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Certification, Consultancy and Technical Services to the Ready mix concrete and Construction industry

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TECHNICAL FACT SHEET

Frost Attack and the associated damage to concrete.

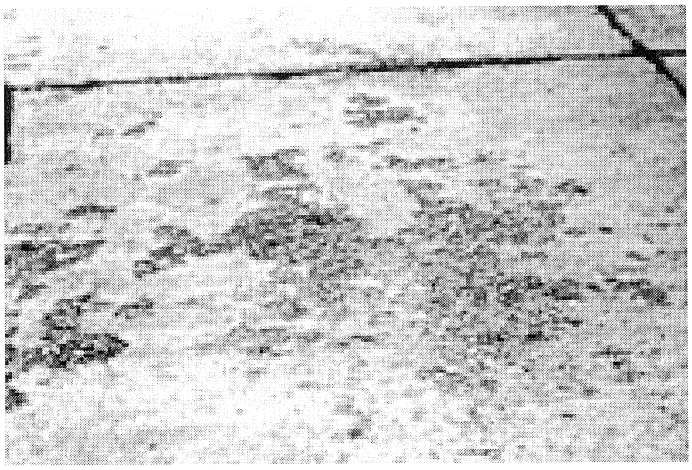
Topics covered

- **Freeze-Thaw Resistance;**
- **Concrete Scaling;**
- **De-icing chemicals;**
- **D-Cracking;**
- **Air entrainment;**

Frost attack does not discriminate where or when it will occur. Unfortunately the winter of 2009/2010 is the coldest for 30 years and the issue is that the ground temperatures have been as low as -15°C and for a sustained period. Past winters may well have been cold but we have not experienced such cold ground temperatures and this is why we are seeing an increase in frost attack issues. However, this is not to say that we will not experience frost damage is a "normal" winter period following a cold snap. The following will give a bit more of an insight into the effects of frost damage.

Freeze-Thaw Resistance

When water freezes, it expands about 9%. As the water in moist concrete freezes, it produces pressure in the pores of the concrete. If the pressure developed exceeds the tensile strength of the concrete, the cavity will dilate and rupture. The accumulative effect of a freeze-thaw cycle and disruption of paste and aggregate can eventually cause expansion and cracking, scaling, and crumbling of the concrete. This break down effect could be from one or twenty freeze-thaw cycles.



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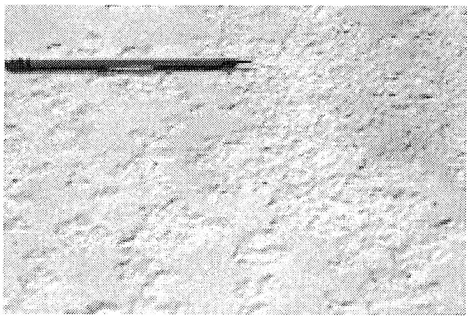
Concrete Scaling

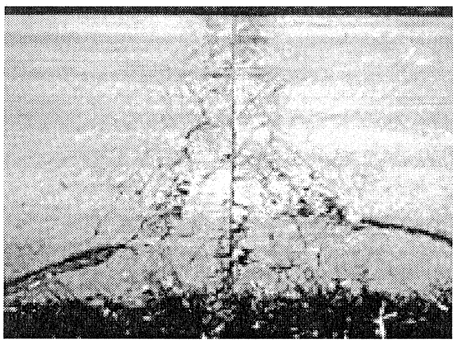
Scaling is defined as a general loss of surface mortar or mortar surrounding the coarse aggregate particles on a concrete surface. This problem is typically caused by the expansion of water due to freezing and thawing cycles and the use of de-icing chemicals; however, properly specified, produced, finished, and cured quality concrete can reduce the risk for this type of deterioration.



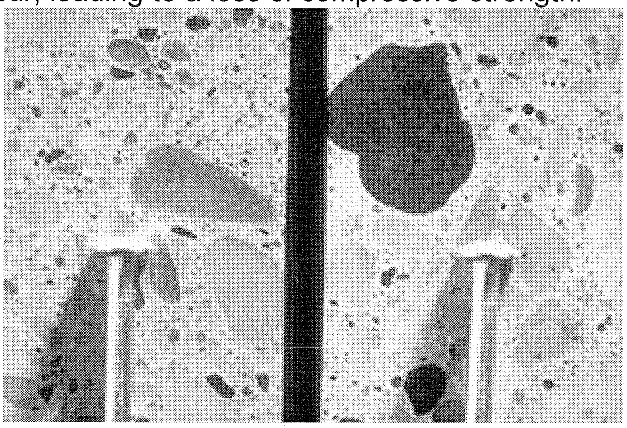
Typical example of scaled concrete surface

De-icing chemicals used for snow and ice removal, such as sodium chloride, can aggravate freeze-thaw deterioration. Heavy trafficked areas such as footpaths and main roads during frost and snow periods will use de-icing salts. Concentrations of these salts then become deposited on drive ways and less trafficked areas. This concentration of salts are slower to be dissipated than on a main thoroughfare resulting in pooling, and therefore further cooling of already cold concrete. Moisture tends to move towards zones with higher salt concentrations (by osmosis). Therefore, if salts are present in the pore solution the osmotic pressure is increased. In addition, the application of de-icing salts to pavements increases the rate of cooling, increasing the potential for freeze-thaw deterioration at the concrete surface. However, the use of any product that thaws ice, i.e. Cat litter, alcohol, act in the same way as de-icing salts by increasing the cooling temperature, the use hot water will cause a thermal shock effect if used on very cold or frozen concrete potentially causing a rapid breakdown of the surface (dusting, scaling, and delamination).

D-Cracking. Cracking of concrete pavements caused by the freeze-thaw deterioration of the aggregate within concrete is called D-cracking. D-cracks are closely spaced crack formations parallel to transverse and longitudinal joints that later multiply outward from the joints toward the centre of the pavement panel. D-cracking is a function of the pore properties of certain types of aggregate particles and the environment in which the pavement is placed. Due to the natural accumulation of water under pavements in the base and sub base layers, the aggregate may eventually become saturated. Then with freezing and thawing cycles, cracking of the concrete starts in the saturated aggregate at the bottom of the slab and progresses upward until it reaches the wearing surface. This problem can be reduced either by selecting aggregates that perform better in freeze-thaw cycles or, where marginal aggregates must be used, by reducing the maximum particle size. Also, installation of effective drainage systems for carrying free water out from under the pavement may be helpful.



Air entrainment. The severity of freeze-thaw exposure varies with different areas of the United Kingdom. Local weather records can help determine the severity of exposure. The resistance of concrete to freezing and thawing in a moist condition is significantly improved by the use of intentionally entrained air. The tiny entrained air voids act as empty chambers in the paste for the freezing and migrating water to enter, thus relieving the pressure in the pores and preventing damage to the concrete. Concrete with a low permeability (that is, a low water-cement ratio and adequate curing) is better able to resist freeze-thaw cycles. In rare cases, air-void clustering can occur, leading to a loss of compressive strength.



Cross section of air-entrained (right) and non-air-entrained concrete. Large size air voids are entrapped air. Small pinpoint size bubbles (entrained air) uniformly distributed through the paste are beneficial air voids. Note comparison with common pin.

In view of these comments, frost attack once started is a progressive breakdown of the concretes surface. Questions often raised in this instance (why is one slab showing signs of frost attack and the one the next door not?). One or several of the following factors could be the answer:

Drainage/fall;
Standing water/ice;
Pooling of de-icing salts on the surface;
Wetter placed concrete; (Excessive use of additional water above specified slump or even water sprayed on to the concrete to obtain a finish)
Protected slab (less likely to be exposed to frost);
Poor mix choice; (Use of wrong mix for specific application, low grade mix, low cement content, too high a workability. The Ideal mix for light traffic drives ways would be above 300kg/m^3 cement content (C30.0N/mm^2) with admixtures plasticisers or AEA and fibres);
No curing (Cast slab left to air cure with no additional protective measures);
Concrete finished to quickly (closing off the concrete slab surface before the bleed cycle has finished);

Remedial action can take several forms, from simple spray on applications to seal the slabs surface to surface dressing, whether concrete, epoxy or similar systems. Separate advice is applicable with any remedial actions.

The following Website will freely give you more information on these topics:

Concrete Society – www.concrete.org.uk
The Concrete Centre – www.concretecentre.com

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