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Resistivity Measurements to Assess the Freeze - Thaw Attack on Concrete – Lab Specimen and Real Structure

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1 Introduction

In Germany concrete for hydraulic structures under the responsibility of the Federal Ministry of Transport and Digital Infrastructure in XF3 exposure has to pass the CIF-Test. Before the mandatory introduction of this test questions concerning the transferability of test results to practical application were intensively discussed. The monitoring of the temperature and moisture exposure of real structures was supposed to be an adequate way to get reliable information on this question. Amongst other structures a newly built lock was equipped with sensors and data has been collected for 16 years during the whole service life of the structure up to now. The paper describes investigations on the freeze-thaw attack during the CIF-Test on lab specimens and concrete cores of concrete elements which were equipped with the same sensors as the lock. This allows for a comparison of the exposure in the CIF-test and the lock.

2 Principles to Monitor the Freeze-Thaw Attack on Concrete

Concrete resistivity is strongly dependent on its moisture content. Therefor resistivity measurements can serve as an indirect determination of the degree of saturation of concrete. By means of a calibration accounting for all relevant influences on the resistivity the resistivity can be transferred into the degree of saturation. Multiring electrodes (MRE) were used for continuous measurements of the resistivity in different distances to the surface.

To cause damage freeze-thaw cycles need to induce freezing and melting of water in the pore structure. Investigations indicated that the freezing of water in the pore structure can be detected by resistivity measurements (Spörel, 2013; Sato and Beaudoin, 2011; Wang *et al.*, 2016). This enables to monitor a freeze-thaw attack in laboratory tests and in real structures.

3 Results

Lab specimens and two concrete elements were equipped with MREs and MTPs. Different testing ages and storing conditions were investigated. Figure 1 shows the resistivity data in a measuring depth of 42 mm during the freeze-thaw-cycles and the development of the relative dynamic modulus of elasticity. As described in (Spörel, 2013; Spörel, 2016) a typical increase and decrease of the resistivity is observed during the freeze-thaw cycles caused by freezing and melting of water in the pore structure. High resistivity is measured when water in the pore structure is frozen at temperatures down to -20 °C and low values when the water is present in a liquid state at temperatures between about 0 and 20 °C.

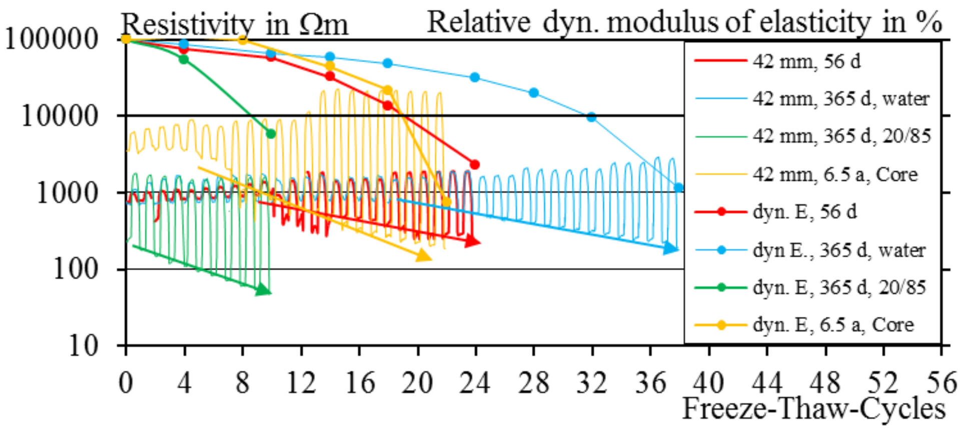

Figure 1. Temperature compensated resistivity and dynamic modulus of elasticity during the CIF-Test.

The low resistivity values decrease over time with each freeze-thaw cycle which is marked by arrows. This indicates the rise of the degree of saturation in that measuring depth. Analogue with that the dynamic modulus of elasticity starts to decrease. The number of freeze-thaw cycles at which that decrease starts is different for the investigated concretes. Both the micro-ice-lens theory (Setzer, 2002) and the theory of the critical degree of saturation (Fagerlund, 1977) seem to be comprehensible. In contrast to the water absorption during the freeze-thaw cycles no water transport was detectable in that distance to the surface during the capillary suction.

4 Conclusions

By means of monitoring the resistivity of concrete the micro-ice-lens theory (Setzer, 2002) and the theory of the critical degree of saturation (Fagerlund, 1977) seem to be comprehensible. As resistivity can be measured at different distances to the surface by MREs a monitoring of the freeze-thaw attack on structures and lab specimen is possible. The results enable to better evaluate the transferability of results of the CIF-Test to practical conditions.

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