

A Novel Methodology for Structural Optimization of Bridge Decks Against Corrosion

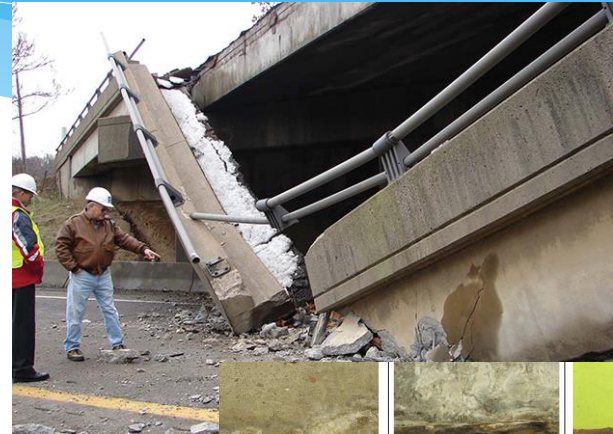
John C Brigham

IRISE ANNUAL MEETING

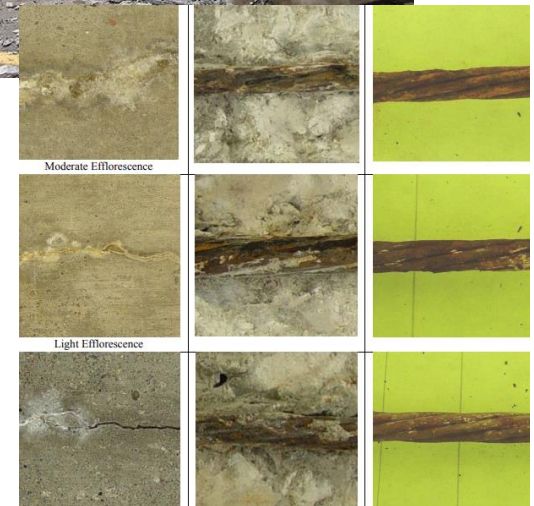
MAY 17, 2023

Bridge Deck Corrosion

Bridge deck corrosion is a common cause of bridge failure and frequent need for rehabilitation.



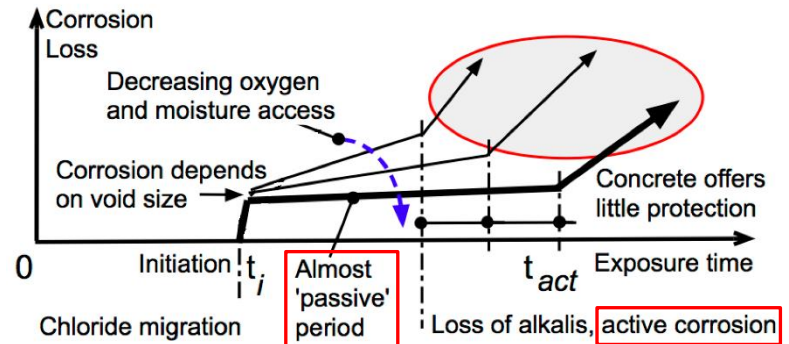
Typical damage caused by steel corrosion:
(1) Steel Degradation, (2) Deck Delamination,
(3) Deck Spalling.



Lake View Drive over I-70 Bridge,
Pittsburgh 2005

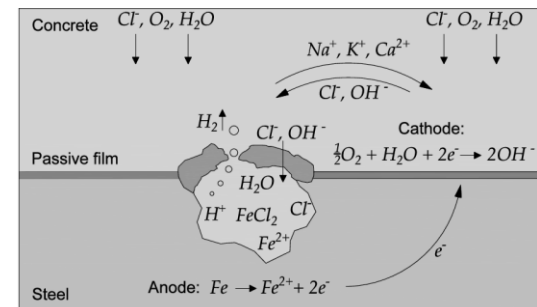
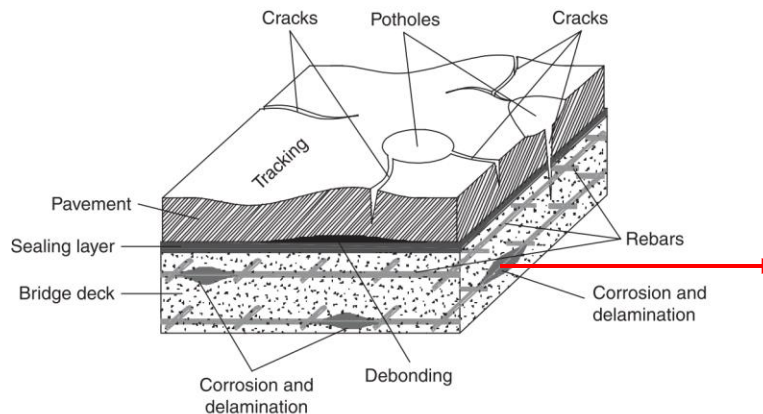
Bridge Deck Corrosion (cont.)

Reinforcement corrosion in concrete is an **Electrochemical Process** with anode, cathode, and electrolyte, where **chloride ions** act as a catalyst by breaking the passivating film of steel caused by the alkalinity of concrete.

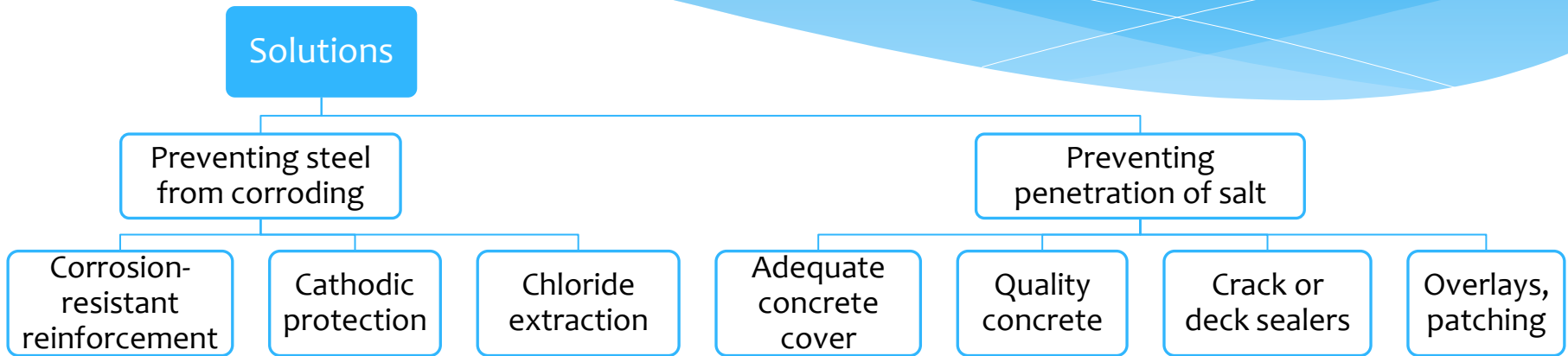


Progression of reinforcement corrosion in concrete of various qualities

Schematic of bridge deck corrosion



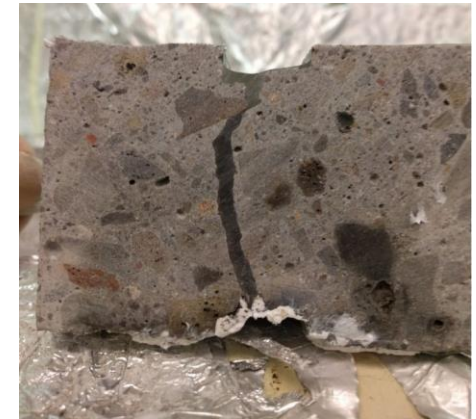
Corrosion Mitigation



UHPC Overlay,
Commodore Barry
Bridge, PA&IA 2020



Corrosion-Resistant Steel

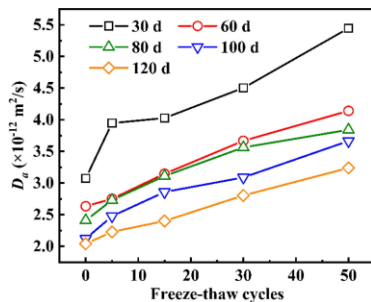


Crack Sealer

Corrosion Modeling

Chloride penetration is a nonlinear mass transport problem with respect to environment, material, and cracking.

We plan to consider:

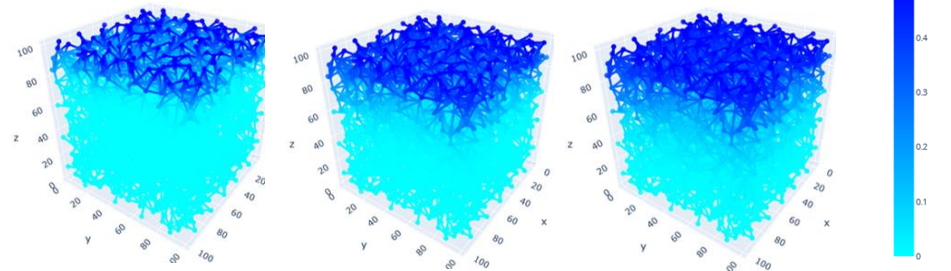


Effect of **Freeze-thaw cycles** on diffusion coefficient of concrete.

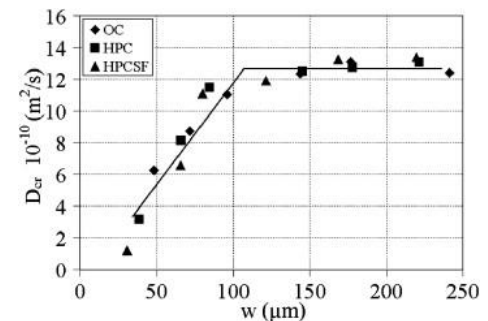
Concrete type	D_c (10^{-12} m ² /s)	
	365 days	720 days
P1M1	1.88	1.76
P1M2	1.76	1.84
P1M3	2.23	2.35
R2M3	1.74	1.88
R3M3	1.43	1.45
R4M2	3.15	3.09
R4M3	2.44	2.56

Effect of **concrete type**

Note: D_c = apparent diffusion coefficient



Preliminary transport simulation using lattice modelling framework

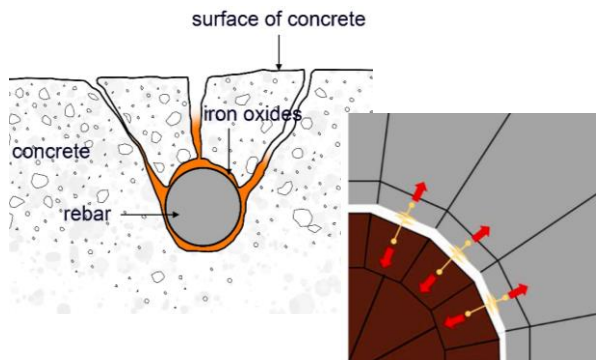


Effect of **crack width**

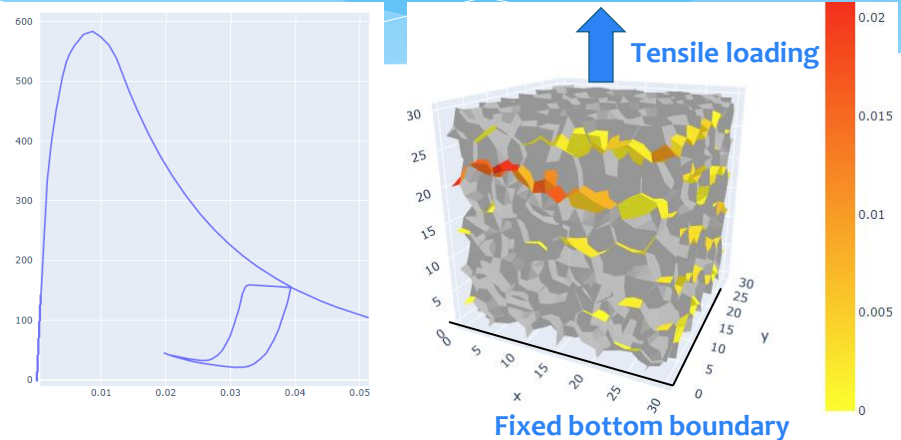
Corrosion Modeling (cont.)

Bridge deck corrosion is a coupled process of chloride ingress, steel rusting, and deck degradation.

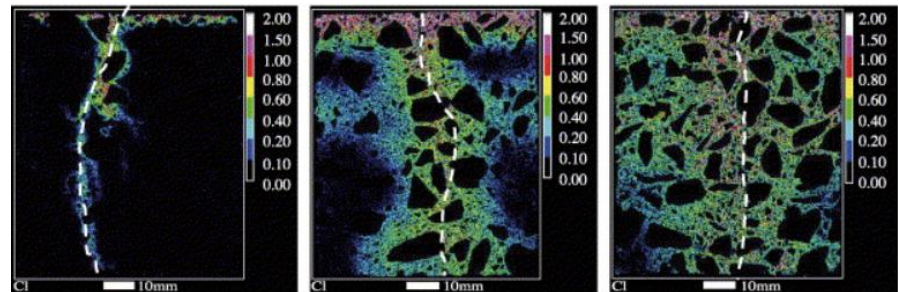
We plan to consider:



Steel rust occupies 3 to 10 times greater volume than the steel.



Mechanical performance and Cracking simulation using Lattice Discrete Particle Model (LDPM)



Multiphysics LDPM coupling mechanical performance and chloride transport

Schedule

Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Literature Review: ~6 months	■	■	■					
Construction of Modeling Framework: ~10 months		■	■	■	■			
Validation of the Model : ~6 months				■	■			
Mitigation Strategy Optimization: ~12 months				■	■	■	■	
Final Report Writing: ~3 Months								■

References

- ❑ Win, P. P., Watanabe, M., & Machida, A. (2004). Penetration profile of chloride ion in cracked reinforced concrete. *Cement and concrete research*, 34(7), 1073-1079.
- ❑ Melchers, R. E. (2020). Long-term durability of marine reinforced concrete structures. *Journal of Marine Science and Engineering*, 8(4), 290.
- ❑ Avadh, K., Jiradilok, P., Bolander, J. E., & Nagai, K. (2022). 3D mesoscale simulation of the influence of corrosion on loss of tension stiffening in reinforced concrete. *Construction and Building Materials*, 339, 127684.
- ❑ Issa, M. A., & Khalil, A. A. (2010). Diffusivity and permeability of high-performance concrete for bridge decks. *PCI journal*, 55(2).
- ❑ Wells, D., Palle, S., Meade, B., & Hopwood, T. (2014). Sealants, Treatments and Deicing Salt Practices to Limit Bridge Deck Corrosion and Experimental Deck Sealants and Pier Cap Coating on Interstate 471 (No. KTC-14-4/FRT194). University of Kentucky Transportation Center.
- ❑ Koulouris, K., & Apostolopoulos, C. (2020). An experimental study on effects of corrosion and stirrups spacing on bond behavior of reinforced concrete. *Metals*, 10(10), 1327.
- ❑ Wang, Y., Liu, Z., Fu, K., Li, Q., & Wang, Y. (2020). Experimental studies on the chloride ion permeability of concrete considering the effect of freeze–thaw damage. *Construction and Building Materials*, 236, 117556.
- ❑ Djerbi, A., Bonnet, S., Khelidj, A., & Baroghel-Bouny, V. (2008). Influence of traversing crack on chloride diffusion into concrete. *Cement and concrete research*, 38(6), 877-883.
- ❑ Al-Nawadi, H. (2019). Corrosion behavior of reinforced concrete bridge decks under laboratory and field conditions (Doctoral dissertation, Rutgers University-School of Graduate Studies).
- ❑ Gucunski, N., Maher, A., Basily, B., La, H., Lim, R., Parvardeh, H., & Kee, S. H. (2013). Robotic platform rabbit for condition assessment of concrete bridge decks using multiple nde technologies. *HDKBR INFO Magazin*, 3(4), 5-12.

THANK YOU