MITIGATING ALKALI-SILICA REACTION

SCA SLAG CEMENT ASSOCIATION

Slag Cement in Concrete *No. 8*

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WHAT IS ALKALI-SILICA REACTION?

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

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

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 alkalis 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 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. 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]

Slag cement reduces the amount of alkali in the system that is available for reaction with the aggregate.

HOW DOES SLAG CEMENT MITIGATE ASR?

The use of slag cement 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 alkalis 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; typically the level needed ranges from 30 to 60% by mass of total cementitious material. Figure 2[2] shows the impact of slag on the 2-year expansion of concrete prisms (ASTM C1293) containing moderately to highly reactive aggregates and cement with a very high alkali content (1.25% Na_2O equivalent).

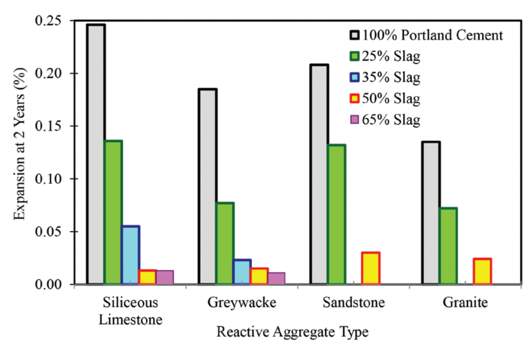

Fig. 2: Effect of slag on the expansion of concrete containing reactive aggregate[2]

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 AASHTO PP65-11[5] can be used. In this standard practice, 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 contains a small amount of alkalis. Typically, the amount of alkali is similar to that of low-to-moderate-alkali portland cement (for example, 0.5 to 0.7% Na_2O equivalent). Some guide specifications and standard practices, such as AASHTO PP65-11,[5] allow the option of limiting the alkali content of concrete when reactive aggregates are used. In such cases, it is not necessary to include the alkalis 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 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 alkalis to the pore solution but actually removes some of the alkalis provided by the portland cement. These alkalis will not be available for reaction with the aggregate.

Figure 4 shows the expansion of concrete prisms at 2 years plotted against the alkali content of the concrete considering only the alkalis provided by the portland cement.[6] It can be seen that for a given amount of portland cement alkalis the expansion is reduced in the presence of slag, especially at higher levels of replacement. This again indicates that rather than contributing alkali to the ASR slag effectively consumes some of the alkalis provided by the portland cement so that they are not available to react with the aggregate.

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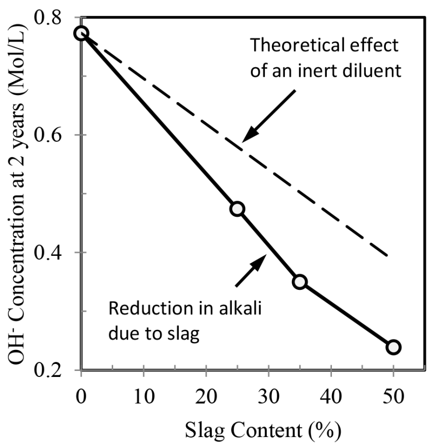

Fig. 3: Effect of slag on pore solution alkalinity

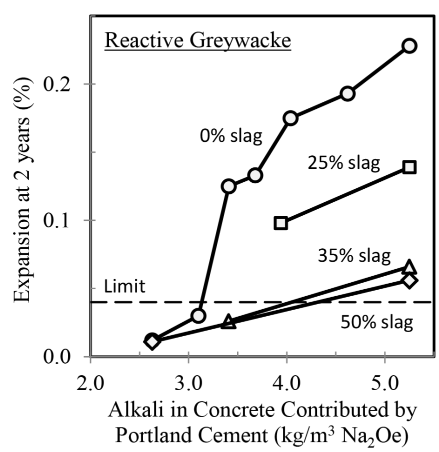

Fig. 4: Effect of alkali contributed by portland cement on expansion of slag cement concrete (1 kg/m³ = 1.686 lb/yd³)

References

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The Slag Cement Association is the leading source of knowledge on blast-furnace slag-based cementitious products. We promote the increased use and acceptance of these products by coordinating the resources of member companies. We educate customers, specifiers, and other end-users on the varied attributes, benefits, and uses of these products.