

Technical Report Documentation Page

1. Report No. FHWA/TX-05/5-4035-01-1		2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Design Standards, Special Specifications, and Monitoring Plan for PCP in Texas			5. Report Date September 2005	
			6. Performing Organization Code	
7. Author(s) Cesar Ivan Medina-Chavez, Moon Won			8. Performing Organization Report No. 5-4035-01-1	
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650			10. Work Unit No. (TRAIS)	
			11. Contract or Grant No. 5-4035-01	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, TX 78763-5080			13. Type of Report and Period Covered Technical Report December 2004-September 2005	
			14. Sponsoring Agency Code	
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Project Title: "Construction and Evaluation of Post-Tensioned Prestressed Concrete Pavement."				
16. Abstract The design and construction of prestressed concrete pavement (PCP) are not common tasks in the pavement industry. However, the promising performance of PCP has raised its support from highway agencies in the last few years. The next step for the full acceptance of PCP is to demonstrate its cost-effectiveness for the long-term. This document describes the tasks that have been pursued for the completion of the design, the preparation of special specifications, and design standards for a project to be built on IH-35, near Hillsboro, Texas in the Waco District.				
17. Key Words Post-Tensioned Concrete Pavement (PCP), tendon, anchor, strand, design standards, special specifications.			18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.	
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 60		22. Price



Design Standards, Special Specifications, and Monitoring Plan for PCP in Texas

Cesar Ivan Medina-Chavez
Moon Won

CTR Research Report:	5-4035-01-1
Report Date:	August 2005
Research Project:	5-4035-01
Research Project Title:	Construction and Evaluation of Post-Tensioned Prestressed Concrete Pavement
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Center for Transportation Research
The University of Texas at Austin
3208 Red River
Austin, TX 78705

www.utexas.edu/research/ctr

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Project Engineer: Moon Won
Professional Engineer License State and Number: Texas No. 76918
P. E. Designation: Research Supervisor

Acknowledgments

The authors express their gratefulness for guidance provided mainly by the TxDOT Waco District Office Engineers including Billy Pigg, Kirk Krause, and Duane Schwarz, who have participated in this project very actively and offered continuous feedback. Likewise, valuable comments and feedback have been received from TxDOT Austin Division Office Engineers including Gary Graham, Hua Chen, and Dr. German Claros.

Products

This report contains Product P1, Design Standards, in Appendix A.

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1. Introduction

1.1 Background

The Texas Department of Transportation (TxDOT) initiated Research Project 0-4035 in fiscal year 2000. The goal of that research project was to develop and recommend an improved design for a prestressed concrete pavement (PCP) that would be a cost-effective state-of-the-art pavement alternative to conventional paving methods like continuously reinforced concrete pavement (CRCP). During the development of the research stage of that project, the researchers developed a design procedure and prepared a first draft of the special specifications that would be used for construction of a new PCP to be constructed in Texas.

The current implementation project has been in charge of finalizing all the details required for the design and construction of the new PCP to be built on the main lanes of IH-35 near Hillsboro. It is expected that the final results obtained from this implementation project will result in substantial benefits to TxDOT.

1.2 Objectives

The main objectives of the current implementation project focus on the effective application of the required procedures for the final design and construction of the new PCP and also on the development evaluation and monitoring plans for both short-term and long-term performance of the PCP. To pursue these objectives, a well-planned approach was prepared by researchers and is presented in this report. Additional objectives of the project include recommendations for materials, a methodology to compare the PCP with CRCP, and a proposed methodology to estimate the financial feasibility of the PCP technology.

The primary objective of this report is to inform about the actions undertaken for Implementation Project 5-4035. The information contained in the report summarizes the tasks conducted for the development of the project according to the original work plan.

1.3 Methodology

This document is organized in five chapters that detail activities performed to accomplish the objectives previously stated. The contents of each chapter in the report can be summarized as follows:

Chapter 1 is an introductory section that provides key background information about the project and describes its objectives.

Chapter 2 contains a summary of the final design details adapted from the original work performed during the research. A series of figures show most of the details contained in the design standards presented in Appendix A.

Chapter 3 discusses some of the most important aspects and discussions held at project meetings with TxDOT personnel collaborating on this project. This chapter intends to document some of the technical support provided to TxDOT.

Chapter 4 presents a proposed monitoring plan that will help evaluate the short-term and long-term performance of the PCP section.

Chapter 5 includes conclusions of the work done from the starting of the project and up to the end of the fiscal year (FY) 2005 and provides recommendations for future work.

2. Design Details

2.1 Introduction

The design of the PCP was originally conducted under TxDOT Research Project 0-4035 “Further Development of Post-Tensioned Prestressed Concrete Pavements in Texas.” Then, during the development of the current implementation project, that design was modified to satisfy the new requirements of geometry. In other words, because the dimensions of PCP slabs and the number of highway lanes changed from the original design to new requirements, an adaptation of the previous design was conducted. Additionally, in order for TxDOT to prepare the PS&E package, a joined effort between CTR and TxDOT was conducted to prepare final design standards and special specifications, contained in Appendix A and B, respectively.

This chapter presents the design details of the PCP as they are presented in the design standard sheets.

2.2 Design Standard Details

This section presents some details of the design standards prepared for the PCP. For a complete detail of the design standard sheets, the reader is referred to Appendix A.

2.2.1 Plan Layout

Figure 2.1 presents a portion of the plan layout for 100 ft long PCP slabs. This layout is very similar for slab lengths of 100 ft. and 300 ft. The only difference between the layouts for different slab lengths is the location of longitudinal and transverse tendons.

For 100 ft long slabs, the spacing of transverse tendons starts with 3 ft. for the first tendon, 4.5 ft. for the second tendon at both ends of the slab. Then, from the middle span of the slabs, where central stressing pockets are located the tendon spacing is 5 ft. for the first and 7.5 ft. for the second, on both sides of the center of the slab. Finally, all the intermediate tendons in the slab will be spaced be 6 ft. center to center.

Similarly, for 300 ft long slabs, the spacing of transverse tendons starts with 5.5 ft. for the first tendon at both ends of the slab. Then, from the middle span of the slabs, where central stressing pockets are located the tendon spacing is the same as for 100 ft long slabs, that is, 5 ft. for the first and 7.5 ft. for the second, on both sides of the center of the slab. All the intermediate tendons in the slab will be spaced be 6 ft. center to center.

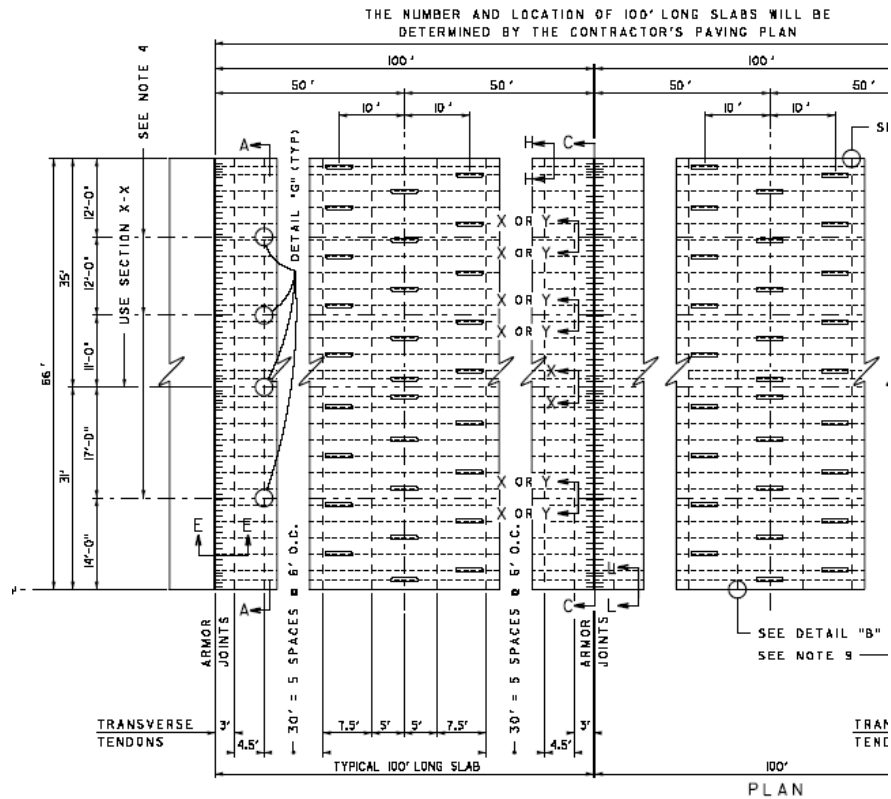


Figure 2.1 Layout of 100 ft.-long PCP slabs

Figure 2.2 displays a detail of longitudinal tendons. As seen, tendons for 100-ft.-long slabs will be spaced at 30 in. and for 300-ft.-long slabs, the spacing will be 15 in. In both cases, small variations must be made at the edges of the slabs to accommodate other hardware in the slab. For further detail of longitudinal tendons, the reader might need to check Sheets 2 and 3 of the design standards contained in Appendix A.

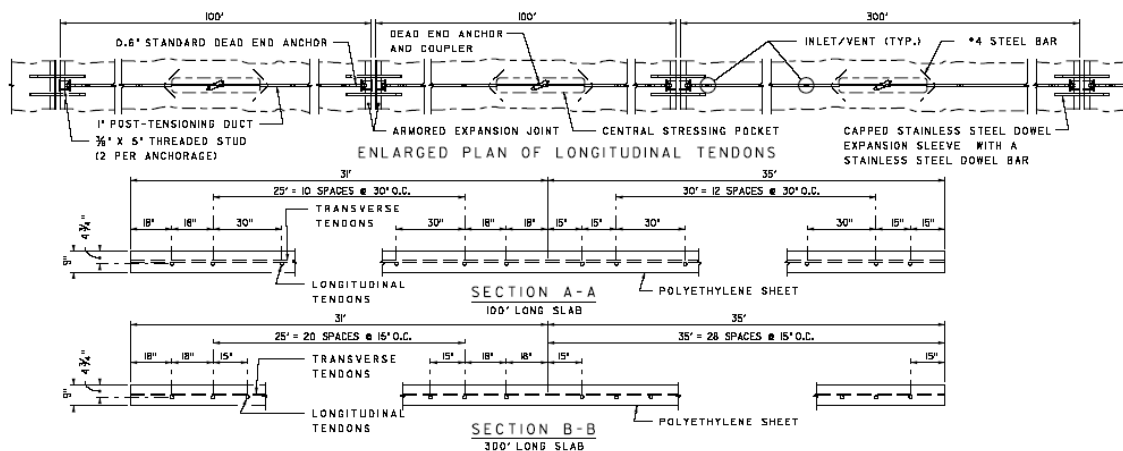


Figure 2.2 Layout of longitudinal tendons for PCP slabs

2.2.2 Miscellaneous Details

The complete set of miscellaneous details for the PCP design standards can be found on Sheets 4 and 5 in Appendix A.

Figure 2.3 displays an enlarged image of Section F-F in the PCP design standards. This figure shows the setup of the transverse joints of the PCP and the required hardware. A Type SSCM2 armored expansion joint will be welded to a plate at the beginning and the end of the project, where the PCP section reaches the contiguous CRCP section, as shown in Detail C. For all the intermediate transverse joints, the Type SSCM2 armored expansion joint will be welded to steel angles to provide the PCP thickness, as shown in Detail D.

A couple of deformed anchor bars will be welded to the armored joint and those will be embedded in the concrete to avoid a rocking effect of the joint when loaded with traffic. Threaded studs will be used to attach anchorages to the armor joint. Stainless steel dowel bars will be used to transfer loads from slab to slab at their ends, just like a conventional jointed pavement.

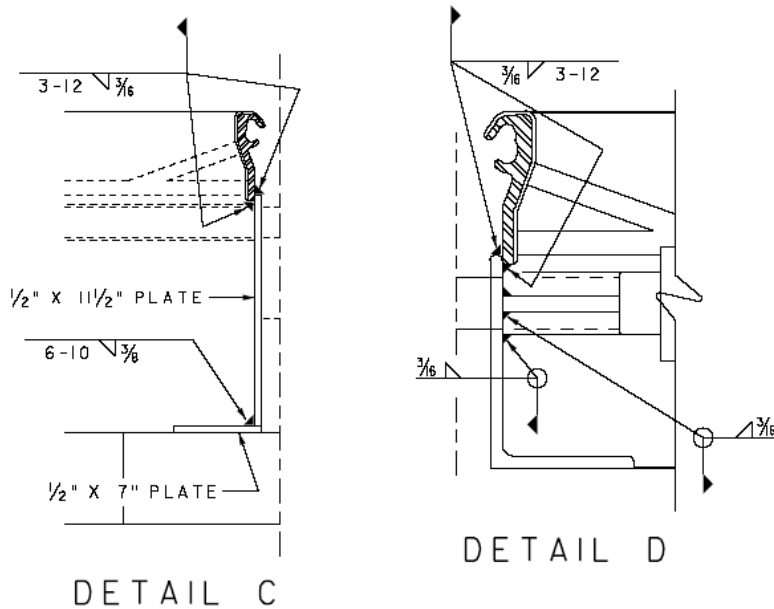
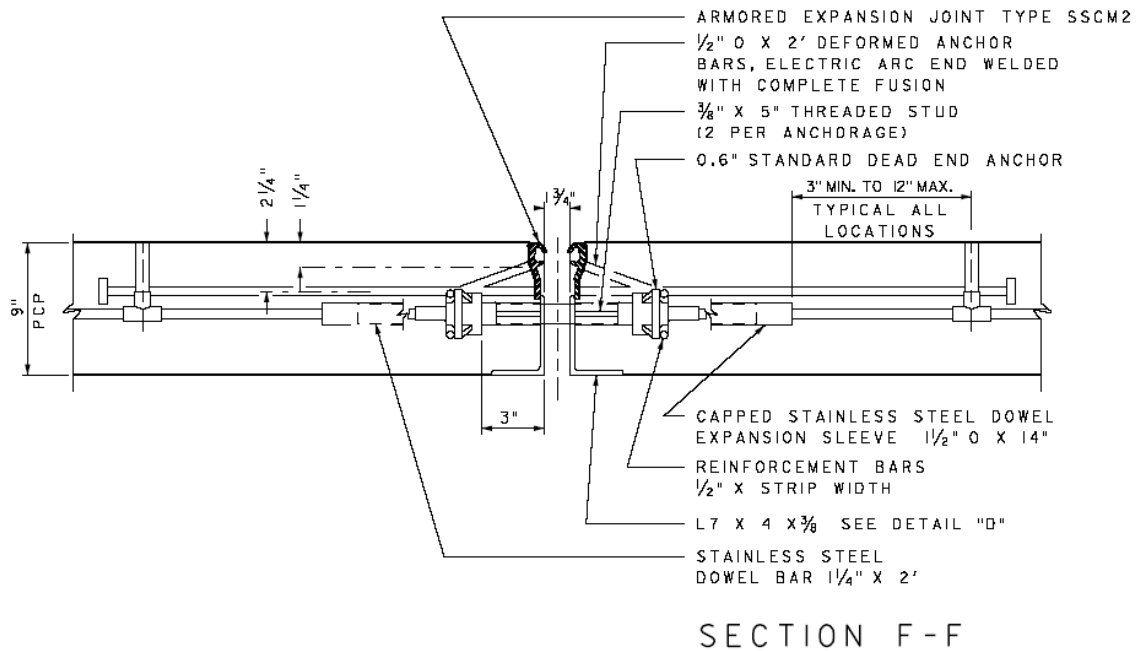


Figure 2.3 Setup and hardware used for transverse joint of PCP

Figure 2.4 shows Section E-E, which will be required for the end slab that will be constructed at the beginning and end of the PCP section. This end slab will act as a transition zone between the CRCP and the PCP sections and will accommodate the expansion and contraction movements of the PCP slabs. Note that longitudinal tendons will only be required on the side of the transverse joint where the PCP is constructed, in

this case the right side. The end slab will not require tendons; it will only need dowel bars and reinforcement steel as indicated.

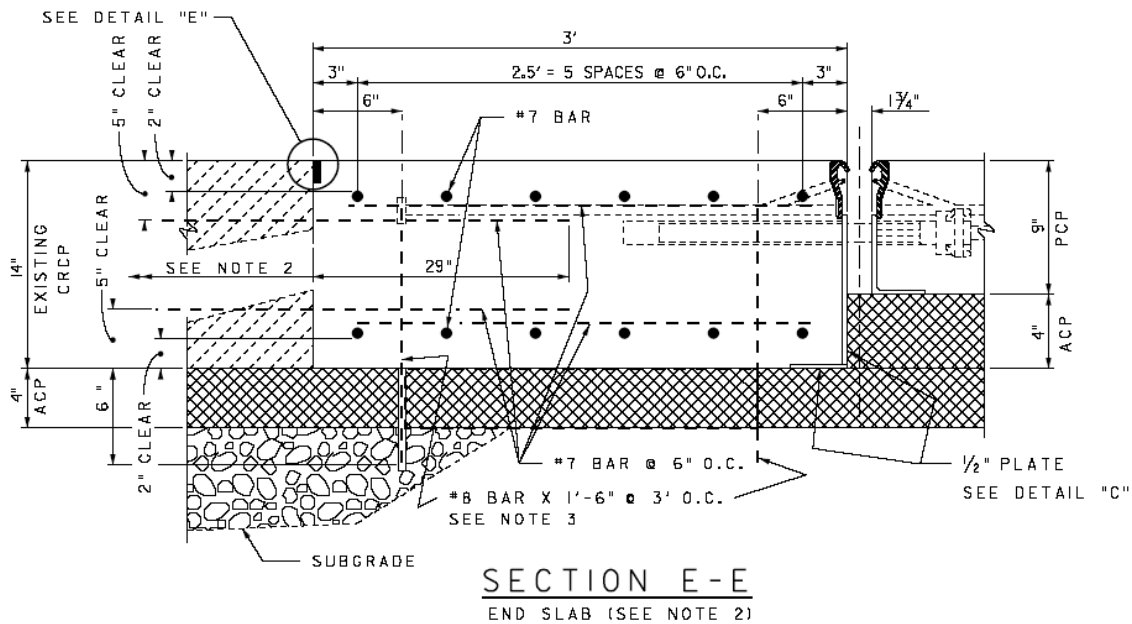


Figure 2.4 Detail of end slab required at start and end of PCP section

Figure 2.5 shows Detail A in the design standards, which represents a layout of a central stressing pocket and the grout vents located nearby. The pocket will be 8 in. wide and 48 in. long with bent reinforcing steel bars located at both ends in longitudinal direction that will prevent corner cracks originating at the pocket. The grout vents will be located between 3 in. to 12 in. from the pocket, as shown in Section J-J.

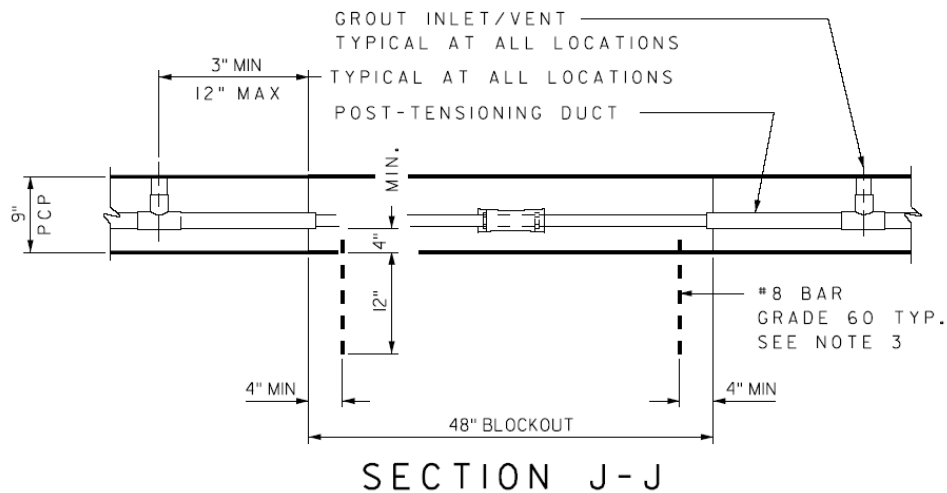
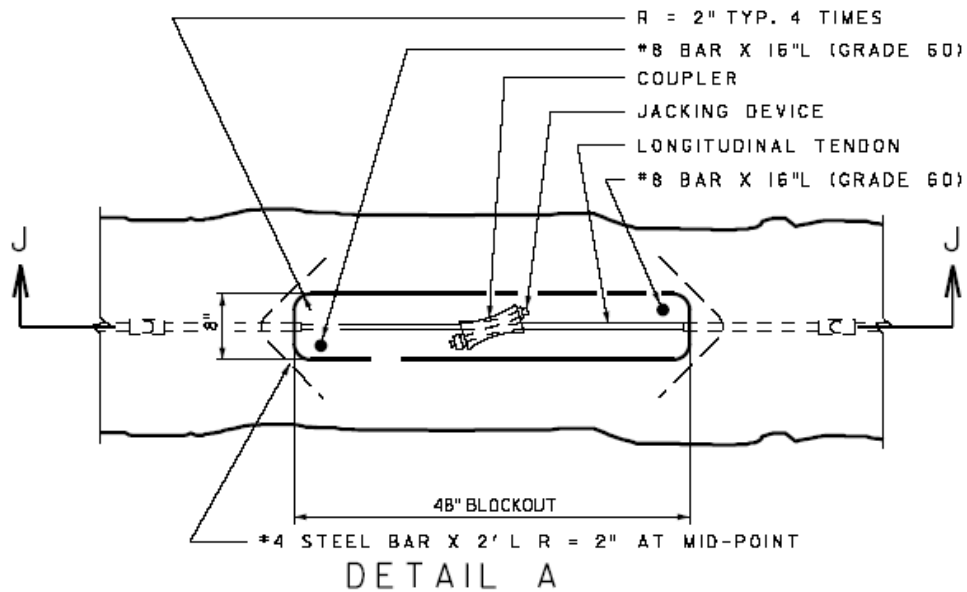


Figure 2.5 Layout of central stressing pocket and grout vents

Figure 2.6 shows Detail F of the design standards. The detail shows a plan view of the transverse tendons that were recommended for the PCP. It can be seen that although the anchorage and grout duct allow inserting three steel strands, only two strands will be used to obtain the required prestress level in transverse direction. The grout vents will be located 15 in. from the longitudinal edge of the PCP slab.

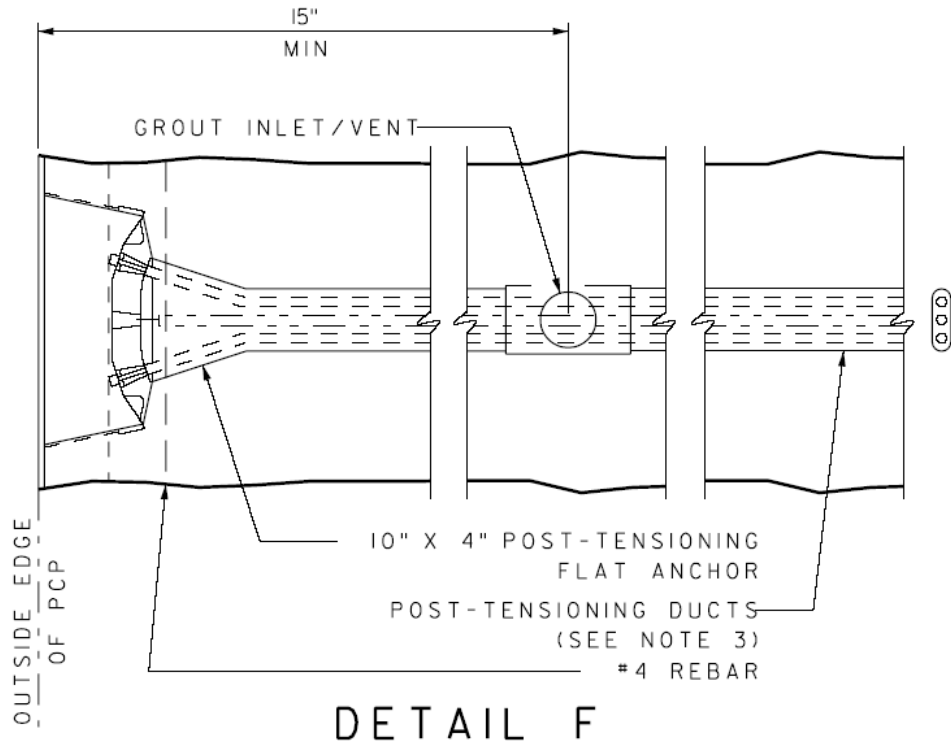


Figure 2.6 Plan view of transverse tendon and grout vent

2.3 Summary

This chapter presented condensed information about the design details of the PCP that will be constructed in the Waco District, on IH-35 near Hillsboro. At press time, no major modifications or changes were made to the information presented here. If the reader requires more detailed information about the design standards or the special specifications drafted for this project, Appendices A or B will be helpful. Otherwise, researchers or the District Pavement Engineer in Waco, Texas, Billy Pigg, should be contacted.

3. Technical Support

3.1 Introduction

The initial design of the PCP was conducted under TxDOT Research Project 0-4035. Due to the uncertainty about the final layout of the pavement section, some changes were made to prepare design standards for the final geometry of the section. The design standards for the final layout of the PCP are contained in Appendix A in this report.

This chapter presents a summary of the technical support provided from CTR to TxDOT and contains the most important technical aspects discussed during meetings and informal conversations with TxDOT personnel collaborating on this project.

3.2 Design-Related Efforts

This implementation project started a few weeks later than originally planned; however, some initial tasks were performed to provide answers to some questions TxDOT had at the time. Among these tasks were the testing of the natural soils along the future PCP and control CRCP sections and the estimation of their elastic properties. The following subsections describe those tasks.

3.2.1 Dynamic Cone Penetration (DCP) Testing

According to the literature (Ref 1), the area where the PCP section will be constructed is described as having clayey soils with low strengths and severe shrinking-swelling characteristics. Figure 3.1 displays a picture taken at one location on the median along IH-35 where the PCP will be located. As can be seen, the natural soil presents wide cracks due to water migration.



Figure 3.1 Clayey soils found along IH-35, Hill County

To determine the strength of the soils, DCP testing was conducted in different locations along the highway. Tests were conducted on the median and outside the current pavement structure. Figure 3.2 shows the field crew running the test on the median.



Figure 3.2 DCP testing conducted on highway median

The DCP test was conducted and in-situ strength of the natural soil was calculated according to ASTM D 6951 “Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications.” Values for California Bearing Ratio (CBR) and Modulus of Elasticity (E) were obtained. Modulus values varied from 4 to 17 psi depending on the location and depth of the soil.

3.2.2 PCP Design Revision

Another task that was conducted as a preliminary effort for the design revision of the PCP was the back-calculation of the elastic properties of the existing pavement and the calculation of the prestress level of the PCP slabs. The obtained results were then used to estimate the new tendon spacing.

As requested by TxDOT, tendon spacings were calculated for slabs with different lengths, including 100, 200, and 300 ft. Longitudinal tendon spacings calculated and reported to TxDOT were 30 in., 20 in., and 16 in., respectively, for the aforementioned lengths. For the final design standards, TxDOT considered only 100 and 300 ft long slabs and tendon spacings were 30 in. and 15 in., respectively.

Along with the design revision of the PCP, CTR provided copies of some literature about post-tensioning systems, extrusion joints fabricated by D. S. Brown and Watson Bowman Acme, to TxDOT. The literature contained application and specifications of the hardware.

3.2.3 Design Standards

As part of this implementation project, design standards had to be drafted so that TxDOT could prepare the plan, specification and estimate (PS&E) package and then continue with the letting of the project. The first set of design standards were prepared at CTR using AutoCAD and went then to TxDOT for review. Next, TxDOT converted the drawings using Microstation, which is the software used at the agency.

The details of the design standards were discussed in a meeting held at TxDOT Waco District Office on February 25, 2005. At that time, CTR and TxDOT discussed some details and decided to add some information to the plans to ensure better understanding by contractors in the letting (bidding) and the construction stages of the proposed contract. The final version of the design standards were prepared by TxDOT in the agency's template and are included in Appendix A.

3.2.4 Special Specifications

Due to the nature of this project and because no standard construction practices exist, it was necessary to prepare a set of special specifications (SS) that will facilitate the construction of the PCP. A first draft of the SS was prepared by the researchers and was submitted to TxDOT for review. As was done with design standards, the SS were always updated after discussions were held between TxDOT and CTR at official meetings and through phone conversations and e-mails.

The final version of the SS is titled "Post-Tensioned Concrete Pavement" and received TxDOT Number 3045, for control-section-job (CSJ) number 0014-24-049. These SS were given to contractors for letting purposes and were clarified during the pre-bid meeting held on July 26, 2005.

3.3 Summary

This chapter briefly documented some of the milestones accomplished during the development of this implementation project. At press time, design standards and special specifications have been drafted and were used for bidding purposes. A pre-construction meeting will be held in December 2005, where TxDOT, CTR researchers, contractor, and other interested entities will have the opportunity to discuss any additional issues related to the construction of the PCP. In the meantime, CTR will continue providing technical support to TxDOT regarding this project.

4. Monitoring Plan

4.1 Introduction

According to TxDOT's plan, the construction of the PCP on IH-35 near Hillsboro, Texas will be performed in several stages, probably during two or more years. A definite plan is not yet available and, therefore, it has not been easy to draft a very concise monitoring plan during construction and post-construction of the pavement. As is well-known, one of the main objectives of this project is to evaluate the cost-effectiveness of the PCP technology compared to conventional CRCP construction. The best approach to compare both paving technologies is by conducting a comprehensive monitoring plan during and after construction. During this implementation project, a close monitoring plan will be followed and construction of the PCP will be documented for future reference. A proposed monitoring plan is presented in this chapter; however, it might need to be modified once construction starts and construction pace adjusts.

4.2 Proposed Tasks

The performance monitoring plan proposed for this project encompasses five subtasks. Although the plan focuses on the evaluation of the PCP, some tasks also will be conducted to assess the control CRCP section. The activities to be performed during construction of the PCP are described in the following subsections.

4.2.1 Evaluation of in-situ Concrete Properties

A number of in-situ concrete properties will be evaluated during and after construction. Some of the properties to be evaluated include concrete strength, modulus of elasticity, drying shrinkage, relative humidity, temperature, and thermal coefficient. Table 4.1 contains the proposed performance monitoring and instrumentation plan, which might be adjusted once construction starts, as previously mentioned.

In Table 4.1, Activity No. 1 will verify that materials or products used for construction of the PCP meet the specified requirements, as per SS. Materials will be sampled and tested per appropriate testing procedures at the given frequency as construction progresses.

Activity No. 2 consists of measuring slab thickness and fresh concrete temperature at discharge. Air content, slump, and unit weight of the fresh concrete will be measured too.

Activity No. 3 evaluates concrete strengths and elastic modulus at various ages. Likewise, the coefficient of thermal expansion of concrete will be measured once per slab. The in-situ concrete strength evaluation for post-tension application will be done by maturity method.

Table 4.1 Monitoring plan for pavement evaluation

Description	Work Plan
Sampling and Testing of Finished Products or Materials	Sample at least once a month, as lots become available
Polyethylene Sheeting, Steel Strands, Strand Anchors, Transverse Joint and Hardware, Strand Ducts, and Grout	Testing to ensure specification requirements are met
Sampling and Testing of Fresh Concrete	
Pavement Thickness and Temperature	3 tests evenly distributed per slab
Air Content, Slump, and Unit Weight	1 test per slab
Testing of Hardened Concrete	
Cylinders	
Compressive Strength	Test at 3,7,14, and 28 days
Splitting Tensile Strength	Test at 3,7,14, and 28 days
Concrete Modulus of Elasticity	Test at 3,7,14, and 28 days
Concrete Thermal Coefficient	Test between 3 and 28 days, 1 test per slab
Concrete Maturity	Test for early age strength, at least 1 test per slab
Beams	
Flexural Strength	Test at 3,7,14, and 28 days
Nondestructive Pavement Testing	
Evaluation of Structural Condition of the Pavement	
Falling Weight Deflectometer (FWD)	Perform test before opening to traffic
Rolling Dynamic Deflectometer (RDD)	Perform test before opening to traffic
Instrumentation	
Short-Term Instrumentation	
Concrete Temperature	Use 1 i-Button assembly per every slab
Weather Information and Concrete Relative Humidity	Set up weather station and use relative humidity gauges. Measure continuous data
Concrete Strain	Install 3 vibrating wire (VW) gauges longitudinally and transversely per every 12 slabs
Horizontal Movement	Install 2 joint meters per instrumented slab at both ends. Compare to caliper
Vertical Movement	Use 4 analog dial gauges or other devices per instrumented slab, 2 at each end of slab
Load-Deflection Profile	Test using FWD and RDD before opening to traffic
Condition Survey	Perform daily inspections during and after construction
Long-Term Instrumentation	
Horizontal Movement	Measure monthly using calipers during first 6 months, once a year thereafter
Vertical Movement	Measure monthly using analog dial gauges during first 6 months, once a year thereafter
Condition Survey	Survey monthly during first 6 months, once a year thereafter
Load-Deflection Profile	Perform test every 1 or 2 years after construction, if possible

Activity No. 4 relates to nondestructive testing (NDT) of the pavement. Ideally, a rolling dynamic deflectometer (RDD) that collects continuous load-deflection profile data will be used in at least one of the two wheel paths in each lane. Additionally, a falling weight deflectometer (FWD) will be used to measure discrete load-deflection locations along the profile of the pavements. Special attention will be given to the transverse joint area to check load transfer efficiency.

Activity No. 5 refers to the short-term and long-term instrumentation schedule of the pavement. During this activity, a series of tasks will be conducted to evaluate the PCP and CRCP during construction and after construction. Among the instrumentation gadgets that will be used are hygro-buttons to measure concrete relative humidity, i-buttons to measure concrete temperature, vibrating wire gauges to measure concrete strain, joint meters to measure joint horizontal movement, and dial gauges to assess slab vertical movement.

4.2.2 Complementary Tasks

A number of additional field tasks will be performed during the monitoring period that corresponds to this implementation project. For the short-term these tasks include recording ambient and fresh concrete temperatures at different depths across the slab, recording end-of-slab longitudinal movements at the time of post-tensioning, measuring tendon elongation to verify that the required prestress force is applied to the concrete, measuring concrete compressive strength in accordance with Tex-418-A or estimate the compressive strength using maturity method in accordance with Tex-426-A to determine the maximum prestressing force that can be applied to the slab at the anchor zone.

Similarly, and for the long-term it will be necessary to record ambient and hardened concrete temperatures at different depths across the slab, to conduct visual condition surveys including a detailed observation of the transverse joints and neoprene seals, to measure horizontal and vertical slab movements and joint widths, to estimate load transfer efficiency at the transverse joints and to evaluate the structural condition of the pavement using RDD and FWD. As already stated, some of these tasks will not be conducted under this implementation project, but possibly under other research projects.

4.3 Preliminary Field Work Schedule

Figure 4.1 presents a working schedule that could be implemented when construction of the pavement takes place. The schedule assumes a working shift of eight hours and is divided in three main categories. Category 1 includes all the necessary tasks that will be conducted to test the fresh concrete such as measurement of slab thickness, concrete temperature, concrete air content, slump, unit weight, and maturity. As can be seen in Figure 4.1, the preparation for these tests should be performed in advance prior to any other tasks are pursued.

Category 2 includes the tests that will be run on hardened concrete samples like strength, modulus of elasticity, and concrete thermal coefficient. Finally, Category 3 includes all the tasks to be performed for the instrumentation of the pavement. Note that

these tasks were intentionally left until the end of the working day because they will help continuing with the tasks in Category 1 for the next working day, when new PCP slabs are poured.

Task Description	T I M E (h r)								
	0	1	2	3	4	5	6	7	8
Fresh Concrete									
Slab Thickness									
Temperature									
Air Content									
Slump									
Unit Weight									
Maturity									
Hardened Concrete									
Compressive Strength									
Splitting Tensile Strength									
Modulus of Elasticity									
Thermal Coefficient									
Flexural Strength									
Pavement Instrumentation									
i-Button									
Concrete Relative Humidity									
Concrete Strain									
Slab Horizontal Movement*									
Slab Vertical Movement*									
Condition Survey									

Nomenclature



Testing / Monitoring Time



Preparation Time

* Instrumentation is only done for PCP section

Figure 4.1 Preliminary field work schedule

4.4 Summary

A comprehensive monitoring plan has been prepared and is ready for implementation when construction of the PCP starts. According to TxDOT's information it is expected that when construction starts, the completion of the project will take between two and three years, depending on the agency's construction budget and priorities. Although the monitoring plan was prepared and this implementation project will only last one more year, it is expected that the plan will be followed possibly under this project, if it is extended, or maybe under another project.

5. Conclusions and Recommendations

5.1 Introduction

The construction of PCPs is not a very frequent task in the highway industry. Nevertheless, it is certain that the level of confidence shown by highway agencies has grown for this promising type of pavement technology. The PCPs constructed nationwide in the past have shown that the performance of PCP is outstanding; however, it has not been clearly demonstrated yet that PCPs are also economically feasible in the long-term. It is strongly believed that once the PCP being implemented by this project is constructed and after some years have passed, TxDOT will be in a better position to consider this technology for more frequent application.

This report briefly summarizes the tasks that have been pursued, according to the proposed original plan, and that relate to the completion of the design of the PCP, the preparation of special specifications, and design standards for the project to be constructed on IH-35, near Hillsboro, Texas in the Waco District.

5.2 Conclusions

The effective communication between TxDOT personnel from the Waco District and CTR researchers has provided very good results for the dynamic flow of the project. During this study a number of tasks have been accomplished. A step forward has been taken for the completion of design standards and they are ready for implementation as soon as TxDOT budget plan allows. The design standards were drafted in TxDOT conventional format and are contained in Appendix A. The drawings include five different sheets that detail the geometric characteristics of the PCP. The drawings also contain general notes that describe important issues related to required PCP materials and construction procedures.

Similarly, the good interaction between TxDOT and CTR has allowed the preparation of a set of special specifications that will serve as guidelines to contractors not only for this particular project, but also for future PCP projects. The specifications are contained in Appendix B and, as mentioned, are fully completed and ready for application. It is hoped that as construction progresses, the specifications are enriched with the gained experience of all parties involved in the project. As a result, much better specifications will be produced that will be more applicable to other PCP projects to be constructed elsewhere.

Finally, a monitoring plan has been completed and will be put into practice when construction starts and will be adjusted to meet the project requirements in terms of working schedule and sampling intensity.

5.3 Recommendations

At this stage no major recommendations might be proposed for this study other than to continue encouraging a good and dynamic interaction between TxDOT and CTR, plus contractor and material suppliers that will be involved in the project soon. Also, it is expected that a reliable documentation of the construction and monitoring of the project will be performed by researchers, with the support of TxDOT, especially the Waco District Office Engineers.

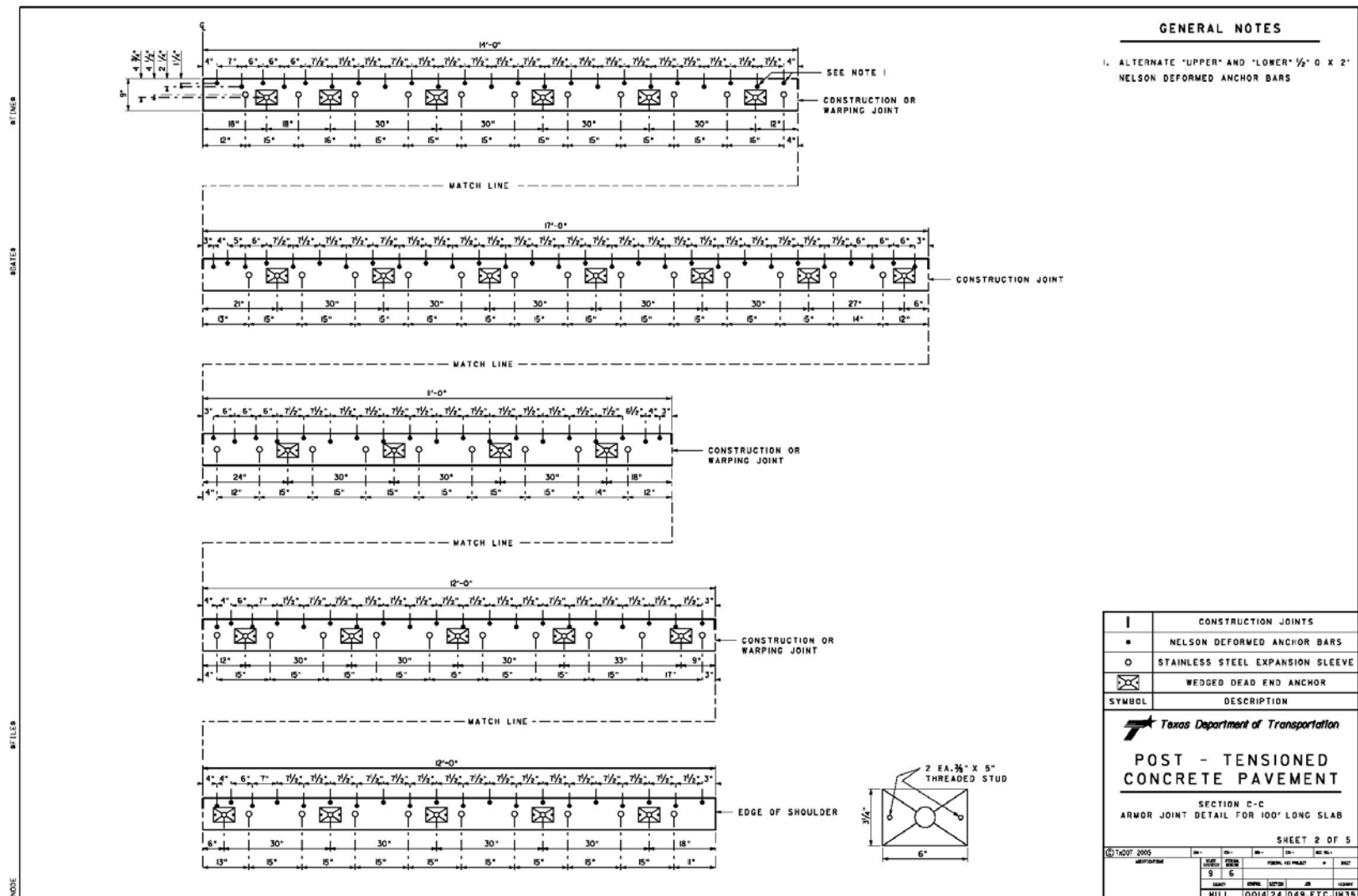
It is recommended that once construction starts and some results about the behavior of the PCP are available, a post-construction meeting be organized by the involved parties to disseminate the information about the project to other state agencies and the Federal Highway Administration (FHWA), who have previously shown interest in this particular project.

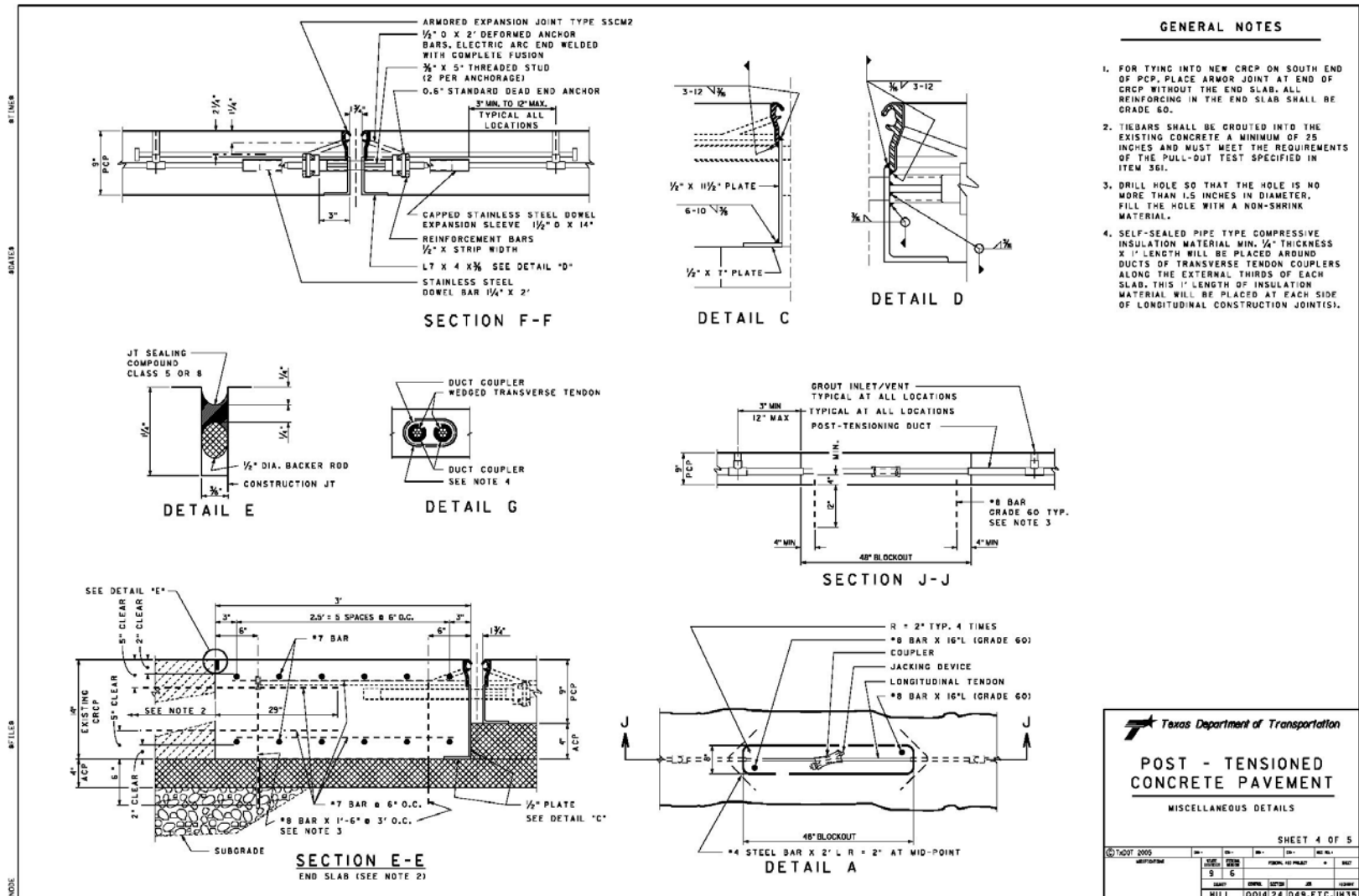
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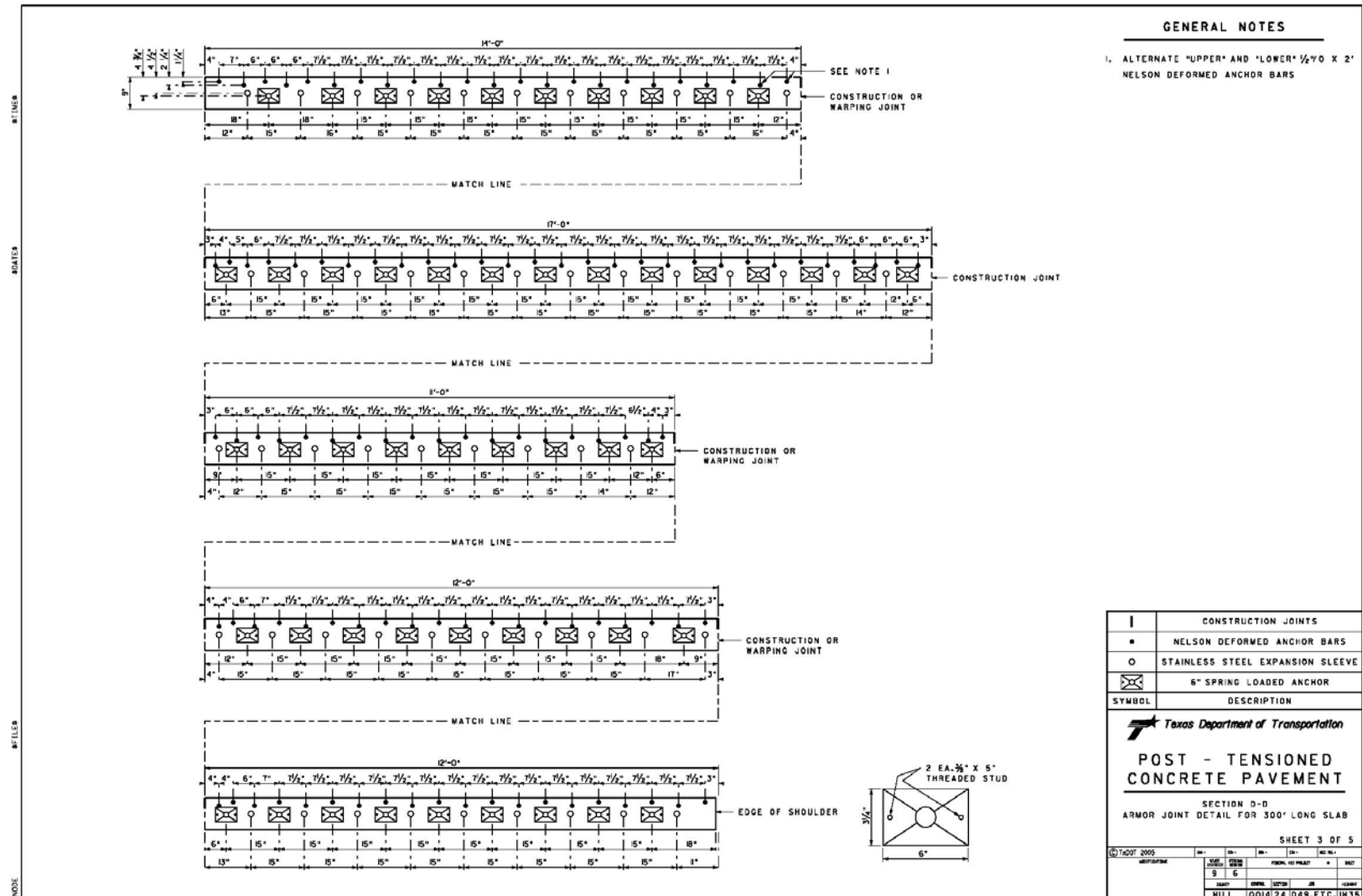
1. Medina-Chavez, Cesar Ivan, B. Frank McCullough, and David W. Fowler. “Design of a Post-Tensioned Prestressed Concrete Pavement, Construction Guidelines, and Monitoring Plan.” Research Report 0-4035-1. Center for Transportation Research, The University of Texas at Austin, August 2003.

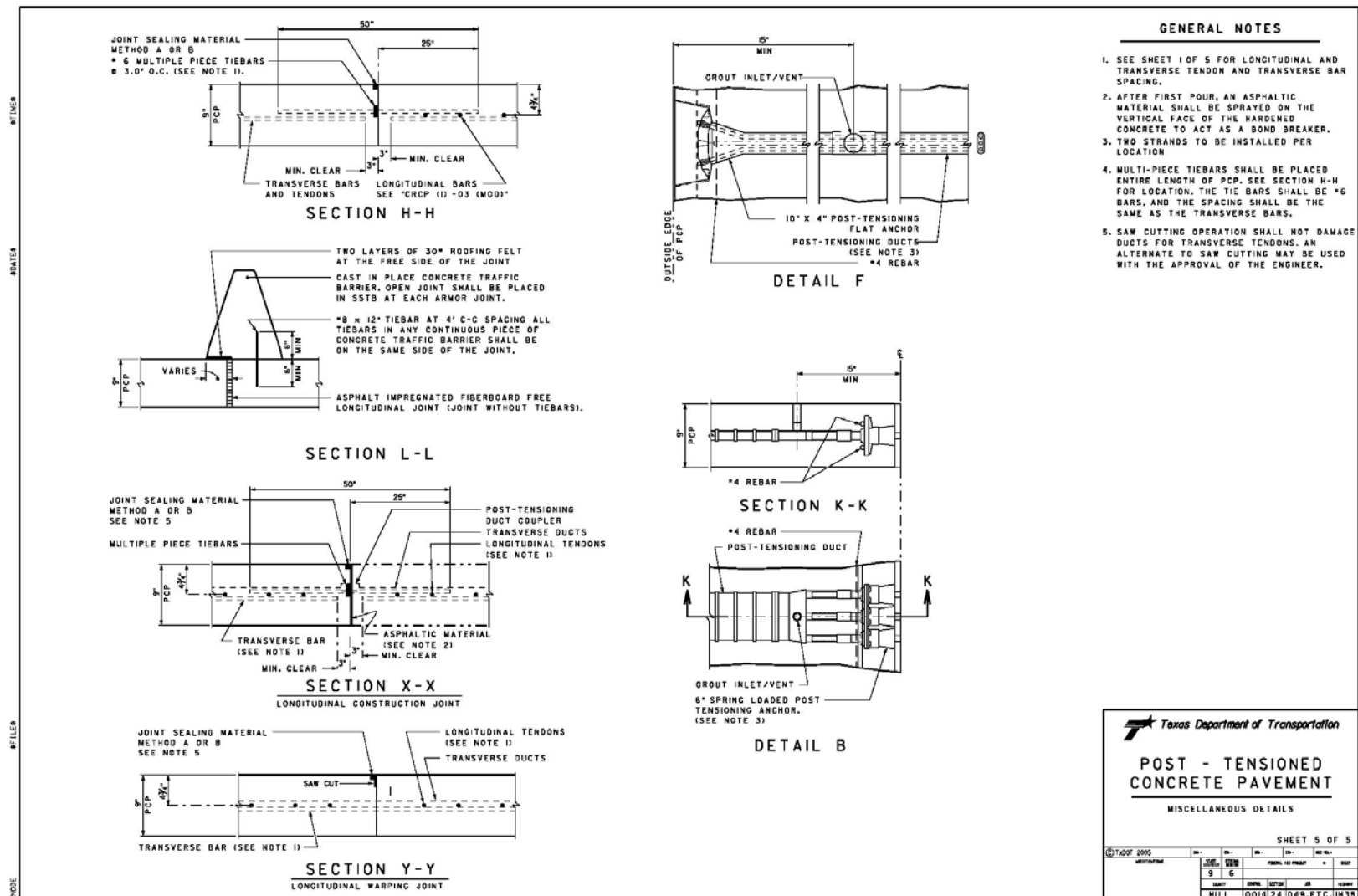
Appendix A

Design Standards for PCP









Appendix B

Special Specifications for PCP

SPECIAL SPECIFICATION**3045****Post-Tensioned Concrete Pavement**

1. **Description.** This Item shall govern for the construction of post-tensioned concrete pavement (PCP) without curbs.
2. **Materials.**
 - A. **Hydraulic Cement Concrete.** Provide hydraulic cement concrete in accordance with Item 421, "Hydraulic Cement Concrete," except that strength over-design in not required. Provide Class P concrete designed to meet a minimum average compressive strength of 5,000 psi at 28 days in accordance with Tex-418-A.

The coarse aggregates used in the concrete paving mixture shall produce concrete with a coefficient of thermal expansion (COTE) not greater than 6.0×10^{-6} inch/inch/°F when tested in accordance with Test Method Tex-428-A. Specimens shall be made and cured in accordance with Test Method Tex-447-A and be at least 7 days old before testing. The Construction Division will perform all testing for COTE for aggregate acceptance, and test results shall be final.
 - B. **Reinforcing Steel.** Provide Grade 60 deformed steel for bar reinforcement in accordance with Item 440, "Reinforcing Steel." Provide approved positioning and supporting devices (baskets and chairs) capable of securing and holding the reinforcing steel in proper position before and during paving. Provide corrosion protection when shown on the plans. Perform periodic tensile strength tests of the reinforcing steel in accordance with Item 440, "Reinforcing Steel."
1. **Dowels.** Provide smooth, straight dowels of the size shown on the plans, free of burrs, and conforming to the requirements of Item 440, "Reinforcing Steel." Coat dowels with a thin film of grease or other approved de-bonding material. Provide dowel caps on the lubricated end of each dowel bar used in an expansion joint. Provide dowel caps filled with a soft compressible material with enough range of movement to allow complete closure of the expansion joint.
2. **Tie Bars.** Provide straight deformed steel tie bars. Provide either multiple-piece tie bars or single-piece tie bars as shown on the plans. Provide multiple-piece tie bars composed of 2 pieces of deformed reinforcing steel with a coupling capable of developing a minimum tensile strength of 125% of the design yield strength of the deformed steel when tensile-tested in the assembled configuration. Provide a minimum length of 33 diameters of the deformed steel in each piece. Use multiple-piece tie bars from the list of "Prequalified Multiple Piece Tie Bar Producers" maintained by the Construction Division, or submit samples for testing in accordance with Tex-711-I.

- C. **Curing Materials.** Provide Type 2 membrane curing compound conforming to DMS-4650, "Hydraulic Cement Concrete Curing Materials and Evaporation Retardants." Provide SS-1 emulsified asphalt conforming to Item 300, "Asphalts, Oils, and Emulsions," for concrete pavement to be overlaid with asphalt concrete under this Contract unless otherwise shown on the plans or approved. Provide materials for other methods of curing conforming to the requirements of Item 420, "Concrete Structures."
- D. **Epoxy.** Provide Type III epoxy in accordance with DMS-6100, "Epoxies and Adhesives," for installing all drilled-in reinforcing steel.
- E. **Evaporation Retardant.** Provide evaporation retardant conforming to DMS-4650, "Hydraulic Cement Concrete Curing Materials and Evaporation Retardants."
- F. **Joint Sealants and Fillers.** Provide Class 5 or Class 8 joint-sealant materials and fillers unless otherwise shown on the plans or approved and other sealant materials of the size, shape, and type shown on the plans in accordance with DMS-6310, "Joint Sealants and Fillers."
- G. **Post-Tensioning Steel Strands.** Provide 0.6 in. in diameter strands that belong to either of the following two groups:
 - 1. Uncoated, low-relaxation wire strand, Grade 270 (1860 MPa)
 - 2. Uncoated, stress-relieved (normal-relaxation) strand, Grade 270 (1860 MPa)

Both groups should conform to AASHTO M203 (ASTM A416), "Uncoated Seven-Wire Steel Strand for Concrete Reinforcement." Additionally, Group B strands should conform to AASHTO M204 (ASTM A421), "Uncoated Stress-Relieved Steel Wire for Prestressed Concrete." Additionally, the capability of the strand to properly develop bond should be certified from the strand supplier. A light bond coating of tight surface rust on prestressing tendons is permissible provided the strand surface shows no pits visible to the unaided eye after rust is removed with a nonmetallic pad.
- H. **Anchors.** Provide anchors as specified in the design standards. The anchorage system hardware used shall ensure that the full prestress force is applied to the joint panel over the length or width of the slab and allows setting the wedges after the strands are inserted into the ducts. Provide bonded tendons that meet the following requirements:
 - 1. An anchorage for bonded tendons tested in an unbonded state will develop 95% of the actual ultimate strength of the prestressing steel, without exceeding anticipated set at time of anchorage. An anchorage that develops less than 100% of the minimum-specified ultimate strength shall be used only where the bond length provided is equal to or greater than the bond length required to develop 100% of the minimum-specified ultimate strength of the tendon.
 - 2. The required bond length between the anchorage and the zone where the full prestressing force is required under service and ultimate loads will be sufficient to develop the specified ultimate strength of the prestressing steel. The bond length is determined by testing a full-sized tendon.

3. If in the unbonded state the anchorage develops 100% of the minimum-specified strength, it need not be tested in the bonded state.

Provide anchorage castings that are nonporous and free of sand, blowholes, voids, and other defects. For a wedge-type anchorage, provide wedge grippers designed to prevent premature failure of the prestressing steel due to notch or pinching effects under static test-load conditions to determine yield strength, ultimate strength, and elongation of the tendon. Provide an acceptable testing program that demonstrates that these basic requirements are met.

The load from the anchorage device will be distributed to the concrete by means of approved devices that will effectively distribute the load to the concrete. These devices shall conform to the following requirements:

1. The allowable concrete bearing stress at anchorages shall be as follows:

At service load:

$$f_{bp} = 0.6 \times f'c \times \sqrt{\frac{A'B}{AB}} \leq f'c$$

At transfer load:

$$f_{bp} = 0.8 \times f'ci \times \sqrt{\frac{A'B}{AB}} - 0.2 \leq 1.25 \times f'ci$$

where

AB = bearing area beneath a tendon anchor, inches²

A'B = maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area, inches²

f'c = 28-day compressive strength of the concrete, psi

f'ci = concrete compressive strength at time of stressing tendons, psi

2. Bending stresses in the plate or assemblies induced by the pull of the stressing will not cause visible distortion when 85% of the ultimate load is applied as determined by the engineer. Plastic flexural strength of the plates or assemblies will be adequate for 125% of the ultimate load. Design will not be based on a yield stress in the plates or assemblies greater than 50 ksi.

- I. **Tendons, Anchors, and Tendon Couplers.** Provide tendon, anchors, and couplers that develop at least 100% of the required ultimate strength of the tendon, with a minimum elongation of 2%. In addition they will withstand 500,000 cycles from 60 to 70% of the required ultimate strength of the tendon without failure or slippage. Provide tendons

that are easily identified by reel number and tagged. Anchors will be identified and furnished by the Contractor for testing purposes in accordance with Test Method Tex-710-I. The Contractor will furnish prestressing tendons including couplers with end fitting attached, to be tested for ultimate strength. Provide tendons that are 5 ft. of net length, measured between ends of fittings. If additional testing is required, specimens will be furnished by the Contractor without cost.

- J. **Transverse Joint Hardware.** Provide a transverse joint assembly as shown on the plans. Provide joint hardware that complies with specifications as follows:
1. **Armor Angles.** Provide armor angles that conform to the requirements as specified in Item 441, "Steel Structures", Item 442, "Metal for Structures" and Item 454, "Bridge Expansion Joints."
 2. **Joint Extrusion.** Provide a joint extrusion that conforms to the requirements of Item 454, "Bridge Expansion Joints." and to the configuration shown on the plans.
 3. **Neoprene Seal.** Supply a neoprene seal or diaphragm that conforms to the requirements as specified in Item 454, "Bridge Expansion Joints."
 4. **Dowel Bars.** Provide dowel bars that conform to the requirements herein, as specified. Provide stainless steel that conforms to the requirements of ASTM 176-99, "Standard Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip."
 5. **Dowel Bar Expansion Sleeves.** Provide expansion sleeves made of stainless steel. They will be properly welded to the armor angle at the locations shown on the plans. The free end of the sleeve will be capped to prevent entry of mortar or grout.
 6. **Nelson Deformed Anchor Bars.** Provide Anchor Bars that conform to the requirements as specified in Item 441, "Steel Structures", Item 442, "Metal for Structures" and Item 454, "Bridge Expansion Joints".
- K. **Strand Ducts.** Provide encasing material or ducts of sufficiently strong polyethylene, conforming to the requirements of Item 426, "Prestressing." Provide corrugated duct with a minimum wall thickness of 0.08 in. Use ducts that are strong enough to retain their shape during construction operations. The duct should prevent the entrance of cement paste or water from the concrete, and it should not cause harmful electrolytic action or deterioration. The inside diameter will be at least 1/4 in. larger than the nominal diameter of a single strand. The inside cross-sectional area of the sheath will be at least twice the net area of the prestressing steel. Ducts should have vents at each end of the slab and near the central stressing pockets to allow injection of the grout.
- L. **Grout.** Provide a grouting material that secures effective bond between steel strands and ducts. Use prepacked grout that meets the requirements of DMS-4670 "Grouts for Post-Tensioning" as specified in Item 426, "Prestressing."
- M. **Friction-Reducing Membrane.** Provide a one-layer friction-reducing membrane that consists of polyethylene sheeting conforming to the requirements of ASTM D2103-97, "Standard Specification for Polyethylene Film and Sheeting." Use a 6-mil-thick Type 4

membrane. Provide sheeting that always exceeds the width and length of the concrete strip being poured by at least 2 ft.

3. **Equipment.** Furnish and maintain all equipment in good working condition. Use measuring, mixing, and delivery equipment conforming to the requirements of Item 421, "Hydraulic Cement Concrete." Obtain approval for other equipment used.
 - A. **Placing, Consolidating, and Finishing Equipment.** Provide approved self-propelled paving equipment that uniformly distributes the concrete with minimal segregation and provides a smooth machine-finished consolidated concrete pavement conforming to plan line and grade. Provide an approved automatic grade control system on slip-forming equipment. Provide approved mechanically operated finishing floats capable of producing a uniformly smooth pavement surface. Provide equipment capable of providing a fine, light water fog mist.

Provide mechanically operated vibratory equipment capable of adequately consolidating the concrete. Provide immersion vibrators on the paving equipment at sufficiently close intervals to provide uniform vibration and consolidation of the concrete over the entire width and depth of the pavement and in accordance with the manufacturer's recommendations. Provide immersion vibrator units that operate at a frequency in air of at least 8,000 cycles per minute. Provide enough hand-operated immersion vibrators for timely and proper consolidation of the concrete along forms, at joints and in areas not covered by other vibratory equipment. Surface vibrators may be used to supplement equipment-mounted immersion vibrators. Provide tachometers to verify the proper operation of all vibrators.

For small or irregular areas or when approved, the paving equipment described in this Section is not required.
 - B. **Forming Equipment.**
 1. **Pavement Forms.** Provide metal side forms of sufficient cross-section, strength, and rigidity to support the paving equipment and resist the impact and vibration of the operation without visible springing or settlement. Use forms that are free from detrimental kinks, bends, or warps that could affect ride quality or alignment. Provide flexible or curved metal or wood forms for curves of 100-ft. radius or less.
 2. **Curb Forms.** Provide curb forms for separately placed curbs that are not slipformed that conform to the requirements of Item 529, "Concrete Curb, Gutter, and Combined Curb and Gutter."
 - C. **Reinforcing Steel Inserting Equipment.** Provide inserting equipment that accurately inserts and positions reinforcing steel in the plastic concrete parallel to the profile grade and horizontal alignment in accordance to plan details.
 - D. **Texturing Equipment.**
 1. **Carpet Drag.** Provide a carpet drag mounted on a work bridge or a moveable support system. Provide a single piece of carpet of sufficient transverse length to span the full width of the pavement being placed and adjustable so that a sufficient

longitudinal length of carpet is in contact with the concrete being placed to produce the desired texture. Obtain approval to vary the length and width of the carpet to accommodate specific applications. Use an artificial grass-type carpet having a molded polyethylene pile face with a blade length of 5/8 in. to 1 in., a minimum weight of 70 oz. per square yard, and a strong, durable, rot-resistant backing material bonded to the facing.

2. **Tining Equipment.** Provide a self-propelled transverse metal tine device equipped with 4-in. to 6-in., steel tines and with cross-section approximately 1/32 in. thick by 1/12 in. wide, spaced at 1 in., center-to-center. Hand-operated tining equipment that produces an equivalent texture may be used only on small or irregularly shaped areas or, when permitted, in emergencies due to equipment breakdown.
- E. **Curing Equipment.** Provide a self-propelled machine for applying membrane curing compound using mechanically pressurized spraying equipment with atomizing nozzles. Provide equipment and controls that maintain the required uniform rate of application over the entire paving area. Provide curing equipment that is independent of all other equipment when production rates are such that the first application of membrane curing compound cannot be accomplished immediately after texturing and after free moisture has disappeared. Hand-operated pressurized spraying equipment with atomizing nozzles may only be used on small or irregular areas or, when permitted, in emergencies due to equipment breakdown.
- F. **Sawing Equipment.** Provide power-driven concrete saws to saw the joints shown on the plans. Provide standby power-driven concrete saws during concrete sawing operations. Provide adequate illumination for nighttime sawing.
- G. **Grinding Equipment.** When required, provide self-propelled powered grinding equipment that is specifically designed to smooth and texture concrete pavement using circular diamond blades. Provide equipment with automatic grade control capable of grinding at least a 3-ft. width longitudinally in each pass without damaging the concrete.
- H. **Testing Equipment.** Provide testing equipment regardless of job-control testing responsibilities in accordance with Item 421, "Hydraulic Cement Concrete," unless otherwise shown in the plans or specified.
- I. **Coring Equipment.** When required, provide coring equipment capable of extracting cores in accordance with the requirements of Tex-424-A. Make provisions to eliminate the possibility of cutting the post-tensioning strands.
- J. **Miscellaneous Equipment.** Furnish both 10-ft. and 15-ft. steel or magnesium long-handled standard straightedges. Furnish enough work bridges, long enough to span the pavement, for finishing and inspection operations. Furnish date stencils to impress pavement placement dates into the fresh concrete, with numerals approximately 2 in. high by 1 in. wide by 1/4 in. deep.
- K. **Strand Stressing Equipment.** Provide hydraulic jacks or rams to stress strands as per indicated in Item 426, "Prestressing." The rams will be equipped with either a pressure gauge or a load cell for determining the applied stress. Use accurate and calibrated

gauges certified by an authorized entity. If a load cell is used, it will be calibrated and will be provided with an indicator showing the equivalent prestressing force applied to the strand. The range of the load cell will be such that the lower 10% of its capacity will not be used in determining the jacking stress. Extra safety measures will be taken by the contractor to prevent accidents due to possible breaking or slippage of the prestressing tendons during post-tensioning activities.

4. **Construction.** These construction specifications are complementary to the applicable specifications provided in Item 421, "Hydraulic Cement Concrete." Prestressing of the PCP slabs will be made in accordance with the plans and the following specifications as closely as possible, and they will govern the furnishing, storing, and handling of prestressing materials. Obtain approval for adjustments to plan grade-line to maintain thickness over minor subgrade or base high spots while maintaining clearances and drainage. Maintain subgrade or base in a smooth, clean, compacted condition in conformity with the required section and established grade until the pavement concrete is placed. Adequately light the active work areas for all nighttime operations. Provide and maintain tools and materials to perform testing.

- A. **Paving and Quality Control Plan.** Submit a paving and quality control plan for approval before beginning pavement construction operations. Include details of all operations in the concrete paving process, including longitudinal construction joint layout, sequencing, curing, lighting, early opening, leave-outs, sawing, inspection, testing, construction methods, other details and description of all equipment. List certified personnel performing the testing. Submit revisions to the paving and quality control plan for approval.
 - B. **Job-Control Testing.** Unless otherwise shown on the plans, perform all fresh and hardened concrete job-control testing at the specified frequency. Provide job-control testing personnel meeting the requirements of Item 421, "Hydraulic Cement Concrete." Provide and maintain testing equipment, including strength testing equipment at a location acceptable to the Engineer. Use of a commercial laboratory is acceptable. Maintain all testing equipment calibrated in accordance with pertinent test methods. Make strength-testing equipment available to the Engineer for verification testing.

Provide the Engineer the opportunity to witness all tests. The Engineer may require a retest if not given the opportunity to witness. Furnish a copy of all test results to the Engineer daily. Check the first few concrete loads for slump, air, and temperature on start-up production days to check for concrete conformance and consistency. Sample and prepare strength test specimens (2 specimens per test) on the first day of production and for each 3,000 sq. yd. or fraction thereof of concrete pavement thereafter. Prepare at least 1 set of strength-test specimens for each production day. Perform slump, air, and temperature tests each time strength specimens are made. Monitor concrete temperature to ensure that concrete is consistently within the temperature requirements. The Engineer will direct random job-control sampling and testing. Immediately investigate and take corrective action as approved if any Contractor test result, including tests performed for verification purposes, does not meet specification requirements.

When job-control testing by the Contractor is waived by the plans, the Engineer will perform the testing; however, this does not waive the Contractor's responsibility for providing materials and work in accordance with this Item.

1. **Job-Control Strength.** Unless otherwise shown on the plans or permitted by the Engineer, use 7-day job-control concrete strength testing in accordance with Tex-418-A.

For 7-day job-control by compressive strength, use a compressive strength of 3,700 psi or a lower job-control strength value proven to meet a 28-day compressive strength of 5,000 psi as correlated in accordance with Tex-427-A.

Job control of concrete strength may be correlated to an age other than 7 days in accordance with Tex-427-A when approved. Job-control strength of Class HES concrete is based on the required strength and time.

When a job-control concrete strength test value is more than 10% below the required job-control strength or when 3 consecutive job-control strength values fall below the required job-control strength, investigate the strength test procedures, the quality of materials, the concrete production operations, and other possible problem areas to determine the cause. Take necessary action to correct the problem, including redesign of the concrete mix if needed. The Engineer may suspend concrete paving if the Contractor is unable to identify, document, and correct the cause of low strength test values in a timely manner. If any job-control strength is more than 15% below the required job-control strength, the Engineer will evaluate the structural adequacy of the pavements. When directed, remove and replace pavements found to be structurally inadequate at no additional cost.

2. **Split-Sample Verification Testing.** Perform split-sample verification testing with the Engineer on random samples taken and split by the Engineer at a rate of at least 1 for every 10 job-control samples. The Engineer will evaluate the results of split-sample verification testing. Immediately investigate and take corrective action as approved when results of split-sample verification testing differ more than the allowable differences shown in Table 1, or when the average of 10 job-control strength results and the Engineer's split-sample strength result differ by more than 10%.

Table 1
Verification Testing Limits

Test Method	Allowable Differences
Temperature, Tex-422-A	2°F
Slump, Tex-415-A	1 in.
Air content, Tex-414-A or Tex-416-A	1%
Compressive strength, Tex-418-A	10%

- C. **Placement of Friction-Reducing Membrane.** Once the subbase and leveling layers of the PCP are placed and compacted to specifications, place a polyethylene sheet membrane on the ground and extend it longitudinally across the entire length of the PCP slab or slabs to be poured. Provide longitudinal and transverse overlaps of at least 2 ft. Provide sheeting at least 2 ft. wider at each side of the concrete strip being poured. Tack and secure the sheeting before continuing with other activities.
- D. **Placement of Transverse Joints.** Place transverse joints at predefined locations. Provide a completely fabricated joint assembled at the provider's facilities, including the insertion of the neoprene seal, dowels, deformed Nelson bars, and all the necessary hardware for the anchors. Weld small steel jumper plates across the top of the joint to keep the assembly closed with the neoprene seal inside. Carry the joint to the site ready for installation, set it in place, and secure it to the ground to avoid being displaced when performing other tasks.
- E. **Prestressing Strand Placement.** Furnish, store and handle prestressing materials. Place longitudinal and transverse post-tensioning strands at the locations defined by the design standards. Use chairs to support strands. Place chairs carefully so as not to damage the strand ducts or the friction-reducing polyethylene sheet. Place tendons accurately; a tolerance of ± 1 in. with respect to the specified tendon spacing is accepted. The tolerance for vertical positioning of strands is $\pm 1/4$ in. Use appropriate chairs at intersections of longitudinal and transverse tendons.
- F. **Central Stressing Pocket Form Placement.** Use material that does not react with the concrete; it should be a non-absorptive, strong material that withstands the imposed forces of placement, vibration, buoyancy, and weight of the plastic concrete during placement. Anchor the forms properly to prevent movement or misalignment during concrete placement. Apply oil or other bond-breaking coating to the sides of the form before concrete reaches it. Avoid materials that might stain or react with the concrete. Once post-tensioning operations are completed, remove pocket forms and fill the pockets with the same type of concrete mixture used in the pavement. Apply texture to the concrete surface accordingly.
- G. **Reinforcing Steel and Joint Assemblies.** Accurately place and secure in position all reinforcing steel as shown on the plans. Use multiple-piece tie bars for longitudinal construction joints. For manual placement, secure reinforcing bars with wire ties or locking support chairs. Tie all splices with wire.
- H. **Joints.** Install joints as shown on the plans. Clean and seal joints in accordance with Item 438, "Cleaning and Sealing Joints and Cracks (Rigid Pavement and Bridge Decks)." Repair excessive spalling of the joint saw groove using an approved method before installing the sealant. Seal all joints before opening the pavement to all traffic.
- I. **Placing and Removing Forms.** Use clean and oiled forms. Secure forms on a base or firm subgrade that is accurately graded and that provides stable support without deflection and movement by form riding equipment. Pin every form at least at the middle and near each end. Tightly join and key form sections together to prevent relative displacement.

Set side forms far enough in advance of concrete placement to permit inspection. Check conformity of the grade, alignment, and stability of forms immediately before placing concrete, and make all necessary corrections. Use a straightedge or other approved method to test the top of forms to ensure that the ride quality requirements for the completed pavement will be met. Stop paving operations if forms settle or deflect more than 1/8 in. under finishing operations. Reset forms to line and grade, and refinish the concrete surface to correct grade.

Avoid damage to the edge of the pavement when removing forms. Repair damage resulting from form removal and honeycombed areas with a mortar mix within 24 hour after form removal unless otherwise approved. Clean joint face and repair honeycombed or damaged areas within 24 hour after a bulkhead for a transverse construction joint has been removed unless otherwise approved. When forms are removed before 72 hour after concrete placement, promptly apply membrane curing compound to the edge of the concrete pavement.

- J. Concrete Delivery.** Clean delivery equipment as necessary to prevent accumulation of old concrete before loading fresh concrete. Use agitated delivery equipment for concrete designed to have a slump of more than 5 in. Segregated concrete is subject to rejection. Place agitated concrete within 60 minutes after batching. Place non-agitated concrete within 45 minutes after batching. In hot weather or under conditions causing quick setting of the concrete, times may be reduced by the Engineer. Time limitations may be extended if the Contractor can demonstrate that the concrete can be properly placed, consolidated, and finished without the use of additional water.

- K. Concrete Placement.** Perform paving activities after transverse joints, prestressing strands, and central stressing pocket forms are in place for a number of slabs. Exercise special attention during placing, vibrating, and finishing of the concrete near transverse joints and forms. Check the correct positions of chairs and tendons continuously. Remove concrete or aggregate trapped in transverse joints.

Place the concrete pavement in an organized predefined sequence to minimize traffic disruptions. Provide a detailed plan for paving activities and the PCP slab placements. Once the first pavement strip is poured, construct consecutive strips using one of the edges of the previously poured strip as side form. Prepare those edges of hardened pavement strips that will serve as side forms to prevent bonding between strips; use asphalt as a bond-breaking interface between concrete slabs.

Do not allow the pavement edge to deviate from the established paving line by more than 1/2 in. at any point. Place the concrete as near as possible to its final location, and minimize segregation and re-handling. Where hand spreading is necessary, distribute concrete using shovels. Do not use rakes or vibrators to distribute concrete.

- 1. Pavement.** Consolidate all concrete by approved mechanical vibrators operated on the front of the paving equipment. Use immersion-type vibrators that simultaneously consolidate the full width of the placement when machine finishing. Keep vibrators from dislodging reinforcement. Use hand-operated vibrators to consolidate concrete in areas not accessible to the machine-mounted vibrators. Do

not operate machine-mounted vibrators while the paving equipment is stationary. Vibrator operations are subject to review.

2. **Date Imprinting.** Imprint dates in the fresh concrete indicating the date of the concrete placement. Make impressions approximately 1 ft. from the outside longitudinal construction joint or edge of pavement and approximately 1 ft. from the transverse construction joint at the beginning of the placement day. Orient the impressions to be read from the outside shoulder in the direction of final traffic. Impress date in DD-MM-YY format. Imprinting of the Contractor name or logo in similar size characters to the date is allowed.
 3. **Curbs.** Where curbs are placed separately, conform to the requirements of Item 529, "Concrete Curb, Gutter, and Combined Curb and Gutter."
 4. **Temperature Restrictions.** Place concrete that is between 40°F and 95°F when measured in accordance with Tex-422-A at the time of discharge, except that concrete may be used if it was already in transit when the temperature was found to exceed the allowable maximum. Take immediate corrective action or cease concrete production when the concrete temperature exceeds 95°F. Do not place concrete when the ambient temperature in the shade is below 40°F and falling unless approved. Concrete may be placed when the ambient temperature in the shade is above 35°F and rising or above 40°F. When temperatures warrant protection against freezing, protect the pavement with an approved insulating material capable of protecting the concrete for the specified curing period. Submit for approval proposed measures to protect the concrete from anticipated freezing weather for the first 72 hour after placement. Repair or replace all concrete damaged by freezing.
- L. **Spreading and Finishing.** Finish all concrete pavement with approved self-propelled equipment. Use power-driven spreaders, power-driven vibrators, power-driven strike-off, and screed, or approved alternate equipment. Use the transverse finishing equipment to compact and strike off the concrete to the required section and grade without surface voids. Use float equipment for final finishing. Use concrete with a consistency that allows completion of all finishing operations without addition of water to the surface. Use the minimal amount of water fog mist necessary to maintain a moist surface. Reduce fogging if float or straightedge operations result in excess slurry.
1. **Finished Surface.** Perform sufficient checks with long-handled 10-ft. and 15-ft. straightedges on the plastic concrete to ensure that the final surface is within the tolerances specified in Surface Test A in Item 585, "Ride Quality for Pavement Surfaces." Check with the straightedge parallel to the centerline.
 2. **Maintenance of Surface Moisture.** Prevent surface drying of the pavement before application of the curing system. Accomplish this by fog applications of evaporation retardant on the pavement surface. Apply evaporation retardant at the rate recommended by the manufacturer. Reapply the evaporation retardant as needed to maintain the concrete surface in a moist condition until curing system is applied. Do not use evaporation retardant as a finishing aid. Failure to take

acceptable precautions to prevent surface drying of the pavement will be cause for shut down of pavement operations.

3. **Surface Texturing.** Perform surface texturing using a combination of a carpet drag and metal tining. Complete final texturing before the concrete has attained its initial set. Draw the carpet drag longitudinally along the pavement surface with the carpet contact surface area adjusted to provide a satisfactory coarsely textured surface.

A metal-tine texture finish is required unless otherwise shown on the plans. Provide the metal-tine finish immediately after the concrete surface has set enough for consistent tining. Operate the metal-tine device to obtain grooves spaced at 1 in., approximately 3/16 in. deep, with a minimum depth of 1/8 in., and approximately 1/12 in. wide. Do not overlap a previously tined area. Use manual methods for achieving similar results on ramps and other irregular sections of pavements. Repair damage to the edge of the slab and joints immediately after texturing. Do not tine pavement that will be overlaid.

4. **Small or Irregular Placements.** Where machine placements and finishing of concrete pavement are not practical, use hand equipment and procedures that produce a consolidated and finished pavement section to the line and grade.
5. **Emergency Procedures.** Use hand-operated equipment for applying texture, evaporation retardant, and cure in the event of equipment breakdown.

- M. **Curing.** Keep the concrete pavement surface from drying by water fogging until the curing material has been applied. Maintain and promptly repair damage to curing materials on exposed surfaces of concrete pavement continuously for at least 3 curing days. A curing day is defined as a 24-hour period when either the temperature taken in the shade away from artificial heat is above 50°F for at least 19 hour or when the surface temperature of the concrete is maintained above 40°F for 24 hour. Curing begins when the concrete curing system has been applied. Stop concrete paving if curing compound is not being applied promptly and maintained adequately. Other methods of curing in accordance with Item 420, "Concrete Structures," may be used when specified or approved.

After texturing and immediately after the free surface moisture has disappeared, spray the concrete surface uniformly with 2 coats of membrane curing compound at an individual application rate of not more than 180 sq. ft. per gallon. Apply the first coat within 10 minutes after completing texturing operations. Apply the second coat within 30 minutes after completing texturing operations.

Before and during application, maintain curing compounds in a uniformly agitated condition, free of settlement. Do not thin or dilute the curing compound.

Where the coating shows discontinuities or other defects or if rain falls on the newly coated surface before the film has dried enough to resist damage, apply additional compound at the same rate of coverage to correct the damage. Ensure that the curing compound coats the sides of the tining grooves.

N. Protection of Pavement and Opening to Traffic. Testing for early opening is the responsibility of the Contractor regardless of job-control testing responsibilities unless otherwise shown in the plans or directed. Testing result interpretation for opening to traffic is subject to the approval of the Engineer.

1. **Protection of Pavement.** Erect and maintain barricades and other standard and approved devices that will exclude all vehicles and equipment from the newly placed pavement for the periods specified. Before opening to traffic, protect the pavement from damage due to crossings using approved methods. Where a detour is not readily available or economically feasible, an occasional crossing of the roadway with overweight equipment may be permitted for relocating equipment only but not for hauling material. When an occasional crossing of overweight equipment is permitted, temporary matting or other approved methods may be required. Maintain an adequate supply of sheeting or other material to cover and protect fresh concrete surface from weather damage. Apply as needed to protect the pavement surface from weather.

O. Pavement Thickness. The Engineer will check the thickness in accordance with Tex-423-A. The Engineer will perform 1 thickness test consisting of 1 reading at approximately the center of each lane every 300 ft. or fraction thereof. Core where directed in accordance with Tex-424-A to verify deficiencies of more than 0.2 in. from plan thickness and to determine the limits of deficiencies of more than 0.75 in. from plan thickness. Fill core holes using a concrete mixture and method approved by the Engineer.

1. **Thickness Deficiencies Greater than 0.2 in.** When any depth test measured in accordance with Tex-423-A is deficient by more than 0.2 in. from the plan thickness, take one 4-inch diameter core at that location to verify the measurement.

If the core is deficient by more than 0.2 in. but not by more than 0.75 in. from the plan thickness, take 2 additional cores from the unit (as defined in Section 4.O.3, "Pavement Units for Payment Adjustment") at intervals of at least 100 ft. and at locations selected by the Engineer, and determine the thickness of the unit for payment purposes by averaging the length of the 3 cores. In calculations of the average thickness of this unit of pavement, measurements in excess of the specified thickness by more than 0.2 in. will be considered as the specified thickness plus 0.2 in.

2. **Thickness Deficiencies Greater than 0.75 in..** If a core is deficient by more than 0.75 in. remove and replace the entire slab between armor joints without additional compensation.
3. **Pavement Units for Payment Adjustment.** Limits for applying a payment adjustment for deficient pavement thickness from 0.20 in. to not more than 0.75 in. are 300 ft. of pavement in each lane. Lane width will be as shown on typical sections and pavement design standards.

Shoulders will be measured for thickness unless otherwise shown on the plans. Shoulders 6 ft. wide or wider will be considered as lanes. Shoulders less than 6 ft. wide will be considered part of the adjacent lane.

- P. **Ride Quality.** Unless otherwise shown on the plans, measure ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces."
- Q. **Post-Tensioning.** Follow the general recommendations as per indicated in Item 426, "Prestressing." Longitudinal strands are stressed first. Perform post-tensioning of the concrete pavement in two stages. Apply the first post-tensioning forces of 15 kips when the concrete gains a minimum compressive strength of 1000 psi. The initial post-tensioning must occur within 8 hours after placing concrete. Perform compressive tests of concrete cylinders at the job site to determine the timing of the post-tensioning. Use the maturity method, Tex-426-a, to determine when to perform compressive tests.
- Apply final longitudinal post-tensioning when concrete has gained a compressive strength of 3000 psi. Use the maturity method, Tex-426-a, to determine compressive strength for final post-tensioning. Apply the maximum tendon prestress force of 46.6 kips. Stress each strand by jacking it at the central stressing pockets. Start loading at the center strands of each pavement strip and continue toward the edges by alternatively loading strands on each side of the center strands. Furnish spare jacking equipment at the job site in case of malfunction of the equipment.
- Insert transverse tendons and apply post-tensioning force of 46.6 kips after the full pavement half-width is completed.
- R. **Miscellaneous Construction Tasks.** Perform additional activities required to instrument the PCP for monitoring purposes.
5. **Measurement.** This Item will be measured as follows:
- A. **Concrete Pavement.** Concrete pavement will be measured by the square yard of surface area in place. The surface area includes the portion of the pavement slab extending beneath the curb.
- B. **Curb.** Curb on concrete pavement will be measured by the foot in place.
6. **Payment.** These prices are full compensation for materials, equipment, labor, tools, and incidentals.
- A. **Post-tensioned Concrete Pavement.** The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the adjusted unit price bid for "Post-tensioned Concrete Pavement." of the type and depth specified as adjusted in accordance with Section 6.B, "Deficient Thickness Adjustment."
- B. **Deficient Thickness Adjustment.** Where the average thickness of pavement is deficient in thickness by more than 0.2 in. but not more than 0.75 in., payment will be made using the adjustment factor as specified in Table 2 applied to the bid price for the deficient area for each unit as defined under Section 4.0.3, "Pavement Units for Payment Adjustment."

Table 2
Deficient Thickness Price Adjustment Factor

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Deficiency in Thickness Determined by Cores (in.)	Proportional Part of Contract Price Allowed (adjustment factor)
Not deficient	1.00
Over 0.00 through 0.20	1.00
Over 0.20 through 0.30	0.80
Over 0.30 through 0.40	0.72
Over 0.40 through 0.50	0.68
Over 0.50 through 0.75	0.57

- C. **Curb.** Work performed and furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Curb” of the type specified.

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