restored to its original position and open to rail traffic forth-eight days later. It was this incident that probably triggered the Order to Alter by the Coast Guard. The Order to Alter was issued in June, 1983 with the cost of construction to be shared by the Federal Government and the Burlington Northern Railroad in accordance with the provisions of the Truman-Hobbs Act as amended.

The 516 foot lift span, which weights 3,940 tons, provides 497 feet of horizontal clearance and 200 feet of vertical clearance for the channel. These expanded clearances allow two aircraft carriers to pass under the bridge at the same time on their way upstream to the port of Portland. The magnitude of the project is reflected by the following statistics:

1. Start of Construction: July, 1987.
2. Completion of Construction: January, 1990.
3. Estimated Construction Cost: $28,000,000.
4. Length of the Lift Span: 516 Feet.
5. Width of the Lift Span: 36 Feet - Double Track Bridge.
6. Height of Lift: 149 Feet.
7. Opening and Closing Time: 3 Minutes.
8. Load to Lift: 7,880,000 Pounds.
9. Structural Steel: 12,108,000 Pounds.
10. Maximum Gusset Height: 14.5 Feet.
11. Number of Bolts in End Connection: 1,884.
12. Total Concrete: 15,620 Cubic Yards.
13. Maximum Single Concrete Pour: 5,250 Cubic Yards.
14. Towers: Rise 280 Feet Above the Water.

Two-200 horsepower motors lift the span. The motors can operate independently if necessary and raise the span at a reduced speed. Also, a stand-by 200 horsepower auxiliary motor can raise the span if the control system becomes inoperable. Primary controls for the bridge operation are at the site with provisions for future remote control.

The owner of the bridge is the Burlington Northern Railroad Company. It was fabricated by Ishikawajima-Harima Heavy Industries Company Limited (IHI) Tokyo. The actual fabricator of structural steel was Samsung Ship Building and Heavy Industries, Korea. Shop drawings were prepared by Tensor Engineering Company of Satellite Beach, Florida.

The general contractor is Riedel International, Inc. and Tokola Engineering Corporation.

The designer is Howard Needles Tammen & Bergendoff.

Sequence of Construction

Construction began in June of 1987 with the encasement of the two piers which currently support the ends of the swing span. Encasement of the piers would allow them to support the new lift span and the towers.

The Contractor constructed a 77-foot by 62-foot cofferdam around each pier which eventually would hold out a 50-foot wall of water at Pier 2 and a 30-foot wall of water at Pier 4. The pier cells were excavated to the Troutdale formation, 82 feet below the river surface for Pier 2 and 45 feet below the surface for Pier 4. Seals were poured and the cofferdam were dewatered allowing the Contractor to work in the dry. The existing granite piers were drilled and reinforcing bars grouted into place. The footings and the columns were formed and cast.

While the piers were being constructed, the fabrication of structural steel for the towers and the lift span machinery and electrical equipment was proceeding. The structural steel was fabricated in Korea and shipped to the project site for erection. While the towers were being erected, the 3,940 ton lift span was erected on a set of four dry docks at the Contractor's main yard. All operational equipment for the lift span was installed while the span was setting on the dry docks. With the towers completed, the main counterweights were erected and suspended from the jacking screws. The eight sheaves were set, the lift span was weighed, the counterweight concrete was cast and the suspending ropes attached.

72-Hour Changeout

Specifications developed by HNTB permitted the Contractor 72 hours to remove the existing swing span, install the new swing span, connect the new lift span to the counterweighted suspension cables and place the bridge in operation for full rail and river traffic. The changeout operation started at 8:30 a.m. on August 8, 1989.

The removal of the existing swing span was accomplished by positioning two partially flooded dry docks under the span and pumping the water out of the dry docks. As water was pumped out of the dry docks, the swing span was lifted off the center pivot pier. The float-in of the new lift span was accomplished in a similar manner. The new span was supported on two dry docks, moved in over the new rest piers and ballasted by flooding until the weight of the new span was transferred to the piers.

The main counterweights were jacked to the appropriate height, the suspending ropes were attached to the lift span and the counterweights were released. The auxiliary counterweight ropes were attached and the auxiliary counterweights were released. The operating ropes were attached, rope tension was adjusted, the lift span was weighed and the weight of the counterweights were adjusted. During this change-out the electrical contractor disengaged power for the swing span, hooked power for lift span systems and placed the auxiliary drive system in operation.

The new span permitted the passage of barges by 8:30 a.m. on August 11, 1989. Taller vessels passed at a later time. It was necessary to install transition rails between the existing span and the new span before rail traffic could be resumed. Rail traffic was resumed at 2 a.m. August 12, 1989.

Construction Problems

Several construction problems were encountered:

1. High rock at Pier 4.

   Prior to the casting of the seal concrete, a diver inspected the cofferdam at Pier 4. He reported a 3-foot wide by 3-foot deep sloped edge of dense material located along the entire side of the cofferdam that was adjacent to the navigation channel. The cofferdam was oversized by this same three feet. The decision was made to leave the material in place as long as it was dense and the seal size at the plan elevation was not compromised.

2. Salt contaminated structural steel.

   The contract specifications designated that metal should be handled so as not to contaminate the surface of the weathering steel. This was particularly directed at chloride contamination of the structural steel. The bridge was fabricated in and shipped from Korea. Much of the steel was contaminated by salt spray from the ocean. The contaminated steel was cleaned by a combination of high pressure water blast and by immersion in the Willamette River.

3. Cross shaft reducers.

   Two identical reducers were furnished rather than one right-hand and one left-hand reducer. The problem was corrected in the field by removing the top of the reducer housing and turning the three interior shafts end for end. This field revision reworked the reducer to be opposite hand from the other reducer.

4. Line shaft vibration.

   The line shaft had excessive vibration during the beginning of the four-hour test. AREA codes require that "Line shafts be straight, true to gage and turned or otherwise well finished throughout their length. Shafts shall be filleted where abrupt changes in section occur." Shop drawings indicated that the shafts were not to be turned down or machined their full length. This was approved because of the high factor of safety against vibration in the initial design. It was assumed that the shafts in other respects met the specifications regarding straight and true.

An inspection of the delivered shafts indicated that the shafts were not straight and true. Several of the line shaft segments had to be machined to reduce the vibration in the line shafts as well as the vibrations in the line shaft walkways.

5. Walkway stiffeners.

   The line shaft vibration resulted in unacceptable vibration of the line shaft walkway which supports the line shaft. To reduce this vibration, plans were made to stiffen the walkway by the addition of bracing angles.

6. 72-Hour Change Out.

   Although the Contractor was permitted 72 hours to change out the bridge, he did not recognize that the lift span had to be lifted 18 inches in order to have the lift span clear the center pivot pier. After dry docks were pumped dry, there was insufficient free board to lift the span over the gearing on the pivot pier. As a result, the Contractor waited 8 hours for high tide to lift the span and watched in silence as God performed another of his miracles and floated the lift span away.

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