Special Award: Special Purpose

Kuparuk River Submersible Bridge

North Slope of Alaska

Jurors Comments

Bold application of steel...a structure that must endure extremely heavy vehicle loads and face one of nature's most hostile environments: arctic cold, large-scale ice flows and overtopping spring floods.

The Kuparuk River on the North Slope of Alaska is a typical northern stream with water flows of less than 5,000 cubic feet per second (cfs) for most of the year, but large spring break up floods that can exceed 140,000 cfs extending over a 2 mile wide flood plain. In addition to this tremendous amount of water, large 5' thick, fresh water ice floes also occur during spring floods. To support development of the new Kuparuk oil field, an access road was built across the Kuparuk River in the late 1970s at a location where the flood plain is approximately 10,000' wide. Economically bridging this flood plain for the spring break up flood has presented a design challenge since the original construction of this access road.

For nineteen years, the gravel road at the east and west channels of the Kuparuk River was breached annually and allowed to wash out during spring breakup, resulting in a six to eight week road closure interrupting access to the Kuparuk oil field. Historically, the cost of permanent bridges to provide access to the field were found to be cost prohibitive due to extreme environmental conditions, gross vehicle loads of up to 4,000,000 pounds and the river hydraulics in which large water flows must be passed during the spring floods. The innovative solution consists of submersible bridges in combination with paved roadway sections that are allowed to overtop during peak spring break-up floods.

The new Kuparuk River east (210' long) and west (150' feet long) channel submersible bridges, completed in 1999, reduce the closure period of this critical road link to a maximum of one week per year and eliminate the need to annually reconstruct the road. The cost savings of more than three million dollars per year in oil field operational and advanced material purchase costs will pay for the project cost in four years.

The crossings pass the peak spring breakup flows (typically more than seven times greater than summer flows) through and across the existing Spine Road by using a combination of welded steel submersible bridges and paved low water roadways. The short-span, stout, welded steel structures are elegant in their simplicity and are a practical, cost-effective answer to permanently crossing large, dynamic arctic coastal plain rivers.

Design and Construction

The bridges are designed to support any oil field vehicle currently in operation on Alaska's north slope. The largest of these vehicles weighs approximately 3.8 million pounds while others have maximum wheel loads that exceed 370 kips (185 tons). The entire load carrying capacity of the bridge is provided by the welded steel structure. The concrete deck was provided as a driving surface, for lateral buckling support of girders, and to ensure composite action for horizontal loads and lateral ice loads.

Environmental loads for the bridge consist of wind, seismic, river current, buoyant and river ice loading. For this design, wind, seismic, current and buoyant forces were insignificant when compared to the ice loading. Design ice thickness was 52" of hard structural ice (5' total nominal ice thickness) that is capable of imposing tremendous loads on the bridge deck and ice breakers.

The bridge substructure consists of large diameter, heavy wall and welded steel pipe piles—the only practical method to support the massive vehicle loads. Each pile bent, spaced at 30' consists of four vertical 36" diameter, 1" wall API 5LX-52 pipe piles driven to 80' penetration to support the heavy vehicle loads and provide lateral support for ice loads. Required vertical capacity (design load) of each pile was 750 kips (375 tons) which was easily achieved using a Delmag D-62 diesel impact hammer, rated at 165,000 foot-pounds of energy. Each in stream pile bent has a steel ice breaking pipe installed at 45 degrees on the upstream side. When impacted by an ice floe, this design will fail the ice sheet in bending, rather than crushing, substantially reducing the lateral force on a single ice breaker from approximately 750 kips to 320 kips. This unique design saved time and cost by reducing the ice loads to the structure, providing reasonable tolerances for field fit-up and utilizing a vertical pile in lieu of more expensive and impractical (for installation in hard permafrost) batter piles.

The pipe piles were slotted at cut off to receive the steel box pile cap. The slotted pile to pile cap connection provided both a full moment connection for lateral load resistance and the load transfer for vertical loads, eliminating the need for bearing stiffeners. Cost saving 1½" interior bearing stiffeners attached to the top flange of the pile cap also eliminated the need for bearing stiffeners in the girders.

The bridge abutment design utilizes open sheet pile cellular structures, a rugged and proven innovation utilized throughout the Pacific Northwest. These abutments are constructed in a circular arc in which the sheet pile cell remains unclosed beneath the roadway. As is found in closed cellular structures, hoop stresses are generated between the sheet piles, but with the open cell abutments the hoop stress is resisted solely by soil friction along at the tail ends of the structure. For these submerged structures, the tail ends of the central cell (tailwalls) were protected from scour by inclusion of short wingwalls on the upstream and downstream sides. Wingwalls were constructed in a circular pattern and behave in the same manner as the central sheet pile cell. This abutment type is not scour sensitive since sheet pile embedment at the streamside face is not required for the abutment stability.

The submersible bridge design utilizes 30' spans that allow an extremely shallow, high-capacity deck and girder system. The superstructure consists of eleven 22½" deep steel plate girders at 3' spacing encased in cast-in-place structural concrete. The girders were constructed using ASTM A572, Grade 50 material meeting Charpy V-notch impact criteria of 15/12 (avg./min.) foot-pounds at -50° F for cold weather performance.

The steel structure also served as formwork for the superstructure concrete by eliminating the need for falsework and minimizing on-site construction time and costs. A 26" diameter fabricated steel half-pipe deck nose is welded to the edge of the upstream girder to provide a round surface that further limits ice crushing loads on the deck. The deck nose is fitted with guardrail support pipes that are welded to the outside girders. A rolled plate welded to the downstream girder provided the concrete formwork on the other side of the bridge. Steel plate placed on the bottom flange of the plate girders and attached with intermittent fillet welds served as the underside concrete form for the bridge.

The bridge design required an easily removable guardrail for the crossing of oilfield vehicles up to 60' wide. Welded steel pipe sleeves at the edges of the deck provide support for the removable guardrails. The identical sections of guardrail, each fourteen feet long, are easily removed and replaced as the pipe legs slide into the pipe supports in the bridge deck. This system has received much praise for its ease of use, especially in extremely cold weather.

Fabrication

Fabrication of welded steel bridge components was a critical element to the success of this project. All of the components of the bridge were shop fabricated into sections that were easily transported to the site to minimize costs. Both the design engineer and general contractor worked carefully with the fabricator to assure that all fabricated pieces would be easily erected in the field. Careful match marking of each fabricated member and the fabricator's careful attention to detail allowed the structure to be erected in temperatures averaging -30° F and wind speeds of up to 20 mph without requiring field modifications.

Conclusion

By utilizing a combination of durable, submersible bridges and paved low water roadways an innovative solution was developed to provide reliable access to the Kuparuk oil field for 51 weeks out of the year. The unique design kept the cost of the project within reasonable limits for crossing two river channels in a flood plain over two miles wide. The project was designed and constructed on time with a tremendous cost savings over traditional, elevated bridge designs. This successful design promises to serve as a model for future expansion of the infrastructure on the North Slope of Alaska and in other climates around the world.

Project Team

Owner
Phillips Alaska, Inc.

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