Reduce Scaling with Slag Cement and Good Concreting Practices

Slag Cement in Concrete No. 29

What is Scaling

Scaling is a surface defect that results from exposure to freezing and thawing conditions.

The number of freeze thaw cycles is a critical factor in determining the existence, severity and extent of deterioration.

Scaling is a surface defect (flaking or peeling of a hardened top surface of concrete) that results from exposure to freezing and thawing conditions. The fundamental mechanism that creates the forces that are responsible for the flaking or peeling of the concrete are from the expansion of water upon freezing.

Scaling generally occurs when the concrete has an inadequate air void system which does not provide an outlet for the hydraulic pressure that is created when water freezes.

Figure 1: Typical scaling seen on concrete pavement

The number of freeze thaw cycles is a critical factor in determining the existence, severity and extent of deterioration. Scaling can be identified as *light*; where partial peeling of the surface has occurred and no coarse aggregate is seen, *moderate*; where exposure of aggregate up to 3/8 inch in depth is visible and *severe*; the coarse aggregate stands out or is being dislodged from the concrete paste.

Deicing chemicals[1] such as calcium chloride, magnesium chloride, etc. cause a significant increase in internal pressure and aggravate the concrete system and should be avoided as much as possible.

Additionally deicing chemicals can increase the number of occurrences of freeze thaw events experienced, by suppressing the freezing temperature of a brine (salt/water) solution.

Deicing chemicals are almost always applied to city streets and highways in climates that experience freeze thaw cycles; even though homeowners might not put them directly on their own driveways, salt laden icy slush mixtures can drip from parked cars onto driveways or garage floors.

To increase a concrete's resistance to scaling, concrete mixtures should be properly proportioned and contain proper graded and clean aggregate.

HOW DO YOU INCREASE A CONCRETE'S RESISTANCE TO SCALING

To increase a concrete's resistance to scaling, the following practices should be followed:

1. The water to cementitious (wcr) ratio of the concrete mixture should be below 0.45.
2. The cementitious factor of the concrete should be at least 564 lbs/yd3[2].
3. Concrete mixtures should be properly proportioned (ACI 211) and contain proper graded and clean aggregate (ASTM C33).
4. The amount of entrained air should conform to the specified amounts in ACI 318, Table 4.4.1 and the average spacing factor of the air void system (determined in accordance to ASTM Standard C 457) should not exceed 0.20 mm (ACI 212.3R)
5. The concrete should be finished properly.
   a. Do not finish while bleed water is still present on the concrete surface (causes an increase in the wcr at the surface of the concrete)
   b. Do not sprinkle water on the surface of the concrete as a finishing aid (causes an increase in the wcr at the surface of the concrete)
   c. Do not finish air entrained concrete with a steel trowel (decreases or eliminates the air from the surface of the concrete). Magnesium or wood floats should be used.
   d. Be careful when finishing with a vibrating screed (can cause a loss of air and a weaker layer of mortar at the surface of the concrete).
   e. Be careful when placing concrete on a dry, windy day (can cause incomplete hydration and a weakened surface).
   f. Do not over finishing concrete (can cause a loss of air at the surface of the concrete).
6. The concrete should be cured properly[3].
   a. Concrete should be cured with wet burlap or pigmented curing compound. Curing should begin as soon as it can be applied without marring the surface of the concrete and should be continued for 7 days or until the concrete has reached 70% of its design strength.
   b. Concrete should be allowed to air dry for a period of one month before experiencing a freeze thaw cycle and/or application of deicer chemicals (NRMCA recommends 1 year before the application of de-icing salts)
   c. Apply concrete sealer when concrete will be exposed to de-icing chemicals before the proper curing period has been completely achieved (concrete sealers, such as silanes, siloxanes, or linseed oil, are not proof against scaling but some studies indicate that their use can provide added resistance to scaling, especially in the first year).

7. Cementitious Material

   a. Fly Ash – Can contain carbon which will affect air content. Fly ash is limited by ACI 318, Table 4.2.3, and ACI 301, Table 4.2.2.8, to a maximum of 25% for concrete exposed to freeze / thaw and de-icer salts.

   b. Slag Cement - Slag cement is limited by ACI 318, Table 4.2.3, and ACI 301, Table 4.2.2.8, to a maximum of 50%.

   c. Silica Fume – Silica Fume is limited to a maximum of 10% by ACI 318, Table 4.2.3 and ACI 318, Table 4.2.2.8.

   d. Ternary blends – ACI 318, Table 4.2.3, and ACI 301, Table 4.2.2.8, limit fly ash to 25%, silica fume to 10%, and the total of slag and fly ash or slag and silica fume to 50%.

When designed, finished, and cured properly, concrete mixtures containing slag cement have the same resistance to scaling as concrete mixtures containing straight portland cement.

Deicer Salt Scaling Resistance
ACI 318 – Building Code Requirements

Cementitious Materials	Maximum % of Total Cementitious Materials Deicing Chem. Exposure
Slag cement, ASTM C989	50
Fly ash/other pozzolans, ASTM C618	25
Silica fume, ASTM C1240	10
Slag + Pozzolan + Silica Fume	50
Pozzolan + Silica Fume	35

SLAG CEMENT AND SCALING

When designed, finished, and cured properly, concrete mixtures containing slag cement have the same resistance to scaling as concrete mixtures containing straight portland cement. Some consideration that need to be taken into effect when using slag cement in freeze thaw environments, in addition to those previously listed, are:

1. Follow ACI 318 recommendations in freeze and thaw environments.

2. Slag Cement when incorporated into a Mix Design will extend the set time, the increase in set time is inversely proportional to the concrete temperature and proportional to amount of Slag Cement in a mix design. Adjustments in the mix design can and should be made to account for any undesired increase in set time. Properly designed mixtures should not have excessive retardation as very slow setting concrete can be more susceptible to premature finishing.

3. Always inform finishers with any mix design changes i.e. longer setting times or slower bleed rates can affect the concrete finishing properties.

4. Make sure finishers do not finish bleed water into the concrete

Slag cement has been manufactured widely in the United States for over 30 years, and there are thousands of bridge decks, concrete pavements, and sidewalks in freeze thaw environments containing slag cement that have shown excellent scaling resistance.

Slag cement has been manufactured widely in the United States for over 30 years.

Figure 1: Typical scaling seen on concrete pavement

References
1. IS001 effective subsistence on concrete.
2. South Dakota Research SD2002-01-G - TPF-5(042)-G.
3. ACI 308.

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About the Slag Cement Association...

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.