IMPLEMENTATION OF COMPOSITE PAVEMENT SYSTEMS

Caltrans Two-Lift Concrete Pavement Construction Project: I-210 EB

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Introduction

The Strategic Highway Research Program 2 (SHRP2) R21 project, *Composite Pavement Systems*, focused on the design and construction of renewable composite pavements using either a hot-mix asphalt (HMA) wearing course or a portland cement concrete (PCC) surface over an underlying structural concrete layer (i.e., either HMA/PCC or PCC/PCC designs). These composite pavement systems are promising technologies for providing sustainable, long-lasting roadways that can be rehabilitated with minimal disruption to the traveling public.

Under the SHRP2 Implementation Assistance Program (IAP), the Federal Highway Administration (FHWA), working in collaboration with the American Association of State Highway and Transportation Officials (AASHTO), administered a series of activities aimed at fostering the implementation of composite pavement systems:

- Provision of technical assistance and support to State Highway Agencies (SHAs) in the planning, design, and construction of new composite pavement systems.
- Development of a workshop on the design and construction of new composite pavement systems and delivery of that workshop to interested SHAs.
- Sponsorship of a multi-state showcase event promoting new composite pavement systems and featuring a visit to a nearby project.
- Conduct of a multi-state peer exchange providing a forum for SHAs to share their knowledge of and experience with new composite pavement systems.
- Provision of technical outreach through technical presentations on new composite pavement systems at national conferences and events.

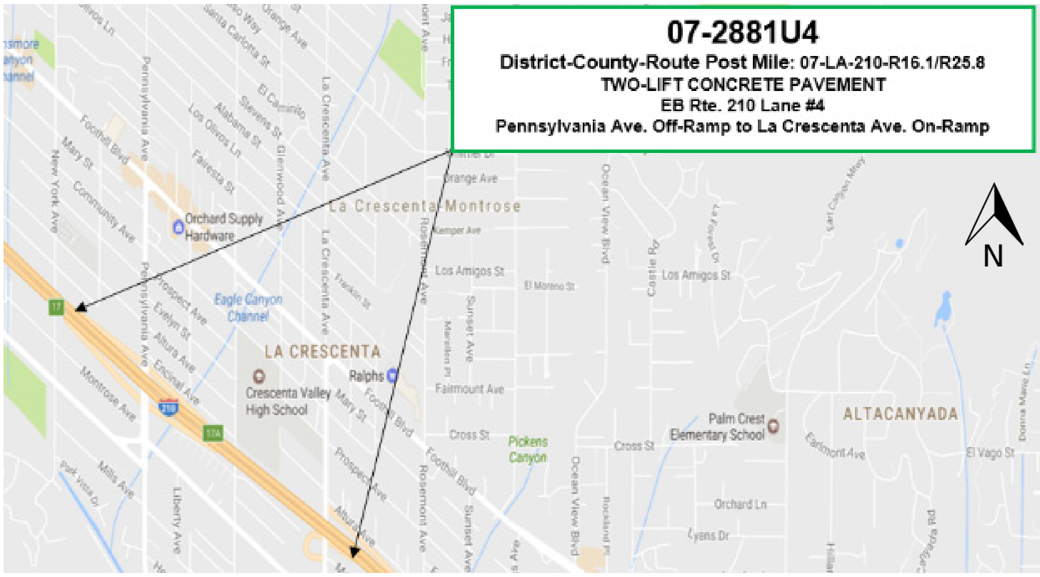
As part of this implementation effort, the California Department of Transportation (Caltrans) expressed interest in the construction of a two-lift (wet-on-wet) concrete composite pavement. Caltrans' interest in two-lift concrete paving was driven by the opportunity to be more cost effective and environmentally sustainable by using recycled concrete aggregate (RCA, derived from the demolition and on-site processing of the existing concrete pavement) in the bottom lift of the concrete.

This report documents the construction of a two-lift concrete composite pavement by Caltrans in late January and early February 2017.

Project Overview

The two-lift concrete pavement was constructed as a part of an approximate 10-mi (16-km) long rehabilitation project on I-210 north of Los Angeles (see project location in figure 1). This project carries about 55,500 vehicles per day (including 9 percent heavy trucks), and has four to five lanes in each direction.

The two-lift pavement section is 5,100 ft (1,554 m) long and the construction work was performed during several nighttime lane closures because of the heavy traffic volumes. The pavement section was constructed in the outer truck lane and adjacent to a traffic lane that had been replaced using precast panels.



Map data ©2017 Google (see Acknowledgments on last page)

Figure 1. Caltrans I-210 two-lift concrete pavement project site location.

Mix Design

Table 1 shows the mix designs for the bottom and top lifts while table 2 provides the aggregate gradations. Three different concrete mixes were initially evaluated for use in the bottom lift of this project, with two ultimately selected for use in the project. The first two mixes evaluated contained RCA, with investigations performed at 10 percent RCA and 15 percent RCA addition levels because of uncertainties about the resulting characteristics of the RCA mixtures. After verification of its characteristics, the mix containing 15 percent RCA content was selected as one of the mixtures for use in the bottom lift. The second mix that was used in the bottom lift was designated as a low-strength concrete and contained conventional aggregate. Approximately 2,000 ft (610 m) of the two-lift section employed RCA concrete mixtures in the bottom lift, while the remaining approximate 3,100 ft (945 m) used the low-strength concrete.

Table 1. Concrete mixture designs for Caltrans two-lift pavement.

Materials	Top Lift	Bottom Lift #1 (10 percent RCA)	Bottom Lift #2* (15 percent RCA)	Bottom Lift #3* (0 percent RCA)
Cement (lb/yd^3)	480 (Type I)	409 (Type I)	409 (Type I)	409 (Type I)
Fly Ash (lb/yd^3)	85 (15%)	61 (13%)	61 (13%)	61 (13%)
1 inch #4 Aggregate (lb/yd^3)	1510	1635	1464	1583
3/8 inch #8 Aggregate (lb/yd^3)	315	327	488 (RCA)	330
Natural Sand (lb/yd^3)	1321	1308	1302	1385
Water (lb/yd^3)	260	235	235	235
Chemical Admixtures	2.5 fl. oz. AEA 20 fl. oz. WRA	2.1 fl. oz. AEA	2.1 fl. oz. AEA	2.1 fl. oz. AEA
Theoretical unit weight (lb/ft^3)	147.0	147.1	146.5	148.2
Design w/c ratio	0.46	0.50	0.50	0.50
Design air content (%)	3.0%	3.0%	3.0%	3.0%
Design flexural strength @ 10 days (lb/in^2)	550	400	400	400

* Used in actual paving AEA: Air Entraining Admixture WRA: Water Reducing Admixture

Table 2. Aggregate gradations for Caltrans two-lift pavement.

TOP LIFT					
Sieve Size	**Durbin 48% 1 inch x No. 4**	**Reliance 10% ⅜ inch x No. 8**	**Durbin 42% W. C. Sand**	**100% Combined**	**Combined Limits**
2 inch (50 mm)	100	100	100	100	-
1.5 inch (37.5mm)	100	100	100	100	100
1 inch (25 mm)	96	100	100	99	90-100
¾ inch (19 mm)	68	100	100	85	55-100
½ inch (12.5mm)	22	100	100	63	-
⅜ inch (9.5 mm)	7	95	100	55	45-75
No. 4 (4.75 mm)	1	19	96	43	35-60
No. 8 (2.36 mm)	1	2	81	35	27-45
No. 16 (1.18 mm)	1	1	66	28	20-35
No. 30 (600 µm)	1	1	46	20	12-25
No. 50 (300 µm)	1	1	22	10	5-15
No. 100 (150 µm)	1	1	8	4	1-8
No. 200 (75 µm)	0.6	0.4	2.2	1.0	0-4
BOTTOM LIFT #1 – 10% RCA (laboratory mix only; not used in paving)					
Sieve Size	**48% 1 inch x No. 4**	**10% Recycled**	**Durbin 40% W. C. Sand**	**100% Combined**	**Combined Limits**
2 inch (50 mm)	100	100	100	100	-
1.5 inch (37.5mm)	100	100	100	100	100
1 inch (25 mm)	97	100	100	99	90-100
¾ inch (19 mm)	75	88	100	86	55-100
½ inch (12.5mm)	34	38	100	61	-
⅜ inch (9.5 mm)	16	15	100	50	45-75
No. 4 (4.75 mm)	3	4	96	40	35-60
No. 8 (2.36 mm)	1	4	81	33	27-45
No. 16 (1.18 mm)	0	3	66	27	20-35
No. 30 (600 µm)	0	3	46	19	12-25
No. 50 (300 µm)	0	3	22	9	5-15
No. 100 (150 µm)	0	2	8	3	1-8
No. 200 (75 µm)	0	1.8	2.2	1.0	0-4
BOTTOM LIFT #2 – 15% RCA (used in paving)					
Sieve Size	**48% 1 inch x No. 4**	**15% Recycled**	**Durbin 40% W. C. Sand**	**100% Combined**	**Combined Limits**
2 inch (50 mm)	100	100	100	100	-
1.5 inch (37.5mm)	100	100	100	100	100
1 inch (25 mm)	97	100	100	99	90-100
¾ inch (19 mm)	75	88	100	87	55-100
½ inch (12.5mm)	34	38	100	61	-
⅜ inch (9.5 mm)	16	15	100	49	45-75
No. 4 (4.75 mm)	3	4	96	40	35-60
No. 8 (2.36 mm)	1	4	81	33	27-45
No. 16 (1.18 mm)	0	3	66	27	20-35
No. 30 (600 µm)	0	3	46	19	12-25
No. 50 (300 µm)	0	3	22	9	5-15
No. 100 (150 µm)	0	2	8	4	1-8
No. 200 (75 µm)	0	1.8	2.2	1.0	0-4

Table 3. Aggregate gradations for Caltrans two-lift pavement. (continued).

BOTTOM LIFT #3 – 0% RCA (used in paving)					
Sieve Size	**48% 1 inch x No. 4**	**Reliance 10% ⅜ inch x No. 8**	**Durbin 42% W. C. Sand**	**100% Combined**	**Combined Limits**
2 inch (50 mm)	100	100	100	100	-
1.5 inch (37.5mm)	100	100	100	100	100
1 inch (25 mm)	97	100	100	99	90-100
¾ inch (19 mm)	75	100	100	88	55-100
½ inch (12.5mm)	34	100	100	68	-
⅜ inch (9.5 mm)	16	95	100	59	45-75
No. 4 (4.75 mm)	3	19	96	44	35-60
No. 8 (2.36 mm)	1	2	81	35	27-45
No. 16 (1.18 mm)	0	1	66	28	20-35
No. 30 (600 µm)	0	1	46	19	12-25
No. 50 (300 µm)	0	1	22	9	5-15
No. 100 (150 µm)	0	1	8	3	1-8
No. 200 (75 µm)	0	0.4	2.2	1.0	0-4

Pavement Design Considerations

The project was designed for a 40-year life and 70 million ESAL applications. The two-lift pavement cross-section shown is shown in figure 2, with the 12-inch (305-mm) total pavement thickness matching the thickness of the adjacent travel lane and consisting of a 9-inch (229-mm) bottom lift and a 3-inch (76-mm) top lift. Originally, the top lift was to be 4 inches (102 mm) thick; however, the thickness of the top lift was reduced to 3 inches (76 mm) due to a concern that the vibration of the top lift might displace the dowel baskets. The entire pavement is constructed on a previously prepared subgrade and a lean concrete base (LCB).

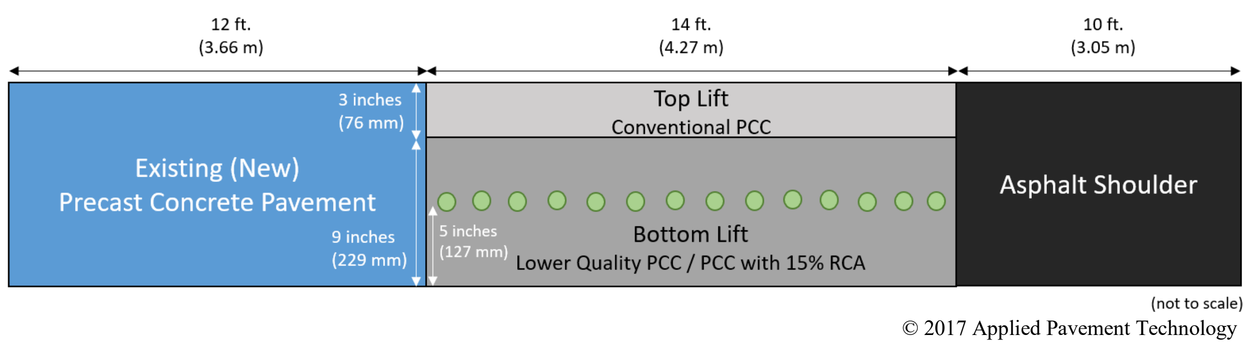


Figure 2. Two-lift concrete composite pavement cross-section.

Construction Process

The two-lift concrete composite pavement construction was completed at night in late January and early February 2017. The project team observed the construction on the evening of January 30, 2017.

Mix Production

Concrete was mixed at an on-site batch plant (see figure 3) set up about 8 mi (12.9 km) from the project site (see figure 4) in the interior portions of the interchange between I-210, I-710, and California State Route 134. The contractor worked to keep the RCA stockpile wet and the aggregates were pre-wetted to prevent any absorption issues. The plant premises also served as the repository for the old concrete that was hauled from the project and crushed and processed for later use (see figure 5). Concrete materials for both lifts were transported to the project site using end-dump trucks.

Figure 3. Concrete plant for I-210 project.

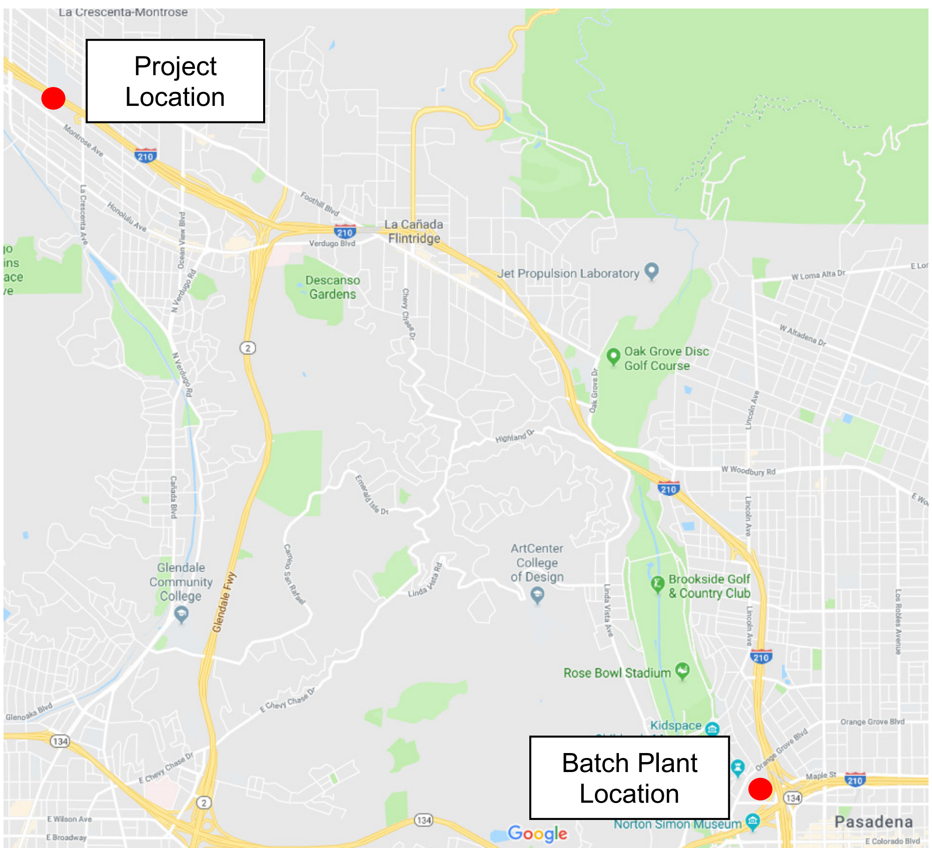


Figure 4. Location of batch plant relative to I-210 project.

(a)

(b)

Figure 5. Rubble from old concrete pavement (left) and processed recycled concrete aggregate (right).

Concrete Demolition

The existing concrete was demolished and removed from grade using stompers and excavators. The existing JPCP was 8 inches (203 mm) thick and placed over a 5.5-inch (140-mm) thick Class A cement-treated base (CTB) and a 2.5-inch (64-mm) thick Class 3 aggregate base course.

Base Layer

After demolition and removal of the existing concrete slab, the existing CTB and aggregate base layers were also removed and replaced with a 4-inch (102 mm) LCB and an 8-inch (204 mm) Class 3 aggregate base course, placed in accordance with Caltrans Standard Specifications. The LCB was not a rapid-set material.

Dowel Bar Basket and Tie Bar Placement

The pavement is transversely jointed at 15-ft (4.6-m) intervals to nominally match the transverse joint spacing of the adjacent travel lane (although in some cases the transverse joints did not always match across lanes). Load transfer is provided by 1.5-inch (38 mm) epoxy-coated round steel dowels on 12-inch (305 mm) centers that were placed in baskets at a height of 5 inches (127 mm) above the surface of the LCB (placing them just slightly below the mid-depth of the 12-inch [305 mm] total composite thickness). A total of 14 dowels were included across the 14-ft (4.3 m) lane.

Dowel baskets were anchored to the base, with the first dowel being located 6 inches (152 mm) from the adjacent travel lane longitudinal joint (see figure 6a). A close-up view of the dowel bars and dowel basket at a header joint is shown in figure 6b.

a. Dowel bars and basket anchors (and fiberboard). b. Close-up of dowel bar and basket at header.

Figure 6. Dowel bar basket placement.

The two-lift pavement was sandwiched between the asphalt shoulder and the adjacent traffic lane, which had been previously reconstructed with precast concrete pavement. Tie bars were not used to tie the new two-lift section with the adjacent pavement; instead, an isolation joint was formed between the precast concrete pavement and the two-lift pavement. This was done using an asphalt-impregnated fiberboard placed next to the existing pavement to break the bond between the two pavement sections (see figure 6a and figure 7).

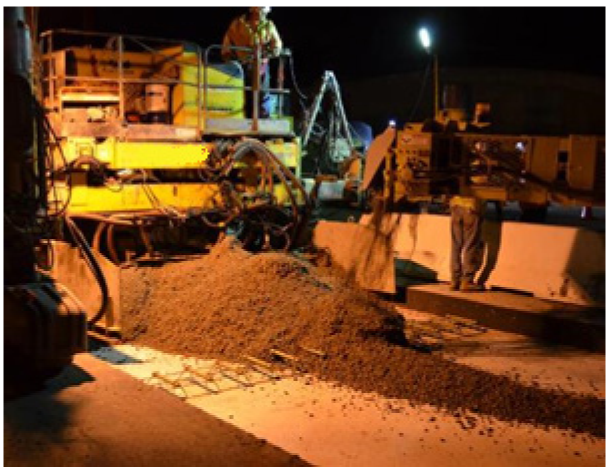
Figure 7. Fiberboard placed on adjacent pavement prior to paving two-lift section.

Concrete Paving

The following sections describe the placement and finishing of the bottom and top lifts. To accommodate the equipment operating from the adjacent traffic lanes and the regular arrivals of the concrete haul trucks, three adjacent traffic lanes were closed during the nighttime paving operations (leaving one through lane in operation for traffic).

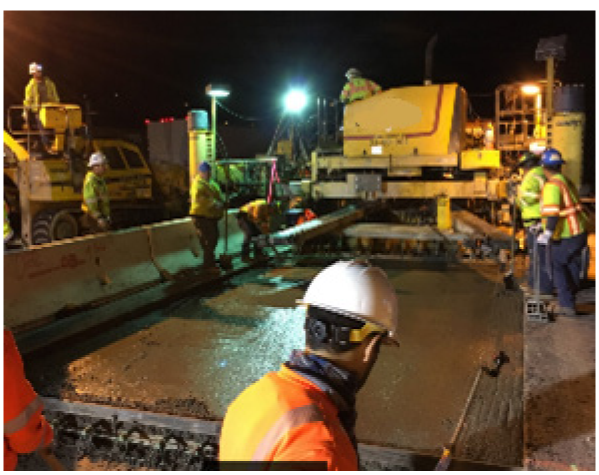
Bottom Lift

The concrete material for the bottom lift was delivered on site by end-dump trucks. The trucks transferred the material into a Gomaco RTP 500 belt placer, which deposited the material on grade in front of the Gomaco Commander III slipform paver. No additional finishing or texturing was performed to the bottom lift surface after it had passed through the paver. The vibrators for the paver working the bottom lift were required to be set between 4,000 and 5,000 cycles per minute. Figure 8 presents some selected photos from the placement of the bottom lift concrete, with additional photos provided in Appendix A.



a. Delivery of bottom lift.

b. Mix delivery close-up.



c. Bottom lift after going through paver.

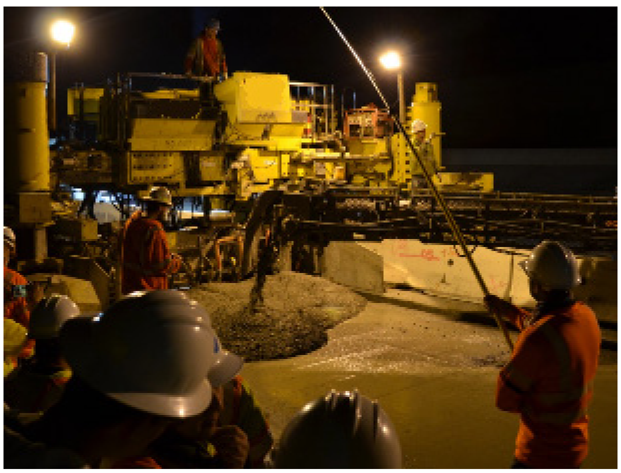
d. Close-up of bottom lift after paver.

Figure 8. Placement of bottom lift concrete.

Top Lift

Caltrans specified a maximum of 45 minutes for the delivery of the top lift after the bottom lift had been placed, and this was routinely achieved. Once again, a Gomaco RTP 500 belt placer was used to convey the material from the haul truck to the grade in front of a Gomaco GHP 2800 slipform paver. The vibrators on the top-lift paver were required to be set at between 7,000 and 8,000 cycles per second, and did not penetrate more than 2 inches (51 mm) into the top lift.

After passing through the paver, some hand work and bullfloating was performed, followed by an initial texturing using a burlap drag. Final texturing was performed using a spring-steel tining device affixed to a self-propelled machine to produce longitudinal tining with grooves 0.09 to 0.13 inches (2.4 to 3.2 mm) wide, approximately 0.19 inches (4.8 mm) deep, and 0.75 inches (19 mm) apart. Figure 9 presents selected photos of the placement of the top lift.



a. Delivery of top lift.

b. Top lift concrete in front of paver.

c. Bull floating operation on top lift.

d. Burlap drag texturing.

Figure 9. Placement of top lift concrete.

Curing and Joint Sawing

The exposed, composite concrete pavement surface was cured by applying an agency-approved, white-pigmented, membrane-forming curing compound onto the surface using mechanical sprayers. Transverse joints were cut the following day at the locations marked on the adjacent pavement prior to the paving operation. The common depth of the sawcuts for the transverse joints is D/3 but the cut was performed down to a depth of 0.5 inches (13 mm) above the top of the dowel basket. Figures 10 and 11 show several pictures of the newly placed two-lift concrete pavement the day after placement.

Figure 10. New two-lift concrete pavement surface after placement.

Figure 11. Transverse joint on new two-lift concrete pavement.

Weather Conditions

The paving operations were performed at the end of January and early part of February 2017 and some data on the weather conditions (for the period of January 31 to February 3 and February 8) is summarized in table 3.

Table 4. Weather conditions from the Burbank-Glendale-Pasadena Station (data source: Weather Underground).

Item	Maximum	Average	Minimum
January 31 – February 3			
Temperature	74 ˚F	58 ˚F	43 ˚F
Dew Point	54 ˚F	42 ˚F	27 ˚F
Precipitation	0.23 inches	0.08 inches	0.00 inches
Humidity	93%	–	19%
Wind	13 mi/hr	4 mi/hr	0 mi/hr
Gust Wind	20 mi/hr	–	–
February 8			
Temperature	72 ˚F	62 ˚F	57 ˚F
Dew Point	59 ˚F	57 ˚F	56 ˚F
Precipitation	0.0 inches	0.0 inches	0.0 inches
Humidity	97%	86%	59%
Wind	9 mi/hr	3 mi/hr	0 mi/hr
Gust Wind	0 mi/hr	–	–

Testing

Caltrans performed concrete material sampling and testing during the placement of both the bottom and top lifts. In addition to the testing performed by Caltrans, an independent contractor (RMA Group) also performed additional testing for quality control (QC) purposes. A summary of the testing is discussed in the following sections.

Fresh Concrete Testing

Fresh concrete testing included Kelly Ball penetration test (in accordance with *California Test Method 557*), air content (in accordance with *California Test Method 504*), and unit weight (in accordance with *California Test Method 518*). Table 4 presents a summary of the fresh concrete test results for each lift as reported by Caltrans and RMA Group.

Table 4. Summary of fresh concrete test results.

Tested By	Test Location	Date and Time	Ambient Temperature	Concrete Mixture Temperature	Average Penetration, inch (mm)	Air Content	Unit Weight, lb./ft^3 (kg/m^3)
Top Lift							
Caltrans	893+00 to 908+00	2/8/2017, 11:00 PM	62°F (16.7°C)	68°F (20°C)	1.50 (38.1)	3.4%	142.8 (2288)
	871+00 to 891+00	2/3/2017, 12:03 AM	54°F (12.2°C)	64°F (17.8°C)	0.50 (12.7)	4.9%	143.1 (2292)
	908+00 to 922+00	1/31/2017, 12:11 AM	55°F (12.8°C)	62°F (16.7°C)	1.50 (38.1)	4.6%	142.4 (2281)
RMA Group	Penn. Ave b/w on and off ramp	2/8/2017, 10:45 PM	63°F (17.2°C)	67°F (19.4°C)	1.50 (38.1)	3.3%	144.7 (2318)
	875+00	2/4/2017, 12:45 AM	55°F (12.8°C)	65°F (18.3°C)	1.25 (31.8)	4.7%	143.8 (2304)
	908+00 to 922+00	1/30/2017, 11:55 PM	55°F (12.8°C)	62°F (16.7°C)	1.50 (38.1)	4.6%	147.4 (2361)
Bottom Lift							
Caltrans	893+00 to 908+00*	2/8/2017, 9:47 PM	62°F (16.7°C)	70°F (21.1°C)	1.00 (25.4)	2.5%	142.2 (2278.0)
	871+00 to 891+00**	2/3/2017, 11:30 PM	56°F (13.3°C)	66°F (18.9°C)	0.25 (6.4)	2.7%	146.0 (2339)
	908+00 to 922+00*	1/31/2017, 10:41 PM	55°F (12.8°C)	59°F (15°C)	0.50 (12.7)	2.1%	144.8 (2320)
RMA Group	Penn. Ave b/w on and off ramp*	2/8/2017, 9:45 PM	62°F (16.7°C)	69°F (20.6°C)	1.00 (25.4)	2.8%	146.4 (2345)
	871+00 to 891+00**	2/3/2017, 11:30 PM	56°F (13.3°C)	64°F (17.8°C)	0.50 (12.7)	2.9%	146.0 (2339)

*Low-strength concrete mixture without any RCA

**Concrete mixture with 15% RCA

Flexural Strength

Flexural strength testing was performed on beam specimens (in accordance with *California Test Method 523, Method 2*) at ages of 10 days, 21 days, 28 days, and 42 days. Two specimens were tested at each age and the average values are reported in table 5.

Table 5. Summary of flexural strength testing results.

Tested By	Test Location	Average Flexural Strength, lb/in² (MPa)			
		10-day	21-day	28-day	42-day
Top Lift					
Caltrans	893+00 to 908+00	570 (3.9)	620 (4.3)	700 (4.8)	NT
Caltrans	871+00 to 891+00	480 (3.3)	570 (3.9)	600 (4.1)	NT
Caltrans	908+00 to 922+00	550 (3.8)	580 (4.0)	650 (4.5)	NT
RMA Group	Penn. Ave b/w on and off ramp	640 (4.4)	NT	640 (4.4)	690 (4.8)
RMA Group	875+00	620 (4.2)*	NT	640 (4.4)	660 (4.6)
RMA Group	908+00 to 922+00	480 (3.3)	NT	540 (3.7)**	560 (3.9)**
Bottom Lift					
Caltrans	893+00 to 908+00[a]	510 (3.5)	600 (4.1)	660 (4.6)	NT
Caltrans	871+00 to 891+00[b]	620 (4.3)	690 (4.8)	680 (4.7)	NT
Caltrans	908+00 to 922+00[a]	640 (4.4)	690 (4.8)	750 (5.2)	NT
RMA Group	Penn. Ave b/w on and off ramp[a]	540 (3.7)*	NT	620 (4.2)	640 (4.4)
RMA Group	871+00 to 891+00[b]	550 (3.8)*	NT	610 (4.2)	680 (4.7)
RMA Group	853+00 to 867+00[a]	630 (4.3)	NT	660 (4.6)	760 (5.2)

NT: Not Tested

*Actual testing performed at 11 days.

**Only one specimen was tested at 28 and 42-days. Tester has noted that additional beams tested at 28 and 42 days exhibited wide variability in results, potentially indicating damaged specimens.

[a]Concrete mixture without any RCA

[b]Concrete mixture with 15% RCA

Summary

The Caltrans I-210 pavement rehabilitation project included a short test section in the eastbound direction that was constructed using two-lift concrete paving technology. Table 6 provides a brief summary of key project information. Some of the key takeaways from the field visit are summarized below.

Table 6. Summary of two-lift concrete pavement details on I-210.

Item	Details
General Project Information	• Two-lift wet-on-wet composite concrete pavement • Location: I-210 East Bound, Lane #4, between the Pennsylvania Avenue Off-Ramp and the La Crescenta Avenue On-Ramp • Length: 5,050 ft (1,539 m)
Pavement Design and Materials Information	• Design Life: 40 years • 12-inch (305-mm) thick JPCP – Top lift: 3-inch (75 mm) thick conventional portland cement concrete with total cementitious = 565 lb/yd^3 [335 kg/m^3] – Bottom lift: 9-inch (229 mm) thick concrete with total cementitious = 470 lb/yd^3 [279 kg/m^3]. Built in two sections, one section with no recycled materials and one section with 15% RCA • Transverse joint spacing: 15 ft (4.6 m) • Dowel bars: 1.5-inch (38-mm) on 12-inch (305 mm) spacings • Base: 4-inch (150 mm) lean concrete
Construction Information	• Construction Dates: January 30-February 8, 2017 • Two-Way Average Daily Traffic: 55,500 vpd (with 9 percent trucks) • Weather Conditions: 50-60˚F (10-16˚C) • Nighttime paving

- The existing concrete pavement was built in 1972 and exhibited failure at the joints. The current traffic level is 55,500 vpd with 9 percent trucks.
- The reconstructed pavement was designed for 40 years and 70 million ESALs.
- A 3-lane closure was necessary to accommodate the construction equipment and prepare the work zone. Only one lane was open to traffic during construction.
- The time between the placement of the two paving lifts was specified as 45 minutes.
- Since the two-lift concrete pavement was sandwiched between the shoulder and the existing lane, slump was not a concern and tie bars were not provided.
- The RCA stockpile needed to be kept wet and the aggregates were pre-wetted to prevent any absorption issues.
- A video clip showing the construction jobsite and the two-lift concrete paving operation can be accessed at: https://goo.gl/c597Lt.

References

Weather Underground. 2017. *Burbank-Glendale-Pasadena, CA*. The Weather Company, an IBM business, Brookhaven, GA.

APPENDIX A – CONSTRUCTION PHOTOS

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Photo A-1. Project overview, looking east from west end.

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Photo A-2. Work zone setup for project.

Photo A-3. Project overview, showing pavement base layer.

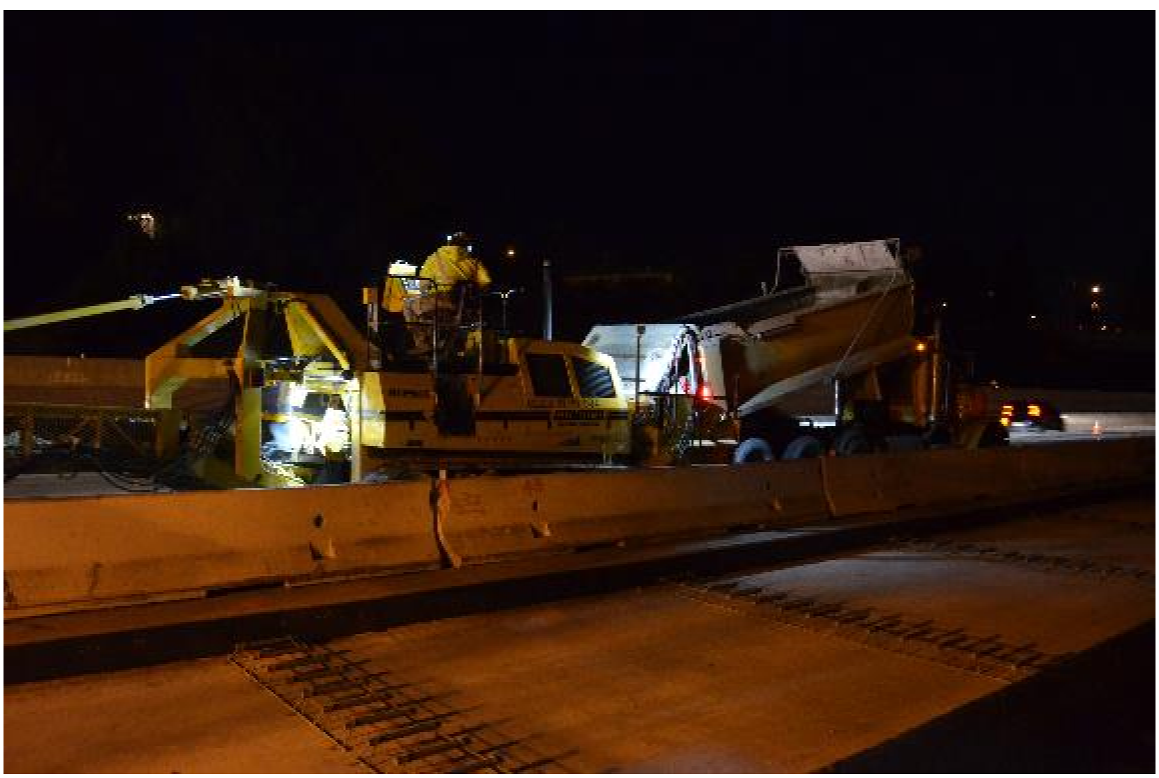

Photo A-4. Project overview, showing pavement base layer, dowel bars and dowel baskets.

Photo A-5. Paver getting ready for the paving operations.

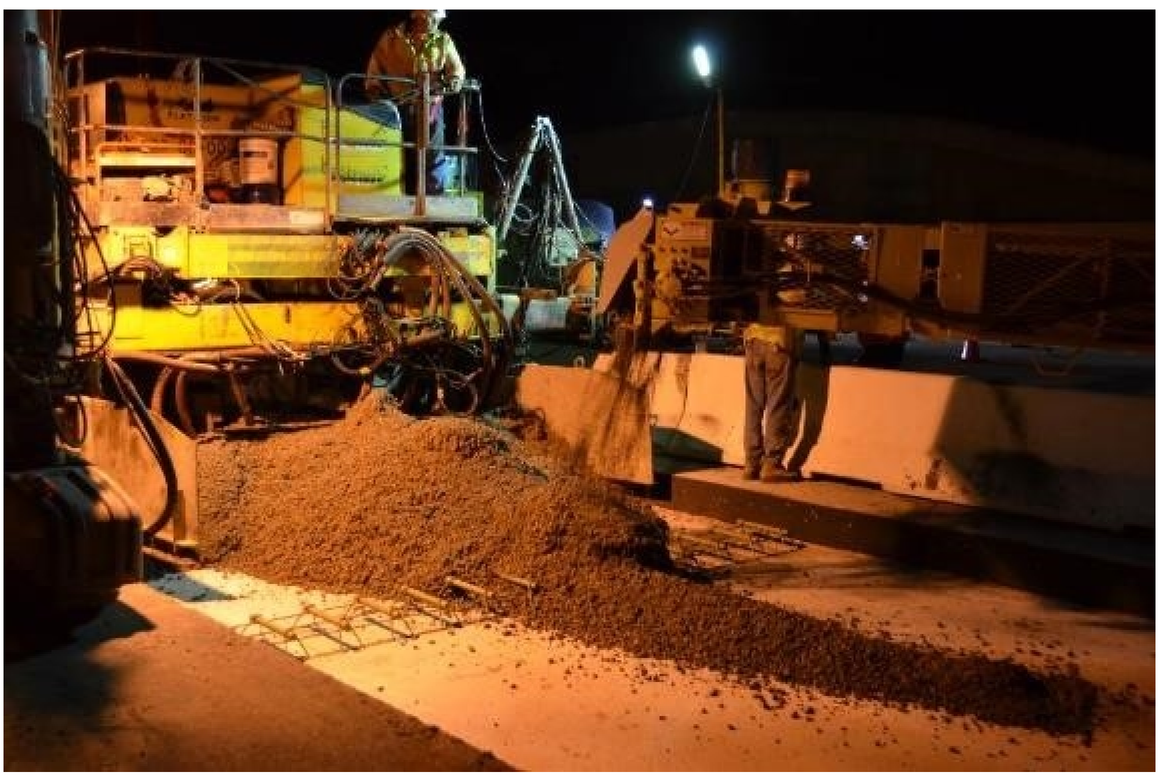

Photo A-6. Concrete mixture for the bottom lift being delivered to the project site.

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Photo A-7. Close-up view of the dowel bars and the dowel basket at a header.

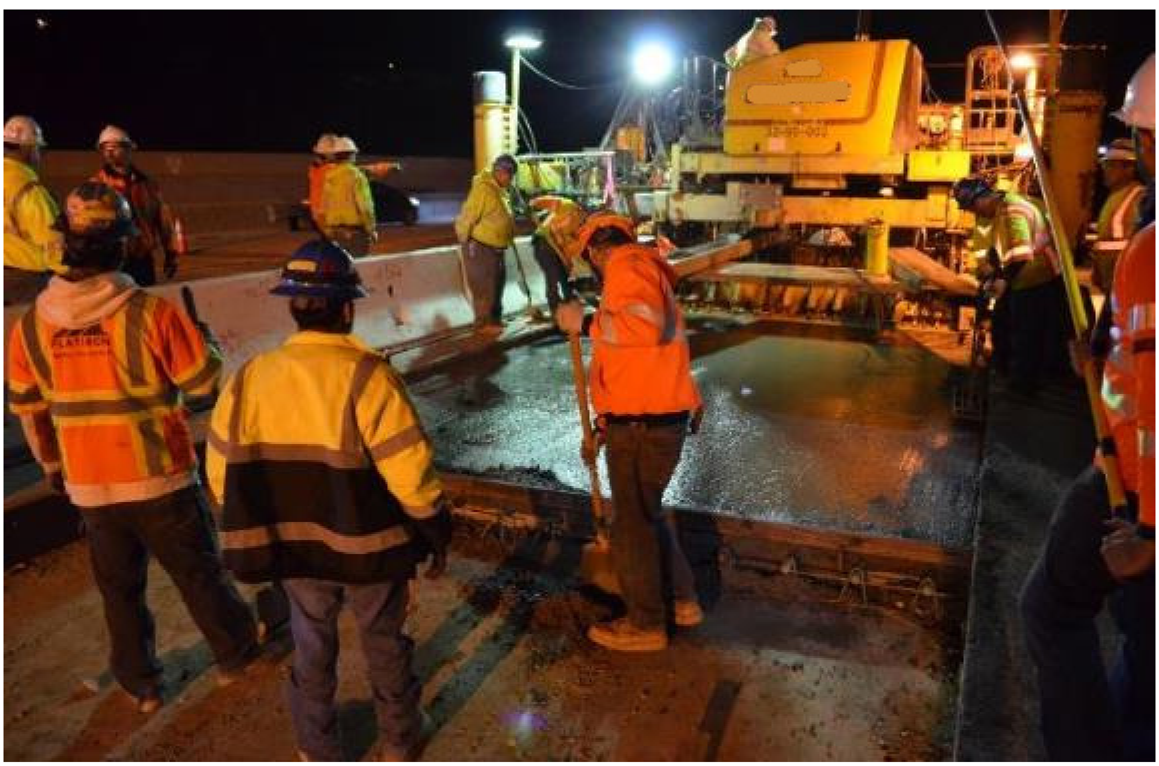

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Photo A-8. Placement of bottom lift of the two-lift concrete pavement on I-210.

Photo A-9. Close-up view of the placement of the bottom-lift.

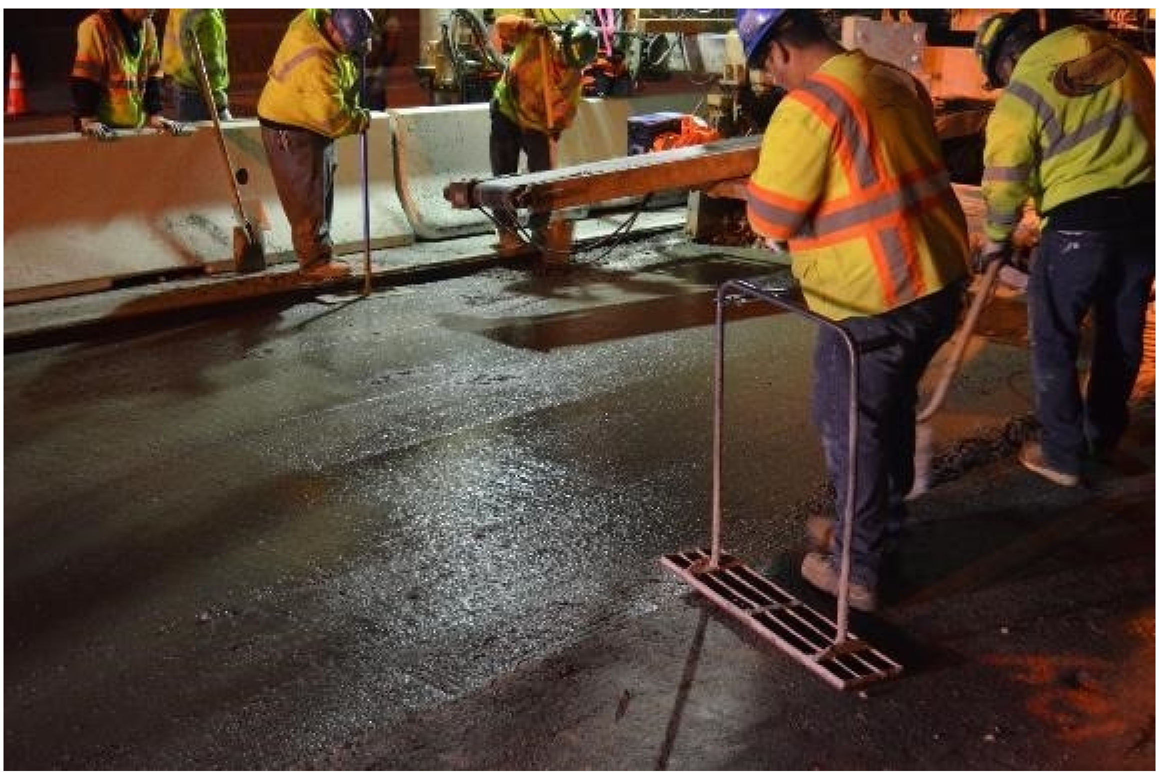

Photo A-10. Close-up view of the surface of the bottom-lift.

Photo A-11. Panoramic view of the construction site. The slipform paver placing the bottom lift can be seen in the far right side of the picture and the paver that will be placing the top lift is seen on the left side of the picture.

Photo A-12. Placement of the top lift of the two-lift concrete pavement on I-210.

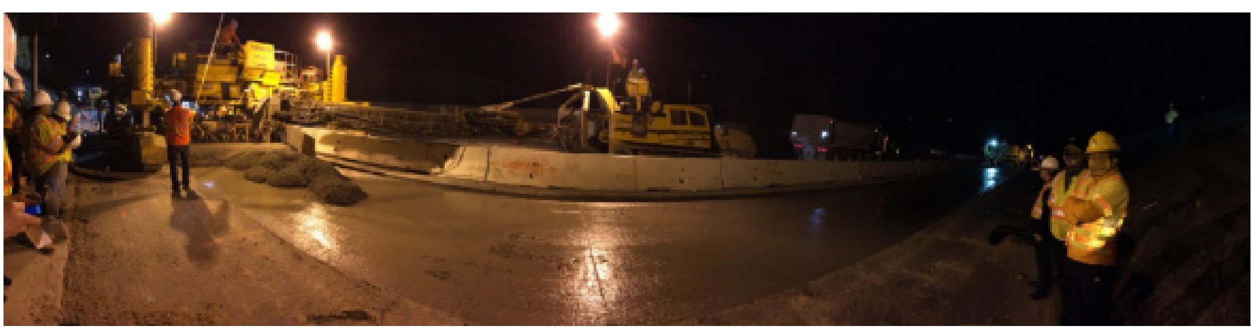

Photo A-13. Panoramic view of the construction site. The slipform paver, which has already placed the bottom lift, can be seen in the far right side of the picture and the paver placing the top lift is seen on the left side of the picture.

Photo A-14. Close-up view of the placement of the top-lift.

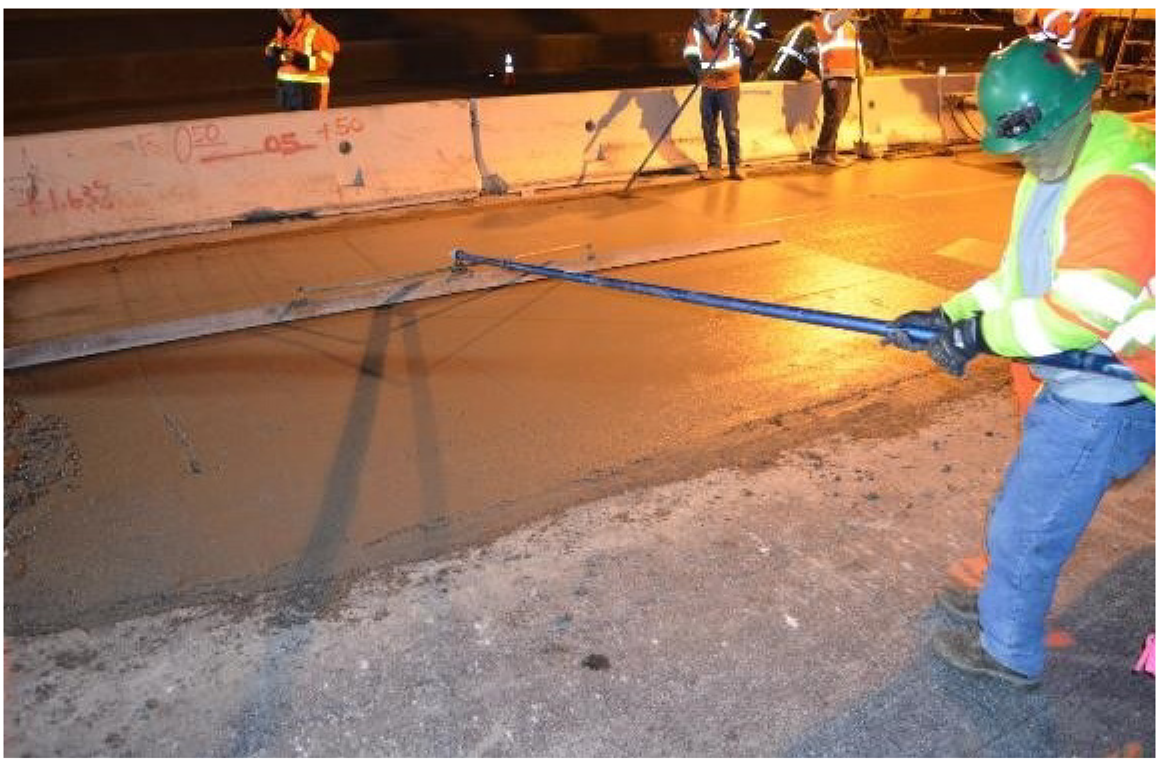

Photo A-15. Bull floating being performed on of the top-lift.

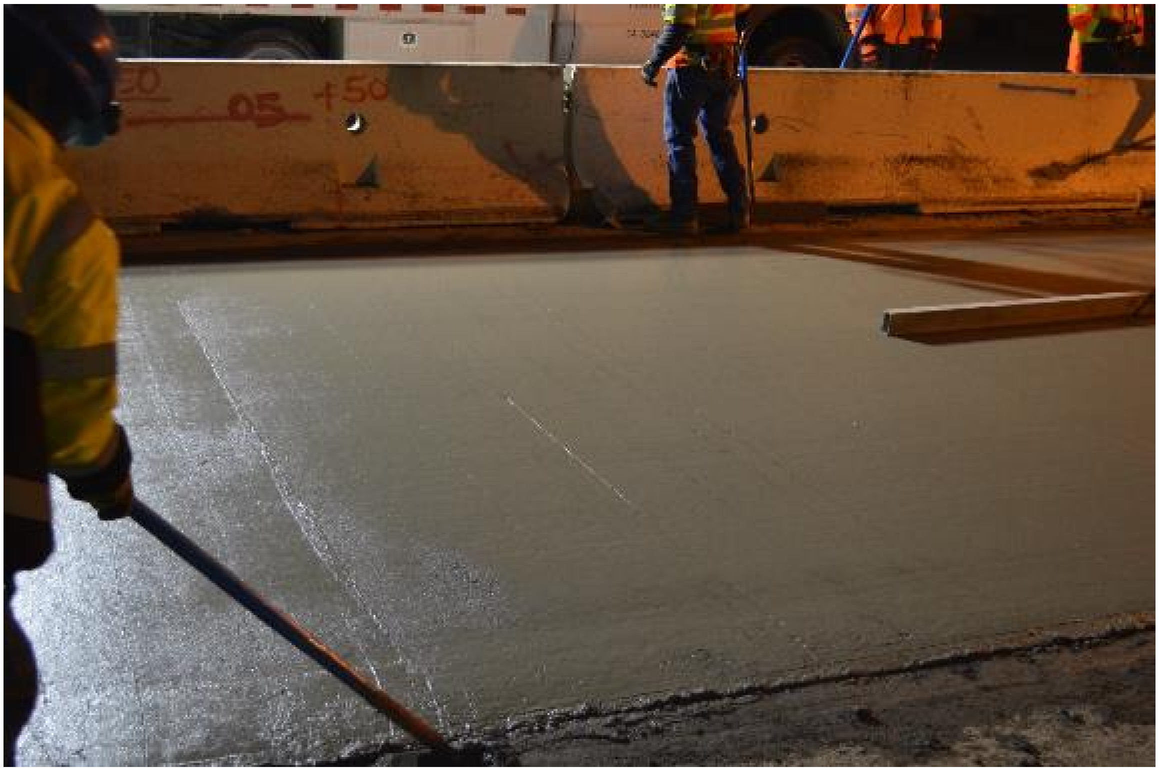

Photo A-16. Close-up view of the surface of the top-lift.

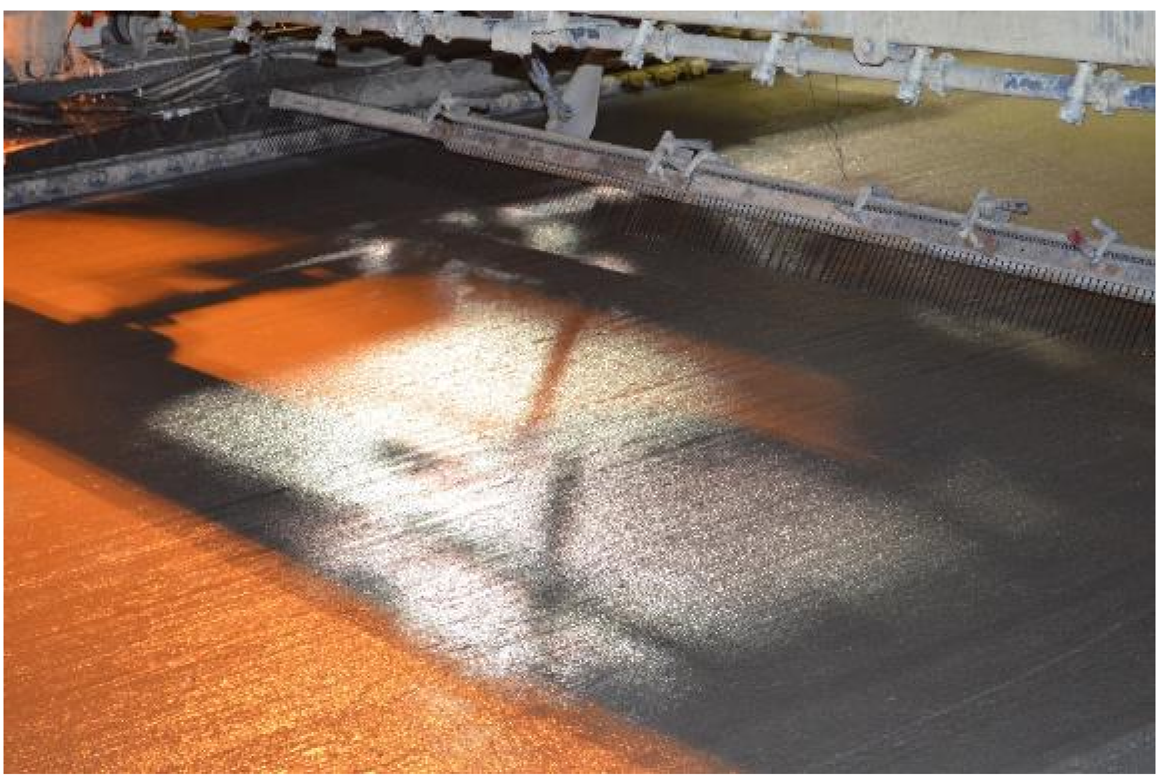

Photo A-17. Longitudinal tining operation about to commence.

Photo A-18. Project site after the nighttime placement of the two-lift concrete pavement.

Photo A-19. Pavement surface the day after placement.

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Photo A-20. Close-up view of pavement surface.

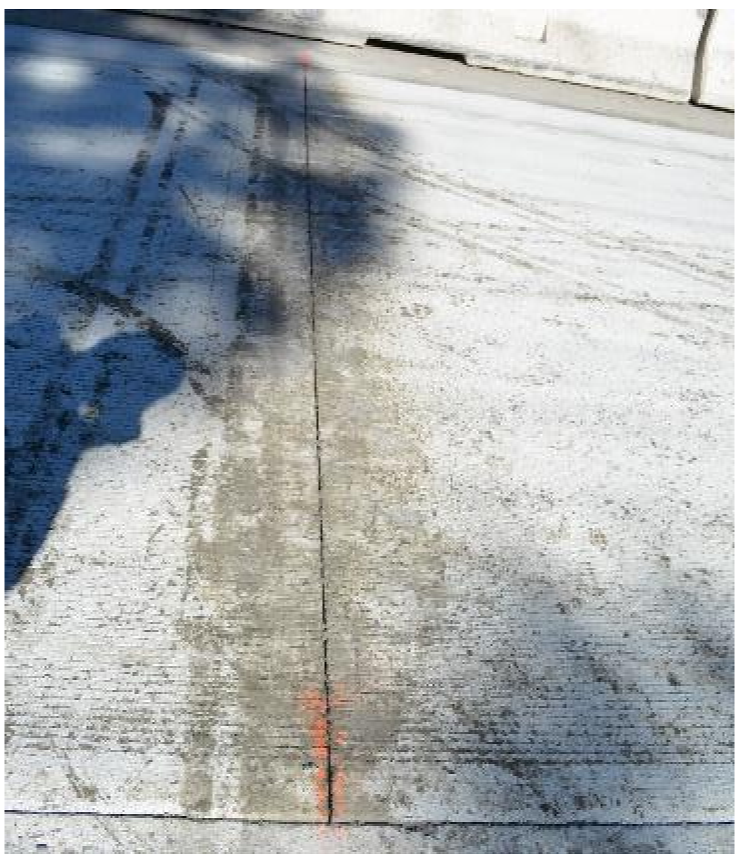

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Photo A-21. Transverse joint.

Photo A-22. Concrete batch plant and on-site recycling facility.

Photo A-23. Stockpile of existing concrete pavement
that has been demolished for on-site recycling.

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Photo A-24. Stockpile of recycled concrete aggregate produced on-site.

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Photo A-25. Close-up view of the recycled concrete aggregate.

ACKNOWLEDGMENTS

The original maps on pages 2 and 5 are the copyright property of Google and can be accessed from https://www.google.com/maps/. The map overlays were developed as a result of this research project. The map overlays on page 2 include lines showing the project location with arrows pointing to the beginning and end as well as a text box insert with details on the location. The map overlays on page 5 show large dots and text boxes indicating the project location and batch plant location.