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Report on Internally Cured Concrete Using Prewetted Absorptive Lightweight Aggregate

Reported by ACI Committee 308
and ACI Committee 213

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This report introduces the concepts of and describes the process benefit and applications for using prewetted lightweight aggregate to increase cement hydration in internally cured concrete. It also describes mixture proportioning and absorptive material selection and discusses the benefits relating to sustainability. The materials, processes, quality control measures, and inspections described should be tested, monitored, or performed as applicable only by individuals holding the appropriate ACI certifications or equivalent.

Keywords: absorption; curing; desorption; durability; high-performance concrete; hydration; internal curing; internally cured concrete; lightweight aggregate; outside curing; permeability; saturated-surface-dry; shrinkage; strength; supplementary cementitious materials; water movement.

CONTENTS

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Portland-cement concrete, including mixtures with supplementary cementitious materials, does not typically develop its durability, strength, and mechanical characteristics without adequate curing. This report on internally cured concrete (ICC) does not presume to change the requirement for water retention at the curing-affected zone on the concrete surface. The curing methods listed in ACI 308R-01 should be consulted for appropriate methods to prevent or mitigate moisture loss from the concrete surface.

Test trial batches should be used during initial mixture proportioning to determine and verify those concrete properties required for each project.

Internally cured concrete uses prewetted absorptive materials that contain moisture. The absorbed moisture is released as the internal humidity of the concrete drops below 100 percent to enhance and maximize the hydration of cement.

High-performance concrete typically has a low *w/cm* that may not supply enough water to hydrate all of the cement. Due to the reduction in permeability of high-performance concrete, even in the first 2 to 3 days, exterior water curing is limited in its ability to supply in-depth hydration to the cement as the products of hydration fill in and disconnect the capillary pore network (Powers et al. 1959). In this case, the beneficial effect of external water curing is limited to the concrete surface. As a result, external water cannot penetrate the interior of the concrete to maintain a saturated capillary pore system thereby avoiding self-desiccation. One solution is to replace a portion of the normalweight aggregate with absorbent materials to desorb water to the hydrating cement. The principal improvements of supplying internal water are the maintenance of a saturated cement paste, which leads to greater hydration of the cement and more complete pozzolanic reactions.

Characteristics of high-performance concrete that may be improved by increased hydration from internally absorbed moisture include resistance to early-age cracking; higher strength; decreased permeability; decreased warping; dimensional stability; resistance to freezing-and-thawing damage, deicing chemicals, and chemical attacks; and creep.

In the past 50 years, portland cement has become finer with higher contents of tricalcium silicate and alkalis (Bentz et al. 2008). These changes have led to generally faster hydrating cements that produce much of their strength in only a few days. Concretes made with these cements, however, can be more prone to early-age cracking due to their increased heat of hydration and significantly increased autogenous strains and stresses that can develop when self-desiccation occurs.

1.2—Scope

Internally cured concrete uses absorptive materials in the mixture that supplement the standard curing practices by supplying moisture to the interior of the concrete (ACI 308R-01). This process adds moisture without affecting the *w/cm*. The moisture is desorbed for internal moisture augmentation at the time needed to further hydrate the cement. This water addition can be achieved using several materials (Jensen and Lura 2006; Kovler and Jensen 2007), including prewetted lightweight aggregate, super-absorbent particles, wood fibers, and absorbent limestone aggregate. This report will focus primarily on the use of prewetted lightweight aggregate.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

C_f = cement factor (content) for concrete mixture, lb/yd^3 (kg/m^3)

CS = chemical shrinkage of cement (mass of water/mass of cement)

M_{LWA} = mass of (dry) lightweight aggregate needed per unit volume of concrete, lb/yd^3 (kg/m^3)

S = degree of saturation of aggregate (0 to 1, measured absorption percentage divided by the absorption percentage at which desorption was measured)

w_{ic}/c = the ratio of the water supplied by internal curing to the cement in the concrete mixture on a mass basis

α_{max} = maximum expected degree of hydration of cement (0 to 1); for ordinary portland cement, the maximum expected degree of hydration of cement can be assumed to be 1 for $w/cm \geq 0.36$ and the value of (w/cm) divided by 0.36 for $w/cm < 0.36$

ϕ_{LWA} = desorption of lightweight aggregate from a prewetted condition down to 93 percent relative humidity (mass water/mass dry lightweight aggregate) in accordance with ASTM C1498-04

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," http://terminology.concrete.org. The definition provided here complements that source.

prewetted—wetting of the aggregate so that it contains the prescribed water content available for cement hydration.

CHAPTER 3—PROCESS

3.1—General

Concrete with a water-cementitious materials ratio (*w/cm*) below 0.42 does not contain enough batch water to fully hydrate all of the cement (Neville 1996). In concrete with a