REPAIR OF A SCOUR-DAMAGED PIER ON THE HISTORIC ROGUE RIVER (GOLD BEACH) BRIDGE

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Abstract

This paper describes a foundation problem on a major historic coastal bridge in Oregon. The solution was to use an innovative contracting method of design-build for the pier repair, within a normal design-bid-build bridge rehabilitation project. The paper describes design solution using large diameter drilled shafts to underpin the damaged pier foundation.

Introduction

The Isaac Lee Patterson Memorial Bridge, known as the Rogue River (Gold Beach) Bridge, carries U.S. Highway 101 across the mouth of the Rogue River (see Photo 1). It is located about 57 kilometers north of the Oregon-California border, just north of the Pacific coast community of Gold Beach. Originally, vehicles crossed the river here by ferry. The bridge was completed in late 1931, and the formal dedication was held on May 28, 1932, with hundreds of people from along the South Oregon Coast celebrating the opening. The bridge is about 588.9 meters long. At the time of it's opening, it was the longest structure between San Francisco, California to the south and the Columbia River on Oregon's northern border. (See Photos 1 & 2)

The Rogue River (Gold Beach) Bridge, has been recognized by the American Society of Civil Engineers as a National Historic Civil Engineering Landmark. It is listed on the National Register of Historic Places. The Rogue River (Gold Beach) Bridge is the first bridge in the United States to utilize the Freyssinet method of arch decentering (precompression) and stress adjustment of arch ribs.

The complex method, introduced by French engineer Eugene Freyssinet, reduced the size of arch ribs, needing less concrete and reinforcing steel to construct the bridge. Freyssinet's method was instrumental in the development of prestressing of structural concrete bridge members, which is considered a common construction practice today.

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Pier 2

The Rogue River (Gold Beach) Bridge crosses the Rogue River on eight piers, six of which were constructed in the river. Pier 1 is the northern abutment pier and Pier 8 is the southern abutment pier. Piers 1 and 8 were founded on rock, the other piers rest on timber pile supported footings. The piles were installed in cofferdams. A concrete seal was placed in the bottom of the cofferdam, and then the footings were installed on top of the seals. At Pier 2, the original bottom of seal elevation is about -9.8 meters, the bottom of footing elevation is about -7.0 meters and the average pile tip elevation is about –16 meters.

First Pier 2 Repair

A dike built upstream of the bridge channelized the river flow and the channel began to migrate towards Pier 2. The channelization caused scour at Pier 2 severe enough to expose the outside rows of timber piles on the northwest corner of the pier. Marine borers (Bankia) had infested the exposed portions of the piles, weakening them.

Oregon started an underwater inspection program after a severe flood in 1968. An in-house dive team began inspecting bridges on a 4 year cycle. Bridge found to have severe scour were inspected on a shorter cycle. These inspections identified the pier 2 damage in the early 1970's.

A repair was designed and constructed between November of 1974 and January of 1975. Steel sheet piles were driven outside of the original Pier 2 seal to elevations ranging from about 12.8 m to 16.5 m and averaging about 14.6 meters. Once the sheet piles were in place, excavation was undertaken so the outermost two rows of piles all around the footing could be inspected by a scuba diver. The damaged sections of the piles were removed by divers using air powered chainsaws. The work proceeded in stages. After 16 piles were cut, they were encased in concrete before another group of piles were cut. H piles were installed around the exterior of the original seal. The H piles extended to an elevation of about -22.9 meters. Grout was pumped in to fill the voids under the existing seal and to form a new seal extending out to the sheet piles. The sheet piles were cut off at the top of the new seal, and riprap was placed around the pier.

Cathodic Protection Project

The Rogue River (Gold Beach) Bridge is one of 14 major coastal bridges built in the 1930's that are a significant cultural resource of the State of Oregon. Beginning in 1980's Oregon DOT biennial routine inspections of these bridges noted significant corrosion of reinforcing steel and concrete spalling. The decision was made to preserve these bridges rather than replace them, both for economic and cultural reasons. Beginning in 1990, Oregon DOT began installing an impressed cathodic protection system using a zinc anode applied to the repaired concrete surfaces of the coastal bridges.

In 2001, the Rogue River (Gold Beach) Bridge was selected by the Bridge Preservation Unit of the Oregon DOT to have the impressed-current cathodic protection installed. This treatment will significantly increase the life of the bridge. The design work for this project was nearing completion when further inspection revealed additional scour problems at Pier 2.

Pier 2 Scour

The sheet piles installed during the 1975 repair were in poor condition with numerous areas that have corroded away completely. Further migration of the channel had exposed the bottom of the new seal along the north side of the pier. Up to 15 timber piles were exposed around the perimeter and had been damaged by marine borers (see Photo 3). Large voids were seen in the areas under the old seal where grout had been pumped during the first repair. Apparently, the grout was not installed effectively.

A detailed hydraulics report was done to set parameters for a new repair design. The report predicted a total scour elevation of about –27 meters which would occur during a 500 year return period flood event. For a total scour elevation of –27 meters, it was assumed the thalweg (elevation –11.8 meters) would migrate to Pier 2 and 0.77 meters of contraction and 15.17 meters of pier scour would occur during the design storm. Scour to an elevation of -11.8 meters would reduce the capacity of the existing piles to the point that they would probably fail. Scour to an elevation of –27 meters would completely undermine all the Pier 2 piles.

In order to assure long term preservation of this historic bridge, it would be necessary to repair Pier 2 for the predicted channel migration and the 500 year return period flood. This repair was needed immediately to assure stability of the foundation. However, the cathodic protection design was nearly complete and ready for contracting before the pier repair design could be completed.

Repair Considerations

A large work bridge would be needed to get the necessary equipment to repair Pier 2. The work bridge, running the full length of the bridge, would be constructed as part of the planned cathodic protection project. It was clear that combining the cathodic protection work with the pier 2 repair would be cost-effective since the work bridge could be used for both projects.

The design on the cathodic protection project, an ODOT design-bid-build project, was nearing completion. Insufficient time remained for ODOT to perform in house design on a foundation repair for Pier 2 prior to the let date for the project. To include the Pier 2 repair as part of the cathodic protection project, the project would have to be delayed one construction season.

The cathodic protection project would take several years to complete after construction had begun. If the Pier 2 repair project was let as a separate project, the cathodic protection project would begin first, but the two projects would be going on simultaneously at some point. While it could be possible to use the same work bridge for both projects, there would be difficulties which include:

- The cathodic protection project contractor would have to design the work bridge before the Pier 2 repair design had been completed, and so would not know the size or weight of the equipment needed for the repair. This could lead to the Pier 2 repair project design being constrained by work bridge location, size and carrying capacity.

- The cathodic protection project contractor would have to plan his construction schedule long before the Pier 2 repair schedule was in existence. This could lead to delays in both projects as the schedules are found to conflict.

Therefore, in December of 2000, it was decided to investigate the possibility of adding the Pier 2 repair as a contractor design-build component to the larger traditional design-bid-build cathodic protection contract. ODOT had not done this before, but if it could be accomplished it would allow time for the Pier 2 repair design, without having to delay the project. This is because the contractor would perform the repair design after the bid date. It would also allow a single contractor to construct both projects, thereby allowing the work bridge design and work schedule to be set up for both projects at the same time, avoiding potential conflicts.

While the possibility of adding a design-build Pier 2 repair module to the cathodic protection project was being investigated, two other components would be needed for success: to arrive at a feasible conceptual design for repair which contractors could use for bidding, and to determine or gather sufficient geotechnical information to supply to contractors to allow them to bid realistically.

Exploration

Existing boring information was inadequate for design purposes. The borings drilled for the original bridge were done with a cable tool drill, so no information on soil strength was available. The borings on the north and south side of the river revealed sand and gravel over rock, but none of the other borings, including the boring near Pier 2, which penetrated to an elevation of -21.3 meters, encountered rock. Obtaining new geotechnical information was necessary. (See Photo 4)

Two complications arose in collecting the geotechnical information. Due to the late addition of the foundation repair to the project, it was imperative that boring information be collected as quickly as possible. To do that, it was necessary to perform exploratory borings at Pier 2. A Biological Assessment had been performed for the cathodic protection project, but exploratory drilling had not been part of that project, so the Biological Assessment did not address drilling. Obtaining a Biological Assessment is a lengthy process and a new Biological Assessment would be needed before ODOT could obtain a permit to proceed with the borings.

The geotechnical borings would have be drilled from a barge on the river. Winter on the Oregon Coast is normally a stormy season with heavy winds and ocean waves at the mouth of the Rogue River, and spring is worse. The Rogue River (Gold Beach) Bridge is located about 1 kilometer from the Pacific Ocean, and the ocean at the mouth of the river is rough with significant tidal flows. If the barge broke free of its anchorage in a storm, it would quickly be washed out to sea, and any crew aboard would be in great danger. To drill the borings safely, we needed good weather, and had to be ready to cease drilling if a storm threatened. It was felt that the danger of storms increased so much during the spring that we were constrained to completing the job by the end of February. If we were not ready to begin before then, the crew would not be sent out. If the job was not completed by then, the crew would be recalled. Therefore, both time and weather were constraints on how much information we could obtain, if we could obtain any at all.

The ODOT Environmental Section worked quickly, and was able to get a Biological Assessment completed and obtain final approval by mid February. Immediately after this, an ODOT drilling crew and geologists were on site to begin the work. Fortunately, good weather held and between February 13 and 17, 2001 the crew was able to complete the two planned borings and added a third. The planned borings were drilled near the northwestern and southeastern corners of Pier 2, and the additional boring was near its northwest corner.

The three borings encountered sandy gravel, gravelly sand, sand and clay over rock. Rock was encountered at elevations ranging between about -20.3 m to -31.9 m.

The bedrock encountered at this site consisted of metavolcanics of the Otter Point Formation. The rocks encountered included Peridotite, blue schist and serpentinite, although serpentinite was most common. This rock has undergone many episodes of shearing during its accretion onto the North American Continent and subsequent thrust faulting.

Much of the rock recovered from core samples taken in the borings was highly fractured, and sheared and commonly friable to silty sand or clayey sand with some gravel in many places. Unconfined compressive strengths varied widely depending on whether the rock was highly sheared, soft and weathered or medium hard and fresh. Unconfined compressive strengths ranged from 145 kPa to 1092 kPa in the softer materials and about 8,000-70,000 kPa in the more intact rock.

Standard Penetration Tests (SPT) were also performed in areas where the cores encountered softer rock. Standard procedure is to drive the SPT sampler 450mm, counting the blows it takes to advance the sampler for each of three 150mm intervals. The result from the first 150mm interval is usually discarded, as this material is considered to be disturbed. However, the if the sampler is driven to refusal in this interval, as defined as 50 or more blows in 150mm, the blow count is recorded and the sampler driven no farther. Again, the results varied. Only one SPT test did encounter refusal in the first 150mm interval. Other tests penetrated the first 150mm interval and the results for penetration below this interval are as follows: 50 blows in 100 mm, 50 blows in 150mm, 76 blows in 290mm and 19 blows in 300mm.

Three conclusions were made from the geotechnical data. First, a good part of the rock mass at Pier 2 appears to be erodeable. Therefore, when designing for scour, it can not be assumed that if rock exists above the scour elevation, scour will stop at the rock-soil contact. Any scour design will need to assume all material down to the predicted scour elevation will be removed during the 500 year return period flood. Second, much of the rock is sheared so severely it may behave more like a soil than like rock. Third, much of the rock is hard enough to stop a driven pile, so penetration into the rock would likely be minimal in most places.

Conceptual Design

As discussed earlier, ODOT had decided to present a feasible conceptual design for the Pier 2 repair which contractors could use for bidding on the design-build component of the contract. For this design, ODOT decided a deep foundation system would likely be needed for the repair, and our conceptual design was based on this assumption. During the design flood, the river bottom in the Pier 2 area would be scoured to elevation -27 meters. Exploratory borings revealed that there is, at most, only about 4.9 meters of soil between the scour elevation and the top of the rock and that the design scour elevation is typically within the rock. The scour elevation at the other two borings was within the rock. It is unlikely piles could be driven deep enough to provide adequate lateral strength during the design flood. Therefore, ODOT chose drilled shafts for the foundation elements for its conceptual design. The drilled shafts would be attached to Pier 2 by post-tensioned members extending through or anchored into the existing Pier 2 seal.

The conceptual design was presented in the project special provisions and preliminary foundation recommendations presented in the Geologic Investigation and Foundation Report that was distributed to contractors interested in bidding the job in a mandatory prebid meeting.

Contracting

The overall project was planned to use a special prequalification process for prime and subcontractor teams since Cathodic Protection (CP) of bridges is unusual construction work. The timing of the procurement was established to give the successful bidder the maximum time to place the necessary work bridges in the river during the permitted in-water work period. These workbridges would extend to Pier 2, where the new foundation needed to be placed. Several options were explored to accomplish the Pier 2 work in conjunction with the CP work. The first was awarding the CP contract, finishing the Pier 2 design and awarding it as a separate contract, where the second contractor would have to rent workbridge access from the first contractor. A second was to fully design the Pier 2 work, combine it into the CP work and delay advertisement until the next year. A third was requesting consideration by the Federal Highway Administration (FHWA) for a change order to the CP project to add the Pier 2 work when fully designed.

The Oregon Division of FHWA recommended that ODOT consider using Design-Build for the Pier 2 work as an encapsulated work item in the CP contract. Neither FHWA nor ODOT was aware of this technique being used previously. This was considered innovative contracting by FHWA and required their approval, which they promptly provided. As the total contract was awarded based on price, no exemption from Oregon's contracting law was required.

ODOT required prospective bidders to submit qualifications for the specific engineer(s) who would design the cofferdam, drilled shafts and the post-tensioning as part of the special prequalification process. Of three teams submitting qualifications, two were accepted and one was rejected. The rejection was based on the requirement that projects submitted had to have been constructed; in this case they had been designed, but not constructed. The firm successfully awarded the contract bid the Pier 2 work right on the Engineer's Estimate.

Design-Build Design

Hamilton Construction Company was awarded the contract and selected OBEC Consulting Engineers to perform the Pier 2 repair design and Golder Consultants to perform the geotechnical portion of this design. The final design was similar to ODOT's conceptual design. A collar would be installed around Pier 2 and attached to Pier 2 by post-tensioned members extending through the Pier 2 seal and anchored to the collar on both sides of Pier 2. Foundation support would be provided by six drilled shafts with diameters of about 2.13m (7 feet). (See Photo 5)

Three of the shafts would be installed on both the east and west sides of Pier 2. This arrangement was chosen because the north and south sides of Pier 2 are under the bridge, and it was felt that the limited vertical clearance under the bridge at Pier 2 would make installing shafts very difficult. The shafts were to be socketed well into the rock below the scour elevation of -27 meters. They were designed to be able to carry the design axial load wholly in the rock socket below scour elevation through both skin friction and end bearing. Originally, two tip elevations were planned, one for the more intact rock, one for the softer rock, but all shafts were installed to the lower of the two elevations, -42 meters. (See Photo 6)

Predictions of deflection at the top of the shafts during the design 500 year return period flood assuming a scour elevation of -27 meters was 26mm, less than the required 38mm maximum.

The drilled shafts were designed to have permanent casing down to the rock elevation and to be uncased below. This was more for ease of construction, as the casing would not need to be removed as the shaft concrete was placed. This did not affect the axial load carrying capacity during the design flood, as the soils around the cased areas were expected to be removed by scour. As the environment aggressively attacks steel, the casing was considered sacrificial, and not included in the shaft section modulus when lateral deflection calculations were performed.

Construction

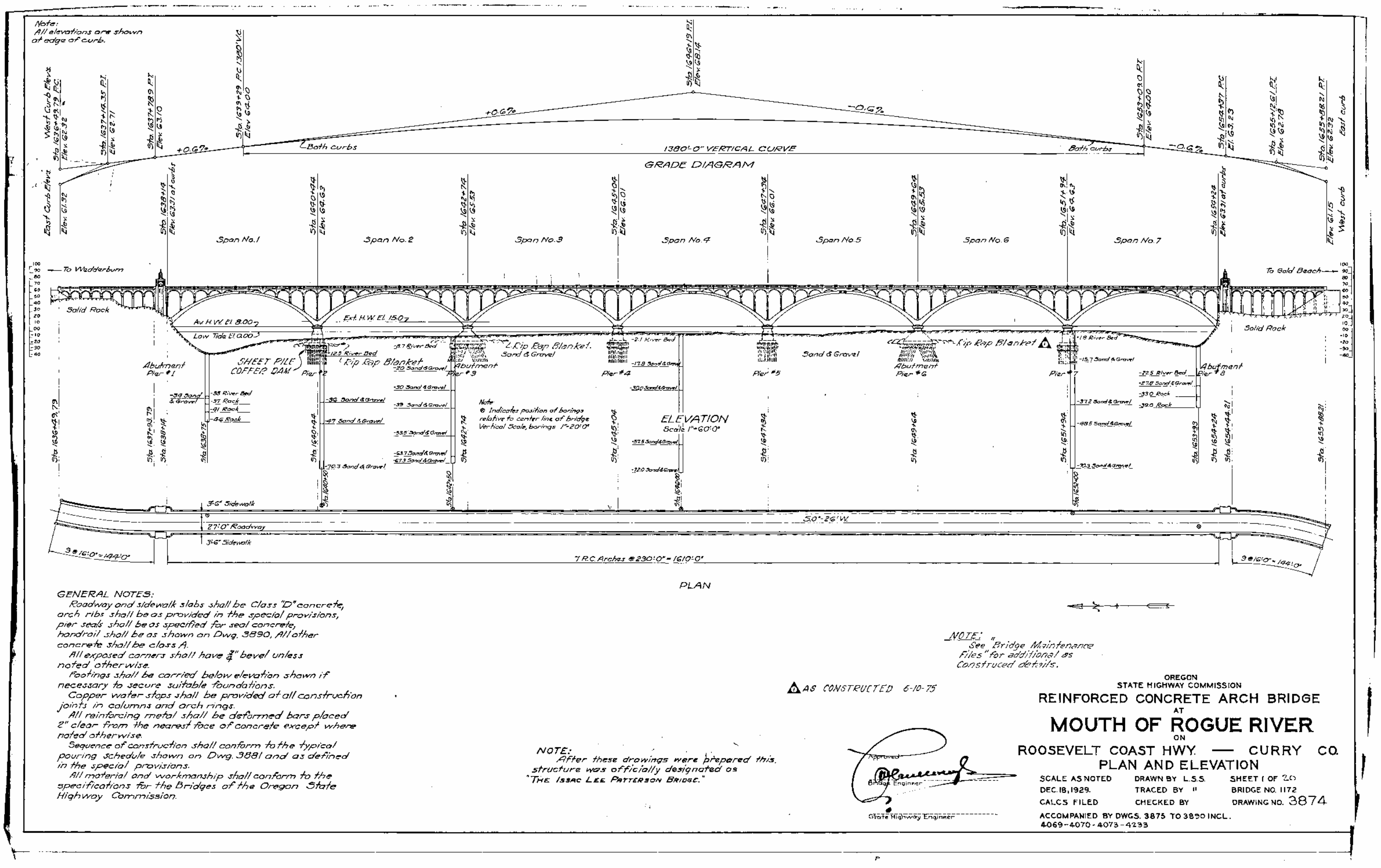
There were many challenges that had to be overcome almost from the beginning of the Pier 2 repair. Obstructions were encountered while installing the cofferdam. The available workspace around Pier 2 was extremely limited. The cofferdam surrounding Pier 2 was limited to maximum dimensions of about 21 by 23 meters. Access to Pier 2 was from the south, so equipment, supplies and spoils from drilling had to be moved almost the entire length of the work bridge to get to or from the worksite. The drilled shaft contractor had difficulty refining the shaft drilling and installation methods to efficiently complete the work during installation of the first shafts. The environmental permits did not allow any material to be deposited into the river, so special care had to be taken with the spoil excavated from the drilled shafts. There wasn't sufficient room to operate a crane large enough to install full length reinforcement cages for the drilled shafts. Therefore, the cages had to be installed in two sections. The first section had to be lowered into the shaft and braced, then the second could be lifted up and spliced to the first, then finally the entire unit lowered to its final elevation. When the horizontal holes for installing the post tensioning elements that connected the drilled shaft supported collar to Pier 2 were drilled, the holes were positioned to miss the existing timber piles. Unfortunately, not all of the piles were positioned where the original plans showed them to be, and the piles had to be drilled through, causing work slowdowns. All during this time the cathodic protection segment of the project was under way, the Rogue River (Gold Beach) Bridge was open to traffic, and tour and sport fishing boats were traveling below it. (See Photos 7 & 8)

Despite all the challenges, Hamilton successfully completed the Pier 2 repair. The cathodic protection work continued, and is very near completion. The Rogue River (Gold Beach) Bridge will be capable of serving the traveling public for many years to come.

Photo 1 – Rogue River (Gold Beach) Bridge.

Photo 2 – Rogue River (Gold Beach) Bridge aerial view.

Photo 3 – Marine Borer damage to timber pile at Pier 2.



Drawing 1 – Original plan sheet of Rogue River (Gold Beach) Bridge

Photo 4 – Drilling subsurface borings at Pier 2.

Photo 5 – Pier 2 Drilled Shaft Construction from Temporary Work Bridge

Photo 6 – New footing underpinning has 6- 2.5 m drilled shafts.

Photo 7 – Drilled shafts were drilled in full length casings 2 m into rock.

Photo 8 – Rebar cage is lowered into place just prior to tremie concrete placement.