STATUS OF POST-TENSIONING CONDITION EVALUATIONS AND ENHANCEMENTS

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ABSTRACT

Until recently, the condition of post-tensioning tendons in the United States has not appeared to be a concern. However, over the past few years, information has been presented relative to grouting and corrosion problems with post-tensioning tendons. Much of the early information originated from the Florida Department of Transportation (FDOT) relative to problems encountered on three bridges. Additional information is now available from preliminary and in-depth evaluations of post-tensioning tendon condition in other states.

This paper will provide current information from condition evaluations for post-tensioned structures nationwide and actions taken by various state DOT's and industry to improve the quality and durability of post-tensioned structures. As a result of conditions identified, several actions have been initiated to improve the quality and durability of post-tensioned bridges.

Keywords: Post-tensioning, tendons**,** voids, ducts, grout, corrosion, inspections

INTRODUCTION

Until recently, the condition of post-tensioning tendons in the United States has not appeared to be a concern. However, over the past few years, information has been presented relative to grouting and corrosion problems with post-tensioning tendons. Much of the early information originated from the Florida Department of Transportation (FDOT) relative to conditions encountered on three bridges. Additional information is now available from inspections and in-depth evaluations of post-tensioning tendon condition in other states.

EVALUATIONS

Twenty-three states have provided information relative to their post-tensioned bridges or reported that they have no post-tensioned bridges with tendons that are classified as high risk for corrosion. Thirteen of the twenty-three states reported that they have bridges that contain high-risk tendons. Ten states have completed or in the process of completing preliminary (walk through) inspections to observe conditions and assess the need for more in-depth investigation. Five of the states have completed or in the process of completing in-depth evaluations of tendon condition. Four states are planning an in-depth investigation.

Access to internal tendons has proven difficult, generally requiring some destructive effort to gain access to critical areas and probable problem locations. This has required removing cover blocks over anchorages, removing grout caps, drilling through grout vents, drilling to the tendon duct and removal of concrete to expose the duct and removal of the duct wall to observe the condition of the tendon and grout. Because access to many tendons was so difficult, most investigations are based on a random sampling of tendons instead of a complete inspection of all tendons. Non-destructive testing techniques have proven minimally beneficial. High- energy radiography and Impact Echo methods have been used with some success and show promise as a useful tool with further development for this application.

Methods used to date to conduct preliminary and in-depth tendon evaluations include:

- Walk through inspections
- Visual Void Inspections
- Impact-Echo
- High Energy Radiograph
- Mag-flux Testing
- Vibration Testing
- Sounding Tendons for Voids
- Borescope Inspection
- Excavation by drilling and concrete removal
- Grout Testing

Some examples of drilling and concrete removal are shown in the photos below.

Fig. 1 Drilling to Duct

Fig. 2 Removal of Concrete

RESULTS

A summary of the in-depth evaluation results reported to date reflect that various types of unacceptable conditions exist in post-tensioning tendons and are representative of the conditions that exist for a large percentage of existing tendons. A high percentage of tendons evaluated contained one or more undesirable defect reflecting poor grouting quality that could reduce the long-term serviceability of the tendons. Some of the more significant types of defects found are:

- Voids in longitudinal tendons at anchorages and at high points
- Voids at anchorages in vertical tendons
- Cracked PE ducts
- Holes in PE ducts
- Poor quality grout
- Voids along the tendon length
- Minor to major corrosion of tendons
- Non-Specification PE duct materials
- Un-grouted tendons
- Corroding anchorages in cracked and spalled end blocks near expansion joints
- Exposed unprotected end anchorages
- Water leakage and efflorescence from tendons

Only one state has reported tendon corrosion severe enough to cause failure of a tendon or cause concern for structure integrity and require immediate repair or replacement of tendons. However, most states that have conducted an in-depth evaluation have reported conditions that will require repair or continuous monitoring to ensure the current condition of the tendons and structure integrity. Deficiencies found such as cracked PE ducts, holes in ducts, voids with strands exposed and water present should be repaired quickly after detection, but in some instances, have not been repaired in a timely manner.

The following photos show issues reflective of conditions reported:

Fig. 3 Cracked PE Duct

Fig. 4 Cracked PE Duct

Fig. 5 Strand Corrosion from Cracked PE Duct

Fig. 6 Hole in PE Duct

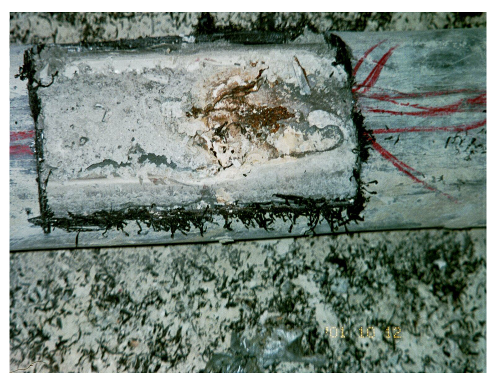

Fig. 7 Localized Strand Corrosion at Hole

Fig. 8 Void With Strands Exposed

Fig. 9 Void without strands exposed

Fig. 10 Void in Top of Duct
Existing Construction

Fig. 11 Void in Top of Duct
Recent Construction

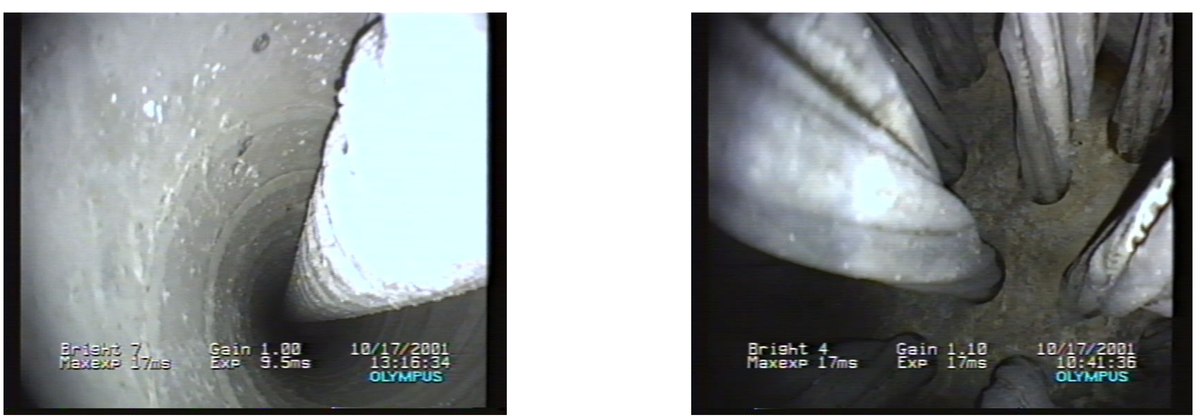

Fig. 12 Vertical Tendons With Void

Fig. 13 Bleed Trail in Draped Tendon
PE Pipe Removed

Fig. 14 Efflorescence from Anchorage

Fig. 15 Exposed Unprotected Anchorage

ACTION

There is no one single cause of the defects detected to date. Generally, the defects can be attributed to one or a combination of issues including but not limited to use of grouts with high bleed characteristics, design details, relaxed inspection, relaxed construction and grouting operations or weak material and construction specifications.

Current reporting reflects localized tendon corrosion where duct defects, voids and poor grout quality have been identified. No recent condition has been reported that has caused immediate concern for the integrity of tendons or a structure. However, many conditions found will require repair to preserve tendon condition or periodic monitoring will be necessary to assure the integrity of the tendons and structure.

Scheduled repairs and or retrofit of conditions found consist of repair to split or damaged PE ducts for external tendons and filling voids in tendons where the possibility of water ingress exists. Some defects found such as holes and cracks in PE ducts and water leakage from ducts in some cases are not being repaired expediently. It is highly recommended that defects found that may contribute to additional deterioration of the tendons be quickly repaired.

Two methods of repair of cracked PE ducts have proven successful. One consists of wrapping the pipe with sheet material and heat shrinking around the existing PE duct. The other consists of the addition of an outer new PE duct by using a split PE pipe with couplers and grouting the annular space between the old and new pipe. The split PE pipe repair concept is reflected in Figure 16 below.

Fig. 16 Split PE Pipe Repair

Two methods of filling voids that have proven successful are pressure grouting and vacuum grouting. Vacuum grouting has proven very successful for small voids such as in anchorage zones or high places in draped tendons. It is not efficient for large voids or long runs of un-grouted ducts. Pressure grouting is more efficient for large voids, but may be unsuccessful in filling the complete void if grout inlet and outlet locations are restricted. Figures 17 and 18 below reflect the effectiveness of the two methods as provided in a mock-up test performed for FDOT.

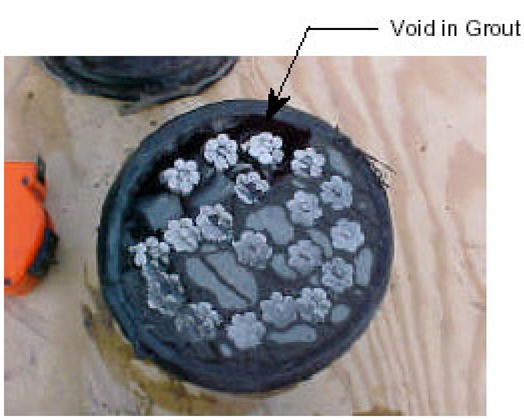

Fig. 17 Voids left with Pressure Grouting

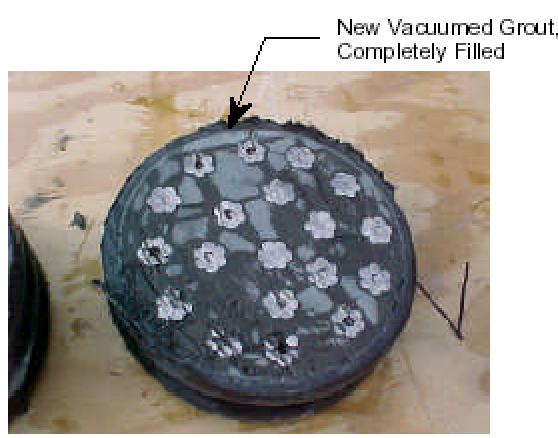

Fig. 18 Voids filled with Vacuum Grouting

Testing of grouts removed from tendons reflects a wide variety in the grout quality and consistency in a tendon. Generally, soft grouts with high water cement ratios and evidence of bleed lenses and trails have been found. Testing has shown variations in the water cement ratio of grouts from 0.4 to 1.0 within the same cross section of a tendon. Color variations in the grout cross section were evident and supports the variation in the water cement ratio. It has been concluded that bleed water and possible entrapped water is the primary cause of this variation in water cement ratio. Further information reflects recharge of grout voids with different grout mixes.

The more recent information somewhat eases the concerns for wide scale severe corrosion problems with post-tensioning tendons and the integrity of post-tensioned bridges as previously reported for some structures and reflected in Figure 19 below. However, the current information clearly supports the need to improve the quality of post tensioning grouting operations to ensure the long-term integrity and service life of post-tensioned bridges. The findings to date reflect weaknesses in several work areas including materials specifications, grouting specifications and procedures, design details and inspection and construction quality.

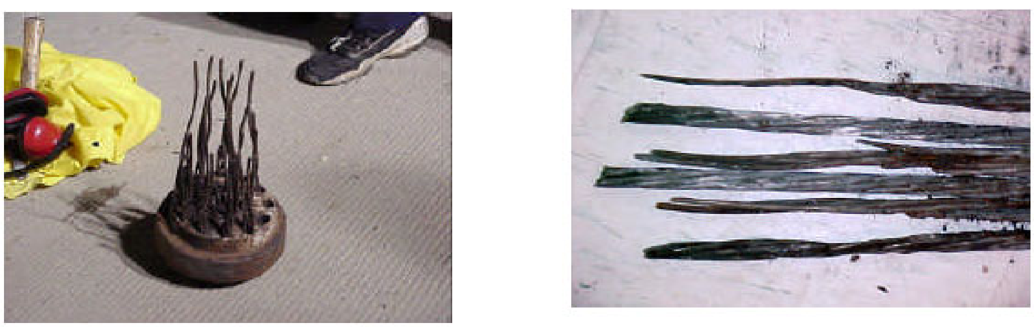

Fig. 18 Condition of Removed Tendon at Anchorage

As a result of previous findings, several key activities have been initiated by industry, state DOT's and FHWA to improve the quality and durability of grouting. These include the adoption of a Grouting Policy and Grouting Technician Certification Program by the American Segmental Bridge Institute, formation of a Grouting Committee and development and issuance of a Guide Specification for Grouting Post-tensioned Structures by the Post-Tensioning Institute (PTI), changes in the AASHTO LRFD Construction Specifications by AASHTO, development of improved pre-bagged grouts by grout suppliers and encouragement by FHWA for states to conduct evaluations to verify the condition of critical post-tensioning tendons.

ASBI has held three Grouting Certification Training Sessions to date with others being scheduled. The training provides very detailed and critical information for all personnel that have a role in the design, inspection or construction of post-tensioned structures. Demonstrations during the training provide the participant an opportunity to observe grouting operations and grout flow under varying conditions.

The PTI Grouting Committee continues to develop changes to improve the PTI Guide Specifications for Grouting Post-Tensioned Structures to provide state-of-the knowledge specifications for grouting. The PTI Grouting Committee is comprised of many leading experts in the grouting field including grout manufacturers, academia, designers, owners and others.

The changes to the AASHTO LRFD Construction Specifications adopted in 2002 by the AASHTO Subcommittee for Bridges and Structures, provide improved requirements for grouting operations. These changes provide an extensive expansion of requirements for planning and verification by the contractor before and after grouting operations.

Pre-bagged grouts have been developed that meet the latest pre-qualification testing and performance requirements for grouts. The pre-bagged grouts remove many variables that currently exist in material properties and quality and provide reasonable assurance that with proper material control and grouting operations, quality-grouted tendons can be achieved. Currently, there are five manufacturers of pre-bagged grouts that can meet supply demands. Initially high costs for the pre-bagged grouts were reported, but the costs are becoming lower as more manufacturers enter the market and competition between manufacturers increases.

CONCLUSIONS

The actions taken to date provide an extensive expansion in awareness of the importance of grouting to post-tensioning performance. However, there are differences in guidance and specification requirements between various documents that should be evaluated for the project conditions and the best provisions used for the specific project requirements.

The actions initiated to date will result in significant improvement in the quality of grouted post-tensioning tendons. However, much information still needs to be developed and disseminated to provide additional guidance, clarify ambiguities between various specifications and practices, gain acceptance and enforcement of requirements, develop better performing materials for special conditions, develop better inspection techniques, procedures and equipment for new and existing structures and design for inspectability. Action is ongoing to research and develop NDT methods and equipment to assist in monitoring post-tensioning tendon conditions.

Everyone involved in activities from the design to construction of post-tensioned structures is encouraged to stay abreast of the issues and ongoing improvement in details, grout materials and construction specifications and practices and to include the latest guidance in ongoing project documents.