Adaptability Through Replaceable Post-Tensioning

by Reggie Holt, Federal Highway Administration

There is great interest within the concrete bridge community regarding promising technologies that provide bridge owners the ability to address unanticipated issues with their in-service bridges. Post-tensioning (PT) technologies have shown great promise in being able to address such unanticipated in-service issues as increased dead load, increased live load, poor in-service PT tendon performance, unforeseen deflections, and structural distress.

Several available PT technologies can provide supplemental structural resistance to in-service bridges to address these unanticipated issues. This article will focus on PT technologies applied to external PT systems, such as the typical external PT tendons in a concrete box girder (**Fig. 1**).

Figure 1. Typical external post-tensioning tendons in a box girder. Photo: Teddy Theryo.

Provisional/Future Post-Tensioning

Bridge engineers have always valued techniques and strategies that address unforeseen issues. Since the first edition, the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] have included requirements to provide provisional or extra prestressing force to compensate for unexpected prestress losses during construction and future dead loads as well as to control cracking and deflections. In the current edition of the AASHTO LRFD specifications, these provisions appear in Article 5.12.5.3.9.[2] This supplemental prestressing force is typically provided by installing supplemental, unused PT tendon anchorages and deviators to allow installation of additional PT tendons during the bridge's service life. However, the prescribed minimum level of future prestressing force (10% of the primary positive- and negative-moment PT force) may be insufficient to address future needs. In addition, in many instances, the future PT tendons are located in structurally inefficient locations due to the limited area available within the structure's cross section.

External Replaceable PT Tendon Details

In the United States, interest in fully replaceable PT systems is a fairly recent trend, although the technology has been used in other countries for decades. These replaceable systems can be designed to allow tendon detensioning, force adjustment, and full or partial replacement. **Table 1** shows replaceable tendon requirements in four countries.

Replaceable external tendons are not bonded to the concrete at any location along the length of the tendon. Forces from the PT tendon are transferred to the superstructure by bearing plates at the anchorages and bearing of the tendon duct against the concrete at the diaphragms and deviators. **Figure 2** shows a replaceable external tendon that uses the double-envelope concept, where the anchorage and duct hardware pass through guide pipes and diabolos, so they are not bonded to the structure and can be replaced. The details for the fully replaceable tendon allow easy removal due to the outer isolating envelope provided by the guide pipes and diabolo void, which eliminates concrete encasement of the tendon anchorage and deviator components.

There are variations on the concept shown in Fig. 2. The tendon can be filled with either a cementitious grout or flexible filler material, typically wax or grease. One advantage to the use of flexible fillers is that the tendon prestressing force can be detensioned and/or adjusted. However, adjustable tendons will require a nonstandard anchorage, typically with threaded heads. Detensionable tendons also require the strands of the tendon to extend past the wedge plate

Table 1. External Tendon Requirements in Selected Countries

Country	Detensionable	Replaceable	Adjustable
France	✓	✓	
Germany	✓	✓	✓
Japan		✓	
United States		✓*	

*Florida and Virginia.

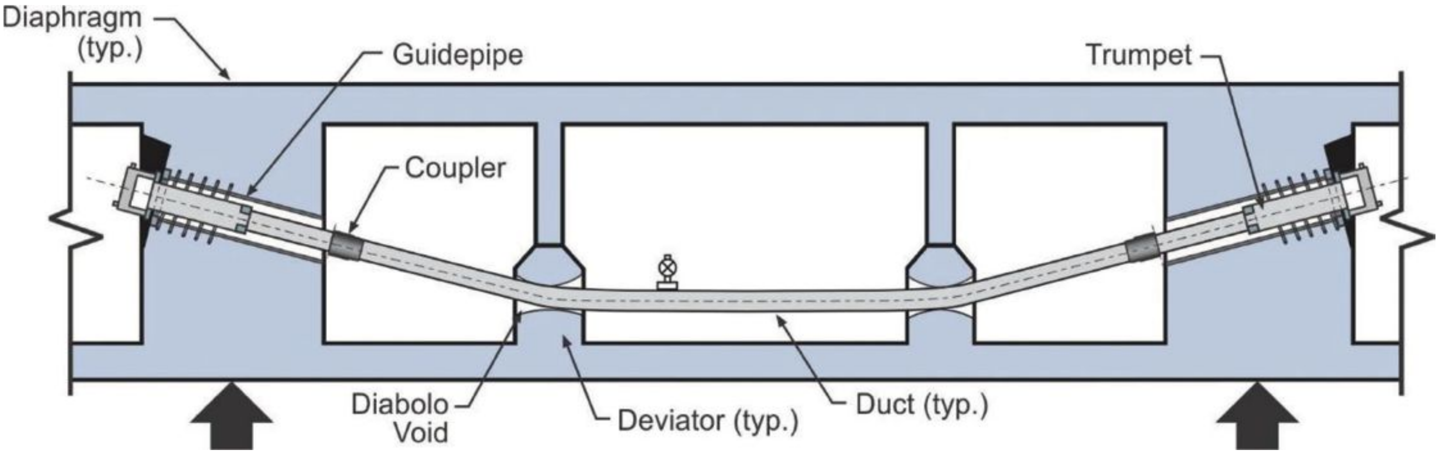
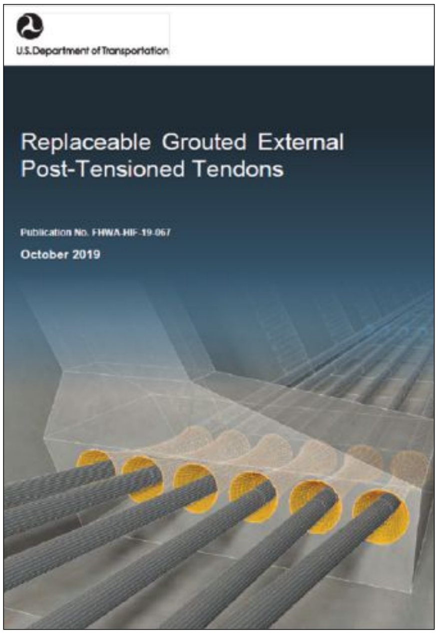


Figure 2. Replaceable external tendons using the double-envelope concept. Figure: WSP.

Figure 3. External tendons using epoxy-coated strands in a box girder. Strands are not enclosed in a duct except where they pass through diaphragms. Photo: Sumiden Wire.



The Federal Highway Administration's *Replaceable Grouted External Post-Tensioned Tendons* guidance document. Figure: Federal Highway Administration.

for a greater than typical length to provide sufficient length to "regrip" the strand. Experience in Europe has shown that removal of a replaceable grouted tendon may be more cost effective than removal of a tendon protected with a flexible filler because effort is required to extract and clean out the flexible filler.

Another replaceable external PT tendon concept slightly different from what is shown in Fig. 2 uses epoxy-coated prestressing strands (see the Concrete Bridge Technology article in the Spring 2020 issue of *ASPIRE*®). The epoxy coating provides a robust layer of protection, which eliminates the need to encase the prestressing strands in a duct and filler material. **Figure 3** shows a replaceable external tendon using epoxy-coated strands.

One significant advantage of the replaceable PT technologies mentioned here is that they can be designed to provide a larger replacement prestressing force, which could provide future benefit when addressing unanticipated issues.

Additional Information

In many bridges, PT tendons provide a significant portion of the load-carrying capacity. Consequently, there is great interest in ensuring that PT tendons perform well during the structure's service life and have the flexibility to address unanticipated in-service issues. Innovative PT technologies that allow removal, adjustment, and addition of prestressing force can offer great value.

To provide the bridge community with information on promising replaceable PT tendon technologies, the Federal Highway Administration (FHWA) has developed a guidance document on external grouted replaceable PT tendons,[3] which is available on the FHWA Concrete Bridges web page. In addition, a video describing the replaceable PT tendon technology is available on YouTube.[4]

References

1. American Association of State Highway and Transportation Officials (AASHTO). 1994. *AASHTO LRFD Bridge Design Specifications*, 1st ed. Washington, DC: AASHTO.
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3. Federal Highway Administration (FHWA). 2019. *Replaceable Grouted External Post-Tensioned Tendons.* FHWA-HIF-19-067. Washington, DC: FHWA. https://www.fhwa.dot.gov/bridge/concrete/hif19067.pdf.
4. FHWA. 2018. *Bridge Technology Series: Replaceable Grouted External Post-Tensioned Tendons.* YouTube video, posted September 2018. https://www.youtube.com/watch?v=N3j8ATiqcAs&index=1&list=PL5_sm9g9d4T3ymcxjfVEdYnd2-Hj-Fozl&t=0s.