



Effect of Cracking on Reinforced Concrete Corrosion

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CP-3

Reinforced Concrete Corrosion

- Concrete is an effective barrier of chlorides, carbonation, and other contaminants reaching the steel
- Keys to concrete success
 - High pH allows for steel to be passive
 - Low permeability of concrete
 - Cover-depth (increase barrier distance to overcome)

Cover Depth

- Cover-depth is one of the most important factors in the service life of a reinforced concrete structure

$$C_{(x,t)} = C_o \left(1 - \operatorname{erf} \frac{x}{2\sqrt{D_c t}} \right)$$

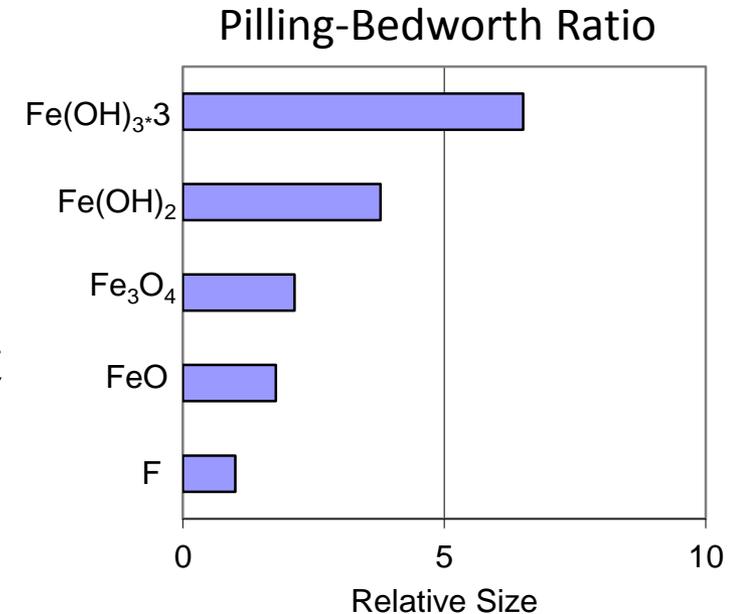
$$t = \frac{1}{D_c} \left[\frac{x}{2 \times \operatorname{inverf} \left(1 - \frac{C_{x,t}}{C_o} \right)} \right]^2$$

$$t = \left(\frac{d}{A} \right)^2$$

- The best quality concrete does not help if the concrete cover is low or cracks are present

Cracks and Corrosion

- Corrosion leads to cracking
 - Iron oxide is expansive
 - Note, some forms of corrosion in low oxygen environments are not expansive, i.e. black rust
- **Cracking leads to corrosion**
 - **Direct path**



Concrete Cracking

- Cracking in the concrete provides a direct pathway to reinforcement for contaminants
- Many causes of concrete cracking
 - Concrete shrinkage
 - Mechanical stress due to overloading or improper concrete strength, under reinforced
 - ASR
 - Freeze thaw damage
- Service life of structure subjected to cracking is significantly reduced

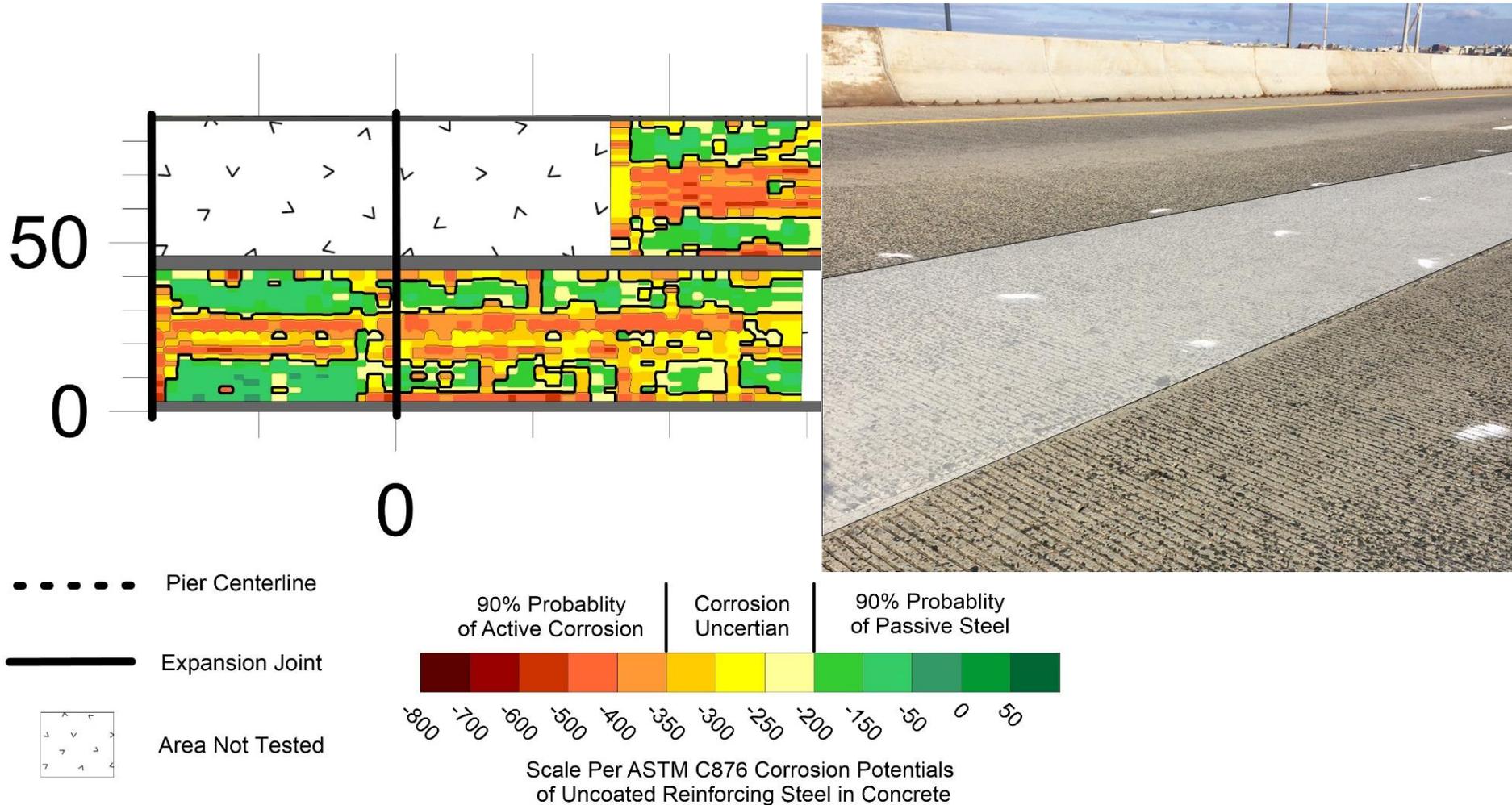
I-395 HOV over Potomac River



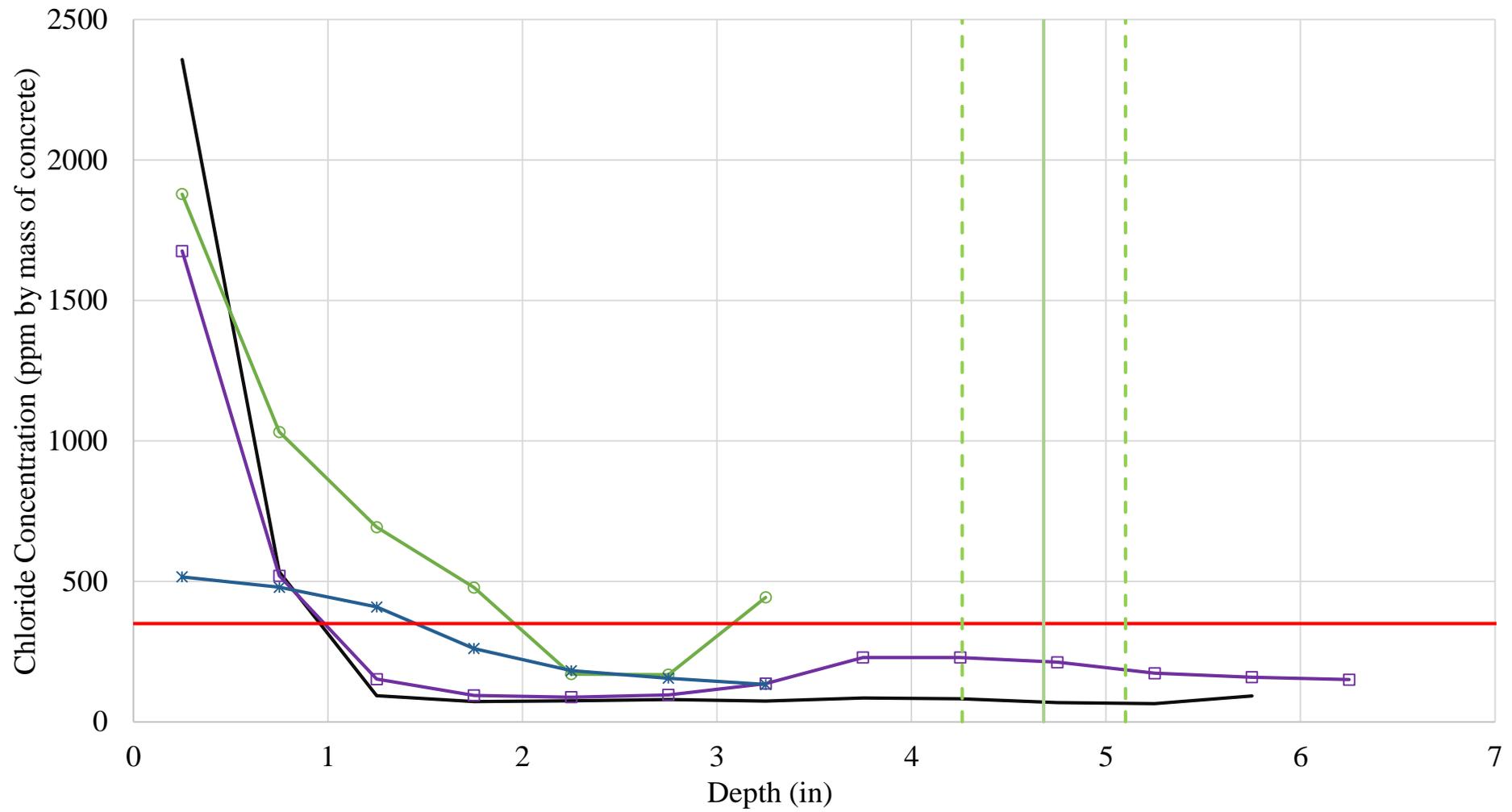
I-395 HOV

- Deck
 - Original concrete deck was overlaid
 - Shrinkage cracking in the overlay has exposed the deck to high concentrations of chlorides
 - Center lane closure pour construction joint has provided a pathway for moisture and chlorides
- Substructure
 - Chloride exposure only at expansion joints

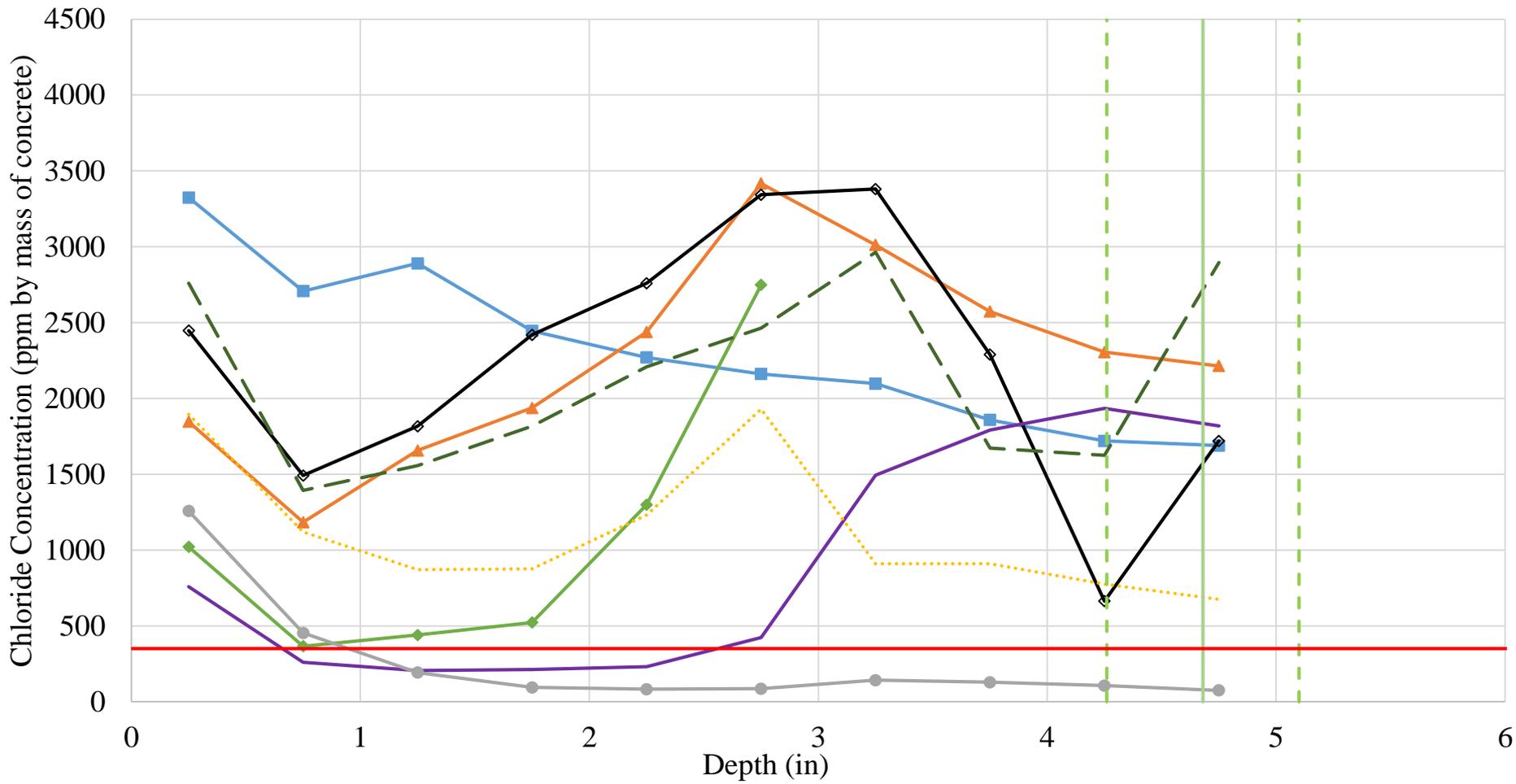
Deck – Corrosion Potentials



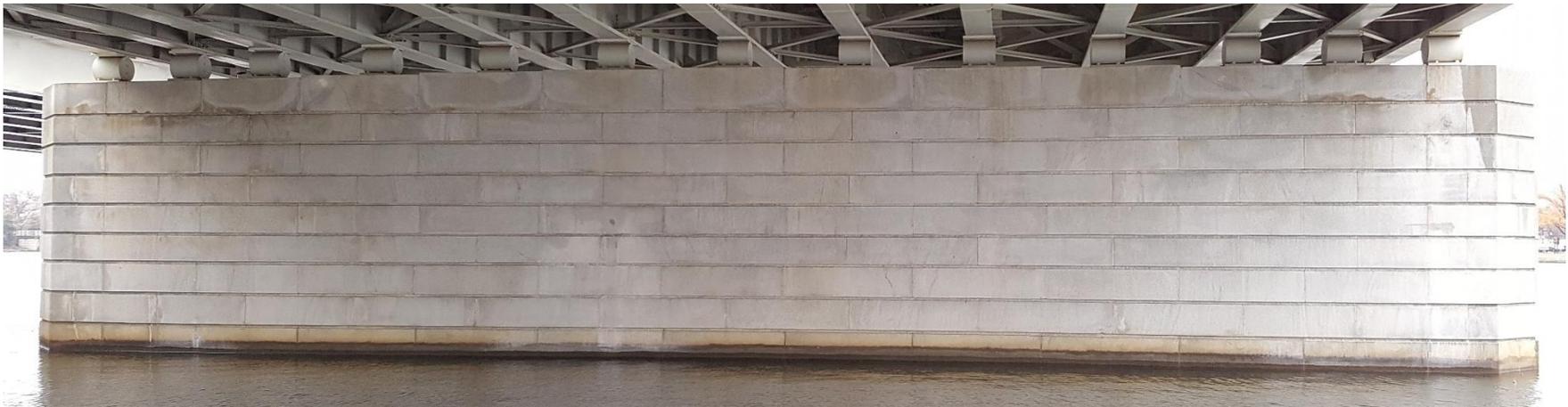
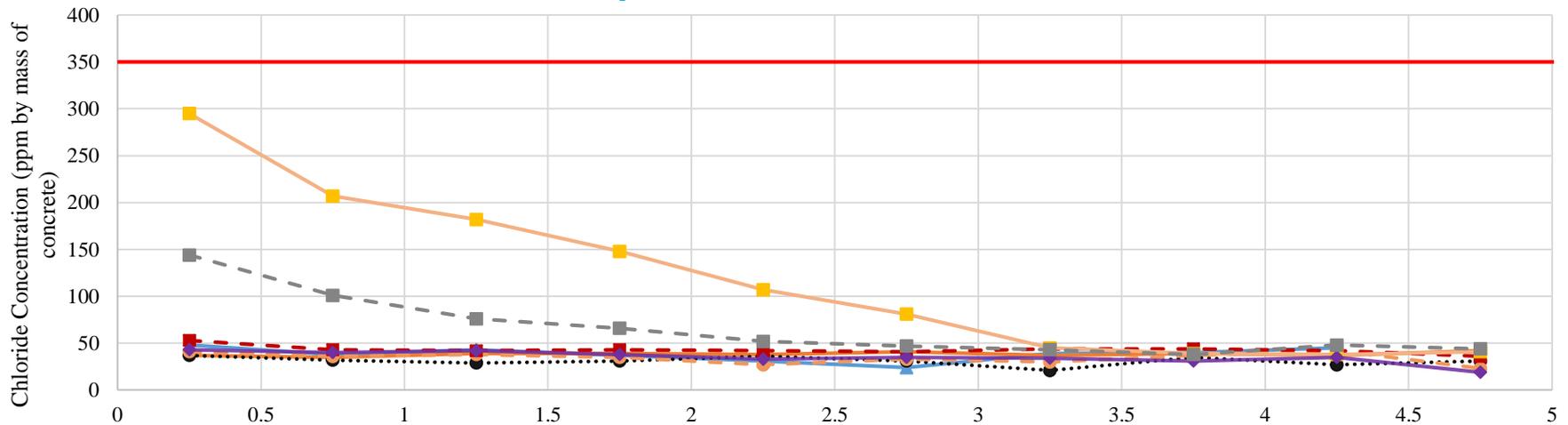
Deck - Sound Concrete



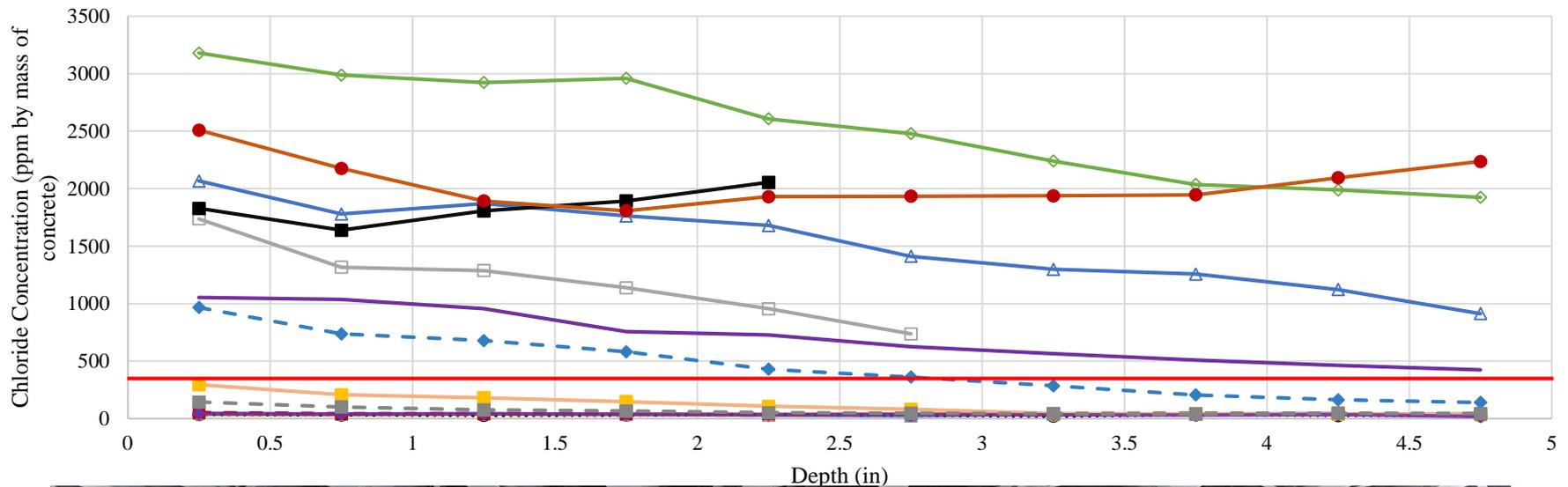
Deck - Cracks/Construction Joints



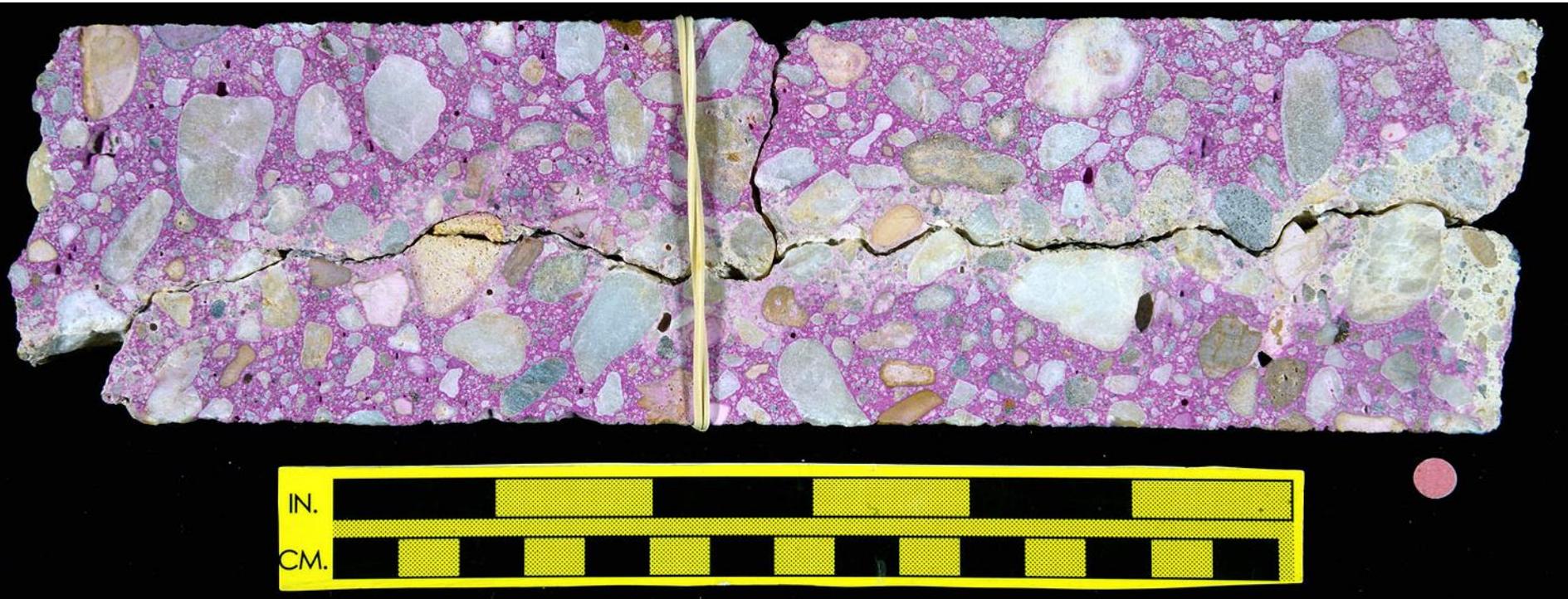
Substructure – Cracked with no Expansion Joint



Substructure – Cracked with Expansion Joint



Substructure - Carbonation



Salt Storage Monolithic Dome



Salt Storage Dome

- Bulk raw salt is stored and bagged within this facility



Poor Shotcrete Application

- Shadowing of welded wire fabric reinforcement



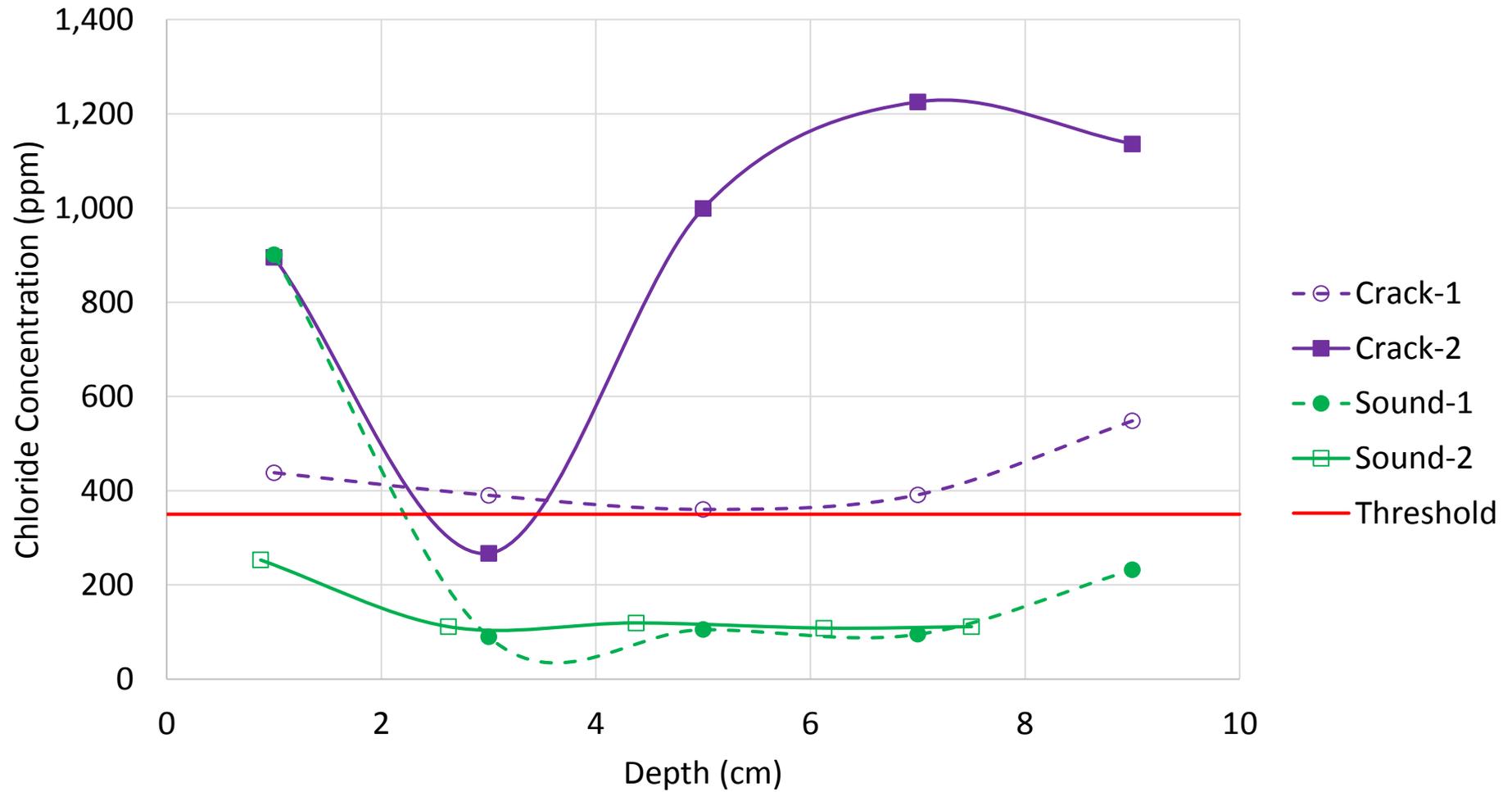
Poor Shotcrete Application



Cracking Along Post Tensioning



Chloride Profile



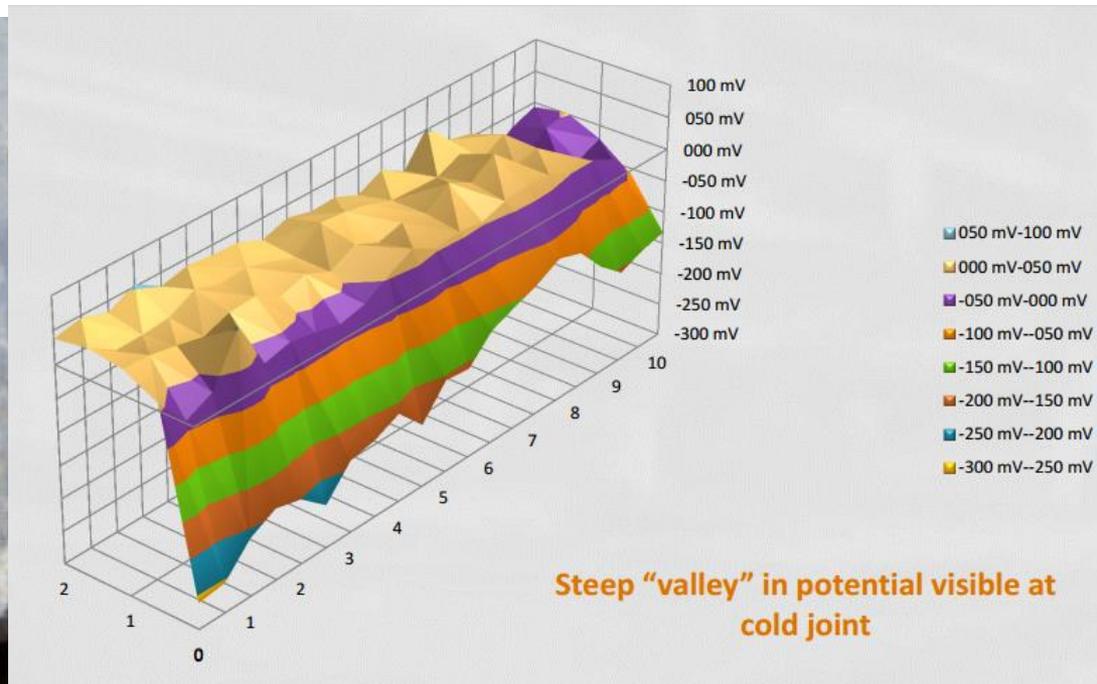
Carbonation Depth

- Sound concrete has a maximum of 0.5 inches of carbonation
- Crack allowed reduction of pH past 3 inches



Aquarium

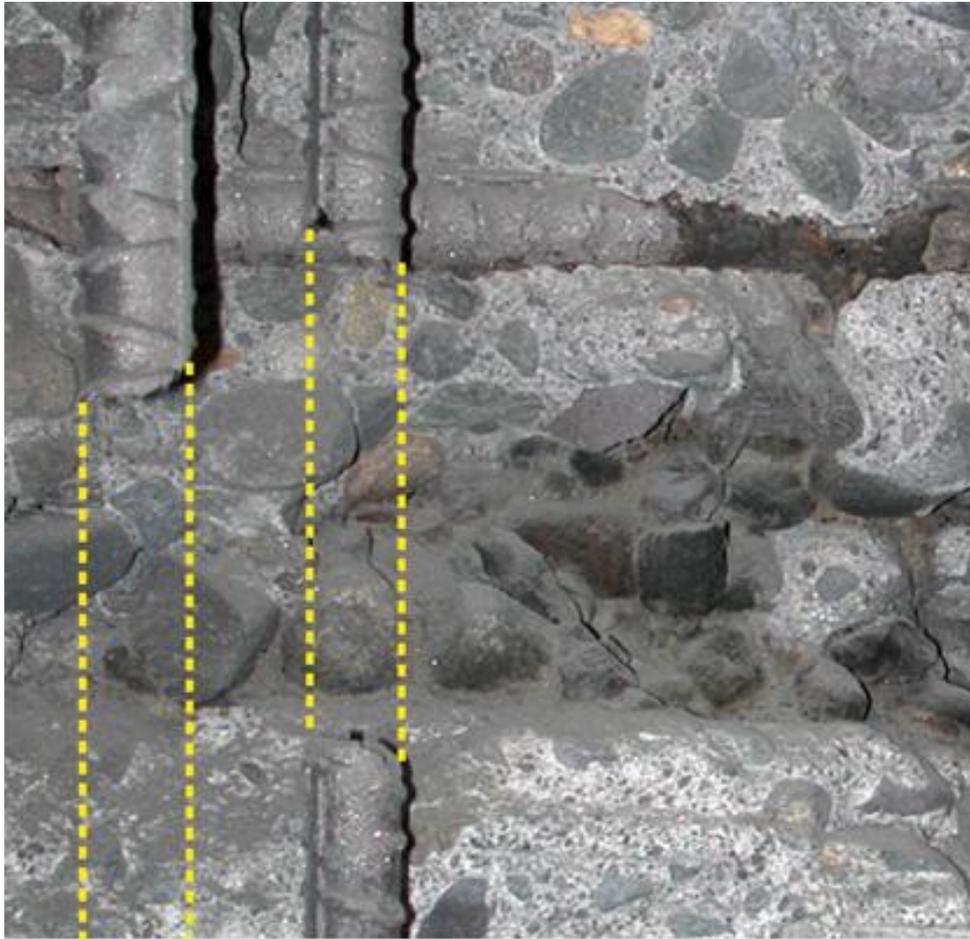
- Project example courtesy of
- Corrosion evaluation of an Aquarium supported on a pier structure



Section Loss At Cold Joint



Section loss at Cold Joint



Peach Street Bridge

- 3-span bridge in Kutztown PA
- Freeze thaw damage leading to corrosion deterioration



Sub-Parallel Cracking



Cores Extracted From Bridge



Leading to Corrosion Activity





Thank you!

Questions?