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Preventing Scaling of Concrete with Portland Limestone Cement

In recent years the construction industry has experienced an increase in the acceptance and adoption of new cement types to reduce the environmental impact of building materials. In Michigan, the first wave arrived in 2022 with the transition from Type I Cement (ASTM C150) to Type IL Cement or Portland Limestone Cement (PLC) (ASTM C595), which is a blended cement with 5% to 15% limestone. This transition warrants revisiting the discussion on concrete scaling and how to prevent concrete scaling.

Scaling, as defined by the American Concrete Institute (ACI) Committee 116, is the "local flaking or peeling away of the near-surface portion of hardened concrete or mortar." This may also be called mortar flaking when it occurs just over the aggregates near the surface. Scaling is primarily a physical action created by hydraulic pressures or stresses from repeated freeze-thaw cycles within the concrete. The expansive forces caused by the formation of ice are exacerbated with deicing chemicals, which increase both the saturation of the concrete and the number of freeze-thaw cycles. The distress mechanisms of scaling are complex on both a microscopic and macroscopic level.

The State of Michigan is in a "severe exposure" climate where exterior concrete is subjected to i) continuous moisture, ii) cycles of freezing and thawing, and iii) the use of deicing chemicals. Therefore, exterior concrete must be proportioned with durable ingredients designed for this type of climate, with an entrained air-void system, and such concrete must be placed using proper placement, finishing, and curing and protection to resist hydraulic pressures (stresses) that can cause scaling.

Severity of Scaling

ACI 116R classifies scaling as:

- Light (loss of surface mortar without exposure of coarse aggregate)
- Medium (loss of surface 0.2 to 0.4 in. in depth and exposure of coarse aggregate)
- Severe (loss of surface 0.2 to 0.4 in. in depth with some loss of mortar surrounding aggregate particles 0.4 to 0.8 in. in depth)
- Very Severe (loss of coarse aggregate particles as well as surface mortar, generally to a depth greater than 0.8 in.)

Causes

The most common causes of scaling are related to one or a combination of the following factors:

- **Curing.** Lack of, or inadequate, curing and protection after placing concrete may compromise the surface of newly placed concrete. Do not let the concrete surface dry out after placement. Cement reacts with the water in the mix. Once the water is gone, the chemical reaction stops and the concrete stops gaining strength. A surface that dries out before it reaches strength will be weak. Curing compounds and/or secured plastic sheeting can be used to keep the surface from drying during the first few days, allowing it to gain full strength. Curing is always critical, but it is more critical on a comfortable feeling, low humidity days than on hot humid days.

- **Finishing.** Improper finishing operations that work or trap water at the surface, resulting in a high water-cementitious ratio and low strength, creating a low-durability surface layer may cause scaling. Delayed or extended finishing will also allow early drying of the exposed concrete surface, prior to curing application, which can result in a weak surface.

- **Air-Entrainment.** The use of non-air-entrained concrete or too little entrained air, resulting in a non-durable concrete mix may cause scaling. A poor air-void system may also be created at the surface via over-manipulation of the plastic concrete during finishing operations.

- **Water-Cement Ratio.** Using concrete with low strength or excessively high water-cementitious ratio will allow for deeper penetration of water and deicing chemicals that can cause scaling.

Examples of scaling (left, light severity, sometimes called mortar flaking; and right, medium severity)

- **Freeze-Thaw Cycles.** Exposure of new concrete to freeze-thaw cycles before it has been adequately cured, and not allowed to air dry may cause scaling of concrete.

- **Deicers**. Exposure to aggressive/corrosive salts and fertilizers may cause scaling. Intentional application or indirect exposure (from vehicle traffic) to deicing chemicals at this early age greatly increases the likelihood of scaling. Never use calcium or magnesium-based deicers on concrete. Sodium chloride (table salt, rock salt, or safe salt) may be used in moderation to melt the ice. Instead, consider using sand for traction over snow and ice.

- **Supplemental Cementitious Materials (SCMs)**. Misunderstanding the use of SCMs may lead to scaling. Properly designed, finished, and cured mixes containing SCMs have the same resistance to scaling as 100% Portland limestone cement mixes. SCMs generally improve strength, durability, and water tightness. However, they also extend the concrete set time. Understanding set time and when to perform the varying finishing operations is crucial to the overall durability of a mix containing SCMs.

Preventing / Minimizing Scaling

It is important to note that all concrete surfaces will wear and scale to some extent over their lifetime. The use of preventative measures to mitigate the potential for scaling when placing concrete is critical to achieving a quality concrete project that will stand the test of time. Please see below for a list of best practices to prevent and minimize the potential of scaling.

1. **Concrete Mix Design.** Use a *"severe exposure" concrete mix* including:
   - Cement. For residential and commercial flatwork concrete mixes should include:
     - Minimum 4,000 psi compressive strength (consistent with the requirements of ACI 332, Code for Residential Concrete).
     - When slag cement is utilized in flatwork, the concrete mix should contain a minimum cementitious content of 564 lb/yd^3.
   - Aggregates. Use durable and well-graded aggregates and ensure that stockpiles are kept moistened at or above the saturated surface dry (SSD) condition at the time of batching.
   - W/C ratio. Low water-cementitious ratio of 0.45 or less.
   - Air Entrainment. 5% to 8% entrained air for 3/4 to 1-inch top size aggregates.
   - Slump. Slump can be increased to 5-7 inches using a Mid-Range or High Range Water Reducer, which will also increase the workability of the concrete.
   - Accelerator. Using a non-chloride accelerator will help in the consistency of the setting of the concrete during cold weather placement.
   - Retarder. When the conditions are prime for rapid evaporation of bleed water on the surface that can contribute to plastic shrinkage cracking, an evaporation retarder should be used.
   - Fibers. Mono filament and fibrillated fiber can be used to help with the consistency of bleed and plastic shrinkage cracking.

2. **Placement and Finishing Practices.** Utilize proper placement and finishing practices. The best practice for exterior concrete consists of i) placing and consolidating the concrete in the forms, ii) then striking off the surface to final grade, and iii) smoothing/flattening with a float to fill in any holes in the surface.

   As the concrete surface starts to stiffen or set up, a final texture is achieved with a burlap drag, light broom, or a patterned stamp. The water in fresh concrete gives the surface a glossy sheen. During the finishing process this sheen dissipates as the surface water evaporates. A curing membrane shall be applied as soon as the surface sheen starts to disappear. During the finishing process it is acceptable to lightly mist the surface (if needed) to replace water that has evaporated, but it is not acceptable for the finishers to mix water into the surface with their finishing tools – this practice leads to a weak concrete surface with a high chance of scaling.

3. **Curing.** Curing is the maintenance of moisture and temperature directly following finishing so that properties such as strength and durability develop, especially at the surface. Curing requirements also include protection from either excessive hot or cold temperatures.

   Apply white curing compound as soon as the finishing and texturing process has been completed. The white curing compound provides a waxy coating on the concrete surface, is the easiest to use, and the white color ensures complete coverage is achieved. Please note that ambient conditions may at times require less or more curing time.

4. **Sealers.** Apply a commercially available, 100% silane or siloxane, penetrating concrete sealer per the manufacturer's recommendations. The concrete should be reasonably dry prior to the sealer application, to

properly absorb the sealer. Ensure joints have been cleaned and sealed at the same time. Using a joint sealant is a best practice to ensure that ingress of water and incompressible material does not fill the joints.

5. **<u>Deicers</u>.** Minimize application of or exposure to deicers until after one year. Concrete placed late in the season, such as in October or November, may not have sufficient drying time (>40 days) before deicer application. Instead, consider using sand for traction over snow and ice.

Repair or Treatment

Although the appearance of a scaled surface may not be aesthetically pleasing, it is generally a cosmetic issue that does not compromise the structural integrity of the concrete and therefore may not require repair or replacement. For larger areas exhibiting pronounced scaling and surface loss, scarifying, grinding, or shot blasting will typically remove the scaled surface. However, the difference in appearance of ground vs. non-ground surfaces will be noticeable due to aggregate exposure in the ground areas.

Example of a diamond-ground street

Additionally, a common treatment for lightly to moderately scaled exterior concrete surfaces is the application of a sealer to help create a moisture barrier, thus preventing water from penetrating into the concrete. This can be accomplished with a light power washing of the surface to remove all loose material and debris. After a short drying period, the surface is treated with a high-quality penetrating sealer product such as a silane sealer. These products are designed to penetrate into the pores of concrete and react with alkaline materials and moisture to form a barrier that limits water and deicer penetration. Application rates will vary based on the specific product.

Application of a penetrating sealer to concrete

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