Abstract

Alkali-silica reaction (ASR) is a well-known deterioration mechanism that can occur in concrete structures. It is a chemical reaction between alkalis, silica minerals and water. The primary sources of alkalis are cement and de-icing salt whilst the silica minerals are present in some types of aggregate. The reaction causes severe cracking of the concrete, which results in significant reductions of the strength parameters. This material degradation has raised serious concerns regarding the safety of ASR-damaged structures; particularly structures, which may be sensitive to shear failure. The Danish Road Directorate has estimated that more than 600 Danish road bridges have the potential to develop ASR in the future. The majority of these bridges has been constructed as slabs without shear reinforcement, i.e. structures where the shear capacity relies entirely on the strength of the concrete. Unfortunately, there exists no satisfactory method to assess the residual shear capacity of ASR-damaged slabs without shear reinforcement - in spite of nearly 80 years of research on ASR.

The aim of this PhD project is therefore to develop an approach that can be used to determine the shear capacity of ASR-damaged slabs without shear reinforcement. The approach includes a shear model as well as recommendations and descriptions of how the relevant strength parameters should be determined by simple tests on samples taken from the structure. The works that have been undertaken to develop this approach are as follows.

In the first part of the project, a literature study on how ASR affects the parameters that are important for the shear capacity is conducted. One of the main findings here is that ASR affects slabs differently than other types of structures, e.g. the way that the ASR-induced cracks are orientated. The majority of the existing ASR research on material characteristics and/or residual capacity of reinforced members is therefore not directly applicable for this PhD project. Based on the findings as well as shortcomings in the existing literature, a number of research questions that need answers in order to develop a shear model for ASR-damaged slabs are formulated.

In the second part of the project, answers to the formulated research questions are found by means of a thorough experimental investigation, where the effects of ASR on the material properties as well as on the structural response are studied. The investigation includes a large shear testing campaign with specimens cut out from two ASR-damaged bridges. The material properties are investigated by means of standard test methods and state-of-the-art optical measuring techniques. By a critical examination of the results and an optical investigation of the underlying mechanisms, recommendations of

testing methods to obtain the anisotropic residual compressive- and tensile strength are formulated.

In the last part of the project, a model to determine the shear capacity of ASR-damaged slabs without shear reinforcement is established. The model is based on the upper bound theorem of plasticity theory, where the specific solutions are derived with inspiration from the failure mechanisms observed in shear tests with the ASR-damaged slab bridge specimens. The calculated shear capacity correlates well with test results, both for simply supported members and for continuous members.

Based on the model, some recommendations are given for how practical assessment of members subjected to arbitrary loading can be carried out.