“Moving Advancements into Practice”

MAP Brief Summer 2023

Best practices and promising technologies that can be used now to enhance concrete paving

NATIONAL CONCRETE CONSORTIUM

Revisiting Concrete Scaling

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PROJECT TITLE
Revisiting Concrete Scaling

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Introduction

The ability of concrete to resist cold weather has been discussed at least since 1950 (PCA 1950) (Figure 1), and the issue of “salt scaling” continues to cause concerns on some city streets.

Surface distress is often caused by a combination of several factors, making it a challenge to pin down a single cause at any location. However, the actions recommended in this MAP brief to reduce the risk of surface distress will address most of the forms it may take.

An unusually high number of problems related to surface distress have been reported in 2023, and questions are being raised about what has changed this year. One change is that the portland limestone cements available now contain up to 15% interground limestone. Although the literature indicates that this change should not directly affect the propensity of a mixture to exhibit distress, one side effect may be that changes in water demand, bleeding, and setting time without appropriate changes in practices may increase the risk of scaling. Secondly, the 2022–2023 winter was especially severe. A brief analysis indicates that Des Moines underwent 18% more freeze-thaw cycles than in 2006–2007 (Taylor 2023). Thirdly, it is possible that turnover of staff (exacerbated by COVID-19) has led to an erosion of finishing skills in the field.

Most of the problems appear to be in hand-placed concrete, which typically has a higher water-to-cementitious materials (w/cm) ratio, a higher likelihood of retempering, and more variability in finishing practices than slipformed sections. Damage is also more prevalent near edge drains or in wheel paths, where salts are more likely to be concentrated.

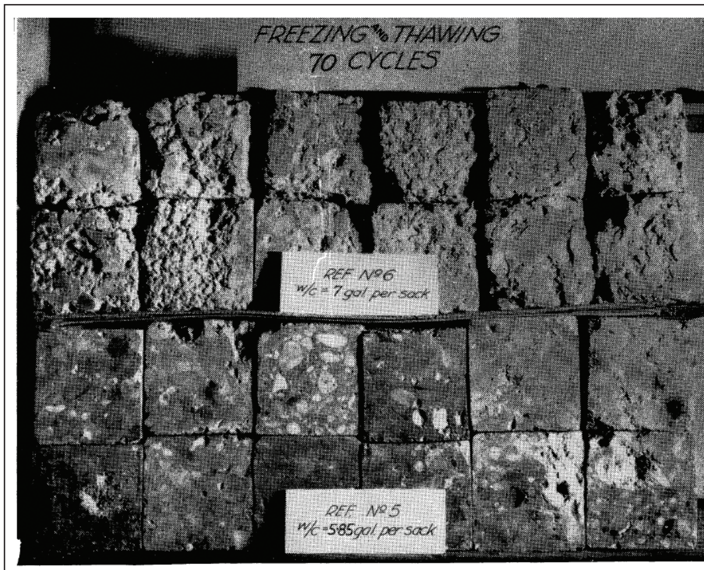

Fig. 3. The durability of concrete exposed to freezing and thawing is affected by the quality of the paste. Specimens in lower part of photograph, made with 5.85 gal. of mixing water per sack of cement, were more resistant than those in upper part, made with 7 gal. Same aggregate was used in all specimens.

PCA 1950

Figure 1. Excerpt from 1950 edition of *Design and Control of Concrete Mixtures*

Forms of Surface Distress

Surface distress can appear in different forms, and it is important to distinguish between them because the causes, means of prevention, and repair approaches are different for each. Cracking is not included in this discussion.

Flakes

Flaking is normally a surface effect, with sound concrete below the flakes (Figures 2 and 3). The key clue to identifying this distress is that thin flakes can be removed from the concrete surface by tapping it with a hammer. Note that the aggregate in Figure 3 is debonded from the paste, indicating that the damage occurred very early in the life of the concrete.

Popouts

Popouts (Figure 4) are typically observed as cone-shaped holes with broken aggregate particles at the bottom, with the other portion of the aggregate still attached to the loose cone.

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Figure 2. Surface flaking

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Figure 3. A surface flake

This distress is due to porous aggregates, such as chert, that absorb water and expand under freezing. The damage is often progressive as water gets to the deeper particles, particularly at joints.

Popouts are prevented by avoiding the use of such aggregates. There is no way to mitigate popouts, although surface sealants may slow the rate of water penetration.

Other Forms of Surface Distress

Loss of surface material is likely due to a combination of permeable, saturated concrete subjected to an aggressive environment, such as one with numerous freezing and thawing cycles (Figure 5), and salt-related distress.

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Figure 4. Popouts

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Figure 5. Freeze-thaw damage

Causes of Surface Distress

The various causes of surface distresses are tabulated below. There is some repetition because the mechanisms are interrelated.

Cause	Effects	Photo
Highly porous aggregates, such as chert	**Popouts**	Figure 4
Aggregates with smooth surfaces	**Mortar flaking** due to reduced bond with paste	—
High dosage of supplementary cementitious materials	**Increased risk of distress**. The exact mechanisms are still debated. Risks include slower hydration, early finishing due to delayed setting, and chemical effects.	—
Portland limestone cement	**Possible variation in finishing timing and bleed rates**	—
Cement with high C_3A or high alkali content	**Increased risk of distress**. The exact mechanisms are still unknown.	—
High w/cm ratio (exceeding maximum w/cm ratio of 0.45 due to poor mix design), retempering, bleeding, and adding surface water during finishing	**Freeze-thaw damage** caused by rapid saturation due to high permeability	—
Early finishing	**Flaking** due to bleed water trapped under the sealed surface **Increased w/cm ratio at the surface** as bleed water is reworked into the surface. See "High w/cm ratio" above. These effects can be avoided by using observations rather than rules of thumb to decide when to start finishing.	Figure 6
Overworking a stiff mixture	**Mortar flaking** as partially hydrated paste flakes are debonded from the tops of aggregate particles. A key clue to identifying mortar flaking is that damage is localized to just above sound, smooth, aggregate particles. **Increased surface w/cm ratio and risk of saturation** as excess water in the paste is worked up to the surface	Figure 7
Insufficient air during proportioning and batching	**Continuous loss of surface** under freeze-thaw action	—
Insufficient hydration and poor curing caused by hot, dry weather or placement late in the season	**Soft concrete**. This leads to progressive abrasion and rapid saturation, accelerating freeze-thaw damage over the whole surface. **Mortar flaking** may also be a symptom.	—
Salts	**Loss of paste** due to expansion or dissolution of surface paste. This is exacerbated by the application of salt to immature (porous) concrete. Dissolution of the surface paste depends on cementitious chemistry and salt type ($CaCl_2$ and $MgCl_2$ are more aggressive) and is distinctive due to the clean aggregate particles left behind. Because salts are used for deicing, these effects are most often seen in cold weather regions, but they can be seen in warm weather industrial applications where salts precipitate.	Figure 8
Ice bonding	**Glue spalling**. Ice that is bonded to the surface shrinks more than the concrete, peeling off the top of the concrete.	—
Old age	**Loss of surface** caused by abrasion and possibly surface freezing and thawing	Figure 9

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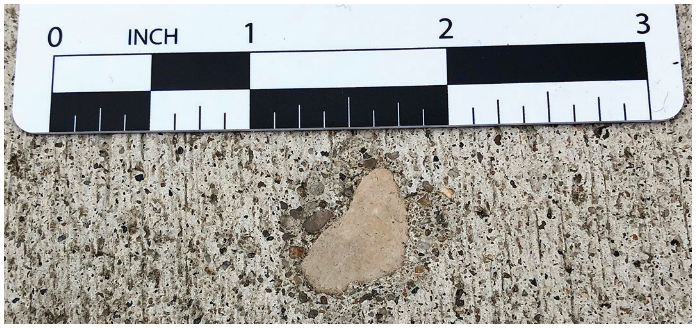
Figure 6. Effects of early finishing



Steve Mallicoat, IRMCA/ICPA, used with permission

Figure 7. Mortar flaking

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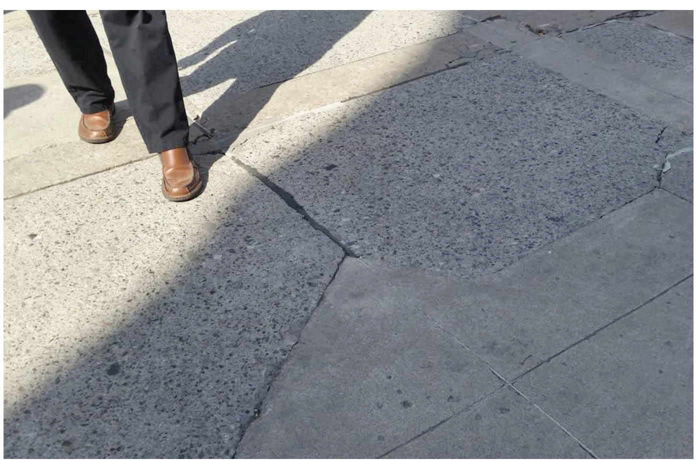
Figure 8. Effects of deicing salts



Tara Cavalline, University of North Carolina, used with permission

Figure 9. 100-year-old concrete

Minimizing Risk of Surface Distress

The following guidelines and actions may reduce the risk of early surface distress:

- The maximum final w/cm ratio in place should be 0.45, with a target of 0.42.
- Mixtures should contain a maximum of 25% fly ash or 50% slag cement for hand-placed concrete.
- The air void spacing factor should be a maximum of 0.008 inch.
- Finishing should occur after bleeding ends and the sheen is off.
- A sufficient amount of high-quality, pigmented curing compound should be applied to the pavement to make it as white as a sheet of paper.
- Salt should be avoided soon after construction. Avoid using $MgCl_2$ and $CaCl_2$ salts except when needed for safety.

Repairs to Address Surface Distress

The options for repair are limited and depend on the mechanism of failure. Repair strategies include the following:

- Do nothing and monitor. If the distress does not progress, then this may be a reasonable approach. Some systems may continue to deteriorate but so slowly that the life of the pavement is not affected.
- Grind off a thin layer. This option is appropriate for distress mechanisms that are not progressive. Grinding will restore ride quality and visual acceptability of the pavement.
- Apply penetrating sealants. This may be considered where the distress mechanism is slowed by preventing water from penetrating the surface. Sealants will have to be reapplied periodically.

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