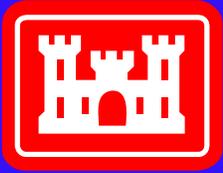


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Corrosive Impacts of Hydrogen Sulfide

Toy Poole
CEERD-GM-C
601-634-3261
poolet@wes.army.mil

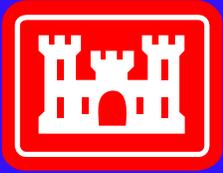


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Introduction

- Direct and indirect effects
- R&D – sewer pipes
- Magnitude of CE problem

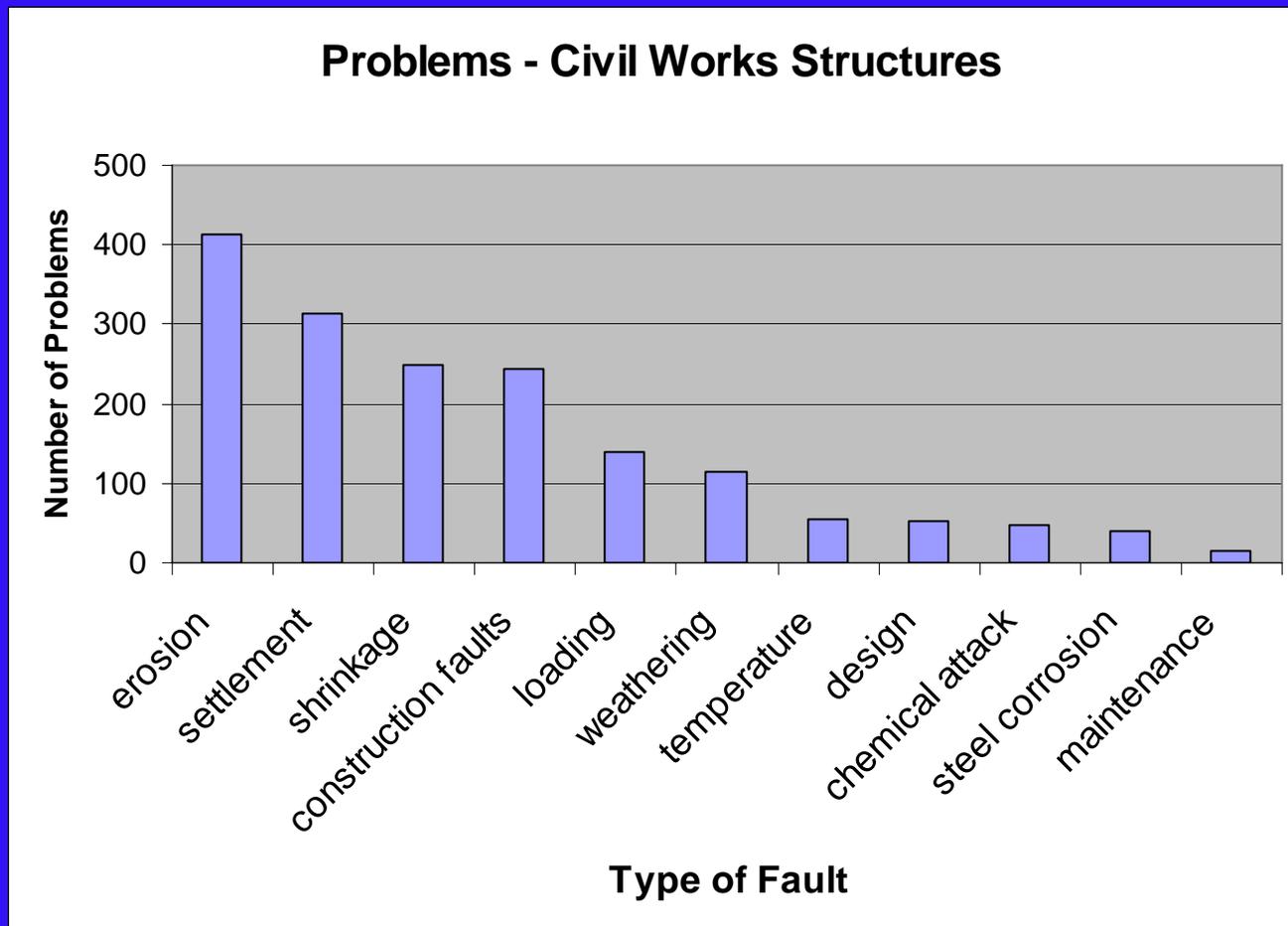


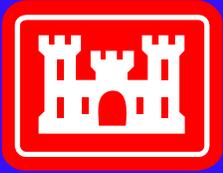


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Corps of Engineers Problems

REMR CS-2

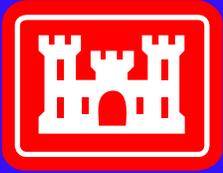




How Sulfides Turn Bad

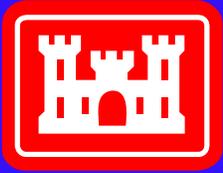
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- $\text{Fe}_x\text{S} + \text{O}_2 \longrightarrow \text{H}_2\text{SO}_4 + \text{Fe}_2\text{O}_3$ (air)
- $\text{H}_2\text{S} + \text{O}_2 \longrightarrow \text{H}_2\text{SO}_4$ (bacterial biofilms)
- $\text{H}_2\text{SO}_4 \longrightarrow \text{H}^+ + \text{SO}_4^-$ (in water)
- Bacterial Species
 - *Thiobacillus concretetivorus*
 - *T. thooxidans*
 - *T. thoparus*
 - *T. denitrificans*



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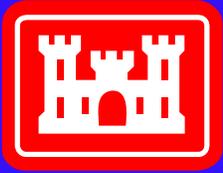




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Affected Structures

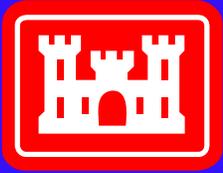
- Metals (acid)
- Concrete
 - aggregates
 - siliceous
 - carbonate
 - hydrated cement paste



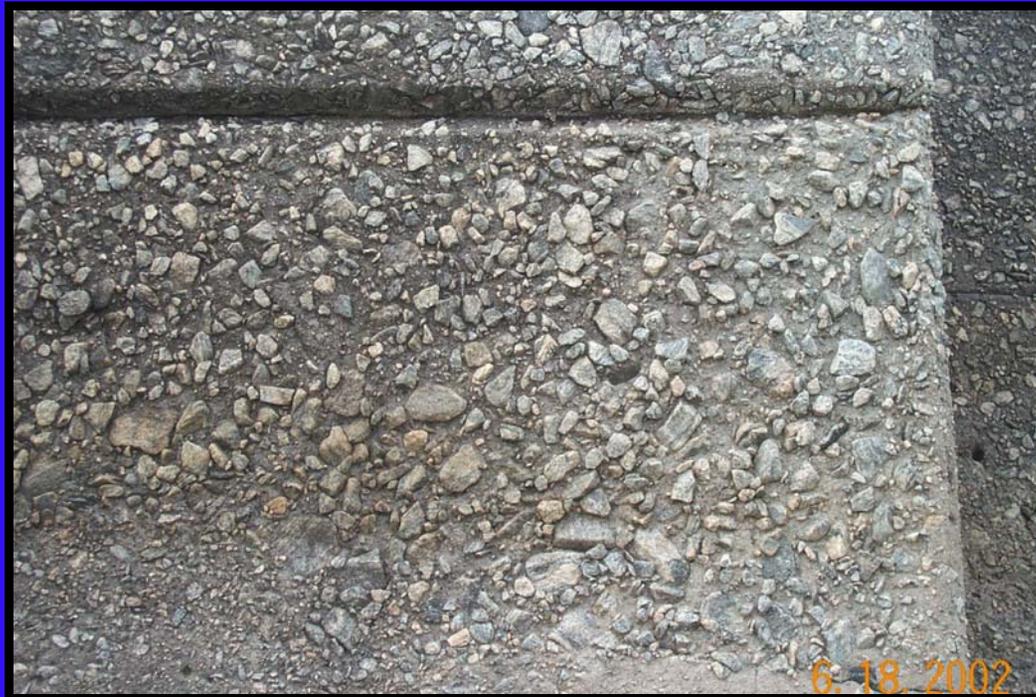
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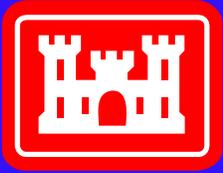


from Tulliani, et. al. *Cem & Concr Res* 32 (2002), 843-849



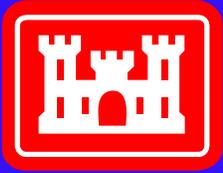
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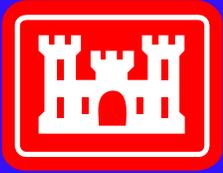
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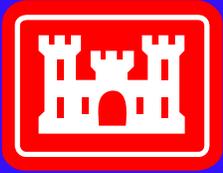
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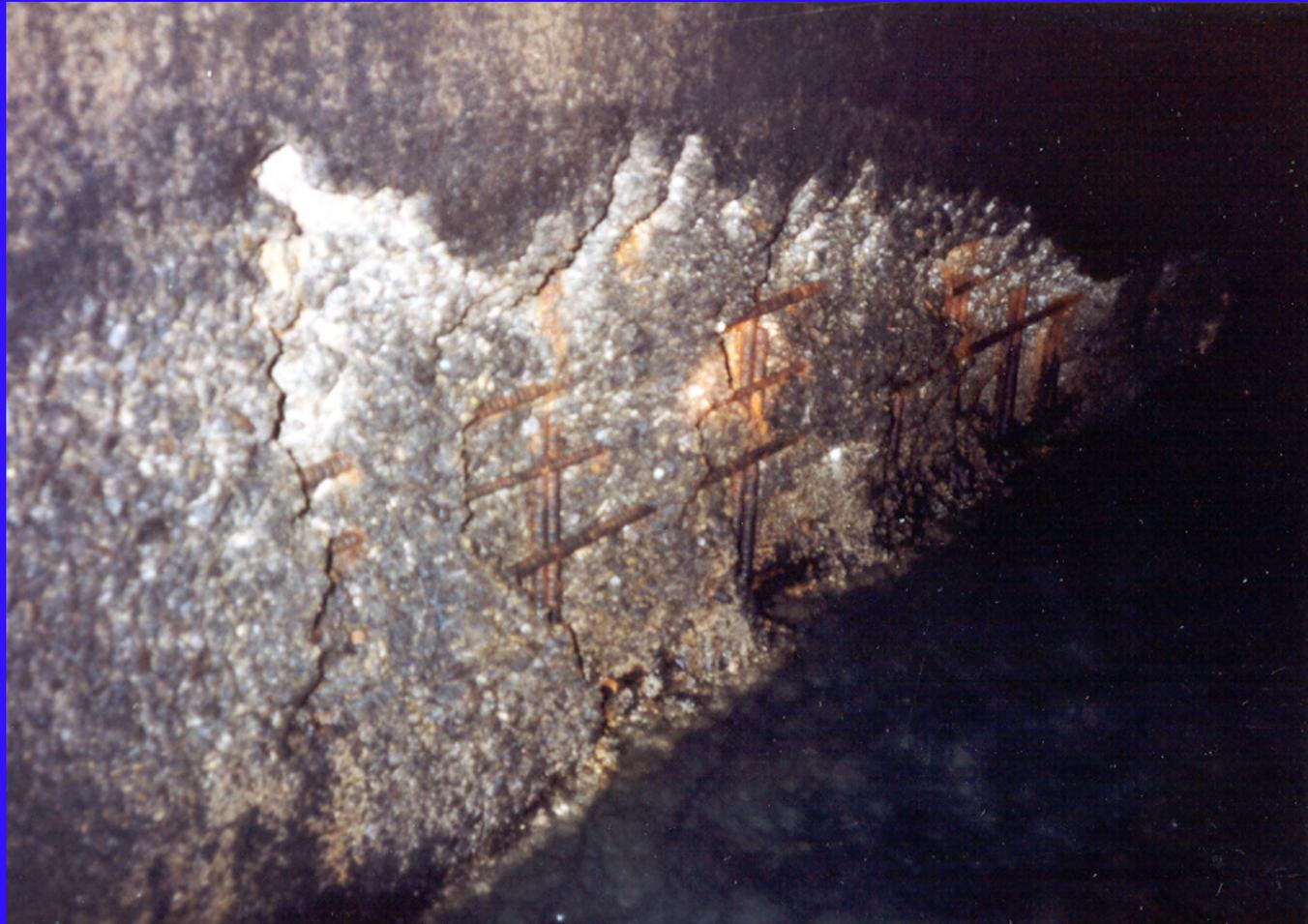


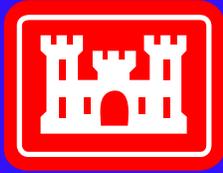
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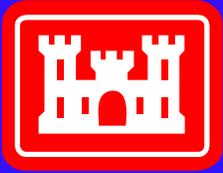




Chemistry of Hydrated Portland Cement

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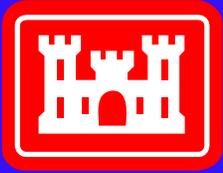
- Unhydrated cement
 - calcium silicates
 - calcium aluminates
- Hydrated cement
 - calcium silicate hydrate
 - calcium aluminate hydrate
 - calcium hydroxide (crystalline, sat'd pore fluid)



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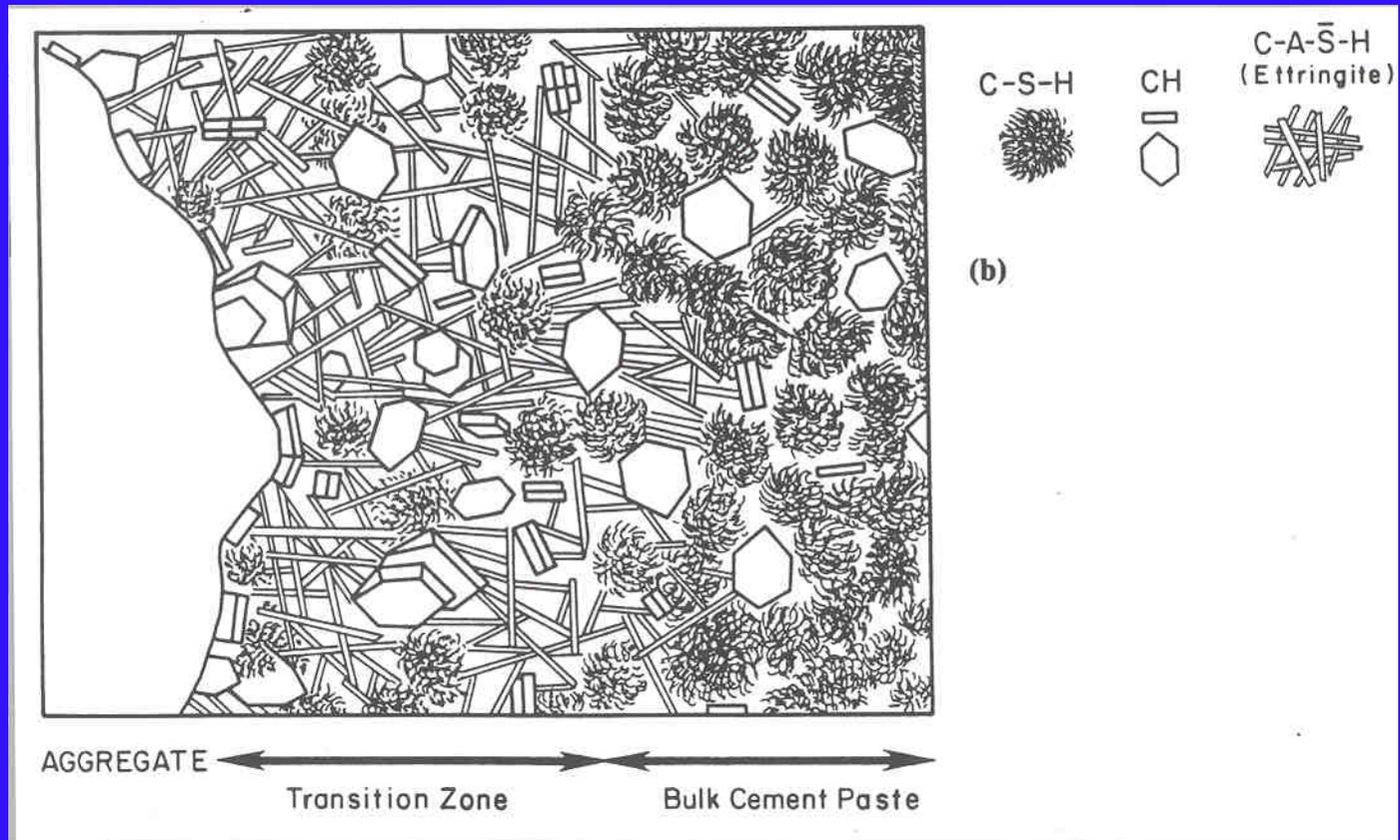
Cement Paste Microstructure

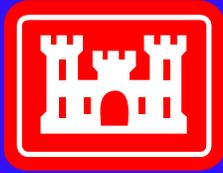




Cement Paste Microstructure

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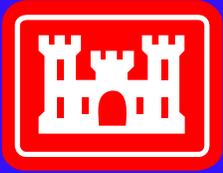




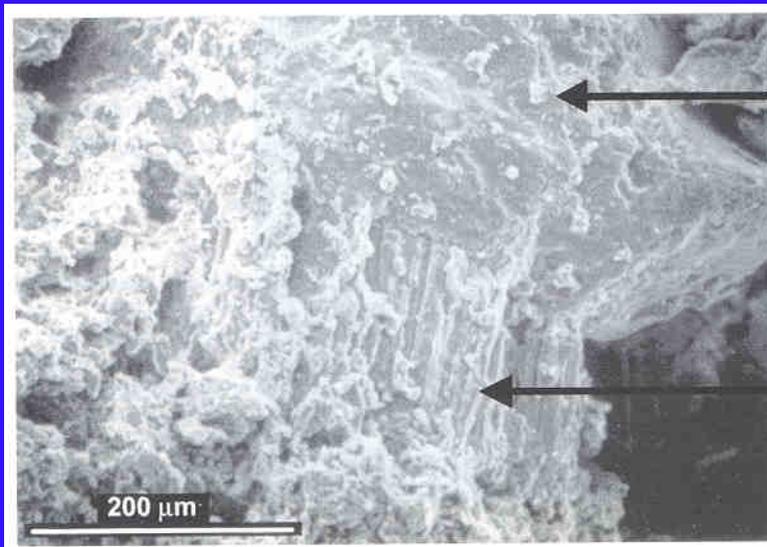
Sulfuric Acid on Hydrated Cement Paste

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- $\text{H}_2\text{SO}_4 + \text{Ca}(\text{OH})_2 \longrightarrow \text{CaSO}_4 + \text{H}_2\text{O}$
- $\text{CaSO}_4 + \text{CAH} \longrightarrow$ ettringite (expansive)
- $\text{CaSO}_4 + \text{CSH} \longrightarrow$ thaumasite (softens)
- When $\text{Ca}(\text{OH})_2$ depletes
 - $\text{CSH} \longrightarrow \text{Ca}(\text{OH})_2 + \text{SiO}_2 \cdot x\text{H}_2\text{O}$

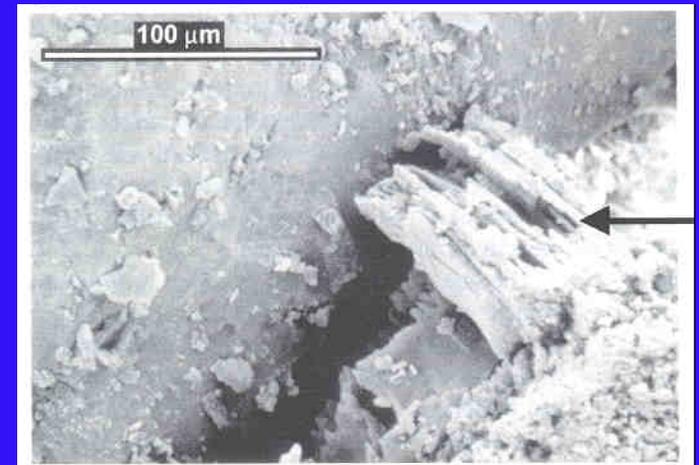


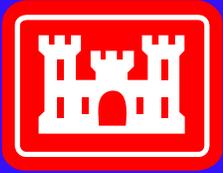
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aggregate

gyp

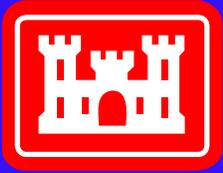




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Rates of Deterioration

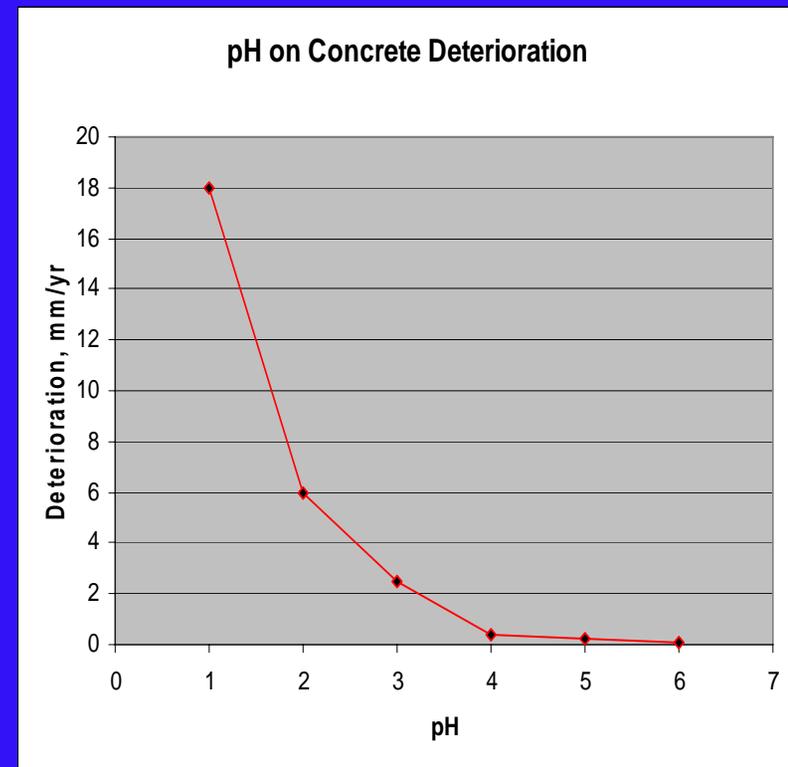
- Concrete – 2 to 15 mm/yr
 - 3 – 25 years to reinforcing steel
- Steel Structures – complete consumption in 6 - 10 yr

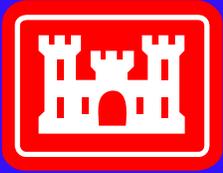


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Pertinent Variables

- Cement composition
- Flow
- Removal of deteriorated material
- Conditions for bacterial growth
- pH

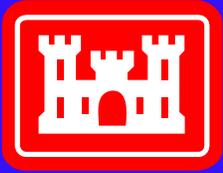




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Prevention in Concrete

- Cement
 - low C3A
 - calcium aluminate
 - sulfur cement
- Polymer coatings
- High alkali concrete
- antibacterial admixtures



Remediation and Repair

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- Remediation
 - reduce H₂S
 - poison thiobacillus
- Repair
 - epoxy
 - polymer liners