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16. Abstract Full-depth, precast concrete deck panels have been heavily used in bridge construction since the 1970's. The use of these panels has traditionally been thought to both accelerate construction and improve the long-term durability performance of the bridge deck. While many engineers and academia are intrinsically aware that confined precast can perform equally or better than non-confined, cast-in-place concrete, evaluation between the two has never been studied holistically. The main objective of this project was to determine the in-service performance of full-depth, precast concrete (FDPC) deck panels compared to conventional cast-in-place (CIP) decks. The secondary objective is to determine successful and problematic details for these members. A survey was developed and distributed to state DOTs. Survey responses were used to develop the FDPC Deck Panel Database. Results from the DOT survey and analysis of the FDPC Deck Panel Database are discussed in this report.			
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Performance Comparison of In-Service, Full-Depth Precast Concrete Deck Panels to Cast-in-Place Decks

Final Report

March 2019

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The author would like to thank the Research Advisory Panel members: Ahmad Abu-Hawash (Iowa DOT), James Corney (Utah DOT), Romeo Garcia (FHWA), and Bruce Johnson (Oregon DOT).

CHAPTER 1: INTRODUCTION

1.1. Project Motivation

The use of full-depth precast concrete (FDPC) deck panels allows for accelerated construction and repair of bridge superstructures, and in some cases decreased overall project costs. These panels have been used for new construction and rehabilitation since 1965 [1]. There are several research projects that have been conducted looking into the behavior of different panel and joint details, but there is minimal published work on the performance of in-service FDPC deck panels. The last study looking at the behavior of these panels was conducted in 1995 by Issa, et al. [2]. These researchers surveyed 51 DOTs and determined 31 of them were utilizing or had utilized some type of full-depth precast deck for rehabilitation or new construction. Those responding to the survey highlighted the time savings offered by precast decks. There were some responses that noted leaking, cracking, or deterioration of the joints mainly caused by material quality or the construction procedure. This study did not compare the performance of these full-depth, precast decks with similar CIP decks. Although full-depth, precast decks have been used alongside conventional CIP decks in bridge construction since 1965, there has never been a formal study to determine if precast deck panels behave the same, better, or worse than CIP decks.

1.2. Research, Objectives, and Tasks

The primary objectives of this research project are the following:

1. Compare the long-term performance of FDPC decks to CIP decks (with similar parameters: ADT, spans, location/climates, crossing, etc.)
2. Identify successful and unsuccessful details for FDPC deck panels and joints
3. Identify owner (state DOT) perceptions of FDPC decks and determine perceived successes and challenges

These objectives were accomplished through the following research tasks.

- *Task 1 – Collection and Analysis of NBI, LTBP, and Other Available Data*: A comprehensive literature review was conducted to gather available information related to performance of in-service bridge decks. The NBI and LTBP databases were used as a starting point to understand general national trends related to bridge deck performance.
- *Task 2 – Industry Survey of Owners*: A survey was developed and administered. The survey was sent to bridge owners (state DOTs).
- *Task 3 – Determine Comparison Projects*: The objective of this task was to select the projects to be included in the performance comparison and to begin to gather information on these bridges. The project selection process incorporated the bridge selection methodology and clusters and corridors approach adopted by the LTBP Program when possible.
- *Task 4 – Collect Required Inspection Information*: The objective of this task was to collect additional information for the bridges selected during Task 3. This was limited to currently available information. It is recommended that more detailed inspections be used in the future to expand on the results presented in this report.
- *Task 5 – Analysis of Inspection Information*: The objective of this task was to analyze the results gathered under Task 4 and both quantitatively and qualitatively compare the performance of full-depth, precast decks to the similar CIP decks. Side-by-side

performance comparisons with the selected comparison projects selected in Task 3 are included in this analysis.

- *Task 6 – Design Recommendations*: Details on panel and joint design were gathered during Task 2 and Task 4. The objective of this task was to suggest panel and joint details that are performing well and are easy to assemble.
- *Task 7 – Final Report*: A final report was prepared meeting the RITA requirements for UTC funded projects. The content of the report contains a detailed summary of the results from the preceding tasks and a recommendation for future phases of the project, if necessary.

1.3. Research Advisory Panel (RAP)

The project work and the developed survey were done in collaboration with the Research Advisory Panel (RAP). The following people participated in the RAP:

- Ahmad Abu-Hawash (Iowa DOT)
- James Corney (Utah DOT)
- Romeo Garcia (FHWA)
- Bruce Johnson (Oregon DOT)

1.4. Report Overview

This report is intended to summarize the results of an extensive literature review related to FDPC and their long-term performance, the FDPC state DOT survey on use and performance, and the development and analysis of a FDPC Deck Panel Database to evaluate long-term performance. Design recommendations for FDPC deck panel systems are summarized; these are also provided in the “ABC-UTC Guide for FDPC Deck Panels” [3].

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

A significant portion of the construction or rehabilitation time is used for the forming, placement and tying of steel reinforcement, and placement and curing of concrete required for conventional cast-in-place (CIP) bridge decks. CIP decks are common because of their relatively low initial cost (without consideration for the cost of traffic delay) and because of their ability to accommodate larger differential cambers and other construction tolerances. Recent considerations for public inconvenience and loss of income for the duration of bridge construction and rehabilitation have caused the exploration of rapid construction techniques for decks. Because of this, full-depth, precast concrete (FDPC) deck panel systems have been used to replace CIP decks to enhance the speed of deck construction for both rehabilitation projects and new bridge construction [1].

FDPC deck panels have been heavily used in bridge construction since the 1960's. While they are primarily used to accelerate construction, other major advantages of FDPC deck panel systems highlighted by previous researchers include: high-quality plant production under tight tolerances, low maintenance cost, low permeability, reduced volume changes due to shrinkage and temperature effects during initial curing [1]. While many engineers and academia are intrinsically aware that confined precast can perform equally or better than tradition CIP decks, evaluation between the two has never been studied holistically.

There are several research projects that have been conducted looking into the behavior of different panel and joint details, but there is minimal published work on the performance of FDPC deck panels. Although FDPC decks have been used alongside conventional CIP decks in bridge construction since 1965, there has never been a formal study to determine if precast deck panels behave the same, better, or worse than CIP decks.

An overview of available literature, previously conducted research, and other resources related to FDPC deck panels is presented in this chapter. FDPC panels are first introduced along with lists of previously completed bridge projects utilizing these panels from the PCI State-of-the-Art Report on FDPC bridge deck panels [4] and the ABC Project Database [5]. Some of the commonly used details from these projects are then summarized.

Next, several of the available resources that collect data on the long-term performance of bridges are summarized. These resources include the National Bridge Inventory (NBI) [6], the Long-Term Bridge Performance (LTBP) InfoBridge (previously the LTBP Portal) [7], and a collection of lessons learned reports from Utah DOT [8]–[12].

2.2. Full-Depth Precast Deck Panels

2.2.1. Introduction

Various types of full-depth precast concrete (FDPC) bridge panel systems have been developed and used during the past 50 years. A summary of the documented bridge projects using FDPC deck panels is provided in this section followed by a summary of some of the previously used details.

2.2.2. Successful Projects

There are many projects that have utilized full-depth precast deck panels with a variety of different details. The projects listed and described in this section were obtained from two primary sources: (1) ABC-UTC Project Database [5] and (2) "State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels" [4].

A list of successful projects is given in the appendix of the PCI State-of-the-Art Report [4]. These projects are summarized in Table 2.1. Several different characteristics are provided for each bridge including:

- State/County
- Year completed
- Type of construction: rehab/new
- Beam type (i.e. superstructure type)
- Total bridge length/width
- Span length
- Skew/curvature/super-elevation
- Panel details (thickness, width, length)
- Material properties (concrete weight/strength, strand type/strength)
- Jacking stress / effective stress after losses
- Joint type/shear pocket details
- Transverse post-tensioning

Only some of these characteristics are included in the below table; additional details on the bridges can be obtained from the PCI report. Most of the connection details used were female-to-female joints with post-tensioning.

Table 2.1: List of successful projects from PCI [4]

	Bridge Name	State	Year Completed	Rehab/ New	Beam Type	Total Bridge Length	Span Length
1	Pintala Creek Bridge	Alabama	Pre 1973	New			4 @ 34’
2	Chulitna River Bridge	Alaska	1992	Rehab	Steel trusses & stringers	790’	
3	No. 1257 – South Fork Bonanza Creek Bridge	Alaska	1992	Rehab	Steel, Timber	90’	1 @ 59’-7”, 1 @ 30’
4	No. 1439 – Atigun River No. 1 Bridge	Alaska	1992	Rehab	Timber	90’	3 @ 30’
5	CA-17 High Street Overhead Separation Bridge	California	1978	Rehab	Rolled steel	1750’	32 spans @ 30’ to 76’
6	Oakland-San Francisco Bay Bridge	California	1961	Rehab	Cable-stayed / Steel Truss		
7	Waterbury Bridge 03200	Connecticut	1989	Rehab	Steel plate girder	700’	
8	Milford Montague Toll Bridge	Delaware			Truss, steel stringer	1150’	2 @ 275’, 2 @ 300’
9	Seneca Bridge	Illinois	1986	Rehab		1510’-3”	9@60’, 2@202’-1 3/8”, 1@364’-4”, 1@201’-9”

	Bridge Name	State	Year Completed	Rehab/ New	Beam Type	Total Bridge Length	Span Length
10	Structure No. 048-0059	Illinois		Rehab	Rolled Steel		2 @ 43.3’, 2 @ 67.6’
11	Structure No. 100-0039	Illinois		Rehab	Rolled Steel		2 @ 43.3’, 2 @ 83.2’
12	US-24 Bayview Bridge over the Mississippi River	Illinois / Missouri		Rehab	Cable-stayed, steel stringers, welded girders		2 @ 200’, 2 @ 400’, 1 @ 900’
13	Bean Blossom Creek Bridge	Indiana			Truss		8 @ 125’
14	Big Blue River Bridge	Indiana			Rolled steel	200’	2 @ 70’, 1 @ 60’
15	Burlington Cable Stayed Bridge	Iowa / Illinois	1994	New	Steel	1065’	1 @ 660’, 1 @ 405’
16	Deer Isle-Sedgwick Bridge over Eggermoggin Reach (Project No. BH-0250)	Maine	1987	Rehab	Rolled shapes		6 @ 65’, 2 @ 282’, 1 @ 1080’
17	William Preston Jr. Memorial Bridge over the Chesapeake Bay	Maryland		Rehab			
18	Chicopee River Bridge	Massachusetts	1984	Rehab	Plate girder	837’	
19	Connecticut River Bridge	Massachusetts				1224’	224’

	Bridge Name	State	Year Completed	Rehab/ New	Beam Type	Total Bridge Length	Span Length
20	Amsterdam Interchange Bridge	New York	1974	Rehab	Steel		1 @ 33', 1 @ 59', 1 @ 66', 1 @ 60'
21	Batchellerville Bridge	New York	1982	Rehab			3075
22	Bridge No. 1 – Kingston Bridge on Wurtz Street Over Roundout Creek	New York		Rehab	Suspension bridge with steel stringers	1100'	700'
23	Bridge No. 6 – Over Delaware River	New York	1978		Steel truss, rolled stringer	675'	
24	Cochecton Bridge Over Delaware River	New York		Rehab	Steel truss	675'	
25	Harriman Interchange Bridge	New York		Rehab	Steel	75'	
26	Kosciuszko Bridge	New York	1971	Rehab	Rolled steel		
27	Krumkill Road Bridge	New York	1977	Rehab	Steel	50'	
28	Route 155 Bridge over Normanskill State Highway 1928	New York	1972	Rehab			
29	Southwestern Blvd. Bridge over Cataraugus Creek	New York	1979		Truss, steel stringer	550'	
30	Vischer Ferry Road Bridge	New York		Rehab	Steel		

	Bridge Name	State	Year Completed	Rehab/ New	Beam Type	Total Bridge Length	Span Length
31	Dublin 0161 Bridge	Ohio	1986	Rehab	Concrete arch		2 @ 73’, 2 @ 95’, 2 @ 100’
32	Welland River Bridge	Ontario, Canada		Rehab	Rolled steel		1 @ 48’-9”, 2 @ 48’
33	Freemont Street Bridge	Pennsylvania	1984	Rehab	Reinforced concrete, no stringers	300’	
34	NB-216 Quakertown Interchange Bridge	Pennsylvania		Rehab			
35	NB-750 Clark Summit Bridge	Pennsylvania	1980	Rehab		1627’	
36	A.T. & S.F. Railway Overpass	Texas		Rehab	Rolled steel		50’
37	Route 229 Bridge Over Big Indian Run	Virginia	1985	Rehab	Rolled steel	54’-6”	
38	Route 235 Bridge Over Dougue Creek	Virginia	1982	Rehab	Rolled Steel		4 @ 38’
39	Route 7 Westbound over Route 50	Virginia	1999	Rehab	Steel plate girder	110’	
40	Woodrow Wilson Memorial Bridge	Virginia / Maryland	1983	Rehab	Steel girder rolled stringers	5,900’	
41	Route 7 Eastbound over Route 50	Virginia	1999	Rehab	Steel plate girder	138’	

Additional bridges utilizing FDPC deck panels can be found in the ABC Project Database [5]. These bridges are separated into two different categories that were developed by the AASHTO T-4 Construction Committee: (1) Full-Depth Precast Deck Panel w/PT and (2) Full-Depth Precast Deck Panel w/o PT. These bridges are listed in Table 2.2 along with the state the bridge is in and the year the ABC portion of the bridge was constructed.

Table 2.2: List of projects from ABC Project Database [5]

	Bridge	State	Year
Full-Depth Precast Deck Panel w/PT			
1	TH 53 Bridge over Paleface River	MN	2012
2	Lake Champlain Bridge	NY	2011
3	I-93 Bridge over Loudon Road (Route 9)	NH	2010
4	I-70 Bridge over Eagle Canyon (Eastbound)	UT	2010
5	24th Street Bridge over I-29/I-80	IA	2008
6	US 131 / Parkview Avenue Bridge	MI	2008
7	Riverdale Road Bridge over I-84	UT	2008
8	Mackey Bridge (Marsh Rainbow Arch Bridge)	IA	2006
9	Nemo Bridge	MO	2004
10	Illinois Route 29 Bridge over Sugar Creek	IL	2001
11	Dead Run and Turkey Run Bridges	VA	1998
Full-Depth Precast Deck Panel w/o PT			
1	Broadway Bridge over Little Timber Creek*	NJ	2012
2	Burnt River & UPRR Bridge	OR	2012
3	I-84 Bridge F-114	UT	2011
4	SH 290 Bridge over Live Oak Creek	TX	2008
5	Grayling Creek Bridge	AK	2006
6	Lewis and Clark Bridge	WA	2004
7	Kouwegok Slough Bridge	AK	2000

*Broadway Bridge over Little Timber Creek only used FDPC deck panels in a temporary expansion

The bridges contained in the ABC Project Database have detailed summary sheets and available resources that include information about:

- Bridge project name

- Description of location
- State where bridge is located
- Coordinates of bridge (latitude and longitude)
- Bridge owner
- Year ABC component of bridge was built
- ID number (both State and National Bridge Inventory)
- Point of contact (generally the bridge owner)
- Mobility impact time (construction time savings using ABC)
- Impact category (Tier 1 through 6 based on total time of impact)
- Benefits of ABC
- Bridge information (length, spans, construction materials, ADT, etc.)
- Existing bridge description
- Replacement bridge description
- Construction methods description
- High performance materials used
- ABC aspects related to:
    - Planning
    - Geotechnical solutions
    - Structural solutions
- Costs
- Funding
- Incentive programs

The available resources that may be available for each project include:

- Photos
- Contract plans
- Specifications
- Bid tabs
- Schedule
- Other related information, including articles and other publications, URLs, etc. [13]

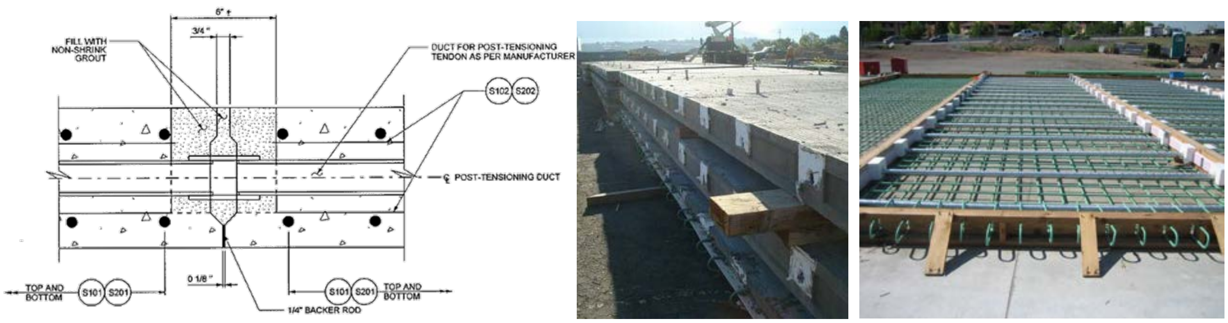
This list of bridges and these available resources were used throughout this project.

2.2.3. Previously Used Details

Plans, construction documents, and photos were obtained for many of the projects listed above. Commonly used details and other observations from the review of these projects are summarized in this section.

2.2.3.1. Post-Tensioned Details

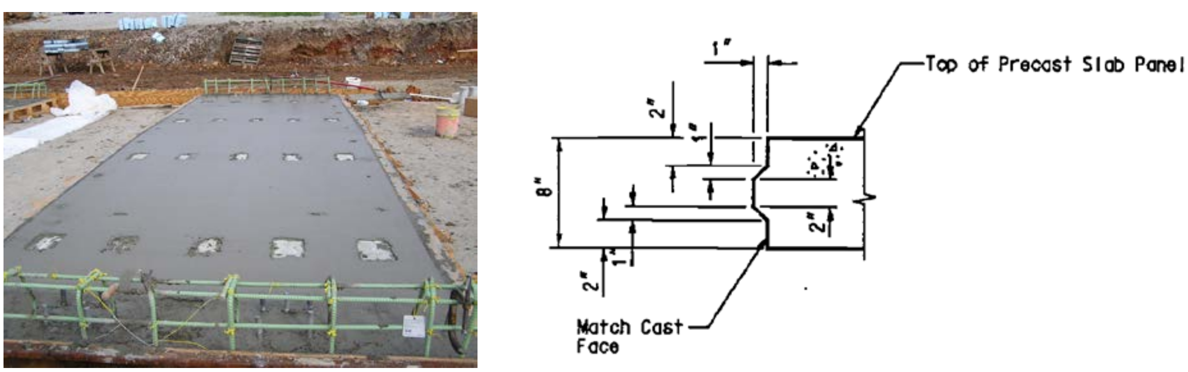
Most of the bridges in these two databases used female-to-female connections with longitudinal post-tensioning, as shown in Figure 2.1. For these details, grout was used to fill the gap between panels prior to post-tensioning and ducts were grouted after post-tensioning.



(a) (b) (c)

Figure 2.1: Typical longitudinal post-tensioned (a) detail, (b) finished panel, and (c) reinforcing cage as demonstrated in the Riverdale Road Bridge over I-84 (Utah, 2008) [5]

There was one instance of a male-to-female match-cast connection detail. For this detail, epoxy was applied to the joint prior to placement and post-tensioning of the panels. Details for this section are shown in Figure 2.2.

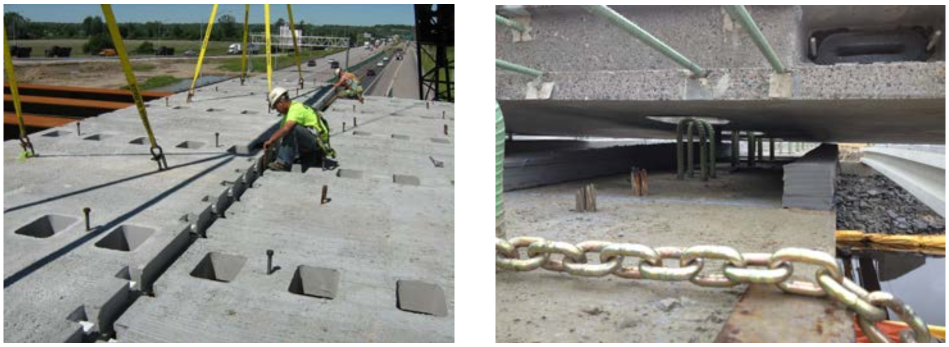


(a) (b)

Figure 2.2: Example of match cast full-depth precast deck panel detail used with post-tensioning: (a) panel being matched cast next to adjacent panel and (b) detail used in Nemo Bridge (Missouri, 2004) [5]

The post-tensioning was achieved by either strands or high-strength steel bars in ducts through the deck panels. These ducts were typically spliced together using duct tape or heat shrink wrap. Ducts were always grouted after post-tensioning.

Pockets were cast in all the deck slabs to allow for the shear studs from the beams to extend into the deck panels, thus achieving composite behavior. Shear studs were typically grouped to allow for fewer pockets in the slabs. This detail is shown in Figure 2.3.



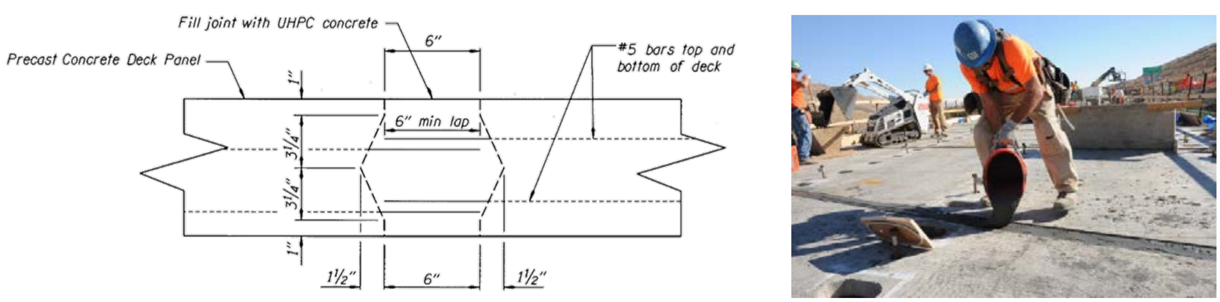
(a) (b)

Figure 2.3: Common shear pockets used to create composite action between beams and deck; shear studs grouped improve constructability used in (a) 24th Street Bridge over I-29/I-80 (Iowa, 2008) and (b) TH 53 Bridge over Paleface River (Minnesota, 2012) [5]

Using transverse or longitudinal post-tensioning puts the panel-to-panel joints under compression, which helps to mitigate any tensile stresses that may result from live loads. Post-tensioning may increase the cost of the deck construction, especially if a qualified contractor is required. Additionally, a lack of practical quality control procedures related to splicing and grouting the post-tensioning ducts may allow corrosion of the longitudinal post-tensioning reinforcement to occur [1]. These concerns have prevented some state DOTs from using FDPC deck panel systems on their bridges and have encouraged the development of non-post-tensioned joint details.

2.2.3.2. Non-Post-Tensioned Details

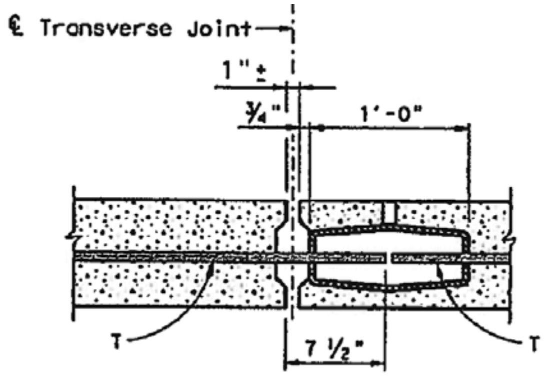
The other category of connections between panels does not use transverse or longitudinal post-tensioning. The two joints used in most of these bridges are shown in Figure 2.4 and Figure 2.5. The first common joint detail uses a non-contact splice and ultra-high performance concrete (UHPC), shown in Figure 2.4. UHPC has high tensile strengths that enable the joint reinforcement to develop in a short distance allowing for smaller joint widths.



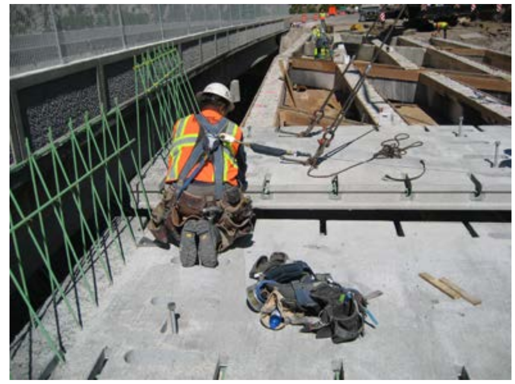
(a) (b)

Figure 2.4: (a) Typical joint detail and (b) pouring of UHPC in joint from the Burnt River and UPRR Bridge (Oregon, 2012) [5]

The other joint that was used for some of the bridges in the database was developed under National Cooperative Highway Research Program (NCHRP) Project 12-65, "Full-Depth, Precast-Concrete Bridge Deck Panel Systems" [1], as shown in Figure 2.5. This connection detail utilizes a galvanized bulged HSS 4x12x3/8 cast at the edge of one panel at a joint.



(a)



(b)

Figure 2.5: Joint detail developed in NCHRP 12-65 used in (a) SH 290 Bridge over Live Oak Creek and (b) I-84 Bridge F-114 (Texas, 2008) [1]

This joint requires that the reinforcement from adjacent panels be slid into the pocket formed by the HSS member, as shown in Figure 2.6. After the placement of the panel, all the pockets and connection are grouted.

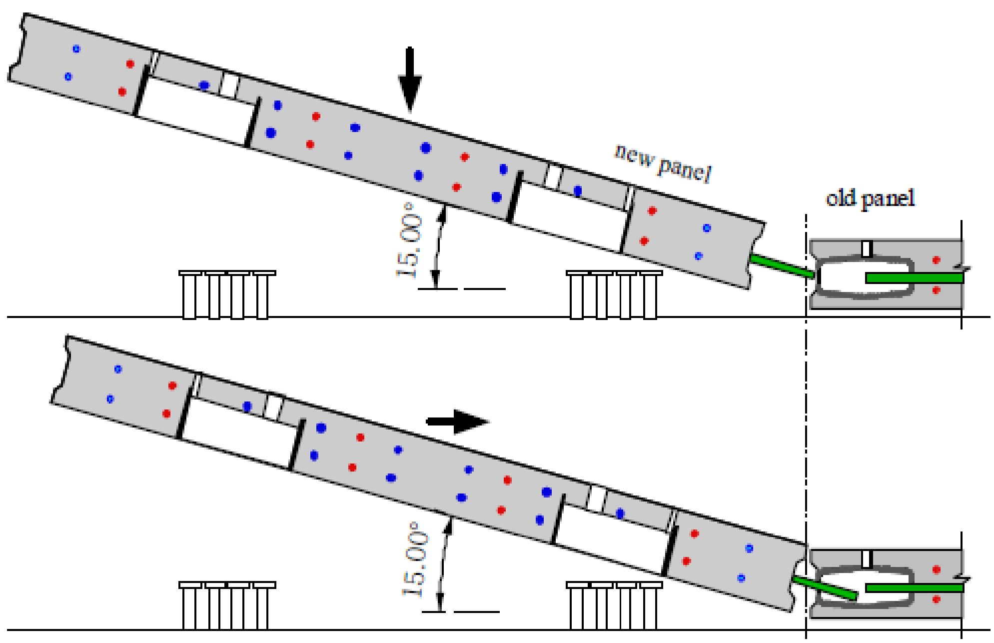


Figure 2.6: Installation of a new panel using NCHRP 12-65 connection (partial figure from [1])

2.2.3.3. Use of Overlays

Bridge decks of any kind are often given additional corrosion protection using overlays. Overlays are also used for aesthetics (by hiding the difference in color between joint and deck) and to improve the riding quality. However, using an overlay reduces the construction speed of the deck and raises the cost of the system [1]. Some of the bridges provided in the two databases have overlays and some do not. The use of overlays will be noted when evaluating the performance of the deck systems in the future stages of this project.

2.3. Previous Investigation on FDPC Deck Panel Use and Performance

There have been several past studies investigating the short-term performance of FDPC deck panels, but few have been related to the long-term performance of these decks. The last investigations focused on the use and performance of FDPC deck panels were conducted in the early 1990's by Issa et al. [2] and Issa et al. [14]. This research effort involved two primary components: (1) a state survey [2] and (2) inspection of several FDPC deck panel bridges [14].

In the first study [2], a state survey was developed and distributed to all state departments of transportation (DOTs) in the U.S. and Ontario, Canada. The objectives of the study were to document various application of precast panels and to evaluate the stability, durability, and performance of precast panels exposed to the harsh environmental condition. Thirteen DOTs had experience using FDPC deck panels in constructions. Some of these states provided detailed information in their responses including: the type of construction and number of bridges using FDPC, deck and panel dimension, joint type, bonding material in joints, observed defects and protection system. The researchers concluded that FDPC deck panels (1) allowed for accelerated construction and less impact to traffic and (2) improved durability and reduced maintenance.

The researchers used the results of the survey to identify bridges with FDPC deck panels for further investigation and visual inspection. Issa et al. [14] reported the results of visual inspections conducted on over 35 bridges with FDPC deck panels in Illinois, Connecticut, Virginia, Iowa, California, New York, Alaska, Ohio, and Pennsylvania. The focus of these inspections was on the performance of the panels, shear stud connection details, and the joints between the panels. Several of the key conclusions are summarized below:

1. FDPC deck panels have generally an excellent performance record; poor performance is generally due to poor performance of the connection between panels
2. Female-to-female connections are preferred to tongue-and-groove connections due to issues with grouting leading to joint leakage
3. Transverse pretensioning and longitudinal post-tensioning are recommended to avoid cracking during handling of the panels and to keep the joints in compression (respectively)
4. An overlay is strongly recommended to enhance long-term performance and improve riding surface
5. Fewer problems were observed in bridges with precast concrete superstructures (compared to steel superstructures) due to less flexibility
6. Low ADT roads generally did not experience any issues

The results from this study will be used to help guide the work of this project.

2.4. National Bridge Inventory (NBI)

The primary focus of this project is on the long-term performance of bridge decks: FDPC deck panels and CIP decks. There are several databases and resources available to help in determining the long-term performance of bridges and bridge components, which will be the focus of the following sections.

The National Bridge Inventory (NBI), compiled by the Federal Highway Administration (FHWA), is a database containing information on all the federal, state, county, city, and privately-owned bridges over 20 feet in length and used for vehicular traffic in the U.S. The NBI was created as a means of tracking the condition and other pertinent information for all the over 600,000 bridges in the U.S. The data contained in the NBI is openly available on the FHWA website.

The NBI contains information including identification information, bridge types and specifications, operational conditions, bridge data including geometric data and functional description, and inspection data [15]. NBI reports also contain structural condition ratings of decks, superstructures, and substructures [6]. This data is often used to analyze bridges and judge their conditions.

The structural evaluation of deck, superstructures, substructures, and culverts are judged on a 0-9 scale, as shown in Table 2.3. These ratings vary from “superior to present desirable criteria,” which is only generally given to newly constructed bridges or bridge components, to “bridge closed.”

Table 2.3: Bridge rating criteria used in NBI [15]

Rating	Rating Description
9	Superior to present desirable criteria
8	Equal to present desirable criteria
7	Better than present minimum criteria
6	Equal to present minimum criteria
5	Somewhat better than minimum adequacy to tolerate being left in place as is
4	Meets minimum tolerable limits to be left in place as is
3	Basically intolerable requiring high priority of corrective action
2	Basically intolerable requiring high priority of replacement
1	This value of rating code not used
0	Bridge closed

During a typical NBI bridge inspection, the following components are evaluated based on the above rating system:

- Deck
  - Surface
  - Expansion Joints
  - Other Joints
  - Railings
  - Sidewalks or Curbs

    - Deck Bottom Surface
    - Deck
    - Drainage
- Superstructure
    - Stringer
    - Piers
    - Section Loss
    - Bearings
- Substructure
    - Abutments
    - Piers
    - Slope Protection
    - Channel
    - Scour Inspection
- Approach
    - Approach Pavement
    - Approach Shoulders and Sidewalks
    - Approach Slopes
    - Utilities
    - Drainage Culverts

The ratings for all the individual components are then used to give an overall rating for the bridge structure and a recommendation for operational status or need for repair. Notes are also generally made for each of the components to help and explain the ratings given. While these notes are contained in the visual inspection report, only the number ratings are input into the NBI.

There are numerous research projects that have been conducted using the NBI database as a source of information for studying the performance of bridges. The topics of some of these studies include: prediction of the future condition of bridge component [16], estimating inspection intervals for bridges [17] and development of deterioration model for bridges [18]. The NBI can also be used within a Geographic Information System (GIS) for geospatial display or analysis. The results of the map-based inventory provide a resource for relationship analysis.

One relevant study, conducted by Chase, et. al [18], used the NBI database, GIS, and advanced statistical methods to create a deterioration model for bridges. These researchers applied three different regression methods to model the relationship between state conditions and factors causing deterioration. The most important variables in this study were age, average daily traffic (ADT), precipitation, frequency of deicing, freeze and thawing cycles and type of bridge construction. Deck, superstructure and substructure deterioration models were developed and compared to actual element condition data. Linear deterioration models were found to best predict deterioration [18].

Another research effort conducted by Nasrollahi and Washer [17] used NBI data to investigate the frequency of bridge inspections. The typical interval for bridge inspection is 24 months. This uniform inspection interval may not be suitable for all bridges; some are in good condition and need less frequent inspection than bridges with damage and deterioration. Determining the frequency of inspection for bridges and bridge components based on NBI data allows for a statistically-based bridge management plan and optimal assignment of available inspection funding. These researchers conducted a statistical analysis of the historical condition data collected from 20 years of routine inspections to determine time-in-condition ratings (TICR) for bridge components. These ratings were used to determine the deterioration of components and then recommendations for frequency of inspection.

These two studies show how data available in the NBI has previously been used in bridge management research.

2.5. Long-Term Bridge Performance Program (LTBP)

2.5.1. Overview

The Long-Term Bridge Performance (LTBP) Program is one of the largest bridge research programs ever undertaken by the Federal Highway Administration (FHWA). The overall goal of the program was to enable the bridge community to better design, construct, and maintain the nations' bridges using data-driven tools and quantitative predictive models. The LTBP Program required the involvement of the entire bridge community (owners, consultants, and industry) to develop the roadmap for the program [19].

The LTBP Program set out to address the following questions:

- How should similar bridges be grouped (what characteristics were distinguishing)?
- Which specific bridges should be monitored?
- What variables should be monitored and what information should be collected?
- How should uniformity of the data collection and summarization be ensured, recognizing the number of different entities involved?

The following sections give a brief overview of some of the significant components of the LTBP Program relevant to this project:

- **Clusters and Corridors**: procedure for grouping bridges together
- **LTBP Protocols**: protocols and procedures to be followed before, during, and after inspections
- **LTBP InfoBridge**: repository where all bridge information is stored and accessed

2.5.2. Clusters and Corridors

The FHWA LTBP Program staff, along with their contract staff and advisors (TRB Oversight Committee and AASHTO COBS), had the following goals for the program [19]:

- Determined high priority areas that were most concerning to bridge owners, such as bridge deck, bearing, joints, and coating systems;
- Determined which bridge systems, subsystems, and components were most critical (failure frequency and performance severity);
- Determined which group of bridges (clusters) should/could be combined for developing necessary data for development of deterioration models and necessary decision-making tools that would consider risk and reliability;
- Determined the appropriate non-destructive tests that should be performed to develop necessary data for later developing deterioration models and other decision tools; and
- Developed an approach to ensure uniformity of collecting data in the form of developing protocols.

The first challenge associated with addressing these above tasks was to determine a system for grouping the bridges. The grouping system, called the "Clusters and Corridors" approach, aims to group bridges based on:

1. **Type of bridge**: specifically including steel multi-girder, pre-stressed concrete multi-girder, and pre-stressed/post-tensioned concrete box girder
2. **Climate**: climate zones from the Department of Energy (DOE) are used

3. **Concentrated geographic areas**: clusters of bridges close to each other are selected to make data collection more cost-effective
4. **Traffic**: average daily traffic (ADT) and average daily truck traffic (ADTT)

The grouping allows for bridge performance to be compared in a few main ways. First, the general performance of different bridge types in different regions can be compared. This would allow users to identify critical bridge types and locations to best allocate resources. The performance of similar bridges under similar conditions could also be compared. This would allow for a comparison of component or detail performance, which is of interest for this project.

The LTBP program determined the most common bridges in the United States are: (1) steel multi-girder, (2) pre-stressed concrete multi-girder, and (3) pre-stressed/post-tensioned concrete box girder. They defined 14 clusters based on the regions with high concentration of these three major bridges type, as shown in Figure 2.7.

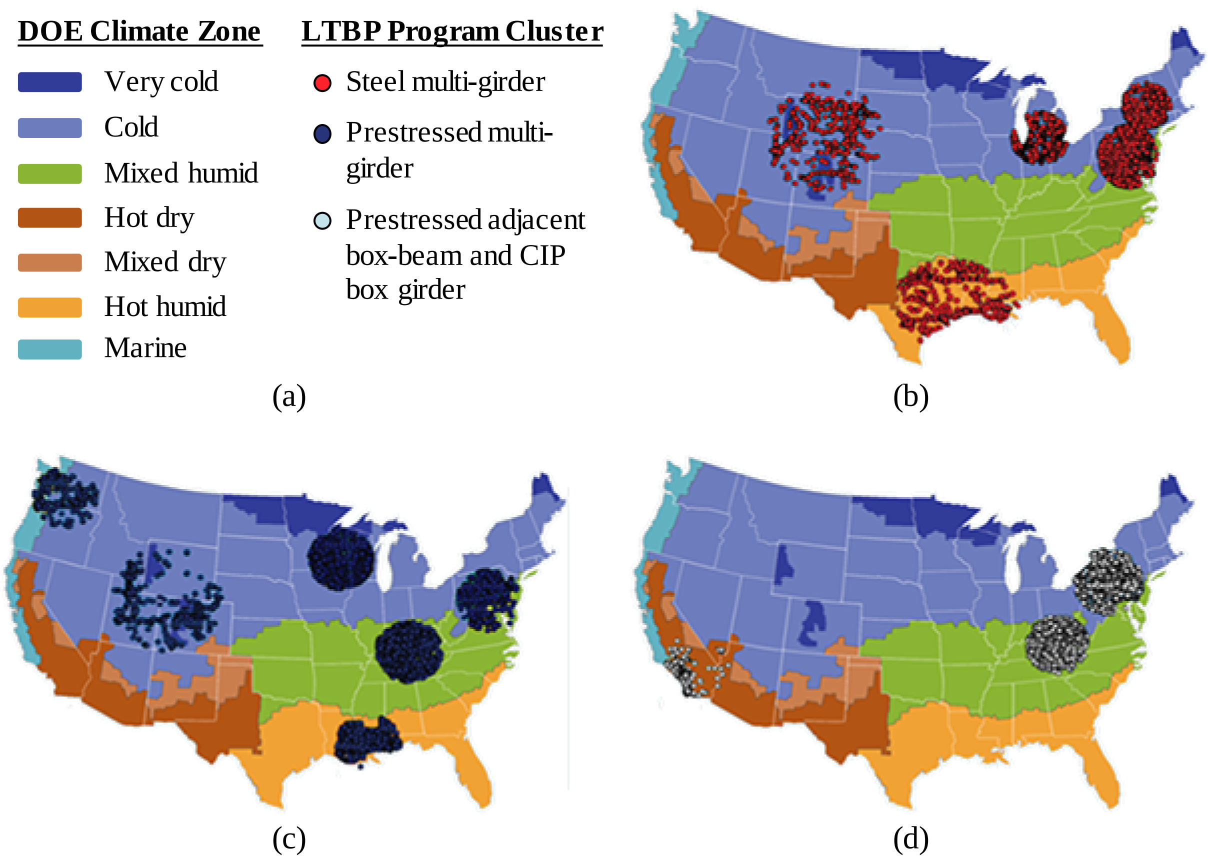


Figure 2.7: Clusters defined by LTBP Program: (a) legend, (b) steel multi-girder, (c) pre-stressed multi-girder, and (d) pre-stressed adjacent box-beam and CIP box girder (based on figures from [19])

These clusters were identified according to region and superstructure type, as shown in Table 2.4.

Table 2.4: Clusters defined by LTBP Program

Superstructure Type (# Clusters)	Cluster Regions/Types
Steel Multi-Girder (5)	Northeast, Mid-Atlantic, East Central, Gulf Coast, Rocky Mountain
Pre-stressed Multi-Girder (6)	Mid-Atlantic, East Central, Midwest, Gulf Coast, Rocky Mountain, Northwest
Concrete Box Girder (3)	Mid-Atlantic (Adjacent Box Beam), East Central (Adjacent Box Beam), Southwest (CIP PT Box Girder)

The LTBP Program also defined ten existing interstate highway alignments as corridors, as shown in Figure 2.8 and Table 2.5.

Table 2.5: Ten corridors defined by LTBP Program

Corridor Direction	Corridor Interstate Route
East-West	I-40, I-70, I-80, I-90, I-94
North-South	I-5, I-15, I-29, I-35, I-95

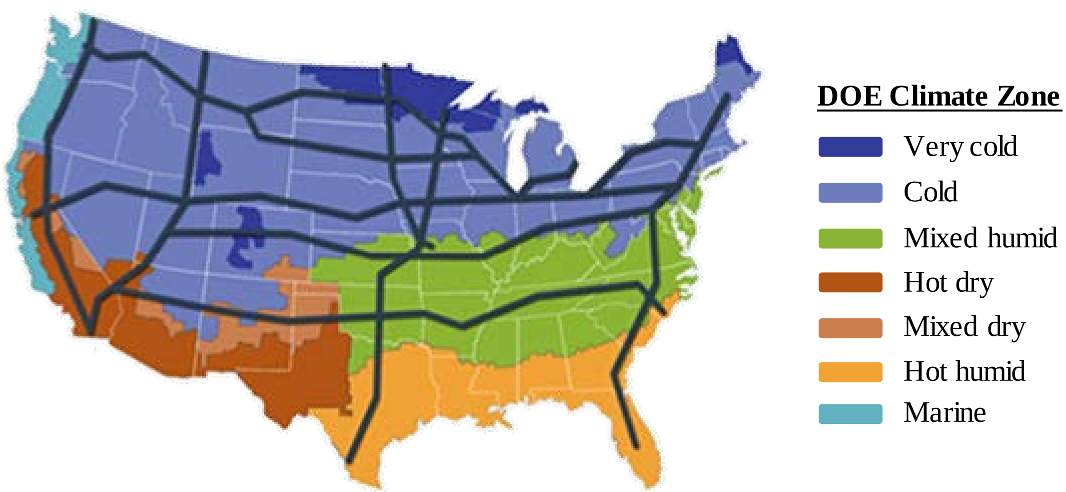


Figure 2.8: Map of interstate corridors included in the LTBP Program [19]

The above defined climate zones, structure types, clusters, and corridors were used in the LTBP Program to select an appropriate group of bridges for study and investigation.

2.5.3. Protocols

LTBP protocols were developed to normalize data collections and storage before a field visit, during a field visit, and after a field visit [20]. These protocols help to determine what kind of information should be collected from reports and available documents and provide instructions for field investigation and tests on bridges. They also contain detailed information on how to identify defects and document their severity on bridge elements.

The first three levels of the proposed hierarchy are:

- Pre-visit protocols (PRE),
- Field visit protocols (FVP), and
- Post-visit protocols (PST).

These protocols are summarized below.

2.5.3.1. Pre-visit Protocols (PRE)

The pre-visit protocols (PRE) cover preparations that are necessary before data collecting at the bridge. The pre-visit protocol gives guidance on bridge selection, recommendations for extracting data from available sources and also preliminary planning for a successful field data collection. Secondary levels of this protocol include [20]:

- **Sampling and Selection (SS)**: define design experiments and sampling algorithms
- **Existing Documentation (ED)**: define information to be collected from different sources like design and engineering documents, inspections records, maintenance history and any other useful documents containing data related to bridge and how data can be used to draw a conclusion before or after field test on specific performance issues
- **Equipment (E)**: includes equipment related to structural testing such as sensors and data acquisition systems; there are specific protocols related to each type of structural testing, including truck testing, long-term monitoring, and vibration testing
- **Preliminary Planning and Logistics (PL)**: about preparing a plan for successful field data collection, considering everything required for field data collection

These protocols are to be completed prior to the field visit.

2.5.3.2. Field Visit Protocols (FLD)

The field visit protocols (FLD) are related to gathering data from visual inspection, material testing and NDE testing, photography, and logistics and safety. These also cover onsite pretest activities and data storage instructions. Secondary levels of this protocol include [20]:

- **Onsite Pretest Activities (OP)**: includes measurements related to preparing activities for testing, such as labeling different parts of the bridge which will undergo field test
- **Field Data Collection (DC)**: contains instructions for data collection; general methods of data collection are a visual inspection, instrumentation, truck testing, long-term testing, material sampling, and NDE testing
- **Data Storage (DS)**: instructions for appropriate storage of raw data and considerations for data safety until uploaded on LTBP InfoBridge

These protocols are to be completed during the field visit.

2.5.3.3. Post-Visit Protocols (PST)

The post-visit protocols (PST) protocols are related to procedures for post-processing the collected data after returning from the field visit. These protocols include data reduction and validation, data interpretation, reporting data, and procedures for archiving integrated data into the LTBP InfoBridge. Secondary levels of this protocol include [20]:

- **Data Reduction and Processing (DR)**: error screening, post-processing, and data reduction for raw data from field investigation
- **Data Interpretation (DI)**: interpretation and evaluation of collected data
- **Archiving and Reporting (AR)**: procedure for reporting results for inclusion in the LTBP InfoBridge; ensures consistency of data reported in the resource

These protocols are to be completed after the field visit.

2.5.4. LTBP InfoBridge (formerly LTBP Portal)

The LTBP InfoBridge was one of the key products produced by the LTBP Program. The LTBP InfoBridge is a web-based platform compiling data including National Bridge Inventory (NBI), National Bridge Element (NBE), traffic, environmental, bridge elevation, inspection, and maintenance data. The eventual goal of the resource is to use all the datasets to develop advanced forecasting and deterioration models to predict the future condition of bridges [21], although there is a substantial amount of work yet required to achieve this goal.

The three stages of the LTBP InfoBridge development are shown in Figure 2.9: (1) version 1, developed in October 2015; (2) version 2, expected completion in 2017-2018; (3) future development [19].

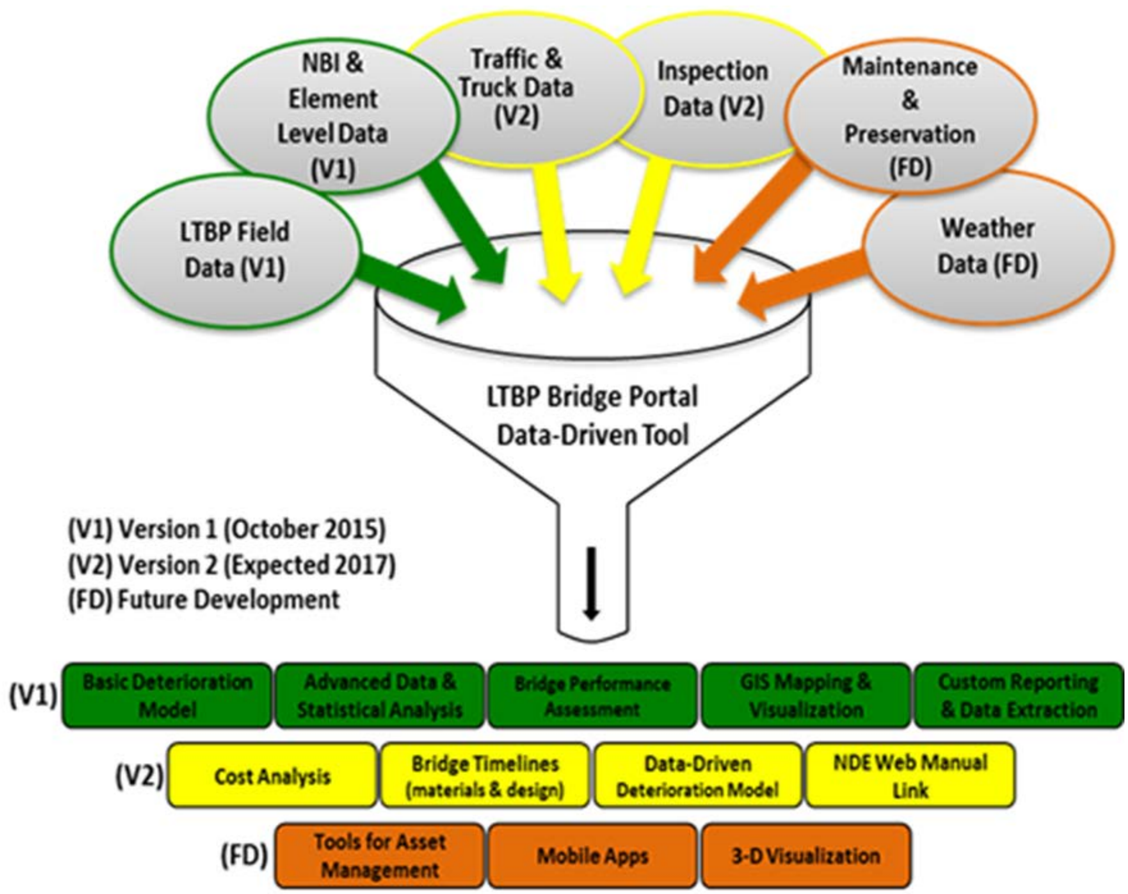


Figure 2.9: Illustration. LTBP Bridge InfoBridge components [19].

The initial version (v1) contains the NBI and element level data and the LTBP field data that was collected on a select number of bridges. This is the version that was available to the research team during this project.

The LTBP Bridge Portal v1.5 was initially available for use by the researchers. This version was accessible through login by employees of FHWA, State Departments of Transportation and local agencies [7]. A screenshot of this version of the LTBP Bridge Portal login screen is shown in Figure 2.10.

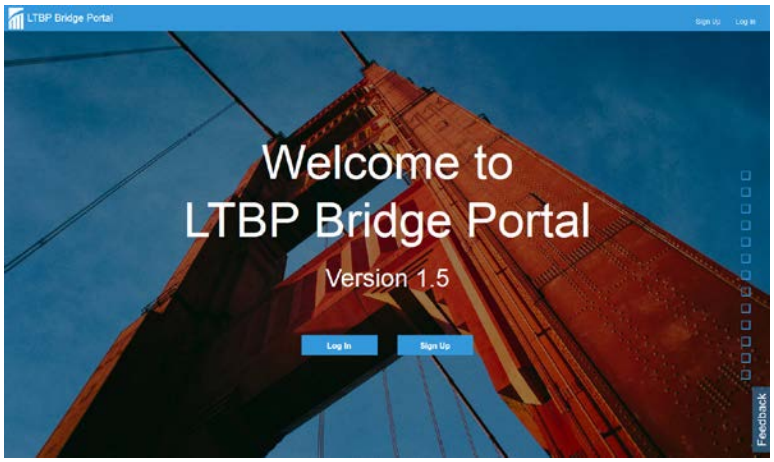


Figure 2.10: Screenshot of LTBP Bridge Portal v1.5 homepage [7]

A new release of the LTBP Bridge Portal, now called "LTBP InfoBridge" was just made available to the researchers. A screenshot of this new release, available without login at https://infobridge.fhwa.dot.gov/, is shown in Figure 2.11.

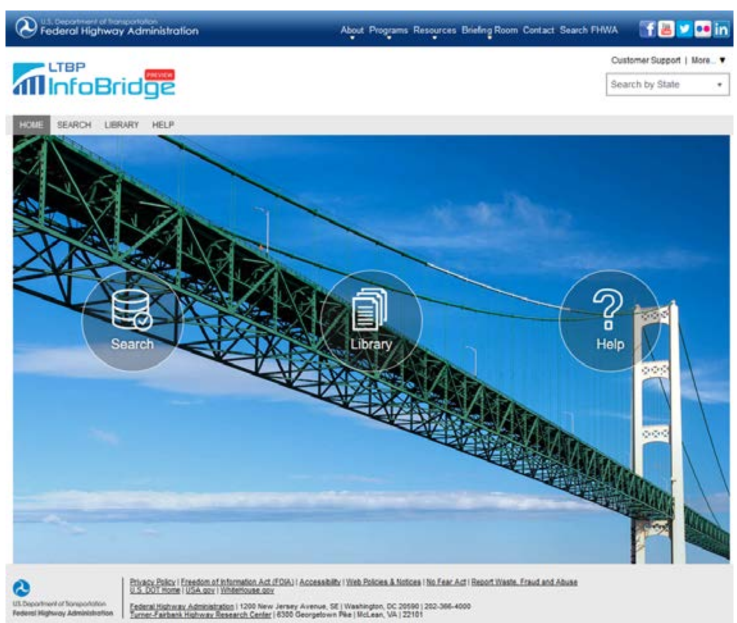


Figure 2.11: Screenshot of LTBP InfoBridge homepage [22]

The bridge portal allows for the bridges in the NBI to be searched using either a simple or advanced search feature. These features allow for filtering of the bridges based on any of the fields provided by the NBI. After searching, the filtered bridges can be displayed either in a list or a map view. A sample of the search results for bridges with precast decks (both partial and full-depth) in map view, which utilizes GIS map visualization capabilities, is shown in Figure 2.12.

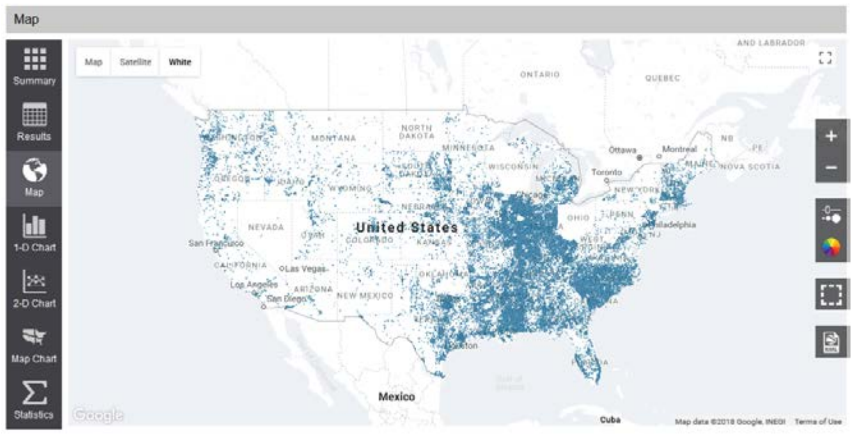


Figure 2.12: Example of filtered results for bridges with precast panels (either partial or full-depth) in map view [22]

A sample of the search results for bridges with precast decks (both partial and full-depth) in list view is shown in Figure 2.13. The fields that are displayed in the different columns can be customized and the data can all be output.

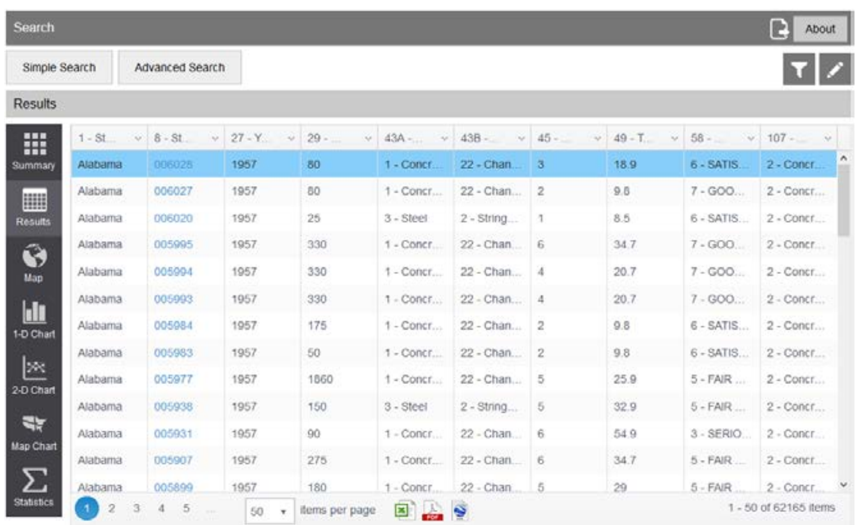
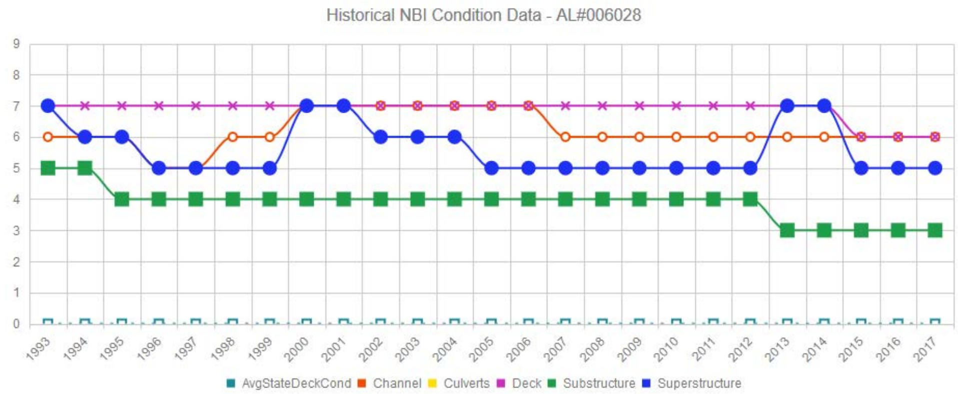
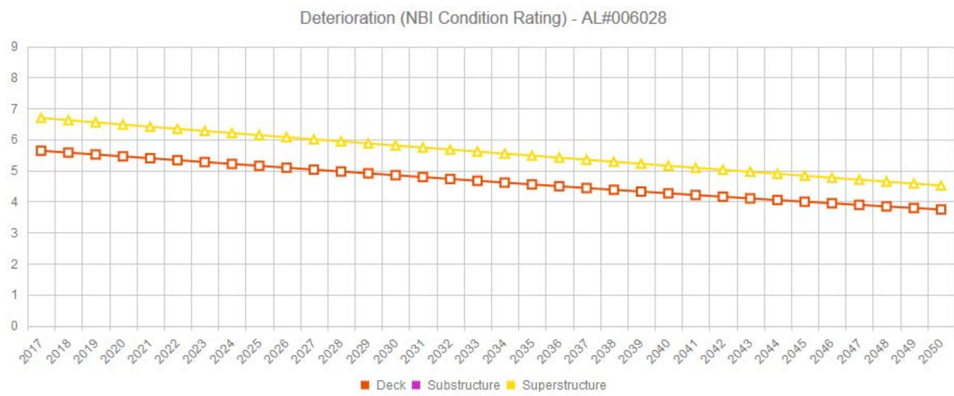


Figure 2.13: Example of filtered results for bridges with precast panels (either partial or full-depth) in list view [22]

Individual bridges can then be selected from either the map or list interfaces. All the data contained in the NBI is available for these projects in addition to the historical condition data and predicted condition data using either the Markovian Distribution or Weibull Distribution deterioration models. A sample of the historical condition data and predicted deterioration is shown in Figure 2.14 for one of the bridges from the above search.



(a)



(b)

Figure 2.14: Example of (a) historical NBI condition data and (b) deterioration predictions available on LTBP InfoBridge for AL#006028 [22]

The historical condition data will be used when assessing the long-term performance of bridges in this project.

2.6. Resources from Utah DOT

2.6.1. Introduction

The Utah Department of Transportation (UDOT) has been one of the leaders in advancing the use of ABC techniques. In addition to using ABC in numerous projects, UDOT has also been tracking the performance of their ABC bridges over time. UDOT has been inspecting their ABC bridges and documenting the inspection findings in "lessons learned" reports since 2009 [8]–[12]. These reports were reviewed and some of the results are summarized in this section.

2.6.2. Summary of Findings

The initial inspections in 2009 included 20 different sites. Additional bridges were inspected in subsequent years; a total of 44 bridges were inspected in 2016. The total number of bridges inspected per year are organized by the type of bridge and presented in **Error! Reference source not found.**. It can be seen that UDOT has inspected numerous bridges with FDPC deck panels.

Table 2.6: Summary of studies between 2009 to 2016 [8]–[12]

ABC Technology/Technique	**Total number of bridges/bridge components inspected in each year**				
	2009	*2010*	*2011*	*2013*	*2016*
Full-Depth Deck Panel: Transverse Connections with Welded Tie Plates	6	8	8	8	7
Full-Depth Deck Panel: Transverse Connections with Longitudinal Post-Tensioning	2	8	13	10	11
Full-Depth Deck Panel: Transverse Commotions with Dowel Bar Pockets	0	0	1	1	1
Full-Depth Concrete Deck Panels with Shear Connector Pockets	7	15	21	18	18
Full-Depth Deck Panel: Connections with reinforced UHPC connections	0	0	0	0	1
Precast Concrete Parapets	5	11	15	18	19
Connection of Approach Slabs to Bridge Decks	0	5	5	6	6
Precast Concrete Abutments with Vertical Thread-bar Connections	2	2	2	2	2
Precast Concrete Pier Elements	2	3	3	3	3
Self-Propelled Modular Transporter (SPMT) Bridge Moves	9	10	11	11	12
Lateral and Longitudinal Slide-in Bridge Moves	0	4	5	8	9
Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS)	0	0	0	1	1
Precast Adjacent Box Beams	0	0	0	1	1

A summary of the main observations from these inspections is provided in Table 2.7.

Table 2.7: Comparisons of performances for a different type of bridges [8]–[12]

ABC Technology/Technique	Results and Recommendation
Full-Depth Deck Panel: Transverse Connections with Welded Tie Plates	• This connection is not performing well; active leaking was observed in positive and negative moment regions • Asphalt overlays performed better than polymer overlays (less leakage) • Repair is expensive and time-consuming and difficult to execute without significant disruption to traffic • This type of connection is no longer recommended and is no longer part of standards
Full-Depth Deck Panel: Transverse Connections with Longitudinal Post-Tensioning	• This connection is performing well • Minor leakage was observed, but likely due to minor concrete shrinkage near the deck ends • This detail was strongly recommended with the use of high-quality concrete for the panels and high-quality grout for the connections to reduce the possibility of leakage
Full-Depth Deck Panel: Transverse Commotions with Dowel Bar Pockets	• This type of connection was first inspected in 2011; only bridge in list completed in 2011 (I-84 Bridge over the UPRR near Taggart) • No observed problems in 2011 after completion, but efflorescence and leakage at many joints from 2013 to 2016 • Deterioration is more than expected for a bridge in 5 years in service • Based on inspection this detail should only be used in positive moment regions
Full-Depth Precast Concrete Deck Panels with Shear Connector Pockets	• The performance is mixed, several bridges showed sign of minor leakage • Performance seems to be linked to the type of grout used and method of curing • The amount of leakage is less than a typical cast-in-place concrete bridge deck and there does not seem to be any major deterioration
Full-Depth Deck Panel: Connections with reinforced UHPC connections	• One bridge with this detail was built and in 2013 and inspected in 2016 • There were no observed deficiencies during inspection • Use of this detail for future projects is strongly recommended
Precast Concrete Parapets	• Overall performance of these elements is good; no significant joint leakage was found • One observed issue was a misalignment between adjacent parapet sections, which was likely due to lack of quality control during casting; a new tolerance detail was developed by the inspector • Longitudinal cracking was found along the inside faces of parapet segments due to insufficient concrete cover

ABC Technology/Technique	Results and Recommendation
Connection of Approach Slabs to Bridge Decks	• A combination of live load forces and thermal movements has led to the deterioration of some of these connections • Cast-in-place concrete connections perform better than mechanical connections
Precast Concrete Abutments with Vertical Thread-Bar Connections	• The performance is generally good and there was no significant leaking between joints • There was an issue with misalignment due to very tight tolerance control • Slower fabrication process increases costs • The grouted joint with a reasonable fit-up tolerance make this type more problematic
Precast Concrete Pier Elements	• There were no significant problems to report and the piers performing very well
Self-Propelled Modular Transporter (SPMT) Bridge Moves	• Cracking was observed in several bridges, but similar cracking was observed in similar bridges using convention construction methods, so it was concluded that cracks were caused by concrete shrinkage • The cracking and leakage are minor in most of the bridges; cracking has worsened from 2009 to 2016 but not significantly enough to lead to major deterioration.
Lateral and Longitudinal Slide-in Bridge Moves	• Generally performing well • Several bridges have isolated diagonal cracking at the corners of the underside of the deck, due to the thermal differential between the deck and end of diaphragms; this is due to a lack of expansion joints
Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS)	• One bridge was inspected in 2013 which was constructed in 2012 (Bridge: F-851, Location: I-84; Echo Frontage Road) • Inadequate drainage led to leakage from joints; an improved drainage detail was recommended
Precast Adjacent Box Beams	• One bridge with this detail was constructed in 2012 and in 2016 it was inspected for the second time (Bridge: F-851, Location: I-84; Echo Frontage Road) • There were no significant problems to report

2.6.3. *Detailed Observations from Welded Tie Connections*

As summarized above, there were several different ABC technologies or techniques that were experiencing early-age deterioration. The technique that performed the worst was the welded tie connection. The bridges using full-depth precast decks with welded tie connections experienced leakage and efflorescence between deck panels, as shown in Figure 2.15.

Figure 2.15: Typical joint leakage at deck panels (I-84 WB over Weber Canyon with welded-tie connections from 2009 inspection)[8]

Reflective cracking was also visible on the surface of the bridges over the joint region. A reflective crack in the asphalt overlay that worsened in the three years between inspections is shown in Figure 2.16.

(a) (b)

Figure 2.16 Typical transverse cracking in the overlay which worsened from 2013 to 2016, I-84; US-89 to SR-167, Weber Canyon (Built 2008)-Joint connection: Welded Tie connections [12]

One of the observed problems in this type of joint was poorly grouted shear keys between panels. An example of a welded-tie connection with poor grout is shown in Figure 2.17.

(a) (b)

Figure 2.17 Cracks with efflorescence in parapet over the deck panel joint and Poorly bonded grout in **shear pocket,** ***I-84; US-89 to SR-167, Weber Canyon (Built 2008), Joint connection: Welded Tie connections [12]***

2.7. Summary

Full-depth precast concrete (FDPC) deck panels have been used in construction since the 1960's by many states. An overview on available databases containing information on projects successfully using FDPC deck panels was first given, followed by a summary of a study investigating their performance conducted in the early 1990's. Next, several different resources were described that contain information on the long-term performance of bridges: National Bridge Inventory (NBI), Long-Term Bridge Performance (LTBP) InfoBridge, and Utah DOT's Lesson's Learned reports. These resources will all be used in the following chapters.

CHAPTER 3. SURVEY

3.1. Introduction

A state survey was developed to determine:

1. Number of FDPC deck panel projects (including NBI information) and type of joint used
2. Reasons why FDPC deck panels are considered over cast-in-place (CIP) decks
3. Observed problems with deck systems (with panels or joints)
4. Repair techniques used for problematic decks
5. Recommendations for comparison projects for later tasks

The survey was sent out to all state departments of transportations (DOTs) and was completed by 43 states. An overview of the survey and the survey responses are summarized in this chapter.

3.2. Survey Results

The state survey was separated into four different sections:

A. Respondent Information
B. FDPC Deck Panel Use
C. FDPC Deck Panel Details and Perceived Performance
D. Bridge Comparison Selections

The survey was distributed to all 50 states through the AASHTO T-4 committee on construction. Forty-three states responded to the survey, as shown in Figure 3.1.

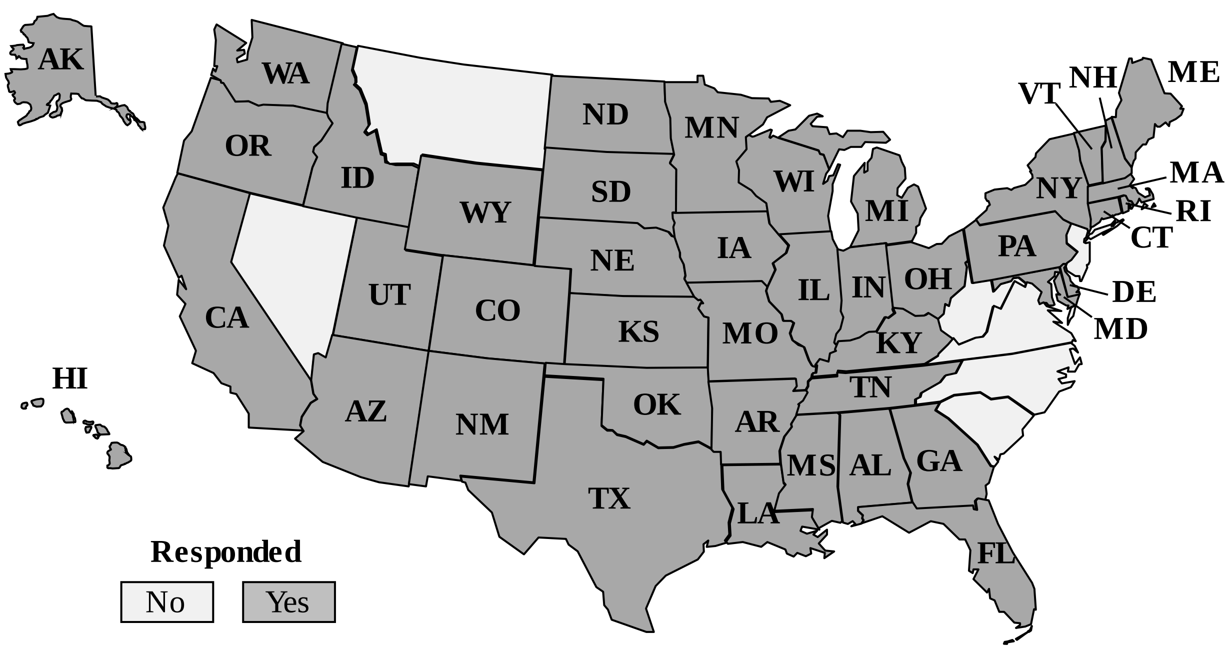


Figure 3.1: Map of states who responded

Of the 43 responding states, 31 states (72 percent) have previously used FDPC deck panels and 31 states (72-percent) currently allow the use of FDPC deck panels, as shown in Figure 3.2.

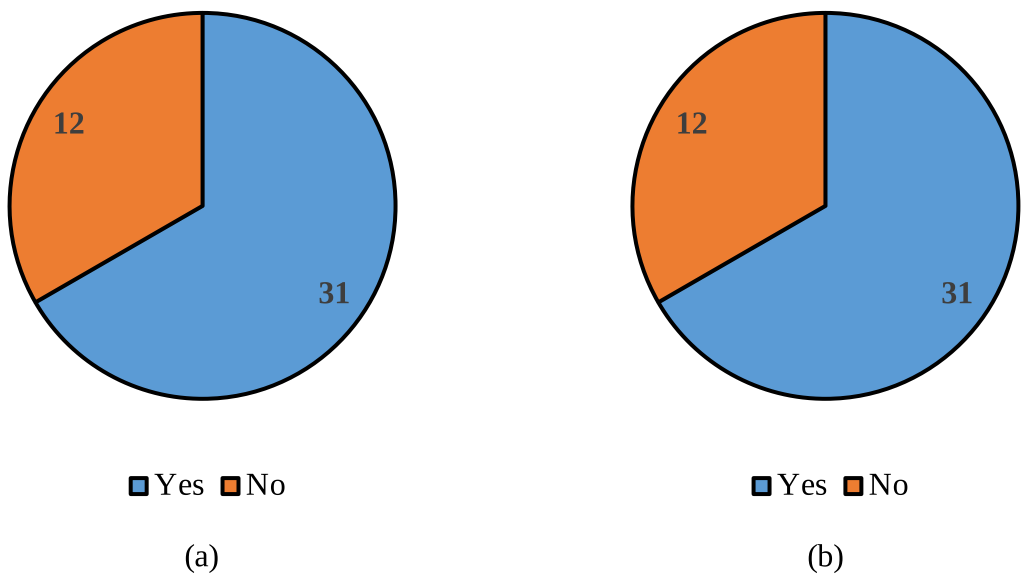


Figure 3.2: Number of states who (a) previously have used FDPC deck panels and (b) currently allow the use of FDPC deck panels

The primary reasons that states use and/or allow the use of FDPC deck panels taken from the survey responses are:

- Decrease construction time
- Reduce traffic impact
- Better final quality of FDPC deck panels compared to CIP decks
- Increase long-term durability due to better quality
- To eliminates in-place curing time

The primary reasons states do not use or do not permit the use of FDPC deck panels are:

- CIP decks can cover up errors or differential cambers between members
- FDPC deck panels are not usually bid by contractors
- Lack of experienced local contractor
- FDPC require quality control and quality assurance program for prohibiting misalignment, which increases costs and decreases the number of qualified contractors
- Dislike need for joints between panels (CIP allows for a jointless bridge)
- Higher cost of FDPC panels compared to CIP decks
- Uncertainty about connection details in FDPC
- Concerns with cracking, connection and long-term performance

There is a total of 301 projects that were reported to utilize FDPC deck panels. These projects are broken down by decade in Figure 3.3. It can be seen that states are becoming more comfortable using FDPC deck panels, so over half of the total FDPC deck panel projects have occurred in the past decade.

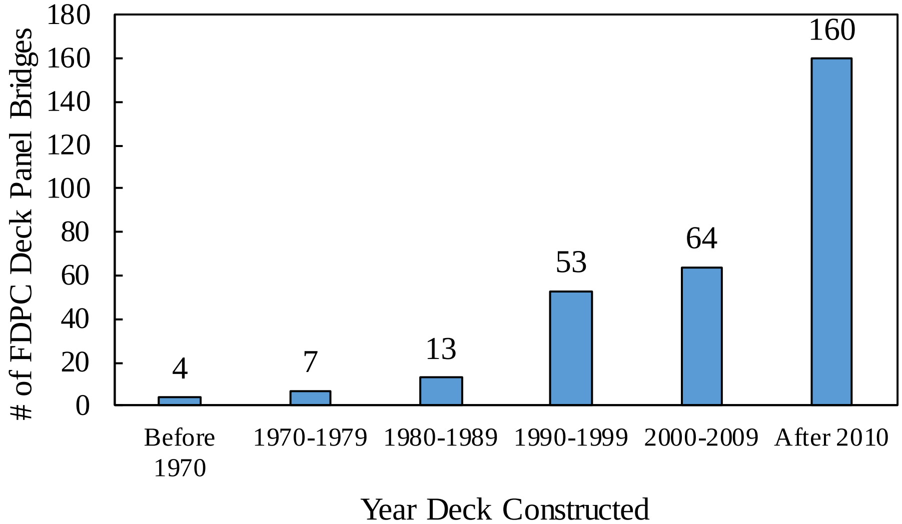


Figure 3.3: Number of bridges utilizing FDPC deck panels in each decade

The total number of bridge projects utilizing FDPC deck panels is also broken down by state and presented in Table 3.1. New York, Alaska, Utah, Pennsylvania, and Tennessee have the largest number of bridges with FDPC deck panels.

Table 3.1: Number of Bridges with FDPC panel decks for each state (based on Survey results)

Number of Bridges with FDPC	State
125	New York
40	Alaska
37	Utah
20	Pennsylvania
17	Tennessee
8	Colorado
6	Massachusetts
5	Connecticut
5	Oregon
4	Florida
4	Illinois
4	Nebraska
3	Maine
3	Minnesota
3	Missouri
2	Delaware
2	New Mexico
2	Rhode Island

Number of Bridges with FDPC	State
1	California
1	Georgia
1	Iowa
1	Louisiana
1	Michigan
1	Mississippi
1	New Hampshire
1	Texas
1	Vermont
1	Wisconsin
1	Wyoming

This total number of bridges per state is shown graphically in Figure 3.4.

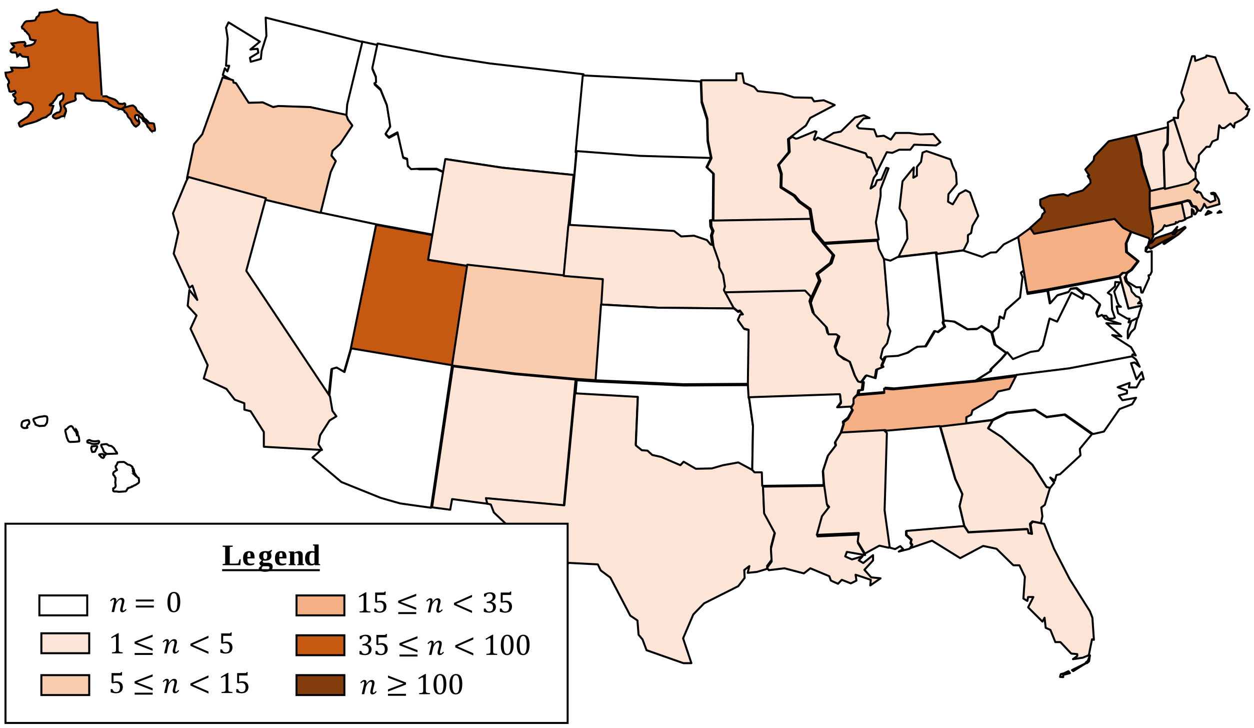


Figure 3.4: Distribution of FDPC deck panels in all states

There were several different common joint details that were found during the literature review, shown in Figure 3.5. These joints were broken into four different categories: (1) post-tensioned, (2) mechanical, (3) ultra-high performance concrete (UHPC), and (4) conventional concrete (CC). The UHPC and CC joint details included straight, headed, and hoop reinforcement splice details. Note that the results from the survey led to a slight modification to the common joint details that were used in the FDPC Deck Panel Database; see Chapter 4.

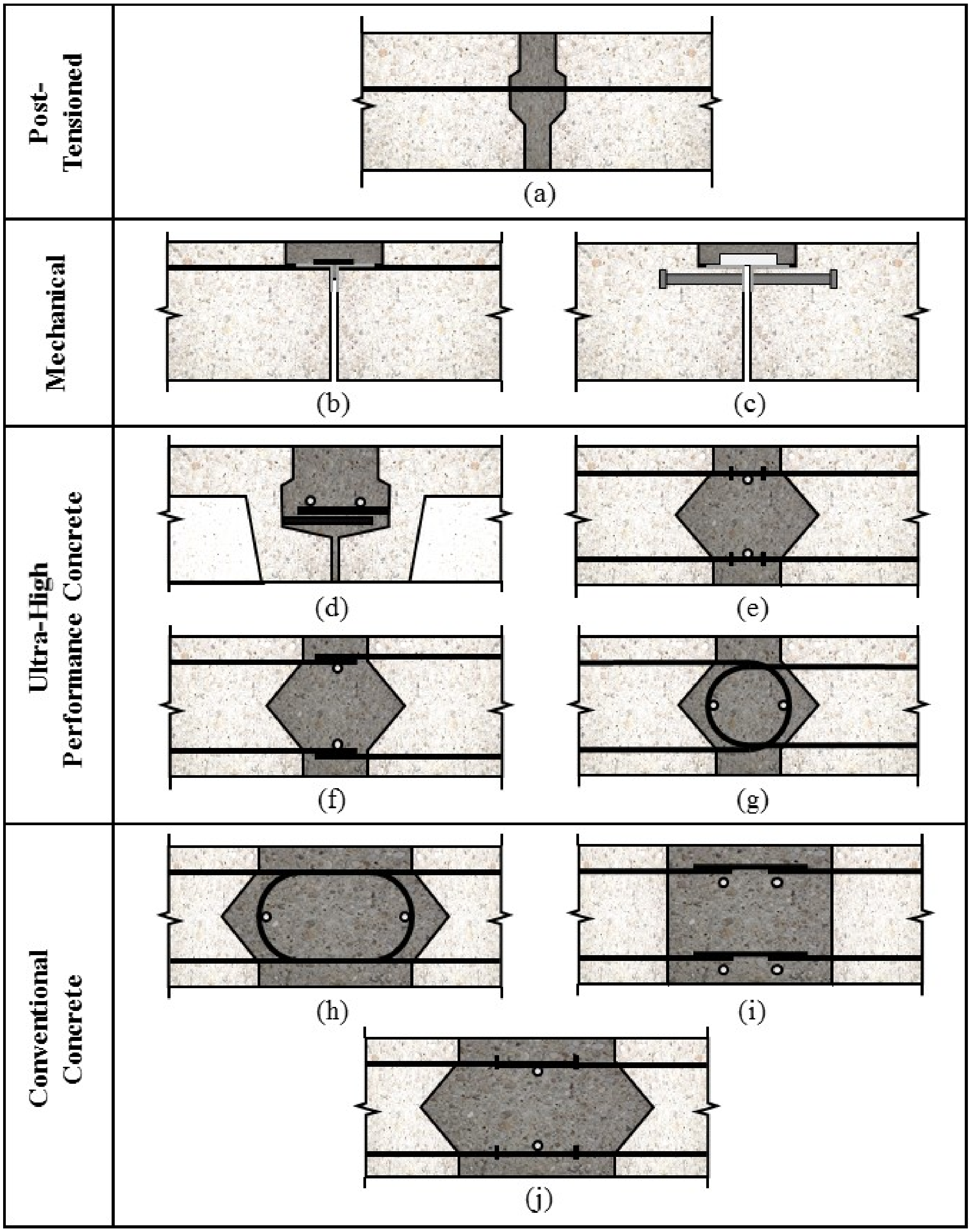


Figure 3.5: Common joint details used in the survey

The types of joints either previously or currently used by a state are shown in Figure 3.6. The post-tensioned joint detail is the most commonly used joint detail (past and present). The UHPC joint with straight bars is the next most commonly used. The conventional concrete joint with hooped bars is the third most commonly used joint. Also note that some states have used mechanical or welded connections in the past, but these are not commonly used anymore because of their long-term performance.

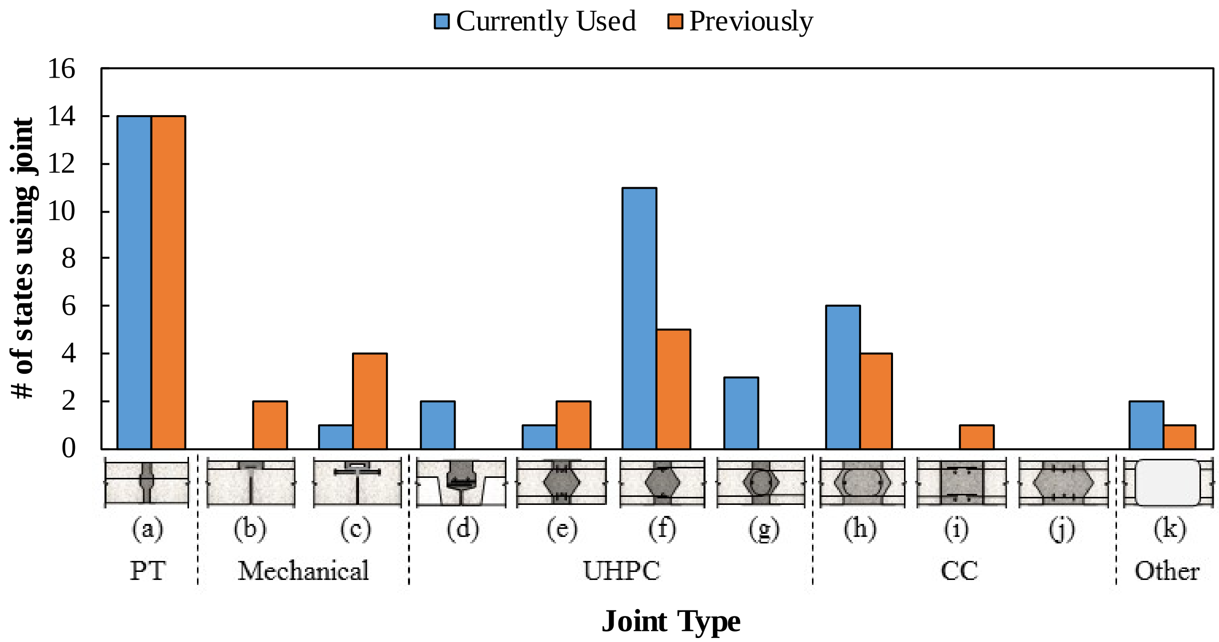


Figure 3.6: Types of joint details used by states

States also responded with the approximate costs for FDPC deck panel decks compared to CIP decks (including the cost of the wearing surface). A summary of the cost information provided by the 23 states that included this information is provided in Table 3.2. The same information is also presented in Figure 3.7 as a ratio of FDPC deck cost versus CIP deck cost.

Table 3.2: Comparison between FDPC Deck Panels price and CIP Deck price

	State	FDPC Deck Panels ($/ft^2)	CIP Deck ($/ft^2)	FDPC Cost / CIP Cost	St. Dev. from Average
1	Alaska	110	115	0.96	-1.52
2	Colorado	34	16	2.13	0.56
3	Connecticut	95[1]	50	1.90	0.16
4	Delaware	150	50	3.00	2.12
5	Florida	34[2]	21	1.62	-0.34
6	Georgia	87	54	1.61	-0.36
7	Illinois	110	50	2.20	0.69
8	Iowa	140[3]	120[3]	1.17	-1.15
9	Louisiana	125[4]	65[4]	1.92	0.20
10	Maine	116	70	1.66	-0.28
11	Massachusetts	50	40	1.25	-1.00
12	Minnesota	59[5]	27[5]	2.19	0.66
13	Missouri	39	32	1.22	-1.06
14	Nebraska	35	25	1.40	-0.73
15	New Mexico	45	20	2.25	0.78
16	New York	75	43	1.74	-0.12
17	Oregon	40	25	1.60	-0.38
18	Pennsylvania	91	29	3.14	2.36
19	Rhode Island	75	75	1.00	-1.45

	State	FDPC Deck Panels ($/ft²)	CIP Deck ($/ft²)	FDPC Cost / CIP Cost	St. Dev. from Average
20	***Tennessee***	90	50	1.80	-0.02
21	***Texas***	65	25	2.60	1.40
22	***Vermont***	80	45	1.78	-0.06
23	***Wyoming***	48	31	1.55	-0.47
Maximum		***150***	***120***	***3.14***	
Minimum		***34***	***16***	***0.96***	
Average		***78***	***46***	***1.8***	

[1] based on 1 project at 90% design completion
[2] $34 for non-prestressed panels, $38 for transversely prestressed panels
[3] cost for entire bridge
[4] cost of superstructure and substructure for 20-foot span length
[5] stated that costs do not include the reinforcement

The average reported cost of FDPC deck panel decks is 1.8 times the cost of CIP decks. Several states can construct FDPC deck panel decks at lower or similar costs to CIP decks. The approximate cost of FDPC deck panel decks in Alaska is lower than CIP decks. Iowa, Massachusetts, Missouri, Nebraska, and Rhode Island reported FDPC deck panel decks costing between 0 and 40 percent more than CIP decks. Delaware and Pennsylvania are the states where FDPC deck panel decks cost the most compared to CIP decks.

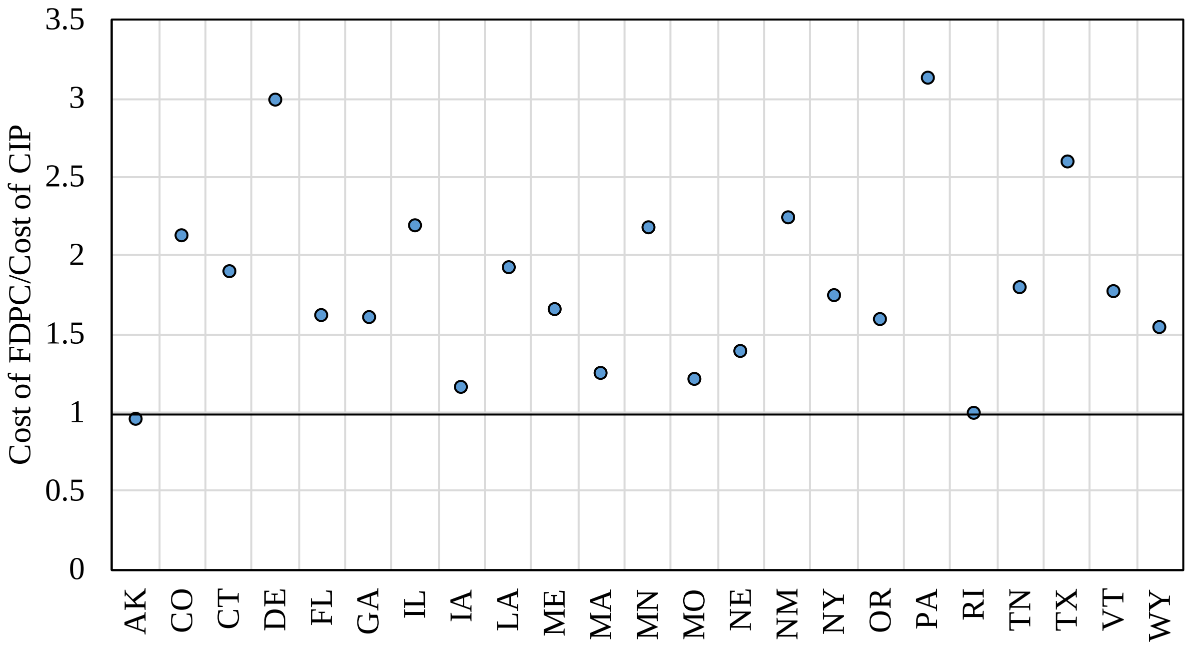


Figure 3.7: Relative Price of FDPC to CIP

3.3. Comparison Projects

Each state was also asked to provide a pair of comparison projects with additional details. Comparison projects were also obtained for most of the projects in the FDPC Deck Panel Database, discussed in the next chapter.

CHAPTER 4. FDPC DECK PANEL DATABASE

One of the significant results from the DOT survey was the development of the FDPC Deck Panel Database. The National Bridge Inventory (NBI) number for bridges utilizing FDPC deck panels was obtained for 280 bridges. These bridges were compiled with appropriate details and NBI inspection data into the FDPC Deck Panel Database. The FDPC Deck Panel Database is valuable as it is a collection of constructed bridges using FDPC deck panels, compared to the NBI deck classification "Concrete Precast Panels" that includes both partial and full-depth panels. This database can be used to evaluate the overall behavior of these bridges and compare it to the typical behavior of CIP decks. An abbreviated version of the FDPC Deck Panel Database is provided in Appendix B.

The number of bridges provided by each state is shown in Table 4.1. Note that not all responding states included NBI information for all their FDPC deck panel bridges, so the total number of FDPC deck panel bridges discussed above is different than the number of bridges with NBI data provided.

Table 4.1: Number of FDPC deck panel bridges provided by the state

State	# Bridges Provided
Alaska	40
California	1
Colorado	1
Connecticut	5
Delaware	3
Florida	4
Georgia	1
Illinois	1
Iowa	2
Louisiana	1
Massachusetts	6
Michigan	1
Minnesota	2
Mississippi	1
Missouri	6
Nebraska	3
New Jersey	1
New Hampshire	1

State	# Bridges Provided
New Mexico	2
New York	136
Oregon	5
Pennsylvania	1
Rhode Island	2
Tennessee	10
Texas	1
Utah	37
Washington	1
Wisconsin	1
Wyoming	1
Vermont	2
Virginia	2

All the bridges contained in the FDPC Deck Panel Database are shown in Figure 4.1. There are concentrations of these bridges primarily in three states: Alaska, New York, and Utah.

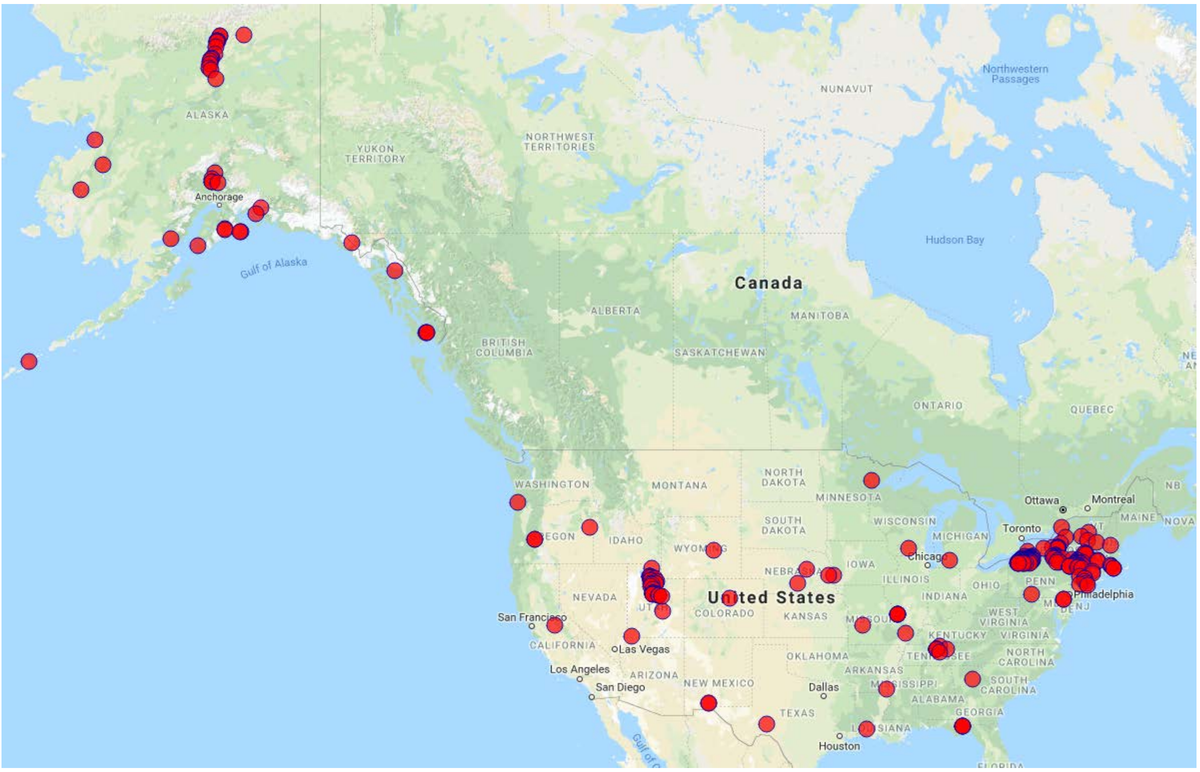
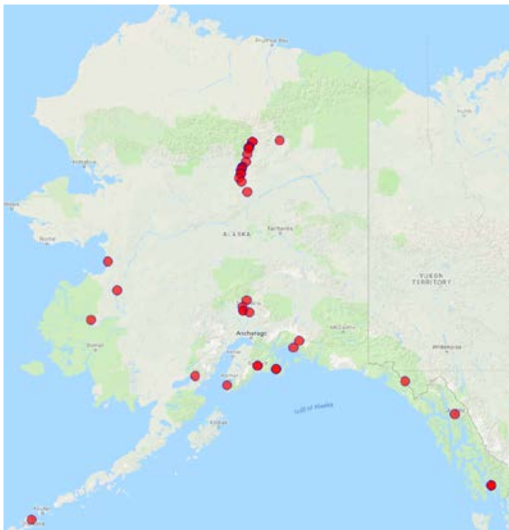
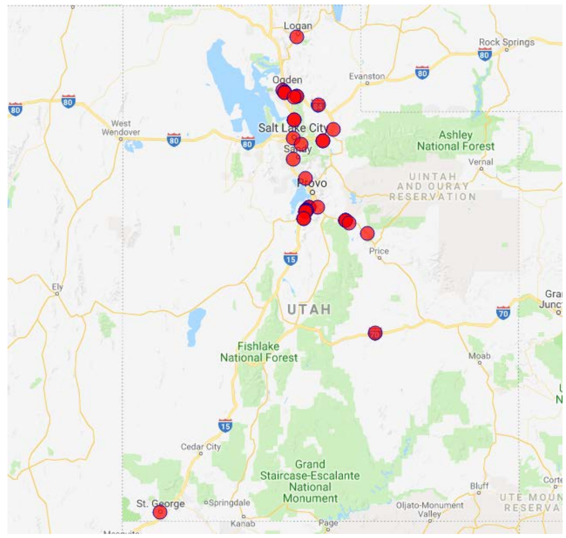


Figure 4.1: Bridges in FDPC Deck Panel Database (Complete Database) [23]

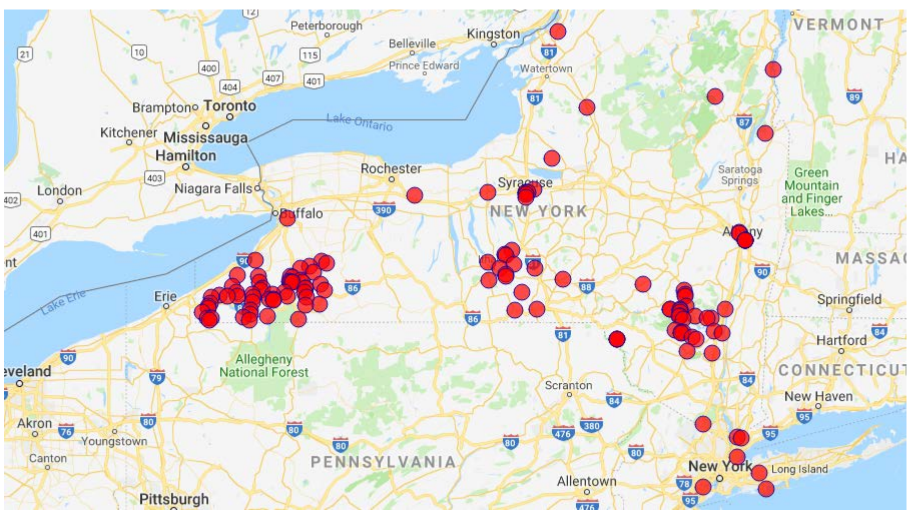
The bridges contained in the FDPC Deck Panel Database in Alaska, Utah, and New York are shown in Figure 4.2. There are noticeable clusters in each of these states as well. Some of these are due to multiple bridges on one road being part of a larger project where all decks utilized the FDPC deck panels. Some of the clusters in Alaska are due to the bridges being in remote locations where it was more difficult to transport concrete. The researchers infer that some of the clusters in New York are likely in areas with experienced local designers, contractors, and precast plants.



(a)



(b)



(c)

Figure 4.2: Bridges in the FDPC Deck Panel Database in (a) Alaska, (b) Utah, and (c) New York [23]

The common joint details were modified based on feedback from the survey. The common joint details referenced in the FDPC Deck Panel Database are shown in Figure 4.3.

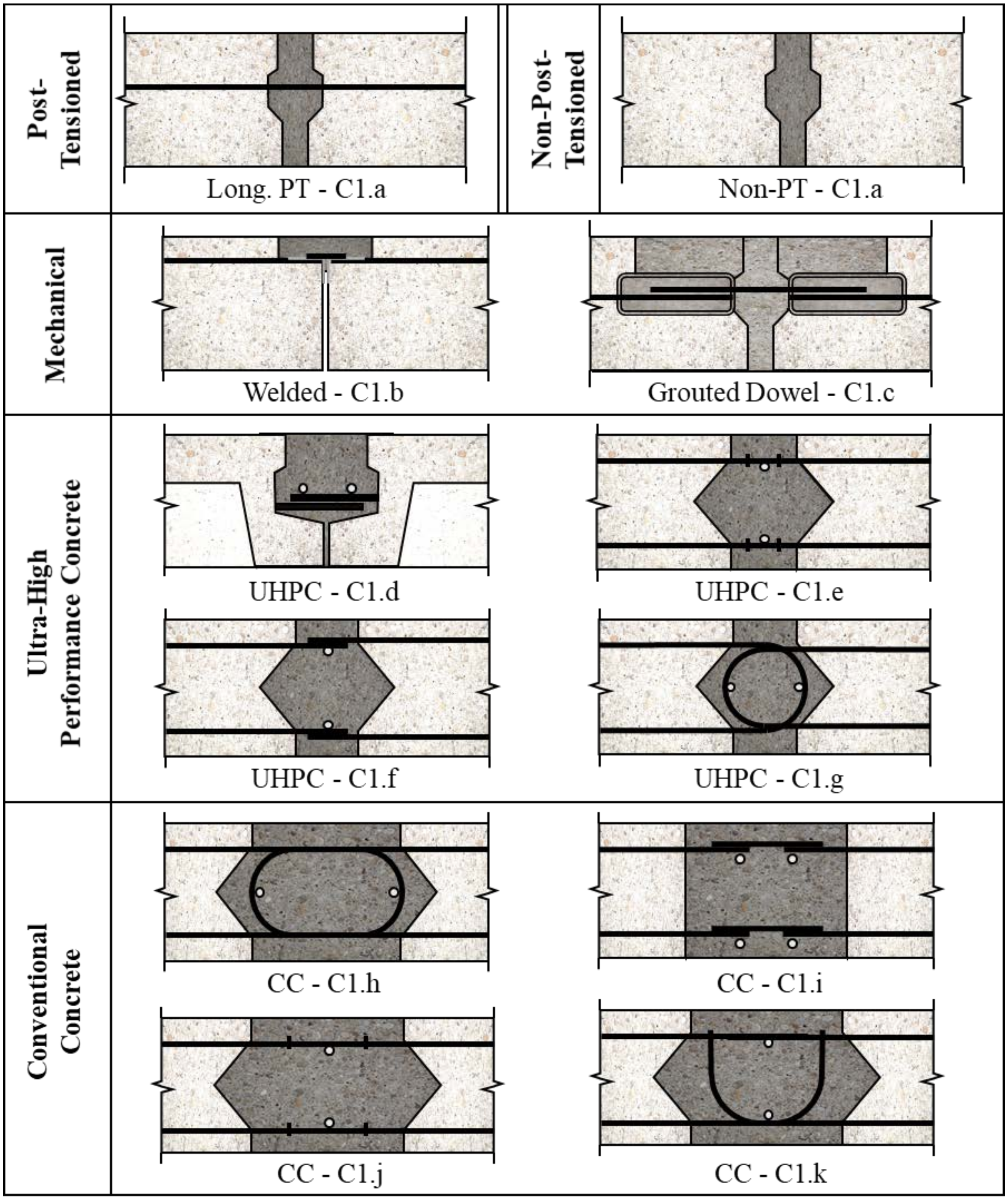


Figure 4.3: Common joint types used to classify longitudinal and transverse joints in FDPC Deck Panel Database

CHAPTER 5. DATABASE ANALYSIS

5.1. Introduction

The Full Depth Precast Concrete (FDPC) Deck Panel Database initially created when analyzing the survey results was expanded to include additional projects with FDPC deck panel decks and comparison projects with cast-in-place (CIP) decks. Information from the National Bridge Inventory (NBI) and Long-Term Bridge Performance (LTBP) InfoBridge was also added to the FDPC Deck Panel Database, including available inspection information for the bridges. Details about data collection and analysis will be provided in this write-up.

5.2. Background on Bridge Management

The U.S. has a bridge inventory of over 600,000 bridges with over one-third of the bridges being past their design life. Research in bridge management is focused on looking at the collection of U.S. bridges as a whole, determining current bridge conditions, estimating deterioration rates, and determining trends to better plan bridge inspections, bridge monitoring, and bridge system repair or replacement. Bridge management involves the collection and analysis of inspection data, design documentation, maintenance recommendations and preservation/maintenance actions. The National Bridge Inspection Standards (NBIS) require that bridges be inspected every two years. The results from these inspections for most of the bridges in the United States are stored in the National Bridge Inventory (NBI) compiled by the Bridge Management Information Systems (BMIS) laboratory [6]. This database has been the source of information for many bridge management studies. However, the variations in inspection procedures, the subjectivity involved in visual inspection rating, and the lack of data on preservation and maintenance actions that impacts ratings, results in some uncertainties associated with NBI data [24]. FHWA initiated the LTBP program to try and normalize inspection procedures and improve the quality and consistency of the inspection data collected by using repeatable NDE methods. This program also aimed to study the performance of bridges and provide predictive models that can be used for bridge and asset-management [25].

In addition to the LTBP program, there have been several research projects looking at the performance of bridges and estimated future condition of bridges based on NBI data. Most of these studies have focused on the superstructure and substrusture of bridges, although a few of them have focuesed on deck behavior.

Chase et al. [26] conducted a study to determine regression models for predicting the deterioration of the deck, superstructure, and substructure. One of the major contributions of these researchers was their combining GIS data with NBI data enabling the study of bridge behavior with location-dependent factors (e.g., climate) and variations in state DOT standards and practices. They developed linear, a non-linear non-parametric, and a non-linear parametric regression models. They recommended the use of the linear model for prediction of deck condition rating, which includes the independent variables of age, average daily traffic, annual precipitation, frequency of salting, temperature range, freeze-thaw cycles, and predominant construction material.

Bolukbasi et al. [24] conducted a similar study for predicting the future condition of bridge components. They used the data collected from 2,601 Illinois bridges filtered to eliminate records with unrecorded improvements by eliminating any bridges where there was a sudden increase in the rating data. A third-degree polynomial equation was found to represent the average deterioration of the different major bridge components (deck, superstructure, and substructure), as shown in Figure 5.1 (a). The overall average was found for all bridges and subsets of the sample (e.g., superstructure material, ADT, interstate/non-interstate). The researchers found that substructures had the longest service life and decks had the shortest service life. They also saw that the ADT had a noticeable effect on the deterioration.

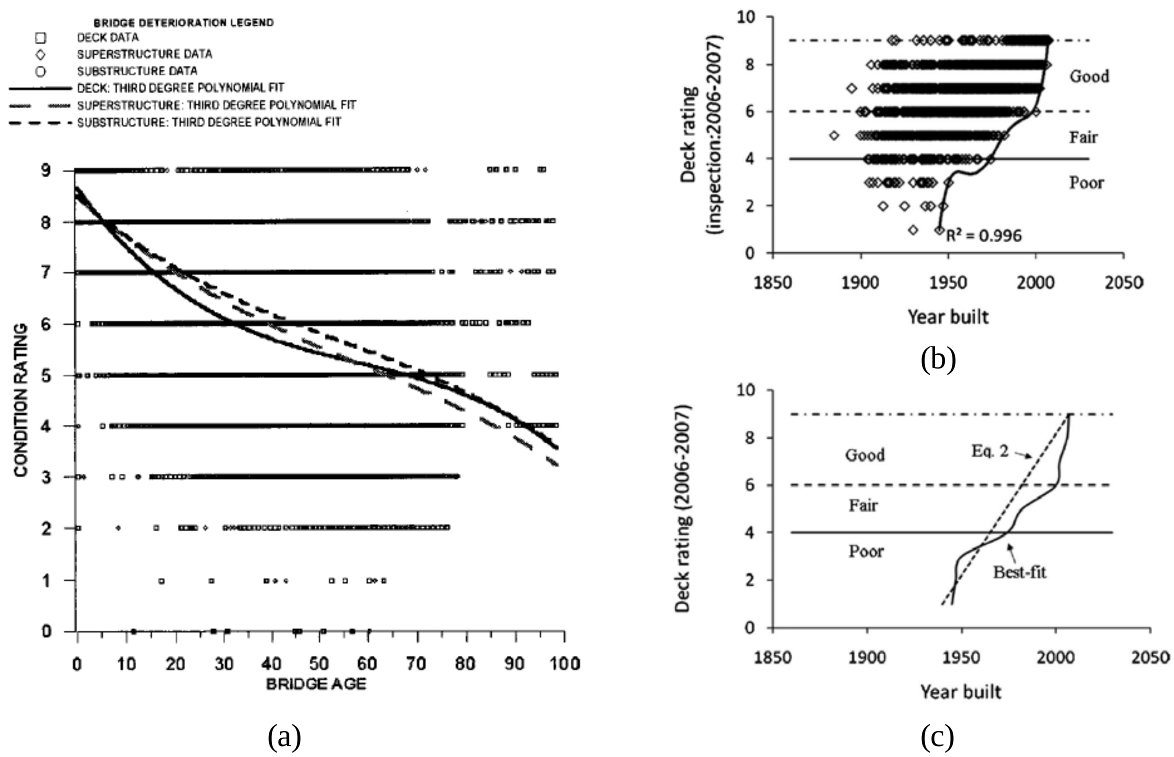
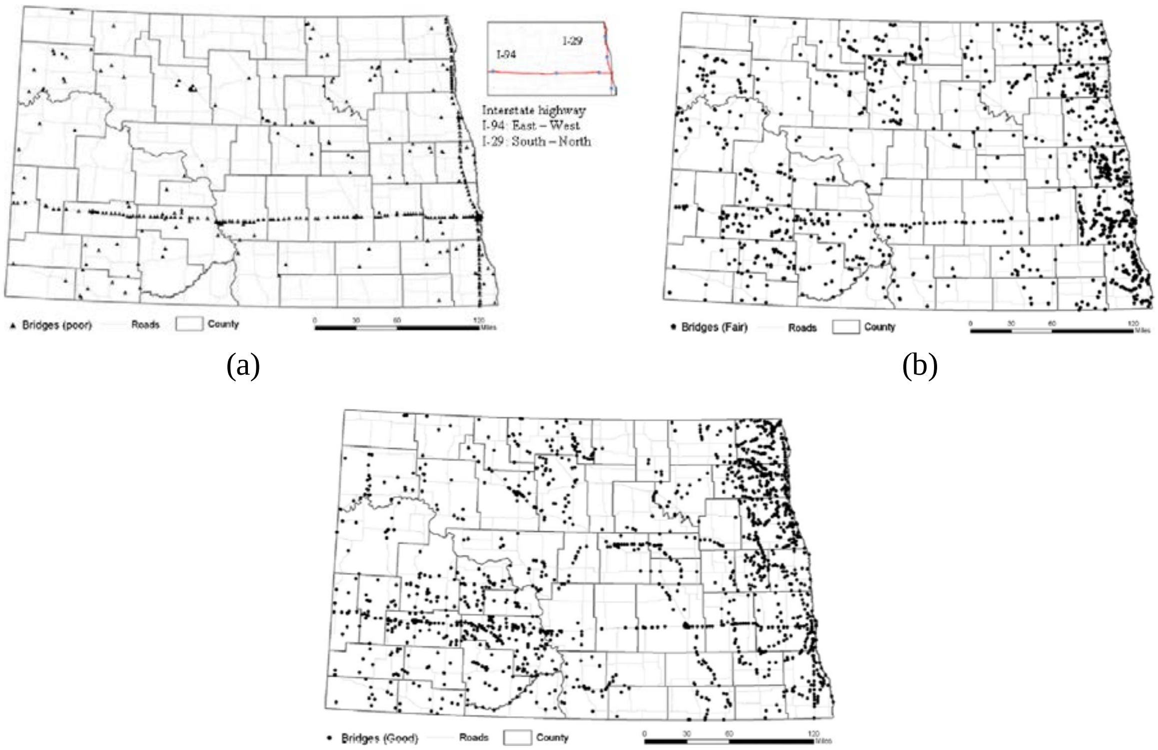


Figure 5.1: Examples of regression models developed based on NBI data from (a) Bolukbasi et al. [24] and (b) Kim and Yoon [27] with a (c) linear regression approximation

Kim and Yoon [27] conducted a study on North Dakota bridges using the NBI to find critical sources of bridge deterioration in cold weather climates. They used GIS data overlaid with NBI data to investigate correlation between location and deterioration, as shown in Figure 5.2. They also developed linear equations for deck deterioration based on the age of the deck and the ADT, shown in Figure 5.1 (b) and (c), which were the two significant factors they found most influenced the behavior of the deck.



(a) (b)

(c)

Figure 5.2: Sample of GIS data overlaid with NBI data from Kim and Yoon [27] showing the current state of bridge decks: (a) poor (rating of 1 to 4), (b) fair (rating of 5 to 6), and (c) good (rating of 7 to 9)

Techniques and strategies used in the above studies were considered during the data collection and analysis stages of this project.

5.3. Expanding FDPC Deck Panel Database

The FDPC Deck Panel Database (described in Task 2) was used as a starting point for data collection. This database only contained bridge projects with FDPC deck panel decks that were collected from the survey results. Additional projects were added to this database from information gathered from the ABC Project Database [28]. An additional ten projects were added to the FDPC Deck Panel Database giving a final total of 280 projects. Each project in the database was given an identification number for future reference.

The study was conducted on FDPC deck panel bridges in all 29 states. All bridges are labeled by state abbreviations for example for the Utah state, bridges are labeled UT-FDPC-1 through UT-FDPC-37.

5.3.1. Selection of Additional CIP Comparison Projects

A cast-in-place (CIP) comparison project was selected for the bridges in the FDPC Deck Panel Database. Comparison projects were initially only selected for the Utah bridges, but were then added for other states. These comparison projects are labeled with same format as FDPC bridges (For the Utah: UT-CIP-1 through UT-CIP-37). The number at the end connects these comparison projects, e.g., UT-CIP-1 is a comparison project associated with UT-FDPC-1.

Several factors were considered when selecting appropriate CIP comparison projects for each one of the FDPC bridges from the FDPC Deck Panel Database. These factors inclucled:

- Location
- Main span materials
- Main span design
- Wearing surface
- Year built
- Length of largest span
- Average daily traffic
- Average daily truck traffic

A sample search for a comparison bridge is shown in Figure 5.3.

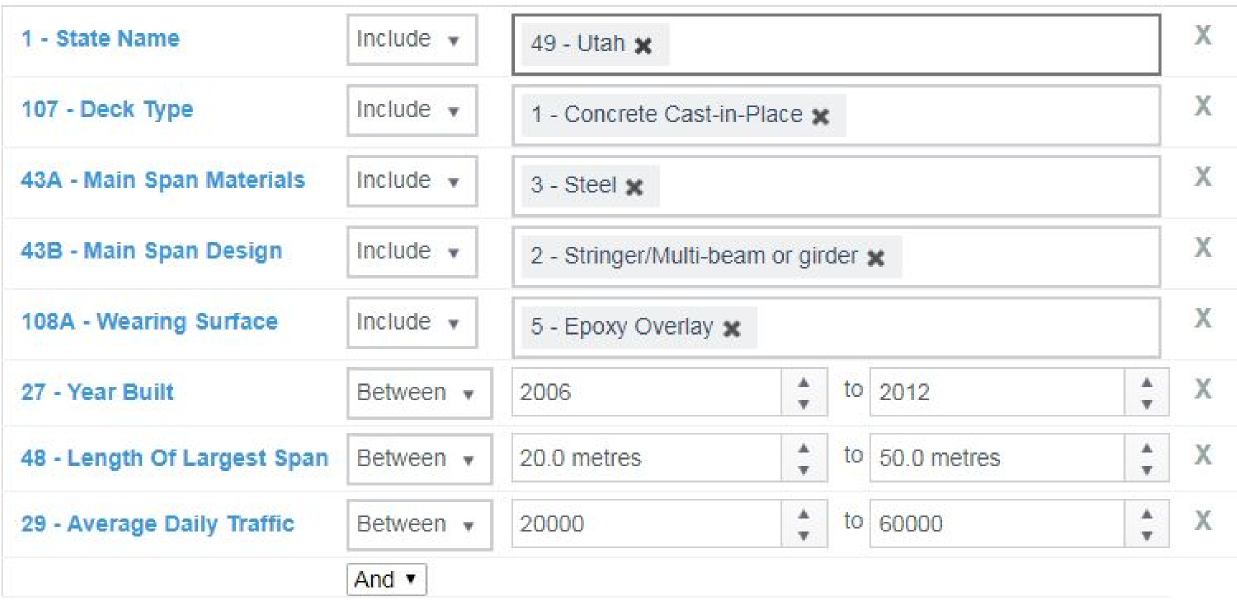


Figure 5.3: Searching criteria for finding CIP for bridge number UT-FDPC-15 [7]

The best comparison project found through this filter was entered into the database. Some of the FDPC deck panel projects had similar characteristics. For some of these cases, when limited CIP projects were available, the same CIP comparison project was used in the database. These duplicate projects were used in the side-by-side comparisons, but duplicates were eliminated for the group comparisons.

5.3.2. Inspection Information from LTBP InfoBridge

Data was gathered from the LTBP InfoBridge, which is a compilation of information from the NBI. The information gathered for the bridges in the FDPC Deck Panel Database included:

- State
- NBI number
- Bridge name
- Owner

- Latitude/Longitude
- Number of main spans
- Length of largest span
- Total bridge length
- Year built
- Year of deck construction
- ADT/ADTT
- Main span material
- Main span design
- Wearing surface
- Deck rating the year of deck construction
- Deck rating for each year since deck construction

Data was collected in an Excel spreadsheet for further analysis.

5.3.3. Additional Information from Other Sources

Additional information was input based on information gathered from the survey, the ABC Project Database, location, or calculated from NBI data. This information included:

- Transverse and longitudinal joint type
- Age / age of deck
- Impact category (defined below)
- Climate zone (as defined by DOE [29])

The impact category is a metric defined by AASHTO Committee on Bridges and Structures Technical Committee T-4 (Construction) to gauge the effectiveness of ABC related to construction time savings. Four different time metrics are used to gauge the overall effectiveness of an ABC project: overall project time, project development time, on-site construction time, and mobility impact time. These terms are all defined on the Keywords page of the ABC Project Database [28]. The impact category is related to the mobility impact time, which is the total amount of time the traffic flow of the transportation network is reduced due to on-site construction activities. The six impact category tiers are:

- Tier 1: traffic impacts within 1 day
- Tier 2: traffic impacts within 3 days
- Tier 3: traffic impacts within 2 weeks
- Tier 4: traffic impacts within 1 month
- Tier 5: traffic impacts within 3 months
- Tier 6: overall project schedule is significantly reduced by months to years

Current definitions count night closures as a full day when counting days for determining the impact category (e.g., night closures for 3 weeks would fall under Tier 4).

The age of the bridge and age of the deck was calculated for all the bridges in the database based on the year built and year of deck construction and the current year. The impact category was found for projects in the ABC Project Database. The climate zone was found based on the Department of Energy (DOE) climate zone map [29], shown in Figure 5.4. The location of the bridge using the latitude and longitude data from the NBI was overlaid on the climate zone map to determine the climate zone for each bridge.

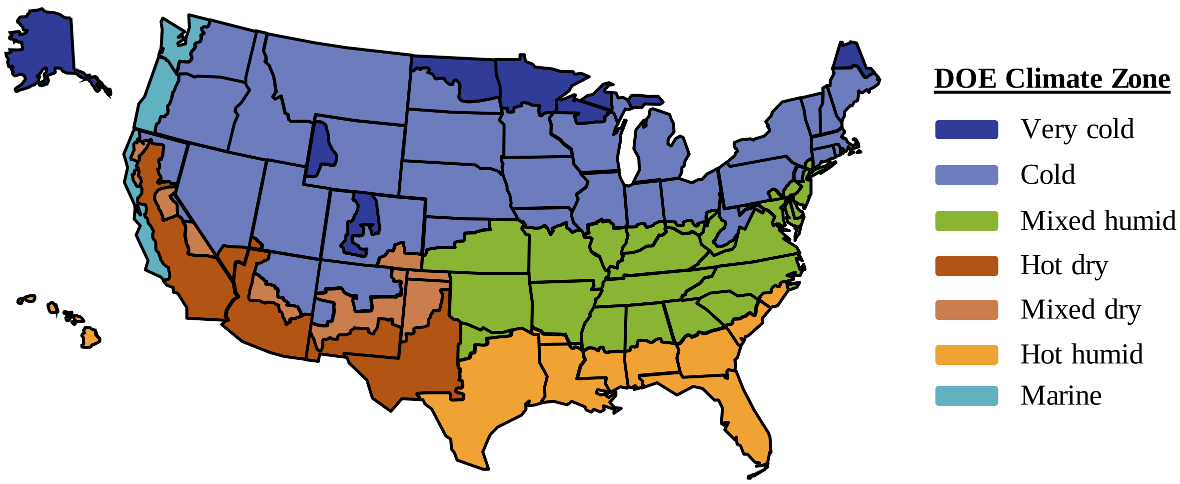


Figure 5.4: Department of Energy climate zones (based on [29])

Utah DOT specified the type of joint for each of their bridges, but not the impact category. Otherwise the joint type and impact category were only available for the bridges in the ABC Project Database. State DOTs were contacted again to attempt to gather additional details on the longitudinal and transverse joint types. Joint information was gathered on 158 of the 280 bridges in the FDPC database. State DOTs were also asked about the impact category for the FDPC deck panel bridge projects. The impact category was only obtained for 70 of the 280 bridges in the FDPC database. Many states do not record and store information related to construction time.

5.4. Comparison Projects

Comparison projects with CIP decks were determined for the majority of the bridges in the FDPC Deck Panel Database. These comparison projects were determined based on the criteria described in §5.3.1. A sample of the selected comparison projects is shown in Table 5.1 for the 37 bridges with FDPC deck panel decks in Utah. Some FDPC deck panel bridges did not have a reasonable comparison project. There were several other projects that have the same CIP comparison project.

Table 5.1: FDPC and CIP bridges for Utah State (*projects are repeated because of no other available comparison project; **FDPC project could not be found on LTBP InfoBridge)

Number	State	FDPC (NBI number)	CIP (NBI number)
UT-1	Utah	0C 401	0C 191R
UT-2	Utah	0C 437	0C 916
UT-3	Utah	2C 457	0C 988
UT-4	Utah	1C 470	2C 997
UT-5	Utah	3C 470	0C 986
UT-6	Utah	2C 476	0C 980
UT-7	Utah	4C 476	0C 753
UT-8	Utah	2C 477	2C 949
UT-9	Utah	2C 495	4C 755
UT-10	Utah	0C 518	2C 876
UT-11	Utah	0C 578	2C 786
UT-12	Utah	0C 588	2C 786*
UT-13	Utah	0C 596	2C 786*
UT-14	Utah	0C 679	0C 986*
UT-15	Utah	0C 966	4C1004
UT-16	Utah	0C 971	0C1015
UT-17	Utah	2F 94	n/a**
UT-18	Utah	2F 114	041025F
UT-19	Utah	4F-114	047065F
UT-20	Utah	1F 127	1F 836
UT-21	Utah	3F 127	3F 836
UT-22	Utah	1F 128	0F 783
UT-23	Utah	3F 128	2F 801
UT-24	Utah	1F 129	1F 836
UT-25	Utah	3F 129	3F 836
UT-26	Utah	1F 130	1F 836*
UT-27	Utah	3F 130	3F 836*
UT-28	Utah	2F 183	1F 435
UT-29	Utah	4F 183	3F 435
UT-30	Utah	0F 400	3F 834
UT-31	Utah	0F 741	1F 745
UT-32	Utah	0F 755	3F 835
UT-33	Utah	2F 759	2F 792
UT-34	Utah	4F 759	4F 792
UT-35	Utah	0F 762	0F 733
UT-36	Utah	0F 770B	1F 752
UT-37	Utah	3F 784	3F 739

5.5. Data Analysis Procedure

Two different procedures were used to compare the performance of bridges with FDPC deck panels to CIP decks:

1. Side-by-side comparison
2. Group comparison based on influential variables
3. Group comparison based on type of joint (UHPC or all others)

For side-by-side comparisons, the performance of a bridge with a FDPC deck panel deck with either UHPC joints or all other joint types was compared directly to the CIP comparison project. For the group comparison, the performance of groups of bridges with FDPC deck panel decks with similar characteristics and UHPC or all other joint types were compared with the performance of groups of bridges with CIP decks with similar characteristics.

Two values were used to compare the performance of bridges with FDPC deck panel decks to those with CIP decks: (a) deterioration rate of the deck and (b) estimated service life. Additionally, each comparison was given a rating based on the similarities between the bridge with FDPC deck panels and the bridge with CIP deck. These are discussed in more detail in the following sections.

5.5.1. Deterioration Rate and Estimated Service Life

The primary variables used to compare the performance of the bridges were deterioration rate and estimated service life. The deterioration rate (*D*) is the slope of the linear regression of the year and deck rating since time of deck construction, as shown in Equation 5-1.

$$D = \frac{n\left(\sum R_{d,i} t_i\right) - \left(\sum R_{d,i}\right)\left(\sum t_i\right)}{n\left(\sum {t_i}^2\right) - \left(\sum t_i\right)^2} \qquad \textbf{\textit{Equation 5-1}}$$

where:

D = deterioration rate for deck calculated based on NBI database (rating / year)

$R_{d,i}$ = deck rating obtained from NBI database for year *i* after deck construction

t_i = time of inspection after deck construction (years)

The estimated service life (*S*) of the deck was calculated based on the time it takes for the deck rating to reach a rating of 5, based on the deterioration rate and the starting deck rating as shown in Equation 5-2. A deck rating of 4 was used as the threshold for deck repair needed as this value corresponds to the boundary between fair and poor behavior used by previous researchers [27].

$$S = \frac{R_{d,0} - 4}{D} \qquad \textbf{\textit{Equation 5-2}}$$

where:

S = estimated service lift based on the deterioration rate calculated using Equation 5-1

$R_{d,0}$ = initial deck rating immediately after deck construction

An example for calculation of the deterioration rate and estimated service life are shown in Figure 5.5.

State	NBI #	Inspection Date	Deck Rating
Utah	0C 596	Oct-07	8 - VERY GOOD CONDITION...
		Jun-09	8 - VERY GOOD CONDITION...
		Jun-11	7 - GOOD CONDITION...
		Jun-13	7 - GOOD CONDITION...
		Jun-15	7 - GOOD CONDITION...

(a)

Age	Deck Rating
0.0	8
1.7	8
3.7	7
5.7	7
7.7	7
Slope =	**-0.155**
Estimated Service Life =	**19.4**

(b)

Figure 5.5: Example for calculation of deterioration rate and estimated service life determined for Utah NBI 0C 596: (a) information from the NBI and (b) calculated data

An upper limit for the estimated service life was set at 40 years. This meant that if a bridge was found to have a deterioration rate of zero, the estimated service life was set to 40 years.

5.5.2. Ranking of Comparison Projects

All comparison projects needed to have the same of the following parameters to be considered valid comparisons:

- Material and structure type
- Overlay or wearing surface
- Climate zone

Note that both comparison projects needed to either have an overlay or wearing surface or not have an overlay or wearing surface. The type of overlay did not need to be the same for the comparison projects.

Other variables could have different values between them. The quality of the comparison was rated based on how similar the comparison projects were with these other criteria. These variables included:

- Span length
- Year of construction
- ADT/ADTT

A rating was given to each comparison based on the degree of similarity of the values for each of the comparison projects. These ratings are summarized in Table 5.2.

Table 5.2: Criteria for rating of comparison projects

Comparison Rating		1	2	3	4	5
Span Length	X_{span}	≥ ± 30%	± 25 to 29.9%	± 20 to 24.9%	± 15 to 19.9%	< ±15%
Year	X_{year}	≥ ±10 yr	± 5 to 9.9 yr	± 3 to 4.9 yr	± 1 to 2.9 yr	< ±1 year
ADT	X_{ADT}	≥ ± 90%	± 70 to 89.9%	± 50 to 69.9%	± 30 to 49.9%	< ±30%
ADTT	X_{ADTT}	≥ ± 90%	± 70 to 89.9%	± 50 to 69.9%	± 30 to 49.9%	< ±30%

An example of how the span length difference and rating were calculated for the comparison of Utah projects 0C 971 and 0C 1015 is shown below:

$$\% \, diff_{Span} = \left(\frac{91.1' - 77.6'}{91.1'}\right) * 100\% = 14.8\% < 15\% \Longrightarrow X_{Span} = 5$$

Two additional factors were considered when determining the quality of the comparison: wearing surface type and number of spans. The overall rating was deducted by 0.5 points if there was a mismatch, as follows:

- Different types of wearing surface, X_{WS} = -0.5 rating
- Number of spans is different by > 3 spans, $X_{\#spans}$ = -0.5 rating

These ratings were then weighted, and then the overall rating deductions for wearing surface type and the number of spans were applied using Equation 5-3. The year was weighted more heavily than the span length and the ADT because of the importance of comparing structures with a similar age.

$$X = \frac{1}{5}\left(X_{span} + 2X_{year} + X_{ADT} + X_{ADTT}\right) + X_{WS} + X_{\#spans} \qquad \textbf{\textit{Equation 5-3}}$$

The comparison projects were included in the following analyses if the overall comparison rating (X) was greater than or equal to 3.0. Comparisons with a lower rating were not considered in the analyses. An additional filter was applied to filter out bridges without sufficient inspection data (at least three inspection records) and bridges with clearly inaccurate information in the LTBP InfoBridge.

5.6. Side-by-Side Comparison

A side-by-side comparison was conducted for the 280 comparison projects from entire FDPC Deck Panel Database. A complete list of the comparison projects with details on each comparison is provided in Appendix C.

Of the 280 total comparisons, 173 of them had an overall comparison rating greater than or equal to 3.0, shown in Figure 5.6 (a). In 52 of the 173 comparison projects, the bridge with a CIP deck had a higher deterioration rate, shown in Figure 5.6 (b). The bridge with a FDPC deck panel deck had a higher deterioration rate in 76 of the 173 comparison projects. The bridges with the two types of decks had the same deterioration rates in 45 of the comparisons.

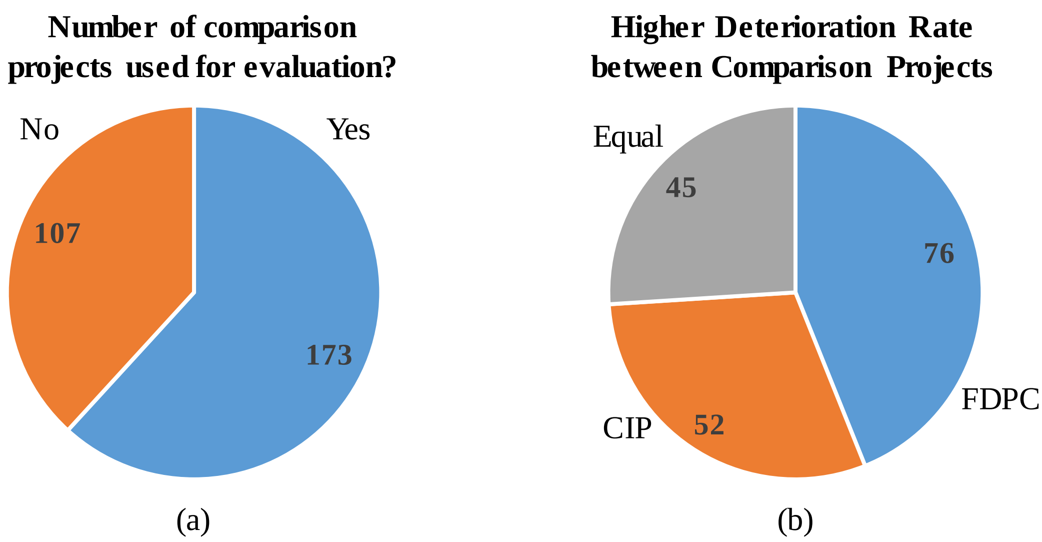


Figure 5.6: (a) Number of comparison projects used for evaluation (b) type of bridge with higher deterioration rate

5.7. Performance Comparison Based on the Classification of Variables

The overall average performance for all the bridges with FDPC deck panel decks and CIP decks is summarized in Table 5.3. The average deterioration rate for bridges with FDPC deck panels is slightly higher than bridges with CIP decks (-0.117 compared to -0.087). This leads to a slightly longer estimated service life for bridges with CIP decks compared to bridges with FDPC deck panels.

Table 5.3: Overall average performance of bridges with FDPC deck panel decks and CIP decks

Deck Type	*FDPC*	*CIP*
$n_{bridges}$	206	178
Avg. $n_{inspections}$ ***per bridge***	12.6	13.0
Avg. Year of 1st Inspection	2004	2005
Deterioration Rate	-0.12	-0.09
Estimated Service Life (year)	33	35

A breakdown of performance based on the following subcategories is provided in the following sections:

- Joint type
- Impact category
- Climate zone
- Wearing surface
- Main span material type
- ADTT and ADT

- Type of construction (new construction versus rehabilitation)

These initial comparisons are for all bridges in Utah including CIP and FDPC.

5.7.1. Performance Based on Joint Type for FDPC Bridges

Based on complimentary information gathered from DOTs, the performance of FDPC deck panels was analyzed and compared based on different joint types for both longitudinal and transverse joints. The average performance of FDPC deck panels for different transverse and longitudinal joint types is summarized in Table 5.4 and Table 5.5 respectively. The number of bridges represented in these tables does not include all bridges in the database, but only the number of bridges with sufficient available inspection information.

The data for joints with only a few bridges or a newer construction date are likely not representative of the true performance of the joint. Newer construction is impacted more by small changes in performance rating than older bridges.

Table 5.4: Average performance of bridges with FDPC deck panel based on transverse joint types

Joint Category	*Long. PT - C1.a*	*Non-PT - C1.a*	*Welded - C1-b*	*Grouted Dowel - C1.c*	*UHPC - C1.f*	*UHPC - C1.g*	*CC - C1.h*
$n_{bridges}$	40	38	10	4	13	1	3
Avg. $n_{inspections}$ ***per bridge***	7.8	14.9	6.2	5.0	5.6	8.0	11.0
Avg. Year of 1^{st} ***Inspection***	2009	2003	2008	2012	2012	2010	2006
Deterioration Rate	-0.12	-0.07	-0.13	-0.03	-0.13	-0.24	-0.17
Estimated Service Life (year)	31	36	29	40	33	21	30

Table 5.5: Average performance of bridges with FDPC deck panels based on longitudinal joint types

Joint Category	*Non-PT - C1.a*	*Welded - C1-b*	*Grouted Dowel - C1.c*	*UHPC - C1.f*	*UHPC - C1.g*	*CC - C1.h*	*CC - C1.i*	*CC - C1.j*	*None*
$n_{bridges}$	4	3	10	12	2	12	16	2	51
Avg. $n_{inspections}$ ***per bridge***	13.5	21.7	4.0	5.8	5.5	6.0	6.4	4.0	12.7
Avg. Year of 1^{st} ***Inspection***	2005	1997	2011	2012	2013	2011	2008	2014	2009
Deterioration Rate	-0.07	-0.07	-0.08	-0.15	-0.37	-0.09	-0.11	-0.40	-0.08
Estimated Service Life (year)	35	40	29	32	16	34	31	11	34

5.7.2. *Performance Based on Impact Category*

The average performance of bridges with FDPC deck panel decks grouped based on the impact categories are shown in Table 5.6. The lowest deterioration rates and longest estimated service life were observed for Tiers 1, 2, and 3, which are the most accelerated construction times.

Table 5.6: Average performance of bridges with FDPC deck panels based on impact category

Deck Type	*FDPC*					
Impact Category	*Tier 1*	*Tier 2*	*Tier 3*	*Tier 4*	*Tier 5*	*Tier 6*
$n_{bridges}$	3	3	3	3	17	11
Avg. $n_{inspections}$ ***per bridge***	4.0	10.3	19.0	3.0	10.1	8.2
Avg. Year of 1^{st} ***Inspection***	2012	2008	2007	2014	2008	2009
Deterioration Rate	0.0	-0.03	-0.09	-0.25	-0.15	-0.18
Estimated Service Life (year)	40	39	34	22	30	30

5.7.3. *Performance Based on Climate Zone*

The average performance of bridges with FDPC deck panel decks grouped based on the DOE climate zone are shown in Table 5.7 alongside the average performance of the CIP deck comparison projects.

Table 5.7: Comparison of average performance of bridges with FDPC deck panels and CIP decks based on climate zone

Climate Category	*Very Cold*		*Cold*		*Mixed humid*		*Hot humid*	
Deck Type	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*
$n_{bridges}$	43	23	92	66	117	117	1	1
Avg. $n_{inspections}$ ***per bridge***	14.3	13.4	5.9	7.9	10.0	14.8	5.0	9.0
Avg. Year of 1^{st} ***Inspection***	2004	2005	2009	2007	2007	2004	2008	2009
Deterioration Rate	-0.08	-0.05	-0.09	-0.09	-0.13	-0.09	-0.10	-0.14
Estimated Service Life (year)	35	38	33	35	33	36	40	28

5.7.4. *Performance Based on Wearing Surface*

The average performance of bridges with FDPC deck panel decks grouped based on the type of wearing surface are shown in Table 5.8 alongside the average performance of the CIP deck comparison projects.

Table 5.8: Comparison of average performance of bridges with FDPC deck panels and CIP decks based on wearing surface

Wearing Surface	*None*		*Monolithic Concrete*		*Integral Concrete*		*Latex Concrete*		*Epoxy overlay*		*Bituminous*		Other	
Deck Type	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*
$n_{bridges}$	3	4	45	35	16	47	7	1	26	21	99	65	14	3
Deterioration Rate	-0.07	-0.11	-0.09	-0.06	-0.14	-0.08	-0.27	-0.08	-0.11	-0.12	-0.11	-0.09	-0.06	-0.12
Estimated Service Life (year)	34	37	35	38	33	35	24	38	30	30	32	35	39	37

5.7.5. Performance Based on Main Span Material

The average performance of bridges with FDPC deck panel decks grouped based on the main-span material and type are shown in Table 5.9 alongside the average performance of the CIP deck comparison projects.

Table 5.9: Comparison of average performance of bridges with FDPC deck panels and CIP decks based on main span material

Main Span Material	*Concrete continuous*		*Steel*		*Steel continuous*		*Prestressed concrete*		*Prestressed concrete continuous*		*Wood or timber*	
Deck Type	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*	*FDPC*	*CIP*
$n_{bridges}$	1	1	143	118	31	27	26	6	2	2	1	1
Deterioration Rate	0.000	0.000	-0.114	-0.083	-0.089	-0.077	-0.127	-0.092	-0.200	-0.107	-0.121	0.000
Estimated Service Life (year)	40	40	34	36	33	37	30	37	25	32	25	40

5.7.6. Performance Based on ADTT and ADT

Previous researchers have found that the ADT and ADTT impact the deterioration of decks: higher truck volumes will lead to faster deck deterioration. The performance of the bridges in the FDPC Deck Panel Database are divided into low volume truck traffic (ADTT < 6,000) and high volume (ADTT > 6,000) and shown in Table 5.10. A similar division was also made based on the ADT, shown in Table 5.11.

Table 5.10: Comparison of average performance of bridges with FDPC deck panels and CIP decks based on ADTT

ADTT	*< 6000*		*> 6000*	
Deck Type	*FDPC*	*CIP*	*FDPC*	*CIP*
$n_{bridges}$	183	167	27	17
Deterioration Rate	-0.11	-0.08	-0.16	-0.09
Estimated Service Life	34	36	28	34

Table 5.11: Comparison of average performance of bridges with FDPC deck panels and CIP decks based on ADT

ADT	*< 30000*		*> 30000*	
Deck Type	*FDPC*	*CIP*	*FDPC*	*CIP*
$n_{bridges}$	180	163	30	20
Deterioration Rate	-0.11	-0.09	-0.15	-0.07
Estimated Service Life	33	36	30	35

5.7.7. Performance Based on Type of Construction

The year of construction for the bridge and year of deck construction are two values that are available in the NBI and LTBP InfoBridge. The type of construction (new versus rehabilitation) was determined using this information. New construction was assumed where the year of bridge construction was equal to the year of deck construction. A rehabilitation project was assumed if the year of bridge construction was at an earlier date than the year of deck construction. The performance based on this classification for bridges with FDPC deck panels is shown in Table 5.12.

Table 5.12: Average performance of bridges with FDPC deck panels based on new construction or rehabilitation

Type of Construction	*New*	*Rehab*
$n_{bridges}$	94	112
Avg. $n_{inspections}$ ***per bridge***	13.6	11.7
Avg. Year of 1st Inspection	2003	2005
Deterioration Rate	-0.12	-0.12
Estimated Service Life (year)	33	33

5.8. Summary

A summary of the inspection data for the bridges in the FDPC Deck Panel Database and CIP comparison projects was presented in this chapter. The performance of these systems was evaluated based on the NBI deck rating. There are limitations to this approach, but this work can be used as a starting point to a more in-depth evaluation of these projects. The average performance of bridges with FDPC deck panels were compared with similar bridges with CIP decks. These performance comparisons were further evaluated in several subcategories. Overall, bridges with FDPC deck panels performed similarly to similar CIP bridges. As the precast panel itself offers superior durability to CIP decks, these results may suggest that there is room for improvement with joint design and construction.

CHAPTER 6. GUIDE FOR DESIGN OF FDPC DECK PANELS

6.1. Introduction

The design of full-depth precast concrete (FDPC) deck panels involves the design of several different components: (1) FDPC deck panel, (2) transverse joint, (3) longitudinal joint, and (4) shear pocket. The major components of the FDPC deck panel deck are highlighted Figure 6.1.

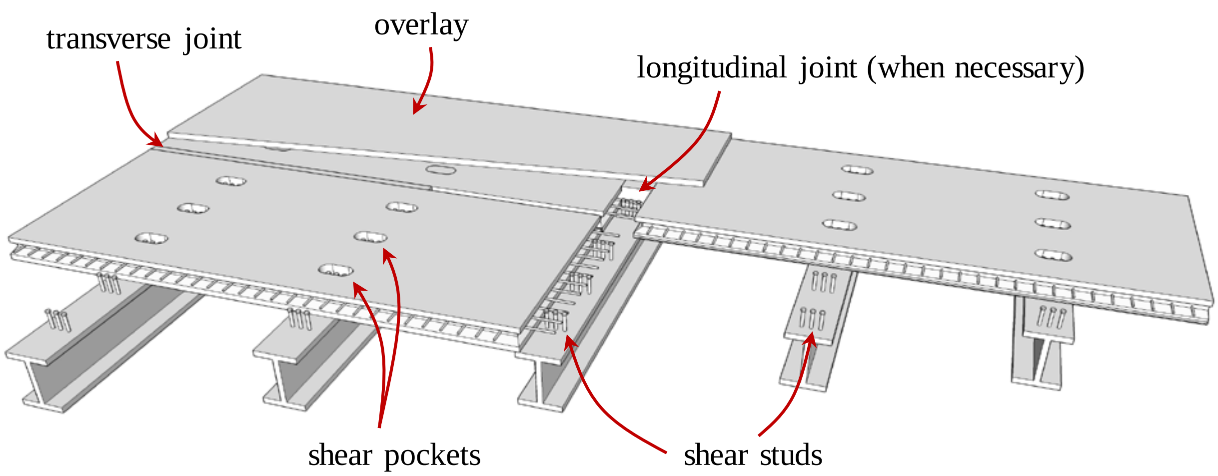


Figure 6.1: Components of FDPC deck panel deck system

The design and detailing of FDPC deck panels and the connection between panels will be discussed in this chapter.

6.2. Overview of Design of FDPC Deck Panel Decks

In design of FDPC deck panels system, designers can choose among a variety of choices. Panels can be designed with pre-tensioning or conventional reinforced concrete design. They can be designed for composite action with girder by providing shear stud connections or be designed as a non-composite member. The designer can also consider post-tensioning for minimizing cracks in joints along with several types of panel to panel joints. Additionally, designers can use a combination of FDPC deck panels and CIP details whenever it is needed based on geometry and project requirements.

The following parameters must be determined during the design process of FDPC deck panel systems:

- Panel dimension and configuration
- Shear pocket configuration for achieving full composite action
- Panel reinforcement detail (including prestressing design if used)
- Concrete mix design for precast panel
- Joint geometry and connection type (including post-tension details if used)
- Filling material for joints and shear pockets
- Type of overlay materials
- Parapets and connection detail to panels
- Handling and transportation

Successful construction and long-term performance of FDPC deck panel systems is dependent on successful design and detailing of each of these parameters.

6.3. Panel Design

6.3.1. Dimensions and Configuration

There are not any standard dimension for FDPC deck panels; the maximum dimensions are typically limited by shipping and handling requirements [30]. The shorter panel dimension is typically between 8 and 12 feet, as shown in Figure 6.2. The short panel dimension is primarily controlled by the maximum width allowed for shipment of the panels from the precaster to the construction site. The long panel dimension is typically less than 40 to 50 feet and equal to the full bridge width when possible [31], [32]. The long panel dimension is primarily controlled by the tensile stress that develops during lifting and placement of the panels. The thickness of the panels is generally governed by the minimum thickness requirements and minimum cover requirements. These requirements typically result in a minimum deck thickness of 7 inches for typical decks and 8.5 inches for post-tensioned decks [31].

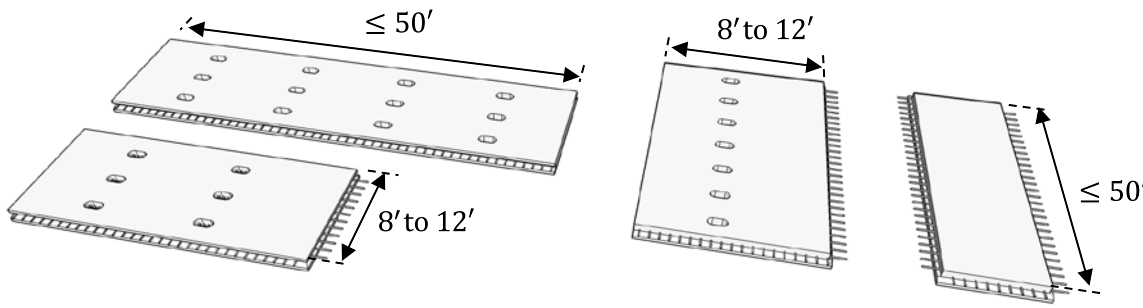


Figure 6.2: Typical maximum dimensions of FDPC deck panels

There are two typical panel configurations that are primarily based on the width of the bridge, shown in Figure 6.3. The FDPC deck panel can be equal to the bridge width for bridge widths less than 40 to 50 feet, which eliminates the need for a longitudinal joint, shown in Figure 6.3 (b). Multiple FDPC deck panels will be needed across the width for bridge widths greater than 40 to 50 feet, shown in Figure 6.3 (a). Both configurations run the precast panels transverse to the girder lines.

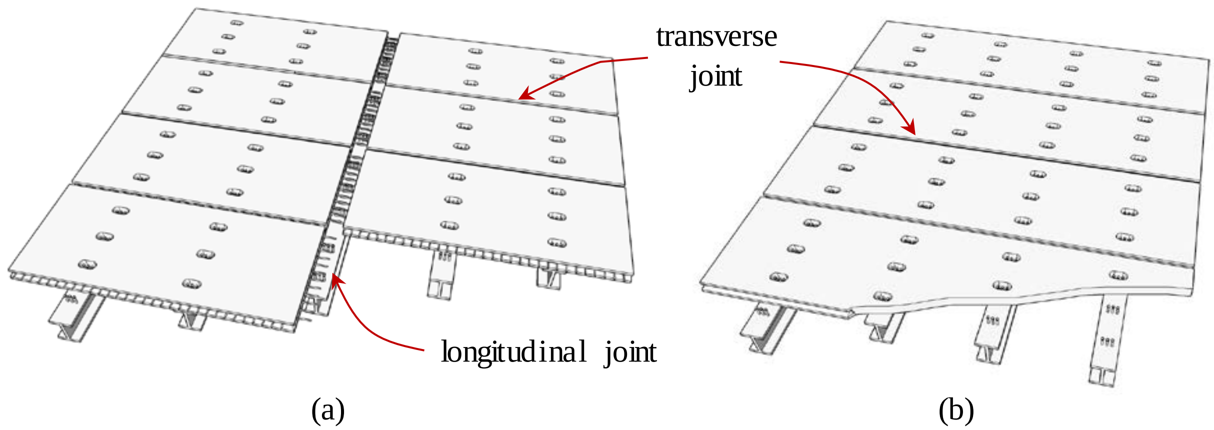


Figure 6.3: Conventional deck panel configurations for (a) bridge widths greater than 40 to 50 feet and (b) bridge widths less than 40 to 50 feet

Alternatively, panels can be run in the longitudinal direction, the same direction of the girders, shown in Figure 6.4. Running panels in the longitudinal direction can help to eliminate the need for shear pockets in most of the panels, although some type of shear pocket will be required for the overhang panels. Because of the elimination of the shear pockets, the designer has flexibility with placement of shear studs, so this detail can be used for situations where a large number of shear studs are required. A similar panel configuration was used on Boston's Commonwealth Avenue Bridge [33].

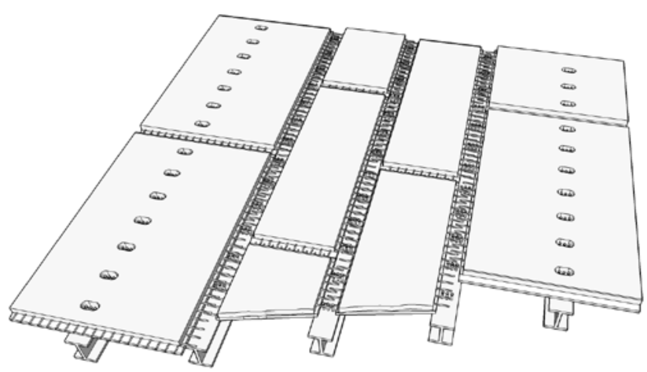


Figure 6.4: Alternate panel configuration, based on [33]

Skew can be handled in FDPC deck panels either by creating skewed panels or using square panels to create a skewed configuration, as shown in Figure 6.5. Skewed panels can be utilized in any of the three configurations described above for light skewed bridges (where reinforcement would be run in the direction of the skew). Creating a skew with square deck panels would primarily be an option when using the longitudinally configured deck panels for larger skewed bridges (where reinforcement would be run perpendicular to the girder lines).

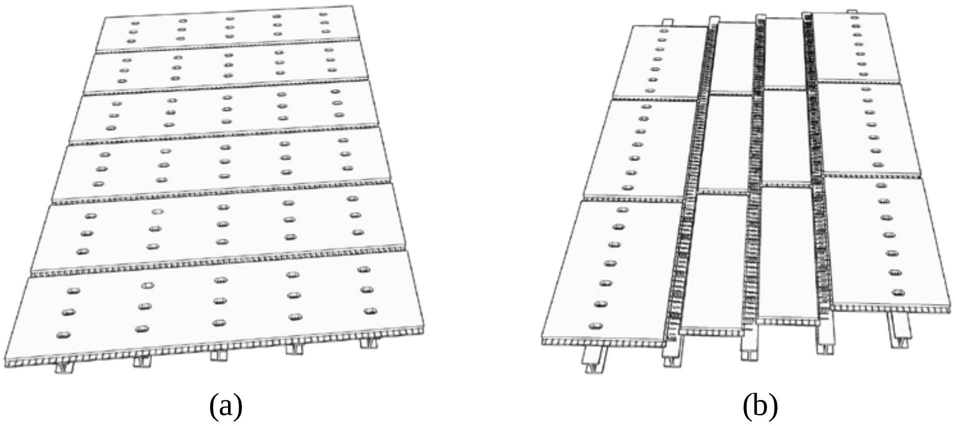


Figure 6.5: Two ways to handle skew in FDPC deck panels: (a) skewed panels and reinforcement for light skews and (b) offset rectangular panels with reinforcement perpendicular to girder lines for larger skews

Utah DOT allows for up to 15-degree skew with skewed panels and up to 45-degree skew with square panels [34].

6.3.2. Precast Panel Reinforcement Detail

Design of deck panels includes transverse design (perpendicular to traffic flow) and longitudinal design (parallel to traffic flow). There are not any specific design provision for FDPC deck panels in the AASHTO LRFD Bridge Design Specification [35]. The LRFD Guide Specification for Accelerated Bridge Construction [30] specifies that FDPC deck panels themselves should be designed using the provisions for CIP concrete decks as specified in the AASHTO LRFD Bridge Design Specifications.

The procedure which normally is used for design purposes is the strip design method, which considers a small transverse strip of the deck as a continuous beam supported on the girders, as shown in Figure 6.6. Design can be done by using non-prestressed, prestressed or combination of them for transverse direction [31].

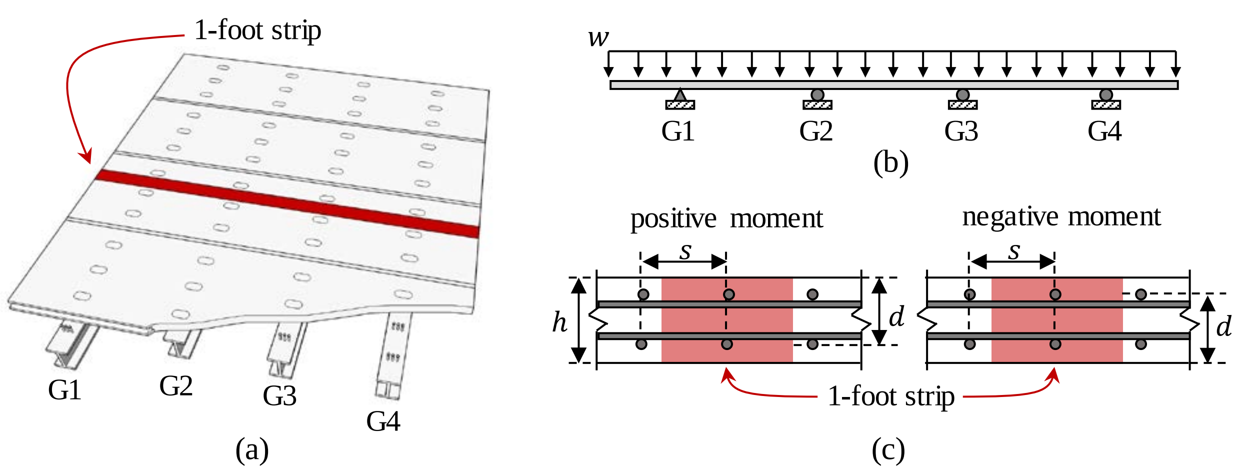


Figure 6.6: Basics of strip design method for designing transverse reinforcement

Reinforcement running in the direction of the girders should be detailed to control shrinkage cracking and distribute live load. Both transverse and longitudinal design should satisfy all requirements on AASHTO LRFD specification. Using smaller bar sizes at a closer spacing is typically preferred to using larger bars at larger spacing. Closer spaced reinforcement helps to control cracking. Most states have a cap for maximum bar size in their design approach, which is typically #6 rebar [31].

Panel reinforcement must be detailed for lifting and placement of the panels. Different lifting procedures will impact the moments and stresses generated during lifting, shown in Figure 6.7. In many cases additional reinforcement will need to be provided to resist stressed during lifting.

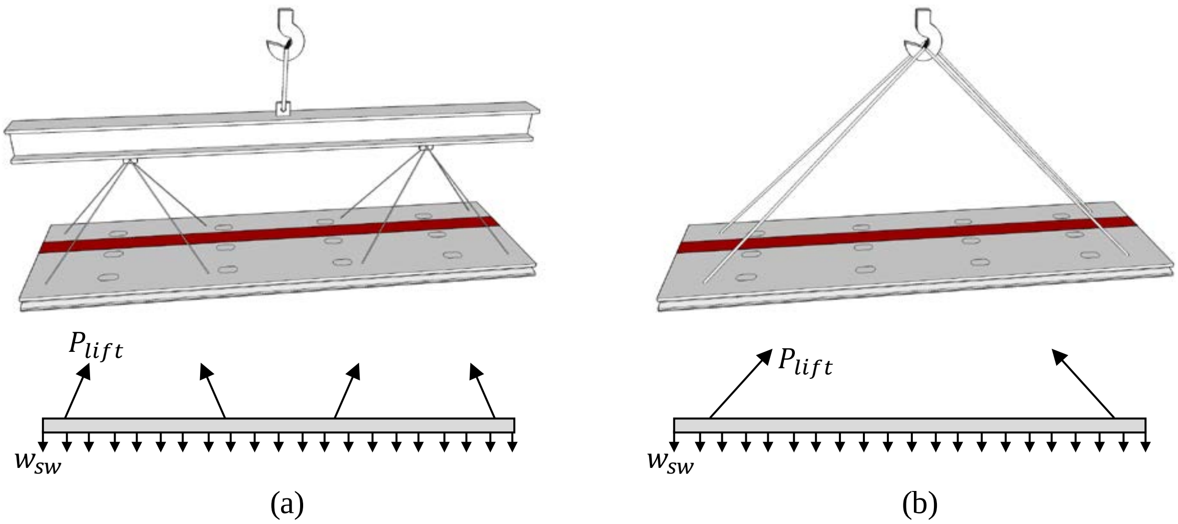


Figure 6.7: Possible lifting points for precast panels (a) with spreader beam and (b) without spreader beam

A sample reinforcement detail obtained through the survey from this project is shown in Figure 6.8. Reinforcement is distributed around the shear pockets. Other sample reinforcement details can be found in the PCI State-of-the-Art Report on FDPC Bridge Deck Panels [34] and the ABC Project Database [28].

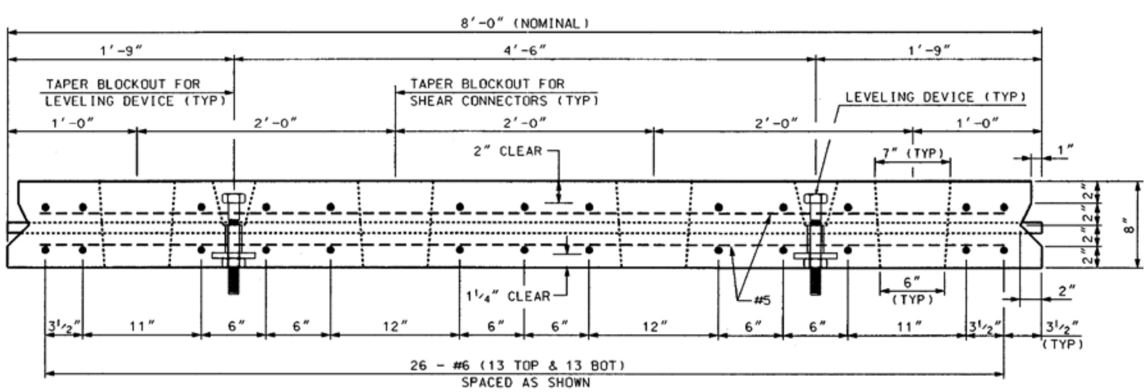


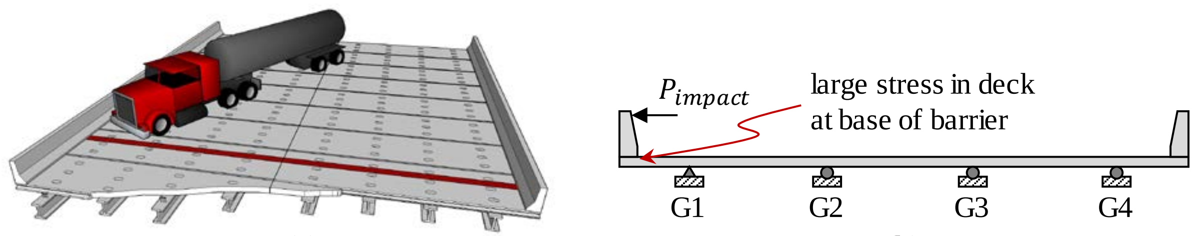
Figure 6.8: Standard FDPC deck panel reinforcement detail (obtained through DOT survey from NHDOT)

Note that the empirical design method is not allowed for FDPC deck panels [30].

6.3.3. *Overhang and Barrier Design*

The provisions for deck overhangs for CIP decks in the AASHTO LRFD Bridge Design Specification [35] can be used for FDPC deck panels. Care should be taken to properly check the stresses in these overhangs and the development of any prestressing strands or reinforcement.

Design of overhangs is often controlled by the forces due to a vehicle impact on the barrier, which will generate large stresses in the deck at the base of the barrier [30], shown in Figure 6.9. The overhang design is based on the assumption that the barrier should fail before the deck overhang fails, so the deck needs to be able to hold the force transferred during impact. Because large stresses can develop near the base of the barrier, the development length of prestressing strands and reinforcement will often control the strength.



(a) (b)

Figure 6.9: Barrier impact often controls design of overhang

An additional challenge in overhang design can result from the presence of shear pockets over the exterior girders. The weight of barriers on the external edge of an overhang can lead to additional reinforcement required over the exterior girder and may lead to congestion around the shear pockets in the panels [32]. A sample detail for barrier and overhang is shown in Figure 6.10.

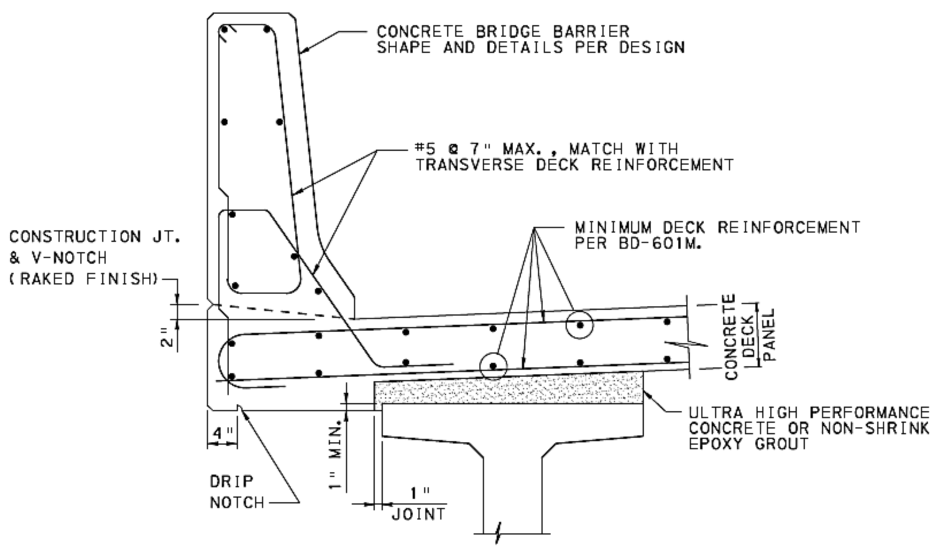
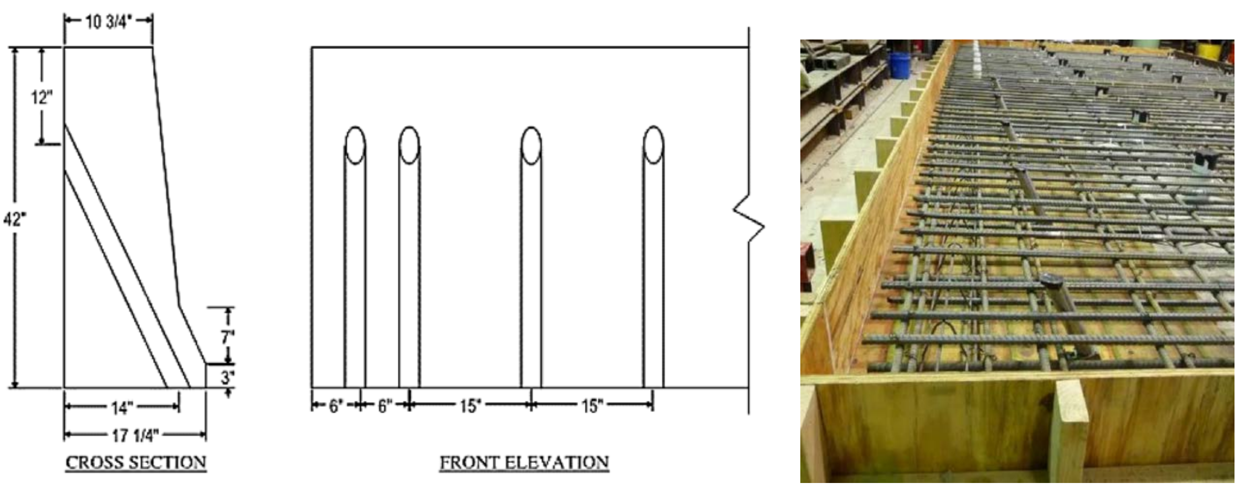


Figure 6.10: Example detail of barrier and overhang (obtained through DOT survey from PennDOT)

Barriers can be cast-in-place after placement of the deck panels, precast separate from the panels and connected to them during construction, or integrally cast with the deck panels (for bridges with a single panel used for the bridge width). An example of a barrier cast integrally with the precast deck panel is shown in Figure 6.11 for a deck panel project in Utah. The added weight of the barriers can increase the demand during lifting and handling, but integrally casting the barriers can further reduce the construction time [32].

Figure 6.11: Precast Concrete Deck Panel with Integral Barrier [32]

A recent project was completed by Iowa State University supported by the Accelerated Bridge Construction University Transportation Center (ABC-UTC) [36]. A detail was developed through static testing for the connection between a deck and a precast barrier, shown in Figure 6.12. Further testing on this connection through impact loading is being planned for the near future through a pooled-fund study.



(a) (b)

Figure 6.12: (a) Recommended detail for connection with precast barriers and (b) inclined blockout required in deck element [36]

6.3.4. Shear Pockets and Horizontal Shear Connectors

Shear pockets and shear studs create composite action between the supporting girders and the deck by preventing any horizontal and vertical movement. Design of the shear studs and composite design should be done similar to conventional concrete decks [30]. Based on LRFD specification, the maximum distance of studs should be less than 2 feet for steel girders and 4 feet for concrete girders for non-welded studs to provide complete composite action between the concrete panel and girder [31], [32], [35]. Typically, shear pockets spaced at 2 feet on center, as shown in Figure 6.8, with groups of three shear studs will be sufficient to create a composite connection between the girder and precast deck.

The typical shear pocket geometry and details are shown in Figure 6.13. Welded stud connectors are used for steel girders. Projecting reinforcement from the top of concrete girders or using welded stud connectors attached to an embedded steel plate are two common transfer methods for concrete girders [30].

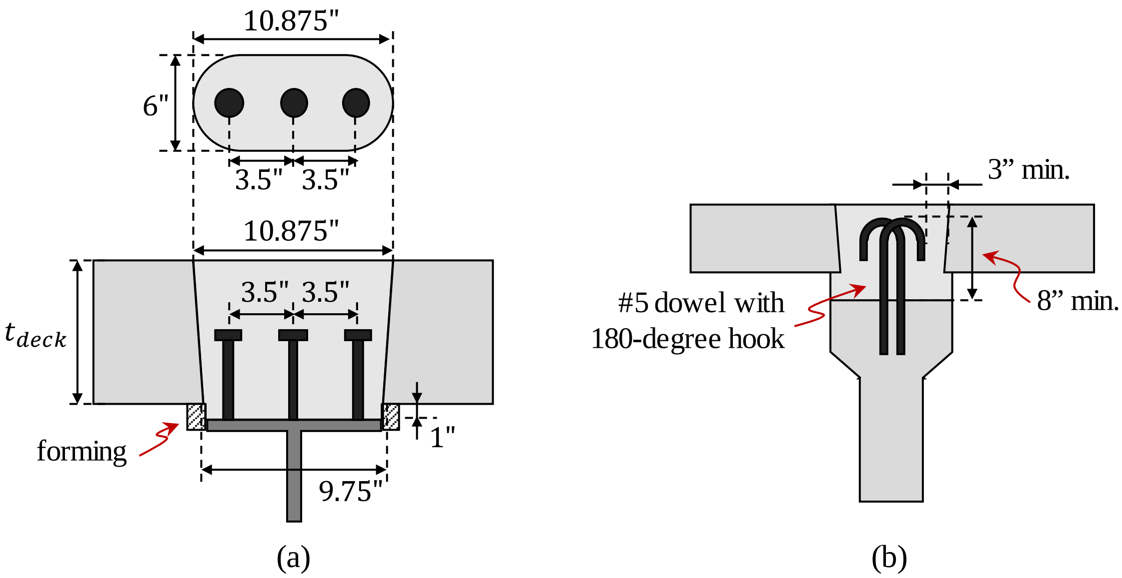


Figure 6.13: Examples of shear pocket and connector details for (a) steel plate girders and (b) prestressed concrete girders, based on [31]

A sample shear pocket and shear connector detail obtained from the DOT survey is shown in Figure 6.14.

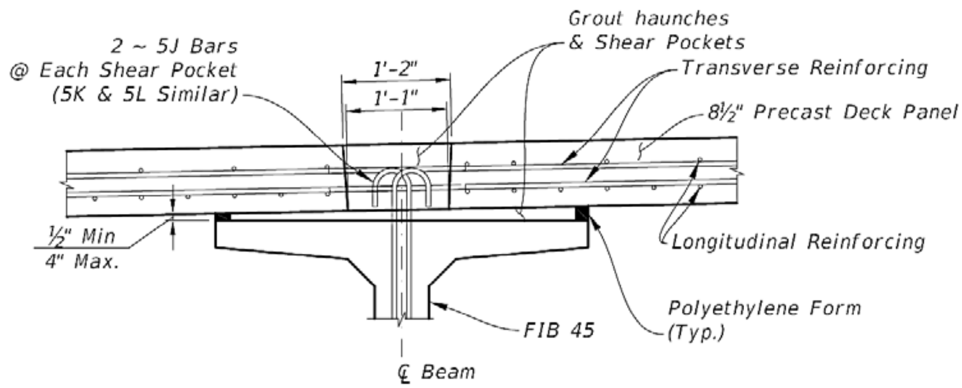


Figure 6.14: Example detail of shear pocket and shear connectors (obtained through DOT survey from FDOT)

Either partial depth or full depth pockets can be used. Previous researchers [37], [38] have found that partial depth pockets can successfully transfer the interface shear between the girder and precast deck. A sample partial depth pocket detail is shown in Figure 6.15. This detail utilizes ultra-high performance concrete (UHPC) to provide a full-composite connection between the deck and girder although the shear studs do not extend past the reinforcement in the precast panels.

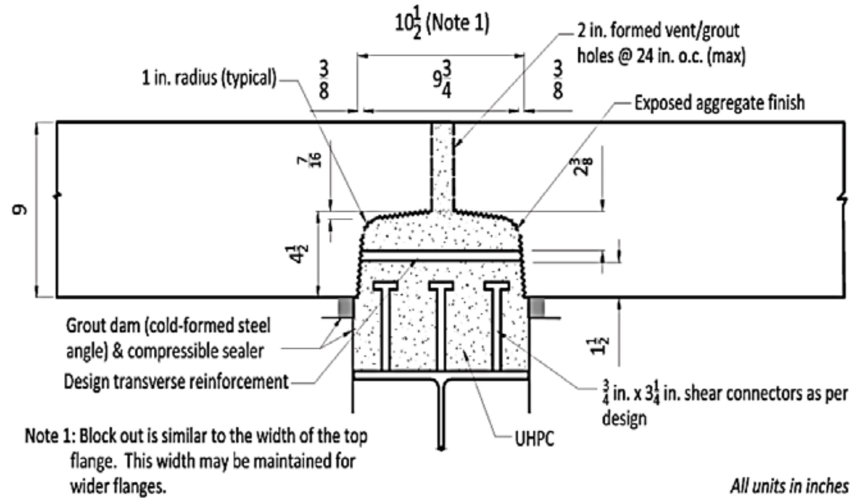


Figure 6.15: Partial depth pocket from Graybeal [38]

Shear connectors can also be placed in the longitudinal joints between panels for panel orientations where multiple panels are used across the bridge width. A sample detail of the shear connector extending from a precast beam into the longitudinal joint between two precast panels obtained from the DOT survey is shown in Figure 6.16.

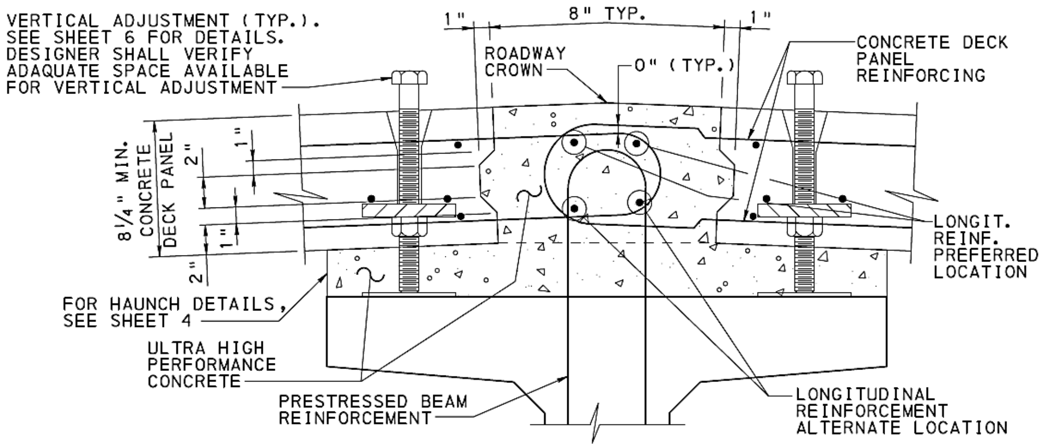
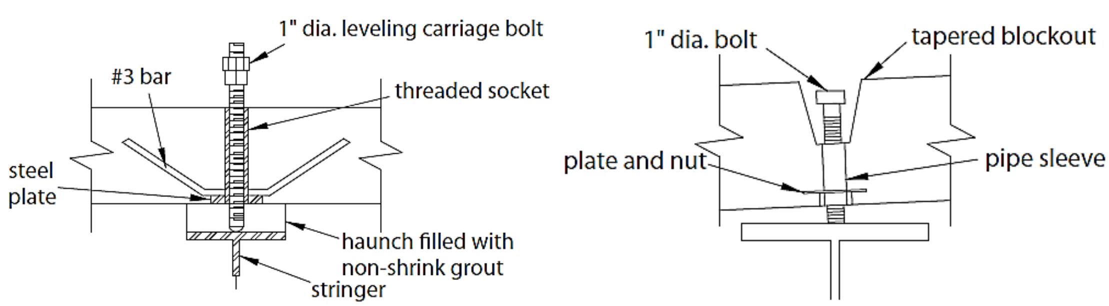


Figure 6.16: Example detail of shear connector extending into longitudinal joint between two precast panels (obtained through DOT survey from PennDOT)

6.3.5. Panel Leveling System

A panel leveling system is required during panel installation to ensure that panels are properly placed and can evenly transfer panel dead loads into the girders prior to joint and shear pocket casting. One common system is to use the bolt and a pipe sleeve which is cast into the panel, shown in Figure 6.16. Several other states have used a similar detail, shown Figure 6.17. Note that it is recommended to consider a minimum 1-inch haunch between panels and girders for tolerances, which is usually provided by using forming at the bottom of the panel in a way that the grout can easily move from one shear pocket to another to be sure that the haunch is fully grouted.



(a) (b)

Figure 6.17: Leveling screw detail from (a) Connecticut River Bridge and (b) PCI New England Recommendation [31]

Different details for forming the haunch have been used. One practical and cost-effective detail utilizes steel angles along the edge of the girders is shown in Figure 6.18.

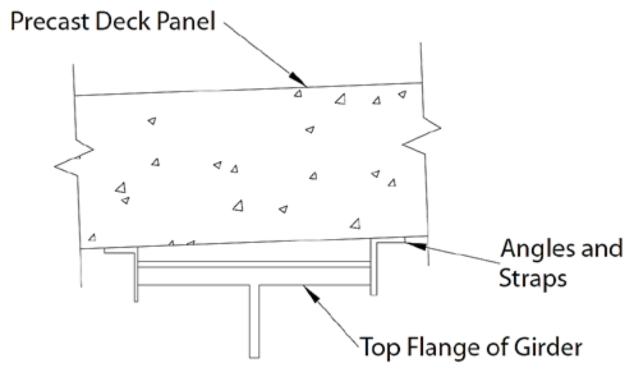


Figure 6.18: Recommended Leveling and haunch forming system similar to Skyline Bridge [31]

6.3.6. Concrete Mixture for FDPC Deck Panels

Typical high performance concrete mixtures used for precast concrete construction can be used for casting FDPC deck panels. Adequate concrete strength for service and strength checks can usually be achieved within the first day or two. It is recommended to wait at least 28 days after panel casting before placement of the panels [31]. Waiting this extra time will help to ensure that shrinkage and creep deformations occur prior to placement of the panels.

6.4. Joint Design

As previously discussed, there are two primary types of joints in FDPC deck panel systems: transverse and longitudinal, shown in Figure 6.3. Longitudinal joints are only required in bridges where multiple panels are required across the bridge width. All joints should be designed and detailed as full moment connections [30].

The most commonly used joint details for bridges contained in the FDPC Deck Panel Database are summarized in Table 6.1 with the percentage of bridges having the detail shown. The longitudinal post-tensioning detail was only used for transverse joints. The grouted shear key without post-tensioning detail was primarily used for off-system bridges in Alaska, although there is one bridge in New York and one in Washington with this detail.

Table 6.1: Joint detail usage for bridges in FDPC Deck Panel Database

Joint Type	**Percent of Bridges in FDPC Deck Panel Database with Joint Type**	
	Transverse Joint	*Longitudinal Joint**
Longitudinal post-tensioning	34.2%	-
Conventional concrete with hooped or straight bar detail	11.4%	29.3%
UHPC with straight bar detail	15.8%	15.3%
Grouted shear key without post-tensioning	24.1%	2.5%

*39.5% of bridges did not have a longitudinal joint

Many bridges utilized deck panels that were the full width of the bridge (around 40 percent), so no longitudinal joint was required. When multiple panels were required across the width of the superstructure, the most common longitudinal joint details with good long-term performance are:

- Conventional concrete with hooped or straight bar details and
- UHPC with straight bar detail.

Schematics of these basic details are shown in Figure 6.19. The convention concrete with straight bar detail is similar to the hooped bar detail only with a slightly wider joint region to provide the additional required splice length.

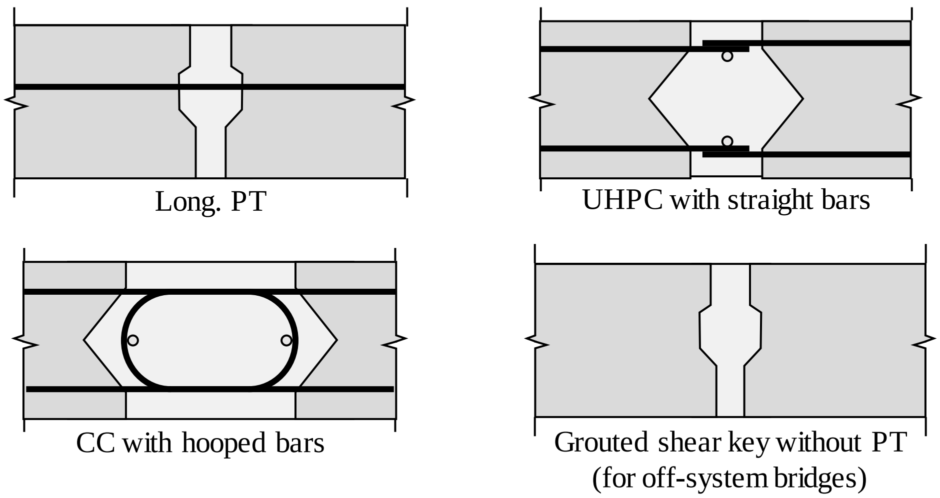


Figure 6.19: Most popular joint details with good long-term performance

There are several configurations of these joints that have been observed through the state survey and development of the FDPC Deck Panel Database. The three most common combinations of transverse and longitudinal joints used in FDPC deck panel systems are shown in Table 6.2.

Table 6.2: Most common joint combinations from the FDPC Deck Panel Database

#	Transverse Joint	Longitudinal Joint	Percent of Bridges*
1	UHPC with straight bar detail	UHPC with straight bar detail	25.3%
2	Longitudinal post-tensioning	Conventional concrete with hooped or straight bar detail	24.2%
3	Conventional concrete with hooped or straight bar detail	Conventional concrete with hooped or straight bar detail	13.7%

*Percent of bridges with a longitudinal joint; bridges without a longitudinal joint were not included

The two most common combinations of transverse and longitudinal joints are shown in Figure 6.20.

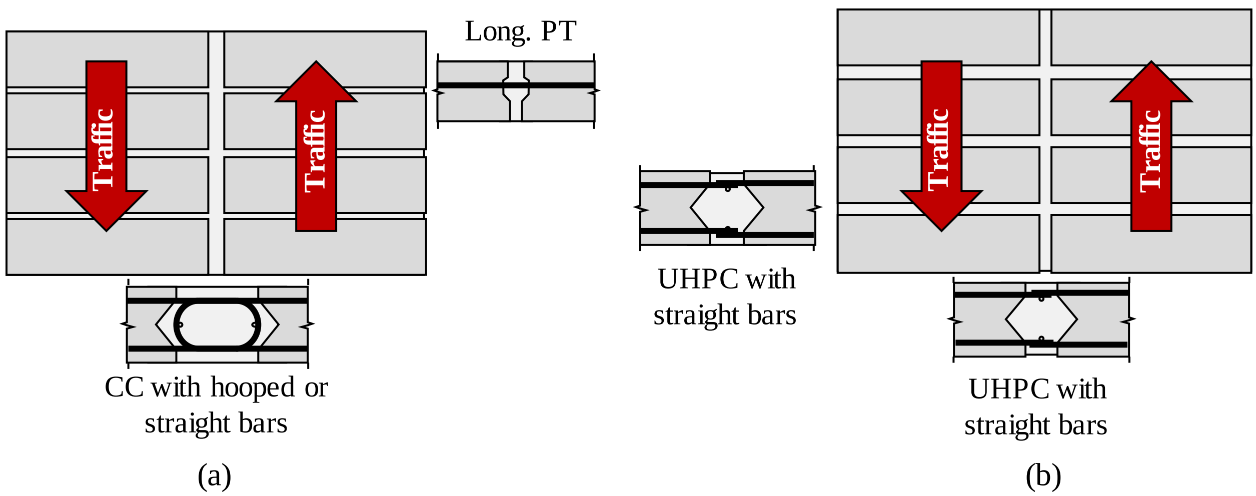


Figure 6.20: Two most common combinations of transverse and longitudinal joints: (a) longitudinal post tensioning with transverse conventional concrete joint and (b) UHPC with straight bar detail for both transverse and longitudinal joints

The four most common joint details will be discussed in more depth in the following sections.

6.4.1. Longitudinal Post Tensioning with Grouted Shear Key

The longitudinal post tensioning with grouted shear key detail has been the most commonly used transverse joint detail. While post-tensioning can increase the construction cost of the bridge deck, it is an effective method for improving the durability of the system. Post tensioning is generally placed at the mid-depth of panels and runs along the entire length of the bridge. Longitudinal post tensioning for FDPC deck panel systems is typically done using high strength threaded rods, mon-strands, or flat multi-strand tendons. For simple spans, sufficient post-tensioning should be provided to provide a minimum prestress level of 0.250 ksi after all prestress losses [35]. Waiting at least 28 days after panel casting for placement and tensioning of the panels will help to decrease the shrinkage and creep losses. Additional details on post-tensioning design and details for FDPC deck panels can be found in PCI's "State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels" [31].

The joint geometry for longitudinal post-tensioned systems can either be a female-to-female joint with a small grouted section between panels or a male-to-female match-cast joint with epoxy or grout between panels, shown in Figure 6.21.

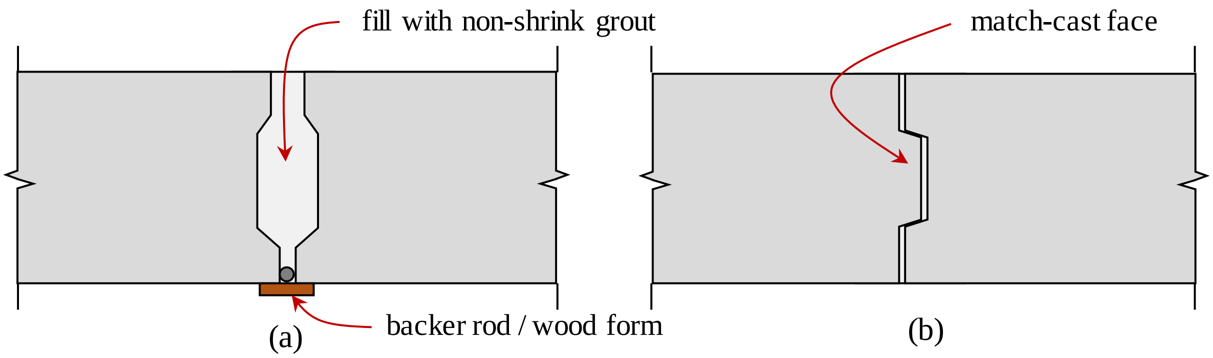


Figure 6.21: Typical longitudinal PT joints: (a) female-to-female and (b) male-to-female match cast

A blockout is created at the location of the longitudinal post-tensioning ducts to house the splice sleeve connector, shown in Figure 6.22. Grout tubes or vents should installed to ensure proper grouting of the duct.

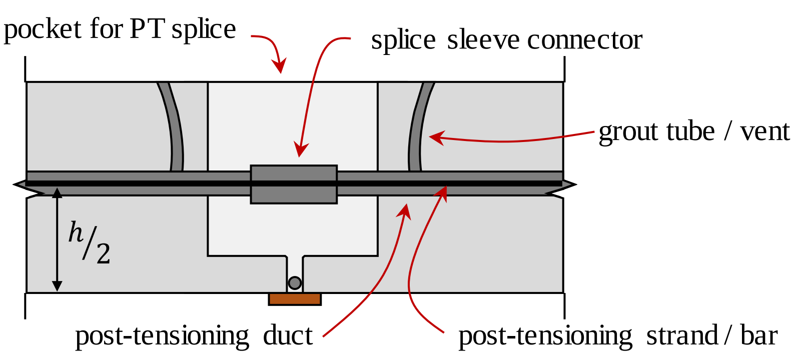


Figure 6.22: Typical blockout detail for splice sleeve connector between PT ducts in adjacent panels

A sample detail for the shear key and blockout detail are shown in Figure 6.23

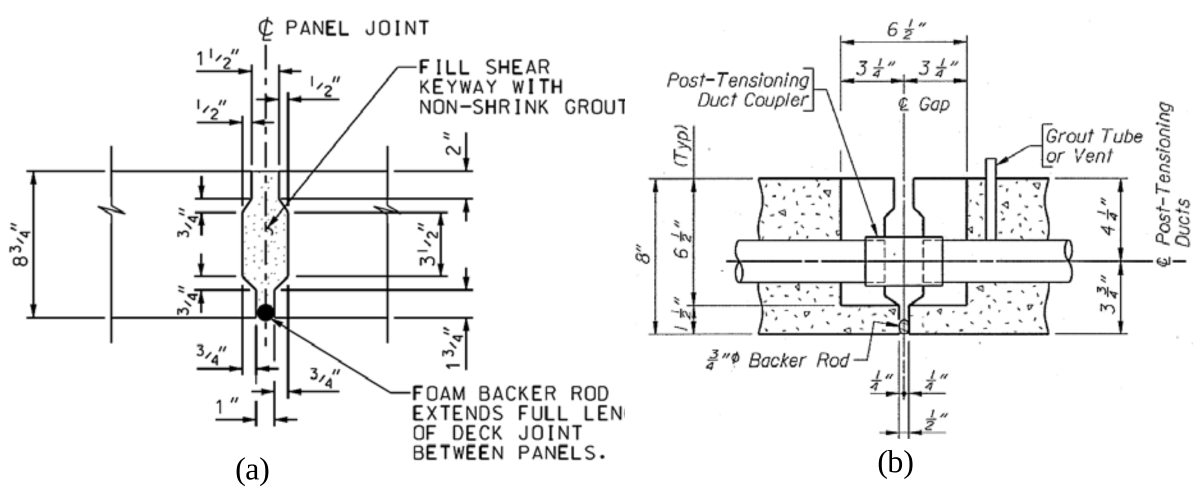


Figure 6.23: Example detail of (a) longitudinal PT keyway and (b) blockout for PT duct coupler (obtained through DOT survey from UDOT and WYDOT, respectively)

6.4.2. Conventional Concrete with Hooped or Straight Bars

The conventional concrete joint detail with hooped or straight bars has been used for both transverse and longitudinal joints. This joint requires a larger width closure pour, so it makes the most sense to be used in the longitudinal direction, where the joint between panels runs along the girder line. The top of the girder can be used as the bottom form for the joint and the larger joint width gives more flexibility with the placement of shear studs and joint reinforcement, as shown in Figure 6.24.

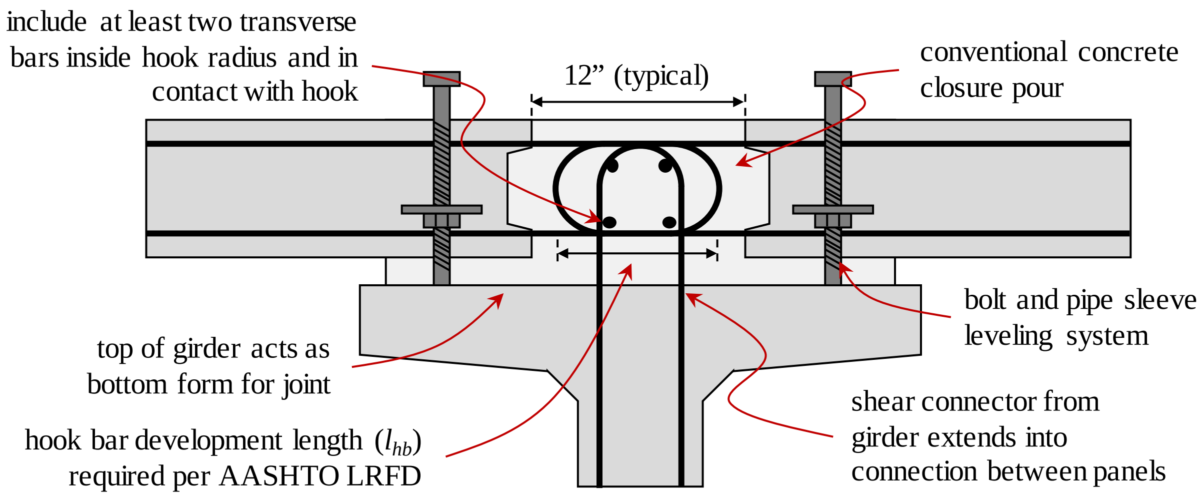


Figure 6.24: Schematic of conventional concrete longitudinal joint over girder

The splice length of the straight bars must satisfy the development length, splice length, and non-contact splice dimension requirements of the AASHTO LRFD Bridge Design Specification [30], [35]. The splice length of hooked bars is only required to be equal to the development length of the hooked bar, l_{hb}, as specified by AASHTO LRFD [30]; previous research [39]–[41] has shown this length to be sufficient. As shown in Figure 6.24, at least one transverse bar of equal size should be set within the inside radius and in contact with each hook [30], which will result in at least two bars contained within the hooked splice. Typical details include four bars included in a hooped bar splice. The joint reinforcement can be staggered for hooked and hooped bars to improve constructability. Hooked and hooped bars can be staggered such that the distance between spliced bars does not exceed 4 inches [30], as shown in Figure 6.25.

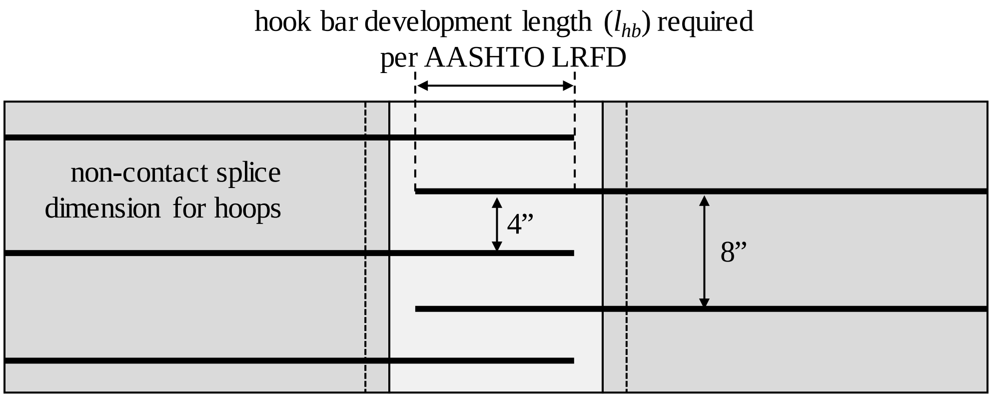


Figure 6.25: Non-contact lap splices are allowed (plan view)

A sample detail for the conventional concrete with hooped bar detail obtained through the DOT survey is shown in Figure 6.26.

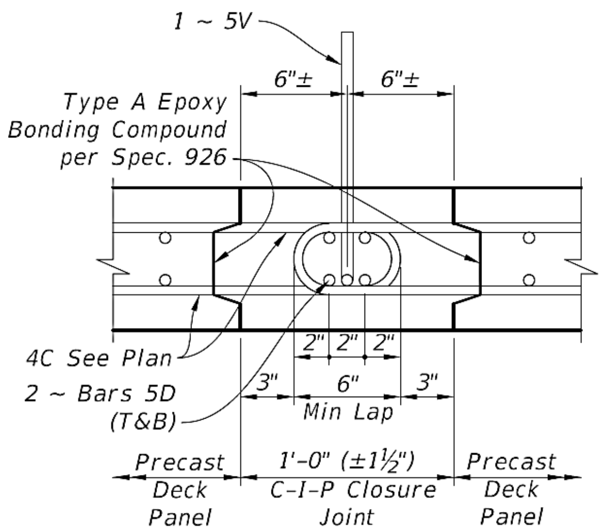


Figure 6.26: Example conventional concrete with hooped bar detail between panels (obtained through DOT survey from FDOT)

6.4.3. UHPC with Straight Bar

The UHPC with straight bar connection has been used in both longitudinal and transverse joints between FDPC deck panels. Several research projects have been conducted on UHPC connections with straight bars [42], [43] and guidance on the connection is provided by Graybeal [38] and AASHTO [30]. A summary of the basic reinforcement requirements for this splice connection are shown in Figure 6.27. There are modifications for higher strength reinforcement and less cover provided by both resources. Additionally, Graybeal [38] allows for the same $8d_b$ required development length for #5 bars with minimum cover greater than or equal to 1.25 inches; this special provision is due to additional research on this specific bar size.

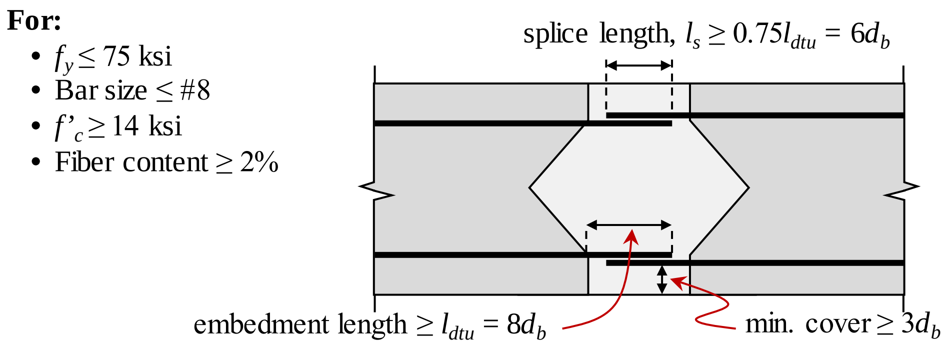


Figure 6.27: Summary of basic recommendations for UHPC connections between panels, based on [30], [38]

A sample detail for the UHPC with straight bar detail obtained through the DOT survey is shown in Figure 6.28.

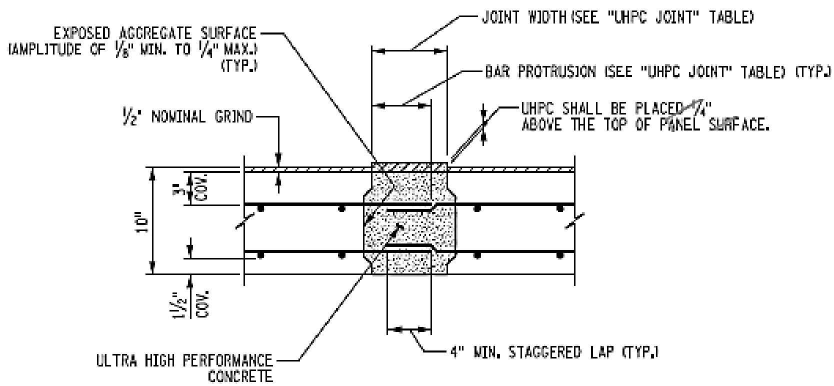


Figure 6.28: Example detail of UHPC with straight bar detail between panels (obtained through DOT survey from NYDOT)

6.4.4. Grouted Shear Key without Post-Tensioning

The grouted shear key without post-tensioning detail has been primarily used for the transverse joint in off-system bridges in Alaska. The majority of these bridges with this joint detail (about 90 percent) have an ADT less than 500, although there are two bridges with ADT of 12,000 and 20,000 that have performed well since the earliest date inspection records were obtained (2004). A sample detail for the grouted shear key without post-tensioning detail obtained through the DOT survey is shown in Figure 6.29.

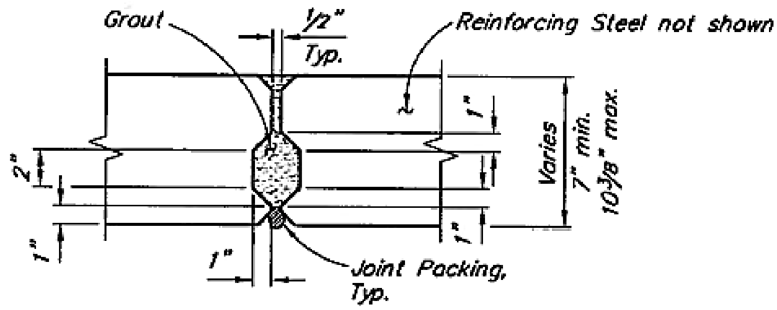


Figure 6.29: Example detail of grouted shear key without post-tensioning detail between panels (obtained through DOT survey from AKDOT)

6.5. Materials for Joints, Shear Pockets, and Post-Tensioning Ducts

6.5.1. Grouts

6.5.1.1. Grout for haunches, pockets, voids, and joints

A low shrinkage, durable material with high early strength and high freeze/thaw resistance is desirable for filling all voids, haunches, and pockets in FDPC deck panel systems [31]. Non-shrink cementitious grouts are the most common grout used for these applications as they are economical and have the desired properties listed above. The recommended grout properties suggested by Nottingham [44] and presented in [31] are shown in Table 6.3.

Table 6.3: Recommended grout properties [31]

Property	Typical Range
Compressive Strength	1.2 ksi @ 6 hours 4.5 ksi @ 1 day 6.5 ksi @ 28 days
Flexural Strength	0.55 ksi @ 1 day 0.60 ksi @ 28 days
Slant Shear Bond	2.5 ksi @ 28 days
Freeze-Thaw Resistance	RDF of 80%
Scaling Resistance	0 scaling rating
Shrinkage	0.03% @ 28 days
Sulfate Resistance	0.10% @ 28 days

Epoxy grouts are also common, but normally have a lower modulus of elasticity and are relatively more expensive than cementitious grouts. Expansive base grouts are also available, but these lead to excessive expansion and bleeding in most cases [45]. Other grout products can be used, but they should satisfy ASTM C1107 (Standard Specification for Packaged Dry, Hydraulic-Cement Non-Shrink Grout) [46].

Grout can be used for smaller joints (e.g., typical PT joint) but becomes too expensive an option for larger joints. Conventional concrete, high performance concrete, or ultra-high performance concrete are typically used for larger joints.

6.5.1.2. Grout for post-tensioning ducts

Cementitious grouts are typically used to fill post-tensioning ducts as they are chemically basic and provide a passive environment around the prestressing strands [47]. Details on grouts for post-tensioning ducts can be found in the FHWA manual "Post-Tensioning Tendon Installation and Grouting Manual" [47] and PTI Publication "Specification for Grouting of Post-Tensioned Structures (PTI M55.1-12)" [48].

These cementitious grouts are composed of ordinary Portland cement (Type I or II), supplementary cementitious materials (fly ash, slag cement, or silica fume), chemical admixtures, fine aggregates, and water. SCMs are used to improve the corrosion resistance by creating a less permeable and denser packed concrete matrix. Chemical admixtures are used to improve the workability (high range water reducers), control the set times, entrain air, prevent excessive bleeding, and inhibit corrosion. Fine aggregates are an inert material used as a filler. Note that the water-to-cement ratio should never exceed 0.45. High-range water reducers can be used to improve workability without adding additional water. Pre-bagged grouts are available and commonly used. Pre-bagged grouts should be stored in dry locations and used within a reasonable amount of time.

Complete grouting of the ducts with high quality grout is required to ensure protection of prestressing strands. Voids in the grout or soft or segregated grout materials can lead to accelerated corrosion of the strands [49]. Deficiencies can occur when pre-bagged grout is improperly stored, excessive water is used, or improperly mixed or placed.

6.5.2. Conventional Concrete

Conventional concrete and high-performance concrete mixtures can be used for joints. Using these materials will typically result in larger width joint regions, due to longer required development and splice lengths. Shrinkage reducing admixtures and proper curing of the joints can be used to reduce the likelihood of shrinkage cracking in larger volume closure pours.

6.5.3. Ultra-High Performance Concrete (UHPC)

Ultra-high performance concrete (UHPC) is a cementitious composite material with high compressive and tensile strengths and low permeability. The typical ranges for some of the most relevant mechanical properties are shown in Table 6.4.

Table 6.4: Typical ranges of mechanical properties for UHPC [38]

Property	**Typical Range**
14-day Compressive Strength	18 to 22 ksi
Direct Tensile Cracking Strength	0.8 to 1.2 ksi
Direct Tension Bond Test	0.35 to 0.6 ksi
Modulus of Elasticity	4,250 to 8,000 ksi
Long-term Drying Shrinkage	300 to 1,200 με
Long-term Autogenous Shrinkage	200 to 900 με

Proprietary UHPC mixtures are available from several different vendors. Proprietary UHPC mixtures typically come in three separate components: a pre-bagged cementitious powder, chemical admixtures, and steel fiber reinforcement. Non-proprietary UHPC mixtures have been developed by several states [50]. A research project is also starting by the ABC-UTC investigating non-proprietary UHPC mixtures. Typical UHPC materials contain 2-percent (by volume) steel fiber content [38].

6.5.4. Polymer Concrete

There are alternative materials that are being researched for use in closure joints between FDPC deck panels. Polymer concrete is being researched for use in closure pours in a parallel ABC-UTC project "More Choices For Connecting Prefabricated Bridge Elements and Systems (PBES)" being conducted by the University of Nevada - Reno [51]. This concrete has a high tensile strength (compared to its compressive strength) and good tensile adhesion, as shown in Table 6.5, which makes it a suitable material for joints.

Table 6.5: Mechanical properties of T-17 polymer concrete [51]

Property	**Typical Range**
Compressive Strength	8 to 9 ksi
Flexural Strength	1.8 to 2.5 ksi
Linear Shrinkage	< 0.2%
Tensile Strength	1 to 1.2 ksi
Compressive Modulus	1,100 to 1,200 ksi
Tensile Adhesion	> 0.25 ksi

6.6. Wearing Surface and Overlays

Overlays are not required on FDPC deck panel systems, but are generally used as they can improve the long-term performance of the deck system and create a smooth riding surface. The typical wearing surfaces and overlays that are used for FDPC deck panel systems are shown in Figure 6.30. These wearing surface and overlays are discussed in depth in PCI's "State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels" [31].

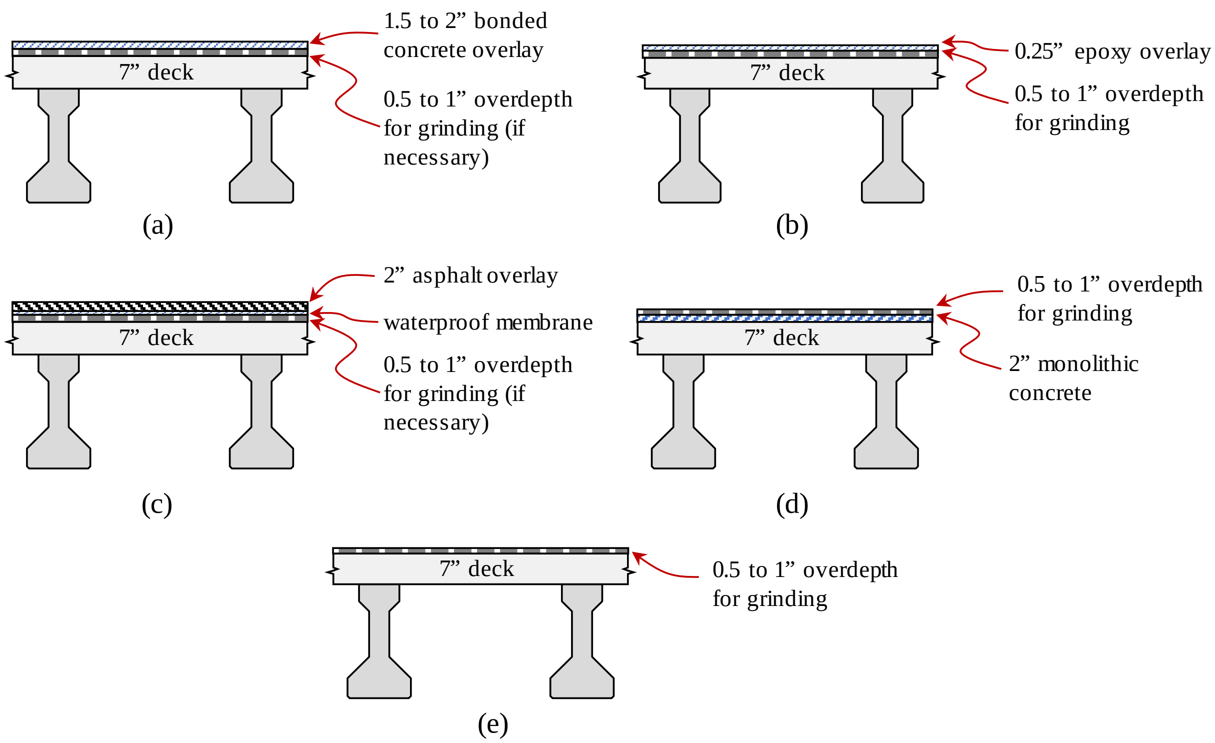


Figure 6.30: Primary types of wearing surfaces and overlays: (a) bonded concrete overlay, (b) epoxy overlay, (c) waterproof membrane with asphalt, (d) monolithic concrete overlay, and (e) low permeability panel with no overlay, based on [31]

The frequency of use for different wearing surface and overlay types for the bridges in the FDPC Deck Panel Database are summarized in Table 6.6.

Table 6.6: Overlay usage for bridges in FDPC Deck Panel Database

Type of Overlay (from NBI)	**Percentage of Bridges**
Bituminous (Asphalt)	47.0%
Monolithic Concrete	19.5%*
Epoxy Overlay	10.9%
Bonded Concrete Overlay (Conventional)	7.1%
Bonded Concrete Overlay (Latex)	6.4%
No Overlay	3.4%
Other Overlay	5.6%

*majority of monolithic concrete bridges are used with the grouted shear key without post-tensioning in Alaska

CHAPTER 7. SUMMARY AND CONCLUSIONS

Full-depth, precast concrete (FDPC) deck panels have been used for new construction and rehabilitation since 1965 [1]. There have been surveys [2] conducted to attempt to determine the performance of bridges with FDPC deck panels, but not recently. The Long-Term Bridge Performance (LTBP) Program, one of the largest bridge research programs ever undertaken by the FHWA, developed protocols and resources to help advance bridge management, specifically related to bridge decks.

The work conducted under this project was aimed at determining the bridges that have been constructed in the US utilizing FDPC deck panels and evaluating their long-term performance. A state DOT survey was used to determine DOT practice and opinion and compile the FDPC deck panel projects completed in each state. The FDPC deck panel bridges from each state were compiled to create the FDPC Deck Panel Database. Inspection information and details from the NBI were gathered for each bridge in the FDPC Deck Panel Database from the LTBP InfoBridge resource. Comparison projects with cast-in-place (CIP) concrete decks were selected for most bridges in the FDPC Deck Panel Database.

The performance of the bridges with FDPC deck panels and CIP deck comparison projects was evaluated based on the NBI deck ratings compiled in the LTBP InfoBridge. These NBI deck ratings were used to determine the deterioration rate and expected service life of these bridges. The average performance of bridges with FDPC deck panels were compared with similar bridges with CIP decks. These performance comparisons were further evaluated in several subcategories. Overall, bridges with FDPC deck panels performed similarly to similar CIP bridges. As the precast panel itself offers superior durability to CIP decks (due to better concrete materials and quality of construction), these results may suggest that there is room for improvement with joint design and construction.

There are limitations to this approach, but this work can be used as a starting point to a more in-depth evaluation of these projects, possibly through non-destructive testing techniques. Additionally, there is less experience with FDPC deck panels. Construction of bridges with FDPC deck panels has increased dramatically since 2010 (with 160 constructed since 2010 compared to a total of 141 constructed between 1965 and 2010). There would be value to continuing to maintenance of this database and revisiting the performance of newer structures in 10 to 20 years.

There is no question that precast and prefabricated elements are the future of bridge construction. The results of this study may suggest though there is room for improvement in joint performance.

The information from the LTBP Deck Panel Database was also used to determine the most popular details for LTBP deck panel systems. Design recommendations were developed and are summarized in the “ABC-UTC Guide for FDPC Deck Panels” [3].

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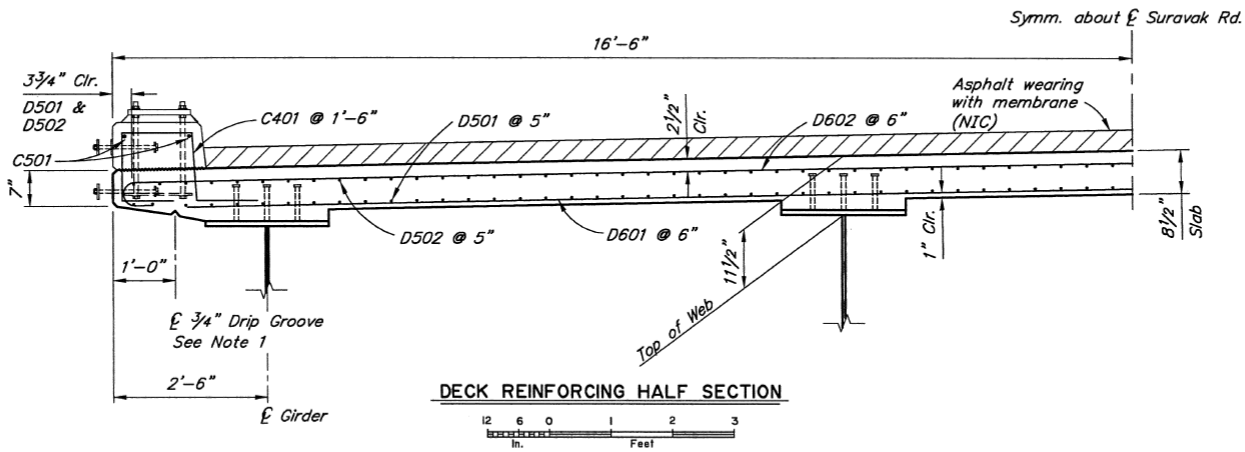
APPENDIX A: OBSERVED DETAILS FROM STATE DOTS

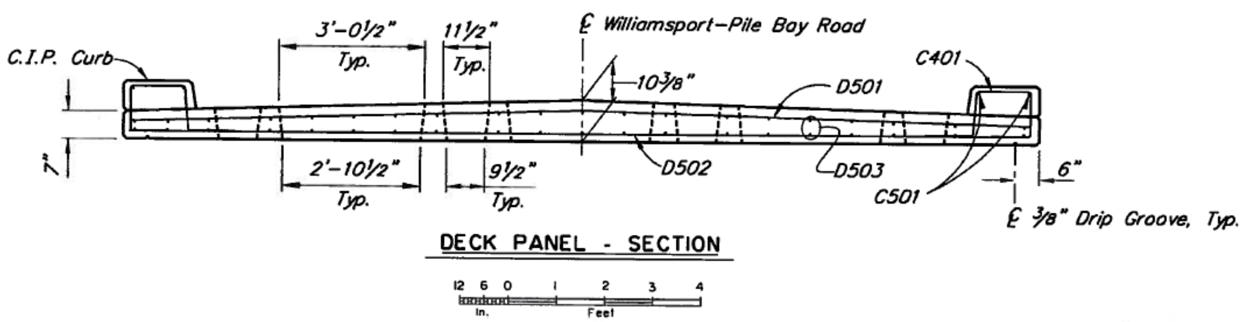
Typical details for CIP and FDPC deck panels were provided by several states or found through the ABC Project Database and are summarized in this section. A citation for the details is provided if they were obtained from the ABC Project Database. Other details were provided by the state in their response to this survey.

A.1. Alaska DOT Typical Details

The typical connection details for CIP and FDPC deck panels provided by Alaska DOT are shown in Figure 7.1 and Figure 7.2.



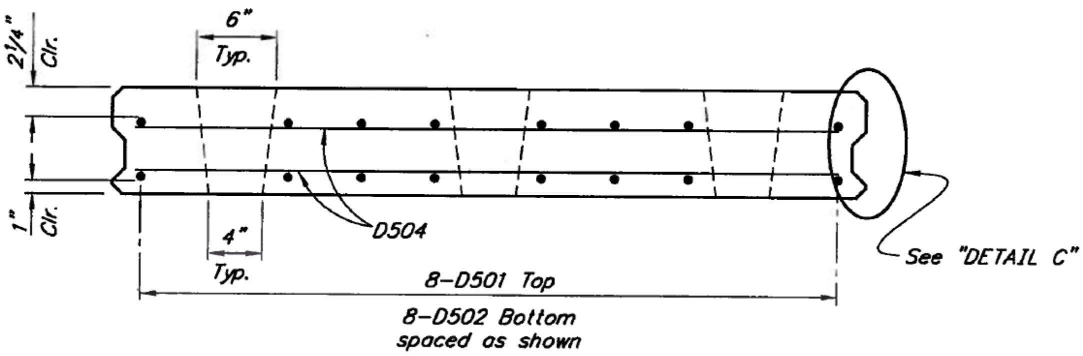
(a)



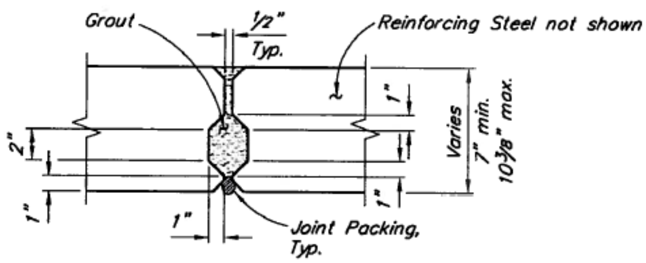
(b)

Figure 7.1: Typical deck details for Alaska: (a) CIP deck and (b) FDPC deck

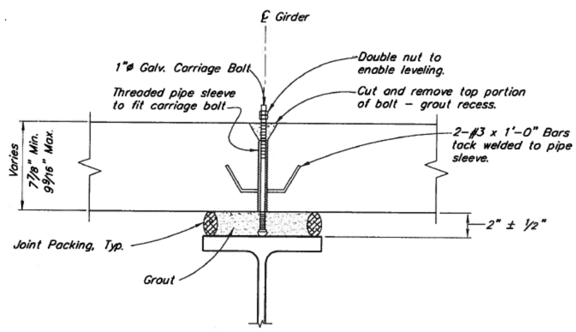
The typical details for FDPC deck panel and the connection between panels are shown in Figure 7.2. The connection has a similar shape to typical post-tensioned joints, but there is no post-tensioning present. Grout is placed in between panels.



(a)



(b)



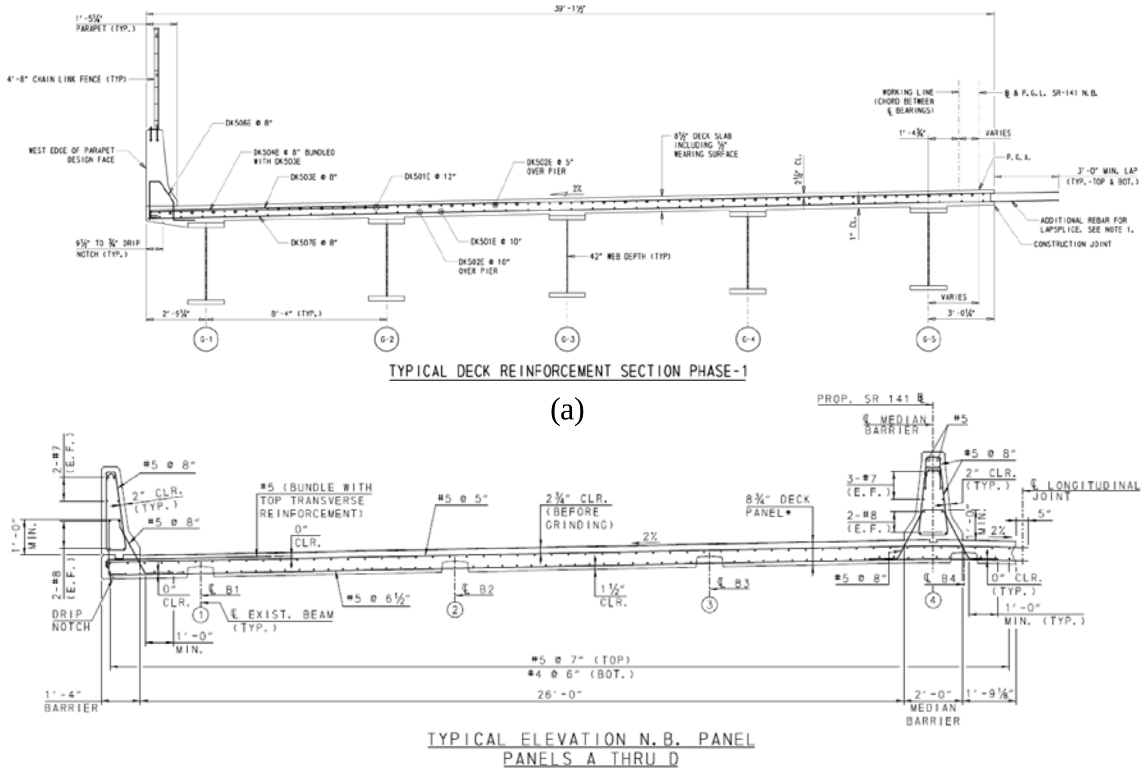
(c)

Figure 7.2: Typical FDPC panel connection details for Alaska: (a) overview, (b) joint, and (c) leveling bolts

Note that Alaska typically uses an asphalt wearing surface for their bridges.

A.2. Delaware DOT Typical Details

The typical connection details for CIP and FDPC deck panels provided by Delaware DOT are shown in Figure 7.3:. Delaware currently and previously has used common UHPC joints in FDPC bridge construction and typically uses a Polyester Polymer Concrete as a protection system for FDPC bridges.



(a)

(b)

Figure 7.3: Typical deck details for Delaware: (a) CIP deck and (b) FDPC deck

Details are provided for the FDPC deck, UHPC longitudinal and transverse joints, shear pockets, and leveling bolt in Figure 7.4. A straight bar, non-contact splice is used in the UHPC joints in both the longitudinal and transverse directions. The leveling bolts are used to level the panels and then UHPC is used to fill the haunch and shear pockets, see Figure 7.4 (d).

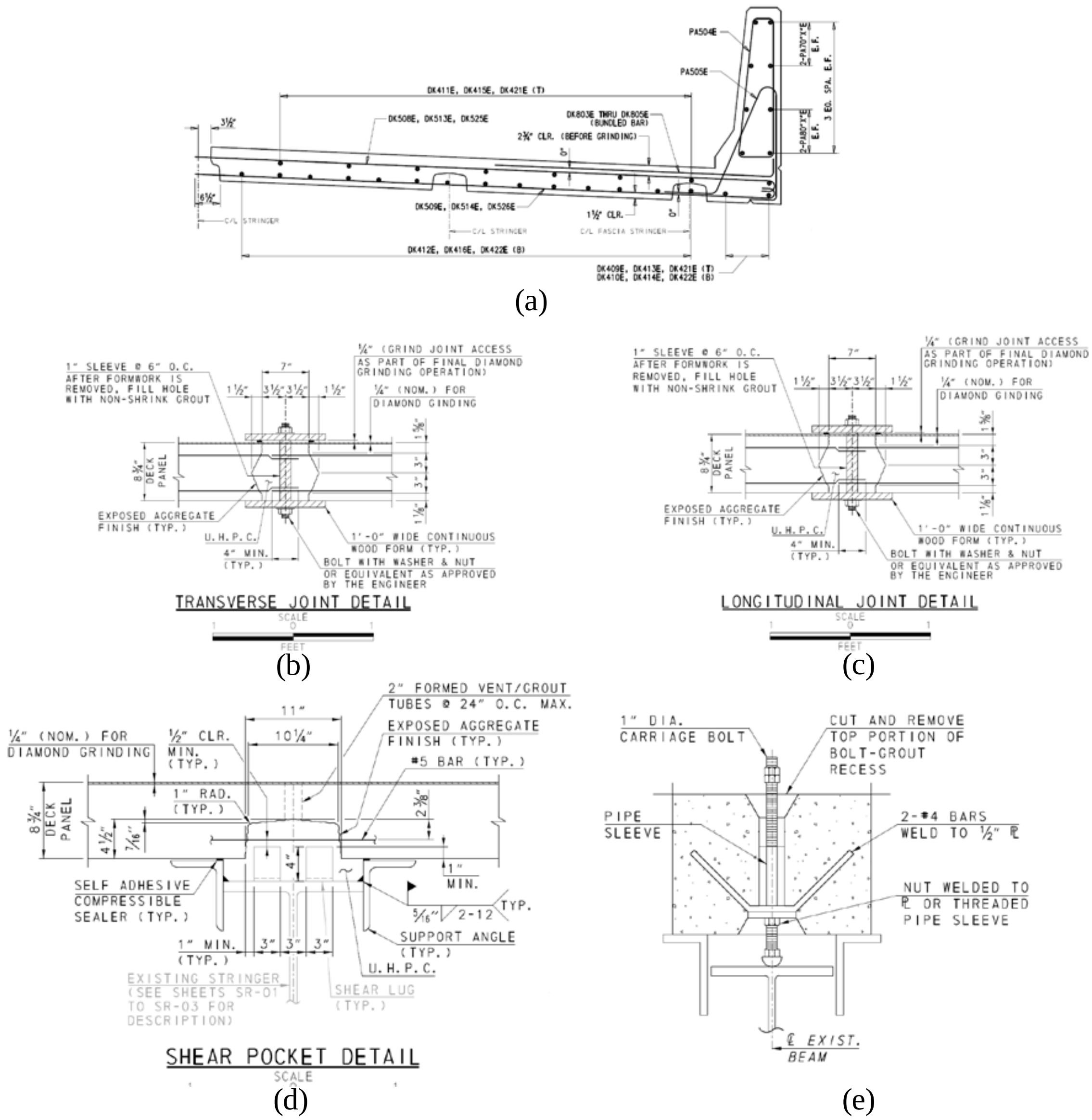


Figure 7.4: Typical FDPC deck panel details for Delaware: (a) FDPC deck detail, (b) transverse joint detail, (c) longitudinal joint detail, (d) shear pocket detail, and (e) leveling bolt detail

A.3. Florida DOT Typical Details

The typical connection details provided by Florida DOT are shown in Figure 7.5:. The provided details are for use with conventional concrete or grout, although FDOT has used a UHPC joint detail for at least one bridge (not provided here).

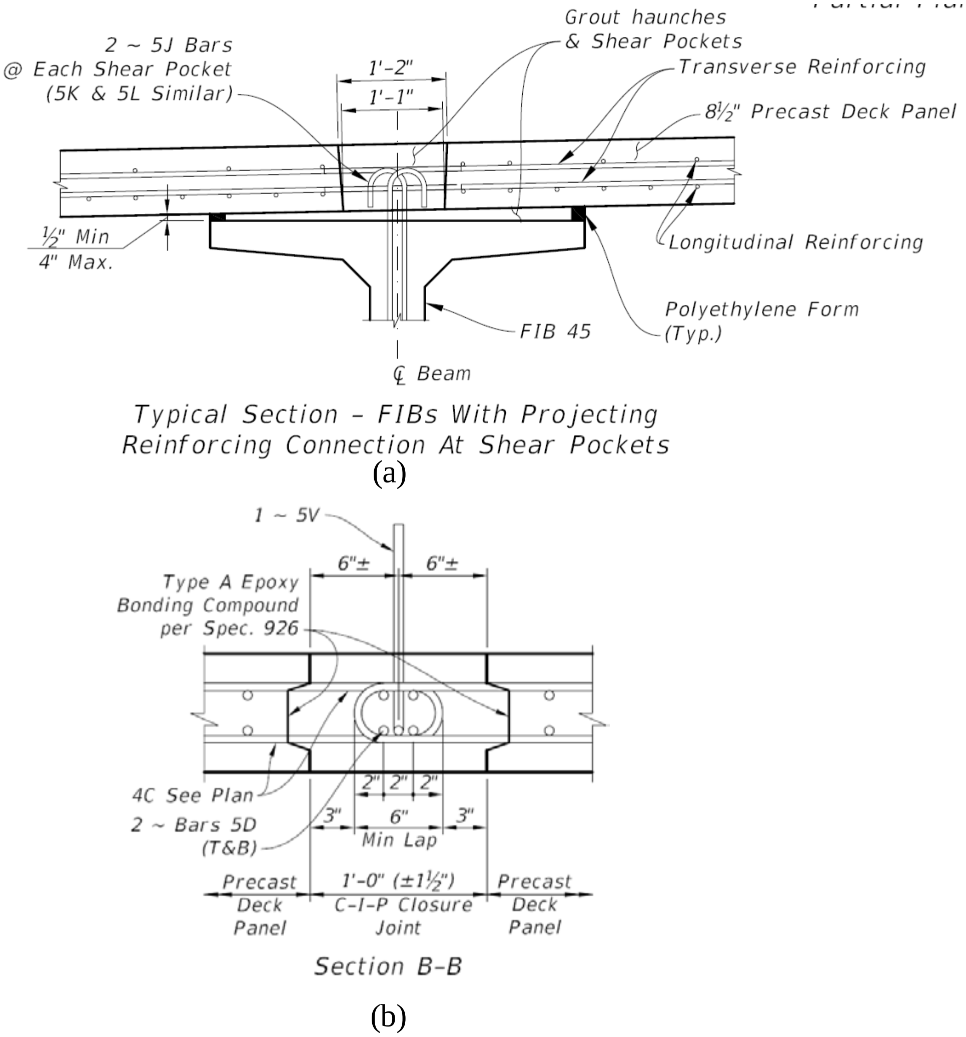
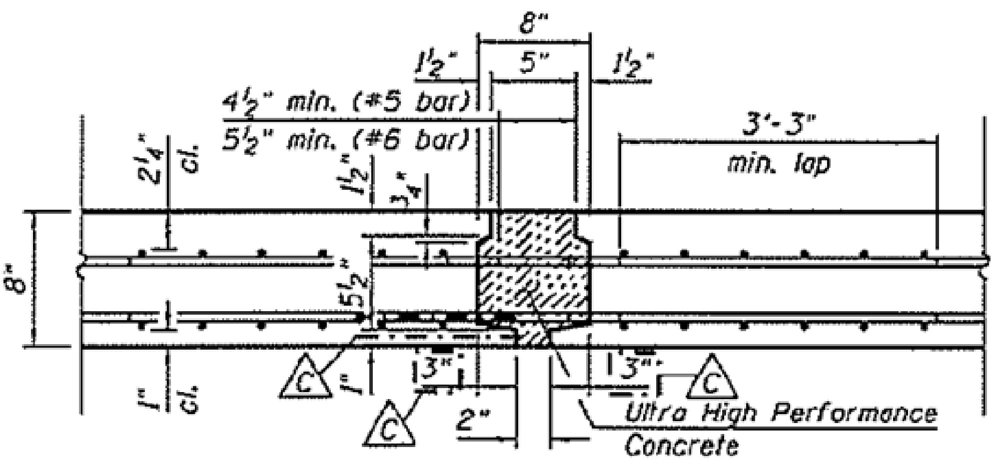


Figure 7.5: Typical FDPC deck panel details for Florida: (a) shear pockets and (b) closure joint between precast deck panel

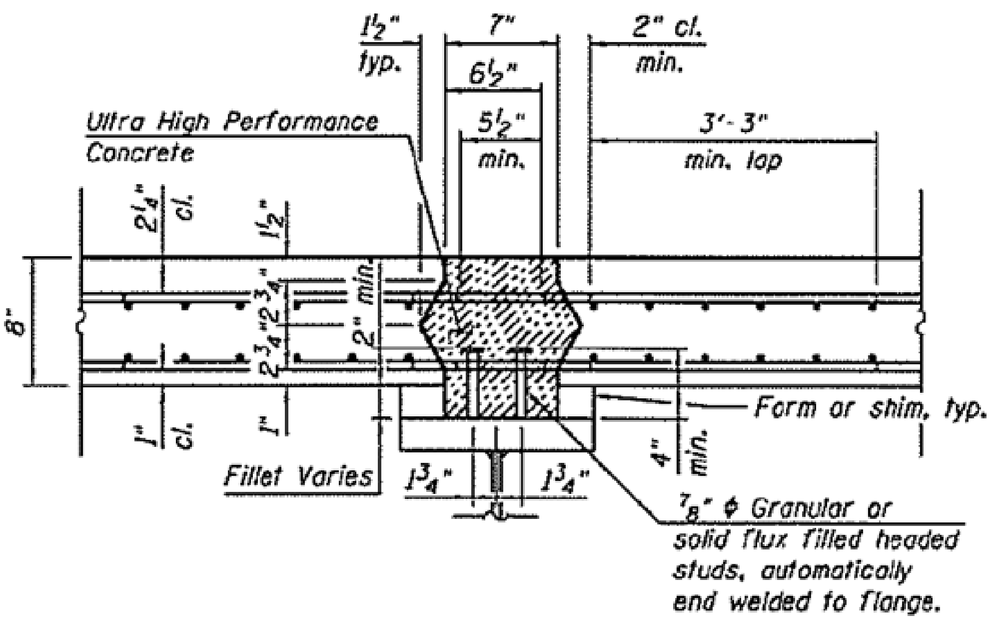
A.4. Illinois DOT Typical Details

Illinois DOT has used both the typical post-tensioned joint detail and a UHPC joint with straight bar splice. The details for the typical longitudinal and transverse UHPC joint detail are shown in Figure 7.6:. Note that Illinois DOT typically uses a 2.5-inch micro-silica overlay as a protection system for bridges.



UHPC Transverse Joint

(a)



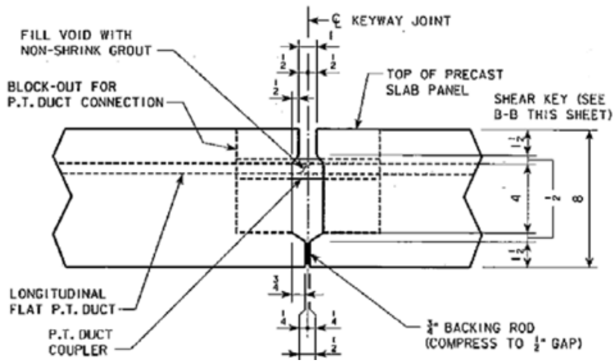
UHPC Longitudinal Joint

(b)

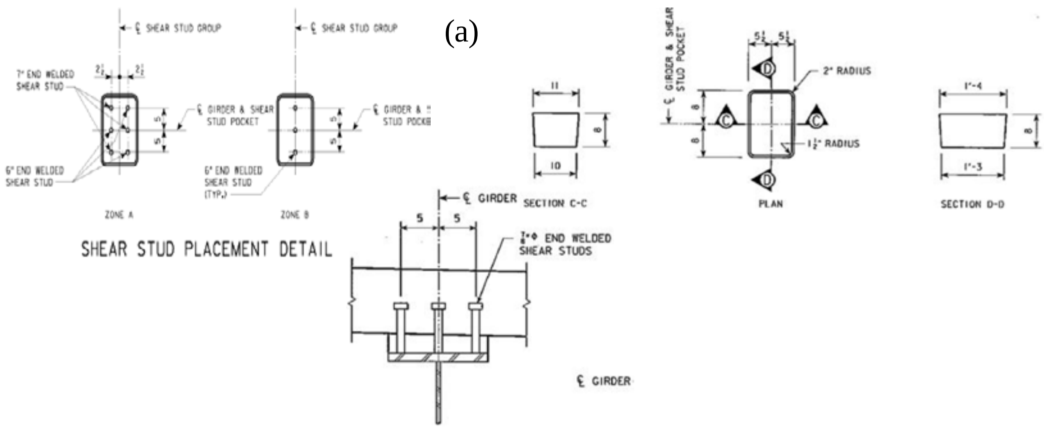
Figure 7.6: Typical FDPC deck panel detail for Illinois: (a) UHPC transverse detail and (b) UHPC longitudinal joint

A.5. Iowa DOT Typical Details

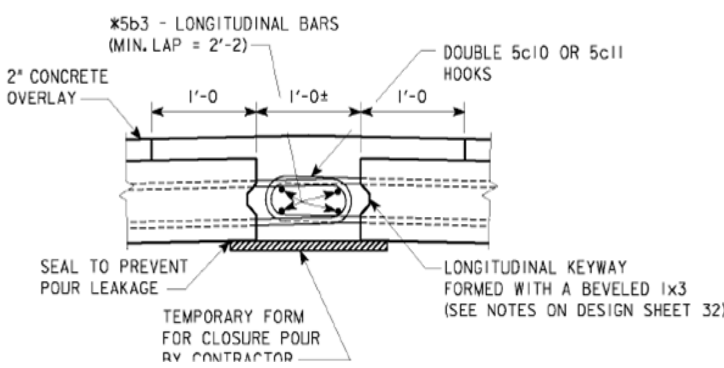
The typical connection details for FDPC deck panels provided by Iowa DOT are shown in Figure 7.7:. Iowa DOT currently uses the common PT joint detail and a conventional concrete hooped bar detail. Iowa DOT typically uses a 2" PCC overlay wearing surface for their bridges and uses non-shrink grout between panels joints.



(a)



(b)

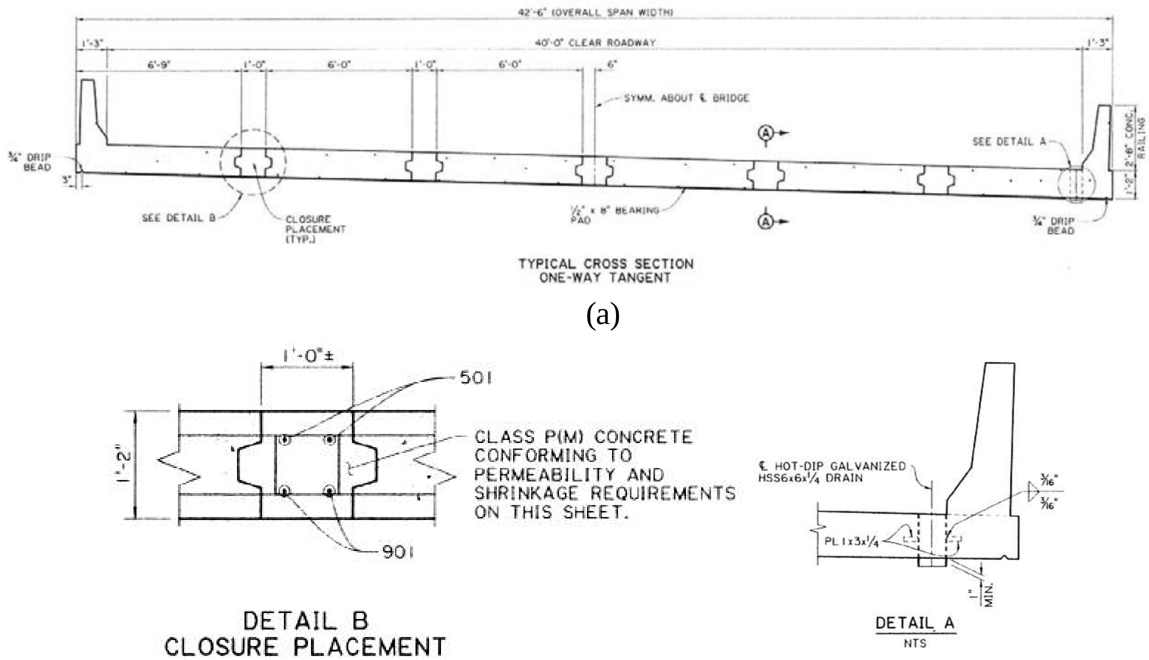


(c)

Figure 7.7: Typical FDPC deck panel details for Iowa: (a) PT joint detail, (b) shear stud placement and pocket detail, and (c) conventional concrete joint detail

A.6. Louisiana DOT Typical Details

The typical details for FDPC deck panels provided by Louisiana DOT are shown in Figure 7.8. Louisiana uses the common PT joint and common non-UHPC joint for their bridges.



(b) (c)

Figure 7.8: Typical FDPC deck panel details for Louisiana: (a) typical deck, (b) closure placement, and (c) connection to parapet

A.7. Maine DOT Typical Details

The typical details for FDPC deck panels provided by Maine DOT are shown in Figure 7.9 to Figure 7.11:. Maine DOT has previous used or currently uses common PT joint, mechanical connections, conventional concrete connections, and common UHPC joints. They provided details for typical UHPC joints.

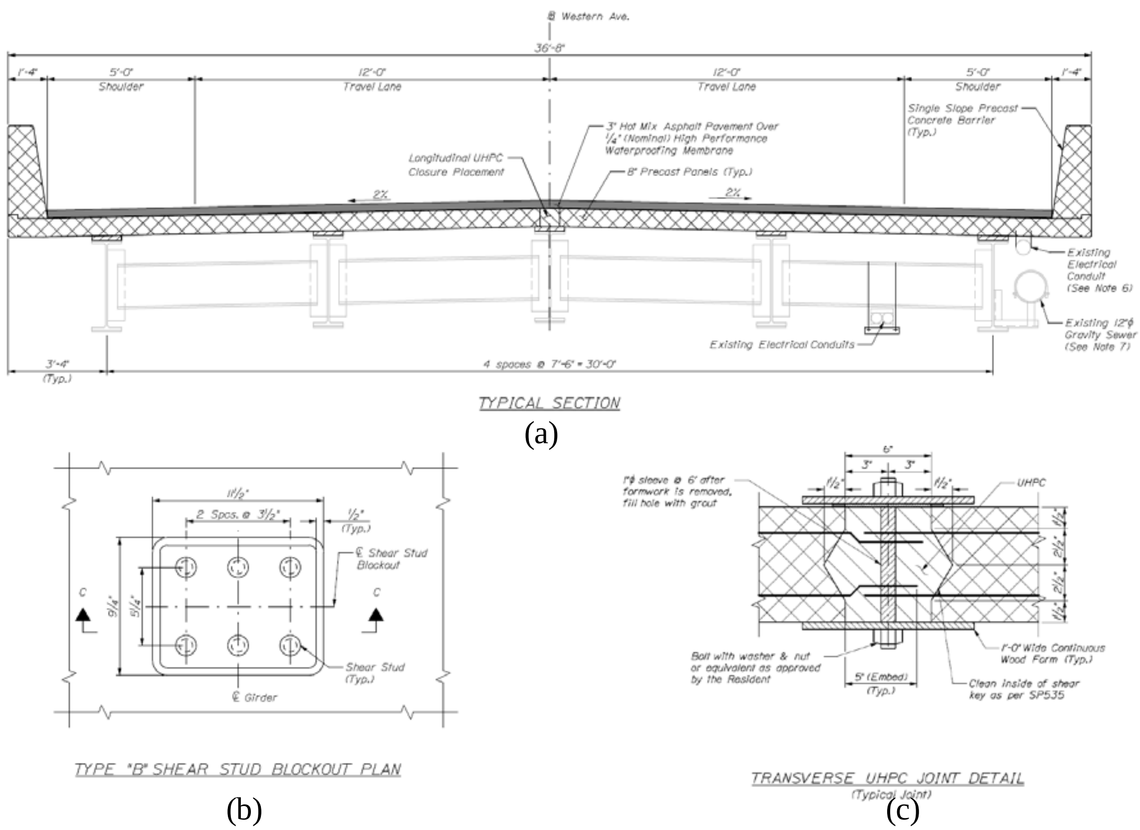


Figure 7.9: Typical FDPC deck panel details for Maine DOT: (a) typical deck panel, (b) shear stud plan, and (c) transverse UHPC joints

Typical details for the FDPC deck panel, UHPC joints, panel leveling, shear pocket details, and connection over interior beams is shown in Figure 7.10.

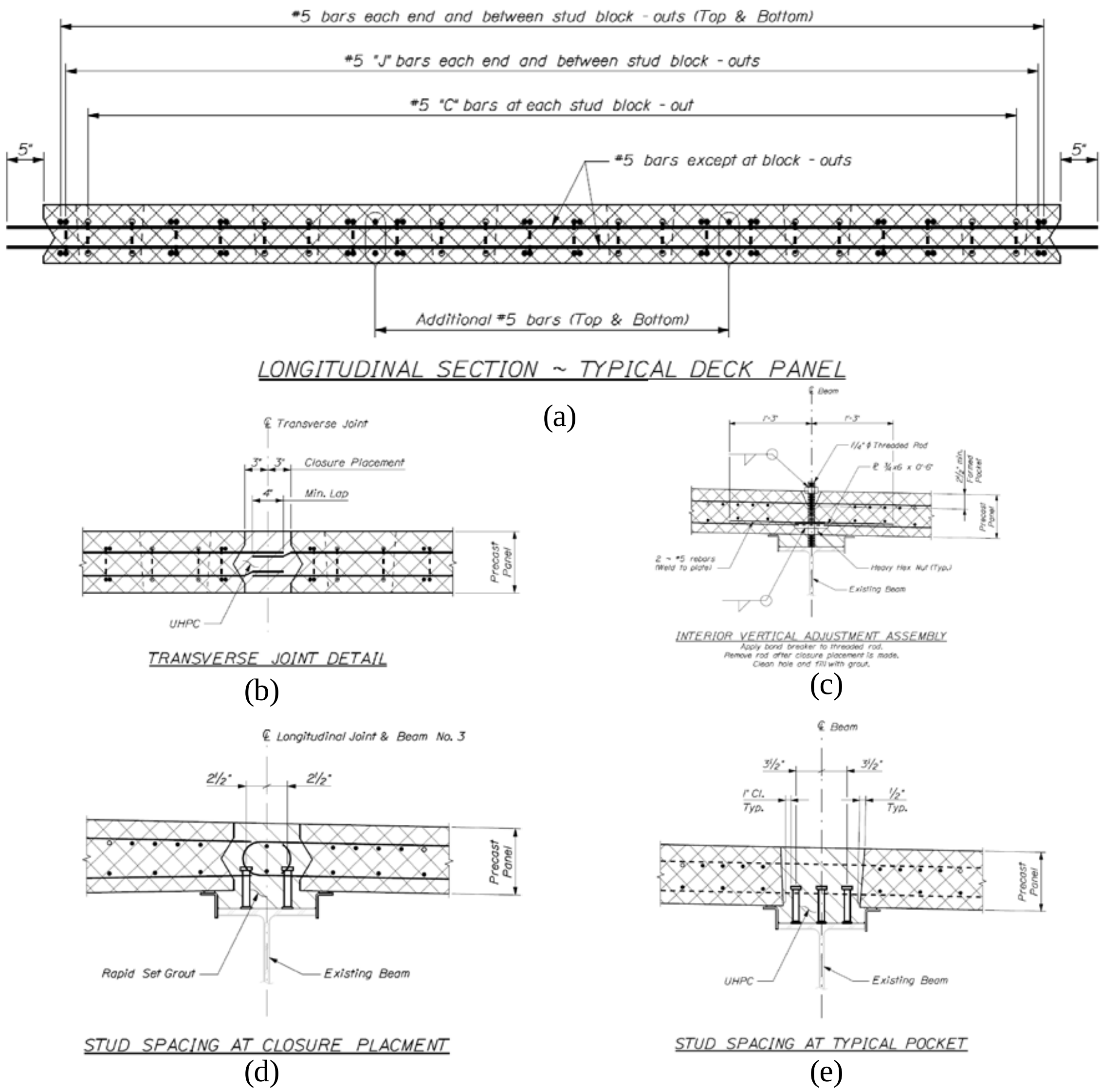
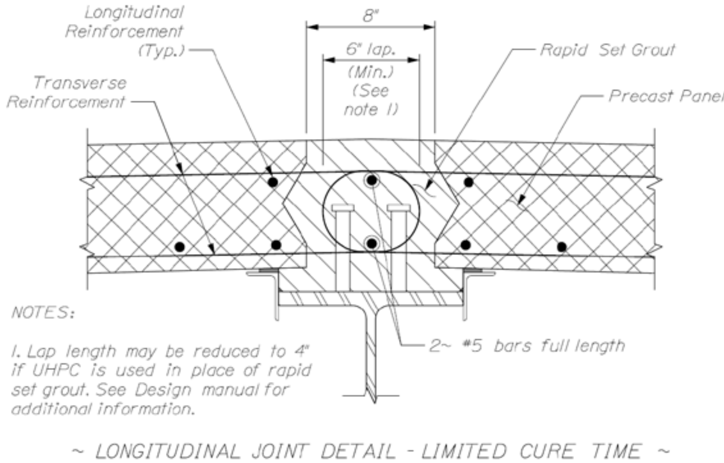
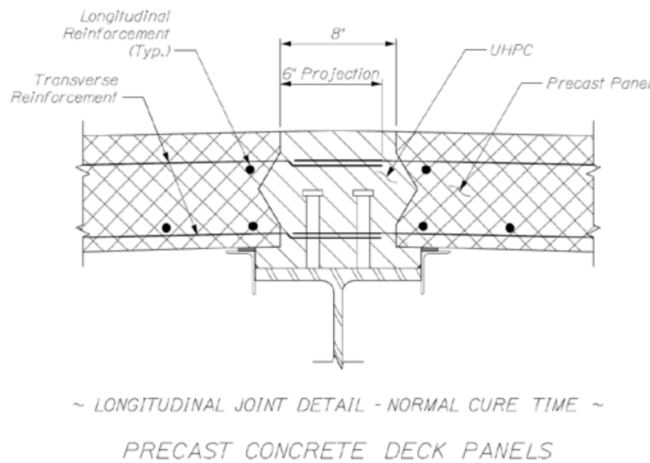


Figure 7.10: Typical FDPC deck panel details for Maine DOT: (a) typical deck panel, (b) transverse joint, (c) leveling bolt, (d) closure between adjacent panel over girders, and (e) typical pocket detail

Finally, two different joint details were provided based on the about of cure time, shown in Figure 7.11:. A hooked bar detail with rapid set grout is used for cases with shorter cure times. A straight bar connection with UHPC is recommended for use with normal cure times available.



(a)



(b)

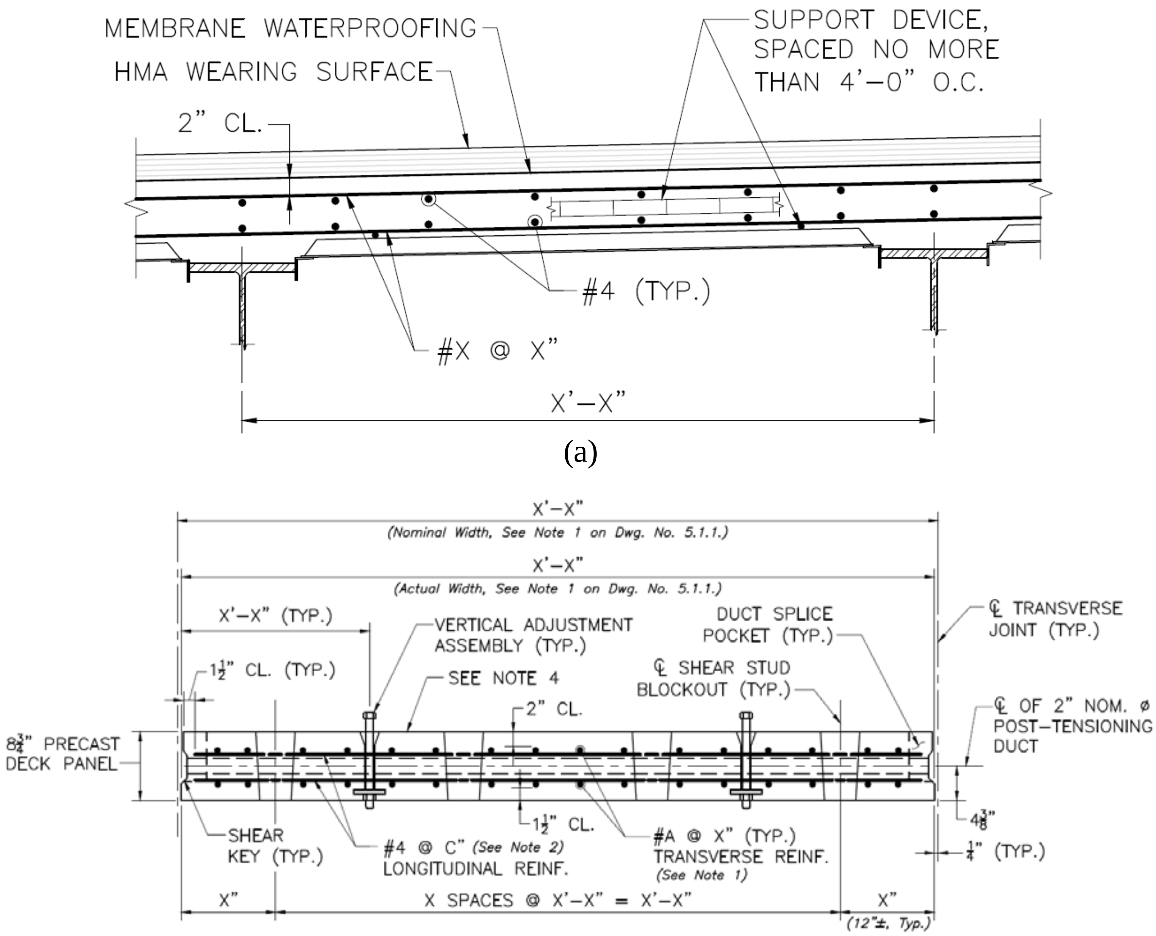
Figure 7.11: Typical FDPC deck panel details for Maine DOT: (a) longitudinal joint detail with limited cure time and (b) longitudinal joint detail with normal cure time

Maine DOT typically uses an asphalt wearing surface for their bridges.

A.8. Massachusetts DOT Typical Details

The details for FDPC deck panels provided by Massachusetts DOT are shown in Figure 7.12Figure 7.12: to Figure 3.23: . Massachusetts DOT currently uses common PT joint, UHPC joints with straight bars, and conventional concrete joints for their bridges. They provided typical details for their PT and conventional concrete joints.

Details for a typical CIP deck and FDPC deck panel are shown in Figure 7.12: As is shown Massachusetts typically uses membrane waterproofing and a wearing surface on their bridges.



(a)

(b)

Figure 7.12: Typical deck panel details for Massachusetts: (a) CIP deck detail and (b) FDPC deck detail

The details for a typical PT joint are provided in Figure 7.13:. These details include the splicing of the PT ducts between members, shear key, leveling bolt, and shear pocket and shear studs.

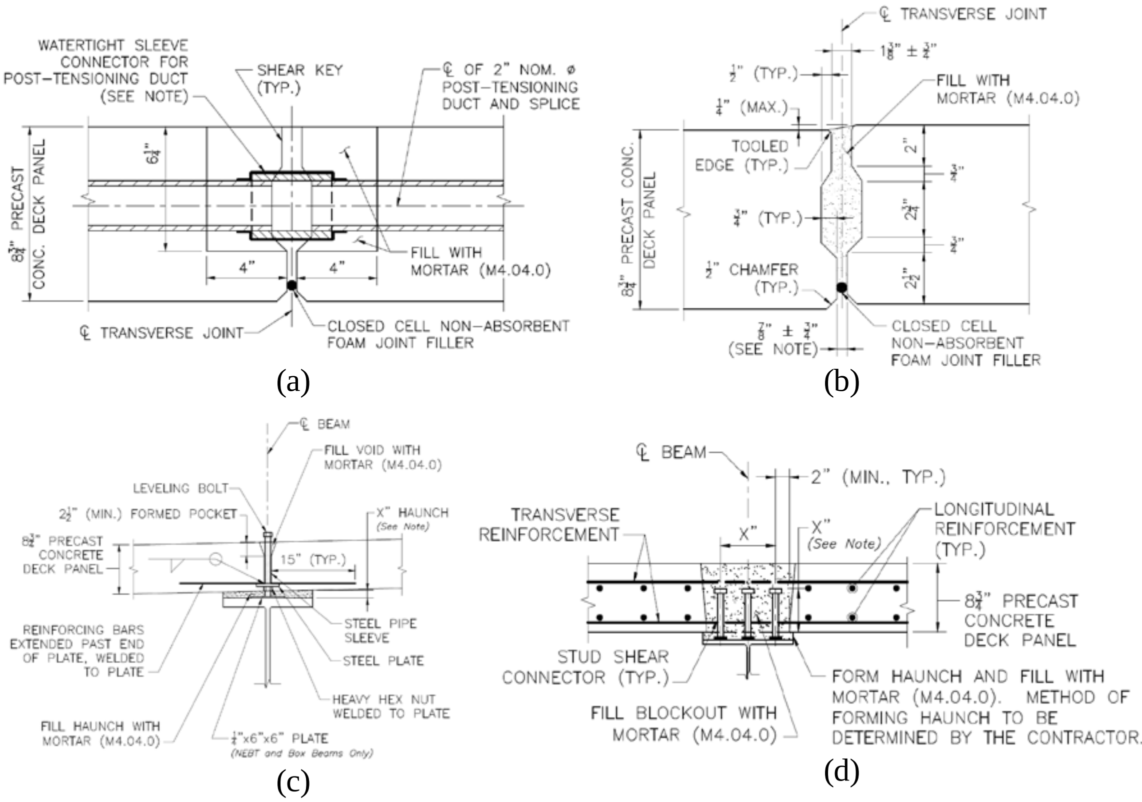
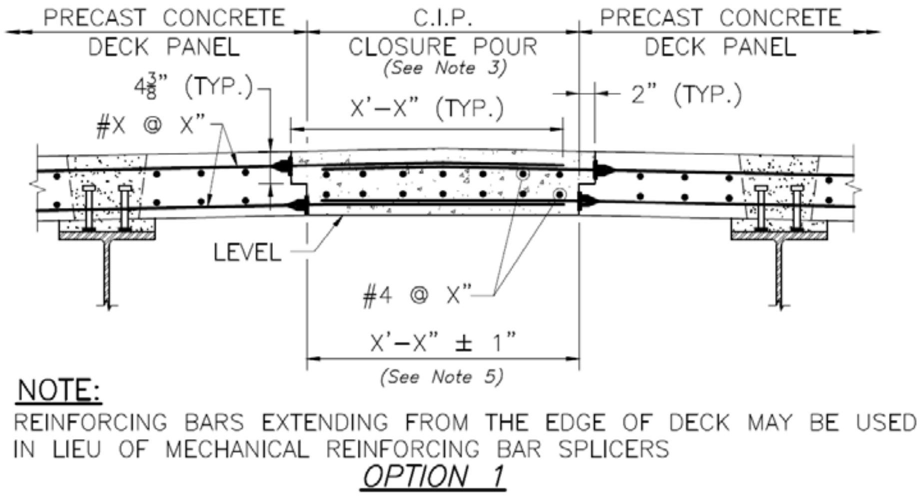
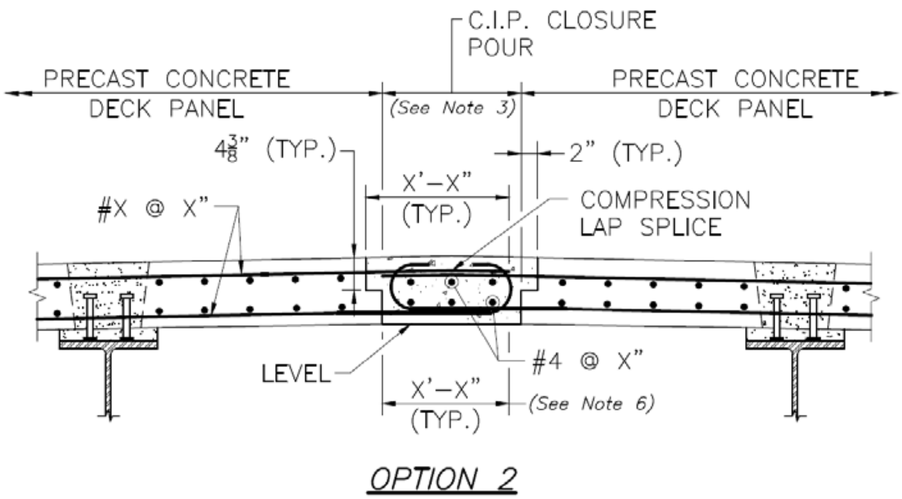


Figure 7.13: Typical FDPC deck panel details for PT joints in Massachusetts: (a) PT duct splice and joint detail, (b) shear key detail, (c) leveling bolt, and (d) shear pocket and shear stud details

Two different types of conventional concrete joint details are shown in Figure 7.14: . One conventional concrete joint option uses a straight bar splice between panels. This closure pour or joint width can be reduced by providing a hoop in the tension reinforcement, as shown in Figure 7.14: (b).



(a)



(b)

Figure 7.14: Alternate FDPC deck panel joint details for Massachusetts DOT: (a) conventional concrete closure pour with straight reinforcement and (b) conventional concrete closure pour with hooked tension reinforcement

A.9. Michigan DOT Typical Details

The details for FDPC deck panels provided by Michigan DOT are shown in Figure 7.15: . Michigan currently uses the common PT joint in the transverse direction and a conventional concrete closure pour in the longitudinal direction.

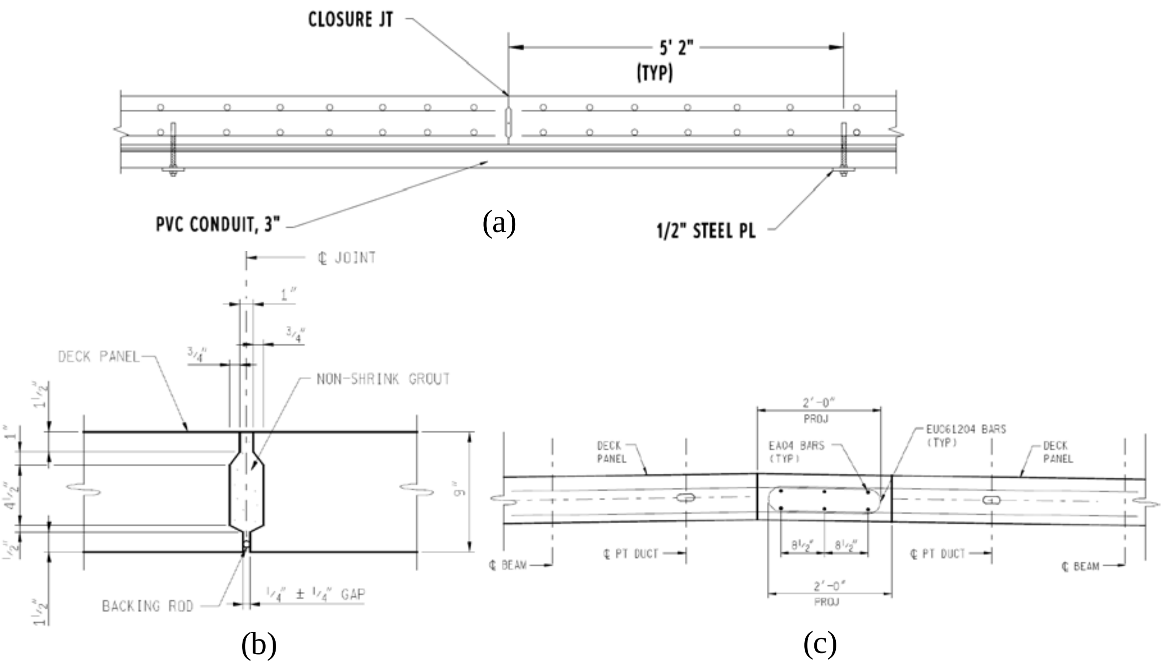
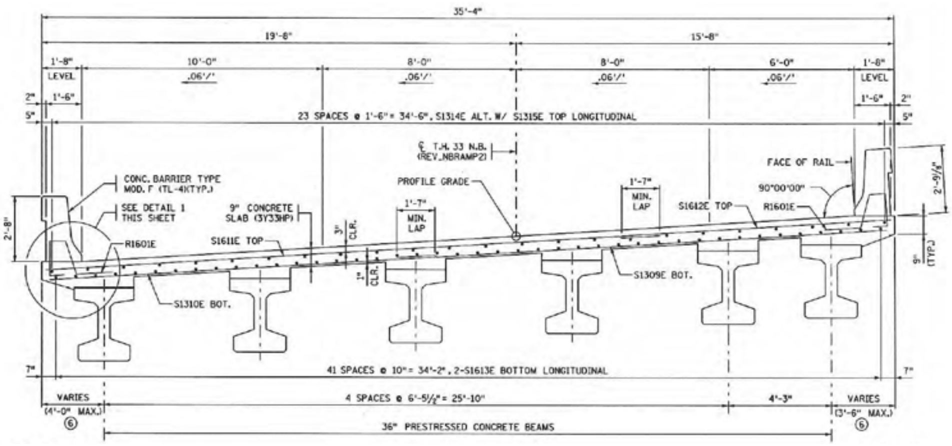


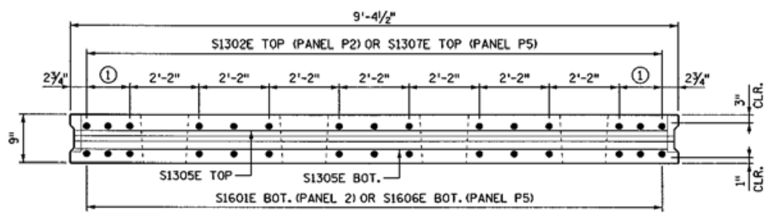
Figure 7.15: Typical FDPC deck panel details for Michigan: (a) typical panel detail, (b) typical joint, and (c) longitudinal closure

A.10. Minnesota DOT Typical Details

The details for FDPC deck panels provided by Minnesota DOT are shown in Figure 7.16: and Figure 7.17Figure 7.15: . The typical CIP deck detail and FDPC deck detail are shown in Figure 7.16:.



(a)



(b)

Figure 7.16: Typical deck detail for Minnesota: (a) CIP Deck and (b) FDPC Deck

More details of the FDPC joint and vertical adjustment level are shown in Figure 7.17. Minnesota typically uses the common PT joint detail and common UHPC join detail for their bridges. Additionally, Minnesota uses Epoxy Chip Seal as a protection system of their bridges especially in small cracks between grout and panel concrete in shear pockets.

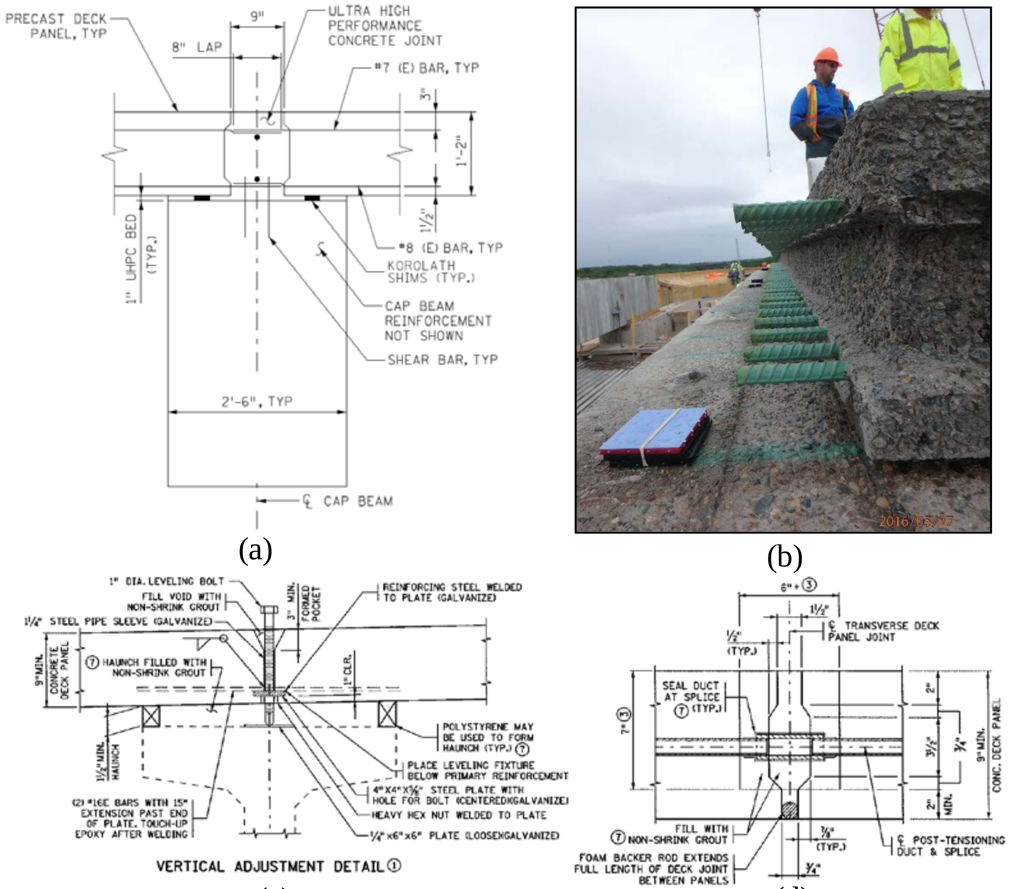


Figure 7.17 Typical FDPC deck panel details for Minnesota: (a) and (b) UHPC joint connection (c) leveling Bolt and (d) transverse joint Detail

Minnesota also uses Polyester Polymer overlay for added protection in their UHPC joint connections.

A.11. Mississippi DOT Typical Details

The details for FDPC deck panels provided by Mississippi DOT are shown in Figure 7.18: . These details are for the FDPC deck panels used in a cable-stayed bridge in Mississippi. Conventional concrete closure strips connected the panels in both transverse and longitudinal directions. Longitudinal post-tensioning was then used to pre-compress the deck.

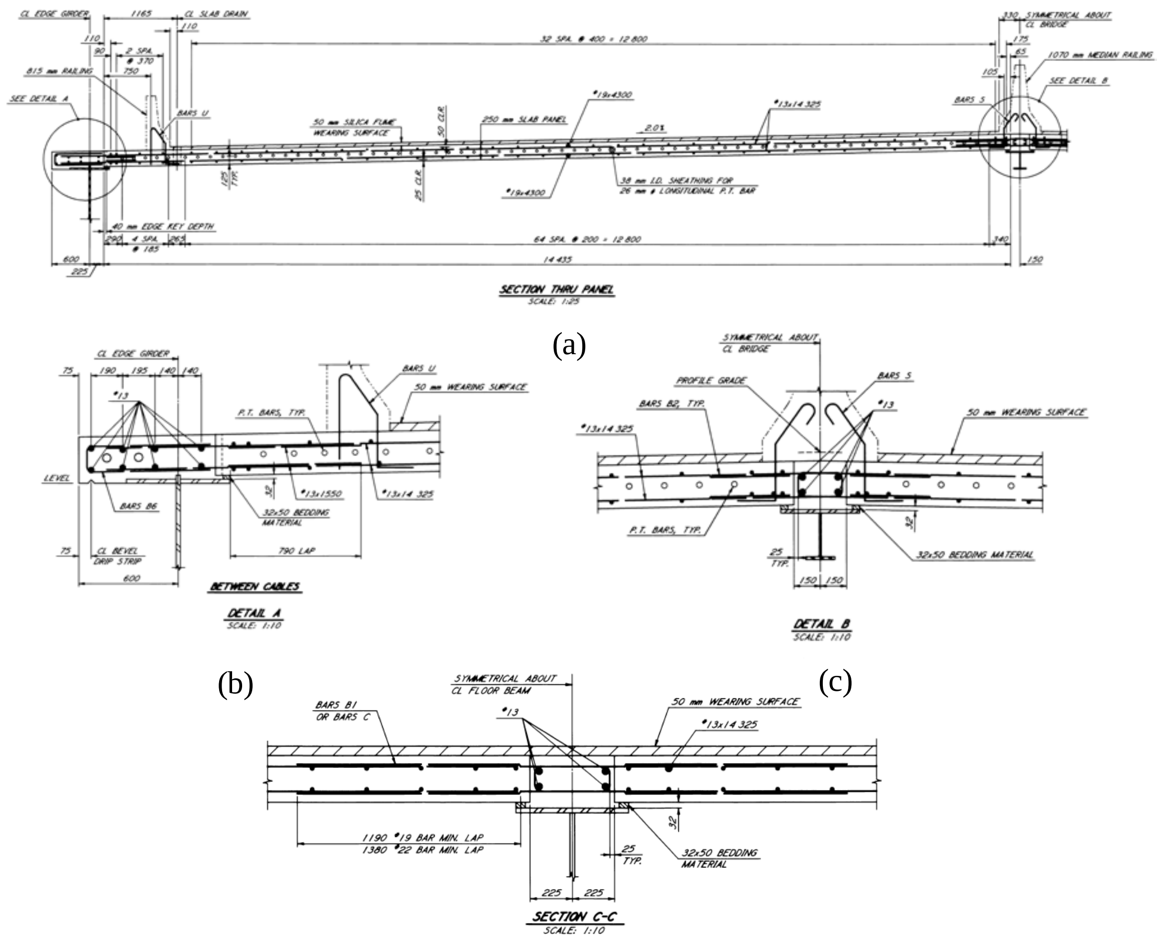
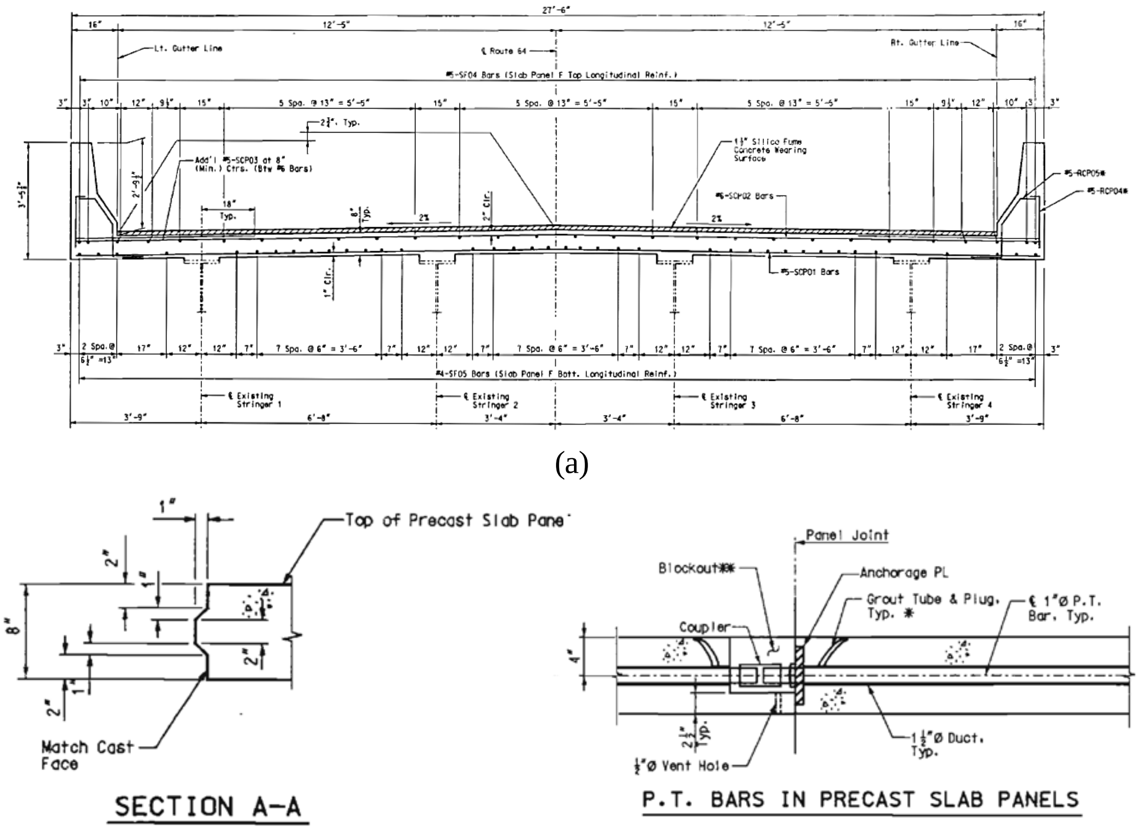


Figure 7.18: FDPC deck panel details for U.S. Highway 82 across the Mississippi River: (a) FDPC deck panel, (b) deck end connection detail, (c) longitudinal joint, and (d) transverse joint detail

A.12. Missouri DOT Typical Details

Details related to FDPC deck panels provided by Missouri DOT are shown in Figure 7.19: . Missouri typically uses 1 ½” silica fume concrete wearing surface as a protection system for their bridges. Missouri was also the only responding state that uses a PT male-to-female joint type in their panel connections. This connection is achieved by match casting adjacent panels.



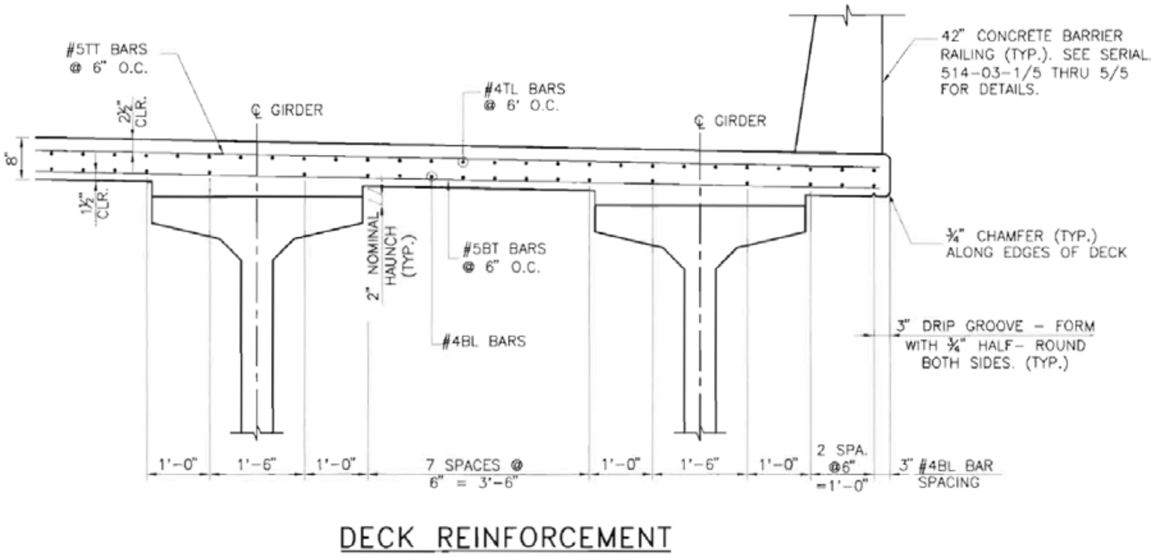
(a)

(b) (c)

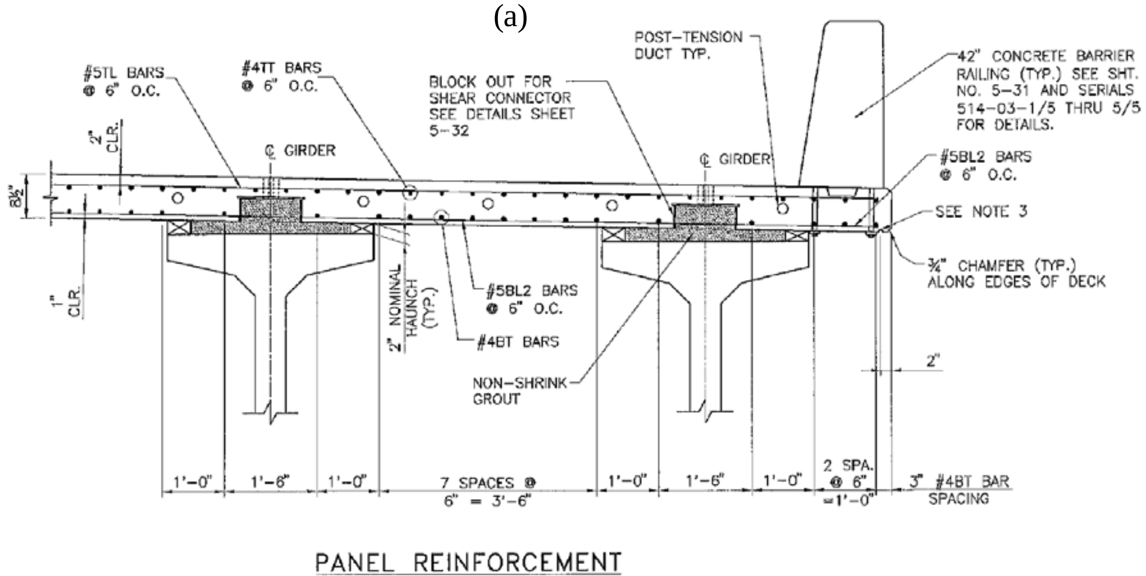
Figure 7.19: Typical FDPC deck panel detail for Missouri: (a) typical deck panel section, (b) male-to-female connection detail, and (c) post-tensioned bars in precast slab panels[5]

A.13. New Mexico DOT Typical Details

The typical connection details for CIP and FDPC deck panels provided by New Mexico DOT are shown in Figure 7.20: and Figure 7.21: . New Mexico currently uses the common PT joint and common UHPC joint with straight bar splice for their bridges. They typically use epoxy as a protecting system.



(a)



(b)

Figure 7.20: Typical deck details for New Mexico: (a) CIP deck and (b) FDPC deck

Details for the typical PT joint and leveling bolts is provided in Figure 7.21: .

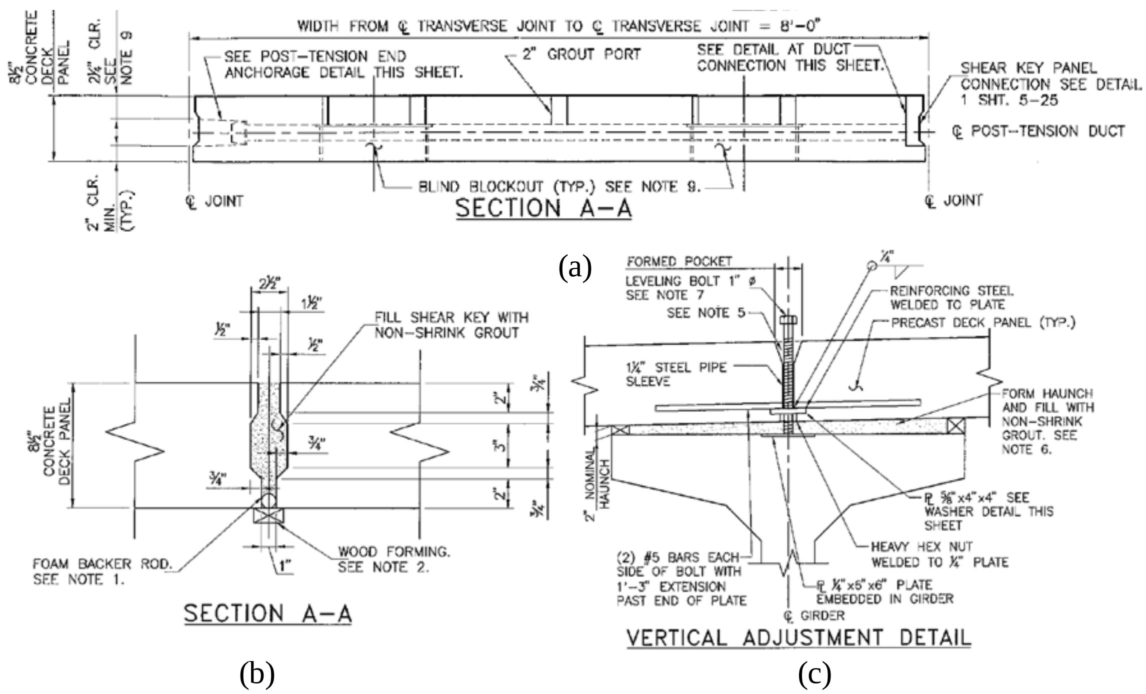


Figure 7.21: Typical FDPC deck panel details for New Mexico: (a) complete panel, (b) joint, and (c) leveling bolt

New Mexico DOT reported leaking from joints in FDPC panels adjacent to the CIP diaphragm. They noted that they typically use cementitious grout in their connection joints and therefore shrinkage of this grout may result in a weak connection between FDPC panel and CIP diaphragm.

A.14. New Hampshire DOT Typical Details

The typical connection details for FDPC deck panels provided by New Hampshire DOT are shown in Figure 7.22: . New Hampshire currently uses PT joints for their bridges, although they have a slightly different joint geometry than is typically used. An asphalt overlay and waterproofing Class I on wearing surface are typically used on their bridges.

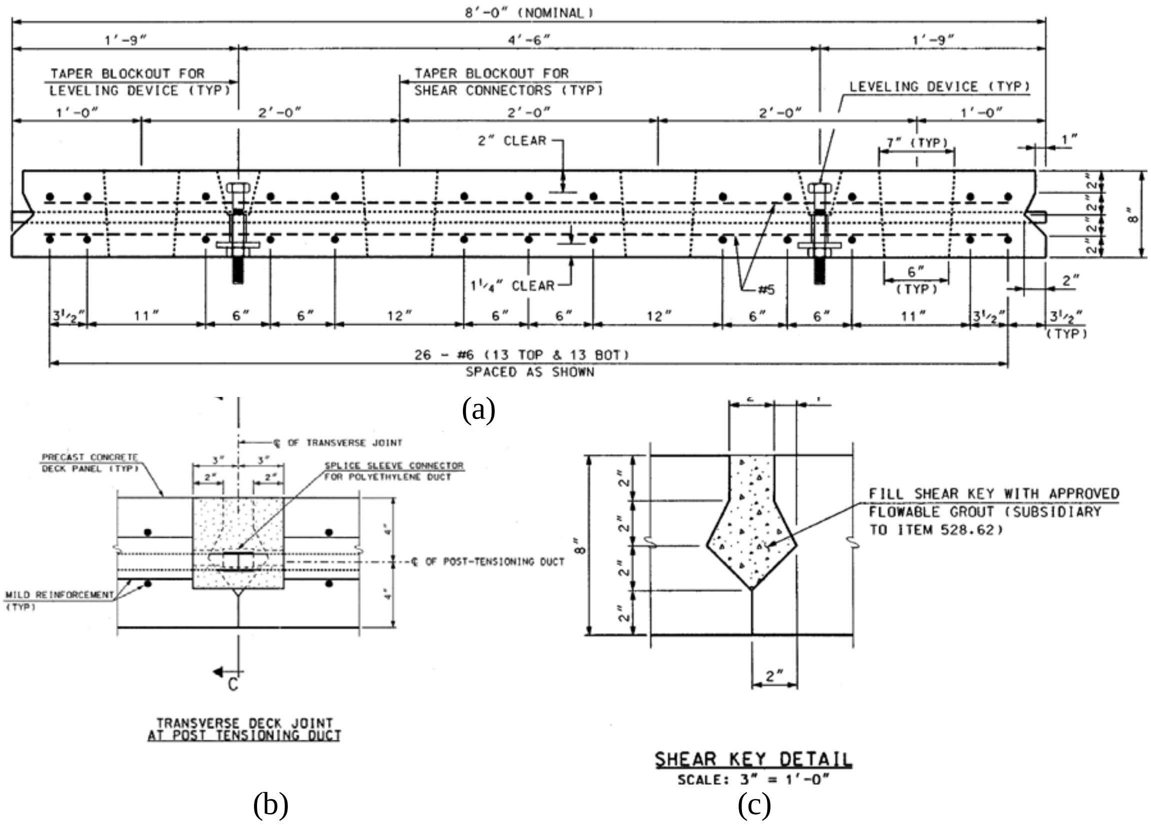


Figure 7.22: Typical FDPC deck panel details for New Hampshire: (a) FDPC panel detail, (b) joint with duct splice, and (c) shear key detail

A.15. New York DOT Typical Details

The typical connection details for FDPC deck panels provided by New York DOT are shown in Figure 7.23: . These details include longitudinal and transverse UHPC joint details for connections over beams and not over beams.

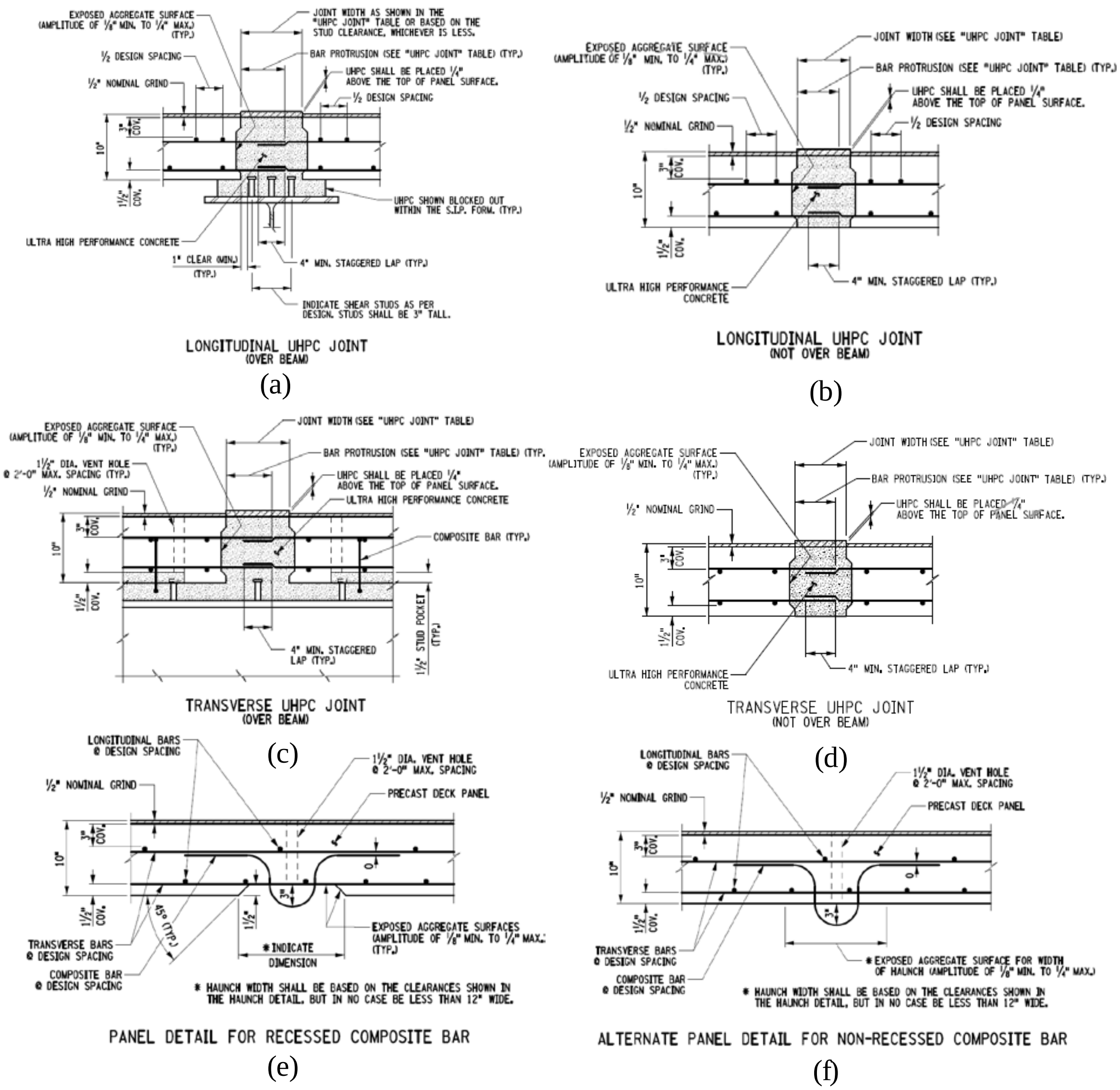


Figure 7.23: Typical FDPC deck panel details for New York: (a) longitudinal UHPC joint over beam, (b) longitudinal UHPC joint not over beam, (c) transverse UHPC joint over beam, (d) transverse UHPC joint not over beam, (e) panel detail for recessed composite bar, and (f) panel detail for non-recessed composite bar

New York currently uses UHPC joints with straight bar splices for their bridges and previously used PT joint and conventional concrete joints in their bridges. They typically use an asphalt overlay and Waterproofing Class I for the wearing surface of their bridges.

A.16. Oregon DOT Typical Details

The typical connection details for FDPC deck panels provided by Oregon DOT are shown in Figure 7.24:Figure 7.23: . Oregon typically uses the UHPC joint detail with straight bar splices for their bridges.

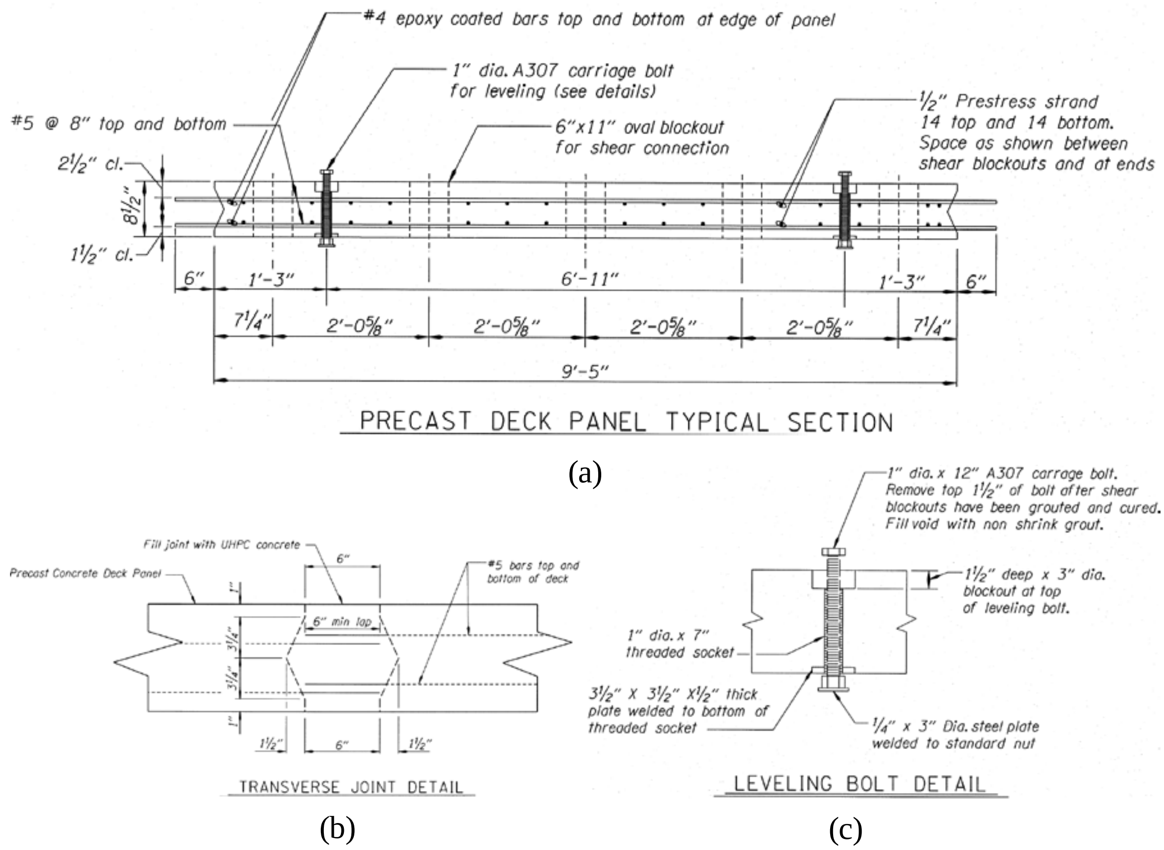


Figure 7.24: Typical FDPC deck panel detail for Oregon: (a) typical deck panel section, (b) transverse joint detail, and (c) vertical adjustment[5]

A.17. Pennsylvania DOT Typical Details

The typical connection details for FDPC panels provided by Pennsylvania DOT are shown in Figure 7.25 and Figure 7.26: . Penn DOT uses common PT joints and UHPC joints with hooped bar splices. Details for longitudinal closure pours and leveling bolts are shown in Figure 7.25.

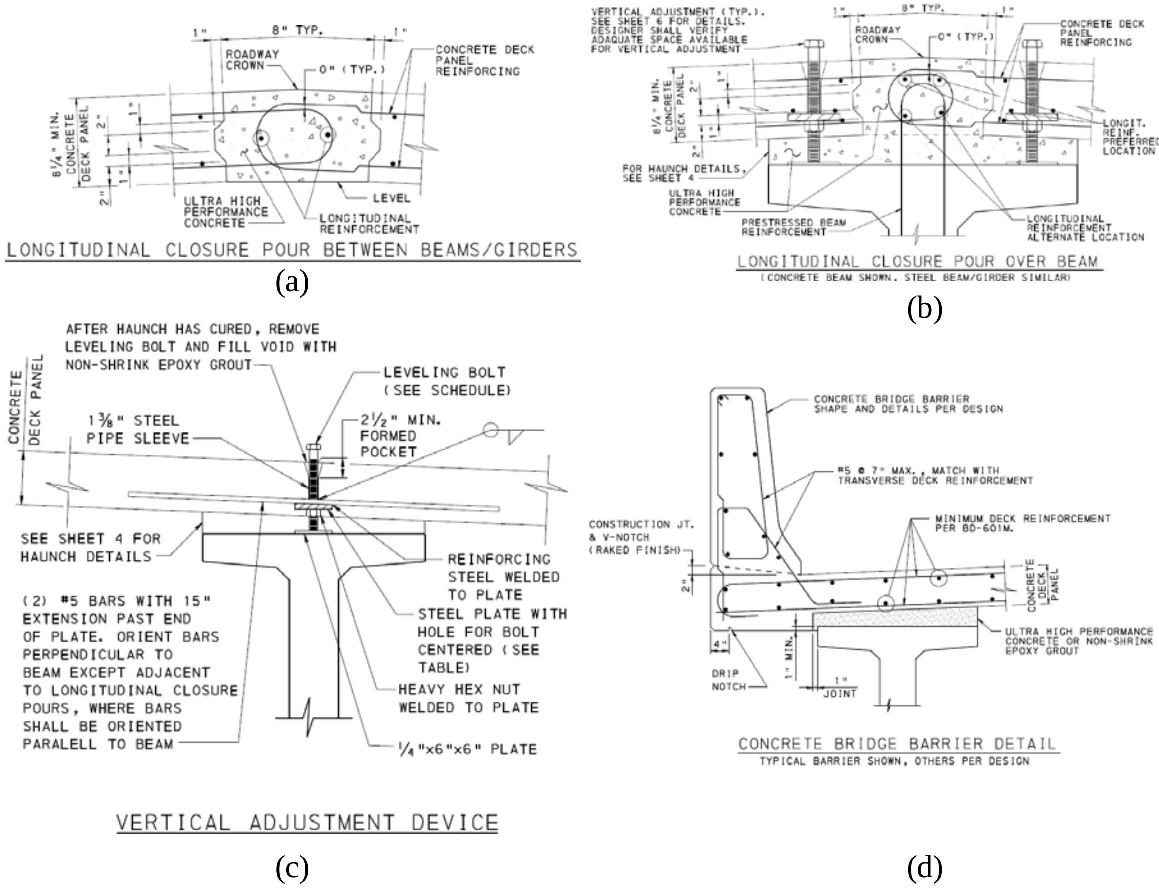
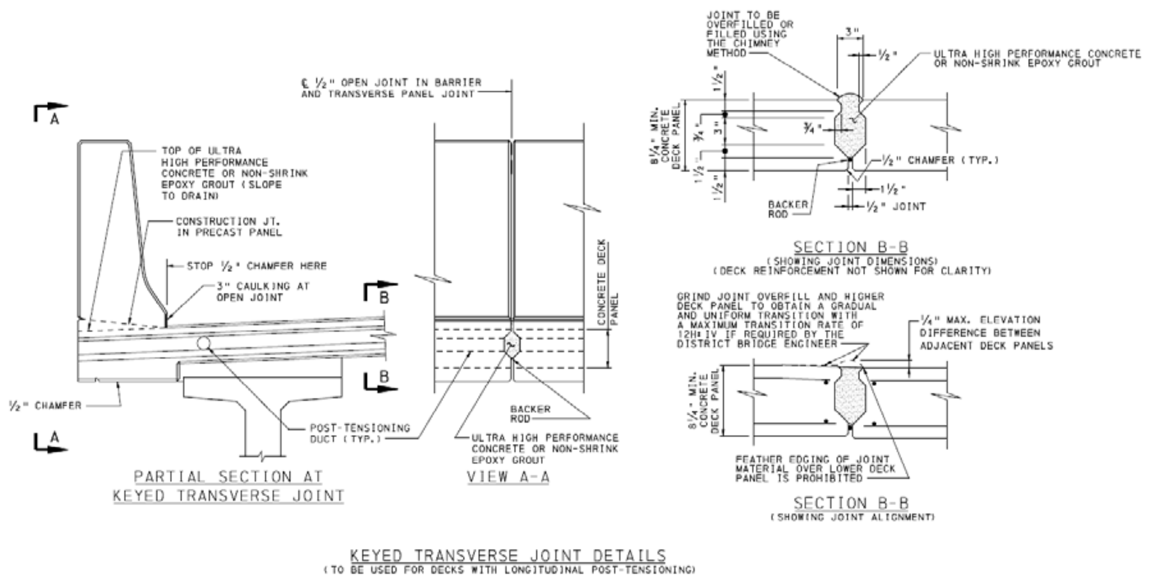
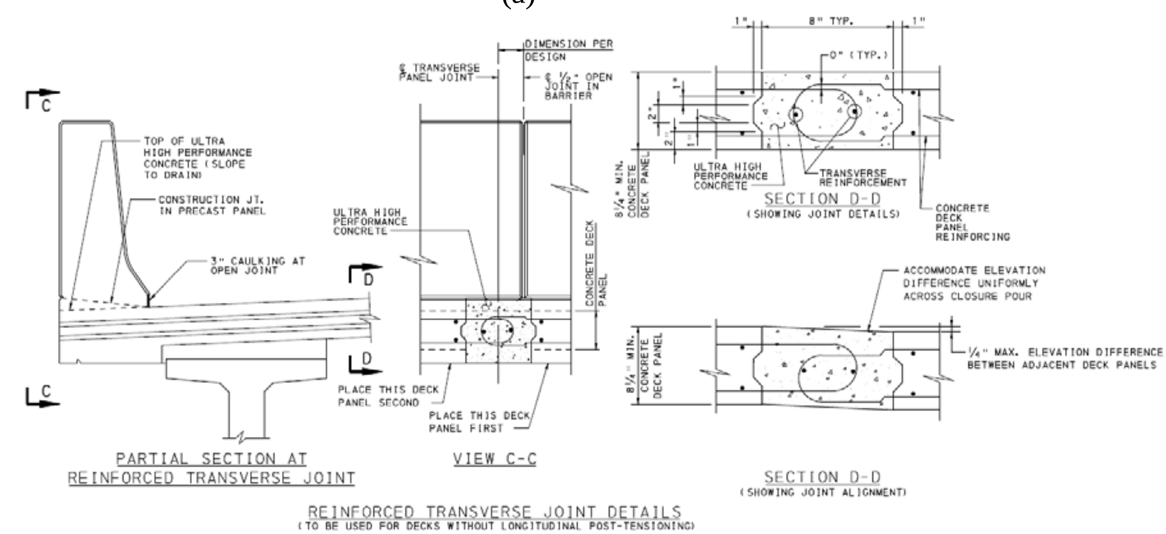


Figure 7.25: Typical FDPC deck panel details for Pennsylvania: (a) longitudinal closure pour, (b) longitudinal closure pour over beam, (c) leveling bolts, and (d) barrier detail

Two different options for transverse joints are provided in Figure 7.26: : keyed detail used with post-tensioning and hooped reinforcement detail used with UHPC. Note that Penn DOT typically uses ½" epoxy-urethane overlay (applied after 1 year) as a protection system for their bridges.



(a)

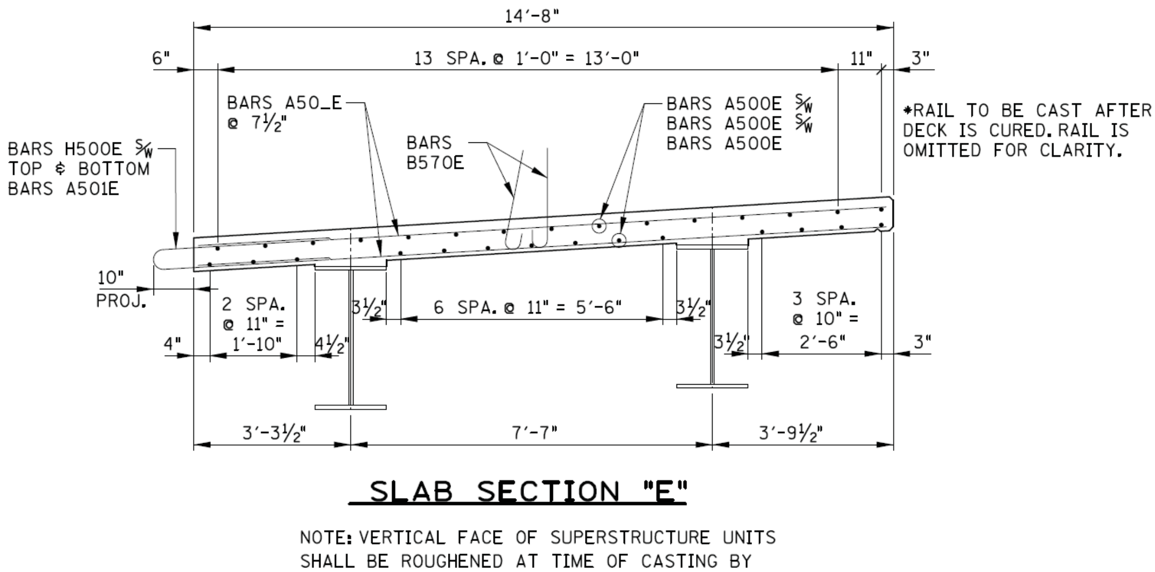


(b)

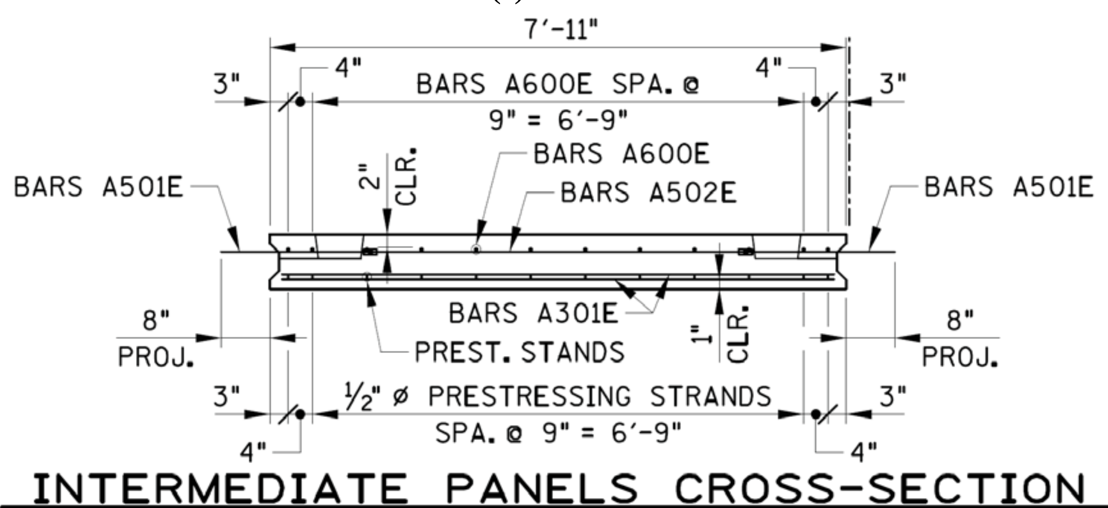
Figure 7.26: Typical FDPC deck panel details for Pennsylvania: (a) keyed transverse joint details for use with post tensioning and (b) reinforced transverse joint details using UHPC

A.18. Tennessee DOT Typical Details

The typical details related to CIP decks and FDPC deck panels provided by Tennessee DOT are shown in Figure 7.27: and Figure 7.28:. Typical section for CIP and FDPC deck panel decks are shown in Figure 7.27:. Tennessee uses a cementitious ready-mix material with admixtures added for early strength gain and reduced shrinkage in bridge joints. They also use an asphalt overlay and epoxy as a protection system in their bridges.



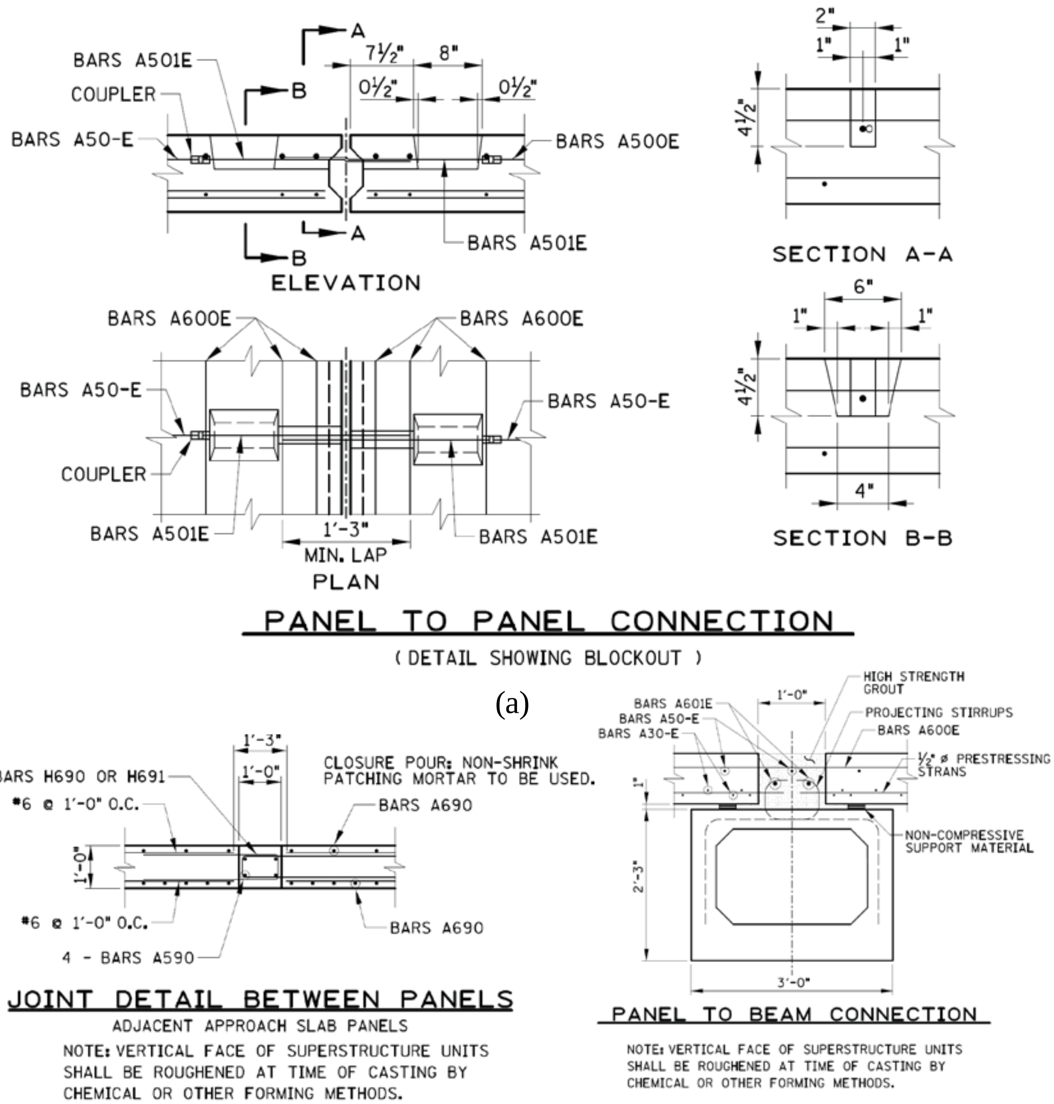
(a)



(b)

Figure 7.27: Typical deck details for Tennessee: (a) CIP deck and (b) FDPC deck

One detail that has been used in Tennessee for the joint between FDPC deck panels is shown in Figure 7.28:. This joint is a non-PT joint detail with pockets to increase development length while keeping a small joint width. The connection is then filled with non-shrink grout. High-strength grout is used to connect the panel to the beams, as shown in Figure 7.28: (c).



(b) (c)

Figure 7.28: Typical FDPC deck panel details for Tennessee: (a) panel-to-panel connection details, (b) joint detail between panels, and (c) panel-to-beam connection detail

A.19. Texas DOT Typical Details

The typical details related to FDPC deck panel provided by Texas DOT are shown in Figure 7.29: and Figure 7.30. These details include panels detail, joint section, and vertical adjustment for a typical PT joint detail. Texas typically uses an asphalt wearing surface for their bridges.

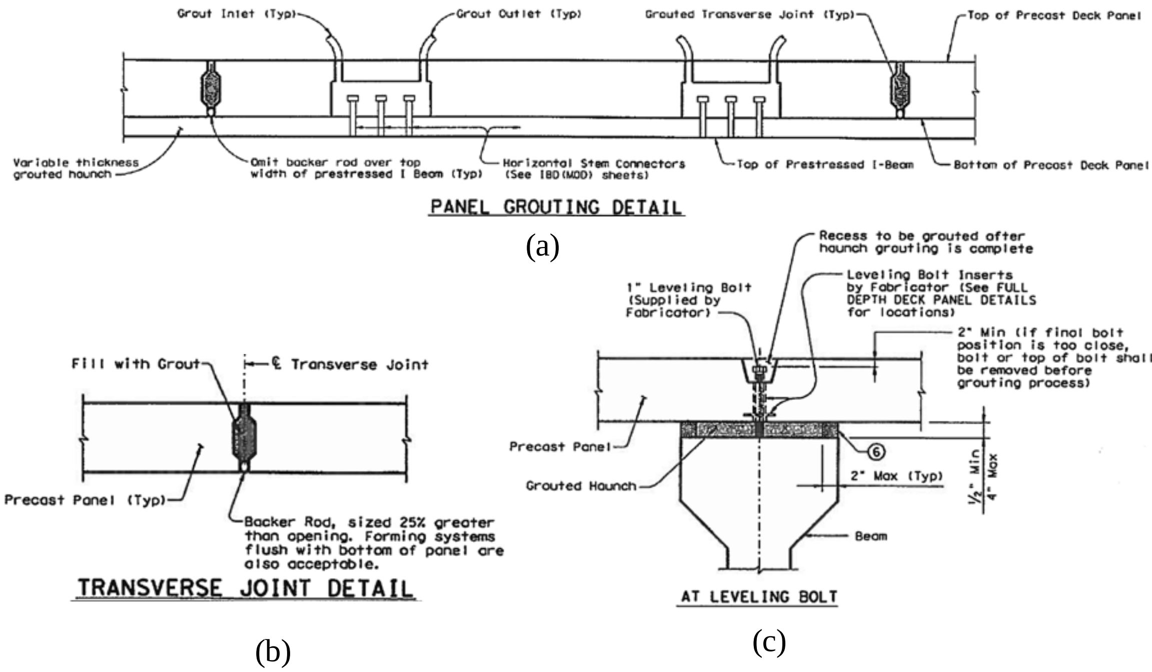
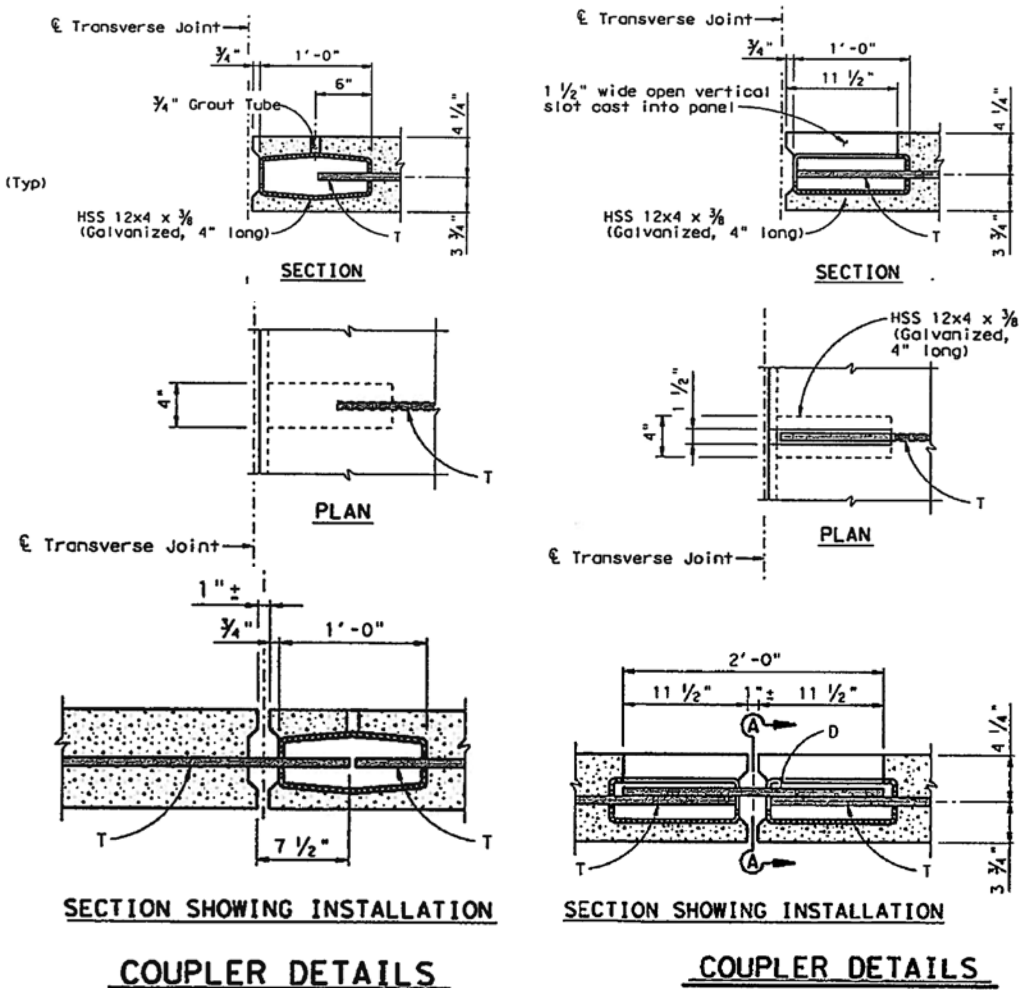


Figure 7.29: Typical FDPC deck panel detail for Texas: (a) panel detail, (b) joint, and (c) leveling Bolt [5]

Two other coupler joint details are shown in Figure 7.30. These joint details were developed during NCHRP 12-65.

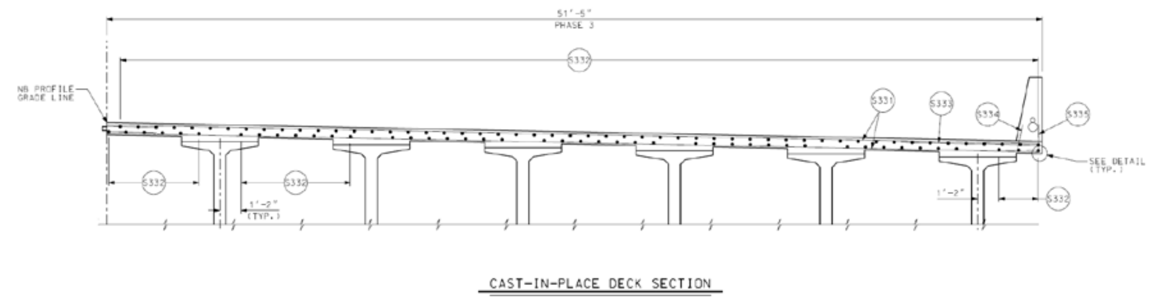


(a) (b)

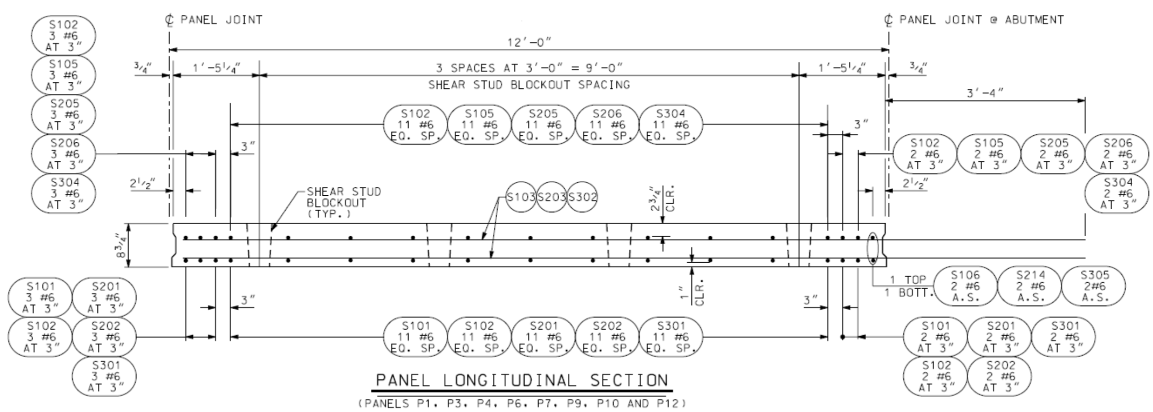
Figure 7.30: Typical FDPC Deck Panel Detail for Texas: (a) Coupler Detail Option 1 and (b) Coupler Detail Option 2 [5]

A.20. Utah DOT Typical Details

The typical details related to CIP and FDPC deck panels provided by Utah DOT are shown in Figure 7.31: to Figure 7.34. The typical CIP deck section and panel longitudinal section are shown in Figure 7.31: .



(a)



(b)

Figure 7.31: Typical (a) CIP deck details and (b) longitudinal panel section for Utah DOT

More details related to the FDPC deck panel are shown in Figure 7.32: . These details include leveling bolts, shear stud details, and PT joint detail.

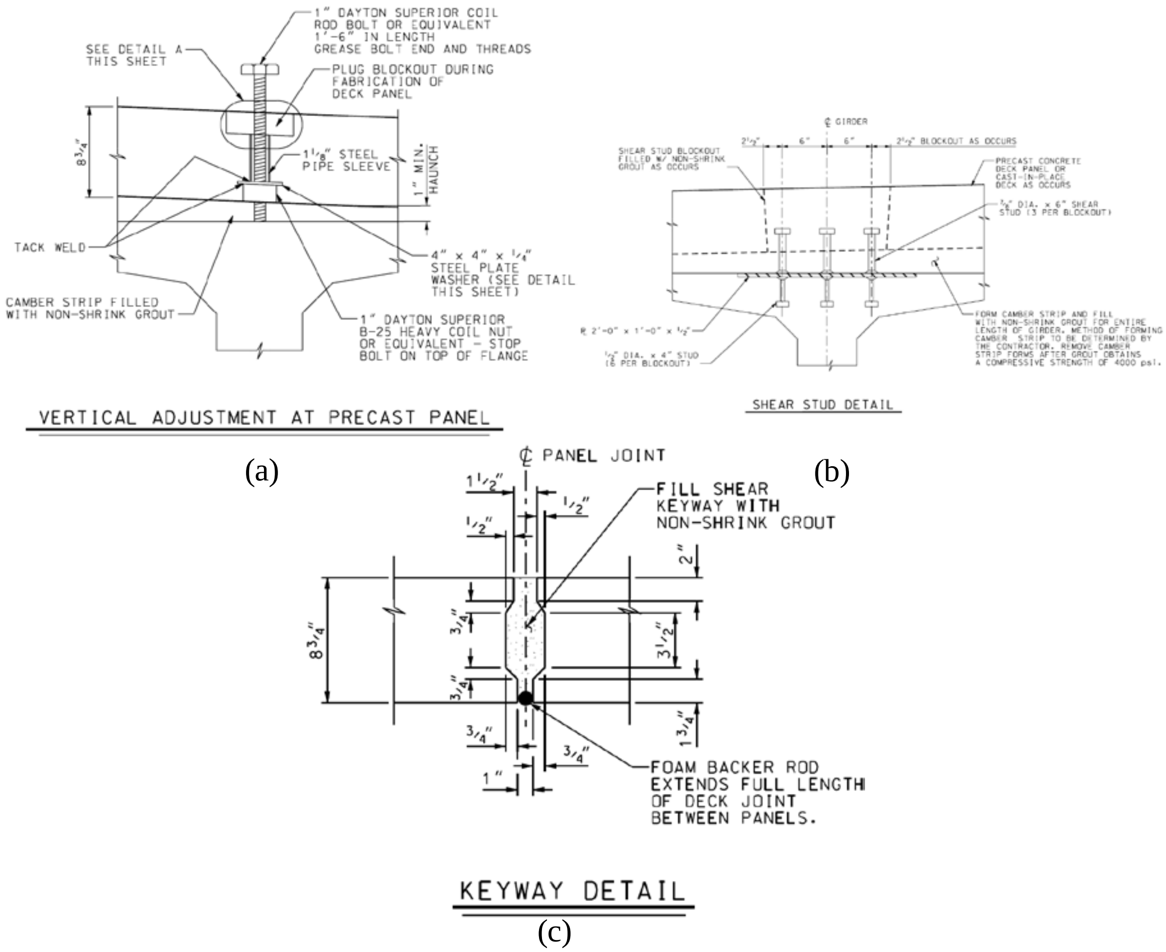


Figure 7.32: Typical FDPC deck panel details for Utah: (a) leveling bolts, (b) shear stud detail, and (c) keyway detail

Utah DOT previously used a welded tie detail for their connections between FDPC deck panels, shown in Figure 7.33:. As mentioned in the previous chapter, this detail is not performing well.

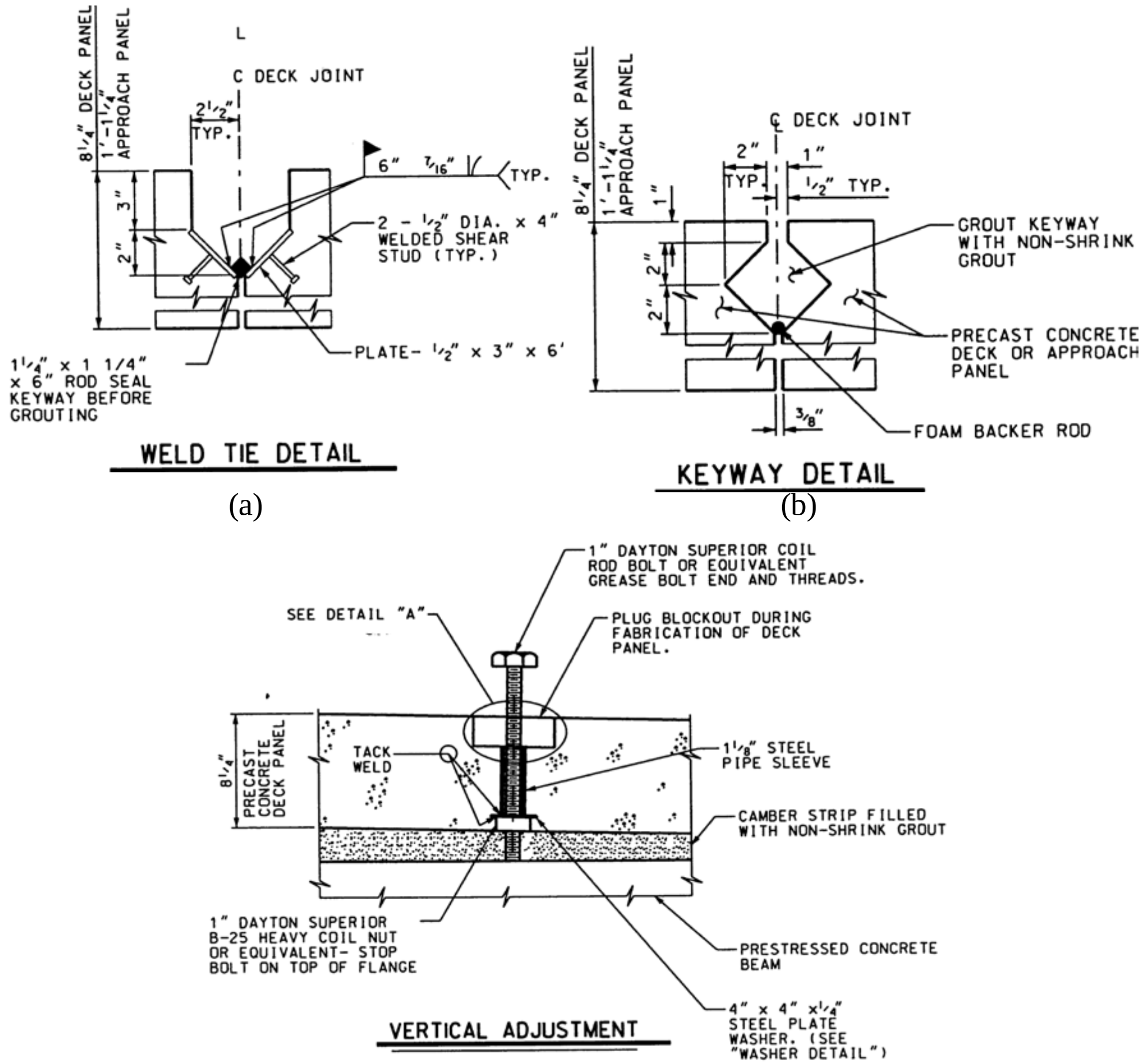


Figure 7.33: Typical welded tie joint detail for Utah: (a) welded tie detail, (b) keyway detail, and (c) vertical adjustment at longitudinal joint

Utah DOT currently uses a UHPC joint with straight bar splices; some of these details are shown in Figure 7.34:.

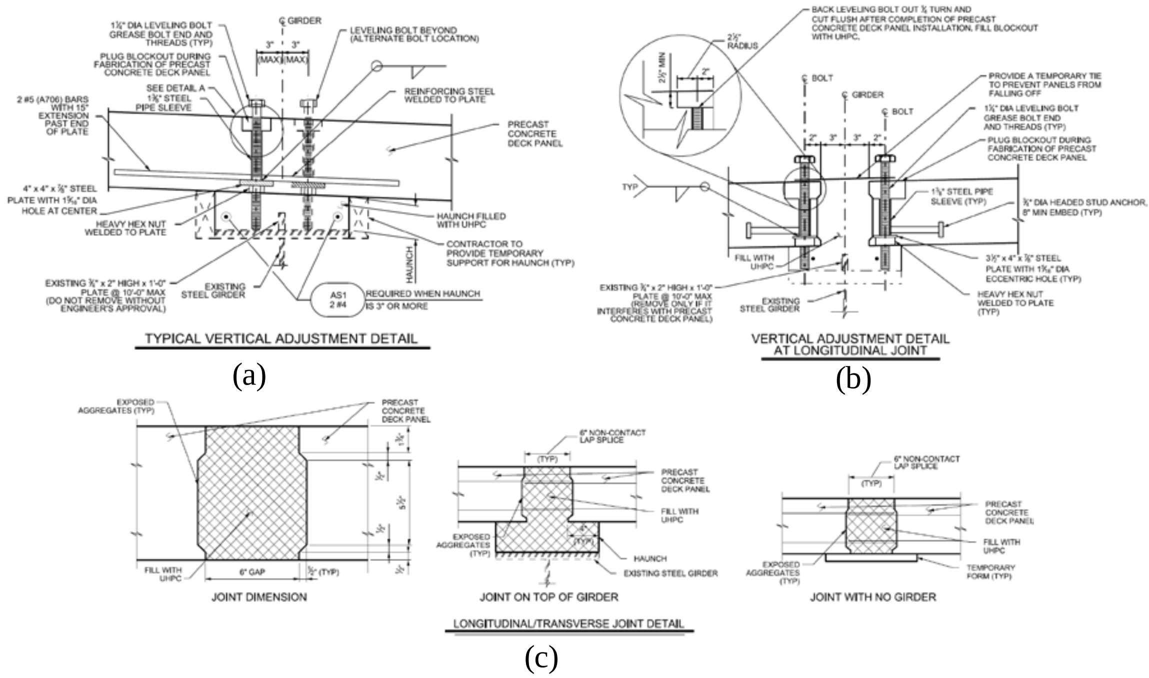


Figure 7.34: Typical UHPC joint detail for Utah: (a) typical vertical adjustment, (b) vertical adjustment at longitudinal joint, and (c) longitudinal transverse joint detail

Utah typically uses epoxy as a protection system for the surface of bridges.

A.21. Wisconsin DOT Typical Details

The typical FDPC details provided by Wisconsin DOT are shown in Figure 7.35:. Wisconsin typically uses a PT detail for joints. Transverse post-tensioned and vertical adjustment details are shown in Figure 7.35:.

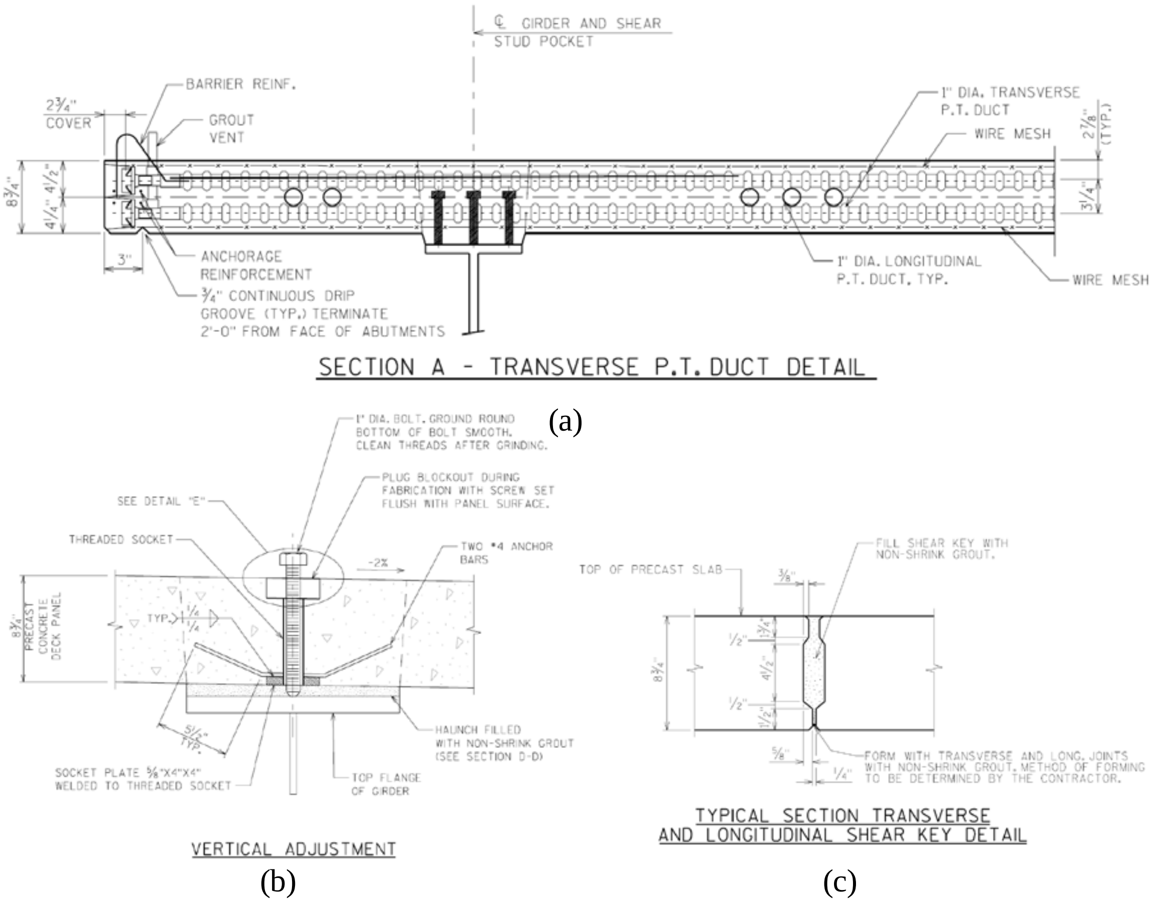


Figure 7.35: Typical FDPC deck panel detail for Wyoming: (a) typical deck detail, (b) vertical adjustment, and (c) PT duct connection detail

A.22. Wyoming DOT Typical Details

The typical details related to FDPC deck panel provided by Wyoming DOT are shown in Figure 7.36: . These details include the joint section, vertical adjustment, and typical deck section. Wyoming typically uses epoxy on overlay as a protection system.

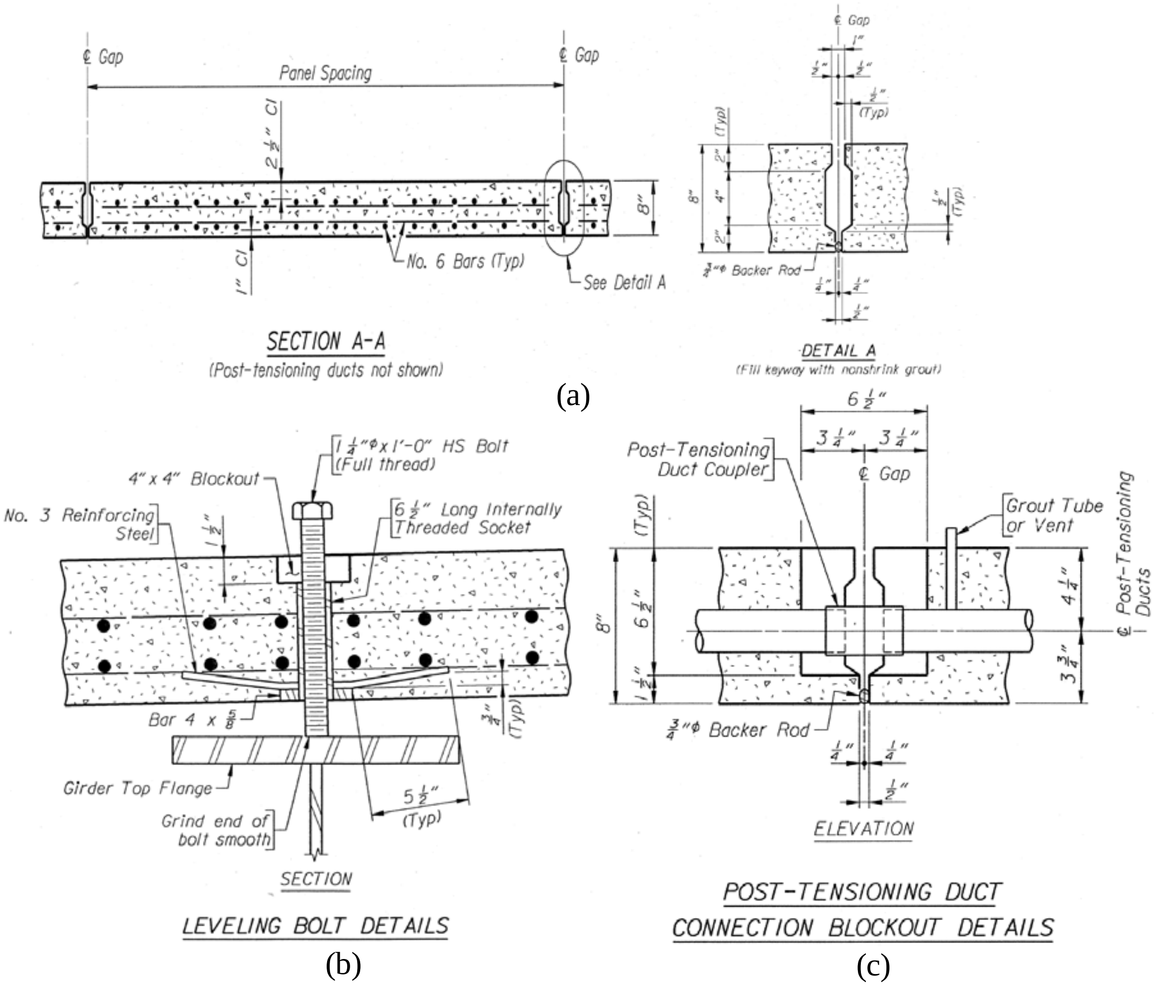


Figure 7.36: Typical FDPC deck panel detail for Wyoming: (a) typical deck detail, (b) vertical adjustment, and (c) PT duct connection detail

APPENDIX B: FDPC DECK PANEL DATABASE

The FDPC Deck Panel Database is shown in Table B.1.

Table B.1: FDPC Deck Panel Database

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
AL-FDPC-1	2125	2012	Non-PT - C1.a	None	Tier 6	Very Cold	1 - Monolithic Concrete
AL-FDPC-2	1298	2006	Non-PT - C1.a	None	Tier 6	Very Cold	1 - Monolithic Concrete
AL-FDPC-3	1308	2000	Non-PT - C1.a	None	Tier 6	Very Cold	1 - Monolithic Concrete
AL-FDPC-4	0183	1995	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-5	0184	1995	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-6	0185	1995	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-7	0255	1970	Welded - C1-b	Welded - C1-b	Tier 5	Very Cold	6 - Bituminous
AL-FDPC-8	0446	1979	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-9	0556	1999	Non-PT - C1.a	Welded - C1-b	Tier 5	Very Cold	1 - Monolithic Concrete
AL-FDPC-10	0797	1955	Non-PT - C1.a	None	-	Very Cold	6 - Bituminous
AL-FDPC-11	1185	2014	Non-PT - C1.a	None	Tier 5	Very Cold	1 - Monolithic Concrete
AL-FDPC-12	1255	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-13	1256	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-14	1257	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-15	1258	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-16	1259	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-17	1260	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-18	1261	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-19	1282	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-20	1283	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-21	1284	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-22	1304	1992	CC - C1.h	Welded - C1-b	-	Very Cold	6 - Bituminous
AL-FDPC-23	1332	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-24	1334	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-25	1335	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
AL-FDPC-26	1336	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-27	1337	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-28	1338	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-29	1423	1967	Non-PT - C1.a	Non-PT - C1.a	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-30	1435	2001	Non-PT - C1.a	None	-	Very Cold	9 - Other
AL-FDPC-31	1436	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-32	1437	1992	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-33	1820	2006	None	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-34	1821	2006	None	None	Tier 5	Very Cold	1 - Monolithic Concrete
AL-FDPC-35	1836	2001	Non-PT - C1.a	None	Tier 6	Very Cold	1 - Monolithic Concrete
AL-FDPC-36	1841	1979	Non-PT - C1.a	None	-	Very Cold	1 - Monolithic Concrete
AL-FDPC-37	2135	1992	Non-PT - C1.a	None	-	Very Cold	6 - Bituminous
AL-FDPC-38	2206	2010	Non-PT - C1.a	None	Tier 5	Very Cold	1 - Monolithic Concrete
AL-FDPC-39	2207	2010	Non-PT - C1.a	None	Tier 5	Very Cold	0 - None
AL-FDPC-40	2226	2010	Non-PT - C1.a	None	Tier 5	Very Cold	0 - None
CA-FDPC-1	32 0018	2017	Long. PT - C1.a	None	Tier 5	Very Cold	0 - None
CO-FDPC-1	F-16-XB	2013	CC - C1.h	CC - C1.j	Tier 5	Cold	6 - Bituminous
CT-FDPC-1	03200	1989	-	-	-	Cold	6 - Bituminous
CT-FDPC-2	00587	1993	Long. PT - C1.a	-	-	Cold	6 - Bituminous
CT-FDPC-3	00255	2019	-	-	-	Cold	6 - Bituminous
CT-FDPC-4	03819	2019	-	-	-	Cold	6 - Bituminous
CT-FDPC-5	00524	2020	-	-	-	Cold	6 - Bituminous
DE-FDPC-1	1717 056	2016	UHPC - C1.f	UHPC - C1.f	Tier 5	Mixed humid	3 - Latex Concrete or similar additive
DE-FDPC-2	1680 006	2018	UHPC - C1.f	UHPC - C1.f	Tier 6	Mixed humid	3 - Latex Concrete or similar additive
DE-FDPC-3	1251 355	1973	UHPC - C1.f	UHPC - C1.f	Tier 5	Mixed humid	1 - Monolithic Concrete
FL-FDPC-1	500151	2015	CC - C1.h	None	Tier 6	Hot humid	N - N/A (no deck)
FL-FDPC-2	500152	2015	CC - C1.h	None	Tier 6	Hot humid	N - N/A (no deck)
FL-FDPC-3	500153	2015	CC - C1.h	None	Tier 6	Hot humid	N - N/A (no deck)

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
FL-FDPC-4	500154	2015	CC - C1.h	None	Tier 6	Hot humid	N - N/A (no deck)
GA-FDPC-1	000000001350580	2016	UHPC - C1.f	UHPC - C1.f	Tier 5	Cold	1 - Monolithic Concrete
IL-FDPC-1	084004000000000	2001	Long. PT - C1.a	None	Tier 5	Cold	9 - Other
IA-FDPC-1	044691	2008	Long. PT - C1.a	CC - C1.h	Tier 6	Cold	2 - Integral Concrete
IA-FDPC-2	78171	2006	Long. PT - C1.a	CC - C1.h	Tier 6	Cold	1 - Monolithic Concrete
LA-FDPC-1	072700140209041	2017	CIP CC Closure - C1.h	-	-	Hot humid	6 - Bituminous
MA-FDPC-1	C1300812HDOTNBI	2013	Long. PT - C1.a	CC - C1.j	Tier 6	Very Cold	6 - Bituminous
MA-FDPC-2	H21039BBMDOTNBI	2013	Long. PT - C1.a	CC - C1.i	Tier 5	Very Cold	6 - Bituminous
MA-FDPC-3	A07016-BAU-DOT-NBI	-	Long. PT - C1.a	CC - C1.h	Tier 6	Very Cold	-
MA-FDPC-4	T01015-BHK-DOT-NBI	-	Long. PT - C1.a	CC - C1.i	Tier 5	Very Cold	-
MA-FDPC-5	S350183U8DOTNBI	2015	Long. PT - C1.a	CC - C1.j	Tier 3	Very Cold	6 - Bituminous
MA-FDPC-6	S350183U9DOTNBI	2015	Long. PT - C1.a	CC - C1.j	Tier 3	Very Cold	6 - Bituminous
MI-FDPC-1	4558	2008	Long. PT - C1.a	CC - C1.h	Tier 5	Cold	6 - Bituminous
MN-FDPC-1	69071	2012	Long. PT - C1.a	CC - C1.h	Tier 5	Very Cold	5 - Epoxy Overlay
MN-FDPC-2	2441	2016	UHPC - C1.f	UHPC - C1.f	Tier 6	Cold	9 - Other
MS-FDPC-1	210008207600010	2010	Long. PT - C1.a	CC - C1.h	Tier 5	Mixed humid	3 - Latex Concrete or similar additive
MO-FDPC-1	649	2004	Long. PT - matchcast	-	Tier 6	Mixed humid	9 - Other
MO-FDPC-2	4089	1997	-	-	-	Mixed humid	9 - Other
MO-FDPC-3	33066	2010	-	-	-	Mixed humid	1 - Monolithic Concrete
MO-FDPC-4	33066	2010	-	-	-	Mixed humid	1 - Monolithic Concrete
MO-FDPC-5	33066	2010	-	-	-	Mixed humid	1 - Monolithic Concrete
MO-FDPC-6	33066	2010	-	-	-	Mixed humid	1 - Monolithic Concrete
NE-FDPC-1	S010 05463R	2016	Long. PT - C1.a	None	Tier 3	Cold	1 - Monolithic Concrete
NE-FDPC-2	C000614205	2014	-	UHPC - C1.e	Tier 3	Cold	2 - Integral Concrete
NE-FDPC-3	SL28B00216	2002	Long. PT - C1.a	None	Tier 3	Cold	1 - Monolithic Concrete
NH-FDPC-1	005201630010600	2010	Long. PT - C1.a	None	Tier 2	Cold	6 - Bituminous
NJ-FDPC-1	(Broadway Bridge over Little Timber Creek in ABC Project Database)	2012	-	-	Tier 1	Mixed humid	6 - Bituminous
NM-FDPC-1	9610	2015	Long. PT - C1.a	-	-	Hot dry	0 - None

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
NM-FDPC-2	9611	2015	Long. PT - C1.a	-	-	Hot dry	0 - None
NY-FDPC-1	00000000552305B	2017	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-2	000000005523052	2017	-	-	-	Mixed humid	-
NY-FDPC-3	00000000552305C	2017	-	-	-	Mixed humid	-
NY-FDPC-4	000000001035460	2016	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-5	000000003045230	2016	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-6	000000002270010	2016	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-7	000000001035450	2016	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-8	000000001035470	2016	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-9	000000001079700	2016	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	-
NY-FDPC-10	000000003320920	2016	-	-	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-11	000000003321940	2016	-	-	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-12	000000003025100	2016	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-13	000000001092839	2016	CC - C1.h	CC - C1.h	-	Mixed humid	2 - Integral Concrete
NY-FDPC-14	000000001092441	2016	CC - C1.h	CC - C1.h	-	Mixed humid	0 - None
NY-FDPC-15	000000001092442	2016	CC - C1.h	CC - C1.h	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-16	000000001092422	2016	CC - C1.h	CC - C1.h	-	Mixed humid	0 - None
NY-FDPC-17	000000001092421	2016	CC - C1.h	CC - C1.h	-	Mixed humid	0 - None
NY-FDPC-18	00000000109283B	2016	CC - C1.h	CC - C1.h	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-19	000000002205540	2016	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-20	000000001033142	2015	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	6 - Bituminous
NY-FDPC-21	000000001033141	2015	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	2 - Integral Concrete
NY-FDPC-22	000000003346880	2014	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-23	000000003322080	2014	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-24	000000002224830	2014	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-25	000000003358710	2014	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-26	000000003347030	2014	-	-	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-27	000000003347100	2013	-	-	-	Mixed humid	6 - Bituminous

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
NY-FDPC-28	000000003321120	2013	-	-	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-29	000000001093672	2013	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-30	000000001031559	2013	-	-	-	Mixed humid	1 - Monolithic Concrete
NY-FDPC-31	000000001031529	2013	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	2 - Integral Concrete
NY-FDPC-32	000000005500019	2013	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	6 - Bituminous
NY-FDPC-33	000000001047689	2013	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-34	000000001009290	2013	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	6 - Bituminous
NY-FDPC-35	000000001024090	2013	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	6 - Bituminous
NY-FDPC-36	000000001007780	2013	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	6 - Bituminous
NY-FDPC-37	000000003370870	2012	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-38	000000003321830	2012	-	-	-	Mixed humid	9 - Other
NY-FDPC-39	000000001021850	2012	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	2 - Integral Concrete
NY-FDPC-40	000000001051091	2014	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	2 - Integral Concrete
NY-FDPC-41	000000001051092	2014	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	2 - Integral Concrete
NY-FDPC-42	000000001051159	2012	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	2 - Integral Concrete
NY-FDPC-43	000000001054720	2012	UHPC - C1.f	UHPC - C1.f	-	Mixed humid	9 - Other
NY-FDPC-44	000000001025200	2011	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-45	000000001025190	2011	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-46	000000001050430	2011	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-47	000000003347680	2011	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-48	000000003025090	2011	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-49	000000003347140	2011	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-50	000000001058509	2011	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-51	000000005521180	2011	Long. PT - C1.a	CC - C1.h	Tier 6	Mixed humid	2 - Integral Concrete
NY-FDPC-52	000000003302930	2011	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-53	000000003346680	2010	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-54	000000003371380	2009	-	-	-	Mixed humid	-
NY-FDPC-55	000000003321270	2009	-	-	-	Mixed humid	3 - Latex Concrete or similar additive

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
NY-FDPC-56	000000003320490	2008	-	-	-	Mixed humid	0 - None
NY-FDPC-57	000000003340240	2008	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-58	000000003370490	2008	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-59	000000003346800	2008	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-60	000000003365200	2008	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-61	000000003346730	2007	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-62	000000003347220	2007	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-63	000000003224180	2007	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-64	000000003302020	2006	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-65	000000003346490	2006	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-66	000000003322480	2006	-	-	-	Mixed humid	9 - Other
NY-FDPC-67	000000003347310	2006	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-68	000000003322620	2006	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-69	000000003325050	2005	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-70	000000003314190	2004	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-71	000000003210030	2004	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-72	000000003321460	2004	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-73	000000003306030	2003	-	-	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-74	000000003322330	2002	-	-	-	Mixed humid	3 - Latex Concrete or similar additive
NY-FDPC-75	000000003322700	2002	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-76	000000003322270	2001	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-77	000000003324850	2001	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-78	000000003320710	2001	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-79	000000003362630	2001	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-80	000000003322630	2001	-	-	-	Mixed humid	9 - Other
NY-FDPC-81	000000003347190	2000	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-82	000000003323210	2000	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-83	000000001044659	1999	Long. PT - C1.a	CC - C1.i	-	Mixed humid	2 - Integral Concrete

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
NY-FDPC-84	000000001044579	1999	Long. PT - C1.a	CC - C1.i	-	Mixed humid	2 - Integral Concrete
NY-FDPC-85	000000003321050	1998	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-86	000000003322360	1998	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-87	000000003321630	1997	-	-	-	Mixed humid	9 - Other
NY-FDPC-88	000000003323270	1997	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-89	000000003322460	1997	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-90	000000002224840	1996	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-91	000000003321980	1996	-	-	-	Mixed humid	9 - Other
NY-FDPC-92	000000003322690	1995	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-93	000000003321570	1995	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-94	000000003346500	1995	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-95	000000003321470	1994	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-96	000000003320560	1994	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-97	000000003322640	1994	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-98	000000003322650	1993	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-99	000000003323520	1993	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-100	000000003325750	1993	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-101	000000003322440	1993	-	-	-	Mixed humid	9 - Other
NY-FDPC-102	000000003325590	1993	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-103	000000003318230	1993	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-104	000000001041800	1993	Non-PT - C1.a	Non-PT - C1.a	-	Mixed humid	6 - Bituminous
NY-FDPC-105	000000003321260	1992	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-106	000000003324160	1991	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-107	000000003324260	1990	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-108	000000003324130	1989	-	-	-	Mixed humid	9 - Other
NY-FDPC-109	000000003323740	1989	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-110	000000002261050	1988	-	-	-	Mixed humid	2 - Integral Concrete
NY-FDPC-111	000000003323990	1988	-	-	-	Mixed humid	6 - Bituminous

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
NY-FDPC-112	000000003314040	1988	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-113	000000001046020	1987	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-114	000000003325600	1987	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-115	000000003314270	1986	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-116	000000003209810	1985	-	-	-	Mixed humid	1 - Monolithic Concrete
NY-FDPC-117	000000003339310	1984	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-118	000000002212730	1981	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-119	000000002212500	1980	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-120	000000002212370	1978	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-121	000000001007350	1975	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-122	000000003210160	1972	-	-	-	Mixed humid	9 - Other
NY-FDPC-123	000000003321240	1970	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-124	000000003325920	1964	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-125	000000003324560	1957	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-126	000000003323930	1956	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-127	000000003346610	2009	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-128	000000003325770	1959	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-129	000000003314420	1949	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-130	000000003324310	1942	-	-	-	Mixed humid	9 - Other
NY-FDPC-131	000000003325360	1940	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-132	000000003324620	1989	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-133	000000003326120	1927	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-134	000000003314260	1984	-	-	-	Mixed humid	6 - Bituminous
NY-FDPC-135	000000001017580	2009	UHPC - C1.g	UHPC - C1.g	Tier 5	Mixed humid	1 - Monolithic Concrete
NY-FDPC-136	000000001079731	0	CC - C1.h	CC - C1.h	Tier 1	-	-
OR-FDPC-1	21252 449 00275	2012	UHPC - C1.f	None	Tier 6	Cold	1 - Monolithic Concrete
OR-FDPC-2	22057 047 01628	2014	Long. PT - C1.a	CC - C1.h	Tier 4	Cold	1 - Monolithic Concrete
OR-FDPC-3	21567 018 05598	2015	Long. PT - C1.a	None	Tier 3	Cold	6 - Bituminous

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
OR-FDPC-4	21568 018 05623	2015	Long. PT - C1.a	None	Tier 4	Cold	6 - Bituminous
OR-FDPC-5	22339 047 06338	2016	UHPC - C1.f	UHPC - C1.f	Tier 4	Cold	-
PA-FDPC-1	48393	2013	Long. PT - C1.a	UHPC - C1.g	Tier 4	Cold	5 - Epoxy Overlay
RI-FDPC-1	02780	2012	-	-	-	Cold	6 - Bituminous
RI-FDPC-2	05500	2013	Long. PT - C1.a	Non-PT - C1.a	Tier 6	Cold	6 - Bituminous
TN-FDPC-1	80SR0240017	2010	Grouted Dowel - C1.c	CC - C1.h	Tier 3	Mixed humid	6 - Bituminous
TN-FDPC-2	83SR0250013	2016	CC - C1.h	CC - C1.h	Tier 1	Mixed humid	6 - Bituminous
TN-FDPC-3	19I00240115	2012	Grouted Dowel - C1.c	CC - C1.h	Tier 1	Mixed humid	1 - Monolithic Concrete
TN-FDPC-4	19I00240113	2012	Grouted Dowel - C1.c	CC - C1.h	Tier 1	Mixed humid	1 - Monolithic Concrete
TN-FDPC-5	19I00240109	2012	CC - C1.h	CC - C1.h	Tier 1	Mixed humid	1 - Monolithic Concrete
TN-FDPC-6	19I00240111	2012	CC - C1.h	CC - C1.h	Tier 1	Mixed humid	1 - Monolithic Concrete
TN-FDPC-7	19I00400065	2015	Grouted Dowel - C1.c	CC - C1.h	Tier 1	Mixed humid	6 - Bituminous
TN-FDPC-8	19I00400337	2015	Grouted Dowel - C1.c	CC - C1.h	Tier 1	Mixed humid	6 - Bituminous
TN-FDPC-9	19I00400335	2015	Grouted Dowel - C1.c	CC - C1.h	Tier 1	Mixed humid	6 - Bituminous
TN-FDPC-10	75SR0010005	2017	CC - C1.h	CC - C1.h	Tier 1	Mixed humid	6 - Bituminous
TX-FDPC-1	070530014008130	2008	Grouted Dowel - C1.c	None	Tier 6	Hot humid	6 - Bituminous
UT-FDPC-1	0C 401	2017	Long. PT - C1.a	None	-	Cold	6 - Bituminous
UT-FDPC-2	0C 437	2004	-	CC - C1.i	-	Cold	5 - Epoxy Overlay
UT-FDPC-3	2C 457	2013	Long. PT - C1.a	None	-	Cold	5 - Epoxy Overlay
UT-FDPC-4	1C 470	2011	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-5	3C 470	2011	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-6	2C 476	2009	Welded - C1-b	None	-	Cold	5 - Epoxy Overlay
UT-FDPC-7	4C 476	2009	Welded - C1-b	None	-	Cold	6 - Bituminous
UT-FDPC-8	2C 477	2008	Welded - C1-b	None	-	Cold	5 - Epoxy Overlay
UT-FDPC-9	2C 495	2010	Long. PT - C1.a	None	Tier 5	Cold	5 - Epoxy Overlay
UT-FDPC-10	0C 518	2004	Long. PT - C1.a	CC - C1.i	-	Cold	5 - Epoxy Overlay
UT-FDPC-11	0C 578	2008	Long. PT - C1.a	CC - C1.i	-	Cold	6 - Bituminous
UT-FDPC-12	0C 588	2008	Long. PT - C1.a	CC - C1.i	-	Cold	6 - Bituminous

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
UT-FDPC-13	0C 596	2007	Welded - C1-b	CC - C1.i	-	Cold	6 - Bituminous
UT-FDPC-14	0C 679	2014	UHPC - C1.f	UHPC - C1.f	-	Cold	5 - Epoxy Overlay
UT-FDPC-15	0C 966	2009	Long. PT - C1.a	CC - C1.h	Tier 1	Cold	5 - Epoxy Overlay
UT-FDPC-16	0C 971	2010	Long. PT - C1.a	CC - C1.i	-	Cold	5 - Epoxy Overlay
UT-FDPC-17	2F 94	2008	Welded - C1-b	None	-	Cold	-
UT-FDPC-18	2F 114	2011	-	None	Tier 4	Cold	6 - Bituminous
UT-FDPC-19	4F-114	2011	-	None	-	Cold	6 - Bituminous
UT-FDPC-20	1F 127	2010	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-21	3F 127	2010	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-22	1F 128	2011	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-23	3F 128	2011	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-24	1F 129	2011	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-25	3F 129	2011	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-26	1F 130	2010	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-27	3F 130	2010	Long. PT - C1.a	Grouted Dowel - C1.c	-	Cold	5 - Epoxy Overlay
UT-FDPC-28	2F 183	2007	Welded - C1-b	CC - C1.i	-	Cold	6 - Bituminous
UT-FDPC-29	4F 183	2007	Welded - C1-b	CC - C1.i	-	Cold	6 - Bituminous
UT-FDPC-30	0F 400	2011	Long. PT - C1.a	CC - C1.i	-	Cold	5 - Epoxy Overlay
UT-FDPC-31	0F 741	2009	CC - C1.h	CC - C1.h	-	Cold	6 - Bituminous
UT-FDPC-32	0F 755	2010	Welded - C1-b	CC - C1.i	-	Cold	5 - Epoxy Overlay
UT-FDPC-33	2F 759	2010	Welded - C1-b	None	-	Cold	5 - Epoxy Overlay
UT-FDPC-34	4F 759	2010	Welded - C1-b	None	-	Cold	5 - Epoxy Overlay
UT-FDPC-35	0F 762	2009	Long. PT - C1.a	CC - C1.i	-	Cold	5 - Epoxy Overlay
UT-FDPC-36	0F 770B	2010	Long. PT - C1.a	CC - C1.i	-	Cold	6 - Bituminous
UT-FDPC-37	3F 784	2010	Long. PT - C1.a	CC - C1.i	-	Cold	5 - Epoxy Overlay
WA-FDPC-1	0003760A0000000	2004	Non-PT - C1.a	Non-PT - C1.a	Tier 2	Cold	5 - Epoxy Overlay
WI-FDPC-1	B13016100000000	2005	Long. PT - C1.a	Trans. PT - C1.a	Tier 5	Cold	1 - Monolithic Concrete
WY-FDPC-1	MMB	2015	Long. PT - C1.a	CC - C1.i	Tier 5	Cold	5 - Epoxy Overlay

Label	NBI	Year of Deck	Trans. Joint Type	Long. Joint Type	Impact Category	Climate Zone	Wearing Surface
VT-FDPC-1	200013009914102	2016	Long. PT - C1.a	None	Tier 3	Cold	6 - Bituminous
VT-FDPC-2	200037006812072	1936	Long. PT - C1.a	CC - C1.h	Tier 5	Cold	6 - Bituminous
VA-FDPC-1	3300001P0000000	1998	Long. PT - C1.a	None	Tier 2	Mixed humid	3 - Latex Concrete or similar additive
VA-FDPC-2	3300002P0000000	1998	Long. PT - C1.a	None	Tier 2	Mixed humid	3 - Latex Concrete or similar additive

APPENDIX C: COMPARISON PROJECTS

The NBI numbers for the 280 FDPC deck panel bridges and their CIP comparison projects are shown in Table C.1.

Table C.1: List of FDPC deck panel projects in the FDPC Deck Panel Database and selected CIP comparison projects

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
Alaska	AL-FDPC-1	2125	AL-CIP-1	2292
Alaska	AL-FDPC-2	1298	AL-CIP-2	1531
Alaska	AL-FDPC-3	1308	AL-CIP-3	1951
Alaska	AL-FDPC-4	0183	AL-CIP-4	1794
Alaska	AL-FDPC-5	0184	AL-CIP-5	1794
Alaska	AL-FDPC-6	0185	AL-CIP-6	1794
Alaska	AL-FDPC-7	0255	AL-CIP-7	1147
Alaska	AL-FDPC-8	0446	AL-CIP-8	2094
Alaska	AL-FDPC-9	0556	AL-CIP-9	0643
Alaska	AL-FDPC-10	0797	AL-CIP-10	1080
Alaska	AL-FDPC-11	1185	AL-CIP-11	1708
Alaska	AL-FDPC-12	1255	AL-CIP-12	1455
Alaska	AL-FDPC-13	1256	AL-CIP-13	1455
Alaska	AL-FDPC-14	1257	AL-CIP-14	1455
Alaska	AL-FDPC-15	1258	AL-CIP-15	1455
Alaska	AL-FDPC-16	1259	AL-CIP-16	1455
Alaska	AL-FDPC-17	1260	AL-CIP-17	1455
Alaska	AL-FDPC-18	1261	AL-CIP-18	1455
Alaska	AL-FDPC-19	1282	AL-CIP-19	1455
Alaska	AL-FDPC-20	1283	AL-CIP-20	1455
Alaska	AL-FDPC-21	1284	AL-CIP-21	1455
Alaska	AL-FDPC-22	1304	AL-CIP-22	-
Alaska	AL-FDPC-23	1332	AL-CIP-23	AFAKFTQW08004
Alaska	AL-FDPC-24	1334	AL-CIP-24	1455
Alaska	AL-FDPC-25	1335	AL-CIP-25	1455
Alaska	AL-FDPC-26	1336	AL-CIP-26	1455
Alaska	AL-FDPC-27	1337	AL-CIP-27	1455
Alaska	AL-FDPC-28	1338	AL-CIP-28	1455
Alaska	AL-FDPC-29	1423	AL-CIP-29	1808
Alaska	AL-FDPC-30	1435	AL-CIP-30	2238
Alaska	AL-FDPC-31	1436	AL-CIP-31	00000000000P651
Alaska	AL-FDPC-32	1437	AL-CIP-32	00000000000P651
Alaska	AL-FDPC-33	1820	AL-CIP-33	1873
Alaska	AL-FDPC-34	1821	AL-CIP-34	2227

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
Alaska	AL-FDPC-35	1836	AL-CIP-35	1531
Alaska	AL-FDPC-36	1841	AL-CIP-36	1409
Alaska	AL-FDPC-37	2135	AL-CIP-37	1389
Alaska	AL-FDPC-38	2206	AL-CIP-38	1504
Alaska	AL-FDPC-39	2207	AL-CIP-39	1504
Alaska	AL-FDPC-40	2226	AL-CIP-40	1504
California	CA-FDPC-1	32 0018	CA-CIP-1	57C0671
Colorado	CO-FDPC-1	F-16-XB	CO-CIP-1	K-16-AL
Connecticut	CT-FDPC-1	03200	CT-CIP-1	06221
Connecticut	CT-FDPC-2	00587	CT-CIP-2	05925
Connecticut	CT-FDPC-3	00255	CT-CIP-3	-
Connecticut	CT-FDPC-4	03819	CT-CIP-4	-
Connecticut	CT-FDPC-5	00524	CT-CIP-5	-
Delaware	DE-FDPC-1	1717 056	DE-CIP-1	-
Delaware	DE-FDPC-2	1680 006	DE-CIP-2	-
Delaware	DE-FDPC-3	1251 355	DE-CIP-3	1830 024
Florida	FL-FDPC-1	500151	FL-CIP-1	-
Florida	FL-FDPC-2	500152	FL-CIP-2	-
Florida	FL-FDPC-3	500153	FL-CIP-3	-
Florida	FL-FDPC-4	500154	FL-CIP-4	-
Georgia	GA-FDPC-1	000000001350580	GA-CIP-1	-
Illinois	IL-FDPC-1	084004000000000	IL-CIP-1	086050000000000
Iowa	IA-FDPC-1	044691	IA-CIP-1	000000000121681
Iowa	IA-FDPC-2	78171	IA-CIP-2	000000000242181
Louisiana	LA-FDPC-1	072700140209041	LA-CIP-1	-
Massachusetts	MA-FDPC-1	C1300812HDOTNBI	MA-CIP-1	L15072B55DOTNBI
Massachusetts	MA-FDPC-2	H21039BBMDOTNBI	MA-CIP-2	W280215X1DOTNBI
Massachusetts	MA-FDPC-3	A07016-BAU-DOT-NBI	MA-CIP-3	-
Massachusetts	MA-FDPC-4	T01015-BHK-DOT-NBI	MA-CIP-4	-
Massachusetts	MA-FDPC-5	S350183U8DOTNBI	MA-CIP-5	-
Massachusetts	MA-FDPC-6	S350183U9DOTNBI	MA-CIP-6	-
Michigan	MI-FDPC-1	4558	MI-CIP-1	000000000007204
Minnesota	MN-FDPC-1	69071	MN-CIP-1	55060
Minnesota	MN-FDPC-2	2441	MN-CIP-2	-
Mississippi	MS-FDPC-1	210008207600010	MS-CIP-1	-
Missouri	MO-FDPC-1	649	MO-CIP-1	30350
Missouri	MO-FDPC-2	4089	MO-CIP-2	2958
Missouri	MO-FDPC-3	33066	MO-CIP-3	32854
Missouri	MO-FDPC-4	33066	MO-CIP-4	32854

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
Missouri	MO-FDPC-5	33066	MO-CIP-5	32854
Missouri	MO-FDPC-6	33066	MO-CIP-6	32854
Nebraska	NE-FDPC-1	S010 05463R	NE-CIP-1	-
Nebraska	NE-FDPC-2	C000614205	NE-CIP-2	U1825A1005
Nebraska	NE-FDPC-3	SL28B00216	NE-CIP-3	S022 03466
New Hampshire	NH-FDPC-1	005201630010600	NH-CIP-1	12301300016500
New Jersey	NJ-FDPC-1		NJ-CIP-1	-
New Mexico	NM-FDPC-1	9610	NM-CIP-1	-
New Mexico	NM-FDPC-2	9611	NM-CIP-2	-
New York	NY-FDPC-1	00000000552305B	NY-CIP-1	-
New York	NY-FDPC-2	000000005523052	NY-CIP-2	-
New York	NY-FDPC-3	00000000552305C	NY-CIP-3	-
New York	NY-FDPC-4	000000001035460	NY-CIP-4	-
New York	NY-FDPC-5	000000003045230	NY-CIP-5	-
New York	NY-FDPC-6	000000002270010	NY-CIP-6	-
New York	NY-FDPC-7	000000001035450	NY-CIP-7	-
New York	NY-FDPC-8	000000001035470	NY-CIP-8	-
New York	NY-FDPC-9	000000001079700	NY-CIP-9	-
New York	NY-FDPC-10	000000003320920	NY-CIP-10	-
New York	NY-FDPC-11	000000003321940	NY-CIP-11	-
New York	NY-FDPC-12	000000003025100	NY-CIP-12	-
New York	NY-FDPC-13	000000001092839	NY-CIP-13	-
New York	NY-FDPC-14	000000001092441	NY-CIP-14	-
New York	NY-FDPC-15	000000001092442	NY-CIP-15	-
New York	NY-FDPC-16	000000001092422	NY-CIP-16	-
New York	NY-FDPC-17	000000001092421	NY-CIP-17	-
New York	NY-FDPC-18	00000000109283B	NY-CIP-18	-
New York	NY-FDPC-19	000000002205540	NY-CIP-19	-
New York	NY-FDPC-20	000000001033142	NY-CIP-20	-
New York	NY-FDPC-21	000000001033141	NY-CIP-21	-
New York	NY-FDPC-22	000000003346880	NY-CIP-22	-
New York	NY-FDPC-23	000000003322080	NY-CIP-23	3339920
New York	NY-FDPC-24	000000002224830	NY-CIP-24	2201530
New York	NY-FDPC-25	000000003358710	NY-CIP-25	1092761
New York	NY-FDPC-26	000000003347030	NY-CIP-26	3324550
New York	NY-FDPC-27	000000003347100	NY-CIP-27	3302250
New York	NY-FDPC-28	000000003321120	NY-CIP-28	3308160
New York	NY-FDPC-29	000000001093672	NY-CIP-29	1018840
New York	NY-FDPC-30	000000001031559	NY-CIP-30	5514182

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
New York	NY-FDPC-31	000000001031529	NY-CIP-31	5053372
New York	NY-FDPC-32	000000005500019	NY-CIP-32	2229410
New York	NY-FDPC-33	000000001047689	NY-CIP-33	1010920
New York	NY-FDPC-34	000000001009290	NY-CIP-34	2016360
New York	NY-FDPC-35	000000001024090	NY-CIP-35	1005911
New York	NY-FDPC-36	000000001007780	NY-CIP-36	3304990
New York	NY-FDPC-37	000000003370870	NY-CIP-37	1034580
New York	NY-FDPC-38	000000003321830	NY-CIP-38	3332440
New York	NY-FDPC-39	000000001021850	NY-CIP-39	1044170
New York	NY-FDPC-40	000000001051091	NY-CIP-40	5053371
New York	NY-FDPC-41	000000001051092	NY-CIP-41	5510690
New York	NY-FDPC-42	000000001051159	NY-CIP-42	2231499
New York	NY-FDPC-43	000000001054720	NY-CIP-43	3362500
New York	NY-FDPC-44	000000001025200	NY-CIP-44	3318540
New York	NY-FDPC-45	000000001025190	NY-CIP-45	2269760
New York	NY-FDPC-46	000000001050430	NY-CIP-46	1022370
New York	NY-FDPC-47	000000003347680	NY-CIP-47	2224510
New York	NY-FDPC-48	000000003025090	NY-CIP-48	1094730
New York	NY-FDPC-49	000000003347140	NY-CIP-49	3305380
New York	NY-FDPC-50	000000001058509	NY-CIP-50	1033822
New York	NY-FDPC-51	000000005521180	NY-CIP-51	1041200
New York	NY-FDPC-52	000000003302930	NY-CIP-52	3344340
New York	NY-FDPC-53	000000003346680	NY-CIP-53	3320750
New York	NY-FDPC-54	000000003371380	NY-CIP-54	-
New York	NY-FDPC-55	000000003321270	NY-CIP-55	3370720
New York	NY-FDPC-56	000000003320490	NY-CIP-56	3340970
New York	NY-FDPC-57	000000003340240	NY-CIP-57	3356150
New York	NY-FDPC-58	000000003370490	NY-CIP-58	3365840
New York	NY-FDPC-59	000000003346800	NY-CIP-59	3221060
New York	NY-FDPC-60	000000003365200	NY-CIP-60	4418070
New York	NY-FDPC-61	000000003346730	NY-CIP-61	3371150
New York	NY-FDPC-62	000000003347220	NY-CIP-62	3352430
New York	NY-FDPC-63	000000003224180	NY-CIP-63	2226820
New York	NY-FDPC-64	000000003302020	NY-CIP-64	2226810
New York	NY-FDPC-65	000000003346490	NY-CIP-65	3025130
New York	NY-FDPC-66	000000003322480	NY-CIP-66	3369500
New York	NY-FDPC-67	000000003347310	NY-CIP-67	3309890
New York	NY-FDPC-68	000000003322620	NY-CIP-68	3312280
New York	NY-FDPC-69	000000003325050	NY-CIP-69	3302970

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
New York	NY-FDPC-70	000000003314190	NY-CIP-70	1029080
New York	NY-FDPC-71	000000003210030	NY-CIP-71	3221620
New York	NY-FDPC-72	000000003321460	NY-CIP-72	2214860
New York	NY-FDPC-73	000000003306030	NY-CIP-73	3341070
New York	NY-FDPC-74	000000003322330	NY-CIP-74	3367380
New York	NY-FDPC-75	000000003322700	NY-CIP-75	1077960
New York	NY-FDPC-76	000000003322270	NY-CIP-76	3347050
New York	NY-FDPC-77	000000003324850	NY-CIP-77	3346360
New York	NY-FDPC-78	000000003320710	NY-CIP-78	3346400
New York	NY-FDPC-79	000000003362630	NY-CIP-79	3347010
New York	NY-FDPC-80	000000003322630	NY-CIP-80	3338710
New York	NY-FDPC-81	000000003347190	NY-CIP-81	3352290
New York	NY-FDPC-82	000000003323210	NY-CIP-82	3353610
New York	NY-FDPC-83	000000001044659	NY-CIP-83	2266630
New York	NY-FDPC-84	000000001044579	NY-CIP-84	2230720
New York	NY-FDPC-85	000000003321050	NY-CIP-85	3302300
New York	NY-FDPC-86	000000003322360	NY-CIP-86	3314340
New York	NY-FDPC-87	000000003321630	NY-CIP-87	3351310
New York	NY-FDPC-88	000000003323270	NY-CIP-88	3335760
New York	NY-FDPC-89	000000003322460	NY-CIP-89	2227310
New York	NY-FDPC-90	000000002224840	NY-CIP-90	3305720
New York	NY-FDPC-91	000000003321980	NY-CIP-91	3351750
New York	NY-FDPC-92	000000003322690	NY-CIP-92	3355260
New York	NY-FDPC-93	000000003321570	NY-CIP-93	3353490
New York	NY-FDPC-94	000000003346500	NY-CIP-94	2270080
New York	NY-FDPC-95	000000003321470	NY-CIP-95	3367430
New York	NY-FDPC-96	000000003320560	NY-CIP-96	3352530
New York	NY-FDPC-97	000000003322640	NY-CIP-97	5524340
New York	NY-FDPC-98	000000003322650	NY-CIP-98	3339320
New York	NY-FDPC-99	000000003323520	NY-CIP-99	2208450
New York	NY-FDPC-100	000000003325750	NY-CIP-100	1039100
New York	NY-FDPC-101	000000003322440	NY-CIP-101	3331820
New York	NY-FDPC-102	000000003325590	NY-CIP-102	3301740
New York	NY-FDPC-103	000000003318230	NY-CIP-103	1003070
New York	NY-FDPC-104	000000001041800	NY-CIP-104	4038470
New York	NY-FDPC-105	000000003321260	NY-CIP-105	5524090
New York	NY-FDPC-106	000000003324160	NY-CIP-106	3331200
New York	NY-FDPC-107	000000003324260	NY-CIP-107	2220560
New York	NY-FDPC-108	000000003324130	NY-CIP-108	5523550

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
New York	NY-FDPC-109	000000003323740	NY-CIP-109	3318450
New York	NY-FDPC-110	000000002261050	NY-CIP-110	1073630
New York	NY-FDPC-111	000000003323990	NY-CIP-111	3354390
New York	NY-FDPC-112	000000003314040	NY-CIP-112	3302170
New York	NY-FDPC-113	000000001046020	NY-CIP-113	3325310
New York	NY-FDPC-114	000000003325600	NY-CIP-114	6064870
New York	NY-FDPC-115	000000003314270	NY-CIP-115	3363580
New York	NY-FDPC-116	000000003209810	NY-CIP-116	3325390
New York	NY-FDPC-117	000000003339310	NY-CIP-117	3322260
New York	NY-FDPC-118	000000002212730	NY-CIP-118	1071050
New York	NY-FDPC-119	000000002212500	NY-CIP-119	2217920
New York	NY-FDPC-120	000000002212370	NY-CIP-120	1023460
New York	NY-FDPC-121	000000001007350	NY-CIP-121	-
New York	NY-FDPC-122	000000003210160	NY-CIP-122	3025110
New York	NY-FDPC-123	000000003321240	NY-CIP-123	3347420
New York	NY-FDPC-124	000000003325920	NY-CIP-124	3344520
New York	NY-FDPC-125	000000003324560	NY-CIP-125	3352490
New York	NY-FDPC-126	000000003323930	NY-CIP-126	5513410
New York	NY-FDPC-127	000000003346610	NY-CIP-127	1044719
New York	NY-FDPC-128	000000003325770	NY-CIP-128	3357600
New York	NY-FDPC-129	000000003314420	NY-CIP-129	3336850
New York	NY-FDPC-130	000000003324310	NY-CIP-130	3306560
New York	NY-FDPC-131	000000003325360	NY-CIP-131	3336510
New York	NY-FDPC-132	000000003324620	NY-CIP-132	3334540
New York	NY-FDPC-133	000000003326120	NY-CIP-133	3327500
New York	NY-FDPC-134	000000003314260	NY-CIP-134	2255440
New York	NY-FDPC-135	000000001017580	NY-CIP-135	000000001000960
New York	NY-FDPC-136	000000001079731	NY-CIP-136	-
Oregon	OR-FDPC-1	21252 449 00275	OR-CIP-1	20871 028 05994
Oregon	OR-FDPC-2	22057 047 01628	OR-CIP-2	21160 074Y00008
Oregon	OR-FDPC-3	21567 018 05598	OR-CIP-3	21160 074Y00008
Oregon	OR-FDPC-4	21568 018 05623	OR-CIP-4	21937 000 00000
Oregon	OR-FDPC-5	22339 047 06338	OR-CIP-5	-
Pennsylvania	PA-FDPC-1	48393	PA-CIP-1	000000000048386
Rhode Island	RI-FDPC-1	02780	RI-CIP-1	-
Rhode Island	RI-FDPC-2	05500	RI-CIP-2	-
Tennessee	TN-FDPC-1	80SR0240017	TN-CIP-1	43018140013
Tennessee	TN-FDPC-2	83SR0250013	TN-CIP-2	-
Tennessee	TN-FDPC-3	19I00240115	TN-CIP-3	94S61830011

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
Tennessee	TN-FDPC-4	19I00240113	TN-CIP-4	430A2700001
Tennessee	TN-FDPC-5	19I00240109	TN-CIP-5	95SR1090017
Tennessee	TN-FDPC-6	19I00240111	TN-CIP-6	16SR0020011
Tennessee	TN-FDPC-7	19I00400065	TN-CIP-7	-
Tennessee	TN-FDPC-8	19I00400337	TN-CIP-8	-
Tennessee	TN-FDPC-9	19I00400335	TN-CIP-9	-
Tennessee	TN-FDPC-10	75SR0010005	TN-CIP-10	-
Texas	TX-FDPC-1	070530014008130	TX-CIP-1	131430126701002
Utah	UT-FDPC-1	0C 401	UT-CIP-1	0C 191R
Utah	UT-FDPC-2	0C 437	UT-CIP-2	0C 916
Utah	UT-FDPC-3	2C 457	UT-CIP-3	0C 988
Utah	UT-FDPC-4	1C 470	UT-CIP-4	2C 997
Utah	UT-FDPC-5	3C 470	UT-CIP-5	0C 986
Utah	UT-FDPC-6	2C 476	UT-CIP-6	0C 980
Utah	UT-FDPC-7	4C 476	UT-CIP-7	2C 949
Utah	UT-FDPC-8	2C 477	UT-CIP-8	2C 949
Utah	UT-FDPC-9	2C 495	UT-CIP-9	4C 755
Utah	UT-FDPC-10	0C 518	UT-CIP-10	2C 876
Utah	UT-FDPC-11	0C 578	UT-CIP-11	2C 786
Utah	UT-FDPC-12	0C 588	UT-CIP-12	2C 786
Utah	UT-FDPC-13	0C 596	UT-CIP-13	2C 786
Utah	UT-FDPC-14	0C 679	UT-CIP-14	0C 986
Utah	UT-FDPC-15	0C 966	UT-CIP-15	4C1004
Utah	UT-FDPC-16	0C 971	UT-CIP-16	0C1015
Utah	UT-FDPC-17	2F 94	UT-CIP-17	2F 94
Utah	UT-FDPC-18	2F 114	UT-CIP-18	041025F
Utah	UT-FDPC-19	4F-114	UT-CIP-19	047065F
Utah	UT-FDPC-20	1F 127	UT-CIP-20	1F 836
Utah	UT-FDPC-21	3F 127	UT-CIP-21	3F 836
Utah	UT-FDPC-22	1F 128	UT-CIP-22	0F 783
Utah	UT-FDPC-23	3F 128	UT-CIP-23	2F 801
Utah	UT-FDPC-24	1F 129	UT-CIP-24	1F 836
Utah	UT-FDPC-25	3F 129	UT-CIP-25	3F 836
Utah	UT-FDPC-26	1F 130	UT-CIP-26	1F 836
Utah	UT-FDPC-27	3F 130	UT-CIP-27	3F 836
Utah	UT-FDPC-28	2F 183	UT-CIP-28	1F 435
Utah	UT-FDPC-29	4F 183	UT-CIP-29	3F 435
Utah	UT-FDPC-30	0F 400	UT-CIP-30	3F 834
Utah	UT-FDPC-31	0F 741	UT-CIP-31	1F 745

State	FDPC		CIP	
	Label	*NBI*	*Label*	*NBI*
Utah	UT-FDPC-32	0F 755	UT-CIP-32	3F 835
Utah	UT-FDPC-33	2F 759	UT-CIP-33	2F 792
Utah	UT-FDPC-34	4F 759	UT-CIP-34	4F 792
Utah	UT-FDPC-35	0F 762	UT-CIP-35	0F 733
Utah	UT-FDPC-36	0F 770B	UT-CIP-36	1F 752
Utah	UT-FDPC-37	3F 784	UT-CIP-37	3F 739
Washington	WA-FDPC-1	0003760A0000000	WA-CIP-1	0012800A0000000
Wisconsin	WI-FDPC-1	B13016100000000	WI-CIP-1	B13016000000000
Wyoming	WY-FDPC-1	MMB	WY-CIP-1	-
Vermont	VT-FDPC-1	200013009914102	VT-CIP-1	-
Vermont	VT-FDPC-2	200037006812072	VT-CIP-2	200171000402152
Virginia	VA-FDPC-1	3300001P0000000	VA-CIP-1	20273
Virginia	VA-FDPC-2	3300002P0000000	VA-CIP-2	534