Moisture Transport in Concrete Structures in Swedish Hydro Power Plants

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Moisture Transport in Concrete Structures in Swedish Hydro Power Plants

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ABSTRACT

Concrete structures in hydro power plants exposed to harsh environment, such as non-frozen freshwater and long cold winters with freezing temperatures, are always in the danger-zone for suffering from concrete damages. Some existing concrete structures already suffer from different damages caused by high water content. The conditions regarding concrete quality, air entrainment, temperature and time will be investigated experimentally and theoretically in this doctoral study. The results could be of great help making better predictions of future degradation or represent a better basis when choosing repair methods and materials for concrete structures.

Key words: Moisture transport, frost resistance, degradation, hydro power plant.

1. INTRODUCTION

The environment surrounding a hydro power plant could be very harsh for the concrete structures regarding the presence of non-frozen freshwater and long cold winters with freezing temperatures combined with freeze/thaw-cycles. This description of the environment is also appropriate for bridges, harbours and other structures in contact with non-frozen freshwater.

Research has throughout times showed that high water content or a high moisture exposure could cause severe damages in concrete structures. For example concrete structures could be damaged by leaching, alkali silica reaction, frost and leakage in joints. In these examples the presence of water or moisture is of vital importance. The moisture transport in the concrete is also important for fully understanding what impact water could have on the degradation of concrete structures.

In late 2010 a new doctoral study was initiated with the purpose of studying frost resistance and effects of moisture transport in concrete structures in Swedish hydro power plants. The doctoral study will be executed at the Division of Building Materials at Lund University and on Vattenfall Research & Development.

2. BACKGROUND

The idea of this doctoral study was based on observations in experiments during a master thesis in 2009. The scope of the master thesis was to investigate the cause of observed scaling on concrete in the waterline on Porsi hydro power plant [1]. The damages could theoretically have been caused by leaching, freeze/thaw-cycles or mechanical abrasion. The hypothesis was that freeze/thaw-cycles of concrete in contact with non-frozen freshwater were the dominant degradation mechanism. The experiments proved that it was possible to create similar scaling in the laboratory by exposing concrete specimens to freeze/thaw-cycles only.

Additional to the scaling in the waterline the specimens were also unexpectedly suffering from internal frost damages above the waterline. This internal degradation increased for every freeze/thaw-cycle. At the end of the experiment the degree of water saturation in the specimens was measured and it was exceeding the critical degree of water saturation of being frost resistant. This finding was interesting since a large moisture transport must have been occurred during the experiment. Unfortunately there was no time to investigate this finding.

3. RESEARCH PROGRAM

The doctoral study will resume the experimental work done during the master thesis and add theoretical work for the possibility of explaining the findings. The doctoral study will be divided into two parts, where each part consists of three research questions. The first part will experimentally and theoretically investigate the frost resistance and how moisture is transported and accumulated in concrete exposed to freshwater in combination with a temperature gradient.

The second part will experimentally and theoretically try to understand how concrete overlays could affect the frost resistance and the moisture content in concrete structures when repaired. Some repair methods or materials might be better compared to other methods or materials when evaluating how the moisture content could affect the risk of future degradation.

The theoretical work will be done by creating mathematical models for simulating the present and future behaviour of existing concrete structures exposed to non-frozen freshwater and freeze/thaw-cycles. The results from the experimental studies will be used to verify the models.

3.1 Part 1

The first research question concerns the risk for macroscopic ice lenses to form in the concrete, similar to frost heave in the roads in wintertime, see figure 1. Previous research has shown abnormal microstructural formations perpendicular to the direction of cooling in young cement paste specimens [2]. These results could indicate growth of ice lenses in the specimens.

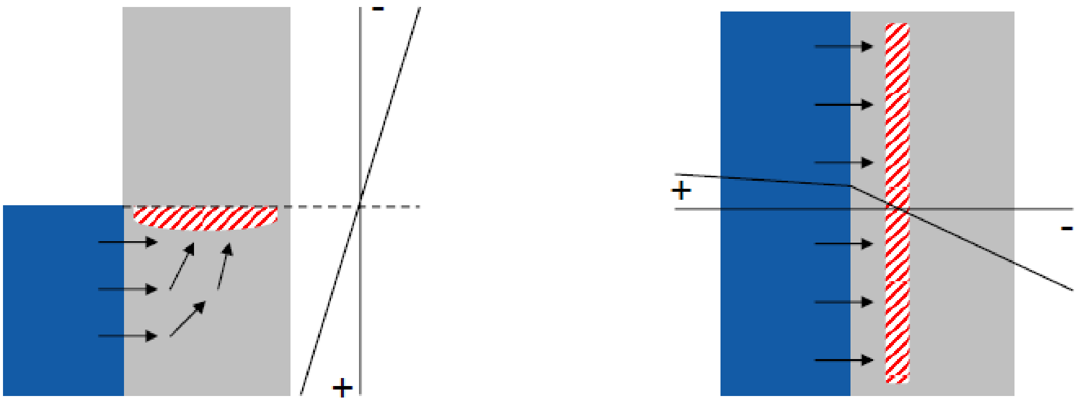

Figure 1 – Two examples of how macroscopic ice lenses theoretically could be formed.

The conditions – concrete quality, air entrainment, temperature and time – for the possibility to form macroscopic ice lenses in mature concrete are to be investigated in the upcoming study. The work will mostly be executed in the laboratory.

The second research question concerns the risk for scaling in the waterline and presence of internal frost damages above the waterline when the temperature is changing from freezing to thawing degrees, see figure 2. Meantime the moisture transport and accumulation in the specimens will be measured. The study will mainly be executed in the laboratory.

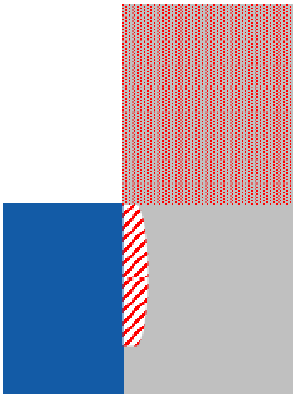

Figure 2 – Scaling in the waterline and internal frost damages above the waterline.

The third research question concerns the potential risk of frost resistant concrete to lose the frost resistance over time when being constantly exposed to non-frozen freshwater. It has been shown that concrete being completely water saturated, under no circumstances could withstand freeze/thaw-cycles [3]. Since a significant amount of water was present in the air voids, when the concrete was water saturated, the frost resistance was lost and the concrete was damaged.

The conditions – concrete quality, air entrainment and time – for the possibility of losing the frost resistance are to be investigated in the upcoming experimental study in the laboratory. The results from the laboratory study will be compared to field measurements from concrete structures having been exposed to similar conditions for either years or decades.

3.2 Part 2

The research questions 4-6 will investigate the effects on moisture transport and frost resistance when concrete structures are repaired with concrete overlays. Since these research questions are planned for the second part of the doctoral study no work has yet begun.

4. MATERIALS

For investigating the research questions, different concrete qualities have to be designed and cast. The combination and number of concrete qualities will vary due to the specific purpose of each experiment. Some experiments will only investigate if or when a phenomena or damage will occur. These experiments demand several different concrete qualities. Some other experiments will investigate the behaviour in terms of moisture transport and frost damages in existing concrete structures. In these cases fewer concrete qualities are needed.

The design of the different concrete qualities will be adapted to historically common concrete qualities. Old handbooks and guidelines for concrete manufacturing to hydro power plants will be of great value for this work. The final design of the concrete qualities will also be confirmed, if possible, by comparison with old records from different construction sites.

Since modern cements and additives differ from old cements and additives, this difference has to be accepted. By having this fact in mind the effects of the differences can be kept at a minimum.

5. DISCUSSION

The overall purpose of this doctoral study is to investigate the potential risk for frost damages, due to high water content, in concrete structures exposed to a very harsh environment. With an increased knowledge about how moisture is transported and accumulated in concrete during such conditions a better understanding could be obtained for the circumstances when concrete structures will get damaged by freeze/thaw-cycles during the winter.

An increased knowledge about frost resistance and moisture transport could also lead to better methods for the prediction of future degradation of concrete structures, such as Swedish hydro power plants. The increased knowledge would also make the work easier to investigate and evaluate old and existing concrete structures and choose appropriate repair methods and materials for each specific situation.

Being able to predict the demand or the effects of repair work the risk could be reduced for future damages or other problems related to frost resistance or moisture transport in concrete structures. This increased knowledge will hopefully be of great interest to the power industry and the society when maintaining a vast number of concrete structures of great value, such as hydro power plants, bridges, harbours and other concrete structures.

6. ACKNOWLEDGMENT

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