October 13, 2021
ICRI 2021 Fall Convention

A Case Study in Corrosion, ASR, and More: Evaluation and Repair of Reinforced Concrete Flood Channels

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Project Engineer
Pivot Engineers

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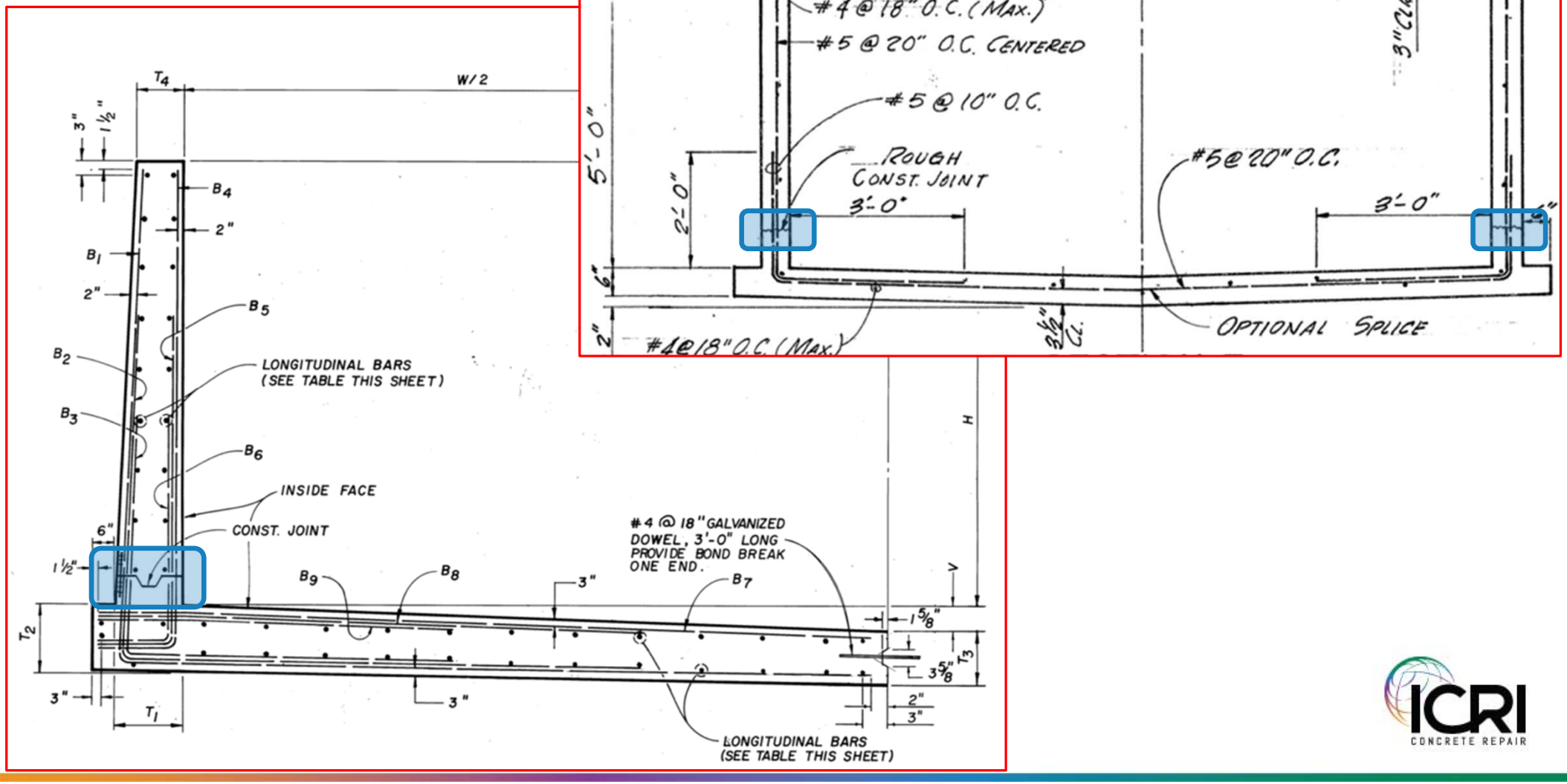

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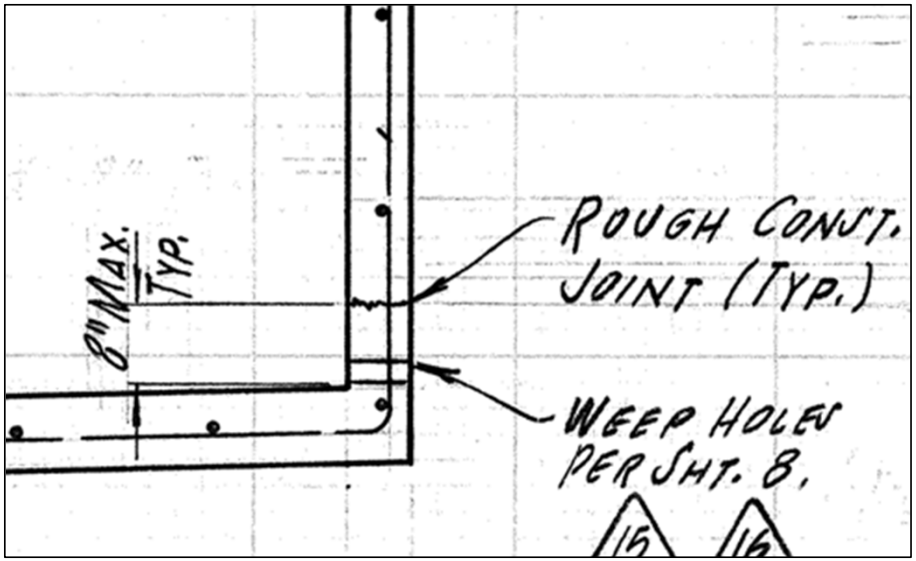

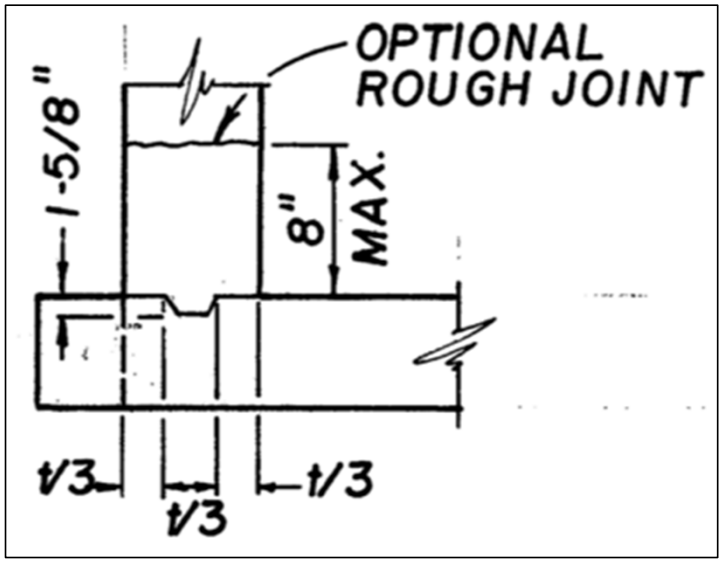

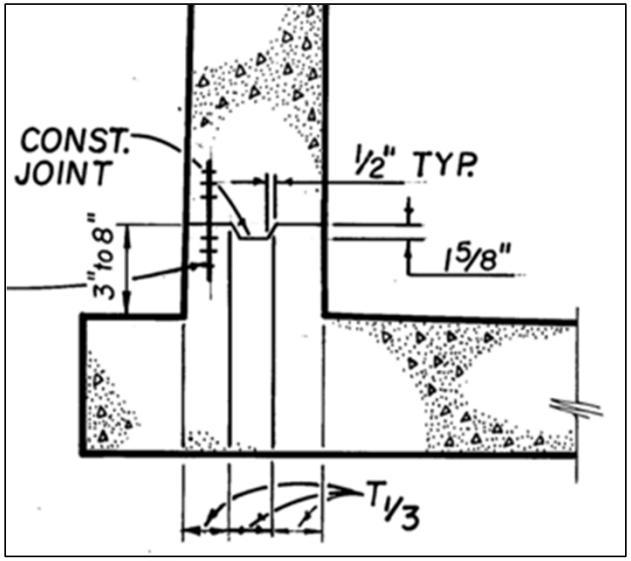

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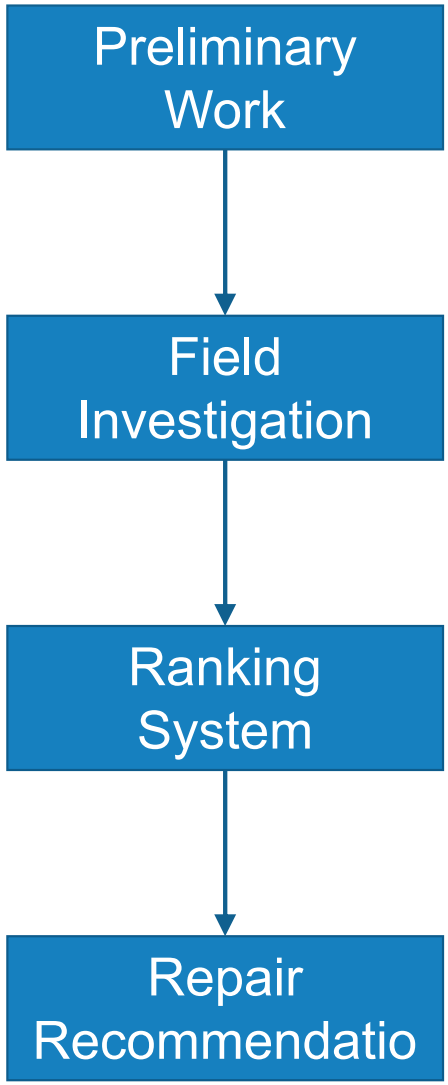
8’ wide channel, 4’ tall wall

30’ wide channel, 16’ tall wall

Photographs courtesy of Ventura County



Document review
Preliminary investigation
Investigation planning

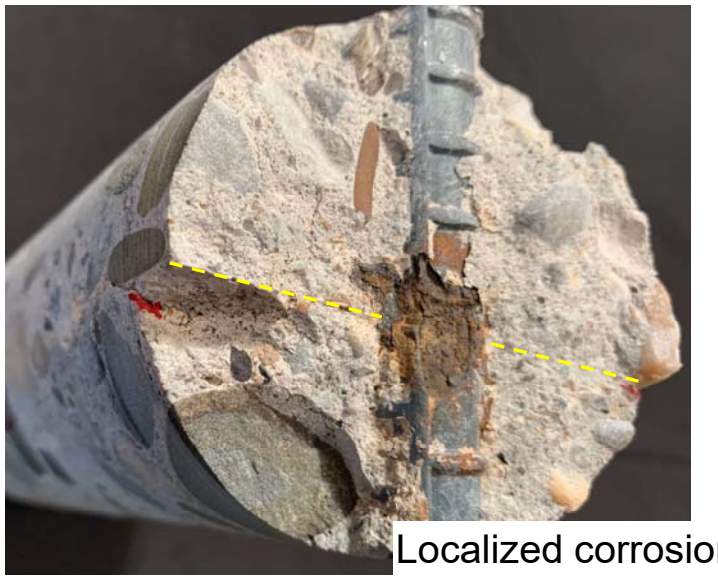
Estimate structural properties (where needed)
Assess conditions

Develop methodology
Prioritize channels
Develop inspection program

Develop repair concepts
Recommend repairs for channels in worst conditions

Primary Conditions Observed

- Localized corrosion
- Alkali-silica reaction (ASR)



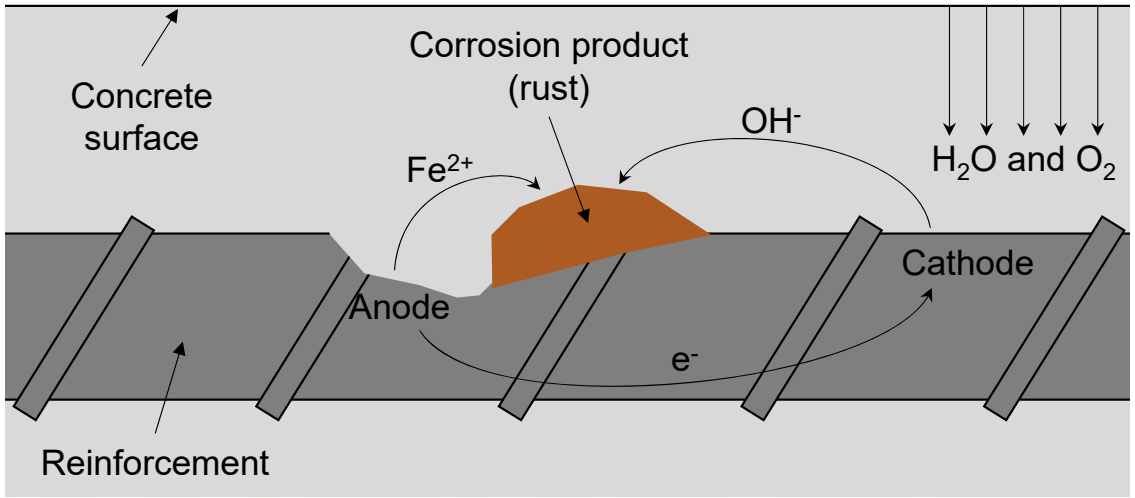
Localized corrosion

Alkali-silica reaction (ASR)

Reinforcement Corrosion: Primer

- Embedded reinforcement is naturally protected against corrosion by high pH of concrete – ”passive layer” forms around reinforcement

- Corrosion reaction needs water, oxygen and electron/ion mobility



Reinforcement Corrosion: Localized

- Corrosion occurs only at isolated locations subjected to corrosion-inducing conditions
  - For example, at a poor-quality construction joint

Photograph from Whitlock, Dalrymple, Poston and Associates' previous investigation of these flood channel walls

Localized Corrosion: Investigation

- Investigation methods:
  - Visual observations
  - Nondestructive testing
  - Destructive verification

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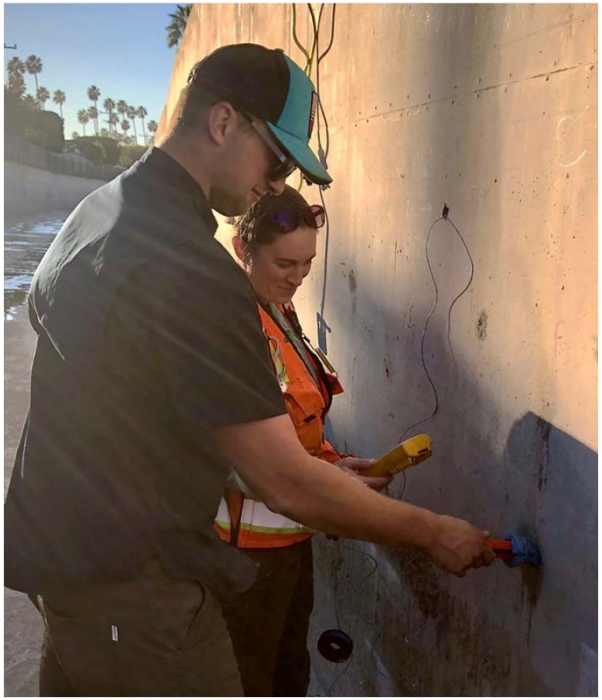

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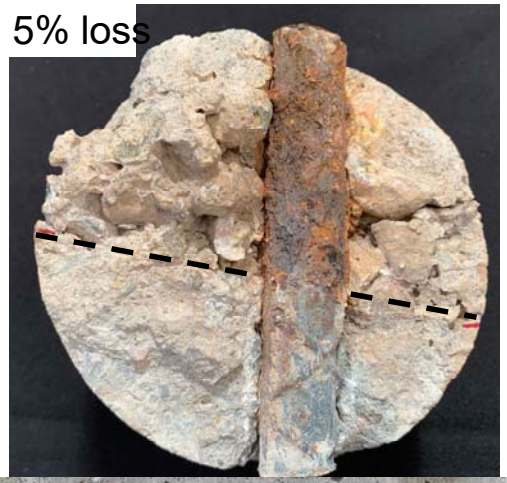
Localized Corrosion: Findings

5% loss

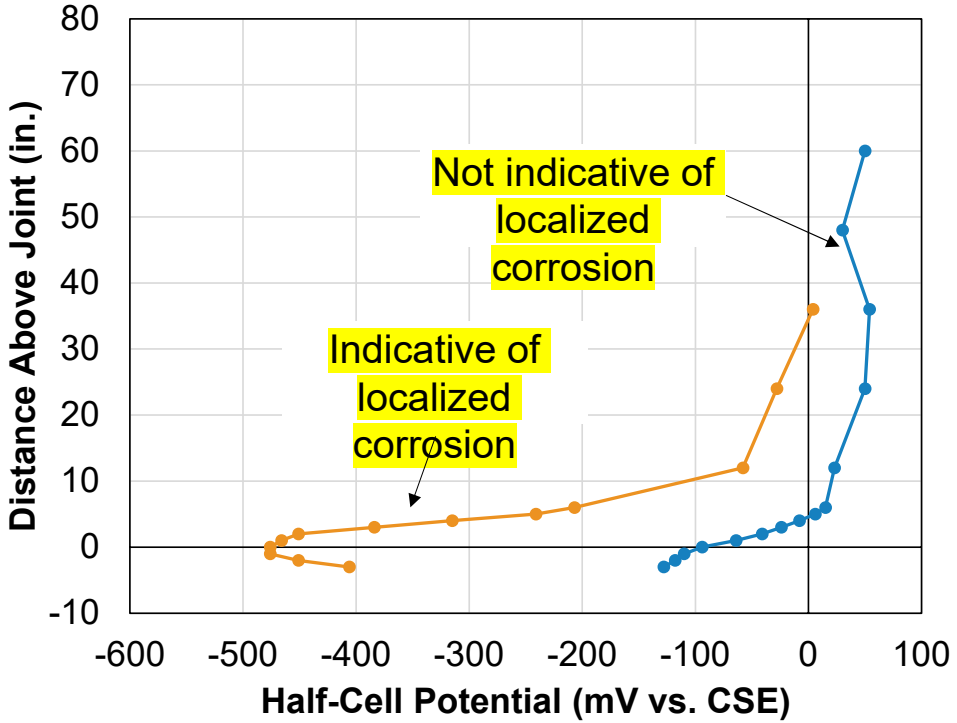


20% loss

70% loss

Localized Corrosion: Findings

Corrosion staining

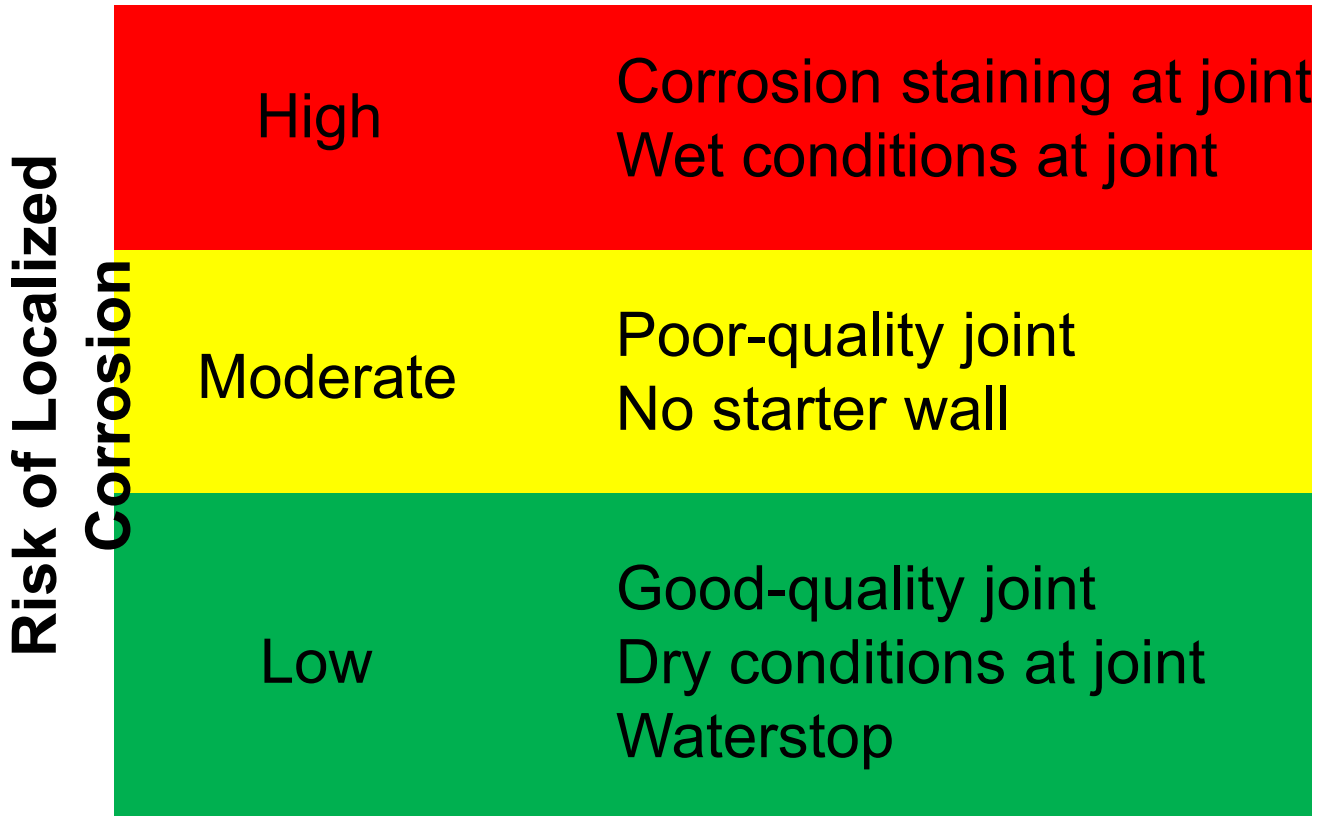


→ ***Back mat reinforcing bars fully corroded (100% loss) at both core locations***

Localized Corrosion: Findings

- Limitations of NDT methods for (localized) corrosion:
  - Results reflect instantaneous conditions only
  - Ineffective for bars farther from surface (~3” depth max)
  - Concrete resistivity has minimal impact on localized corrosion
  - Corrosion rate measurements have not been developed for localized corrosion conditions

Localized Corrosion: Findings



Localized Corrosion: Findings

- Localized corrosion is most likely cause of wall failures to date
- Moisture availability is most important risk factor
- Destructive verification is most reliable identification method

Localized Corrosion: Repairs

- Mitigate ongoing corrosion activity with anodes
- Inject areas of poor consolidation with grout
- Strength repairs to address significant section loss of primary reinforcement due to corrosion

ASR: Primer

- Alkali-silica reaction (ASR) is a chemical reaction between alkali and silica in concrete matrix, fueled by moisture, that causes concrete to expand internally
- ASR causes internal microcracking and surface macrocracking in concrete
  - Cracking patterns influenced by reinforcement and restraint
- Reinforcement helps to preserve structural integrity by restraining the concrete expansion (prestressing effect)

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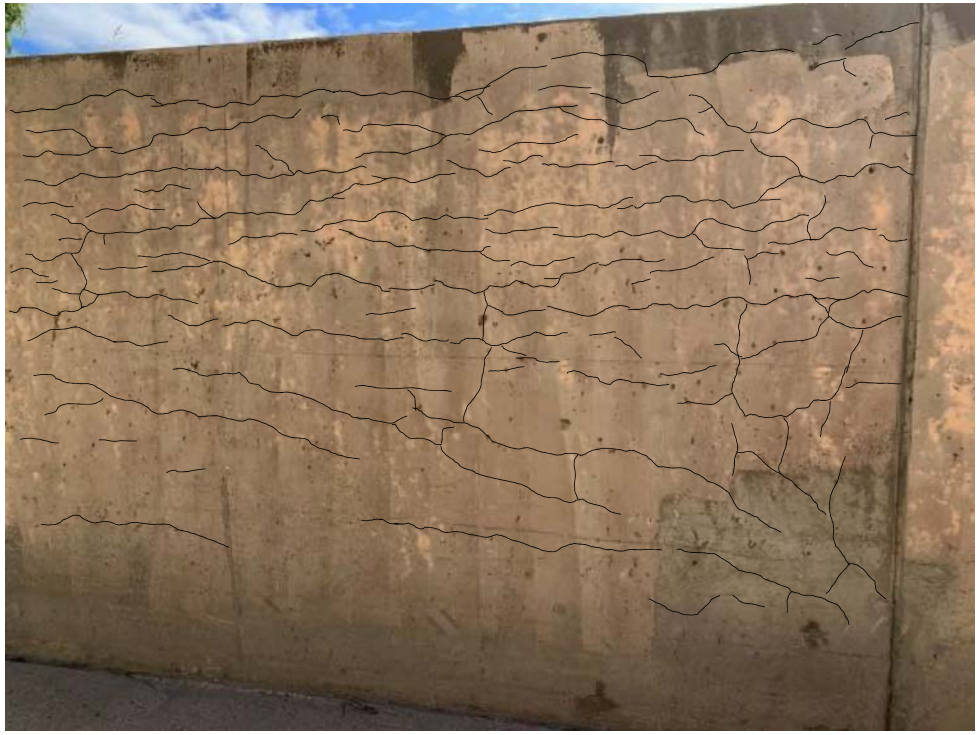
ASR: Investigation

- Investigation methods:
  - Visual observations
  - Nondestructive testing
  - Destructive verification
  - Laboratory testing (petrography)



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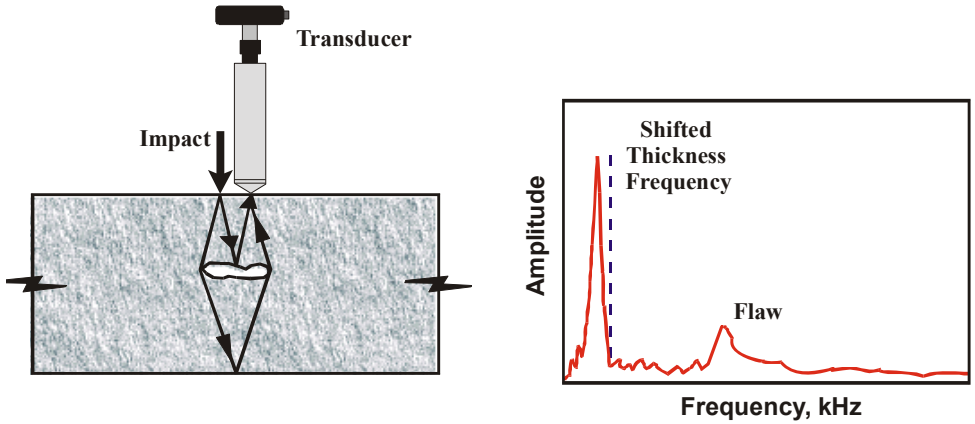

Figure adapted from "Impact-Echo: Nondestructive Evaluation of Concrete and Masonry," MJ Sansalone and WB Streett

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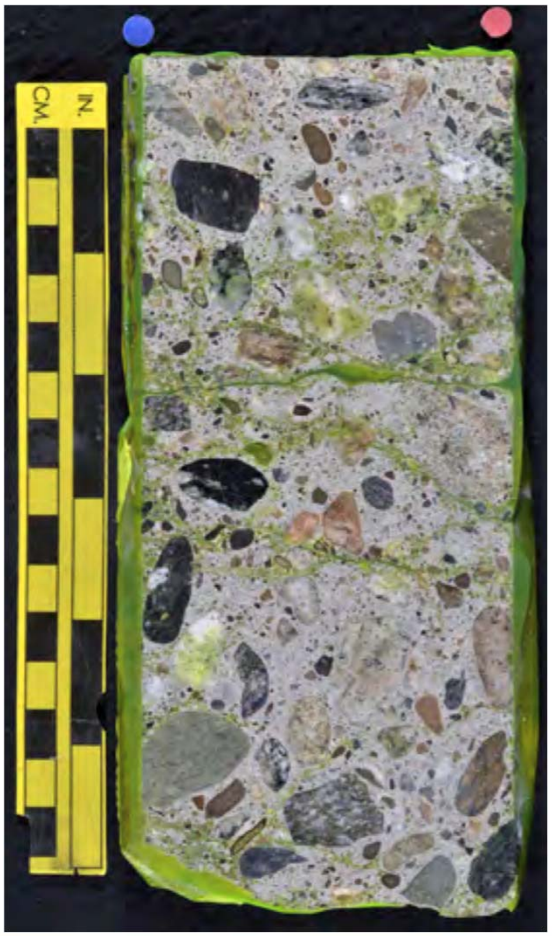

Photographs courtesy of DRP Petrographic & Materials Investigation

ASR: Findings

- Concrete typically includes reactive components susceptible to ASR
- Significant ASR distress only observed where moisture is available to fuel the reaction and expansion
- Lack of transverse reinforcement allows for extensive subparallel cracking which could result in a future loss in strength
  - No evidence that ASR is contributing to strength concerns yet

ASR: Repairs

- Primary repair goal – prevent water ingress into cracks on top face of wall to mitigate expansion
  - Route and seal cracks on top face of walls
  - For wide cracks on top face of walls, inject or gravity feed grout or epoxy to fill internal (subparallel) cracks
- Future repair considerations – if indications of structural impacts develop, provide alternate means of force transfer across subparallel cracks
  - Install epoxied tie rods through wall thickness

Conclusions: General

- As structures and infrastructure continue to age, there is an increasing need for evaluation and repair of existing structures
  - Usually, limited resources are available, highlighting the importance of evaluation in this process
- Nondestructive testing is a valuable tool for evaluating reinforced concrete structures
  - Limitations of NDT methods should be understood
  - Destructive methods should be used to verify NDT results

Conclusions: Localized Corrosion

- Localized corrosion can have significant structural implications, often without obvious indications of distress
- Destructive methods are most reliable to identify localized corrosion
- Mitigate localized corrosion at construction joints in new construction using good construction practices (e.g., good consolidation, waterstops)

Conclusions: ASR

- Mitigating ongoing ASR distress can be challenging, especially for environmental structures where moisture availability cannot be well-controlled

- Evaluation and remediation strategies for ASR in reinforced concrete structures should:
  - Aim to reduce moisture access to the concrete
  - Consider the structural implications of the ASR distress

Questions?

Special thanks to:
- Ventura County Public Works Agency – Water Protection team
- Dr. Michael Thomas and Dr. Keith Kesner
- Pivot team

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