RECLAMATION

Managing Water in the West

Effects of Alkali Migration Through Water Retaining Structures

Research and Development Office
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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Executive Summary

Alkali silica reaction (ASR) is a chemical reaction in concrete between hydroxyl ions of the alkalies and certain siliceous aggregates. ASR is a form of alkali aggregate reaction (AAR). ASR is present in Reclamation structures.

In order for ASR to form, the aggregates must contain reactive silica, the concrete pore solution must contain potassium or sodium ions and sufficient moisture present in the concrete. When concrete is in a dry in-service condition, it is very difficult for ASR to form due to the fact there is not sufficient moisture available. Many of Reclamation's structure are in a wet in-service condition. This constant source of moisture is optimum for ASR generation and puts those structures at a higher risk for ASR damage.

A better understanding of the condition of Reclamation concrete structures is needed. It is known that several structures have active ASR attack as is it visible. The number of ASR affected structures within Reclamation's inventory is not known as ASR is only visible in cases of extreme attack.

Contents

Background

Alkali Silica Reaction (ASR) occurs when aggregates containing certain minerals are used in concrete. These minerals react with alkali hydroxides present in cement and can produce an expansive gel. There are three conditions that have to exist in order for alkali silica reaction to occur: the aggregates must contain reactive silica; the concrete pore solution must have a high pH (alkaline) from potassium or sodium ions; sufficient moisture present in the concrete. Alkali silica reaction has been a known source of potential concrete damage since the 1940s [1].

Proposal Development

A literature review was performed to determine what has been published regarding alkali migration. Documentation of alkali migration was found from 1979 [2]. Research is underway with regard to pore water chemistry and the transportation of the pore water ions within the concrete matrix and its effects on the concrete.

Results

Fine and coarse aggregate comprise the matrix of concrete. The voids between the aggregate particles are filled with paste which is made up of cement, water and pozzolans (fly ash, slag cement, silica fume). Within the paste are interconnected pores which allow for the migration of pore water. The pore water contains mostly sodium and potassium hydroxides and a low concentration of calcium ions. The sodium and potassium ions are primarily cement minerals but can also come from aggregates, pozzolans or chemical admixtures. The potential for ASR increases with high concentrations of sodium or potassium ions. The sodium and potassium ions react with the silica in the aggregates and form alkali-silica gel. This gel will then absorb water, swell and cause cracking of the surrounding aggregate and concrete [3].

Moisture will allow the migration of the potassium and sodium hydroxides to reaction sites. ASR Expansion can occur in concrete with a relative humidity above 80% [4]. Repeated cycles of wetting and drying can create locally high levels of alkalies. As moisture travels through concrete, the dissolved alkalies move in the solution and will be deposited when the moisture evaporates from the surface. This process can cause high alkali levels at an evaporation surface even when the concrete has a low alkali content [5]. While reaction products may be present, ASR may not be occurring.

Transport models have been developed, and are in use today. These software packages model the various types of alkali transport that may occur within concrete including diffusion, electromigration and thermal migration. The migration of alkali hydroxide ions in the concrete pore solution is essential for the development of ASR. Understanding the amount of the ions available and how they migrate is necessary to predict the potential for ASR.

It can take years for enough alkalis to accumulate and ASR generation to begin. Structures that have historically not demonstrated signs of ASR damage can begin to exhibit ASR. It is thought that this is due to the transport and accumulation of alkalies at the drying surface. ASR can be slowed by reducing available moisture.

Reclamation has hundreds of concrete structures in its inventory. These structures range in age from new to 100 years old. Many of these structures have surfaces that are subjected to wetting and drying cycles. These structures are in contact with water thus providing the available moisture needed for alkali transport as well as creating a favorable condition for the formation of ASR. Water retaining structures are known to have seepage to some degree making the migration of alkalis through the concrete inevitable.

Concrete technology has changed since Reclamation first began building concrete structures and so have the constituents that make up concrete. Cements are now ground finer, cement minerology has changed, quality aggregate sources are more challenging to find at times and there is a greater reliance on chemical admixtures. These changes would make it difficult to estimate alkali contents in older structures based on experience with today's materials.

In order to determine alkali levels within Reclamations structures, cores would need to be removed (if concrete mix constituent data was not available) from each structure, alkali levels measured at varying depths and internal humidity and temperature measured. This would establish a baseline for each structure. At regular intervals (approximately every five years) another set of cores would be removed from each structure and the alkali levels determined for comparison with the baseline values. This data would provide Reclamation with valuable information on each of its structures. Not only could alkali contents at various depths be measured, petrography could be performed to determine if ASR gel is present within the structure. Not all structures crack due to ASR formation so ASR may be present even though there is not visible signs of ASR distress. This systematic removal of cores could provide valuable information on alkali migration in operating structures and help advance our understanding of the transport of alkalis.

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