SCA SLAG CEMENT ASSOCIATION

Information Sheets

6: Reducing Permeability

Concrete Permeability

Permeability is a measure of how easy it is for water, air and other substances such as chloride ions to enter concrete. Concrete contains pores that allow these substances to enter. Larger pores allow easier entry, while smaller pores decrease the rate at which these substances enter the concrete.

A common way to measure permeability of concrete is standard test method ASTM C1202 "Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration," also known as the rapid chloride permeability test. This method is the most accepted test to determine the relative permeability of concrete. A 60 V electrical potential is established across a sawed four inch diameter concrete cylinder section. The total current passing through the section over time and measured in Coulombs is reported as an indication of permeability. Lower Coulomb values indicate lower permeability. The permeability required is a function of the concrete application.

Figure 1: Penneable concrete is a principal reason for concrete deterioration due to reinforcing steel corrosion and other deterioration mechanisms.

Permeability and Chloride Induced Corrosion

Low permeability concrete can help reduce the potential for reinforcing steel to corrode when exposed to chlorides by limiting the permeation of those chlorides into concrete. When reinforcing steel comes into contact with plastic concrete, a chemical reaction occurs between the steel and the concrete that causes a protective layer (a passive layer) to develop around the reinforcing steel. This passive layer protects against corrosion of the reinforcing steel.

If the concrete is exposed to de-icing salts, these salts can migrate down to the reinforcing steel through small pores in the concrete. Over time, the chlorides in these salts can react with the reinforcing steel, breaking down the passive layer and causing the steel to corrode. When reinforcing steel in concrete corrodes, the product of that corrosion (rust) takes up more volume than the original steel, and causes the concrete to crack. After cracks develop, the deterioration accelerates as chlorides are allowed easy ingress to the reinforcing steel. The deterioration of both the concrete and reinforcing steel compromises the integrity of the structure.

Reducing Permeability with Slag Cement

When portland cement hydrates, it forms calcium-silicate hydrate gel (CSH) and calcium hydroxide (Ca(OH)2). CSH is the "glue" that provides strength and holds the concrete together. Permeability is related to the proportion of CSH to Ca(OH)2 in the cement paste. The higher the proportion of CSH to Ca(OH)2, the lower the permeability of the concrete.

When slag cement is used as part of the cementitious material in a concrete mixture, it reacts with Ca(OH)2 to form additional CSH, which in turn lowers the permeability of the concrete. Generally, the higher the percentage of slag cement in a concrete mixture, the lower the permeability of the concrete. Concrete with lower permeability can generally be achieved by substituting between 25 to 65 percent slag cement for portland cement. Figure 2 shows the ability of a specific slag cement to reduce the permeability of concrete as measured by the rapid chloride permeability test.

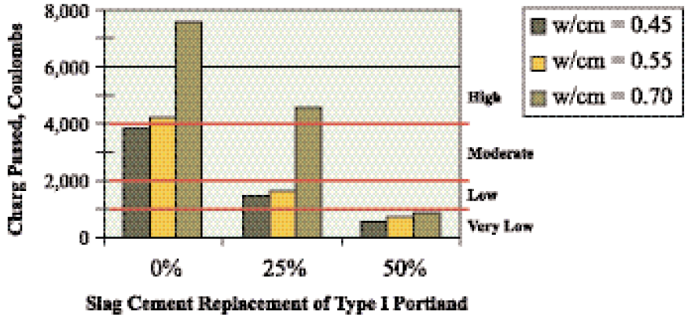

Figure 2: Effect of Slag Cement on Concrete Chloride Ion Penetrability (ASTM C1202)

References

1. ASTM C1202-19, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration," American Society for Testing and Materialsl, West Conshohocken, PA, 2019

2. Fernandez, J and Malhotra, V. M., "Mechanical Properties, Abrasion Resistance, and Chloride ermeability of Concrete Incorporating Granulated Blast-Furnace Slag," Cement, Concrete and Aggregates, CCAGDP, Vol. 12, No. 2, Winter 1990.