

Alkali-Silica Reactivity (ASR) in Concrete



Alkali-Silica Reactivity, (also referred to as ASR), in concrete is a chemical reaction that occurs between the alkali hydroxides in Portland cement and reactive forms of silica found in some aggregates. This reaction produces an expansive gel, which absorbs water and swells, leading to various detrimental effects on the concrete.

Key Aspects of Alkali-Silica Reactivity

Reaction Process:

The alkali hydroxides (primarily sodium and potassium hydroxides) in the cement react with amorphous or poorly crystalline silica present in certain aggregates. This reaction forms an alkali-silica gel, which has a high affinity for moisture.

Expansion and Cracking:

The gel absorbs water and expands, creating internal pressures within the concrete. This expansion leads to cracking, which can propagate throughout the concrete, reducing its structural integrity.

Symptoms and Effects:

- **Cracking:** Visible cracking patterns, often in a network or map-like pattern, on the surface of the concrete.
- **Expansion:** The overall expansion of the concrete element, which can cause misalignment and structural issues.
- **Decreased Durability:** Increased permeability due to cracking, which allows other aggressive agents like water and chlorides to penetrate more easily, leading to further deterioration.
- **Spalling:** Pieces of concrete may break off from the surface.

Figure 1: Effects of ASR on a Concrete Structure



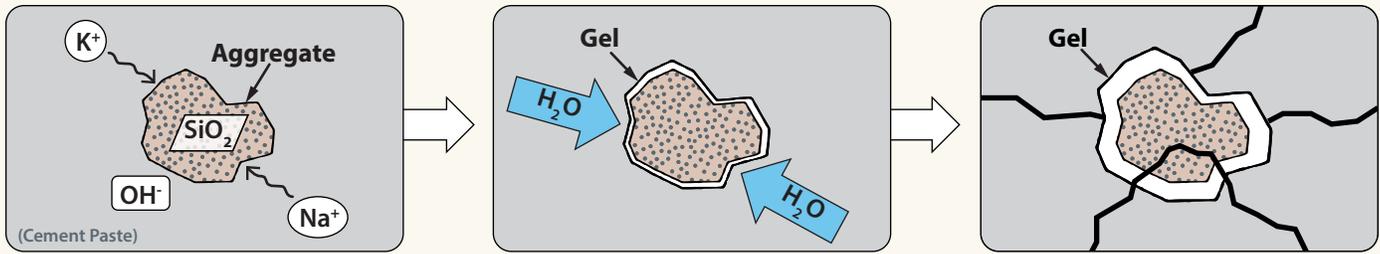
Can Alkali-Silica Reactivity Be Predicted?

Alkali-Silica Reactivity (ASR) in concrete can be predicted through various testing methods and evaluations. Here are some approaches used to predict ASR:

Petrographic Analysis:

- **Microscopic Examination:** Evaluates the mineral composition and texture of aggregates to identify the presence of reactive silica.
- **Petrographic Reports:** These detailed reports provide insights into the potential reactivity of aggregate based on its mineralogy.

Figure 2: The Process of Alkali-Silica Reaction in Concrete



1. Alkali hydroxides (primarily sodium and potassium hydroxides) in the cement react with unstable silica present in certain aggregates.

K^+ represents positively charged potassium ions

OH^- represents negatively charged hydroxide ions.

Na^+ represents positively charged sodium ions.

SiO_2 represents silicon dioxide.

2. This reaction forms an alkali-silica gel around the aggregate. This gel has a high affinity for moisture. The gel absorbs water and expands, creating internal pressures within the concrete.

3. This expansion leads to cracking, which can propagate throughout the concrete, reducing its structural integrity.

Chemical Testing:

- **Alkali-Silica Reactivity (ASTM C289):** A chemical test that determines the potential reactivity of aggregates by measuring the amount of silica dissolved in an alkaline solution.
- **Mortar-Bar Test (ASTM C1260):** A rapid test that involves casting mortar bars with the aggregate in question and storing them in a high-alkali environment. The expansion of the bars is measured over time to assess reactivity.

Accelerated Mortar Bar Test (ASTM C1567):

- **Modified Test:** Similar to ASTM C1260, but uses additional supplementary cementitious materials like fly ash or slag to determine their effectiveness in mitigating ASR.

Concrete Prism Test (ASTM C1293):

- **Long-Term Test:** Involves casting concrete prisms with the aggregate in question and storing them under controlled conditions. The expansion of the prisms is measured over a period of one to two years to assess reactivity.

Field Performance History:

- **Historical Data:** Reviewing the performance history of concrete structures using the same or similar aggregates in similar environmental conditions can provide valuable insights into potential ASR issues.

Alkali Content Analysis:

- **Cement Alkali Content:** Analyzing alkali content in the cement to ensure it is within acceptable limits to reduce the risk of ASR.
- **Alkali Loading:** Calculating the total alkali loading in the concrete mix, considering both the cement and any supplementary cementitious materials.

By employing these methods, engineers and researchers can predict the potential for ASR in concrete and take appropriate measures to mitigate its effects. This proactive approach is crucial in preventing ASR-related damage and ensuring the longevity and durability of concrete structures.

Prevention and Mitigation

Alkali-Silica Reactivity in concrete can be prevented or mitigated (lessened) through several strategies. These methods aim to minimize the conditions that lead to ASR or to counteract its effects if reactive aggregates are used.

1. **Use Low-Alkali Cement:** Using cement with a low alkali content (typically less than 0.60% Na_2O equivalent) reduces the availability of alkalis that contribute to ASR.
2. **Blended Cements:** Using blended cements containing pozzolans or slag can also help reduce the effective alkali content.
3. **Supplementary Cementitious Materials (SCMs):** Adding SCMs such as fly ash, silica fume, or slag to the concrete mix can mitigate ASR. These materials react with the alkalis, reducing their availability to react with the silica in the aggregates. SCMs participate in pozzolanic reactions that consume alkalis, thereby lowering the potential for ASR.
4. **Chemical Admixtures, Lithium-Based:** Adding lithium compounds (e.g., lithium nitrate) to the concrete mix can help mitigate ASR by preventing the formation of expansive ASR gel.