CONCRETE PAVEMENT CPTP TECHNOLOGY PROGRAM

Concrete Pavement Technology Update

www.fhwa.dot.gov/pavement/concrete

CPTP provides new technology for loan to State highway agencies. Shown above, MIT Scan-2, a nondestructive testing device for evaluating dowel or tie bar placement, is available through the loan program. Maturity testing systems and impact-echo devices are also available for loan or demonstration (see page 6).

The Concrete Pavement Technology Program

CPTP is an integrated, national effort to improve the long-term performance and cost-effectiveness of concrete pavements by implementing improved methods of design, construction, and rehabilitation and new technology. Visit www.fhwa.dot.gov/pavement/concrete for more information.

About CPTP Updates

The CPTP Update is one facet of CPTP's technology transfer and implementation effort. Updates present new products and research findings that emerge from CPTP studies. To place your name on the mailing list, call (202-347-6944), fax (202-347-6938), or e-mail (dblumenthal@woodwardcom.com).

In This Update

U.S. Department of Transportation
Federal Highway Administration

Paving Concrete: Yesterday, Today, and Tomorrow

Concrete technology is continually changing and growing with numerous researchers and practitioners seeking ways to make pavements that are more cost effective, longer lasting, and safer, smoother, and quieter. Some of the developments related to concrete that are being researched and implemented include:

- Use of increasingly complex mixtures containing a number of cementitious materials and chemical admixtures.
- Optimization of paving mixtures (e.g., dense grading).
- Improved test methods to track concrete properties with time (e.g., maturity and compatibility).
- Increased understanding of factors that affect noise and how to control them.
- Application of specifications addressing materials variability.
- Education of personnel in the field, so they can troubleshoot problems early in the process.

Many of these research initiatives have been funded or supported through CPTP.

Not Your Father's Concrete

The concrete used in pavements today is similar in many ways to the product used in the first pavements built in the early 1900s (it still contains portland cement, sand, gravel or crushed stone, and water), but in other ways it is significantly different:

- Chemical admixtures are included in almost all paving mixtures to modify the water content or workability of a mixture. These admixtures greatly facilitate construction and normally lead to improved performance and reduced costs.
- Air is deliberately entrained in all cold-climate pavements to improve freeze-thaw resistance.
- Supplementary cementitious materials (SCMs) are now used in most concrete pavements to enhance concrete performance and durability while reducing costs and helping to reduce disposal issues.

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Accelerated schedules, extended construction seasons, and more stringent cost controls have led to the use of more complex and less forgiving mixtures.

To address the need to understand and control the variabilities inherent in increasingly complex mixtures, new processes and procedures are being evaluated in CPTP projects.

Mix Optmization Workshop

CPTP offers a workshop focused on the compatibility of concrete mix materials and related variables. The workshop covers new procedures and technologies used to optimize mixes, monitor and control concrete variability during construction, and predict long-term strength and durability.

The workshop will be presented in Kansas City, MO, on March 1 at an ACPA Missouri-Kansas Chapter conference and in Oklahoma City, OK, on March 15, sponsored by the ACPA Oklahoma Chapter and the Oklahoma Department of Transportation.

For more information on attending or scheduling a Mix Optimization workshop, contact Shiraz Tayabji (STayabji@CTLGroup.com).

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- More recently, ternary combinations of SCMs have been employed to gain the benefits of more than one material.
- Cement chemistry has changed, mainly leading to higher early strengths.
- Combined aggregate grading is being optimized, leading to a reduction in required cement content and improved mixture properties.

At the same time, practitioners have been demanding tighter and tighter requirements on the concrete in order to accelerate construction rates and extend the construction season while still reducing costs. Specifically, tighter limits on the fresh properties (workability), setting times, early strengths, crack prevention, and durability of our pavement mixtures are being demanded.

The increasing complexity of mixtures, combined with greater demands, has led to the use of systems that are less forgiving. Consequently, there is a strong need for better understanding of the material, more information about how each mixture will perform, and tighter controls on variability.

Some new processes and procedures that have been developed to address these needs include the following:

- A protocol to assess the risk of incompatibility for a given set of mixtures. Incompatibility is when a combination of normally acceptable materials interact in a given environment to cause unexpected and unacceptable mixture performance, and it has become a greater risk as increasingly complex mixtures are used. Incompatibility is typically exhibited as problems with stiffening and setting rates of the fresh concrete and with a change in the air-void system.
- Models that will help optimize the proportions for a given mixture based on the materials available while achieving the required performance, both in the fresh and hardened concrete.
- Specifications that are centered on the performance of the concrete rather than setting out a recipe. These specifications depend upon appropriate tests being available to measure the performance required.
- Methods that allow field monitoring of the hydration of the cementitious system (e.g., maturity). These tools allow contractors to optimize the timing of their finishing and saw-cutting activities. Models (e.g., HIPERPAV™) are also available that assist in assessing the risk of cracking in the environment, and provide guidelines on actions to take to minimize these risks.
- Improved guidance on pavement curing. The need for curing to achieve adequate durability is well known, and work continues on developing tools to assess when curing should commence, and if necessary, when it can stop. If curing compounds are applied to a concrete surface before bleeding has stopped, rising water can disrupt the membrane, leading to a weak surface layer. On the other hand, if bleeding is slower than the rate of evaporation, the risk of plastic shrinkage cracking is significantly increased. Approaches to address these concerns have been developed and disseminated.

Test Methods

In order to track the performance of a concrete mixture, several innovative approaches have been developed and are being implemented:

- The air void analyzer is an instrument that reportedly can assess the quality of the air void system in fresh concrete. A sample of mortar can be extracted, after compaction of the mixture in the paver, and placed in the instrument. After 30 minutes, a spacing factor is reported, based on the rate at which bubbles are released from the mortar as it is agitated. Reports of the correlation between the results from this approach and using a hardened air determination are mixed, but the instrument may well provide useful information on the uniformity of concrete delivered, and on the effects of vibration on the air void system of the finished product.

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HIPERPAV II Wins ACPA Recognition

The American Concrete Pavement Association awarded its 2005 Marlin J. Knutson Award for Technical Achievement to the Federal Highway Administration and The Transtec Group for their "contributions in developing this unprecedented software," HIPERPAV II (HIgh PERformance PAVing software).

HIPERPAV, a one-of-a-kind tool capable of predicting the early-age behavior of concrete pavements, successfully integrates construction materials, pavement design, construction operations, and environmental conditions into an easy-to-use, Windows-based, software package. Using a systems approach, the software considers all factors influencing concrete pavements to predict a pavement's strength and stresses during the first 72 hours after construction.

An updated and expanded version of HIPERPAV was released in 2005. As in the first edition, HIPERPAV II provides guidance on the design and construction of concrete pavements and helps users anticipate and prevent pavement performance problems. HIPERPAV II also incorporates guidelines for the proper selection of design and construction variables to minimize early-age damage to jointed plain concrete pavement (JPCP) and continuously reinforced concrete pavement. In addition, the software can be used to determine the effect of early-age behavior factors on the long-term performance of JPCP. The new version also provides the capability to optimize concrete mix designs to meet specific performance criteria and predict early-age behavior of dowel bars in rigid pavements. The software, the accompanying three-volume documentation (project summary, user's manual, and technical appendices), and HIPERPAV II workshops are available through FHWA (see sidebar).

HIPERPAV II is used by pavement planners, designers, and contractors in the public and private sectors across the United States and around the world for a wide variety of functions. Planners can develop quality control specifications for projects based on available materials and regional climatic conditions, and designers can optimize pavement designs so that a better pavement is constructed with improved long-term pavement performance.

Contractors can use the software package to increase pavement performance and to prevent expensive pavement repairs. For example, unexpected changes in the weather can have a dramatic influence on strength development and stresses within the pavement. Using HIPERPAV II, the impact of these changes can be quantified, and an alternative construction time or curing method can be implemented to reduce or prevent pavement damage. In addition to its use in planning and developing projects, HIPERPAV II is also being used as a forensic tool to analyze pavement damage and poor pavement performance.

As HIPERPAV's success has grown, some State highway departments are beginning to require its use in projects. For example, the Ohio Department of Transportation (ODOT) specifications (Section 451.08) require contractors to use HIPERPAV prior to construction operations to prevent early-age cracking of concrete. For more information please refer to ODOT's Web site: www.dot.state.oh.us/construction/OCA/Specs/SSandPN2005/103307152005%20for%202005.pdf#search+'HIPERPAV.

For more information, contact Fred Faridazar at FHWA (202-493-3076; fred.faridazar@fhwa.dot.gov) or Mauricio Ruiz at The Transtec Group (512-451-6233; mauricio@thetranstecgroup.com).

HIPERPAV II software—available on CD and downloadable from the FHWA Web site: www.fhwa.dot.gov/pavement/pccp/hipemain.cfm.

Free Training on HIPERPAV II

Highway agencies can schedule a one-day workshop on HIPERPAV II through the FHWA Resource Center. The training provides an overview of the HIPERPAV II project and software, as well as hands-on experience using HIPERPAV II to solve realistic case studies that demonstrate the software's capabilities.

The hosting agency is asked to supply a copy of the presentations for each participant and a training room with enough computers for the participants to work the case studies.

To schedule a HIPERPAV II workshop, contact Angel Correa (404-562-3907; angel.correa@fhwa.dot.gov) or Gary Crawford (202-366-1286; gary.crawford@fhwa.dot.gov).

HIPERPAV II Documentation

Computer-Based Guidelines for Concrete Pavements

Volume I (FHWA-HRT-04-121), Project Summary.

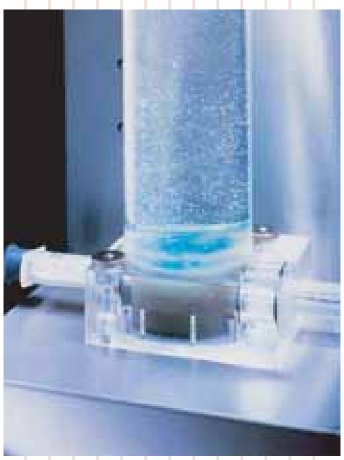
Volume II (FHWA-HRT-04-122), User's Manual.

Volume III (FHWA-04-127), Technical Appendices, which document investigation, modeling, validation, and software.

Maturity Documentation

The CPTP TechBrief, *Maturity Testing for Concrete Pavement Applications* (FHWA-IF-06-004), describes a maturity method for predicting concrete strength at early ages, basic maturity concepts, expected benefits, needed equipment, and guidelines for use on a concrete pavement project.

Rheometers provide useful information about the risk of early or late stiffening and setting.



The air void analyzer is under investigation as an approach to evaluating the uniformity of delivered concrete and the effects of vibration on the air void system of the finished product.

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- A number of devices and systems are available that track and report the development of heat in concrete over time. These data are used to calculate the maturity of the hydrating system, which provides useful information about strength development. The temperature data can also be used as inputs to the models that estimate cracking risk and to confirm that the cementitious system is indeed hydrating as it should.
- Work is continuing on using various methods to determine the rheology of the mixture and how it changes with time. A device that is currently used to monitor asphalt products (and is therefore in many State DOT laboratories) can be modified to provide useful information about the risk of early (or late) stiffening and setting in a mixture.

Methods are also being developed to assess the condition of the hardened concrete:

- The smoothness of a pavement is the parameter that is most obvious to the user, in terms of the noise generated (fine scale) and in the feeling of motion sickness (coarse scale). Devices and methods of measuring these parameters have been developed and evaluated and are being implemented.
- Tools are becoming available that are able to locate the position of dowel bars with increasing accuracy. This is important to ensure that adequate load transfer is provided across joints, thus increasing the life of the pavement.
- Some authorities are starting to use parameters other than strength as pay factors in order to encourage the use of mixtures with improved durability. One such parameter is the spacing factor of the air void system, measured in the hardened concrete using microscopical methods. Another parameter being considered is the uniformity of the grading of the combined aggregates based on sieve analyses.

High Early Strength

In addition to work focused on everyday paving, considerable attention has been focused on high early strength concrete for overnight repair applications. Such mixtures are often based on proprietary systems using specialized cements or on carefully proportioned mixtures using conventional cementitious materials with chemical admixtures and possibly accelerated curing. These efforts have meant that repairs can be conducted in pavements overnight, thus minimizing disruptions to the users and significantly improving safety to the construction team.

Implementation and Education

An integral part of any new approach, protocol, or test method is its implementation. The CPTP is providing implementation support through a number of different methods:

- Publications to educate users on the tools available to them, and on the best practices they should be following. Target audiences for these documents range from designers and specifiers through senior technicians and engineers at the construction site.
- Training courses ranging from 1-hour sessions to multi-day seminars. These courses have been developed and presented to State, local authority, and trade association gatherings. The CPTP implementation project is providing resources for the training to be made available to those involved in pavement construction.
- Software programs that address some of the models discussed above.
- Field demonstrations and equipment loans (see page 6).

Smoother Pavements to Come

Research to improve concrete pavement ride quality for automobiles and commercial vehicles (CPTP tasks 16, 53, 62, and 63) supports FHWA's national goal to significantly improve pavement smoothness on the National Highway System by the year 2008. The research is aimed at resolving specific issues unique to portland cement concrete (PCC) pavements:

- Improve smoothness criteria, addressing the effect of texture and joints on ride quality.
- Develop guidelines on the effects of material properties to assist highway agencies and contractors.
- Minimize slab curvature (and faulting) to improve ride and reduce the rate of structural deterioration.

The LTPP GPS-3 experiment showed that adjustments in design features, materials properties, and construction procedures provide smoother-built pavements with longer service life (see *Achieving a High Level of Smoothness in Concrete Pavements Without Sacrificing Long-Term Performance*, FHWA-HRT-05-069).

In terms of design features, dowels are recommended whenever there is the slightest chance that joint faulting will occur. Even with dowels, performance appears to be enhanced when slab lengths are 4.8 m (16 ft) or less.

For both doweled and non-doweled pavements, using PCC with higher flexural strength seems to be beneficial for maintaining long-term smoothness. For non-doweled pavements, conditions that are detrimental to long-term smoothness are higher elastic modulus values (greater than 35,000 MPa [5 million psi]) and ratios between elastic modulus and splitting tensile strength of greater than 8000. Those trends do not apply to doweled pavements. Further evidence suggests that higher ratios of coarse to fine aggregate in the concrete mixture result in pavements that maintain their smoothness over longer periods.

Among the construction issues addressed in FHWA-HRT-05-069 is the use of dowels and tiebars attached to chairs and fixed to the pavement base as opposed to those placed by an inserter mounted on the paver (see *PCC Pavement Smoothness: Characteristics and Best Practices for Construction*, FHWA-IF-02-025, and *Constructing Smooth Concrete Pavements*, ACPA Technical Bulletin TB-006.0-C, for guidelines). Although the fixed bars may generally be more costly, test results indicate that a smoother pavement may result.

The measurement of pavement smoothness is another key issue. The surface of the pavement must be clean when profile measurements are performed. Any residue from joint sawing or other operations should be removed prior to profiling. Further, profiles should not be measured when the joint sealant reservoir has been formed but the sealant not yet installed, as the reservoir will appear in the profile data unless a filter that removes the joint from the profile is used. Since filters have not been standardized, profiles are measured differently by different pieces of equipment. Transverse tined sections also can present a problem with some profilers, although new "smaller footprint" lasers may soon alleviate both joint and tine concerns. Finally, profilers scheduled for use on PCC pavements must be certified on PCC pavements. Profilers certified on asphalt surfaces may not produce comparable data because of the way profilers treat the joint and tine issues.

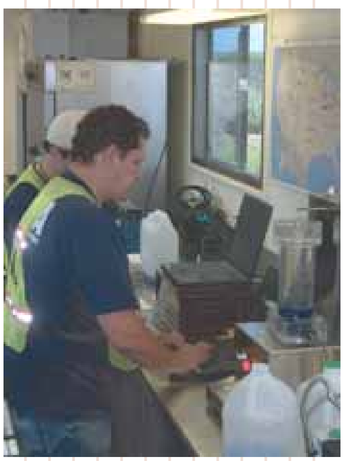
Further information on CPTP smoothness efforts is available from FHWA staff members Peter Kopac (peter.kopac@fhwa.dot.gov) and Mark Swanlund (mark.swanlund@fhwa.dot.gov).

Putting It in Perspective

- Road condition is the public's number one criterion for satisfaction. (2002 FHWA survey)
- Improved smoothness extends pavement performance life by as much as 50 percent. (NCHRP analysis)

Concrete pavement smoothness begins with quality materials and proper proportioning procedures and ends with satisfactory batching, delivery, placement, and curing of the concrete.

CPTP Equipment Loan Program



Above, some of the devices available through the CPTP loan and onsite demo program: MIT Scan-2 dowel bar placement evaluator (demonstrated at the January 2006 Transportation Research Board meeting); DOC-500 impact-echo device; air void analyzer.

To promote the implementation of new technologies, CPTP is providing onsite demonstrations and month-long loans of equipment tested under the program. States will be able to borrow the following devices:

- MIT Scan-2—a nondestructive testing (NDT) device for evaluating dowel or tie bar placement (three devices available). CPTP evaluations showed the MIT Scan-2 to be reliable, efficient, and accurate within reasonable limits for both basket and insertion bar installation methods. The device can be used on fresh concrete and can measure up to 200 joints in an 8-hour shift. FHWA's Sam Tyson characterized the technology as one that can be used at the start of a paving operation to identify and correct dowel misalignment that otherwise could lead to locked joints and early distress.
- Maturity testing system—to estimate in situ concrete strength (three systems will be available). The systems predict concrete strength development with time, provide continuous feedback on curing conditions, and can be used to determine appropriate times for joint sawing or opening a pavement to traffic.
- NDT impact-echo device—used to determine concrete slab thickness and to detect the integrity of concrete (two Germann Instruments DOC-500 units available). The system uses impact-generated waves that propagate through portland cement concrete and are reflected by abrupt changes in internal characteristics (voids, etc.) and external surfaces. Sensing those changes or surfaces enables the equipment to estimate slab thickness and assess integrity.
- Air void analyzer—a device for testing fresh concrete to evaluate the air void system (one available).

Conditions for Loans

- Onsite demonstrations and equipment loans are provided on a first-come, first-served basis.
- Limited onsite training and technical support, if needed, are provided with each loan.
- The basic loan period is 1 month, excluding the time for shipping and training.

The primary purpose of equipment loans is to provide agencies opportunities to evaluate the devices. However, since an important aspect of evaluation is to determine if the devices are practical in actual construction applications, the States may use the devices in limited production work. There are no restrictions on the use of the data collected using the borrowed equipment.

Agency Responsibilities

To help the loan program run smoothly and to further evaluate the capabilities of the equipment, requesting agencies are charged with the following responsibilities:

- Safekeeping of the device while it is in the agency's possession.
- Return shipment of the device to the location designated by FHWA.
- A brief report documenting the agency's experience, to include the following:
  - A description of the evaluation conducted, including photos, if possible.
  - The agency's assessment of the device—whether it was found useful, practical, or not suitable. Include suggestions for improvement, if any.
  - The agency's potential future plans—how the agency may use the device (e.g., as part of a specification requirement, quality control/quality assurance program, or research study).

To Arrange a Loan or Demo

Access the CPTP Equipment Loan Request Form at www.fhwa.dot.gov/pavement/concrete/cptploan.cfm.

E-mail or fax the completed form to Sam Tyson, FWHA (sam.tyson@fhwa.dot.gov; fax 202-493-2070), or to Shiraz Tayabji, CTL Group (STayabji@ CTLGroup.com; fax 410-997-8480).

Precast Prestressed Concrete Pavement – CPTP Project Update

Precast prestressed concrete pavements offer a number of potential benefits to justify their higher initial cost in comparison to conventional slipformed and cast-in-place concrete. The principal benefits of precast pavement construction and rehabilitation include reduced lane closure times and longer pavement life. A section of precast pavement can be placed quickly overnight or during a weekend and can carry traffic immediately. Reduced lane closures and longer pavement life result in lower user costs, reducing the life cycle cost of the pavement.

A pilot project in Texas was constructed on the northbound frontage road of I-35 just north of Georgetown. The project length was 701.5 m (2300 ft) post-tensioned in four equal sections. Individual panels measured 3.1 m (10 ft) in the direction of traffic and had a transverse dimension of 11.0 m (36 ft) including two traffic lanes and pavement shoulders. The project also utilized partial-width panels and transverse post-tensioning at certain locations. The base was a leveling course of asphalt with a thickness of 50 mm (2 in.). The installation rate averaged 25 panels/ 6 hours; 339 panels were installed.

In California, a demonstration project was constructed on eastbound I-10 in El Monte, just before the Meeker Road overpass. The project length was 75.6 m (248 ft) post-tensioned in two sections of equal length. This project utilized 8-ft panels with a width of 11.3 m (37 ft) and a variable slab thickness of 250 to 330 mm (10 to 13 in.). The installation rate averaged 15 panels/ 3 hours; 31 panels were installed.

The Missouri DOT completed a demonstration project in December 2005 on I-57 near Sikeston. The 305-m (1000-ft) installation included three expansion joints for the four equal-length post-tensioned pavement sections. The pre-tensioned panels included a keyway (and matching slot on the opposing face), 18 post-tensioning ducts, a crowned pavement surface, and integral shoulders (see figure at top right). Unlike earlier designs in Texas and California, the keyway in the Missouri design does not continue into the shoulders; however, one of the post-tensioning strands runs through the inside shoulder, and four strands are in the outside shoulder.

A 2006 rehabilitation project in Indiana will use the precast prestressed system to increase clearance at a bridge underpass on Route 13 below I-69 northeast of Indianapolis near Fortville. To improve safety the existing jointed concrete pavement will be removed and replaced with a precast section that is about 100 mm (4 in.) thinner than the jointed design—with a load capacity and long-term performance that exceed that of a typical jointed concrete pavement design.

An innovative use of the precast prestressed pavement system in Texas will incorporate special panels for the installation of weigh-in-motion (WIM) scales. Scheduled for construction during 2006 on the east- and west-bound lanes of Route 175 near Kaufman, the precast design for two lanes in each direction includes panels for 153-m (500-ft) approach sections followed by the special panels that will receive the WIM scales. These panels will be precast with blockouts and fittings to accommodate installation of the WIM scales later. At the precast plant the blockouts will be filled with a low-strength concrete that can carry traffic temporarily and be easily removed when the WIM scales are installed. The Texas DOT anticipates installing WIM scales at some 19 locations, and nationwide there will be several hundred installations during the next few years. Thus the potential for the use of precast panels for this important application continues.

In Iowa, bridge approach slabs will be constructed using precast prestressed pavement. The precast approaches will be attached on a skew to the integral abutments of two newly constructed bridges on Route 60 over the Floyd River near Sheldon. The panels will extend approximately 24 m (80 ft) from the abutment, where an expansion joint will accommodate expansion and contraction of the pavement and the bridge deck.

In the Missouri project, the precast panel depth at the crown is 280 mm (11.0 in.) tapering to a 200-mm (8.0-in.) minimum at either side of the 7.3-m (24-ft) roadway. The integral concrete shoulders taper from the edges of the roadway to 190 mm (7.5 in.) on the inside lane and 150 mm (5.75 in.) on the outside lane.

Dave Merritt, The Transtec Group, presenting "Precast Prestressed Concrete Pavement Applications" at the January 2006 Transportation Research Board meeting.

For more information on CPTP's precast demonstration projects, contact Sam Tyson, FHWA (sam.tyson@fhwa.dot.gov).

CPTP Sponsors the 2006 International Conference on Long-Life Concrete Pavements

Call for Papers

October 25-26, 2006 • Chicago, Illinois

For the conference brochure, see www.fhwa.dot.gov/pavement/concrete

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Transportation Research Board

The steering committee of the International Conference on Long-Life Concrete Pavements has issued a call for papers for the October 2006, 2-day event. Various aspects of concrete pavement design, construction, and materials technologies that result in long-life pavements will be addressed. The conference is targeted at pavement, materials, and geotechnical engineering professionals who are involved in various aspects of concrete pavement design, construction, testing and evaluation, and rehabilitation.

Papers on topics related to long-life concrete pavements are solicited:

- best construction practices
- innovations in materials and construction
- lessons learned from early failures
- improved joint systems
- surface characteristics and drainage requirements
- effective maintenance, repairs, and rehabilitation to extend service life
- life cycle cost considerations
- and other emerging topics

Paper acceptance will be based on peer review of the manuscript (not longer than the lesser of 7500 words or 25 pages). Presentations of a commercial nature or that have been previously published will not be accepted. Submit paper abstracts by March 1 to Seungwook Lim, CTLGroup, 5565 Sterrett Place, Ste. 312, Columbia, MD 21044, USA; e-mail: SWLim@CTLGroup.com; fax: 410-997-8480; phone: 410-997-0400.

The conference venue and hotel are conveniently located near Chicago's O'Hare International Airport. Discounted hotel rooms ($144 plus tax) can be reserved at the Doubletree Hotel in Rosemont using the group reservation code "2006 Concrete Conference." The hotel is adjacent to the conference center. For additional conference or exhibit information, contact Shiraz Tayabji (STayabji@CTLGroup.com; 410-997-0400).

Send address corrections to: Woodward Communications, 1420 N St., NW, Ste. 102, Washington, DC 20005; fax: 202-347-6938; e-mail: dblumenthal@woodwardcom.com.

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January 2006
FHWA-IF-06-029