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THE MECHANISM OF COMBINED SALT- AND FROST ATTACK ON POROUS, BRITTLE MATERIALS

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ABSTRACT

A current project on the mechanism of combined salt- and frost attack on porous, brittle building materials is presented. Some earlier results and a working hypothesis on the mechanism of salt frost attack are briefly presented.

Key words: Frost, salt, mechanism, concrete

1 INTRODUCTION

1.1 General

The service life of a concrete structures is dependent on a concrete cover with a good ability to protect the reinforcement from corrosion. Service life estimations often presumes the thickness of the cover to remain constant throughout the service life of the construction. However if the cover is damaged for some reason, service life will be pronouncedly shorter than was initially estimated. Such damages therefore have to be avoided or at least we need a good technique for estimating them. As part of this, good knowledge on the mechanisms of salt frost attack is required. At our department these mechanisms are currently beeing studied in a project mainly sponsored by the Swedish Research Council for Engineering Sciences.

1.2 History

In [1] and [2] some studies on the salt frost resistance of concrete were reported. In both papers, the authors found that a moderate salt concentration (about 2-4%) were the most detrimental and also that this was true irrespective of type of deicing chemical. The authors concluded that the mechanism had to be of physical rather than chemical character. Some hypotheses on the destructive mechanism have been proposed, but so far none has been fully accepted.

2 EXPERIMENTS

2.1 Ordinary scaling tests

Some ordinary scaling tests have been carried out in the project. In the first one, effects of different frost cycle design, salt concentrations and salt distributions on total scaling were investigated. The test method was a slight modification of the Swedish standard test method SS137244. It was found, as expected, that an outer salt concentration of about 3% by weight was the most detrimental case. These results were reported at the Nordic Concrete Research Meeting in Gothenburg 1993.

Further, similar tests were carried out on high strength concrete in order to find out more precisely the "pessimum" salt concentration for such concretes. Surprisingly, it was found that salt concentration played no role for a concrete of water cement ratio 0.35 (5% silica fume) without air entrainment. Instead, scaling was very high no matter what concentration was used. The test was repeated on a concrete of W/C 0.30 (10% silica fume). This time scaling was very low but still it was clearly seen that a salt solution would give worse damages than would pure water.

3 HYPOTHESIS AND FIRST TEST

3.1 Hypothesis

A hypothesis to explain the mechanism of salt frost surface attack has been developed originating from theories for frost heaving in soils and the isotherm expansion behaviour registred by Powers and Brownyard in 1953 [3]. The key idea is that micro ice lenses which form in the paste are able to grow by gathering moisture from nearby pores (as was proposed by Powers and Brownyard for inner damages). In a moisture isolated specimen this means all ice lenses compete for the same available moisture and damages will be spread across the entire specimen volume. However, in the case of a non moisture isolated specimen, ice lenses that are close enough to the surface will be able to gain moisture from outside if a liquid phase is present at the specimen surface. Such a liquid phase will exist if the outer water is contaminated with some kind of deicer. In this way micro ice lenses close to the surface will be able to grow more than ice lenses in the specimen interior and thus the surface will be damaged. This hypothesis is described in more detail in [4].

3.2 First test

According to the proposed hypothesis scaling will not depend on salt concentration if the test is carried out in such a way that salts never get in to the pores. This means that the salt solution has to be removed while the temperature is above 0° in order to avoid diffusion of salts. Certainly, some diffusion also takes place while temperature is below 0°C, but partly due to the temperature beeing low and partly due to that the coarser pores are filled with ice, this diffusion will be very slow.

Such a test was carried out on mortars of W/C 0.45, 0.50 and 0.65, all with a moderate air entrainment of about 6.5%. Salt concentrations used were 0, 1, 3 and 7.5%. 7-10 cycles were run (some specimens showed leakage and thus testing had to be interrupted). For specimens which had never been dried before testing, the results indicated no pessimum concentration, perfectly in accordance with what had been predicted from the hypothesis. Neither specimens that had been dried for two days and then water stored for three days before testing showed any pessimum around 3%, it rather seemed that a higher salt concentration would give worse damages.

More tests of the hypothesis are under way in our laboratory.

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