 **Corrosion Evaluation of Post-Tensioned Tendons on Mid-Bay Bridge**

by
Siva Venugopalan
Principal
SCS, Inc.

siva007@verizon.net
(610) 692-6551


March 7, 2007 Count on Concrete for Performance Slide 1

 **Location of the Bridge – Florida SR 293**




Mid-Bay Bridge, Destin, Florida

March 7, 2007 Count on Concrete for Performance Slide 2

 **Corrosion Guys – What Do they Do?**

- Identify areas of corrosion
- Measure rate of corrosion
- Define factors that cause corrosion
- Quantify section losses for use in remaining strength analysis
- Design corrosion protection system to prevent additional section losses
- Extend the life cost effectively


March 7, 2007 Count on Concrete for Performance Slide 3

 **Corrosion Evaluation of Post-Tensioned Bridges**

- Rust classification
- Moisture content of the grout (ASTM C566)
- Chloride content of the grout (AASHTO T260)
- Alkalinity (pH) of the grout.
- Corrosion potentials (ASTM C876)
- Corrosion rate (ASTM G59)
- Petrographic Evaluation of the grout

March 7, 2007 Count on Concrete for Performance Slide 4


Siva Corrosion Services, Inc.
materials and corrosion specialists

 **When does corrosion initiate on strands**


- When there is sufficient chlorides
- When the grout is carbonated
- When the combination of chlorides and partially carbonated grout results in condition conducive for corrosion
- When the air voids and/or carbonated grout are in contact with the strands

March 7, 2007 Count on Concrete for Performance Slide 5

Siva Corrosion Services, Inc.
materials and corrosion specialists

 **The Mid Bay Bridge**

- Segmental precast concrete box girders - eight to nine segments held together by six post-tensioning tendons.

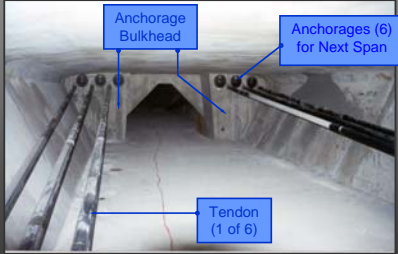


March 7, 2007 Count on Concrete for Performance Slide 6

Siva Corrosion Services, Inc.
materials and corrosion specialists

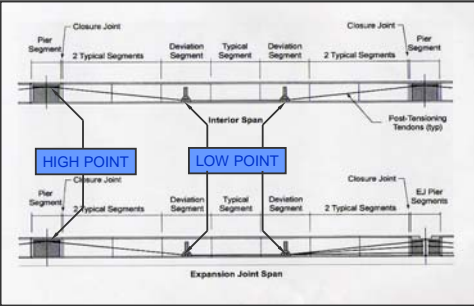
Typical View of the Anchorage

- Each tendon = 19 strands, each strand = 7 spirally wound 5/8 inch diameter wires.



March 7, 2007 Count on Concrete for Performance Slide 7

The Schematics

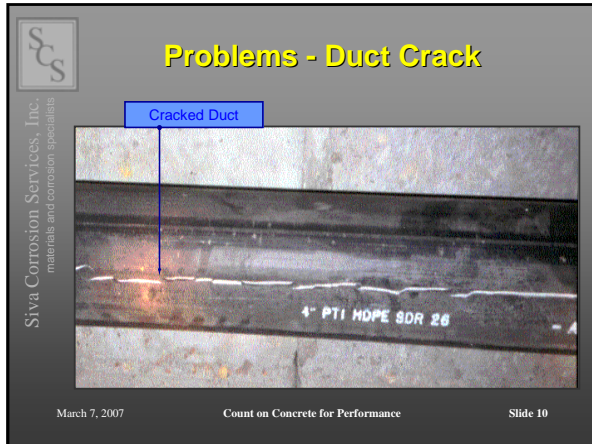


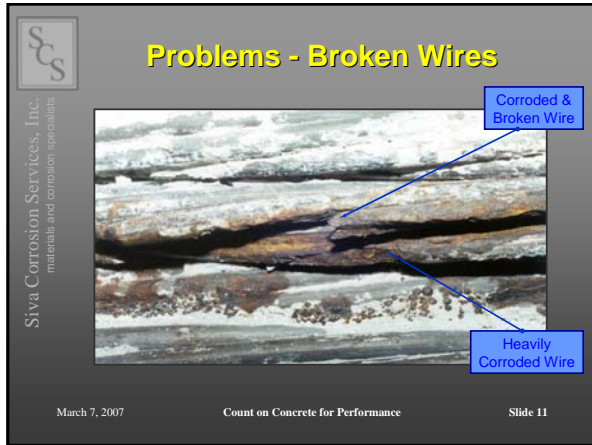
March 7, 2007 Count on Concrete for Performance Slide 8

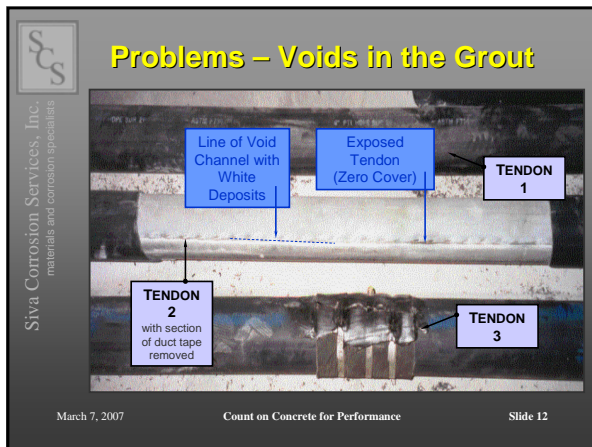
The Magnitude of the Problem

- As many as 13 tendons were replaced in about 8 years of operation.
- Can we determine the extent of the problem?
- Is there a systematic way to identify problem spans?

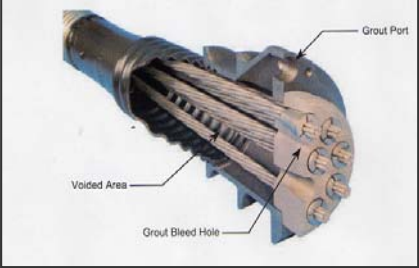
March 7, 2007 Count on Concrete for Performance Slide 9







Problems – Voids in the Anchorage




Grout Port
Grout Bleed Hole
Voided Area

Siva Corrosion Services, Inc.
materials and corrosion specialists

March 7, 2007 Count on Concrete for Performance Slide 13

Problems - Air Void Clusters



Bleed Channel

Siva Corrosion Services, Inc.
materials and corrosion specialists


March 7, 2007 Count on Concrete for Performance Slide 14

Are voids problematic?

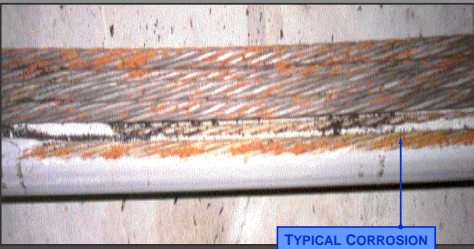
- Voids are a problem. The common industry thinking is: no voids – no problems.
- If there is carbonated grout in contact with the tendon, it will lead to corrosion.
- Remember, it is not just the voids that are of concern on post-tensioned structures.

Siva Corrosion Services, Inc.
materials and corrosion specialists

March 7, 2007 Count on Concrete for Performance Slide 15


 **Problems – Corrosion on Strands**

Siva Corrosion Services, Inc.
materials and corrosion specialists




TYPICAL CORROSION

March 7, 2007 Count on Concrete for Performance Slide 16


 **Problems – Corrosion at the Anchors**

Siva Corrosion Services, Inc.
materials and corrosion specialists



Corrosion at Anchorage

March 7, 2007 Count on Concrete for Performance Slide 17

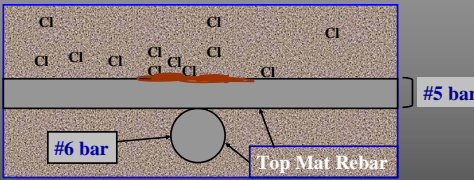
 **Significance of Corrosion**

Siva Corrosion Services, Inc.
materials and corrosion specialists

- Reduced cross section resulting in increased stress on individual wires
- Increased stress can lead to wire breaks, which in turn can lead further increase in stress
- Subsequent wire breaks occurs more frequently until the strand/tendon is completely lost

March 7, 2007 Count on Concrete for Performance Slide 18

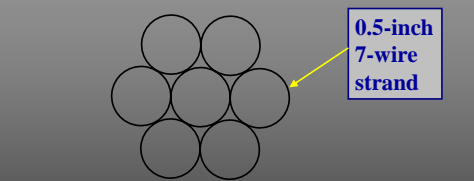
Time to 50% Section Loss of a 0.5-inch Rebar



At 1 mil per year, time-to 50% section loss of 0.5-inch rebar is >100 years.

March 7, 2007 Count on Concrete for Performance Slide 19

Time to 50% Section Loss of a 0.5-inch Strand



At 1 mil per year, time-to 50% section loss of outer wires is about 25 years

March 7, 2007 Count on Concrete for Performance Slide 20

Questions

- Were the strands free of corrosion prior to grouting?
- Were the ducts dry prior to grouting?
- What was the quality of the grout?
- What is the alkalinity of the grout?
- What was the W/CM ratio of the grout, as installed?
- Any pumping aids used?

March 7, 2007 Count on Concrete for Performance Slide 21

Field Investigations

- Grout composition and quality
- Variation in grout quality along the tendon
- Electrochemical tests
- Chloride content of the grout material

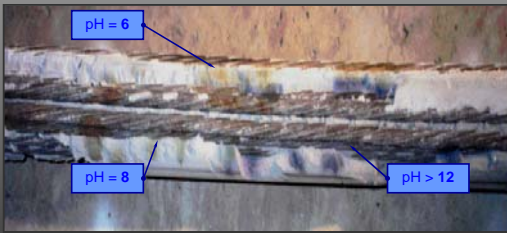
March 7, 2007 Count on Concrete for Performance Slide 22

Anomalies

- Corrosion potential data indicated no active corrosion.
- Chloride content of the grout material was well below the standard threshold level.

March 7, 2007 Count on Concrete for Performance Slide 23

Variation in Grout pH



March 7, 2007 Count on Concrete for Performance Slide 24

Distribution of Grout pH

March 7, 2007 Count on Concrete for Performance Slide 25

Distribution of W/C Ratio based on Petrographic Analysis

March 7, 2007 Count on Concrete for Performance Slide 26

Recommendations

- Identify and replace problem/failed tendons.
- Seal all the duct cracks and anchorage assemblies to eliminate direct access to moisture, oxygen, and chlorides.


March 7, 2007 Count on Concrete for Performance Slide 27

 **Internal Tendon at Anchorage in Bridge A**


Siva Corrosion Services, Inc.
materials and corrosion specialists




March 7, 2007 Count on Concrete for Performance Slide 28

 **Internal Tendon at High Point in Bridge A**


Siva Corrosion Services, Inc.
materials and corrosion specialists



March 7, 2007 Count on Concrete for Performance Slide 29

 **Typical Void Channel in Bridge A**

Siva Corrosion Services, Inc.
materials and corrosion specialists



March 7, 2007 Count on Concrete for Performance Slide 30

Void at High Point (1)

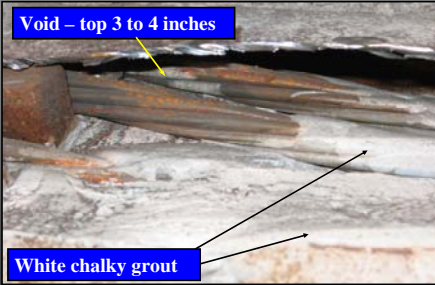


Void in the top half of the tendon

March 7, 2007 Count on Concrete for Performance Slide 31

Siva Corrosion Services, Inc.
materials and corrosion specialists

Void in the Coupler



Void – top 3 to 4 inches

White chalky grout

March 7, 2007 Count on Concrete for Performance Slide 32

Siva Corrosion Services, Inc.
materials and corrosion specialists

Broken Wire at High Point




Broken Wire (possibly during stressing)

March 7, 2007 Count on Concrete for Performance Slide 33

Siva Corrosion Services, Inc.
materials and corrosion specialists


Typical Condition near Anchorage



Siva Corrosion Services, Inc.
materials and corrosion specialists

March 7, 2007 Count on Concrete for Performance Slide 34

Tendon in Ramp D – Bottom Slab



Severe corrosion of strands (with several wire breaks)

Siva Corrosion Services, Inc.
materials and corrosion specialists

March 7, 2007 Count on Concrete for Performance Slide 35

Air void in contact with tendon trace



7X GROUT 4 1 mm

Siva Corrosion Services, Inc.
materials and corrosion specialists

March 7, 2007 Count on Concrete for Performance Slide 36

