# Alkali-silica reaction in the Netherlands: Experiences and current research

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**In 1992, the first structure with deleterious ASR was diagnosed in the Netherlands, followed by the publication of the first Dutch guideline on the prevention of ASR in 1994. Since, ASR has been demonstrated in 40 to 50 structures over the country. Development of ASR in a series of structures on a major Dutch motorway, built in the late sixties – early seventies of last century, has provoked new research and discussions, aiming at the revising of guidelines on ASR-prevention and development of guidelines dealing with ASR-affected structures. In the present paper, an overview is given of experiences with ASR in the Netherlands, and current research is introduced.**

*Key words: ASR, assessment, regulations, The Netherlands*

## 1 Introduction

In 1957, in a paper in Cement, alkali-silica reaction in concrete, ASR, was mentioned for the first time in Dutch literature (Bosschart 1957). This stimulated some early research on the alkali-silica reactivity of aggregates commonly used and quarried in the Netherlands (Van de Fliert et al. 1962); these authors concluded that sands and gravel from fluviatile deposits in the Netherlands were not alkali-silica reactive. No cases of concrete damage due to ASR were reported meanwhile, until in 1992 ASR was demonstrated in a bridge in Schoonhoven, a small town on the northern shore of the river Lek (Heijnen 1992). The diagnosis was the result of recently build up knowledge on ASR, necessary to prevent ASR in the Netherlands as a consequence of then expected major imports of aggregates. Result was the development of the first Dutch guideline on the prevention of ASR, CUR-Recommendation 38, published in 1994. Since, ASR has been diagnosed in 40 to 50 structures over the country, notably a series of bridges in and over motorway A59 built in the late sixties – early seventies of last century. Discussions and new research provoked by the A59 discovery resulted in the establishment of two commissions by the regulatory body CUR, one to revise the guideline on ASR-prevention, i.e. CUR-Recommendation 38, the other to devise a guideline how to deal with ASR-affected structures. The new guideline on ASR-prevention, CUR-Recommendation 89, has just been published; publication of the CUR-Recommendation on structural consequences of ASR is pending. The present issue of *Heron* is devoted to past experiences and current research with ASR in the Netherlands.

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## 2 Cases of ASR in the Netherlands

Since the early nineties of last century, ASR has been diagnosed some in 40 to 50 tunnels, bridges and locks in the Netherlands. In addition, innocuous ASR, i.e. cases where the occurrence of alkali-silica reaction on microscale is diagnosed by microscopy, but in which ASR did not result or is not responsible for concrete damage has been reported from several structures.

In the Netherlands, deleterious ASR mainly occurs in structures made with (usually coarse grained) Portland cement. The affected structures vary in age between 25 to over 70 years. In addition to structures made with Portland cement concrete, 3 to 4 cases are known where deleterious ASR occurs in structures made with Portland slag cement, i.e. Portland cement with a intermediate (35 – 40 vol.%) amount of ground granulated blast furnace slag and two structures with concrete made with, possibly, a minor amount of powder coal fly ash (PFA; about 15 vol.%) in addition to Portland cement. In most structures, the water/cement ratio, as estimated by fluorescence microscopy, varies between 0.45 and 0.60, with some cases up to 0.65 – 0.70, and one structure in which the w/c is extremely variable, between 0.35 and 0.70. In cases where ASR developed, total and acid soluble alkali contents of both unaffected and ASR-affected concrete commonly exceed 3.0 kg $m^{-3}$ $Na_2O_e$ (Nijland & Jansen 2001). In several structures, where individual elements have been made of concrete with similar potentially alkali-silica reactive aggregates but with different cements, and exposed to the same conditions, ASR developed in elements made with ordinary Portland cement, and not in those made with blast furnace slag cement. In all cases in the Netherlands where ASR would allegedly be occurring in structures made with blast furnace slag cement, concrete damage has been shown to be due to other causes.

Several structures showing considerable concrete damage have been supposed to have been affected by ASR. About half of these cases involve concrete made with (usually coarse grained) Portland cement, one structure with a cement with 15 – 20 vol.% slag, three structures with a Portland slag cement with 35 – 40 vol.% slag, two structures with a blast furnace slag cement with > 65 vol.% slag, and three with an unknown slag content. These suspicions raised questions whether cements with high slag contents should be regarded as preventive measure against ASR. In all cases, the cause of concrete damage was definitively shown not to be due to ASR. The actual cause of concrete damage in these structures varies. Shrinkage and frost have been involved in some cases.

## 3 Alkali-silica reactivity of aggregates common in the Netherlands

Polarisation-and-fluorescence studies of ASR-affected structures show that aggregate grains taking part in the reaction are commonly porous chert, chalcedony, impure sandstones like greywacke, sericitic sandstone, etc. The impure sandstones react as often as porous chert grains. Microcrystalline quartzite has been identified to participate in the reaction in three structures, schist / slate in one. Up to now, all cases of deleterious ASR in the Netherlands involved sands and gravel from fluviatile deposits, like those of the rivers Meuse and Rhine. Marine aggregates have been used in the Netherlands for only about a quarter of a century now.

Alkali-silica reactivity of aggregate may be determined on various levels. In the scale of individual particles, reactivity is, amongst others, defined by the crystallinity of the silica minerals present. Especially siltstone, lydite and chert (both porous and non-porous) show low crystallinities, both in Rhine and Meuse gravel and in North Sea gravel (Jansen 2002). The amount of chalcedony present in the individual grains is highly variable, occasionally quite high in some sandstones in river-derived gravel, and commonly very low in chert in marine gravel. The highly reactive silica variety moganite is absent in most grains (Jansen 2002). Determination of porous chert plus chalcedony contents by polarization-and-fluorescence microscopy conform RILEM TC 106-1 has shown that not only in marine aggregate but also in land based aggregates from several localities, their contents exceed the limit of 2 vol.% (Larbi 2000ab, Larbi & Heijnen 2001). Ultra-accelerated mortar bar expansion tests conform the RILEM TC 106-2 method, and subsequent petrographic investigations (Larbi 2000ab) demonstrate that the reactivity of impure sandstones present in gravel strongly depends on geological provenance.

## 4 Assessment of ASR affected structures

The investigations on the ASR-affected bridges in the motorway A 59 (Siemes & Bakker 2000) have been used as a basis for the CUR-Recommendation on structural consequences of ASR whose publication is pending. The basis for these investigations was found in the British Guidance (ISE 1992). Just to verify this guidance, mechanical tests (compressive, splitting tensile and uniaxial tensile) were added to the investigations. Quite unexpected, it was found that the uniaxial tensile strength was much lower than would be expected on basis of the compressive strength. The splitting tensile strength was in line with the compressive strength (Siemes & Visser 2000).

No special shear reinforcement was present in the investigated bridges. The shear capacity is therefore completely dependent on the tensile strength of the concrete. Because of the serious doubts with respect to this capacity, special measures have been taken, varying from demolition, pay load reduction, strengthening to monitoring (Siemes & Gulikers 2000).

Investigation of some beams that were sawn out of the concrete decks of two brides with serious ASR and low uniaxial tensile strength, showed that the shear capacity of these beams was also lower than would be expected on basis of the compressive strength (Den Uyl et al. 2000). The shear capacity was, however, higher than could be expected on basis of the uniaxial tensile strength. The type of failure of these beams differed from normal shear failure. A new model for the shear failure was developed.

Meanwhile, it has been found that the low uniaxial tensile strength is not unique for structures with damage due to ASR (Siemes & Visser 2000). The same phenomenon was also found in other, relatively old concrete structures where no ASR is present.

## 5 Current research and regulations

During recent years, several research projects on the monitoring of ASR-affected structures, characterization of supplementary cementing materials (GGBS, PFA), alkali-silica reactivity of aggregate, and structural properties and behaviour of ASR-affected concrete have proceeded. This special issue of Heron gives an overview of recent research and developments in the Netherlands. It covers the new Dutch guideline on ASR-prevention, the monitoring and repair of ASR-affected structures in a major Dutch motorway, the implications of low concrete tensile strength, possibly resulting from ASR, the structural behaviour of elements removed from an ASR-affected structure, and the characterization of gravel dredged from the North Sea.

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