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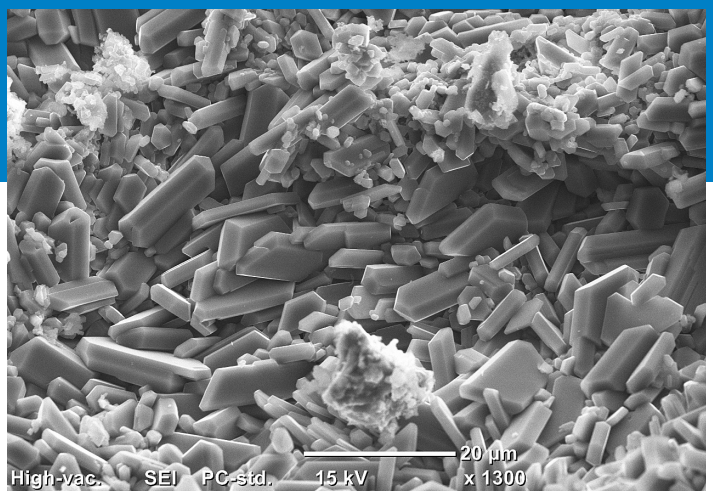

Sulfate Attack on Concrete: A Holistic Perspective

Editors:
Mohamed T. Bassuoni, R. Doug Hooton and Thanos Drimalas

SP-317

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Preface

The papers presented in this volume were included in a three-part session sponsored by ACI Committee 201, Durability of Concrete, about sulfate attack on concrete at the ACI Convention in Philadelphia, PA, on October 23-24, 2016. In line with the practice and requirements of the American Concrete Institute, peer review, followed by appropriate response and revision by authors, has been used.

Deterioration of concrete due to sulfate attack is a complex process characterized by multiple damage manifestations including volumetric expansion, cracking, spalling, softening, and in some cases mushiness. Sulfate attack can generally be classified as internal or external to the cementitious matrix, and the underlying damage modes can be chemical or physical. The scope of papers involves a multitude of theoretical and experimental aspects of different forms of sulfate attack. Readers are urged to critically evaluate the work presented herein, in the light of the large body of knowledge and scientific literature on this durability topic.

We dedicate this volume of papers to the memory of Prof. Robert L. Day, past chairman of Canadian Standards Association (CSA) Committee A23.1/A23.2 (Concrete Materials and Construction), for his invaluable contributions to the field of durability of concrete.

The editors sincerely thank all the presenters in this session and authors of the articles included in this SP, as well as the reviewers for their objective assessment of the papers. Their technical contributions provided a holistic perspective of sulfate attack on concrete.

Mohamed T. Bassuoni, Chairman and Editor
R. Doug Hooton, Co-chairman and Co-editor
Thano Drimalas, Co-chairman and Co-editor

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Criteria for Concrete Mixtures Resistant to Chemical Sulfate Attack

Karthik H. Obla and Colin L. Lobo

SYNOPSIS:
This paper presents research on the sulfate resistance of concrete mixtures as it relates to ACI 318 Code requirements for sulfate resistance. The study evaluates the provisions of ACI 318 for various concrete mixtures containing sulfate resisting portland cements and supplementary cementitious materials with w/cm varying between 0.40 and 0.60. The sulfate resistance of concrete mixtures was evaluated using prolonged exposure in a concentrated sulfate solution in accordance with USBR Test 4908. The results on the concrete evaluation reveal that the ACI requirements are considerably conservative for most concrete mixtures that contain a sulfate resisting cementitious system with supplementary cementitious materials. Sulfate resisting portland cements did not perform as well in the associated exposure class defined in ACI 318. While a performance-based alternative to the requirement for a maximum w/cm was attempted, no clear criteria could be achieved. The paper proposes alternative criteria to those in ACI 318 for sulfate resistance based on the performance of concrete mixtures evaluated in this study.

KEYWORDS:
ACI 318, chemical sulfate attack, Code requirements, specifications, sulfate resistance

AUTHOR BIOGRAPHY:

Karthik H. Obla, FACI, is Vice President of Technical Services at NRMCA, Silver Spring, MD. He serves on several ACI committees, including 201, Durability of Concrete; 211, Proportioning Concrete Mixtures; 214, Evaluation of Results of Tests Used to Determine the Strength of Concrete; 232, Fly Ash in Concrete (Past Chair); 236, Material Science of Concrete; 240, Natural Pozzolans; 329, Performance Criteria for Ready Mixed Concrete; 365, Service Life Prediction; 555, Concrete with Recycled Materials; and C601-B, Concrete Quality Technical Manager. He is a winner of ACI's Young Professional Achievement Award. He served as Vice-President and President for the ACI San Antonio Chapter. He received his BS in Civil Engineering from IIT (BHU) Varanasi, India and his MS and PhD in Civil Engineering from the University of Michigan, Ann Arbor, and is a licensed engineer in the state of Maryland.

Colin L. Lobo, FACI, is Senior Vice President of the Engineering Division at NRMCA, Silver Spring, MD. He serves on several ACI committees, including 132, Responsibility in Concrete Construction; 211, Proportioning Concrete Mixtures; 214, Evaluation of Results of Tests Used to Determine the Strength of Concrete; 228, Nondestructive Testing of Concrete; 301, Specifications for Concrete; 318, Structural Concrete Building Code; and 329, Performance Criteria for Ready Mixed Concrete, and E701, Materials for Concrete Construction. He received his BE in civil engineering from Mysore University, India; his MS from Northeastern University, Boston, MA; and his PhD from Purdue University, West Lafayette, IN. He is a licensed engineer in the state of Maryland.

INTRODUCTION

Exposure of concrete members to water-soluble sulfates from external sources can be a significant cause of deterioration. This type of durability problem is typically prevalent where higher sulfate concentrations are present in soil or water in contact with concrete. It can also be an issue in facilities that generate sulfate bearing solutions that will come in contact with concrete. There are three types of phenomenon observed when concrete members are exposed to an external source of sulfates[1] – chemical sulfate attack[2]; physical sulfate attack resulting from crystallization of some salts of sulfate[3, 4, 5]; and thaumasite formation when concrete mixtures contain finely divided carbonates[6, 7].

This paper is limited to chemical sulfate attack, often referred to as *classical* sulfate attack. Chemical sulfate attack is governed by two factors[1, 8, 9]:

1. Type and characteristics of cementitious materials – Increased quantity of tri-calcium aluminate phase, C_3A, in portland cement decreases its sulfate resistance. Aluminate phases in some supplementary cementitious materials (SCM), such as in some Class C fly ash[10], or higher alumina content in slag cement[11], can contribute to sulfate attack.
2. Permeability of concrete – Water-soluble sulfates penetrate concrete by a combination of capillary sorption and diffusion. Concrete mixtures with a low w/cm and containing SCM reduce the rate of penetration of sulfates into the concrete.

The ACI 318 Building Code, ACI 318-14[12], limits its durability provisions to chemical sulfate resistance in the sulfate exposure category. It defines sulfate exposure classes based on the concentration of sulfate in soil or water concrete members will be exposed to. The requirements for concrete mixtures that will be exposed to these exposure classes are summarized in Table 1. ACI 318-14 also permits a cementitious materials combination that has been qualified when tested by ASTM C1012[13] with expansion criteria listed in Table 1. Service records of acceptable performance of concrete mixtures containing SCM are also permitted in lieu of ASTM C1012 tests.

The objective of this research project was to evaluate the current requirements for sulfate resistance in ACI 318 and to evaluate whether a rapid index test that provides an indicator of the permeability of concrete could be proposed as an alternative to the maximum w/cm. The maximum w/cm limit is invoked as a prescriptive requirement to reduce the permeability of concrete that controls the rate of penetration of water-soluble sulfates from external sources into the concrete. Besides w/cm, however, the permeability of concrete is also impacted by the composition of the cementitious materials used in the mixture and this benefit from using SCMs is not accounted for in the current provisions.

The sulfate resistance of concrete was evaluated by a long-term immersion test used by the US Bureau of Reclamation (USBR) in their research work on sulfate resistance. A modified version of USBR 4908[14] test was used