National Award Winner

South Slough Bridge #91

Snohomish County, Washington

2008 APWA National Project of the Year
Transportation Category, Projects Less Than $2 million

Snohomish County
Public Works

Table of Contents

Project Summary

Snohomish County's Bridge #91, located 40 miles north of Seattle, carries Smokey Point Boulevard over South Slough. The two-span concrete arch structure is near Interstate 5 Exit 208 and 5,000 vehicles use the bridge daily.

It was an elegant and sturdy concrete arch bridge when built in 1918, but an inspection in 2005 deemed it functionally obsolete and identified it for replacement with a wider structure to meet current safety and design standards.

Square footage of the bridge deck was increased by 62% without adding weight. By using the existing concrete arches, engineers designed a wider two-lane bridge deck, eliminated the need for a complete bridge replacement, and shortened the project by 4.5 years.

Key Points

Final Project Cost: $929,100

Cost of total replacement would have been approximately $6 million. Saved $5 million.

Duration: 17 months

- 17 months from start of design to end of construction.
- Typical bridge replacement of this magnitude takes approximately 6 years.
- Using the original arch foundation shortened the project by 4.5 years.

Schedule: On Schedule

- Scheduled 55 days for construction.
- Completed in 55 days, on September 12, 2007.

Good Construction Management Techniques

- Critical path method schedule was developed and followed.
- Design and construction staffs stayed in close communication throughout the project.

Safety: No Injuries

- Daily field meetings and monthly department safety meetings promoted a safe construction site.

Community Relations

County staff maintained direct interaction with stakeholders and utilized internet, mailings, a newspaper ad and flashing message boards to minimize impacts to the community.

Environmental Protection

Reusing the existing arches kept construction out of the wetlands and out of the floodplain. Banks were re-vegetated with native shrubs.

Unusual Accomplishments

- New 62% larger deck area did not add weight to the arches.
- This was the largest bridge project constructed by County Road Maintenance crews.
- Reusing existing arches reduced project duration by approximately 4.5 years.
- To prevent overloading the arches, earth fill within the arches was replaced with light-weight cellular concrete.
- To prevent unbalanced loading of the arches, soil was removed incrementally from both sides of the bridge.
- 32 precast concrete slabs, 8 feet by 31 feet, were placed side by side and bolted together above the existing arches and cantilevered 4.5 feet on each side.
- The crew lost less than 2 hours of productivity when bones were unearthed. The archeological consultant was on site early the next morning and identified them as cow bones.

South Slough Bridge

Historical Setting

The story of South Slough Bridge begins in the 1900s—a time of exciting changes in transportation.

It is 1907. Teddy Roosevelt is the U.S. President and construction is underway on the Panama Canal. The Wright Brothers have been flying for more than three years, at speeds of up to 40 miles per hour. In less than a year the first Model "T" Ford will roll off the assembly line, and it has been six years since the first automobile arrived in Snohomish County, some 30 miles north of Seattle.

By 1916 the number of automobiles registered in Washington State totals 49,937, and Snohomish County is nearing the end of its historic bridge-building period. Between 1910 and 1919, with the surge of road construction, 63 new bridges are built to span the network of rivers and streams in the county. This is more than during any equivalent time in the past, and has not been matched in the decades since.

Original Bridge Built in 1918

The earliest bridges in the area were built of timber harvested from the abundant forests of the region, but by 1918 Snohomish County had begun using "artificial stone," as concrete was originally called. This durable, yet free-form material freed engineers to design bridges with graceful curved arches.

South Slough Bridge was just such a structure—a two-span concrete Luten arch bridge. This particular design was named for designer Professor Daniel B. Luten of Illinois.

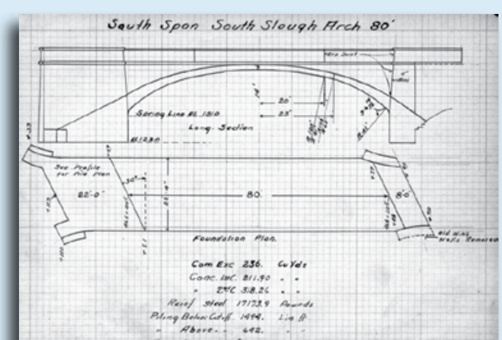
The original bridge was 22 feet wide with two 80-foot arches end to end for a total of 222 feet in length at the centerline. The reinforced concrete slab deck was 19 feet

Snohomish County's first bridge of record was built in the 1870s over the Pilchuck River.

South Slough Bridge was built in 1918 as part of the state's early highway system.

Professor Luten patented over 30 bridge designs. He was also an enthusiastic salesman, emphasizing the advantages of his bridge designs in company catalogs and at professional presentations.

He was quoted in the American Concrete Institute Proceedings of 1912: "Concrete as a structural material is full of surprising possibilities and one of these is that the most beautiful and appropriate applications of concrete to bridges, that is in the arch form, is also the most satisfactory from almost every engineering standpoint."



wide from curb to curb, and the two traffic lanes were each only 9.5 feet wide with 1.5-foot wide parapets on each side. There were no shoulders.

Each arch had a rise of 14 feet; the total height of the bridge from the foundation to the top of the roadway was 23.5 feet.

The bridge was built in two sections. The first arch was completed in 1918. In 1920 the bridge was lengthened with the addition of the second arch on its south side.

The south span roadway slab sat on a reinforced concrete arch, and spandrel walls on either side were filled with soil. It appears that this was also the original construction of the north arch. However, the 1920 construction plans for the north arch seem to indicate that when the south span was added, the soil fill was removed and replaced with concrete support ribs. It is unclear why this was done or how these supports were anchored to the arch.

The arches rest on concrete abutments which are founded on piles. At the center abutment, the south arch was designed to rest partially on "shoulders" cut into the original north arch abutment, as well as a new 8-foot long portion of the abutment sitting on 24 new piles. The south abutment is 22 feet long and is supported by 83 piles; the number of piles at the north abutment and north half of the center abutment is unknown.

Obsolete By 2005

At 9.5 feet wide, the travel lanes were just right for Model Ts and other narrow vehicles of the day, but were no longer adequate for today's wider loads. Since there were also no shoulders, it was clear that a wider structure was needed to meet current safety and design standards. An August 2005 inspection report prepared by the Snohomish County Public Works Department deemed the bridge functionally obsolete and identified it for replacement.

Considering Alternatives to Replacement

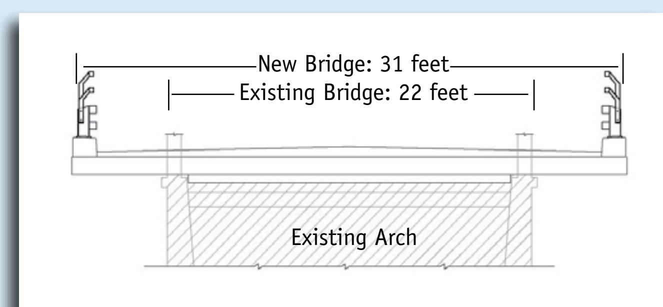
Although the inspection had revealed several major deficiencies of the bridge, the Luten arch foundation was structurally sound. The possibility of keeping it and replacing the other portions of the bridge interested project engineers. In order to determine the feasibility of this option, engineers conducted an in-depth investigation of the existing structure and the loads it carries. Two essential requirements had to be met:

- First, the new wider design had to maintain approximately the same dead load distribution on the original arches, which was necessary to keep them in compression.
- Second, the load increase on the substructure and foundations had to be minimized to reduce the risk of excessive settlement.

Although arch bridges are expected to tolerate increased dead and live loads, there was concern among the project engineers since the original design and construction records were not available to verify the capacity of the bridge.

Widening Without Added Weight

Pre-cast concrete slabs that would form the wider deck would also add a substantial amount of weight to the bridge. To counterbalance the additional dead load,



Snohomish County currently maintains 200 bridges. Five of these are reinforced concrete Luten arch bridges built in the early 1900s.

The cellular concrete used was Elastizell. It is produced by mixing an expansion material to a cement mixture. The result is a low-density (load-reducing) material used as fill for applications such as behind retaining walls, at bridge approaches, over culverts, under roadways and over poor soils. The density ranges from 30 to 110 pcf; Normal compression strength can range from 140 to 2400 psi, depending on what is required for the application.

engineers needed to find a way to reduce weight somewhere else. They studied several light-weight materials to replace the existing heavier soil fill in the arches.

Engineered styrofoam was considered as it has a very low density of approximately 2 pounds per cubic foot (pcf) in contrast to 125 pcf for soil. The extremely low weight of this material would minimize the load increase on the existing structure. However, it was not known in what condition the top surface of the arches would be once the soil was removed. This, and the fact that the ribs were curved and skewed, would make the on-site installation and quality control of the pre-formed styrofoam blocks a challenge. Because of this concern and the need for a weight that would keep the arch in compression, the styrofoam option was eliminated.

Cellular concrete was chosen because it is light weight and can be formed in place.

Another material—light-weight cellular concrete—had significantly less density than soil fill (approximately 30 pcf for light-weight concrete versus soil's 125 pcf). The concrete could also be formed in place to create an even contact on top of the existing structure. Because of this, it was the chosen for the project.

A Balancing Act

A correct load distribution and a well-planned construction sequence were essential for the success of this widening project.

To maintain the integrity of the arches and ensure safety during construction, the process of removing existing soil fill from the arches and replacing it with the lighter cellular concrete had to be conducted incrementally in 2- to 4-foot lifts, alternating between the arches.

The following is an overview of the construction sequence:

- Removed existing concrete slab.
- Partially removed the existing parapet; used the remaining portion as a form for the new light-weight concrete fill.
- Removed the existing soil fill in uniform lifts, alternating from one arch to the other to maintain a balanced distribution of weight.
- Filled arches with lightweight concrete in uniform lifts, again alternating from one arch to the other.
- Added a layer of crushed rock to serve as the base for the new pre-cast concrete slabs.
- Laid the 32 pre-cast slabs on top of the crushed rock, working from the center outward.
- Added a lift of asphalt and new galvanized steel bridge rail system.

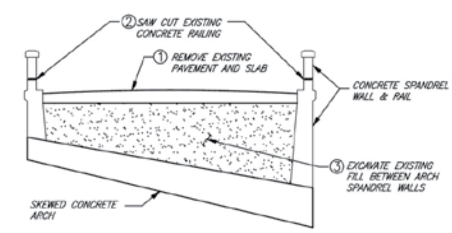
Working With the Community

Approximately 5,000 vehicles cross South Slough Bridge each day but many do not live in the immediate area surrounding the site. In 2006, 900 newsletters were mailed to a wider area to explain the project and the need for a road closure.

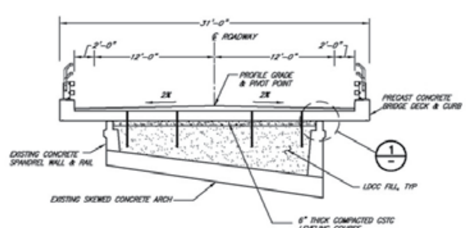
In 2007 the County produced another newsletter. It contained information about the South Slough Bridge project, as well as seven other state, city and county road projects scheduled for 2007 and 2008 in the greater Arlington/Marysville area. The information was used to coordinate lane and road closures among the jurisdictions and to update citizens on construction impacts. The newsletter was distributed to 7,000 residents.

In addition, notice of the bridge project and road closure was listed in the County's weekly roads update that is emailed to representatives of the media, transit agencies, cities, school districts, utilities, fire districts and tribes. A display ad was placed in the newspaper

Engineers used the existing arched foundation, widened the bridge, and increased the square footage of the deck by 62% without adding any new weight to the supporting double arch foundation.



Schematic Section of 1920 Arch



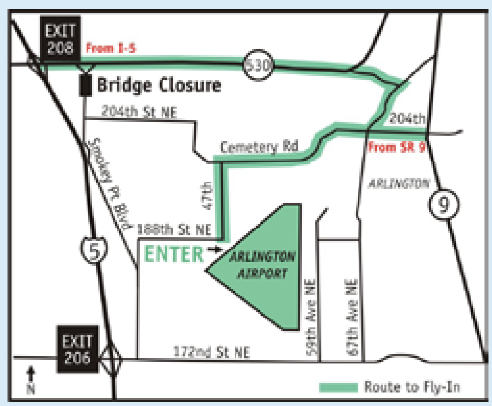
2007 Widening

> *"Not knowing how often you get letters of praise for the work of Public Works employees, I wanted to take this opportunity to let you know that (Engineering, Transportation Planning, Communications, Graphics and Road Maintenance) staff members working on the South Slough Bridge worked as a team to turn a very troublesome issue into immediate resolution with skill and professionalism."*
>
> –Barbara Tolbert, Executive Director
> Northwest EAA Fly-In

and signs were posted on site to provide advance notice of the closure. The newsletter was also posted on the web sites of County projects listed in the newsletter.

The biggest communications challenge was notifying the more than 50,000 people who were expected to come from all over the Western United States to attend the 39th Annual Arlington Fly-In in mid-July. The Northwest EAA Fly-In is a 5-day aviation convention, the second largest event of its kind in the nation, which takes place at the Arlington Airport between the cities of Marysville and Arlington.

> South Slough Bridge is on the preferred route to the airport and was completely closed to through traffic during the air show.



To prepare, County staff worked closely with event organizers and staff from the City of Arlington and Washington State Department of Transportation to plan the detour route and signage. Two mobile readerboard signs were placed near the exit to Interstate 5 that many visitors would use on their way to the Arlington Airport, site of the Fly-In. Detour signs and event signs were posted together all along the route to the airport. In addition, County graphics staff created a detour map for the Fly-In which event organizers posted on their web site.

The Fly-In was a great success—the Wright brothers would have been amazed—traffic was successfully rerouted, and there were no reported complaints about the "new route."

Schedule on Fast Track

This fast tracked project was completed in 17 months from start of design to end of construction.

During the initial scoping of the project it was decided that the County's Road Maintenance Division would be the prime contractor for the construction. It was also determined at the scoping meeting that construction crews will be scheduled to work on this project during the summer of 2007. Time savings could be gained for the project with the engineers and contractor working together as a design-build team. The designers could discuss issues with the builders and resolve the matter quickly. Several months were saved by avoiding the prime contractor selection process (advertise for bids, award, notice to proceed).

Abilities of the construction crews were assessed and some work (concrete cutting and steel fabrication) was developed for skilled sub-contractors. It was important to issue contracts with the suppliers in early spring so that production schedules and delivery dates were secured. Before the pre-construction meeting in early June 2007, the entire construction team (County, utilities, suppliers, and subs) was onboard.

Design began .... April 16, 2006

Design finished.............. April 15, 2007

Ad date .... April 23, 2007
(for pre-cast concrete,
cellular concrete,
bridge rail, crane)

Construction began .... June 25, 2007
(road closed)

Construction finished...... September 12, 2007

Time Saving Measures:

- Early coordination with utility companies during the design phase and continued coordination throughout the project.
- Underground water and sanitary sewers were avoided by modifying excavation at abutments.
- Overhead electrical lines were de-energized while crane was on site placing pre-cast units.
- The design team stayed with the project through construction and provided support to the construction inspector. Tasks included bid support, shop drawing review, utility coordination and delivery scheduling.
- The County's Road Maintenance personnel built the bridge, eliminating the need for a lengthy bid process.
- Parsons Brinckerhoff, a County on-call consultant, was utilized to prepare the structural engineering.

Keeping the Site Safe

- There were no injuries on the South Slough Bridge construction project.
- Daily tailgate meetings were held each morning to discuss the plan for the day—work to be done and safety measures to be followed during the process.
- Crew members wore proper safety equipment such as orange t-shirts or vests, hard hats, steel-toed boots, safety glasses, and leather gloves when needed.
- The construction manager attended monthly safety meetings. All of the County's construction managers meet monthly as a group with the County's safety trainers and report back to their project crews. At the safety meetings the group reviews all injury and non-injury accidents in the division, and discusses what went wrong and prevention of future accidents. They also review close calls.
- All members of the crew had CPR and First Aid training. Defensive driving certification was also required. Some crew members also had confined space training.

Saving Money

Cost of this Project: $929,100

It was determined before the design began that reusing the arches could save time and money.

A new bridge in Snohomish County had a construction cost of $423 per square foot. Engineering, construction administration and right-of-way added an additional cost of $159 per square foot. The total cost for a new bridge project should cost on average $582 per square foot. The South Slough Bridge widening project had a cost of $129 per square foot for the new deck.

	Actual Cost	Estimate for Total Replacement
Construction	$779,150	4,332,000
Design/Const. Inspection	$149,950	1,516,000
Total	**$929,100**	$5,848,000

Snohomish County Project Team

Design Supervisors:	Darrell Ash PE/SE Kinyan Lui, PE
Project Manager:	Larry Brewer, PE
Construction Inspector:	Chuck Seyler
Project Engineer:	Mario Accetturo
Technician:	Mike Huston
Environmental:	Julie Highton, Planner Irene Sato, Biologist
Traffic Operations:	Dale Valliant Greg Nixon
Survey:	Paul Fenner, LS Lee Morrell Laurie Nowak
Geotech:	Jeff Jones, Geologist
Construction Supervisor:	Bud Klintworth
Construction Foreman:	Jason Hoeye
Construction Crew:	Brian Bryant Mike Conrad Brian Earnheart Clint Engebretsen Shane Frolich Greg Kazen Karla Kittleson Jim Parker
Road Maint. Staff:	Nancy Orsborn Sue Studzinski
Summer Staff:	Abe Bourasaw Allen Wesson
Contract Admin.:	Neil Brimacombe Pam Kane
Special Contractor Support:	Charlie Green
Graphic Design:	Deb Harvey
Communications:	Tina Hokanson

County Executive

Aaron Reardon

County Council

Mike Cooper
Dave Gossett
John Koster
Dave Somers
Brian Sullivan

Public Works Administration

Steve Thomsen, Director
Owen Carter, County Engineer
Art Louie, Engr. Services Director
Bruce DuVall, Engineering Manager
Ron Torrence, County Surveyor
Bobann Fogard, TES Director
Jim Bloodgood, Traffic Engineer
Roy Scalf, Acting Road Maint. Dir.
Steve Pratt, Retired Road Maint. Dir.

Structural Consultant

Parsons Brinckerhoff
Yuhe Yang, PE/SE, Project Manager
Yanqiang (Carl) Gao, PE
Clayton Binkley

Archaeological Consultant

BOAS, Inc., Seattle, WA
Astrida Blukis Onat, PhD, Principal
Lucy Flynn Zuccotti, Archaeologist

Front cover photo:
Brian K. Blechschmidt, Inc.,
Renton, WA

Suppliers

Lightweight Concrete Fill:
Builders EF, Woodinville, WA

Precast Slabs:
Concrete Technology Corporation,
Tacoma, WA

Bridge Railing:
Beko's Welding, Canby, OR

Crane Rental:
Ness Cranes, Seattle, WA

Concrete Sawing:
Cascade Concrete Sawing,
Seattle, WA