STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

ROCK PRODUCTS COMMITTEE (RPC)

California Department of Transportation Lessons Learned I-680 Precast Pavement

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Precast Pavement Project Team
Precast Sub-Task Group
Concrete Products Task Group
Rock Products Committee (RPC)

PROJECT INFORMATION

This project involves the rehabilitation of Interstate 680 in Contra Costa County. The 12.8-mile project begins at the Alcosta Boulevard Interchange in San Ramon and ends just north of Rudgear Road in Walnut Creek. A one-mile extension of the southbound high-occupancy vehicle (HOV) lane is also included in the project.

Particularly significant about this project is the use of innovative pavement construction technology. 7300 cubic yards of Precast Concrete for new pavement slabs will be used to replace damaged concrete pavement slabs.

Key project information also includes the following:

- Contractor: Bay Cities Paving and Grading, Inc.
- Precast Fabricator: Con-Fab California Corporation
- Engineer's Estimate: $63,640,334
- Contract Days: 154
- Project Award Date: 18 November 2010
- County-Route-PM: CC-680-0/12.8
- Project EA: 04-4470U4
- Location Description: In Contra Costa County from Alcosta Boulevard Overcrossing to 0.2 mile north of Rudgear Road Undercrossing

BACKGROUND DISCUSSION AND CONTRACT REQUIREMENTS

Many of the Department's existing specifications and systems guided the Contractor in their fabrication and performance of Quality Control (QC), and also postured the Department for success in their performing the necessary Quality Assurance (QA).

This project utilized the 2006 Standard Specifications, and the QC and QA systems typically reference the following two Sections of this specification:

- Standard Specifications Section 5 "Control of Work"
- Standard Specifications Section 6 "Control of Materials"

In addition, the project Special Provisions (SPs) also guided the Contractor in the performance of QC. Requiring the Contractor to communicate their QC systems (especially for the new technologies proposed for this project) was a key element of the Department's QA operations. The communication often comes in the form of submittals to the Engineer.

Contractor Submittals for this I-680 Rehabilitation project included:

- CEM-3101 "Notice of Materials to be Used" in accordance with Section 6-1.01 of the Standard Specification
- Structural Precast Concrete Facility Audit Requirement
- Precast Concrete Quality Control Plan (PCQCP)
- Portland Cement Concrete Mix Designs based on requirements of Standard Specification Section 90

- Working Drawing submitted in accordance with Section 5-1.02 (reviewed/approved prior to production)

SCOPE OF CHALLENGES – DURING FABRICATION

Challenges during fabrication that were unique to Precast Pavement Operations for this I-680 project included:

- Inclusion of two different Sections for Precast Pavement in the Special Provisions (i.e. Sections 10-1.52 and 10-1.53) for Precast non-post-tensioned Concrete Pavement (PCP) and Precast Post-Tensioned Concrete Pavement (PPCP)
- Contractor-Proposed system approval
- Field dimension verification and transfer of information to the fabricator and the Department's QA
- Fast-paced project delivery timeline
- Tolerances for Panel dimensions
- Surface finish requirements and compliance
- Releasing of Panels to jobsite based on casting date (as opposed to individual panels)
- Microfiber use in the precast post-tensioned concrete pavement system mix design
- Post-tensioning anchorage system approval
- Underslab and Post-Tensioning grout specification

With the Contractor proposing a unique precast pavement system that differed from the one shown in the project plans, the review and approval of Contractor-submitted Working Drawings was vital. It was also important to communicate these changes in a timely manner with all units within the Department, so as to ensure the necessary QA measures had been taken. Communicating the specific design criteria for the precast pavement system may also allow for more efficient QA measures to be taken during the fabrication process.

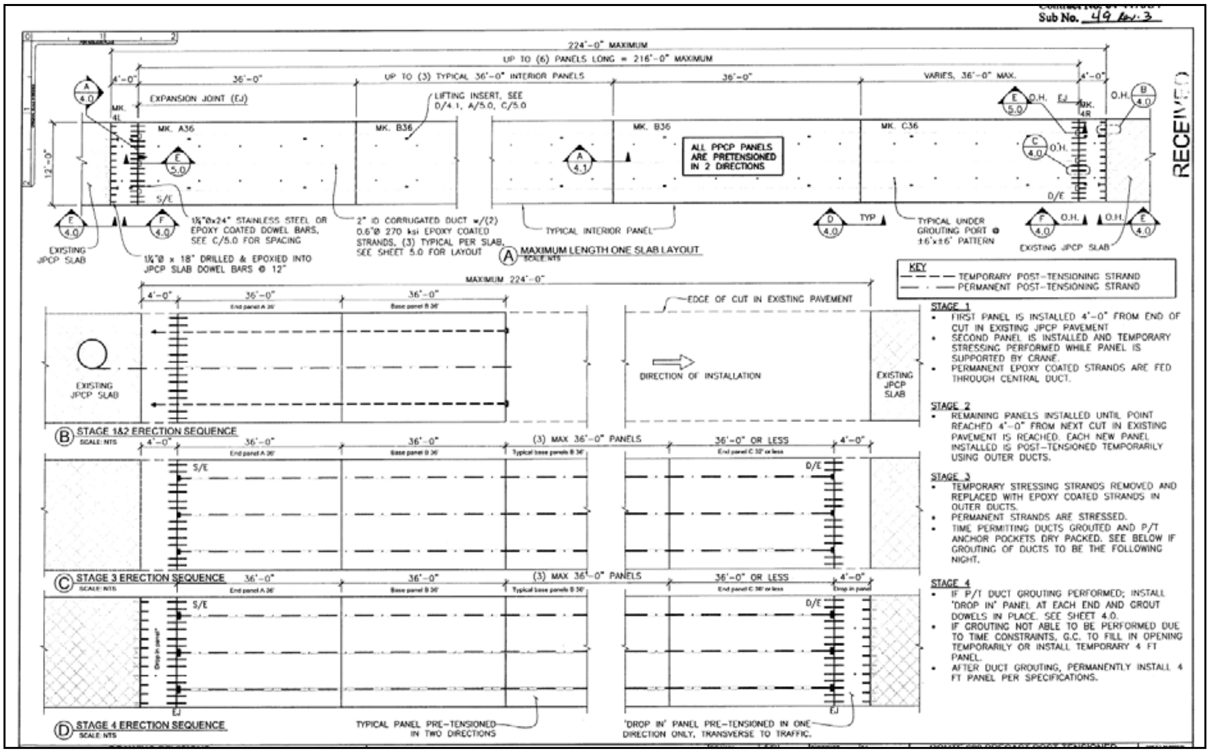

Figure 1 – Proposed PPCP Working Drawings Submitted by Contractor

Because the exact dimensions of each precast pavement panel were to be determined by the Contractor (as per the project plans), a system had to be created to communicate the daily requirements at the jobsite to the precast fabricator. The system used came in the form of a spreadsheet, authored by Contractor staff and periodically verified by field Engineer staff.

The spreadsheet outlined daily precast panel dimensional needs based on measurements taken in the field by the Contractor, and at the location of the work. This spreadsheet was shared with the Precast fabricator, and the Department's source inspection staff, which provided a daily/custom design.

HIGHWAY 680 ALCOSTA to RUDGEAR

CDOT # 04-4470U4

RE: PPCP, FIELD MEASUREMENTS

DIRECTION: NORTHBOUND

NORTHBOUND, LANE #3

PPCP RUN	BEGINNING STATION (APPROXIMATE)	LENGTH	WIDTH	SUBMITTED (TO CON-FAB)	NOTES/COMMENTS
PTNB3-1	2+42	188'	11' - 11"	4/25/2011	
PTNB3-2	9+05	315'	11' - 11"	4/25/2011	added in field
PTNB3-3	32+95.5	116'	11' - 11"	4/25/2011	added in field
PTNB3-4	47+67	115' - 7"	11' - 11"	4/25/2011	
PTNB3-5	67+86	87'	11' - 11"	4/26/2011	
PTNB3-6	86+40	115'	11' - 11"	4/26/2011	
PTNB3-7	332+06	299'	11' - 11"	4/26/2011	
PTNB3-8	335+33	937'	11' - 11"	5/2/2011	tapered end
PTNB3-9	347+90	103'	11' - 11"	5/2/2011	tapered start/end
PTNB3-10	373+12	1,262'	11' - 11"	5/2/2011	tapered start/end

tapered start and end of run (11'6" to 11"11")

tapered start or end of run

Figure 2 – Field Dimension Verification Spreadsheet

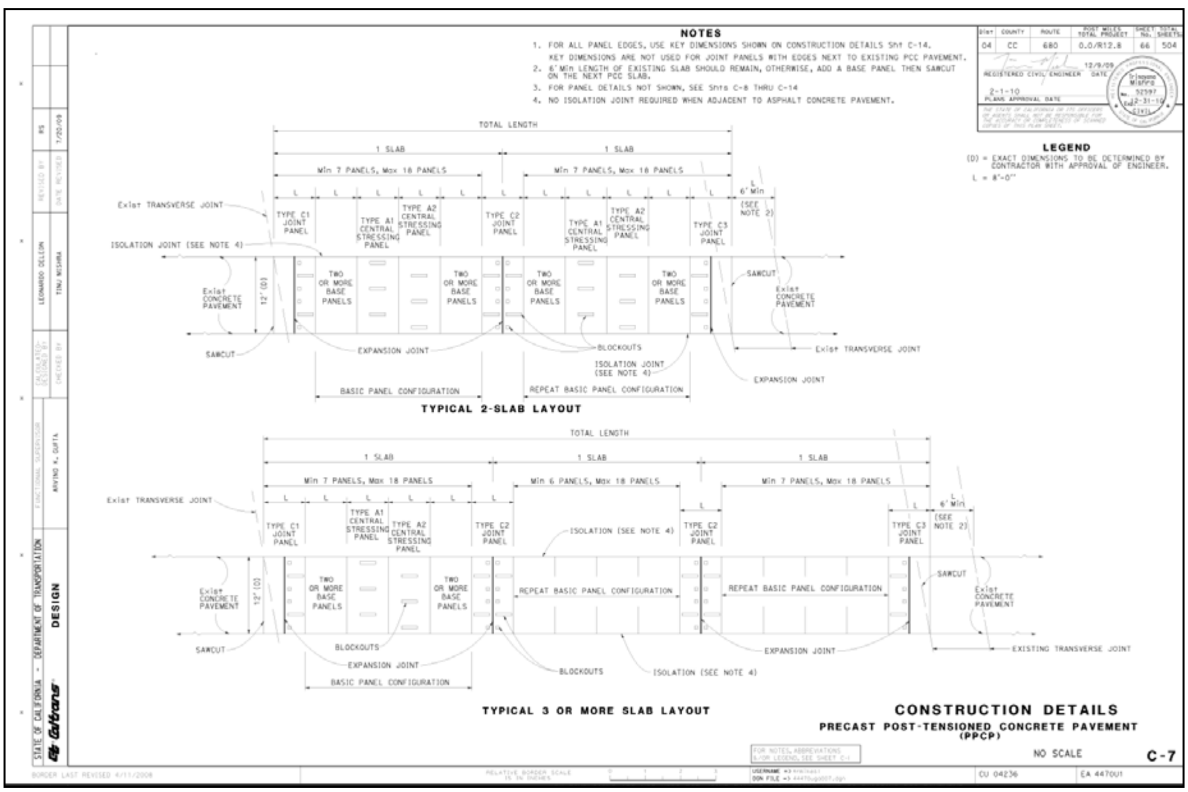

Figure 3 – PPCP Project Plans

Multiple Special Provisions sections devoted to Precast Concrete Pavement (specifically, 10-1.52 and 10-1.53) increases the potential for discrepancies, particularly when the sections have different materials and construction language. A different course of action would be to place all Precast Pavement-related items into one standard section, so as to have one source for all system requirements.

With the project timeline being set at 154 working days, constant communication between all Department QA entities was vital. This placed extra importance on the aforementioned precast panel spreadsheet. Constant communication between the fabricator, the Contractor, and the Department was needed to ensure the right panel size was fabricated at the right time.

Production rates for casting typically ranged from about 4-8 precast pavement panels per day. On average, this equated to roughly 30-80 cubic yards (CY) of PPCP and PCP. Since this was a pilot project and was projected to be completed within 154 days, it was very important to keep production rates and project schedule concerns in mind.

Dimensional tolerances for the precast pavement panels were included in Section 10-1.52 and 10-1.53 of the SPs, and had to be acknowledged in order to perform QA at the source. The tolerances, as shown below, were different between the two sections:

Table of Allowable Tolerances

Dimension	Tolerance
Length (parallel to long axis of panel)	+ 3/16 inch
Width (normal to long axis of panel)	+ 3/16 inch
Nominal Thickness	+ 1/8 inch
Squareness (difference in measurement from corner to corner across top surface, measured diagonally)	+ 3/16 inch
Deviation of ends (horizontal skew)	+ 1/8 inch
Deviation of ends (vertical batter)	+ 1/8 inch
Keyway dimensional tolerance	+ 1/8 inch
Vertical dowel alignment (parallel to bottom of panel)	+ 1/8 inch
Horizontal dowel alignment (normal to expansion joint)	+ 1/8 inch
Dowel location (deviation from shop drawings)	+ 1/4 inch (vertical)[1] + 1/4 inch (horizontal)
Dowel embedment (in either side of expansion joint)	+ 1 inch
Position of lifting anchors	+ 2 inch[2]

Notes:
1. Measured from bottom of panel.
2. From position shown in precast shop drawings.

Figure 4 – Table of Allowable Tolerances in Section 10-1.52 of the SPs

Table of Allowable Tolerances

Dimension	Tolerance
Length (longitudinal to C/L)	± 1/4 inch
Width (transverse to C/L)	± 1/4 inch
Nominal thickness	± 1/16 inch
Horizontal alignment (upon release of prestress) – deviation from straightness of mating edge of panels	± 1/8 inch
Deviation of ends from shop plan dimension (horizontal skew)	± 1/8 inch
Position of strands	± 1/8 inch (vertical) ± 1/8 inch (horizontal)
Position of post-tensioning ducts at transverse joints*	± 1/8 inch (vertical) ± 1/8 inch (horizontal)
Straightness of post-tensioning ducts	± 1/4 inch
Squareness (corner-corner measurement)	± 1/8 inch
Position of lifting anchors	± 3 inch

Note: *Measured from bottom of panel

Figure 5 – Table of Allowable Tolerances in Section 10-1.53 of the SPs

A single table of allowable tolerances may be desired in the future in order to ensure definitive tolerances during the QC and QA process.

Top surface finish requirements for the precast pavement panels were also included in Section 10-1.52 and 10-1.53 of the SPs, and were a vital aspect to the system design. This is especially true, given the performance requirements of pavement. Section 10-1.52 indicated that the top surface was to be textured with an initial burlap drag or broom finish in accordance with Section 40-3.12, “Final Finishing,” of the Standard Specifications, however, the Contractor requested and chose to use a “Tined-surface” finish in accordance with Figure 6 below. It was the Contractor’s responsibility to ensure that the individual high points on the panel top surfaces were adequate upon release.

Figure 6 – Final Surface Finish

Approval of the Post-Tensioning system to be used for Precast Post-Tensioned Concrete Panels also requires additional concern. In order to conform to the requirements of Standard Specification Section 50, the Post-tensioning system must undergo prequalification testing. Because Precast Post-Tensioned Concrete Panels are a relatively new technology, only a small number of Prestressing system are available, and few (if any) have undergone previous testing and approval.

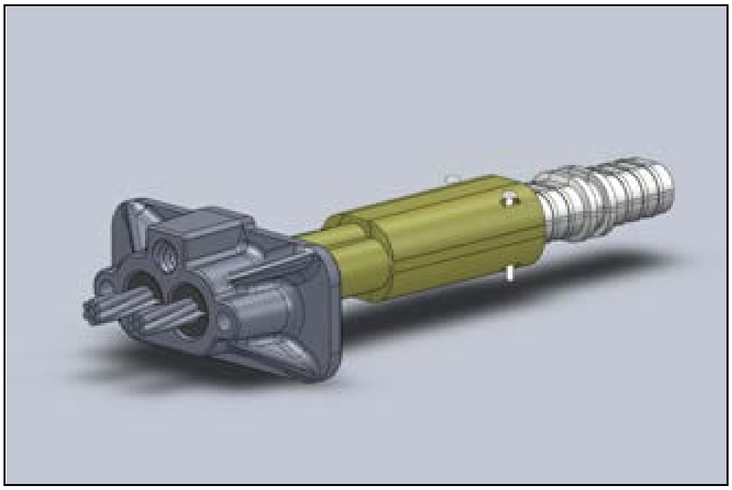

Figure 7 – Post-Tensioning System proposed for Use

The final QA inspection and release of precast panels from the fabricator required constant effort from the Department, given the rapid timeline of the project. QA personnel monitored the anticipated shipment times and performed final inspection of the precast pavement in a manner that supported the nightly installations. As a result, releasing of panels to the jobsite was frequently performed based on casting date of the panels.

The precast panel material requirements, to include the precast concrete compressive strength and inclusion of fiber reinforcement, were also unique. The precast post-tensioned concrete mix was to be fiber reinforced with monofilament polypropylene microfiber in compliance with ASTM Designation: C1116, Type 3, Section 4.1.3 and per the manufacturer's recommendations.

This fiber reinforcement often caused variations in the workability of the PCC, as the PCC often varied between wet, dry, and "sticky" when the fiber was used. The fabricator, however, did work with the fiber producers and industry experts in order develop a more workable mix. The Mix design was adjusted through the use of chemical admixtures to make the mix more workable.

The precast concrete was to also have a minimum compressive strength of 6,100 psi at 28 days and a minimum compressive strength of 3,500 psi at the time of release. Review of Contractor submittals and review of the Contractor's Quality Control systems was vital to ensure these requirements were met. Panels were released after the 28-day strength was achieved, which typically occurred between 5-7 days.

The underslab grouting and the grouting for post-tensioning occurred after panel emplacement. The grout material used was to comply with the requirements listed in the project Special Provisions. Particular attention was to be placed regarding approval of the grout material, as the Special Provisions contained different requirements for underslab grout versus the post-tensioning grout. In order to ensure design requirements are met, a uniform standard for grout that is to be used for both occasions may be desired in the future.

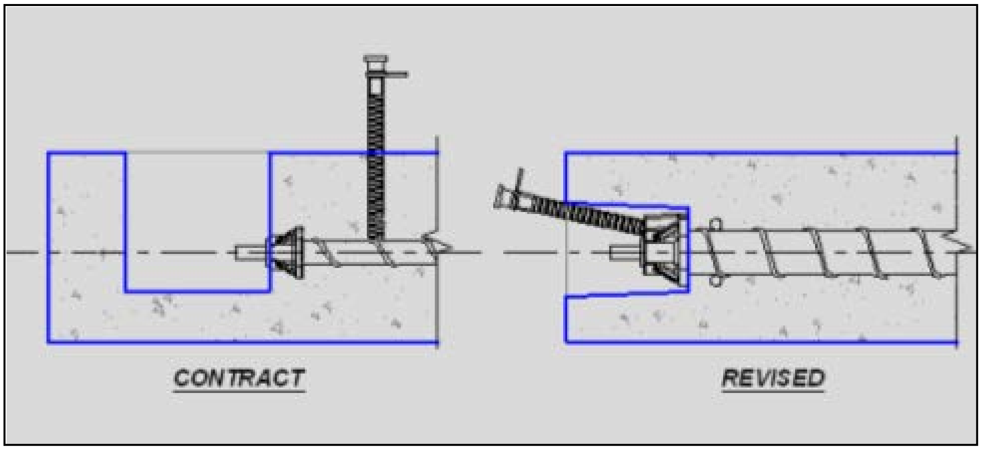

Figure 8 – Grout for Post-Tensioning (as per Plans versus the Proposed System)

SCOPE OF CHALLENGES – DURING INSTALLATION

The following section outlines the challenges during installation that were unique to Precast Pavement Operations for the I-680 project.

Being one of the first projects of its kind, the installation of the precast systems came with its set of new experiences. Below is a list of observations and challenges faced during the PPCP and JPPCP installation:

Drop-in panels - Underslab grouting can't be done until final drop-in panels are installed. Thus, dowels need to be drilled into existing PCC and drop-in panel placed and grouted.

Check alignment and spacing of dowels. Make sure dowels aren't in contact with side slots on drop-in panels. Ensure dowels lie in a longitudinal direction (in the direction of the flow of traffic)

Ensure PT grout is pumped upslope. When grout was injected downslope, a void was left on the high side. Pump upslope until grout comes out of the other side of the PT duct. This ensures grout fills the duct.

Ensure PT strands are epoxied on ends after cutting, prior to patching of blockout. This is done to minimize corrosion at ends of strands.

Figure 9 – Various Installation Notes

Ensure LCB-RS is properly placed and graded. Underslab grouting may need to be done the same night, if large voids exist between LCB-RS and PPCP panels.

Opening age strength of LCB-RS. In our case it took around 4 hours to reach the desired 725 psi opening age strength. Therefore the crane used to hoist the PPCP panels was not allowed to traverse the installed precast panels during placement.

Ensure coating on PT tendons isn't removed exposing steel as a result of dragging tendons on the ground or when fed into PT ducts.

Check for elongation of epoxy coated steel strands after final post-tensioning. and compare with theoretical - $\delta = PL/AE$.

Figure 10 – Various Installation Notes

Figures 11-12 – Drilling dowel slots, placing joint filler material and setting grade for LCB-RS

Some additional notes during the precast pavement installation also include the following:

1. In an effort to verify the elongation of the post-tensioning strands after stressing (see Figure 10), the following relationship was used to compare theoretical values with actual elongation measured in the field:

$$\delta = \frac{PL}{E_{steel}A_{steel} + E_{epoxy}A_{epoxy}} = \frac{44{,}000 \times L \times 12(inches)}{28 \times 10^6 \times (\pi \times \frac{0.6^2}{4}) + 35 \times 10^5 \times (\pi \times \frac{0.025^2}{4})}$$

Where L was the length of the slab, and E_{epoxy} (Modulus of Rupture of the Epoxy) was approximated. Random checks were conducted, and in all instances, the actual elongations were close to the theoretical.

2. It is also essential to check for other sources of prestressing losses, such as incomplete closure of transverse joints. However, there was no incomplete closure of traverse joints. Panels had keyways and lined up sufficiently during temporary post tensioning.

3. Every effort should be made to avoid loss of epoxy-coating on prestressing strands due to abrasion from edge of corrugated metal post-tensioning (PT) duct, as well as inside the duct.

4. Check for leaks around ends of PT ducts. PT system couplers should have adequate seal to contain grout.

5. Inspect the lean concrete base-rapid set (LCB-RS) grades to ensure precast panels sit flush with adjacent roadway. It is also necessary to visually inspection at the traverse joints and in grout ports to see if there was a significant gap between base of panels and top of LCB. The surface of the LCB-RS should be carefully inspected so corrections can be made. Spot grinding was also required for high spots and depressed areas in an effort to minimize voids beneath the panels. This became less of an issue over the course of the project, as the contractor became more and more comfortable with placing and grading the LCB-RS.

6. It would be ideal to fasten the foam pad for the isolation joint to prevent it from coming out when the underslab grout makes its way to the isolation joint.

7. Check for sag in panels coming from precast yard, and ensure panels are stacked in a manner that would minimize sagging. Also, check to ensure adequate dunnage. It is the responsibility of the Contractor to provide this adequate dunnage, and to ensure there was not sag in transported panel. However three-point dunnage could also be problematic on longer panels, as it creates a possible sine wave feature.

8. Additional care is required to prevent chipping and damage due to handling of precast panels during installation and demolition. Ensuring that adequate dunnage is used during delivery is also important. Significant spalls or corners breaks led to rejection of the damaged panels, while others with less distress were left in place with the contractor taking some sort of deduction.

9. The existing pavement joints were not consistent, which led to varying isolation joint widths at some locations. Some isolation joint widths were up to 2.5” after a precast

panel was installed. There were occurrences of wide isolation joints. The Contractor used polyester and precast panels to keep the joint isolated. It should also be required that surveying be done to ensure sawcuts are precise. The contract documents contained joint tolerance requirements that put the responsibility of accuracy on the contractor, but a better requirement for this might be prudent.

10. At some locations on the I-680 project, the existing lane widths and joints were not consistent, leading to varying widths in an excavation. This resulted in some isolation joint width of up to 63.5mm (2.5in) after precast panel was installed. To address this issue, additional panels were cast with a length of 3.63m (11.92 ft) instead of the original 3.7m (12ft) required by the contract

11. Production rates for placement and casting was very important for determining the working days on a project with PCP and PPCP panels. The average installation rates for PPCP was 8 panels per day on average, and 4 to 6 panels of PCP panels per day on average.

12. A rough breakdown of the installation timeline, for example, LCB-RS base placement time to first panel placement time to grouting time, to opening to traffic time, is as follows:
    - Demolition of a PPCP section took about 1-1.5 hours.
    - Grading of base lasted about 30 minutes (including drilling dowel holes and pacing joint filler material between existing PCC and PCP).
    - Pouring, grading and curing LCB-RS lasted approximately 2-3 hours
    - Placement of bond breaker
    - Placement of PPCP (6-8 panels) took approximately 30 minutes.
    - Post tensioning (2 hours) or PCP panels (7-10).
    - Open to traffic (within 8 hour work window).

13. The work area for placing the panels for the outside lane needed only lanes 3 and 4. For lanes 2 or 3, 3 lanes of work area (1, 2, 3, or 2, 3, 4) were required for panel installation.

INNOVATIONS DURING INSTALLATION

As the project progressed and the Contractor became more and more comfortable with the installation operation, it became desirable to explore new avenues with precast concrete pavement in an effort to demonstrate its usefulness. Below is a list of successfully implemented innovations:

1. <u>The installation of PPCP under a structure</u>. Panels were cast smaller to an 8' length by 12' width for ease of handling under an overcrossing (see figure 11). A total of 27 panels were installed and post-tensioned (216') in a single 10-hour night shift.

Figure 11 – PPCP installation under a structure (17' clearance)

2. <u>The fabrication of tapered panels to correct varying width joints</u>. In a few locations, existing lane widths were not the standard 12’ dimension (some were reduced to as small as 11’ 6”). As a result of this, the fabricator was asked to cast tapered panels to accommodate a new sawcut to a standard 12’ lane width. Tapered panels were fabricated to carry the joint outward and to increase the lane width to 12’. The layout of a tapered panel is shown in Figure 12.

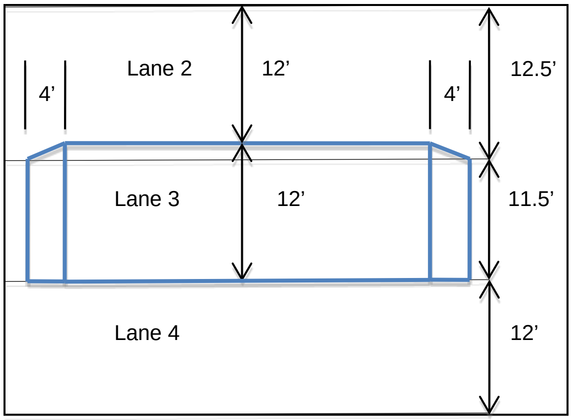

Figure 12 – Tapered panels to accommodate varying lane widths and installed tapered panel (6” over a 4’ length)

3. The fabrication of custom-fit panels to accommodate varying lane widths. There were several instances where the lane widths varied slightly from 12’ to 12’ 2”. As a result, a “one size fits all” panel was not desirable, but rather custom fit panels to fit varying lane widths. Originally, the Department agreed to use a fixed 11’11” width panel to fit 12’ wide excavations. As the project progressed, it was decided to cast two different dimensions, 11’11” and 12’ wide panels, to accommodate the varying widths.

4. The installation of PPCP panels on curved sections. While curved PPCP panels were not installed on this project, the precast fabricator and the Engineer began to strategize ways to fabricate panels ranging in radius from 10000’ to 3200’. Mock-up Panels were fabricated in a casting bed that had flexible siderails and adjustable bulkheads. This was essentially performed to research new means and methods.

5. LCB-RS was finished using a screed that sat on rails. The rails were laid out based on existing cross slope and grades of the roadway. A straight edge was used to ensure there weren’t large depressions or voids on the LCB-RS surface.

6. To ensure LCB-RS is properly placed, Underslab grouting may need to be done the same night if large voids exist between LCB-RS and PPCP panels. ½” Voids were used as a guideline to fill.

CONCLUSIONS

While many of the Department’s existing specifications and systems led to the successful execution of this project, the unique and relatively-new use of precast pavement technology presented the Department with various lessons learned.

These lessons learned include, but are not limited to, the following:

- There may be value in the development of standard specifications and standard plans for the fabrication of precast concrete, as this may result in added clarity during the bidding and construction phases of projects.
- A standard specification for precast concrete might also assist with project-delivery, as it would help clarify the precast panel tolerances, the panel surface finish requirements, the post-tensioning system approval, and the material specifications.
- In order to ensure design requirements for both underpanel grouting and post-tension grouting are met, a uniform standard for grout that is to be used for both occasions may also be desired in the future.

RECOMMENDATION

It is recommended that the Department continue to work through proper channels (i.e. Office of Structural Materials, District Materials, Pavement Program, Rock Products Committee) to develop methods to compare design life and performance characteristics for precast prestressed concrete pavement systems and non-standard proprietary systems.

This would allow the Department to refine and improve their systems for contracts utilizing precast pavement technology.

Please contact Bobby Petska at 510-599-9993 for any questions regarding this matter.

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