APPENDIX

J Micropiles

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Specification Example - Micropiles for Earth Retention

Contract No. 04-1S2804
04 - SON - Rte116, PM 3.2
Duncan's Mills Retaining Wall
Construction completed in 2007.

Note – this project utilized the *2006 Standard Specifications*. Use the *2010 Standard Specifications* for your current projects with micropiles, the current micropile specifications are very different from those described here.

Description of Work:

The micropile retaining wall was constructed along the eastbound shoulder of Highway 116 in Sonoma County and separates the roadway from the Russian River, which flows west approximately 15 feet below the road surface. The wall consists of a reinforced concrete cap beam and curtain wall supported on micropiles. The face of the curtain wall has an architectural surface (textured shotcrete). Type ST-30 bridge rail (modified) is on top of the wall. The length of the wall is approximately 300 feet long. The 100 micropiles are 12-inch diameter with steel pipes installed to a depth of 50 feet and spaced 3 feet on center with another set of 100 piles set at an angle to form a buttress to ***stabilize the soil and the roadway***. Inclinometers (slope indicators) were installed in six micropiles.

Construction Issues:

Pile production was slow at the western end of the wall due to the hard rock conditions. At another location along the wall, loose sand and ground water contributed to the caving of the drilled holes during drilling while waiting for the holes to be grouted.

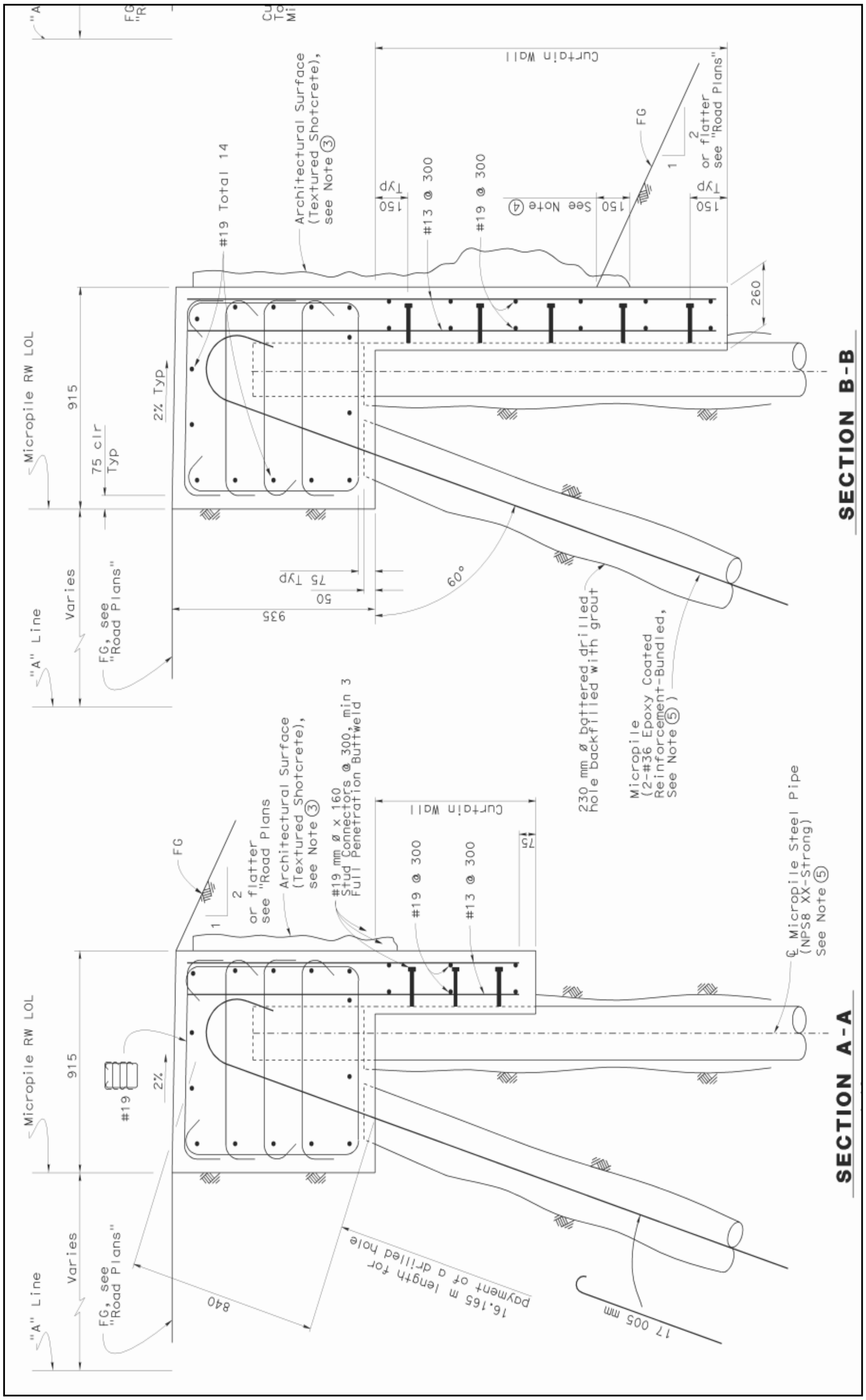


Figure J-1. Duncan's Mills Retaining Wall – Typical Cap Beam-Curtain Wall Cross Sections

Figure J-2. Duncan's Mills Retaining Wall – Cap Beam Construction.
Photo from Jim Cook, Sr Br Engr

Excerpts from Contract Special Provisions

Piling

General

Piling shall conform to the provisions in Section 49, "Piling," of the Standard Specifications, and these special provisions.

Micropiling

Micropiling consisting of steel pipe NPS 8 double extra strong and epoxy coated bar reinforcing steel that is grouted in place shall conform to the design requirements and layout shown on the plans and these special provisions.

Materials

Double extra strong steel pipe shall conform to the requirements of ASTM Designation: A53, Grade B. Galvanized pipe is not required.

The stud connectors shall conform to the provisions in Section 55, "Steel Structures," of the Standard Specifications and these special provisions.

Grout shall be non-shrink type. Grout shall conform to the provisions in Section 50-1.09, "Bonding and Grouting," of the Standard Specifications

Working Drawings

The Contractor shall submit complete project specific working drawings for the micropile system to the Office of Structure Design (OSD) in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications.

No micropile shall be installed until the Engineer has approved, in writing, the working drawing submittal for micropiling.

Construction

Steel pipe NPS 8 double extra strong and epoxy coated bar reinforcing steel shall be installed using centralizers as shown on the plans.The pipe shall be placed vertically and grouted in place. Grout shall be injected at the bottom of the pile and may be placed before or after placing the steel pipe.

Inclinometer Monitoring System

General

The Contractor shall furnish and install an inclinometer monitoring system consisting of slope inclinometer casing at the location shown on the plans. The Contractor shall use a specialist to design and oversee installation of the instrumentation system.

Measurement and Payment (Piling)

Measurement and payment for the various types and classes of piles shall conform to the provisions in Sections 49-6.01, "Measurement," and 49-6.02, "Payment," of the Standard Specifications and these special provisions.

Micropiles will be measured and paid for by the meter.

Case Study – Micropile Retaining Wall Foundation

Contract No. 12-043214
12-ORA-74 PM 13.3/16.6
Route 74 Widening Project (Anchored Walls)
Construction began in 2007.

Note – this project utilized the *2006 Standard Specifications*. Use the *2010 Standard Specifications* for your current projects with micropiles, the current micropile specifications are very different from those described here.

Description of Work

The structure work to be done consisted, in general, of constructing 13 anchored shotcrete retaining walls ***founded on micropiles***. The anchored shotcrete walls were founded on steel pipe micropiles and capped with concrete barrier slabs and concrete barriers. The applied architectural treatment included sculptured shotcrete at various walls and stain application at all walls.

The project site is located on Route 74 (Ortega Highway), between the Orange/Riverside county line and San Juan Creek Bridge. Route 74 is a two-lane highway cut into the side of the Santa Ana Mountains along the San Juan Creek valley. The existing roadway consists of substandard 3.05 meter (10 feet) lanes and no shoulders.

The purpose of the project was to bring the lanes to the standard 3.66 meter (12 feet) width with 1.2 meter (4 feet) shoulders on each side and to increase the sight distance for this 5.3 kilometers of roadway. Since the existing roadway is cut into the mountains, it was necessary to cut further into the mountains, build viaducts, or add retaining walls on the downhill (north) side of the road in many locations. A total of 20 structures (13 anchored retaining walls, 3 sidehill viaducts, and 4 retaining walls) were planned throughout the project limits. ***The anchor walls are supported on micropiles.***

Structure Representative Comments

The drilling operation and drilling conditions were difficult; however, the drilling was being completed rapidly. The solid rock is between 9,000 and 15,000 psi, the fractured rock is even more difficult to drill because it has a tendency to cave in and jam the drill stem.The time required to drill a 50 feet deep, 6-inch diameter anchor is approximately 1 hour. The time needed to drill a 21 feet deep, 12-inch diameter micropile is about 1.25 hours.

There were several factors affecting the anchored wall (rock anchor and micropile) drilling operation:

1. The experience of the drilling contractor.
2. The suitability of the equipment used.
3. The material characteristics of the earth at the site.

Drilling had been difficult. The "specialty" drilling subcontractor, required by the special provisions (documentation of 3 previous similar and successful installations), was directed to leave the job due to lack of performance. The special provisions also required the drilling to be done with minimal deleterious effects (airborne drilling dust) to the sensitive "environmental area" and endangered species (Arroyo Toad) in the creek 50 feet from the wall construction area. The constraints of the work area, the requirement to maintain the road open to traffic, requiring the drilling subcontractor to work at night (combined with the need to capture all dust), caused the drilling subcontractor to throw in the towel and cease operations. The drilling subcontractor had equipment that may or may not have been able to complete job.

The prime contractor, faced with this setback, started performing the drilling even though they had never done any drilling prior to this project. The contractor purchased an Austrian-made Triton drilling machine that was designed to drill vertical blast holes for mining operations and redesigned and modified it to drill horizontally. The machine created a hole using a pneumatic hammer and had the capability of capturing drill cuttings as well as using water to minimize dust. The rig was used for installing both the 6-inch diameter anchor holes 50 feet deep into hard and fractured rock, and the 12-inch diameter micropile holes.

(Comments and project photos from Victor S. Francis, P.E.)

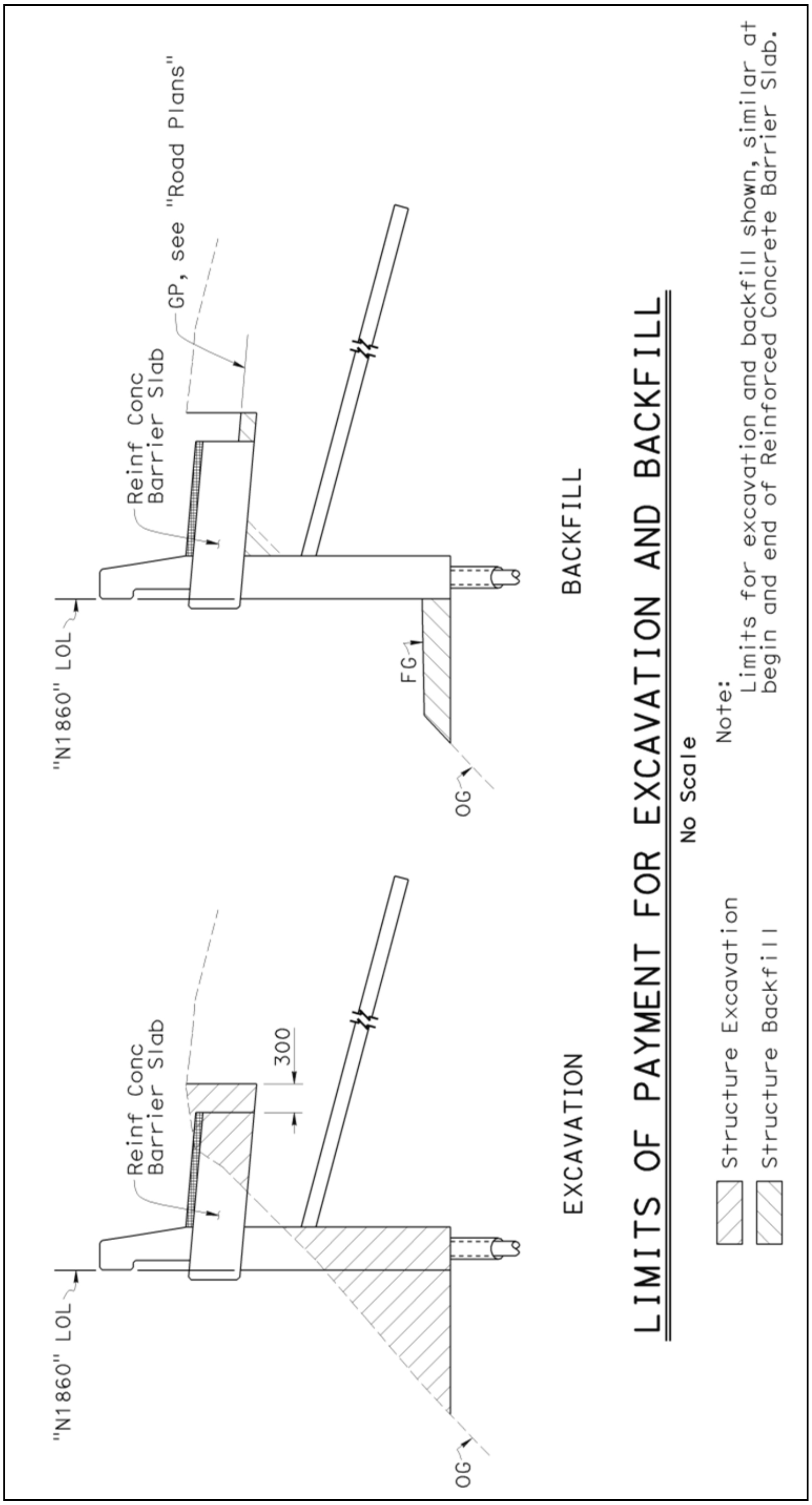
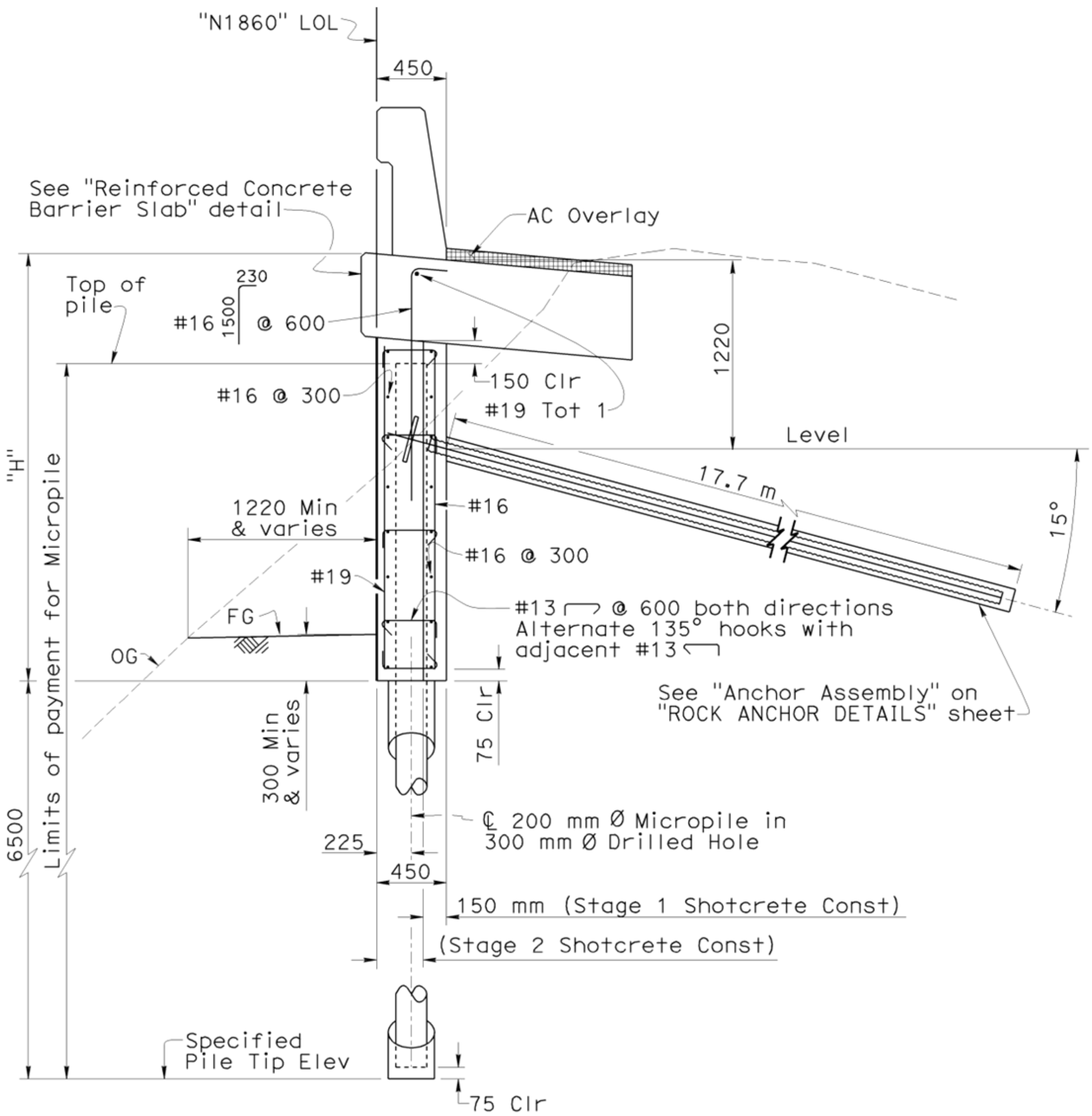


Figure J-3. Ortega Highway Excavation and Backfill Details.



TYPICAL SECTION
("H" LESS THAN OR EQUAL TO 4 METERS)

1:25

Notes:

- Equivalent size wire mesh reinforcement steel may be substituted in Stage 1 Shotcrete Construction upon approval of the Engineer.

- Anchor length is based on a design bonded length of 6.7 meters.

Figure J-4. Ortega Highway Micropile Details 1.

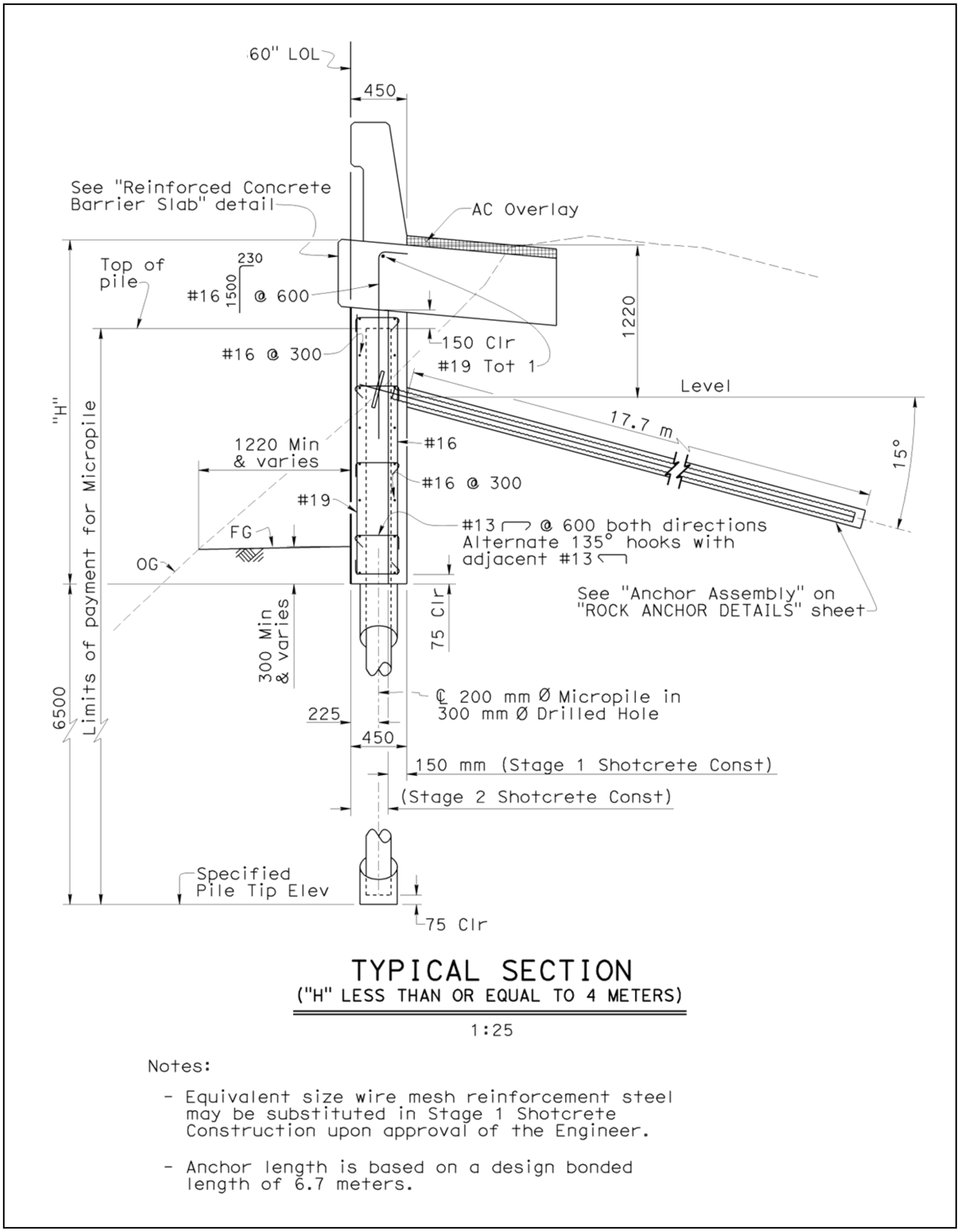


Figure J-5. Ortega Highway Micropile Details 2.

Micropile (NPS 8-XX Strong Steel Pipe) in a 300-mm dia drilled hole. On the ground –Sections of Rock Anchors to be installed later. Date: 2007.

Figure J-6. Ortega Highway Micropile Construction Photo 1.

Total wall length = 753 ft. The area is mostly comprised of very hard rock croppings. The road, Rte 74, is open to traffic. Date: 2007.

Figure J-7. Ortega Highway Micropile Construction Photo 2.

Case Study - Micropile Seismic Retrofit

Contract No. 04-0438U4 04-CC,Mrn-580-6.1/7.8,0.0/2.6
Seismic Retrofit of the Richmond-San Rafael Bridge (Br. No. 28-0100)
Work started August 2001; work completed February 2004.

Note – this project utilized the *1995 Standard Specifications*. Use the *2010 Standard Specifications* for your current projects with micropiles, the current micropile specifications are very different from those described here.

Description of Work:

The Richmond-San Rafael Bridge is one of the toll bridges in the San Francisco Bay Area. The Richmond-San Rafael Bridge includes two single-deck reinforced concrete approach trestles, two steel plate girder approach structures which convert from single-deck to double deck at each end of the bridge, two variable-depth, double-deck, cantilever-truss-type structures and 38 constant-depth 289 feet span, double-deck trusses which span between the two cantilever spans and between the cantilever spans and the approach structures. The structure has a combined length of approximately 21,335 feet (4.04 miles).

The bridge work on this project consisted of the replacement of the concrete trestle portion and the seismic retrofit on the rest of the structure. ***The seismic retrofit included constructing 481 micropiles in the substructure.*** The micropiles were installed underwater.

Per the special provisions, micropiles (substructure) were specified to consist of small diameter steel pipe reinforcement grouted in place and conforming to the design requirements and layout shown on the contract plans and the special provisions.

Figure J-8. Richmond-San Rafael Bridge (Photo from Caltrans Office of Geotechnical West Photo Gallery).

California Department of Transportation
Division of Maintenance

Structure Maintenance and Investigations

BRIDGE
INSPECTION
RECORDS
INFORMATION
SYSTEM

The requested documents have been generated by BIRIS.

These documents are the property of the California Department of Transportation and should be handled in accordance with Deputy Directive 55 and the State Administrative Manual.

Records for "Confidential" bridges may only be released outside the Department of Transportation upon execution of a confidentiality agreement.

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Figure J-9. BIRIS Cover Sheet.

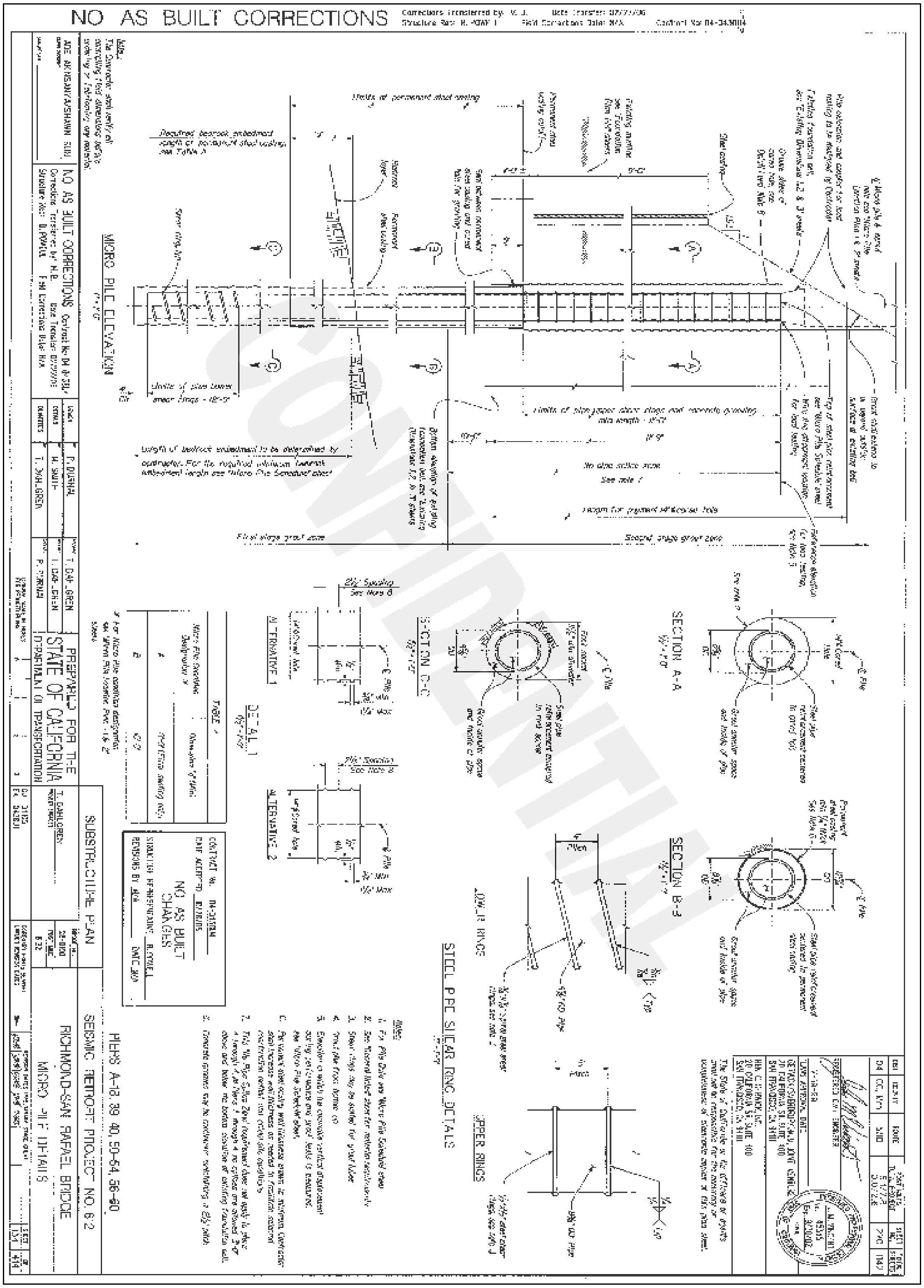

Figure J-10. Richmond-San Rafael Bridge Micropile Details.

Case Study – Micropile Retaining Wall Foundation (Devil's Slide)

Contract No. 04-1123U4, 04-SM-1 KP 61.2/64.9
South Portal Retaining Wall No.1 (retaining wall on micropiles) was completed in 2007.

Note – this project utilized the *2006 Standard Specifications*. Use the *2010 Standard Specifications* for your current projects with micropiles, the current micropile specifications are very different from those described here.

Description of Work

On Hwy 1, San Mateo County near the City of Pacifica in the San Francisco Bay Area, construction was completed in 2007 on the South Portal Retaining Wall No. 1, a ***retaining wall supported on micropiles.*** The retaining wall is on a steep cliff facing the Pacific Ocean. On one portion of the wall, the micropiles are battered in opposite directions providing lateral support. The retaining wall is also supported laterally with tieback anchors and with anchor bars connected to an anchor beam. On top of the wall is a concrete railing with chain link fence. A pedestrian sidewalk runs parallel to the concrete railing.

The South Portal Retaining Wall No. 1 is part of the overall work to re-align Route 1 at the south portal of the Devil's Slide Tunnel. The micropile wall was placed to provide a future parking lot and a turn-around when the tunnel is complete. In addition, the wall provides valuable work space for construction (i.e., haul road and construction yard) without closing Hwy 1 during the tunnel construction.

Total length of wall: 103 meters.
Total micropiles: 144 piles
Length of pile: 7.5m (piles 1 through 36); 10.0m (piles 37 through 144);

Construction Issues / Comments

- Comments from Peter Lam, P.E., Assistant Structure Representative:
- The micropiles were ConTech Titan System piles.
- The micropile contractor was Condon-Johnson & Associates.
- Specs required non-shrink grout, but normal grout was allowed.
- CT Foundation Testing Branch (FTB) specified pull tests into zones. Testing was by FTB. The specs required non-shrink grout, which hydrates quicker and cost 2 to 3 times more than regular grout. Regular grout is the industry standard for micropile installation. Initially, the CT Geotechnical designer felt comfortable waving the load test requirement if non-shrink grout was used. However since regular grout was used, load testing was required. The test results came out great with little or no movement. The CT Geotechnical designer speculated that a grout beam was created below grade due to the piles being spaced so closely.

- In some areas, soft soil caused grout bubbling through adjacent piles; the excess grout probably formed a grout curtain.
- Micropile operation is very messy operation; proper SWPPP measures are needed.
- Pile production/installation was approximately 1 pile per 30 to 40 minutes

Comments from Jeremy Light, Assistant Structure Representative:

- The original wall design did not provide enough embedment in the retaining wall for wind load stability. The revised design specified a spread "L" footing that provided the proper stability.
- The addition of the footing to the structure satisfied the wind load requirements and enabled the Contractor to backfill the wall prior to anchor rod (Sta. 1+00 to 1+36) & tieback installation (Sta. 1+36 to 2+03). Tiebacks were installed from the outside of the wall with a reach-over drill rig. The plans called for temporary supports (Sta 1+36 to 2+03) to temporarily retain the wall during backfill operations and the footing satisfied this. Installing the tiebacks from behind the wall and using them for temporary supports was considered but tieback testing and working around the exposed tendons during the backfill operation proved to be an inefficient method of construction. The Designer initially wanted tiebacks installed & tested behind the wall but it was brought up that the tendons would be compromised by "bite" marks from the wedges as well as the exposure of the tendons during the construction operations (a temporary waler was called out in the specs to achieve this; impractical with the geometry of the site). Following this, the Designer proposed installing three sacrificial tendons for testing, but this proved to be a problem with again, the issue of providing a temporary waler to support the tieback loads. This was the main construction issue of this project,"How do we build it?" The addition of the footing, at a cost to the State in this case, proved to be a good solution.

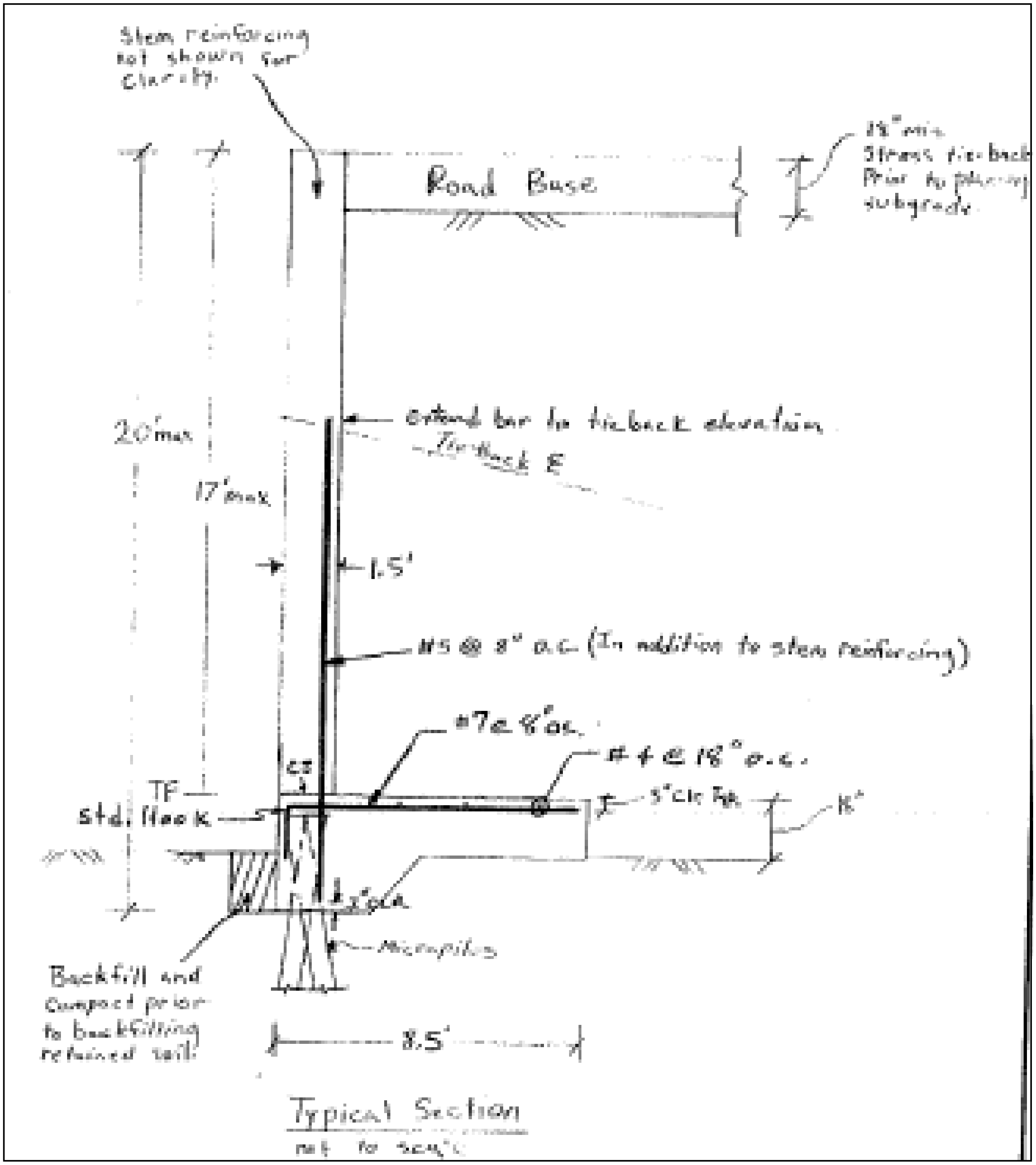

Figure J-11. Devil's Slide – Revised Wall Design Sketch – "L" Footing.

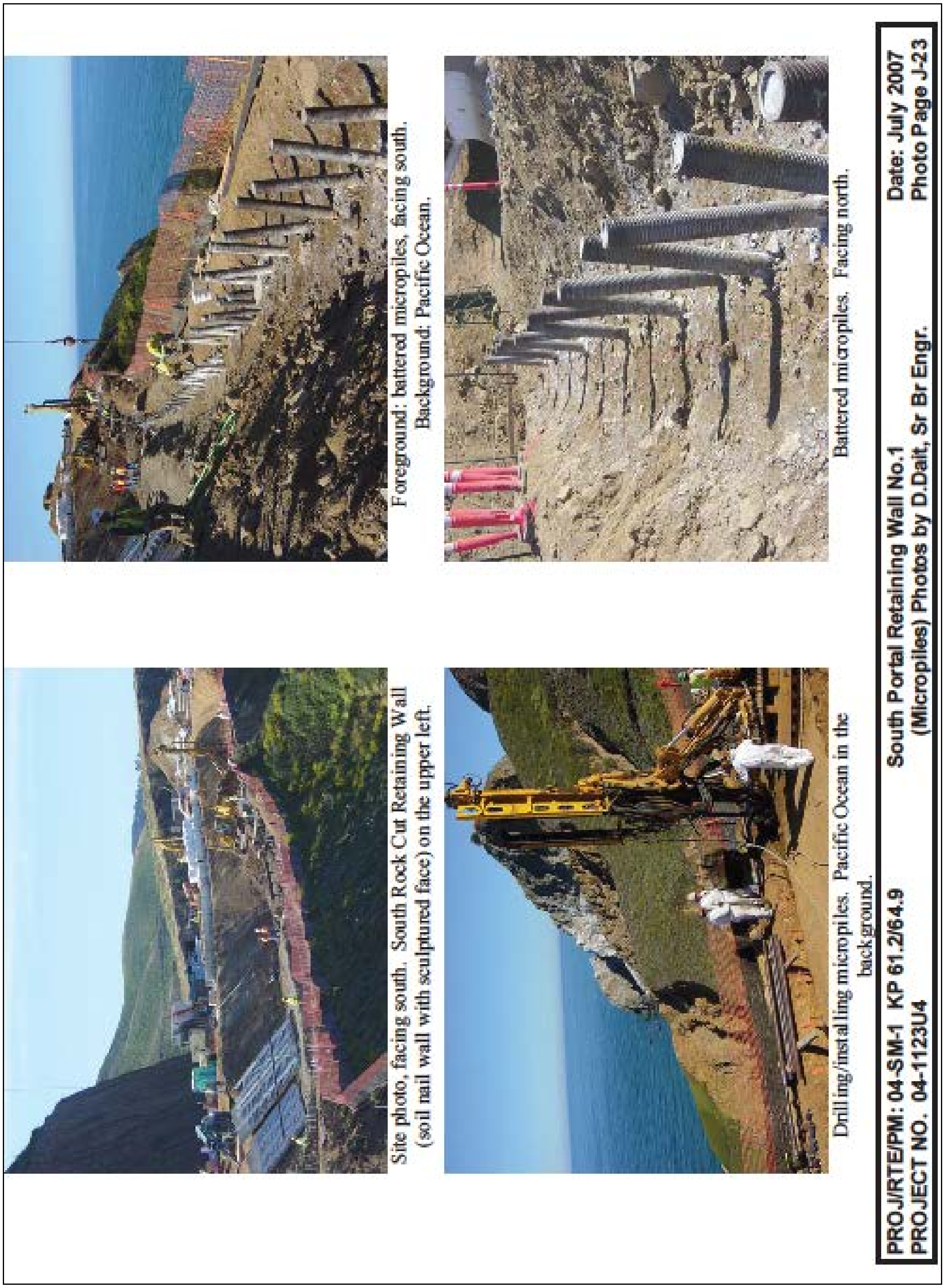

Figure J-12. Devil's Slide Micropile Construction Photos 1.

Figure J-13. Devil's Slide Micropile Construction Photos 2.

Left: Crawler mounted drill rig w/hydraulic rotary percussive head; hose grout hose on left. Right: excavator.

Grout mixer. Grout is pumped to the micropile drill rig.

Forklift. Background: South Rock Cut Retaining Wall (soil nail wall with sculptured face)

Cement sacks covered with plastic.

PROJ/RTE/PM: 04-SM-1 KP 61.2/64.9 South Portal Retaining Wall No.1 Date: July 2007
PROJECT NO. 04-1123U4 (Micropiles) Photo Page J-26

Figure J-14. Devil's Slide Micropile Construction Photos 3.

Figure J-15. Devil's Slide Micropile Testing Photos.

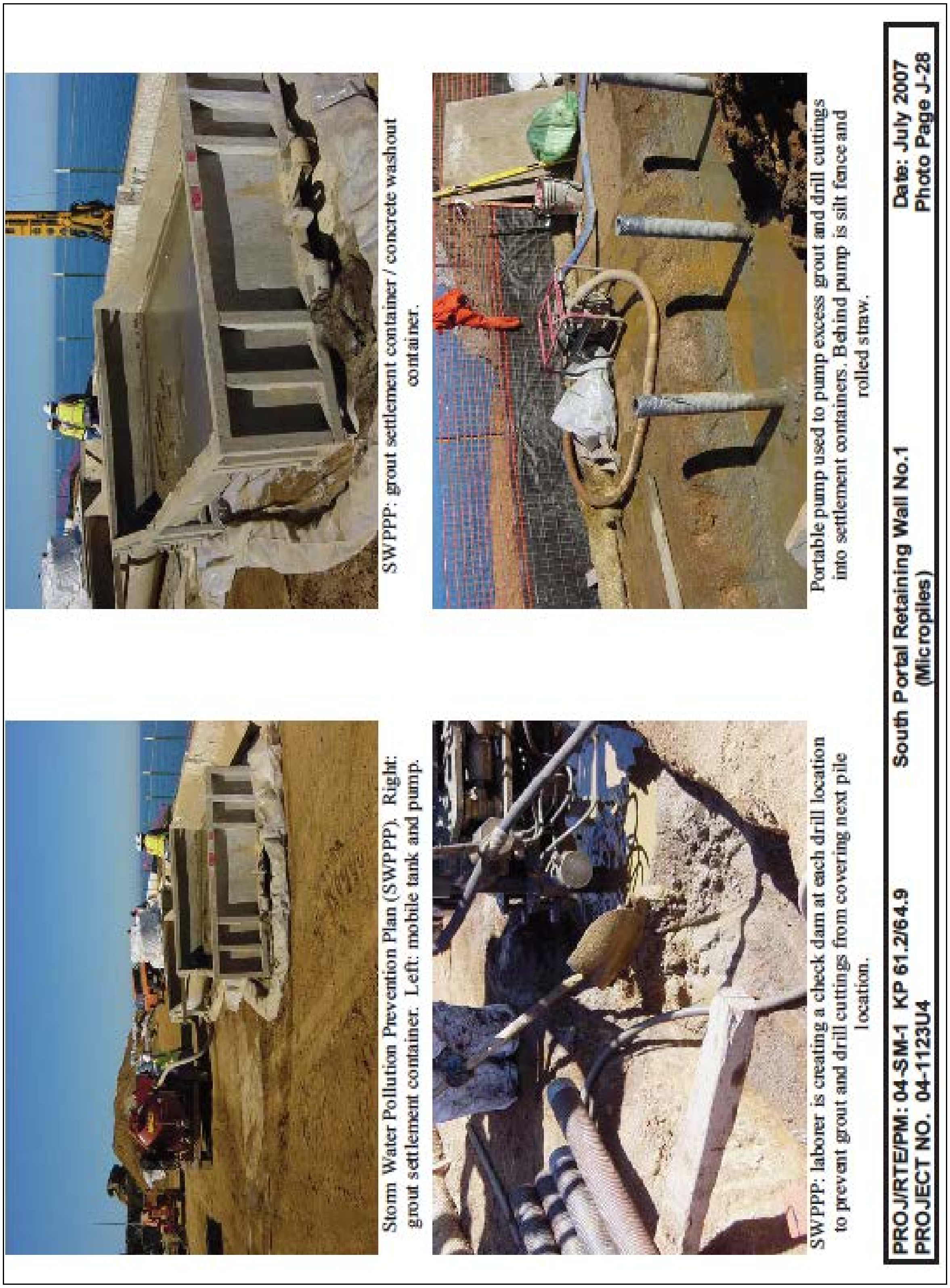

Figure J-16. Devil's Slide Micropile Construction – SWPP Measures.

Case Study – Micropile New Bridge Foundation (Spanish Creek Bridge)

Contract No. 02-373104
02-Plu-70 KP 56.5/57.2
Spanish Creek Bridge (Replace) Br. No. 09-0077
Construction began in 2010

Note – this project utilized the *2006 Standard Specifications*. Use the *2010 Standard Specifications* for your current projects with micropiles, the current micropile specifications are very different from those described here.

Description of Work:

The Spanish Creek Bridge (09-0077) replacement project consists of a newly constructed conventionally reinforced structure measuring 40 feet in width and 627 feet in length. The new structure replaces a 1933 steel truss classified as a fracture critical structure. A significant feature of this new structure is the solid concrete twin arch ribs spanning 368 feet rising 140 feet above the canyon.

The arch ribs are supported on footings at Piers 2 and 6 measuring roughly 33 feet wide, 24 feet in length and 17 feet high. Each footing is supported on a ***micropile foundation*** consisting of 77 piles oriented at an inclination of 55 degrees from horizontal, closely matching the inclination of the arch rib as it meets the footing. The micropiles are embedded in a weak rock foundation material.

The micropiles consist of a 7-inch outside diameter API N80 casing with 0.5-inch wall thickness, 20 feet in length, and with a gusseted bearing plate mounted on the upper end which is embedded within the pile cap. Through the center of the API casing there is a 1.75-inch diameter thread rod extending 40 feet to the bottom of a 10-inch diameter boring. The 7-inch casing was designed for compressive loads, whereas the threaded rod provides tensile resistance. Approximately 3500 linear feet of casing was required for this project.

Ten percent of the micropiles were compression tested by the Caltrans Foundation Testing Branch for contract compliance with a micropile test frame constructed as part of this contract.

The Federal Highway Administration's Pub. No. FHWA-SA-97-070, *Micropile Design and Construction Guidelines* (June 2000) was used as a guide during the design phase.

Construction Issues:

Pile installation progressed at a rapid pace. Drilling of the 10-inch diameter borings and installation of the piling was performed during 24 hour/day continuous operations. Typically 15 piles were drilled, installed and grouted within a 24-hour period.

The planned pile spacing was 3.2 feet. A few issues were noted during drilling and grouting. While drilling adjacent to an open hole, cross-communication to the adjacent hole was occasionally noted in the form of drill tailings being expelled through an adjacent open boring. The specifications did not preclude drilling next to an open hole or drilling next to a freshly grouted hole.

Drilling of the micropiles was performed by an excavator mounted articulated down hole rotary percussive hammer. Some drifting of the borings were noted, occasionally causing binding of the 20-feet long casing during installation breaking the plastic centralizers. The use of steel centralizers would alleviate the centralizer issue. The requirement for an alignment check after drilling with a follower device would be useful in identifying boring alignment deviations.

The specifications require the use of 7-inch outside diameter API (American Petroleum Institute) N80 casing with a marked API monogram. Additionally, “Buy America” provisions were was required due to the contract being funded with Federal funds. The FHWA micropile manual substantiates their recommendation for using API casing due to the wide availability of secondary material thereby reducing installation costs. Secondary casing is cut-off surplus material from oil field work. Once the secondary casing material is deemed secondary, the heat numbers are typically ground off and mill certification reports are no longer available. Proving domestic origin becomes impossible once heat numbers are removed. On this project, the Contractor was required to order a mill run of the API N80 material due to the need for 3500 linear feet. This increased the contractor’s anticipated material costs. Project costs could be reduced if an alternative casing material was specified.

Proof testing of 10 percent of the production piling was performed to 75% of the axial nominal resistance in compression. This was a good verification of the capacity of the micropiling. Due to the micropile test frame utilizing neighboring piles as reaction piles, perimeter pilings were unable to be tested due to the lack of reaction piles for test frame mounting.

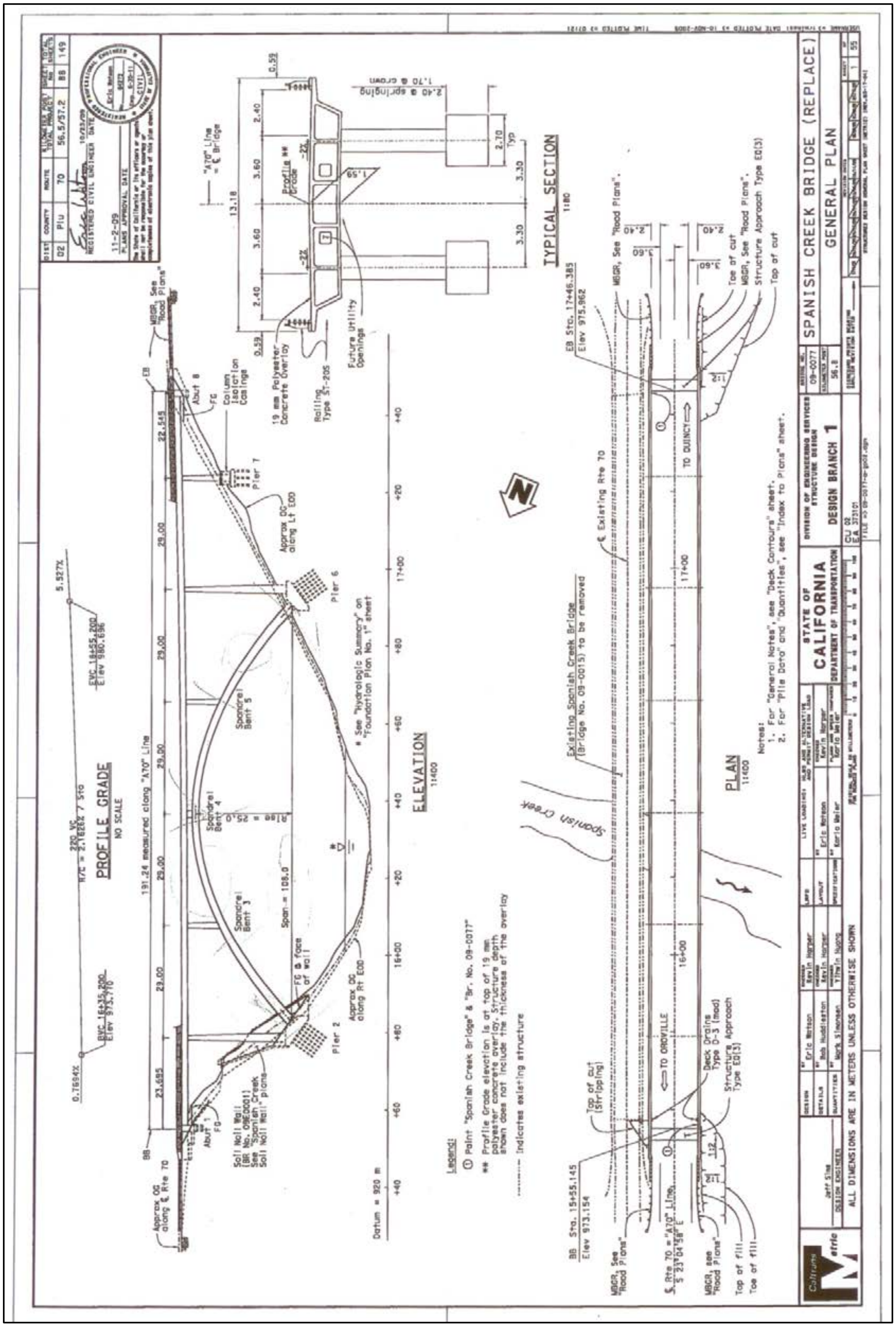

Figure J-17. Spanish Creek General Plan.

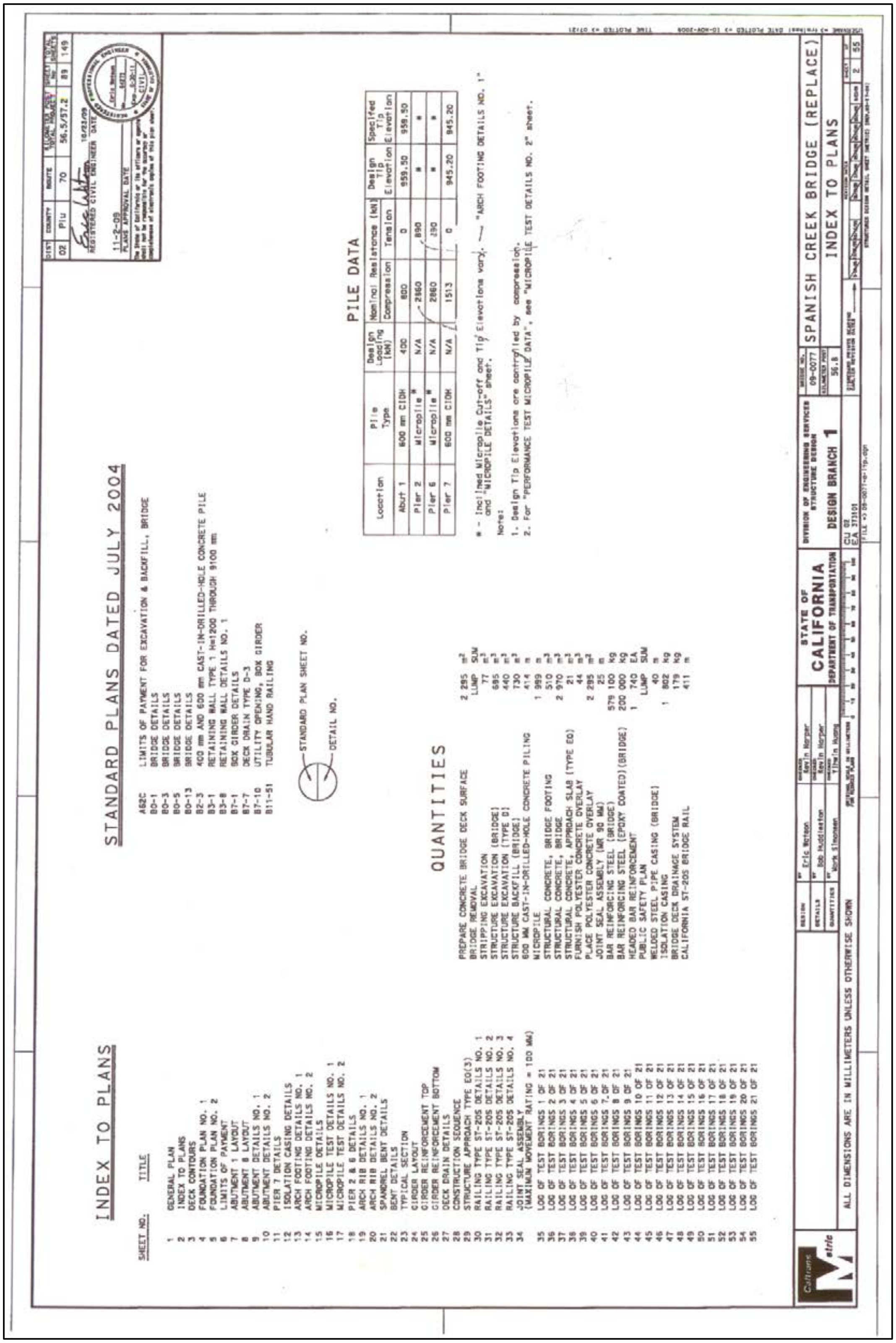

Figure J-18. Spanish Creek Pile Data.

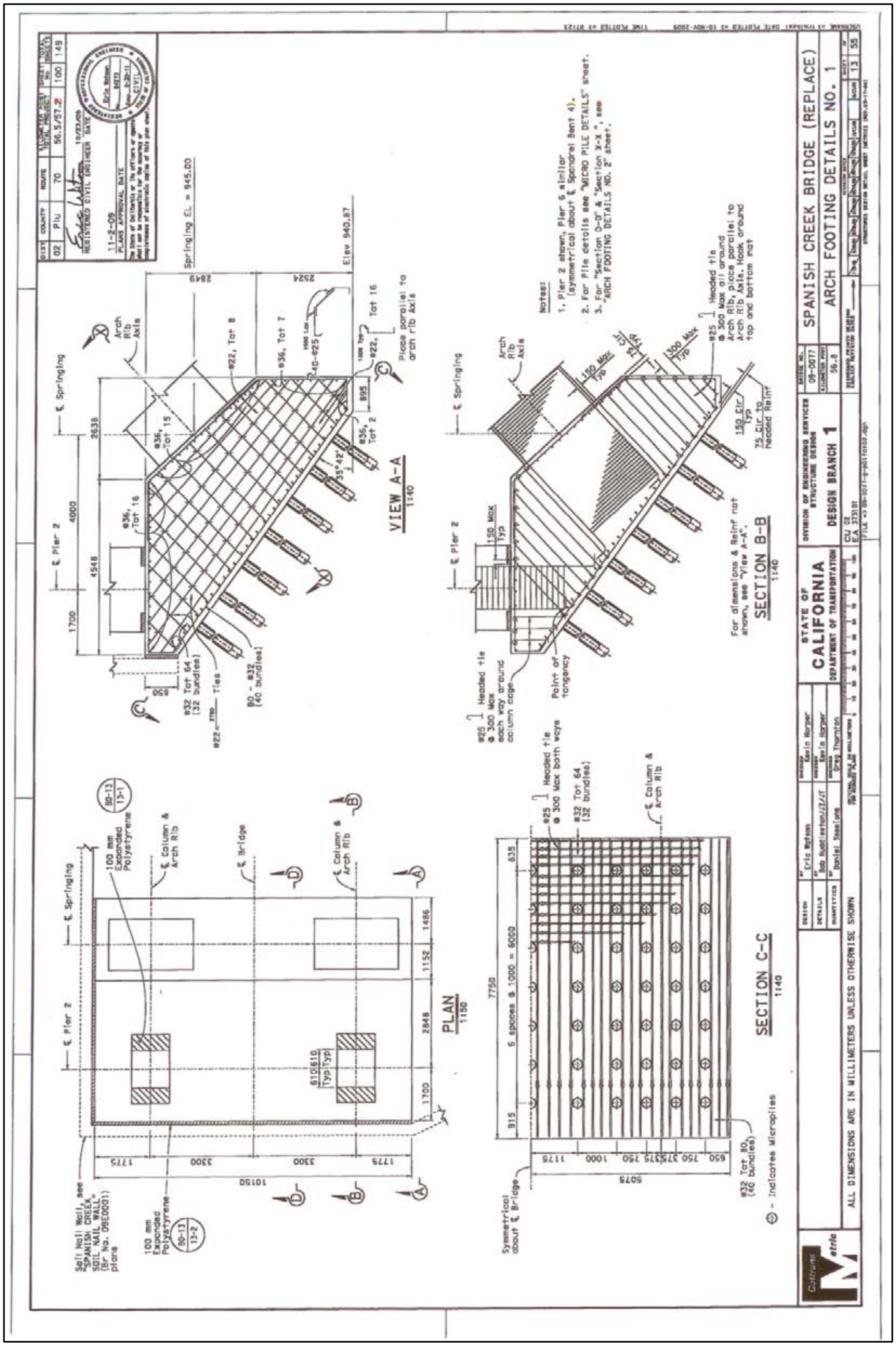

Figure J-19. Spanish Creek Footing Details No. 1.

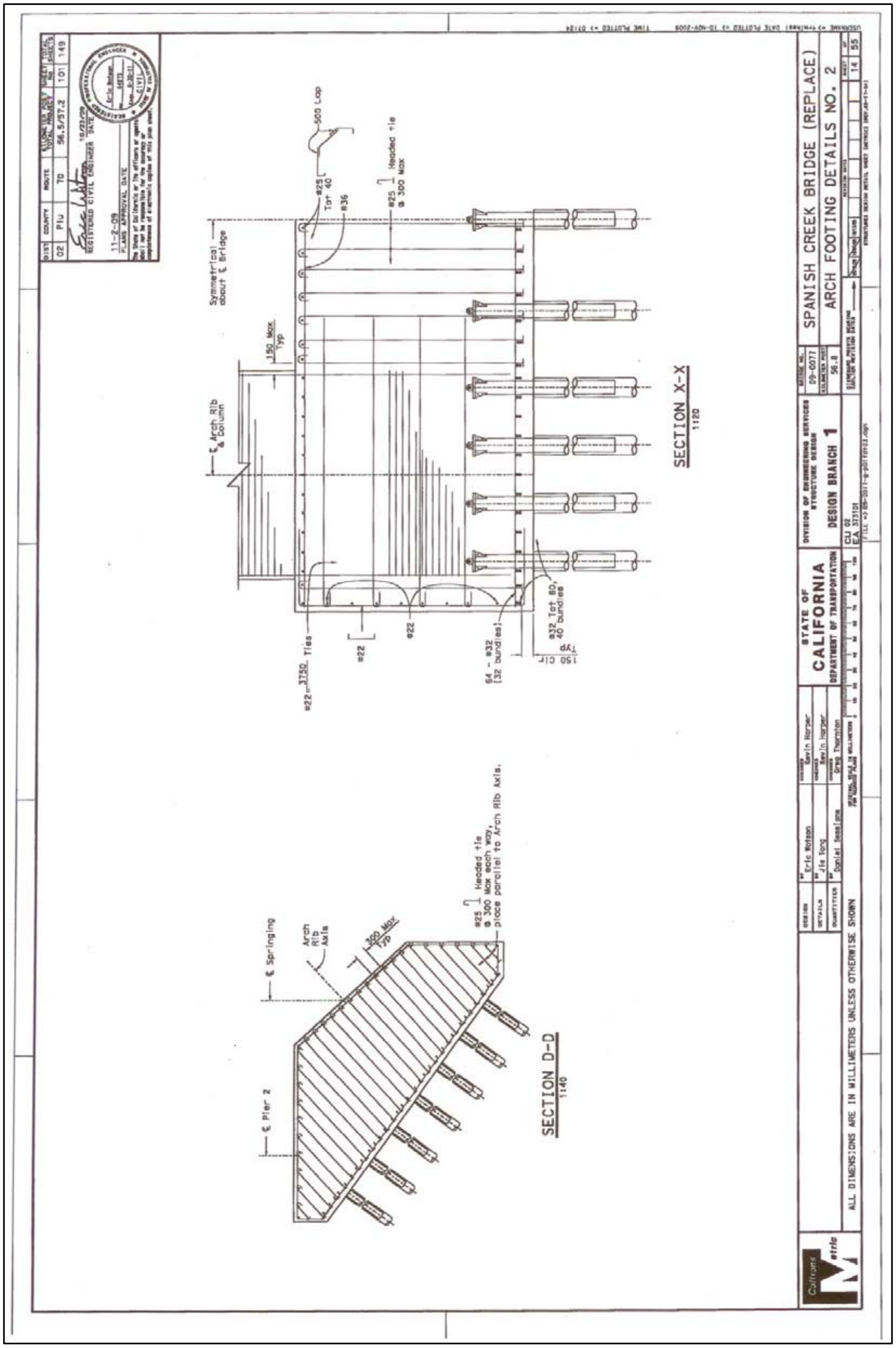

Figure J-20. Spanish Creek Footing Details No. 2.

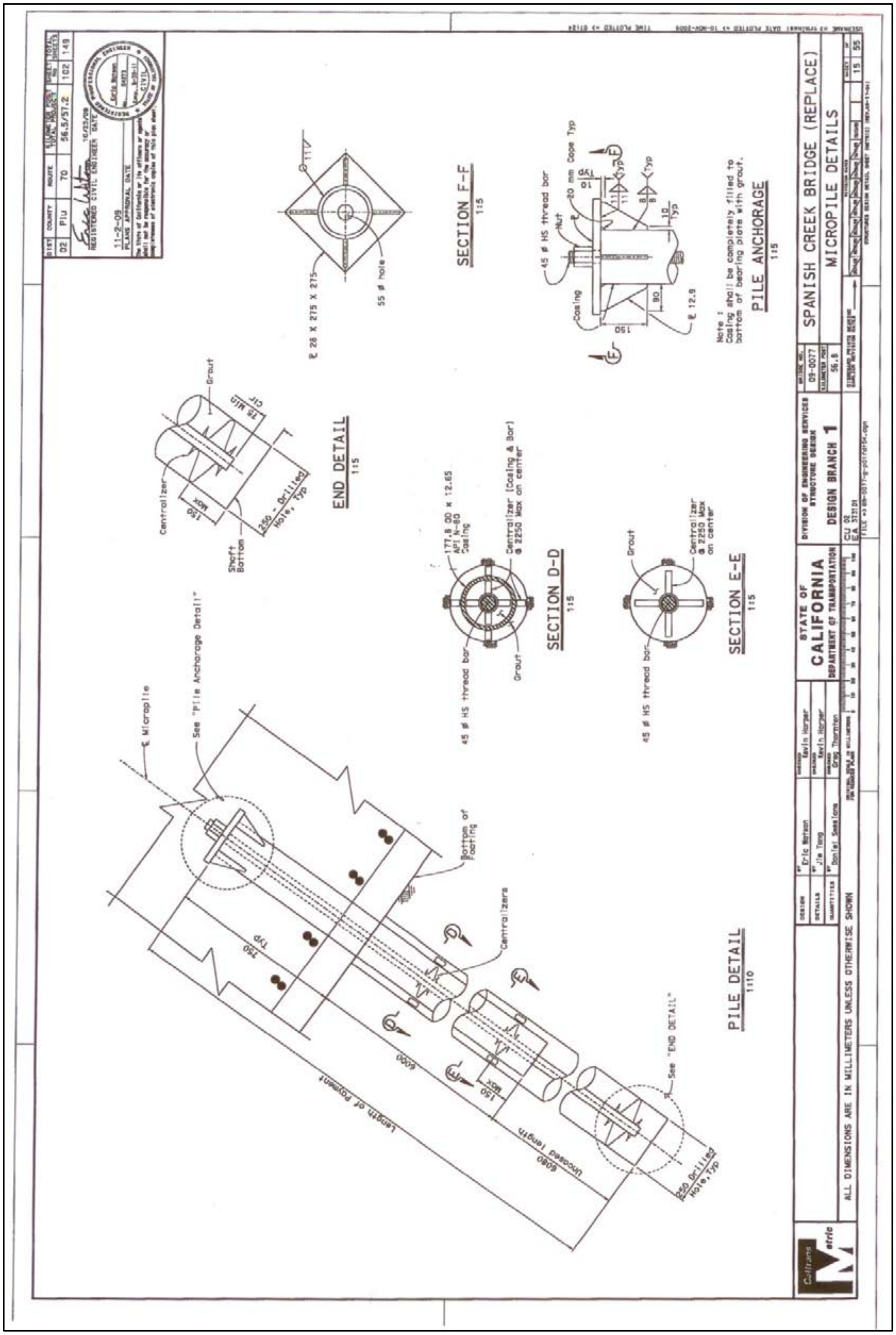

Figure J-21. Spanish Creek Micropile Details.

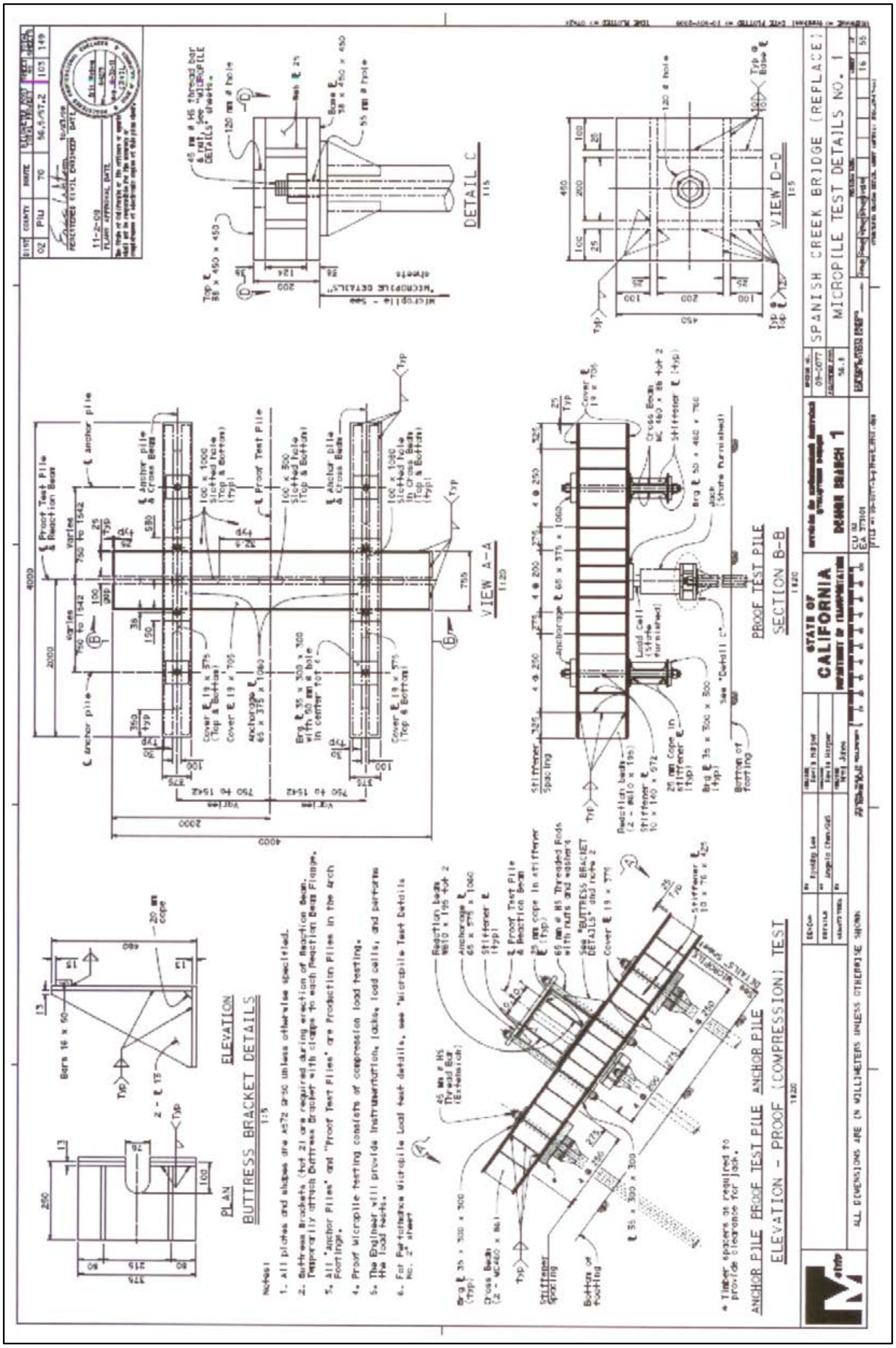

Figure J-22. Spanish Creek Micropile Test Details No. 1.

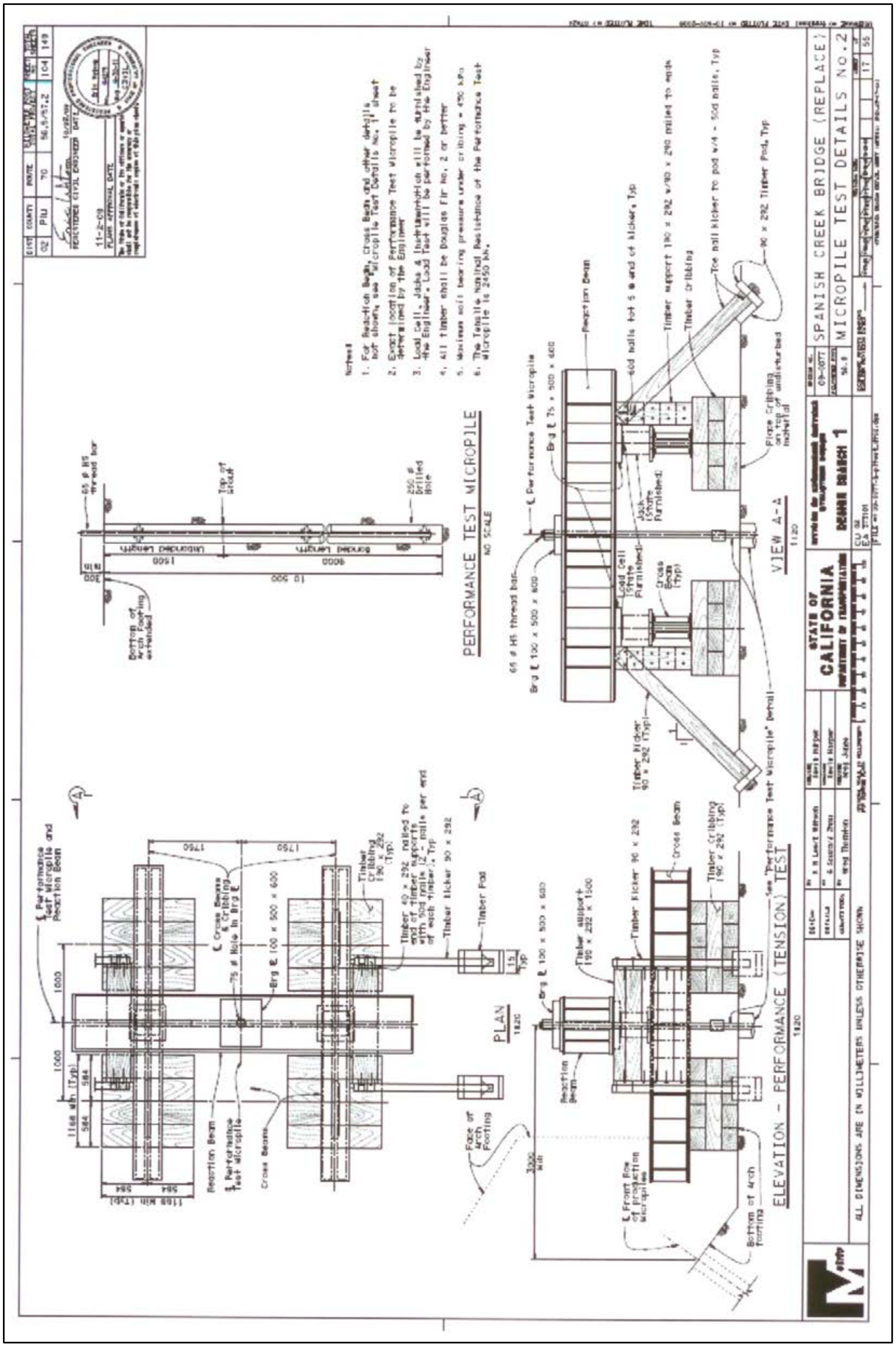

Figure J-23. Spanish Creek Micropile Test Details No. 2.

Figure J-24. API N80 Casing Prior to Threaded Rod Installation. Photo taken by Jeff Rothgery

Figure J-25. Micropile Assemblies Ready for Installation. **Photo taken by Jeff Rothgery**

Figure J-26. Foreground – Micropile Assembly Installation Underway with Post Grouting Tube. Background – Pier 6 Micropile Drilling with Articulated Down-hole Percussive Rotary Method. Photo taken by Jeff Rothgery

Figure J-27. Pier 6 Micropile Installation. **Photo taken by Jeff Rothgery**

Figure J-28. Pier 2 Installed Micropiles. **Photo taken by Jeff Rothgery**

Figure J-29. Pier 2 Installed Micropiles, Preparing for Load Testing. Photo taken by Jeff Rothgery

Figure J-30. Pier 6 Micropiles with Load Test Frame. Photo taken by Jeff Rothgery