Construction of the Iowa Highway 60

Precast Prestressed Concrete Pavement

Bridge Approach Slab Demonstration Project

PUBLICATION NO. FHWA IF 07 034 JULY 2007

U.S. Department of Transportation
Federal Highway Administration

Office of Infrastructure
Office of Pavement Technology
Washington, DC 20590

CONCRETE PAVEMENT
CPTP
TECHNOLOGY PROGRAM

Technical Report Documentation Page

1. Report No.
FHWA-IF-07-034

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Construction of the Iowa Highway 60 Precast Prestressed Concrete Pavement Bridge Approach Slab Demonstration Project

5. Report Date
July 2007

6. Performing Organization Code

7. Author(s)
David K. Merritt, Alberto J. Miron, Richard B. Rogers, Robert Otto Rasmussen

8. Performing Organization Report No.

9. Performing Organization Name and Address
The Transtec Group, Inc.
6111 Balcones Dr.
Austin, Texas 78731

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFH61-05-C-00035

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Highway Administration
1200 New Jersey Avenue, SE, HIPT-20
Washington, DC 20590

Iowa Highway Research Board
Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010

13. Type of Report and Period Covered
Final Report
March 2005—September 2006

14. Sponsoring Agency Code
HIPT-20

15. Supplementary Notes
Contracting Officer's Technical Representative: Sam Tyson, FHWA Office of Pavement Technology
1200 New Jersey Avenue SE, HIPT-20 / E73-440, Washington, DC 20590
E-mail: sam.tyson@dot.gov, Phone: 202-366-1326

16. Abstract
Reconstruction of bridge approach slabs that have failed due to a loss of support from embankment fill consolidation or erosion can be particularly challenging in urban areas where lane closures must be minimized. Precast prestressed concrete pavement is a potential solution for rapid bridge approach slab reconstruction which uses prefabricated pavement panels that can be installed and opened to traffic quickly. To evaluate this solution, the Iowa Department of Transportation constructed a precast prestressed approach slab demonstration project on Highway 60 near Sheldon, Iowa in August/September 2006. Two approach slabs at either end of a new bridge were constructed using precast prestressed concrete panels.

This report documents the successful development, design, and construction of the precast prestressed concrete bridge approach slabs on Highway 60. The report discusses the challenges and issues that were faced during the project and presents recommendations for future implementation of this innovative construction technique.

17. Key Word
precast pavement, precast prestressed concrete pavement, bridge approach, prestressed pavement, rapid construction

18. Distribution Statement
No restrictions.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 102	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^{o}C	Celsius	1.8C+32	Fahrenheit	^{o}F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

Executive Summary ix

CHAPTER 1. INTRODUCTION 1
- The Problem 1
- FHWA Demonstration Projects 1
- Benefits of Precast Prestressed Concrete Pavement 3
  - Rapid Construction 3
  - Improved Durability and Performance 4
  - Reduced Slab Thickness 5
  - Extended Construction Season 5
  - Benefits of PPCP for Bridge Approach Slabs 5
- Report Objectives 6

CHAPTER 2. KEY FEATURES OF PRECAST PRESTRESSED CONCRETE PAVEMENT 7
- Prestressed Pavement 7
- Full-Depth Panels 7
- Keyed Panel Joints 7
- Base Preparation 7
- Grouting 8
- Construction Process 8

CHAPTER 3. IOWA HIGHWAY 60 DEMONSTRATION PROJECT 11
- Project Scope 11
  - Location 11
  - Demonstration Project Goals 11
- Partnering and Project Coordination 12
- Project Layout 12
  - Roadway Geometry 12
  - Integral Bridge Abutment 14
  - Precast Panel Layout Options 14
  - Selected Precast Panel Layout 16

CHAPTER 4. DESIGN 21
- Design Considerations 21
  - Slab Bridging 21
  - Traffic Loading 21
  - Bridge and Approach Slab Movement 21
- Highway 60 PPCP Design 22
  - Traffic Loading 22
  - Initial Flexural Design 22
  - Final Flexural Design 23
  - Transverse Prestress 24
  - Slab Movement Analysis 24

CHAPTER 5. PANEL FABRICATION 27
- Procedure 27

Tolerances 27
Panel Details 27
  Keyways 27
  Post-Tensioning 29
  Anchor Sleeves 30
  Expansion Joint 30
  Reinforcement 30
  Lifting Anchors 31
Mixture Design 31
Finishing and Curing 32
Handling and Storage 34
Trial Assembly 34
Panel Repairs 35
Fabrication Issues and Challenges 38
  Post-Tensioning Ducts 38
  Pocket Reinforcement 38
  Formwork 38
  Panel Damage 38

CHAPTER 6. APPROACH SLAB CONSTRUCTION 39

Pre-Construction Meetings 39
Base Preparation 39
Panel Installation 40
  Procedure 40
  Joint Epoxy 41
  Temporary Post-Tensioning 41
Post-Tensioning 42
Grouting 44
  Tendon Grouting 44
  Underslab Grouting 45
Finishing and Tie-in 46
  Longitudinal Joint 46
  Pocket Filling 47
  Bridge Abutment Anchor 47
  Expansion Joint 47
  Diamond Grinding 48
Construction Issues and Challenges 49
  Panel Placement 49
  Post-Tensioning 51
  Grouting 51
Instrumentation and Monitoring 52
  Bridge Instrumentation 52
  Approach Slab Instrumentation 52
Showcasing Workshop 53

CHAPTER 7. PROJECT EVALUATION AND RECOMMENDATIONS FOR FUTURE PROJECTS 55

Project Layout 55
Design 55

        Design Procedures 55
        Design Details..56
    Panel Fabrication 57
    Construction..58
        Base Preparation 58
        Panel Installation..58
        Post-tensioning..59
        Grouting 60
    Post-Construction Evaluation 60
    Project Cost..61

CHAPTER 8. SUMMARY AND RECOMMENDATIONS 63

    Summary 63
    Recommendations for Future Implementation 63

REFERENCES..65

ACKNOWLEDGMENTS 66

APPENDIX A: Project Plans From the Iowa Department of Transportation 67

APPENDIX B: Agenda From IADOT/FHWA Showcasing Workshop..................................89

LIST OF FIGURES

Figure 1. Illustration. Flowchart for the overall PPCP construction process................................. 9
Figure 2. Illustration. Location of the Iowa precast pavement demonstration project. 11
Figure 3. Illustration. Situation Plan for the Highway 60 bridge and precast approach slabs..... 13
Figure 4. Illustration. Schematic layout of full-width panels with variable thickness. 15
Figure 5. Illustration. Schematic layout of partial width panels with uniform thickness............ 16
Figure 6. Illustration. Selected precast panel and post-tensioning tendon layout........................ 17
Figure 7. Illustration. Selected precast panel layout... 18
Figure 8. Illustration. Longitudinal joint at the centerline of the approach slab.......................... 18
Figure 9. Illustration. Approach slab Abutment Panels.. 19
Figure 10. Illustration. Approach slab Base Panels.. 19
Figure 11. Illustration. Approach slab Joint Panels.. 19
Figure 12. Equation. Load combination used to calculate total load... 22
Figure 13. Equation. Equation used to calculate flexural capacity of the approach slab. 23
Figure 14. Equation. Equation used to calculate yield strength of the prestressing steel............. 23
Figure 15. Illustration. Transverse keyway dimensions for the precast panels. 28
Figure 16. Illustration. Keyway dimensions for the longitudinal joint.. 29
Figure 17. Illustration. Post-tensioning tendon gasket detail... 30
Figure 18. Photo. Placement of concrete for an abutment panel. 32
Figure 19. Photo. Application of the light broom texture to the panel surface............................ 33
Figure 20. Photo. Curing tent being lowered to cover a precast panel after casting. 33
Figure 21. Photo. Precast panels stored at the fabrication plant.. 34
Figure 22. Photo. Trial assembly of precast panels at the fabrication plant................................ 35
Figure 23. Photo. Damaged panel corner after trial assembly... 36
Figure 24. Photo. Damaged keyway after trial assembly. 36
Figure 25. Photo. Battered keyway after removal from forms. 37
Figure 26. Photo. Keyway after completion of grinding. 37
Figure 27. Photo. Grading and compaction of the aggregate base material................................ 39
Figure 28. Photo. Installation of Panel 1A at the south bridge abutment.................................... 40
Figure 29. Photo. Finished approach slab prior to final post-tensioning..................................... 41
Figure 30. Photo. Application of joint epoxy during panel installation....................................... 42
Figure 31. Photo. Temporary post-tensioning used to pull panels together. 42
Figure 32. Photo. Inserting the longitudinal strands into the approach slab................................ 43
Figure 33. Photo. Inserting the transverse strands into the approach slab................................... 44
Figure 34. Photo. Grouting of the post-tensioning tendons... 45

Figure 35. Photo. Rod and level were used to check for slab lifting during the underslab grouting operation. 46
Figure 36. Photo. Filling of the longitudinal joint (photo by Iowa State University).... 47
Figure 37. Illustration. Abutment anchor detail for PPCP approach slabs. 48
Figure 38. Photo. Dowels for the EF expansion joint prior to its installation in the precast panels. 48
Figure 39. Photo. Diamond grinding the south approach slab.... 49
Figure 40. Photo. Joint between south approach slab and bridge abutment. 50
Figure 41. Photo. Minor joint spall that occurred during panel installation. 51
Figure 42. Photo. Slight misalignment of transverse post-tensioning ducts at the longitudinal joint. 52
Figure 43. Photo. Vibrating wire strain gage mounted in the precast panel during fabrication. .. 53
Figure 44. Photo. Presentations were provided by those involved in the Highway 60 project. ... 54
Figure 45. Photo. Site visit during installation of the precast approach slab. 54
Figure 46. Photo. Finished north approach slab prior to opening to traffic. 64

LIST OF TABLES

Table 1. Factored Design Moments for Highway 60 Approach Slab 22
Table 2. Flexural Capacity of Various Prestressing Configurations.... 23
Table 3. Predicted Movements at the Ends of the Approach Slabs 25
Table 4. Table of Panel Tolerances From the Project Plans 28

EXECUTIVE SUMMARY

The “bump at the end of the bridge” caused by bridge approach slab settlement is an ongoing problem for Iowa and many other State highway agencies. The bump not only degrades the ride quality of a roadway, but also presents a safety issue for drivers and increases impact loads on bridges. Approach slab settlement is generally caused by a loss of support due to consolidation or erosion of the underlying embankment fill, and can be accompanied by failure of the paving notch. While problems with the embankment fill material and paving notch must ultimately be resolved through improved construction practices, a separate but equally important issue is how to reconstruct bridge approach slabs that have already failed due to settlement. This is particularly challenging in urban areas where lane closures must be minimized to reduce the impact of reconstruction on the traveling public. The solution must not only be something that will permit the approach slab to be reconstructed quickly (during overnight or weekend closures), but something that will provide good long-term performance even if future loss of support occurs.

The primary objective of this research was to evaluate the viability of using precast prestressed concrete panels for bridge approach slab reconstruction. Ultimately, this construction process will be utilized for bridge approach slabs in urban areas where lane closures for reconstruction must be minimized. A secondary objective was to evaluate and develop standard details for precast prestressed concrete bridge approach slabs that can be adapted to virtually any approach slab configuration.

The demonstration project was constructed on the northbound lanes of a new bridge over the Floyd River on the realignment of Highway 60 just east of Sheldon, Iowa. Precast prestressed concrete approach slabs were constructed at either end of the bridge. The layout for the precast panels was selected such that it could be adapted to various approach slab configurations of different thicknesses, widths, lengths, and skew angles.

The precast panels were post-tensioned in both directions after installation on site. Post-tensioning not only improves the performance of the approach slab by keeping it in compression to minimize or even eliminate cracking, but also gives the approach slab the ability to act as a “slab bridge,” spanning over voids that may form due to consolidation or erosion beneath it over time. Post-tensioning also allows for a longer section of continuous pavement between joints, permitting the expansion joint to be moved as far away from the abutment as feasible to minimize the risk of water infiltrating the embankment fill at the abutment.

The precast panels were fabricated in summer 2006 and installed over a 2-day period (for each approach slab) in August and September 2006. In general, each panel was installed in approximately 15–30 minutes. This installation rate will likely improve as contractors become more familiar with the construction technique. While this project was constructed on a new bridge and the roadway was completely closed to traffic during construction, the intent was to evaluate the overall process and project details. The viability of this construction technique was clearly demonstrated, and rapid reconstruction of existing approach slabs under stringent time constraints will be the next step.

CHAPTER 1. INTRODUCTION

THE PROBLEM

The “bump at the end of the bridge,” caused by bridge approach slab settlement, is an ongoing problem for many State highway agencies. The bump not only degrades the ride quality of a roadway, but also presents a safety issue for drivers and increases impact loads on bridges. Approach slab settlement is generally caused by a loss of support due to consolidation or erosion of the underlying embankment material and may be accompanied by failure of the paving notch/paving seat at the abutment. While problems with the embankment material can be prevented with improved construction practices, a separate but equally important issue is how to reconstruct bridge approach slabs that have already failed. This is particularly challenging in urban areas where lane closures must be minimized to reduce the impact of reconstruction on the traveling public.

The Iowa Department of Transportation (IADOT) is addressing this issue by investigating the use of precast prestressed concrete pavement (PPCP) for expedited bridge approach slab reconstruction. Precast panels are fabricated and stockpiled at a precast plant, then delivered to the jobsite and quickly installed as needed. Precast panels can support traffic immediately after installation, thereby facilitating overnight or weekend construction operations. Prestressing the approach slab benefits performance by keeping the pavement in compression to minimize or even eliminate cracking. Further, prestressing gives the approach slab a “bridging” ability to span voids in the embankment material that may redevelop over time, helping to achieve the ultimate goal of longer lasting pavements.

In August 2006, IADOT constructed a PPCP approach slab on a new bridge along Highway 60 near Sheldon, Iowa. This successful project allowed IADOT to evaluate and refine design and construction details for PPCP bridge approach slabs. IADOT is currently planning a second project in which failed approach slabs at either end of twin bridges will be reconstructed under traffic. In addition to utilizing precast concrete for the approach slab, IADOT will also be evaluating the use of precast concrete for replacement of deteriorated or poorly constructed paving notches on these bridges. The end result will be an innovative method for rapid reconstruction of bridge approach slabs with minimal disruption to the traveling public.

FHWA DEMONSTRATION PROJECTS

The Highway 60 PPCP bridge approach slab demonstration project was part of a recent effort by the Federal Highway Administration (FHWA) to evaluate the viability of PPCP construction for a variety of paving applications through a series of demonstration projects throughout the United States. These demonstration projects provide State highway agencies the opportunity to evaluate PPCP for pavement rehabilitation and reconstruction, and also help to familiarize local contractors with the technology. FHWA provides design and construction support for these projects and, if necessary, limited funding for construction.

The FHWA demonstration projects stemmed from an initial feasibility study completed in 2000 by the Center for Transportation Research at The University of Texas at Austin.(1) This feasibility study resulted in the development of a viable concept for PPCP that was subsequently evaluated through three demonstration projects in Texas, California, and Missouri between 2001 and 2006. The PPCP concept was adapted to the constraints of each particular project. The Iowa Demonstration Project, described herein, represents the fourth PPCP demonstration project and a fourth adaptation of the PPCP concept to meet the specific needs of State highway agencies. A summary of the four demonstration projects completed to date is provided below.

Interstate 35 Frontage Road—Georgetown, Texas(2)

Completed in spring 2002, the I-35 frontage road demonstration project, constructed by the Texas Department of Transportation, was the first project to demonstrate the viability of the PPCP concept. While not constructed under traffic and short time windows, the intent of this project was to evaluate the design details and construction procedures for PPCP. Approximately 700 m (2,300 ft) of PPCP were constructed the full width of the frontage road. Both full-width and partial-width panels were utilized. The full-width panels spanned the entire 11-m (36 ft) width of the roadway, including two traffic lanes and inside and outside shoulders. The partial-width panels were constructed in two adjacent sections, one 6 m (20 ft) wide and the other 5 m (16 ft) wide, to achieve the full 11-m (36 ft) roadway width. The adjacent sections were tied together with additional transverse post-tensioning. Many aspects of PPCP were demonstrated by this project:

- Overall fabrication and construction feasibility of PPCP.
- Use of an armored expansion joint cast into the precast panels.
- Use of central stressing for precast, post-tensioned pavement panels.
- Use of non-match-cast precast panels with interlocking keyways.
- Installation of precast panels over a hot-mix asphalt leveling course.
- Construction of precast pavement on a vertical curve.
- Lane-by-lane construction of precast pavement using “partial width” precast panels.

Interstate 10—El Monte, California(3,4)

The second PPCP demonstration project was constructed by the California Department of Transportation in April 2004. PPCP was incorporated into a project to widen eastbound I-10 near El Monte, California. A section of PPCP 76 m (248 ft) long was installed adjacent to the existing main lanes, adding 8 m (27 ft) of traffic lanes and a 3-m (10 ft) shoulder to the existing pavement. Several aspects of the demonstration project were unique:

- Incorporation of a change in pavement cross slope into the surface of the precast panels.
- Nighttime installation of precast panels during a 5-hour construction window.
- Installation of precast panels over a lean concrete base.
- Use of epoxy-coated strands for longitudinal post-tensioning.
- Use of a nonarmored, dowelled expansion joint.
- Diamond grinding of the finished surface to achieve pavement smoothness requirements.

Interstate 57—Sikeston, Missouri(5,6,7)

The third PPCP demonstration project was constructed by the Missouri Department of Transportation on I-57 near Sikeston, Missouri, in 2005. PPCP was used for the reconstruction of 308 m (1,010 ft) of mainline pavement on I-57. The full 11.6-m (38 ft) pavement width was reconstructed with precast panels, including two main lanes and inside and outside shoulders. Unique aspects of this project include the following:

- Incorporation of a crowned pavement cross section into the precast panels.
- Post-tensioning from the joint panels as opposed to central stressing.
- Use of a "header type," nonarmored expansion joint.
- Use of noncontinuous keyways for the panel joints.
- Installation of precast panels over a permeable asphalt-treated base.
- Diamond grinding of the finished surface to achieve smoothness requirements.

Highway 60—Sheldon, Iowa(8)

The most recently completed demonstration project, constructed by IADOT on State Highway 60 near Sheldon, is described in more detail in this report. This project demonstrated several aspects of PPCP construction:

- Use of precast prestressed panels for bridge approach slab construction.
- Use of bi-directional post-tensioning.
- Lane-by-lane construction (partial-width panels) installed on a crowned pavement section.
- Installation of panels over an aggregate base.
- Diamond grinding of the finished surface.

BENEFITS OF PRECAST PRESTRESSED CONCRETE PAVEMENT

While the benefits of PPCP have been documented more thoroughly elsewhere,(1,2,3,9) a summary of these benefits is provided below, including specific benefits for bridge approach slabs.

Rapid Construction

The primary benefit of PPCP is rapid construction. More accurately stated, PPCP permits faster opening of the pavement to traffic. Precast panels are cast and cured off site, allowing them to reach opening-to-traffic strength before installation. The need for rapid construction techniques is perhaps even more critical for bridges (and bridge approach slabs) than it is for pavements. Bridges are critical links within a highway system, and it is often not possible to divert traffic around a bridge during reconstruction without significant inconvenience and cost. Consequently, staged reconstruction is often required, permitting only part of the bridge to be reconstructed at any given time, squeezing traffic into fewer lanes, and often increasing user delays. With proper planning, PPCP will permit rapid reconstruction of bridge approach slabs during nonpeak travel times, minimizing lane closures and associated user delays.

Reduced User Delay Costs

State highway agencies are continually seeking new techniques for pavement reconstruction and rehabilitation that minimize disruption to the traveling public and the associated user delay costs caused by lane closures. In many urban areas, agencies are often limited to overnight or weekend windows for lane closures. These constraints necessitate solutions that will permit the pavement to be opened to traffic quickly. Because precast concrete panels are fabricated and cured off site, they can be hauled to the jobsite, installed quickly, and opened to traffic almost immediately after installation. A reduction in user delay costs is where the primary economic benefit of PPCP construction will be realized.

Reduced Disruption to Local Businesses

Roadway users are not the only people impacted by pavement construction. Construction of intersections and noncontrolled access roadways can also have a significant impact on local businesses by limiting access to these businesses by customers and suppliers. PPCP permits construction to be completed during nonpeak business hours, thereby minimizing inconvenience to both customers and local businesses.

Improved Safety and Reduced Traffic Control Costs

Rapid construction helps improve safety for both construction workers and vehicle drivers by limiting construction operations and associated lane closures to nonpeak travel times. During these limited operations, construction workers are less exposed to traffic, and drivers are less exposed to traffic control measures. Also, by eliminating the need to build temporary traffic lanes around the project and by avoiding lengthy detour routes, traffic control costs can be greatly reduced.

Improved Durability and Performance

Savings in user delay costs from expedited construction are only beneficial if the solution for reconstruction is a durable, high-performance solution and not just a temporary "quick fix." Precast prestressed concrete has provided durable, high-performance solutions for the bridge and commercial building industries for decades, and can do the same for pavement. Precast concrete manufacturing plants have a very high degree of control over the concrete mixture and the production process, helping to ensure a very consistent, high-quality, final product. Further, by incorporating prestress, many additional performance benefits can be realized.

Mixture Properties

The precast concrete manufacturing process offers a great deal of flexibility in formulating the concrete mixtures used for precast products. Mixtures with very low water-to-cementitious materials ratios and various combinations of pozzolans and water-reducing and air-entraining admixtures permit the product to be tailored for the needs of the paving project. Concrete mixtures are produced in a very consistent manner and hauled only short distances from the batch plant to the forms, helping to minimize problems that are often encountered with cast-in-place pavement construction. Precast concrete manufacturing also permits the use of lightweight aggregates and hollow-core manufacturing processes to reduce the weight of the precast panels.

Curing

The precast manufacturing process also permits a great deal of flexibility in the curing process. Precast concrete products can be steam cured, wet-mat cured, cured under plastic sheeting, or simply coated with curing compound. The curing process can be selected to meet the requirements of both the concrete mixture and production rate. Proper curing will help to eliminate problems that can result from inadequate curing such as surface strength loss and will help to reduce other problems such as “built in” curling.

Reduced Cracking and Number of Joints

Prestressing benefits the durability and performance of PPCP by inducing a compressive stress in the concrete through pretensioning and post-tensioning. This compressive stress helps to minimize or even eliminate the occurrence of cracking that can lead to further distress. Any cracks that do form will be held tightly closed by the prestressing force in the concrete. While cracking can be a maintenance issue for pavements, so can joints. Prestressing significantly reduces the number of joints required in a pavement slab by post-tensioning long sections of pavement. This benefit has been documented for both cast-in-place and precast concrete pavements.(1,10)

Reduced Slab Thickness

Another primary benefit of prestressing is a reduction in the required pavement slab thickness. By inducing a compressive stress in the pavement slab, tensile stresses caused by traffic loading and environmental effects (curling and warping) can be significantly reduced, permitting the use of thinner pavement slabs in situations where current designs would call for a much thicker slab. This not only provides savings in concrete material and transportation costs for precast panels, but also permits pavement reconstruction with in-kind slab thickness. For bridge approach slabs, this is an important benefit as it allows the pavement thickness to be dictated by the specific project requirements such as the slab depth at the bridge abutment or the pavement thickness at the adjoining pavement.

Extended Construction Season

Another benefit of precast concrete pavement, particularly for construction in cold climates, is the potential it provides for extending the construction season. Precast panels can be installed in extreme cold (and warm) temperatures that would normally prohibit cast-in-place pavement construction.

Benefits of PPCP for Bridge Approach Slabs

The benefits presented above are inherent benefits of PPCP that can be realized through essentially any PPCP project. However, there are additional benefits of PPCP for bridge approach slabs. First, prestressing gives PPCP an improved ability to span voids and non-ideal base materials beneath the slab. This permits PPCP to be designed as a “slab bridge” that is unsupported (or has poor support) over a certain length of the pavement. Prestress levels can be adjusted to account for the flexural stresses produced by traffic loading on an unsupported or poorly supported slab. For bridge approach slabs, where a loss of support due to erosion or consolidation of the underlying embankment might be anticipated in the future, this is a significant benefit.

Another benefit of PPCP for bridge approach slabs is the permissible slab length between expansion joints. By prestressing the approach slab, expansion joints can be moved further away from the abutment where water infiltration into the embankment can cause erosion and consolidation of the embankment material. Prestressing can also be used to permanently tie the approach slab to the bridge abutment, keeping the joint between the abutment and approach slab tightly closed.

REPORT OBJECTIVES

The primary objective of this report is to summarize the construction of the PPCP demonstration project on Highway 60 near Sheldon, Iowa. This includes the design, fabrication, and panel installation processes for the project. The report also presents recommendations for future PPCP bridge approach slab projects based on lessons learned from this project. The following is a summary of the remaining chapters of this report:

- Chapter 2 presents the key features of PPCP that were developed through the feasibility study and refined through the course of previous demonstration projects.
- Chapter 3 presents an overview of the Highway 60 approach slab demonstration project, including the precast panel layout.
- Chapter 4 presents the design of the Highway 60 project, including the design procedure and design details.
- Chapter 5 discusses the fabrication of the precast panels for the Highway 60 demonstration project, including issues that should be addressed for future projects.
- Chapter 6 discusses the construction or installation of the precast pavement on site. This includes base preparation, transportation, panel placement, post-tensioning, grouting, and instrumentation.
- Chapter 7 presents an evaluation of all aspects of the Highway 60 demonstration project and some considerations for future projects.
- Chapter 8 contains a summary and recommendations for future implementations.

CHAPTER 2. KEY FEATURES OF PRECAST PRESTRESSED CONCRETE PAVEMENT

The concept for PPCP that formed the basis for the Highway 60 demonstration project was developed through the original FHWA feasibility study.(1) While the bridge approach slab application differs somewhat from the original concept in terms of design features, many of the basic aspects of the project are the same. Below is a brief summary of these aspects.

PRESTRESSED PAVEMENT

The PPCP concept utilizes prestressing through either a combination of pretensioning and post-tensioning, or just post-tensioning. It is critical that prestress is provided in both directions, as previous experience with cast-in-place prestressed pavements has shown that prestress in only one direction can lead to cracking above the prestressing tendons.(10) The original PPCP concept featured precast panels that were pretensioned in the transverse direction during fabrication and post-tensioned together in the longitudinal direction after installation, generally in 76-m (250 ft) sections.(2) However, as will be discussed later, bi-directional post-tensioning can also be used, as was done for the Highway 60 demonstration project. Regardless of whether post-tensioning is in one or both directions, the post-tensioning system is a grouted or bonded system.

FULL-DEPTH PANELS

Another key aspect of the PPCP concept is the use of full-depth precast panels. Using full-depth panels, the top surface of the precast panels is the riding surface. Although diamond grinding may be required to achieve high-speed facility smoothness requirements, the pavement can generally be opened to traffic prior to diamond grinding. This was successfully demonstrated by the Texas demonstration project, which has not been diamond ground after 5 years in service.(2) Full-depth panels provide an efficient solution as they do not require a hot-mix asphalt or bonded concrete overlay for the final riding surface. Full-depth panels do require careful attention to base preparation, however, to ensure that the panels are set to the proper elevation and are not resting on high points, which could cause them to shift.

KEYED PANEL JOINTS

Another important feature of the PPCP concept, particularly for full-depth precast panels, is the use of continuous keyways along the edges of the panels. These keyways help to ensure vertical alignment between the panels as they are installed, minimizing the amount of grinding and surface correction required for the final driving surface. It is important to note that the precast panels are not match-cast. Match-casting is a more time-consuming and costly operation, and may only be viable for small projects. The dimensions and tolerances for the keyways are such that match-casting is not required to achieve a well-fitting joint between panels. Non-match-cast panels permit more efficient manufacturing operations such as long-line fabrication.

BASE PREPARATION

PPCP panels are installed over a prepared base. Materials used for the base on previous projects have included dense-graded hot-mix asphalt, permeable asphalt-treated base, and lean concrete base.(2,3,9) Regardless of the material used, strict tolerances on surface deviation of the prepared base will help to ensure full support beneath the panels and minimize any voids or stress concentrations from the panels resting on high points. Experience has shown that the precast panels tend to settle into flexible (hot-mix asphalt) base materials.(2) If voids are expected or observed during construction, it may be necessary to use underslab grouting to fill these voids after construction.

Over the prepared base it is necessary to place a friction-reducing material, such as a single layer of polyethylene sheeting. The polyethylene sheeting prevents the pavement from bonding to the base and also reduces the frictional restraint stresses that can accumulate in the pavement slab as it expands and contracts with daily and seasonal temperature cycles. Polyethylene sheeting has proven to be an effective and constructible material for both precast and cast-in-placed post-tensioned pavements.(2,11)

GROUTING

Grouting encompasses both post-tensioning tendon grouting and underslab grouting (if required). Grouting of the post-tensioning tendons provides an additional layer of corrosion protection for the strands. It also provides continuity between the prestressing steel and concrete to reduce the amount of non-prestressed reinforcement required, and to permit sections of the pavement to be cut out and removed in the future if necessary. Although prestress will be lost in the section that is removed, prestress in the rest of the pavement will remain intact. It is important that tendon grouting be done properly because improperly or poorly grouted tendons can result in premature failure of the tendons.(12) Proper grout materials, suitable for post-tensioning tendons, and trained workers should be part of the tendon grouting operation.

Underslab grouting is only necessary if significant voids are observed beneath the precast panels as they are installed. For most applications, this will be a necessary process because very precise grading of the prepared base material is often not possible within short construction windows. Ports for underslab grouting can be cast into the precast panels or drilled into the panels after installation. It should be noted that both underslab and tendon grouting can be completed separately from the panel installation process if time constraints so require. If significant voids are observed beneath the panels, however, underslab grouting should be completed prior to opening the pavement to traffic.

CONSTRUCTION PROCESS

Figure 1 shows a generic flowchart for the construction process for PPCP. While every project will be different and may not require each of the steps shown, these are the most common processes for PPCP construction. It is important to note, as the flowchart shows, that many of the steps in the process can be completed independently of each other, allowing the pavement to be opened to traffic between steps, provided that necessary precautions are taken for issues such as temporarily filling or covering the stressing pockets. As with any project constructed under stringent time constraints, proper preconstruction planning is essential to ensuring the success of the project.

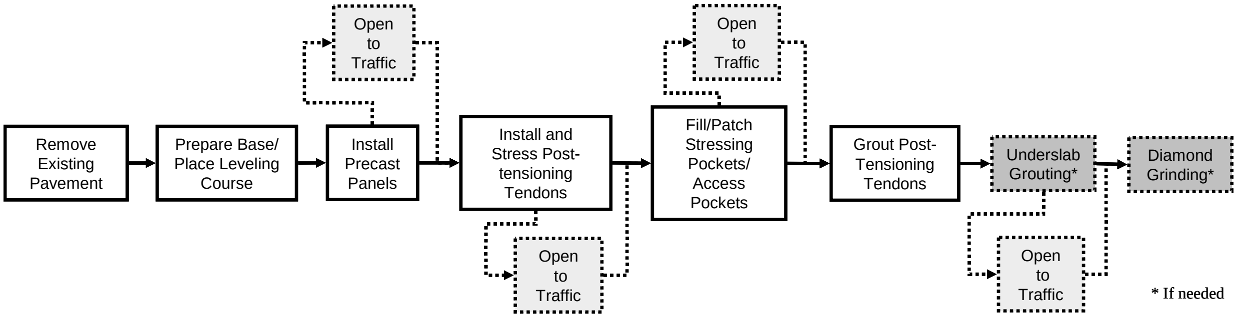


Figure 1. Illustration. Flowchart for the overall PPCP construction process.

CHAPTER 3. IOWA HIGHWAY 60 DEMONSTRATION PROJECT

PROJECT SCOPE

The intent of the Highway 60 demonstration project was to evaluate the viability of the PPCP concept for bridge approach slab applications. Although the ultimate goal is to utilize PPCP for rapid reconstruction of existing approach slabs in urban areas, with minimal lane closures, this initial project used PPCP for construction of the approach slabs on a new bridge that was closed to traffic during construction.

Location

The Iowa demonstration project was located on a newly constructed section of northbound Highway 60 east of Sheldon, Iowa, as shown in figure 2. This project was incorporated into a larger project to realign Highway 60 around the city of Sheldon. The PPCP approach slabs were constructed at either end of the northbound bridge over Floyd River. The twin bridge for the southbound lanes was constructed with conventional cast-in-place approach slabs.

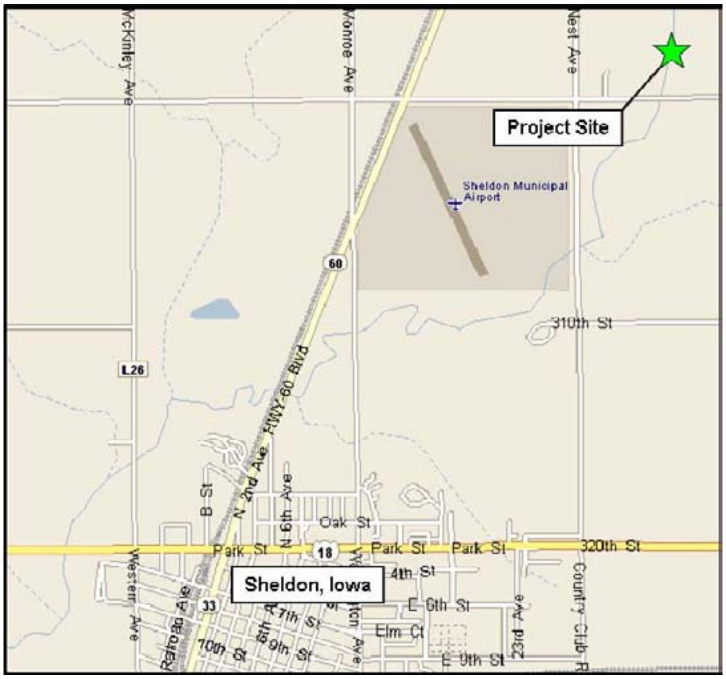


Figure 2. Illustration. Location of the Iowa precast pavement demonstration project.

Demonstration Project Goals

The overreaching goal of this demonstration project was to evaluate PPCP for bridge approach slab construction, with the intent that it will eventually be used for urban applications under stringent time constraints. This evaluation included all aspects of the design and construction processes, including the design details, fabrication, and installation operations. Because this project was constructed on a section of roadway closed to traffic, it provided an opportunity to carefully evaluate the construction process to identify refinements that can be made to both the design details and construction requirements for future projects.

A secondary goal of the Highway 60 demonstration project was to monitor PPCP approach slab behavior and performance over time for comparison with traditional cast-in-place approach slab construction. Extensive instrumentation of the approach slabs (both cast-in-place and precast), bridge girders, and bridge abutments was completed by the Bridge Engineering Center at Iowa State University, and are described in more detail in chapter 6.

PARTNERING AND PROJECT COORDINATION

As with any project utilizing a construction technique for the first time, coordination between all parties throughout the project is essential. For the Highway 60 project, IADOT designers and FHWA contractors worked closely together to develop a conceptual precast panel layout and initial design. These conceptual ideas were then used to solicit rough cost estimates from precasters. Once a precaster was identified, the project team worked closely with the firm to develop the precast panel details to ensure a viable solution. The designers continued to work closely with the precaster throughout the fabrication process and worked closely with the installation contractor throughout the construction of the project.

PROJECT LAYOUT

Figure 3 shows the Situation Plan for the Highway 60 bridge, including the layout of the precast panels. The specific details of the project site and the process by which the precast panel layout was selected are discussed below.

Roadway Geometry

A tangent section of Highway 60 was selected for the location of the demonstration project. Although roadways with horizontal curves and superelevations may eventually be encountered, this project location allowed for evaluation of the overall process on a less complex pavement section. The roadway had a “rooftop” crown with a 2 percent cross slope on either side of the pavement centerline. This required a precast panel layout that could accommodate a crowned pavement section, common in Iowa.

As figure 3 shows, the bridge abutments were skewed at 30 degrees right ahead. While this presented a challenge in developing the layout of the precast panels, skewed bridges are common in Iowa and throughout the United States, and this project allowed for the development of a solution that could accommodate skewed abutments.

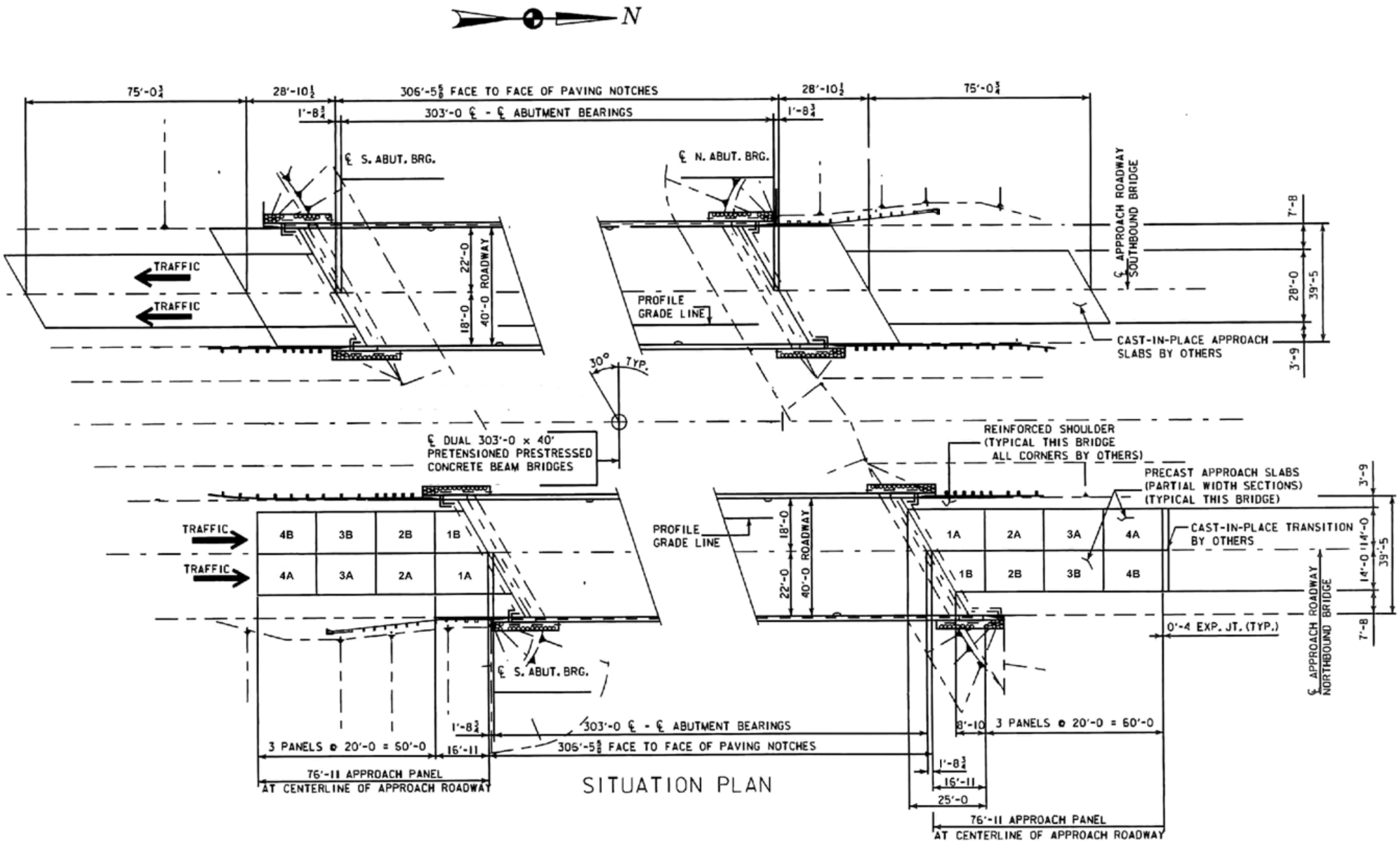


Figure 3. Illustration. Situation Plan for the Highway 60 bridge and precast approach slabs.
(Note: 1 ft = 0.305 m, 1 in. = 25.4 mm)

Integral Bridge Abutment

The Highway 60 bridge was designed with an integral abutment. This type of bridge abutment moves horizontally with the expansion and contraction movement of the bridge itself. Normally, an expansion joint is provided between the abutment and approach slab to accommodate this movement. However, research by IADOT has found this expansion joint to be a source of water infiltration into the underlying embankment, which can lead to consolidation or erosion of the embankment material.(13)

A new approach slab detail being implemented by IADOT ties the approach slab to the abutment so that the approach slab moves with the abutment, shifting the expansion joint out to the end of the approach slab. This plan requires consideration of the length of the approach slab not only to optimize how far the expansion joint is moved away from the abutment, but also what length of pavement could feasibly be "pushed" and "pulled" by the abutment without causing excessive stresses in the bridge structure.

Precast Panel Layout Options

One of the underlying goals of this demonstration project was to develop a solution that is both practical from a fabrication and construction standpoint and adaptable to various approach slab configurations. Three options were considered for the precast panel layout to accommodate the approach slab characteristics listed above. These options were based primarily on precast panels that were used successfully on previous demonstration projects. The two preliminary alternate solutions are described below.

Skewed full-width panels with variable thickness

The first precast panel layout considered uses skewed full-width panels with variable thickness. Full-width panels have been used successfully in three previous demonstration projects in Texas, California, and Missouri,(2,3,6) and provide an efficient solution in terms of fabrication and installation as only half the number of panels are needed as compared to partial-width construction. Additionally, full-width panels with variable thickness were used successfully in California and Missouri to achieve the necessary change in cross slope in the pavement surface. Figure 4 shows a schematic of the layout of skewed full-width panels with variable thickness.

Full-width, variable-thickness panels presented several drawbacks for application on this project. First, the paving notch on the bridge abutment would have required modification since it was constructed with a crowned cross section and uniform 305-mm (12 in.) depth. A level (horizontal) paving notch would have been necessary for full-width panels with variable thickness. Paving notch modification for future rehabilitation projects with crowned paving notches will likely not be possible. Second, the complexity of fabricating full-width panels with both skewed edges and variable thickness would likely have significantly increased the cost of the panels. Finally, full-width panels would not have demonstrated single-lane (or lane-by-lane) construction. While single-lane construction was not required for the Highway 60 project, it will likely be required for future projects in urban areas to allow for traffic flow on the remaining lanes.

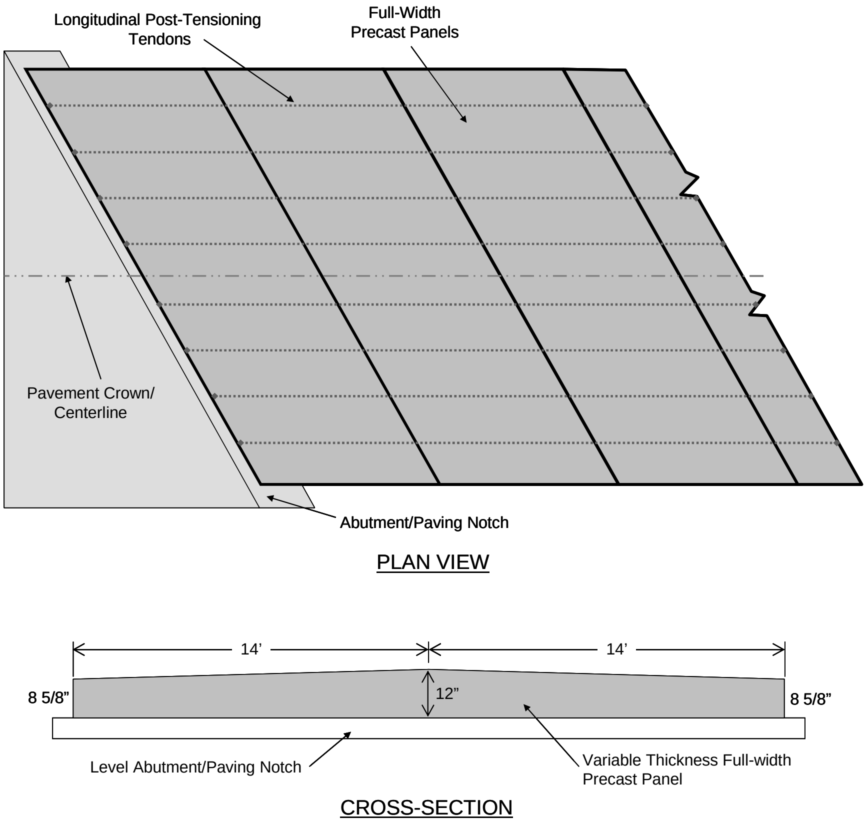


Figure 4. Illustration. Schematic layout of full-width panels with variable thickness.
(Note: 1 ft = 0.305 m, 1 in. = 25.4 mm)

Skewed partial-width panels with uniform thickness

The second alternative precast panel layout considered uses skewed partial-width panels with a uniform thickness. Partial-width panels permit single-lane (lane-by-lane) construction, which will be important for future projects where construction staging will likely permit the closure of only one lane at a time. The use of panels with a uniform thickness also greatly simplifies the fabrication process over variable thickness panels. Figure 5 shows a schematic layout of this alternative.

The primary drawback to this alternative is the increased complexity of panel installation. With this layout, both the transverse and longitudinal post-tensioning tendons cross joints between adjacent panels at nonperpendicular angles, as shown in figure 5. During the stressing operation, this could cause horizontal slip in the joints, offsetting the panels from each other. To counter this slip force, additional "slip pins" would be required at all of the joints between panels, increasing the complexity of the panel fabrication and assembly processes. An additional drawback is the complexity of fabricating these panels. The acute angles at the corners of the panels would have required very strict dimensional tolerances on the panels to ensure that both transverse and longitudinal joints align properly.

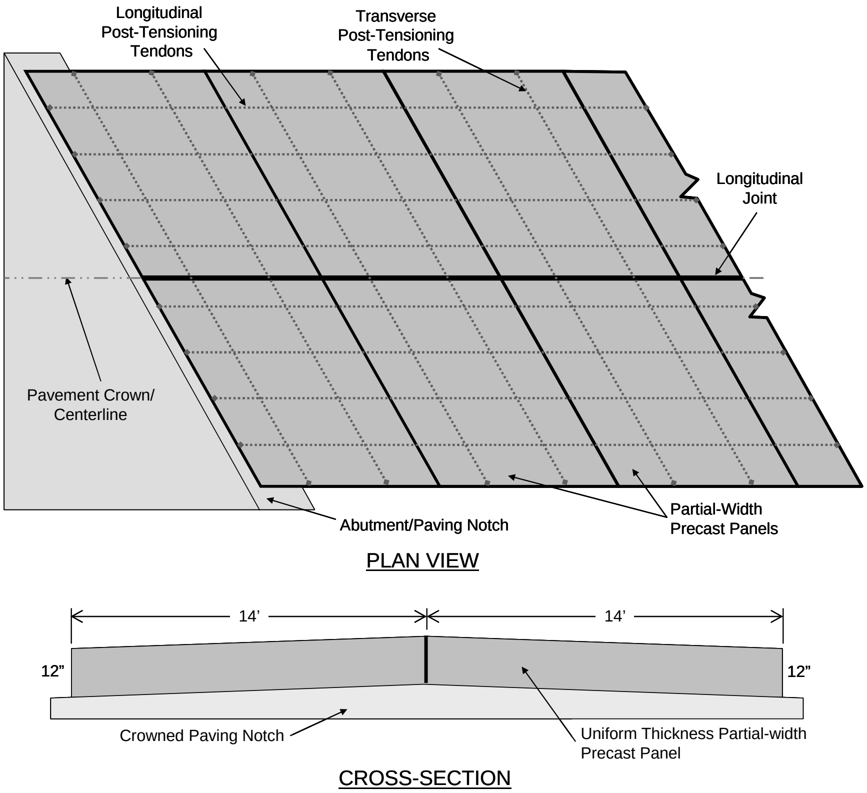


Figure 5. Illustration. Schematic layout of partial width panels with uniform thickness. (Note: 1 ft = 0.305 m, 1 in. = 25.4 mm)

Selected Precast Panel Layout

The final selected precast panel layout consists of partial-width panels with a uniform thickness, as shown in figures 3 and 6. The total length of the approach slab layout is approximately 23 m (77 ft) at the pavement centerline. With this layout, the skew at the bridge abutment is "removed" with the first panel, transitioning to perpendicular joints and square panels for the remainder of the approach slab. This eliminates potential horizontal slip problems during post-tensioning. This solution also greatly simplifies the fabrication process as the majority of the precast panels are square, with only two trapezoidal panels required for each approach slab. The uniform panel thickness also simplifies fabrication and does not require modification of the paving notch.

Perhaps most importantly, this panel layout provides a great deal of flexibility in accommodating different bridge characteristics, such as variations in skew angle and approach slab width, length, and thickness. Partial-width panels will also permit single-lane construction for future applications.

As figure 6 shows, bi-directional post-tensioning is used for this panel layout. Because of the thickness and size of the panels, pretensioning is not necessary for counteracting lifting and handling stresses. Bi-directional post-tensioning simplifies the fabrication process but does require special attention to ensure that both the transverse and longitudinal post-tensioning ducts will align when the panels are installed.

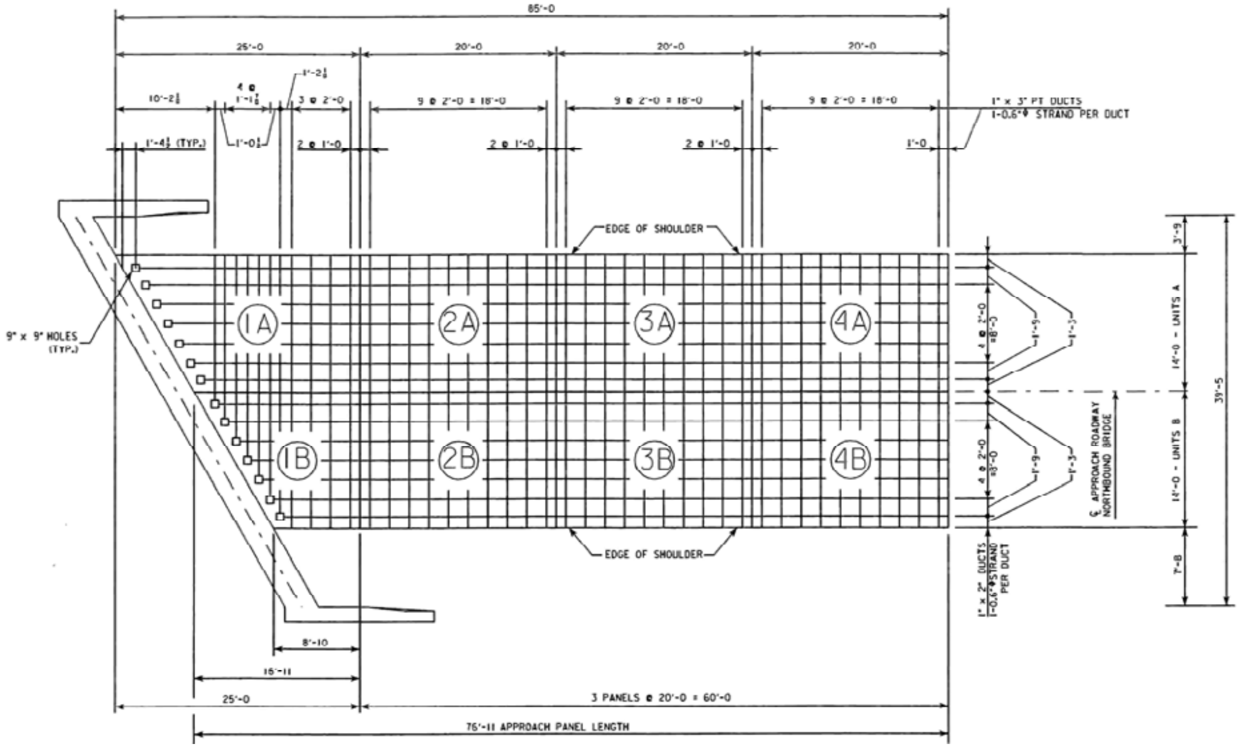


Figure 6. Illustration. Selected precast panel and post-tensioning tendon layout.
(Note: 1 ft = 0.305 m, 1 in. = 25.4 mm)

Panel Assembly

Figure 7 shows the final precast panel assembly. The first two panels resting on the paving notch are pinned to the abutment with dowels drilled and grouted into the paving notch. This causes the approach slab to move with the bridge abutment during seasonal temperature cycles. At the far end of the approach slab, a standard IADOT “EF” expansion joint(14) is constructed between the approach slab and adjoining pavement.

The longitudinal joint at the centerline of the approach slab is a keyed grouted joint, as shown in figure 8, which is filled prior to completion of transverse post-tensioning. This type of joint provides tolerance for slight misalignment of the precast panels, and does not require a perfect fit between panels at the longitudinal joint.

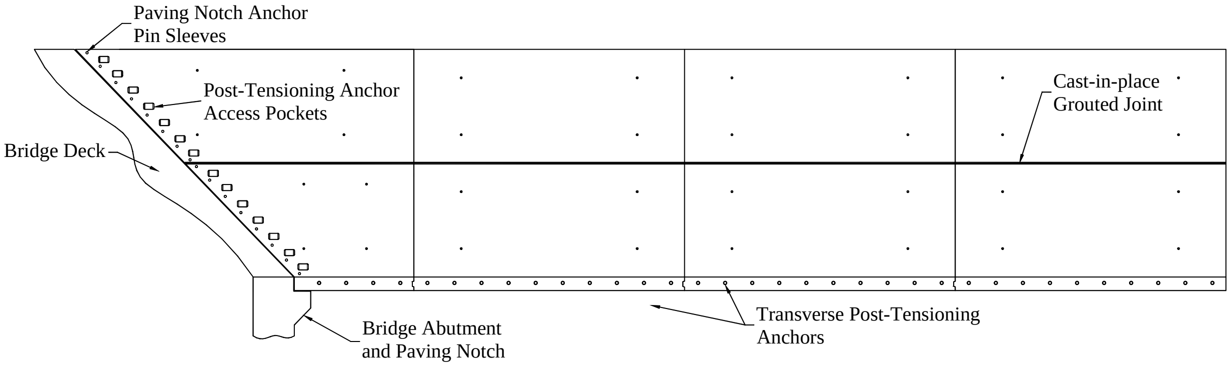


Figure 7. Illustration. Selected precast panel layout.

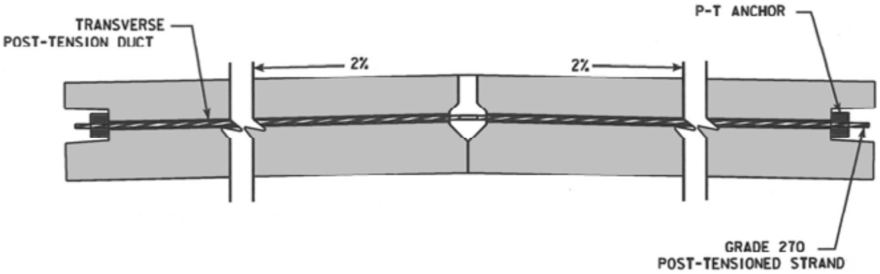


Figure 8. Illustration. Longitudinal joint at the centerline of the approach slab.

Panel Types

The panel layout consists of essentially three types of panels. The “abutment panels,” shown in figure 9, transition the joint in the approach slab from skewed to perpendicular. These panels have a variable length that can be adjusted based on the bridge skew. The panels have keyways cast into the mating edge of the panel. The panels also have anchor access pockets and paving notch anchor pin sleeves cast into them. The pockets provide access to all of the longitudinal post-tensioning anchors and the transverse post-tensioning anchors in the skewed section of the pavement (figure 6). The anchor pin sleeves, 50 mm (2 in.) in diameter, receive dowels that anchor the approach slab to the abutment. The length of the abutment panels varies from 2.7 m (8 ft 10 in.) to 5.2 m (16 ft 11 in.) for the smaller of the two panels and 5.2 m (16 ft 11 in.) to 7.6 m (25 ft) for the larger of the two panels (see figure 6). The abutment panels are all 4.3 m (14 ft) wide and 305 mm (12 in.) thick.

“Base panels,” shown in figure 10, are the “standard” panels that make up the majority of the approach slab. Keyways are cast into the mating edges of the panels, and the transverse post-tensioning anchors are cast into the outside edges of the panels. Base panels for the Highway 60 project were 6.1 m (20 ft) long, 4.3 m (14 ft) wide, and 305 mm (12 in.) thick.

Finally, the “joint panels” located at the end of the approach slab provide the transition to the adjoining cast-in-place pavement. Sleeves for the dowels used in the EF joint at the end of the approach slab are cast into the ends of these panels, as shown in figure 11. The live end post-tensioning anchors for the longitudinal tendons are cast into the ends of these panels as well.

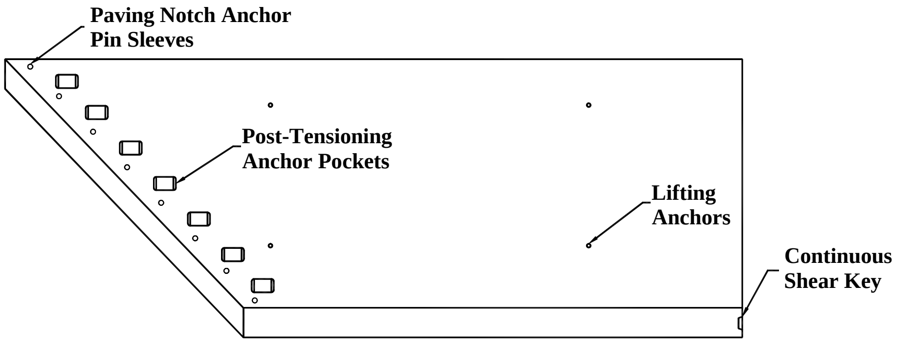


Figure 9. Illustration. Approach slab Abutment Panels.

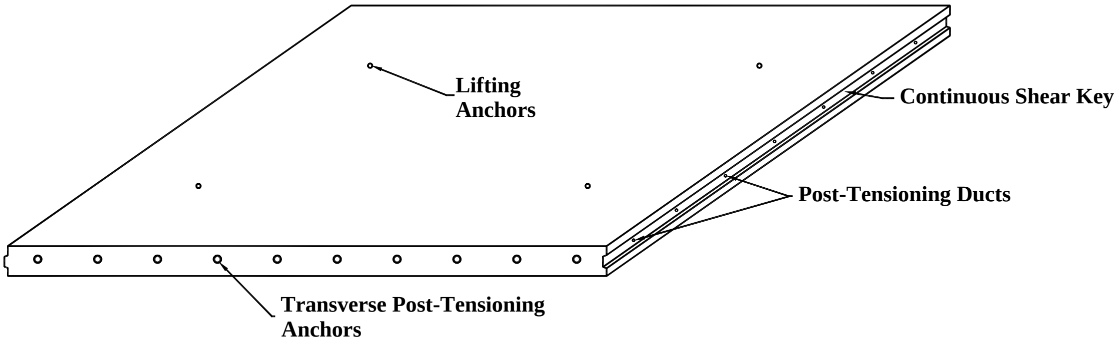


Figure 10. Illustration. Approach slab Base Panels.

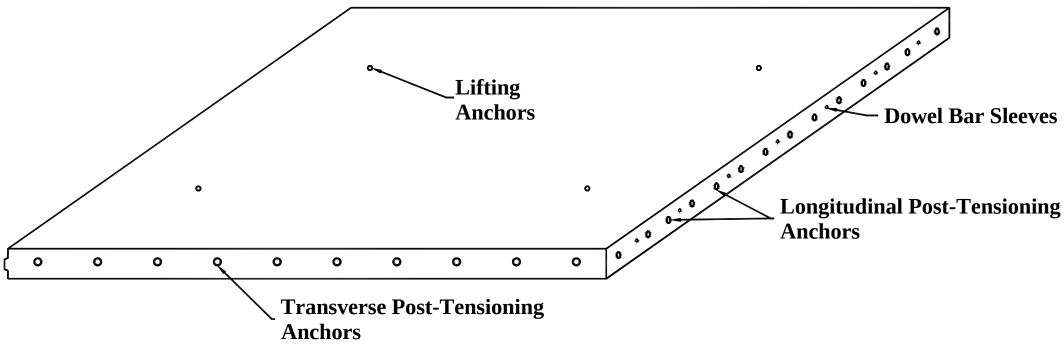


Figure 11. Illustration. Approach slab Joint Panels.

CHAPTER 4. DESIGN

DESIGN CONSIDERATIONS

The Highway 60 site conditions dictated many of the approach slab characteristics, such as the overall slab length, width, and thickness. The design of the precast panels was therefore primarily used to determine the prestress requirements for the given slab characteristics. While design considerations for PPCP are discussed more thoroughly elsewhere,(1,2) below are some of the design considerations specifically related to bridge approach slab applications.

Slab Bridging

Pavements are normally designed such that they will withstand a given number of 80-kN (18 kip) equivalent single-axle load applications (ESALs) over the life of the pavement.(15) Bridge approach slabs, however, present a unique design challenge in that a significant loss of support can be expected if voids form beneath pavement due to embankment consolidation or erosion. Traditional pavement design does not take such a significant loss of support into account. Therefore, the basis for the design of the Highway 60 project was to treat the approach slabs as a simply supported slab bridge spanning over a void in the underlying embankment extending away from the bridge abutment. Using this procedure, flexural stresses in the approach slab were determined and prestress levels were adjusted to ensure the slab had adequate flexural capacity.

Traffic Loading

Traffic loading for traditional pavement design procedures is quantified by an estimate of the number of 80 kN (18-kip) ESALs the pavement will experience over its design life. However, because the Highway 60 approach slab was designed as a simply supported slab bridge, the traffic loading normally used for bridge design was used for calculation of flexural stresses in the approach slab. As per IADOT standard practice, HS 20 loading was used for the traffic loading on the approach slab.(16)

Bridge and Approach Slab Movement

Integral bridge abutments are designed to move horizontally (and rotate) with the expansion and contraction of the bridge itself. By tying the approach slab to the abutment, this movement must be accommodated at the expansion joint at the end of the approach slab. In addition, movement of the approach slab itself, which will expand and contract with daily and seasonal temperature cycles, must also be accommodated.

The polyethylene friction-reducing material beneath the approach slab will help to reduce frictional restraint to movement of the approach slab, helping to reduce stresses in the approach slab and bridge structure. It is important that the connection between the bridge abutment and approach slab is strong enough to withstand the forces from the abutment “pushing” and “pulling” the approach slab.

HIGHWAY 60 PPCP DESIGN

The design procedure for the Highway 60 approach slabs was based on determining the prestress required to give the approach slab the flexural capacity to act as a simple span slab bridge for a given span length. For the initial design, a span length of 4.6 m (15 ft) was used as voids up to this length were observed beneath existing approach slabs in Iowa in a recent study.(13)

Traffic Loading

Traffic loading on the approach slab was based on HS 20 loading according to the American Association of State Highway and Transportation Officials' (AASHTO) *Standard Specifications for Highway Bridges*.(16) Using this traffic loading, design load moments were calculated for the following load combination:

$$TL = 1.3(D + 1.67L) = 1.3D + 2.17L$$

Figure 12. Equation. Load combination used to calculate total load.

Live load moment was calculated using the estimate provided in section 3.24.3.2 of the AASHTO specifications,(16) assuming a span length of 4.6 m (15 ft). Dead load moment was calculated for the self-weight of the approach slab with 305 mm (12 in.) thickness assuming a concrete unit weight of 2,403 kg/m^3 (150 lb/ft^3). Table 1 summarizes the moments used for design for a 4.6-m (15 ft) simple span approach slab.

Table 1. Factored Design Moments for Highway 60 Approach Slab
(4.6-m [15 ft] simple span)

	Moment per ft of slab width N-m (ft-lb)
Live Load	39,720 (29,295)
Dead Load	7,435 (5,484)
Total	**47,155 (34,779)**

Initial Flexural Design

The initial flexural design of the approach slab assumed a 4.6-m (15 ft) simple span slab bridge with 305-mm (12 in.) slab thickness. Initially, the prestressing tendons were assumed to be at mid-depth of the slab. Prestress levels in the slab were adjusted by varying the spacing of the prestressing tendons, the depth of the tendons, and the type of prestressing material (7-wire strand and high-strength bars).

The AASHTO Load Factor Design method for flexure was used to compute the ultimate moment capacity of the simply supported approach slab. The following equations from section 9.17.2 of the AASHTO specifications were used to compute flexural strength.(16) Although mild steel reinforcement was included in the precast panels, the initial design only considered the prestressed reinforcement in carrying tensile stresses since mild steel reinforcement will not be continuous through the approach slab (between precast panels).

$$\phi M_n = \phi\left[A_s^* f_{su}^* d\left(1-0.6\frac{p^* f_{su}^*}{f'_c}\right)\right]$$

Figure 13. Equation. Equation used to calculate flexural capacity of the approach slab.

$$f_{su}^* = f'_s\left(1-\frac{\gamma^*}{\beta_1}p^*\frac{f'_s}{f'_c}\right)$$

Figure 14. Equation. Equation used to calculate yield strength of the prestressing steel.

A^*_s = Area of prestressing steel
f^*_{su} = Yield strength of prestressing steel
$f's$ = Ultimate strength of prestressing steel
$f'c$ = Concrete compressive strength
p^* = Reinforcement ratio for prestressing steel
β_1 = Concrete strength factor
ϕ = Strength-reduction factor (0.9 for flexure)

Variations of both prestressing strand configurations and high-strength prestressing bars were used for the capacity analysis. Table 2 summarizes the flexural capacity of the approach slab with these varying configurations. Any of these configurations will provide the necessary flexural capacity for a 4.6-m (15 ft) simply supported approach slab.

Table 2. Flexural Capacity of Various Prestressing Configurations

		Tendon Spacing mm (in.)	**Depth From Surface m (in.)**	**Flexural Capacity per Foot of Slab Width N-m (ft-lb)**
15-mm (0.6 in.) Grade 270 Strand		305 (12)	220 (8.75)	48,130 (35,500)
		200 (8)	160 (6.25)	47,230 (34,835)
Grade 150 Bar	**25-mm (1 in.) diameter**	610 (24)	210 (8.25)	48,680 (35,907)
		305 (12)	150 (6)	54,750 (40,380)
	32-mm (1.25 in.) diameter	610 (24)	165 (6.5)	48,830 (36,014)

Final Flexural Design

While the prestressing configurations presented above will provide the necessary flexural capacity for a 4.6-m (15 ft) simply supported approach slab (using only prestressing steel to carry tensile stresses), the prestressing required is significantly more than that used for previous projects, and

IADOT believed it to be excessive for this application. Therefore, a standard 610-mm (24 in.) monostrand tendon spacing, using 15-mm (0.6 in.) Grade 270 7-wire strand, was specified for the final prestressing configuration.

Using this standard spacing of 610 mm (24 in.), the allowable span length was back-calculated based on the flexural capacity of the slab. The calculated allowable span length considering just the prestressing steel for carrying tensile stresses is approximately 1.9 m (6.1 ft). When also considering the contribution of the mild steel in the bottom of the precast panels (25-mm [No. 8], Grade 60 reinforcing bars at 305 mm [12 in.] on center in the longitudinal direction) for carrying tensile stresses, the spanning ability of the approach slab increases to approximately 5.7 m (18.8 ft). The mild steel reinforcement in the precast panels may or may not contribute to flexural capacity since it is not continuous through the approach slab (i.e., it is isolated in each individual precast panel). If a void were to form directly beneath one of the individual precast panels, the mild reinforcement would likely give the approach slab this additional flexural capacity; but if a void formed beneath multiple panels, the reinforcement may not provide this additional capacity.

It should be noted that designing an approach slab for flexural capacity is believed to be a very conservative approach as voids as large as 4.6 m (15 ft), while they have been observed, are likely very rare. Additionally, failure of an approach slab due to exceeding the flexural capacity would not likely have catastrophic consequences on the safety of the motoring public, as it could on a bridge.

Transverse Prestress

Transverse prestress was specified the same as the longitudinal prestress, with monostrand tendons spaced at 610 mm (24 in.) on center over the length of the approach slab. However, because the transverse post-tensioning tendons follow the contour of the crowned pavement cross section (figure 8), there was the potential for the prestress force to cause uplift of the precast panels during stressing, hinging about the longitudinal joint. A calculation of these uplift forces, which are resisted by both the weight of the precast panels and the horizontal component of the prestressing force, revealed that the total uplift force was only 32 percent of the resistance to uplift, and therefore would not present a problem.

Slab Movement Analysis

Normally, the expansion and contraction movement of a precast post-tensioned pavement slab is a governing factor in determining how long each post-tensioned section of panels should be. For the Highway 60 approach slab, however, the length of the approach slab was predetermined, and the slab movement analysis was only used to ensure that the expansion joint at the end of the approach slab was adequate. By tying the approach slabs to the integral abutments of the bridge, the approach slabs will be “pushed” and “pulled” by the abutments with movement of the bridge itself. IADOT estimated the total movement of each end of the bridge to be approximately 33 mm (1.3 in.).

Expansion and contraction movements of the approach slab itself were calculated using a methodology originally developed for cast-in-place post-tensioned pavement.(11,17) This methodology takes into account the slab geometry (length, width, and thickness), concrete properties (modulus of elasticity, coefficient of thermal expansion, creep and shrinkage), prestress (and prestress losses), slab–base frictional resistance, and local temperatures for summer and winter conditions. Both long-term (seasonal) movements as well as short-term (daily) movements of the slab are taken into account. Table 3 shows the results of the slab movement analysis for the Highway 60 bridge approach slabs. The values shown in this table represent the maximum anticipated movement of the free end of the approach slabs at the centerline and short and long edges of the approach slabs. This movement is additive to the 33 mm (1.3 in.) anticipated from bridge movement. The expansion joint at the free end of the approach slab, therefore, should be able to accommodate the “Total Movement” of up to 44 mm (1.74 in.) shown in table 3.

Table 3. Predicted Movements at the Ends of the Approach Slabs

Approach Slab Length	**Approach Slab Movement**	**Total Movement**
21 m (69 ft)—short edge	9 mm (0.36 in.)	42 mm (1.66 in.)
23 m (77 ft)—centerline	10 mm (0.40 in.)	43 mm (1.70 in.)
25 m (85 ft)—long edge	11 mm (0.44 in.)	44 mm (1.74 in.)

CHAPTER 5. PANEL FABRICATION

PROCEDURE

The precast panels for the Highway 60 approach slabs were fabricated by IPC, Inc., in Iowa Falls, Iowa. The fabrication plant was located approximately 280 km (175 miles) from the project site in Sheldon. The panels were fabricated on an indoor bed large enough to cast one panel at a time. Because of the limited number of panels for the project, a larger fabrication operation (e.g., long line fabrication) was not necessary. Also, because pretensioning was not used, the panels did not need to be cast on a bed set up for prestressing. The sideforms were specially made for this project in-house by IPC using laminate wood.

In general, bed setup took approximately a full day to complete, particularly for the abutment panels which had additional reinforcement and post-tensioning anchor pockets. Concrete placement for each panel was completed in approximately 30 to 45 minutes. Following surface finishing, curing compound was applied to the panel surface and the panel was then covered and heat-cured overnight. In general, the panels were removed from the forms the day after casting and stacked for storage in the yard. Additional details of the fabrication process will be discussed below.

TOLERANCES

As with all previous PPCP demonstration projects, the precast panels for the Highway 60 project were not match-cast. This required special attention to tolerances to ensure that adjoining panels would fit together and provide a satisfactory riding surface. Table 4 summarizes the tolerances for the precast panels as specified in the project plans. It is important to note that while most of these tolerances are tighter than normally specified for similar precast products and those recommended by the Precast/Prestressed Concrete Institute, they are based on experience from previous demonstration projects in which there were no problems in achieving these tolerances.

PANEL DETAILS

The Highway 60 approach slab was a very unique application for PPCP and required unique details to be developed. Below are some of the key details of the precast panels (see appendix A for all detailed panel drawings).

Keyways

Keyways were used for both the transverse joints between individual panels, and for the longitudinal joint at the centerline of the pavement. The primary purpose of the transverse keyways was to help ensure vertical alignment between panels as they were assembled. This permitted the panels to be installed over a base that was not perfectly flat while still providing load transfer between panels prior to post-tensioning. Figure 15 shows the transverse keyway dimensions. These dimensions, which were based on experience with previous PPCP demonstration projects, ensured no more than a 6-mm (1/4 in.) vertical differential between panels, while also providing a keyway that was “loose” enough to accommodate minor irregularities in the keyway. The chamfer along the bottom edge of the panel helps to reduce the chance of spalling as the panel is removed from the forms.

Table 4. Table of Panel Tolerances From the Project Plans

Measurement	Tolerance
Length (parallel to long axis of panel)	+/- 6 mm (1/4 in.)
Width (normal to long axis of panel)	+/- 3 mm (1/8 in.)
Nominal thickness	+/- 3 mm (1/8 in.)
Skew angle (ends of panel relative to mating edges)	+/- 1 degree
Squareness (deviation from plans, measurement from corner to corner across top surface, measured diagonally)	+/- 3 mm (1/8 in.)
Deviation of ends (horizontal skew)	+/- 3 mm (1/8 in.)
Deviation of ends (vertical batter)	+/- 3 mm (1/8 in.)
Keyway dimensional tolerance	+/- 1.6 mm (1/16 in.)
Position of post-tensioning ducts at transverse joints	+/- 3 mm (1/8 in.) vertical +/- 6 mm (1/4 in.) horizontal
Straightness of post-tensioning ducts (vertical and horizontal)	+/- 6 mm (1/4 in.)
Squareness (corner-corner measurement)	+/- 3 mm (1/8 in.)
Alignment of dowel sleeves (parallel to bottom of panel)	+/- 3 mm (1/8 in.)
Position of non-prestressed reinforcement	+/- 6 mm (1/4 in.)
Dimensions of blockouts/pockets	+/- 3 mm (1/8 in.)
Location of abutment anchor sleeves	+/- 3 mm (1/8 in.)
Position of lifting anchors	+/- 50 mm (2 in.)

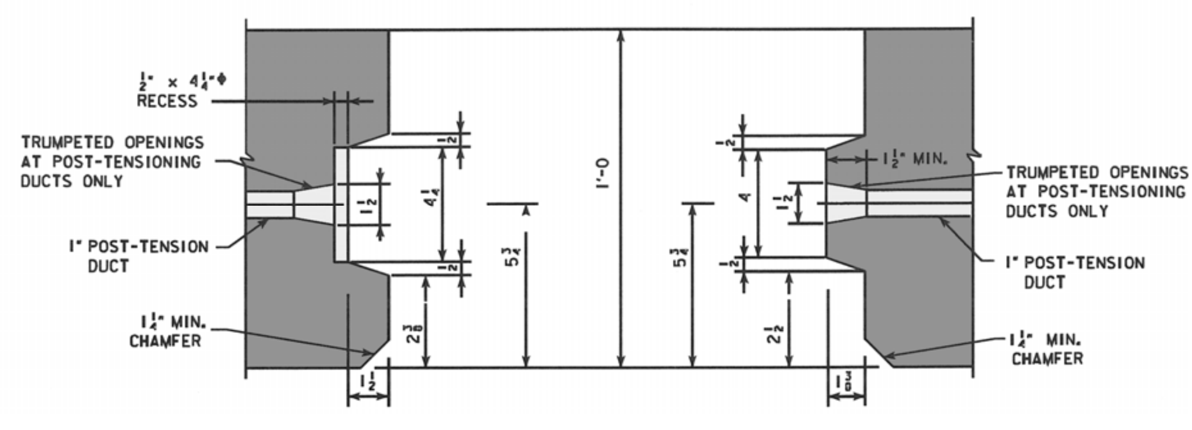


Figure 15. Illustration. Transverse keyway dimensions for the precast panels (dimensions in inches). (Note: 1 in. = 25.4 mm)

An open keyway was specified for the longitudinal cast-in-place joint in order to accommodate the crowned pavement cross section. Figure 16 shows the dimensions of this keyway. Because the panels on either side of the pavement centerline were set at opposing cross slopes, the edges of the panels at the longitudinal joint would need to be battered to achieve full contact across the joint. The open keyway, which is grouted after the panels are installed, provides tolerance for imperfections in the panel edges and slight vertical and horizontal misalignment of the precast panels. Load transfer across the joint is established after grouting and post-tensioning across the joint. The keyway is filled with a low-slump mortar or grout with minimal shrinkage. Partial post-tensioning of the joint as soon as the fill material has developed strength helps to prevent shrinkage cracking in the joint.

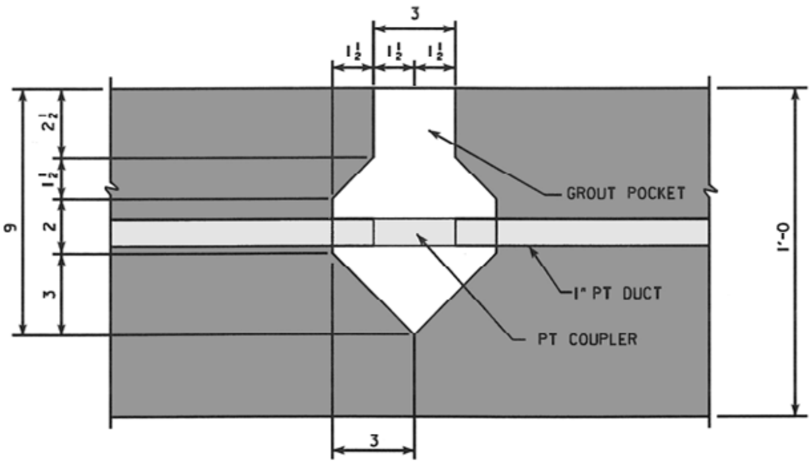


Figure 16. Illustration. Keyway dimensions for the longitudinal joint
(dimensions in inches). (Note: 1 in. = 25.4 mm)

Post-Tensioning

Figure 6 (chapter 3) shows the layout of the post-tensioning tendons for the approach slabs. Monostrand post-tensioning tendons were spaced at approximately 610 mm (24 in.) on center in both the transverse and longitudinal directions. Longitudinal post-tensioning anchors were located near the abutment and at the far end of the approach slab, abutting the adjacent pavement. To provide access to the anchors near the abutment, 230-mm (9 in.) square pockets were cast into the panels behind the anchors. These pockets allowed the anchor wedges to be seated in the anchor by hand after the strands were inserted. Flared openings were provided at the end of each post-tensioning duct, at the joints between panels, to facilitate feeding the strands through the ducts, even with slight misalignment of the panels. Additionally, to prevent grout leakage, recesses were formed around each post-tensioning duct to receive compressible foam gaskets, as shown in figure 17.

Anchors for the transverse post-tensioning tendons were located at the outside (shoulder) edges of the approach slab for the non-skewed section of the slab. For the skewed section, the anchors were located at the same anchor access pockets used for the longitudinal tendons, as shown in figure 6. Using these pockets for the transverse tendons resulted in tendon spacing of approximately 305 mm (12 in.) on center for the skewed section of the approach slab.

Semi-rigid polypropylene ducts with a 23-mm (0.9 in.) inside diameter were used for all post-tensioning tendons. The ducts used were specifically designed for bonded monostrand tendons, with corrugations to provide better bond with the concrete and a rib along the length of the duct to facilitate the flow of grout through the duct. Post-tensioning anchors were coated or encapsulated to provide corrosion protection. Grout ports were located just in front of each post-tensioning anchor. The grout port inlets were located on the edges of the precast panels and faces of the anchor access pockets to minimize protrusions from the top surface of the precast panels.

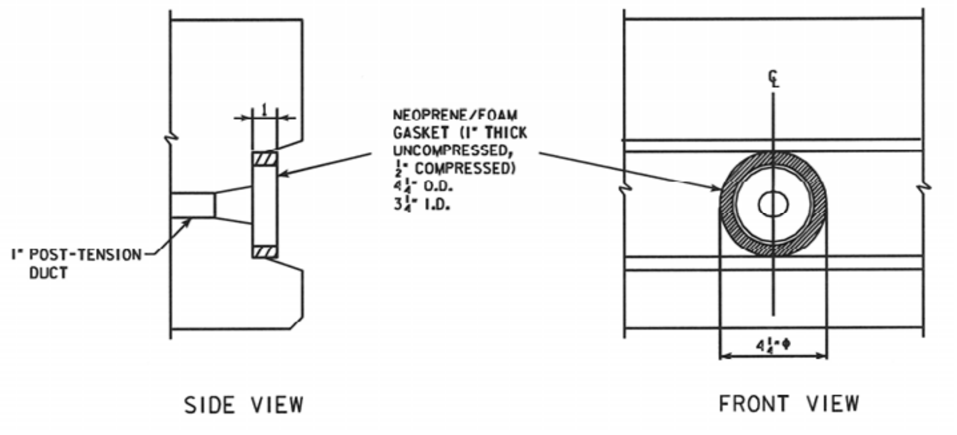


Figure 17. Illustration. Post-tensioning tendon gasket detail (dimensions in inches). (Note: 1 in. = 25.4 mm)

Anchor Sleeves

Sleeves for the anchor pins used to tie the approach slab to the paving notch were cast into the skewed panels at 610 mm (24 in.) on center across the width of the approach slab. Anchor sleeves, 50 mm (2 in.) in diameter, were specified to receive stainless steel anchor bars, 25-mm (1 in.) in diameter. The larger sleeves provided enough room for a core bit to be used to drill the holes into the paving notch.

Expansion Joint

As discussed previously, a dowelled expansion joint was constructed at the end of the approach slab. Sleeves with a 41-mm (1 5/8 in.) inside diameter were cast into the ends of the precast panels to receive dowel bars with a 38-mm (1 1/2 in.) diameter for the expansion joint.

Reinforcement

In addition to post-tensioning, mild steel reinforcement was provided in all of the precast panels. A double mat of epoxy-coated reinforcement, similar to that normally used for the doubly-reinforced section of cast-in-place approach slabs, was provided. For the skewed panels (1A and 1B), this consisted of 25-mm (No. 8) bars at 305 mm (12 in.) on center in the bottom of the panel and 19-mm (No. 6) bars at 610 mm (24 in.) on center in the top of the panel in the longitudinal direction, and 16-mm (No. 5) bars at approximately 305 mm (12 in.) on center in the top and bottom of the panel in the transverse direction. For the square panels (2A thru 4B), mild reinforcement consisted of 19-mm (No. 6) bars at 610 mm (24 in.) on center in the top and bottom of the panel in the longitudinal direction, and 16-mm (No. 5) bars at 610 mm (24 in.) on center in the top and bottom of the panel in the transverse direction. Additional mild steel reinforcement was provided through and around the post-tensioning anchor pockets, around the anchor pin sleeves, and in front of the post-tensioning anchors.

In addition to the reinforcement, tie bars were also cast into the edges of the skewed panels to tie the cast-in-place concrete shoulders to the approach slab. Tie bars were only included in the two skewed panels abutting the bridge. Two-piece tie bars were used with half of the tie bar cast into the panel, and the other piece screwed into place prior to placement of the concrete shoulders.

Lifting Anchors

Threaded coil inserts were specified for the lifting anchors. Coil inserts leave only a small recess in the surface of the panel, which can be easily patched. A four-point lifting anchor arrangement was used, with the anchors positioned to minimize lifting stresses in the precast panels.

MIXTURE DESIGN

Precast fabrication plants use concrete mixtures and curing methods that will permit maximum productivity while still meeting the materials requirements and strength criteria for the final product. In general, precast plants turn over beds every day or every other day, depending on the amount of time required to set up the bed. The Highway 60 panels were produced in such a manner, using a concrete mixture and curing process that would allow IPC to cast a panel at least every other day.

The mixture design used for the panels was required to reach a compressive strength of 24 MPa (3,500 lbf/in^2) at form removal and 34 MPa (5,000 lbf/in^2) at 28 days. The mixture contained 19-mm (3/4 in.) crushed limestone coarse aggregate and sand, had a water/cement (Type I) ratio of 0.4, and included an air-entraining admixture, water-reducing admixture, and set-retarding admixture. The target air content was 6.5 +/- 1 percent before vibration.

A higher strength mixture was provided by IPC, and IADOT inspectors reported average compressive strengths of 38 MPa (5,500 lbf/in^2) at 12 hours and 59–62 MPa (8,500–9,000 lbf/in^2) at 28 days. No problems with the concrete mixture were encountered during the fabrication process. Figure 18 shows placement of concrete for one of the abutment panels at the fabrication plant.

Figure 18. Photo. Placement of concrete for an abutment panel.

FINISHING AND CURING

Based on experience with previous demonstration projects, it was anticipated that diamond grinding would be required to achieve the level of smoothness required for mainline highway pavements. For this reason, only a light broom surface texture was applied to the precast panels to provide a “temporary” surface texture until grinding was completed. Figure 19 shows the light broom texture being applied to the panel surface.

Following application of the surface texture, a heavy coat of curing compound was applied to the surface of the precast panels to minimize moisture loss from the panel surface during curing. Following the application of curing compound, the panel was covered with a curing tent and heat cured until the required compressive strength was reached. Heat curing was used in lieu of steam curing to minimize any swelling of the wood forms used for the precast panels. Figure 20 shows the curing tent being lowered over a precast panel after application of the curing compound.

Figure 19. Photo. Application of the light broom texture to the panel surface.

Figure 20. Photo. Curing tent being lowered to cover a precast panel after casting.

HANDLING AND STORAGE

After the required compressive strength was reached, the curing tent was removed and the forms were stripped from the precast panel. The panel was moved to a storage location at the precast plant, and a coat of curing compound was applied to the edges of the precast panels to minimize any moisture loss from the exposed surfaces. This curing compound was subsequently sandblasted off prior to shipment of the panels to the jobsite. Panels were stacked four high in groups according to the post-tensioned section each belonged to. Figure 21 shows a stack of panels stored at the precasting plant.

TRIAL ASSEMBLY

One of the requirements for the Highway 60 project was a trial assembly of the first "set" of precast panels prior to continuing fabrication. After the first four panels (1A through 4A) were fabricated, a trial assembly was conducted at the precast plant to test the fit of the panels. The panels were assembled on the rails of a casting bed to provide a level surface, as shown in figure 22. While some minor damage was sustained to one of the panels during this trial assembly (discussed below), the fit was good and approval was given to complete fabrication of the remaining panels. This trial assembly allowed inspectors and plant personnel to identify any issues with the precast panels that could affect construction on site prior to fabricating all of the panels.

Figure 21. Photo. Precast panels stored at the fabrication plant.

Figure 22. Photo. Trial assembly of precast panels at the fabrication plant
(photo by Iowa DOT, reprinted by permission).

PANEL REPAIRS

Based on experience with previous demonstration projects, minor damage to the precast panels at the fabrication plant was anticipated. Damage was addressed on a case-by-case basis by IADOT. For pavement panels, the keyways and the top surface are the critical areas, because damage to the keyways can adversely affect installation of the panels and damage to the top surface can affect the final ride quality of the pavement.

Based on damage sustained at the precast plant during the trial assembly and general handling, a repair procedure was established by IADOT. Any deep spalls, corner breaks, or keyway fractures were required to be removed, cleaned, and patched. One significant corner repair and one keyway repair were required from damage during the trial assembly, as shown in figures 23 and 24.

In addition to damage sustained during the trial assembly, additional grinding of the keyways was required prior to shipping the panels to the project site. As figure 25 shows, mortar trapped behind the keyway former on some of the sideforms and swelling of the forms due to repeated use resulted in battered top and bottom vertical faces on a few of the panels. This batter was removed by grinding the face of the keyway so that it was vertical and true. Figure 26 shows the keyway surface after grinding, prior to installation of the panel.

Figure 23. Photo. Damaged panel corner after trial assembly.

Figure 24. Photo. Damaged keyway after trial assembly.

Figure 25. Photo. Battered keyway after removal from forms.

Figure 26. Photo. Keyway after completion of grinding.

FABRICATION ISSUES AND CHALLENGES

While the fabrication process was completely successful and no precast panels were rejected, several issues were discovered during the course of the process. Below are some of the key issues that need to be specifically addressed for future projects.

Post-Tensioning Ducts

The post-tensioning ducts used for this project are ideal for monostrand post-tensioning tendons. However, because this duct material has some flexibility, it requires bar stiffeners to be inserted into the ducts prior to placing concrete in the forms. It also requires adequate chairing to prevent the duct from sagging.

Pocket Reinforcement

As mentioned above, additional reinforcement was provided around the post-tensioning anchor access pockets. Combined with the reinforcement for the anchor pin sleeves, this added reinforcement created a very congested region around the pockets. This required a significant amount of time to tie all of the reinforcement and required special attention to concrete placement around the pockets to ensure that concrete had filled in around all of the reinforcement. For future projects, different options for reinforcing this region should be examined to reduce congestion.

Formwork

As discussed above, the wood sideforms used for the precast panels accumulated mortar beneath the keyway former, resulting in vertical batter of the keyway faces for some of the panels. While wood forms provide an economical solution and can be manufactured to the tolerances required for this type of fabrication, they are probably not suitable for significant reuse. Although they can be much more costly, larger projects may necessitate the use of steel forms, which are more durable and less susceptible to the issues encountered with the Highway 60 panels.

Panel Damage

The primary damage that occurred at the fabrication plant happened during the trial assembly. While this damage was adequately repaired, damage to precast pavement panels should be avoided at all costs as it can cause problems with the assembly of the panels and can also affect the smoothness of the riding surface. For future projects, damage tolerances and repair procedures should be prepared and approved in advance of the fabrication process so they can be addressed and resolved quickly.

CHAPTER 6. APPROACH SLAB CONSTRUCTION

PRE-CONSTRUCTION MEETINGS

Pre-construction meetings with the installation contractor were an essential part of this project, particularly since the contractor had not constructed a project of this nature previously. Several pre-construction meetings and conference calls were conducted to work out the installation schedule and other construction details such as materials to be used and coordination with the post-tensioning subcontractor. Dixon Construction of Correctionville, Iowa, constructed the bridges for Highway 60 and was responsible for installation of the PPCP approach slabs.

BASE PREPARATION

The Highway 60 approach slabs were constructed over a layer of crushed limestone aggregate that was placed over the bridge embankment fill. The base was graded as closely as possible to the required cross slope with a bulldozer, then fine-graded by hand. A tripod-mounted rotating laser with x- and y-axis tilt control was used to fine-grade the base to the proper cross slope and elevation. A portable plate vibratory compactor was used to consolidate the coarse aggregate base to the proper elevation. Because it was important for the precast panels to rest on the paving notch at the bridge abutment, the aggregate base was graded slightly lower than the paving notch. Over the aggregate base, the single layer of 0.15-mm (6 mil) thickness polyethylene sheeting (friction-reducing material) was rolled out just prior to placement of the panels. Figure 27 shows the base-grading operation.

Figure 27. Photo. Grading and compaction of the aggregate base material.

PANEL INSTALLATION

Precast panel installation for the south and north approach slabs took place the weeks of August 28, 2006, and September 4, 2006, respectively. Panels were shipped to the jobsite one panel per truck due to the weight of each panel. Panel installation required between 15 and 30 minutes per panel, depending on how much fine-grading of the base was required to set the panels at the correct elevation.

Procedure

Prior to installing the panels, neoprene pads, 13 mm (1/2 in.) thick, were placed over the paving notch and against the vertical face of the abutment. The neoprene pads provided more uniform support for the precast panels on the paving notch and will permit some degree of hinging action at the abutment–approach slab interface as the abutment rotates over time. The skewed panels (1A and 1B) were installed first into their final position, aligning the longitudinal joint with the centerline of the roadway. The panels for each section of panels (A and B) were then installed separately. A gap was initially left between each of the panels for applying the joint epoxy and installation of the foam gaskets around the duct openings.

After all four panels of a section were temporarily in place, the post-tensioning strands were fed from the end of the approach slab (panels 4A and 4B) through the panels to the anchors at the abutment end. Epoxy was then applied to the keyways of each joint just prior to the crane moving each panel into its final position. Temporary post-tensioning (using two of the strands) was used to snug the panels together to seat the keyway in the epoxy. Slight tension was maintained on the lifting lines during the temporary post-tensioning process. The sequence was then repeated for the adjacent section of panels. Figures 28 and 29 show the installation of the skewed panels at the bridge abutment and a finished approach slab prior to post-tensioning, respectively.

Figure 28. Photo. Installation of Panel 1A at the south bridge abutment.

Figure 29. Photo. Finished approach slab prior to final post-tensioning.

Joint Epoxy

The epoxy used for the panel joints was a high-viscosity, gel-paste epoxy, suitable for bonding hardened concrete to hardened concrete. The epoxy had a pot life of 45 minutes and a 1-day compressive strength of 62 MPa (9,000 lbf/in^2). The epoxy sealed the joints between panels to prevent water from infiltrating the embankment and helped prevent leakage of the tendon grout. The epoxy also helped to compensate for unevenness in the keyway surfaces. By applying a layer of epoxy 3 mm (1/8 in.) thick to the keyways and squeezing the panels together lightly, the epoxy filled any irregularities in the keyway surface, ensuring full contact between panels to eliminate stress concentrations. Figure 30 shows epoxy being applied to a keyway before the panel was pulled into its final position.

Temporary Post-Tensioning

Temporary post-tensioning was used to snug adjacent panels together as each was installed. This process helped to seat the keyways together, squeezing out excess epoxy. Two strands, located at approximately the quarter points, were used for temporary post-tensioning. Only enough pressure to pull the panels together was applied so that spalling would not occur if there were any unevenness in the joint. This pressure was maintained long enough for the epoxy to reach an initial set. The temporary post-tensioning was then released, and the next panel was pulled into place. After all four panels were installed, the two temporary post-tensioning strands were tensioned long enough for the epoxy in all of the joints to reach a final set. Figure 31 shows the application of temporary post-tensioning to one panel.

Figure 30. Photo. Application of joint epoxy during panel installation.

Figure 31. Photo. Temporary post-tensioning used to pull panels together.

POST-TENSIONING

All transverse and longitudinal post-tensioning tendons consisted of single, 15 mm (0.6 in.) in diameter, Grade 270, 7-wire strand. The longitudinal post-tensioning strands were fed through the ducts as the panels were installed to ensure that all strands could be inserted. After all of the panels for each approach slab were installed, the transverse post-tensioning strands were then fed through the panels and across the longitudinal joint. Figures 32 and 33 show the longitudinal and transverse strands being fed through the panels, respectively.

Longitudinal post-tensioning was completed first to ensure that any differential longitudinal movement of the sections on either side of the longitudinal joint had occurred prior to transverse post-tensioning. The longitudinal tendons were stressed only after the approach slab had been anchored to the paving notch to ensure that it did not pull away from the bridge abutment during stressing. Wedges were seated by hand into the post-tensioning anchors from the anchor access pockets. The strands were tensioned to 75 percent of their ultimate strength or approximately 1.4 MPa (203 ksi). Tensioning began with strands near the middle of each post-tensioned section and alternated out to the edges of the slab.

After insertion of the transverse post-tensioning strands, the ducts extending from each of the panels into the longitudinal joint were spliced together to create a continuous duct. The longitudinal joint was then filled prior to tensioning the strands. After the joint had gained adequate strength (approximately 3 to 4 hours after placement), the transverse tendons were partially tensioned to prevent shrinkage cracking in the joint. After the joint had cured for approximately 24 hours, final transverse post-tensioning was applied. Strand tensioning began with the tendons at the bridge abutment and progressed to the end of the approach slab.

Figure 32. Photo. Inserting the longitudinal strands into the approach slab.

Figure 33. Photo. Inserting the transverse strands into the approach slab.

GROUTING

Grouting was completed after all post-tensioning had been completed and the pockets (anchor access and instrumentation pockets) and longitudinal joint had been filled. Initially, tendon grouting was started prior to underslab grouting. However, after experiencing significant grout leakage from the tendons, the process was reversed and underslab grouting was completed first.

Tendon Grouting

As discussed previously, the purpose of grouting the post-tensioning tendons is both to provide an additional layer of corrosion protection for the strands and to bond the strands to the concrete so that individual panels can be cut out and removed in the future for repairs or replacement without compromising the prestress of the entire approach slab.

A prepackaged cable grout mixture, specifically formulated for post-tensioning strands, was used for the tendon grout. Grout was pumped from the inlet port at the anchor at one end of the tendon to the port at the anchor at the other end of the tendon. Although some grout leakage was observed when grouting the longitudinal tendons, grout flow from the outlet of each tendon indicated full grouting. No leakage was observed during transverse tendon grouting. Figure 34 shows the tendon grouting operation.

Figure 34. Photo. Grouting of the post-tensioning tendons (photo by Iowa State University, reprinted by permission).

Underslab Grouting

Underslab grouting was used to fill any voids beneath the approach slab. Because a very course crushed stone base was used beneath the panels, it was not possible to fine-grade the base to the point that complete support was provided. The grout mixture used was a standard IADOT underslab grout mixture consisting of Type 1 portland cement, Class C fly ash, and water, according to Section 2539 of the IADOT Standard Specifications.(18) Grout was pumped beneath the approach slab through ports cast into the precast panels for this purpose. The grout was pumped at very low pressure (< 20 kPa [30 lbf/in^2]) to reduce the risk of lifting the slab. Grout was pumped until it would not flow anymore (after reaching the maximum pressure) or until it began to flow out of an adjacent grout port. A rod and level was used to monitor any slab lifting during the underslab grouting operation, as shown in figure 35. The polyethylene sheeting beneath the approach slab helped to prevent the grout from bonding the approach slab to the underlying base. While some leakage through the polyethylene sheeting is likely unavoidable, it should not be significant enough to restrain movement of the approach slab.

Figure 35. Photo. Rod and level were used to check for slab lifting during the underslab grouting operation. (photo by Iowa State University, reprinted by permission).

FINISHING AND TIE-IN

Longitudinal Joint

As discussed above, the longitudinal joint was filled after completion of longitudinal post-tensioning, but prior to transverse post-tensioning. A pea gravel concrete mixture was used to fill the longitudinal joint. After placing the material, wet burlap was placed over the joint for curing. Within 3 to 4 hours after filling the joint, the transverse post-tensioning tendons were tensioned to approximately 10 percent of their final load to compress the joint to prevent cracking from shrinkage. Approximately 24 hours after filling the joint, the full and final transverse post-tensioning force was applied. Figure 36 shows the filling operation for the longitudinal joint.

Figure 36. Photo. Filling of the longitudinal joint
(photo by Iowa State University, reprinted by permission).

Pocket Filling

At the same time that the longitudinal joint was filled, the post-tensioning anchor access pockets and the post-tensioning tendon instrumentation pockets were also filled. The same concrete mixture used for the longitudinal joint was also used for the pockets, and the pockets were also covered with wet burlap mats for curing.

Bridge Abutment Anchor

Before the final longitudinal post-tensioning was completed, the approach slab was anchored to the paving notch, as shown in figure 37. A hole 32 mm (1 1/4 in.) in diameter was drilled into the paving notch using a core drill bit that would not damage the paving notch. A grout mixture was then poured into the hole, and the anchor pins were inserted.

Expansion Joint

After installation of the panels, post-tensioning, and grouting, an IADOT standard EF expansion joint was constructed at the end of the approach slab. Epoxy-coated dowel bars, 38 mm (1 1/2 in.) in diameter, were inserted into the ends of the precast panels, and a flexible foam expansion joint was placed over the dowels to provide a joint 100 mm (4 in.) wide. The cast-in-place pavement was then placed up to the expansion joint, encasing the other end of the dowels, and the expansion joint was sealed. Figure 38 shows the end of the south approach slab prior to inserting the dowels.

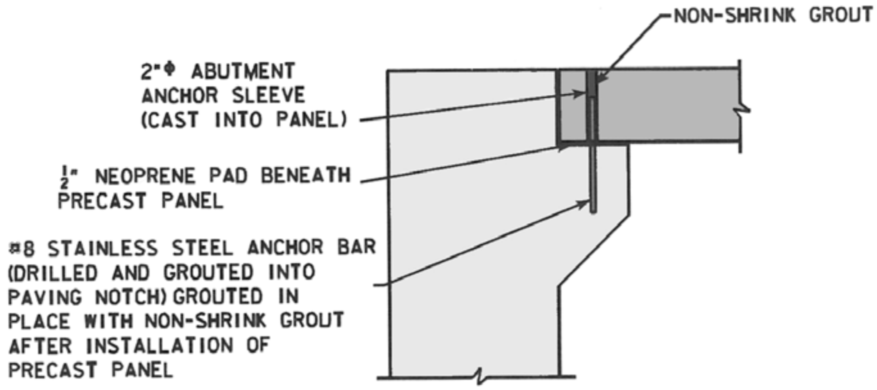


Figure 37. Illustration. Abutment anchor detail for PPCP approach slabs.
(Note: 1 in. = 25.4 mm)

Figure 38. Photo. Dowels for the EF expansion joint prior to its installation in the precast panels (photo by Iowa State University, reprinted by permission).

Diamond Grinding

The as-constructed smoothness of the approach slabs did not meet IADOT requirements for multilane primary divided highways, and required diamond grinding to achieve an acceptable level of smoothness. This was anticipated, however, as previous demonstration projects also required diamond grinding to provide a high-speed facility level of smoothness. Diamond grinding was also required for the bridge deck between the approach slabs. It is important to note, however, that the level of smoothness prior to diamond grinding was adequate for opening the approach slabs to traffic if necessary.

Both approach slabs were ground across the full width of the slab. Up to 19 mm (3/4 in.) of material was removed from some areas, particularly at the abutment where the top surface of the precast panels was slightly higher than the surface of the bridge deck. Grinding of both approach slabs took approximately 10 hours to complete. Figure 39 shows the diamond-grinding operation for the south approach slab.

Figure 39. Photo. Diamond grinding the south approach slab.

CONSTRUCTION ISSUES AND CHALLENGES

Construction of the Highway 60 PPCP approach slabs presented several challenges and revealed several details that could be improved for future projects. Below are some of the key issues that were encountered during the construction process.

Panel Placement

Paving Notch Elevation—When the bridge was constructed, the top of the paving notch was constructed 380 mm (15 in.) below the top elevation of the bridge deck, rather than 330 mm (13 in.) per IADOT bridge abutment standards. An additional 76 mm (3 in.) was subsequently added to the paving notch to accommodate the 305-mm (12 in.) thickness of the precast panels. Unfortunately, the thickness of the neoprene pad was not accounted for, and consequently the precast panels at the abutment were 13 mm (1/2 in.) higher than the bridge deck. Although this was corrected later with diamond grinding, careful attention to the paving notch elevation is needed when designing the thickness of the precast panels.

Bridge Skew—The Highway 60 bridge was designed with a 30-degree right ahead skew. However, the actual as-constructed skew was not field-verified prior to fabricating the precast panels. Consequently, the skew angle on the panels did not match exactly the skew angle of the bridge when aligning the centerline edge of the precast panels to the centerline of the roadway. This discrepancy resulted in a larger gap at one end of the joint between the bridge and abutment, as shown in figure 40. While the difference in angle for the Highway 60 project was very small and did not cause a major problem with construction, verifying the as-constructed skew angle prior to panel fabrication is critical. Also, because it is impractical to achieve a perfect match of the skew angle, a plan for accommodating a joint gap should also be considered. For the Highway 60 bridge, the additional joint width was sealed with bituminous material.

Figure 40. Photo. Joint between south approach slab and bridge abutment.

Base Leveling—As discussed previously, the coarse crushed stone used for the base beneath the precast panels was difficult to trim and level, leaving noticeable voids beneath the panels. While underslab grouting can be used to fill these voids, they should be minimized if possible. The use of a finer material at the surface of the base should be considered on future projects if practical. Bituminous base materials have also been successfully used on previous projects.

Joint Spalling—The only distresses of significance that occurred during panel installation were two shallow spalls that occurred on the top surface of two of the panels on the south approach slab. These spalls occurred when the temporary post-tensioning was applied and were likely the result of slight unevenness in the top face of the keyway at the ends of these two panels. Figure 41 shows one of the spalls. Fortunately, these shallow spalls were mostly removed by the diamond-grinding process.

Figure 41. Photo. Minor joint spall that occurred during panel installation.

Post-Tensioning

Transverse Duct Alignment—To align the precast panels with the centerline of the road and with the bridge abutment, adjacent sections of precast panels were offset, resulting in slight misalignment of the transverse post-tensioning ducts, as shown in figure 42. While the amount of misalignment did not cause any problems with the transverse post-tensioning system, the use of flat, multistrand ducts should be considered for future projects, since these ducts would permit up to 50 mm (2 in.) of misalignment if needed. Flat ducts will require special adapters, however, to transition the flat multistrand duct to a monostrand anchor.

Grouting

Grout Leakage—As discussed above, significant grout leakage from the longitudinal post-tensioning ducts was observed during grouting of the tendons of the south approach slab. This indicates that an adequate seal was not provided at some of the transverse joints, despite the use of both foam gaskets and epoxy around the ducts. While grout leakage was substantially reduced after underslab grouting had been completed, efforts should be made to reduce grout leakage for future projects. Wider and thicker gaskets will likely help reduce leakage, as would positive duct connections.

Post-Tensioning Anchor Recess—A conical shaped recess is normally formed behind post-tensioning anchors and subsequently patched with a dry-pack concrete mortar after stressing to protect the anchor and seal it from grout leakage. This recess was not provided behind anchors for the Highway 60 approach slab panels, and consequently grout leaked from the anchors during tendon grouting. Because a bonded post-tensioning system was used, corrosion protection for the anchors is not so critical, but providing these recesses would have prevented grout leakage.

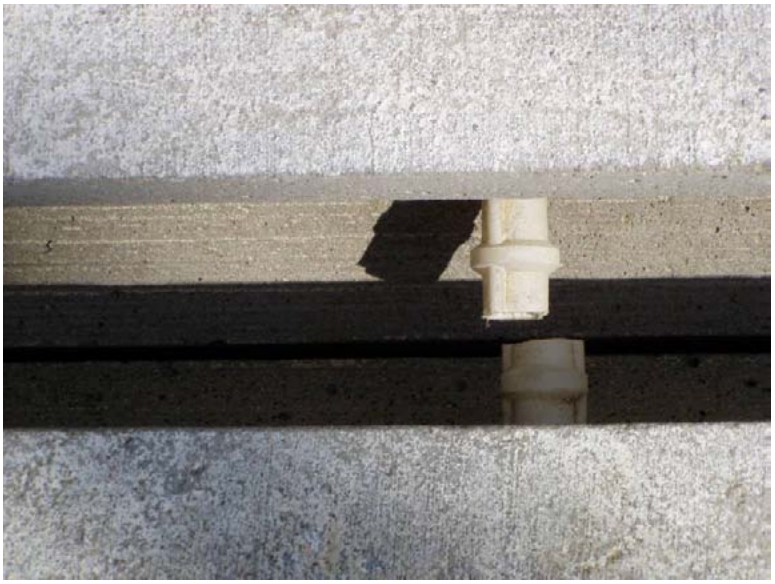


Figure 42. Photo. Slight misalignment of transverse post-tensioning ducts at the longitudinal joint.

INSTRUMENTATION AND MONITORING

To monitor the behavior of the PPCP approach slabs and the potential effects they have on the behavior of the bridge, both the bridge and south approach slab were instrumented by Iowa State University through a separate effort sponsored by the Iowa Highway Research Board. To compare the behavior of the PPCP approach slab with that of a typical cast-in-place approach slab, the south approach slab on the southbound Highway 60 bridge was also instrumented. While the details of the instrumentation and monitoring can be found elsewhere,(8) the following is a brief summary of the instrumentation.

Bridge Instrumentation

The behavior of the northbound bridge was monitored through a series of strain gages and displacement transducers. Strain gages were mounted at the ends and midpoints of the bottom flange of three of the bridge girders of the south end span, as well as to three of the H-piles beneath the south abutment. Tilt meters were mounted at either end of the south abutment to monitor abutment rotation, and displacement transducers were attached to the either end of the south abutment to monitor longitudinal and transverse abutment movement. A total of 35 sensors were mounted to the northbound bridge.

Approach Slab Instrumentation

Behavior of the PPCP approach slab was monitored through crack meters mounted to the precast panels to measure joint movement between panels and between the abutment and the approach slab. Concrete strain was monitored using vibrating wire strain gages embedded in each of the precast panels of the south abutment (figure 43). Additionally, strains in the post-tensioning strands were monitored using strand meters mounted to selected longitudinal and transverse tendons after grouting had been completed. A total of 33 sensors were used to monitor the behavior of the PPCP approach slab.

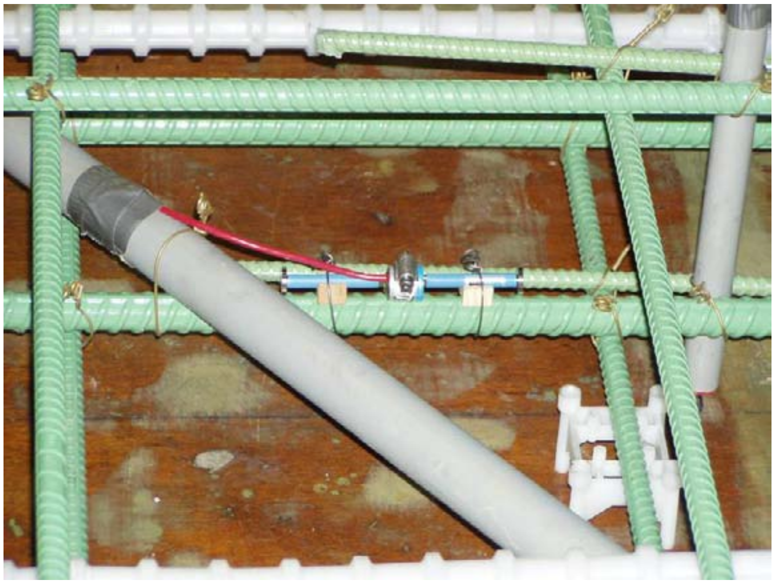


Figure 43. Photo. Vibrating wire strain gage mounted in the precast panel during fabrication.

SHOWCASING WORKSHOP

To provide IADOT and other State highway agencies, contractors, and industry representatives with a better idea of the PPCP bridge approach slab application, IADOT and FHWA sponsored a showcasing workshop that was held during construction of the Highway 60 approach slabs. The workshop was held on August 31, 2006, and featured presentations by those involved with each aspect of the project and a visit to the jobsite during installation of the panels for the south approach slab. Just over 40 attendees were present at the workshop from IADOT, industry, and other transportation agencies. Figures 44 and 45 show the presentation and site visit portions of the workshop (the agenda appears in appendix B).

Figure 44. Photo. Presentations were provided by those involved in the Highway 60 project.

Figure 45. Photo. Site visit during installation of the precast approach slab.

CHAPTER 7. PROJECT EVALUATION AND RECOMMENDATIONS FOR FUTURE PROJECTS

The Highway 60 approach slab demonstration project provided many unique challenges for the design and construction of PPCP. Many new ideas were developed and many lessons were learned throughout the course of the project. Some of the more salient issues related to the overall project layout, design, fabrication, and construction are presented below with recommendations for future projects.

PROJECT LAYOUT

The precast panel layout for the Highway 60 project worked very well. Using the first two panels at the abutment to "remove" the skew from the approach slab minimized the number of specialty panels that had to be fabricated. Using rectangular panels of the same size for the majority of the approach slab greatly simplified panel fabrication and installation. Two-way post-tensioning also simplified fabrication by eliminating pretensioning.

The cast-in-place keyed longitudinal joint accommodated the crowned pavement section and simplified fabrication of the mating panel edges. Transverse post-tensioning will keep the longitudinal joint in compression and help ensure that it remains closed over time. Dowel sleeves cast into the ends of the precast panels facilitated construction of the expansion joint at the end of the approach slab and eliminated the need for any connection to tie or anchor the approach slab to the adjoining pavement. Future projects, which may not have a leave-out for cast-in-place pavement at the end of the approach slab, will require some technique for dowelling the approach slab to existing pavement.

A similar panel layout should be considered for future projects. This layout provides flexibility with varying skew angles, pavement cross sections (crowned or uniform cross slope), and approach slab length and width. Also, by using partial-width panels, lane-by-lane construction can be utilized when full closure of the approach slab is not possible during reconstruction. Two-way post-tensioning should also be considered for future projects, but larger panel sizes may necessitate pretensioning to compensate for lifting and handling stresses.

An alternative panel layout proposed by IADOT would use only a single panel on either side of the longitudinal joint. These panels would likely be pretensioned in the longitudinal direction for handling purposes and post-tensioned together across the longitudinal joint after installation. The ends of the precast panels would be skewed to match the bridge abutment skew. This panel layout would limit the length of the approach slab (and the distance the expansion joint is from the abutment) to the maximum length of precast panel that could be safely fabricated, handled, and shipped. This layout option will likely be considered for future approach slab reconstruction projects.

DESIGN

Design Procedures

As discussed in chapter 4, no design procedures for precast prestressed bridge approach slabs have been established. The methodology employed for the Highway 60 approach slabs was a design for flexure, treating the approach slab as a simple span “slab bridge.” While this provided a sound procedure for approach slab design, it resulted in very high prestress requirements for the Highway 60 approach slabs, particularly if the contribution of the mild steel reinforcement to flexural strength is ignored. For future projects, other design procedures may be examined or standardized prestress requirements could be adopted based on the Highway 60 project.

Design Details

While many of the basic design details stemmed from previous PPCP demonstration projects, most had to be modified for this project, and other unique details had to be developed.

Keyways—The keyway dimensions for the Highway 60 precast panels were based on dimensions used successfully for previous demonstration projects in Texas, California, and Missouri. Because of the increased panel thickness, however, the depth of the interior vertical face was increased to provide more surface area around the post-tensioning ducts to seal the duct openings better. The keyways helped align the panels vertically and resulted in a satisfactory finished surface with essentially no “faults” or lips at the joints between panels. Similar keyway dimensions should be considered for future projects.

Longitudinal Joint—The primary benefit of the cast-in-place keyed longitudinal joint was accommodation of the crowned pavement cross section, permitting the panels on either side of the joint to be set at opposing cross slopes. While a cast-in-place joint does add an additional step to the construction process, the amount of fill material needed was minimal, and if necessary, the joint could have been temporarily filled or covered and opened to traffic prior to filling. A similar longitudinal joint detail should be considered for future projects with crowned cross sections. For a uniform cross slope, a butt joint could potentially be used at the longitudinal joint.

Post-tensioning Anchor Pockets—In detailing the post-tensioning anchor pockets, the goal was to keep them as small as possible while making them large enough to permit the post-tensioning anchor wedges to be manually inserted in the anchors. While the contractor would have preferred larger pockets, the size was adequate for inserting the anchor wedges by hand, and it also minimized the amount of fill required. Similar pocket dimensions should be considered for future projects. It is important to note, however, that these smaller pockets can only be used for dead-end post-tensioning anchors and not for feeding the strands into the ducts.

In some situations it may be necessary to feed the post-tensioning strands from the bridge end of the approach slab rather than at the pavement end. In this situation, it may be possible to cast narrow slots into the surface of the panels, behind the anchor pockets, that are wide enough to receive the post-tensioning strands as they are fed into the anchors. This would allow the strands to be laid out on the bridge deck prior to feeding them through the panels.

Abutment Anchor—The pins drilled and grouted into the paving notch provided a simple solution for anchoring the approach slab to the abutment. Instrumentation on the south approach slab will provide an indication of how well the pinned connections perform. Future projects should consider a similar detail, but may also consider an option for post-tensioning the approach slab to the abutment. While post-tensioning to the abutment would add complexity to the construction process and would require very careful attention in matching the skew angle of the approach slab to the abutment, a post-tensioned connection may provide a tighter and more durable joint, reducing the probability of water infiltration at the joint.

Underslab Grouting—The ports cast into the precast panels for underslab grouting appeared to be adequate for ensuring that voids beneath the precast panels were filled. In most instances, grout pumped into one port could be seen flowing from an adjacent port, indicating full grouting beneath the slab. Similar grout port details should be provided for future projects.

PANEL FABRICATION

Below are some of the key aspects of the panel fabrication process for the Highway 60 project and recommendations for future projects.

Tolerances—Other than problems with out-of-tolerance keyways, discussed in chapter 5, no problems were reported in achieving the specified tolerances. These tolerances should be used as a baseline for future projects.

Formwork—As discussed in chapter 5, with a very limited number of panels to fabricate, the precast producer opted to use wood formwork for the panels, and no problems were reported in achieving the tolerances specified in the contract documents. There were, however, problems with the keyway sideforms that occurred over the course of the fabrication process, as discussed in chapter 5. These problems could be mitigated on future projects with closer inspection of the sideforms on a daily basis. Alternatively, steel sideforms, which are produced to very precise tolerances and are less susceptible to problems that occur with continual reuse, may be used. Steel forms may not be cost effective for smaller projects with a very limited number of panels, however.

Reinforcement—No problems were reported with the reinforcement layout other than around the post-tensioning anchor access pockets where reinforcement was somewhat congested and difficult to install properly. For future projects, the reinforcement layout in the anchor region should be re-evaluated to ensure that there will not be any problems with placing the reinforcement and placing the concrete around the reinforcement.

Finishing—Neither the precast producer nor the IADOT inspectors reported any problems with the finishing operation. A uniform panel thickness kept the finishing process simple, with a vibratory screed used to level the top surface of the precast panels. A light broom texture was applied to the surface to provide “temporary” texture until diamond grinding was completed. Minimizing the number of protrusions from the panel surface also benefited the finishing operation. Only the tubes used to form the underslab grout ports and the post-tensioning anchor/instrumentation pockets were protruding from the surface.

For future projects, uniform thickness panels should be specified whenever possible, although previous demonstration projects have successfully used variable thickness panels. The precast producer should also try to minimize protrusions from the panel surface. When diamond grinding is anticipated, a light broom texture should provide adequate surface texture until diamond grinding is complete.

Curing—No problems were reported with the panel curing operation. A heavy coat of curing compound was applied to the panel surface after texturing, and the panels were then heat-cured overnight. Curing compound was applied to the edges of the panels after they were removed from the forms and later sandblasted from the keyway prior to shipment of the panels. This curing process produced the concrete strength required by the precaster and did not result in any noticeable shrinkage cracking in the panels. A similar process should be utilized on future projects, although other alternative curing processes such as steam curing and wet-mat curing have been successfully used elsewhere.

Handling and Storage—Although some minor damage was sustained during handling of the precast panels at the fabrication plant, no major problems with handling and storage were encountered. The threaded-insert lifting anchors were adequate for the project and left only a small hole in the panel surface to be filled.

CONSTRUCTION

Panel installation was a successful process, as discussed in chapter 6. There were, however, some issues that could be improved for future projects.

Base Preparation

Materials—While the crushed limestone aggregate worked adequately for the base beneath the Highway 60 approach slabs, the coarse nature of the material made it difficult to grade precisely, leaving voids beneath the approach slabs. While underslab grouting filled these voids, ideally they should be minimized during grading of the base. The use of a finer material that can be graded more easily at the surface should be considered for future projects. Any finer material that is used, however, should be checked to see that it has the necessary drainage characteristics and that it does not have an excessive percentage of very fine (passing No. 200 sieve) particles.

Leveling Technique—The crushed limestone base was graded by hand and compacted with a portable plate vibrator. A rotating laser mounted on a tripod, which is commonly used for site grading, established the grade line and 2 percent cross slope for the surface of the aggregate base. This technique provides a very precise grade line and should be utilized for future projects whenever possible.

Alternative Techniques—An alternative technique proposed by the contractor for quickly establishing the proper elevation would be to set steel plates on the base at the proper elevation at the location of the corners of the precast panels. Setting the precast panels on these steel plates would ensure that the surface of the pavement was at the proper elevation and cross slope. The void beneath the pavement would then be filled with grout or flowable fill through underslab grout ports in the panel. While this technique would likely require a significant amount of grout/flowable fill beneath the approach slab, it would minimize time-consuming precision grading of the base. If this technique is utilized on future projects, however, it is essential that the grouting operation be completed before opening the pavement to traffic because the panels would only be supported at the corners prior to grouting.

Panel Installation

Joint Treatment/Epoxy—High-viscosity, gel-paste epoxy was applied to the panel keyways as they were installed. This epoxy helped lubricate the keyways for installation and sealed the joints to prevent water intrusion. The epoxy also helped to compensate for slight unevenness and irregularities in the mating surfaces of the panels. The epoxy filled in any “low” areas of the keyway such that the panels were in complete contact across the joint. This type of epoxy material and assembly technique should be utilized for future projects, particularly if unevenness is observed in the keyways. If unevenness is observed, it is important that only partial post-tensioning force be applied to the joint until the epoxy has set, as stress concentrations from nonuniform contact could result in spalling of the keyway if the full post-tensioning force were applied. When using this two-stage post-tensioning process under strict time constraints (e.g., overnight construction), an epoxy with an appropriate set time should be used.

Temporary Post-Tensioning—The purpose of temporary post-tensioning is to close the joints between panels as much as possible prior to final post-tensioning. It has been used successfully on all previous demonstration projects, and was beneficial for the Highway 60 project as well. Depending on the size of the precast panels, no more than two panels should be installed between temporary stressing operations. If an epoxy with a short pot life is used, temporary post-tensioning should be applied after each panel is installed to ensure that the panels are fully bedded in the epoxy before it sets.

Panel/Duct Alignment—No problems were experienced with longitudinal post-tensioning duct alignment. A mark on the top surface of the precast panels at mating joints above a given post-tensioning duct should always be used for alignment, rather than aligning the ends of the panels. This will help to ensure alignment of the post-tensioning ducts even if the edges of the panels do not line up.

As discussed in chapter 7, there was slight misalignment of the transverse post-tensioning ducts across the longitudinal joint. While this minor misalignment did not cause any problems, provision should be made to allow for slight misalignment. For future projects with a longitudinal joint, flat post-tensioning ducts (25 mm [1 in.] by 76 mm [3 in.]) should be considered for the transverse tendons. These will permit as much as 50 mm (2 in.) of misalignment across the longitudinal joint.

Post-Tensioning

Ducts—The post-tensioning ducts used for the Highway 60 project are ideally suited for bonded monostrand post-tensioning tendons. The polyethylene duct material is corrosion resistant, and the channels running along the length of the duct facilitate the flow of grout even if a strand is pressing against the duct. Although the precast producer reported some challenges with installing the ducts in the forms, this material is recommended for future projects. A larger diameter duct or flat duct of the same material will permit some misalignment of the panels.

Post-Tensioning Tendons—No problems were reported with the strand used for the post-tensioning tendons. Grade 270, 15 mm (0.6 in.) diameter, strand is commonly used in the post-tensioning industry and maximizes the prestress provided by each tendon, permitting almost 42 percent more prestressing force (when tensioned to 75 percent of ultimate strength) than comparable 13-mm (1/2 in.) diameter strand. If corrosion of the post-tensioning tendons (particularly at the joints between panels) is a concern, epoxy-coated strand and grit-impregnated epoxy-coated strand are available.

An alternative to post-tensioning strand would be high-strength post-tensioning bars. One advantage of bars is a significant reduction in anchor seating loss during stressing of the tendon. Bars would also permit the panels to be incrementally stressed together as they are installed. Sections of bar the length of each panel could be pre-installed in the ducts of the panel and coupled together with the bars from the adjoining panel as the panel is installed. This would require special attention to detailing of the ducts and anchors, but may provide a more efficient solution in certain cases.

Post-tensioning Anchors—Post-tensioning was completed from the live-end anchors at the edges and ends of the approach slabs. Dead-end anchors were located at either the anchor access pockets (longitudinal tendons) or at the edges of the approach slabs (transverse tendons). For future reconstruction projects, there may not be access to the edges and ends of the approach slab. This situation may require additional stressing pockets for the live-end anchors within the precast panels for the longitudinal and transverse tendons. Fortunately, this has been accomplished successfully with previous demonstration projects.(6,7)

Grouting

Grouting Sequence—Based on the grouting operations for the Highway 60 project, it is recommended that underslab grouting be completed prior to tendon grouting. Underslab grouting will fill voids beneath the approach slab so that tendon grout cannot flow beneath the slab. This will help minimize loss of tendon grout, which is a more expensive material specially formulated for tendon grouting.

Joint Seal/Gasket—Significant leakage of grout during grouting of the longitudinal post-tensioning tendons indicated that a proper seal was not provided across all of the panel joints. The gaskets were carefully installed in recesses around the post-tensioning ducts as each panel was installed, so it is unlikely that the gaskets fell off or shifted. The gaskets likely leaked due to the pressure from the grouting operation. For future projects, the combination of gaskets and gel paste epoxy are still recommended. However, wider gaskets which provide greater bearing area (minimum of 25 mm [1 in.] wide) should be used, and a stiffer foam or neoprene material should also be considered.

Grout Vents—Tendon grout vents were "daylighted" at the edges of the panels and inside the anchor access pockets to minimize protrusions from the surface of the precast panels. For future projects, where access to the edges of the panels may not be possible, it may be necessary to daylight the vents at the surface of the pavement or within the stressing pockets only.

Smooth plastic tubes were used to form the underslab grout vents in the panels. This made the connection between the grouting hose and vent difficult even with the low grouting pressures that were used. For future projects, traditional ribbed or threaded grout vent tubing should be considered so that couplers can be screwed into the vents for attaching the grout hose.

POST-CONSTRUCTION EVALUATION

Following installation and diamond grinding of the Highway 60 approach slabs, a visual condition survey was conducted to look for distresses that may have occurred during construction. The only visual distress observed was a hairline crack extending across Panel 2A of the south approach slab. The crack began at the edge of the approach slab and extended diagonally to the centerline joint, but did not cross the joint. This crack will be monitored over time to determine if it is indicative of a structural problem with the approach slab.

The instrumentation installed in the south approach slab and northbound bridge will be monitored for a minimum of 12 months after construction by Iowa State University. In addition to data collected from the instrumentation, regular visual surveys will be conducted to identify any distresses in the approach slabs over time.

PROJECT COST

The final unit cost for the Highway 60 PPCP approach slab demonstration project was approximately \$890/m^2 (\$739/yd^2). This cost includes all fabrication and installation costs, including grading of the base and anchoring the slab to the abutment. While this unit cost is significantly higher than that of conventional concrete pavement, the higher cost was not unexpected for several reasons. First, the project was experimental in nature, and neither the precast producer nor the installation contractor had any prior experience with this construction technique. As precast producers and contractors become more familiar with the construction technique, costs will likely decrease substantially. Second, the Highway 60 project was relatively small in size. As with any project, there are economies of scale, and the larger a project is, the lower the unit cost will likely be. Finally, this project was included as a field change order for a much larger project to realign Highway 60. Whenever unexpected items are added to an existing project, particularly when the change order involves something vastly different from the rest of the project, higher costs can be expected. Future projects, which will be competitively bid and will have improved design and construction details, will likely be substantially lower in cost.

CHAPTER 8. SUMMARY AND RECOMMENDATIONS

SUMMARY

The bridge approach slab project on Highway 60 near Sheldon, Iowa, shown in figure 46, demonstrated one more application for PPCP. The primary objective of this demonstration project was to evaluate the viability of PPCP for bridge approach slab construction. Although this project was constructed on a new bridge, the design and construction details that were developed through this project lend themselves for approach slab reconstruction as well. The project helped to familiarize IADOT as well as local contractors and precast producers with this innovative construction technique. It also allowed IADOT to develop design details and construction procedures for precast approach slabs that may eventually be adopted as standards.

This project demonstrated some important features of PPCP:

- Use of full-depth precast panels for bridge approach slabs.
- Use of bi-directional post-tensioning in lieu of pretensioning.
- Use of partial-width precast panels on a crowned pavement cross section.
- Construction over a crushed stone aggregate base.

The project demonstrated the adaptability of the PPCP concept to a unique application. The design details and precast panel layout used for this project are adaptable to various approach slab lengths, widths, thicknesses, and skew angles. The concept can be used for full-width approach slab construction or partial-width (lane-by-lane) construction.

RECOMMENDATIONS FOR FUTURE IMPLEMENTATION

The next step in bringing this construction technique into standard practice will be to use PPCP for reconstruction of an existing approach slab under traffic. This will bring additional considerations into play, such as staging construction and panel installation. Different precast panel configurations, as discussed in the previous chapter, may also be considered based on site constraints.

Reconstruction of existing approach slabs also requires consideration of the condition of the paving notch. A failed or poorly constructed paving notch will likely need to be replaced. IADOT is already addressing this need by developing details for a precast concrete paving notch that can be quickly bolted to the bridge abutment to replace the existing paving notch. This paving notch, used in conjunction with precast pavement panels, will provide IADOT with a long-term solution for rapid reconstruction of bridge approach slabs.

Figure 46. Photo. Finished north approach slab prior to opening to traffic.

REFERENCES

1. Merritt, David K., B. Frank McCullough, Ned H. Burns, and Anton K. Schindler. *The Feasibility of Using Precast Concrete Panels to Expedite Highway Pavement Construction.* Research Report No. 1517-1. Center for Transportation Research, University of Texas at Austin. February 2000.
2. Merritt, David K., B. F. McCullough, and Ned H. Burns. *Construction and Preliminary Monitoring of the Georgetown, Texas Precast Prestressed Concrete Pavement.* Research Report 5-1517-01-1. Center for Transportation Research, University of Texas at Austin. December 2002.
3. Merritt, David K., B. F. McCullough, and Ned H. Burns. "Design-Construction of a Precast, Prestressed Concrete Pavement for Interstate 10, El Monte, California." *PCI Journal,* vol. 50, no. 2. Precast/Prestressed Concrete Institute, Chicago, IL. March/April 2005.
4. Merritt, David K., Kirsten Stahl, Samuel S. Tyson, and B. F. McCullough. "Expedited Construction Using Precast Prestressed Concrete Pavement in California," *Proceedings, 8th International Conference on Concrete Pavements.* Colorado Springs, CO, August 2005. pp. 808–823.
5. Gopalaratnam, Vellore S., Brent Davis, Cody Dailey, and John Donahue. "Precast Prestressed Panels for Rapid Full-Depth Pavement Repairs." *Structures Congress 2006: Structural Engineering and Public Safety,* Proceedings of the 2006 Structures Congress, May 18–21, 2006, St. Louis, MO. Structural Engineering Institute, American Society of Civil Engineers, Reston, VA. May 2006.
6. Dailey, Cody L. *Instrumentation and Early Performance of an Innovative Prestressed Precast Pavement System*. Master's Thesis. University of Missouri–Columbia. December 2006.
7. Davis, Brent M. *Evaluation of Prestress Losses in an Innovative Prestressed Precast Pavement System*. Master's Thesis. University of Missouri–Columbia. December 2006.
8. McDonald, Norman, Dean Bierwagen, Michael D. LaViolette, and Brent Phares. "Precast, Post-Tensioned Bridge Repair Solutions." *Proceedings, 2006 PCI National Bridge Conference,* October 23–25, 2006, Grapevine, TX. Precast/Prestressed Concrete Institute, Chicago, IL. 2006.
9. Merritt, David K., and Samuel S. Tyson. "Precast Prestressed Concrete Pavement—A Long-life Approach for Rapid Repair and Rehabilitation." *Proceedings, International Conference on Long-Life Concrete Pavements,* October 25–27, 2006, Rosemont, IL. Federal Highway Administration, Washington, DC. pp. 497–512.
10. Cable, Neil D., B. F. McCullough, and N. H. Burns. *New Concepts in Prestressed Concrete Pavement*. Research Report 401-2. Center for Transportation Research, University of Texas at Austin. December 1985.
11. Mendoza Diaz, Alberto, B. Frank McCullough, and Ned H. Burns. *Design of the Texas Prestressed Concrete Pavement Overlays in Cooke and McLennan Counties and Construction of the McLennan County Project*. Research Report No. 555/556-1. Center for Transportation Research, University of Texas at Austin. February 1986.

12. Poston, R. W., and J. P. Wouters. *Durability of Precast Segmental Bridges*. NCHRP Web Document 15 (Project 20-7/Task 92). National Cooperative Highway Research Program, Transportation Research Board, Washington, DC. June 1998.
13. White, David, Sri Sritharan, Muhannad Suleiman, Mohamed Mekkawy, and Sudhar Chetlur. *Identification of the Best Practices for Design, Construction, and Repair of Bridge Approaches*. Research Report No. 02-118. Center for Transportation Research and Education, Iowa State University. December 2004.
14. *Standard Road Plans*. Iowa Department of Transportation, Ames. April 2005.
15. *AASHTO Guide for Design of Pavement Structures.* American Association of State Highway and Transportation Officials, Washington, DC. 1993.
16. *Standard Specifications for Highway Bridges, 17th Edition.* American Association of State Highway and Transportation Officials, Washington, DC. 2002.
17. Mendoza Diaz, Alberto, Ned H. Burns, and B. Frank McCullough. *Behavior of Long Prestressed Pavement Slabs and Design Methodology*. Research Report No. 401-3. Center for Transportation Research, University of Texas at Austin. September 1986.
18. *Standard Specifications*. Iowa Department of Transportation, Ames. October 2005.

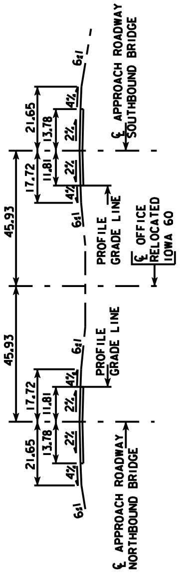
ACKNOWLEDGMENTS

The researchers would like to acknowledge the Federal Highway Administration and Iowa Highway Research Board for sponsoring this project. The authors would also like to acknowledge all of the individuals involved in making this a successful project from the Office of Bridges and Structures, Research and Technology Bureau, District 1 and District 3 Offices, FHWA Office of Pavement Technology, FHWA Iowa Division Office, and Bridge Engineering Center at Iowa State University.

APPENDIX A

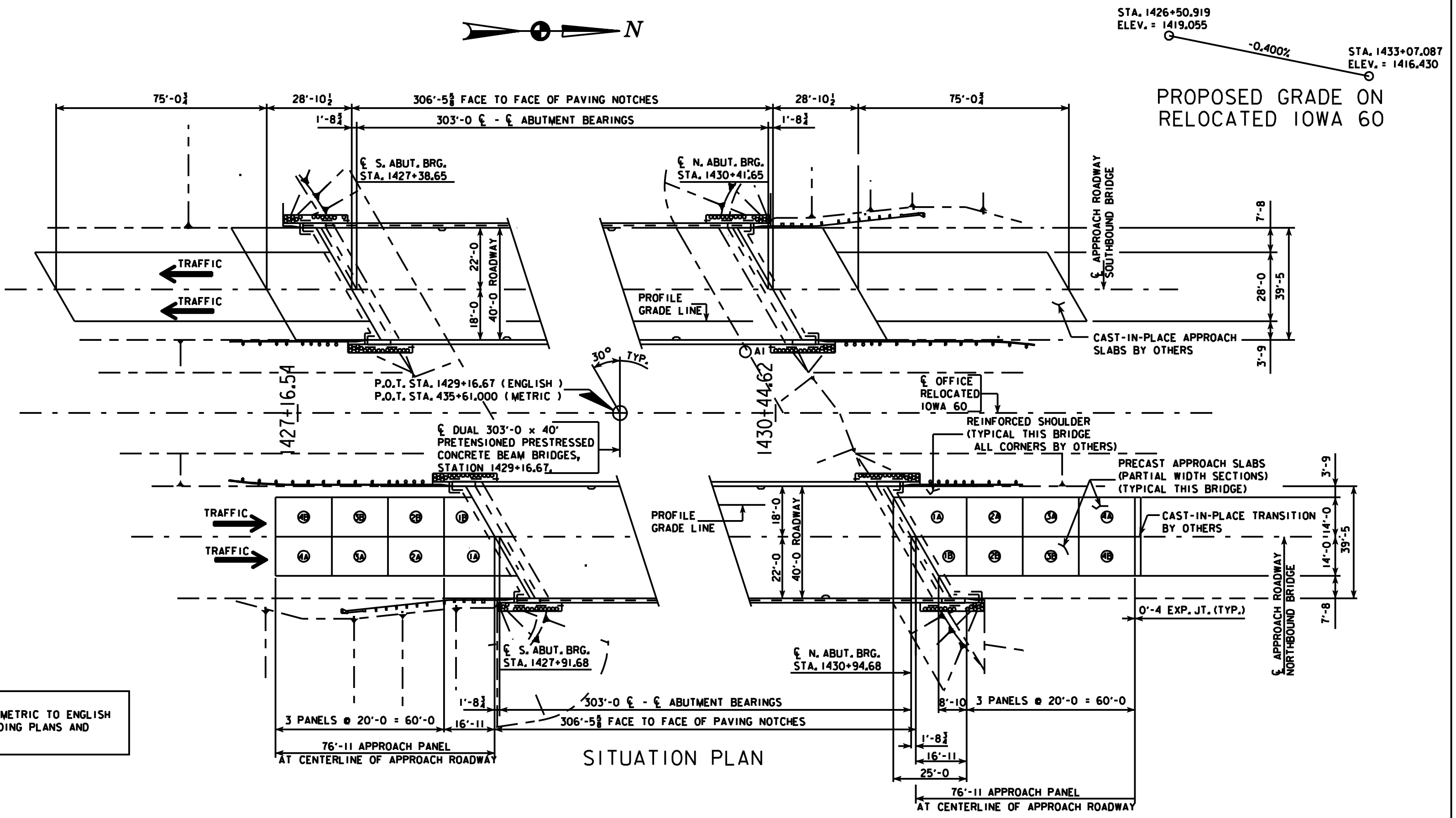
Project Plans From the Iowa Department of Transportation

BENCH MARK : NO. 615 ; WEST SIDE OF NEST AVE., 0.5 MILES NORTH OF 300th STREET, R.R. SPIKE IN POWER POLE, ELEV. = 1424.557.



TYPICAL APPROACH SECTION

NOTE :
THIS BRIDGE HAS BEEN CONVERTED FROM METRIC TO ENGLISH FOR DESIGN AND CONSTRUCTION. THE GRADING PLANS AND SURVEY HAVE REMAINED IN METRIC.



PROPOSED GRADE ON RELOCATED IOWA 60

SITUATION PLAN

LOCATION :
RELOCATED IOWA 60
OVER FLOYD RIVER
SECTION 16
T-97 N R-42 W
FLOYD TWP.
O'BRIEN COUNTY

FHWA NO. 608885 (SB)
608890 (NB)

NOTE :
ALL DIMENSIONS IN FEET UNLESS OTHERWISE NOTED OR SHOWN.
ALL STATIONS AND ELEVATIONS ARE IN FEET.
THIS PLAN NOT TO SCALE.

NOTE :
THIS PLAN NOT
TO SCALE

DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
SITUATION PLAN
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 1 OF 20 FILE NO. ______ DESIGN NO. ______

DESIGN TEAM | O'BRIEN COUNTY | PROJECT NUMBER | SHEET NUMBER

GENERAL NOTES.

THIS PROVISION SHALL COVER THE FABRICATION, INSTALLATION, POST-TENSIONING, AND GROUTING OF PRECAST PRESTRESSED CONCRETE PANELS FOR A BRIDGE APPROACH SLAB. THE TERM "SLAB" SHALL REFER TO A POST-TENSIONED SECTION OF PRECAST PANELS BETWEEN THE BRIDGE ABUTMENT AND THE EXPANSION JOINT.

MATERIALS: MATERIALS SHALL CONFORM TO THE REQUIREMENTS OF THE STANDARD SPECIFICATIONS NOTED HEREIN, WITH THE EXCEPTIONS NOTED IN THESE NOTES.

PRECAST PANEL FABRICATION:
TOLERANCES FOR PRECAST PANELS, REGARDLESS OF TYPE SHALL BE AS SHOWN BELOW:
LENGTH (PARALLEL TO LONG AXIS OF PANEL): $\pm\frac{1}{4}$"
WIDTH (NORMAL TO LONG AXIS OF PANEL): $\pm\frac{1}{8}$"
SKEW ANGLE (ENDS OF PANELS RELATIVE TO MATING EDGES)" ±1 DEGREE
NOMINAL THICKNESS: $\pm\frac{1}{8}$"
SQUARENESS (DEVIATION FROM PLANS, MEASUREMENT FROM CORNER TO CORNER ACROSS TOP SURFACE, MEASURED DIAGONALLY): $\pm\frac{1}{8}$"
HORIZONTAL ALIGNMENT (UPON RELEASE OF STRESS)-DEVIATION FROM STRAIGHTNESS OF MATING EDGE OF PANELS: $\pm\frac{1}{8}$"

DEVIATION OF ENDS (HORIZONTAL SKEW): $\pm\frac{1}{8}$"
DEVIATION OF ENDS (VERTICAL BATTER): $\pm\frac{1}{8}$"
KEYWAY DIMENSIONAL TOLERANCE: $\pm\frac{1}{16}$"
POSITION OF STRANDS: $\pm\frac{1}{8}$" VERTICAL (MEASURED FROM BOTTOM OF PANEL); $\pm\frac{1}{4}$" HORIZONTAL

STRAIGHTNESS OF POST-TENSIONING DUCTS: $\pm\frac{1}{4}$" VERTICAL (MEASURED FROM BOTTOM OF PANEL); $\pm\frac{1}{4}$" HORIZONTAL
VERTICAL DOWEL ALIGNMENT (PARALLEL TO BOTTOM OF PANEL): $\pm\frac{1}{8}$" (MEASURED FROM BOTTOM OF PANEL)

DOWEL LOCATION (DEVIATION FROM PLANS): $\pm\frac{1}{4}$" VERTICAL (MEASURED FROM BOTTOM OF PANEL); $\pm\frac{1}{4}$" HORIZONTAL
DOWEL EMBEDMENT (IN EITHER SIDE OF EXPANSION JOINT): ± 1"
POSITION OF LIFTING ANCHORS: ± 2"
POSITION OF NON-PRESTRESSED REINFORCEMENT: $\pm\frac{1}{4}$"
STRAIGHTNESS OF EXPANSION JOINTS: $\pm\frac{1}{8}$"
INITIAL WIDTH OF EXPANSION JOINTS: $\pm\frac{1}{8}$"
DIMENSIONS OF BLOCKOUTS/POCKETS: $\pm\frac{1}{8}$"
LOCATION OF ABUTMENT ANCHOR SLEEVES: $\pm\frac{1}{8}$"

CONCRETE MIX: THE CONCRETE MIX USED WILL BE REQUIRED TO REACH A COMPRESSIVE STRENGTH OF 5,000 PSI AT 28 DAYS AS PER ARTICLE 2407.03 OF THE STANDARD SPECIFICATIONS. THE COARSE AGGREGATE USED WILL HAVE A MINIMUM OF CLASS 3 DURABILITY, AS PER ARTICLE 4115.04 OF THE STANDARD SPECIFICATIONS. THE MIX WILL BE WORKABLE ENOUGH TO ACHIEVE THE REQUIRED SURFACE FINISH AS DESCRIBED BELOW. THE CONTRACTING AUTHORITY MUST APPROVE THE COARSE AGGREGATE TO BE USED BY THE PRECAST FABRICATOR PRIOR TO FABRICATION TO ENSURE COMPATIBILITY WITH GRINDING EQUIPMENT.

NON-PRESTRESSED REINFORCEMENT:
ALL NON-PRESTRESSED REINFORCEMENT, INCLUDING TIE BARS, SHALL BE GRADE 60 EPOXY-COATED REINFORCEMENT, CONFORMING TO THE REQUIREMENTS OF ARTICLE 4151.03 OF THE STANDARD SPECIFICATIONS. PRECASTING: PRECASTING MATERIALS AND PROCEDURES SHALL CONFORM TO SECTION 2407 OF THE STANDARD SPECIFICATIONS.

POST-TENSIONING MATERIALS: POST-TENSIONING DUCTS SHALL BE RIGID GALVANIZED CORRUGATED METAL OR RIGID CORRUGATED POLYPROPYLENE. THE DUCTS SHALL HAVE AN INSIDE DIAMETER A MINIMUM OF $\frac{3}{8}$ INCH LARGER THAN THE NOMINAL DIAMETER OF THE POST-TENSIONING STRAND.

GROUT PORTS SHALL BE LOCATED IN THE PANELS AS SHOWN ON THE PLANS. THE GROUT PORTS SHALL HAVE A MINIMUM $\frac{1}{2}$ INCH INSIDE DIAMETER AND SHALL BE COMPATIBLE WITH THE POST-TENSIONING DUCTS, PROVIDING A WATER-TIGHT SEAL BETWEEN THE DUCT AND PORT. GROUT PORTS SHALL NOT PROTRUDE FROM THE FINISHED SURFACE OF THE PANELS.

LIFTING ANCHORS: LIFTING ANCHORS SHALL BE APPROVED BY THE ENGINEER PRIOR TO USE. LIFTING ANCHORS SHALL BE LOCATED AS SHOWN IN THE PLANS. THE TOP OF THE LIFTING ANCHORS SHALL BE RECESSED $\frac{1}{2}$ INCH MINIMUM FROM THE SURFACE OF THE PANEL.

DOWELS FOR THE EXPANSION JOINTS SHALL BE GRADE 60 EPOXY-COATED DOWELS CONFORMING TO THE REQUIREMENTS OF ARTICLE 4151.02. THE ENTIRE LENGTH OF THE DOWEL SHALL BE COATED WITH GRAPHITE GREASE OR OTHER APPROVED BOND BREAKER. DOWELS SHALL REMAIN PARALLEL TO THE BOTTOM SURFACE OF THE PANEL

UNLESS OTHERWISE
SHOWN ON THE PLANS, THE MINIMUM LENGTH OF DOWEL EMBEDMENT ON EITHER SIDE OF THE EXPANSION JOINT SHALL BE ONE-HALF THE LENGTH OF THE DOWEL MINUS THE SPECIFIED INITIAL WIDTH OF THE EXPANSION JOINT.

DOWEL EXPANSION CAPS SPECIFIED IN THE PLANS SHALL BE APPROVED BY THE ENGINEER PRIOR TO USE.

FINISHING AND TEXTURING: UNLESS OTHERWISE DIRECTED BY THE ENGINEER, THE TOP SURFACE OF THE PANELS (DRIVING SURFACE) SHALL RECEIVE A ARTIFICIAL TURF OR CARPET DRAG TEXTURE CONFORMING TO THE REQUIREMENTS OF SECTION 2301.16 OF THE STANDARD SPECIFICATIONS. THE TEXTURE SHALL BE APPLIED IN A TIMELY MANNER AFTER FINAL SCREEDING SUCH THAT THE DESIRED TEXTURE DEPTH IN ACHIEVED WITHOUT DISTURBING THE UNDERLYING CONCRETE OR TURNING OVER AGGREGATE. THE SURFACE TEXTURE MAY BE APPLIED EITHER PARALLEL OR NORMAL TO THE LONG AXIS OF THE PANEL, AT THE DISCRETION OF THE ENGINEER.

PLACEMENT IN FORMS: CONCRETE FORMWORK AND PLACEMENT PROCEDURES SHALL CONFORM TO THE REQUIREMENTS OF SECTION 2407 OF THE STANDARD SPECIFICATIONS. CONCRETE SHALL BE PLACED IN A SINGLE LIFT AND DISTRIBUTED IN SUCH A MANNER THAT EMBEDDED ITEMS SUCH AS REINFORCEMENT, DUCTS, DOWELS, ANCHORS, AND LIFTING DEVICES ARE NOT DISLODGED BY THE CONCRETE MASS. PROPER CONSOLIDATION MUST BE ACHIEVED SUCH THAT HONEYCOMBING OR SEGREGATION OF THE CONCRETE DOES NOT OCCUR AND ALL SPACES AROUND EMBEDDED ITEMS AND AROUND THE PANEL FORMS ARE FILLED.

CURING: CURING OF THE PRECAST PANELS SHALL CONFORM TO THE REQUIREMENTS OF ARTICLE 2407.09 OF THE STANDARD SPECIFICATIONS, WITH THE EXCEPTIONS NOTED BELOW. THE PRECAST FABRICATOR SHALL SUBMIT THE PROPOSED CURING METHODS AND PROCEDURES TO THE ENGINEER FOR APPROVAL PRIOR TO PLACING CONCRETE. CURING SHALL COMMENCE IMMEDIATELY AFTER THE SURFACE FINISHING OPERATION AND AS SOON AS MARRING OF THE CONCRETE WILL NOT OCCUR. LIQUID CURING COMPOUND MAY BE APPLIED IN ACCORDANCE WITH ARTICLE 2301.19 AND SECTION 4105 OF THE STANDARD SPECIFICATIONS TO THE TOP SURFACE OF THE PRECAST PANELS WHILE IN THE FORMS AT THE DISCRETION OF THE ENGINEER. A MINIMUM TWO APPLICATIONS OF THE CURING COMPOUND, APPLIED IMMEDIATELY AFTER SURFACE TEXTURE FINISHING, SHALL BE REQUIRED FOR LIQUID CURING. CURING COMPOUND RESIDUE SHALL BE REMOVED FROM ALL ADJOINING SURFACES PRIOR TO SHIPMENT OF THE PANELS TO THE JOBSITE.

CURING SHALL BE MAINTAINED FOR A MINIMUM OF 72 HOURS FROM THE BEGINNING OF CURING OPERATIONS ON THE SIDES AND TOP SURFACE OF THE PANELS. WHILE IN THE FORMS, THE FORMS WILL BE CONSIDERED TO PROVIDE ADEQUATE CURING FOR THE EDGES (VERTICAL FACES) OF THE PANELS. IF ANY PART OF THE FORM IS REMOVED, THE EXPOSED SURFACE SHALL BE COVERED IN ACCORDANCE WITH ARTICLE 2407.09 OF THE STANDARD SPECIFICATIONS. REMOVAL OF PANELS FROM THE FORMS TO A STORAGE AREA SHALL BE DONE IN SUCH A MANNER THAT CURING IS NOT INTERRUPTED FOR MORE THAN FOUR HOURS FOR ANY MEMBER. AFTER REMOVAL FROM THE FORMS, THE PANELS MAY BE CURED USING WET BURLAP MATS CONFORMING TO SECTION 4104 OF THE STANDARD SPECIFICATIONS UNTIL THE END OF THE 72 HOUR CURING PERIOD.

FORM REMOVAL AND STORAGE: PANELS SHALL BE REMOVED FROM THE FORMS IN SUCH A MANNER THAT NO DAMAGE OCCURS TO THE PANEL. FORM REMOVAL SHALL CONFORM TO THE REQUIREMENTS OF ARTICLE 2407.10 OF THE STANDARD SPECIFICATIONS. ANY MATERIALS FORMING BLOCKOUTS IN THE PANELS SHALL BE REMOVED SUCH THAT DAMAGE DOES NOT OCCUR TO THE PANEL OR THE BLOCKOUT. PANELS SHALL BE STORED IN SUCH A MANNER THAT ADEQUATE SUPPORT IS PROVIDED TO PREVENT CRACKING OR CREEP-INDUCED DEFORMATION (SAGGING). SUPPORTS BENEATH THE PANELS SHALL BE LOCATED AT APPROXIMATELY THE SAME LOCATION AS THE LIFTING ANCHORS. PANELS WITH A UNIFORM THICKNESS MAY BE STACKED NO HIGHER THAN FIVE PANELS PER STACK, WITH ADEQUATE SUPPORT BETWEEN PANELS. PANELS SHALL BE STACKED SUCH THAT INDIVIDUAL PANELS OR STACKS OF PANELS ARE NOT TOUCHING ONE ANOTHER. PANELS STORED FOR LONG PERIODS OF TIME (LONGER THAN ONE MONTH) SHALL BE CHECKED AT LEAST ONCE PER MONTH TO ENSURE CREEP-INDUCED DEFORMATION DOES NOT OCCUR.

UNOBSTRUCTED DUCTS AND CONDUIT: AFTER REMOVAL FROM THE FORMS AND PRIOR TO SHIPMENT, THE PRECAST FABRICATOR SHALL CHECK FOR OBSTRUCTIONS IN ALL POST-TENSIONING DUCTS. THE POST-TENSIONING DUCTS SHALL BE CHECKED BY FEEDING A POST TENSIONING STRAND OF THE SAME SIZE AS THAT SPECIFIED FOR ACTUAL POST-TENSIONING COMPLETELY THROUGH EACH DUCT. IF THE STRAND DOES NOT SLIDE FREELY THROUGH THE DUCT, THE CAUSE OF THE OBSTRUCTION SHALL BE REMEDIED, AT THE EXPENSE OF THE CONTRACTOR, BEFORE THE PANEL IS SHIPPED.

LIFTING AND HANDLING: PANELS SHALL BE HANDLED IN SUCH A MANNER AS NOT TO DAMAGE THE PANEL DURING LIFTING OR MOVING. LIFTING ANCHORS CAST INTO THE PANELS SHALL BE USED FOR LIFTING AND MOVING THE PANELS AT THE FABRICATION PLANT. THE ANGLE BETWEEN THE TOP SURFACE OF THE PANEL AND THE LIFTING LINE SHALL NOT BE LESS THAN SIXTY DEGREES, WHEN MEASURED FROM THE TOP SURFACE OF THE PANEL TO THE LIFTING LINE. DAMAGE CAUSED TO ANY PANEL, SHALL BE REPARIED AT THE EXPENSE OF THE CONTRACTOR TO THE SATISFACTION OF THE ENGINEER.

TRANSPORTATION: PANELS SHALL BE TRANSPORTED IN SUCH A MANNER THAT THE PANEL WILL NOT BE DAMAGED DURING TRANSPORTATION. PANELS SHALL BE PROPERLY SUPPORTED DURING TRANSPORTATION SUCH THAT CRACKING OR DEFORMATION (SAGGING) DOES NOT OCCUR. IF MORE THAN ONE PANEL IS TRANSPORTED PER VEHICLE, PROPER SUPPORT AND SEPARATION MUST BE PROVIDED BETWEEN THE INDIVIDUAL PANELS. PANELS SHALL BE LYING HORIZONTALLY DURING TRANSPORTATION, UNLESS OTHERWISE APPROVED.

REPAIRS: REPAIRS OF DAMAGE CAUSED TO THE PANELS DURING FABRICATION, LIFTING AND HANDLING, OR TRANSPORTATION SHALL BE ADDRESSED ON A CASE-BY-CASE BASIS. DAMAGE WITHIN ACCEPTABLE LIMITS CAUSED TO THE TOP SURFACE (DRIVING SURFACE) OR TO KEYED EDGES OF THE PANELS SHALL BE REPAIRED USING AN APPROVED REPAIR METHOD AT THE FABRICATION PLANT AT THE EXPENSE OF THE CONTRACTOR. REPETITIVE DAMAGE TO PANELS SHALL BE CAUSE FOR STOPPAGE OF FABRICATION OPERATIONS UNTIL THE CAUSE OF THE DAMAGE CAN BE REMEDIED.

DEMONSTRATION OF PANEL FIT: THE PRECAST FABRICATOR SHALL INITIALLY FABRICATE ONE FULL SET OF FOUR PANELS AND ASSEMBLE THESE PANELS AT THE FABRICATION PLANT TO DEMONSTRATE THE FIT OF THE PANELS TO THE SATISFACTION OF THE ENGINEER. THE PANELS SHALL BE ASSEMBLED OVER A LEVEL SURFACE THAT WILL NOT CAUSE DAMAGE TO THE PANELS DURING OR AFTER ASSEMBLY. POSTTENSIONING SHALL NOT BE REQUIRED FOR THIS TRIAL ASSEMBLY, AND EPOXY SHALL NOT BE REQUIRED IN THE JOINTS BETWEEN PANELS. JOINTS BETWEEN PANELS SHOULD NOT BE MORE THAN $\frac{1}{4}$ INCH WIDE WHEN ASSEMBLED. ANY PROBLEMS WITH FITTING THE PANELS CAUSED BY IMPERFECTIONS IN THE PANELS SHALL BE CORRECTED PRIOR TO PROCEEDING WITH PANEL FABRICATION. PANEL FABRICATION MAY COMMENCE FOLLOWING THE TRIAL ASSEMBLY ONLY UPON APPROVAL FROM THE ENGINEER.

INSTRUMENTATION: THE PRECAST FABRICATOR SHALL PERMIT THE INSTALLATION OF INSTRUMENTATION IN THE PANEL FORMS PRIOR TO PLACEMENT OF CONCRETE. A SCHEMATIC LAYOUT AND INSTRUMENTATION PLAN SHALL BE PROVIDED TO THE FABRICATOR AND THE ENGINEER FOR APPROVAL PRIOR TO BEGINNING PANEL FABRICATION. THE PRECAST FABRICATOR SHALL PROVIDE AT LEAST 7 DAYS ADVANCED NOTICE TO THE INSTRUMENTATION INSTALLER BEFORE CASTING THE INSTRUMENTED PANELS. INSTRUMENTATION SHALL INCLUDE, BUT IS NOT LIMITED TO, TEMPERATURE SENSORS, STRAIN GAGES, AND LOAD CELLS. INSTRUMENTATION SHALL NOT COMPROMISE THE INTEGRITY OF THE REINFORCING STEEL, PRESTRESSING SYSTEM, OR THE PRECAST PANEL ITSELF. THE PRECAST FABRICATOR SHALL PROTECT THE INTEGRITY OF THE INSTRUMENTATION, INCLUDING LEAD WIRES AND CONNECTORS AT THE SURFACE AND EDGES OF THE PRECAST PANELS, DURING FABRICATION AND HANDLING OF THE INSTRUMENTED PANELS.

DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS

APPROACH PANEL NOTES
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 2 OF 20 FILE NO. ______ DESIGN NO. ______

DESIGN TEAM
O'BRIEN COUNTY
PROJECT NUMBER
SHEET NUMBER

CONSTRUCTION NOTES:

BASE PREPARATION: THE PRECAST PANELS SHALL BE PLACED OVER A PREPARED SURFACE AS SHOWN IN THE PLANS. THE SURFACE SHALL BE FREE FROM DEBRIS AND OTHER MATERIALS THAT PREVENT THE PANELS FROM FULLY RESTING ON THE BASE.

GRADE CONTROL FOR PLACEMENT: GRADE CONTROL WILL BE ESTABLISHED FOR PLACEMENT OF THE BASE MATERIAL TO ENSURE LONG-WAVELENGTH ROUGHNESS IS NOT BUILT INTO THE BASE. GRADE CONTROL WILL BE ESTABLISHED USING STRINGLINES, LASER GUIDANCE, OR OTHER COMPARABLE METHODS. GRADE CONTROL METHODS MUST BE APPROVED BY THE ENGINEER PRIOR TO BASE PREPARATION.

PANEL INSTALLATION ON SITE:
EQUIPMENT: THE CONTRACTOR SHALL HAVE ALL EQUIPMENT REQUIRED FOR PANEL INSTALLATION, POST-TENSIONING, AND GROUTING ON-SITE PRIOR TO BEGINNING PANEL INSTALLATION. LIFTING AND TRANSPORTING EQUIPMENT SHALL NOT DAMAGE THE PREPARED BASE MATERIAL PRIOR TO OR DURING PANEL INSTALLATION. ANY DAMAGE TO THE PREPARED BASE MATERIAL WILL BE REPAIRED AT THE CONTRACTOR'S EXPENSE TO THE SATISFACTION OF THE ENGINEER.

FRICTION REDUCING MEMBRANE: A SINGLE LAYER OF DRAINABLE ENGINEERED FABRIC WITH FRICTIONAL PROPERTIES SIMILAR TO POLYETHYLENE SHEETING WILL BE PLACED OVER THE PREPARED BASE MATERIAL, BENEATH THE PRECAST PANELS, TO SERVE AS A FRICTION REDUCING MEMBRANE. THE FABRIC SHALL HAVE MATERIAL PROPERTIES CONFORMING TO SECTION 4196.01B OF THE STANDARD SPECIFICATIONS, UNLESS OTHERWISE APPROVED BY THE ENGINEER. PROVISION SHALL BE MADE TO PREVENT FOLDS AND CREASES IN THE FABRIC BENEATH THE PANELS. THE SURFACE OF THE PREPARED BASE SHALL BE FREE FROM LOOSE DEBRIS, WHICH MAY PUNCTURE THE FABRIC PRIOR TO PLACEMENT OF THE FABRIC. ANY TEARS OR PUNCTURES IN THE FABRIC SHALL BE REPAIRED TO THE SATISFACTION OF THE ENGINEER PRIOR TO PLACEMENT OF THE PRECAST PANELS OVER THE FABRIC. PROVISION SHALL BE MADE TO PREVENT THE FABRIC FROM BECOMING PINCHED IN THE JOINTS BETWEEN INDIVIDUAL PRECAST PANELS DURING PANEL INSTALLATION.

TEMPORARY POST-TENSIONING: PANELS SHALL BE TEMPORARILY POST-TENSIONED TOGETHER DURING PLACEMENT TO ENSURE CLOSURE OF TRANSVERSE JOINTS PRIOR TO FINAL POST-TENSIONING. UNLESS OTHERWISE SPECIFIED, TEMPORARY POST-TENSIONING SHALL BE COMPLETED AFTER PLACEMENT OF NO MORE THAN TWO ADJACENT PANELS. A MINIMUM OF TWO TEMPORARY POST-TENSIONING STRANDS SHALL BE REQUIRED FOR EACH SET OF PRECAST PANELS. STRAND USED FOR TEMPORARY POST-TENSIONING SHALL BE EITHER $\frac{1}{2}$ INCH OR 0.6 INCH NOMINAL DIAMETER, WITH CORRESPONDING TEMPORARY ANCHORAGE. ANY DAMAGE TO THE PRECAST PANELS DURING TEMPORARY POST-TENSIONING SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE TO THE SATISFACTION OF THE ENGINEER PRIOR TO INSTALLATION OF ADDITIONAL PANELS. NO MORE THAN TWO PANELS MAY BE PLACED IN SEQUENCE BETWEEN TEMPORARY POST-TENSIONING OPERATIONS.

JOINT TREATMENT: EPOXY SHALL BE APPLIED TO THE ADJOINING SURFACES OF THE PRECAST PANELS PRIOR TO ASSEMBLY. THE EPOXY MATERIAL SHALL BE SUITABLE FOR BONDING HARDENED CONCRETE TO HARDENED CONCRETE AND SHALL BE APPROVED BY THE ENGINEER PRIOR TO USE. EPOXY SHALL BE PROPORTIONED AND APPLIED ACCORDING TO THE MANUFACTURER'S RECOMMENDATIONS. EPOXY SHALL BE APPLIED TO BOTH FACES OF ADJOINING PANELS, AND SHALL BE KEPT A MINIMUM OF $\frac{1}{2}$ INCH AWAY FROM DUCT OPENINGS. THE SET TIME OF THE EPOXY SHALL BE SUCH THAT FINAL POST-TENSIONING IS COMPLETED BEFORE THE EPOXY HARDENS. EXCESS EPOXY SQUEEZED OUT OF THE JOINT ONTO THE DRIVING SURFACE OF THE PRECAST PAVEMENT DURING ASSEMBLY AND/OR POST-TENSIONING SHALL BE REMOVED BEFORE IT HARDENS. A COMPRESSIBLE FOAM OR NEOPRENE GASKET SHALL BE PLACED AROUND THE OPENING OF EACH POST-TENSIONING DUCT AS SHOWN IN THE PLANS. THE SEAL SHALL BE CONTINUOUS AROUND EACH DUCT OPENING AND SHALL BE COMPRESSIBLE SUCH THAT IT WILL NOT PROTRUDE FROM THE GASKET RECESS SHOWN IN THE PLANS WHEN COMPRESSED. THE SEAL SHALL NOT COVER ANY PART OF THE OPENING TO THE DUCT AND SHALL NOT INHIBIT THE FLOW OF GROUT. PROVISION SHALL BE MADE TO PREVENT DAMAGE TO THE GASKETS DURING PANEL INSTALLATION.

PLACEMENT TECHNIQUE: PANELS SHALL BE INSTALLED ONE AT A TIME, AND SHALL BE INSTALLED IN SUCH A MANNER THAT NEITHER THE BASE MATERIAL NOR THE UNDERLYING FABRIC IS DAMAGED DURING INSTALLATION. THE ANGLE BETWEEN THE TOP SURFACE OF THE PANEL AND THE LIFTING LINE ATTACHED TO EACH LIFTING ANCHOR SHALL NOT BE LESS THAN SIXTY DEGREES, WHEN MEASURED FROM THE HORIZONTAL SURFACE OF THE PANEL TO THE LIFTING LINE. PANELS SHALL BE ALIGNED IN THE LONGITUDINAL DIRECTION (PARALLEL TO THE ROADWAY CENTERLINE) USING THE CENTERLINE OF THE PANELS. THE CENTERLINE OF EACH PANEL SHALL BE MARKED ON THE TOP SURFACE OF THE PANEL AT THE ADJOINING EDGES. THE LOCATION OF THE CENTERLINE ON EACH PANEL SHALL BE DETERMINED FROM THE LOCATION OF THE POST-TENSIONING DUCT OPENINGS AT THE ADJOINING EDGES OF THE PANELS.

PANELS MAY BE PULLED TOGETHER DURING PLACEMENT USING APPROVED TEMPORARY DEVICES. ANY DAMAGE TO THE PANELS CAUSED BY TEMPORARY DEVICES SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE TO THE SATISFACTION OF THE ENGINEER. THE CENTERLINE OF THE PANELS SHALL BE ALIGNED TO A LINE LAID OUT BY A SURVEYOR (PROVIDED BY THE CONTRACTOR) ON THE SURFACE OF THE BASE PRIOR TO PLACEMENT OF THE PANELS. SHIMS MAY BE PLACED IN THE JOINTS BETWEEN PANELS TO CORRECT HORIZONTAL MISALIGNMENT OF THE CENTERLINE OF THE PANELS. THE TOTAL THICKNESS OF SHIMS USED IN ANY JOINT SHALL BE NO MORE THAN $\frac{1}{8}$ INCH. ANY DAMAGE CAUSED TO THE PANELS BY SHIMS SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE TO THE SATISFACTION OF THE ENGINEER.

PLACEMENT TOLERANCES: THE CENTERLINE OF THE PANELS SHALL BE WITHIN $\frac{1}{4}$ INCH OF THE PRE-SURVEYED CENTERLINE MARKED ON THE SURFACE OF THE BASE, AND THE CENTERLINE OF ADJOINING PANELS SHALL BE WITHIN $\frac{1}{8}$ INCH OF EACH OTHER AT THE ADJOINING EDGES. VERTICAL ALIGNMENT OF THE PANELS SHALL BE SUCH THAT THE TOP SURFACE OF AN INDIVIDUAL PANEL IS NO MORE THAN $\frac{3}{16}$ INCH HIGHER OR LOWER THAN THE TOP SURFACE OF AN ADJOINING PANEL AT ANY POINT ALONG THE JOINT BETWEEN THE PANELS. THE WIDTH OF THE GAP BETWEEN ADJOINING PANELS AT THE TOP SURFACE OF THE JOINT SHALL BE NO MORE THAN $\frac{1}{8}$ INCH AFTER COMPLETION OF TEMPORARY POST-TENSIONING.

PATCHING AND REPAIRS: ANCHOR ACCESS POCKETS (PANEL 1A AND 1B) SHALL BE PATCHED ONLY AFTER COMPLETION OF FINAL STRESSING BUT PRIOR TO GROUTING THE POST-TENSIONING TENDONS. THE POCKETS SHALL BE PATCHED WITH AN APPROVED CEMENTITIOUS PATCHING MATERIAL WITH A MAXIMUM AGGREGATE SIZE OF AT LEAST $\frac{3}{8}$ INCH, BUT NO GREATER THAN 1 INCH. A FAST-SETTING PATCHING MATERIAL, CONFORMING TO THE REQUIREMENTS OF ARTICLE 2529.02B OF THE STANDARD SPECIFICATIONS, SHALL BE PERMITTED WITH THE APPROVAL OF THE ENGINEER. THE PATCHING MATERIAL SHALL BE FINISHED FLUSH WITH THE SURFACE OF THE SURROUNDING CONCRETE AND GIVEN A TEXTURE SIMILAR TO THE SURROUNDING CONCRETE. DAMAGE CAUSED TO THE PRECAST PANELS DURING ANY PART OF THE PANEL INSTALLATION PROCESS SHALL BE REPAIRED BY THE CONTRACTOR AT THE CONTRACTOR'S EXPENSE TO THE SATISFACTION OF THE ENGINEER. REPAIRS OF DAMAGED AREAS WILL BE ADDRESSED ON A CASE-BY-CASE BASIS BY THE ENGINEER. DAMAGE WITHIN ACCEPTABLE LIMITS CAUSED TO THE TOP SURFACE (DRIVING SURFACE) OR TO KEYED EDGES OF THE PANELS SHALL BE REPAIRED USING APPROVED REPAIR METHODS AND MATERIALS. REPETITIVE DAMAGE TO PANELS SHALL BE CAUSE FOR STOPPAGE OF INSTALLATION OPERATIONS UNTIL THE CAUSE OF THE DAMAGE CAN BE REMEDIED. PATCHING LIFTING ANCHOR RECESSES, ABUTMENT ANCHOR SLEEVES, AND DAMAGED AREAS SHALL BE COMPLETED USING APPROVED PATCHING MATERIALS AND METHODS.

VOIDS BENEATH PAVEMENT: THE PAVEMENT SHALL BE INSPECTED DURING PANEL INSTALLATION FOR VOIDS BENEATH THE PRECAST PANELS. AT THE DISCRETION OF THE ENGINEER, THE CONTRACTOR SHALL BE REQUIRED TO STOP PANEL INSTALLATION AND CORRECT IMPERFECTIONS IN THE BASE MATERIAL CAUSING VOIDS BENEATH THE PRECAST PANELS.

TYING TO EXISTING PAVEMENT/BRIDGE ABUTMENT: THE PRECAST PANELS SHALL BE TIED INTO THE BRIDGE ABUTMENT AND EXISTING PAVEMENT AS SHOWN ON THE PLANS. THE TOP SURFACE OF THE PRECAST PAVEMENT SHALL BE NO MORE THAN $\frac{1}{4}$ INCH ABOVE OR BELOW THE SURFACE OF THE PRECAST PAVEMENT AND BRIDGE DECK. DIAMOND GRINDING SHALL BE USED TO BRING THE TOP SURFACE OF THE EXISTING PAVEMENT AND PRECAST PAVEMENT INTO TOLERANCE IF NECESSARY. TIE BARS USED TO TIE THE PRECAST PANELS TO ADJACENT PAVEMENT SHALL BE GRADE 60 CONFORMING TO THE REQUIREMENTS OF ARTICLE 4151.02 OF THE STANDARD SPECIFICATIONS.

ABUTMENT ANCHORS: THE ABUTMENT ANCHOR SLEEVES SHALL BE PATCHED PRIOR TO FINAL STRESSING OF THE BRIDGE APPROACH SLAB PANELS.

INSTRUMENTATION: THE CONTRACTOR SHALL PERMIT ACCESS TO INSTRUMENTATION IN THE PRECAST PANELS DURING THE PANEL INSTALLATION PROCESS AND SHALL PERMIT INSTRUMENTATION OF THE PRECAST PANELS AND POST-TENSIONING SYSTEM DURING THE CONSTRUCTION PROCESS. A SCHEMATIC LAYOUT AND AN INSTRUMENTATION PLAN SHALL BE PROVIDED TO THE ENGINEER AND CONTRACTOR FOR APPROVAL AT LEAST TWO WEEKS PRIOR TO COMMENCEMENT OF PANEL INSTALLATION ON SITE. INSTRUMENTATION SHALL INCLUDE, BUT IS NOT LIMITED TO, TEMPERATURE SENSORS, STRAIN GAGES, AND LOAD CELLS. INSTRUMENTATION SHALL NOT COMPROMISE THE INTEGRITY OF THE BASE MATERIAL, PAVEMENT, OR THE POST-TENSIONING SYSTEM. THE CONTRACTOR SHALL PROTECT THE INTEGRITY OF THE INSTRUMENTATION, INCLUDING LEAD WIRES AND CONNECTORS EXTENDING FROM THE SURFACE OF THE PRECAST PANELS, DURING THE PANEL INSTALLATION AND POST-TENSIONING PROCESS.

POST-TENSIONING: POST-TENSIONING MATERIALS, EQUIPMENT, AND PROCEDURES MUST BE APPROVED BY THE ENGINEER PRIOR TO CONSTRUCTION, AS PER ARTICLE 2407.11 OF THE STANDARD SPECIFICATIONS. THE CONTRACTOR SHALL USE THE POST-TENSIONING SYSTEM SHOWN IN THE PLANS, UNLESS A COMPARABLE SYSTEM IS SUBMITTED TO THE ENGINEER AND APPROVED FOR USE. THE DIMENSIONS OF THE ANCHOR ACCESS POCKETS MAY BE ADJUSTED AS NEEDED PRIOR TO FABRICATION OF THE PANELS.
THE POCKET DIMENSIONS SHALL BE SUCH THAT CONSTRUCTION TRAFFIC CAN PASS OVER THE POCKETS WITHOUT DAMAGE TO THE VEHICLE OR DISRUPTION TO THE DRIVER. DIMENSIONS OTHER THAN THOSE SHOWN IN THE PLANS SHALL BE APPROVED BY THE ENGINEER PRIOR TO FABRICATION OF THE PANELS.

MATERIALS: LOW-RELAXATION, GRADE 270 STRANDS WITH 0.6 INCH NOMINAL DIAMETER CONFORMING TO ARTICLE 4151.05 OF THE STANDARD SPECIFICATIONS, SHALL BE USED FOR LONGITUDINAL AND TRANSVERSE POST-TENSIONING OF THE ADJOINING APPROACH PAVEMENT.

TENDON INSTALLATION: LONGITUDINAL POST-TENSIONING STRANDS SHALL BE INSERTED INTO THE DUCTS AS SHOWN ON THE PLANS. STRANDS SHALL BE EITHER PUSHED OR PULLED THROUGH THE DUCTS BY HAND OR USING AN APPROVED MECHANICAL STRAND PUSHER. PROVISION SHALL BE MADE TO PREVENT SEPARATION OF THE INDIVIDUAL WIRES FROM THE STRAND DURING STRAND INSERTION. TRANSVERSE POST-TENSIONING STRANDS SHALL BE INSTALLED BUT NOT STRESSED PRIOR TO STRESSING OF THE LONGITUDINAL TENDONS.

POST-TENSIONING TENDONS SHALL BE STRESSED TO 75 PERCENT OF THE GUARANTEED ULTIMATE TENSILE STRENGTH OF THE STRAND SUPPLIED. STRESSING SHALL BE COMPLETED IN A SINGLE STAGE UNLESS OTHERWISE SPECIFIED. STRESSING OF LONGITUDINAL TENDONS (PARALLEL TO THE ROADWAY CENTERLINE) SHALL START WITH THE TENDON AT OR NEAR THE MIDPOINT OF THE PANELS, SUBSEQUENTLY ALTERNATING BETWEEN THE TENDONS ON EITHER SIDE OF THE CENTERLINE UNTIL ALL TENDONS HAVE BEEN STRESSED. TENDON ELONGATIONS SHALL BE MEASURED AND RECORDED, IN ACCORDANCE WITH ARTICLE 2407.06 OF THE STANDARD SPECIFICATIONS. STRESSING OF THE TRANSVERSE TENDONS SHALL BE COMPLETED ONLY AFTER FINAL STRESSING OF THE LONGITUDINAL TENDONS IS COMPLETE. AFTER COMPLETION OF POST-TENSIONING, THE TAILS OF THE POST-TENSIONING STRANDS SHALL BE TRIMMED, AND AN APPROVED GREASE CAP WILL BE USED TO COVER AND SEAL THE END OF THE STRAND AND POST-TENSIONING ANCHOR. FAULTY ANCHORS AND WIRE

FAULTY ANCHORS AND WIRE FAILUIRES:
IN THE EVENT OF A FAULTY POST-TENSIONING ANCHOR, THE CONTRACTOR SHALL SUBMIT A REPAIR OR ALTERNATE STRESSING STRATEGY FOR APPROVAL. NO WIRE FAILURES SHALL BE ACCEPTED. THE CONTRACTOR SHALL PROVIDE AND INSTALL A NEW STRAND IN THE EVENT OF A WIRE FAILURE.

TENDON GROUTING: THE POST-TENSIONING SYSTEM SHALL CONSIST OF GROUTED TENDONS FOR BOTH THE BRIDGE APPROACH SLAB.

MATERIALS: THE GROUT MIXTURE SHALL BE A PRE-PACKAGED GROUT SPECIFICALLY MANUFACTURED FOR PRESTRESSED TENDON GROUTING, AND SHALL BE APPROVED BY THE ENGINEER PRIOR TO USE. GROUT SHALL BE PROPORTIONED WITH WATER ACCORDING TO THE MANUFACTURER'S RECOMMENDATIONS.

DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS

CONSTRUCTION NOTES

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 3 OF 20 FILE NO. ______ DESIGN NO. ______

EQUIPMENT: GROUTING EQUIPMENT SHALL CONSIST OF AT LEAST THE FOLLOWING:

- EQUIPMENT FOR ACCURATELY MEASURING AND PROPORTIONING BY VOLUME OR WEIGHT THE VARIOUS MATERIALS COMPOSING THE GROUT,
- A COLLOIDAL MIXER, CAPABLE OF OPERATING IN A RANGE FROM 800 RPM TO 2,000 RPM AND THOROUGHLY MIXING THE VARIOUS COMPONENTS OF THE GROUT IN AN APPROVED MANNER,
- A POSITIVE ACTION PUMP CAPABLE OF FORCING GROUT INTO THE POST-TENSIONING DUCTS. THE INJECTION PUMP SHALL BE CAPABLE OF CONTINUOUS PUMPING AT RATES AS LOW AS $1\frac{1}{2}$ GALLON PER MINUTE, - THE DISCHARGE LINE SHALL BE EQUIPPED WITH A POSITIVE CUT-OFF VALVE AT THE NOZZLE END, AND A BYPASS RETURN LINE FOR RECIRCULATING THE GROUT BACK INTO A HOLDING TANK OR MIXER UNLESS OTHERWISE APPROVED, AND
- A STOP WATCH AND FLOW CONE CONFORMING TO THE DIMENSIONS AND OTHER REQUIREMENTS OF ARTICLE 2530.03 OF THE STANDARD SPECIFICATIONS

PROCEDURES: A GROUTING PLAN SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL AT LEAST FOUR WEEKS BEFORE STARTING GROUTING OPERATIONS. GROUTING SHALL BE COMPLETED WITHIN SEVEN DAYS AFTER STRESSING OF THE POST-TENSIONING TENDONS, UNLESS OTHERWISE APPROVED. GROUTING SHALL NOT BE PERFORMED UNTIL THE ANCHOR ACCESS POCKETS HAVE BEEN PATCHED. THE SIDES OF THE PAVEMENT SLAB SHALL BE SEALED OR BACKFILLED TO PREVENT GROUT LEAKAGE FROM BENEATH THE SLAB IF GROUTING IS COMPLETED PRIOR TO PLACEMENT OF ADJACENT PAVEMENT. THE GROUT FLUIDITY SHALL BE CHECKED IN ACCORDANCE WITH ARTICLE 2539.03 OF THE STANDARD SPECIFICATIONS. EFFLUX TIME FOR FLUIDITY SHALL BE BETWEEN 10 AND 30 SECONDS AFTER MIXING, BUT NO MORE OR LESS THAN RECOMMENDED BY THE MANUFACTURER. FLUIDITY SHALL BE ADJUSTED TO ACHIEVE THE NECESSARY FLOW REQUIREMENTS TO ACHIEVE FULLY GROUTED TENDONS. IF EXCESSIVE BLEEDING OF THE GROUT IS OBSERVED, THE ENGINEER MAY REQUIRE THE CONTRACTOR TO ADJUST THE GROUT MIXTURE TO REDUCE BLEED. THE FLUIDITY OF THE GROUT SHALL BE CHECKED AT THE BEGINNING OF EACH GROUTING OPERATION AND AFTER EACH TIME THE GROUT PUMP AND HOSE IS FLUSHED. SAMPLES FOR GROUT COMPRESSIVE STRENGTH DETERMINATION WILL BE COLLECTED AT LEAST ONCE PER DAY DURING GROUTING OPERATIONS. A MINIMUM OF THREE STRENGTH CUBES SHALL BE MADE DURING EACH SAMPLING. THE AVERAGE COMPRESSIVE STRENGTH OF THREE CUBES SHALL BE A MINIMUM OF 5,000 PSI AT 28 DAYS. GROUT SHALL BE PUMPED INTO THE LOWEST END OF EACH THE TENDON. GROUTING PRESSURE SHALL NOT EXCEED THE BURSTING PRESSURE OF THE DUCT/PORT CONNECTION OR 145 PSI, WHICHEVER IS LESS. IF GROUT DOES NOT FLOW FROM THE NEAREST INTERMEDIATE PORT OR FROM THE PORT AT THE OPPOSITE END OF THE TENDON AFTER THE MAXIMUM GROUTING PRESSURE HAS BEEN REACHED, GROUT MAY BE PUMPED INTO AN INTERMEDIATE PORT OR INTO THE OTHER END OF THE TENDON. A DIAGRAM OF GROUT FLOW SHALL BE PRODUCED BY THE CONTRACTOR TO DEMONSTRATE FULL GROUTING OF THE TENDONS.

GROUTING PROBLEMS: IF GROUT IS OBSERVED LEAKING INTO AN EXPANSION JOINT, FROM THE END OF A JOINT BETWEEN PANELS, FROM BENEATH THE SLAB, OR OUT OF AN ADJACENT DUCT, PUMPING SHALL BE STOPPED AND GROUT SHALL BE PUMPED INTO THE NEAREST INTERMEDIATE PORT. ANY GROUT THAT FLOWS INTO AN EXPANSION JOINT SHALL BE FLUSHED FROM THE EXPANSION JOINT IMMEDIATELY. ANY GROUT THAT HARDENS IN AN EXPANSION JOINT SHALL BE REMOVED AT THE CONTRACTOR'S EXPENSE.

CLEANUP: UPON COMPLETION OF GROUTING, RECESSES IN THE SURFACE OF THE PANELS AT THE GROUT PORTS SHALL BE FILLED WITH AN APPROVED MORTAR AND FINISHED FLUSH WITH THE SURFACE OF THE PAVEMENT. ANY GROUT THAT FLOWS ONTO THE FINISHED SURFACE OF THE PAVEMENT DURING THE GROUTING OPERATION SHALL BE IMMEDIATELY FLUSHED FROM THE SURFACE. ANY RESIDUAL GROUT WHICH HARDENS ON THE PAVEMENT SURFACE SHALL BE REMOVED USING AN APPROVED TECHNIQUE TO THE SATISFACTION OF THE ENGINEER AT THE EXPENSE OF THE CONTRACTOR.

UNDERSLAB GROUTING: UNDERSLAB GROUTING SHALL BE USED TO FILL ANY VOIDS BENEATH THE PRECAST PANELS THAT MAY BE PRESENT AFTER PLACING THE PANELS OVER THE PREPARED BASE. UNDERSLAB GROUTING SHALL UTILIZE THE UNDERSLAB GROUT PORTS CAST INTO THE PANELS.

MATERIALS: GROUT MATERIALS SHALL CONFORM TO THE REQUIREMENTS OF SECTION 2539 OF THE STANDARD SPECIFICATIONS. ALL MATERIALS SHALL BE FURNISHED BY THE CONTRACTOR.

EQUIPMENT: EQUIPMENT FOR UNDERSLAB GROUTING SHALL CONFORM TO THE REQUIREMENTS OF SECTION 2539 OF STANDARD SPECIFICATIONS, WITH THE EXCEPTION THAT DRILLING EQUIPMENT SHALL NOT BE REQUIRED UNLESS DIRECTED BY THE ENGINEER.

PROPORTIONING GROUT MIXTURE: THE MIXTURE USED FOR UNDERSLAB GROUTING SHALL CONFORM TO THE REQUIREMENTS OF SECTION 2539 OF THE STANDARD SPECIFICATIONS. THE SEVEN DAY COMPRESSIVE STRENGTH OF THE GROUT SLURRY SHALL NOT BE LESS THAN 200 PSI. THE CONTRACTOR SHALL FURNISH THE ENGINEER THE PROPOSED MIX DESIGN MEETING THESE REQUIREMENTS.

PROCEDURES: UNDERSLAB GROUTING PROCEDURES SHALL CONFORM TO THE REQUIREMENTS OF SECTION 2539, WITH THE EXCEPTIONS NOTED BELOW. UNDERSLAB GROUTING SHALL BE COMPLETED AFTER STRESSING OF THE POST-TENSIONING TENDONS, BUT NOT MORE THAN SEVEN DAYS AFTER PLACEMENT OF THE PRECAST PANELS. THE ENGINEER MAY REQUIRE GROUTING TO BE COMPLETED PRIOR TO OPENING THE PAVEMENT TO TRAFFIC IF SIGNIFICANT VOIDS ARE OBSERVED DURING PANEL PLACEMENT. UNDERSLAB GROUTING MAY BE COMPLETED PRIOR TO TENDON GROUTING ONLY IF UNDERSLAB GROUTING WILL NOT INTERFERE WITH TENDON GROUTING.

SLAB EDGES SHALL BE BACKFILLED OR SEALED TO PREVENT GROUT LEAKAGE FROM BENEATH THE SLAB IF THE ADJACENT PAVEMENT HAS NOT BEEN PLACED PRIOR TO GROUTING. LIKEWISE, THE BOTTOM OF ALL EXPANSION JOINTS SHALL BE SEALED PRIOR TO UNDERSLAB GROUTING TO PREVENT GROUT LEAKAGE INTO THE JOINTS. THE SEALANT MATERIAL SHALL BE COMPRESSIBLE SUCH THAT IT WILL NOT INHIBIT FREE MOVEMENT AND FULL CLOSURE OF THE EXPANSION JOINTS.

UNDERSLAB GROUTING SHALL REQUIRE MINIMAL PRESSURE TO FORCE THE GROUT BENEATH THE PAVEMENT SLAB. SLAB MOVEMENT SHALL BE MONITORED IN ACCORDANCE WITH ARTICLE 2539.05 OF THE STANDARD SPECIFICATIONS. UNDER NO CIRCUMSTANCES SHOULD UNDERSLAB GROUTING CAUSE THE PAVEMENT SLAB TO LIFT. GROUT SHALL BE PUMPED INTO EACH UNDERSLAB GROUT PORT OF EACH PANEL. GROUT SHALL BE PUMPED UNTIL IT FLOWS OUT OF AN ADJACENT GROUT PORT OR UNTIL THE LINE PRESSURE ON THE GROUT PUMP REACHES 5 PSI. GROUTING PRESSURE OF 5 PSI MAY BE EXCEEDED (NO GREATER THAN 15 PSI) IF THE CONTRACTOR CAN DEMONSTRATE THAT SLAB LIFT IS NOT OCCURRING AT HIGHER PRESSURES.

THE FLUIDITY OF THE GROUT SHALL BE CHECKED AT THE BEGINNING OF EACH GROUTING OPERATION AND AFTER EACH TIME THE GROUT PUMP IS FLUSHED. GROUT FLUIDITY SHALL BE CHECKED IN ACCORDANCE WITH ARTICLE 2539.03 OF THE STANDARD SPECIFICATIONS. FLUIDITY SHALL BE ADJUSTED TO ACHIEVE THE NECESSARY FLOW REQUIREMENTS TO ACHIEVE FULL UNDERSEALING. IF EXCESSIVE BLEEDING OF THE GROUT IS OBSERVED, THE ENGINEER MAY REQUIRE THE CONTRACTOR TO ADJUST THE GROUT MIXTURE.

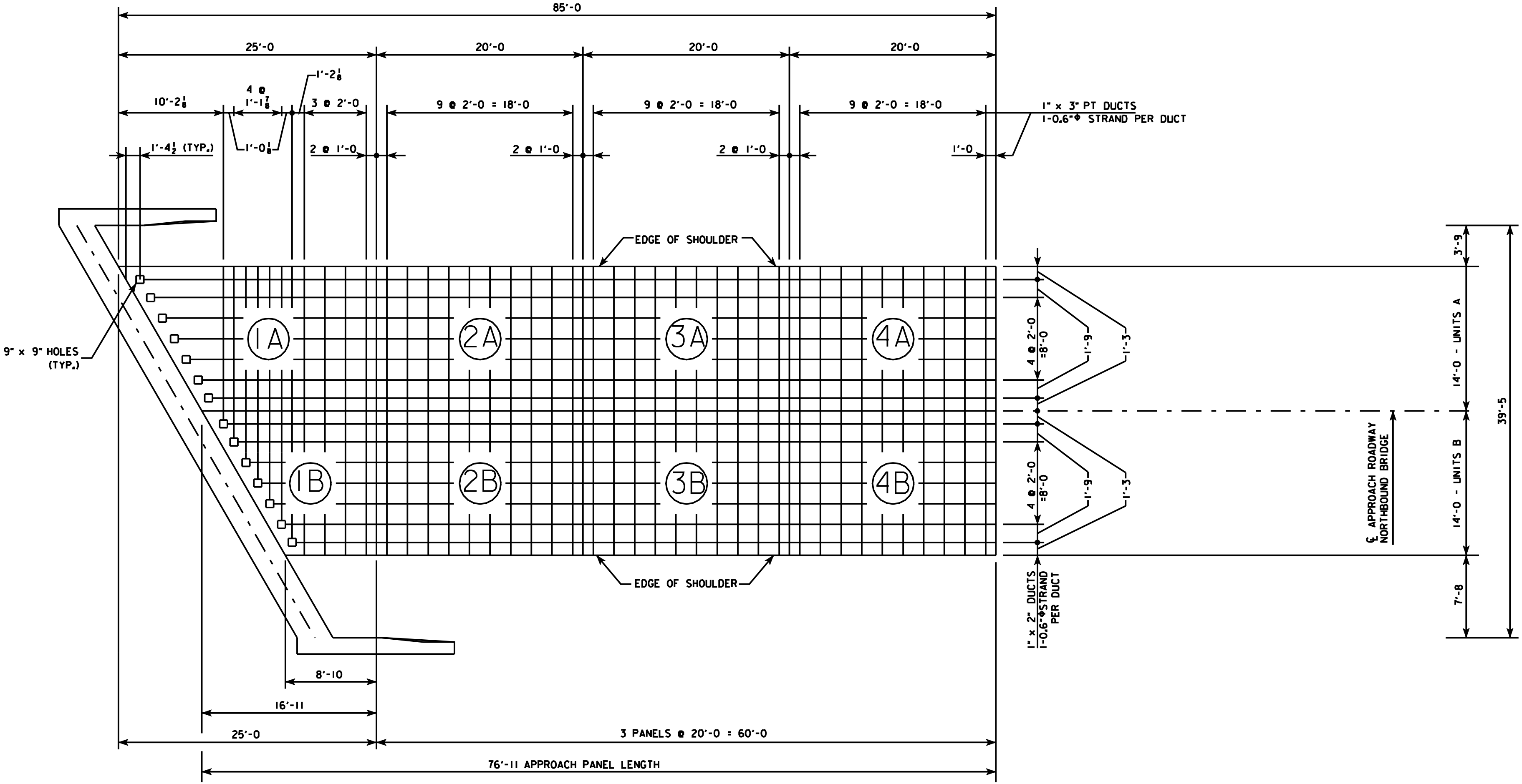
CLEANUP: UPON COMPLETION OF GROUTING, RECESSES IN THE SURFACE OF THE PANELS AT THE GROUT PORTS SHALL BE FILLED WITH AN APPROVED MORTAR AND FINISHED FLUSH WITH THE SURFACE OF THE SURROUNDING PAVEMENT. ANY GROUT THAT FLOWS ONTO THE FINISHED SURFACE OF THE PAVEMENT DURING THE GROUTING OPERATION SHALL BE IMMEDIATELY FLUSHED FROM THE SURFACE. ANY RESIDUAL GROUT WHICH HARDENS ON THE PAVEMENT SURFACE SHALL BE REMOVED USING AN APPROVED TECHNIQUE TO THE SATISFACTION OF THE ENGINEER AT THE EXPENSE OF THE CONTRACTOR.

FINISHED SURFACE: THE FINISHED PAVEMENT SURFACE SHALL BE TESTED FOR SMOOTHNESS BY PROFILOGRAPHING IN ACCORDANCE WITH SECTION 2316 OF THE STANDARD SPECIFICATIONS. BOTH LANES OF THE FINISHED PAVEMENT SHALL BE TESTED FOR SMOOTHNESS. CORRECTIVE ACTION TO IMPROVE THE PROFILE INDEX SHALL BE ACCOMPLISHED BY DIAMOND GRINDING IN ACCORDANCE WITH SECTIONS 2316 AND 2532 OF THE STANDARD SPECIFICATIONS (GRINDING REQUIREMENT OF SECTION 2316 SUPERSEDE SECTION 2532). GRINDING DEPTH SHALL NOT EXCEED $\frac{1}{4}$ INCH AT THE EXPANSION JOINTS. GRINDING SHALL BE PERFORMED WITH AN ABRASIVE GRINDING EQUIPMENT, DESIGNED SPECIFICALLY FOR GRINDING PAVEMENT SURFACES TO CLOSE TOLERANCES, UTILIZING DIAMOND CUTTING BLADES WITH A MINIMUM CUTTING WIDTH OF 36 INCHES. SUCH EQUIPMENT SHALL ACCURATELY ESTABLISH SLOPE ELEVATIONS AND PROFILE GRADE CONTROLS. THE FINAL GROUND SURFACE SHALL NOT BE SMOOTH OR POLISHED.

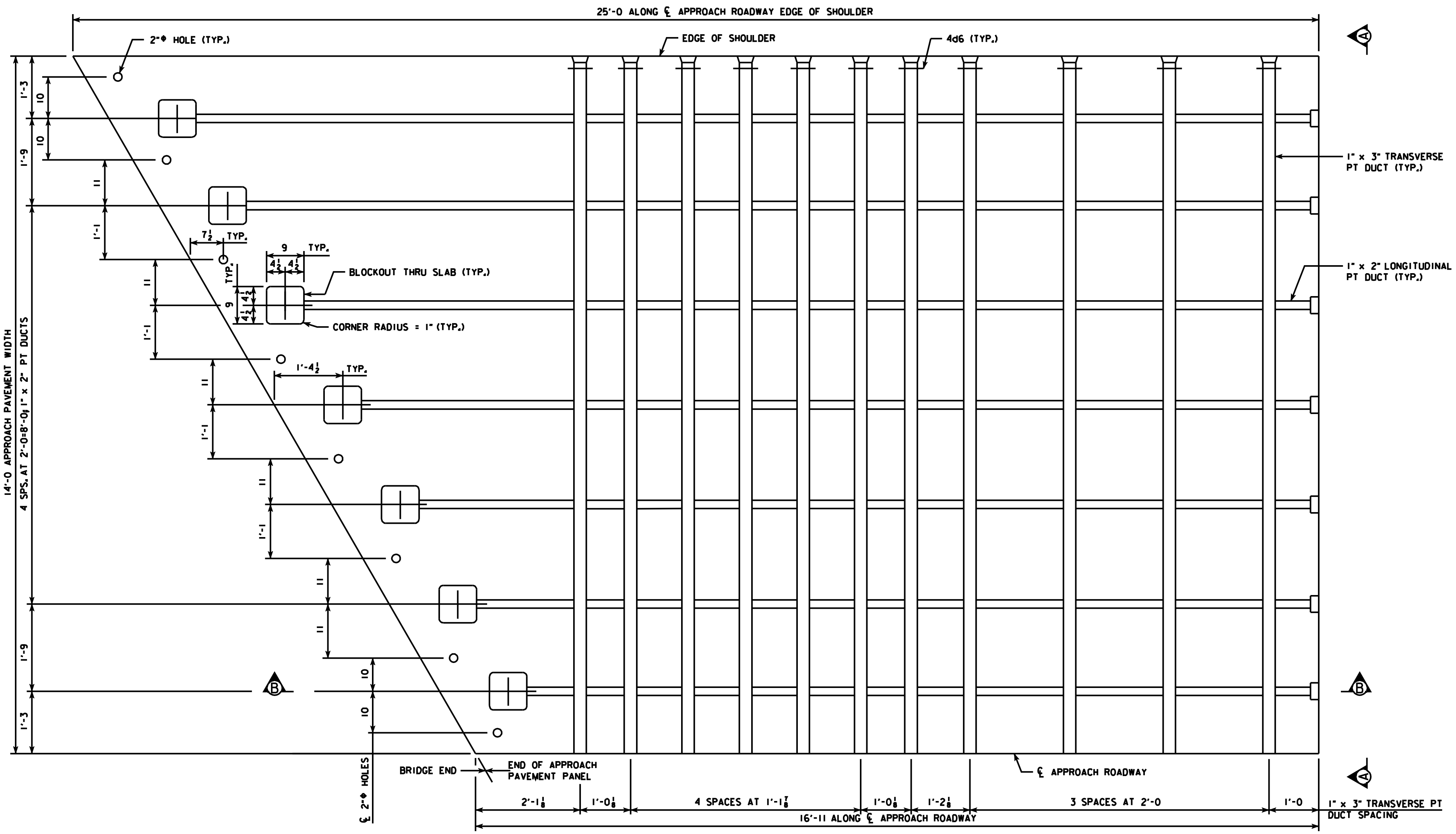
DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS

CONSTRUCTION NOTES

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 4 OF 20 FILE NO. ______ DESIGN NO. ______



DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
POST-TENSIONING LAYOUT
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 5 OF 20 FILE NO. ______ DESIGN NO. ______

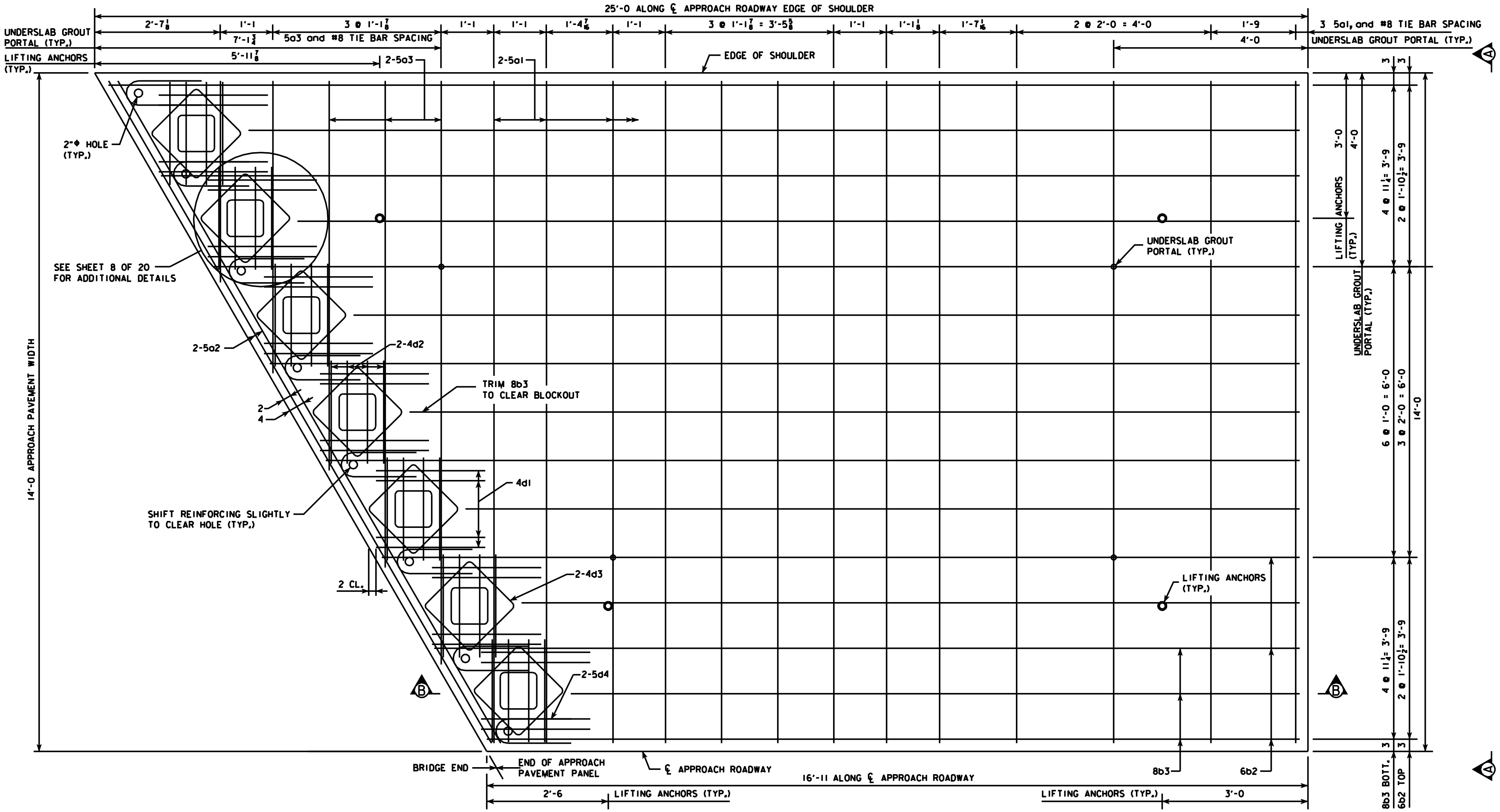


PLAN VIEW OF UNIT 1A
(SHOWING PT DUCT SPACING AND BLOCKOUTS)

DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS

UNIT 1A PANEL PT DUCT SPACING
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 6 OF 20 FILE NO. ______ DESIGN NO. ______

DESIGN TEAM | O'BRIEN COUNTY | PROJECT NUMBER | SHEET NUMBER



NOTE: SEE SHEET 19 OF 20 FOR REINFORCING BAR LIST.

PLAN VIEW OF UNIT 1A

(SHOWING SLAB REINFORCING)

DESIGN FOR

PRECAST REINFORCED CONCRETE
APPROACH PANELS

UNIT 1A PANEL REIN. SPACING

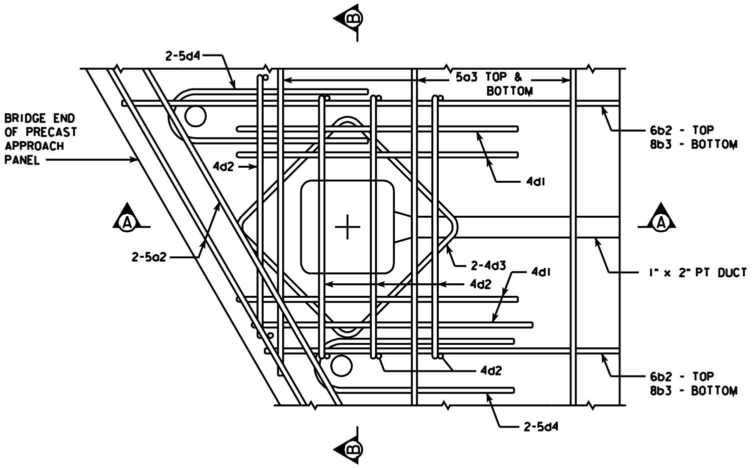
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

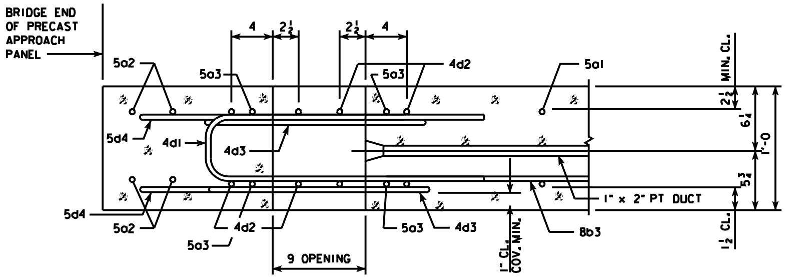
DESIGN SHEET NO. 7 OF 20 FILE NO. ______ DESIGN NO. ______

DESIGN TEAM	O'BRIEN COUNTY	PROJECT NUMBER	SHEET NUMBER



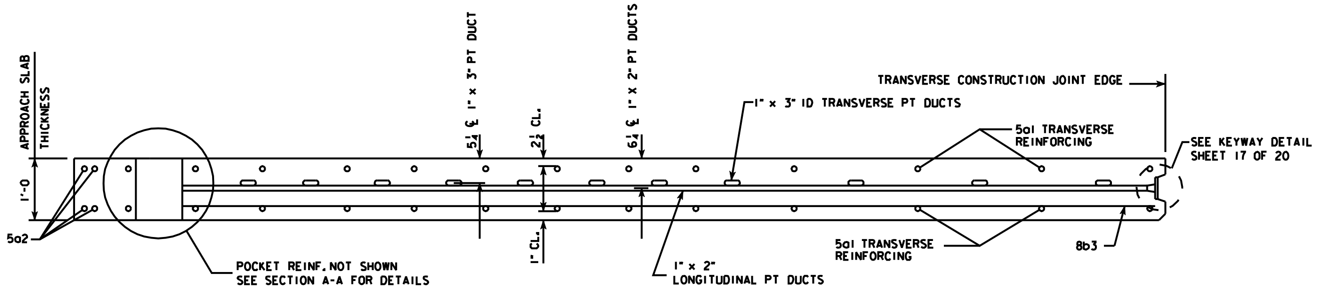
PART PLAN VIEW - UNIT 1A

(SHOWING TYPICAL BLOCKOUTS AT BRIDGE APPROACH END)

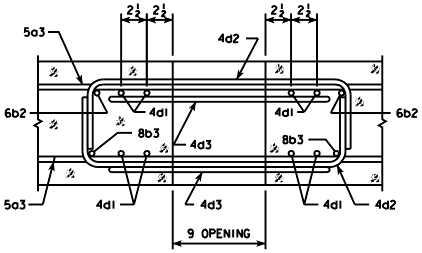


SECTION A-A

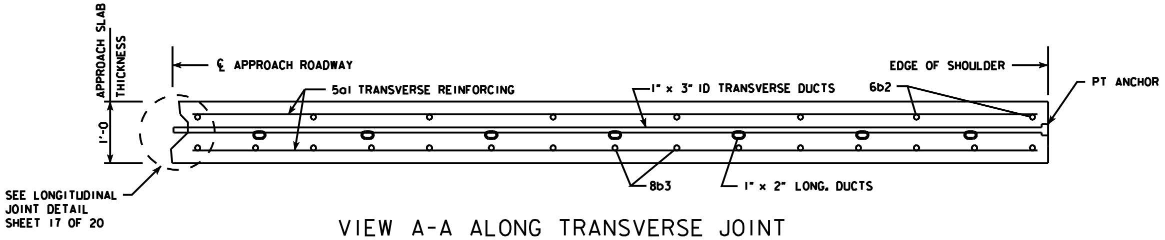
(SECTION ALONG ℄ 1" x 2" PT DUCT)



VIEW B-B ALONG ℄ PT DUCTS



SECTION B-B



VIEW A-A ALONG TRANSVERSE JOINT

DESIGN FOR

PRECAST REINFORCED CONCRETE
APPROACH PANELS

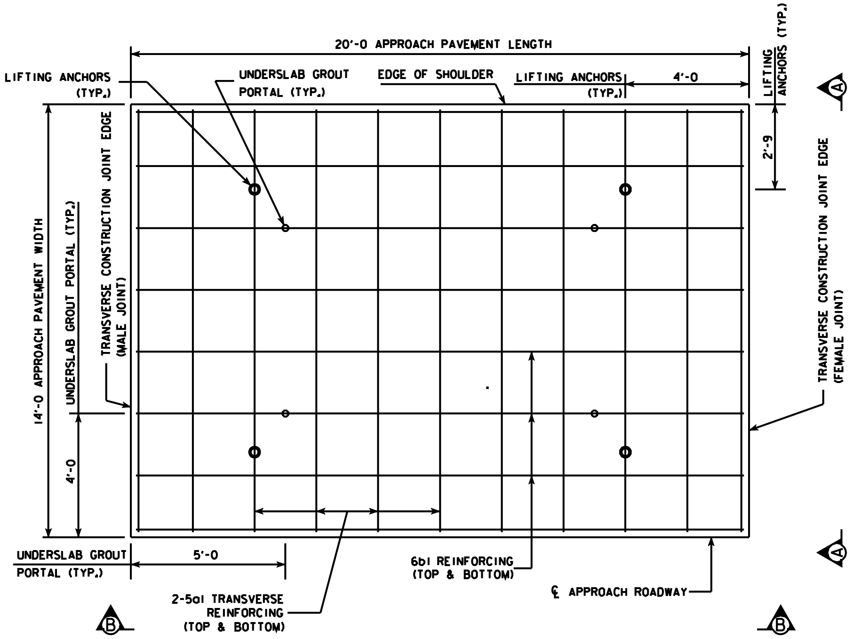
SECTION UNIT 1A ADD. DETAILS

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60)　FEBRUARY, 2006

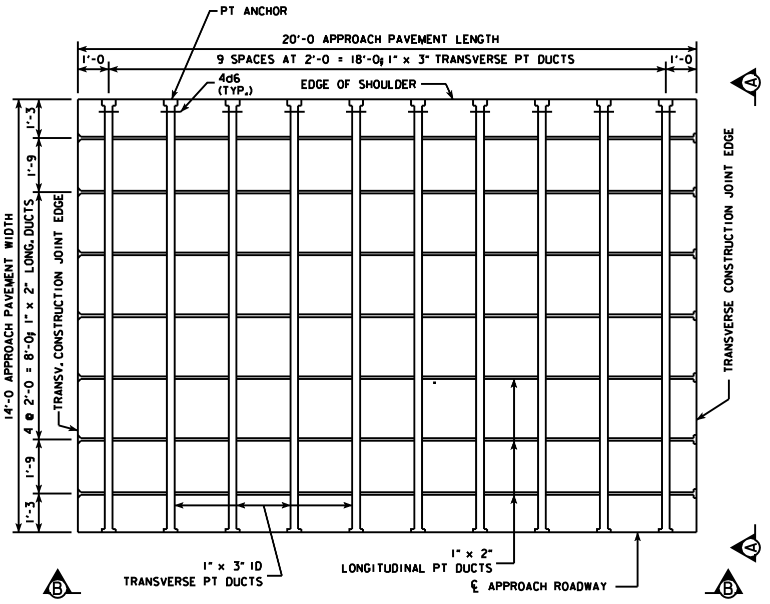
O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

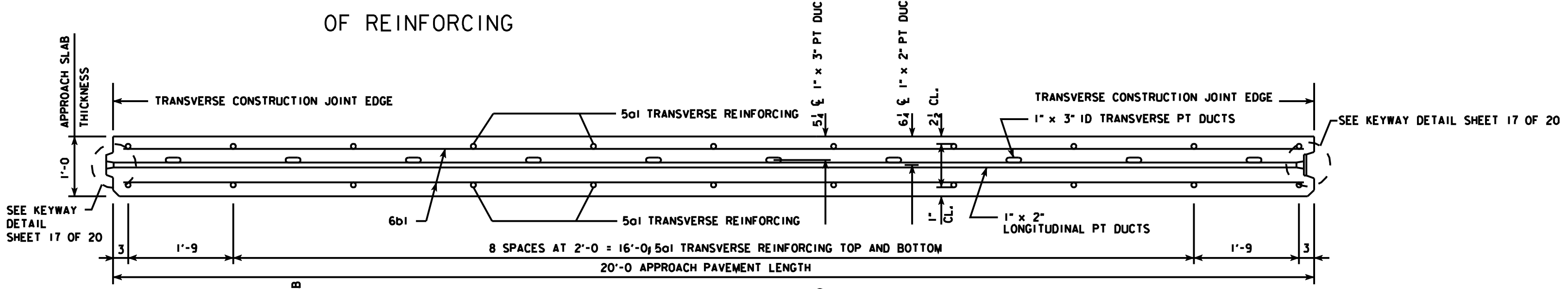
DESIGN SHEET NO. 8 OF 20　FILE NO. ______　DESIGN NO. ______



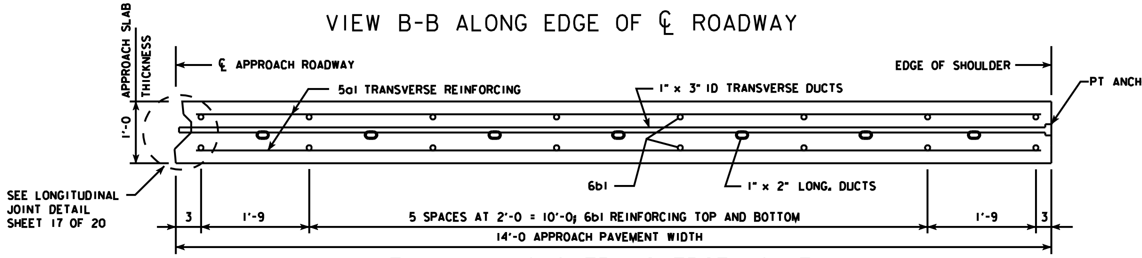
PLAN VIEW SHOWING TOP & BOTTOM MAT OF REINFORCING



PLAN VIEW SHOWING POST-TENSIONING DUCTS TRANSVERSELY AND LONGITUDINALLY



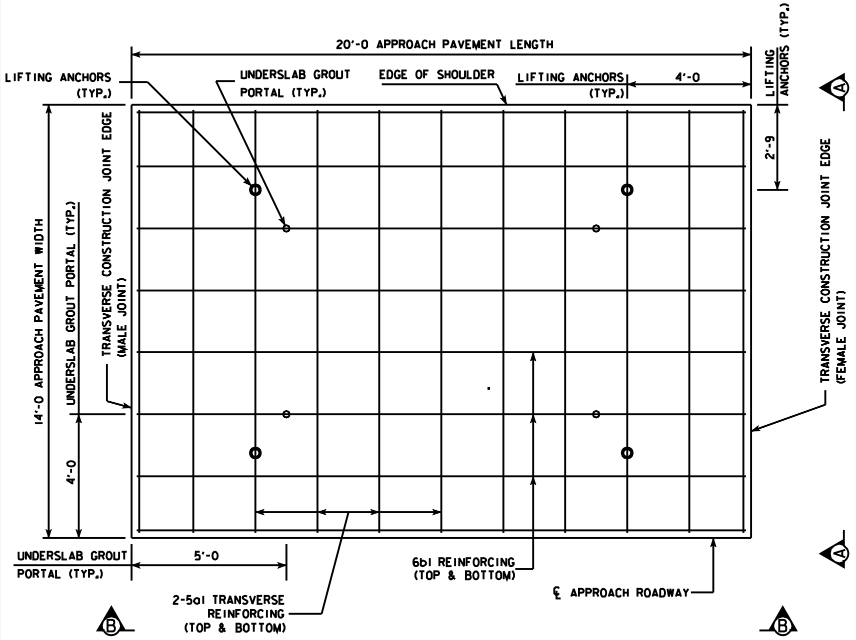
VIEW B-B ALONG EDGE OF ℄ ROADWAY



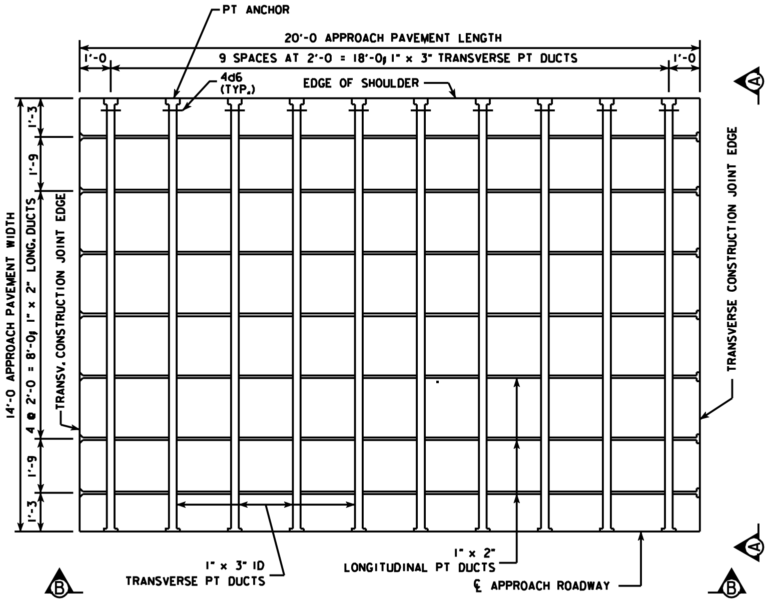
VIEW A-A ALONG TRANSVERSE JOINT

ALL REINFORCEMENT TO BE EPOXY COATED

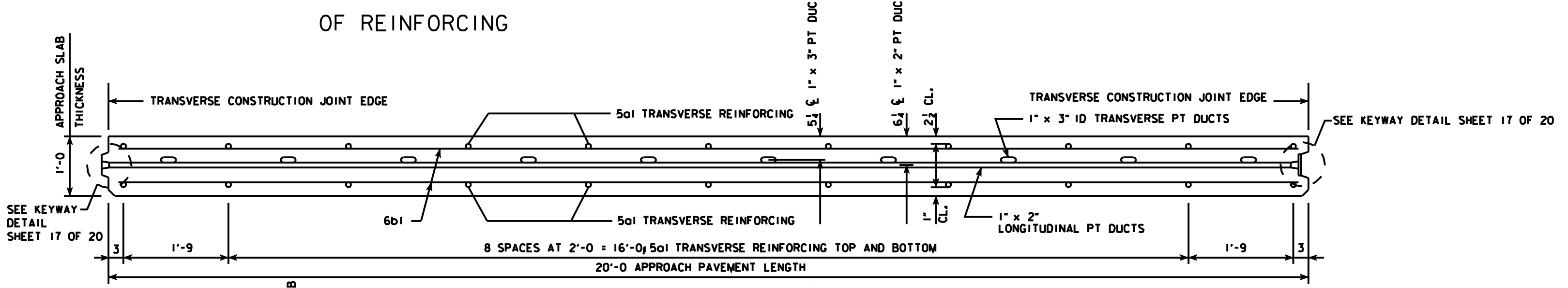
DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
SECTION UNIT 2A
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 9 OF 20 FILE NO. ______ DESIGN NO. ______



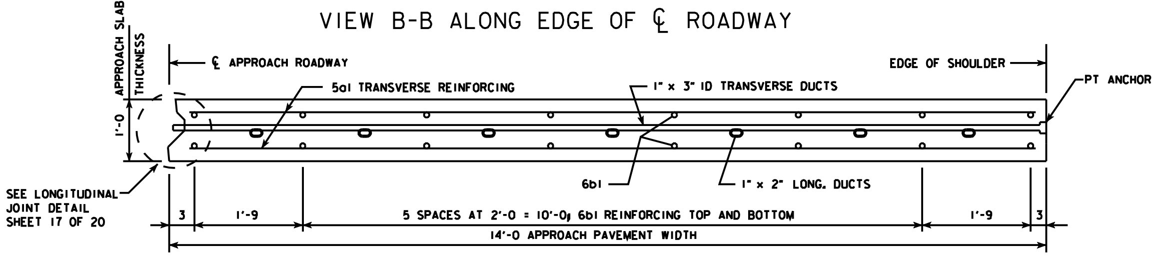
PLAN VIEW SHOWING TOP & BOTTOM MAT OF REINFORCING



PLAN VIEW SHOWING POST-TENSIONING DUCTS TRANSVERSELY AND LONGITUDINALLY



VIEW B-B ALONG EDGE OF ℄ ROADWAY



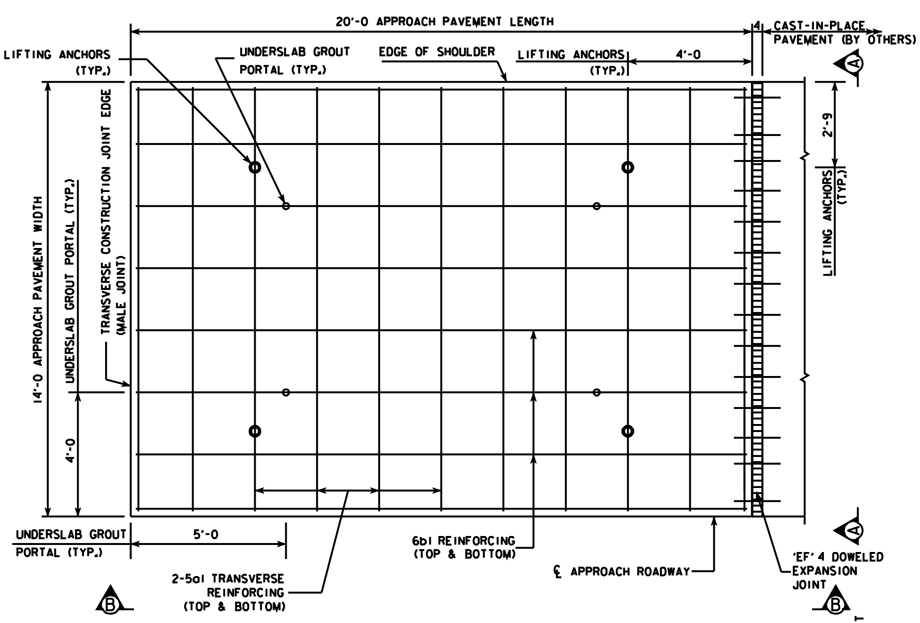
VIEW A-A ALONG TRANSVERSE JOINT

ALL REINFORCEMENT TO BE EPOXY COATED

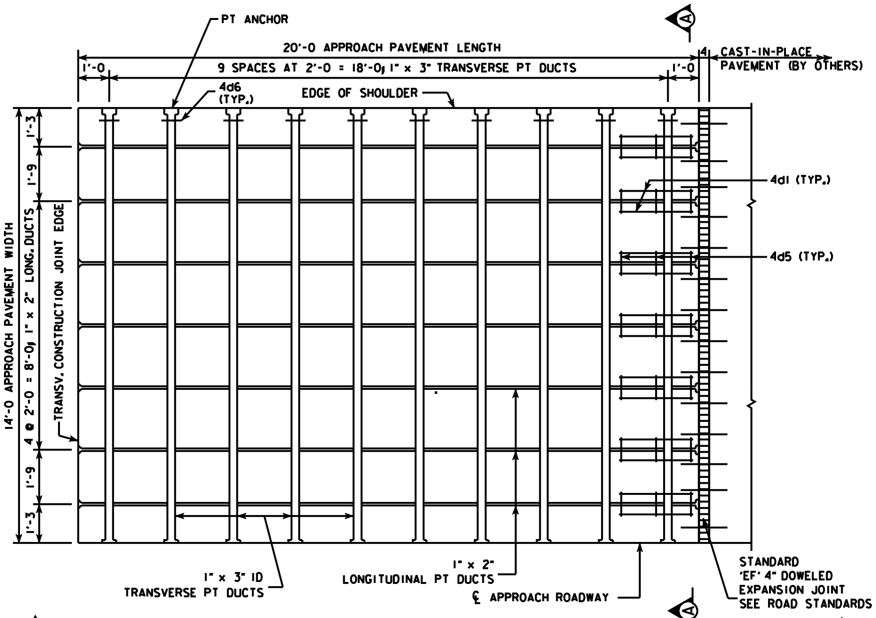
DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
SECTION UNIT 3A
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 10 OF 20 FILE NO. ______ DESIGN NO. ______

DESIGN TEAM | O'BRIEN COUNTY | PROJECT NUMBER | SHEET NUMBER

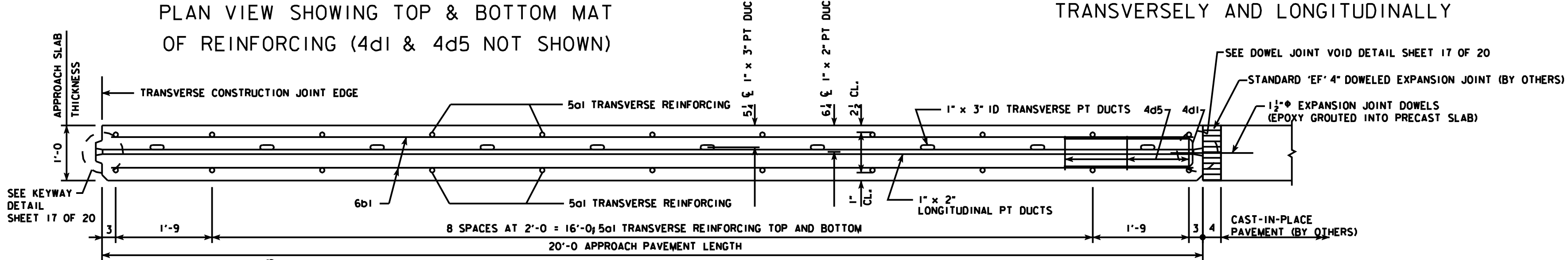
XXXXXXXXXXSYSTEMTIME XXXXXXXUSERNAME XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXDGNSPEC



PLAN VIEW SHOWING TOP & BOTTOM MAT OF REINFORCING (4d1 & 4d5 NOT SHOWN)

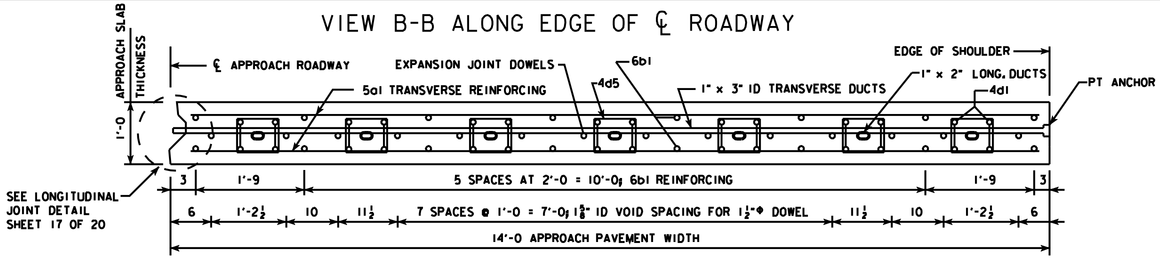


PLAN VIEW SHOWING POST-TENSIONING DUCTS TRANSVERSELY AND LONGITUDINALLY



VIEW B-B ALONG EDGE OF ℄ ROADWAY

PLACE CAST-IN-PLACE SLAB CONCRETE AFTER PRESTRESSING AND GROUTING OF DUCTS ARE COMPLETE



VIEW A-A ALONG TRANSVERSE JOINT

ALL REINFORCEMENT TO BE EPOXY COATED

DESIGN FOR

PRECAST REINFORCED CONCRETE APPROACH PANELS

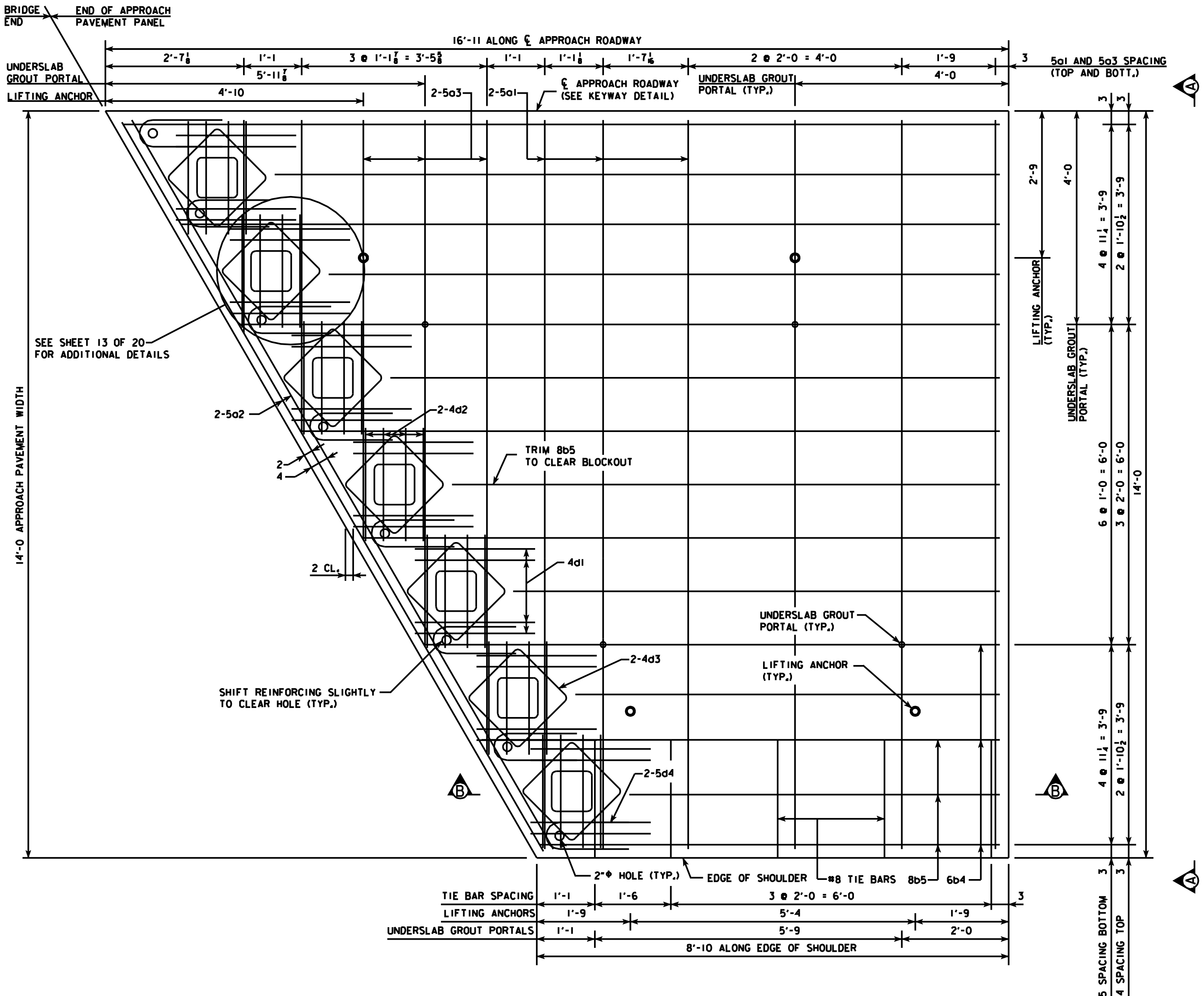
SECTION UNIT 4A

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

DESIGN SHEET NO. 11 OF 20 FILE NO. ______ DESIGN NO. ______



PLAN VIEW OF UNIT 1B

(SHOWING SLAB REINFORCING)

DESIGN FOR

PRECAST REINFORCED CONCRETE APPROACH PANELS

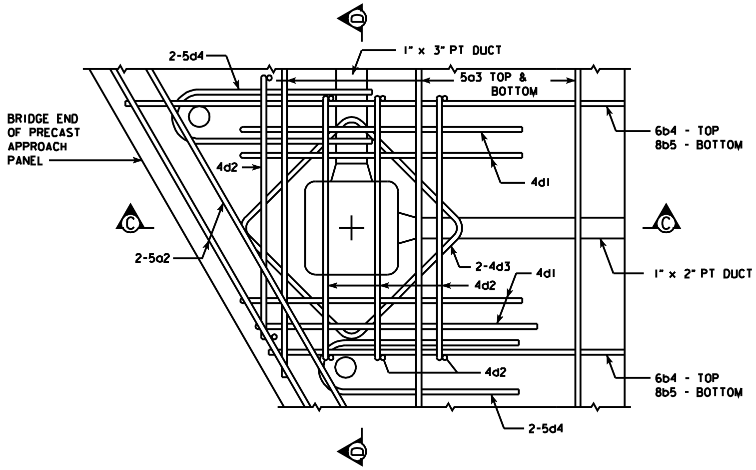
UNIT 1B PANEL REINF.

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

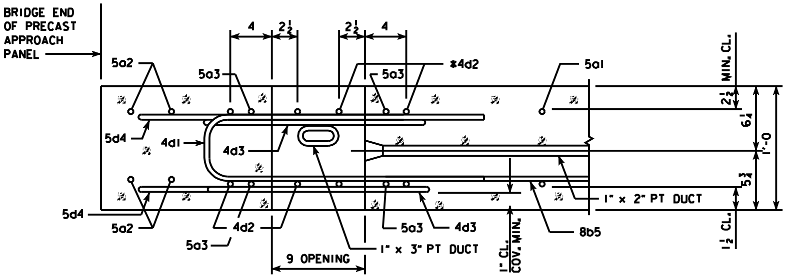
DESIGN SHEET NO. 12 OF 20 FILE NO. ________ DESIGN NO. ________



PART PLAN VIEW - UNIT 1B

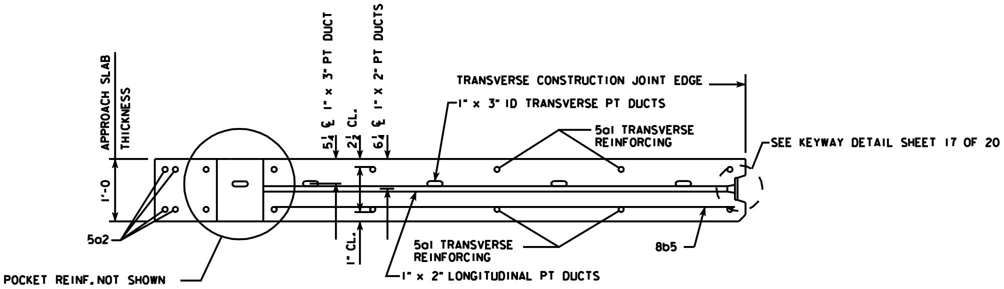
(SHOWING TYPICAL BLOCKOUTS AT BRIDGE APPROACH END)

*NOTE: THE TOP 4d2 BARS IN THE OPEN 9 x 9 POCKET MAY BE TRIMED IF NECESSARY FOR POST-TENSIONING ACCESS

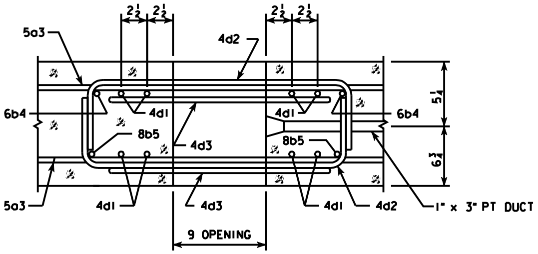


SECTION C-C

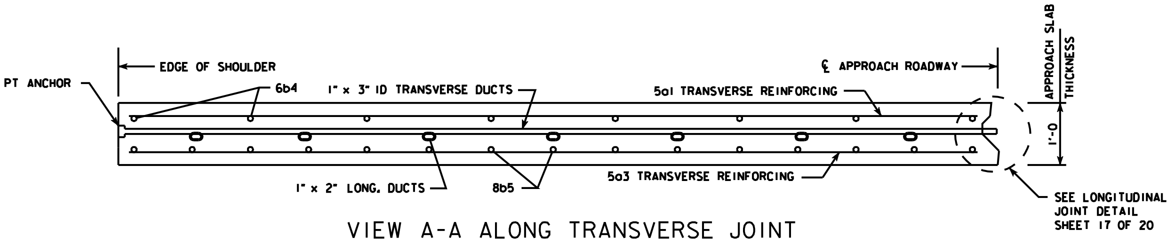
(SECTION ALONG ℄ 1" x 2" PT DUCT)



VIEW B-B ALONG ℄ PT DUCTS



SECTION D-D



VIEW A-A ALONG TRANSVERSE JOINT

DESIGN FOR

PRECAST REINFORCED CONCRETE
APPROACH PANELS

SECTION UNIT 1B ADD. DETAILS

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

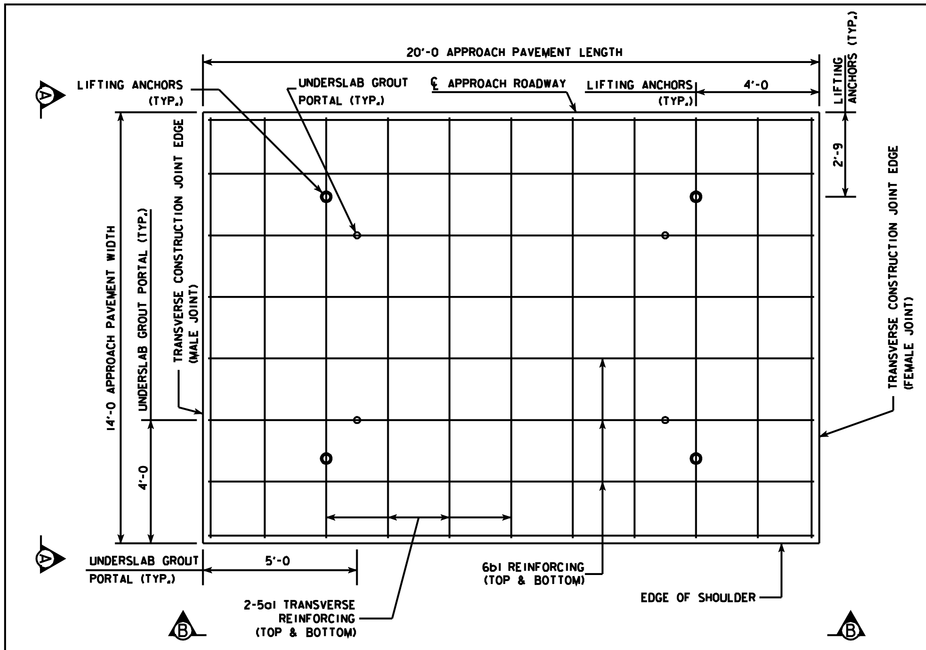
O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

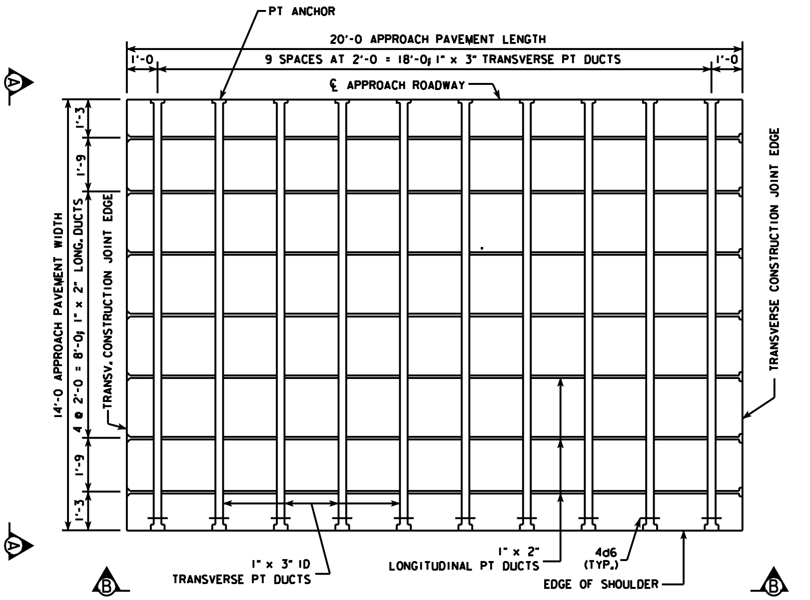
DESIGN SHEET NO. 13 OF 20 FILE NO. ______ DESIGN NO. ______

DESIGN TEAM | O'BRIEN COUNTY | PROJECT NUMBER | SHEET NUMBER

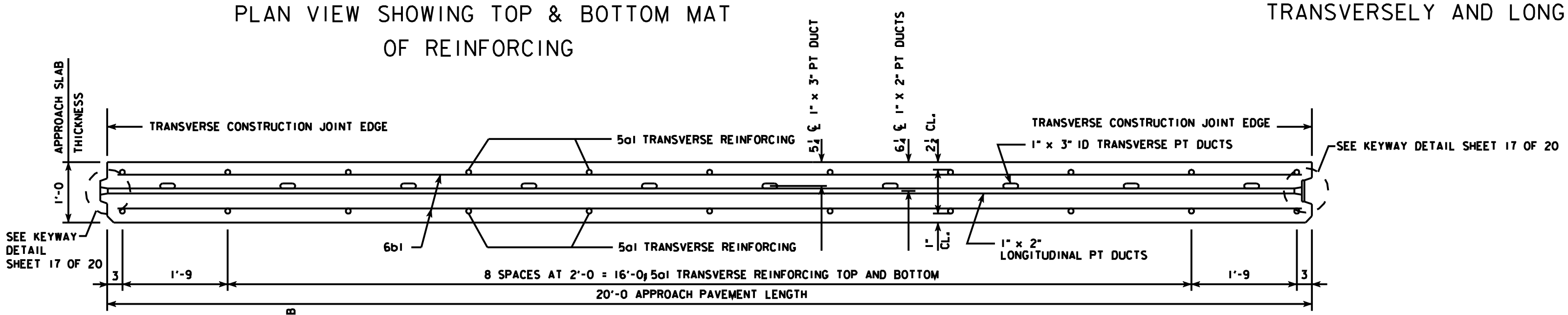
XXXXXXXXXXSYSTEMTIME XXXXXXXUSERNAME XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXDGNSPEC



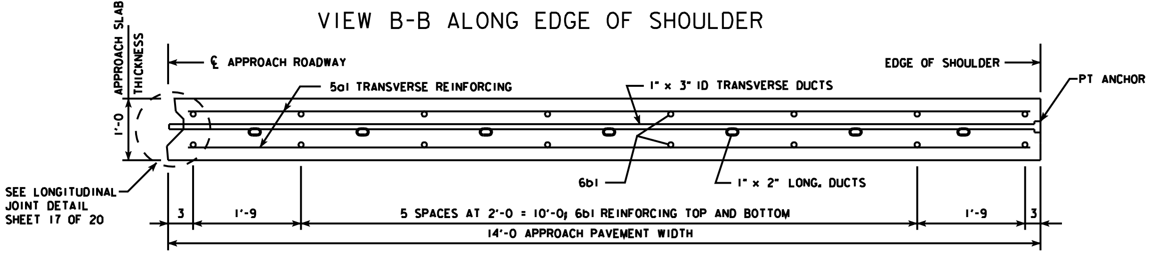
PLAN VIEW SHOWING TOP & BOTTOM MAT OF REINFORCING



PLAN VIEW SHOWING POST-TENSIONING DUCTS TRANSVERSELY AND LONGITUDINALLY



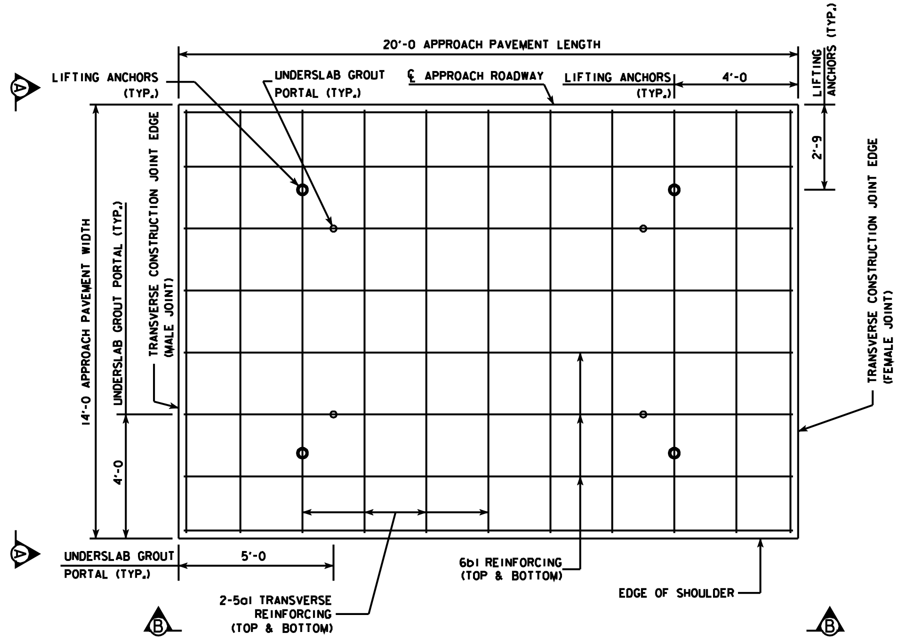
VIEW B-B ALONG EDGE OF SHOULDER



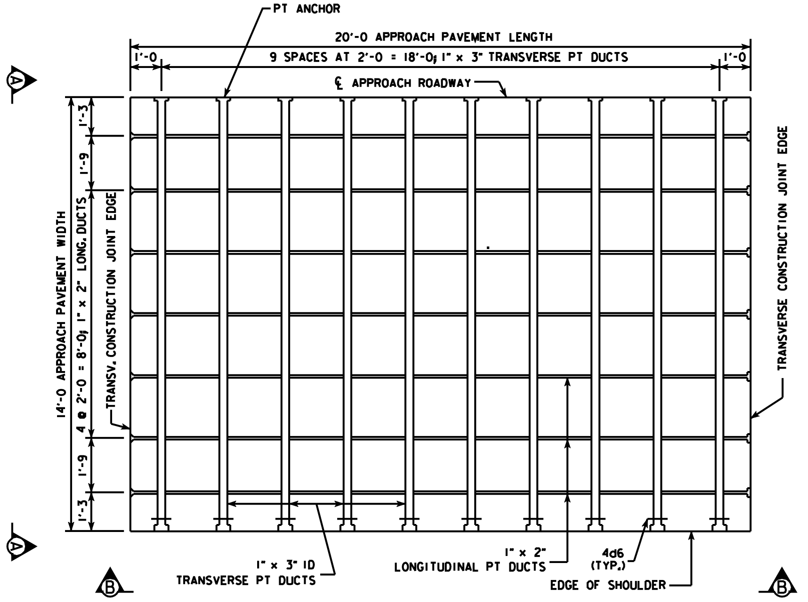
VIEW A-A ALONG TRANSVERSE JOINT

ALL REINFORCEMENT TO BE EPOXY COATED

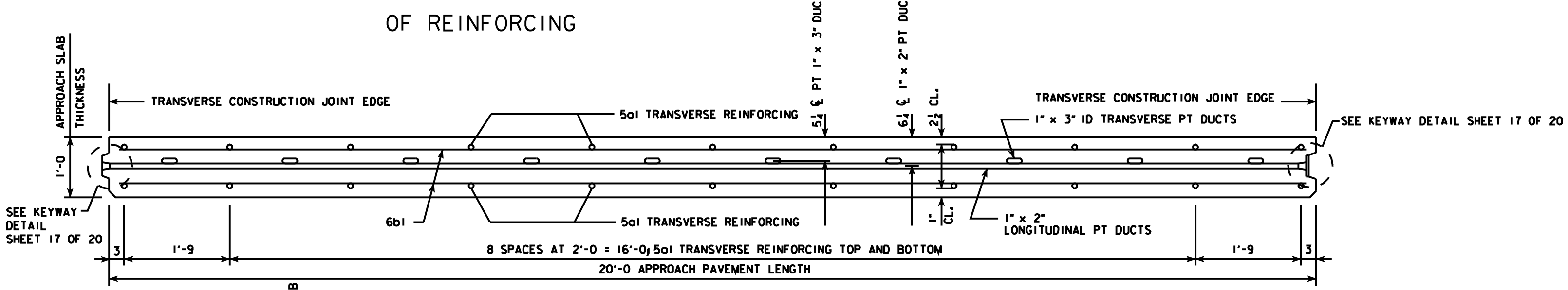
DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
SECTION UNIT 2B
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 14 OF 20 FILE NO. ________ DESIGN NO. ________



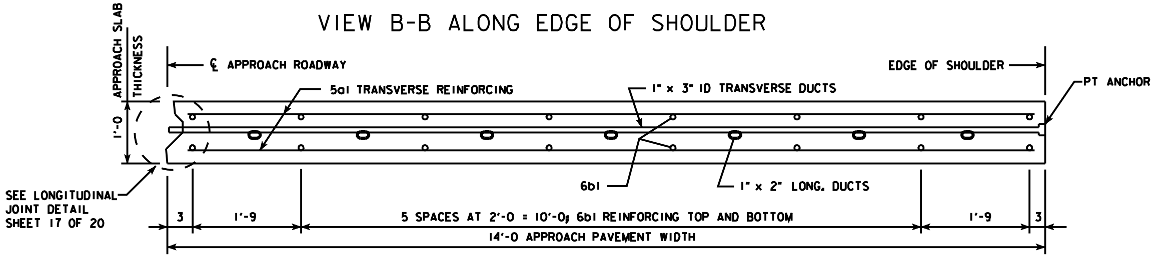
PLAN VIEW SHOWING TOP & BOTTOM MAT OF REINFORCING



PLAN VIEW SHOWING POST-TENSIONING DUCTS TRANSVERSELY AND LONGITUDINALLY



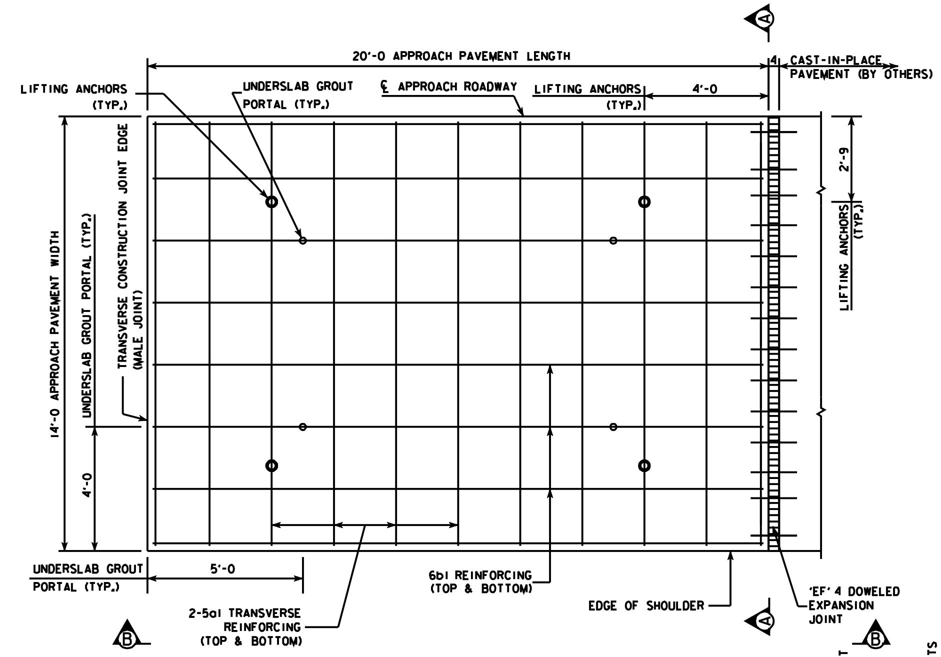
VIEW B-B ALONG EDGE OF SHOULDER



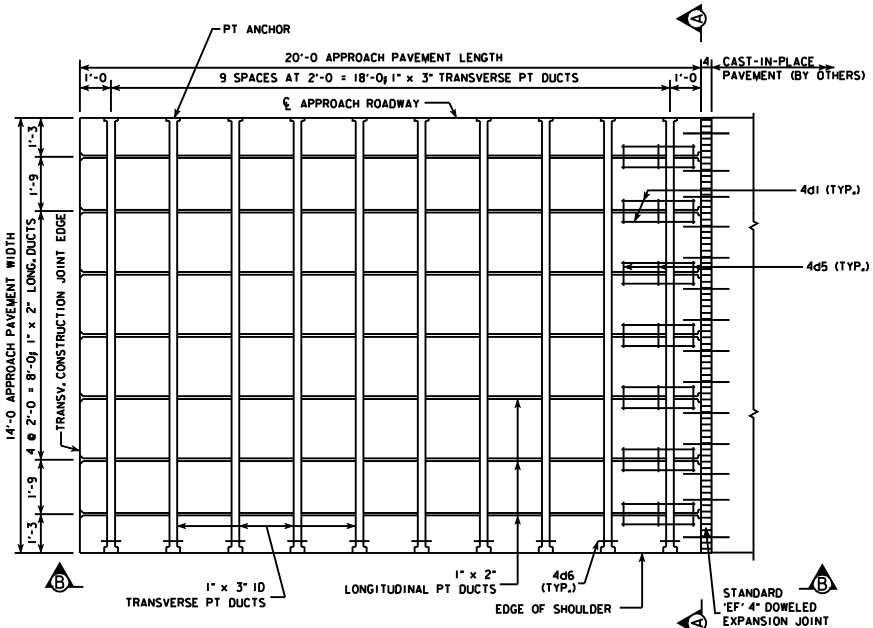
VIEW A-A ALONG TRANSVERSE JOINT

ALL REINFORCEMENT TO BE EPOXY COATED

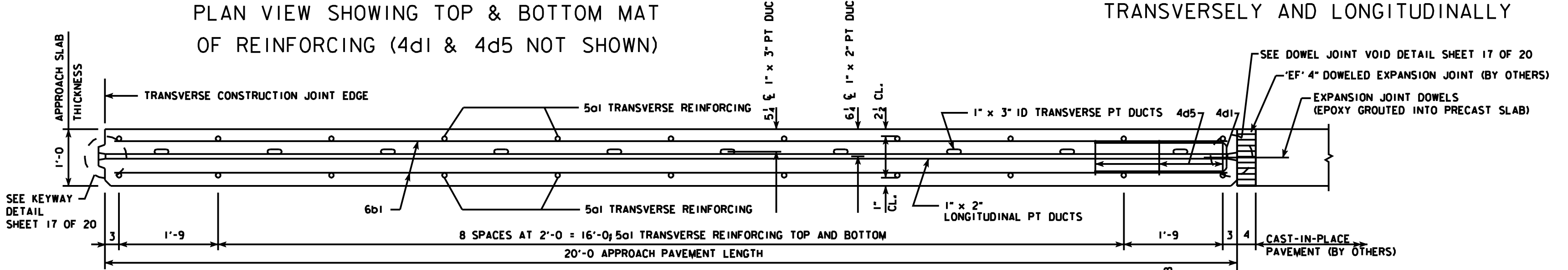
DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
SECTION UNIT 3B
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 15 OF 20 FILE NO. ______ DESIGN NO. ______



PLAN VIEW SHOWING TOP & BOTTOM MAT OF REINFORCING (4d1 & 4d5 NOT SHOWN)

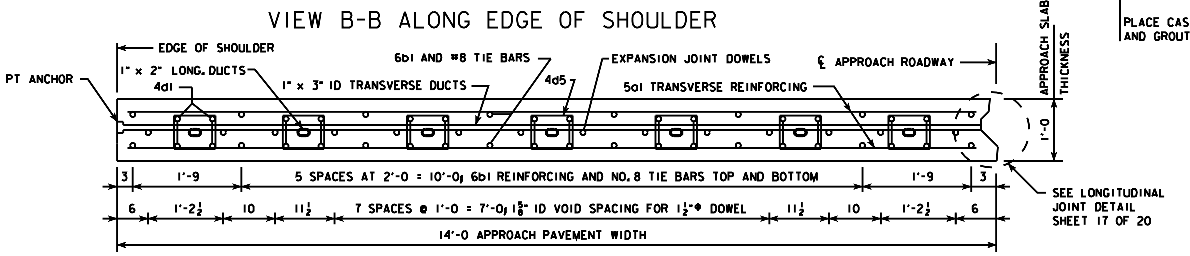


PLAN VIEW SHOWING POST-TENSIONING DUCTS TRANSVERSELY AND LONGITUDINALLY



VIEW B-B ALONG EDGE OF SHOULDER

PLACE CAST-IN-PLACE SLAB CONCRETE AFTER PRESTRESSING AND GROUTING OF DUCTS ARE COMPLETE



VIEW A-A ALONG TRANSVERSE JOINT

ALL REINFORCEMENT TO BE EPOXY COATED

DESIGN FOR

PRECAST REINFORCED CONCRETE
APPROACH PANELS

SECTION UNIT 4B

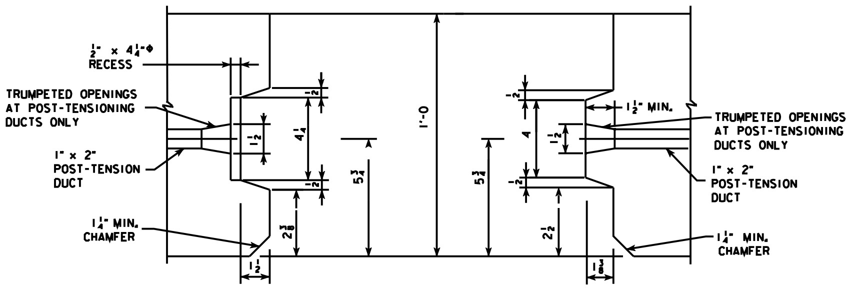
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

O'BRIEN COUNTY

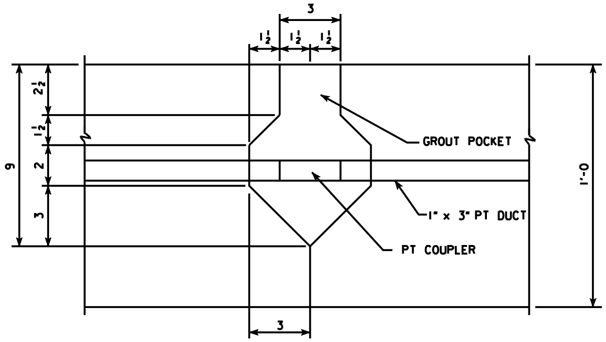
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

DESIGN SHEET NO. 16 OF 20 FILE NO. ________ DESIGN NO. ________

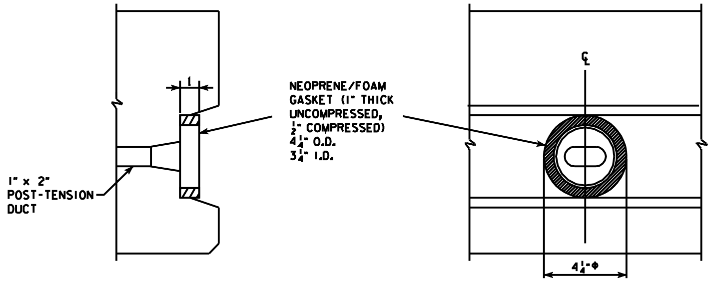
DESIGN TEAM | O'BRIEN COUNTY | PROJECT NUMBER | SHEET NUMBER



KEYWAY DIMENSIONS FOR TRANSVERSE JOINTS



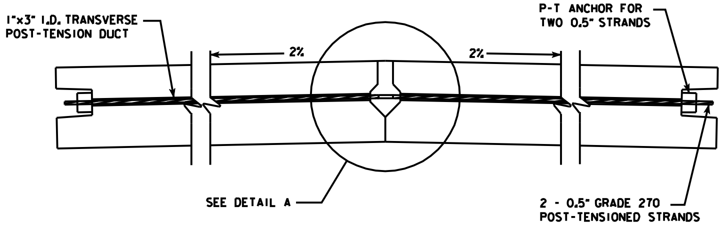
DETAIL A



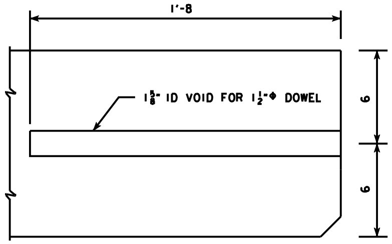
SIDE VIEW

FRONT VIEW

TENDON GASKET DETAIL FOR TRANSVERSE JOINTS



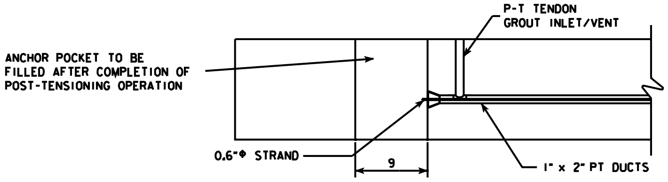
TYPICAL LONGITUDINAL JOINT



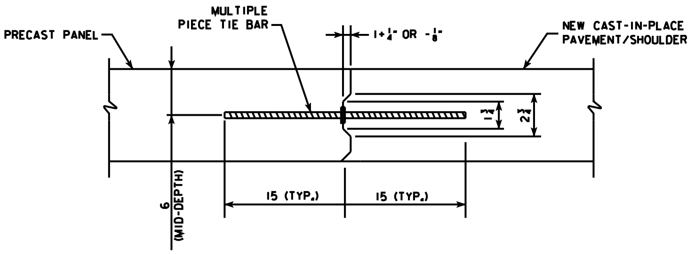
EXPANSION JOINT DOWEL VOIDS
UNITS 4A & 4B

DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS
MISC. JOINT DETAILS
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 17 OF 20 FILE NO. ____ DESIGN NO. ____

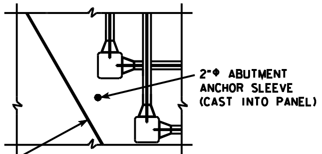
DESIGN TEAM
O'BRIEN COUNTY
PROJECT NUMBER
SHEET NUMBER



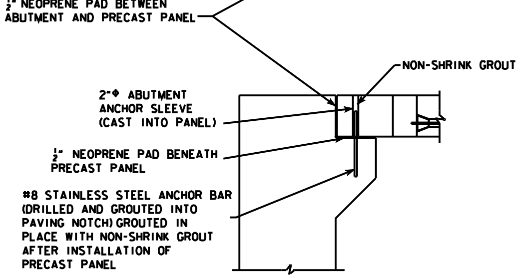
POST-TENSION ANCHORAGE DETAIL FOR
DEAD END OF STRANDS



KEYWAY DIMENSIONS LONGITUDINAL JOINTS
AT ENDS OF PRECAST PANELS



PLAN VIEW



CROSS-SECTION VIEW

DESIGN FOR
PRECAST REINFORCED CONCRETE
APPROACH PANELS

MISC. DETAILS UNIT 1A & 1B
STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006
O'BRIEN COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. 18 OF 20 FILE NO. ________ DESIGN NO. ________

REINFORCING BAR LIST - UNIT 1A

BAR	LOCATION	SHAPE	NO.	LENGTH	WEIGHT
5a1	SLAB TRANSV. TOP & BOTT.	—	26	13'-8	371
5a3	SLAB TRANSV. TOP & BOTT.	—	10	4'0 TO 11'-11	83
6b2	SLAB LONGIT. TOP	—	8	16'-9 TO 24'-6	248
8b3	SLAB LONGIT. BOTT.	—	15	16'-9 TO 24'-6	826
4d1	BLOCKOUT	⊐	28	4'-10	90
4d2	BLOCKOUT	⊔	56	3'-2	118
4d3	BLOCKOUT	▭	14	6'-1	57
5d4	2"ΦHOLE	⊃	16	3'-8	62
4d6	TRANSVERSE PT ANCHOR	▭	11	3'-5	25
5a2	SLAB TRANSV. TOP & BOTT. AT BRIDGE END	—	4	15'-9	66
	REINFORCING STEEL EPOXY COATED - TOTAL (LBS.)				1946

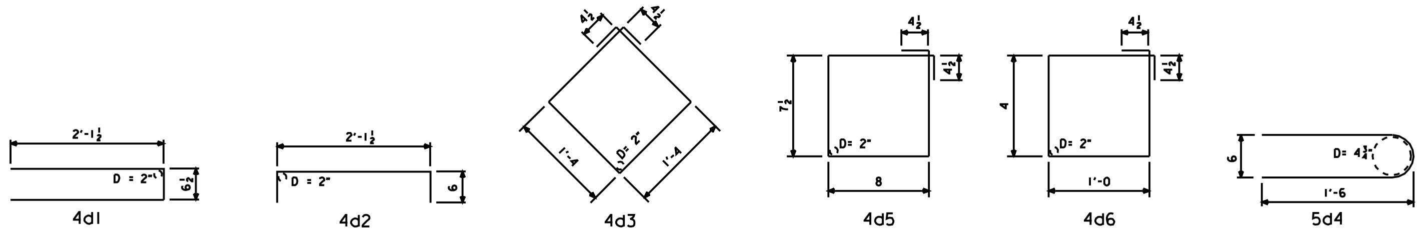
REINFORCING BAR LIST - UNIT 2A OR 3A

BAR	LOCATION	SHAPE	NO.	LENGTH	WEIGHT
5a1	SLAB TRANSV. TOP & BOTT.	—	22	13'-8	314
6b1	SLAB LONGIT. TOP & BOTT	—	16	19'-8	473
4d6	TRANSVERSE PT ANCHOR	▭	10	3'-5	23
	REINFORCING STEEL EPOXY COATED - TOTAL (LBS.)				810

REINFORCING BAR LIST - UNIT 4A

BAR	LOCATION	SHAPE	NO.	LENGTH	WEIGHT
5a1	SLAB TRANSV. TOP & BOTT.	—	22	13'-8	314
6b1	SLAB LONGIT. TOP & BOTT.	—	16	19'-8	473
4d1	LONGITUDINAL PT ANCHOR	⊐	14	4'-10	45
4d5	LONGITUDINAL PT ANCHOR	▭	21	3'-4	47
4d6	TRANSVERSE PT ANCHOR	▭	10	3'-5	23
	REINFORCING STEEL EPOXY COATED - TOTAL (LBS.)				902

BENT BAR DETAILS



NOTE: ALL DIMENSIONS ARE OUT TO OUT. D = PIN DIAMETER.

DESIGN FOR

PRECAST REINFORCED CONCRETE APPROACH PANELS

UNIT QUANTITIES 1A, 2A, 3A, 4A

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

DESIGN SHEET NO. 19 OF 20 FILE NO. ______ DESIGN NO. ______

REINFORCING BAR LIST - UNIT 1B

BAR	LOCATION	SHAPE	NO.	LENGTH	WEIGHT
5a1	SLAB TRANSV. TOP & BOTT.	—	12	13'-8	171
5a3	SLAB TRANSV. TOP & BOTT.	—	10	4'0 TO 11'-11	83
5a2	SLAB TRANSV. TOP & BOTT. AT BRIDGE END	—	4	15'-9	66
6b4	SLAB LONGIT. TOP	—	8	8'-8 TO 16'-5	152
8b5	SLAB LONGIT. BOTT.	—	15	8'-8 TO 16'-5	502
4d1	BLOCKOUT	⊐	28	4'-10	90
4d2	BLOCKOUT	⊓	56	3'-2	118
4d3	BLOCKOUT	□	14	6'-1	57
4d6	TRANSVERSE PT ANCHOR	□	4	3'-5	9
5d4	2"ΦHOLE	⊃	16	3'-8	62
	REINFORCING STEEL EPOXY COATED - TOTAL (LBS.)				1310

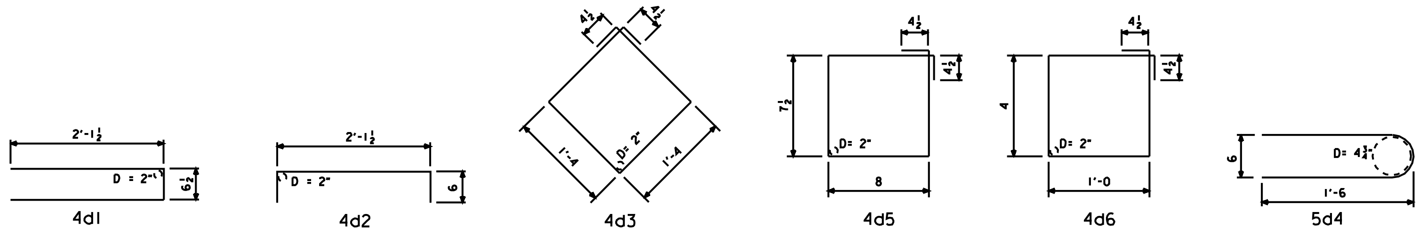
REINFORCING BAR LIST - UNIT 2B OR 3B

BAR	LOCATION	SHAPE	NO.	LENGTH	WEIGHT
5a1	SLAB TRANSV. TOP & BOTT.	—	22	13'-8	314
6b1	SLAB LONGIT. TOP & BOTT.	—	16	19'-8	473
4d6	TRANSVERSE PT ANCHOR	□	10	3'-5	23
	REINFORCING STEEL EPOXY COATED - TOTAL (LBS.)				810

REINFORCING BAR LIST - UNIT 4B

BAR	LOCATION	SHAPE	NO.	LENGTH	WEIGHT
5a1	SLAB TRANSV. TOP & BOTT.	—	22	13'-8	314
6b1	SLAB LONGIT. TOP & BOTT.	—	16	19'-8	473
4d1	LONGITUDINAL PT ANCHOR	⊐	14	4'-10	45
4d5	LONGITUDINAL PT ANCHOR	□	21	3'-4	47
4d6	TRANSVERSE PT ANCHOR	□	10	3'-5	23
	REINFORCING STEEL EPOXY COATED - TOTAL (LBS.)				902

BENT BAR DETAILS



NOTE: ALL DIMENSIONS ARE OUT TO OUT. D = PIN DIAMETER.

DESIGN FOR

PRECAST REINFORCED CONCRETE APPROACH PANELS

UNIT QUANTITIES 1B, 2B, 3B, 4B

STATION: 1429+16.67 (℄ SURVEY RELOC. IA. 60) FEBRUARY, 2006

O'BRIEN COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

DESIGN SHEET NO. 20 OF 20 FILE NO. ______ DESIGN NO. ______

APPENDIX B

Agenda from IADOT/FHWA Showcasing Workshop

U.S. Department of Transportation Federal Highway Administration

Iowa Department of Transportation

THE TRANSTEC GROUP

Iowa DOT/FHWA Showcasing Workshop

Precast Prestressed Concrete Pavement for Bridge Approach Slabs

August 31, 2006
Northwest Iowa Community College
603 W. Park St. (Building A, Room 116/119)
Sheldon, Iowa

WORKSHOP AGENDA

Moderator: Ahmad Abu-Hawash (IADOT)

10:00 a.m.	Session 1 – IADOT Perspective (*Mark Dunn, Iowa DOT*)
10:15 a.m.	Session 2 – FHWA Perspective (*Sam Tyson, FHWA*)
10:30 a.m.	Session 3 – Background of FHWA Precast Pavement Demonstration Projects (*David Merritt, Transtec*)
10:45 a.m.	Session 4 – Iowa 60 Project Details (*Dean Bierwagen, Iowa DOT*)
11:00 a.m.	Session 5 – Project Instrumentation and Monitoring (*Mike LaViolette, Iowa State University/CTRE*)
11:20 a.m.	Session 6 – Panel Fabrication Process (*Marc Lamoreux, Iowa DOT & IPC*)
11:40 a.m.	Session 7 – Construction Process (*Wayne Sunday, Iowa DOT & Dixon Construction*)
12:00 p.m.	*Lunch and Panel Discussion*
1:00 p.m.	Vans leave NCC for project site
3:00 p.m.	Vans return to NCC on the half-hour until 5:00 pm

U.S. Department of Transportation
Federal Highway Administration

Office of Infrastructure
Office of Pavement Technology
Federal Highway Administration
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Telephone: 202-366-0120
Fax: 202-493-2070
www.fhwa.dot.gov/infrastructure/pavement/concrete

FHWA-IF-07-034