DESIGN AND CONSTRUCTION OF THE SOUTH CHANNEL BRIDGE

Derek Soden, PE, Alaska Department of Transportation and Public Facilities, Juneau, AK

ABSTRACT

The port of Dutch Harbor, 800 miles southwest of Anchorage in Alaska's Aleutian chain, has quickly grown into one of the largest fisheries ports in the nation. The South Channel Bridge carries the only surface route between Dutch Harbor and the neighboring community of Unalaska. To accommodate unanticipated economic growth and address severe deterioration and seismic vulnerability of the existing 520-foot steel box girder bridge over South Channel, the Alaska Department of Transportation is constructing a 700-foot prestressed concrete replacement bridge. The new bridge consists of five 140-foot prestressed decked bulb-tee girder spans founded on nine-foot diameter drilled shafts socketed into hard volcanic bedrock.

In accommodating design considerations such as severe maritime weather, remote location, high seismic demand and a short construction season, this new bridge is illustrative of why the decked bulb-tee girder has been the predominant structure type for new bridge construction in Alaska since the 1970's. The bridge design also incorporates complex geometric details such as skew, vertical curve and a superelevation transition from a horizontal curve on the bridge approach.

Construction of the new South Channel Bridge commenced in May, 2007 with completion expected in late summer, 2008.

Keywords: Case Studies, Precast Decks, Seismic Design

INTRODUCTION

Located in Alaska's Aleutian island chain, the South Channel Bridge connects the busy fishing port of Dutch Harbor with the neighboring community of Unalaska. The Alaska Department of Transportation and Public Facilities (Alaska DOT) is near completion on a $28.2 million project that will replace the existing 520-foot long steel box girder bridge over South Channel with a 700-foot long, five span precast decked bulb-tee girder bridge. The new South Channel Bridge incorporates many of the design features and capabilities developed in the thirty-five years since Alaska built its first decked bulb-tee girder bridge.

PROJECT BACKGROUND

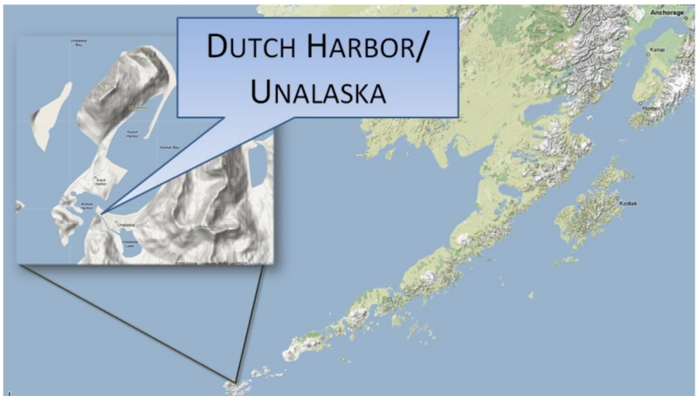

Figure 1: Project Location

In the decade following the construction of the existing South Channel Bridge in 1980, Dutch Harbor grew dramatically into the largest fisheries port in the United States, with the volume of seafood caught and processed in the area increasing tenfold. This growth resulted in increased, largely unregulated, truck traffic hauling the catch from ship to processor to shipper. This increase in heavy truck traffic has resulted in an accelerated deterioration of the existing bridge's steel box girders and timber deck. Concern about this deterioration, in addition to the bridge's high seismic vulnerability and failure of the paint system in Dutch Harbor's aggressive maritime climate, led Alaska DOT, in the mid-1990's, to evaluate rehabilitating or replacing the bridge. Preliminary analysis indicated that replacement was the most cost-efficient option.

The bridge site presented several design constraints, including:

- The remote location and harsh Aleutian weather, increasing the importance of properly staging and timing the project
- Steep, hilly terrain on both approaches and a winding alignment over a short project length (1,950 feet)

- Water up to forty feet deep and a channel bottom consisting of fifteen to forty feet of loose sand and gravel overlaying a narrow rubble layer and hard andesite bedrock
- High seismic demand (PGA = 0.4g), and
- A culturally and archeologically significant home- and midden-site at the western end of the bridge. Excavating and documenting the site in large part controlled the project scheduling.

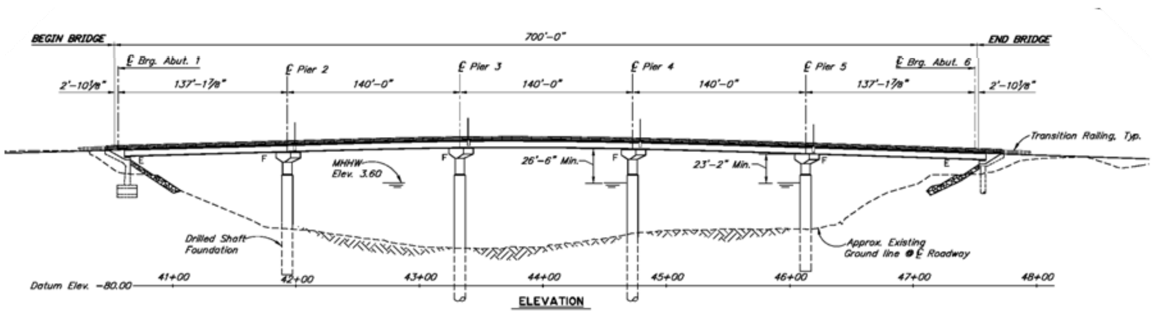

Figure 2: Bridge Elevation

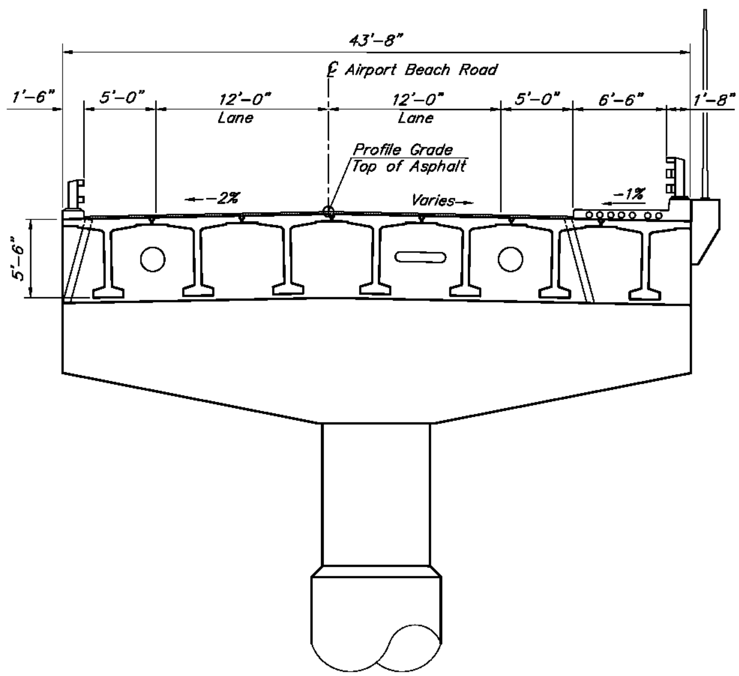

Figure 3: Bridge Section

A bridge type selection study completed by Alaska DOT identified a bridge constructed of precast decked bulb-tee girders founded on large diameter drilled shafts as the preferred option. Decked bulb-tee girders were chosen for their superior constructability and maintenance characteristics which have long benefitted Alaska.

THE PRECAST DECKED BULB-TEE IN ALASKA

Alaska first used the decked bulb-tee in the emergency reconstruction of the Carlanna Creek Bridge in Ketchikan in 1973. Since that time, the decked bulb-tee has become the predominant structure type for new bridge construction in Alaska, where they now make up almost twenty-five percent of the state's bridge inventory. For most new bridges in the northern and central part of the state (the areas accessible via the Alaska road system) precast girders can be fabricated in Anchorage, allowing for considerable savings in time and cost over other bridge types that must be fabricated out of state and shipped to Alaska.

Figure 4: Decked bulb-tee overpass in Anchorage

Figure 5: Decked bulb-tee girder bridge over the Atigun River, north of the Arctic Circle

Using a precast bridge deck eliminates a major construction operation, which is particularly important considering Alaska's short construction season (early May through September for most of the state). Contractors can often complete smaller, simpler bridges in less than two months. Depending on mobilization timing and bridge complexity, contractors can complete larger bridges in a single building season.

As in other states, Alaska has seen that the use of precast elements results in reduced maintenance needs and associated costs, compared to steel and reinforced concrete bridges. Some of this savings can be linked to the relatively low structure age between bulb-tee bridges compared the steel bridges in the state's inventory, but older bulb-tee bridges have aged well and rarely require girder-related maintenance. Much of the bulb-tee's improved durability can be attributed to fabrication in a controlled environment, but another factor could be Alaska's policy of allowing zero tension stress in the girder under service loads (Service III load case in the AASHTO LRFD

Bridge Design Specifications). Keeping the girder section completely in compression under service loads reduces the number cracks and openings into which water can penetrate. However, this practice does have implications in other aspects of the girder design, as will be discussed below.

DESIGN OF THE SOUTH CHANNEL BRIDGE

SUPERSTRUCTURE

The new South Channel Bridge consists of five 140-foot long spans of seven 5'-6" deep decked bulb-tee girders. The girders are constructed of normal weight concrete with a release strength of 6.5ksi and a 28-day strength of 7.5ksi and 54 prestressing strands (36 harped and 28 straight). The harped strands are bundled at midspan and fanned at the ends, effectively lowering the centroid of the prestressing force and increasing their eccentricity.

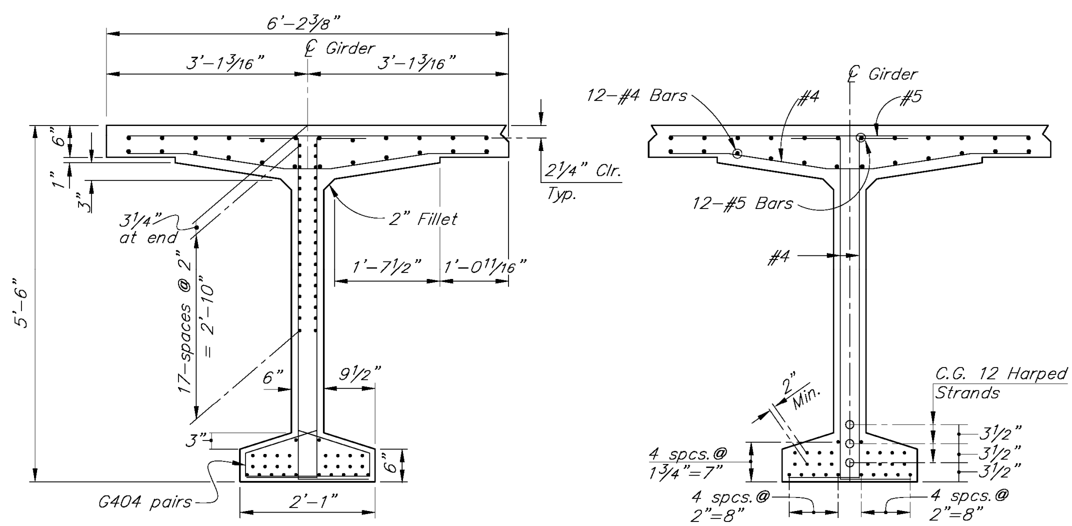

Figure 6: Girder sections showing strand layout at girder ends (left) and at midspan (right)

Longitudinal connection between the girders is achieved through a grouted shear key with welded shear connectors spaced at four feet. The girders are also connected by a single cast-in-place concrete diaphragm at midspan. The concrete diaphragm is intended mostly to distribute lateral loads - for live load distribution, the articulated deck formulation (in AASHTO, cross-section type "j" connected only enough to prevent relative vertical displacement) is considered to be the most accurate approximation.

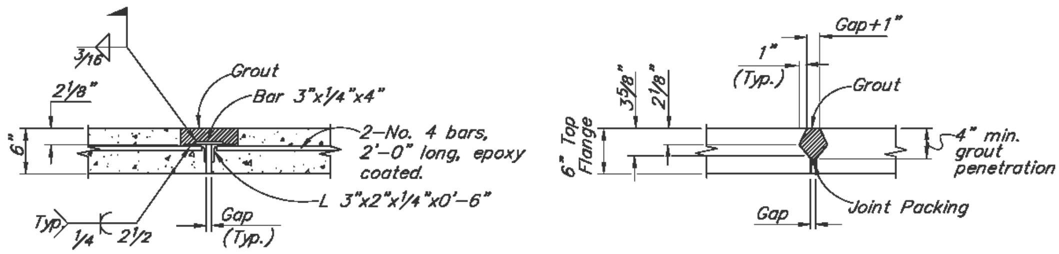

Figure 7: Longitudinal girder joint details

The girder bear on reinforced elastomeric pads and are cast into concrete end diaphragms. To better tie the girder into the diaphragms, several strands and reinforcing steel bars are extended from the girder end and a nominal amount of diaphragm reinforcing steel is passed through holes cast into the girder webs.

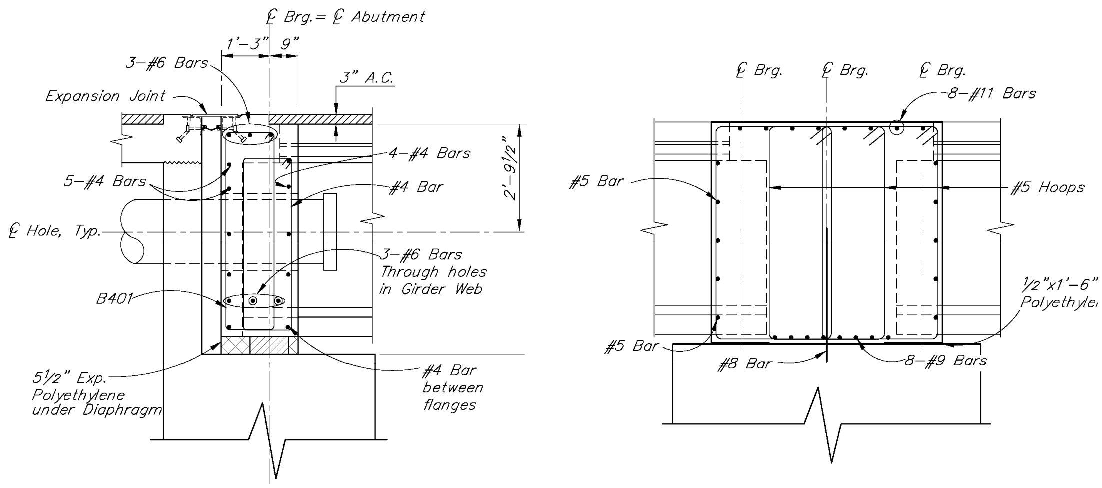

Figure 8: Cast-in-place concrete diaphragms at the abutments (left) and at the piers (right)

Geometry

The project roadway design strived to straighten the existing alignment as much possible, considering the terrain, and increase the roadway design speed. Bridge costs had to be balanced with rock excavation costs to find a suitable and cost effective horizontal alignment. The design alignment improved the approach to the bridge, but included a 380-foot radius horizontal curve ending thirty-five feet from the end of the bridge and a superelevation transition extending onto the bridge. To accommodate this geometry, the design incorporated a superelevation transition into the girder flanges. The details to accomplish this are fairly straightforward, but require cooperation between the bridge and roadway designer.

Superelevation transition is achieved using a top flange tapered both transversely (at a cross-slope equal to the superelevation grade minus the typical crown grade) and longitudinally (from the above described cross slope at one end of the girder to flat at the other end). By setting the girders on the crown grade (on a stepped seat at the superelevated end) the roadway deck can approximate a superelevation transition.

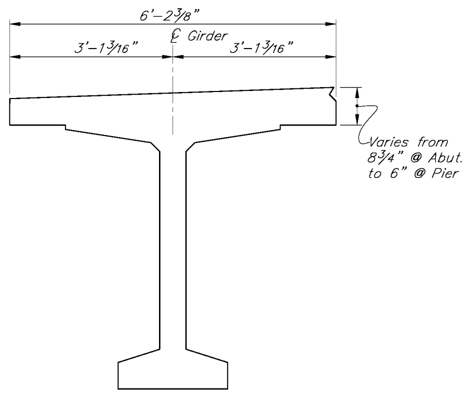

Figure 9: Tapered Girder Section

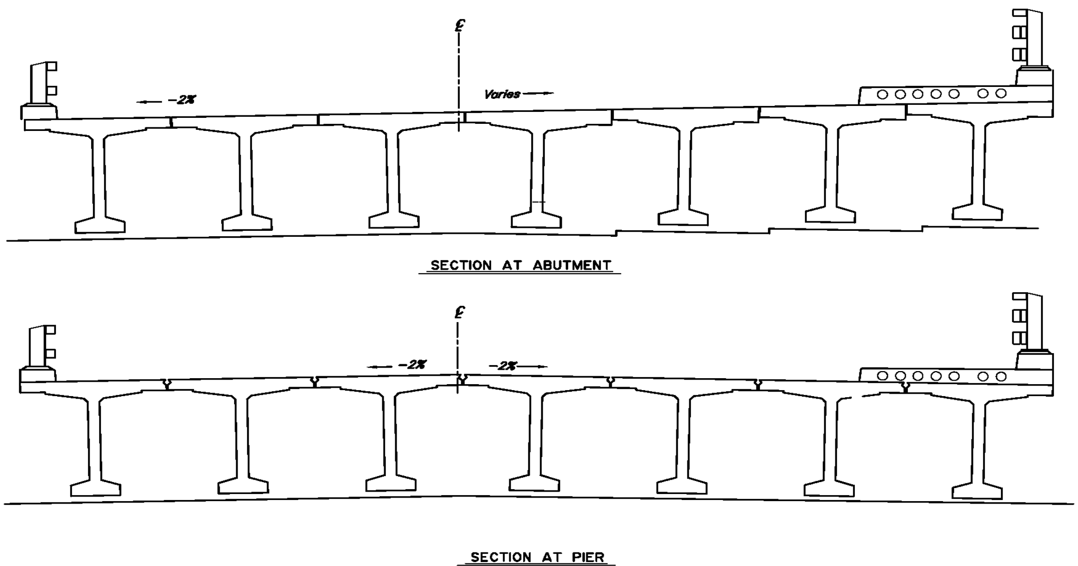

Figure 10: Typical sections showing superelevation transition

Some caveats on this method:

- The superelevation transition will be linear, not the typical dual parabolic shape
- As the method is reliant on the proper alignment of the top and bottom flanges, the transition must extend the length of the span
- Possible transition slope capabilities are limited by the length of the span and the allowance in the design for additional dead load

The South Channel Bridge design accommodates a superelevation transition from +1.7% to -2% using a top flange tapering 2¾" per each 74" flange width (2¾"/74" = 3.7% = 1.7% - (-2%)).

The bridge also incorporates a fifteen degree skew and a 420-foot (+2.7% to -3.4%) crest vertical curve. Accommodating this vertical curve required that the girders in the three interior spans have a final midspan camber of 4¼".

Service Level vs. Strength Level Design

As mentioned above, Alaska DOT policy is to design prestressed girders to remain in compression at the Service III Limit State. A result of this policy is that girders designed to zero tension will, at the Strength Limit State, have moment capacities up to thirty percent higher than the moment demand, yet similar overstrength will not occur in the calculated shear capacity of the girder. The consequence of this disparity is that the girder load rating for moment capacity will exceed that for shear capacity and the capacity of the girder will be controlled by a non-ductile mode. Alaska DOT remedies this situation in its designs by performing a load rating concurrent with the design and adjusting the spacing of shear stirrups to achieve a shear load rating similar to, or above, the moment load rating.

SUBSTRUCTURE

The substructure design for the South Channel Bridge takes advantage of the hard, fresh andesite bedrock (unconfined compressive strengths ranging from 5,000 to 25,000 psi) that is characteristic of the bridge site. The design of the piers for the original bridge relied on driven piles, for which the soil/rock stratigraphy of the site proved to be problematic. One of the four piles in that bridge hit refusal at an embedment depth of eight feet, leaving the pile effectively pinned at the base. Rock bolting through the tip of the pile increased its uplift capacity but left the pile (and the pier) vulnerable to lateral loading.

In light of the foundation issues with the original bridge and the depth of the channel, Alaska DOT chose to found the hammerhead piers of the new bridge on single nine-foot diameter cased drilled shafts socketed seventeen feet into bedrock. Casing the pier drilled shafts down to bedrock allowed for shaft construction using the wet method (drilling through the casing and placing concrete via tremie tube) without the need for a cofferdam. The near and far end abutments are founded on a stepped spread footing on exposed bedrock and shallow four foot diameter drilled shafts, respectively.

The seismic design of the piers followed the provisions of the AASHTO LRFD (pre-2008 revisions), with earthquake loads determined using a multi-mode analysis and with the bridge being modeled as equivalent elastic system. Designing in accordance with AASHTO provisions resulted in a reinforcement ratio of 3.5% (two rings of forty #18 bars). The pier design utilizes ductile detailing and is designed to form a plastic hinge at the bedrock surface. A separate displacement-based evaluation of the piers indicates that under the design multihazard displacement demand, the piers remain elastic ($\Delta_{EQ} < \Delta_y$, the displacement at first yield of the section).

CONSTRUCTION OF THE SOUTH CHANNEL BRIDGE

The South Channel Bridge replacement project was advertised in the fall of 2006. The winning bidder was American Civil Constructors West Coast Construction of Seattle, Washington with a bid of $28.2 million for the project, $10.8 million of that for the bridge.

Construction began in April, 2007 with the fabrication of the drilled shaft casing and reinforcing steel cages in Seattle. Precast girder production began in May at Concrete Technology Corporation's (CTC's) Tacoma, Washington plant.

Figure 11: Materials Barge Arriving in Dutch Harbor. For scale, the orange boxes at the stern are standard shipping containers

Most of the equipment and materials required to construct the bridge (with the exception of the girders) arrived by barge in early July. Shaft drilling operations began shortly thereafter.

Figure 12: The Teredo T40-4 pile top shaft drilling rig

To construct the piers, the contractor used an APE 400 vibratory hammer to drive the pier shaft casings to bedrock, and a Teredo T40-4 pile top drilling rig to drill the shafts to depth. After acceptance of a shaft excavation, the reinforcement cage, weighing up to ninety tons, was lifted in one piece and placed in the excavated hole and the shaft filled with concrete.

Construction of the piers and abutments continued through the summer and early fall in anticipation of the arrival of the girder barge in late September. Cooperative weather allowed the contractor to continue working into early November and set all thirty-five girders before shutting down for the winter.

Figure 13: A pier ready for girders

Figure 14: A Girder being offloaded from the delivery barge.

Figure 15: The South Channel Bridge nearing completion, July 2008.

CONCLUSIONS

Completion of the new South Channel Bridge is anticipated in late summer, 2008, after which the existing bridge will be decommissioned and removed.

The design of the South Channel Bridge using precast decked bulb-tee girders overcame geometric, location and environmental constraints to provide an economical bridge solution for Alaska DOT. Additionally, the accelerated construction of the bridge will benefit the travelling public with a shortened project timeline and period of inconvenience. The South Channel Bridge project illustrates why the versatility, constructability and durability of the decked bulb-tee girder has made it the preferred structure type for bridges in Alaska.