Plastic Ducts in Prestressed Concrete

Requested by
Jim Cook, SC, PS Technical Team E, Division of Engineering Services

December 29, 2025

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List of Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ANSI	American National Standards Institute
BDM	Bridge Design Memorandum
Caltrans	California Department of Transportation
CDOT	Colorado Department of Transportation
DOT	department of transportation
EIT	electrically isolated tendon
EPDM	Ethylene Propylene Deine Monomer
FHWA	Federal Highway Administration
FIB	International Federation of Structural Concrete
GPR	ground-penetrating radar
HDPE	high-density polyethylene
IABSE	International Association for Bridge and Structural Engineering
MnDOT	Minnesota Department of Transportation
NCHRP	National Cooperative Highway Research Program
NDE	nondestructive evaluation
NMDOT	New Mexico Department of Transportation
PE	polyethylene
PennDOT	Pennsylvania DOT
PL	protection level
PT	post-tensioning
PTB	post-tensioned beams
PTI	Post-Tensioning Institute
TxDOT	Texas Department of Transportation
UPE	ultrasonic pulse echo
WSDOT	Washington State Department of Transportation

Executive Summary

Background

The typical post-tensioned bridge constructed by the California Department of Transportation (Caltrans) uses galvanized metal ducting. This practice meets the requirements of the 2024 edition of Caltrans' Standard Specifications, which indicates that ducts for prestressing steel must be galvanized rigid ferrous metall. However, design exceptions have permitted the use of plastic ducts in a few successful bridge projects.

Caltrans is investigating the potential of plastic as an alternative to the current specification for metal ducting in prestressed concrete. The agency's investigation will assess the viability of this alternative in reducing construction time, eliminating uncertainties associated with grouting and corrosion protection, and increasing the overall long-term quality of the structure.

To gather information that will aid Caltrans' investigation, CTC & Associates surveyed state departments of transportation (DOTs) about their experiences with plastic ducts in post-tensioned structures. A review of in-progress and completed research about plastic ducts in prestressed concrete supplemented survey findings.

Summary of Findings

Survey of Practice

An online survey distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures received responses from 16 representatives from 15 state transportation agencies:

- Five agencies use plastic ducts only.
- Three agencies use both metal and plastic ducts.
- Seven agencies use galvanized metal ducts only, but one agency is considering plastic ducts.

Respondents from three of these agencies reported that their agencies do not construct (or do not construct many) cast-in-place prestressed box girder or post-tensioned spliced precast girder bridges.

In addition, representatives from five state transportation agencies did not participate in the survey but communicated by email. Four of these agencies (Alaska DOT & Public Facilities, Arkansas DOT, South Carolina DOT and South Dakota DOT) do not use post-tensioned or other ducts in girders. Wisconsin DOT does not use cast-in-place prestressed box girder or post-tensioned spliced precast girder bridges to any significant extent, so did not have meaningful input to the survey.

In all, 20 state transportation agencies engaged with CTC regarding the survey. Table ES1 summarizes responding agency use of plastic and metal ducting. Following the table are highlights of details provided by survey respondents.

Table ES1. Use of Ducting in Post-Tensioned Bridge Construction

State	Plastic Ducts Only	Both Metal and Plastic Ducts	Galvanized Metal Ducts Only	Galvanized Metal But Considering Plastic Ducts	Other	Description
Alaska					X	Does not use post-tensioned or other ducts in girders.
Arizona			X			
Arkansas					X	Does not use post-tensioned or other ducts in girders.
Colorado		X				
Idaho			X			Constructs very few post-tensioned bridges.
Kansas			X			Does not use cast-in-place prestressed box girder or post-tensioned spliced precast girder bridges.
Minnesota	X					
Missouri			X			
New Hampshire			X			
New Mexico		X*				
Ohio	X					
Oklahoma		X				
Oregon 1			X			
Oregon 2				X		
Pennsylvania	X					
South Carolina					X	Does not use post-tensioning in its bridges. Has two trapezoidal box girder bridges that were built 30+ years ago.
South Dakota					X	Does not use post-tensioned or other ducts in girders.
Texas	X					
Virginia			X			Does not construct many post-tensioned bridges.
Washington	X					
Wisconsin					X	Does not use cast-in-place prestressed box girder or post-tensioned spliced precast girder bridges to any significant extent.
Total	**5**	**3**	**7**	**1**	**5**	

* Partial response.

Summarized below are survey findings in three topic areas.

- Plastic duct use only.
- Plastic and metal duct use.
- Metal duct use only.

Plastic Duct Use Only

Five state transportation agencies — Minnesota DOT (MnDOT), Ohio DOT, Pennsylvania DOT (PennDOT) Texas DOT (TxDOT) and Washington State DOT (WSDOT) — reported using plastic ducts only in both cast-in-place prestressed box girder bridge and post-tensioned spliced precast girder bridge construction.

Four of the five respondents assessed the factors that could contribute to the decision to use plastic ducts. Increased corrosion resistance of the prestress system received the highest rating, with all four agencies indicating it is extremely important. Following increased corrosion resistance in importance is installation process. Respondents' opinions diverged regarding dent and puncture resistance; cost is the least important factor among these agencies.

Bridge Design

Responding agencies provided limited information about design efficiencies and drawbacks that have been observed since implementing plastic ducting. In Minnesota, galvanized ducts were discontinued many years ago, so designs have changed for other reasons, making it difficult to isolate the impact of duct change alone. WSDOT's use of plastic duct is complaint with the Post-Tensioning Institute's (PTI's) relevant specification.

None of these five responding agencies have used both metal and plastic ducting in the same project. Some addressed whether using plastic ducting has impacted other bridge design practices, such as increasing laboratory testing requirements, increasing the stem width in box girder bridges, decreasing the amount of prestress strand needed and increasing the number of ducts per girder.

Plastic vs. Metal Ducting

Survey respondents briefly compared selected attributes of plastic and metal ducting to indicate their preference for ducting material in bridge construction. Four responding agencies indicated that plastic duct is easier to use than metal (WSDOT has no preference). and all five reported that plastic ducting is more durable than metal ducting. The Ohio DOT respondent added that the agency is able to achieve successful pressure tests with plastic duct systems. The MnDOT respondent indicated that plastic ducting damages easily. While none of the respondents indicated that it cracks easily, the PennDOT respondent reported cracking issues due to corrugated plastic tubing spacing with rebar.

Construction and Installation

The MnDOT and Ohio DOT respondents reported duct movement during concrete placement due to the characteristics of plastic over metal ducting. The MnDOT respondent added that location is important in relation to duct movement, so a ridged connection to rebar is needed. Ohio DOT has also experienced issues with slipping when using plastic ducting. Additional details about duct movement and slipping in Ohio were not provided. The WSDOT respondent noted that there have been no reported cases of significance regarding cracking, slipping and duct movement, and the agency's use of plastic ducting has not impacted its construction practices.

Cost Considerations

None of the responding agencies has conducted a cost comparison between metal ducting and plastic ducting. In addition, none of the agencies reported a cost savings resulting from the use of plastic ducting. The Ohio DOT respondent reiterated that the decision to use plastic ducting was made for pressure testing to ensure watertightness.

Benefits of Use

Contractors for MnDOT and TxDOT have reported advantages to using plastic ducting. MnDOT contractors find plastic ducting easier to place. The TxDOT respondent commented that plastic duct is lighter, easier to transport, less prone to corrosion and required by Protection Level 2 (PL-2), which is the minimum PL for all post-tensioned bridges in Texas.

Note: Tendon PLs are identified in specifications developed by PTI. Information about PTI's PL designations is provided in a callout on page 17 of this report.

Assessment

Increased corrosion protection (MnDOT), sealed splices (MnDOT) and successful air pressure tests (Ohio DOT) have been achieved by responding agencies after implementing plastic ducting. In Texas, all projects have used plastic ducts for some time, making it difficult to distinguish successes with using plastic ducting from common practice. Similarly, WSDOT has used plastic duct in cast-in-place concrete for several years, making it difficult to isolate its impacts at this point.

While the TxDOT respondent reported no significant drawbacks with plastic ducting, the MnDOT respondent noted that splicing was more difficult, and the PennDOT respondent reported that the agency has experienced cracking.

The MnDOT respondent explained that the agency's use of plastic duct for "many years" was for "corrosion reasons" and MnDOT "will never use galvanized duct again." Ohio DOT's use of shrink sleeves over fittings has produced best results. The PennDOT respondent cited rebar spacing around corrugate plastic tubing as a lesson learned. WSDOT practices are now fully compliant with PTI specifications, and the respondent recommends that other agencies follow PTI specifications as a best practice.

Plastic and Metal Duct Use

Three state DOTs — Colorado (CDOT), New Mexico (NMDOT) and Oklahoma DOT — use both metal and plastic ducts in cast-in-place prestressed box girder and post-tensioned spliced precast girder bridge construction (see Table ES1). The NMDOT respondent provided a partial response to the survey, only describing the agency's reasons for using plastic ducts. Oklahoma DOT has not done much post-tensioned construction in recent years and noted the need for more information to change this approach.

Bridge Design

CDOT and Oklahoma DOT differed on the bridge design implications of the use of plastic ducts:

- The CDOT respondent noted no change in design efficiency, and the need for thicker webs in precast U and I girder webs for plastic duct. CDOT has also not needed more ducts per girder due to increased wall thickness over metal duct.
- Oklahoma DOT has experienced an increase in laboratory testing requirements; CDOT has not.

- Stem width for box girder bridge designs has increased in Colorado but not in Oklahoma.
- Neither agency has experienced a decrease in the amount of prestressed strand needed to meet the design requirements due to change in duct friction.
- CDOT has not needed more ducts per girder due to increased wall thickness over metal duct.

Plastic vs. Metal Ducting

Both respondents reported that plastic ducting is more durable. The Oklahoma DOT respondent noted that plastic ducting is easier to use, and the CDOT respondent reported that metal ducting is easier to use, adding that couplings can be challenging in cold weather and require "extra security measures to make sure they stay put during concrete placement." The CDOT respondent noted that plastic duct can be "squished or ovaled" at duct supports where there are changes in profile.

Both respondents reported that plastic ducting does not crack easily, and neither agency has had issues with slipping. CDOT has experienced duct movement during concrete placement due to the characteristics of plastic over metal, adding that a duct "will float or get ovaled" if stepped on or concrete is placed directly onto the duct.

Friction coefficient is not a concern for CDOT when using plastic ducting, as long as it is accounted for in the design. Neither respondent noted issues with shear strength, thermal expansion or wear resistance. The CDOT respondent reported that void detection with plastic ducting is "easier than metal ducting." The CDOT respondent also reported constructability issues, noting that sealing metal duct at girder splices needs to be "done properly," and plastic duct requires more support to maintain its profile and "prevent wobble in the path." Plastic ducting has not impacted construction practices at either agency.

Cost Considerations

Neither agency has conducted a cost comparison between metal and plastic ducting, and neither can report a cost savings as a result of using plastic ducting.

Benefits of Use

Successes and benefits reported by the CDOT respondent include that it is pressure-rated and offers better corrosion protection. Drawbacks are increased web thickness and the need for more attention on-site to ensure the duct is properly supported and connected.

Assessment

The Oklahoma DOT respondent reported "too little experience" to provide best practices or lessons learned. The CDOT respondent suggested pressure testing before grouting and keeping the duct indoors before using. He added that it's not the duct size that will cause the most issues, but the coupler in thin webs.

Metal Duct Use Only

Seven responding agencies use only metal ducts (see Table ES1). One of these agencies — Oregon DOT — provided two responses to the survey. The second Oregon DOT respondent described the agency's consideration of the use of plastic duct:

> Oregon DOT hopes to complete specification changes in 2025 that will incorporate language from PTI M50.3-19, Specification for Multistrand and Grouted Post-Tensioning, and address the tendon PLs identified by PTI.

The agency plans to adopt PTI's PL-2, which requires the use of a plastic duct for post-tensioning tendons, as the state's default PL. Also under consideration is use of PL-1B for portions of the state and PL-3 for marine environments.

Related Research and Resources

Design and Installation

Though somewhat dated, design and installation manuals from Federal Highway Administration (FHWA) that address post-tensioned box girders and tendon installation and grouting provide perspective on the transition from metal to plastic ducts that began in the U.S. in the early 2000s. State DOT manuals address prestressed concrete structures (New York) and post-tensioned concrete bridges (Washington).

A sampling of international resources includes a 2024 conference paper that highlights the 50-year history of the use of plastic ducts in post-tensioning, describes the selection of tendon PLs, and addresses the design and detailing information available for structural engineers in International Federation of Structural Concrete (FIB) Bulletin 75, which is also cited in this report. Findings from an experimental study on the performance of two duct types in post-tensioned beams — galvanized steel and recycled waste plastic — are presented in an October 2023 journal article, and a 2022 investigation examines the bond behavior of mono-strand post tension systems with different duct types, sizes and embedment length.

Repair and Maintenance

The 2021 National Cooperative Highway Research Program (NCHRP) Synthesis 562 provides a brief history of the use of plastic duct for post-tensioning tendons and highlights duct issues requiring repair. The authors note that PTI had not, at the time of the NCHRP publication, offered repair recommendations to address duct issues encountered in bridge construction. A 2018 FHWA publication that evaluated 11 nondestructive evaluation (NDE) technologies that can be used to evaluate post-tensioning tendons addressed issues such as locating grout voids, locating strands within the ducts and evaluating corrosion of the strands. A 2016 NCHRP project report offered additional details of NDE methods.

Assessment and Evaluation

An August 2021 FHWA TechBrief examined the use of electrically isolated tendon technology to "permit post-grouting inspection of anchorages." A series of publications sponsored by TxDOT, though somewhat dated, offers perspective on agency efforts to evaluate the performance of post-tensioned structures by examining shear behavior, corrosion resistance and durability. Publications that take a broader view of post-tensioning practices include a 2024 journal article that offers details of PTI's PT system prequalification testing and certification program and three PTI manuals that describe certification program requirements.

Related resources include a webinar describing a risk assessment process for post-tensioned tendons that is illustrated using an example bridge; a 2022 FHWA TechBrief provided further details of this risk-based assessment. Finally, a *PTI Journal* article describes two nondestructive methods that allow for the detection of grouting defects within a duct that can lead to corrosion.

Gaps in Findings

While 20 agencies engaged with CTC regarding the survey, relatively few respondents reported on their agencies' experiences with the use of plastic ducts in post-tensioned structures. The literature search uncovered few state DOT manuals providing specifications for the use of plastic ducts, and the national guidance provided by a 2016 FHWA manual for post-tensioned box girder design is somewhat dated. Additional outreach to agencies not responding to the survey may also yield findings of interest to Caltrans.

Next Steps

Moving forward, Caltrans could consider:

- Reaching out to three responding agencies reporting a history of plastic duct use — MnDOT, TxDOT and WSDOT — to learn more about agency practices. **Note:** MnDOT reported limited experience with certain aspects of plastic duct use and has constructed only one spliced post-tensioned prestressed concrete bridge.
- Engaging with the Oregon DOT respondent, who described a specification change in process during 2025 that will include reference to PL-2, which requires the use of plastic duct, as the state's default PL.
- Connecting with respondents describing constructability issues associated with plastic duct to learn more about agency experiences and practices:
  - CDOT's experience with plastic duct being "squished or ovaled" at duct supports.
  - MnDOT's use of a ridged connection to rebar.
  - Ohio DOT's issues with slipping when using plastic ducting.
  - PennDOT's reporting of cracking issues due to corrugated plastic tubing spacing with rebar.
- Following up with a representative from PTI to gain additional perspective on how to specify plastic ducts as an alternative ducting option.

Detailed Findings

Background

The California Department of Transportation (Caltrans) typically uses galvanized metal ducting when constructing post-tensioned bridges. This practice is in compliance with the 2024 edition of Caltrans' Standard Specifications, which indicates that ducts for prestressing steel must be galvanized rigid ferrous metal (see Section 50-1.02D, Prestressing Concrete — Ducts). However, in a few successful bridge projects, the agency has made design exceptions permitting the use of plastic ducts.

To resolve construction issues associated with traditional cast-in-place prestressed box girder bridge construction, Caltrans is investigating the potential use of plastic as an alternative ducting option and seeking practices and research results from state transportation agencies that will inform the adoption of plastic ducting as an alternative to the current specification for metal ducting in prestressed concrete. This alternative will potentially reduce construction time, eliminate uncertainties associated with grouting and corrosion protection, and increase the overall long-term quality of the structure.

Below is a presentation of information gathered about these issues. The materials and experience discussed in this investigation were gathered through a survey of state departments of transportation (DOTs) and a review of in-progress and completed research.

Survey of Practice

An online survey distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures sought information about DOT use of plastic ducts in both cast-in-place prestressed box girder bridge and post-tensioned spliced precast girder bridge construction. Sixteen representatives from 15 state transportation agencies responded to the survey:

- Arizona DOT
- Colorado DOT (CDOT)
- Idaho Transportation Department
- Kansas DOT
- Minnesota DOT (MnDOT)
- Missouri DOT
- New Hampshire DOT
- New Mexico DOT (NMDOT)
- Ohio DOT
- Oklahoma DOT
- Oregon DOT (two responses)
- Pennsylvania DOT (PennDOT)
- Texas DOT (TxDOT)
- Washington State DOT (WSDOT)
- Virginia DOT

In addition, representatives from five state transportation agencies did not participate in the survey but communicated by email. Four of these agencies (Alaska DOT & Public Facilities, Arkansas DOT, South Carolina DOT and South Dakota DOT) do not use post-tensioned or other ducts in girders. The South Carolina DOT respondent added that the agency only has two trapezoidal box girder bridges in its inventory, which were built more than 30 years ago. Wisconsin DOT does not use cast-in-place prestressed box girder or post-tensioned spliced precast girder bridges to any significant extent, so did not have meaningful input to the survey.

In all, 20 state transportation agencies engaged with CTC regarding the survey.

Survey questions are provided in Appendix A. Survey results are summarized below in four categories:

- Plastic duct use only.
- Plastic and metal duct use.
- Metal duct use only.
- Considering use of plastic duct.

Plastic Duct Use Only

Five state DOTs — MnDOT, Ohio DOT, PennDOT, TxDOT and WSDOT— reported using plastic ducts only in both cast-in-place prestressed box girder bridge and post-tensioned spliced precast girder bridge construction. Survey respondents described their experience with plastic ducts in six categories:

- Reasons contributing to agency use.
- Bridge design.
- Construction and installation.
- Cost considerations.
- Benefits of use.
- Assessment.

Reasons Contributing to Agency Use

Four of the five state DOT representatives rated the importance of six factors that contributed to their agencies' decision to use plastic ducts in cast-in-place prestressed box girder bridge and post-tensioned spliced precast concrete bridge construction:

- Cost.
- Dent and puncture resistance.
- Increased corrosion resistance of prestress system.
- Installation process.
- Project-specific need.
- Reduced friction factor.

Respondents rated these factors on a scale of extremely important, very important, important, somewhat important, not at all important or not applicable. Increased corrosion resistance of the prestress system received the highest rating, with all four agencies indicating it is extremely important. Following increased corrosion resistance in importance is installation process; respondents' opinions diverged regarding dent and puncture resistance. Cost is the least important factor among these agencies, with PennDOT rating it as somewhat important and MnDOT and TxDOT rating it as not at all important. All of the responding agencies indicated that project-specific need is not applicable. Table 1 summarizes survey responses.

Table 1. Importance of Factors in Decision to Use Plastic Ducts (Plastic Duct Use Only)

State	Cost	Dent/Puncture Resistance	Increased Corrosion Resistance	Installation Process	Project-Specific Need	Reduced Friction Factor
Minnesota	Not at all important	Somewhat important	Extremely important	Very important	N/A	Important
Pennsylvania	Somewhat important	Not at all important	Extremely important	Very important	N/A	Important

State	Cost	Dent/Puncture Resistance	Increased Corrosion Resistance	Installation Process	Project-Specific Need	Reduced Friction Factor
Texas	Not at all important	Very important	Extremely important	Important	N/A	Somewhat important
Washington	Somewhat important	Very important	Extremely important	Important	Important	Somewhat important

N/A Not applicable.

Bridge Design

Responding agencies provided limited information about design efficiencies and drawbacks that have been observed since implementing plastic ducting. In terms of efficiencies, the TxDOT respondent noted that one project with concrete post-stressed I beams is acceptable. He added that plastic ducts were used for an adjacent box beam bridge transversely to tension the beams together. In this project, there was an issue with spacing around the plastic duct.

For WSDOT, agency practices comply with the relevant Post-Tensioning Institute (PTI) specification. In terms of design drawbacks, the slightly large outside diameter of plastic duct can require larger web sizes or create more congestion. In Minnesota, galvanized ducts were discontinued many years ago, so designs have changed for other reasons, making it difficult to isolate the impact of duct change alone.

Impact on Design

None of these five responding agencies have used both metal and plastic ducting in the same project. Similarly, none of them have taken any additional measures in their bridge designs to address excessive heat from a potential fire, especially at the high and low points of the duct path.

Some of the survey respondents discussed whether using plastic ducting has impacted other bridge design practices, such as increasing laboratory testing requirements, increasing the stem width in box girder bridges, decreasing the amount of prestress strand needed and increasing the number of ducts per girder.

Laboratory Testing Requirements

Only the Ohio DOT respondent noted that plastic ducting required more laboratory testing than metal ducting, pointing to the agency's specifications for plastic duct requirements. Ohio DOT's *Supplemental Specification 855: Post-Tensioning* describes the testing requirements for corrugated plastic duct on page 15 of the specification; discussion of the minimum bending radius begins on page 16. (See page 13 of this report for the citation for the Ohio DOT specification.)

TxDOT's specifications require that materials meet the requirements of PTI M50 and M55. While the TxDOT respondent did not provide further details of the PTI publications that guide agency practices, excerpts below from the 2024 PTI catalog describe the specifications and other guidance associated with PTI M50 and M55:

> **M50.3-19, Specification for Multistrand and Grouted Post-Tensioning**
> This updated specification provides minimum requirements for the post-tensioning system component testing and acceptance, design, and installation of multistrand and grouted post-tensioning systems.

M50.2-00, Anchorage Zone Design
This manual provides guidance on the comprehensive treatment of tendon anchorage zone requirements and analysis methods.

M50.1-98, Acceptance Standards for Post-Tensioning Systems
This publication provides specific technical requirements for the approval and acceptance of post-tensioning systems. Standards and performance requirements for prestressing materials, bearing plates, wedge plates, connections and sheathing are discussed in detail.

M55.1-19, Specification for Grouting of Post-Tensioned Structures
This updated specification provides minimum requirements for the selection, design, testing and installation of cementitious grouts.

Increased Stem Width in Box Girder Bridge Designs

None of these five survey respondents noted that using plastic ducting resulted in increasing the stem width for box girder bridge designs. MnDOT has only constructed one spliced post-tensioned prestressed concrete bridge project, which was built many years ago. TxDOT doesn't typically design post-tensioned box girder bridges.

Prestress Strand and Duct Friction

Ohio DOT indicated that using plastic duct decreased the amount of prestress strand needed to meet the design requirements due to change in duct friction. The respondent did not provide additional information about this increase. The TxDOT respondent noted that using plastic duct did not significantly decrease the amount of prestress strand needed, if at all. The WSDOT respondent noted that the effect of plastic duct on the amount of prestress stand needed is not clear and "may be true at the margins." However, this is not anticipated to be a significant issue.

Increase in Number of Ducts Per Girder

None of the responding agencies indicated that using plastic ducts resulted in the use of more ducts per girder due to increased wall thickness over metal duct, though the WSDOT respondent noted that the effect of plastic duct is not clear in this case. While it may be "true at the margins," it is not anticipated to have a significant impact on design. The TxDOT respondent added that using plastic duct did not significantly increase the number of ducts needed per girder, if at all.

Construction Specifications and Guidance

Ohio DOT, TxDOT and WSDOT have established specifications or other guidance for using plastic duct (see the citations below). The MnDOT respondent noted that guidance is typically provided in project-specific special provisions for materials not on the approved/qualified product lists or boilerplate special provisions.

Ohio

Supplemental Specification 855: Post-Tensioning, Ohio Department of Transportation, April 20, 2018.
https://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/855_04202018_for_2023.pdf
Below are selected excerpts from this supplemental specification that address the use of plastic ducts:

- Use only plastic duct, steel pipe or a combination of plastic duct and steel pipe as specified below.

- Use smooth plastic duct in all post-tensioning systems used for external tendons. Use corrugated plastic duct in all post-tensioning systems used for all internal tendons except where steel pipe is required.
- Steel pipe and plastic duct may be connected directly to each other when the outside diameters do not vary more than ± 0.08 inch. Use a reducer when the diameters of the steel pipe and the plastic duct are outside of this tolerance.
- Ensure that the duct system components and accessories meet the requirements of Chapter 4, Articles 4.1 through 4.1.8 of International Federation of Structural Concrete (FIB) Technical Report, Bulletin 7, titled "Corrugated Plastic Duct for Internal Bonded Post-Tensioning" as modified herein. [See **Updating Post-Tensioning FIB Bulletin 7** below for more information.]
- Use heat welding techniques to make splices between sections of plastic duct, in accordance with the duct manufacturer's instructions or make connections with electrofusion coupler or other mechanical couplers meeting the material requirements of this Supplemental Specification.
- Ensure all connections between steel pipe embedded in concrete and plastic duct are made by using a mechanical coupler or a circular sleeve made of Ethylene Propylene Deine Monomer (EPDM), having a minimum pressure rating (working pressure) of 100 psi.

Updating Post-Tensioning FIB Bulletin 7

FIB updated and amended its 2000 FIB Bulletin 7 with the 2014 FIB Bulletin 75, *Polymer-Duct Systems for Internal Bonded Post-Tensioning*. Below is the product abstract that describes the updated bulletin and what prompted it*:*

> The purpose of this recommendation — *fib* Bulletin 75: *Polymer-duct systems for internal bonded post-tensioning* — is to update and amend *fib* Bulletin 7: *Corrugated plastic ducts for internal bonded post-tensioning*, a technical report published in 2000.
>
> *fib* Bulletin 75 is meant as a cornerstone for the technical approval of polymer (plastic) ducts for internal bonded post-tensioning and possibly for the test procedures of a future testing standard.
>
> The updated bulletin includes new information on the design and detailing of concrete structures containing tendons with polymer ducts. The recommendation provides detailed test specifications for polymer materials, duct components and duct systems. In addition, the report contains recommendations for approval testing and attestations of conformity for polymer-duct systems.
>
> Although the new generation of corrugated polymer ducts for bonded post-tensioning have now been around for approximately twenty years, products still differ in material properties, geometrical detail, installation procedures and on-site use. Unlike corrugated steel ducts or smooth polyethylene (PE) pipes, they have not yet become standardized. It is the opinion of *fib* Task Group 9.16 and Commission 9 that these plastic ducts should, therefore, still be subjected to a systems approval process. This recommendation offers information acquired from twenty years of experience as well as new specifications that will, hopefully, lead to the standardization of polymer-duct systems.

Texas

Bridge Design Manual—LRFD, Bridge Division, Texas Department of Transportation, September 1, 2024.
https://www.txdot.gov/content/dam/txdotoms/brg/lrf/lrf.pdf
From Section 16: Spliced Precast Girders, which begins on page 3-38 of the manual, page 56 of the PDF:

> Provide post tension system in accordance with Item 426, "Post-Tensioning" of the Texas Department of Transportation Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, with the following exceptions:
>
> - Non-Severe Corrosive Environments:
>   - Galvanized or plastic duct can be used.
>   - Meet requirements for Protection Level 1B.
>   - Do not use tape-sealed connections.
> - Severe Corrosive Environments:
>   - Use plastic duct only.
>   - Meet requirements for Protection Level 2.
>
> All stressed tendons in the finished structure must be grouted. All permanent tendons that are stressed at the precast yard must be grouted prior to transport.

From page 3-44 of the manual, page 62 of the PDF:

> Reference Item 426 "Post Tensioning" in the General Notes for all post tensioning, grouting materials and construction. Note exceptions if Protection Level 1B is used in the design (galvanized duct allowed).

Related Resource:

> **Item 426, Post-Tensioning**, Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Texas Department of Transportation, September 2024.
> https://www.txdot.gov/content/dam/docs/specifications/2024/spec-book-0924.pdf
> This item begins on page 585 of the manual, page 595 of the PDF. *From the Materials section*:
>
> > **Post-Tensioning System**. Furnish a post-tensioning system following the minimum requirements for Protection Level 2 (PL-2), or higher protection level when shown on the plans, in accordance with PTI/ASBI M50. Prequalify post-tensioning systems using tests on complete tendons for compliance with the requirements of PTI/ASBI M50.
> >
> > The following exceptions apply.
> >
> > - The embedded parts of the anchorage are not required to be galvanized or epoxy coated, unless otherwise shown on the plans.
> > - Provide pre-packaged grouts in accordance with DMS-4670, "Grouts for Post-Tensioning." Do not use grouts that exceed the manufacturers' recommended shelf life or 6 mo. after date of manufacture, whichever is less.
> > - Provide unbonded single-strand tendons in accordance with PTI M10.2-00, Specification for Unbonded Single Strand Tendons.

Washington

2026 Standard Specifications for Road, Bridge and Municipal Construction, Washington State Department of Transportation, undated.
https://wsdot.wa.gov/publications/manuals/fulltext/M41-10/Division6.pdf
From page 6-131 of the manual, page 374 of the PDF:

> **6-02.3(26) Post-Tensioned Concrete**
> Multistrand post-tensioned structures and grouted post-tensioned structures shall conform to the requirements of PTI/ASBI M50.3-19 Specification for Multistrand and Grouted Post-Tensioning. Grouting for post-tensioning systems shall conform to the requirements of PTI M55.1-19 Specification for Grouting of Post-Tensioned Structures. Permanent unbonded single-strand post-tensioning shall conform to the requirements of PTI M10.2-17 Specification for Unbonded Single Strand Tendons. These specifications shall be collectively referred to as the "PTI requirements." Within the PTI requirements, the term "Construction Engineer" shall be taken as the Engineer.

Construction and Installation

In a comparison of material characteristics, survey respondents indicated their preference for using plastic or metal ducting in bridge construction and installation. Respondents also addressed selected issues with installation and field repair.

Plastic vs. Metal Ducting

Survey respondents briefly compared selected attributes of plastic and metal ducting to indicate their preference for ducting material in bridge construction. All five responding agencies indicated that plastic ducting is more durable than metal ducting. All but the WSDOT respondent indicated that plastic ducting is easier to use than metal ducting (WSDOT has no preference). The Ohio DOT respondent added that the agency is able to achieve successful pressure tests with plastic duct systems. The MnDOT respondent indicated that plastic ducting damages easily. While none of the respondents indicated that it cracks easily, the PennDOT respondent reported cracking issues due to corrugated plastic tubing spacing with rebar. Table 2 summarizes survey responses.

Table 2. Attributes of Plastic Ducting

State	Easier to Use	More Durable	Easily Damaged	Easily Cracked
Minnesota	X	X	X	
Ohio	X	X		
Pennsylvania	X	X		
Texas	X	X		
Washington		X		*

* WSDOT has received no reported cases of significance.

Duct Movement, Slipping and Repair

The MnDOT and Ohio DOT respondents reported duct movement during concrete placement due to the characteristics of plastic over metal ducting. The MnDOT respondent added that location is important in relation to duct movement, so a ridged connection to rebar is needed. Ohio DOT has also experienced issues with slipping when using plastic ducting. Additional details about duct movement and slipping in

Ohio were not provided. WSDOT has received no reported cases of significance regarding duct movement and slipping.

None of the agencies reported issues with performing field repairs on damaged ducting after it was placed in the structure. WSDOT has received no reported cases of significance regarding field repairs.

Additional Considerations

Three of the five survey respondents have had very little experience or issues with plastic ducting related to friction coefficient, shear strength or behavior in girders, thermal expansion, void detection and wear resistance. The PennDOT respondent reported no issues with any of these considerations, and the MnDOT respondent noted only limited experience. In Ohio, void detection is performed with bore hole cameras for both material types; issues with the remaining considerations are unknown. The TxDOT and WSDOT respondents did not address these survey questions.

Using plastic ducting has not impacted any of the responding agencies' construction practices.

Cost Considerations

None of the responding agencies has conducted a cost comparison between metal ducting and plastic ducting. In addition, none of the agencies reported a cost savings resulting from the use of plastic ducting. The Ohio DOT respondent reiterated that the decision to use plastic ducting was made for pressure testing to ensure watertightness.

Benefits of Use

Respondents also addressed additional benefits to using plastic ducting, including a reduction in greenhouse gas emissions or other environmental gains, and advantages to contractors.

None of the survey respondents reported a reduction in greenhouse gas emissions or other environmental gains.

Contractors for MnDOT and TxDOT have reported advantages to using plastic ducting. MnDOT contractors find plastic ducting easier to place. The TxDOT respondent noted that plastic duct is lighter, easier to transport, less prone to corrosion and required by Protection Level 2 (PL-2), which is the minimum PL for all post-tensioned bridges in Texas. See **Post-Tensioning Institute's Protection Levels** below for further details.

Post-Tensioning Institute's Protection Levels

The three tendon PLs identified in PTI's M50.3-19, Specification for Multistrand and Grouted Post-Tensioning, are described in an August 2021 Federal Highway Administration TechBrief:

> Designers select the protection levels for a PT [post-tensioning] system based on the aggressiveness of the environment and protection provided by the structural element. The non-binding PTI publication lists three tendon protection levels (PL):
>
> - Protection Level 1A (PL-1A) — Duct with filling material providing durable corrosion protection.
> - Protection Level 1B (PL-1B) — PL-1A plus engineered grout and permanent grout cap.

- Protection Level 2 (PL-2) — PL-1B plus an envelope, enclosing the tensile element bundle over its full length, and providing a permanent leak-tight barrier.
- Protection Level 3 (PL-3) — PL-2 plus electrical isolation of tendon or encapsulation to be monitorable or inspectable at any time.

Assessment

Respondents offered their assessment of the successes and drawbacks of the use of plastic ducts and shared limited feedback regarding best practices and lessons learned.

Successes and Drawbacks

Increased corrosion protection (MnDOT), sealed splices (MnDOT) and successful air pressure tests (Ohio DOT) have been achieved by responding agencies after implementing plastic ducting. The MnDOT respondent noted that galvanized duct has duct tape splices that are not waterproof. In Texas, all projects have used plastic ducts for some time, making it difficult to distinguish successes with using plastic ducting from common practice.

While the TxDOT respondent reported no significant drawbacks with plastic ducting, the MnDOT respondent noted that splicing was more difficult, and the PennDOT respondent reported that the agency has experienced cracking.

Best Practices and Lessons Learned

The MnDOT respondent explained that the agency's use of plastic duct for "many years" was for "corrosion reasons" and MnDOT "will never use galvanized duct again." Ohio DOT's use of shrink sleeves over fittings has produced best results. The PennDOT respondent cited rebar spacing around corrugate plastic tubing as a lesson learned. While more use of post-tensioning systems might result from additional training and development of projects appropriate for its use, the PennDOT respondent commented, "Future use [is] not on the horizon."

TxDOT's best practice is to follow guidance in the agency's specification, which draws from PTI's M50 and M55 specifications — M50.3-19, Specification for Multistrand and Grouted Post-Tensioning, and M55.1-19, Specification for Grouting of Post-Tensioned Structures. Plastic ducts have been adopted as the standard in Texas, with the respondent commenting, "PL-2 with plastic ducts is the minimum protection level required in Texas under our specifications, so the use of plastic ducts is not considered a new practice for us."

Similarly, WSDOT practices are now fully compliant with PTI specifications, and the respondent recommends that other agencies follow PTI specifications as a best practice. While WSDOT has used plastic duct in cast-in-place concrete for several years, the respondent noted that the impacts are difficult to isolate at this time. The agency recently adopted plastic duct for precast components. To date, the WSDOT Bridge and Structures Office has identified no significant issues when using plastic duct in precast applications.

Plastic and Metal Duct Use

Three agencies — CDOT, NMDOT and Oklahoma DOT — use both metal and plastic ducts in cast-in-place prestressed box girder and post-tensioned spliced precast girder bridge construction. The NMDOT respondent provided a partial response to the survey, only describing the agency's reasons for using plastic ducts. Oklahoma DOT has not done much post-tensioned construction in recent years and the respondent noted the need for more information to change this approach.

Survey respondents described their experience with plastic ducts in six categories:

- Reasons contributing to agency use.
- Bridge design.
- Construction and installation.
- Cost considerations.
- Benefits of use.
- Assessment.

Reasons Contributing to Agency Use

Respondents rated the importance of six factors that contributed to their agencies' decision to use plastic ducts in cast-in-place prestressed box girder bridge and post-tensioned spliced precast concrete bridge construction. As with the respondents using only plastic ducts, this group of respondents rated these factors on a scale of extremely important, very important, important, somewhat important, not at all important or not applicable.

Dent and puncture resistance received the highest average rating from two of the three agencies using plastic and metal ducts. This was followed by increased corrosion resistance of the prestress system, with all three agencies indicating it is very important. This assessment is similar to the plastic-duct-only respondent group, which uniformly provided the highest rating — extremely important — for increased corrosion resistance. Unlike the plastic-duct-only respondent group, which identified project-specific need as not applicable, the respondents using both plastic and metal ducts considered project-specific need as an extremely important (CDOT) or somewhat important (Oklahoma DOT) factor in determining when to use plastic ducts. Cost is the least important factor among these agencies. Table 3 summarizes survey responses.

Table 3. Importance of Factors in Decision to Use Plastic Ducts (Plastic and Metal Duct Use)

State	Cost	Dent/Puncture Resistance	Increased Corrosion Resistance	Installation Process	Project-Specific Need	Reduced Friction Factor
Colorado	Not at all important	Not provided	Very important	Important	Extremely important	Somewhat important
New Mexico	Not at all important	Extremely important	Very important	Important	Not applicable	Somewhat important
Oklahoma	Important	Very important	Very important	Very important	Somewhat important	Very important

Note: The remainder of the survey was completed by the respondents from CDOT and Oklahoma DOT. A summary of their responses follows.

Bridge Design

CDOT and Oklahoma DOT differed on the bridge design implications of the use of plastic ducts:

- The CDOT respondent noted no change in design efficiency, and the need for thicker webs in precast U and I girder webs for plastic duct.
- Oklahoma DOT has experienced an increase in laboratory testing requirements; CDOT has not.
- Stem width for box girder bridge designs has increased in Colorado but not in Oklahoma.
- Neither agency has experienced a decrease in the amount of prestressed strand needed to meet the design requirements due to change in duct friction.
- CDOT has not needed more ducts per girder due to increased wall thickness over metal duct.

CDOT has tried a combination of metal and plastic ducting on the same project. The agency has used metal ducts in webs and plastic flat duct in the deck. Neither agency has taken any additional measures in case of excessive heat from a potential fire.

Construction Specifications and Guidance

Colorado

Section 618, Prestressed Concrete, Division 600, Miscellaneous Construction, Standard Specifications for Road and Bridge Construction, Colorado Department of Transportation, 2023.
https://www.codot.gov/business/designsupport/cdot-construction-specifications/2023-construction-specifications/2023-specs-book/2023-division-600
This section of the manual begins on page 618-1 of the manual, page 153 of the PDF. *From page 618-13 of the manual, page 165 of the PDF:*

3. Duct Fabrication and Placement. Duct enclosures for prestressing steel shall be either rigid, corrugated plastic or galvanized, corrugated, rigid ferrous metal.

Oklahoma

Section 517, Post-Tensioning, Standard Specifications for Highway Construction, Oklahoma Department of Transportation, 2019.
https://oklahoma.gov/content/dam/ok/en/odot/documents/c-manuals/specbook/2019-full-spec-web-version.pdf
From Section 517.02G. Duct and Pipe, which begins on page 486 of the manual, page 500 of the PDF:

G. Duct and Pipe

(1) General

Provide plastic duct, steel pipe or both. Provide airtight and watertight connectors, connections and post-tensioning hardware components that pass the pressure test. Provide smooth, plastic duct in post-tensioning systems for external tendons. Provide corrugated plastic duct in post-tensioning systems for internal tendons.

(2) Duct or Pipe Minimum Diameter

Provide duct with an internal diameter at least ½ in [13 mm] larger than the outside diameter of the post-tensioning bar. For post-tensioning bars with couplers, provide duct ½ in [13 mm] longer than the outside diameter of the coupler.

Provide ducts for multi-strand tendons with a cross-sectional area at least two and one-half times larger than the cross-sectional area of the post-tensioning steel.

(3) Connection Tolerance Between Pipe and Duct

Connect steel pipe and plastic ducts directly if the outside diameters vary by less than 0.08 in [2 mm]. Use a reducer to fit steel pipes and plastic ducts with diameters outside the tolerances required by the Contract.

(4) Steel Pipes

Use galvanized Schedule 40 steel pipes where shown on the Plans and in deviation blocks. Equip steel pipes in the tendon anchorage zones with shear transfer devices as shown on the Plans.

(5) Corrugated Plastic Duct

The Department will not allow the use of ducts manufactured from recycled material. Manufacture ducts using seamless fabrication methods.

Provide corrugated duct manufactured from uncolored, unfilled polypropylene, in accordance with ASTM D 4101. Provide polypropylene with a cell classification range from PP0340B44544 to PP0340B65884. Provide white duct with antioxidants with an OIT of at least 20 min, in accordance with ASTM D 3895. Provide duct with a non-yellowing light stabilizer. Use Table 517:1 to determine the minimum duct thickness.

Construction and Installation

In a comparison of material characteristics, survey respondents indicated their preference for using plastic or metal ducting in bridge construction and installation. Respondents also addressed selected issues with installation and field repair.

Plastic vs. Metal Ducting

Both respondents reported that plastic ducting is more durable. The Oklahoma DOT respondent noted that plastic ducting is easier to use, and the CDOT respondent reported that metal ducting is easier to use, adding that couplings can be challenging in cold weather and require “extra security measures to make sure they stay put during concrete placement.” The Oklahoma DOT respondent reported that plastic ducting does not damage easily, but the CDOT respondent noted that plastic duct can be “squished or ovaled” at duct supports where there are changes in profile.

Both respondents reported that plastic ducting does not crack easily, and neither agency has had issues with slipping. CDOT has experienced duct movement during concrete placement due to the characteristics of plastic over metal, adding that a duct “will float or get ovaled” if stepped on or concrete is placed directly onto the duct. The respondent also noted difficulty performing field repairs on damaged ducting after it is placed in the structure. According to the respondent, duct protruding from ends of girders for field splices may be used as ladders and get crushed or broken, adding that “[l]ots of steel congestion at ends makes repairs difficult.”

Additional Considerations

Friction coefficient is not a concern for CDOT when using plastic ducting, as long as it is accounted for in the design. Neither respondent noted issues with shear strength, thermal expansion or wear resistance. The CDOT respondent reported that void detection with plastic ducting is “easier than metal ducting.” The CDOT respondent also reported constructability issues, noting that sealing metal duct at girder splices needs to be “done properly,” and plastic duct requires more support to maintain its profile and “prevent wobble in the path.” Plastic ducting has not impacted construction practices at either agency.

Cost Considerations

Limited information was received about cost. Neither agency has conducted a cost comparison between metal and plastic ducting, and neither can report a cost savings as a result of using plastic ducting. In addition, neither agency noted a reduction in greenhouse gas emissions or other environmental gains, and is not aware of advantages to contractors when using plastic ducting.

Benefits of Use

Successes and benefits reported by the CDOT respondent include that it is pressure-rated and offers better corrosion protection. Drawbacks are increased web thickness and the need for more attention on-site to ensure the duct is properly supported and connected.

Assessment

The Oklahoma DOT respondent reported "too little experience" to provide best practices or lessons learned. The CDOT respondent suggested pressure testing before grouting and keeping the duct indoors before using as best practices. He added that it's not the duct size that will cause the most issues, but the coupler in thin webs.

Metal Duct Use Only

Seven responding agencies use only metal ducts:

- Arizona DOT
- Idaho Transportation Department
- Kansas DOT
- Missouri DOT
- New Hampshire DOT
- Oregon DOT
- Virginia DOT

Three respondents provided additional context:

- Very few post-tensioned bridges are constructed in Idaho. The respondent noted that the agency tends to follow the direction of state DOTs that are more experienced in this method of construction.
- Kansas DOT has not constructed cast-in-place prestressed bridges or post-tensioned spliced precast girder bridges.
- Virginia DOT does not construct many post-tensioned bridges.

A second Oregon DOT respondent noted that the agency is considering use of plastic ducts; see below for details.

Considering Use of Plastic Duct

While Oregon DOT currently uses only galvanized metal ducts, the agency is finalizing its approach for incorporating "recent language from M50.3" into the agency's specifications. This PTI specification, M50.3-19, Specification for Multistrand and Grouted Post-Tensioning, is described by PTI as addressing "the selection of tendon protection levels, system components, materials, installation and stressing of post-tensioning tendons."

The agency hopes to complete specification changes in 2025 that will incorporate the PTI guidance and address the tendon PLs identified by PTI. Oregon DOT plans to adopt PTI's PL-2, which requires the use of a plastic duct for post-tensioning tendons, as the state's default PL. Also under consideration is use of PL-1B for portions of the state and PL-3 for marine environments.

Related Research and Resources

A review of domestic and international published and in-progress research and related resources sought information about the galvanized metal and plastic used in internal ducting in the prestressed concrete used to construct post-tensioned box girder bridges. Findings are presented in three topic areas:

- Design and installation.
- Repair and maintenance.
- Assessment and evaluation.

Citations are further categorized as national, state, international or related resources.

Design and Installation

Though somewhat dated, design and installation manuals from Federal Highway Administration (FHWA) that address post-tensioned box girders and tendon installation and grouting provide perspective on the transition from metal to plastic ducts that began in the early U.S. State DOT manuals address prestressed concrete structures (New York) and post-tensioned concrete bridges (Washington).

A sampling of international resources includes a 2024 conference paper that highlights the 50-year history of the use of plastic ducts in post-tensioning, describes the selection of tendon PLs, and addresses the design and detailing information available for structural engineers in FIB Bulletin 75, which is also cited. Also included is a presentation of findings from an experimental study on the performance of two duct types in post-tensioned beams — galvanized steel and recycled waste plastic — and an investigation of the bond behavior of mono-strand post tension systems with different duct types, sizes and embedment length.

National Resources

Post-Tensioned Box Girder Design Manual, John Corven, Office of Infrastructure – Bridges and Structures, Federal Highway Administration, June 2016.
https://www.fhwa.dot.gov/bridge/concrete/hif15016.pdf
This manual provides limited information about corrugated plastic duct "used for tendons internal to the concrete. These ducts should be seamless and fabricated from polyethylene or polypropylene meeting the requirements of section 4.3.5.2 of 'Guide Specifications for Grouted Post-Tensioning, (PTI/ASBI M50.3-12, 2012)'" (see page 30 of the PDF).

Post-Tensioning Tendon Installation and Grouting Manual, Version 2.0, John Corven and Alan Moreton, Office of Bridge Technology, Federal Highway Administration, May 2013.
Publication available at https://rosap.ntl.bts.gov/view/dot/53649
The use of plastic duct is addressed in its early applications, with the manual noting a "move toward the use of plastic ducts in some states." *From page 58 of the PDF*:

> **2.3 Ducts**
> Ducts are used to form a continuous void through the concrete for later placement of the post tensioning tendon steel. Originally, little attention was paid to the possible role of the duct as a

barrier to corrosive agents. Today, strong emphasis is placed on the quality, integrity and continuity of the duct as a corrosion barrier in itself. This has resulted in a move toward the use of plastic ducts in some states. Nevertheless, previous duct materials are still available and their use continues in other regions. Consequently, the following recommendations should be adapted as appropriate to meet local needs and conditions in accordance with Protection Levels specified in Section 3.0 of "Guide Specification for Grouted Post-Tensioning PTI/ASBI," M50.3 12.

State Resources

New York

Prestressed Concrete Construction Manual, Office of Structures, New York Department of Transportation, Revised January 2019.
https://www.dot.ny.gov/divisions/engineering/structures/repository/manuals/PCCM_3rd_Edition_4-2017_rev2019.pdf
Section 4.6.3, Ducts, which begins at the bottom of page 4-11 of the manual, page 59 of the PDF, addresses corrugated plastic and steel ducts. See also Section 4.6.3.2, Plastic Ducts (page 4-13 of the manual, page 61 of the PDF), and Section 4.6.3.3, Duct Connections, Fittings and Grout Vent Pipes (page 4-14 of the manual, page 62 of the PDF).

Washington

Chapter 5, Concrete Structures, WSDOT Bridge Design Manual, Washington State Department of Transportation, June 2025.
https://wsdot.wa.gov/publications/manuals/fulltext/m23-50/chapter5.pdf
Section 5.1.5, Post-tensioning Systems, which begins on page 5-27 of the manual, page 37 of the PDF, is excerpted in part below:

> Designers should consult post-tensioning system supplier product guides to ensure that multiple suppliers can satisfy the design. Corrugated plastic duct shall be used and shall conform to standard sizes where possible. Common post-tensioning system component sizes and combinations are shown in Table 5.1.5-1. The nominal diameter for plastic duct may be used when interpreting code provisions that reference duct size or diameter without further clarification (i.e., inside diameter, outside diameter, etc.). The interior diameter of plastic duct shall be used when interpreting code provisions that reference duct area without further clarification.

Table 5.1.5-1 Post-tensioning System Sizes

Duct Size (Round)	ID	OD	Corrug. Dia.	Max # Strands (Pull, 0.6"ø)	Max # Strands (Push, 0.6"ø)	Common Anchorage Size (0.6"ø)
3"	2.99"	3.19"	3.63"	12	16	12
3-⅜"	3.35"	3.55"	3.94"	16	20	15, 19
4"	3.93"	4.29"	4.63"	22	27	19, 22
4-½"	4.49"	4.80"	5.28"	29	36	27

"Post-Tensioned Bridge Design, Materials and Construction Requirements in Washington State," Anthony Mizumori and Bijan Khaleghi, *2022 PTI Convention,* April 2022.
https://www.post-tensioning.org/Portals/13/Files/PDFs/Events/Conventions/2022LaJolla/2022PTIConvPP-Recover%20Bijan.pdf
This PTI conference presentation has the following learning objectives:

- Understand WSDOT's implementation of PTI specifications.
- Understand WSDOT's construction requirements for post-tensioned concrete bridges
- Understand WSDOT's practices for post-tensioned spliced concrete bridge girders.
- Post-tensioning ducts, anchorage and grouting requirements.

From the overview:

- WSDOT - PTI specifications represent industry best practices, and their use will improve the durability and quality of post-tensioned concrete bridges and structures.
- Protection Level 2 (PL-2) provides enhanced corrosion protection and durability to the entire post-tensioning, tendons and anchorages, requiring the use of plastic duct and additional protection measures at anchorages.
- Protection levels identify the appropriate materials and construction quality control practices used for a post-tensioning system to achieve a desired level of durability.

Post-Tensioned Concrete, Bijan Khaleghi, Bridge Design Memorandum, Bridge and Structures Office, Washington State Department of Transportation, December 24, 2021.
https://wsdot.wa.gov/sites/default/files/2022-01/09-2021-BDM-Memo-Post-Tensioned-Concrete.pdf
From the memorandum: This design memorandum updates WSDOT's design policy for post-tensioned concrete bridges to be consistent with the Post-Tensioning Institute's construction specifications in PTI/ASBI M50.3 19 Specification for Multistrand and Grouted Post-Tensioning, PTI M55.1-19 Specification for Grouting of Post-Tensioned Structures, and PTI M10.2-17 Specification for Unbonded Single Strand Tendons. These PTI construction specifications are adopted in Section 6-02.3(26) of the 2022 Standard Specifications. Permanent post-tensioned concrete bridges shall be designed and constructed as complete post tensioning system conforming to Protection Level 2 (PL-2), as defined by the PTI requirements. PL-2 provides enhanced corrosion protection and durability to the entirety of the post-tensioning system, which includes tendons and anchorages. The key features that define PL-2 are the use of plastic duct, engineered (Class C) thixotropic grout, and additional protection measures at anchor ages. Since plastic duct is adopted more broadly, this design memorandum also clarifies terminology and code interpretation regarding duct size, diameter and area. Certain obsolete sections and requirements of the BDM [Bridge Design Memorandum] regarding post-tensioning have been deleted.

Related Resource:

> **2026 Standard Specifications for Road, Bridge and Municipal Construction**, Washington State Department of Transportation, undated.
> https://wsdot.wa.gov/publications/manuals/fulltext/M41-10/Division6.pdf
> *From page 6-131 of the manual, page 374 of the PDF*:
>
> > **6-02.3(26) Post-Tensioned Concrete**
> > Multistrand post-tensioned structures and grouted post-tensioned structures shall conform to the requirements of PTI/ASBI M50.3-19 Specification for Multistrand and Grouted Post-Tensioning. Grouting for post-tensioning systems shall conform to the requirements of PTI M55.1-19 Specification for Grouting of Post-Tensioned Structures. Permanent unbonded single-strand post-tensioning shall conform to the requirements of PTI M10.2-17 Specification for Unbonded Single Strand Tendons. These specifications shall be collectively referred to as the "PTI requirements." Within the PTI requirements, the term "Construction Engineer" shall be taken as the Engineer.

International Resources

"Design and Detailing of Durable and Sustainable Post-Tensioning Structures with Polymer Ducts According to FIB Bulletin 75," Klaus Lanzinger and Larry Krauser, *IABSE (International Association for Bridge and Structural Engineering) Symposium Manchester 2024: Construction's Role for a World in Emergency*, 2024.
https://gti-usa.net/wp-content/uploads/2024/04/IABSE-2024-Durable_Plasticducts_Lanzinger.pdf
From the abstract: In order to build durable and sustainable prestressed concrete bridges and structures, preventing the steel components and the tendons from corrosion is key. Accordingly, for bridges with internal bonded post-tensioning, polymer duct systems should be used. The article gives an overview of the 50-years history of plastic ducts in post-tensioning, the selection of tendon protection levels (PL's) according to fib bulletin 33 and information for structural engineers regarding design and detailing of concrete structures with polymer ducts according to fib bulletin 75.

Related Resource:

> **FIB Bulletin 75: Polymer-Duct Systems for Internal Bonded Post-Tensioning**, FIB International, 2014.
> Product description at https://fib-international.org/publications/fib-bulletins/polymer-duct-systems-for-internal-bonded-post-tensioning-164-detail.html
> *From the abstract*: The purpose of this recommendation – *fib* Bulletin 75: *Polymer-duct systems for internal bonded post-tensioning* – is to update and amend *fib* Bulletin 7: *Corrugated plastic ducts for internal bonded post-tensioning*, a technical report published in 2000. *fib* Bulletin 75 is meant as a cornerstone for the technical approval of polymer (plastic) ducts for internal bonded post-tensioning and possibly for the test procedures of a future testing standard. The updated bulletin includes new information on the design and detailing of concrete structures containing tendons with polymer ducts. The recommendation provides detailed test specifications for polymer materials, duct components and duct systems. In addition, the report contains recommendations for approval testing and attestations of conformity for polymer-duct systems. Although the new generation of corrugated polymer ducts for bonded post-tensioning have now been around for approximately twenty years, products still differ in material properties, geometrical detail, installation procedures and on-site use. Unlike corrugated steel ducts or smooth polyethylene (PE) pipes, they have not yet become standardized. It is the opinion of *fib* Task Group 9.16 and Commission 9 that these plastic ducts should, therefore, still be subjected to a systems approval process. This recommendation offers information acquired from twenty years of experience as well as new specifications that will, hopefully, lead to the standardization of polymer-duct systems.

"Moment Capacity for Steel and Recycled Waste Plastic Ducts in Post-Tensioned Beams," Milad Khatib, Zaher Abou Saleh and Oussama Baalbaki, *Journal of Building Engineering*, Vol. 76, October 2023.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S2352710223015929
From the abstract: Generally, in post-tension construction practices, the contractors tend to use galvanized steel ducts for cost and availability reasons. An experimental study was conducted on two duct types, galvanized steel and recycled waste plastic. Four post-tensioned beams (PTB) were prepared 7.87 in. (200 mm) wide, 11.8 in. (300 mm) deep, and 16.40 ft (5000 mm) in length. Different parameters were used to clarify the advantage of recycled waste plastic ducts against galvanized steel. The PTB, provided with strands of 0.5 in. (12.7 mm) diameter, were tested up to flexural failure using 3 points bending machine. Minimum reinforcements were used to reinforce the PTB and resist the applied loads. The moment capacity results were compared to ACI [American Concrete Institute] provisions. The lower friction related to galvanized steel ducts as opposed to those of recycled waste plastic ones gives a result with a significant reduction in prestressing steel needed, regardless of the length of the system.

However, it was proved that there is no loss of moment capacity by using recycled waste plastic ducts. The experimental studies were modeled using finite element software to compare the obtained results. A good correlation was noticed between both experimental and numerical results. This paper shed[s] light on the advantages of using recycled waste plastic ducts such as corrosion resistance, lightweight, friction losses and durability. However, the use of recycled waste plastic materials for manufacturing plastic ducts contributes effectively to sustainability and saving the environment and natural steel resources.

"Effect of Duct Type, Size and Embedment on Bond Behavior of Post-Tensioned Mono-Strand Concrete Members," Houssam Kobrosli, Oussama Baalbaki, Ali Jahami, Zaher Abou Saleh, Jamal M. Khatib and M. Sonebi, *Materials Today Proceedings*, Vol. 58, Issue 4, February 2022.
Publication available at
https://www.researchgate.net/publication/358522221_Effect_of_duct_type_size_and_embedment_on_bond_behavior_of_post-tensioned_mono-strand_concrete_members
From the abstract: This research investigated the bond behaviour of mono-strand post tension systems with different duct types, sizes and embedment length. Six specimens were considered in this study. Two different types of ducts were considered: plastic ducts and galvanic ducts. Two different duct sizes (9 cm × 4.2 cm and 6 cm × 2.4 cm) and embedment lengths (5 cm and 10 cm) for each duct type were considered in this study. Results showed that specimens with galvanic ducts had stronger bond than those with plastic ducts. In addition, it was found that extending the embedment length of the galvanic ducts form 5 cm to 10 cm improved the bond strength which was not the case for plastic ducts where the effect was null. Furthermore, specimens with galvanic ducts had greater bond strength when duct size was increased than those with plastic ducts.

Repair and Maintenance

The 2021 National Cooperative Highway Research Program (NCHRP) Synthesis 562 provides a brief history of the use of plastic duct for post-tensioned tendons and highlights duct issues requiring repair. The authors note that PTI had not, at the time of publication, offered repair recommendations to address duct issues encountered in bridge construction. A 2018 FHWA publication that evaluated 11 nondestructive evaluation (NDE) technologies that can be used to evaluate post-tensioning tendons addressed issues such as locating grout voids, locating strands within the ducts and evaluating corrosion of the strands. A 2016 NCHRP project report offered other details of NDE techniques, noting that "NDE techniques are first needed to detect defects such as corrosion, section loss, breakage, compromised grout, voids and water infiltration, for post-tensioning and stay cable systems."

National Resources

NCHRP Synthesis 562: Repair and Maintenance of Post-Tensioned Concrete Bridges, Natassia Brenkus, Garrett Tatum and Isaac Kreitzer, 2021.
Publication available at https://nap.nationalacademies.org/catalog/26172/repair-and-maintenance-of-post-tensioned-concrete-bridges
Below are excerpts addressing plastic duct from Chapter 1, Literature Review and Background. *From page 2 of the report, page 11 of the PDF*:

> Internal tendons are in direct contact with the primary concrete member, while external tendons are placed outside of the cross-section of the primary member and are anchored directly at the ends. The standard practice in the United States to construct both internal and external tendons has been to use prestressing strands, sheathed or placed in plastic ducts, with cementitious grout as a filler material. Both types of tendons may experience durability issues associated with construction practice and filler material quality; rarely have internal tendons been identified with evidence of

corrosion. Lacking complete encasement in the primary concrete member, external tendons may experience an increased occurrence of durability issues.

From page 24 of the report, page 33 of the PDF:

Sheathing/Duct
Early U.S. PT bridge structures used metal duct; since the early 2000s, most PT tendons have been constructed with plastic duct. Issues encountered with a post-tensioning tendon's duct are influenced by the chosen duct material. Typically, internal tendons are detailed with corrugated polypropylene; external tendons are now commonly made with HDPE [high-density polyethylene]. Each material has its own characteristic resistance to damage.

Duct issues requiring repair include duct corrosion, duct misalignment, duct kinking at deviation points, duct splicing failures, duct bursting during filler injection and duct damage of unknown origin. Most duct issues occur during construction. Issues encountered during construction, if caught prior to filler injection, are repaired to pass tendon pressure tests, which are often set as a project requirement before the injection may proceed. Duct bursting has been documented in multiple structures during filler injection. In some cases (such as the issues described in the case example of the Veterans' Glass Skyway deck replacement), duct damage can occur during later structure modification. Duct damage also occurs during invasive tendon investigation and must be repaired to ensure adequate tendon protection.

Currently, repair recommendations to address duct issues encountered in bridge construction are not available from the Post-Tensioning Institute. However, its repair committee, DC-80, has published recommendations and guidance documents for the repair of sheathing of the more uniform scenarios encountered with the single-strand tendons used in building construction.

Designing and Detailing Post-Tensioned Bridges to Accommodate Nondestructive Evaluation, TechBrief, Office of Bridges and Structures, Federal Highway Administration, August 2018.
https://www.fhwa.dot.gov/bridge/concrete/hif18029.pdf
From the publication: Post-tensioned concrete is an important material used for the construction of bridges in the United States. The material is composed of conventionally reinforced concrete with post-tensioning tendons used to induce forces in the concrete to resist applied loads. The components of a typical post-tensioning tendon include prestressing strands, ducts that enclose the strands, grout and anchorages that transfer forces from the tendons to the concrete. The design details of these components sometimes preclude effective in-service inspection. Recent instances of post-tensioning tendon corrosion have indicated a need to have tendons that can be more readily inspected using nondestructive evaluation (NDE) technology.
….

The research team reviewed 11 NDE technologies with regard to evaluating post-tensioning tendons. Each of the NDE technologies reviewed addressed one or more of three primary concerns: locating grout voids, locating strands within the ducts and evaluating corrosion of the strands.

Condition Assessment of Bridge Post-Tensioning and Stay Cable Systems Using NDE Methods, Stefan Hurlebaus, Mary Beth D. Hueste, Madhu M. Karthik and Tevfik Terzioglu, NCHRP Project No. 14-28, National Cooperative Highway Research Program, September 2016.
https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP14-28_FR.pdf
From Chapter 1, Introduction: Although there is a need for routine inspection of post-tensioning and stay cable systems using NDE techniques, it is not widely used among the bridge owners. Among various

factors, the lack of know-how regarding the various NDE techniques that could be used for the condition assessment of post-tensioning and stay cable systems, and limitations of currently used NDE techniques are a road-block for the widespread use and application of non-destructive evaluation techniques.

Condition assessment of post-tensioning and stay cable systems could allow bridge owners to take timely, proactive actions to mitigate or prevent further deterioration and unanticipated failure. As inspection and replacement of these systems are expensive, guidelines are needed to assist engineers in assessing the condition of post-tensioning and stay cable systems, to correlate this information to structural performance, and to provide recommendations, if necessary, to mitigate or prevent the deterioration process. In particular, reliable NDE techniques are first needed to detect defects such as corrosion, section loss, breakage, compromised grout, voids and water infiltration, for post-tensioning and stay cable systems.

Assessment and Evaluation

An August 2021 FHWA TechBrief examined the use of electrically isolated tendon technology to "permit post-grouting inspection of anchorages." A series of publications sponsored by TxDOT, though somewhat dated, offers perspective on agency efforts to evaluate the performance of post-tensioned structures by examining shear behavior, corrosion resistance and durability. Publications that take a broader view of post-tensioning practices include a 2024 journal article that offers details of PTI's PT system prequalification testing and certification program and three PTI manuals that describe certification program requirements.

Related resources include a webinar describing a risk assessment process for post-tensioned tendons that is illustrated using an example bridge; a 2022 FHWA TechBrief provided further details of this risk-based assessment. Finally, a *PTI Journal* article describes two nondestructive methods that allow for the detection of grouting defects within a duct that can lead to corrosion.

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Development of Reference Criteria for Electrically Isolated Post-Tensioning Tendons in U.S. Bridge Applications, TechBrief, Office of Bridges Technology, Federal Highway Administration, August 2021.
https://www.fhwa.dot.gov/bridge/concrete/hif20042.pdf
From page 1 of the TechBrief: This Technical Brief provides an overview of "Advancing Steel and Concrete Bridge Technology to Improve Infrastructure Performance Program." The objective was to research design details of Electrically Isolated Tendon (EIT) technology for post tensioning systems in concrete bridges to accommodate epoxy coated mild steel reinforcement and permit post-grouting inspection of anchorages, as are common to U.S. practice.

State Resources

Texas

Shear Behavior of Spliced Post-Tensioned Girders, Andrew Moore, Chris Williams, Dhiaa Al-Tarafany, James Felan, Josh Massey, Trang Nguyen, Katie Schmidt, David Wald, Oguzhan Bayrak, James Jirsa and Wassim Ghannoum, Texas Department of Transportation, April 2015.
https://library.ctr.utexas.edu/ctr-publications/0-6652-1.pdf
From the abstract: The findings of this experimental study are described in detail within this dissertation, but can be summarized by the following two points. (i) No differences were observed in the ultimate or service level shear behavior in girders containing plastic grouted ducts when compared to those containing steel grouted ducts and (ii) The current procedure of reducing the effective web width

to account for the presence of a post-tensioning duct is ineffective because it addresses the incorrect shear transfer mechanism. A method that correctly addresses the reduction in shear strength due to the presence of a post-tensioning duct was developed and verified using the tests performed during this experimental program and tests reported in the literature.

Evaluation of Corrosion Resistance of Improved Post Tensioning Materials After Long-Term Exposure Testing, R.D. Kalina, S. MacLean, M.E. Ahern, J.E. Breen and S.L. Wood, Texas Department of Transportation, October 2011.
https://library.ctr.utexas.edu/ctr-publications/0-4562-4.pdf
From the abstract: Ten full-scale post-tensioned beam specimens were subject to [four] years of aggressive cyclic ponded saltwater exposure. Three of those specimens were additionally exposed to saltwater spray once per month on one anchorage face. Non-destructive monitoring was conducted during the exposure period. This consisted of half cell potential measurements, AC impedance measurements (for specimens with fully encapsulated tendons), and regular visual inspections. Chloride samples were extracted from the specimens at the end of exposure. After [four] years, the specimens were autopsied, and all reinforcing elements from the middle of each specimen were examined for corrosion and damage. Anchorage regions were also autopsied and examined for corrosion. Duct systems included galvanized metal ducts, plastic ducts and encapsulated duct systems. Strand types included conventional strand, hot dipped galvanized strand, copper clad strand and stainless steel strand. Complete observations are presented.

Durability Evaluation of Post-Tensioned Concrete Beam Specimens After Long-Term Aggressive Exposure Testing, G.P. Turco, R.M. Salas, A.J. Schokker, J.S. West, M.E. Kreger and J.E. Breen, Texas Department of Transportation, November 2007.
https://library.ctr.utexas.edu/ctr-publications/0-4562-2.pdf
From the abstract: This report focuses on the forensic analysis and evaluation of large-scale post-tensioned beam specimens after nearly [eight] years of extremely aggressive exposure testing. The research was funded jointly by both FHWA and TxDOT. The relationship between durability performance and the following variables was evaluated in this study: level of applied load and initial cracking, level of prestress, duct type, strand type, grout type, grouting method, use of encapsulated system for anchorage protection, and galvanized duct splice type. In addition, the applicability of half-cell potentials and chloride penetration tests for evaluating the likelihood of corrosion was examined. Major findings were: 1) mixed reinforcement (also known as partial prestressing) performed poorly from a durability standpoint. Only fully prestressed beams offered better durability performance than those which were not prestressed at all. 2) Corrugated steel galvanized ducts performed very poorly. Large holes were found in the ducts, and in some cases several inches of the ducts completely corroded away. 3) Corrugated plastic ducts offer better performance as long as they are "robust." 4) Non-flowfilled epoxy coated strand and galvanized strand offered no significant improvement in long-term durability over conventional strand. 5) Installing plastic caps over anchorheads rather than just filling the anchorage pocket with nonshrink grout increases the long-term durability of the anchorage.

Related Resources

"Post-Tensioning Institute Launches Post-Tensioning System Prequalification Testing and Certification Program," Miroslav Vejvoda and Tim Christle, *ASPIRE*, pages 33-35, Summer 2024.
https://www.aspirebridge.com/magazine/2024Summer/NCBCMemberSpotlight-PostTensioningInstitute.pdf
From the journal article: The Post-Tensioning Institute's (PTI's) Post-Tensioning System Qualification Testing and Certification program was developed to standardize the approval process for post-tensioning (PT) systems and provide independent certification of multistrand and grouted PT systems

for use in bridges and other structures. The certification of a PT system under this program indicates that the system meets all requirements and is in conformance with PTI/ASBI M50.3, Specification for Multistrand and Grouted Post-Tensioning. The program is intended to provide uniform objective acceptance criteria, validation that the PT systems were tested and met those criteria, and an online registry of approved systems.

….

There are three key PTI program manuals, outlined in the following paragraphs, that define the technical, administrative and management structure requirements that the PTI CRT-70 Committee has established for this program. PTI's goal is to keep these program documents updated and to simultaneously publish new editions of each document when updates occur. [These three publications are cited in *Related Resources* immediately below.]

Related Resources:

PTI Technical Manual for PT Systems Qualification Testing and Certification, Post-Tensioning Institute, March 2022.
https://www.post-tensioning.org/Portals/13/Files/PDFs/Certification/QualityManagementProgram/PTI-CRT70%20G3-0322-Technical%20Manual%20for%20PTS%20Qualification%20Testing%20and%20Certification.pdf
As described in the *ASPIRE* article cited above, this manual "addresses the requirements from the M50.3 specification and provides a checklist for each protection level for use during audits."

PTI Quality Management System Manual for Certification Programs*,* Post-Tensioning Institute, February 2022.
https://www.post-tensioning.org/Portals/13/Files/PDFs/Certification/QualityManagementProgram/PTI-CRT140%20G2-0222%20.pdf
As described in the *ASPIRE* article cited above, this manual "outlines the management structure of all PTI certification programs, including the ANSI [American National Standards Institute]-accredited PTI plant-certification program, and the procedures for monitoring performance and quality."

PTI Administrative Manual for PT Systems Qualification Testing and Certification, Post-Tensioning Institute, July 2022.
https://www.post-tensioning.org/Portals/13/Files/PDFs/Certification/PT%20Systems%20Qualification/PTI-CRT70%20G1-0722%20Administrative%20Manual.pdf
As described in the *ASPIRE* article cited above, this manual "outlines the PT system application process, audits by independent agencies, PT system certification, re-reviews and the registry of certified systems."

Methodology for Risk Assessment of Post-Tensioning Tendons, Glenn A. Washer, Webinar, American Segmental Bridge Institute, May 2022.
https://asbi-assoc.org/wp-content/uploads/2023/07/2022-May-Webinar.pdf
This webinar describes a risk assessment process for post-tensioned tendons by providing steps for conducting the risk assessment, describing individual attributes of these tendons, and then applying the methodology to an example bridge. *From the webinar*:

PT Materials and Components Attributes
The criteria reflect the generally increased likelihood of metal ducts being breached as compared with a plastic duct.

Example Bridge

- Precast segmental bridge
- Consider two cases
  - Case 1: Current best-practices are used, PL2 with plastic ducts
  - Case 2: Current best-practices not used, PL1 with plastic ducts
- Compare the risk values from the two cases

Related Resource:

Methodology for Risk Assessment of Post-Tensioning Tendons, TechBrief, Office of Bridges and Structures, Federal Highway Administration, February 2022.
https://www.fhwa.dot.gov/bridge/concrete/hif20041.pdf
From the introduction: The objective of this document is to provide a rationale for conducting risk assessment of Post-Tensioning (PT) tendons to aid designers in the selection of appropriate corrosion protection strategies for PT systems in bridges. The risk assessment is intended to prioritize the need for protective technologies and processes considering the likelihood and consequences of corrosion damage (i.e., the risk) based on the attributes of specific PT system designs.

PT system attributes that affect the likelihood of corrosion damage during the service life of a bridge are considered, such as tendon profile, alignment and protection, the surrounding environment, and quality processes used during construction. The consequences of corrosion damage resulting in tendon failure are considered in terms of structural reliability, ease of tendon replacement and the overall importance of a bridge.

"NDT Investigation of PT Ducts," David Corbett, Technical Session Paper, *PTI Journal*, Vol. 14, No. 2, December 2018.
https://www.post-tensioning.org/Portals/13/Files/PDFs/Publications/Reprints/2018_December/PJ2018_V14_N2_Corbett.pdf
From the technical session paper: Nondestructive investigation of PT ducts is a challenging task, but modern technology is making it possible. Both ground-penetrating radar (GPR) and ultrasonic pulse echo (UPE) technology can be used for this purpose.

There are two major tasks that need to be addressed. The first is the location of the PT duct. This is the easier of the two and both GPR and UPE can be used for this purpose. The second is to detect grouting defects within the duct that can lead to corrosion and eventually failure of the PT cable. This is not so straightforward, but we will see that UPE can be used for this purpose successfully.

Contacts

CTC engaged with the individuals below to gather information for this investigation.

State Agencies

Alaska

Leslie Daugherty
Chief Bridge Engineer
Alaska Department of Transportation and Public Facilities
907-465-8891, leslie.daugherty@alaska.gov

Arizona

David Benton
State Bridge Engineer
Arizona Department of Transportation
602-712-7910, dbenton@azdot.gov

Arkansas

Charles "Rick" Ellis
Division Head, Bridge
Arkansas Department of Transportation
501-569-2361, charles.ellis@ardot.gov

Colorado

Jacob O'Brien
Bridge Portfolio Manager
Colorado Department of Transportation
303-757-9763, jacob.obrien@state.co.us

Idaho

Mike Johnson
State Bridge Engineer
Idaho Transportation Department
208-334-8487, michael.johnson@itd.idaho.gov

Kansas

Dominique N. Shannon
State Bridge Design Engineer
Kansas Department of Transportation
785-207-1346, dominique.shannon@ks.gov

Minnesota

Edward Lutgen
State Bridge Engineer
Minnesota Department of Transportation
651-398-7082, edward.lutgen@state.mn.us

Missouri

Bryan Hartnagel
State Bridge Engineer, Bridge Division
Missouri Department of Transportation
573-751-0267, bryan.hartnagel@modot.mo.gov

New Hampshire

John Stockton
In-House Design Chief, Bureau of Bridge Design
New Hampshire Department of Transportation
603-271-7403, john.g.stockton@dot.nh.gov

New Mexico

Jeff C .Vigil
Bridge Management Engineer, Bridge Bureau
New Mexico Department of Transportation
505-490-2699, jeff.vigil@dot.nm.gov

Ohio

Sean Meddles
Administrator, Office of Structural Engineering
Ohio Department of Transportation
614-466-2464, sean.meddles@dot.ohio.gov

Oklahoma

Walter Peters
Assistant Bridge Engineer, Maintenance
Oklahoma Department of Transportation
405-834-3769, wpeters@odot.org

Oregon

David Dobson
Structural Materials Engineer, Structure Services
Oregon Department of Transportation
971-900-7118, david.dobson@odot.oregon.gov

Scott D. Nelson
Structure Services Engineer
Oregon Department of Transportation
503-986-3056, scott.d.nelson@odot.oregon.gov

Pennsylvania

Joe Bracken III
Chief Structural Materials Engineer, Structural Materials Division, Bureau of Bridge
Pennsylvania Department of Transportation
717-787-1566, jbrackenii@pa.gov

South Carolina

Terry Koon
Structural Design Support Engineer
South Carolina Department of Transportation
803-737-4814, koontb@scdot.org

South Dakota

Steve Johnson
Chief Bridge Engineer
South Dakota Department of Transportation
605-295-1313, steve.johnson@state.sd.us

Texas

Seth Cole
Bridge Division Construction and Maintenance Branch Manager
Texas Department of Transportation
512-416-2150, seth.cole@txdot.gov

Washington

Anthony Mizumori
Bridge Engineer, Concrete Specialist
Washington State Department of Transportation
360-561-9954, anthony.mizumori@wsdot.wa.gov

Wisconsin

Aaron Bonk
Chief Structures Design Engineer, Bureau of Structures
Wisconsin Department of Transportation
608-261-0261, aaron.bonk@dot.wi.gov

Appendix A: Survey Questions

The online survey represented below was distributed via email to the member list of AASHTO Committee on Bridges and Structures and other selected contacts.

Caltrans Survey on Plastic Ducts in Prestressed Concrete

The California Department of Transportation (Caltrans) typically uses galvanized metal ducting when constructing post-tension bridges. However, the lack of airtightness of ferrous metal duct and other material characteristics of metal ducting make it challenging in the construction process. To resolve the issues associated with traditional cast-in-place prestressed box girder bridge construction and post-tensioned spliced precast girder bridge construction, Caltrans is investigating the use of plastic as an alternative ducting option for internal post-tensioning.

The survey below is seeking information about your agency's experience and practices with plastic ducting to inform the adoption of an alternative to Caltrans' current specification for metal ducting in prestressed concrete. We estimate the core survey will take 15 to 20 minutes to complete. In addition, the questions that are marked optional could take up to an additional 15 minutes if you choose to respond to these questions. We would appreciate receiving your responses by Tuesday, August 19.

If someone else in your agency would be more appropriate to address questions related to this issue, please forward this survey to that person.

The final report for this project, which will include a summary of the responses received from all survey participants, will be available on the Caltrans website.

If you have questions about completing the survey, please contact Carol Rolland at carol.rolland@ctcandassociates.com. If you have questions about Caltrans' interest in this issue, please contact Tori Kanzler at tori.kanzler@dot.ca.gov.

Thanks very much for your participation.

(Required) Please provide your contact information.

Name:
Division/Title:
Agency:
Email Address:
Phone Number:

Note: Responses to the question below determined how respondents were directed through the survey.

(Required) Please identify the type of ducting your agency uses in both cast-in-place prestressed box girder bridge and post-tensioned spliced precast girder bridge construction.

- Both metal and plastic ducts. (Directed the respondent **to Reasons for Using Plastic Ducts** and the remaining sections of the survey.)
- Plastic ducts only. (Directed the respondent to **Reasons for Using Plastic Ducts** and the remaining sections of the survey.)

- Galvanized metal ducts only, but we are considering the use of plastic ducting in this application. (Directed the respondent to **Considering the Use of Plastic Ducting in Bridge Construction** and **Wrap-Up**.)
- Galvanized metal ducts only. (Directed the respondent to **Wrap-Up**.)

Reasons for Using Plastic Ducts

Please rate the importance of the factors below that may contribute to the decision to use plastic ducts in cast-in-place prestressed box girder bridge and post-tensioned spliced precast concrete bridge construction using the rating scale of extremely important to not at all important.

- Cost
- Dent and puncture resistance
- Increased corrosion resistance of prestress system
- Installation process
- Project-specific need
- Reduced friction factor

Bridge Design

1. Please briefly describe the **design efficiencies** your agency has observed in its implementation of plastic ducting.
2. Please briefly describe the **design drawbacks** your agency has observed in its implementation of plastic ducting.
3. Are **laboratory testing requirements** greater with plastic ducting than with metal ducting?
    - No
    - Yes

3A. *Optional* – If answered yes, please briefly describe these requirements.

4. Has the use of plastic ducting resulted in **increasing the stem width** for box girder bridge designs?
    - No
    - Yes

4A. *Optional* – If answered yes, please briefly describe the increased stem width.

5. Has the use of plastic duct **decreased the amount of prestress strand** needed to meet the design requirements due to change in duct friction?
    - No
    - Yes

5A. *Optional* – If answered yes, please briefly describe this decrease.

6. Has the use of plastic ducts resulted in the **use of more ducts per girder** due to increased wall thickness over metal duct?
    - No
    - Yes

6A. *Optional* – If answered yes, please briefly describe this issue.

7. Has your agency tried a **combination of metal and plastic ducting on the same project**?
    - No
    - Yes

7A. *Optional* – If answered yes, please briefly describe the project.

8. Has your agency taken any **additional measures** in case of excessive heat from a potential fire, especially at the high and low points of the duct path?
    - No
    - Yes

8A. *Optional* – If answered yes, please briefly describe these measures.

9. Has your agency established construction specifications, policies or guidance for using plastic ducting?
    - No
    - Yes (Please provide links to these specifications or policies. Send any files not available online to carol.rolland@ctcandassociates.com.)

Construction and Installation

1. In your agency's experience, which type of ducting is **easier to use**? Select one response.
    - Plastic ducting
    - Metal ducting
    - No preference

1A. *Optional* – Please briefly explain your response.

2. In your agency's experience, which type of ducting is **more durable**? Select one response.
    - Plastic ducting
    - Metal ducting
    - No preference

2A. *Optional* – Please briefly explain your response.

3. In your agency's experience, does plastic ducting **damage** easily?
    - No
    - Yes

3A. *Optional* – If answered yes, please briefly describe any issues with damage.

4. In your agency's experience, does plastic ducting **crack** easily?
    - No
    - Yes

4A. *Optional* – If answered yes, please briefly describe any issues with cracking.

5. Has your agency experienced issues with **slipping** when using plastic ducting?
    - No
    - Yes

5A. *Optional* – If answered yes, please briefly describe these issues.

6. Has your agency experienced **duct movement** during concrete placement due to the characteristics of plastic over metal?
    - No
    - Yes

6A. *Optional* – If answered yes, please briefly describe the movement.

7. Has your agency had trouble in performing **field repairs** on damaged ducting after placed in the structure?
    - No
    - Yes

7A. *Optional* – If answered yes, please briefly describe the issues.

8. Please briefly describe your agency's experience or concerns with the following considerations when using plastic ducting:
    - Friction coefficient
    - Shear strength/behavior in girders
    - Thermal expansion
    - Void detection
    - Wear resistance
9. Has your agency experienced any other constructability issues?
    - No
    - Yes

9A. *Optional* – If answered yes, please briefly describe these issues.

10. Has using plastic ducting impacted your agency's **construction practices**?
    - No
    - Yes

10A. *Optional* – If answered yes, please briefly describe these impacts.

<u>Cost Considerations</u>

1. Has your agency conducted a **cost comparison** between metal ducting and plastic ducting?
    - No
    - Yes

1A. *Optional* – If answered yes, please briefly describe the results of the comparison.

2. Has using plastic ducting resulted in **cost savings** for your agency?
    - No
    - Yes

2A. *Optional* – If answered yes, please briefly describe the savings.

<u>Additional Benefits</u>

1. Has using plastic ducting resulted in **a reduction in greenhouse gas emissions**?
    - No
    - Yes

1A. *Optional* – If answered yes, please briefly describe these reductions.

2. Has using plastic ducting resulted in **other environmental gains**?
    - No
    - Yes

2A. *Optional* – If answered yes, please briefly describe these gains.

3. Has using plastic ducting produced any **advantages for contractors**?
    - No
    - Yes

3A. *Optional* – If answered yes, please briefly describe these advantages.

4. Please describe any **other benefits** of using plastic ducting.

Assessment

1. What **successes** has your agency observed in the implementation of plastic ducting?
2. What **drawbacks** has your agency experienced with using plastic ducting?
3. Please share any **best practices** for using plastic ducting.
4. Please describe any **lessons learned** when your agency began implementing plastic ducting in its projects.
5. Please provide links to documents associated with your agency's use of plastic ducting other than those already provided. Send any files not available online to carol.rolland@ctcandassociates.com.

Considering the Use of Plastic Ducting in Bridge Construction

1. Please briefly describe the activities your agency is considering regarding the use of plastic ducting in both cast-in-place prestressed box girder bridge and post-tensioned spliced precast girder bridge construction.
2. What is needed for your agency to begin implementing plastic ducting?
3. When do you anticipate your agency will adopt plastic ducting as an alternative material in bridge construction?

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.