PCA Portland Cement Association

CONCRETE TECHNOLOGY Today

Conductive Concrete for Bridge Deck Deicing

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Figure 1 (above): Two 89 x 89 x 6-mm (3½ x 3½ x ¼-in.) angle irons spaced about 1 m (3.5 ft) apart were embedded in each slab for electrodes in a back-to-back fashion. (IMG14730)

Figure 2 (below): Deicing system in operation in February 2004. (IMG14728)

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Contents

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Heated deck of Roca Spur Bridge in Nebraska is the world's first implementation using conductive concrete for deicing

Roca Spur Bridge is a 46-m (150-ft) long and 11-m (36-ft) wide, three-span highway bridge over the Salt Creek at Roca, located on Nebraska Highway 77 South about 24 km (15 miles) south of Lincoln. A railroad crossing is located immediately following the end of the bridge, making it a prime candidate for electrical deicing application. The Roca Bridge project began in December 2001, and construction was completed in November 2002. The bridge deck has a 36-m (117-ft) by 8.5-m (28-ft) by 100-mm (4-in.) conductive concrete inlay, which is instrumented with thermocouples to provide data for deicing monitoring during winter storms.

Mix Design

Conductive concrete contains a certain amount of electrically conductive components in the regular concrete matrix to attain stable and relatively high electrical conductivity. The mix design used in this project contained steel fibers and carbon products for conductive materials. Steel fibers of variable lengths amounted to 1.5% and the carbon products of different particle sizes amounted to 25% per volume of the conductive concrete. Crushed limestone of 13-mm (0.5-in.) maximum size and Nebraska 47B fine aggregate were also used in the mix. Due to its electrical resistance and impedance, a thin conductive concrete overlay can generate

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Conductive Concrete for Bridge Deck Deicing

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enough heat to prevent ice formation on a bridge deck when connected to a power source.

Project Significance

It is expected that this project will demonstrate that conductive concrete technology has national and international importance. Statistics indicate that 10% to 15% of all roadway accidents are directly related to weather conditions. This percentage alone represents thousands of human injuries and deaths and millions of dollars in property damage annually. Ice accumulation on paved surfaces is not merely a concern for motorists; ice on pedestrian walkways accounts for numerous slip and fall injuries. The payoff potential for this project is tremendous: it could eliminate icy bridge roadways and save lives. This revolutionary deicing technology is applicable to accident-prone areas such as bridge overpasses, exit ramps, airport runways, street intersections, sidewalks, and driveways.

Construction Sequence

A 100-mm (4-in.) thick inlay of conductive concrete was cast on top of a 256-mm (10.5-in.) thick regular reinforced concrete deck. The inlay consists of 52 individual 1.2-m x 4.1-m (4-ft x 14-ft) conductive concrete slabs. In each slab, two angle irons were embedded for electrodes (Figure 1). Coupling nuts were welded to one end of the angle irons for making an electrical connection. A thermocouple was installed at the center of each slab at about 13 mm (0.5 in.) below the surface to measure the slab temperature. The power cords and thermocouple wiring for each slab were secured in two PVC conduits and are accessible from junction boxes along the centerline of the bridge deck.

The conductive concrete inlay was cast after the regular bridge deck had been cured for 30 days. The westbound lane was placed first. After hardening, the conductive concrete inlay was saw cut to a 100-mm (4-in.) depth along the perimeters of the individual slabs, and the gaps were filled with polyurethane sealant. There was a 150-mm (6-in.) gap along the centerline of the bridge to allow power cord connections with the coupling nuts of the angle irons. The gap was then filled with a non shrink, high-strength grout.

Integration of Power Supply, Sensors, and Control Circuit

A three-phase, 600 A and 220 V AC power source is available from a power line nearby. In a control room a microprocessor monitors and controls the deicing operation of the 52 slabs. The system includes four main elements: (1) a temperature-sensing unit, (2) a power-switching unit, (3) a current-monitoring unit, and (4) an operator-interface unit. The temperature-sensing unit takes and records the thermocouple readings of the slabs every 15 minutes. A slab's power will be turned on by the controller if the temperature of the slab is below 4.5°C (40°F) and turned off if the temperature is above 12.8°C (55°F). The power-switching unit controls power relays to perform the desired on/off function. To ensure safety, a current-monitoring unit limits the current going through a slab to a user-specified amount. The operator-interface unit allows a user to connect to the controller with a PC or laptop via a phone modem. The operator interface displays all temperature and electrical current readings of every slab in real time. A user also has the option of using a PC or laptop to download controller-stored data into a spreadsheet.

Deicing Operation

The deicing controller system was completed in March 2003 and was tested successfully under snow storms in January and February 2004 (Figure 2). The system was activated in 2003 for an early April storm with less than 6 mm (1/4 in.) of sleet. The slush on the bridge deck was melted during the storm period. Temperature distribution was uniform across the bridge. The controller system kept the slab temperature about 9°C (16°F) above the ambient temperature.

The 52 slabs were energized in an alternating fashion to avoid a power surge. Groups of two slabs were started up in turn at 3-minute intervals and energized at 208 V for 30 minutes. This alternating form of energizing the slabs was followed throughout the storm. The maximum current recorded varied between 7 and 10 amps, with an average of 8. Peak power density delivered to the slabs varied between 360 and 560 W/m^2 (33 to 52 W/ft^2) with an average of 452 W/m^2 (42 W/ft^2). Energy consumed by the conductive slabs during the three-day period varied from 47 to 70 kW-hr, with an average of 58 kW-hr per slab. Total energy consumption was about 3,000 kW-hr.

The conductive concrete bridge deck will continue to be studied for the next several winters to evaluate the effect of electrical deicing and compare it to alternatives. This promising new technology should prove to be a valuable tool in the fight against icy conditions on roadways.

Reference

More information on the conductive concrete bridge deck project can be found at: *www.conductive-concrete.unomaha.edu*.

New Canadian Standard: A3000-03

The 2003 edition of CSA A3000, *Cementitious Materials Compendium,* was consolidated into two product and three testing standards.

The first edition of the A3000 compendium, published in 1998, began consolidation of test methods contained in Standards A5, A8, A23.5, A362 and A363. Redundancies and inconsistencies were eliminated and the test methods were compiled into a new CSA A456 series.

With the second edition of the CSA A3000 compendium the consolidation is complete (see box).

CSA A3000-03 Cementitious Materials Compendium

CSA A3001 *Cementitious Materials for Use in Concrete*
supersedes A5 (Portland Cement)
A23.5 (Supplementary Cementing Materials)
A362 (Blended Hydraulic Cement)
A363 (Cementitous Hydraulic Slag)

CSA A3002 *Masonry and Mortar Cement*
supersedes A8 (Masonry Cement)

CSA A3003 *Chemical Test Methods for Cementitious Materials for Use in Concrete and Masonry*
supersedes A456.1 (Chemical Tests)

CSA A3004 *Physical Test Methods for Cementitious Materials for Use in Concrete and Masonry*
supersedes A456.2 (Physical Tests)

CSA A3005 *Test Equipment and Materials for Cementitious Materials for Use in Concrete and Masonry*
supersedes A456.3 (Material and Equipment)

Changes in CSA A3001 – Cementitious Materials

Portland Cements—Changes in CSA A3001-03 include new nomenclature for portland cements: two-letter descriptive type designations (see Table). The former Type 20 cement was split into two types by intended use; MS for moderate sulfate resistance and MH for moderate heat of hydration.

Blended Hydraulic Cements—The nomenclature for blended hydraulic cements has been modified to a three-letter descriptive designation to address its equivalent performance to portland cements with up to three supplementary cementing materials (see Table). Upon request, the designations for blended cements can also provide information on the composition of blended hydraulic cements. The designations then follow the form:

BHb-Axx/Byy/Czz, where BHb is the blended hydraulic cement type, xx, yy, and zz are the supplementary materials used in the cement in proportions A, B, and C respectively.

Covered supplementary cementitious materials include ground granulated blast furnace slag (S), silica fume (SF), natural pozzolans (N), and fly ash (Classes F, CI, and CH). Class F, CI, and CH fly ashes are low (less than 8% CaO by mass), medium (between 8% and 20% CaO by mass), and high calcium oxide (more than 20% CaO by mass) contents, respectively.

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Table: Type Designations for Canadian Portland and Blended Hydraulic Cements

New type designations, CSA A3001-03			Previous type designations		U.S. type designations	
Portland cement	**Blended hydraulic cement**	**Type descriptions**	**Portland cement**	**Blended cement**	**ASTM C 150**	**ASTM C 1157**
GU	GUb	General use hydraulic cement	10	10E-x	I	GU
MS	MSb	Moderate sulphate-resistant hydraulic cement	20	20E-x	II	MS
MH	MHb	Moderate heat of hydration hydraulic cement	20	20E-x	II	MH
HE	HEb	High early-strength hydraulic cement	30	30E-x	III	HE
LH	LHb	Low heat of hydration hydraulic cement	40	40E-x	IV	LH
HS	HSb	High sulphate-resistant hydraulic cement	50	50E-x	V	HS

Examples:

MS—portland cement (with no supplementary cementitious materials) for use when moderate sulfate resistance is required.

GUb-30F/5SF—general use blended cement containing 30% by mass Class F fly ash (F) and 5% silica fume (SF).

Q&A—Cold Weather Concreting

Q: I am a contractor involved with a variety of concrete projects including commercial buildings, residential foundations and flatwork, as well as pavement and curb and gutter. The projects are located in a northern climate. I must ensure that provisions taken for cold weather conditions follow acceptable industry practice to assure a quality finished product. When should I be concerned about cold weather placement conditions and what practices should be used to achieve quality results?

A: Cold weather concreting is a common and necessary practice, and every cold weather application must be considered carefully to accommodate its unique requirements. The current American Concrete Institute definition of cold-weather concreting, as stated in ACI 306 is, "a period when for more than 3 successive days the average daily air temperature drops below 5°C (40°F) and stays below 10°C (50°F) for more than one-half of any 24 hour period." This definition can potentially lead to problems with freezing at early age of the concrete. Rule number ONE is that ALL concrete must be protected from freezing until it has reached a minimum strength of 3.5 MPa (500 psi), which typically happens within the first 24 hours. In addition, whenever air temperature at the time of concrete placement is below 5°C (40°F) and freezing temperatures within the first 24 hours after placement are expected, the following general issues should be considered: (1) Adjustment of construction schedule regarding loads imposed on the new concrete structure, and (2) Placing and curing temperatures to produce quality concrete.

The exposure of concrete to cold weather will extend the time required for it to gain strength. In structures that will carry large loads at an early age, concrete must be maintained at a minimum of 10°C (50°F) to accommodate stripping of forms and shoring and to permit loading of the structure. In many cases, achieving the required durability will require a protection period of more than 24 hours. This may not be an issue with residential applications where applied loads are typically small and may be applied in small increments over several days or weeks. In no case should concrete be allowed to freeze during the first 24 hours after it has been placed. Since cement hydration is an exothermic reaction, the concrete mixture produces some heat on its own. Protecting that heat from escaping the system may be all that is required for good concrete quality, while more severe temperatures may require supplemental heat.

More information is available from the following references:

ACI Committee 306, *Cold-Weather Concreting*, ACI 306-88, reapproved 2002, American Concrete Institute, 2002, 23 pages.

PCA, *Cold-Weather Concreting*, IS154, 2002, 20 pages.

New Canadian Standard: A3000-03

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Blended Supplementary Cementing Materials—Blended SCMs are designated as BMb and have reporting requirements similar to blended hydraulic cements.

Summary of Additional Changes

Other points of interest in the new A3000-03 include:

- Provisions are given for blended hydraulic cements consisting of a portland cement and up to three supplementary cementing materials and blended supplementary cementing materials containing up to three components
- A provision has been included for the testing of processing additions when slag, fly ash, or natural pozzolans are present
- The C_3A limit for MH and MS (A3001-98 Type 20) has been revised to 8% maximum, similar to ASTM C 150 Type II
- The maximum silica fume content of blended hydraulic cements has been increased to 15%
- A definition for hydraulic cement has been added: hydraulic cement is defined as either a portland cement, a blended hydraulic cement, a mortar cement, or a masonry cement
- The uniformity requirements clause has been modified to clarify that the uniformity requirement is intended for the predominant product
- Annex C has been added to explain the changes to the nomenclature of portland and blended hydraulic cement types
- Annex D has been added as a guide for the evaluation of alternative supplementary cementing materials for use in concrete

CSA A3000-03 is available in English and French and can be obtained at *www.csa.ca*.

For more information please contact:

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Concrete Thinking for a Sustainable World

By David Shepherd, Director of Sustainable Development, PCA

It would be difficult not to notice the movement for environmentally preferred products sweeping the nation. Hybrid cars, citrus oil based cleaners, "ozone friendly" spray propellants, Energy Star ratings on our televisions and stereos. We can see evidence of this in almost every industry, and the construction industry is no exception. Labeled "sustainable development" or "green building," it is a rapidly growing force in the marketplace.

What's Happening?

As the national and global population continues to swell, we see the effects of a growing demand on a finite amount of resources. The supply of abundant energy, clean air, clean water, and land suitable for agriculture and habitation are under pressure from increasing demand. As an example, water is becoming a precious and increasingly expensive resource in the southwest portion of the U.S. And common sense tells us that our actions have consequences, sometimes long lasting or devastating.

The Impact of Buildings

Research has shown that buildings in the U.S. use 40% of our material resources and 39% of our annual energy consumption. Even more telling is that U.S. buildings use almost three times the energy of our European counterparts in similar climates. With such an impact, it makes sense to invest a little time considering how we develop our built world. Sustainable development attempts to balance three primary factors in making design and construction decisions:

- Economic–Consideration for the financial health of an organization.
- Social–Weighing the impacts to employees and customers; the people portion of the equation, locally, regionally, and nationally.
- Environmental–Considering the short and long term impacts on our resources and habitat.

Where Does Cement Fit In?

Modern portland cement research yields a product that continues to improve in production and performance. For example, the manufacturing of cement is an energy intensive process, but the average amount of energy needed to make cement has been reduced by 33% since 1972. As new plants replace older ones, this decrease will continue.

Research has also identified some industrial byproducts that provide an alternate source of raw ingredients required for portland cement manufacturing. These include foundry sand, fly ash, mill scale, slag, and lime sludge. This has a two-fold effect by reducing the need for virgin raw materials and redirecting the byproducts from landfills.

Win-Win Situation

Cement enables other industrial byproducts to be incorporated into concrete. In the right proportions, fly ash combined with portland cement can enhance durability and reduce permeability of concrete. Other effects of this combination can include improved workability, a lower heat of hydration, and increased working time for large placements. Fly ash is one of several supplementary cementing materials derived from industrial byproducts. Slag cement from blast furnaces and silica fume from electric arc furnaces have other beneficial properties to offer. Properties of these materials will vary with the source, so a discussion with the local ready-mix concrete supplier is recommended.

Full Circle

Another aspect of sustainable development is to consider what happens at the end of a construction material's useful life. One of the best solutions is to recycle a product on site. This saves energy by eliminating transportation of the material. While this is not a practical solution for steel, in-situ concrete pavement and structures can be crushed on location to make an ideal base for new parking lots, interior slabs and as backfill around foundations. This also saves costs for extracting virgin materials and shipping to the site.

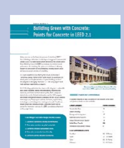
Resources:

You'll find more information about the sustainable benefits of concrete at:

Portland Cement Association Web site:
www.sustainableconstruction.org

Environmental Council of Concrete Organizations (ECCO): ***www.ecco.org***

Building Green with Gray Concrete **(IS311)**



Building Green with Concrete: Points for Concrete in LEED 2.1 **(IS312)**

Concrete: Sustainability and Life Cycle **(CD033)**

Concrete Builds the Sustainable Movement **(RP417)**

All publications are available at *www.cement.org/bookstore.*

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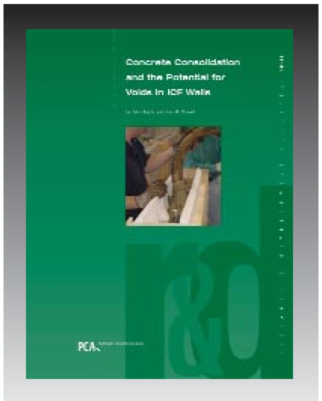
Comparative Performance of Portland Cement and Lime Stabilization of Moderate to High Plasticity Clay Soils, RD125

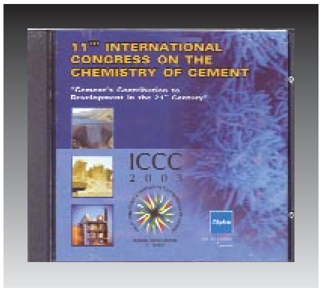
Comprehensive comparison between portland cement and lime stabilized clay soils through a series of tests including plasticity indices (Atterberg limits), unconfined compressive strength, California bearing ratio, strength after vacuum saturation (to evaluate freeze-thaw performance), mass loss in wet-dry test, and hydraulic conductivity, leaching, and permeability.

Concrete Consolidation and the Potential for Voids in ICF Walls, RD134



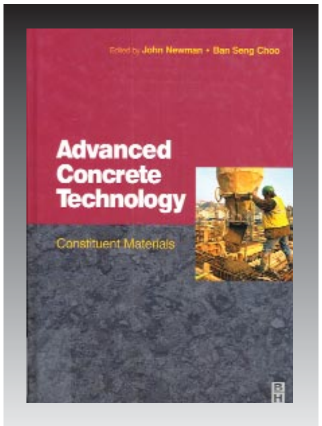
This report summarizes the findings of a study regarding concrete consolidation and the potential for voids in insulating concrete form (ICF) walls. Internal and external mechanical vibration, as well as admixture technology were evaluated in a variety of wall conditions. The document also highlights the proper methods for use with internal vibration. Additionally, the applicability of nondestructive test methods such as impulse radar to detect reinforcing steel and voids within the ICF walls was investigated.

Proceedings of the 11th International Congress on the Chemistry of Cement (2003), CD048



The ICCC conference is one of the major events for the cement industry worldwide, and the proceedings offer a wealth of technical information of critical value and interest. The 11th Congress, held in Durban, South Africa, included 240 papers on all aspects of cement, from raw materials in cement production to concrete durability and environmental applications. The authors are international experts from universities, research institutes, and other organizations, and their papers present the latest research results, test methods, and technologies. The CD is completely searchable, making access to specific information extremely efficient.

Advanced Concrete Technology–Constituent Materials, LT279



An excellent new volume covering all aspects of concrete materials. Contributions by international experts cover cement manufacture, chemistry and types of cement, supplementary cementitious materials, admixtures and their effects, and aggregates. Based on the syllabus for a course offered by the Institute of Concrete Technology. A good resource for concrete materials technologists and advanced students. London: Butterworth Heinemann

Masonry Mortars, IS040

Get all the essential information on mortar components, properties, specifications, types, and use. Covers mixing and measuring, all-weather construction, white and colored mortars, and special mortar production techniques.

Masonry Mortars: Developing a Quality Assurance Program, RP415

Reprint of a continuing education section published in the August 2003 issue of *Architectural Record*.

Learning CD on Supplementary Cementing Materials for Use in Concrete

This self-contained interactive distance learning CD, complete with narration, explores the use of the most common supplementary cementing materials: **fly ash, slag, silica fume and natural pozzolans**. Topics include the production process of each SCM and its impact on the fresh and hardened properties of concrete, including strength, durability, and workability.

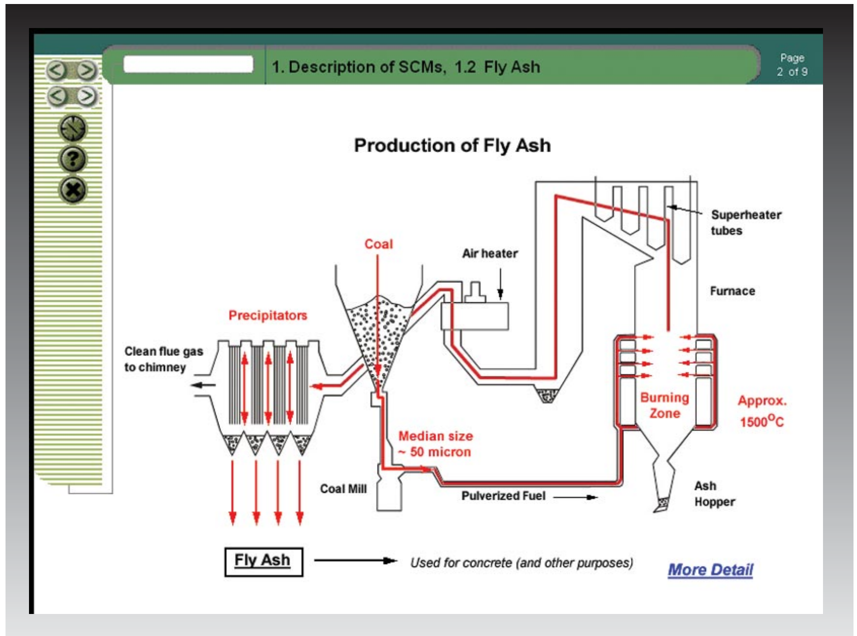
Example

Among many other topics, an overview of the production of fly ash is discussed within the CD:

Fly Ash

Fly ash is the finely divided residue produced in coal-fired electric power generating plants as an industrial by-product of the combustion of ground or powdered coal.

Production of Fly Ash



This image shows a simplified cross-section through a coal-fired electrical generating station. Coal is first pulverized in grinding mills before being blown with air into the burning zone of the boiler. In this zone the coal ignites producing heat with temperatures reaching approximately 1500°C (2700°F). At this temperature the non-combustible inorganic minerals associated with the coal melt and form small liquid droplets. These droplets are carried from the burning zone with the flue gases and are rapidly cooled forming small spherical glassy particles as they leave the chamber. These solid particles are collected from the flue gases using mechanical and electrical precipitators. This is the material we call fly ash: fine, spherical, glassy particles that are used in concrete and other applications.

Supplementary Cementing Materials for Use in Concrete, CD038

Ordering information: *www.cement.org/scm*

PowerPoint® Presentations are available for the following topics:

Concrete Slab Surface Defects, PT177

Demonstration of causes, prevention, and repair of 10 common concrete slab surface defects: dusting, scaling, popouts, crazing, cracking, discoloration, blisters, spalling, low spots, and curling. Describes how petrographic (microscopical) analysis can be used to determine the cause of most concrete defects.

Identification of Alkali-Silica Reactivity in Highway Structures, PT315

Offers guidance for the field identification of alkali-silica reactivity (ASR) and how to distinguish ASR from other types of deterioration. Several color photographs illustrate ASR damage, and a simple and rapid field procedure for detecting ASR is described.

Guide Specification for Concrete Subject to Alkali-Silica Reactions, PT404

Provides several options for the user to control alkali-silica reaction. Discussed are aggregates, pozzolans, slag, and blended cements. Related test methods are noted to direct the user toward effective control of ASR. PowerPoint® presentation to IS415, *Guide Specification for Concrete Subject to Alkali-Silica Reactions*.

New *Concrete Technology Today* Web site

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July 11–14, 2004 at PCA in Skokie, Illinois

CENTER FOR ADVANCED CEMENT-BASED MATERIALS

Portland Cement Association

Sponsored by the Center for Advanced Cement-Based Materials (ACBM) and PCA the Faculty Workshop will address issues of adding and expanding coverage of concrete materials properties in undergraduate and graduate courses and laboratories.

The goal of the workshop is to provide a forum to introduce the most current research in concrete materials properties. Participants will learn how to effectively facilitate teaching of concrete, see demonstrations and hear explanations of student laboratory experiments, and exchange information on successful implementation of concrete-related subject matter into curricula.

For more information on agenda, housing, and registration visit *http://www.cement.org/learn/acbm_workshop.asp*.

2004 Structural Professors' Seminars

Engineering and Economics of Concrete Buildings (August 2–4, 2004)

Design of Concrete Bridges by the AASHTO Load and Resistance Factor Design—LRFD (August 5–6, 2004)

For information on either of these annual seminars, please contact Caron Johnsen at 847.972.9058, e-mail: cjohnsen@cement.org. Participating professors are sponsored by local concrete industry groups. Such groups include: Regional Cement Promotion Groups, State Ready Mixed Concrete Associations, CRSI Chapters, ACPA State Associations, and PCI Regional and State Associations.

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PUBLISHER'S NOTE:
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