construction issues

Grouting of Post-Tensioning Tendons

Overview of Recent Developments

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Recent developments in the United States have resulted in a new emphasis on the quality of the grouting of post-tensioning tendons. This article discusses problems and concerns found during inspections in different states, the improvements and enhancements that have resulted, and recommendations on specifications, details, and materials.

Status of Post-tensioned Bridges in the US

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. The survey also included 187 concrete segmental bridges that have been built over the past 26 years in the US.

"...less than 10 tendons have been replaced due to corrosion failure..."

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, even the small number of defective tendons raised concerns in state DOTs, with the FHWA and within the bridge design and construction industry.

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.

Problems Identified

Normal maintenance inspections of bridges have identified some defects in grouted post-tensioning tendons. These defects were given extensive scrutiny and research by the Florida Department of Transportation (FDOT). The FDOT Bureau of Structures has exhaustive information available on their website as a resource for others. **www11.myflorida.com/structures/**

"...problems were traced back to construction and material issues..."

The two main problems found are:

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

In all cases, the problems were traced back to construction and material issues that have been resolved by the post-tensioned bridge industry. In addition, the FHWA directed each state to perform a survey of their post-tensioned bridges to determine if there were problems on a national level. The results indicate that only 2 states (Florida and Oregon) found any corrosion requiring repair in the post-tensioning tendons. This validates that the vast majority of post-tensioned bridges in America are in excellent shape and performed as intended.

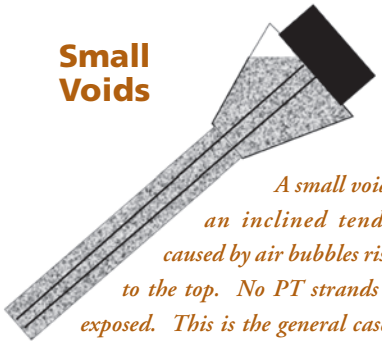
A key point to understand is that a void in a grouted tendon will not affect the durability of the tendon all by itself. Dr. Randy Poston of Whitlock, Dalrymple, Poston & Associates, serves on the Post-Tensioning Institute (PTI) Grouting Committee and has stated that voids are a result of air entrapped 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.

"There must be a breach in the multiple layers of protection in the PT system..."

Voids by themselves do not cause corrosion. There must be a breach in the multiple layers of protection in the PT system, and there must be a supply of water and oxygen that can be recharged for corrosion to occur, and keep occurring. The multiple layers of the protection system include:

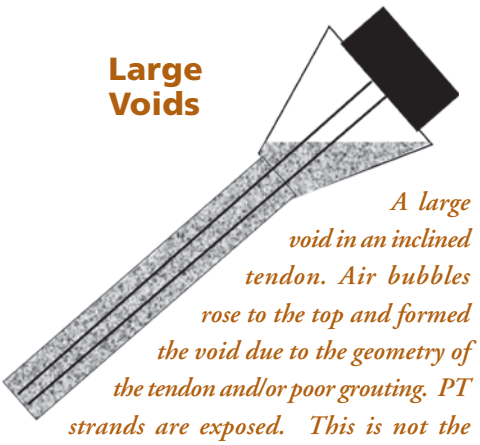
- Tendons inside the bridge
- Tendons inside a sealed duct
- Duct filled with grout

Small Voids



A small void in an inclined tendon, caused by air bubbles rising to the top. No PT strands are exposed. This is the general case in post-tensioning tendons and has no durability concerns.

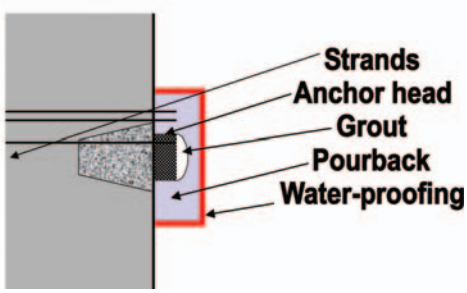
Large Voids



A large void in an inclined tendon. Air bubbles rose to the top and formed the 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 will not cause corrosion unless there is a path to the void for air and water.

Problems with defective duct material, split over time, have also been identified. 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 after four or five years. FDOT was able to trace the problem to defective material. The material supplied to the Contractors was certified to meet ASTM requirements of the specifications, but when later tested 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.



A critical area is the PT anchorage. The figure above depicts the multiple layers of protection that should be provided. Recent improvements in specifications have been addressed that further enhance the end anchor protection.

Resulting Improvements

These problems 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 the American Segmental Bridge Institute (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 serving as 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.

Setup for the Full Scale Grouting Mock-Up for the Maumee River Bridge.

• ASBI formed a Grouting Committee, including representatives from DOTs, Contractors, PT Suppliers, Consultants and Grout suppliers, to develop position papers and a national training program for Grout Applicators. Projects can now require and use certified grout applicators, similar to the way certified welders are used.

• Gene Figg, FIGG Engineering, was a strong leader in addressing these issues. He instructed the FIGG staff that the goal is Zero Defects. He then engaged Dr. Poston and his firm to investigate the issues raised regarding PT grouting, and to independently review FIGG practices, designs, and specifications with the goal of developing a list of improvements for all bridge projects.

"...large strides in improving the durability of post-tensioned bridges..."

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. Under Gene Figg's leadership, FIGG implemented many improvements that others in the industry are also addressing. These improvements are part of the project specifications for two major bridges that were let in the past two years – Maumee River Bridge in Toledo, Ohio and the expansion of the Leroy Selmon Expressway Extension in Tampa, Florida.

Listed below are the improvements that have been implemented. Many of these improvements came from Dr. Randy Poston, PTI, Florida Bureau of Structures, and ASBI.

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 Plans that the Contractor must develop and follow

• Detailed Inspections checks that will be followed to ensure the Contractor is adhering to 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.

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 sooner, 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 water and debris out.

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. This is an effective way to ensure that the PE duct supplied will meet the specifications and be durable.

"...post-tensioning tendons can be properly grouted using the improved specifications."

The improved PT specifications have been in use on the Maumee River Bridge Replacement Project in Toledo, Ohio for the past 16 months. The new PT specifications have demonstrated that the post-tensioning tendons can be properly grouted using the improved specifications.

On the Maumee River Project, inspections of the tendons after grouting have shown that the improved grout, certified grouting applicators, full scale mock-up and other enhancements of the specifications have led to almost no need for re-grouting to fill voids. To date they have grouted 3,890 transverse tendons and the subsequent inspections have found zero that had voids. They have also grouted 126 large multi-strand tendons in the approach spans and found only three that needed to have a void filled by re-grouting.

On the Leroy Selmon Expressway Extension, the improved grouting specifications have been utilized for the past 10 months. As of August 20, 2003 there have been 1,266 transverse tendons grouted and no voids have been detected in subsequent inspections. The results demonstrate that the enhanced specifications are delivering tendons with minimized voids. Consequently, the durability of these structures is enhanced as well.

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

• FHWA directed inspections showed that the vast majority of tendons are in good shape.

Despite the issues addressed in this article, post-tensioned bridges are America's most durable bridge type. There have been minor problems, but Owners and the Industry have responded positively and developed improvements to avoid issues on future projects. The Industry is continuing to examine other ways to improve post-tensioned bridges and to increase durability. These include new materials, new procedures, design details and construction details. The success in grouting on the Maumee River Bridge and the Leroy Selmon Expressway Extension shows that specification enhancements have eliminated the minor problems that had been found.

Richard Lee, P.E., District Engineer for Mississippi Department of Transportation recently reflected on two of that state's bridges with post-tensioning. *"Both the Biloxi I-110 Bridge and the 613 Bridge in Escatawpa were concerns for us when we heard about the problems that had occurred with post-tensioning in Florida. They've both been in operation for about 15 years and we decided that we should go in and do a thorough investigation of the systems. We found no problems and no concerns – and naturally, we're very pleased with that."*

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