Evaluation of Pile Jackets on the Hampton Roads Bridge and Tunnel

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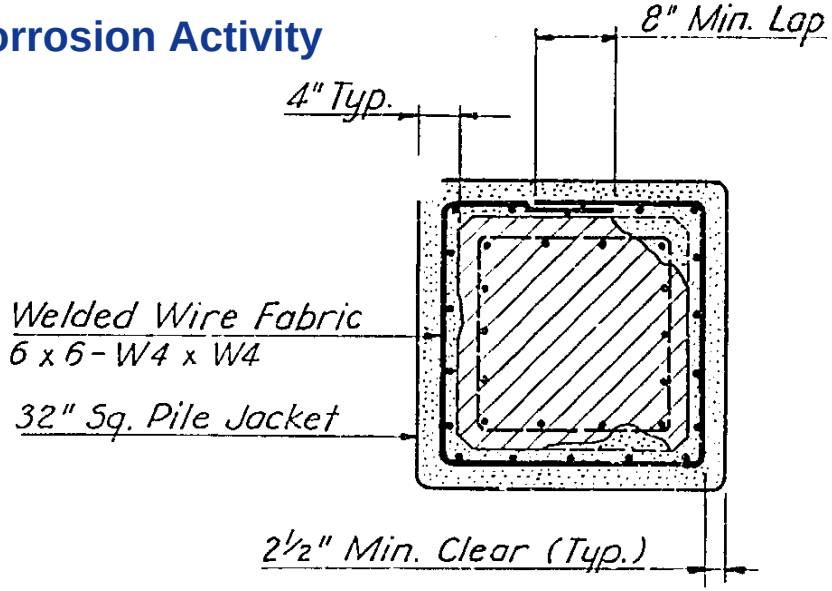
Outline

- What is Pile Jacketing
- Conclusions from a Study Conducted by Florida Department of Transportation (FDOT) on Jacketed Piles
- Hampton Roads Bridge and Tunnel (HRBT)
- Methods of Pile Evaluation
- Results
- Conclusions
- Recommendations

Pile Jacketing

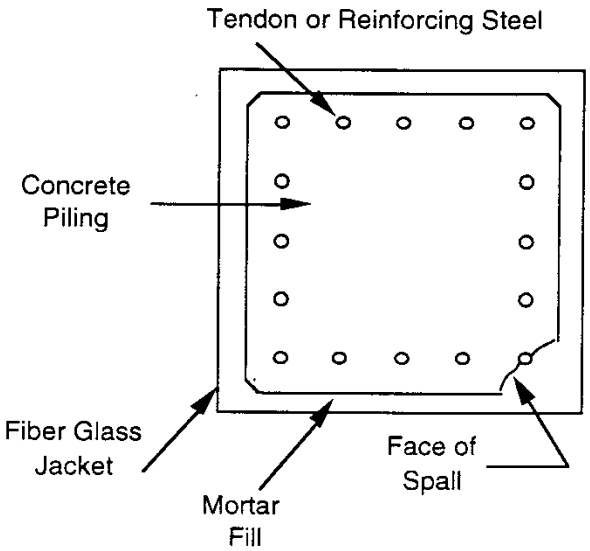
What are Pile Jackets

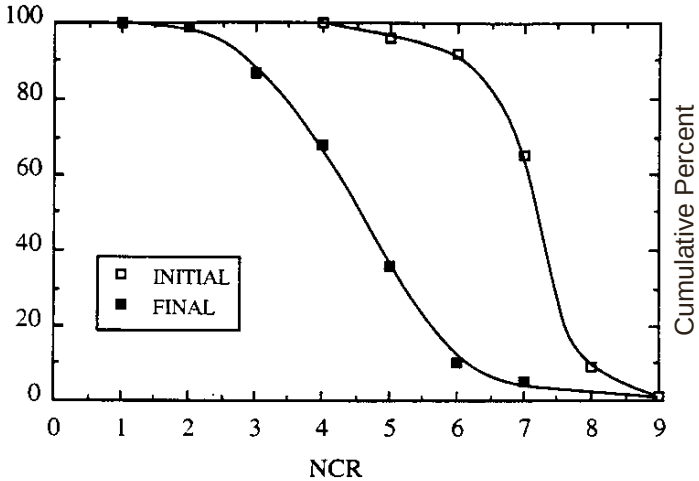
- **Method of Protecting Marine Piles from Corrosion Damage**
- **Fiberglass Stay-in-Place Form**
- **Mortar or Epoxy Fill**
  - **Steel Reinforcement in Mortar Fill**
- **Intended to Prevent Oxygen, Water, and Chloride Intrusion to Pile Substrate**
  - **Stopping any Current or Future Corrosion Activity**



FDOT's Results

- **Jackets Removed from Piles Revealed Extensive Damage**
- **Accelerated Corrosion**
- **Damage Hidden Behind Jacket**





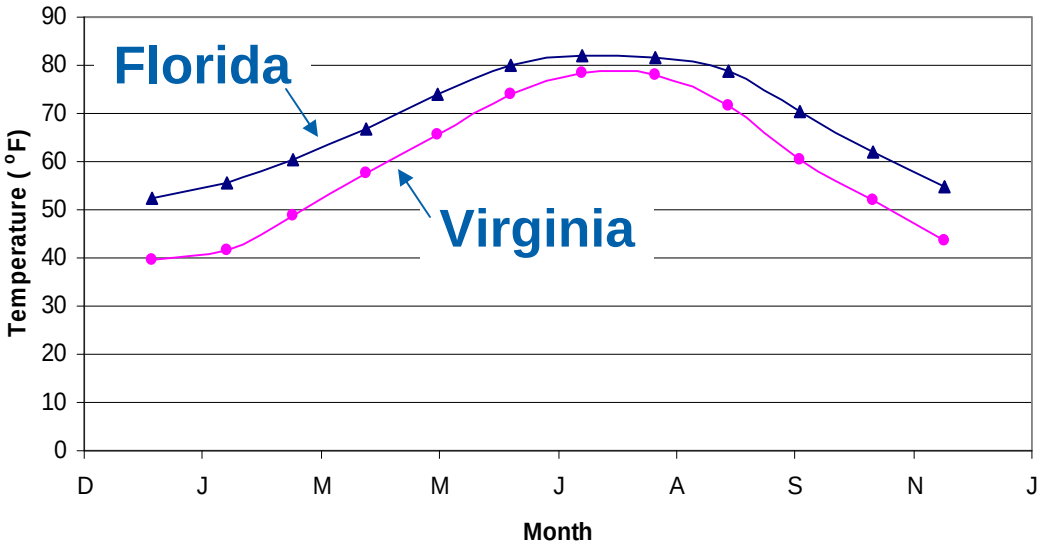
Cumulative distribution plot of pre- and post-inspection NCRs for jacketed prestressed pilings.

Figures Courtesy of William Hartt

Differences Between Florida & Virginia

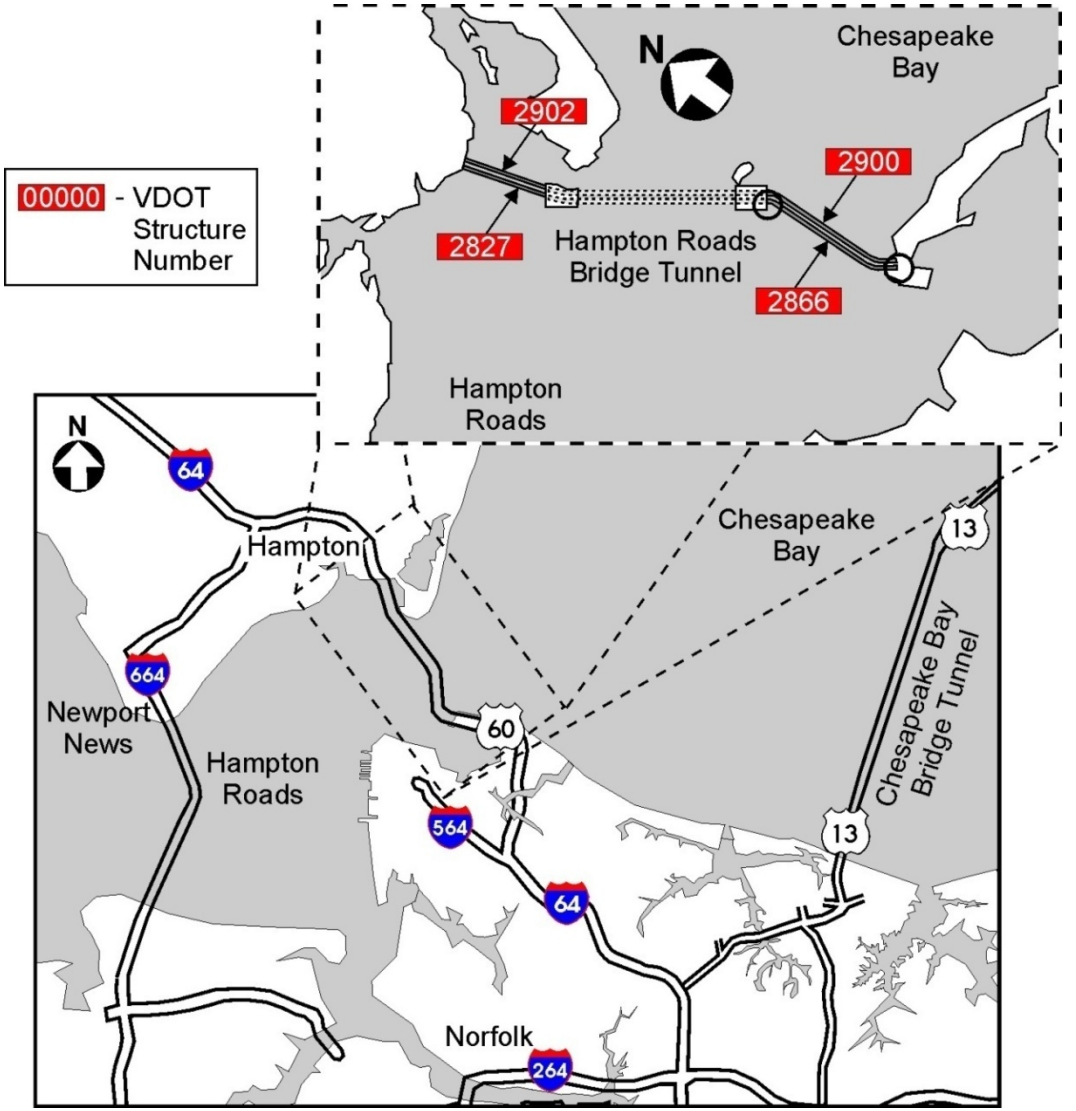
From a Corrosion Standpoint, Harsher Environment in Florida

- Florida
  - Higher Average Temperatures
  - Bridge Located in Salt Water
- Virginia
  - Lower Average Temperatures
  - Bridge Located in Brackish Water

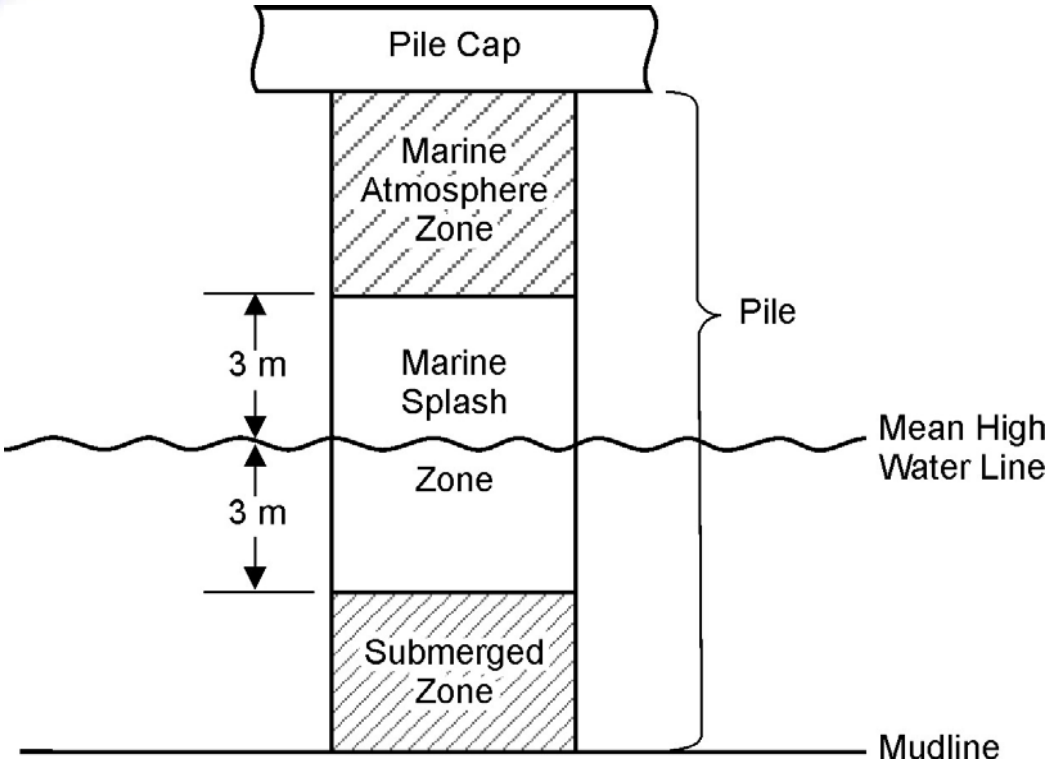


Hampton Roads Bridge Tunnel

- 2 Tunnel Sections
- 4 Bridge Structures
- 1840 Total Piles
- 1511 Piles Jacketed
- Structures 2902 & 2827 Sheltered by Old Point Comfort
- Approximately Half of the Piles Have Been in Service for 53 years



TEST AREA


Pile Cap
Marine Atmosphere Zone
Pile
3 m
Marine Splash
Zone
Mean High Water Line
3 m
Submerged Zone
Mudline

Methods of Evaluation

- **Visual Assessment**
  - **Initial Visual Inspection Performed from a Boat**
- **Half-Cell Potential Measurements**
  - **Copper/Copper Sulfate Reference Electrode**
  - **Measurements made in Marine Splash Zone**
- **Chloride Analysis**
  - **Collected Concrete and Mortar Samples**
    - Samples from Marine Splash Zone
  - **Determined Total Chloride Content at ½" Increments**
- **Resistivity Measurements**
  - **4 Point Werner Probe**
  - **Measurements made in Marine Splash Zone**
- **Jacket Autopsy**
  - **Removed Sections of Jackets on Select Piles**

Visual Condition Rating

Jacket Condition 0

Jacket Condition 1

Jacket Condition 2

Jacket Condition 3

Jacket Condition 4

Jacket Condition 5

Fiberglass Condition

0. **Jacket Not Installed**
1. **Fiberglass Intact**
2. **Fiberglass Split**
3. **Less Than 50% of the Fiberglass is Missing**
4. **More Than 50% of the Fiberglass is Missing**
5. **Fiberglass is Completely Missing**

Visual Condition Rating

Mortar Condition 0

Mortar Condition 1

Mortar Condition 2

Mortar Condition 3

Mortar Condition 4

Mortar Condition 5

Mortar Condition

0. Jacket Not Installed or Fiberglass obstructs view of Mortar
1. Mortar Intact
2. Corrosion Product Formed from WWF
3. Less Than 50% of the Mortar is Missing
4. More Than 50% of the Mortar is Missing
5. Mortar is Completely Missing

Visual Condition Rating

Substrate Condition 0 Substrate Condition 1 Substrate Condition 2 Substrate Condition 3 Substrate Condition 4* Substrate Condition 5**

Substrate Condition

0. **Jacket Obscures View of Substrate**
1. **No damage**
2. **Corrosion Product**
3. **Significantly Large Cracks are Visible**
4. **Concrete has Spalled Away**
5. **Severe Section Loss in the Pile, Necking**

Visual Condition Rating

Overall Condition Rating

- **Determined by Equation that was Developed**
  - **Overall Condition Rating = Jacket Condition + Mortar Condition*3 + Substrate Condition*6**

Weighted Summation Value	Overall Visual Condition Rating
1	Condition 1
2 - 8	Condition 2
9 - 14	Condition 3
15 - 21	Condition 4
22 - 50	Condition 5

Legend

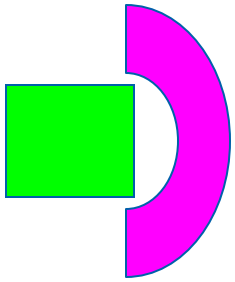
Condition 1 Pile

Condition 2 Pile

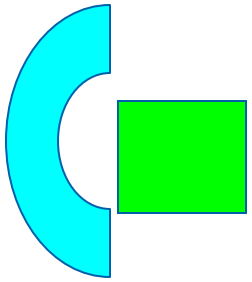
Condition 3 Pile

Condition 4 Pile

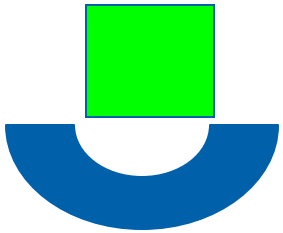
Condition 5 Pile



Pile with Preexisting Damage



Pile Evaluated During Study



Pile Scheduled to Receive 2nd Gen. Jacket

N
℄ BENT 1
℄ BENT 5
℄ BENT 10
℄ BENT 15
℄ BENT 20
℄ BENT 25

N
2827
2902
Hampton Roads Bridge Tunnel
Chesapeake Bay
2866
2900

3/17/2010

N

℄ BENT 30
℄ BENT 35
℄ BENT 40

N
2827
2902
Hampton Roads
Bridge Tunnel
Chesapeake
Bay
2866
2900

N
℄ BENT 5
℄ BENT 10
℄ BENT 15
℄ BENT 20
℄ BENT 25
℄ BENT 30
℄ BENT 35

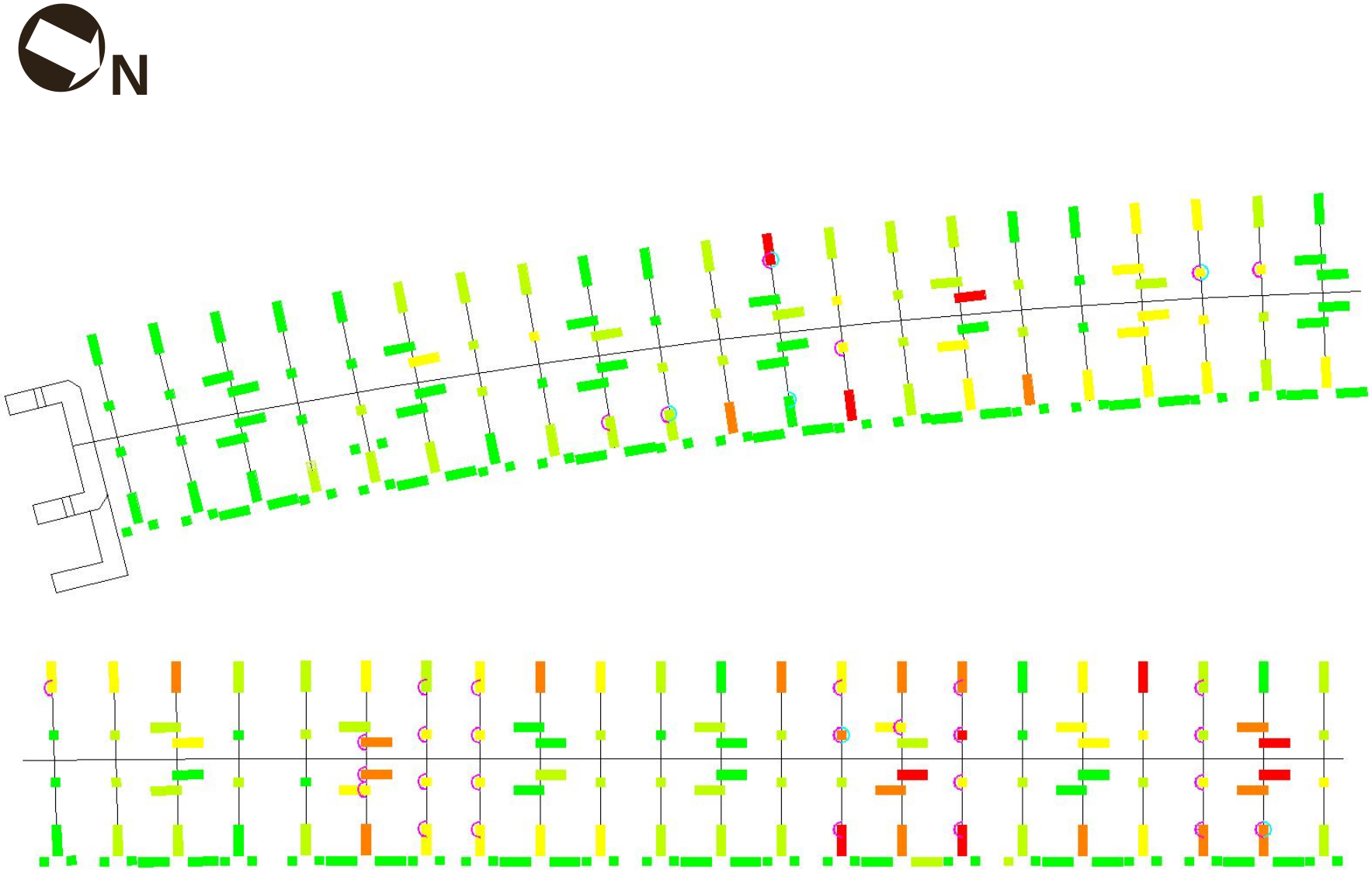
N
Chesapeake Bay
Hampton Roads Bridge Tunnel
2827
2902
2900
2866

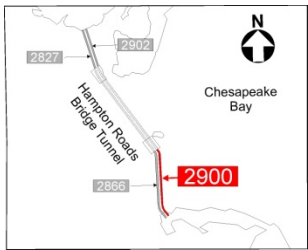
N

℄ BENT 40
℄ BENT 45
℄ BENT 50
℄ BENT 55

℄ BENT 60
℄ BENT 65
℄ BENT 70
℄ BENT 75

N
Chesapeake Bay
Hampton Roads Bridge Tunnel
2827
2902
2900
2866




N
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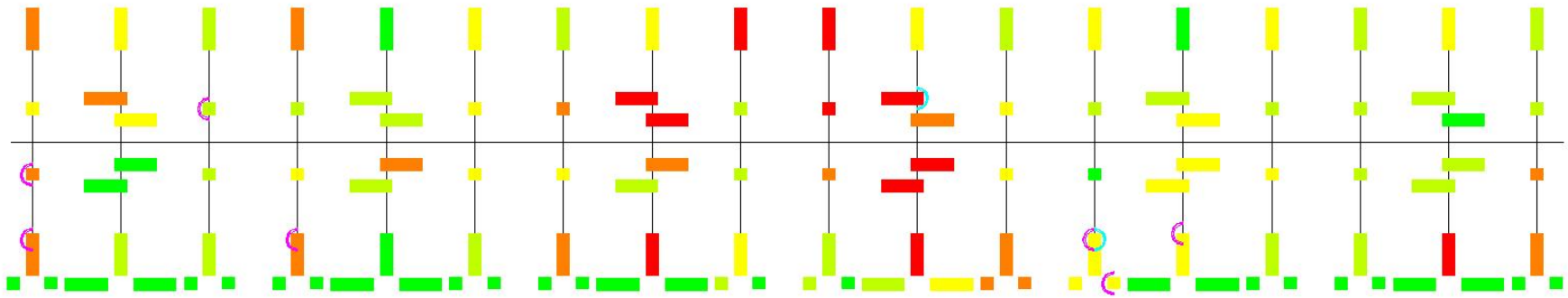
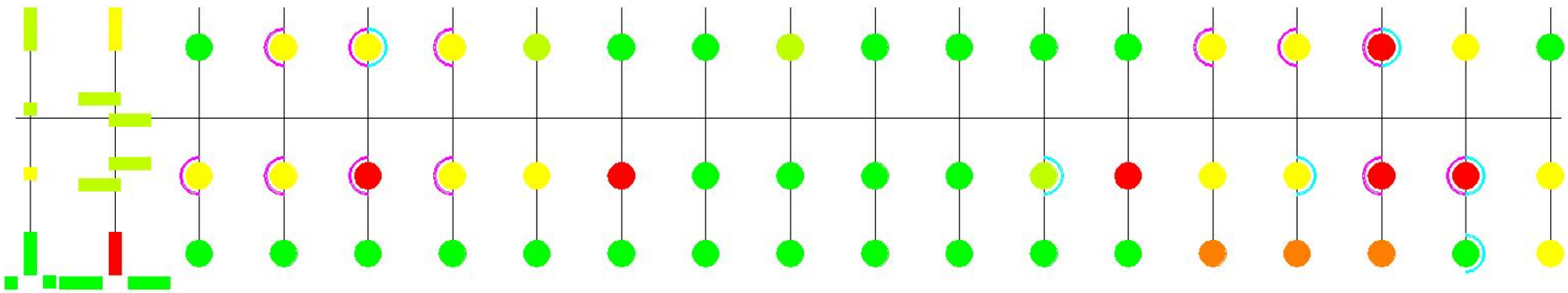
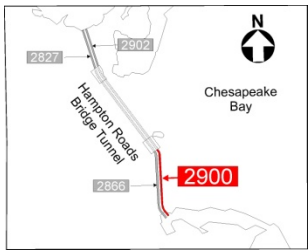
2902
Hampton Roads
Bridge Tunnel
Chesapeake
Bay
2900
2866

N



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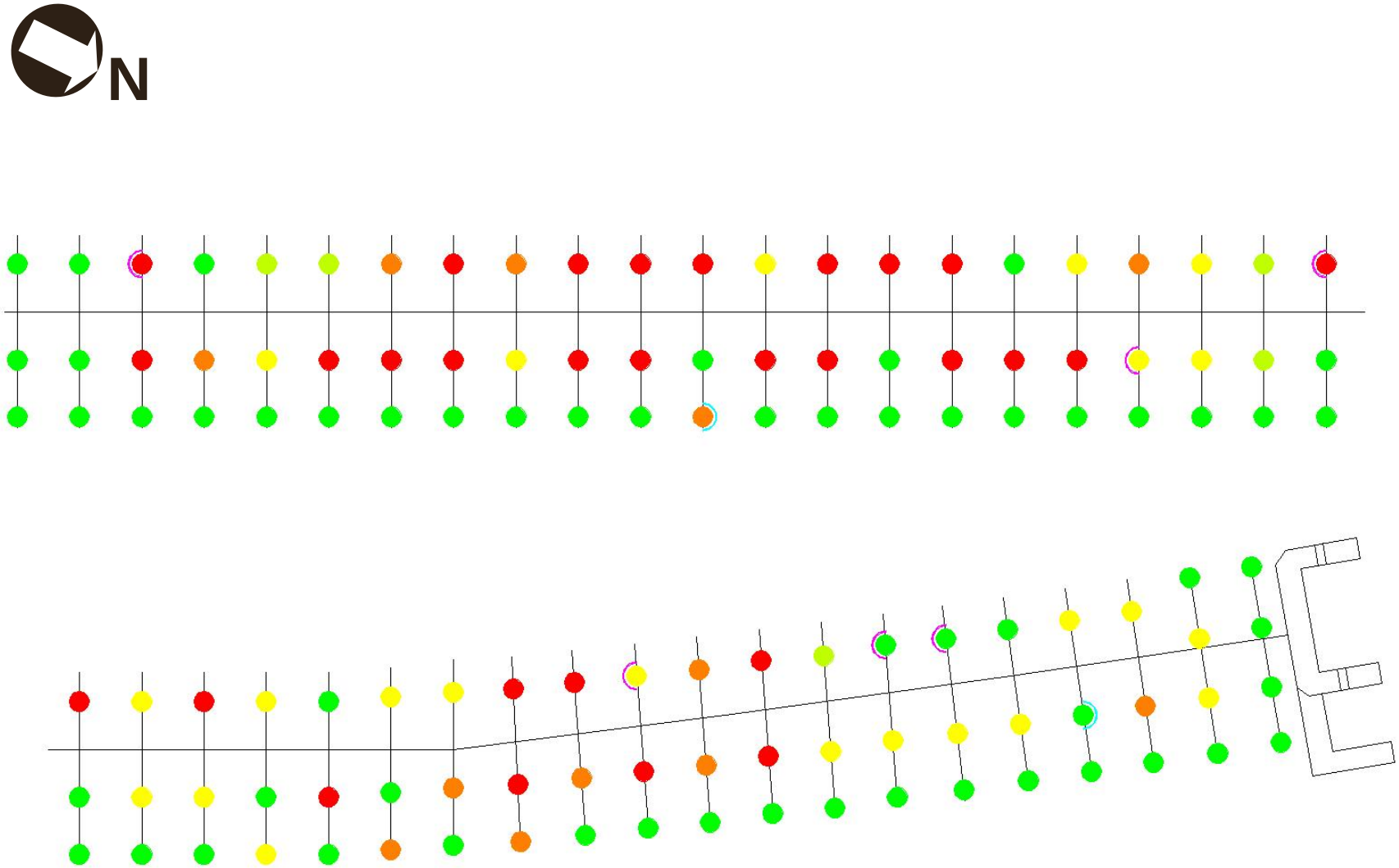
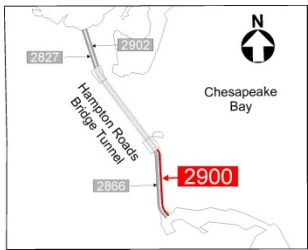
Bridge Tunnel
Chesapeake
Bay
2900
2866

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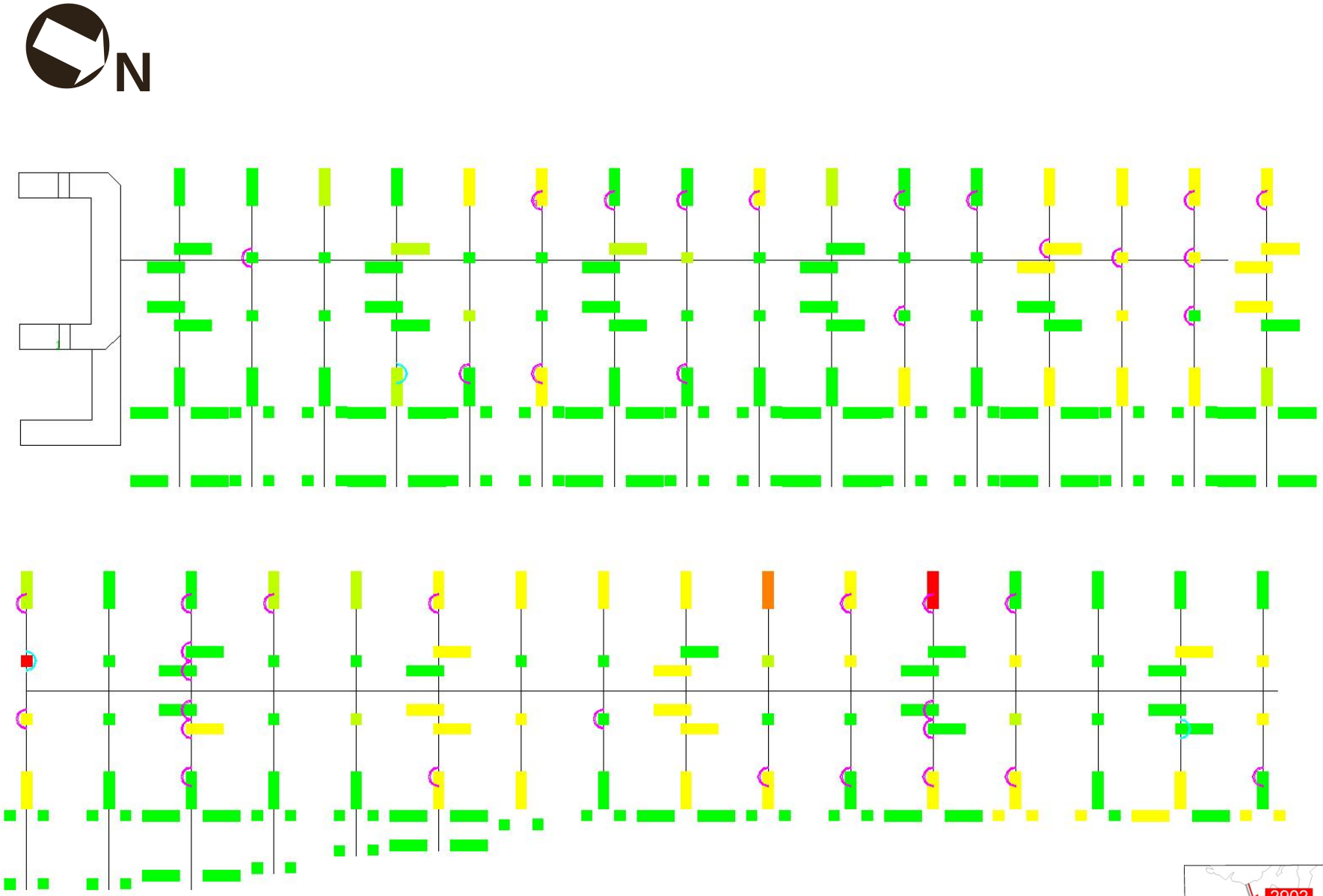

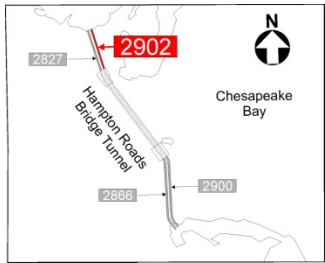
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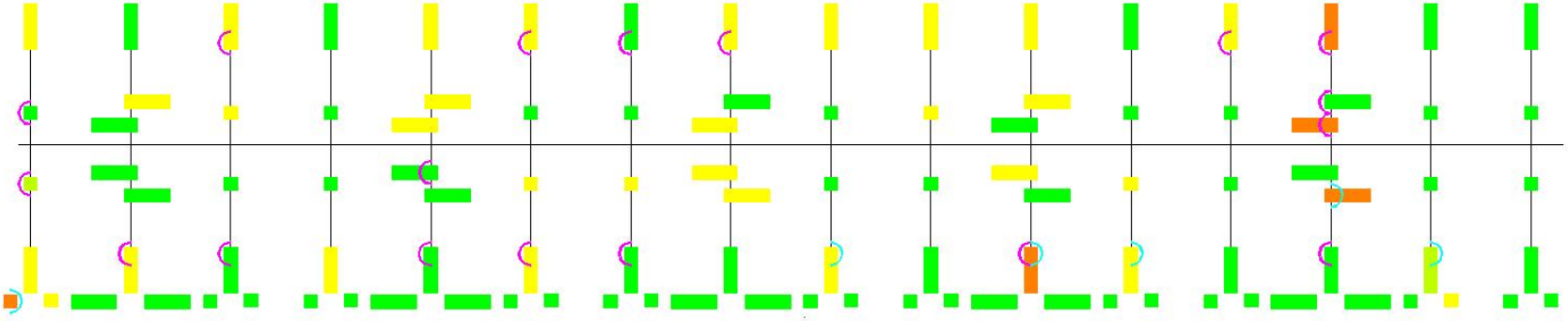
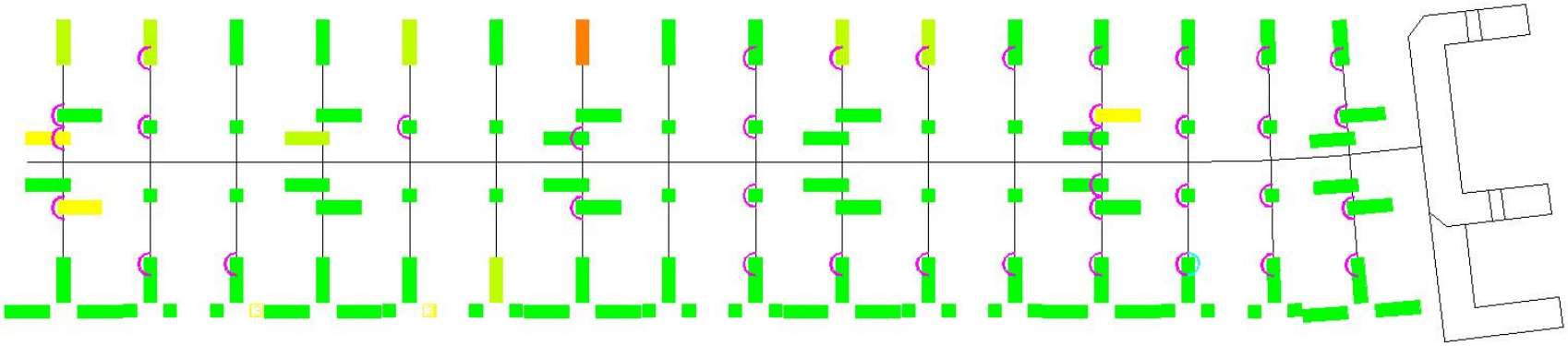
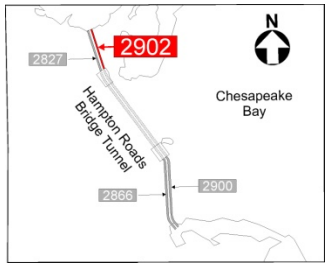
2827
Hampton Roads
Bridge Tunnel
Chesapeake
Bay
2900
2866

N

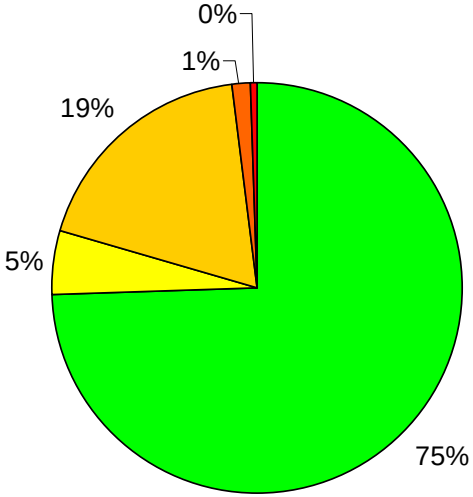




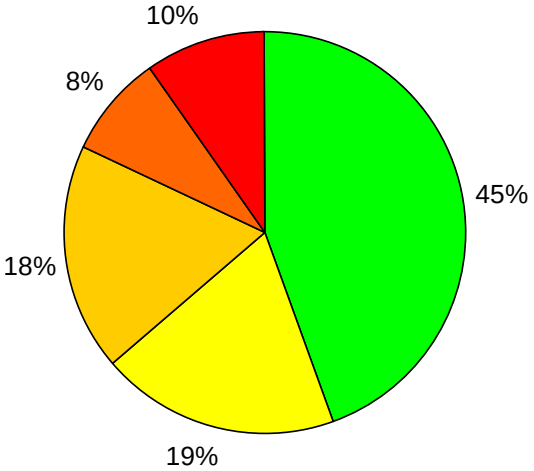

N
2902
2827
Hampton Roads
Bridge Tunnel
Chesapeake
Bay
2900
2866

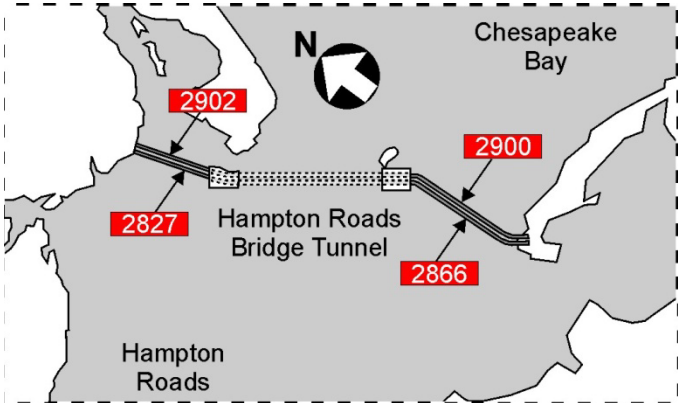
Visual Condition Rating

Structure 2902

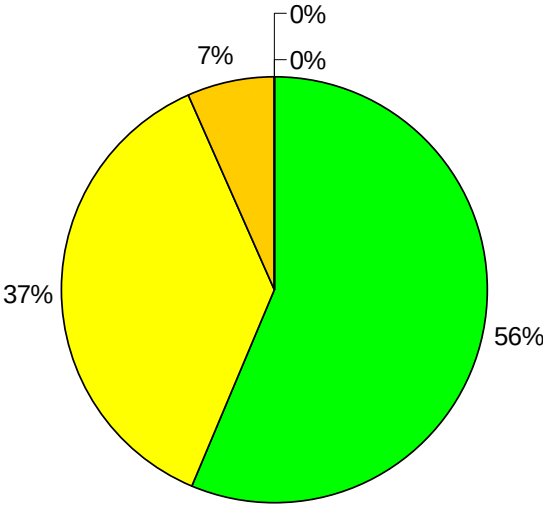


Structure 2900





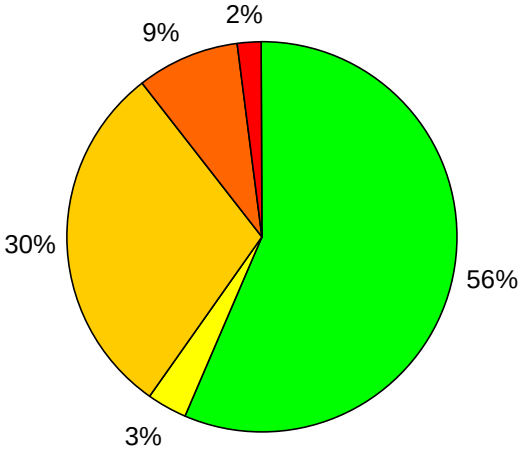
Structure 2827



Condition Rating

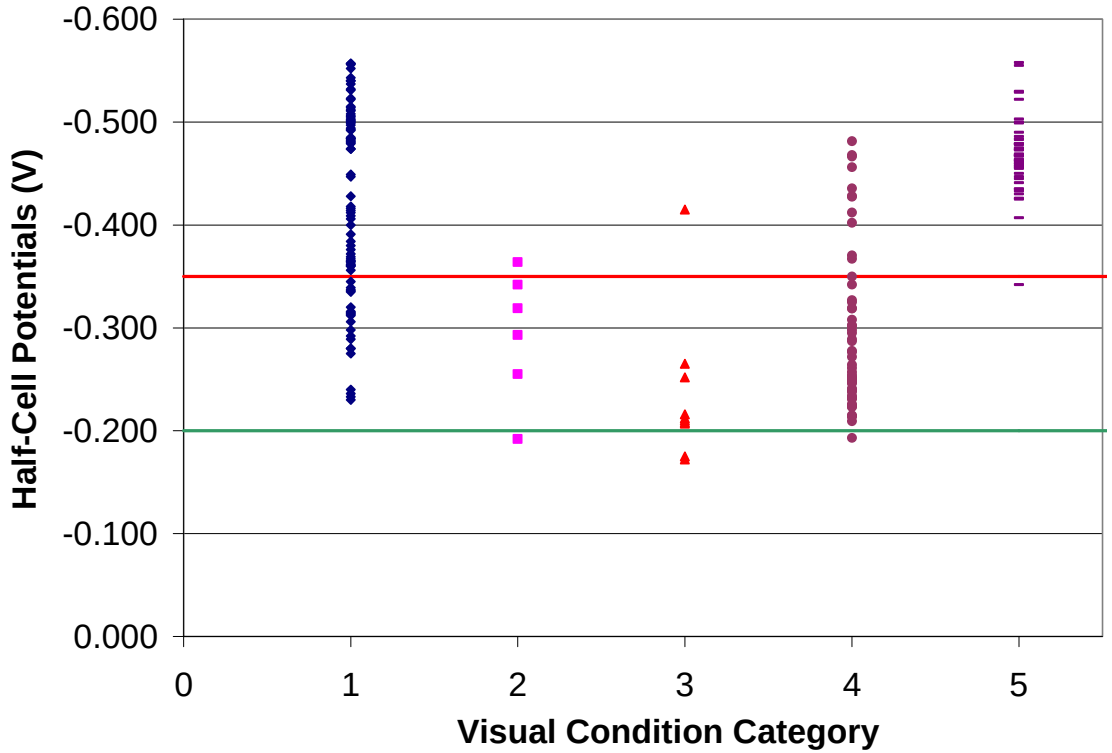
1 2 3 4 5

Structure 2866



Half-Cell Measurements

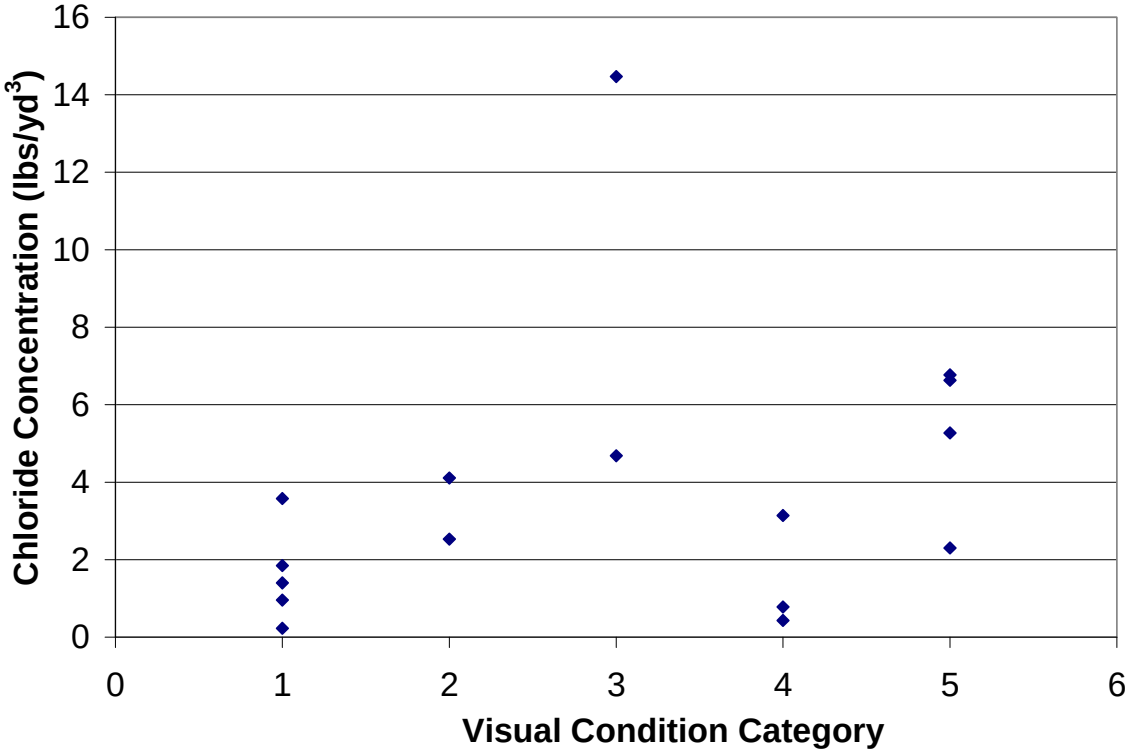
- High Potentials Even in “Good” Piles
- 64% of the Measured Potentials more Negative Than -0.300 V



Chloride Analysis

Chloride Content at Steel depth

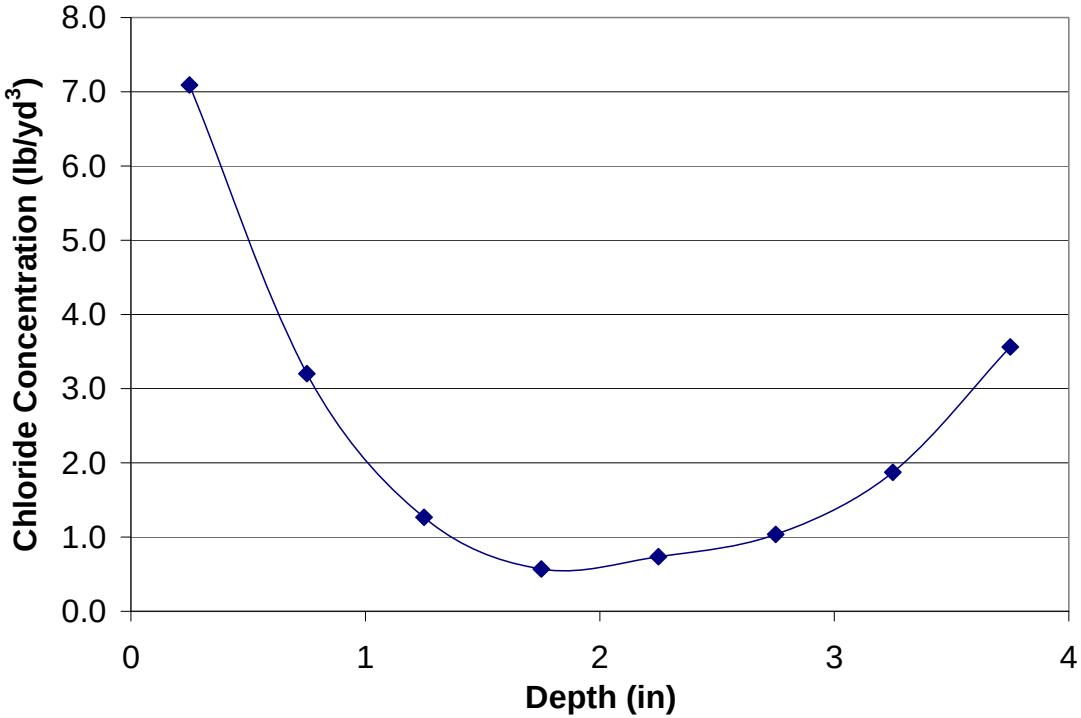
- **25% of Samples Below 1 lb of Cl/yd^3 of Concrete**
- **63% of Samples Above 2 lb of Cl/yd^3 of Concrete**
- **The Chloride concentration for Corrosion Activity are Present in many Jacketed Piles**



Chloride Analysis

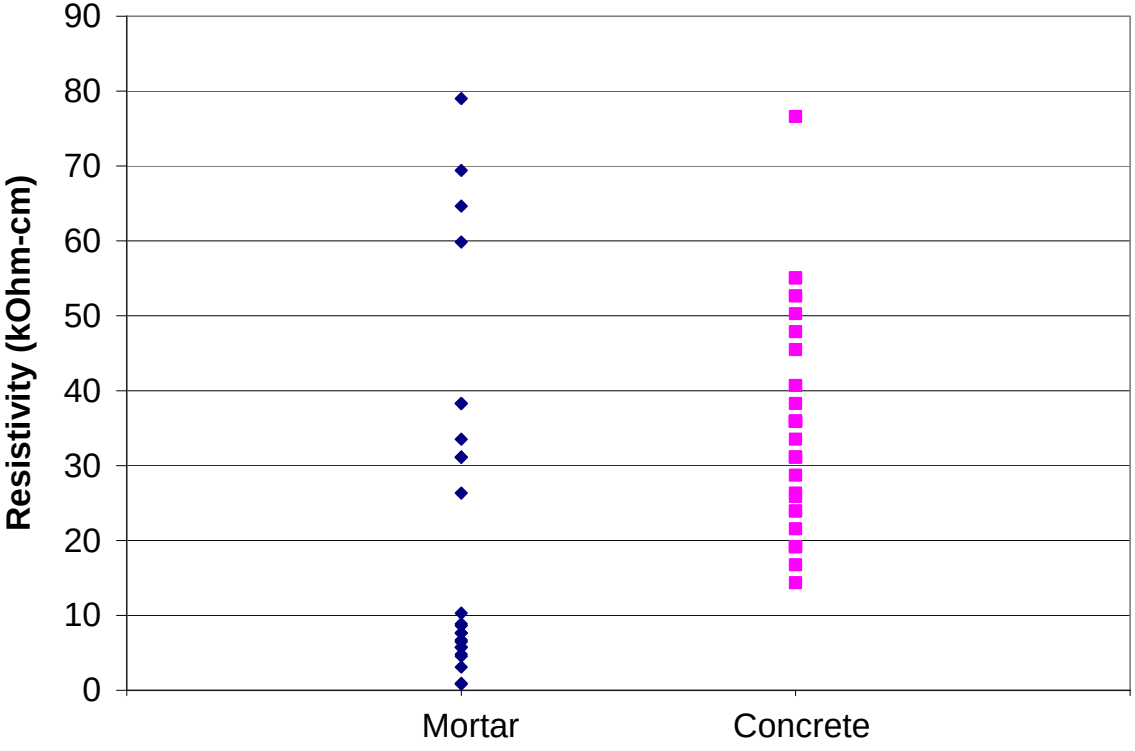
Chloride Diffusion of Mortar Occurring in Both Directions

- **Jacket Wicks Water**
- **Diffusion from Substrate**



Resistivity

- 54% of Mortar Resistivities Below 10 kOhm-cm
- All Substrate Concrete Resistivities above 10 kOhm-cm
- Mortar Less Resistant to Corrosion Activity than Concrete



Jacket Autopsy

Steel in Jackets

- **Minimal Mortar Cover**
- **Corrosion Initiates Quickly**
  - **Causing Mortar Section Loss**

Jacket Autopsy

Mortar without Steel

- **No Corrosion Product**
- **Mortar in Good Condition**
- **Mortar Intact on Pile**

Jacket Autopsy

Pour Mortar Quality

- **Significant Honeycombing**
- **Objects Cast into Mortar**

Jacket Autopsy

Damage Behind Condition 1 Jacket

- **Jacket Appeared to be in Excellent Condition**
- **Cracking of Substrate Hidden**
- **Light Corrosion Product on Substrate Steel**

Jacket Autopsy

Severe Damage Behind Condition 5 Jacket

- **Large Cracking**
- **Significant Section Loss of Prestressed Tendon**

Jacket Autopsy

- **Piles rated before and after autopsy**
- **Condition rating values increased following autopsy**

Structure	Bent	Pile	Pre-Autopsy Condition Rating	Post-Autopsy Condition Rating
2866	67	G	1	4
2866	67	H	1	3
2900	5	B	1	4
2900	45	A	1	2
2900	45	B	5	5
2902	23	C	4	5

Conclusions

- Observed Damage Not as Severe as in Florida
  - Most Likely Due to Milder Environment
- Jackets Hide Damage
- Jackets do not Rehabilitate or Stop Corrosion when Applied to Piles with Existing Corrosion Damage
- Steel Reinforcement in Jacket Mortar is Detrimental to Jacket Life
- Jacket Mortar is of Low Quality and Poor Construction

Recommendations

- Discontinue Use of Traditional Pile Jacketing with Mortar Fill
- If Jackets Are Used on Newly Constructed Piles, They Should be Epoxy Filled
- If Jackets Are to be Used on Existing Piles, They Should Include Cathodic Protection
- Prioritize Piles For Repair of HRBT Structure
  - Start with Condition 5 Piles and Piles with Damage Prior to Jacket Installation

VTRC
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Research Council

Thank You

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