BSc-Project, 15-20 ECTS, MSc-Project, 30-35 ECTS

Kurt Kielsgaard Hansen, Hans Christian Brolin Thomsen, Ricardo Antonio Barbosa, Bent Grelk

Alkali-Silica Reaction in Concrete

In Denmark and worldwide, the deterioration of concrete structures by alkali-silica reaction (ASR) has been well documented. In Denmark, an increasing numbers of bridges with severely cracked and deteriorated concrete decks, columns and edge beams have been identified. In some cases, the findings have led to a demolition and reconstruction of the ASR damaged structure or have led to significant expensive repairs.

Prerequisites

Course 11561 and 11562.

Course 11563 Concrete Technology, but this is only compulsory for MSc projects.

Background and motivation

Alkali-silica reaction in concrete will in many cases lead to unacceptable cracking and expansion of concrete. Cracking due to ASR can lead to severe deterioration, resulting in uncertainties about the structural integrity of reinforced structures. In combination with other degradation mechanisms such as frost action and reinforcement corrosion the deterioration of the concrete structure will often be accelerated. Despite the fact that alkali-silica reaction has been researched for decades and still is a main topic in the concrete research field today, there is still a large uncertainty upon the physical, mechanical and structural consequences of the reaction.

Purpose and method

At DTU-BYG, we conduct fundamental research on the controlling mechanisms leading to ASR and on the influence of ASR-cracking on the physical, mechanical and structural behaviour of existing structures. We also conduct research to develop valuable assessment methodologies or improve existing methodologies for ASR-affected structures including understanding of the time-dependent influence of ASR-deterioration on the assessment of existing structures.

Our student projects are based on relevant innovative research topics. Our student projects include primarily **experimental work (in the laboratory and in the field)** combined with statistical analysis and etc. Most of our student projects are conduct in cooperation with external partners, such as building owners and consulting companies.

In the following pages, five detailed project descriptions are presented.

Possible partners:

Building owners

Consulting companies

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Photo: Severe surface ASR cracking in concrete bridge deck.

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Alkali-Silica Reaction in Concrete

Influence of NaCl concentration on the expansion of Danish and foreign ASR reactive coarse aggregate types

Prerequisites

Course 11561 and 11562.

Course 11563 Concrete Technology, but this is only compulsory for MSc projects.

Background and motivation

Alkali-silica reaction is a well-known deterioration mechanism in Denmark and abroad.
Alkali-silica reaction (ASR) is a complex physical-chemical reaction in the concrete that occurs when alkalis in the cement (or from other sources) reacts with certain forms of silica particles in the aggregates and water. Four key parameters must be present for the reaction occurs: 1) reactive silica particles in the aggregate, 2) alkalis in the concrete pore solution, 3) water and 4) a high pH-value in the cement paste. An absence of any of the above parameters will reduce or prevent the reaction to occur.
The expansion of concrete due to ASR depends on the type of alkali compound in the concrete pore solution and its concentration. The general view among international researchers is that only alkali hydroxides take part in the expansive reaction. However, the possible role of alkali salts (e.g. NaCl) and its concentration on the expansive reaction of coarse ASR reactive aggregates is not fully understood.

Purpose and method

The purpose of this research is to improve our understanding on the role of alkali salts, specially NaCl, and its concentration on the expansion of Danish and foreign reactive coarse aggregates. This project include extensive experimental work combined with statistical analysis. Among others the experimental work will consist of:

- Casting of concrete mixes with different composition of coarse reactive aggregates
- Exposure of concrete mixes to elevated temperature and alkali salt solutions
- Evaluation of cracking pattern by the naked eye and by use of polarization microscope
- Evaluation of the extent of reaction product by use of polarization microscope

Possible partners:

Building owners

Consulting companies

Photo: Alkali salt as NaCl.

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Alkali-Silica Reaction in Concrete

Effectiveness of surface treatments on the durability of potential ASR reactive concrete and natural stone

Prerequisites

Course 11561 and 11562.

Course 11563 Concrete Technology, but this is only compulsory for MSc projects.

Background and motivation

Alkali-silica reaction (ASR) typically develops in concrete with internal relative humidity above 80-85%. However, the higher the internal relative humidity in the concrete the larger is the ASR induced expansion and extent of cracking. Limiting the moisture ingress to the concrete limits or even prevents the deleterious expansion. Since the degradation mechanisms of not only concrete but also natural stone require a certain amount of moisture or water, a reduction of moisture absorption of building materials in outdoor environments will often have a positive effect on durability and service life of structures.

Surface coating treatments concern preserving the surface and visual appearance of building materials while protecting the building material or construction against the outdoor climate that may alter its properties, durability and appearance. The effectiveness of a surface treatment will depend on the effectiveness of the specific product to control moisture exchange between the concrete and the atmosphere. Surface coatings that permit the escape of moisture are preferable to allow progressive drying of the materials while simultaneous preventing a critical water uptake/critical saturation of the material). However, the quality of products varies considerably.

Purpose and method

The purpose of this research is to investigate the effectiveness of different surface coating products to enhance the durability of potential ASR reactive concrete and natural stones (marble and limestone) subject to aggressive environments. This project include extensive experimental work combined with statistical analysis. Among others the experimental work will consist of:

- Casting of concrete specimens
- Exposure and measurement of concrete specimens to elevated temperature and NaCl solution
- Surface treatment of concrete specimens and natural stone including selection of most suitable surface coating products
- Investigation of the frost resistance of natural stones

Possible partners:

Consulting companies

Surface coating consultants

Photo: Water drops on a coated concrete surface.

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Alkali-Silica Reaction in Concrete

Influence of alkali sources to the reactivity of potential ASR reactive concrete

Prerequisites

Course 11561 and 11562.

Course 11563 Concrete Technology, but this is only compulsory for MSc projects.

Background and motivation

Alkali hydroxides (Na^+, K^+ and OH^-) in the concrete pore solution is the driving force for alkali-silica reaction (ASR). The alkali hydroxides in the concrete pore solution originate from the cement or from other sources, e.g. aggregates, unwashed sea dredged aggregates or externally from de-icing salts, sea water and etc. In general it is alleged that the expansion of concrete increases with increasing total alkali content.

Many accelerated expansion tests of potential ASR reactive concrete are conduct by adding additional alkalis as e.g. NaOH to the mix water in order to raise the total alkali content in the concrete and thereby accelerate the reactivity of aggregates. However, research on the impact of raising the total alkali content in the concrete compared to a natural high alkali content from the cement is rarely reported in the literature. Additionally, there is no literature that shows that the use of NaOH is better than the use of NaCl to raise the alkali content in the concrete and obtain a faster reactivity.

Purpose and method

The purpose of this research is to improve our understanding on the role of internal and external sources of alkalis and its concentration on the expansion of potential ASR reactive concrete. This project include extensive experimental work combined with statistical analysis. Among others the experimental work will consist of:

- Casting of concrete mixes with different composition of cement types both without and with additional alkalis
- Exposure of concrete mixes to elevated temperature and exposure conditions
- Evaluation of cracking pattern by the naked eye and by use of polarization microscope
- Evaluation of the extent of reaction product by use of polarization microscope

Possible partners:

Building owners

Consulting companies

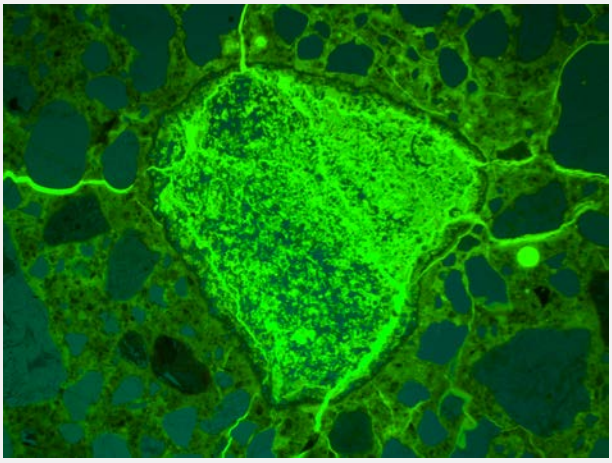

Photo: ASR reactive sand particle seen under polarization microscope.

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Alkali-Silica Reaction in Concrete

Quantification of ASR cracking extent in concrete by digital image analysis

Prerequisites

Course 11561 and 11562.

Course 11563 Concrete Technology, but this is only compulsory for MSc projects.

Background and motivation

Alkali-silica reaction (ASR) can cause extensive cracking in concrete structures. For the selection of appropriate remedial actions for ASR damaged structures, evaluation of the extent and severity of the reaction is crucial. Currently, one petrographic method aims to quantify the condition and extent of cracking in ASR damaged drilled concrete cores. Unfortunately, this method is rather simplified and is strongly dependent on the operator conducting the visual quantification. In order to improve the evaluation of ASR cracking extent in concrete, digital image analysis may be applied to attain more objective quantification of cracking extent. However, there are significant challenges in selecting the most appropriate image analysis algorithms and the preparation of drilled concrete prior to the image analysis.

Purpose and method

The purpose of this research is to develop or improve existing methodologies to quantify the cracking extent in ASR deteriorated concrete. Basic or elevated MatLab skill is required. This project include experimental work combined with implementation of image analysis algorithms in MatLab. Among others the experimental work will consist of:

- Drilling of ASR damaged concrete cores and preparation of drilled cores – including fluorescence impregnation of the concrete cores and polishing
- Development of specific procedure for image photography
- Evaluation of cracking extent by image analysis – including implementation of existing image analysis algorithms in Matlab or review of existing methods
- Evaluation of cracking pattern by the naked eye and by use of polarization microscope

Possible partners:

Building owners

Consulting companies

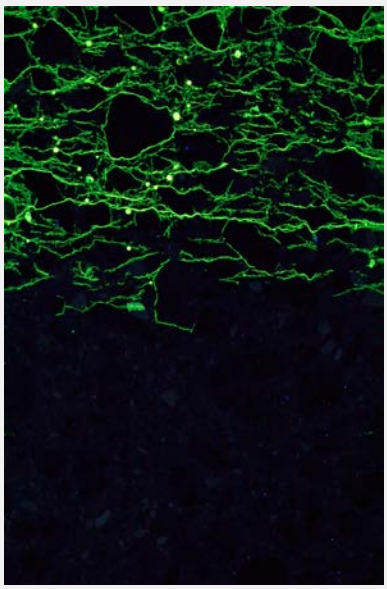

Photo: ASR induced crack extent and propagation in slabs. The ASR induced cracks are visualized as bright green colour.

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Alkali-Silica Reaction in Concrete

Alkali Release from Aggregates to Potential ASR Reactive Concrete

A large number of Danish concrete structures are suffering from alkali-silica reaction (ASR) which is severely lowering the expected lifetime of the given structures. By controlling the parameters surrounding the formation of ASR inside concrete one can obtain enhanced control and hopefully guarantee better reliability for future concrete structures.

Prerequisites

Course 11561 and 11562.

Course 11563 Concrete Technology, but this is only compulsory for MSc projects.

Background and motivation

ASR in concrete is a well-known deterioration mechanism affecting the long-term durability of Danish concrete structures. Deleterious ASR cracking can be significantly reduced or prevented by limiting the total alkali content of concrete under a certain threshold limit, which in Denmark is recommend to 3 kg/m^3 of concrete. However, this threshold limit does not account for the possible internal contribution of alkali to the concrete pore solution by release from aggregates. Methods for testing the alkali release capabilities of potential aggregates were developed but relating these results to actual release inside concrete is still questionable.

Purpose and method

The main scope of the project is to study the release of alkali from typical Danish aggregates and relating these findings to release inside concrete.

A fair amount of experimental work is included in the project with adjacent results treatment and discussion. This can be combined with statistical analysis. The final outline of the project is not settled initially and will be sculptured during the project with common interest in mind. Among others the experimental work will consist of:

- Preparation of relevant aggregates, crushing and estimation of grain size distributions.
- Casting of concrete specimens.
- Preparation of release solutions and measure alkali content as a derivative of time.

Possible Partners

- Building owners.
- Consulting companies.

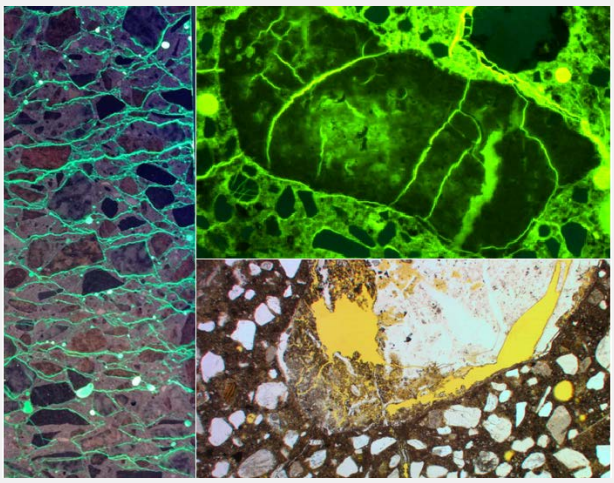

Photo: ASR damaged concrete sample impregnated with florescent epoxy and subjected to UV lighting.

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