SCA
SLAG CEMENT
ASSOCIATION

Information Sheets

8: Mitigating the Risk of Alkali Silica Reaction

Alkali-silica reaction (ASR) is a chemical reaction between the alkalies in portland cement and certain types of silica minerals present in some aggregates. The reaction product is a hygroscopic gel, which absorbs moisture and swells. Under certain circumstances, the formation of the gel can cause expansion and, eventually, cracking of the concrete. Factors that affect the rate and severity of ASR include:

- The reactivity of the aggregate (amount and type of reactive silica minerals present).
- The availability of alkalies in the concrete.
- The exposure conditions (moisture availability and temperature).
- The type of concrete element (size and reinforcement details).

In some cases, ASR may cause severe concrete deterioration, leading to a loss in serviceability or rendering the concrete more susceptible to damage by other processes, such as freezing-and- thawing or chloride ingress and corrosion.

Mitigating the Risk of ASR

It is very difficult, if not impossible, to halt the ASR reaction once it begins. It may be possible in some instances to limit the ingress of water into the concrete, but this will only slow down rather than stop the progress of deterioration. The best way to mitigate ASR is to prevent its occurrence through the proper use of materials in the concrete mixture.

Figure 1: ASR causes expansion and cracking of concrete structures and pavements.

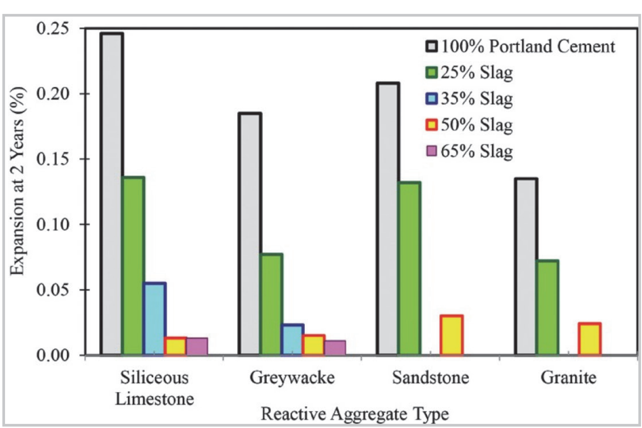

Figure 2: Effect of slag on the expansion of concrete containing reactive aggregate. Max limit of 0.04%.

There are several ways to mitigate ASR. One option is to limit the alkali content of the concrete by minimizing the amount of alkali contributed by the portland cement. Another solution is to limit or prohibit the use of reactive aggregates. It is often impractical to specify either of these options if suitable materials (low-alkali cements or nonreactive aggregates) are not available. Another alternative is to specify slag cement to prevent ASR when reactive aggregates are used.[1]

How Does Slag Cement Mitigate ASR?

The use of slag cement (also referred to as slag in this document) will reduce the potential of ASR occurring by reducing the amount of alkali in the system that is available for reaction with the aggregate. A greater proportion of the alkalies are bound by the hydration products of slag cement compared with portland cement and this means that the alkali concentration in the concrete pore solution is reduced which, in turn, reduces the risk of reaction with the aggregate. The amount of slag required will depend on the reactivity of the aggregate and the alkali contributed by the portland cement; the level needed typically ranges from 25 to 70% by mass of total cementitious material. Figure 2 shows the impact of slag on the 2-year expansion of concrete prisms (ASTM C1293[4]) containing moderately to highly reactive aggregates and cement with an alkali content of 1.25% Na_2O equivalent).

The amount of slag required with a particular reactive aggregate can be determined by testing various slag-aggregate combinations in the accelerated mortar-bar test (ASTM C1567)[3] or the concrete prism test (ASTM C1293).[4] Alternatively, the prescriptive approach of ASTM C1778[5] can be used. In this standard guide, the minimum level of slag is determined by consideration of aggregate reactivity, alkali availability, the exposure conditions, and the size and type of the concrete structure.

Alkalis in Slag Cement and ASR

Slag cement can be used to reduce alkali loading in concrete. ASTM C1778 provides an option of limiting the alkali content of concrete when reactive aggregates are used. In such cases, it is not necessary to include the alkalies in the slag in the calculation of the concrete alkali content, as they are generally considered to be unavailable for reaction with the aggregate.[2]

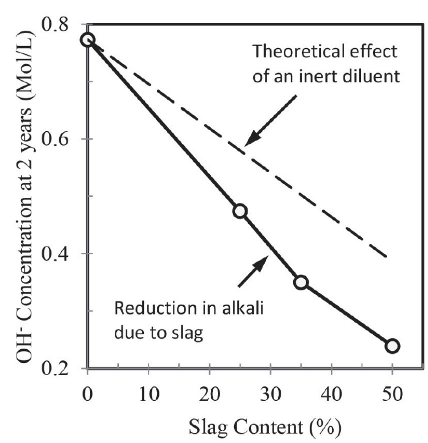

Figure 3: Effect of slag on pore solution alkalinity.

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Alkali-silica reaction (ASR) is a chemical reaction between the alkalies in portland cement and certain types of silica minerals present in some aggregates.

Slag cement is also used in concrete to mitigate ASR by performance. Figure 3 shows the alkali concentration (expressed in terms of hydroxyl ion, OH^-, concentration) of the pore solution extracted from 2-year-old cement paste samples produced with high-alkali cement and various levels of slag.[6] The slag reduces the concentration of the hydroxyl ions beyond that expected from mere dilution of the portland cement. This means that slag does not contribute its alkalies to the pore solution but actually removes some of the alkalies provided by the portland cement. These alkalies will not be available for reaction with the aggregate.

References

1. ACI 201.2R-16, "Guide to Durable Concrete," American Concrete Institute, Farmington Hills, MI, 2016, pp. 19-30.

2. Thomas, M. D. A., and Innis, F. A., "Effect of Slag on Expansion due to Alkali-Aggregate Reaction in Concrete," ACI Materials Journal, V. 95, No. 6, Nov.-Dec.1998, pp. 716-724.

3. ASTM C1567-13, "Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)," ASTM International, West Conshohocken, PA, 2013.

4. ASTM C1293-20a, "Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction," ASTM International, West Conshohocken, PA, 2020.

5. ASTM C1778-20, "Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete," ASTM International, West Conshohocken, PA, 2020.

6. Bleszynski, R. F., "The Performance and Durability of Concrete with Ternary Blends of Silica Fume and Blast-Furnace Slag." PhD thesis, University of Toronto, Toronto, ON, Canada, 2002, 1074 pp.

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