

RAPID REPLACEMENT OF TWO WASHINGTON DOT STREAM CROSSING BRIDGES USING PREFABRICATED ARCH BRIDGE SYSTEMS

Michael G. Carfagno, P.E., Contech Engineered Solutions, (513) 645-7535, mcarfagno@conteches.com
Kali Dickerson, P.E., Stantec, (425) 289-7348, Kali.Dickerson@stantec.com

ABSTRACT

The Washington Department of Transportation (WSDOT) used different approaches to solve challenges faced on two stream crossing bridge replacement projects in 2018. Using the same contractor for both projects, the same prefabricated bridge system was implemented to successfully replace both bridges in record times. To improve fish passage in the Little Pilchuck Creek under State Route 92 in Snohomish County, Washington, WSDOT engineers proposed replacing a 12'x 6' concrete box culvert with one of three alternate precast concrete structures, each one detailed in the bid drawings in a conventional design-bid-build project. To minimize impacts to the 12,000 drivers who travel SR 92 every day, the contract only allowed for two weekend closures and one two-week continuous closure of SR 92 with liquidated damages accruing if construction extended past the two-week closure. The successful low bidder, as well as the majority of the other bidders, chose the 66'-0" span twin-leaf precast arch alternate which allowed the use of precast strip foundations in lieu of the pedestal foundations required by the other two alternatives. Modular block MSE walls were used as headwalls and wingwalls to complete the bridge structure. Although the contractor ran over the two-week closure by a few days, due to some unforeseen delays during construction, the project was deemed a success by all parties. On the second project, WSDOT planned to replace the existing 3-span, 150-foot-long Wildcat Creek Bridge, on a remote section of US 12 east of White Pass in Mount Rainier National Park, with a new pre-stressed concrete girder bridge using the Design-Build delivery method. Using Design-Build allowed the contractor to be innovative and develop a proposal that used a 54'-0" span twin-leaf precast concrete arch buried structure with precast foundations and MSE retaining walls with a short-term detour to minimize traffic impacts. This scheme reduced the construction time and traffic impact from over three months utilizing the pre-stressed girder option to just 17 days. The precast arch structure also resulted in a savings of \$2 million over the pre-stressed girder option. Other benefits from the buried bridge structure were the avoidance of pile-driving, as well as a reduced footprint of the bridge structure and limited tree removal. This paper will introduce the concept of twin-leaf precast arch structures, how they can be a strong alternative to conventional bridges and will discuss these two WSDOT Accelerated Bridge Construction projects highlighting the construction sequencing, challenges faced, and the lessons learned.

INTRODUCTION

Multi-leaf precast arch structures can be economical substitutes for short to medium span conventional bridges. The Washington Department of Transportation took advantage of twin-leaf precast arch structures using two different delivery methods to solve challenges faced on two stream crossing bridge replacement projects in 2018. Both projects were determined to be candidates for using accelerated bridge construction techniques to reduce impacts to traffic and as such twin-leaf precast arch structures ended up being the chosen structure for both projects. This paper will provide details of the design and construction of both bridge replacement projects illustrating how twin-leaf precast arch structures can reduce construction time significantly over conventional bridges.

MULTI-LEAF PRECAST ARCHES

Multi-leaf precast arches are structures that have been split into 2 or 3 pieces in order to simplify shipping to the jobsite. A number of different systems exist in both twin and triple leaf configurations. The main differences between the systems are the number of segments that the arch is broken up into and how the joints between segments are detailed. Some systems treat and detail the joint as a pin connection while others make the connection fixed with full moment continuity. The BEBO bridge systems that were used

on both of the WSDOT projects in this paper were twin-leaf structures that have fixed connections at the joint between segments at the crown of the arch. The BEBO Bridge System was developed in Switzerland in the mid 1960's.

Segments of multi-leaf precast arch structures are shipped to the jobsite on their sides on flatbed trailers. The most typical method of erecting twin leaf arch structures is by use of two double drum cranes that allow the arch units to be lifted off the flatbed trailers and then rotated in the air into the setting position and then moved into their final resting location (Figure 1). If two cranes are not used, then a shoring system must be used to hold the first half of the arch in place when the crane is moving the second piece into position.



Figure 1: Twin-leaf arch erection

US 12 WILDCAT CREEK BRIDGE REPLACEMENT

WSDOT utilized a fast-tracked design-build project approach to replace the aging 150-foot span timber and steel girder Wildcat Creek Bridge under a tight construction window—seven months after project award. Located on US Highway 12, one of only three routes across Washington's Cascade Mountains, the bridge is a critical piece of infrastructure for an important freight route. The bridge is located in the WSDOT south central region, just east of white pass, and services approximately 2100 vehicles per day.

Existing Bridge – Deteriorated Condition

The original Wildcat Creek Bridge, constructed in 1936, was showing significant signs of deterioration due to age and normal wear. The bridge was comprised of a 35-foot main span and three 19-foot side spans on either side of the main span. The main span was composed of steel girders with a cast-in-place concrete deck and supported by rigid concrete frame piers. The side spans were each composed of timber girders and concrete deck and supported by braced timber piers.

The bridge was showing significant signs of deterioration and constant repairs were required (Figure 2). The bridge steel elements were accumulating rust. The bridge deck was experiencing several significant deterioration locations, some even as large as 3-feet by 3-feet and completely penetrated through the 6-inch thick deck. The concrete piers exhibited significant spalling and excessive exposed rebar.



Figure 2: Existing Bridge Deterioration

WSDOT Preliminary Design

WSDOT's preliminary design included a standard girder bridge made of precast, prestressed concrete girders, cast-in-place (CIP) deck, and CIP concrete barriers (Figure 3). The preliminary design increased the curb-to-curb width by 3-ft, and utilized a single bridge structure, spanning the full 150-foot crossing.

The preliminary design also proposed a temporary detour bridge to be used while the permanent structure was being constructed.

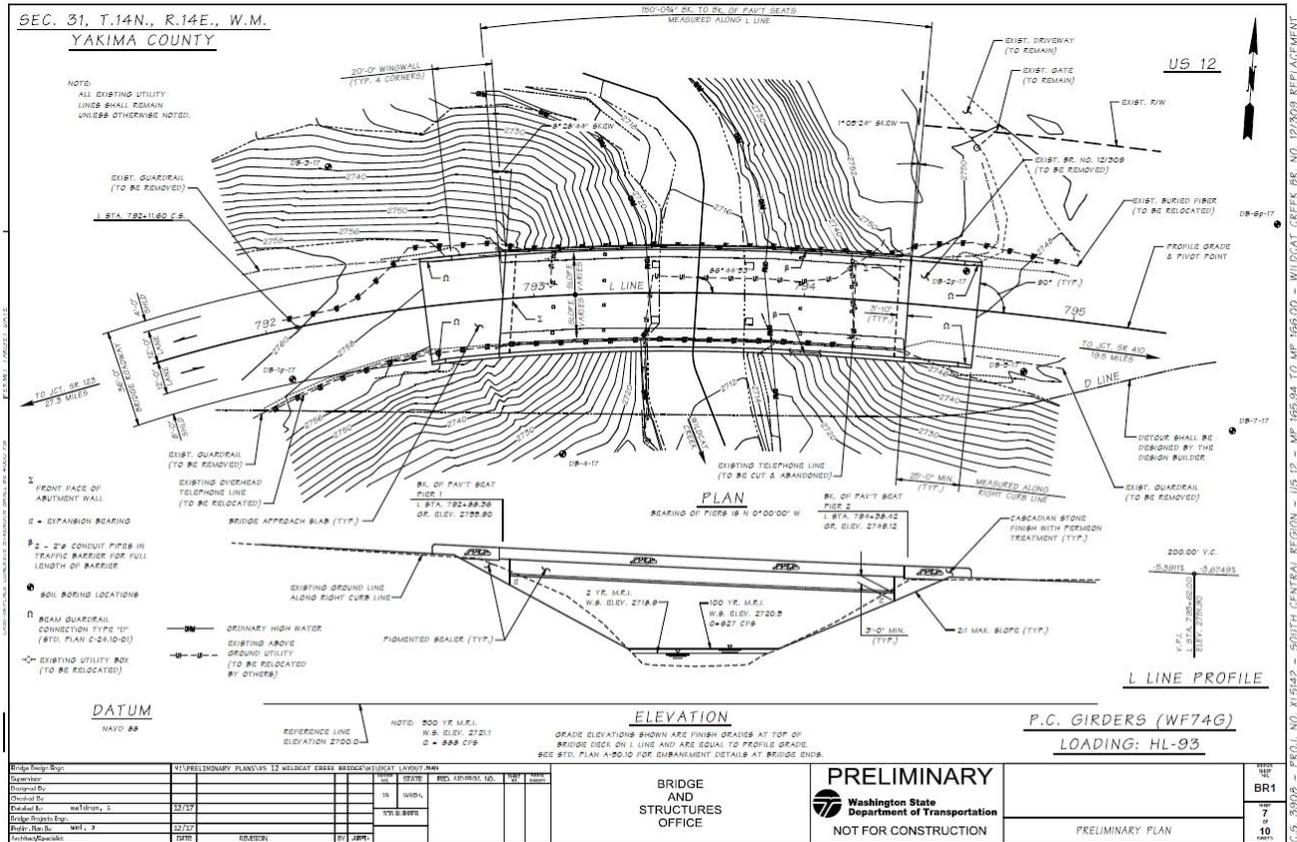


Figure 3: WSDOT Preliminary Design

In addition to the significant added cost of building two bridges (instead of one), this temporary alignment had significantly more environmental impacts than the DB team's proposed solution. By eliminating the need for a second, temporary bridge, the team was able to reduce the number of trees removed from the project site.

Design Build method of delivery

WSDOT obtained accelerated funding from Connecting Washington Transportation Funding Package for the Wildcat bridge replacement. Bridge replacements fall under the Highway Preservation Budget, which addresses the most critical needs for bridges and allows WSDOT the option to use expedited contracting for emergency protection of highways. Therefore, the project needed to be delivered very quickly. The agency budgeted \$12 million and four to five months of construction. The DB team developed effective design and construction methods to accelerate the bridge replacement timeline while reducing impacts to the environment, traffic, and the surrounding community, all primary goals of the project. Overall project goals included,

- Minimizing Impacts – design and construction methods that accelerate structure replacement and reduce impacts to the environment and traffic.
- Collaboration – collaborate effectively to identify issues early in the schedule and efficiently develop positive solutions.
- Environmental Compliance – Meet or exceed environmental requirements with no permit violations.

The design-build delivery method was used for this project to allow for design and construction innovations and reduce the overall cost and schedule for the project. Alternative Technical Concepts (ATCs) were utilized by the DB teams to propose deviations from the WSDOT basic configuration. The project was awarded and delivered on an accelerated schedule, with the bridge opening to traffic only 6-months after notice to proceed!

Project Timeline:

- Qualifications – less than one month
- Proposal – two months
- Notice to Proceed – two months after Proposal
- Bridge Open to Traffic – six months after NTP

Design Build Team

The winning design-build team was composed of the following firms:

Owner – WSDOT
Contractor – Graham
Lead Designer – Stantec
Arch Designer – Contech Engineered Solutions
Wall Designer – Reinforced Earth

The multi-discipline design-build design team conducted an alternatives analysis and developed an innovative solution utilizing a 54-foot pre-cast arch buried bridge structure. Stantec also eliminated a temporary detour bridge in favor of a full road closure. The design-build team generated several ideas for ATCs, but eventually only decided to use one.

Maintenance of Traffic

Through the approval of an ATC, the design-build team was able to eliminate the temporary detour bridge in favor of a full road closure. The team worked with local authorities and stakeholders to develop a detour based on a previously used route familiar to the public. The detour route used added an additional 20 minutes around the bridge site (Figure 4). The full closure lasted for 17 continuous calendar days, and work was conducted during the allowable in-water work window.

Prior to full closure of the bridge, the DB team performed a full inspection of the whole detour route and made repairs along the route as necessary before using. Additional inspection and repairs were made along the detour route after the bridge was opened to traffic. This project approach reduced traffic impacts from three months to just seventeen days.

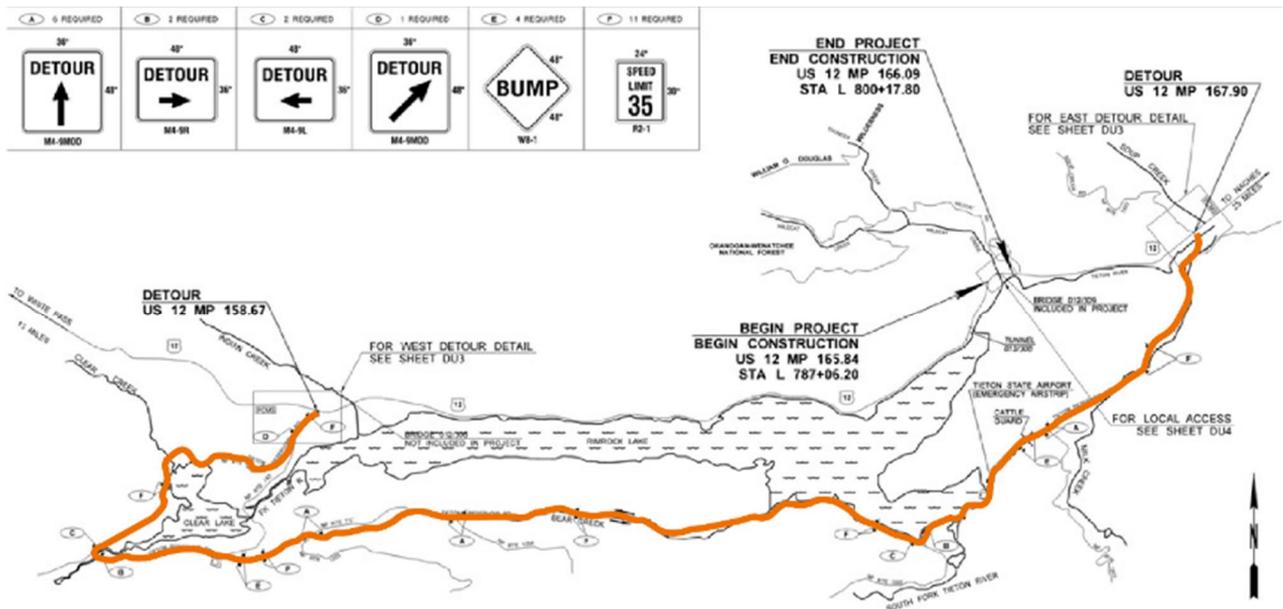


Figure 4: Detour Route

Utilities

The project included close coordination with utility owners including AT&T for both temporary and permanent locations of sensitive fiber optic lines and Rimrock Water Association (RWA) for potable water and fire suppression lines to confirm that utility relocations occurred on time to keep the project on schedule. The team worked with AT&T to develop conduit locations and collaborated with RWA, assisting with concept development for the use, size, and location of pipe sleeves.

The design team was able to avoid underground telephone cable and sewer lines near the east abutment of the bridge. Several utility lines were able to be abandoned, including a powerline for RWA, a Rimrock store area cable and an above ground telephone line owned by WSDOT.

Construction Schedule

The installation logistics for this remote project location, on a tight timeframe, were quite complex. Through careful planning and sequencing, all the parts and pieces were brought together in the correct progression.

Through an approved ATC, the DB team was able to eliminate the temporary detour bridge originally proposed in favor of a full road closure. To determine how long the road would need to be closed, the team built a highly detailed, hour-by-hour schedule that penciled out to 17 days of round-the-clock construction. The team worked with Yakima County and other stakeholders to develop a detour based on a previously used route familiar to the public. By reducing construction to 17 days, the team cut inconvenience to the traveling public, residents, and local businesses by 80% and eliminated the safety concerns and expense of managing live traffic adjacent to the project. Construction was completed using two shifts per day, seven days per week.

US 12 was closed on the evening of October 5th, 2018 and reopened to traffic on October 22nd, 2018—ahead of schedule. The new arch structure adds stability, maintains natural hydrology and fish habitat, and compliments local and regional aesthetics.

BEBO Twin Leaf Arch Buried Bridge

The design build team selected a BEBO twin-leaf C54' span x 26'-4" rise structure with 13'-0" of soil cover as the best fit structure for the site (Figures 5 & 6). The bridge consisted of eight (8), six foot wide arch rings with an overall width of 48'-0". The maximum height of soil cover over the arch is 13'-0" with a live load of AASHTO HL-93.

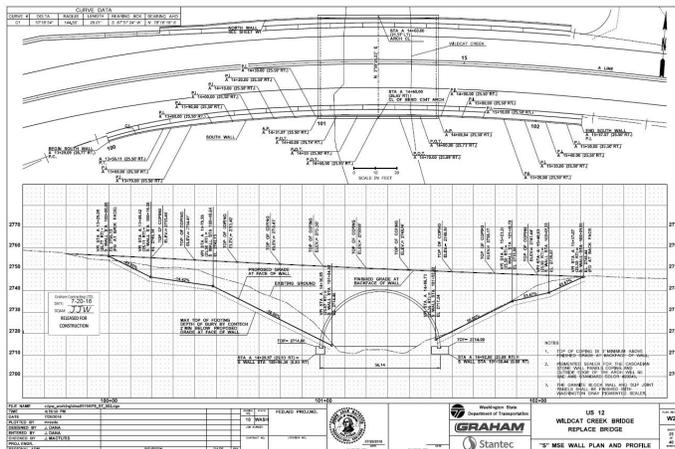


Figure 5: Wildcat Creek Plan and Profile

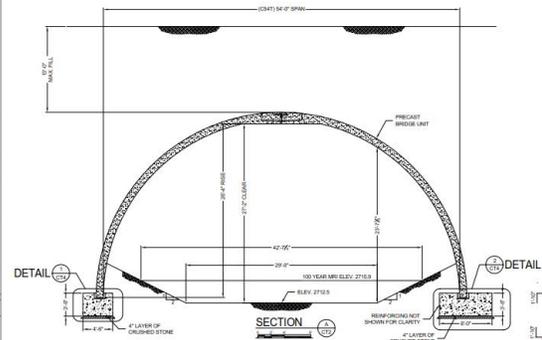


Figure 6: Typical Cross Section

Precast Foundations and Closure Pour

Precast strip foundations were used in order to speed construction (Figure 7). Cast-in-place concrete closure pours between precast foundation segments were used to provide continuity to the foundation. Based on the varying soil conditions the strip foundations were different widths under each arch leg. The precast foundations were set on a 4" layer of crushed stone and had longitudinal reinforcing bars extending from each precast foundation segment to provide longitudinal continuity. Once the foundation segments were set transverse reinforcing bars were tied in and then high-early strength concrete was cast in the closure pours (Figure 8). A minimum compressive strength of 4000 psi was required before the arch sections could be set on the foundations.



Figure 7: Precast Foundations Set in Place



Figure 8: Foundation Closure Pours

Arch Unit Installation

Once the foundation closure pours had cured overnight and reached the required 4000 psi compressive strength the arch units were installed. Cranes on each side of the bridge structure at the existing roadway elevation were used to set the arch units. The arch units are set on top of a 1" nominal stack of either Masonite or plastic shims that are set on top of the keyway that was formed into the top of the strip foundations. Hardwood wedges are used to keep the arch sections from spreading and to align the arches. There is a tongue and groove joint at the middle or "bullnose" section of each arch ring to provide alignment during arch erection (Figure 9). Once an arch ring (2 arch halves) are set, a curved bolt is installed as a safety precaution to make sure the arch halves do not separate. Each arch segment has reinforcing bars extending out at mid-span into the crown joint so that splice bars (Figure 10) can be tied across the joint to make the reinforcing continuous and provide a moment connection once cast-in-place concrete is cast into the crown joint. It took approximately 9 hours to erect all 8 arch rings.



Figure 9: BEBO Crown Joint



Figure 10: Crown Joint Reinforcing in-place

Once the arch units were set, the foundation keyway was grouted and then the crown joint concrete was placed. Once the crown joint concrete reached a compressive strength of 5000 psi, the backfilling and MSE wall construction could commence.

MSE Wall Construction

A Reinforced Earth MSE wall was used for the headwalls and wingwalls of the bridge structure. The contractor stockpiled granular backfill for the MSE walls on either side of the bridge structure and used bulldozers to push the material down to the wall elevation where an excavator on each side of the bridge placed the material which was then compacted (Figure 11). MSE wall construction lasted 5 days and was the construction item that took the longest to complete.



Figure 11: MSE Wall Construction

Lessons Learned – Contractor’s Perspective

The Contractor provided feedback that there could have been better quality control of the precast arch units as an error by the precaster caused a delay of approximately 2 hours during arch setting due to fabricating not enough tongue arch units and too many groove arch units. The contractor also stated that better quality control of the MSE wall panel deliveries with the right number of the right type of panels being delivered at the appropriate time would have also sped up construction. Even with these two minor delays, the contractor was able to demolish the existing bridge and construct the new bridge in 17 days working two shifts per day.

WSDOT Experience

After the project was complete (Figure 12), the Washington Department of Transportation put together an information sheet on the project titled “Practical Solutions in the Workplace” which was distributed throughout their offices. The information sheet outlined that the original plan was to replace the existing deteriorated bridge with a new pre-stressed concrete girder bridge with a span of about 150 feet. It explained that the “practical solution” was the project was delivered using the design-build method which allowed the contractor to be innovative in proposing a precast concrete arch bridge that allowed for rapid construction. The outcome was approximately \$2 million in savings, reduced traffic impact by 3 months and a more sustainable solution that reduced the project footprint and tree removal. The project has won numerous awards from AGC, ACEC as well as being named the #7 bridge project of 2019 by Roads & Bridges magazine.



Figure 12: US 12 Wildcat Creek Final Construction

LITTLE PILCHUCK CREEK

The Washington State Department of Transportation (WSDOT) utilized a conventional design-bid-build project approach to replace an existing 12' x 6' box culvert that was a fish barrier in Lake Stevens, Washington, a town located approximately 35 miles northeast of Seattle (Figure 13). The project objective was to remove the fish barrier culvert which would provide full fish passage an additional 1.7 miles upstream of the project site. At the 30% plan set stage with the drawings showing a standard WSDOT precast structure shape, the project engineer’s office (PEO) decided to leverage industry competition by asking industry competitors to provide alternate structure designs for the contract. A small stipend was provided to both the Pretek Group and Contech Engineered Solutions to provide alternate structure designs for the project so that contractors could choose which alternate they felt was best and then submit a bid for that alternate.

Due to the volume of traffic that would be affected during the box culvert replacement, WSDOT only allowed for two weekend road closures for ground improvement and one 13 calendar day full roadway closure. Jet-grouted columns were installed under the spread foundations in order to mitigate a 10' thick layer of liquefiable soil (Figure 14)



Figure 13: Existing Box Culvert on Little Pilchuck Creek



Figure 14: Jet-Grouted Column Installation

Structure Alternates

Structure Alternate 1 was the WSDOT standard precast 3-sided structure “VC60” culvert shape with a 60’ span and 8’-3” rise (Figure 15). It is a shape that has 3 flat chords to make the arch along with large haunches. The precast culvert was set on precast pedestal walls which resulted in about 12’ of fill over the top of the structure.

Structure Alternate 2 was the Pretek Eco-Span single leaf precast arch with a 60’-8 5/8” span and 11’-6” rise on precast pedestal walls with CIP foundations (Figure 16). The maximum cover on top of this structure was approximately 7’.

Structure Alternate 3 was the Contech BEBO twin-leaf arch with a 66’-0” span and 24’-0” rise on precast strip foundations. The maximum cover on top of this structure was about 6’-6” (Figure 17).

Alternate 3 had the advantage of not requiring pedestal walls to achieve the vertical clearance which was only able to be achieved using a twin leaf structure.

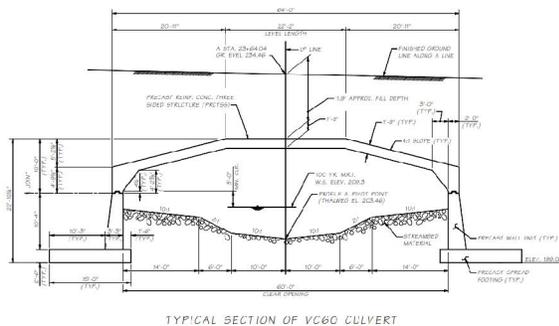


Figure 15: Structure Alt. 1 – WSDOT 3-sided

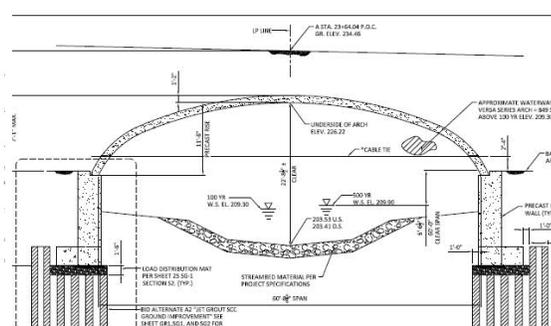


Figure 16: Structure Alt. 2 – Pretek Eco-Span Arch

