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Cementing the Future

Center for Advanced Cement-Based Materials

SCC 2008: Call for Papers

ACBM is hosting the Third North American Conference on the Design and Use of Self-Consolidating Concrete (SCC 2008). The theme for SCC 2008 is "Challenges and Barriers to Application."

The three-day conference will be held November 10–12, 2008 in Chicago, Illinois. As indicated from the theme, the conference will focus on issues that have become apparent as a result of widespread implementation of SCC. SCC 2008 will feature a special "practitioners track" to address issues of special interest to contractors, producers, architects, and engineers. This is the premier U.S. meeting to learn about new research, practical application, and recent developments in SCC technology.

The First and Second North American Conferences were held in Chicago in 2002 and 2005 and were highly successful, with almost 400 participants at each. The conference proceedings are published and widely distributed by Hanley Wood.

More information on the call for papers is included as an insert to this newsletter or can be found on the conference website: www.scc2008.info. ❖

In this issue:

Featured Research

AIR-COUPLED IMPACT-ECHO IMAGING FOR CONCRETE

John S. Popovics, The University of Illinois at Urbana-Champaign
Jinying Zhu, The University of Texas at Austin

Abstract

In this paper, work on air-coupled impact-echo is described. The method is applied to locate and to determine the depth of simulated delamination and void defects in a concrete slab. A small (6 mm diameter) measurement microphone is used to sense impact-echo response without contacting the surface of the concrete. Ambient acoustic noise effects are significantly reduced by a specially-designed sound insulation device. Test results show that air-coupled sensors work as effectively as do contact impact-echo sensors when proper impactors are used. An air-coupled impact-echo scan was conducted over the entire slab area, and the defects are located in a generated 2-D contour image. Experiments show that the areal size of near-surface delamination defects can be accurately determined if the scan spacing is smaller than ½ of the expected defect size. The study presented in this paper shows air-coupled sensing offers an approach for rapid and effective evaluation of concrete deck structures through imaging.

Introduction

Non-destructive evaluation (NDE) techniques that can detect, localize and characterize damage and flaws in the infrastructure are of great interest. Impact-echo has emerged as one of the most commonly used NDE methods for concrete defect detection since it was first proposed in the 1980s (Carino et al., 1986). It can be used to determine the location and extent of flaws such as cracks, delaminations, voids, honeycombing, and debonding in concrete structures. Impact-echo is especially effective for locating and estimating depth of delaminations (Sansalone and Streett, 1997). Impact-echo is a mechanical wave-based NDE technique, where a steel ball applies a transient point load (e.g., an impact event) on the surface to generate waves in the concrete. The resulting transient surface motion, which is set up by a vibrational resonance through the thickness of the element, is detected by a sensor mounted on the surface. The obtained time domain signal is transformed to frequency domain (amplitude spectrum), where the frequency value at the maximum amplitude (peak) is monitored. The slab thickness, (or depth to defects) H is related to P-wave velocity C_p and peak frequency f by

$$H = \beta C_p / 2f \qquad (1)$$

where β is approximately 0.96 for plate-like structures. A recent study shows that the impact-echo resonance actually corresponds to the S_1 mode Lamb wave at the zero group

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Student Profile: Farshad Rajabipour, Purdue

A civil engineer must have an understanding of the behavior of materials to be able to design structures properly against mechanical and durability failures. Such understanding of materials behavior, which can be gained during the college education, will lead toward more efficient and cost-effective designs that make use of better and more innovative materials. I personally experienced the problem of working as a structural engineer who did not have a sufficient knowledge of the science and engineering of materials.

After completing my bachelor's degree in civil engineering at Sharif University of Technology in Tehran, Iran, I worked for two

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Letter from the Director

Nanotechnology for Construction Materials

Fundamental properties of concrete such as strength, ductility, early age rheology, creep and shrinkage, fracture behavior, durability, etc are affected by material properties at the nano-scales. In order to improve cement and concrete properties, it is necessary to understand the nanostructure and how this relates to the properties such as the local mechanical properties. Characterization at nano-scale is an essential ingredient of this research area and key advances in computation and in technical instrumentation are crucial, namely the development of powerful microscopes such as the Scanning Tunneling Microscope (STM, 1981) and the Atomic Force Microscope (AFM, 1986), which have allowed us to see and manipulate atoms, molecules and nano-sized objects. The difference between the scientific disciplines becomes indistinct at this scale and collaboration between scientists from different disciplines, such as chemistry, physics and materials science is required.

To identify areas with the greatest potential for applications, investment and exploitation of nanotechnology in the construction industry and review achievements and current research and development, the 1st International Symposium on Nanotechnology in Construction Materials was held in June 2003 hosted by the University of Paisley (UK). In continuing the action initiated, the 2nd International Symposium on Nanotechnology in Construction Materials was held in November 2005 and hosted by the Center for Nanomaterials Applications in Construction (NANOC), LABEIN-Technalia. The U.S. government's National Nanotechnology Initiative (NNI) started formally in the year of 2000 as a multi-agency coordinated approach to develop technology, which takes advantage of the unique properties of matter at the submicron to nano-scale. The Civil and Mechanical Systems Division of the National Science Foundation's Engineering Directorate has been very active in the National Science Foundation's overall NNI activities. A National Science Foundation Workshop on Nanomodification of Cementitious Materials was held in August 2006 with the objective of bringing together national and international researchers and practitioners with an interest in nanomodification of cementitious construction materials and developing a Roadmap for Research in this emerging area. With the Roadmap for Research, a White Paper was developed by the workshop Scientific Advisory Committee and a task force was formed by the Transportation Research Board.

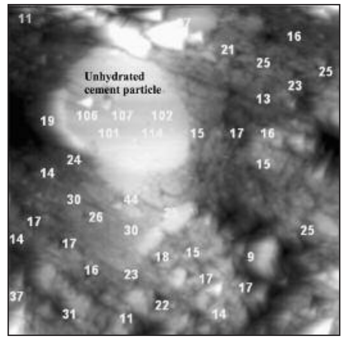

Figure 1. 60 μm × 60 μm image of cement paste with unhydrated particle showing location of indents and Young's modulus in GPa.

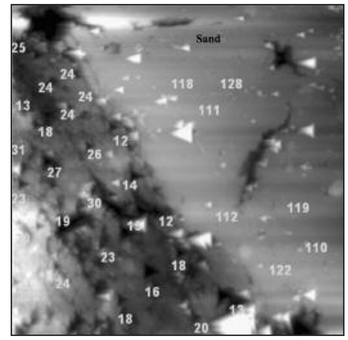

Figure 2. 60 μm × 60 μm image of mortar shows location of indents and Young's modulus determined (in GPa) on the cement paste, sand and ITZ area.

There are three aspects in which the development in nanotechnology can help concrete construction: characterization, new materials and sensors. ACBM has been pioneering development in all three areas. For example, ACBM has pioneered the use of nuclear magnetic resonance to characterize the hydration of calcium silicate. Recently, researchers Andrew J. Allen of NIST, Jeffrey J. Thomas and Hamlin M. Jennings both of Northwestern published their findings regarding the structure of calcium-silicate-hydrate in the journal *Nature Materials.* In other research, a nanoindenter with the unique advantage of in-situ scanning probe microscopy imaging is being used for the determination of local mechanical properties. As an example, Figures 1 and 2 show local mechanical properties of different areas of cement paste and mortar samples. This research could be the first step in developing new materials with specific properties in the future.

ACBM will continue to research the application of nanotechnology in the development of new materials with improved properties and bring the latest updates to the forefront via conferences and workshops while working with our industrial partners. ❖

News Briefs

The December 2006 issue of *Concrete Construction* named ACBM Director **Surendra P. Shah** one of the ten most influential people in the cement and concrete industry. The magazine states that "[Shah's] combination of an enquiring mind and a collaborative spirit is a nearly unstoppable force." Shah was named to the top ten list because of his research, education, and technology transfer initiatives, which include his research in microscopic behavior, the training of hundreds of students and visiting scholars at ACBM, and organizing conferences on cutting edge topics. The full article can be found at http://www.concreteconstructiononline.com/industry-news.asp?articleID=403381.

Jason Weiss received the ACI Young Member Award for Professional Achievement at the 2007 American Concrete Institute convention. He also has been promoted by Purdue University to the rank of Full Professor.

Congratulations to the following students for completing degrees:

- **Chun-Tao Chen,** University of Illinois at Urbana-Champaign; Leslie Struble, advisor; Ph.D. dissertation "Interactions Between Portland Cements and Carboxylated and Nathphalene-Based Superplasticizers"

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Conference Opportunities

JUNE 2007 • SKOKIE, ILLINOIS

ACBM Undergrad Faculty Enhancement Workshop

The 14th Undergraduate Faculty Enhancement Workshop will be held June 18–20, 2007 at the Portland Cement Association headquarters in Skokie, Illinois. The workshop series began in 1992 under a National Science Foundation grant. The mission of the workshop series is to provide innovative methods for teaching cement and concrete science in the undergraduate curricula. The workshop provides faculty with materials to teach the fundamental science as well as laboratory activities.

Workshop topics include Fundamentals of Concrete, Cement and Hydration, Supplementary Cementing Materials, Chemical Admixtures, Fresh Concrete Properties, and Mix Design. The workshop also features a session on Teaching Methodologies, a student competition, and a tour of the CTL Group Laboratories.

Registration for the workshop is $195 and includes all hand-out materials. More information can be found on the ACBM website (www.acbm.info).

SEPT 2007 • GHENT, BELGIUM

RILEM Symposium on SCC (SCC2007)

The Fifth International RILEM Symposium on Self-Compacting Concrete (SCC2007) will take place September 3–5 2007 in Ghent, Belgium, in conjunction with the 61st International RILEM Annual Week. SCC2007 will focus on all aspects of SCC from components and over mix design, to rheology, hydration, mechanical properties, structural aspects, and durability. Attention also will be given to practical case studies from all over the world.

The technical program of SCC2007 includes three invited presentations by internationally known colleagues:

- Prof. S. Shah, USA, "Research on SCC: Some emerging themes"
- Dr. M. Ouchi, Japan, "Self-compacting concrete as repairing material; generalisation of SCC technologies within modern concrete technology"
- F. Cussigh, France, "SCC in practice: Opportunities and bottlenecks"

Approximately 200 papers will be presented during SCC2007. Registration forms, hotel information, and other information can be found on the symposium website at www.scc2007.ugent.be. The website also includes links to SCC2007 sponsors: Omya, BASF, BBRI, Carmeuse, Febelcem, Schleibinger Geräte, Belgian Concrete Society, Grace, Socea, and ULg.

Participants also will be able to explore the marvelous old city of Ghent, offering many splendid buildings along picturesque canals.

DEC 2007 • LAHORE, PAKISTAN

Advances in Cement Based Materials and Applications in Civil Infrastructure

ACBM is proud to be a sponsor of the conference, Advances in Cement Based Materials and Applications in Civil Infrastructure. The international conference will be held December 12–14, 2007, in Lahore, Pakistan. The conference is intended for professionals in the concrete industry, academia, practicing consulting engineers, individual engineers and architects, construction industry professionals, public/private sector managers, builders, government officials in the construction sector and other development professionals.

Conference themes will focus on the following: materials; fracture mechanics, fatigue, and creep; concrete structures; bridges; structures for developing countries; technology transfer; instrumentation; monitoring; and testing, and durability of structures. In addition to the paper presentations, keynote talks will be given by an international delegation of top researchers in the field. Included in the list are professors who have past ACBM connections: Professor Byung Hwan Oh, Korea (ACBM visiting scholar); Professor Claudia Ostertag, USA (ACBM Faculty Workshop organizer); Professor Pietro Gambarova, Italy (ACBM affiliate member); and Professor Zongjin Li, HK, China (ACBM graduate). Professor Barzin Mobasher (ACBM graduate) will lead an American delegation supported by NSF.

Lahore, the second largest city in Pakistan, is located near the River Ravi and is the capital of the Punjab Province. Lahore is considered the Mughal "Show-Window" of Pakistan, with beautiful gardens, historical forts, mosques and shrines, Mughal architecture, museums, and many festivals.

Prior to the conference, NED University of Engineering and Technology in Karachi, Pakistan will hold an International Workshop on Cement Based Materials and Civil Infrastructure December 10–11, 2007.

Registration, travel and other information can be found on each of the event websites: Lahore conference (www.acbm-aci.org); Karachi workshop (www.neduet.edu.pk/CBM-CI).

MAY 2008 • ISTANBUL, TURKEY

International Conference on Durability of Building Materials

The 11th International Conference on Durability of Building Materials and Components will be held May 11–14, 2008 at Lütfi Kırdar Convention and Exhibition Centre in Istanbul, Turkey. The conference will bring together national and international experts for an exchange of ideas and research findings on studies pertaining to the service life and durability of construction and building materials, components and systems at the global and local levels.

The perpetual interaction of activities carried out by researchers and professionals at these two levels constitute the sub-theme of this conference: "Globality and Locality in Durability." Global is concerned with overall or conceptual issues, while local focuses on more regional or specific problems. The intention of the conference is to merge both of these efforts on durability.

This conference, complemented by related CIB, RILEM and ISO meetings, is to take place in an historic setting at the geographical as well as cultural gateway between two continents. Istanbul also has the distinction of having been the capital city of the Byzantine and Ottoman empires, respectively. In the spirit of these contextual, geographic and historic dualities it is anticipated to receive stimulating and provocative as well as conventional contributions from various disciplines intended to spawn further developments towards a sustainable built environment.

For further information, visit the conference website at www.11dbmc.org. ❖

Featured Research

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velocity frequency condition (Gibson and Popovics, 2005). When an internal air-filled defect lies below the impact-echo test location, the impact–echo resonance frequency is altered. The nature of the defect determines the extent to which the vibration resonance behavior changes. In the particular case when impact-echo is applied above a near-surface delamination defect, another resonance mode (the fundamental flexural mode) dominates the transient response and obscures the impact-echo resonance (Sansalone and Streett, 1997). Equation (1) is not appropriate and should not be applied when flexural modes are measured. Impact-echo, like many other mechanical wave based NDE methods, is a local point inspection method. Therefore, it can be time consuming and labor intensive to test large structures or pavements.

Visual images that map the location, size and shape of embedded damage or flaws provide a direct way for engineers to evaluate the condition of concrete structures. Many individual data are needed to construct a single image, however, and the inherent large size of concrete structures results in an enormous amount of data needed to construct an adequate image. However, the use of mechanical wave data to create visual images is limited by the required physical contact and coupling of the transducers: mechanical wave NDE techniques require good contact between the sensor and tested concrete surface to obtain reliable data. One solution for the problem of slow testing rate of mechanical wave methods is the application of contact-less sensing. By eliminating the contact between sensors and concrete surfaces, the possibility of an automated scanning system is enabled. Recently air-coupled sensing for surface waves in concrete structures was proposed by Zhu and Popovics (2001). Subsequent studies by Zhu (2005), Popovics and Zhu (2006) and Ryden et al. (2006) have shown that air-coupled sensors can replace contact sensors in most surface wave measurement tests, e.g. SASW (Spectral Analysis of Surface Waves) and MASW (Multi-channel Analysis of Surface Waves). Furthermore, air-coupled surface wave sensing can also be applied to locate surface cracks in concrete slabs (Zhu and Popovics, 2005).

Testing Configuration

The testing setup of air-coupled impact-echo is similar to conventional impact-echo except there is no contact between the sensor and the test surface. The sensor is located nearby the impact location; the distance between the sensor's axial projection point on the surface and the impact point is less than 40% of the slab thickness. The impact source causes much acoustic noise in the received signals, which cannot be isolated in the time domain and removed because of the relatively small source-receiver spacing in the impact-echo test setup. To overcome this difficulty, adequate sound insulation is required to reduce the energy of acoustic waves detected by the sensor, and the impactor must excite impact-echo resonances in concrete without generating excessive acoustic noise.

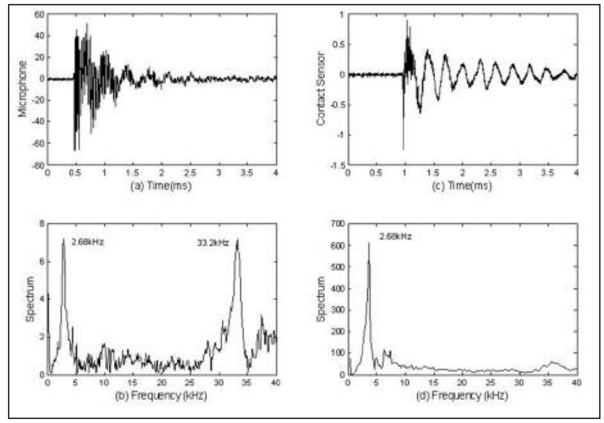

Figure 1. Time domain signals (a) and (c) and associated frequency spectra (b) and (d) collected over a shallow delamination defect in concrete using an air-coupled sensor (left) and a conventional contact sensor (right).

The sensor used in the air-coupled impact-echo tests is a measurement microphone manufactured by PCB Inc. It has a small size (6.3 mm diameter), broad frequency range (4-80 kHz at ±2dB), and high sensitivity (4 mV/Pa). A special enclosure was designed to support the microphone; it also provides sound insulation to shield ambient noise and direct acoustic waves. A set of wire-mounted steel balls is used as impact sources. These impactors allow effective excitation of impact-echo resonance in concrete without generating excessive acoustic noise. The slab vibrations set up by the impact source are detected by the microphone and the signal is then digitized by a digital oscilloscope. Each transient signal is collected for duration of 4 ms with a sampling interval of 1μs. A Labwindows® program was developed to facilitate signal acquisition and analysis.

Figure 1 shows typical signals obtained using the air coupled sensor, as compared to those collected with a conventional contact sensor. The signals were collected from a concrete slab that contains a shallow delamination (60 mm depth) defect. Both sensors indicate the delamination flexural mode at 2.83 kHz, but only the air-coupled sensor detects the high frequency impact-echo mode at 33.2 kHz. Thus the air-coupled sensor is function, and in fact is superior to the contact sensor in this case.

Test Specimens

Two steel-reinforced concrete slabs were cast. The slabs are nominally 0.25 m thick with 1.5 m by 2.0 m lateral dimensions. Slab No. 1 contains two continuous embedded ducts: one plastic (wall thickness = 5 mm) and one metal (wall thickness = 1 mm). Each duct is divided into three sections: fully-grouted, half-grouted and ungrouted. The voids in the half-grouted regions are simulated by foam inserts. The diameters of both ducts are 70 mm, and the centerlines of the ducts are 125 mm below the surface.

Slab No. 2 contains artificial delaminations and voids of varying size and depth. Since the loading capacity of the slab is significantly reduced by the artificial defects, the slabs are reinforced in two dimensions and at two layers. The top layer of steel bars is supported by five steel chairs. The concrete cover thickness is 60 mm. Metal wire mesh (150 by 150 mm) was placed above each rebar layer. Artificial delaminations were simulated by embedding six double-layer plastic sheets. Three double-layer sheets are located 60 mm below the surface (top sheets), and three 200 mm below the top surface (bottom sheets). The actual depths of the sheets were measured in the slab form before casting concrete. Internal voids were simulated by embedding 300 mm and 100 mm diameter soft foam blocks. The plastic sheets and foam blocks were secured to the wire mesh with tie wire.

The P-wave velocity measured by UPV test is 4100 m/s, which results in a nominal full-thickness impact-echo frequency of 7.81 kHz, according to Eq. (1).

Experimental Results

Delamination Detection. A 2-D scanning test was carried out over the entire area of slab No.2 (200 cm by 150 cm). The measurement grid spacing is $\Delta x = \Delta y = 10\ cm$ in both directions; therefore in total $19 \times 14 = 291$ signals were obtained. (No data were collected along the slab edges.) The contact-less property of the sensor allowed efficient scanning of the specimen. Data were collected along parallel scan lines. A 2-D matrix composed of the peak frequency of a signal's amplitude spectrum for each testing location is used for image construction. The locations and areal size of most of the defects are identified in the image. For large and shallow delaminations and voids, the approximate areal size of damage regions are determined, and agree well with the actual areal size. In this case, the peak frequencies are significantly lower than the full-thickness impact-echo frequency 7.81 kHz. The vibrations are dominated by low frequency flexural resonant modes. For the small defects, the image shows frequencies that are slightly lower than the normal full-thickness frequency; this indicates the possible presence of small defects. Although the size and depth of the small defects cannot be accurately determined, they can still be differentiated from the surrounding solid regions. White spots (high frequency) are observed over two defects, which indicate existence of deep delaminations. However, the areal size of the defects cannot be accurately determined; the high frequency corresponding to the impact-echo resonance set up by deep delamination is observed only within a small region near the center of damaged area. The peak frequency shifts to a lower frequency when the test point is located over edges of the defect.

Duct Void Detection. Air-coupled impact-echo tests were carried out over slab No. 1 to examine the grouting quality of the ducts. Line scans were first conducted above and along the centerline of the ducts to investigate the ability to differentiate grouted from ungrouted ducts. The scan line starts at the ungrouted end and moves to the fully-filled end. The spacing between measurement points along the scan line is 5 cm.

Figure 2 shows the air-coupled impact-echo line scan image across the plastic and metal ducts along three different scan lines, across ungrouted, partially-grouted and fully grouted conditions respectively. At each test point along the duct, the impact-echo frequency amplitude spectrum is plotted in gray scale, where dark color indicates high amplitude and light color low amplitude. A line scan image is then constructed by stacking the spectra from all test points along the ducts; this image configuration is also known as a "B-scan". To improve contrast of the image, the amplitude spectra data are raised to the 4th power.

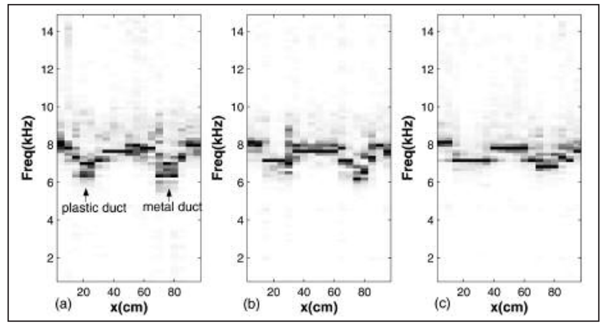

Figure 2. Air-coupled impact-echo scans across the centerlines of the plastic and metal ducts: (a) ungrouted section, (b) half-grouted section and (c) fully grouted sections.

At metal duct locations, the peaks of the amplitude spectra shift to lower frequency range as expected. The duct locations can be identified on the images, even in the fully-filled sections. Although the peak frequencies from the ungrouted and half-grouted duct sections appear lower than that at the fully-grouted section, it is difficult to differentiate the type of duct and the internal grouting condition. The images show distinction between the fully-grouted section and the remaining sections of the metal duct. The fully-grouted sections show higher frequency than the ungrouted and half-grouted sections, which indicates higher slab stiffness in the fully-grouted section (Sansalone and Streett, 1997). Although there are some differences between the ungrouted and half-grouted sections, it is difficult to differentiate them because the difference in frequency is small.

The grouting condition within the plastic duct cannot be determined conclusively from the line scan image. The same limitation also applies to the conventional contact impact-echo test. The geometry of the duct itself likely causes this behavior. The thick-walled plastic duct is much more rigid than the thin-walled metal duct. Thus the grouting condition within the duct has relatively little contribution to the overall stiffness of the slab in the duct regions. Therefore the impact-echo scans cannot conclusively differentiate sections with different grouting conditions within rigid ducts.

Summary

Air-coupled sensing offers an approach for rapid and effective evaluation of concrete structures through imaging. Multiple point data that are presented together in an image provide more diagnostic information than the same data evaluated individually. In 2-D impact-echo scan images, flexural resonances from shallow delaminations allow accurate definition of defect areal size. The depth of shallow delaminations cannot be determined directly from the flexural resonance frequency. The areal size of deeper defects, which are set up by impact-echo resonance, cannot be determined precisely although a boundary of low frequencies around high can provide some guidance to size. The depth of deep defects can be determined directly from the impact-echo resonance frequency when measured above the center of the defect. Impact-echo line scans along the axis of an internal duct can provide comparative information about the grout filling condition of thin-walled (compliant) ducts; fully-grouted sections can be identified and differentiated from partially-filled and empty sections. The filling condition of thick-walled (rigid) ducts cannot be determined from the impact-echo line scans. ❖

Acknowledgments

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References

Carino, N. J., Sansalone, M. and Hsu N. N., 1986, A Point Source-Point Receiver, Pulse-Echo Technique for Flaw Detection in Concrete: *ACI Materials Journal*, 83, 199–208.

Gibson, A. and Popovics, J. S., 2005, Lamb Wave Basis for Impact-Echo Method Analysis: *ASCE Journal of Engineering Mechanics*, 131, 438–443.

Popovics, J. S. and Zhu J., 2006, Air-coupled impact-echo imaging of concrete decks and slabs: in *Proceedings of the 2006 Highway Geophysics Conference*, edited by N. Anderson. The University of Missouri-Rolla, Rolla Mo.

Ryden, N., Lowe, M., Cawley, P. and Park, C., 2006, Non-contact surface wave measurements using a microphone: *Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP 2006)*, Seattle, April 2–6, 2006.

Sansalone, M.J. and Streett, W.B., 1997, *Impact-echo — Nondestructive Evaluation for Concrete and Masonry*, Bullbirer Press, Ithaca, NY.

Zhu, J., 2005, Non-contact NDT of concrete structures using air-coupled sensors, Ph.D. dissertation, the University of Illinois at Urbana.

Zhu, J. and Popovics, J. S., 2001, Non-contact detection of surface waves in concrete using an air-coupled sensor: *Review of Progress in Quantitative Nondestructive Evaluation*, 20B, edited by D.O. Thompson and D.E. Chimenti, 1261–1268. American Institute of Physics, Melville, NY.

Zhu, J. and Popovics, J. S., 2005, Non-contact imaging for surface-opening cracks in concrete with air-coupled sensors: *Materials and Structures*, 38, 801–806.

For More Information

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Farshad Rajabipour

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pioneering structural engineering firms in Tehran: Pasilo Engineering Consultants and Hexa Engineers. At these companies, I was a design engineer for highway concrete bridges and retaining walls. I worked as part of a team of engineers responsible for design, construction management, and quality control for a number of high-rise concrete buildings, bridges, and pavements in Tehran.

During these years, I realized that although we were using state-of-the-art design specifications for static and seismic loadings, we were effectively treating the material as a black box by only considering the compressive strength and occasionally the elastic modulus in our designs. As a result, the structural designs were accurate, however the concrete would deteriorate after only a few years in service, causing significant serviceability problems. I was curious as to why prescribing higher-strength concretes helped very little if any in alleviating these problems.

With these thoughts in mind, I started graduate school at Purdue in August 2001 in civil engineering and construction management programs, with an emphasis on cement-based materials. In December 2003, I earned my master's degree and enrolled in the Ph.D. program. During the past four years, I have worked under the advisement of Professor Jason Weiss on a project on sensor development and material health monitoring for the purpose of condition assessment and durability performance prediction of concrete

Farshad measuring the electrical response of a concrete slab to monitor moisture transport.

structures. During this research, which has been funded by the National Science Foundation, I realized that to assess the health of concrete, in situ sensors must provide information on three aspects: 1) the material's microstructure; 2) internal chemistry, and 3) the state of moisture inside concrete.

A four-component sensing system was developed including three electrical conductivity-based sensors (measuring concrete conductivity, pore solution conductivity, and relative humidity) and a temperature sensor. Measurements from these sensors are combined and analyzed simultaneously to estimate several material properties (e.g., permeability and ion diffusivity), and state parameters (ion concentrations, humidity, and moisture content) of concrete. The process of development of this sensing system has been documented in my Ph.D. dissertation, which was completed in August 2006.

In addition to this research component, during my time at Purdue, I was interested in understanding how students learn and how teaching techniques can be tailored accordingly to enhance learning. Specifically, it has become evident to me that the first step in the learning process is getting motivated. I experienced that students become extremely interested when they are faced with real-world problems and can discuss how science and engineering can be applied to solve these problems. By including students in these discussions, they become active participants in their learning.

To further this approach, we have recently worked on using a problem-based peer interactive learning methodology which makes use of a student response keypad (i.e., clicker) system. In this methodology, students discuss questions in pairs or groups and improve their learning by developing arguments to convince others of their position. Meanwhile, the instructor is able to monitor students' learning during the lecture. While this method was received positively by students, it was also acknowledged and recognized with an award by the American Society for Engineering Education during the Midwest section conference in September 2005. ❖

News Briefs (continued from page 2)

- **Zachary Grasley**, University of Illinois at Urbana-Champaign; David Lange, advisor; Ph.D. dissertation, "Measuring and Modeling the Time-Dependent Response of Cementitious Materials to Internal Stresses." Grasley is now Assistant Professor of Civil and Environmental Engineering at Texas A&M University.
- **Robert Rodden,** University of Illinois at Urbana-Champaign; David Lange, advisor; Ph.D. dissertation "Analytical Modeling of Environmental Stresses in Concrete Slabs"
- **Benjamin Birch,** University of Illinois at Urbana-Champaign; David Lange, advisor; M.S. thesis "Formwork Pressure Exerted by Self Consolidating Concrete"
- **Salvador Villalobos Chapa,** University of Illinois at Urbana-Champaign; David Lange, advisor; M.S. thesis "Fracture Properties of Concrete and Determination of Saw-cut Timing and Saw-cut Depth of Concrete Pavements"
- **Qiang Li,** University of Illinois at Urbana-Champaign; Leslie Struble, advisor; M.S. thesis "The Alkali Silica Reaction: XRD, NMR, Optical and SEM Examinations of Mortar Samples at Room Temperature." Qiang Li has taken a position at CTLGroup.
- **Kambiz Raoufi,** Purdue University; Jason Weiss, advisor; M.S. thesis "Saw-Cutting Guidelines for Concrete Pavements: Examining the Requirements for Time and Depth of Saw-Cutting"
- **Gaurav Sant,** Purdue University; Jason Weiss, advisor; M.S. thesis "Examining Volume Changes, Stress Development and Cracking in Cement Based Systems"

Raissa P. Ferron was selected as the inaugural winner of the 2006 ASTM International Katherine and Bryant Mather Scholarship. Raissa is a Ph.D. candidate at Northwestern University and a research assistant in the Center for Advanced Cement-Based Materials. She is conducting her research under the advisement of Professor Surendra P. Shah, and her dissertation focuses on understanding the mechanisms controlling flocculation and thixotropy of cementitious materials during the early stages of hydration.

Andrew Allen of NIST and **Jeff Thomas** and **Hamlin Jennings** of Northwestern had their paper "Composition and density of nanoscale calcium-silicate-hydrate in cement" published in the April 2007 issue of *Nature Materials.* ❖

BUILDING *bridges*

by Jason Weiss, Associate Director

Bridging the Gaps Between Research and Application

ACBM has a three-fold mission of research, education, and technology transfer dedicated to the cement and concrete industries.

Unfortunately, scientific research is frequently observed to be slow in finding its way to real world applications. This is partly due to the difference in the research priorities of academic and industry groups. Industry is frequently driven by imminent daily needs that are driven by their customers while academic research is frequently driven by personal curiosities. ACBM seeks to bridge this gap by providing a platform where research needs and ideas can be exchanged between industry professionals and academics. This enables industrial members to shape the research interests of the academic researchers by identifying the most challenging real-world problems. This provides an excellent opportunity to engage a broad group of researchers with diverse backgrounds that can seek solutions that meet both the immediate needs of industry as well as planning for the future.

ACBM recently has been conducting break-out sessions to discuss industry needs in an effort to develop research programs that can address these needs. During 2006–07, ACBM has conducted research in two main areas: 1) Early Age Concrete Behavior and 2) Self Consolidating Concrete. The early-age research group focused on development of new testing procedures to assess early age property development. Researchers from various labs have tested a common cementitious mixture using a wide variety of early age testing and computer simulations. In addition, several researchers have investigated procedures that will dramatically improve how construction operations are scheduled. This work comes from state-of-the-art computer simulation of early age and fracture behavior of concrete pavements. The self-consolidating concrete research has focused on development of improved scientific understanding of the behavior of self-consolidating concrete. This includes an improved understanding of rheological test methods, improved mixture design that can enable more robust concrete mixtures, and a better understanding of how concrete form pressures develop.

In Spring 2007, industrial professionals, students, and faculty exchanged ideas that will refine the research program in the upcoming year. The ACBM group will focus on three overarching goals of the concrete industry: 1) making concrete more environmentally friendly without any reduction in performance, 2) the development of early age tests to predict long-term performance, and 3) removing barriers that impede the use of self-consolidating concrete. Toward this end, ACBM researchers have formed several smaller working groups to develop plans to bridge gaps between research and application in five main areas:

- self-consolidating concrete (lead: David Bonen),
- early age crack reduction (lead: Jason Weiss),
- permeability measurement (lead: Farshad Rajabipour),
- environmental impact and use of supplementary materials (lead: Will Hansen), and
- models for performance (lead: Hamlin Jennings).

Over the next six months, each working group will assess the current state of knowledge in each of these topics. During this critical review, they will determine the gaps that exist in the current understanding of these fields that are essential to solving the most critical industry problems. The working groups will then develop a plan to address the research that is needed to move the field forward. By formulating teams with diverse backgrounds and expertise, the fall semi-annual meeting (October 3–4) will provide an exciting plan that will show how research can build a bridge to the future. ❖

Industry Professionals Select Poster Winners at Semiannual Meeting

Recently, ACBM held its Spring Semiannual Technical Review. These meetings are designed to foster an exchange between ACBM researchers and industry representatives. The agenda included technical presentations by faculty from both ACBM's U.S. research consortia as well as international participants.

A panel of industry representatives also discussed the education and training of students today for successful careers in the future. Mohammad Khan of PSI, David McDonald of USG, and Phil Dyer of St. Gobain each presented their thoughts on this timely subject.

At each Semiannual Technical Review, students and post-docs present posters on the research they are conducting at their home institutions. There were 21 posters in total. The industry representatives vote to pick the top three of the group. The top three winners for the Spring meeting were:

- First Place: **Paramita Mondal,** Northwestern University, "Characterization of Cementitious Materials at Nano-Scale"
- Second Place: **Aleksandra Radlinska,** Purdue University, "Shrinkage-Based Design Approach for Concrete Mixtures"

Paramita Mondal

Aleksandra Radlinska

Matthew D. D'Ambrosia

- Third Place: **Matthew D. D'Ambrosia,** University of Illinois, "Properties and Performance of Design Optimized Concrete." ❖

ACBM / NIST To Hold Computer Modeling Workshop

The 18th annual ACBM/NIST Computer Modeling Workshop will be held June 25–27, 2007 at the National Institute of Standards and Technology in Gaithersburg, Maryland. The focus of the workshop is on cement-based materials, showing how microstructure development during hydration and subsequent properties can be computed with three-dimensional models. An emphasis of the workshop is how experimental materials science data can combine synegeristically with computational materials science results to help solve the complex problems of concrete.

The three-day workshop is tutorial in nature and is intended to be useful both to those who do experimental work and would like to learn how computer models can contribute to their research, as well as to those who do computer modeling. The workshop is sponsored by the ACBM Center, NIST, and ASTM Committees C01 and C09.

The workshop lectures will cover computational experimental materials science and concrete topics, including simulation of microstructural development and prediction of physical properties. Microstructure ranges from nanometer to meter length scales, while physical properties include pressure-driven fluid flow, rheology, mechanical properties, neutron scattering, scanning electron microscopy, and various X-radiation probes like diffraction and tomography. Close cooperation between computation and experiment is crucial for making progress in the materials science of concrete and so is an emphasis on the workshop. There also will be coverage of the Virtual Cement and Concrete Testing Laboratory. The workshop will have a mix of tutorial lectures and short 15-minute talks by participants describing their technical work.

Instructors include: Edward Garboczi, Dale Bentz, Jeff Bullard, Nicos Martys, Paul Stutzman, and Kenneth Snyder, all from NIST Materials and Construction Research Division; Richard Livingston, Federal Highway Administration; Zachary Grasley, Civil Engineering, Texas A&M University; Jeff Thomas, Civil and Environmental Engineering, Northwestern University; and George Scherer, Civil Engineering, Princeton University.

There is no registration fee to attend the workshop, but pre-registration is required. Registration information can be found on the NIST website at http://ciks.cbt.nist.gov/monograph (click on 2007 Workshop). The deadline to register is June 11, 2007. ❖

CALENDAR

More information on all ACBM events can be found on the ACBM website.

June 18–20, 2007
ACBM / PCA Faculty Enhancement Workshop
Portland Cement Association
Headquarters, Skokie, IL
Website: www.acbm.info

September 3–5, 2007
SCC 2007 Fifth International RILEM Symposium on Self-Compacting Concrete
Ghent, Belgium
Website: www.scc2007.ugent.be

December 12–14, 2007
Advances In Cement Based Materials and Applications in Civil Infrastructure
Lahore, Pakistan
Website: www.acbm-aci.org

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