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Life Beyond 80. Concrete Aging

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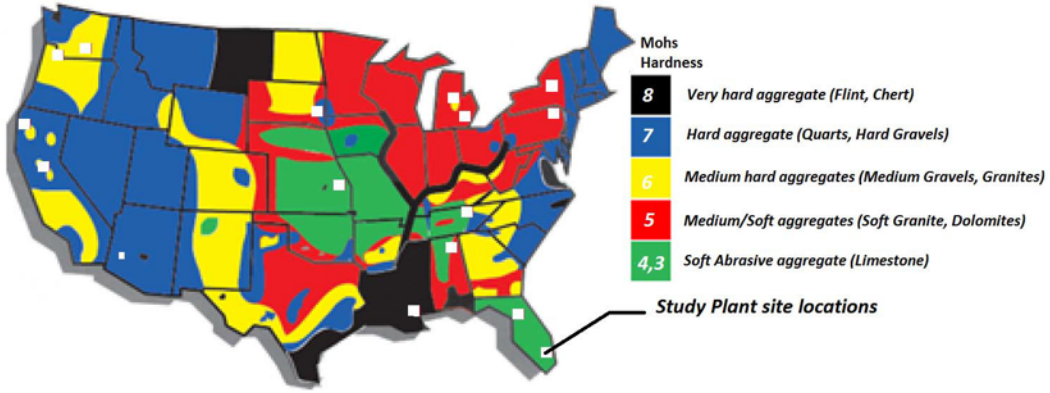
Nuclear Structures and Construction Group

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

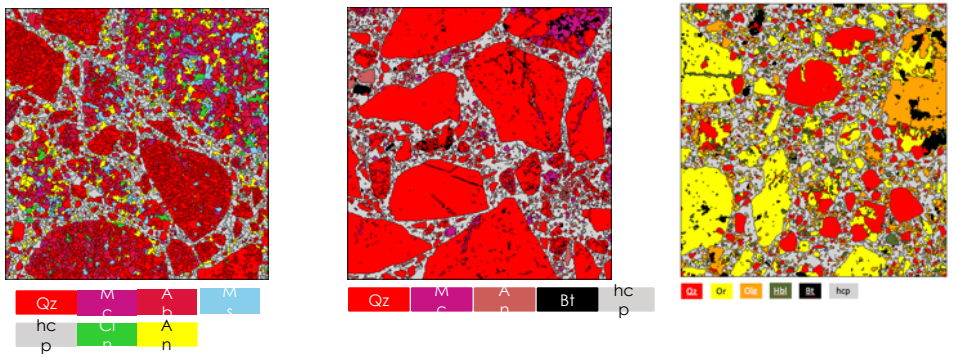
U.S. DEPARTMENT OF ENERGY

Varied Structures and Concrete in Light Water Reactors

US Geology and NPP locations

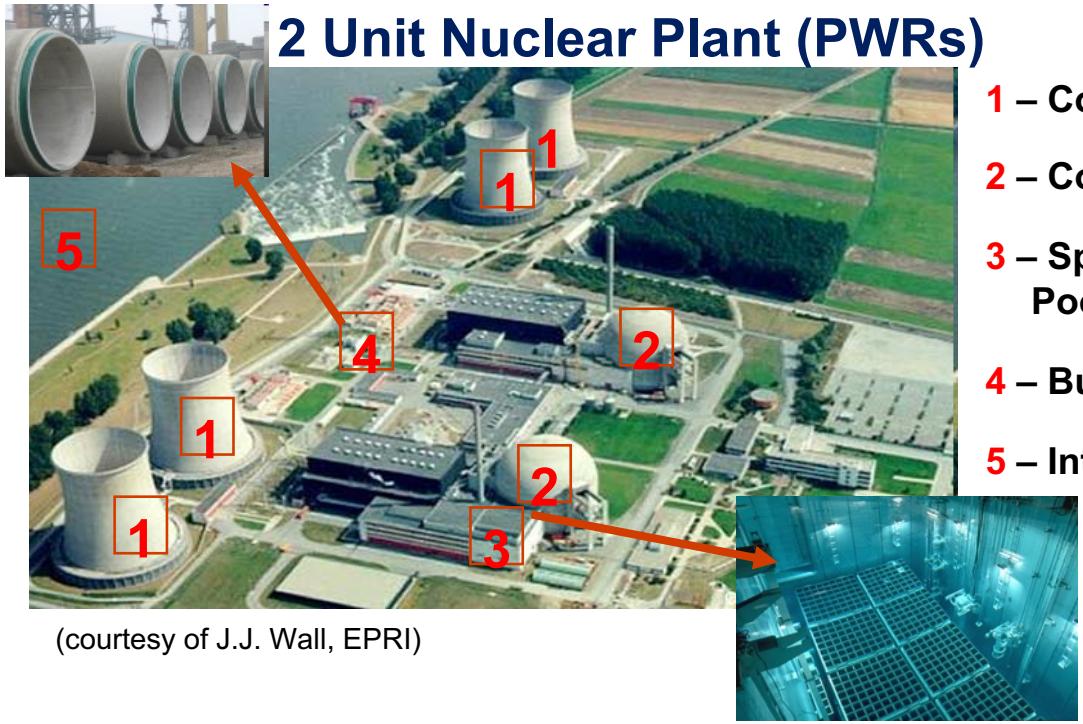


[Esselman et al., 2013]



Examples of mineral phase maps for varied concretes tested at ORNL

2 Unit Nuclear Plant (PWRs)



(courtesy of J.J. Wall, EPRI)

1 – Cooling Towers

2 – Containments

3 – Spent Fuel Pools/Transfer Cana

4 – Buried Pipe

5 – Intake Structure

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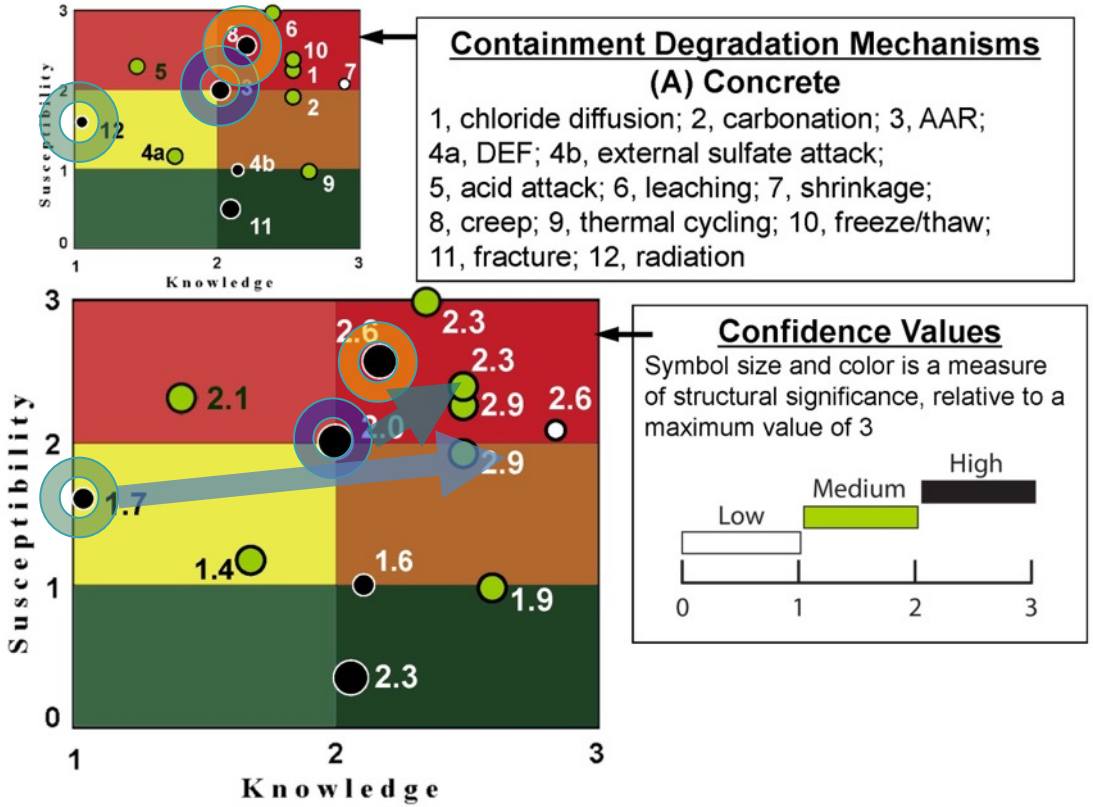
Aging Mechanisms of Priority Interest (2014) and Progress



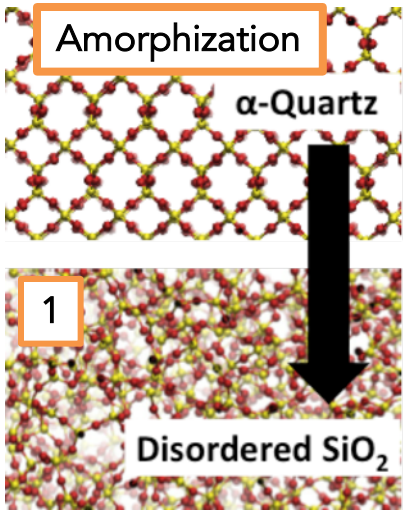
- Irradiation
- Alkali-silica reaction (ASR)
- Creep / creep-fracture

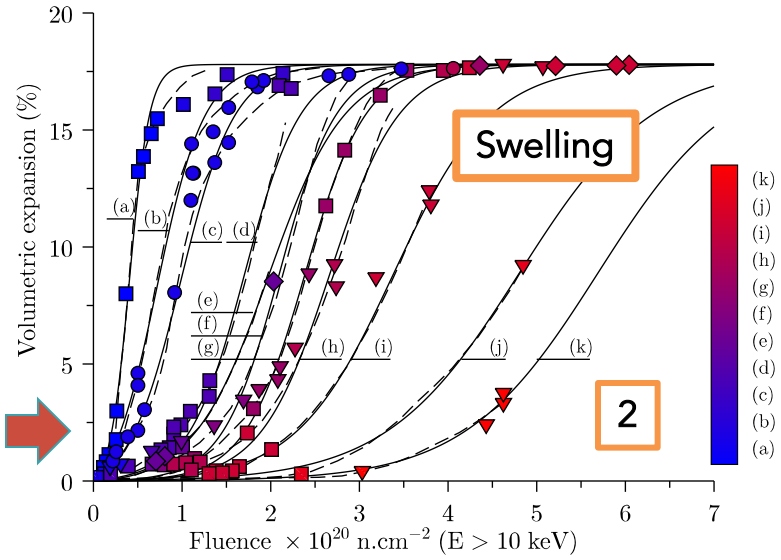
Excerpt from Expended Materials Degradation Analysis report (2014):

'Irradiation for "Containments-Concrete Component" emerged as the most important degradation mechanism, mainly driven by the fact that insufficient data is available to improve the level of knowledge about the effects of irradiation on concrete mechanical properties.'

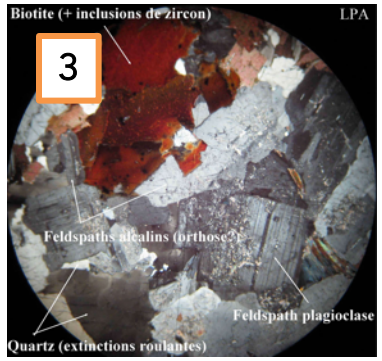
'Though ASR is well documented by the operating experience (for bridges and dams in particular) and scientific literature, its high ranking in the EMDA analysis describes the need to assess its potential consequences on the structural integrity of the containment.'

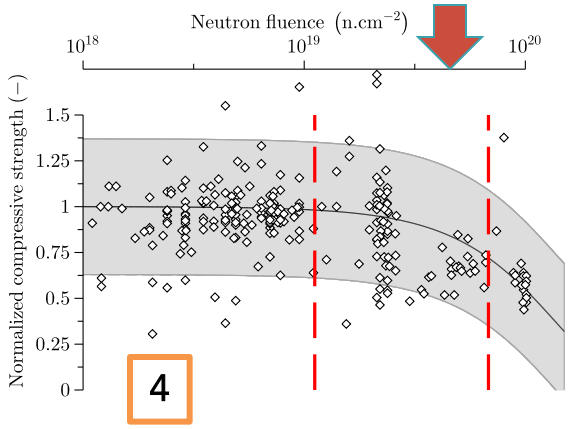
Irradiated Concrete in a Nutshell

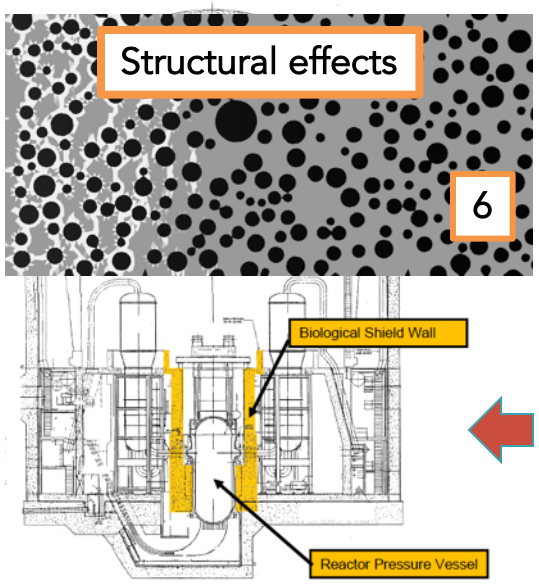




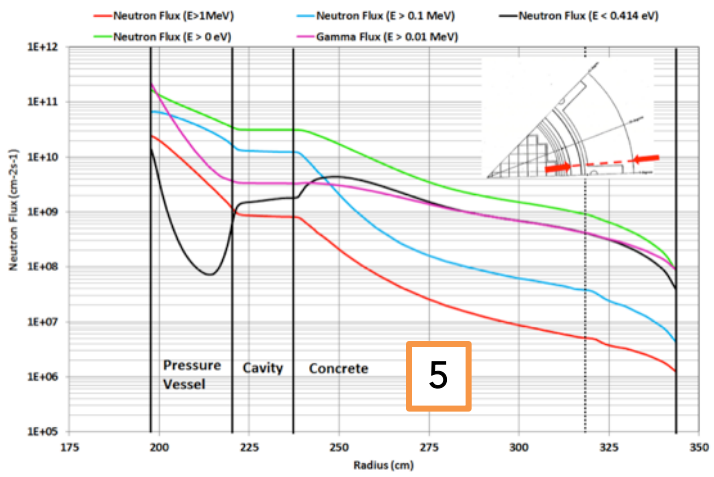
Cracking/swelling

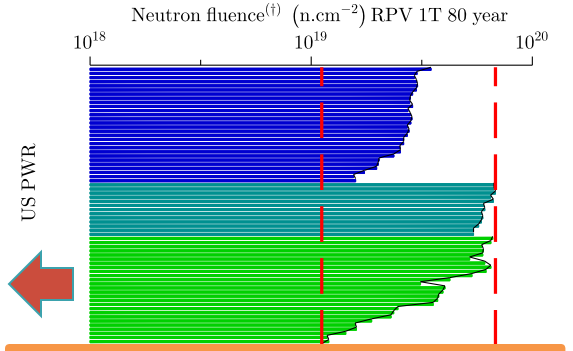






Flux attenuation





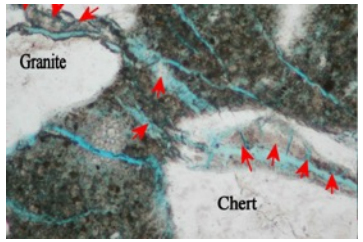
Loss of Engineering Properties

Alkali-Silica Reaction in a Nutshell

www.chaneyenterprises.com

Cement **alkali**

\+ *Reacts with*



www.cmc-concrete.com

Aggregate reactive **silica**

\+ *And absorbs*

www.borealwater.com

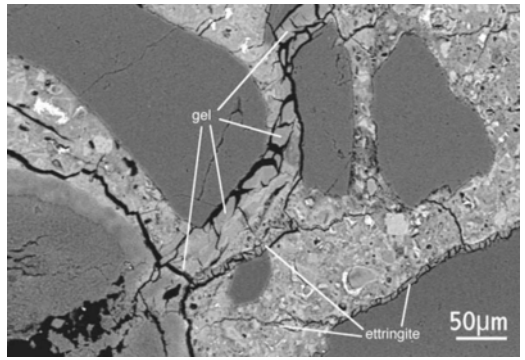
Water
>~70% moisture content

www.fhwa.dot.gov

Thermal activation
(accelerated test 100°F)

Expansive gel resulting from the **alkali-silica reaction** and **micro-cracking**

=



Macro-cracking / Swelling

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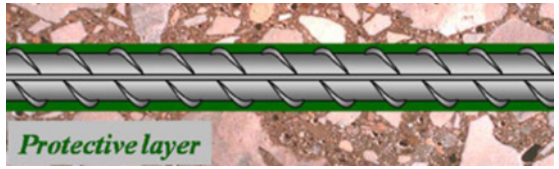
Corrosion of Embedded Steel in Concrete in a nutshell

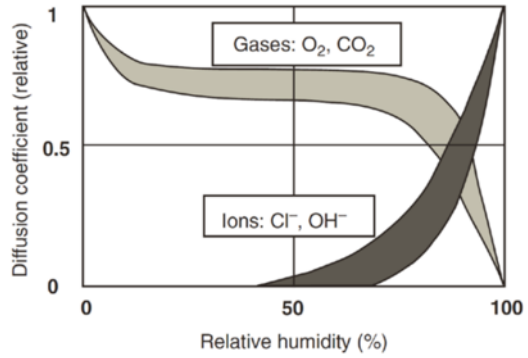
Passivation

1



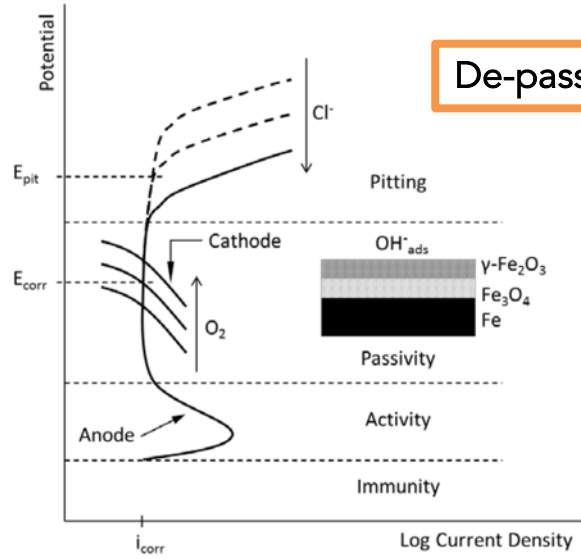
2

Chloride diffusion / carbonation



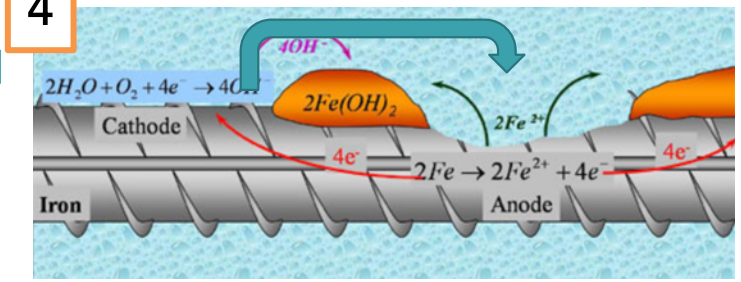
3

De-passivation



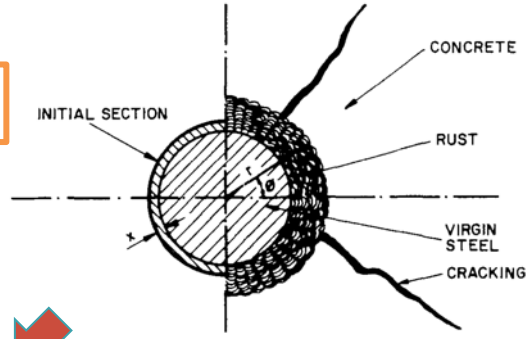
4

Oxydo-reduction



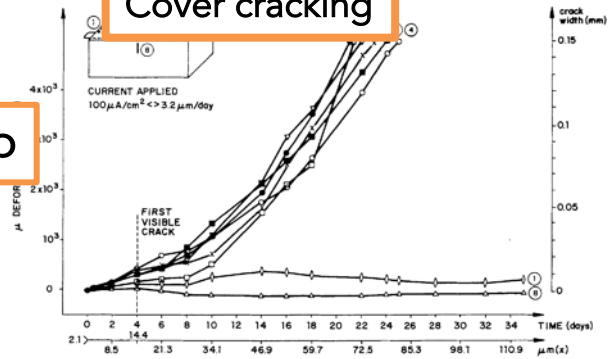
5

Rust formation



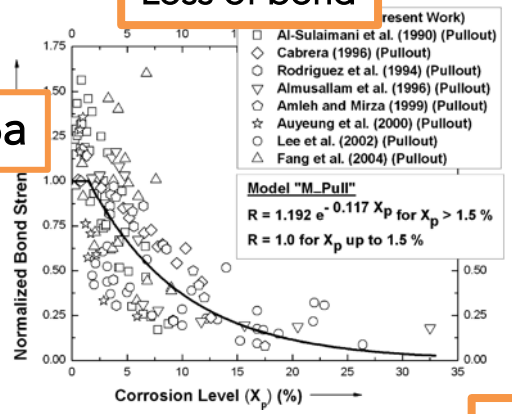
6b

Cover cracking



6a

Loss of bond



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ment.org/learn/concrete-technology/durability/corrosion-of-embedded-materials

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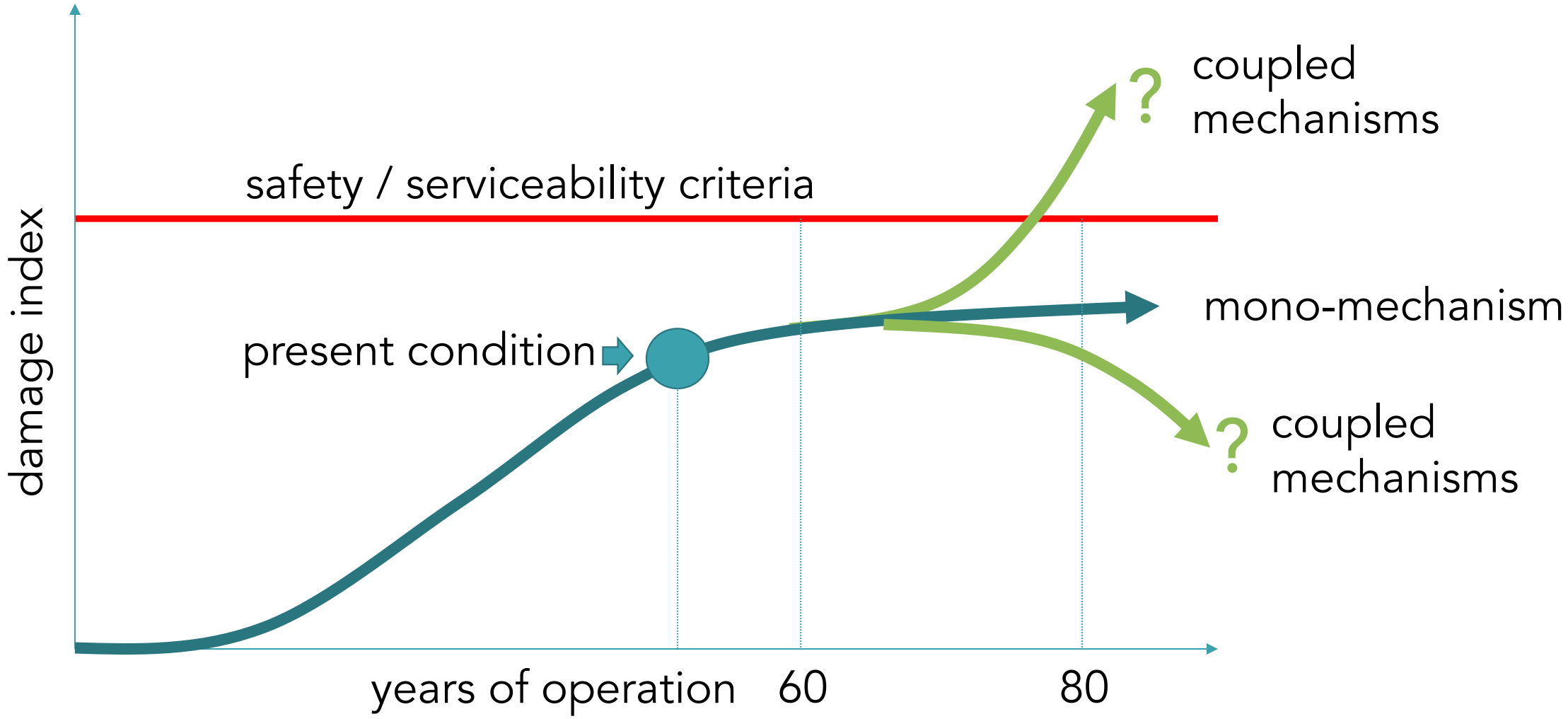
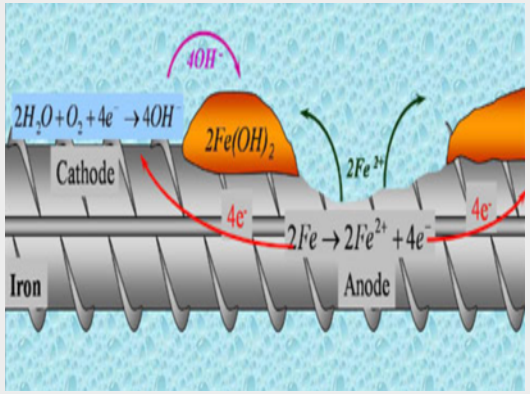
Kinetics and Synergies Effects



Examples of Possible Synergies

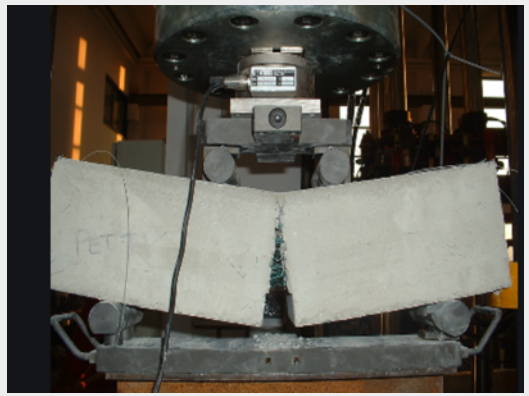
Alkali-silica reaction

?



Corrosion

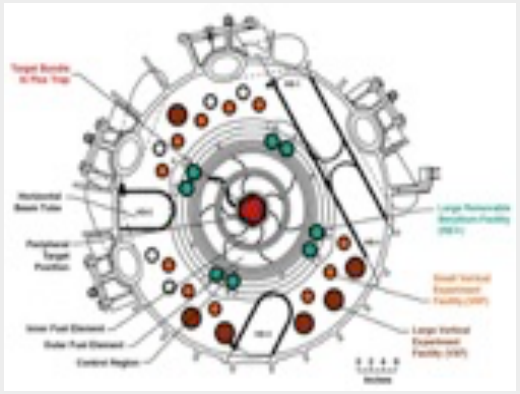
Creep



Fracture

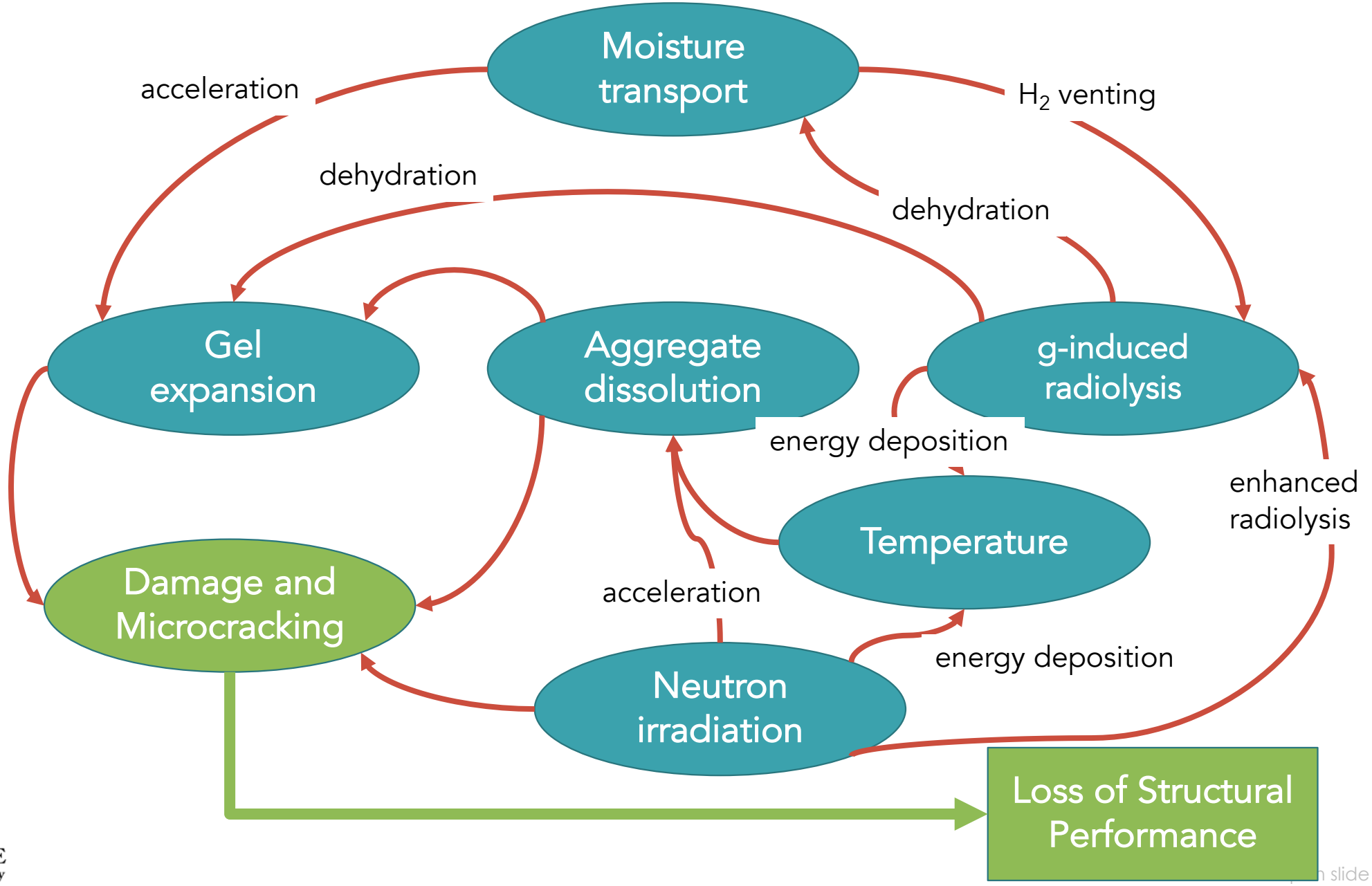
Alkali-silica reaction

?

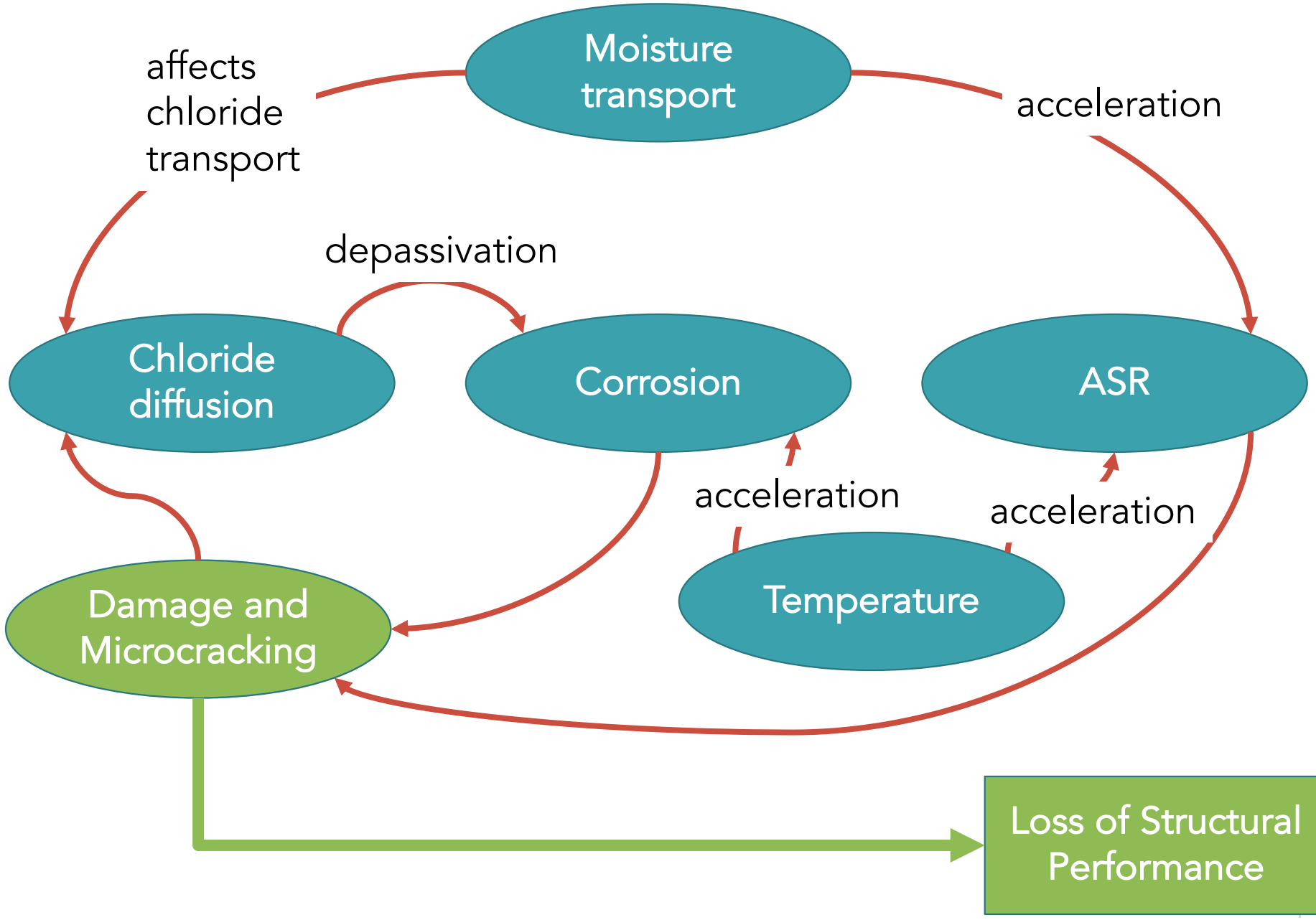


Irradiation

Possible Interactions between Alkali-Silica Reaction and Irradiation



Interactions between Corrosion and Alkali-Silica Reaction



Conclusions and Perspectives

DOE, NRC and Industry materials research programs advanced considerably the understanding, characterization, modeling of concrete subjected to irradiation and alkali-silica reaction

Some knowledge gaps still exist:

- Irradiation: rate effects, neutronic effects on creep, bond strength properties between concrete and embedded steel
- ASR: role of the aggregates' mineralogy on ASR kinetics and damage development

Synergies between irradiation, ASR, corrosion, creep and damage are still largely unknown for an assessment of operation beyond 80 years