

Concrete Durability

What is Durability?

Concrete durability refers to the ability of concrete to resist deterioration and maintain its intended performance throughout its service life when exposed to environmental and service conditions. While concrete is inherently durable, it can deteriorate when exposed to aggressive agents or adverse conditions. Understanding common durability mechanisms is essential for proper design, material selection, construction practices, and long term maintenance.

Durability Mechanisms

Concrete is deteriorated in a number of ways including:

- Chloride induced corrosion
- Carbonation induced corrosion
- Freeze-Thaw Attack
- Sulphate Attack
- Alkali-Aggregate Reaction
- Others

Chloride Induced Corrosion

Chloride induced corrosion is one of the most common durability issues affecting reinforced concrete structures. Chlorides can enter concrete from deicing salts, marine environments, or contaminated materials. When chlorides reach the reinforcing steel in sufficient concentration, they break down the protective passive layer on the steel surface, initiating corrosion. Corrosion products occupy a greater volume than the original steel, leading to cracking, delamination, and spalling of the concrete cover, and a reduction in structural capacity.

Carbonation Induced Corrosion

Carbonation occurs when carbon dioxide from the atmosphere penetrates the concrete and reacts with hydration products, reducing the alkalinity of the concrete. As the pH decreases, the protective passive layer around reinforcing steel can be lost. If moisture and oxygen are present, corrosion can initiate. Carbonation induced corrosion is more common in concretes with high permeability, low cement content, or inadequate

cover, and is often observed in older structures or those exposed to dry indoor or urban environments.

Freeze Thaw Attack

Freeze thaw damage occurs when concrete is exposed to cycles of freezing and thawing while in a critically saturated condition. Water within the pore structure expands upon freezing, generating internal stresses that can cause cracking, surface scaling, and loss of material. Proper air entrainment, adequate strength development, and good drainage are key factors in resisting freeze thaw deterioration, particularly in cold climates where deicing salts may also be present.

Sulphate Attack

Sulphate attack results from the reaction between sulphate ions and components of the hardened cement paste. Sulphates may originate from soils, groundwater, or industrial environments. These reactions can lead to expansion, cracking, loss of strength, and softening of the concrete. Resistance to sulphate attack depends on cement composition, the use of supplementary cementitious materials, low permeability, and appropriate mix design for the exposure conditions.

Alkali-Aggregate Reaction

Alkali aggregate reaction refers to deleterious reactions between alkalis in the cement paste and certain reactive aggregates. Two primary types of alkali aggregate reaction are recognized.

Alkali silica reaction, ASR, is the most common form and occurs when reactive silica in aggregates reacts with alkalis in the pore solution. This reaction produces an expansive gel that absorbs moisture and swells, leading to internal stresses, cracking, and characteristic map cracking patterns.

Alkali carbonate reaction, ACR, is much rarer and involves specific dolomitic limestone aggregates. In North America, ACR has been identified only in select regions, primarily near southern Ontario and parts of the upper United States. Although uncommon, ACR can

Concrete Durability

cause significant expansion and cracking when susceptible aggregates are present.

Mitigation of both ASR and ACR includes careful aggregate selection, appropriate testing, the use of supplementary cementitious materials where effective, and controlling the alkali content of the concrete mixture.

Other Mechanisms

In addition to the mechanisms described above, concrete may deteriorate due to acid attack, abrasion and erosion, leaching, thermal cracking, fire exposure, and combined or synergistic mechanisms that accelerate damage.

How to Ensure Durability?

Durability begins at the design stage, where careful consideration must be given to specifying the appropriate concrete exposure class based on the anticipated environmental and service conditions. The exposure class should be selected in accordance with CSA A23.1, Tables 1 and 2, to ensure that the concrete mixture and performance requirements are suitable for the intended application.

Three Rules to Consider:

1. Design for conditions. Choose the right concrete exposure class and mix for the expected environment.
2. Protect reinforcement. Control permeability, cover depth, and use materials to prevent corrosion.
3. Resist deterioration mechanisms. Use air entrainment, supplementary cementitious materials, and proper aggregates to prevent freeze-thaw, sulphate attack, and alkali-aggregate reactions.

References

1. CSA A23.1 A23.2 2024. *Concrete materials and methods of concrete construction Test methods and standard practices for concrete*. CSA Group

2. *Design and Control of Concrete Mixtures*. 9th Edition. Cement Association of Canada

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