Measuring and modelling the deteriorating impact of Alkali-Silica Reaction in concrete on the mechanical characteristics

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Preface

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The latest Miniseminar " Residual capacity of deteriorated concrete structures" was held in Oslo, 21st of April. Extended abstracts from this miniseminar is published in this volume of NCR.

Vodskov, December 2015

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Editor, Nordic Concrete Research
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Measuring and modelling the deteriorating impact of Alkali-Silica Reaction in concrete on the mechanical characteristics

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ABSTRACT
Unaffected and ASR-affected concrete, experimentally, appear as substantially different materials. Since the material characterization is one of the main points of attention within a structural assessment, the deteriorating impact of ASR on concrete in terms of both expansion and degradation of the mechanical properties is studied. Both experimental and modelling approaches are followed.

Key words: Alkali-silica reaction, mechanical characteristics, micro-mechanical modelling

1. INTRODUCTION

The assessment of concrete structures affected by alkali-silica reaction (ASR) is a complex problem due to the multiscale nature of this long-term phenomenon, Figure 1. The reaction starts within the concrete constituents with the formation of an expansive alkali-silicate gel at reaction products level. Being the expansive gel confined within the concrete micro-structure, an internal pressure is built up that induces damage at aggregate level. This micro-cracking affects the mechanical characteristics of the material at concrete level. At structural level, the performance of members and of structures itself can thus be compromised by the reaction.

For any structural assessment of affected structures, the material characterization is a key item. An overview of the PhD work of the first author is given (Esposito, 2016). The emphasis is on the deteriorating impact of ASR on concrete in terms of both expansion and degradation of the mechanical properties, Figure 2. Both experimental and modelling approaches are followed. The perspective is structural assessments.

2. EXPERIMENTAL INVESTIGATIONS

The experimental investigation, which includes laboratory tests supplemented with literature data, shows a statistically relevant relationship between the concrete expansion and the degradation of mechanical properties of ASR-affected concrete samples stored in free-expansion conditions. Figure 3 gives an overview of these results (Esposito, Anaç et al., 2016). In the left panel, the relation between normalised mechanical properties and concrete expansion is given. The elastic modulus was found to be the best indicator of ASR signs in concrete. The data show a relevant degradation, already at early expansion, which is characterized by the highest rate. In

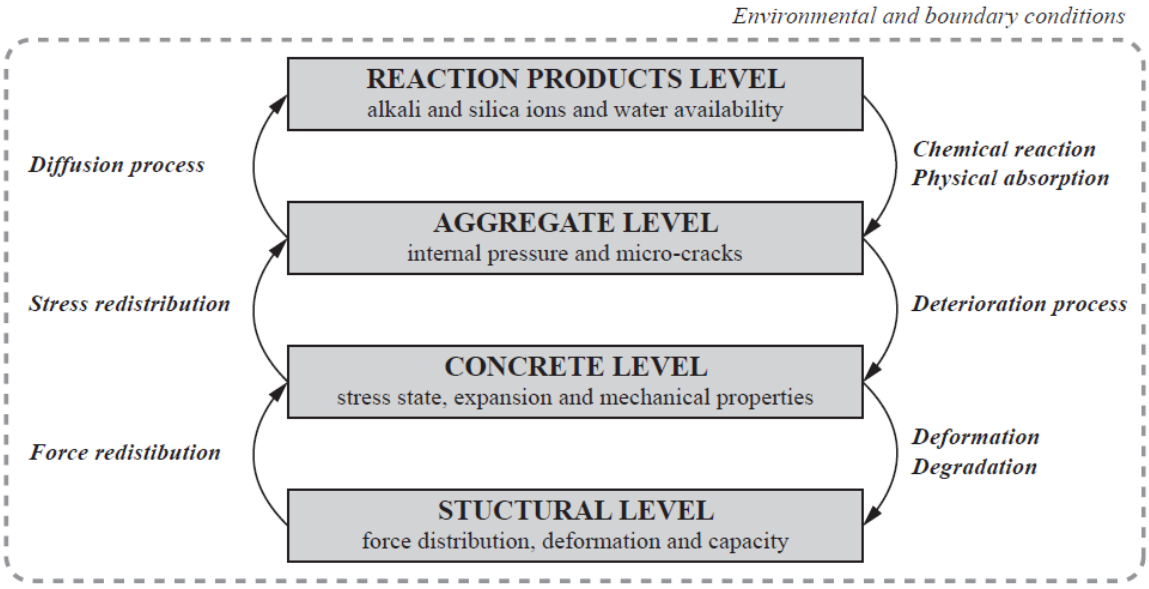

Figure 1: The alkali-silica reaction in concrete structures: interaction of the various phenomena at the different scales (Esposito, 2016).

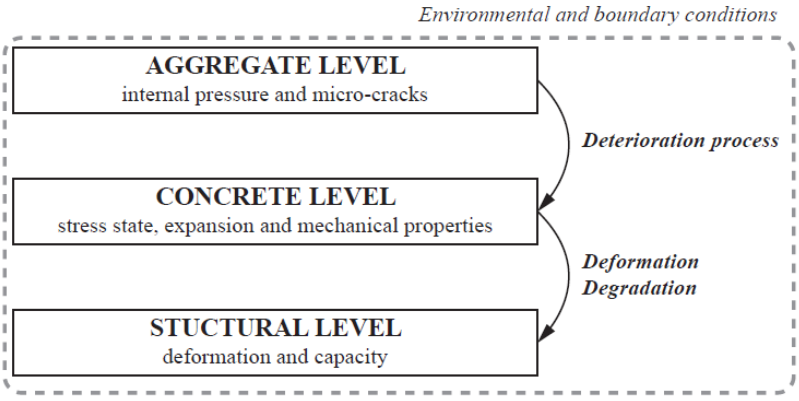

Figure 2: Scope of the present research (Esposito, 2016).

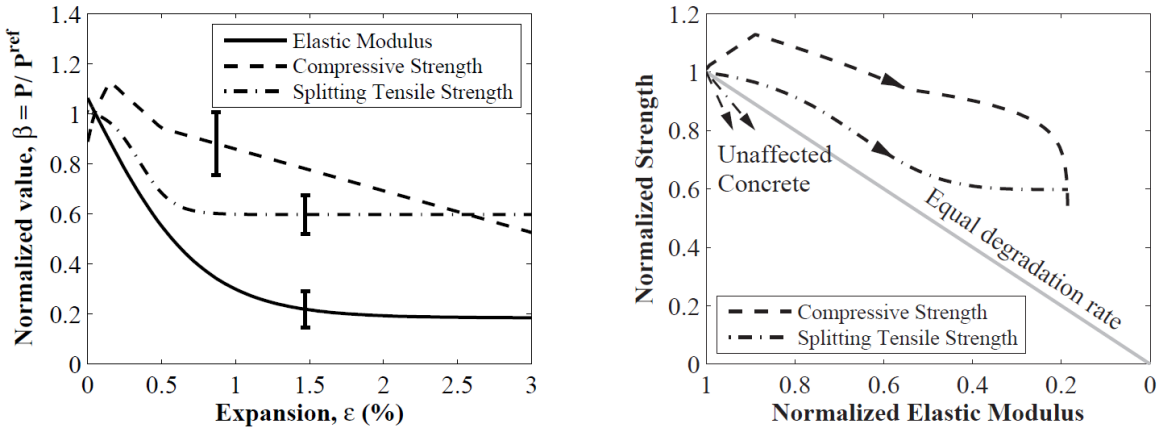

Figure 3: Summary of experimental results. Relation between normalised mechanical properties and concrete expansion and relation between normalised elastic modulus and normalised strengths (Esposito, Anaç et al., 2016).

the right panel of the Figure, the relation between normalised elastic modulus and normalised strengths is presented. In engineering, it is common practice to express the stiffness and tensile strength of unaffected concrete as a function of its compressive strength. This results makes clear that these relations definitely do not apply to ASR affected concrete.

3. MODELING APPROACHES

Considering that unaffected and affected concrete experimentally appear as substantially different materials at concrete level, a multiscale modelling approach, ranging between aggregate and concrete level, is adopted to explore the deteriorating impact induced by ASR. An analytically solved micro-poro-fracture-mechanical model, which is based on a limited number of input parameters, is adopted. The approach considers the micro-cracking phenomenon as the common damage mechanism associated to the internal swelling and the external mechanical loading.

Figure 4 shows typical results of this model. It is emphasized that this model *generates* softening curves of concrete in tension or hardening-softening curves in compression, whereas most nonlinear structural engineering software will use this as a point of departure. The purpose of the developed micro-poro-fracture-mechanical model is that it could also be used for more complicated stress situations, e.g. with confinement stresses, and that the effect of the swelling of the ASR-gel could be included and studied.

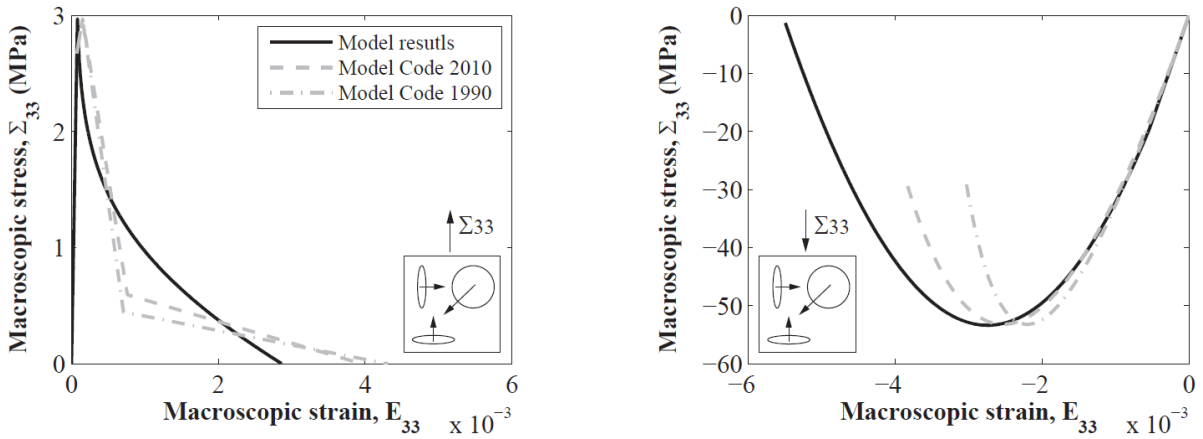

Figure 4: Simulation results of the micro-poro-fracture-mechanical model: resulting uniaxial tension softening and compression hardening-softening behaviour (Esposito and Hendriks, 2015).

4. CONCLUDING REMARKS

Combined experimental and material modelling activities are seen essential to understand the mechanical behaviour of ASR-affected concrete. More systematic laboratory investigations focussed on the correlation between, microscopic damage, concrete expansion and degradation of mechanical properties for concrete under various stress states are recommended.

Also the step from understanding the material behaviour towards understanding the structural behaviour requires both experiments and modelling components. Full-scale in-situ experiments on ASR-affected structures can be considered to develop an assessment strategy. The model can be implemented in a finite element framework. Redistribution effects, e.g. within a cross section of a structural element could then be evaluated.

ACKNOWLEDGEMENT

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