TECHBRIEF

Guidelines for Sampling, Assessing, and Restoring Defective Grout in Prestressed Concrete Bridge Post-Tensioning Ducts

FHWA Publication No.: FHWA-HRT-13-027

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This document is a technical summary of the Federal Highway Administration report, *Guidelines for Sampling, Assessing, and Restoring Defective Grout in Prestressed Concrete Bridge Post-Tensioning Ducts* (FHWA-HRT-13-028).

Introduction

The objectives of this study were to provide recommended guidance for grout sampling, testing, data analysis, and interpretation of results and to propose courses of action by State transportation departments where grout deficiencies are identified. Grout is a cementitious material typically used to provide corrosion protection to the prestressing strands used in post-tensioned (PT) concrete bridges. Based on collected information and data analysis, State transportation departments can evaluate if grout deficiencies are present in the tendons of their PT bridges and determine the significance of those deficiencies.

Durability concerns associated with PT tendons were raised as early as 1999. Tendon failures were seen in some PT bridges as a result of strand corrosion due to the collection of bleed water in grout voids at tendon profile locations like anchorages and crest areas. While the development of prepackaged thixotropic grout was thought to provide a solution to the bleed water problem, corrosion-caused tendon failures on relatively new PT bridges have occurred, and the forensic studies performed to-date have revealed separation and segregation of grout materials as well as the presence of soft material, free water, and high chloride, and sulfate content in some instances.[1–3] Consequently, it is important to examine the overall quality of materials and construction for some in-place grouts in existing PT bridges. The product of this study is a guide for State

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transportation departments to employ in sampling in-place grouts from tendons in PT bridges.

Approach

A review is provided for different types of PT tendons, bridge design, and construction approaches. In addition to discussing the role of chlorides and other chemical deficiencies in causing strand corrosion and tendon failure, the main report also covers other deficiencies such as lack of consistency and consolidation, segregation, and presence of free water. Specific issues and topics addressed in the main report include the following:

- The types of tendons from which grout samples should be obtained.
- The number of extracted grout samples required from each tendon type on a statistical basis.
- An explanation of proposed methods for retrieving grout samples from tendons, including anchorages, such that any impact on future durability is not compromised.
- Recommendations regarding the amount of grout and the tests required for property characterization.
- Recommendation of a systematic procedure for recording and reporting grout composition in order to define its quality and project its future performance.
- Recommended repair/rehabilitation procedures for tendons in order to minimize the impact on future durability caused by sampling.
- Presentation on a decision path guideline based on the grout analysis results that recommends future tendon inspection and, if necessary, grout sampling intervals.

Sampling Methodology and Risk Projection

It is important that the number and location of acquired grout samples are statistically representative of the overall PT tendons. Factors to be considered in this regard include the number of grout lots employed, the availability of a grouting log, and the quality of workmanship. There are two grout sampling options: option 1 involves sampling for chlorides only, and option 2 tests for all grout deficiencies. Under each option, there are two levels of grout sampling: level 1 provides an initial indication of grout condition via preliminary screening tests, and level 2 involves the following steps, as shown in figure 1: (1) review the as-built plans, PT shop drawings, specifications, and construction records; (2) conduct a walk-through visual inspection for the length of the bridge; (3) examine and document the grout condition, obtain grout samples, and inspect for any indications of tendon defects; and (4) analyze and evaluate the grout samples.

Each tendon is classified as being of low, medium, or high risk of failure. This classification is defined as the product of an indicator of defect probability and a consequence of failure indicator (see figure 2). The indicator of defect probability is comprised of the following four factors:

1. Bridge condition.
2. Availability of construction records.
3. Visual condition evaluation.
4. Tendon geometry and length.

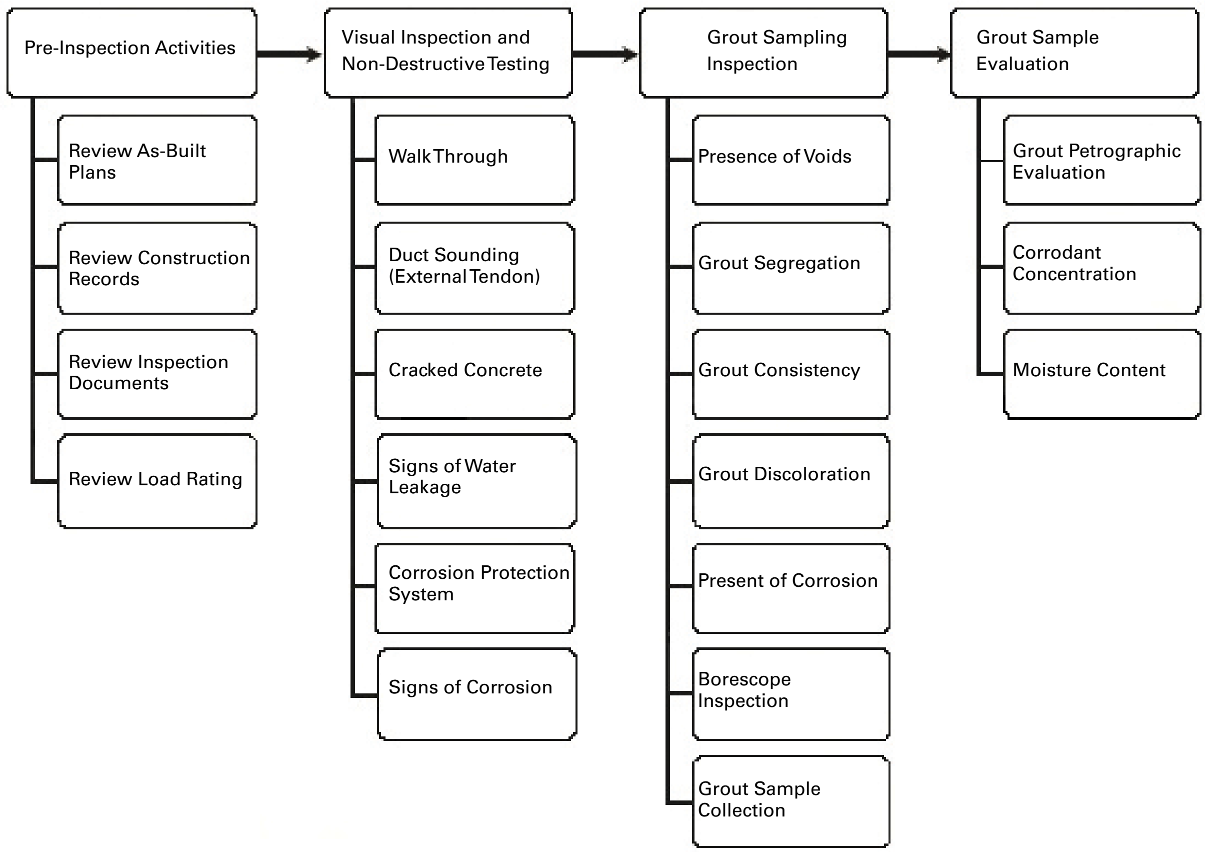
Examples

In order to show how the proposed guidelines can be implemented, example analyses are provided for four different types of PT bridges including a typical precast balanced cantilever segmental bridge, a typical PT spliced girder bridge, a typical span-by-span segmental bridge, and a typical PT bridge with draped internal tendons. The precast segmental balanced cantilever and PT spliced girders are from actual projects, whereas the other two cases were conceived as examples.

Analysis of Grout Samples

Grout sampling should be performed during the overall bridge and tendon inspection

Figure 1. Grout inspection processes.



process and can be performed at an opened end cap or at an intermediate coupling location. Grout sampling can also be performed by cutting away a section of duct, which involves concrete excavation due to internal tendons. Researchers should collect free water and corrosion products, if present, and acquire samples of each grout type (i.e., segregated, soft, etc.).

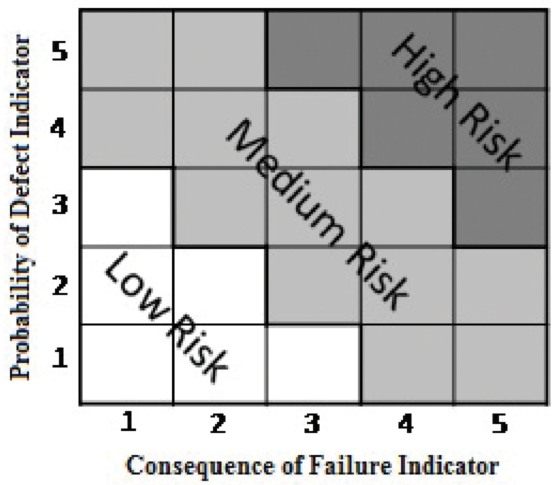
Grout characterization requires that both composition and structure (macro and micro) be determined. Composition should be determined by wet chemistry analysis for total chlorides and soluble chlorides and by analytical techniques such as ion chromatography (solution only), X-ray florescence (solid or powdered samples only), and energy dispersive spectroscopy (solid or powdered samples only).[4] The structure should be determined by petrographic methodologies, electron microscopy, and X-ray diffraction.

Minimally, X-ray florescence and wet chemistry analysis for total chlorides should be performed. Petrographic analysis should be performed in accordance with the applicable ASTM standard.[5] If strand corrosion is ongoing, then corrosion state and rate can be assessed by appropriate electrochemical methods.[6–8]

Sampling Locations

After the number of randomly selected tendons to be sampled is determined, sampling locations should be strategically located. Typically, grout chemical and physical deficiencies are found at high elevations along tendons, so the most straightforward approach is to collect grout samples from cap internal areas. Duct or coupler removal, as is

Figure 2. Risk matrix.



required for access to grout at intermediate locations, has a greater chance of causing distress. It is not always possible to remove grout samples from a cut window in a duct away from anchorages of internal tendons because of strand configuration. For both option 1 and option 2 inspections, at least one grout sample should be collected from each preselected tendon.

Restoration Methods

Proper restoration of tendon damage that results from inspection and grout sampling is critical because paths for ingress of corrosives into the PT system may result, and long-term durability may be compromised. Restoration can either be temporary or permanent, where temporary restoration is due to short-term adverse weather or unexpected findings (or both). Conversely, permanent restoration meets the original design life.

Materials and methods should be included in a work plan for the restoration and be approved by the bridge owner. Methods and materials may vary for external versus internal tendons.

Interpretation of Results and Courses of Action

Table 1 lists chemical deficiency (CD) classifications for option 1 inspections in terms of four chloride (Cl^-) levels. Based on the findings, individual tendons are assigned a grade from 1 to 10, where a higher grade indicates a more problematic tendon condition. This in turn defines the recommended courses of action(s) (A). Table 2 shows the CD classification for option 2 in terms of the same four chloride levels as in option 1 as well as six degrees of physical deficiency (PD) (note that it is six degrees since PD0 has no deficiency).

Table 1. CD classifications as determined by grout Cl^- levels from an option 1 inspection and resultant recommended actions.

CD[a]					
CD1	$Cl^- \leq 0.08$	X			
CD2	$0.08 < Cl^- \leq 0.20$		X		
CD3	$0.08 < Cl^- \leq 0.20$[b]			X	
CD4	$Cl^- > 0.50$[b]				X
		Grade			
Action		1	5	7	9
A1	None	X			
A2	Expand sampling			X	X
A3	Reinspect in 5 years		X		
A4	Reinspect in 2 years			X	X
A5	Tendon monitoring			X	X

[a] Chloride concentration units are weight percent cement.
[b] If strand corrosion or fracture(s) are found (PD5 or PD6 under option 2 in table 2), then grade 9 or 10 should be assigned as appropriate per option 2 actions.

Table 2. CD and PD classifications as determined by grout Cl^- levels and in-place grout structure by an option 2 inspection and resultant recommended actions.

CD[a]											
CD1	$Cl^- \leq 0.08$	X	X	X	X						
CD2	$0.08 < Cl^- \leq 0.20$					X	X				
CD3	$0.08 < Cl^- \leq 0.20$							X	X		
CD4	$Cl^- > 0.50$									X	X
PD											
PD0	Sound grout	X									
PD1	Grout air pocket		X	X	X	X	X	X	X	X	X
PD2	Exposed strand/tendon			X	X	X	X	X	X	X	X
PD3	Soft or segregated grout				X	X	X	X	X	X	X
PD4	Tendon surface corrosion (no section loss)						X	X	X	X	X
PD5	Tendon surface corrosion (< 5 percent section loss)								X	X	X
PD6	Tendon with partial or full fracture (≥ 5 percent section loss)										X
		Grade									
Action		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A1	None	X	X								
A2	Expand sampling							X	X	X	X
A3	Reinspect in 5 years				X	X	X				
A4	Reinspect in 2 years							X	X	X	X
A5	Tendon monitoring							X	X	X	X
A6	Consider repairing deficiency as necessary[b]		X	X	X	X	X	X	X	X	X
A7	Structural evaluation/load rating										X
A8	Tendon replacement										X

[a] Chloride concentration units are weight percent cement.
[b] This applies to PD1, PD2, and PD3.

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Key Words—Bridges, Post-tensioning, Grout, Chlorides, Corrosion, Fracture, Inspection, Sampling, Repair.

MAY 2013

FHWA-HRT-13-027

HRDI-60/05-13(600)E