

# US-189 BRIDGE OVER THE DEER CREEK DAM SPILLWAY IN PROVO CANYON

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## INTRODUCTION

The US-189 widening project in Provo Canyon, Utah included many engineering challenges to upgrade a two lane highway to four lanes to improve safety along this stretch of highway from Wildwood to Deer Creek State Park. The project includes split level alignments, rock cuts, an avalanche shed, and a bridge in front of the Deer Creek Dam, spanning the spillway. The roadway alignment in front of the dam is along a curved alignment, and the steel plate girder superstructure uses high performance steel, a first for The Utah Department of Transportation (UDOT). The avalanche shed, located just east of the bridge, is the first to be designed in the state of Utah, although the shed was excluded from the final contract documents and will not be constructed at this time.

## BRIDGE OVERVIEW

The Deer Creek Dam was constructed by the Bureau of Reclamation (BOR) between 1938 and 1941. It is a zoned earth and rock-fill structure constructed to create the Deer Creek Reservoir and carries traffic from US-189 across the dam. The new bridge will be located along the base of the embankment of the dam. It will support two lanes of traffic in each direction with a center median. The alignment at this

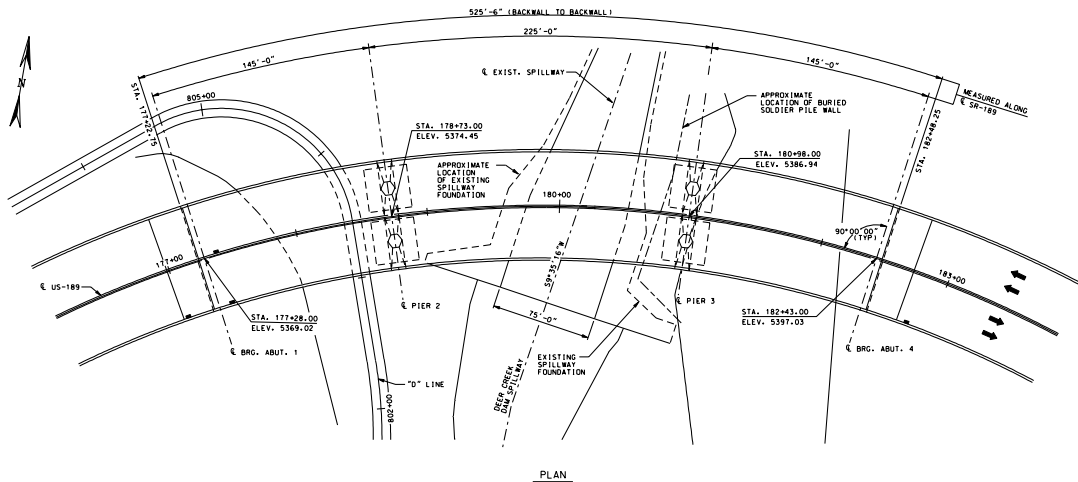
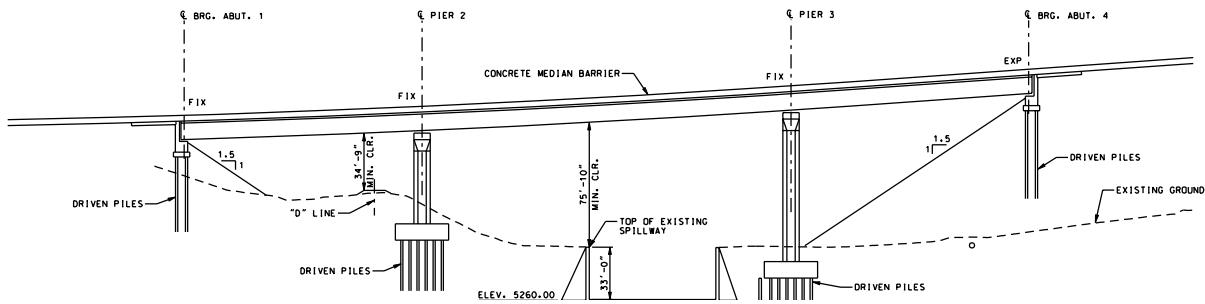


Figure 1: Bridge Plan

location is along an 835'-0" radius with the roadway super-elevated at 6% cross slope. The profile of the roadway is approximately 100 feet above the base of the spillway. The bridge is in a sag vertical curve with a maximum profile grade of 7.0%. Figure 1 includes the plan and elevation.



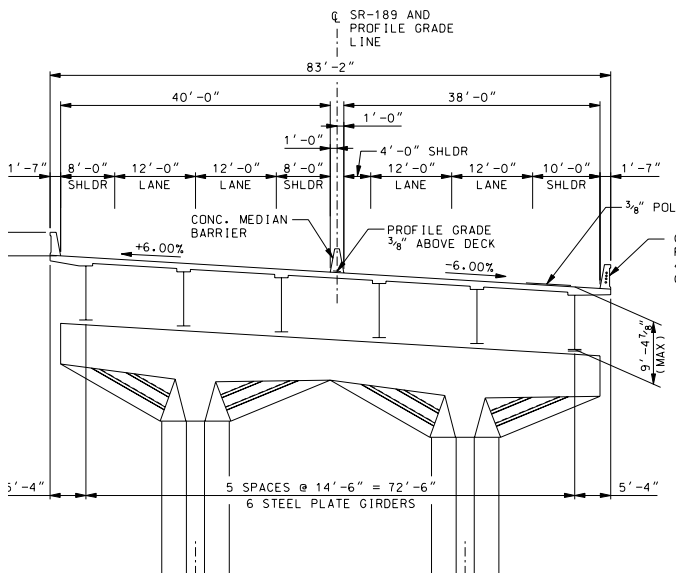
**Figure 1: Bridge Elevation**

The US-189 Bridge over the Dam Spillway is 515 feet long. It consists of three spans (145'-0" – 225'-0" – 145'-0"). The Bridge is 83'-2" wide and consists of 6 steel plate girders at 14'-6" spacing with 5'-4" deck overhangs. The reinforced concrete deck is 10" thick. Figure 2 depicts the bridge cross section.

**DESIGN CONSIDERATIONS**

The bridge is designed according to AASHTO Standard Specifications for Bridge Design and Construction, Sixteenth Edition and the AASHTO Guide Specifications for Horizontally Curved Highway Bridges, 1993. At the time design commenced on the bridge, the AASHTO Guide Specifications for Horizontally Curved Steel Girder Highway Bridges, 2003, was not available to be considered part of the design criteria, however NCHRP Report 424, the basis for the new specification, was available for reference. Where NCHRP Report 424 proved to be more conservative, the recommendations were followed.

The most significant design approach where NCHRP was found more conservative was use of a curved girder with a hybrid cross section. The 1993 Specifications would permit the design to allow the web to yield, similar to design of a straight girder with a hybrid cross section. NCHRP Report 424 indicated that sufficient research has not been completed and documented showing this is acceptable. Future research could suggest a curved girder with a hybrid cross section could be utilized.



**Figure 2: Bridge Section**

The entire steel superstructure is specified to be AASHTO M270 Weathering Steel to reduce the initial steel cost and eliminate future maintenance cost relating to painting steel. The steel superstructure design incorporated HPS Grade 70W steel in field sections in negative moment regions and Grade 50W steel in field sections for positive moment regions. All cross frames, field splice plates, and miscellaneous steel details use Grade 50W weathering steel.

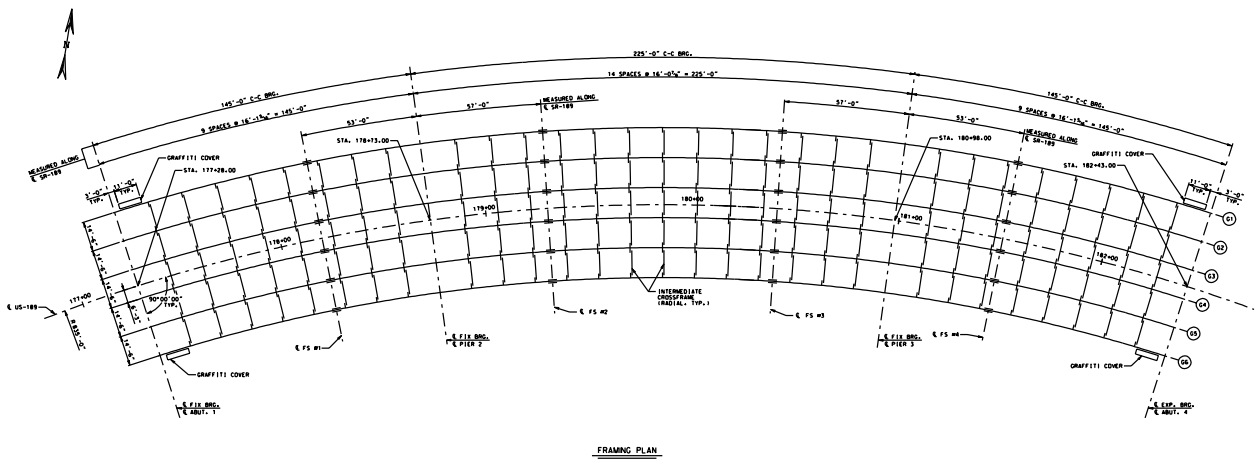
The form and shape of the bridge high across the face of the dam will be seen from far down the canyon. The aesthetic design for the bridge was a major issue. Large deck overhangs of 5'-

4" were provided to shadow the edge girders to give the structure a slender appearance. Form liners on the outside of the barriers were specified for a fractured fin appearance to add interest to the structure and in its surroundings. Modified octagonal shaped columns flare at the top to transition to the rectangular shape of the pier caps for a sculptured look.

## CONSTRUCTION CONSIDERATIONS

### Steel Superstructure Erection and Transportation

The bridge location makes shipment and erection of girders difficult. US-189 winds through the bottom of Provo Canyon between the Provo River and the steep mountainsides. Shipment of curved steel girders will be a challenge. To minimize this cost, field splice locations were chosen more to minimize girder shipment length than proximity to dead load contra flexure points. The use of HPS 70W resulted in lighter field sections that will ease transport to the site and girder erection. A wide girder spacing of 14'6" was used to minimize field segments, and also to balance the large deck cantilever. Erection of the steel



**Figure 3: Framing Plan**

girders over the spillway will also be a challenge. Figure 3 shows the Framing Plan.

Temporary roads will be needed along the face of the dam to gain access for the steel erection. Tall cranes will also be needed to reach above the 40 to 80-foot tall piers to set the steel girders.

### Existing Spillway Foundations

The existing BOR dam spillway extends approximately 98 feet from each side of the spillway centerline. The new bridge crosses the spillway at a skew, resulting in a long center span to avoid impacts to the existing spillway foundations. In the original bridge study by UDOT, consultants recommended using a five span pre-stressed concrete bridge and rebuilding the spillway under the shorter pre-stressed girder span. Re-building the spillway would have generated additional agreements, construction scheduling coordination, dam spillway operation impacts, and increased cost, difficulties UDOT chose to avoid.

### BOR Soldier Pile Wall

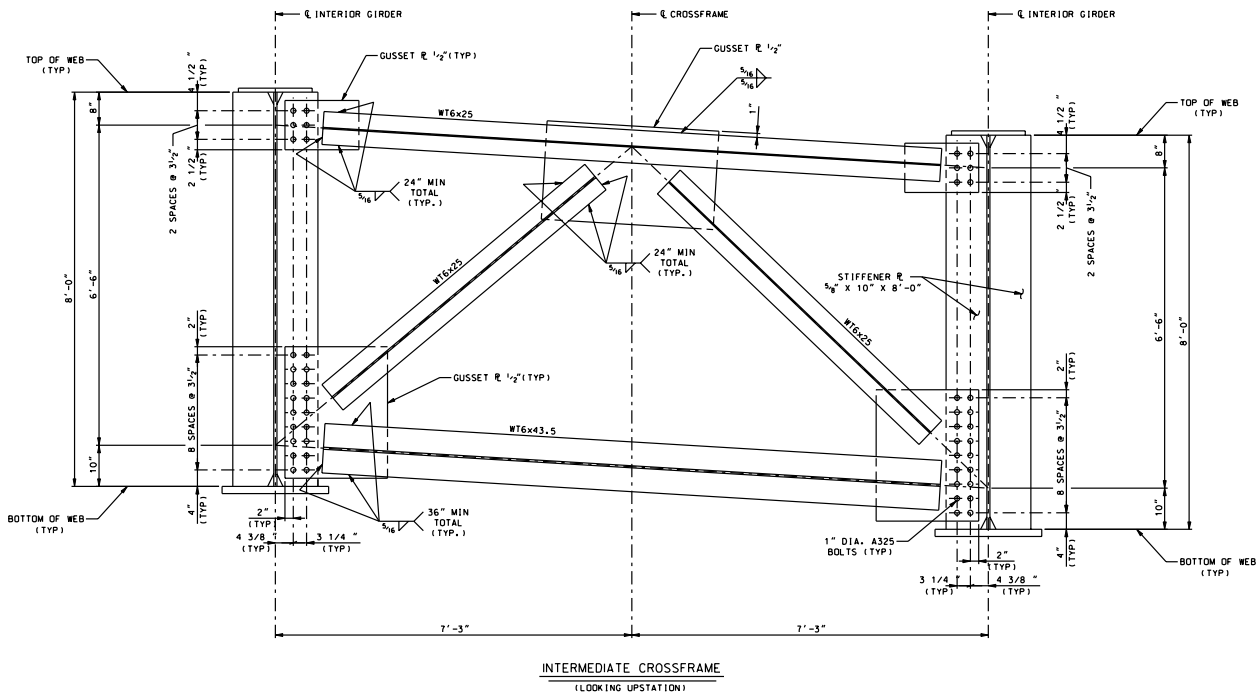
The BOR was developing a construction contract for Deer Creek Dam Improvements while UDOT's design studies for widening US-189 were being performed. Dam improvements required construction of a 50-foot high temporary soldier pile wall on the south side of the existing spillway so existing soft dam foundation soils could be removed and replaced with stronger material. While design of the new bridge was progressing, the soldier pile wall was moved further from the spillway to reduce wall height, and cost of the wall. This created a conflict with the footing for Pier 3 of the bridge, which had been designed to

resist large seismic forces at the bent. The soldier piles were to be left in place, and subsequently covered with fill to the final grade. The location of the wall presented potential future conflicts for contractors driving piles to construct the pier foundation.

The conflict was resolved by moving Pier 3 ten feet further from the spillway, increasing the length of center span to 225'-0" from the original length of 215'-0". To achieve a balanced arrangement of spans while maintaining the same bridge length to work within available funding, abutments were shifted five feet upstation. This successfully addressed concerns for uplift at abutments during construction and service conditions. The reanalysis of the superstructure showed the required design changes would not have significant impacts to the bridge cost.

## STEEL DETAILING

### Cross Frames

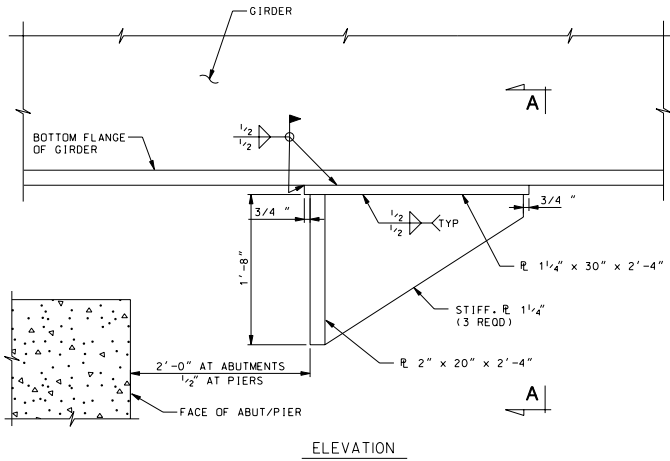


**Figure 4: Intermediate K-Frame**

Several measures were utilized to minimize steel fabrication cost. All cross frames were designed to be identical. A k-frame layout was used for its efficiency with girder spacing to depth ratio. Top and diagonal chord members are WT6x25. Bottom chord members are WT6x43.5. The major difference in requiring a larger section was the longer unbraced length of the member. Figure 4 shows the typical cross frame.

### Seismic Details

Provo Canyon has potential for high seismic activity, and the new US-189 Bridge was designed according to AASHTO Category D specifications with a horizontal acceleration of 0.5 g. To maintain an economic substructure design, the seismic strategy requires bearings to provide sufficient horizontal capacity during smaller seismic events and other service load combinations, but to fail during larger extreme event conditions and loads. Welds connecting bearing assemblies to masonry plates are designed to act as a fuse when loads are reached which could cause significant damage to substructure elements. The superstructure then moves horizontally (bearing assembly sliding on masonry plate) without transferring significant load until energy can be dissipated. A secondary mechanism is required to ensure the superstructure does not become unseated from the substructure. Structural steel restrainer brackets are

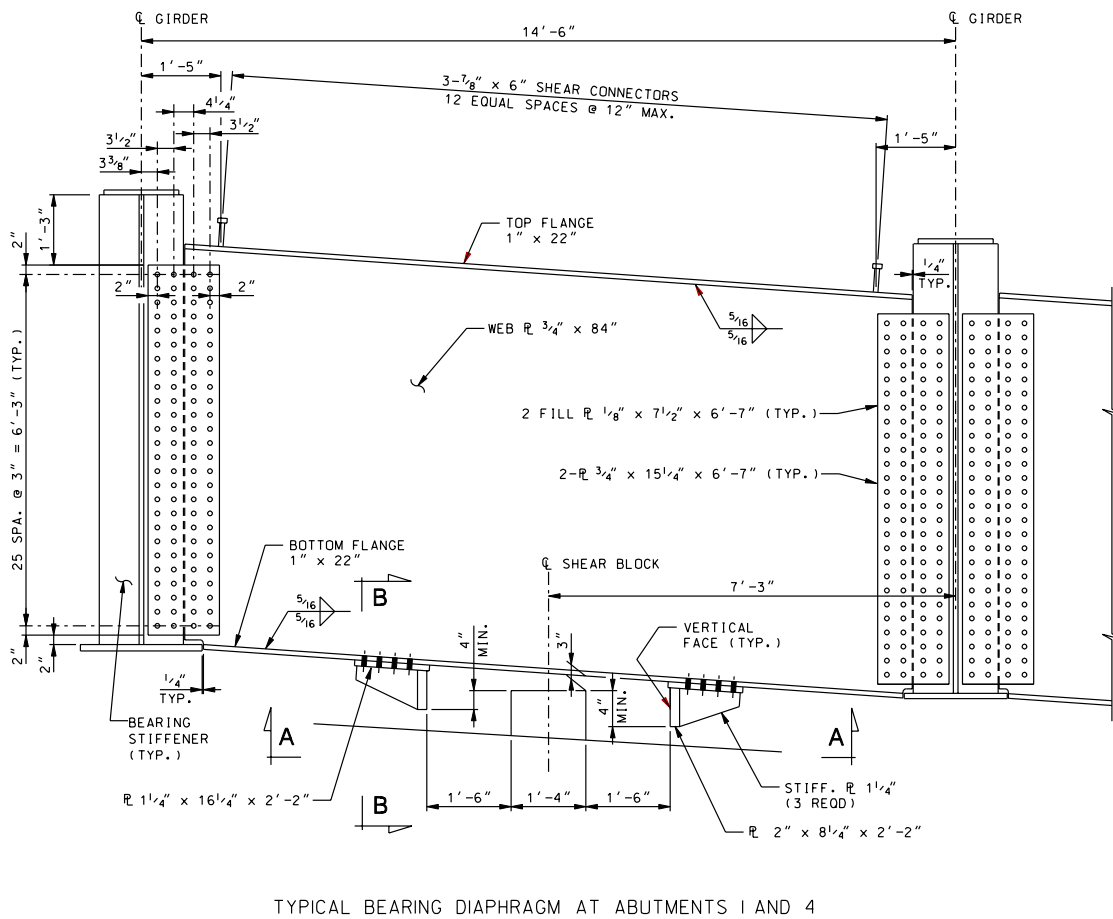


**Figure 5: Longitudinal Keeper Bracket**

specified to be attached to the bottom of girders to impact the face of pier caps and abutments to resist longitudinal seismic forces. Brackets are also specified to be attached to full depth plate diaphragms at piers and abutments. Figure 5 shows the longitudinal keeper bracket and Figure 6 shows the keeper blocks.

**Steel Plate Transitions – Negative Moment Regions**

Fabrication of flanges with welded shop splices can be costly. Fabrication cost can be minimized by using the same flange thickness for all girders and constant flange width through each girder, so plates can be nested together to weld plates in groups. For curved



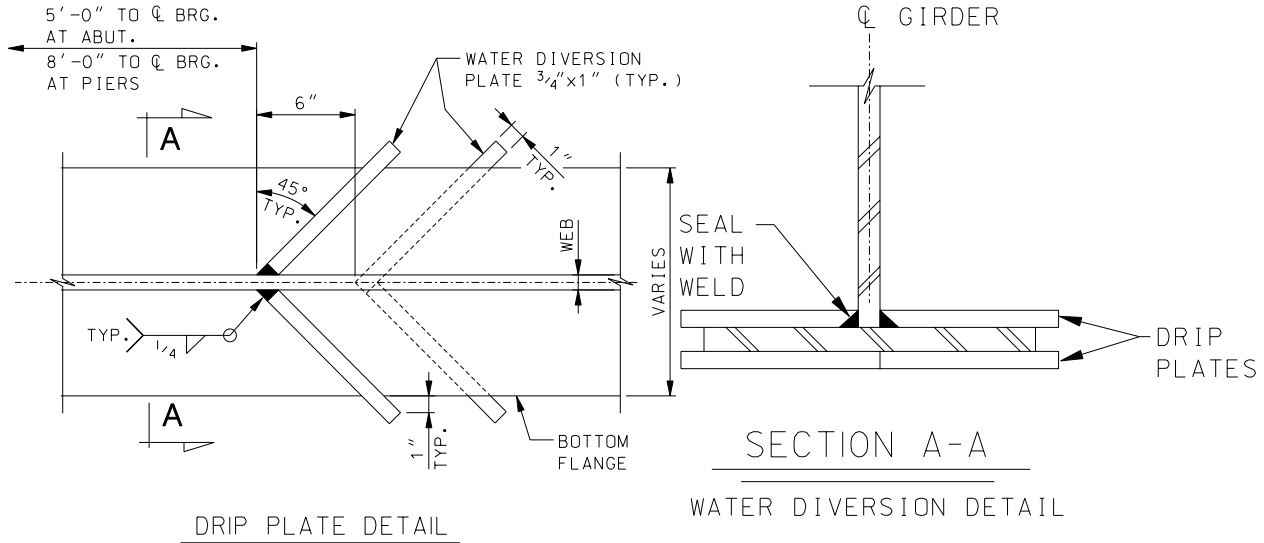
**Figure 6: Abutment Diaphragm with Keeper Brackets**

girder bridges, loads on each girder vary across the superstructure cross section, with the girder on the exterior of the curve attracting the most load. The exterior girder will govern the thickness based on b/t ratios for Grade HPS 70W Steel, which is a lower ratio than for Grade 50W. The remaining girder flanges were then sized with smaller widths based on load distributions. Bottom Flange widths varied across the

section from 18" to 26". UDOT also requires bottom flange width to be constant along the length of the girder.

**Weathering Steel Considerations**

Weathering steel is used for the steel girders and cross frames to eliminate the need for painting and still provide a natural color that fits well in a canyon setting. While there are significant economic advantages



**Figure 7: Drip Plate Details**

to using weathering steel, it is important to incorporate details which address the staining nature of the material. Drip plates are specified to be attached to the bottom flange of each girder on the high side of pier and the lower abutment. Girders are painted 5'-0" from the centerline of bearing at the abutments to resist rusting due to possible leakage at the expansions joints. The abutment diaphragms are painted as well. Figure 7 shows the Drip Plate details.

**DECK SLAB**

The deck slab is cast-in-place reinforced concrete with epoxy-coated rebar. There were two concerns with the deck. The first one was safety and the second was corrosion.

The deck is on an 835-foot radius with a 6% super-elevation and a 7% profile at the high end. Vehicles will have difficulty stopping and negotiating the curve if the deck is slippery. A requirement for an anti-icing system was included in the contract special provisions to prevent icing and eliminate corrosion problems associated with salting. Potential suppliers were given preliminary bridge design information and anti-icing system requirements. The suppliers submitted a concept design with estimated material and installation costs. The anti-icing system requirements were coordinated with UDOT's IT Section and the BOR for pump house and weather station location and system communication and control.

The anti-icing system is a fixed automated system that automatically treats the bridge deck with a liquid anti-icing agent. The anti-icing agent is automatically sprayed on the deck based on information provided by active and passive sensors mounted in the bridge deck along with atmospheric sensors. The system can be activated by remote telephone using data transmission or by manual activation from the pump house. The system is capable of dispensing varying quantities and types of liquid anti-icing agent in variable spray sequences depending on such road surface conditions at the site as black ice, snow or freezing rain. The anti-icing agent, potassium acetate, is non-corrosive. Its use should not affect the weathering steel since it will be contained within the bridge roadway. A similar system is currently being used by UDOT on the I-215 bridges at 6200 South in Salt Lake City.

A thin bonded polymer overlay was also specified to reduce corrosion problems by sealing the concrete deck and increase traction. The 3/8 inch overlay system provides a protective crack treatment and epoxy-urethane polymer overlay with a broadcast aggregate wearing surface. The system consists of surface preparation, applying a crack filling and bonding pre-treatment, and two coats of an epoxy-urethane polymer resin broadcast with a high wear, high skid resistant aggregate that chemically cures to provide an impervious wearing surface. The thin bonded polymer overlay is expected to extend the life of the deck at least 10 years. UDOT has used it on many urban bridges to extend deck life and reduce maintenance costs.

## CONSTRUCTION



**Photo 1: Pier 3**

Ames Construction was awarded the contract in the fall of 2004. They began driving piling for Pier 3 in March of 2005. There are 45 HP102 piles per footing and 2 footings per pier. Although very hard driving was expected in the new and existing dam cobble, only one out of the 90 piling driven for Pier 3 was out-of-tolerance. Pile No. 53 tilted about 7 degrees from vertical just before it reached end bearing at about 60 feet (See Photo 1). Pile 53 was an edge pile second from the corner. Rather than try to straighten or pull the pile, it was cut-off and left in place with adjustments to the footing rebar. A review analysis showed that it could be ignored in providing any support. Driving 90 piles for Pier 2 was completed with no problems, although the piling were driven about 20-feet longer than estimated from the design soil investigation. Grade 50 pilings were used for increased lateral capacity for seismic resistance.

The 10-foot thick footings were formed, the 9'-6" diameter column rebar cage was set and the footing reinforcement placed prior to the concrete pours in May of 2005 (See Photo 2). After the footings were placed, the columns were formed



**Photo 2: Footing pour at Pier 2**



**Photo 3: Partial columns**



**Photo 4: Splicing column cage**

and placed. Pier 3 columns were placed to a 35-foot height with 15' of rebar extending above to accommodate the required seismic lap splices at the mid-height of the columns. The column forms were made rectangular on the outside and octagonal on the inside to conform to the design aesthetic column shape (See Photo 3). In June 2005, the top part of the column cages for Pier 3 were set in preparation for the forming and placement of concrete. The Pier 3 columns will be about 80-foot tall (See Photo 4). The Pier 2 cap was being formed in July of 2005. The pier columns are complete as shown in Photo 5. The crest of the dam is in the background. The dam spillway is located between Piers 2 and 3. The sculptured look of the Pier 2 cap has taken shape with the removal of forms shown in Photo 6.

Structural steel fabrication started in September of 2005 with erection scheduled for October. Final completion is scheduled for November of 2006.

## **CONCLUSION**

The design of the US-189 Bridge over the Deer Creek Dam Spillway incorporated different engineering solutions





**Photo 5: Forming Pier 2 cap.**



**Photo 6: Pier 2 cap.**

to build a high level bridge on a curved alignment in a cold climate area subject to adverse weather conditions and seismic potential. The use of high performance weathering steel proved to be a practical constructible solution. The use of simple steel details also was beneficial in developing a seismic approach capable of being easily constructed.

## **ACKNOWLEDGEMENTS**

Utah Department of Transportation

## **REFERENCES**

AASHTO Standard Specifications for Bridge Design, 1996

AASHTO Guide Specifications for Horizontally Curved Highway Bridges, 1993

AASHTO Guide Specifications for Horizontally Curved Steel Girder Highway Bridges, 2003

NCHRP Report 424

UDOT Structures Division Design and Detailing Standards