NEW SEGMENTAL DUCT COUPLER FOR POST-TENSIONING TENDONS

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General Technologies, Inc. (GTI) has developed a new coupler for post-tensioning ducts at precast concrete segment connections. Coupling post-tensioning tendons at segment joints has long been a concern of the industry. Now there is a coupler that has been developed after years of research, listening to industry advocates, and working with post-tensioning companies. The GTI Precast Segmental Duct Coupler® improves quality of construction by adapting high performance materials and concepts to the specialized needs of the segmental bridge industry.

GTI developed a revised concept for the GTI Precast Segmental Duct Coupler® during 2006-2007. Their development and testing program was accelerated by the urgency of providing the duct coupler in early 2008 for the SR 9 (I-95)/SR 9A (I-295 North) Interchange Project, Jacksonville, FL. This paper will describe how this was successfully accomplished.

BACKGROUND

The bridge industry for years has been looking for a coupler that would maintain the integrity of the tendon across the joint while allowing easy installation and construction techniques. The GTI Segmental Coupler achieves those goals. Some of the industry performance requirements for corrosion protection, durability, and constructability of a segmental duct coupler are:

1. Create an air and water-tight connection at the most vulnerable location in the tendon – the segment joint.
2. Epoxy does not leak through the segmental couplers or attachments.
3. The segmental duct coupler maintains the integrity of the post-tensioning tendon duct for grouting purposes.
4. The segmental duct coupler can accept angles up to 15 degrees in any direction at the segment joint to maintain tendon alignment.
5. Variance in duct alignment from segment to segment of up to 1/4 inch (6mm) in any axis.

The Florida Department of Transportation (FDOT) is the leader in developing requirements and specifications for duct and grouting. Their experiences have proven that in precast segmental construction there is a need for protection of the post-tensioning tendon through the segment joint. Their Post-Tensioning Specification, FDOT Section 462-4.2.5.5.3 Corrugated Duct Connections and Fittings states in the third paragraph:

> "For post-tensioned systems intended for use with segmental constructed box girder bridges, the post-tensioning system shall include duct couplers at the segment joints. The tendon duct coupler located at the segment joint shall be mounted perpendicular to the bulkhead and designed to receive a duct at an angle of 6 degrees deviation from perpendicular. The coupler must be able to accommodate angular deviation of the duct without the tendon strands touching the duct or coupler on either side of the segment joint."

Within the FDOT Post-Tensioning Specification (FDOT 462) is testing criteria for segmental duct couplers. FDOT's Certification Program requires independently certified test reports to confirm that their testing criterion has been achieved. FDOT Section 462-4.2.7.3 Internal Duct System Test Parameters states in the second paragraph:

> "Test the coupler for proper function by casting the coupler into a two part concrete test block using match cast techniques. Use blocks that are at least 12 inches x 12 inches x 12 inches. After the concrete has hardened, pull the blocks apart and clean the surface of any bond breaker materials. Using an external apparatus clamp the blocks together and maintain 40 psi pressure on the block cross-section during the pressure test. Do not apply epoxy between the blocks for this portion of the test. Pressurize the duct within the test block to 5 psi and lock-off the outside air source. The assembly must sustain a 5 psi internal pressure for five minutes with no more than a 0.5 psi reduction in pressure. Separate the duct coupler blocks from the duct system remove the clamping device and place a 1/16 inch layer of epoxy on the face of both blocks, clamp the blocks together and maintain a pressure of 40 psi on the block cross-section for 24 hours. Upon removal of the clamping force, demolish the blocks. The coupler and the attached ducts should be intact and free of epoxy, and properly attached without crushing, tearing or other signs of failure."

TESTING PROGRAM

GTI began a comprehensive testing program during the months leading up to the SR9 (I-95)/SR 9A (I-295 North Interchange Project. This testing program not only included the functionality testing required by FDOT; it also included materials testing to meet specific FDOT requirements.

Materials Testing - GTI Gasket

FDOT calls out specific material requirements in FDOT Section 462-4.2.6.2 for the "segment seal assemblies for large diameter compression seals, used to couple ducts at segment joints" – in this case the GTI Gasket. These requirements are in addition to their "O-ring material" requirements.

The actual material used to make the gasket is derived from several sources. It is up to the manufacturer (GTI) to select material that will meet the required performance specification. Many discussions took place with different suppliers to develop the performance specifications. The FDOT Performance Specification follows:

> Furnish standard O-ring material conforming to the following requirements:
>
> **Mechanical Properties**
> Shore hardness, A ASTM D2240 30-40
> Ultimate elongation %, ASTM D412 .... 250 % Min.
> Tensile strength, ASTM D412 .... 600 psi Min.
> **Accelerated Testing**
> Thermal Deterioration 70 hours @ 257° F, ASTM D573
> Change in tensile strength .... ± 30 %
> Change of elongation .... -50 %
> Change of hardness. .... ± 15 points
> Compression Set Method B 22 hours @257° F, ASTM D395 .... 60 %
> Volume change due to absorption of H2O, Method D, for 70 hours
> @ 212° F, ASTM D471 ....+ 10 %
> **Environmental Resistance**
> Ozone Resistance Exposure Method B, ASTM D1171 ....Pass
> Low Temp. Non-brittle after 3 Min. @ -40° F, ASTM D2137..................Pass

After several iterations of testing, the optimum material was selected. This material was then verified for suitability by independent testing at a qualified laboratory.

FDOT Section 462-4.2.6.2 also has the following additional requirements for the O-ring (GTI Gasket):

> "**Compression Force -** The maximum force to compress the O-ring to its final compressed position shall not be greater than 25 psi times the area encircled by the O-ring.
> **Voided Area -** The seal shall be designed to accommodate the material flow within its own cross sectional area by using a hollow or voided design.
> **Mounting Assemblies -** Assemblies holding the O-ring must mount to the form bulkhead and provide for duct alignment."

The "compression force" requirement noted above is proven during functionality testing while the "voided area" and "mounting assemblies" are part of product design.

Functionality Testing

Product design and functionality testing go hand in hand. As the design of a product evolves it must be sequentially tested to confirm that it will function as required at various stages. When the product does not achieve the desired results, an analysis to determine the cause is performed after which potential solutions are developed and an improvement strategy is implemented. This process will be re-cycled until the desired results are achieved.

GTI went through numerous iterations of product design during the testing phase; interfacing what was learned at various stages of testing into the product. Industry performance requirements were always defined as the preferred state. Cost affects of product changes both in product manufacture and jobsite efficiencies is also of prime importance to the overall development.

The functionality testing was divided into four stages as follows:

1. Match casting of 12 inch (300mm) concrete cubes containing the bulkhead element and the match cast element.
2. Testing that the GTI Gasket would compress to its final condition with a force not greater than 25 psi (170 kPa) times the area encircled by the GTI Gasket.
3. Air pressure testing of connection without epoxy by clamping the match cast blocks together with 40 psi (275 kPa) pressure on the block cross-section and then pressurizing the duct to 5 psi (35 kPa) internal pressure for five minutes with no more than 0.5 psi (3.5 kPa) reduction in pressure.
4. Check that the coupler and ducts are intact and free of epoxy and no crushing, tearing, or other signs of failure occur with segment connection simulation. Apply 1/16 inch (1.5mm) layer of epoxy on the face of both blocks, clamp the match cast blocks together with 40 psi (275 kPa) pressure on the block cross-section for 24 hours, remove the clamping force, and demolish the blocks.

Stage 1 was simple and just consisted of casting concrete blocks. The dilemma here was that each time the design of the elements changed, new concrete blocks had to be cast. Figure 1 shows match cast concrete blocks used in one of the tests.

Figure 1: Match Cast Concrete Cubes

Stage 2 testing proves that the GTI Gasket will compress to its final condition without exceeding 25 psi (170 kPa) which is FDOT's requirements. In this test, a force of 25 psi (170 kPa) times the area encircled by the GTI Gasket is applied to the concrete blocks by clamping. No epoxy is applied. The force is removed after 5 minutes and the GTI Gasket is checked that it compressed to its final condition. Figure 2 shows this test in progress.

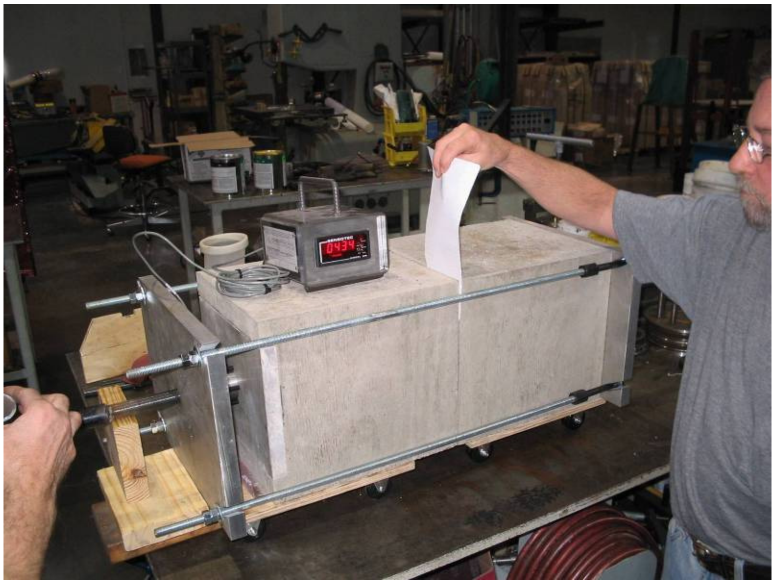

Figure 2: Testing of the GTI Gasket

Stage 3 testing is conducted after successful completion of the previous stages. The air pressure test is to confirm that all connections within the "tendon" will achieve the specified requirements. The connections being tested are duct to boot, boot to bulkhead element, bulkhead element to GTI Gasket, GTI Gasket to match cast element, match cast element to boot, and boot to duct. When this test is not successful, an analysis was performed to determine the cause and a solution was developed. Many times this required that testing return to Stage 1 or Stage 2. Figure 3 shows the blocks clamped together with 40 psi (275 kPa) pressure on the block cross-section and an internal air pressure of at least 5 psi (35 kPa).

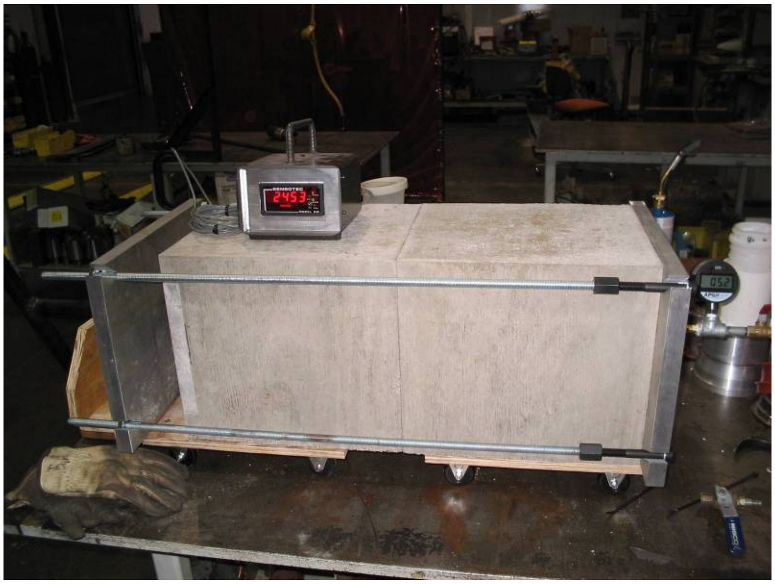

Figure 3: Air Pressure Test

Stage 4 testing confirms that the product will function properly when actual segment connection occurs. Simulation of segment erection/connection occurs by applying a 1/16 inch (1.5mm) layer of epoxy on the face of both blocks, clamping the match cast blocks together with 40 psi (275 kPa) pressure on the block cross-section, and holding the pressure for 24 hours. Then the blocks are demolished and the individual pieces (duct, boots, couplers, and gaskets) checked for performance. Figure 4 shows a match cast element after demolition; there is no epoxy ingress or crushing, tearing, or other signs of failure to the individual pieces.

Figure 4: Match Cast Block after Demolition

CONSTRUCTION PROCEDURES

Installation procedures for the segmental duct coupler must be available for construction site personnel. GTI held numerous discussions with various site personnel throughout the development stages. Of prime importance was the ability to maintain duct alignment through the segment joint during casting. This created an issue with the original “load plug” (attachment device) which was a solid piece. A “load plug” with a hole to pass a bladder or pipe was necessary.

In addition to construction concerns with the “load plug”, the bulkhead thickness plays an important role. Using plywood bulkhead forms requires a different thickness than using a metal bulkhead form. Therefore, different size “load plugs” will be required based upon the bulkhead material thickness. This will have to be identified early in the project so as not to delay shipments of the correct pieces.

GTI developed installation procedures concurrently with product design and testing. Confirming that what is designed will actually work on site was tasked to GTI’s Design and Field Services Departments. Installation procedures are complemented with Assembly Drawings to give the site personnel a visual as well as written content on how they should be installing the segmental duct coupler. Figure 5 shows jobsite instruction by DSI personnel on the SR9 (I-95)/SR 9A (I-295 North) Interchange Project.

Figure 5: Jobsite Instruction

ACTUAL PROJECTS

The SR9 (I-95)/SR 9A (I-295 North) Interchange Project, Jacksonville, FL was the first use of the optimized GTI Precast Segmental Duct Coupler. The project has 234 segments requiring 4708 76mm segmental duct couplers. The project needed segmental duct couplers by mid-January, 2008, when segment casting was to begin. Negotiations were held throughout the fall of 2007 with DSI, the post-tensioning supplier, and GTI was awarded the project mid-December, 2007. The several sizes of duct were proposed for this project and thus the segmental duct coupler size was only determined when the 76mm GTI Plastic Duct was selected.

The time frame of improving the segmental duct coupler was critical. GTI Staff worked constantly for four months during this development.

Since the SR 9/SR 9A project, the GTI Segmental Coupler was selected for the Danube River Bridge connecting Vidin, Bulgaria, to Calafat, Rumania. This bridge is 1,971 meters long and will accommodate road, rail and pedestrian traffic. For this project segmental couplers are being used for 100mm, 115mm and 130mm duct.

A similar coupler design has also been requested for the Bahrain-Qatar Causeway project currently being designed.

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