Technical Advisory

U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration

Subject

Recommendations for Assessing and Managing Long-Term Performance of Post-Tensioned Bridges having Tendons Installed with Grout Containing Elevated Levels of Chloride

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Par.

1. What is the purpose of this Technical Advisory?
2. Does this Technical Advisory supersede another Technical Advisory?
3. What is this background of this Technical Advisory?
4. What are the recommendations for assessing and managing the long-term performance of post-tensioned bridges having tendons installed with grout containing elevated levels of chloride?

1. **What is the purpose of this Technical Advisory?** The purpose of this Technical Advisory is to give guidance to bridge owners on assessing and managing the long-term performance of post-tensioned bridges having tendons installed with grout containing elevated levels of chloride.

2. **Does this Technical Advisory supersede another Technical Advisory?** No. This is a new Technical Advisory.

3. **What is this background of this Technical Advisory?**

   a. The discovery in 2010 of post-tensioning grout with elevated chloride levels in a post-tensioned (PT) concrete bridge in Texas triggered a follow-up investigation by the grout manufacturer that supplied the PT grout. The preliminary investigation determined that grout produced for this project had chloride levels exceeding the specified limit. FHWA learned from Sika Corporation (Sika) that its SikaGrout® 300 PT produced at its plant in Marion, Ohio, contained varying levels of chloride sometimes well above the AASHTO and PTI specification limit of 0.08% chloride by weight of cementitious material. Sika also identified that the major ingredient by weight of product, Portland cement produced by a third-party vendor, was the source of the elevated chloride in the grout. The potential time period for this issue was from 2001, when Sika introduced its original pre-bagged PT grout under the name Sika Cable Grout, to April 2010, when production of its secondgeneration PT grout, SikaGrout® 300PT, ceased at the Marion, Ohio plant. By 2011, Sika had notified many recipients of the Marion-produced grout and began a program of field sampling to determine the levels of chloride in the grout produced during the entire Marion production period.

b. PT grout is typically used to protect PT strands from corrosion. The cementitious grout provides a high pH environment that contributes to the corrosion prevention by the formation of a protective oxide film on the strand surface. With the discovery that some installations may have grout with chloride levels above the specified limit, information on the tolerable chloride limits under varying circumstances was needed.

c. As a result, Sika and FHWA each initiated independent research programs to address corrosion concerns related to SikaGrout® 300 PT containing elevated levels of chloride. These research studies were initiated to better understand the effects of chlorides at various levels on the long-term corrosion resistance of 7-wire post-tensioning strands. The intent of the studies was to provide the basis on which tolerable chloride concentrations could be identified. Both the FHWA and Sika research programs showed that sustained corrosion is not likely at chloride levels below 0.75% chloride by weight of cement. The FHWA research observed a small amount of corrosion pitting on PT strand encased in SikaGrout® 300 PT with 0.4% chloride by weight of cement. This guidance uses these chloride concentrations in establishing its long term corrosion risk levels.

d. It is important to understand that sustained corrosion, if any, resulting from SikaGrout® 300 PT with elevated chlorides should not pose an immediate safety issue for the traveling public. Any strand corrosion and corresponding prestress loss that might develop over time is expected to produce visible signs of distress that should be noticed during its in-service bridge inspections. Also, PT structures typically possess substantial redundancy that can accommodate the corrosion or weakening of multiple tendons.

4. **What are the recommendations for assessing and managing the long-term performance of post-tensioned bridges having tendons installed with grout containing elevated levels of chloride?**

a. <u>Assessment of post-tensioning (PT) long-term performance</u>

The five steps detailed in this section provide a process to assess and manage bridges with SikaGrout® 300 PT containing elevated levels of chloride.

Step 1 – Determine PT Grout Chloride Level

To assist in making this determination, a production catalog is available with records of known bridges that received Marion-produced SikaGrout® 300PT during the relevant time period. This catalog shows known chloride levels for certain production lots and can be viewed by going to http://www.fhwa.dot.gov/bridge/t514033cat.pdf. Comprehensive grouting records can assist in identifying and locating production lots within a bridge. Bridge owners with limited or no chloride data or grouting records may make determinations based on either sampling the in-place PT grout or assuming the in-place PT grout has a chloride level at the maximum level known for its particular production period. Due to varying chloride concentrations within a production lot, multiple samples may be needed to determine the maximum chloride level for a production lot.

The table below shows the maximum chloride levels currently known for each production year of the SikaGrout® 300 PT product at the Marion OH, plant.

Maximum Chloride Concentration by Production Period (% Cl^- per wt. of cement)				
2001 to 2006	**2007**	**2008**	**2009**	**2010**
0.25%	0.43%	0.48%	0.56%	0.18%

Table 1 – Maximum Chloride Concentration by Production Period

Step 2 – Determine PT tendon Protection Level

Owners should perform a review of the bridge drawings to identify the PT details and components used in the bridge. The Post Tensioning Institute / American Segmental Bridge Institute's (PTI / ASBI) *Guide Specification for Grouted Post-Tensioning (June 2012)* [1] has identified four tendon protection levels with each level providing increased protection as one goes from protection level PL-1A to protection level PL-3 . The PTI / ASBI protection levels are delineated by the material and components used. This guidance uses these established PTI / ASBI levels of protection to measure a PT tendons' level of robustness. The requirements for each PTI protection level are provided in Appendix A.

Step 3 – Determine Corrosion Risk Level

The level of corrosion risk is determined using the SikaGrout® 300 PT chloride concentration and the PT tendon protection level determined in steps 1 and 2. Table 2 sets risk levels (RL) for varying combinations of chloride concentration and PT protection levels. The risk may range from risk level RL 1 (lowest risk) to risk level RL 4 (highest risk).

This guidance assumes that the PT tendon is grouted without voids and segregation and that the chloride in the in-place PT grout is primarily from the pre-bagged SikaGrout® 300 PT material. During placement, chloride can also be introduced through the water added to the pre-bagged grout, but this guidance assumes that possibility is negligible.

Protection Level	**Chloride Concentration (% Cl^- per wt. of cement)**				
	$Cl^- \leq 0.08\%$	**$0.08\% < Cl^- \leq 0.30\%$**	**$0.30\% < Cl^- \leq 0.50\%$**	**$0.50\% < Cl^- \leq 0.65\%$**	**$Cl^- > 0.65\%$**
PL-1A	No Risk	RL 1	RL 2	RL 3	RL 4
PL-1B		RL 1	RL 2	RL 3	RL 4
PL-2 & PL-3		RL 1	RL 2	RL 2	RL 4

Table 2 - Corrosion Risk Levels (RL)

Step 4 – Assess Bridge System Redundancy and Element Ductility
Ensuring a ductile PT element response during the possible loss of PT force is paramount. Ductile response and a bridge system's ability to transmit forces between structural elements (system redundancy) can safeguard against unexpected loss of element capacity prior to noticeable cracking or deformation. A ductility check is recommended as a PT element goes through a possible fractional loss of PT force. A PT element passes a ductility check if calculations demonstrate that there will be easily detectable cracking before debilitating strength loss.

Table 3 sets a structure classification based on the bridge's redundancy and ductility. The bridge's redundancy is quantified by its load rating system factors (Øs). Appendix B includes two tables that provide information on determining system factors for post-tensioned multi-girder and box structures. The structure classifications range from a highly redundant and ductile bridge (S1) to bridges with limited ductility and/or redundancy (S3).

Structure Classification	Indicators	Expected Performance
S1	• System factor: $Ø_s \geq 1.10$ • Pass ductility check	A highly redundant bridge that develops easily detectable cracking before debilitating strength loss.
S2	• System factor: $1.10 > Ø_s \geq 1.00$ • Pass ductility check	A moderately redundant bridge that develops easily detectable cracking before debilitating strength loss.
S3	• System factor: $Ø_s < 1.00$ • Fail ductility check	A bridge with limited ductility and / or redundancy.

Table 3 - Structure Classification

Step 5 – Determine Management Follow-up Actions

Based on the corrosion risk level (RL1 – RL4) and structure classification (S1 – S3) determined in steps 3 and 4, the recommended management follow-up actions (FA) are determined using Table 4. Four management follow-up actions were established. These four management follow-up actions are FA I - no additional measures needed, FA II - biennial in-depth inspection needed, FA III - annual in-depth inspection needed and FA IV - plan repairs/replacement. Recommended in-depth inspection procedures for post-tensioned bridges are listed in the next section, titled “In-Depth Inspection Procedures for Post-Tensioned Bridges”.

Corrosion Risk Level	Structure Classification (Table 3)		
	S1	**S2**	**S3**
RL 1	FA I	FA I	FA II
RL 2	FA I	FA II	FA III
RL 3	FA II	FA III	FA III
RL 4	FA IV	FA IV	FA IV

Table 4 –Recommended Management Follow-up Actions

b. <u>In-Depth Inspection Procedures for Post Tensioned Bridges</u>

The Manual for Bridge Evaluation (MBE)[5] defines an in-depth inspection as "a close-up, hands-on inspection of one or more members above or below the water level to identify any deficiencies not readily detectable using Routine Inspection procedures." The intent of this in-depth inspection is to provide a higher level of observation on these bridges than typically performed in a routine inspection. For bridges with prestressed members, routine inspections look for signs of distress commonly associated with a loss of prestress force which typically include bridge misalignment, deck surface irregularities (humps/sags), concrete cracking, and deterioration. The in-depth inspection procedures recommended in this advisory are developed with the goal of providing earlier detection of cracking, corrosion, and loss of prestress force. This in turn should provide bridge owners the ability to implement preservation measures in a timely manner.

Below is a summary of good inspection procedures that should be included in the in-depth inspection. These procedures were taken from the MNDOT guidance titled *Development of Best Practices for Inspection of PT Bridges in Minnesota* [4].

General External Visual Evaluations for All PT Members

- Review plans for details and tendon profiles to plan inspection (have plans available during inspection).
- Note any cracking that could be related to loss of PT force and any cracking that could increase chloride and moisture intrusion.
  - Record all cracks parallel to tendon
  - Record all cracks around pour-backs (if accessible)
- Note any rust staining on cracks and evaluate from proximity clues if rust is likely from PT or mild steel corrosion
- Note any puddles or misdirected drainage on project that would subject cracks or joints in proximity of tendons to moisture

Internal Inspection of Internal Tendons

- Follow the same procedures as for external visual inspection to find cracks, corrosion, and moisture.
- Identify drainage or leakage problems that would result in the interior of the box collecting moisture, particularly chloride laden moisture from deicing salt runoff.
- Look for any areas that would indicate patching in proximity of tendons and carefully evaluate these areas for moisture, cracking, or separation from the base material.

Internal Inspection of External Tendons

- Check for cracking along the length of duct.
- Check deviators and anchor areas for good seal.
- Look for any indications of tendon movement at anchors or deviators that might indicate release of prestress force (broken strand).
- Indicate any moisture, drainage or leakage problems, particularly chloride laden moisture from deicing salt runoff
- Tap tendons with hammer to identify potential voids (hollow sound), do not put a hole in the duct unless it can be immediately patched after investigation.

For each bridge assessed, the need for and frequency of the follow up actions should be documented in the bridge records. This documentation should include the information used to determine the follow up actions, a detailed list of the elements requiring follow up actions, and the level of and interval of inspection required for those elements.

/s/ signed by
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Appendix A [1]

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3.1 — Protection Level 1A (PL1A)

Duct with filling material providing durable corrosion protection.

Performance requirements:

- Bare strand or bar per Sections 4.2.1 and 4.2.2, respectively;
- Duct sufficiently strong and durable for fabrication, transportation, installation, concrete placement, and tendon stressing, sufficiently leak-tight for concrete placing and grout injection. Duct shall meet the requirements of Section 4.3.5 and may be one of the following:
  - Galvanized duct per Section 4.3.5.1;
  - Plastic duct per Section 4.3.5.2;
  - Plastic pipe per Section 4.3.5.3;
  - Duct connections per Section 4.3.6;
- Filling material to be chemically stable, nonreactive with prestressing steel and tendon duct, and may be one of the following:
  - Basic grout Class A per PTI's "Specification for Grouting of Post-Tensioned Structures";
  - Engineered grout Class B, C, or D per PTI's "Specification for Grouting of Post-Tensioned Structures"; and
- Grout filling procedure to leave no voids in duct

3.2 — Protection Level 1B (PL-1B)

PL-1A plus engineered grout and permanent grout cap.

Performance requirements:

- Bare strand or bar per Sections 4.2.1 and 4.2.2, respectively;
- Permanent grout caps meeting the requirements of Section 4.3.3;
- Duct sufficiently strong and durable for fabrication, transportation, installation, concrete placement, and tendon stressing, sufficiently leak-tight for concrete placing and grout injection. Duct shall meet the requirements of Section 4.3.5 and may be one of the following:
  - Galvanized duct per Section 4.3.5.1;
  - Plastic duct per Section 4.3.5.2;
  - Plastic pipe per Section 4.3.5.3;
  - Duct connections per Section 4.3.6;
- Filling material to be chemically stable, nonreactive with prestressing steel and tendon duct, and be engineered grout Class B, C, or D per PTI's "Specification for Grouting of Post-Tensioned Structures"; and
- Grout filling procedure to leave no voids in duct.

3.3 — Protection Level 2 (PL-2)

PL-1B plus an envelope, enclosing the tensile element bundle over its full length, and providing a permanent leak-tight barrier.

Performance requirements:

- PTS shall meet the system pressure tests contained in Section 4.4.5;
- Bare strand or bar per Sections 4.2.1 and 4.2.2, respectively;
- Galvanize or epoxy coat the embedded part of the anchorage;
- Permanent grout caps meeting the requirements of Section 4.3.3;
- Envelope to be watertight and impermeable to water vapor over entire length. Envelope material to be chemically stable, without embrittlement or softening during anticipated exposure temperature range and service life, no free chloride ions extractable from material. Duct shall meet the requirements of Section 4.3.5 and may be one of the following:
  - Plastic duct per Section 4.3.5.2;

    - Plastic pipe per Section 4.3.5.3;
    - Duct connections per Section 4.3.6;
- Precast segmental duct couplers for precast segmental construction per Section 4.3.8.
- Filling material to be chemically stable, nonreactive with prestressing steel and tendon duct, and shall conform to:
    - Engineered grout Class C or D per PTI's "Specification for Grouting of Post-Tensioned Structures"; and
    - Thixotropic in nature.
- Grout filling procedure to leave no voids in duct

3.4 — Protection Level 3 (PL-3)

PL-2 plus electrical isolation of tendon or encapsulation to be monitorable or inspectable at any time.
Performance requirements:

- PTS shall provide complete electric isolation of entire tendon and meet the system pressure tests contained in Section 4.4.5;
- PTS shall have the ability to be monitorable or inspectable at any time;
- Bare strand or bar per Sections 4.2.1 and 4.2.2, respectively;
- Electrically isolate the tensile elements;
- Permanent grout caps meeting the requirements of Section 4.3.3;
- Envelope to be watertight and impermeable to water vapor over entire length. Envelope material to be chemically stable, without embrittlement or softening during anticipated exposure temperature range and service life, no free chloride ions extractable from material. Duct shall meet the requirements of Section 4.3.5 and may be one of the following:
    - Plastic duct per Section 4.3.5.2;
    - Plastic pipe per Section 4.3.5.3;
    - Duct connections per Section 4.3.6;
- Precast segmental duct couplers for precast segmental construction per Section 4.3.8.
- Filling material to be chemically stable, nonreactive with prestressing steel and tendon duct, and shall conform to:
    - Engineered grout Class C or D per PTI's "Specification for Grouting of Post-Tensioned Structures"; and
    - Thixotropic in nature.
- Grout filling procedure to leave no voids in duct.

Appendix B (2) (3)

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Number of Girders in Cross Section	Span Type	# of Hinges required for mechanism	System Factors (ϕ_s) No. of Tendons per Web 1	2	3	4
2	Interior span	3	0.85	0.90	0.95	1.00
	End span	2	0.85	0.85	0.90	0.95
	Simple span	1	0.85	0.85	0.85	0.90
3 or 4	Interior span	3	1.00	1.05	1.10	1.15
	End span	2	0.95	1.00	1.05	1.10
	Simple span	1	0.90	0.95	1.00	1.05
5 or more	Interior span	3	1.05	1.10	1.15	1.20
	End span	2	1.00	1.05	1.10	1.15
	Simple span	1	0.95	1.00	1.05	1.10

- Above values may be increased by 0.05 for spans containing more than 3 intermediate, evenly spaced diaphragms in addition to the diaphragms at the end of each span.
- Higher values may be considered on a case-by-case basis with the approval of the Department.
- In no case shall the System Factor exceed 1.25.
- System Factor need not be less than 0.85.

Table 7.3 – System Factor Values for Post-Tensioned Beams

Bridge Type	Span Type	# of Hinges to Failure	System Factors (ϕ_s) No. of Tendons per Web 1/web	2/web	3/web	4/web
Precast Balanced Cantilever Type A Joints	Interior Span	3	0.90	1.05	1.15	1.20
	End or Hinge Span	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	n/a	0.90	1.00	1.10
Precast Span-by-Span Type A Joints	Interior Span	3	n/a	1.00	1.10	1.20
	End or Hinge Span	2	n/a	0.95	1.05	1.15
	Statically Determinate	1	n/a	n/a	1.00	1.10
Precast Span-by-Span Type B Joints	Interior Span	3	n/a	1.00	1.10	1.20
	End or Hinge Span	2	n/a	0.95	1.05	1.15
	Statically Determinate	1	n/a	n/a	1.00	1.10
Cast-In-Place Balanced Cantilever	Interior Span	3	0.90	1.05	1.15	1.20
	End or Hinge Span	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	n/a	0.90	1.00	1.10

(For box girder bridges with 3 or more webs, table values may be increased by 0.10).

Table 7.2 – System Factors for Longitudinal Flexure

Note: For local details involving local shear and/or strut-and-tie action or analysis where the resistance is provided by local post-tensioning tendons or bars, a system factor of 1.00 is considered appropriate for two or more tendons. A reduced factor of 0.90 should be used where only one tendon or bar provides the resistance. (AASHTO, MBE, C 6A.5.11.6)

References

1. Post-Tensioning Institute & American Segmental Bridge Institute, “Guide Specification for Grouted Post-Tensioning,” PTI/ASBI M50.3-12
2. Florida Department of Transportation, “New Direction for Florida Post-Tensioned Bridges,” Volume 10A - Load Rating Post-Tensioned Concrete Segmental Bridges, Oct. 8, 2004
3. Florida Department of Transportation, “New Direction for Florida Post-Tensioned Bridges,” Volume 10B - Load Rating Post-Tensioned Concrete Beam Bridges, Oct. 8, 2004
4. Minnesota Department of Transportation, “Development of Best Practices for Inspection of PT Bridges in Minnesota,” MN/RC 2012-09
5. American Association of State Highway and Transportation Officials, “The Manual for Bridge Evaluation,” Second Edition, 2011