

BANJO BILL ROCK CATCHMENT BASINS

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ABSTRACT

Public safety and maintaining environmental integrity are the two most important features highway departments consider when designing and procuring construction projects along scenic highway corridors. Design, contract procurement and construction of two rock catchment basins on SR 89A in scenic Oak Creek Canyon near Sedona, Arizona required innovative thinking to meet the many environmental and technical challenges presented on this project. Anchored micropile earth retention structures were chosen as the most feasible alternative to create the two basins to catch and contain falling boulders and rocks from entering the roadway and adjacent campground.

This paper will present and discuss descriptions of the environmental and geotechnical assessments, retention method selection, anchored micropile wall design features, alternative procurement technique used to contract the project, construction and site challenges, monitoring; and performance of the basin retention system.

PROJECT DESCRIPTION

The project site is located in Oak Creek Canyon approximately 11-kilometers north of Sedona, Arizona on State Route 89A. One side of the canyon consists of scenic sandstone cliffs, with Oak Creek following the roadway alignment below. The project side of the canyon consists of a boulder strewn talus slope with an inclination of 30 to 40-degrees rising towards the canyon rim which is located 430-meters above the roadway. In the slope across the roadway from the Banjo Bill day use site are two natural drainage swales which terminate at the roadway. These drainage swales are within approx 90-meters of each other, and are the sites for this project. For the purpose of the project they are referred to as the north and south basins.

PROJECT DESIGN CONCEPT

SR89A had been blocked on six occasions over a fifteen year period by rockfall and debris flows thru the two basins. In the fall of 1999, two 2-meter diameter boulders rolled down the slope between the two basins, breaking trees and coming to rest against the guardrail across the roadway. A debris flow north of the north basin in December 2003 included a 2-meter diameter boulder which bounced across the road and came to rest against a large tree in the campground area. There had luckily been no injuries from the rockfall and debris flow incidents.

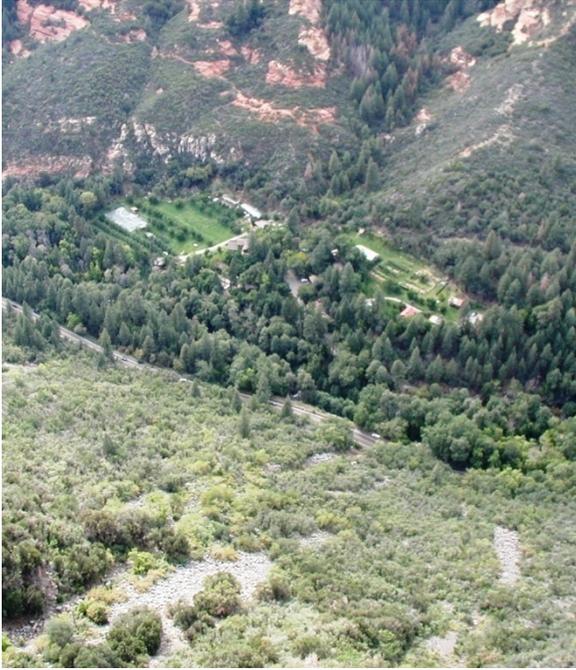


Photo 1 - Looking Down Canyon at Site



Photo 2 – Base of South Basin

Starting in 1991 ADOT commissioned several studies to develop concepts to deal with the rockfall and debris flow problem. The conclusion of the study by URS Corporation in 2002 was that the rockfall was attributed to undercutting of the talus slopes by water runoff resulting in loosening of the boulders in the slope. Options for reducing the risk to the roadway and public from the rockfall were considered. Scaling to make the slopes safer was not considered practical due to the extensive range of the upslope boulderfields. The Forest Service did not want to use fences for the containment due to aesthetic considerations. Realignment of the roadway was not feasible due to the close proximity of Oak Creek.

It was decided that the best plan was to provide basins at the base of the slope next to the roadway for containment of the rockfall. Based on volumes of previous slides, the basins needed to be designed to contain 190 and 380 cubic meters of material for the north and south basin respectively. Retaining walls up to approximately 9-meters in height would need to be installed to form the uphill side of the catchment basins. Due to the difficult terrain and ground conditions it was obvious that a unique retaining wall design would be necessary to meet the challenges of the site.

SUBSURFACE CONDITIONS

Geotechnical investigations were performed at the site in late 2000 and late 2003/early 2004 to determine the ground conditions and design parameters of the walls. The ground conditions were shown to consist of a steep boulder filled “talluvium” slope over Coconino sandstone. The top surface of the sandstone was somewhat irregular but was generally in close proximity to the roadway grade elevation, and sloped uphill from the roadway at approximately five-degrees.

Inclinometers and piezometers were installed in several of the borings to measure for slope movement and ground water elevation. The inclinometers indicated a slow downhill creep of the taluvium layer. The static water table elevation was approximately at the top of the sandstone layer.

CATCHMENT WALL DESIGN PARAMETERS

Due to the difficult boulder filled ground conditions and steep slope access conditions, it was decided that an anchored micropile wall would be best suited for the back walls of the catchment basins. An “A-frame” battered arrangement of the micropiles with a single row of anchors on a top cap beam was considered, but the large bending moments induced by the span between the top cap and sandstone embedment was considered to be more than the micropiles could support. Vertical micropiles laterally supported by multiple rows of anchors were determined to be the best solution.

Testing was performed on the collected samples to determine the design properties of the taluvium and weak sandstone. A variety of methods of analysis were used to examine the wall lateral design pressures, including finite element analysis. Analyses were run with the following parameters to examine the range of resulting lateral design pressures:

- Taluvium – $\phi = 42$ -degrees, c from 0 to 200-psf, $\gamma = 130$ -pcf
- Sandstone – $\phi = 41$ to 42-degrees, c from 0 to 1,000-psf, $\gamma = 130$ -pcf
- Top of Sandstone Elev assumed to be either at the base of the wall or 40% of the wall height above the base.
- Target factor of safety = 1.5

The finite element analysis produced a range for the rectangular lateral earth pressures of 62H to 100H psf (H = wall height). The 100H value was considered to be too conservative as it ignored all cohesion. The next most conservative value of 78H was selected for the wall design which considered $\phi = 42$ -degrees and $c = 100$ -psf for both materials. In addition to being used for determining the lateral earth pressures, finite element design methods were also employed in analyzing the stresses in the micropiles and shotcrete facings.

WALL DESIGN DETAILS

Each wall is approximately 27-meters long, and aligned to follow the contours of each basin location. The walls were installed to support the design height for the full length of the wall. The basic features of the walls are as follows:

- Vertical micropiles which are spaced at 41-cm on-center along the length of the wall. The piles consist of a 14.3-cm OD steel pile in a 25.4-cm diameter drilled hole grouted with neat cement grout. The micropiles provide vertical support for a shotcrete facing and the vertical load component of the anchors. The micropile embedment also provides lateral support for the base of the wall. The piles were designed to have adequate bending strength to support the full lateral soil design pressure while spanning between each row of anchors.

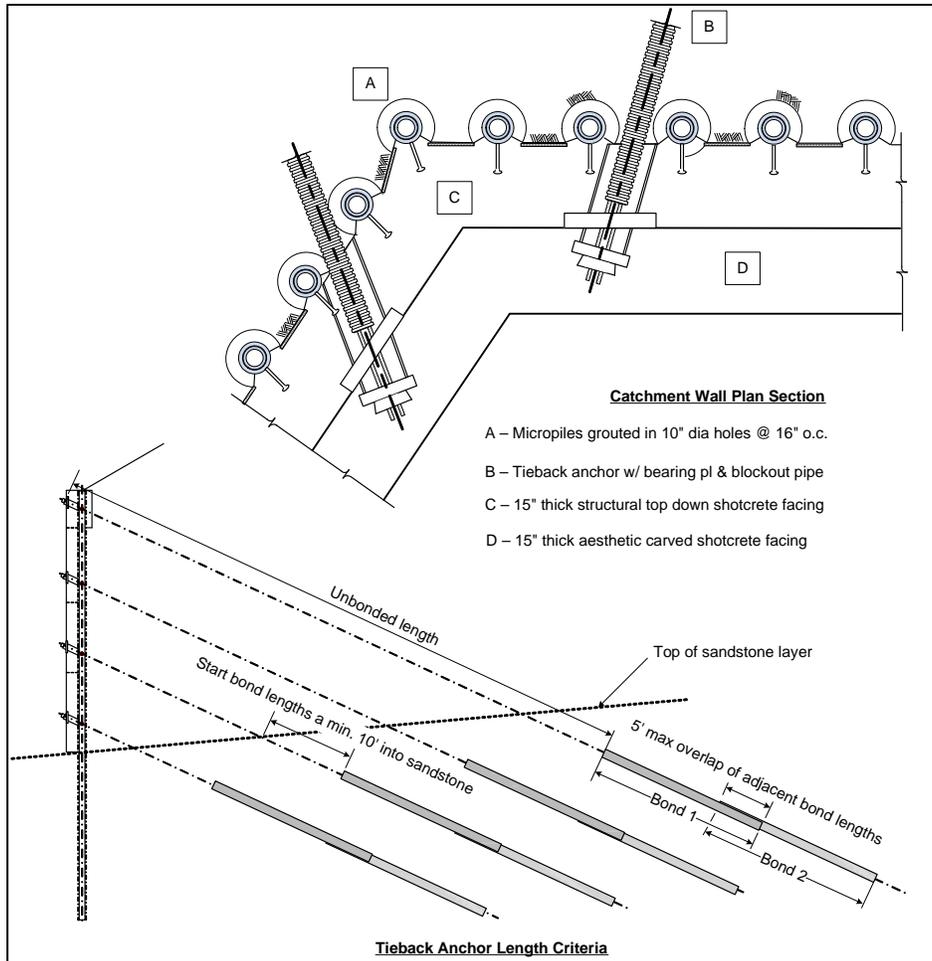


Figure 1 – Wall Design Details

- A 0.9-meter square reinforced concrete cap beam located at the top of piles to connect the piles together and provide a connection point for the top row of anchors.
- A 0.4-meter thick structural shotcrete facing which served to distribute the soil loads to the micropiles and provide connection points for the remaining rows of anchors. This facing was heavily reinforced to act as a waler along the anchor rows. The facing was installed in a top-down manner in lift heights which matched the anchor row spacing.
- The final walls were anchored with four rows of double corrosion protected tieback anchors. The anchors were connected to the structural shotcrete facing with bearing plates and embedded blockout pipes. The anchor bond lengths were founded in the underlying sandstone bedrock.
- A 0.4-meter thick aesthetic outer shotcrete facing which was carved and stained to emulate the features of the natural rock in the area.

Additional features of the basin construction included the following:

- Temporary soil nail walls which support the sides of the excavations from the ends of the micropile walls down to the edge of roadway.
- Gabion berms which form the permanent side slopes of the basins and bury the temporary soil nail walls.
- Drilled horizontal drains were constructed to relieve hydrostatic water pressure at the base of wall.

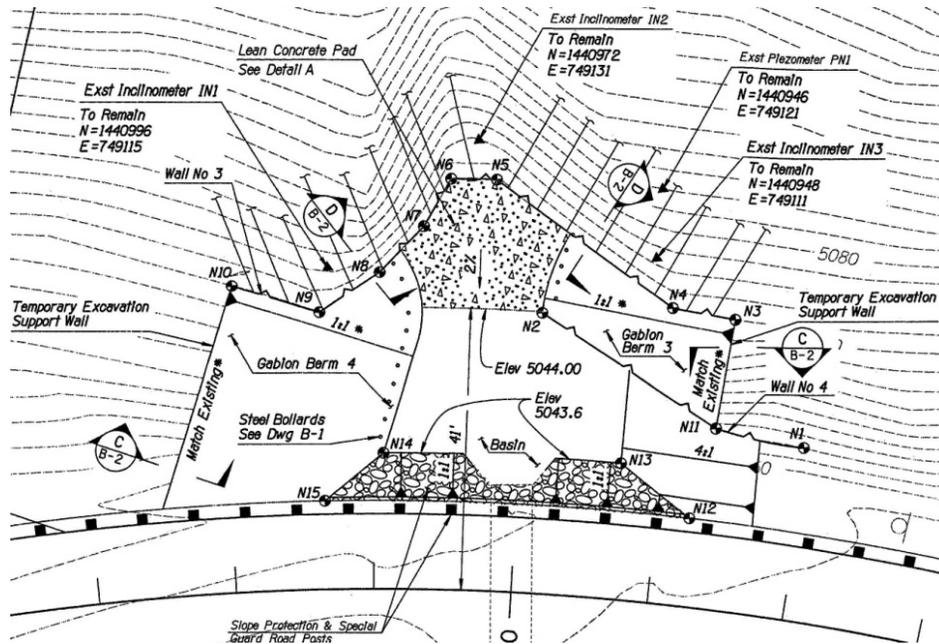


Figure 2 – North Wall Layout Plan

PROJECT CHALLENGES

The construction of the project presented many unique challenges, including:

- *Equipment Access* – Prior to the start of work the access along the wall alignment was a steep boulder strewn slope (approx. 40-deg inclination). Reinforced soil benches were built to provide a 9-meter plus bench width for access by the drill rigs and excavators along each top of wall location. The bench soils were reinforced with geotextile fabric at the South wall, and ecology blocks plus fabric for the North wall where room to build stable walls was more limited.
- *Difficult Ground Conditions* – The boulder filled upper soils were a challenge to the drilling of the micropiles and anchors. Care had to be taken to maintain verticality of the micropiles due to their close spacing and the need to thread the splayed anchors between them. Cased hole drilling techniques using down-the-hole hammers and “Super-Jaw” wing bits successfully met these challenges.
- *Limited Construction Schedule* – The project had to be completed during a construction window between September 1st, 2007 and March 30th, 2008. This limit was set to complete construction outside of the busy local tourist season, and



Photo 3 – North Wall Access Bench

to avoid interfering with the breeding season of the Mexican Spotted Owl, which is protected under the Endangered Species Act. Expanding the schedule outside of this allowed time was not an option. Double shifts, Saturday work, and contractor initiated alternative design changes aided in completing the project on schedule.

- *Environmental Aspects* - The Oak Creek Canyon is a very scenic and protected area of Arizona. The project is located on Coconino National Forest lands. The Forest Service played a major role in establishing the aesthetic requirements for the project design and monitored the impact to the site during construction. The foliage could not be disturbed outside of the direct wall locations. Weekly testing and inspection of the adjacent creek waters and spring water source for the local residences was done to monitor for contamination from the surface runoff and placement of grout in the anchors and micropiles.
- *Slope Stability During Construction* – There was concern for movement of the slopes during the interim phases of the top down wall construction. The support provided by the temporary access benches helped address these concerns. Movement of the slopes was monitored on a daily basis throughout the drilling work with reading of the inclinometers and the surveying of a series of points on the slopes above the walls.
- *The Need for a Successful Completion* – There was an initial failed attempt at completing this project in 2004. The General Contractor and Drilling Subcontractor were apparently not up to the site difficulties and contractor design aspect of the work. This first attempt resulted in a cancelled contract and completion of only 16 of the micropiles, which were subsequently removed as part of the successful wall installation.



Photo 4 – Shotcrete Fascia @ Anchor Row 2

The method of contracting the job was changed for the 2007 project. ADOT selected a procurement process where a select group of contractors were prequalified prior to bid time with their capabilities for completing the work established ahead of time. The project specifications required that the general contractor self perform the installation of the micropiles and tieback anchors.

ALTERNATIVE DESIGN

The project specifications allowed the contractor to propose an alternative design for the reinforcement of the micropiles and anchors as well as an alternative number of anchors. The original project design included five rows of anchors with a working load which ranged from 250 to 550-kN's. There was also a requirement for the anchor tendons to have a minimum steel area of 6.5 to 16-square cm which provided the stiffness values use in the wall design finite element analysis.

An alternative design was proposed by DBM which included reducing the number of anchor rows from 5 to 4, increasing the bending strength of the piles and shotcrete facing to support the larger span between anchor rows, and using an anchor tendon design which was based on strength instead of stiffness. The contract allowance for constructing the alternate design greatly aided in being able to meet the specified project completion date, which was in the interest of all involved parties.

CONCLUSION

The project was successfully completed in more ways than one. The walls have performed well to date as indicate by the installed instrumentation, which includes six



Photo 5 – Completed North Basin

inclinometer casings located above the wall for monitoring wall movements and two load cells on each anchor row on each wall (8-total) for monitoring changes in the anchor loads. No notable changes in the readings have been reported to date.

ADOT has a program for implementing a formal partnering procedure on all of their projects. This process was particularly successful and beneficial on this project and aided in dealing with the constant flow of structural and aesthetic design issues. The open lines of communication greatly aided to the successful completion of the project and the satisfaction of the Ownership group and Contractor. The project was recently announced as a winner of one of the 2008 ADOT Partnering Excellence Awards.

Key members of the team that completed the project include:

- Arizona DOT – Owner - Astrid Potter & Jim Monnett
- DBM Contractors – GC – John Bickford, Craig Henke, Paul Groneck
- URS Corporation – Structural Design – Randy Simpson
- NCS Consultants – Geotechnical Design – Naresh Samtani
- Schraner Associates – Architectural Design – Dave Schraner
- Forest Service – Owner – Judy Adams
- Boulderscape – Carved Shotcrete – Steve Jimenez
- Ground Support – Alternative Designer – Chris Wolschlag