IMPROVED PERFORMANCE USING CORRUGATED PLASTIC DUCT IN TIGHT-RADIUS POST-TENSIONING APPLICATIONS

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Abstract

Corrugated plastic duct is used in post-tensioning applications worldwide, corrosion protection being one of its primary functions. This includes protection of tendon enclosures and prevention of concrete spalling and deterioration due to expansion of corroding elements (metal/galvanized duct). Using corrugated plastic duct, also, eliminates the corrosion potential of highly stressed post-tensioning steel in contact with galvanized metal.

Typically, corrugated plastic duct is used along the entire length of the tendon from anchorage to anchorage. However, as design and construction of structures becomes more proficient, there is additional demand for post-tensioning tendon profiles to be more severe. This occurs as tendons exit the structure into anchorage blisters or external tendons are deviated at high and low points.

Specially formulated composite materials allow corrugated plastic duct to be used for tight-radius post-tensioning applications such as anchorage blisters and deviators. Required testing conforming to Fédération International du Béton (fib) Bulletin 7[1] must be achieved.

This paper will examine testing requirements of corrugated plastic duct per fib Bulletin 7[1]; discuss how new material blends allow plastics to meet fib Requirements; provide examples of how corrugated plastic duct may be used in tight-radius applications; and discuss advantages of using corrugated plastic duct in tight-radius applications.

Keywords: Post-tensioning, corrugated plastic duct, anchorage blisters, deviators, tight-radius duct

1 Tight-Radius Post-Tensioning Applications

In post-tensioned structures, several applications have tendon profiles that require tighter radii than might normally occur. These include anchorage blisters (see **Fig. 1**), deviators for use with external tendons (see **Fig. 2**), and radical high-points or horizontal curves. Corrugated plastic duct is used in post-tensioning applications worldwide – its primary function is corrosion protection of tendon.

What is tight-radius corrugated plastic duct? It is corrugated plastic post-tensioning duct that can be bent to a tight radius while still achieving wear resistance requirements through the use of specially formulated, proprietary composite, high-performance materials.

Why use tight-radius corrugated plastic duct? It is light-weight and made of corrosion resistant materials with superior bonding properties; it prevents concrete spalling and deterioration due to expansion of corroding elements (metal or galvanized metal duct; and it eliminates the stress corrosion potential between highly stressed post-tensioning strand and galvanized metal.

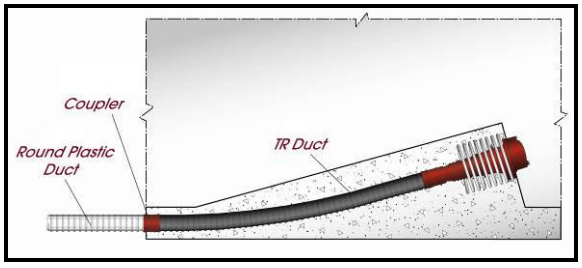

Fig. 1 Anchorage Blister

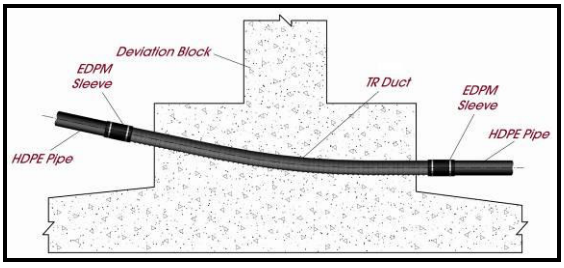

Fig. 2 External Tendon Passing Through Concrete Deviation Block

2 Corrugated Plastic Duct

fib Bulletin 7[1] was published in 2000 and contains standards for testing of corrugated plastic duct. Until its publication there were no standard performance requirements and inadequate materials were sometimes used giving plastic duct a flawed performance and quality reputation. Currently, high quality products are being manufactured and used on post-tensioning projects. Designers and owners who are utilizing corrugated plastic duct are encouraged to require all duct be tested and affirmed to meet the requirements of *fib* Bulletin 7[1].

The minimum bend radius of duct is defined as the minimum allowable curve a tendon can have while the duct wall maintains at least a specified thickness during stressing due to wearing of prestressing steel on the duct. This is important because maintaining continuity of tendon enclosures without gaps or breaches that could possibly allow contaminants to enter the tendon is critical to the overall durability of a structure. Prestressing steel typically wears on the duct at points of tendon curvature. Individual tendons within a structure may have different radii at each point of curvature. Corrugated plastic duct should be manufactured and tested for the most severe curve (tightest radius) that it may be used on. Each corrugated plastic duct manufacturer typically declares a minimum bend radius for their standard duct. This number varies based upon the specific material formulations that the manufacturer uses and varies with the minimum remaining wall thickness confirmed by testing.

Corrugated plastic duct is subjected to the following performance tests: flexural behavior, flexibility, lateral load resistance, longitudinal load resistance, leak tightness, wear resistance, and bond behavior. All the tests are important for different reasons. Some tests only check duct performance while others also include duct-to-duct connections. Designers and owners may demand more stringent tests and/or acceptance criteria – project-specific specifications should always be evaluated.

Tight-radius corrugated plastic duct is typically manufactured using the same profile as standard corrugated plastic duct – the difference being specially formulated composite materials that allow better performance in tight-radius applications. Wear resistance performance testing is critical for tight-radius applications since it confirms that the duct can sufficiently resist wear caused by prestressing steel during stressing when bent to the specified minimum radius.

Annex 7 of fib Bulletin 7[1] describes the process of testing for wear resistance of duct. Acceptance criteria for remaining wall thickness after wear resistance of duct testing per *fib* Bulletin 7[1] is 1 mm for all sizes while FDOT Specifications[2] call out 1.5 mm for duct up to 85 mm and 2.0 mm for duct larger than 85 mm. **Tab. 1** shows current published minimum bend radius for General Technologies, Inc. TR Duct.[3]

Tab. 1 Recommended Minimum Bend Radii (MBR) for Tight-Radius Corrugated Duct.

	48 mm	59 mm	76 mm	85 mm	100 mm	115 mm	130 mm	130 mm
Quantity of 15.2 mm Strands	5	7	12	15	19	27	31	37
MBR for GTI TR Duct (m)	2.4	3.0	3.1	3.7	3.8	4.2	4.3	4.9

Table Notes:
1. Data for GTI TR Duct was found in *GTI TR (Tight-Radius) Corrugated Plastic Duct* Flyer[3].
2. GTI TR Duct minimum radii based upon 1.5 mm residual wall thickness.

3 Anchorage Blisters

Internal post-tensioning tendons are often anchored at intermediate locations within a structure. Anchorage blisters allow access for tendon installation and stressing. In segmental construction, anchorage blisters are used to install and stress longitudinal tendons thus not impeding or delaying erection of the structure. **Fig. 1** shows a sketch of a tendon exiting the structure at an anchorage blister.

Typically, corrugated plastic duct is used along the entire length of the tendon from anchorage to anchorage. The tendon exiting the structure through an anchorage blister generally must be bent to a tighter radius than anywhere else in the structure. In addition, during stressing, the prestressing steel will elongate the greatest at the anchorage thus wear-through of duct is of prime importance. As design and construction of structures becomes more proficient, there is additional demand for post-tensioning tendon profiles to be more severe at anchorage blisters. Designers must require that the bend radius of corrugated plastic duct at this location be performance tested per *fib* Bulletin 7[1] and FDOT Specifications[2] as appropriate.

Using tight-radius corrugated plastic duct at anchorage blisters maintains integrity of the tendon enclosure thus ensuring the protection required by owners, designers, and codes. Connections of tight-radius corrugated plastic duct to anchorages and duct-to-duct connections are the same as used with standard corrugated plastic duct so there are no additional connections required.

4 External Tendon Deviators

External post-tensioning tendons are popular in bridge structures. In many cases, there use allows the concrete section of bridges to be more slender with less concrete. External tendons in bridge structures are typically profiled passing through concrete diaphragms at each change of direction. **Fig. 2** shows a graphical depiction of a tendon passing through a concrete diaphragm.

The use of tight-radius corrugated plastic duct for deviation points on external tendons provides many benefits to contractors, designers, and owners. It allows the use of light-weight, corrosion resistant materials that are easy to transport, handle, and install. It bonds to the concrete diaphragm like an internal post-tensioning tendon. It eliminates corrosion potential between highly stressed post-tensioning strand and galvanized metal pipe. Radii are pre-applied to tight-radius corrugated plastic duct prior to shipment and can be applied in multiple directions. It allows an easy orientation fix if incorrectly placed in concrete (procedure is provided by manufacturer). It provides significant cost savings against both galvanized metal pipe and diabolos. [3]

5 Radical High-Points or Horizontal Curves

Tight-radius corrugated plastic duct is an excellent choice when tendons pass through a radical high-point or horizontal curve similar to anchorage blisters. When post-tensioning tendons'

profiles have radii beyond the capabilities of standard plastic duct, an alternative enclosure must be substituted. In order to maintain the corrosion protection requirements, tight-radius corrugated plastic duct should be used rather than metal flex duct or metal pipe. Performance testing of the tight-radius corrugated plastic duct should be completed for the minimum bend radii per *fib* Bulletin 7[1] and FDOT Specifications[2].

6 Conclusions

Tight-radius corrugated plastic duct is an exceptional selection for tight-radius post-tensioning applications such as anchorage blisters, external tendon deviation points, and radical high-points or horizontal curves. Tight-radius corrugated plastic duct maintains the corrosion protection of the tendon enclosure and has the same bonding capabilities as standard plastic duct. There is no possibility of concrete spalling and deterioration due to expansion of corroding elements as with metal/galvanized duct or metal pipe. Use of corrugated plastic duct (standard or tight-radius) eliminates any corrosion potential between prestressing steel and galvanized metal.

Wear resistance of tight-radius corrugated plastic duct should be confirmed for the minimum bend radii it will be used in. Performance testing should be per *fib* Bulletin 7[1] and FDOT Specifications[2] as appropriate. Tight-radius corrugated plastic duct is typically manufactured using the same profile as standard corrugated plastic duct thus duct-to-duct and duct-to-anchorage connections are the same.

The benefits of tight-radius corrugated plastic duct are many. Specially formulated, proprietary composite, high performance materials allow light-weight, corrosion resistant post-tensioning duct for tight-radius post-tensioning applications that is easy to transport, handle, and install. Pre-bending with multi-directional bends is achievable so tight-radius corrugated plastic duct is ready to install when it reaches the jobsite. And best-of-all, tight-radius corrugated plastic duct provides significant cost savings when compared to other alternatives.

References

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[3] "GTI TR (Tight-Radius) Corrugated Plastic Duct" Flyer, General Technologies, Inc., Stafford, TX, 2010.

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