RECLAMATION

Managing Water in the West

Service Life Prediction Model for AAR Affected Concrete

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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14. ABSTRACT: This report is a scoping study to determine if a service life prediction model exists for ASR affected concrete structures. Models exist to determine how ASR may affect a structure but no model was found that provides service life prediction specifically for ASR affected structures.

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Executive Summary

Alkali Aggregate Reaction (AAR) has two forms – alkali silica reaction (ASR) and alkali carbonate reaction (ACR). Reclamation inventory has structures that are currently being degraded by ASR. A service life prediction model for AAR affected structures would help users determine the remaining life of concrete structures affected by AAR. To date, a service life predictive model is not available.

There are numerous factors that affect the generation of AAR as well as the level of distress it may impart on a structure. The amount of variables are what makes a service life model so difficult to devise. The mechanisms of AAR formation are well known and models exist that can determine if AAR will form and to what degree. What cannot be modeled is the level of degradation it may have on a structure due to the number of variables that may occur during the useful life of a structure.

Reclamation is able to determine if the potential of AAR exists by testing the concrete materials. We are able to specify a concrete mix that will be durable and reduce the potential for the formation of AAR within our structures. Our structures have a service life in excess of 50 years and modeling all of the potential external contributors to AAR formation would be onerous.

Reclamation would be well served to partner with entities currently developing predictive models of concrete structures. Our wealth of concrete data from a wide variety of structures in a wide variety of in-service conditions would greatly benefit the developers. Our inventory would also lend itself to analyzing concrete of various ages and various levels of AAR attack and help gain a better understanding of some of the lesser known aspects of AAR development.

Contents

Background

Alkali Aggregate Reaction (AAR) occurs when aggregates containing certain minerals are used in concrete. These minerals react with alkali hydroxides present in concrete and produce an expansive gel. There are two types of AAR – alkali silica reaction (ASR) and alkali carbonate reaction (ACR). Alkali silica reaction is more prevalent than alkali carbonate reaction because aggregates containing reactive silica are more abundant. Alkali silica reaction has been a known source of potential concrete damage since the 1940s [1].

While the mechanisms that cause AAR are well understood, the ability to accurately predictively model the reaction and its effects on service life has proven to be a challenge. There are several ASTM test methods that aid in identifying potentially reactive aggregates but they are not without their shortcomings. The test methods are good tools for predicting the potential for AAR development within concrete but they can provide both false positive and false negative results. They do not account for in-service conditions for all scenarios. In-service conditions can change throughout the life of a structure which further complicates the service life predication.

Proposal Development

A literature review was performed to determine what service life prediction models for AAR affected concrete may exist. Many numerical models were documented. These models predict the generation of ASR but do not predict service life for new structures or remaining service life of a structure already demonstrating ASR distress. Several entities were approached either in person or by email to discuss their AAR research and modeling capabilities. Models exist for service life predication of concrete structures as well as concrete structures exposed to chlorides. These include Life-365, LeachXS and ORCHESTRA.

Previous Work

MERL-2012-36 and MERL-2009-23 by Hurcomb

Results

Many models exist for modeling ASR degradation but none incorporate service life predication. There are entities working on developing a service life predictive model for AAR affected concrete structures. These entities include National Institute of Standards and Technology (NIST), SIMCO STADIUM, Penn State University, Delft University of Technology and the MIT Concrete Sustainability Hub. The Army Corp of Engineers is not currently developing modeling technology for service life prediction of AAR affected structures.

In order to accurately model alkali aggregate reaction, background information must be provided. These include minerology of the aggregates, cement chemistry, supplemental cementitious material (SCM) chemistry, concrete mix design constituent quantities, planned service conditions of the concrete structure including exposure to water, transport properties of the specific concrete mix and presence of external alkalis and depth of saturation. Unless this data is available, any model will not be an accurate representation of the structure and its constituents. The only way to be able to model the remaining service life if you do not have material and mix data available would be preforming destructive testing (extensive coring) of the structure to obtain the necessary data for implementation into the model.

Transport models have been developed by NIST and SIMCO and are in use. These software packages model the various types of sodium and potassium ion 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 is necessary to predict the potential for ASR and accurately model ASR generation. While reaction products may be present, ASR may not be occurring.

Other factors that need to be considered include temperature, wetting and drying and the presence of external alkalis. ASR rate of generation is affected by temperature. Structures in warmer climates are more prone to ASR generation since the ASR rate increases with higher temperatures [2]. Concrete in a dry service condition have a reduced potential for the formation of ASR. Concrete that has a high water/cement ratio that is not allowed to dry will have a high relative humidity which can lead to the development of ASR provided the alkali and silica are present in enough quantity. If there is wetting and drying, alkali migration can occur and the alkalis will be deposited at the drying face of the structure. If a high enough concentration of alkalis exists, ASR can form. It can take years for enough alkali to accumulate. The presence of external alkalis can increase ASR expansion provided that the concrete is permeable either by more mix design practice or the concrete has become cracked.

It would benefit Reclamation to partner with an entity that is currently developing a service life prediction model for AAR affected structures. Reclamation has decades of concrete data that could be used to populate the data needed for determining the potential for AAR as well as the level of AAR progression. Reclamation also has numerous structures (both affected by AAR and not affected) that can be studied to validate the model and further the science of predictive concrete modeling.

References

[1] T. Stanton, "Expansion of Concrete Through Reaction Between Cement and Aggregate," in *American Society of Civil Engineers*, Vol 66, pages 1781-1811, New York, 1940.

[2] W. Perenchio, I. Kaufman and R. Krause, "Concrete Repair in a Desert Environment," *Concrete International*, pp. 23-26, February 1991.