

# Identifying Broken and Corroded Post-Tensioned Bars and Tendon Tendons

Purdue Road School

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Siva Venugopalan

Principal Engineer

Siva Corrosion Services (SCS)

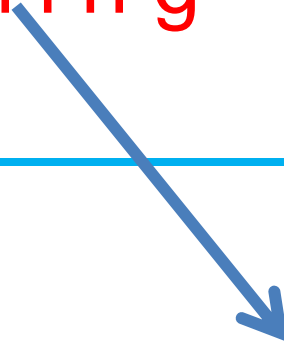
[Siva@SivaCorrosion.com](mailto:Siva@SivaCorrosion.com)

[www.SivaCorrosion.com](http://www.SivaCorrosion.com)



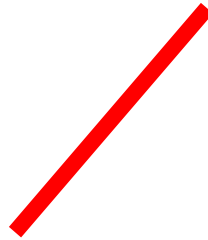
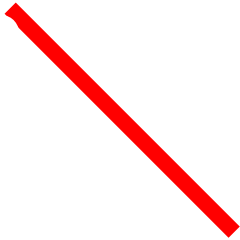
Structure	PT Rods
B-4 00 2 8-5 3 7 A	3 5 1
B-4 00 2 8-5 3 7 B	4 1 6
B-4 00 2 8-5 3 7 C	1 9 5
B-4 00 2 8-5 3 8 A	3 1 2
B-4 00 2 8-5 3 8 B	2 6 0
B-4 00 2 8-5 3 8 C	2 8 3
B-4 00 2 8-5 3 8 D	1 9 5
<u>Total Rods</u>	<u>2 0 1 2</u>

Opening





- PT Rods were installed to develop concrete superstructure over the piers
- General conditions of severe rail uplift on PT Rod conditions were of particular concern
- Only the ends of the Rods were accessible
- Inspection difficulties openings too small, false work from original construction
- A number of Rods appeared to experience fracture



- Concerns that some Rods were experiencing continued corrosion and were possibly
- Past inspections limited to sounding the ends (when accessible)
- Problem Rods may have significant corrosion yet still sound good giving a false sense of security
- Remaining strength of structure dependent on number of PT Rods still in good condition



- Load carrying capacity could be reduced if a certain number of PT Rods were corroded
- Unlike RC structures, reduction in PT strength can result in sudden structural failure
- Department placed the structure on a 6-month inspection cycle
- Inspection firm recommended a NDT cycle for further testing



## Owner Will Achieve the Following Goals

- Identify broken and severely corroded
- Discount Rods (that are broken or severely corroded) in calculating the existing capacity of Unit 38C
- Solve problems before problems become much larger and more costly

More economical to proactively replace a small number of rods instead of performing emergency repairs later





### Past Inspections:

- More visible corrosion than other Units
- A higher number of suspected broken/
- Some Rods were ineffective in carrying (loose rod)

### Phased Approach:

- With 2012 Rods, and limited funding, Rods Phases
- Benefit of Phased testing is to investigate results and decide best course of action at each step







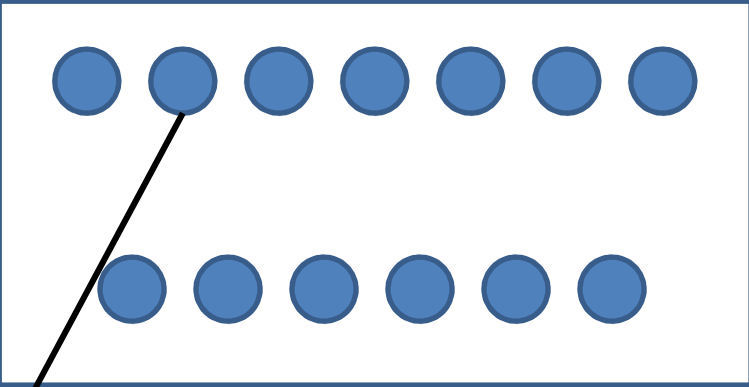
∅ Construction detail prohibited visual  
of both ends of Rods (in some cases)

∅ Rods were electrically continuous bec  
electrical short that exists through th  
reinforcement

- Connected to both ends of each Rod
- A set amount of current is applied (using a computer driven system), and the voltage is recorded
- Resistance of the Rod is calculated using Ohm's law
- After statistical analysis, broken/severely corroded Rods are identified

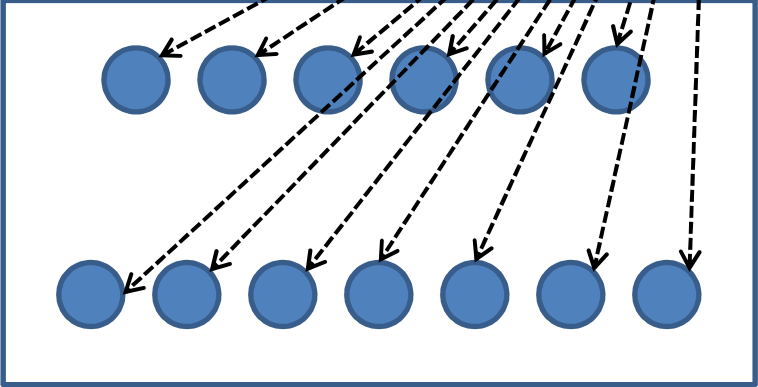


Test Sequ  
Interior E



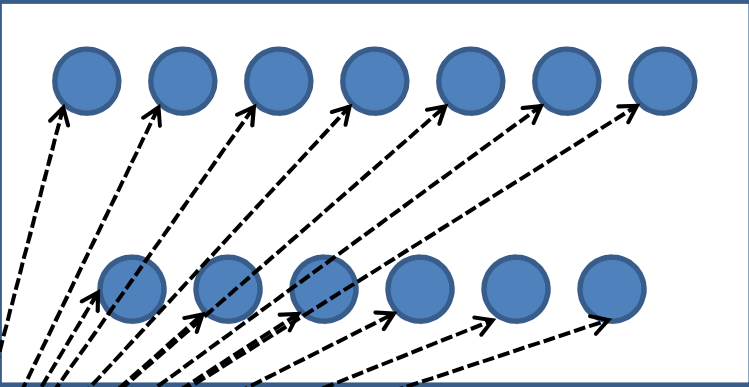
Exterior

Potential



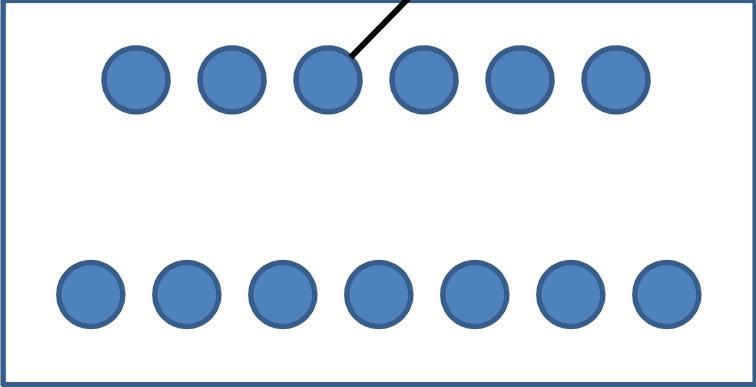
Interior

Test Sequ  
Exterior E



Exterior

Potential

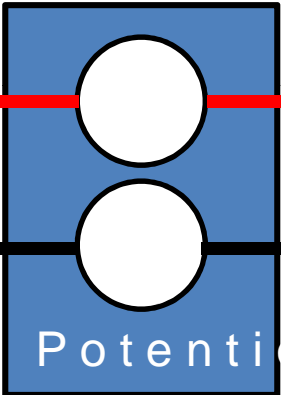
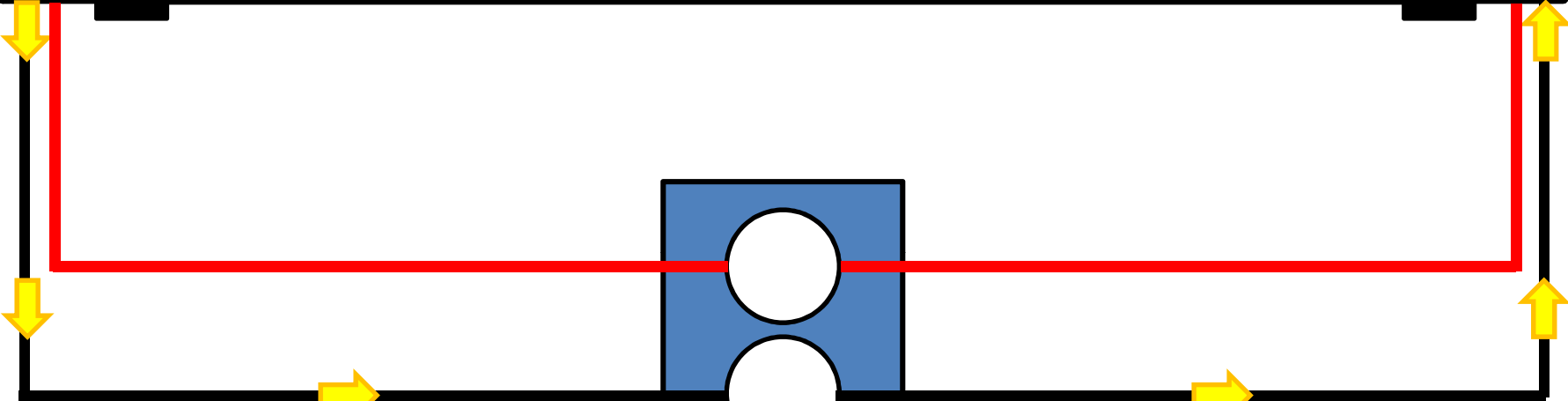
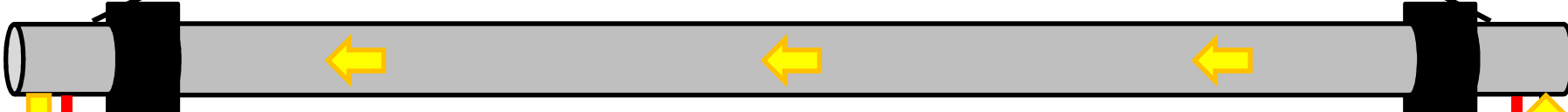


Interior

Measure voltage between rod ends

between

rod ends



Computer/  
Data Logger



• CS performed STAT test on  
• The results were analyzed s  
• The average and standard d  
calculated.

• Identified all rods that had  
than 97.5% of all rods.



• Mean: the average value of a data set

• Standard Deviation: a measure of variability of data around the mean

i.e. Are the measurements all about the mean or are there resistance values that are significantly from the mean?

• Probability: The chance that a particular event will (or did) occur

Probability Density  
Mean

$z$  is the number of standard deviations away from the mean

~ 68 %



~ 95 %



13.6 %

13.6 %

~ 99.7 %



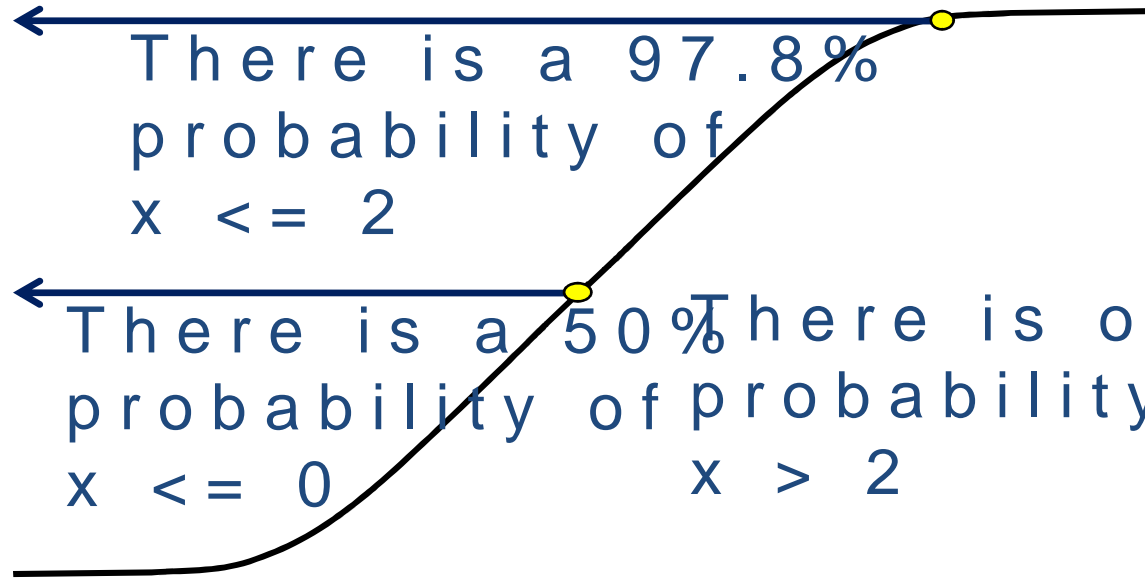
13.6 %

13.6 %

2.1 %

2.1 %

Probability:  $F(x)$



There is a 97.8% probability of  $x \leq 2$

There is a 50% probability of  $x \leq 0$

There is only a 2.2% probability of  $x > 2$

x

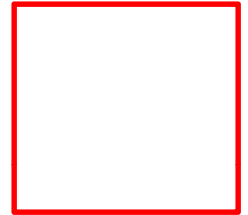
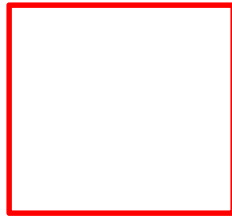
- Employing statistics, one can evaluate with proper distribution of sufficient t (i.e. no more testing than necessary)
- Distributions also help us to identify problems (e.g. issues with PT Rods)



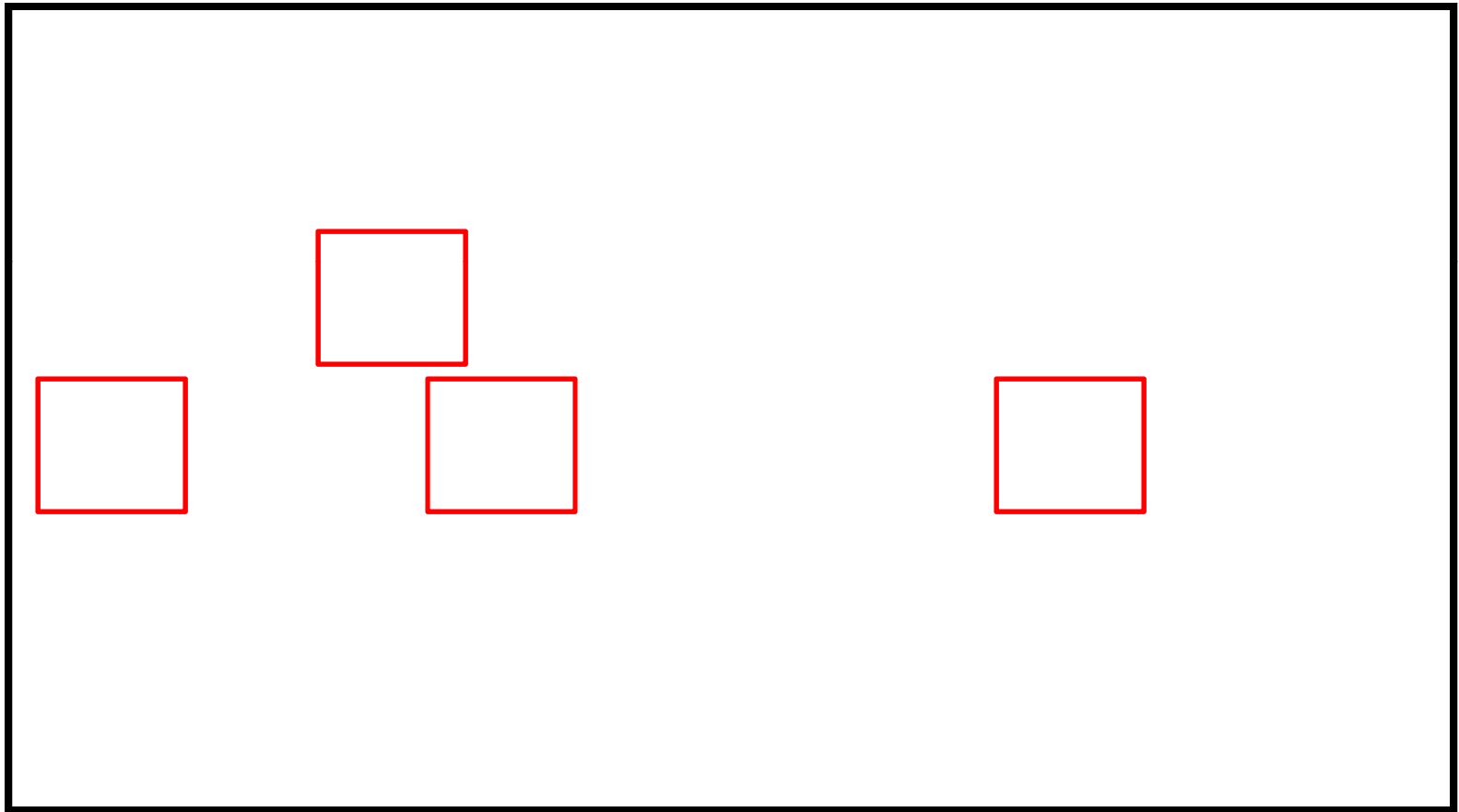




# Problem Rods



# Problem Rods



Cell Number	Corroded/Brakes 95% Confidence Level
2F	Interior # 9
2G	Interior # 3
	Interior #4
	Exterior # 11
	Exterior # 13
2J	Exterior #3
3A	Interior #3
	Interior #5
3B	Interior #14
3C	Interior #5
	Interior #12
3F	Interior #2
	Interior #7
3J	Interior #2
	Interior #7
	Interior #9
	Interior #12
	Exterior #1
	Exterior #7
	Exterior #9
3K	Interior #10
	Interior #12
	Interior #13
	Exterior #5







21 powder samples were collected

6 of 21 locations exhibited chloride level  
depth below the corrosion threshold (end)

Chloride levels throughout shiplap area  
exceed threshold and initiate corrosion

If left unaddressed, corrosion and cost  
increase exponentially



∅ The measured resistances clearly indicate the number of rods that are broken or severely corroded

∅ The mean ( $\frac{1}{4}$ ) and the standard deviation of the resistance are 3.1 and 1.04, respectively

∅ About 8% of rods have experienced significant corrosion/section losses

∅ The structure can be restored to full capacity if severely corroded rods are identified and replaced soon

• GPR was effective in identifying reinf  
well as the boundaries of the boxes

• Core locations were chosen within the  
the inaccessible boxes (between the p  
shiplaps) while avoiding drilling throu  
reinforcement

• Chloride contamination in the shiplap

• Corrosion of the reinforcement and re  
concrete damage will continue and ac

• Corrosion will lead to expensive repair  
addressed soon

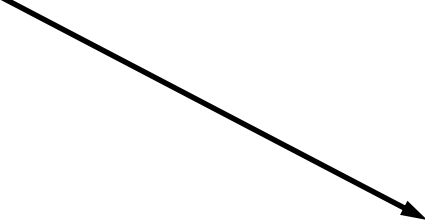
- Remove and replace all rods identified significantly corroded or already broken
- After removal, correlate measured section to measured resistances and determine correlation coefficient, if any
- Perform additional analysis of Unit 38 the correlation coefficient and identify rods that may be severely corroded.
- Perform similar resistance testing on to determine the integrity of the PT rods

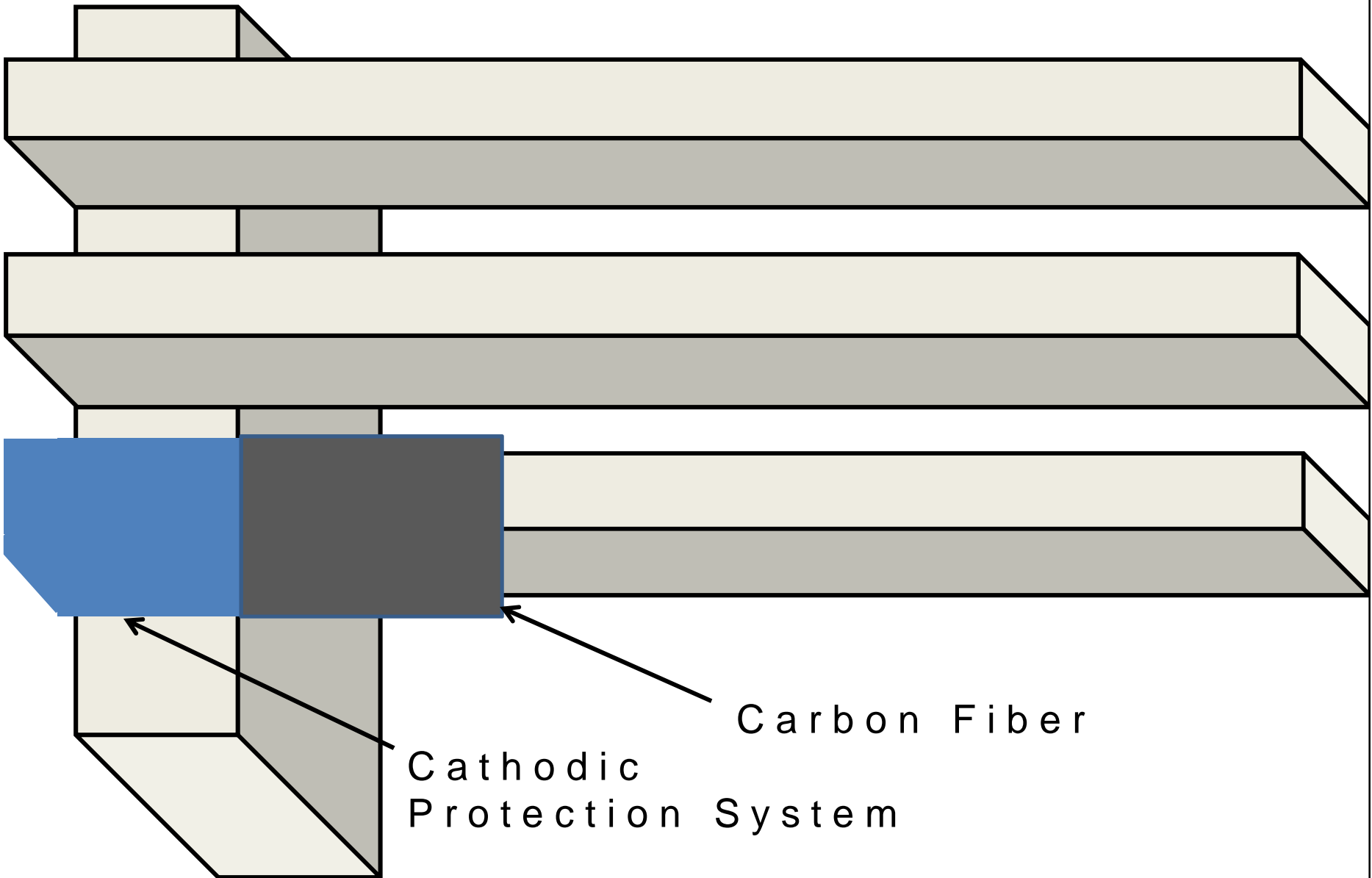
ø Perform additional chloride testing aw  
shiplap region and on the top slab to  
the extent of contamination throughou  
structure

ø Install a corrosion protection system  
further damage to the structure

ø Perform an NDT evaluation of the top  
(chloride contamination of deck is hig

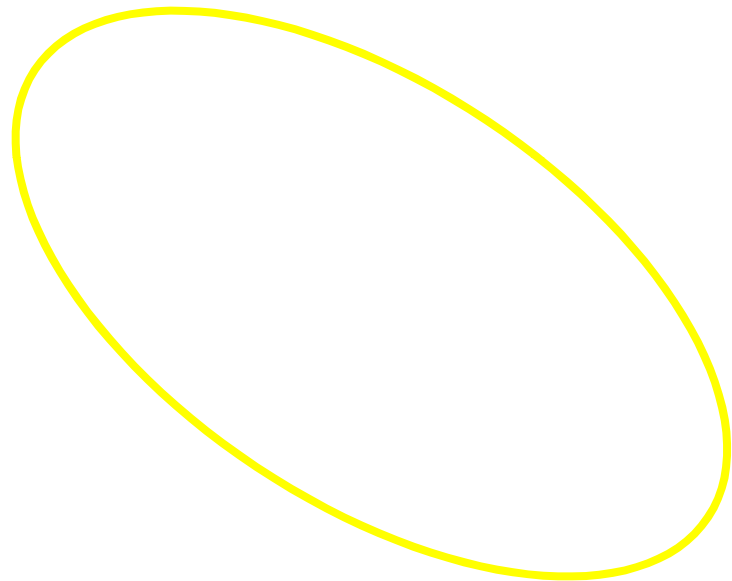






Carbon Fiber

Cathodic Protection System

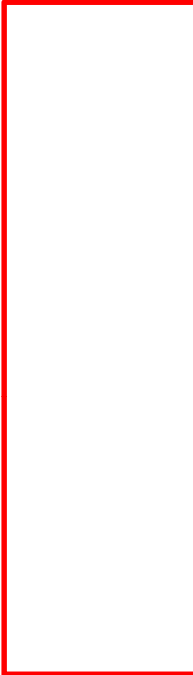


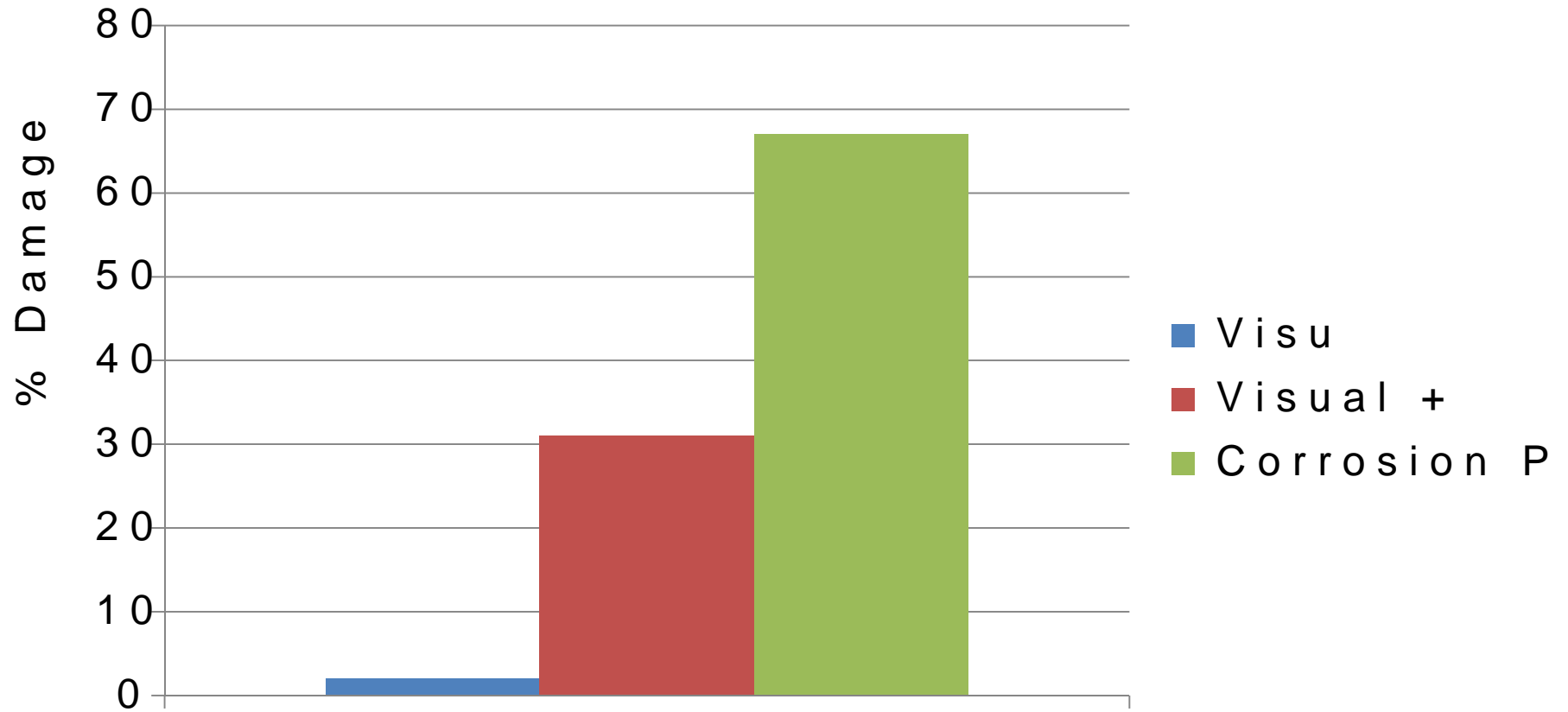
- Performed tests at site and in laboratory
- Quantified the extent, causes of corrosion
- Designed a Cathodic Protection System to extend service lives of piles
- Ruled out unnecessary mitigation measures (Owner saved costs)



### Problems:

- Significant cracking, spalls and delaminations
- Visible strand corrosion not yet visible?
- Are there tools that can accurately measure the condition?
- Is preservation possible in this case?





ø The owner better understood proper combinations of NDT tools needed to:  
Quantify existing deterioration  
Predict the future deterioration of b

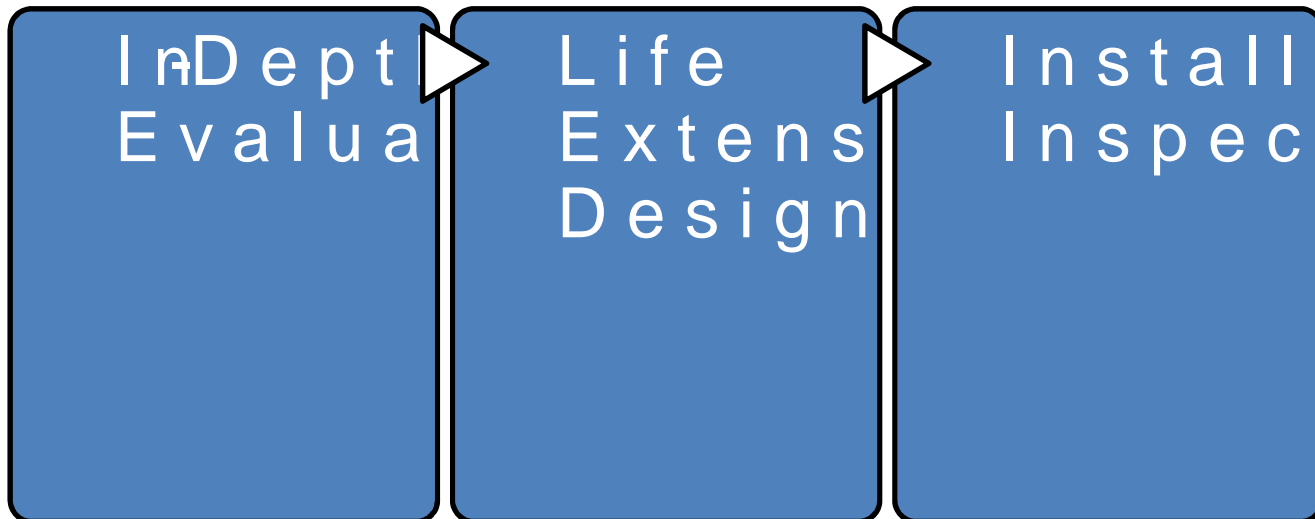
# Closing: About SCS

## Service Life Extension

• Typically only 2-5% of replacement cost

• Solutions for simple & complex steel & concrete structures

• Our Goal: Life Extension at the lowest overall cost



# Thank You

# Questions?

Siva Venugopalan  
Principal Engineer  
Siva Corrosion Services (SCS)  
[Siva@SivaCorrosion.com](mailto:Siva@SivaCorrosion.com)  
[www.SivaCorrosion.com](http://www.SivaCorrosion.com)