5.7 Physical Attack

Description:

Concrete is vulnerable to multiple mechanisms of physical attack that may lead to deterioration over time and potential failure. Physical processes include non-structural cracking, salt crystallization, freezing and thawing, abrasion and erosion, thermal exposure, irradiation, fatigue and vibration, and settlement. Shrinkage cracking, thermal exposure, fatigue and settlement are discussed elsewhere in separate Failure Modes.

Salt crystallization is a process where dissolved salts move through the concrete by capillary action and crystallize on or under the surface as the water evaporates. The growing crystals can exert pressure on the "skin" of the concrete, resulting in spalling of the surface. This process can continue as long as there is a ready supply of moisture from the soil or atmosphere and the concrete experiences cycles of wetting and drying.

Freezing and thawing is a process where water freezes inside the concrete, exerting pressure from the inside as it turns into ice of larger volume. Repeated cycles of freezing and thawing can cause spalling of the surface in concrete that is not adequately air-entrained.

Abrasion and erosion are processes where surface material is removed from the concrete by either dry rubbing/grinding or impact of fluid carried particles. Cavitation is a destructive process where air bubbles carried by the water collapse while in contact with the concrete. The localized high pressure can, after large number of applications, cause significant surface wear.

Irradiation by either neutrons or gamma rays can cause changes to concrete's physical properties and/or volume change of aggregates (a summary of concrete irradiation is provided FM 5.7 Exhibit 5)

This document will attempt to identify potential processes and determine if any occurred in a way that impacted the observed failure.

Data to be collected and Analyzed:

1. Permeability of the concrete (Industry Standards; mix design; Petrographic reports; pour card analysis)
2. Air entrainment from pour records.
3. Freezing temperature information for CR3
4. IWL inspections record of damage related to physical attacks
5. Radiation exposure records

Verified Supporting Evidence: None

5.7 Physical Attack (cont.)

Verified Refuting Evidence:

a. The concrete has very low Water to Cement (W/C) ratio and permeability (FM 5.7 Exhibit 2 is a graph summary of pour records).
b. Petrographic reports did not detect salt crystallization inside the concrete (FM 5.7 Exhibit 3).
c. IWL reports did not identify significant surface salt crystallization (efflorescence) or concrete spalling that is associated with salt crystallization (FM 5.7 Exhibit 4 is a summary of the latest IWL report).
d. IWL Inspections did not detect any indication of damage due to other physical attack processes (FM 5.7 Exhibit 4).
e. The structure was not exposed to abrasion or erosion causing processes from mechanical abrasion or flowing water.
f. Irradiation levels are low (FM 5.7 Exhibits 6) and will not have a detrimental effect on the containment structure's concrete.
g. Review of winter temperature records at CR3 revealed that during the 2002-2009 period there were a total of thirteen (13) freezing incidences (FM 5.7 Exhibit 7). When extrapolated to the 1970-2009 period this level is insignificant for air-entrained concrete and no freezing/thawing damage is expected.

Discussion:

a. Industry standards use water to cement (W/C) ratio as an indication of concrete's permeability. It has been established that concrete with W/C of 0.4 or lower has voids system that is mostly made of disconnected discreet small voids – making it practically impermeable (FM 5.7 Exhibit 1). FM 5.7 Exhibit 2 is a graph based on data from all pour cards of concrete used in panel RB-15 of the containment structure. It shows that all the concrete was placed with W/C ratio of less than 0.41, with an average of 0.40. Based on the above it is concluded that the concrete has very low permeability.
b. Some of the physical attack modes mentioned above require moisture transmission through the concrete. Impermeable concrete will be resistant to damage by salt crystallization and will have reduced exposure to freezing.
c. W/C ratio is also a good indicator of concrete strength. The low W/C ratio resulted in strong concrete, able to resist higher stresses caused by physical attack.
d. The adequate air entraining found in the containment structure provides the concrete with resistance to damage from freezing/thawing cycles. The number of freezing cycles the structure experiences is very low and would not create a problem.
e. Irradiation levels at the containment wall are very low and would not have any significant effect on the concrete's physical properties.

Conclusion: The containment structure's concrete did not undergo physical attack . Therefore, physical attack was not a contributor to the delamination.

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