MICROPILE FOUNDATIONS FOR RECONSTRUCTION OF HISTORIC LA LOMA BRIDGE IN PASADENA, CALIFORNIA

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ABSTRACT:

The historic La Loma Bridge, which crosses the Arroyo Seco in Pasadena, California, was built in 1914 to replace the 1898 California Street Bridge. The bridge is an open spandrel concrete arch bridge with a neoclassical design, which draws inspiration from Greek and Roman architectural design features with Renaissance interpretations of the classical forms. Inspired by the City Beautiful Movement, the bridge was built in response to the advent of the automobile and the increase in population in the surrounding areas.

Built just a year after, the La Loma Bridge, pictured in Figure 1, displays similarities of its “big sister”, Pasadena’s famous Colorado Street Bridge, nicknamed “Suicide Bridge”, which spans the Arroyo Seco less than a mile away. While the Colorado Street bridge connected Pasadena to Los Angeles, the La Loma Bridge played a substantial part in Pasadena’s development of the west side of the Arroyo, largely called San Rafael Heights, which was annexed by the City of Pasadena by the completion of this bridge. For several years, the two bridges were the only crossings over the Lower Arroyo and represent the city’s economic and physical need to facilitate automobile traffic over the Arroyo, while also providing impressive picturesque structures for the nearby communities.

Figure 1 – Original La Loma Bridge

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On July 14, 2004, the bridge was added to the National Register for Historic Places under both Criterion A and C for its significance in transportation history and embodiment of distinguishing features of a Neoclassical bridge design and reflection of the City Beautiful movement in Pasadena. Besides its deck rehabilitation in 1962, the bridge remained unchanged from its original design and appearance. However, similar to when the Colorado Street Bridge was closed for a substantial seismic retrofit in 1989, the La Loma Bridge was in need of an extensive seismic retrofit and rehabilitation, made evident by its visual signs of distress through concrete spalling and exposure of reinforcing members.

At the end of 2014, the City of Pasadena advertised the La Loma Bridge Reconstruction project, which included the construction of new abutments and pier structures, shoring of existing spandrel columns and archways, and demolition of existing concrete slab-girder deck and replacement with new post-tensioned concrete box girder superstructure. Micropiles were the selected foundation type for the new pier structures largely due to the limited access at the bottom of the Arroyo Seco Canyon and between the existing bridge structures. The project was a collaborative effort between the City of Pasadena and California Department of Transportation with an estimated cost of approximately $16 million, funded by approximately $13.3 million in federal funds and the remaining in city funds. The City selected OHL USA, Inc. as the general contractor for the project, who listed Malcolm Drilling Co., Inc. as the micropile subcontractor. Construction began in June 2015 and is expected to be completed in early 2017.

PROJECT DESCRIPTION:

In an effort to preserve the historical value of the bridge, the project design consisted of constructing a completely new bridge superstructure supported on new abutments and pier columns built within the existing bridge structure. As such, the original bridge structure (spandrels and archways) would become the new bridge’s stunning and historic façade. The project site is located at the bottom of the Arroyo Seco canyon, which consists of a concrete lined channel and a narrow access road surrounded by dense vegetation and popular pedestrian trails, with the west side of the project only accessible by a small pedestrian bridge. As such, access for any type of construction was challenging. Micropile foundations were selected for the structural support of the new bridge in part due to the limited access within the Arroyo Seco canyon and the minimal disturbance and versatility the micropile equipment and installation process provide. See Figure 2 for the profile of the existing and proposed bridge and Figure 3 for a typical cross-section of the proposed and existing bridge.

The micropile foundations were advertised as a design-build foundation element to be designed to increase the uplift and compression capacity of the four new pier footings. The project specifications also required four (4) preconstruction verification test micropiles, two (2) on each side of the bridge, to verify and demonstrate that the design-build micropiles meet the required capacity. In addition, two (2) production micropiles per footing, for a total of eight (8) micropiles, were required to be proof tested.9

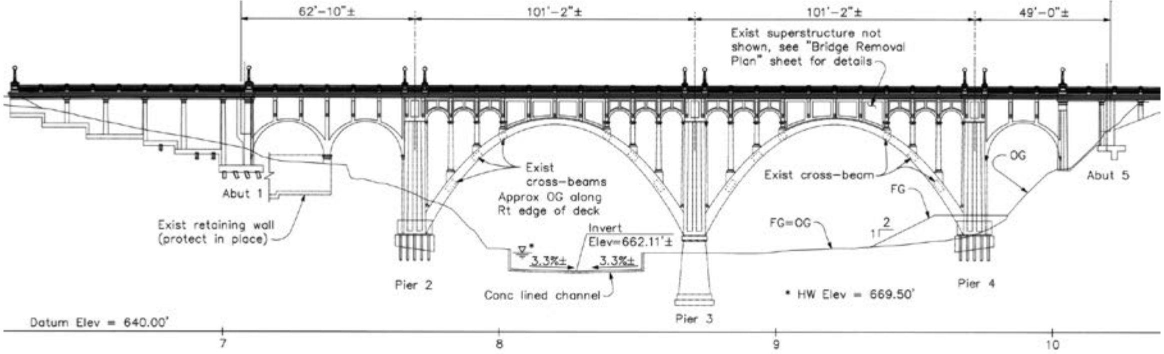

Figure 2 – Proposed Bridge Profile

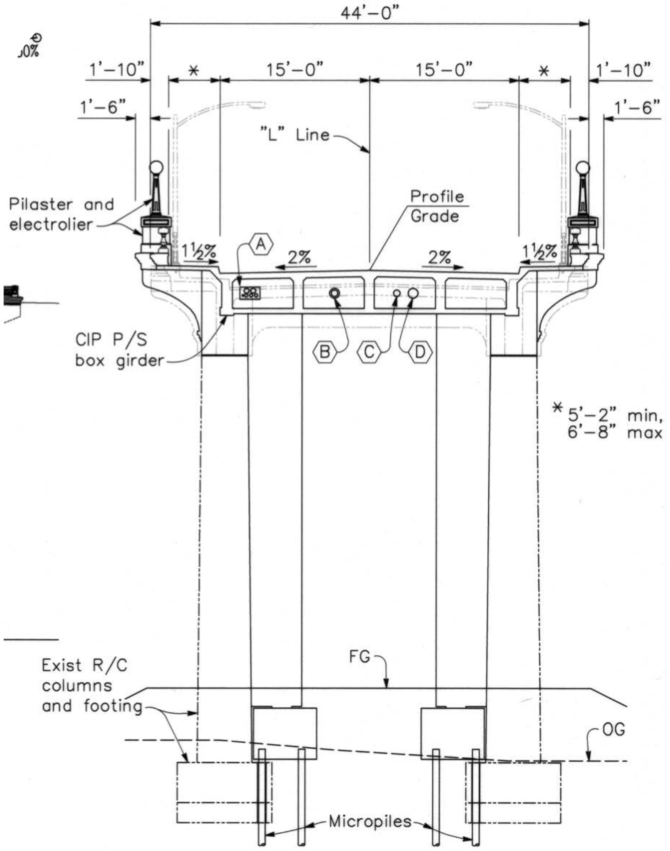

Figure 3 – Typical Cross-Section

SUBSURFACE CONDITIONS:

The existing bridge spans across the Eagle Rock Fault, which divides the underlying bedrock formations of which the bridge is founded on. On the east side of the fault (Pier 4), the site is underlain with highly weathered and oxidized intrusive quartz diorite rock, while the west side (Pier 2) is underlain with the Topanga Formation, a weathered sandstone conglomerate sedimentary rock.

Various depths of fill and recent alluvium were encountered at the surface at the bottom of the Arroyo Seco canyon consisting of interbedded layers of poorly graded to well graded sand with variable amounts of gravel and abundant cobbles and boulders within the fill layers. The geologic cross-section along the bridge profile is illustrated in Figure 4. All production micropiles were located at areas were the bedrock formations were exposed at the ground surface. Pre-construction photos of existing ground surface are shown in Figure 5 and 6 at Pier 4 (quartz diorite bedrock) and at Pier 2 (Topanga Formation), respectively.

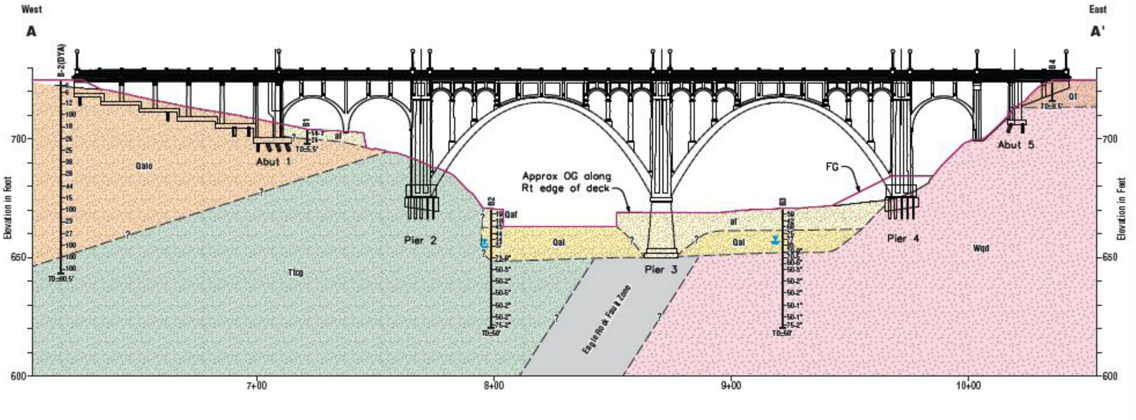

Figure 4 – Geological Cross-Section

Figure 5 – Pre-construction Conditions at Pier 4 (Quartz Diorite)

Figure 6 – Pre-construction Conditions at Pier 2 (Topanga Formation)

MICROPOILE DESIGN:

The proposed bridge foundations consist of forty (40) new micropile foundations with ten (10) micropiles per pier. Figure 7 illustrates the proposed foundation plan for the new bridge structure with the micropile foundations located at both Pier 2 and 4. At each pier location, the proposed pier footings are founded partially on the existing bridge foundation and partially on the exposed bedrock formation with the micropiles bridging through the existing footings with casing, which plunges into the underlying bedrock. Each micropile is designed to have a capacity of 270 kips in compression and 45 kips in tension.

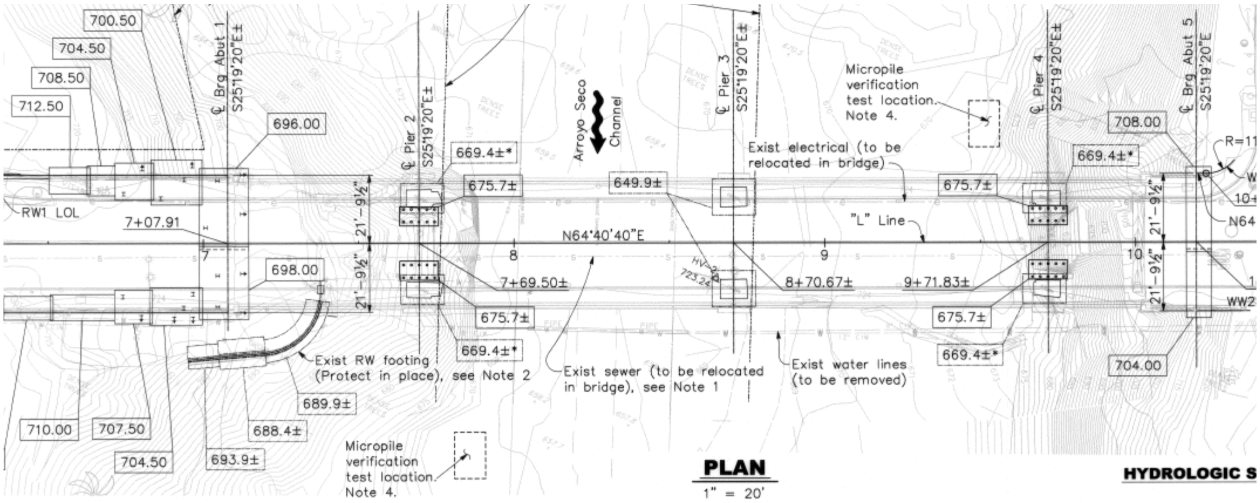

Figure 7 – Foundation Plan with New and Existing Structures

The micropiles are designed in accordance with the recommendations presented in FHWA NHI-05-039. An ultimate bond stress of 60 psi for gravity grouted micropiles (Type A) was selected for both the quartz diorite and sandstone bedrock formations based on recommendations in the geotechnical report, the PTI Manual "Recommendations for Prestressed Rock and Soil Anchors", and past experience. For the design load of 270 kips, a bond length of 24 feet was determined based on utilizing a factor of safety of 2 and a micropile diameter of 10 inches. In order to meet the structural demand for the specified design load, a continuous #20 Grade 80 reinforcing bar was selected along with an 8.625" x 0.593" Sch. 100 steel pipe to plunge through the existing bridge footing, where applicable, and into the bedrock formation a minimum of 4 feet from bedrock surface or 3 feet below the bottom of footing. The length of pile spanning through the existing bridge footing was not counted as attributing to the frictional capacity of the micropile resulting in an overall micropile depth of approximately 30 feet. The micropile detail is shown in Figure 8.

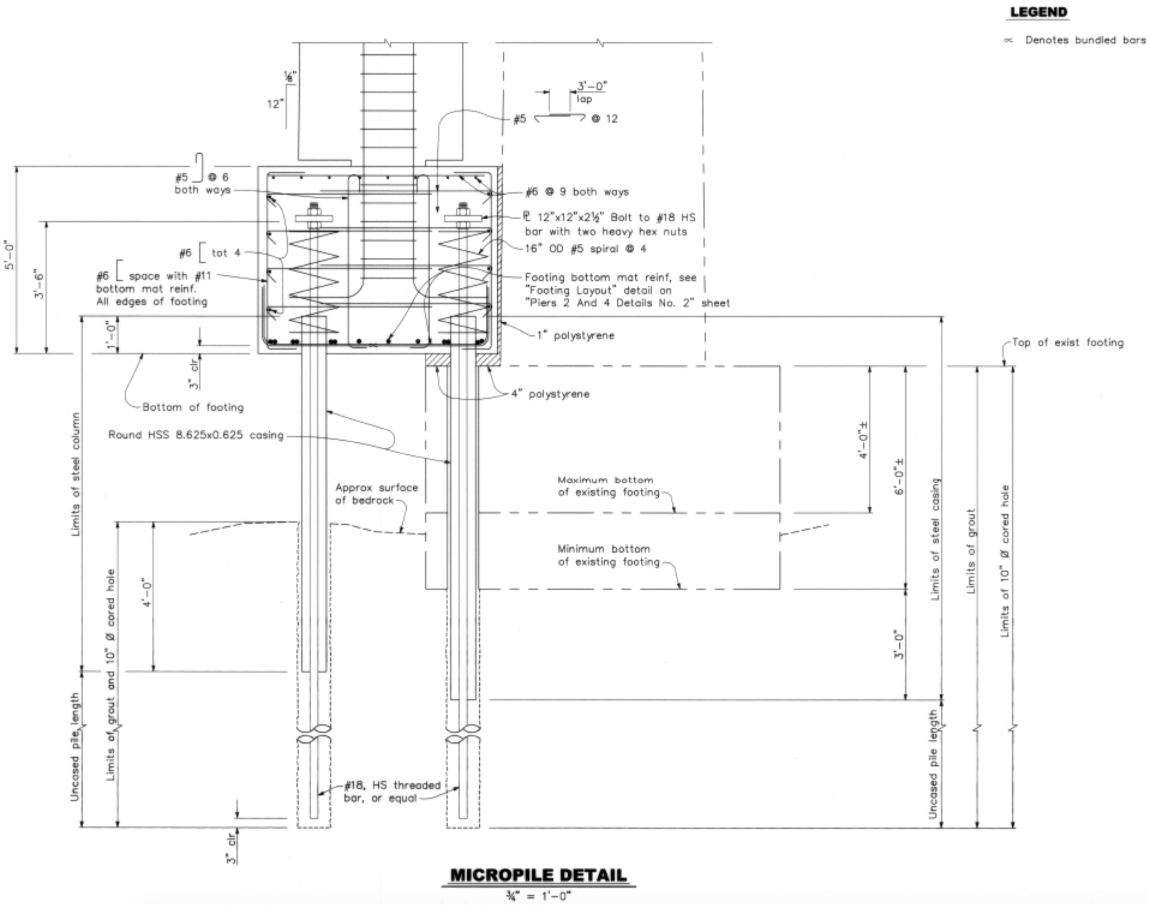

Figure 8 – Typical Micropile Detail

For verification and proof testing, the project specifications required the micropiles to be tested to 200% of the design load, which resulted in a maximum test load of 540 kips, which was tested in tension for both the preproduction verification tests and proof tests of production micropiles. In order to facilitate testing of the grout-to-ground bond value to the required tension load, the reinforcing bar was upsized to a 2 ½" Grade 150 bar.

MICROPILE CONSTRUCTION:

Due to the limited access between the existing bridge pier columns and underneath the existing archways and crossbeams, a small Klemm 702-2 micropile drill rig was utilized to drill and install the micropiles. See Figure 9, which shows the drilling equipment being utilized. The presence of full depth competent bedrock at each pile location required the use of a down-the-hole hammer equipped with a 10" carbide-button hammer bit (see Figure 10). After the shaft was drilled to tip, the reinforcing bar was placed inside the open shaft with plastic centralizers and neat cement grout (water/cement ratio of 0.40 – 0.45) was placed by tremie method into the low end of the shaft. All micropiles were gravity grouted in a single stage for the entire depth of the hole. Post-grouting of the micropiles was not elected due to its limited effectiveness in bedrock type formations. Both the reinforcing center bar and the steel casing were placed at the proper elevation and tied off at the surface using timber and/or angle iron with wire. See Figure 11, which shows the completed micropiles for one of the proposed pier footings.

Figure 9 – Micropile Installation

Figure 10 – 10” Hammer Bit

Figure 11 – Completed Micropiles at Pier 2

MICROPILE TESTING:

The project specifications required four (4) total preconstruction verification test micropiles, two (2) near each pier location, and two (2) production proof test micropiles per footing, for a total of eight (8) micropiles. All verification and proof micropiles were required to be tested 200% of the design load, for a total of 540 kips. The maximum factored test load was conservatively tested in tension only for both the verification and proof tests to avoid adding additional reaction piles. All micropiles were tested in accordance with ASTM D 3689 as shown in Figure 12, which details the test setup. The tension load was applied to the verification and proof test piles using a reaction system consisting of beams and cribbing. The applied load was measured using a calibrated jack and pressure gauge graduated in 100-psi increments. The micropile movement was measured with two dial displacement indicators capable of measuring to 0.001 inches. A minimum clear distance of 5 times the diameter of the micropile (4'-2") was maintained between the tested pile and the reaction cribbing bearing on competent bedrock material. The sacrificial verification test piles were located near each pier location such that they were installed in representative soil strata for the full depth of the micropile, which was challenging due to the topography of the site and varying layers of fill and recent alluvium located throughout the site. In addition, due to the site constraints and the proposed micropile layout, it was impractical to perform proof testing on many of the production micropiles due to the micropile spacing and proximity to existing bridge column. As such, the proof test locations were pre-selected and limited to only two locations per footing. See Figure 13 for the verification test setup at Pier 2 and Figure 14 for a typical proof test setup.

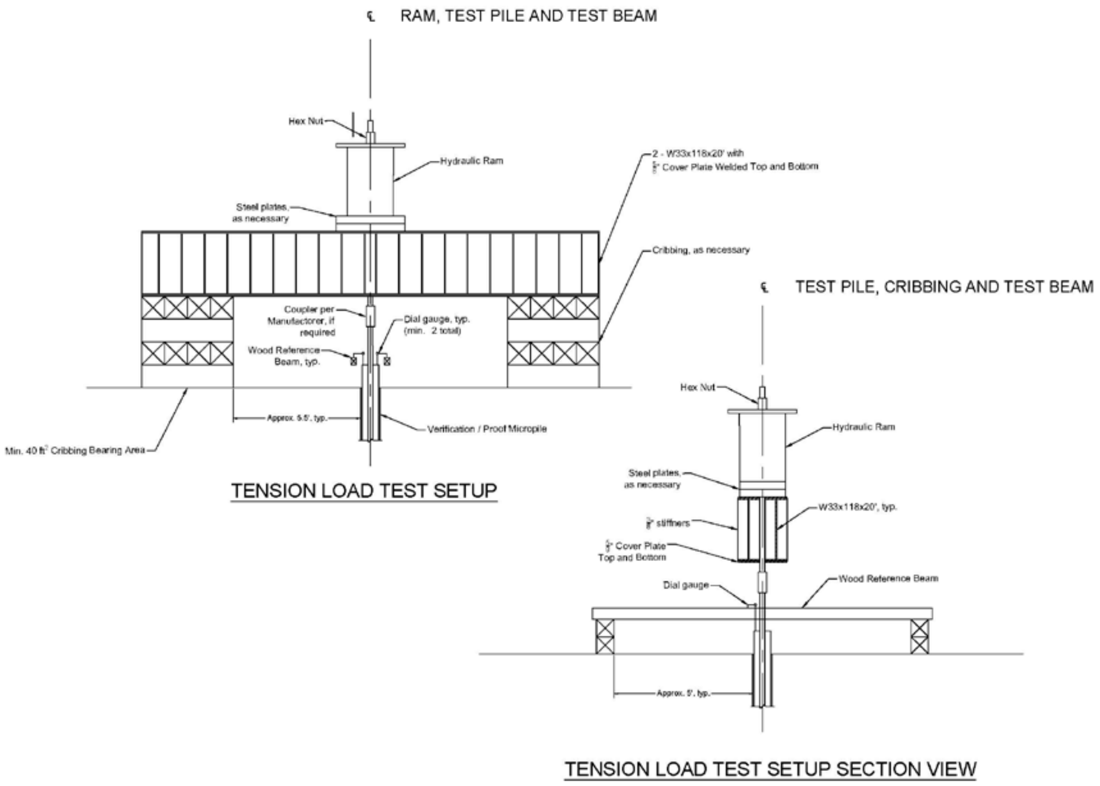

Figure 12 – Tension Load Test Setup Drawing

Figure 13 – Pier 2 Verification Test Set-up

Figure 14 – Proof Test Set-up

The tension test loads were incrementally loaded and unloaded according the test schedule shown in the project specifications. The project specifications also established three acceptance criteria for both the verification tests and proof tests. The first criterion was that axial movement at the top of the micropile measured from the initial alignment load to the first application of 100% of the design load must not exceed 0.5 inch. The second criterion was that the slope of the applied test load versus the top of micropile movement must not exceed 0.025 inch per kip at the maximum test load. The last criterion was that the creep test movement must not exceed 0.04 inch measured from 1 to 10 minutes or 0.08 inch measured from 6 to 60 minutes with the rate of movement being linear of decreasing in time when graphed on a logarithmic scale. The applied load versus top of micropile movement was plotted for all verification and proof tests. Figure 15 shows the pile movement curve for one of the verification test. All verification and proof test micropiles were successfully tested to 200% of the design load and satisfied all acceptance criteria. Both bedrock formations, the intrusive quartz diorite and sandstone conglomerate bedrock, behaved fairly similarly. See Table 1 for a summary of all verification and proof test results.

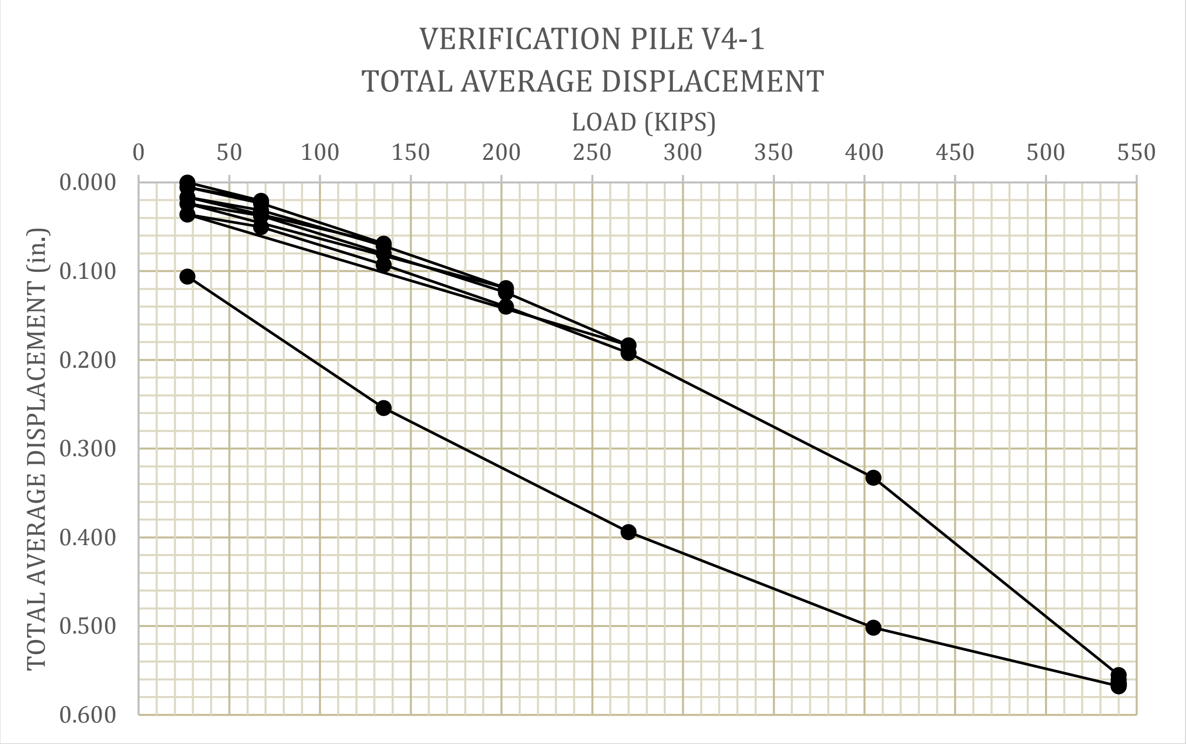

Figure 15 – Displacement Curve for Verification Test at Pier 4

Table 1 – Summary of Test Results

Test Pile Number	Test Type	Location	Bedrock Type	Axial Movement at 100% DL	Movement / Load @ Max Test Load	Creep Movement (1 to 10 minutes)
				(in.)	(in. / kip)	(in.)
V2-1	Verification	Pier 2	Topanga	0.135	0.00089	0.006
V2-2	Verification	Pier 2	Topanga	0.188	0.00173	0.016
V4-1	Verification	Pier 4	Quartz Diorite	0.184	0.00164	0.007
V4-2	Verification	Pier 4	Quartz Diorite	0.184	0.00139	0.008
R2-3	Proof	Pier 2	Topanga	0.177	0.00115	NR
R2-5	Proof	Pier 2	Topanga	0.104	0.00089	NR
L2-6	Proof	Pier 2	Topanga	0.145	0.00119	NR
L2-8	Proof	Pier 2	Topanga	0.130	0.00126	NR
R4-1	Proof	Pier 4	Quartz Diorite	0.136	0.00130	NR
R4-3	Proof	Pier 4	Quartz Diorite	0.122	0.00144	NR
L4-6	Proof	Pier 4	Quartz Diorite	0.237	0.00163	NR
L4-8	Proof	Pier 4	Quartz Diorite	0.204	0.00152	NR

CONCLUSION:

The micropiles were completed and successfully tested in October 2015. In order to preserve the historic value of the original La Loma Bridge and perform the necessary retrofitting and reconstruction of the bridge, the project design included the construction of a new bridge structure within the original bridge column and archway structures. As a result, micropiles provided the ideal foundation for the support of the new pier columns due to the limited access in the Arroyo Seco canyon and between the existing bridge structures as well as the installation process’s minimal disturbance to the existing structure. Micropiles allowed for the new pier columns to be constructed immediately adjacent to the existing bridge columns so the new structure could be seamlessly integrated into the original bridge design.

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General Contractor – OHL USA – Irvine, CA
Foundation Contractor – Malcolm Drilling Co., Inc. – Irwindale, CA

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