1 INTRODUCTION

The research project V 473 “Studies on the saturation of concrete during freezing” had the aim to examine possible damage by freezing processes measured with MRE. Two types of concrete were produced as similar as possible to existing buildings, also equipped with MRE (multi-ring electrode). The concretes of a lock in Hohenwarthe (CEM III + fly ash, w/c 0,47) and of the Gäubahntunnel (CEM I + fly ash, w/c 0,5) were simulated.

In a first step the concrete structures were examined with various tests. Afterwards freezing processes and the process of the saturation degree were measured with MRE. By measuring the ultrasonic running time continuously during these tests the process of the inner damage could be analysed.

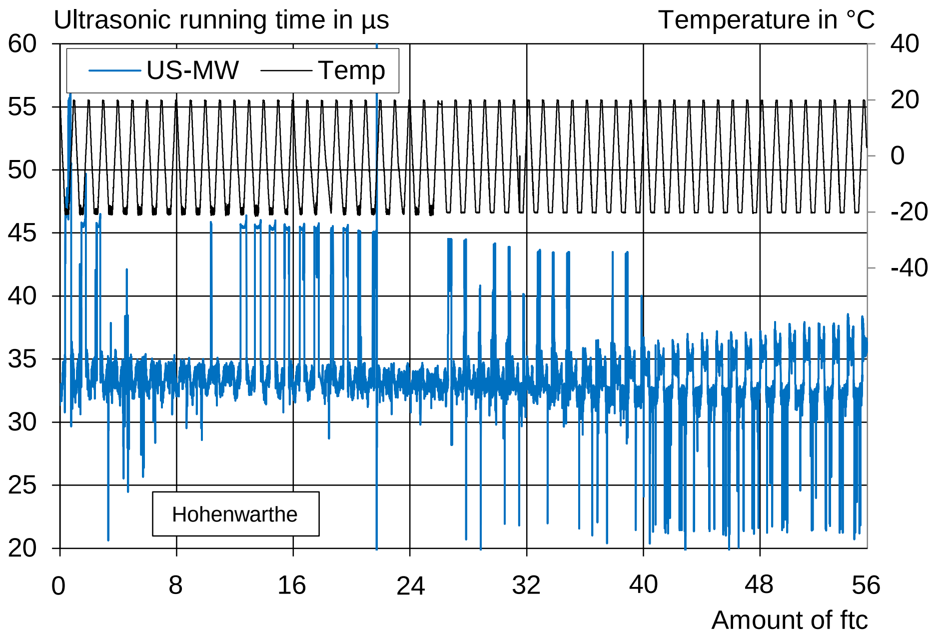
2 RESULTS

The pore size distribution investigated with mercury intrusion showed a finer pore structure of the concrete Hohenwarthe. The concrete Gäubahntunnel had more capillary pores. This result was expected as CEM III-concretes develop a denser structure than CEM I-concretes and furthermore the concrete Gäubahntunnel was produced with a higher w/c ratio.

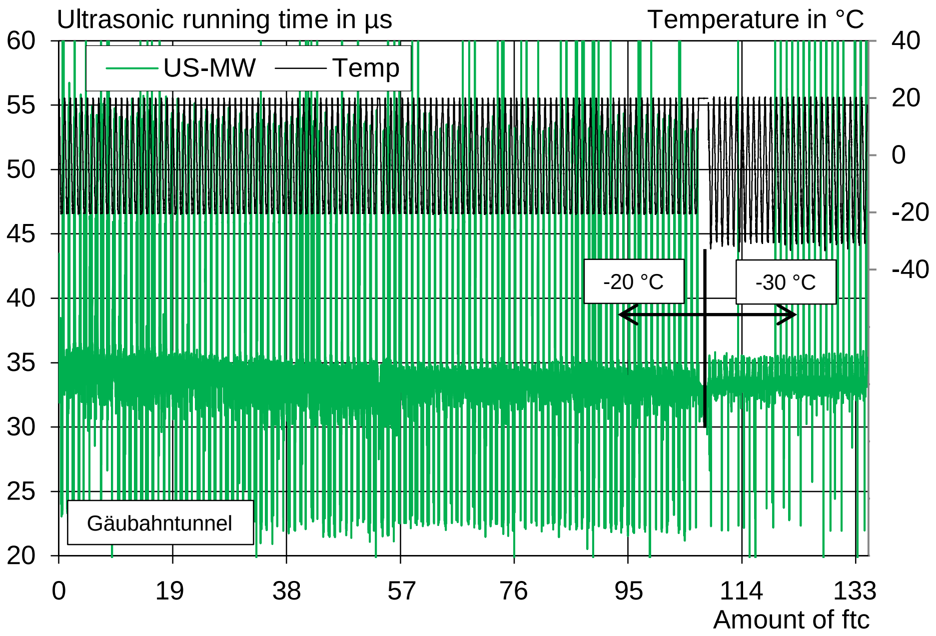
The critical degree of saturation determined with the method of Fagerlund amounts to 93 % of the concrete Hohenwarthe and to 89 % of the concrete Gäubahntunnel. However, the critical degree of saturation of the concrete Hohenwarthe could not be determined exactly and has to be regarded as a rough estimate.

The frost resistance was examined with the CIF-test. The concrete Gäubahntunnel showed a high freeze thaw resistance but had also a high air content. The concrete Hohenwarthe displayed no freeze thaw resistance at the age of 28 days and after 56 days.

The freezing processes were measured with MRE and the inner damage of concrete was determined by measuring the ultrasonic running time continuously during freezing. After 26 to 30 freeze-thaw cycles, one can see the beginning of an inner damage of the concrete Hohenwarthe. The inner damage is displayed by an increase of the ultrasonic running time at 20 °C, see picture 1. The ultrasonic running time of the concrete Gäubahntunnel only increased slightly after lowering the minimum temperature to -30 °C after 112 ftc, see picture 2. This can probably be traced back to a higher number of frozen pores at a lower temperature.

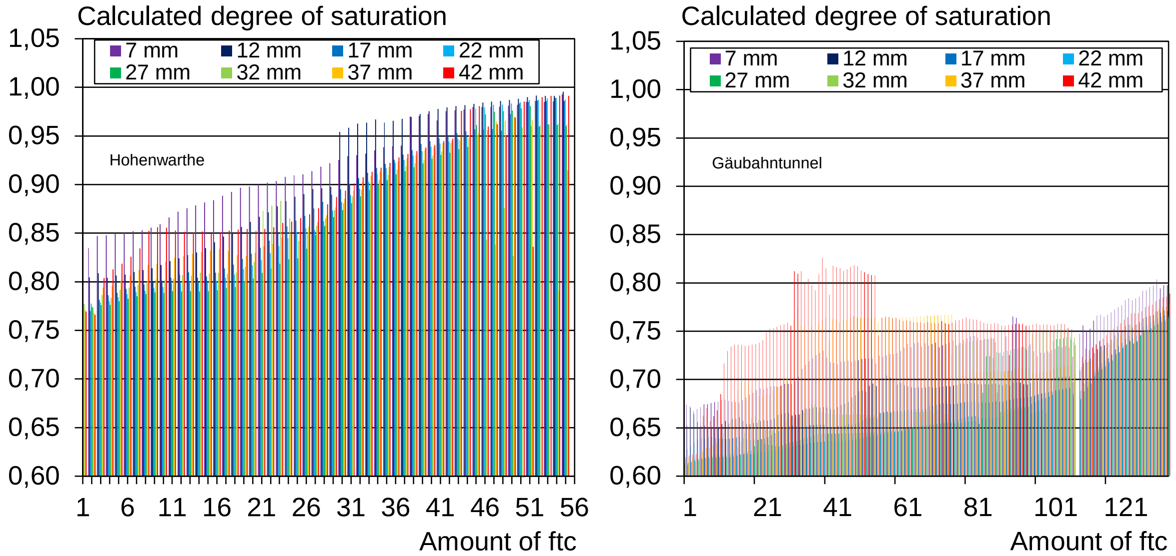


Picture 1: Ultrasonic running time of the concrete Hohenwarthe during freezing cycles



Picture 2: Ultrasonic running time of the concrete Gäubahntunnel during freezing cycles

After the start of the inner damage the calculated saturation degree of the concrete Hohenwarthe also increases, see picture 3. The degree of saturation amounted between 85,4 % and 88,3 % in a depth of 35 mm. These values were interpolated as in this depth the ultrasonic running time was measured. This result is in the range of the critical degree of saturation determined with the method of Fagerlund. To confirm this relation it is suggested to report the tests with further concretes.



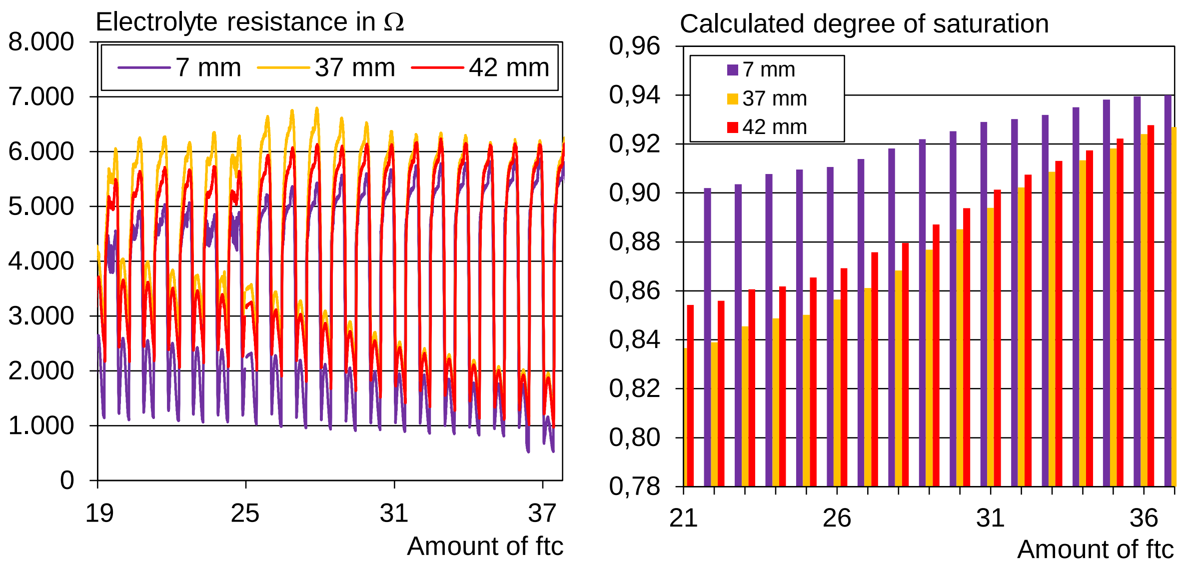
Picture 3: Calculated degrees of saturation of the concretes Hohenwarthe and Gäubahntunnel

The saturation of the concrete Gäubahntunnel increases faster after lowering the minimum temperature. Thus, through the micro ice lens pump more water gets in the concrete. But no continuous decline of the relative dynamic elastic modulus was measured within the test duration. The reason for that can be the measured degrees of saturation are lower than the critical degree of saturation determined with the method of Fagerlund.

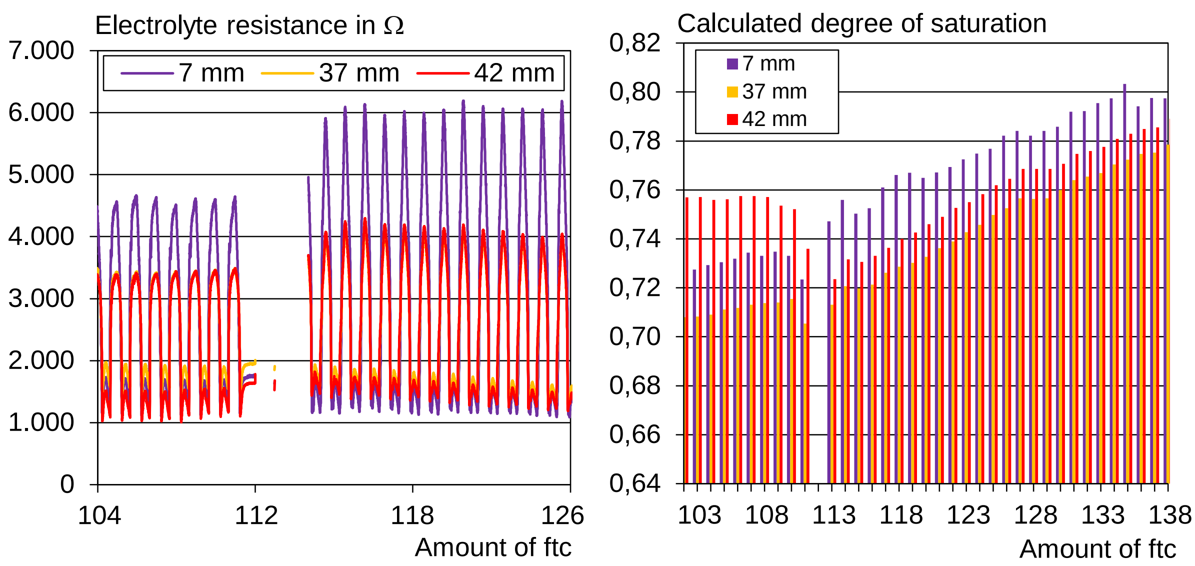
Since the beginning of the freeze-thaw cycles one can see freezing processes of both concretes. After the concrete Hohenwarthe was damaged the amplitudes of the electrolyte resistances increased, see picture 4. The reason for that is the bigger amount of water being able to freeze.

One can also see a water transport from the outer to the inner regions of the specimen as the degrees of saturation in different depths are getting equal with time.

The amplitude of the electrolyte resistance is also dependent on the minimum temperature. The measurement of electrolyte resistance of the concrete Gäubahntunnel shows a strong increase of the amplitudes after lowering the minimum temperature, see picture 5.



Picture 4: Freezing processes and calculated degrees of saturation at 20 °C of the concrete Hohenwarthe at the time of damage



Picture 5: Freezing processes and calculated degrees of saturation at 20 °C of the concrete Gäubahntunnel at the time of lowering the minimum temperature

The freezing processes themselves don't lead to damage as the measurements of the concrete Gäubahntunnel showed. But one can assume damage if the amplitudes start rising at the same minimum temperature.

In former research projects freezing processes started only above certain degrees of saturation. This could not be shown in this project. Right from the beginning freezing processes could be measured. But measurements in situ cannot be compared with measurements in the laboratory as dimensions are smaller, the freezing rate or the variation in temperature are higher and the minimum temperature is lower.

The degree of saturation of the concrete Hohenwarthe was between 75,22 % and 77,67 % at the beginning of the freeze-thaw cycles. The one of the concrete Gäubahntunnel was between 52,1 % and 57,87 %. To find the point at which freezing processes start being measurable it is advisable to dry the specimens before testing.

In summary it can be said that damage of the building can be assumed after a strong increase of the amplitudes of electrolyte resistance at the same minimum temperature and with water being available.