

CONCRETE BRIDGE CONFERENCE

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OVERVIEW OF RECENT DEVELOPMENTS IN THE GROUTING OF POST-TENSIONED TENDONS

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Recent developments in the United States have caused new emphasis on the quality of the grouting of post-tensioning tendons. This paper will discuss the problems and concerns found during inspections in different states and then discuss the improvements and enhancements that have resulted. The paper will summarize the current status of grouted post-tensioning tendons in different states and also give a recommendation on specifications; details; and materials to help ensure that future grouting is done properly.

Status of Post-tensioned bridges in the US

This information is prefaced with the fact that post-tensioned bridges are America's most durable bridges. A 1999 survey of Owners by Maurice Miller for ASBI showed that 99% of all post-tensioned concrete bridges had condition ratings of satisfactory or better. This is much better than any other bridge type including structural steel, timber and reinforced concrete bridges. This survey also included 187 concrete segmental bridges that have been built over the past 26 years in the US.

There are well over 1,000 bridges in the US that have post-tensioning. A conservative estimate of the number of tendons is 250 tendons per bridge for a total of 250,000 grouted tendons. To date, less than 10 tendons have been replaced due to corrosion failure- **a success rate of 99.996%**. However, the small number of defective tendons raised concerns in State DOTs ;with the FHWA and within the bridge design and construction industry. The goal of all of these parties is Zero defective tendons!

Many improvements have been implemented in the past two years to reduce the chance for defective tendons in the future and to increase the durability of post-tensioned bridges. These improvements will help post-tensioned bridges remain as the most durable bridges in America.

Problems Identified

Normal maintenance inspections of bridges has identified some defects in grouted post-tensioning tendons. This area was given extensive scrutiny and research by the Florida Department of Transportation and they are to be commended for taking a responsible lead in improving America's bridges. The FDOT Bureau of Structures has exhaustive information available on their web site as a resource for others.

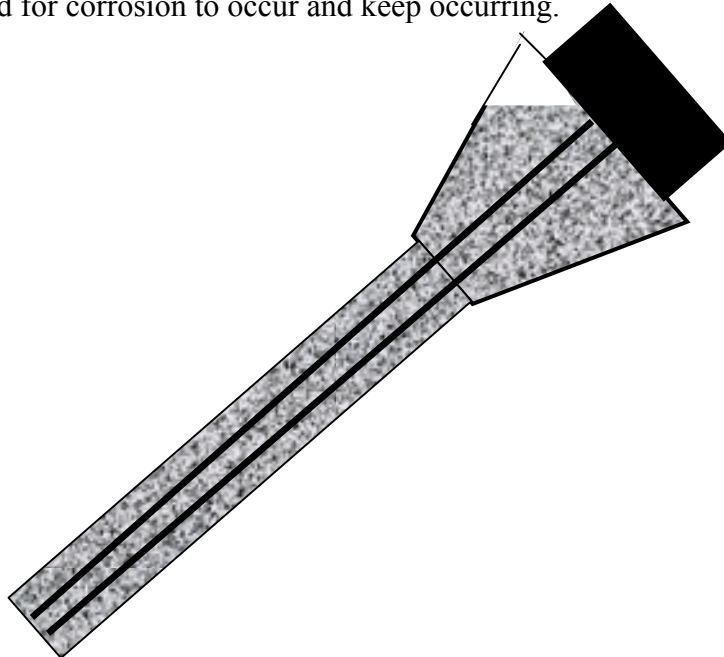
The two main problems found are:

- Corrosion in a Void
- Defective Polyethylene (PE) Duct

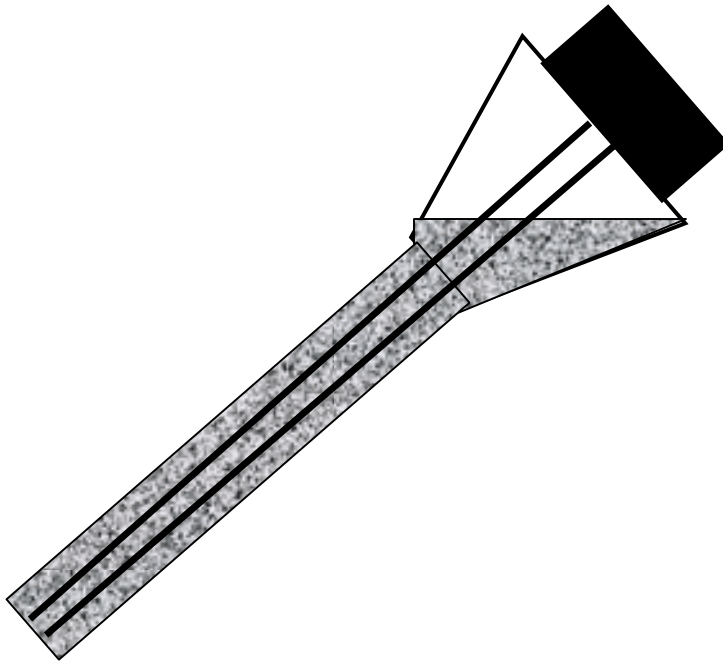
In all cases the problems found have been traced back to construction and material issues that have been resolved by the post-tensioned bridge industry. The actions that lead to resolution of these items are discussed later.

A key point to understand is that a void in a grouted tendon will not affect the durability of the tendon all by itself.

Dr. Randy Poston of Whitlock, Dalrymple, Poston & Associates serves on the PTI Grouting Committee and he has stated that voids are a result of air entrapped in grout and the subsidence of the grout. All post-tensioning will have voids due to the nature of how it is mixed and pumped into the tendons. Normally the voids are small. Voids by themselves will not cause corrosion- there must be a supply of water and oxygen that can be recharged for corrosion to occur and keep occurring.



The figure above depicts a small void in an inclined tendon. The air bubbles have risen to the top and formed a small void. No PT strands are exposed. This is the general case in post-tensioning tendons and has no durability concerns.

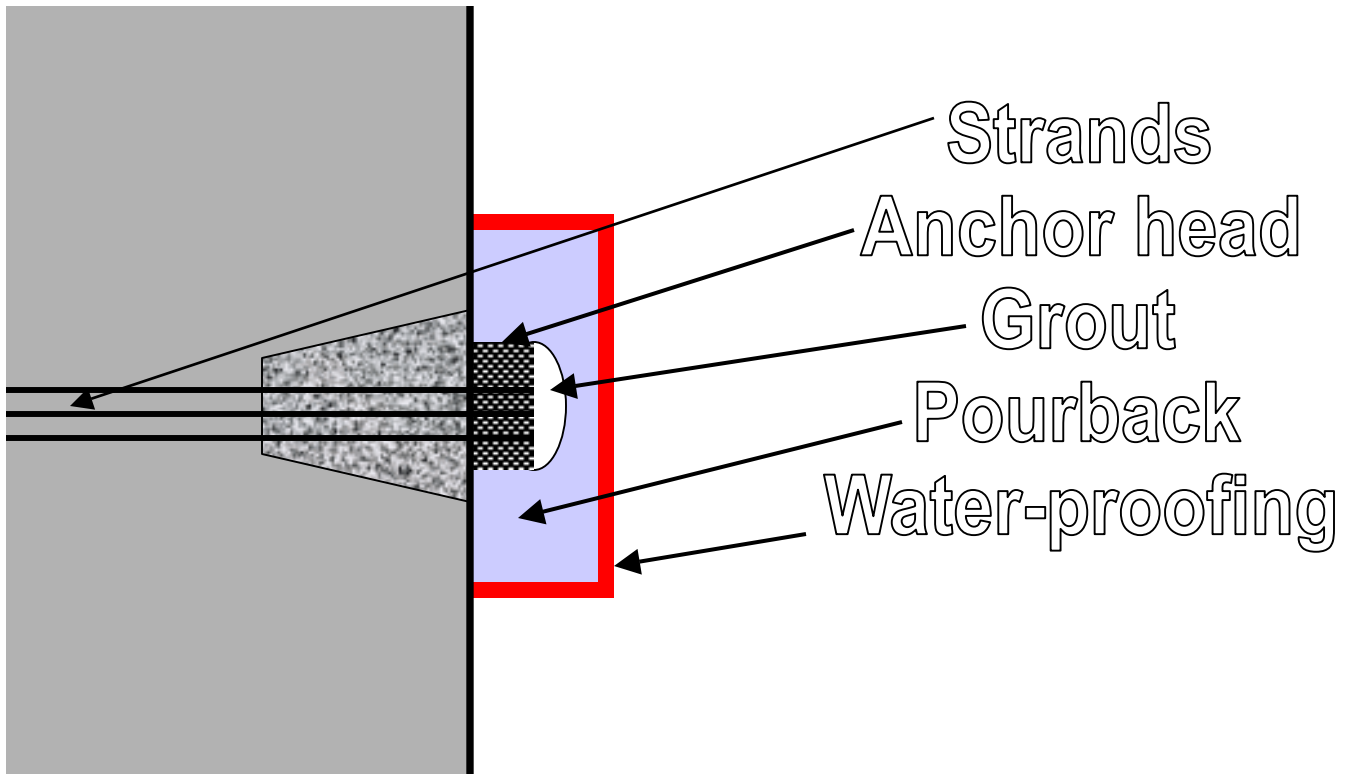


The figure above depicts a large void in an inclined tendon. The air bubbles have risen to the top and formed a large void due to the geometry of the tendon and/or poor grouting. PT strands are exposed. This is not the general case in post-tensioning tendons. This is undesirable but this will not cause corrosion unless there is a path to the void for air and water.

Voids by themselves do not cause corrosion. For corrosion to occur there must be a breach in the multiple layers of protection in the PT system. The multiple layers of the protection system include:

- Tendons inside the bridge
- Tendons inside a sealed duct
- Duct filled with grout

A critical area is the PT anchorage, which also has multiple layers of protection that must be constructed properly and maintained.



The figure above depicts the multiple layers of protection that should be provided at the PT anchorages. Recent improvements in specifications have been addressed that further enhance the end anchor protection. These will be discussed later.

A second problem that has been identified is defective duct material that has split over time. This would be a breach of the protection system for the tendon where the duct is external to the concrete. On several bridges the PE duct used for external tendons began splitting in some locations after 4 or 5 years. The FDOT was able to trace the problem to defective material. The material supplied to the Contractors was certified to meet the ASTM requirements of the specifications but when later tested it was found not to meet the specifications for key aspects which control the duct's durability over time. This problem has now been identified and resulting improvements in specifications will eliminate it in future bridges.

Resulting Improvements

The problems that have been found affected a small number of tendons in a small number of bridges. However, when the problems did occur the State DOTs, FHWA, and the

bridge industry responded quickly and decisively to address them. The Florida Bureau of Structures was a leader in this area, along with national agencies like PTI and ASBI. Certain firms and individuals also responded decisively to address the issues raised and to improve post-tensioned bridges. Some of these actions include:

- FDOT revising PT specifications, publishing information on findings and being a national leader in addressing the issues found.
- FHWA requiring states and divisions to conduct surveys to determine if the issues found in Florida occur in other states and if so how frequently. The FHWA is the national clearinghouse for information on the durability of PT and is gathering facts so that the entire bridge community can rationally approach this issue.
- PTI published new specifications that will improve grouting materials; grouting practices; and grouting inspections.
- ASBI formed a Grouting Committee that included representatives from DOTs; Contractors; PT Suppliers; Consultants and Grout suppliers to develop position papers and to develop a national training program for Grout Applicators. Projects can now require and use certified grout applicators similar to the way certified welders are used.

The bridge industry as a whole has made large strides in improving the durability of post-tensioned bridges to address the PT issues that have been raised. These improvements are part of the project specifications for two major bridges that were let this year- Maumee River Bridge in Toledo, Ohio and the Brandon Expressway in Tampa, Florida. These improvements will be a part of all future bridge projects to help post-tensioned bridges remain the most durable in America.

Listed below are the improvements that have been implemented and how they will improve the bridges. Many of these improvements came from Dr. Randy Poston, PTI, Florida Bureau of Structures, and ASBI and their contributions are greatly appreciated.

Minimizing voids by:

- Structured injection and venting procedures detailed on the Contract Plan Sheets
- Enhanced thixotropic grouts which are low bleed (note that all grouts will have bleed water to some extent)
- Required use of ASBI Certified Grout Applicators on the project
- Detailed Quality Control Plan that the Contractor must develop and follow
- Detailed Inspections checks that will be followed to ensure the Contractor is following the approved Grouting Plan and QC plan.
- Checking for voids after grouting and before final end anchor protection
- Full Scale Mock-Up of grouting operations prior to start of grouting so that the Contractor can demonstrate that his Grouting Plan; Grouting materials, Grouting equipment and certified personnel can properly grout a tendon. Shown below is a picture of the set up for the Full Scale Grouting Mock-Up on the Maumee River Bridge.



Potential For Corrosion Minimized by:

- Improved End Anchor details and materials – details are shown on Contract Drawings to clearly depict the required protection.
- Reduced time between installation of tendons and grouting- grouting will now follow construction much closer to ensure that corrosion does not occur after stressing and before grouting.
- Improved sealing of ducts from the time that the duct is installed – ducts themselves will be sealed during the construction process to keep out water and debris.

Defective PE Duct Eliminated by:

- Improved PE duct specification that more clearly calls for the correct cell classification to avoid environmental cracking. This part of the ASTM designation is now highlighted for suppliers.
- On-site sampling of duct material and laboratory testing of samples is required. Not all other specifications call for on-site sampling and this is an effective way to ensure that the PE duct supplied will meet the specifications and be durable. This testing will eliminate defective PE duct.

SUMMARY

While the problems encountered were unfortunate they also served to highlight some of the major benefits of post-tensioned bridges including:

- Structural redundancy with multiple tendon concept
- Replacement of tendons under traffic
- Value of Owner's Manuals and periodic inspections

Post-tensioned bridges are the most durable bridge type in America. There have been minor problems but the Owners and Industry have responded positively and developed improvements to avoid the identified issues on future projects. The Industry is continuing to examine other ways to improve post-tensioned bridges and to increase the durability. These include new materials, new procedures, design details and construction details. The goal is a constant improvement of bridges that already have a history of exceptional service and durability.