Research Will REVOLUTIONIZE Concrete Pavement DESIGN

By Tom Kuennen

New concrete 'road map' offers a path to sustainable concrete of the future

Texas Dept. of Transportation photo

Precast concrete U-beams made of high-performance concrete (HPC) await placement on the first HPC bridge project – in 1994 on Louetta Road Overpass over Texas 249 northwest of Houston.

The announcement of a 10-year, 12-track research program for portland cement concrete (PCC) pavements in January 2006 is only the latest milestone on a path to long-lived, durable, environmentally sustainable concrete pavements for the new century.

The Concrete Pavement Road Map is a strategic plan for the spending of some $250 million on concrete pavement research over the next decade. And it's joined by the recent establishment at Iowa State University at Ames of a National Concrete Pavement Technology Center – dubbed the CP Tech Center – which will oversee research being undertaken for the Road Map, and other research.

Concrete research also will be spurred by the new Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, 2005), the Innovative Pavement Research and Deployment Program of which provides $4.1 million in each of six years through 2009 for research to improve concrete pavement for the National Highway System.

SAFETEA-LU also provides funds to research improved aggregates used in highways of the NHS, and also provides money for research on alkali-silica reactivity (ASR), a long-term chemical reaction that can destroy concrete when reactive aggregates are used.

And the CP Tech Center parallels an exciting concrete technology transfer program launched by the Federal Highway Administration (FHWA) in 2003 to promote high-performance concrete pavements, called the Concrete Pavement Technology Program (CPTP). Funded

FHWA PHOTOS

by SAFETEA's predecessor legislation, the Transportation Equity Act for the 21st Century (TEA-21), it's undertaking research, product development, and market outreach of technology that will help end users improve long-term performance – and lower costs – of concrete pavement.

In the meantime, the CP Tech Center will not be undertaking research by itself, but coordinating and supervising research activity, with a goal of facilitating construction of more durable concrete pavements. The center was conducting over $8 million in research projects prior to establishment of the Road Map this January, and the center is looking forward to some $10 million of the concrete research funds provided by SAFETEA-LU to help it leverage funding from other sources.

"The idea of the Road Map came from the industry," said Gerald F. Voight, P.E., president and CEO, American Concrete Pavement Association (ACPA). "The federal government, states, and private industry had ongoing research into concrete pavements, but none of that was coordinated in any way, and this led to delays in implementing new technologies. As a shared activity between federal, state, the academia, and the private sector, the Road Map will break down that barrier."

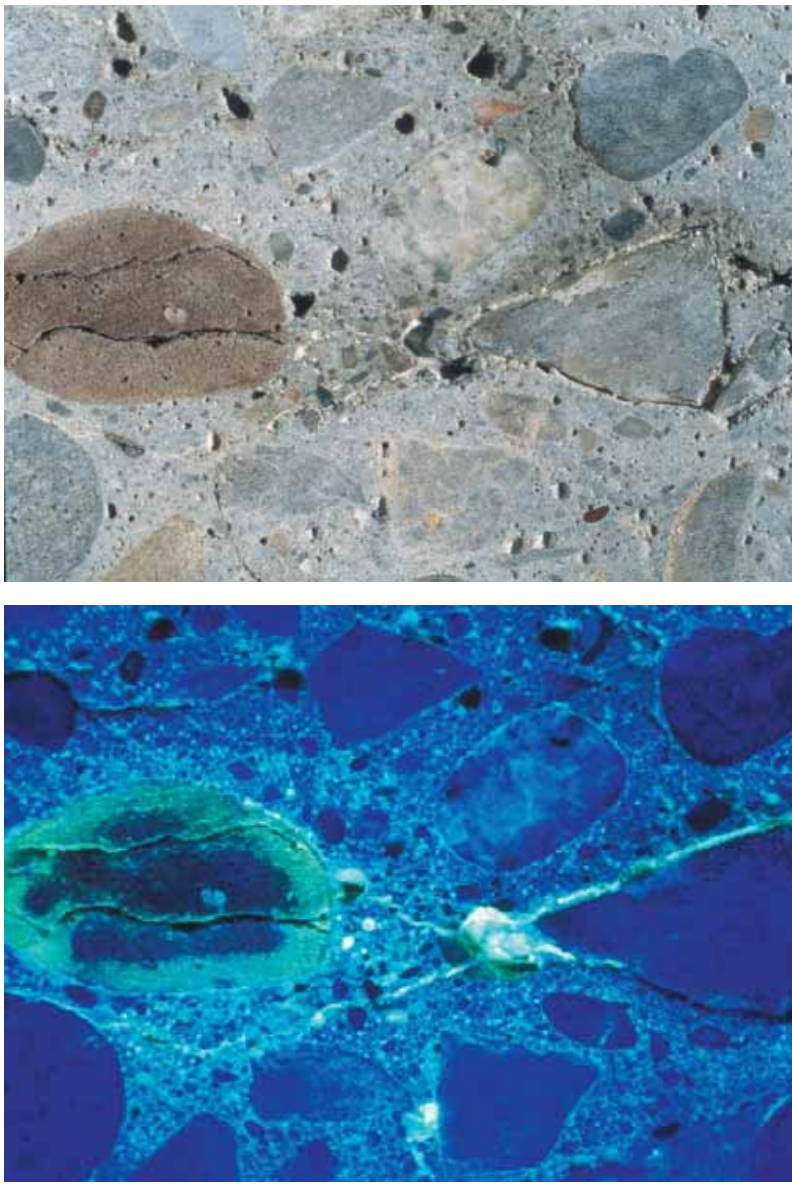
Also, the Road Map will help both public- and private-sector stakeholders get their arms around all the different tasks and issues that need to be addressed to create a consolidated system for concrete pavement research.

"The Road Map brings all the different research needs and brings them to one place, including technical issues, down to business systems that you wouldn't necessarily associate with past research programs," Voight said. "The Road Map will produce a forward-looking, integrated system for design, construction, materials, and preservation of concrete pavements. And because it will be integrated, when a change is made to one focus area, we will understand the impact it will have on the other areas."

"From the get-go, the industry has been shaping the contents of the Road Map," said Leif Wathne, P.E., ACPA director of highways. "It truly has been a partnership between the FHWA, state DOTs, and industry. The Road Map will help optimize our concrete paving practices, from bottom to top, including surface characteristics. It also will help us improve our mix designs, especially using industrial byproducts, which will become more of a priority as we move into more environmentally friendly practices, including recycled concrete, recycled aggregate, or even recycled asphalt pavement."

Elements of the Road Map

Research problem statements are essays from industry stakeholders that describe technical or application issues that need research and resolution, and are solicited to shape the direction of research in the highway community. The new Concrete Pavement Road Map has 12 tracks of research combining more than 250 research problem statements from both the public and private sectors.



Concrete afflicted with alkali-silica reactivity (ASR) – from inadvertent use of reactive aggregates found in virtually every state – exhibits characteristic internal expansion, which cracks the concrete and results in ultimate failure. The bottom photo shows ASR fluorescing under lab conditions, compared to the top photo, which shows the same concrete under normal light. SAFETEA-LU contains funding explicitly aimed at fighting ASR in concrete.

"The concrete industry spent a great deal of time all around the country, participating in outreach efforts," said E. Tom Cackler, P.E., director, CP Tech Center. "To meet the challenges of the future, we needed a guide for our investments and research dollars, and we needed to promote cooperation in a common plan."

FHWA PHOTO

The first of the Road Map's tracks is a Performance-Based Concrete Pavement Mix Design System, resulting in an innovative concrete mix design procedure which should result in the concrete lab of the future. It also will ease the private sector (contractor) element of concrete paving in assuming more responsibility for mix designs, as state highway agencies move from method specifications to more advanced acceptance tools.

It dovetails with the second track, Performance-Based Design Guide for New and Rehabilitated Concrete Pavements, which will expand the mechanistic approach of pavement design from design of new pavements to pavement restoration and preservation strategies. It will build on the existing American Association of State Highway & Transportation Officials *2002 Guide for the Design of New and Rehabilitated Pavement Structures*, also called the mechanistic-empirical pavement design guide.

That guide is part of the shift from designs that begin with "cookbook" specs and finish in the field, to those based on how a pavement will perform in the field, and work backward to the design. Here, "mechanistic" refers to the interaction between the materials and structure of a pavement, and how it stresses and strains under load deflection. The principle relates these pavement mechanics to empirical or experimental performance data obtained in field or lab.

"As time marches on, the number of items of what we can put in concrete grows and grows," Voight said. "Slag, fly ash, cold-weather concrete admixtures, the list goes on and on. Also, the whole industry is changing to a model in which the contractors are responsible for developing the concrete mixes, and the agencies will not be telling them what the recipe is. Contractors now have the responsibility of bringing these materials together, and they need a system that will help them discern what the workability and durability will be for construction, under different temperature conditions. This track will result in a product that will provide a linkage between design, materials, construction, and preservation."

Old-school methods of pavement testing, in which a core sample was drilled from a built pavement and tested in the lab, were destructive. More and more, nondestructive testing in the field before and after construction is desired, because a pavement is not damaged by specimen removal or testing.

The third research track, High-Speed Nondestructive Testing and Intelligent Construction Systems, will develop fast, nondestructive systems to continuously monitor pavement properties during construction, so on-the-fly adjustments can be made to ensure the highest quality finished product that meets given performance specifications.

"The specifiers have driven the need for equipment innovation," Voight said, "and the makers follow rather quickly. This track will study instrumented pavements and new capability equipment that will help us understand what the long-term performance of the pavement will be right up front. That gives the specifier added confidence in the product they're getting."

HPC is for pavements as well. In this photo, high performance concrete pavement is placed on I-40 in North Carolina in 2003.

One beef users have with concrete pavements is that they can be noisy, especially when grooved to improve traction and shedding of rain water. Intensive research is being conducted on how to reduce noise from concrete pavements, and the fourth track – Optimized Surface Characteristics for Safe, Quiet and Smooth Concrete Pavements – will help designers meet or exceed requirements for friction/safety, pavement-tire noise, smoothness, splash and spray, wheel path wear hydroplaning, light reflection, rolling resistance, and durability (longevity).

"The goal of track four is to optimize pavement surface," Voight said. "There is a spectrum with quiet at one end, and skid-resistance at the other, and a balance has to be struck between them. If we put all the emphasis on noise, then you may compromise the safety of the system. Preliminary studies show that the accident rates on concrete are much less than on the other paving medium. We're learning more about this in track four, in which we can create or modify an existing texturing method or surface that will strike that balance without compromising safety."

The fifth track, Equipment Automation and Advancements, is expected to result in improved equipment for high-speed, high-quality paving, utilizing onboard microcomputers, global positioning systems, and much more.

Improving Joint Design

A familiar aspect of concrete pavements are their joints, and the Road Map is investigating how joint performance can be improved through the sixth track, Innovative Concrete Pavement Joint Design, Materials and Construction.

"We know we need [load transfer] dowels in joints," Voight said. "Dowels, by far, have proven to be the most influential performance improvement in the last 25 years. We used to hear the thump-thump as we drove down the road, as individual slabs faulted with respect to each other. That used to be a critical performance issue for the industry. Now, years after they were built, we have very few performance issues with concrete pavements which were built with dowels between the slabs. Now we will look at what we can do to improve the dowel system, including dowel shape, number, spacing, or materials. Can we use fibers to replace dowels? These are the questions we will pursue."

Concrete pavements feature long lives, but fixing concrete pavements often revolves around joint repair. The seventh track, High-Speed Concrete Pavement Rehabilitation and Construction, will address the ways concrete pavement restoration can be made less expensive or time consuming. "The techniques are proven effective, but improvements may be possible through automation and precast technology," Voight said.

The eighth track, Long Life Concrete Pavements, dovetails with the current FHWA emphasis on Highways for LIFE. "We know we can get 30 to 40 years out of a good concrete pavement," Voight said. "The question is, how do we get 60 years or more? A few states have built high-performance concrete (HPC) pavements with a goal of a 50- to 60-year lifespan, using things like stainless steel dowel bars and very-low-permeability mixtures to keep chlorides out of the pavement. We will look at ways to develop long-lived concrete pavements, and ways to lengthen the life of continuously reinforced concrete pavements, which cost more, but perform excellently under very heavy traffic loads."

Performance Data for Future

The ninth track of the Road Map concentrates on Concrete Pavement: Accelerated and Long-Term Data Collection, and will consider the infrastructure needed to collect and report data on lab and real-time testing of concrete pavements. It overlaps with the 10th track, Concrete Pavement Performance, in which concrete will be studied as to its performance in pavement management systems (PMSs) and asset management systems. Such systems are used by road owning agencies to gauge current and future road conditions, and when pavement preservation techniques should be applied to best maximize the "bang for the buck."

"When we implement new pavement designs – varying the features – we need to start collecting data on their performance immediately, so we can gauge their performance and plug them into the design models," Voight said. "Otherwise we will have to wait another 20 to 30 years before we know what that generation of pavement's performance is. We want to start right off the bat in collecting the information we need, not just structural and stress, but surface characteristics, and all other aspects of the pavement."

The 11th track is Concrete Pavement Business Systems and Economics. As government staffs shrink, contractors are being asked to assume more control of the operation and quality control inspections. Owning agencies are including warranty provisions in project contracts, asking for additional assurance that pavements will be built and will perform as expected.

"The agencies are changing," Voight said. "The responsibilities for design are falling more and more onto the contractor. As these agencies change over time, and their technical experience lessens due to

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attrition, the business structure changes. Contractors and consultants are designing and building pavements, rather than the agency designing the structure and the contractor building it. In the future, the contractor will look on the pavement as its asset, to be maintained and preserved. And that favors concrete, because it may cause a contractor to spend a little bit more money up front for an asset that will be longer lasting, like concrete. This track will help our industry be more ready for the big changes of today and the future."

The last track, Advanced Concrete Pavement Materials, will study new materials and refine or reintroduce existing advanced materials that may enhance performance, improve construction, and reduce waste (examples follow).

New Way of Looking at Pavements

"We're looking at pavements a way we've never looked at them before," said Bill Davenport, ACPA vice president, communications and membership. "We're considering some of the macrotrends that are emerging. Ten, 20 years ago, we did not understand the concept of sustainability, confusing it with environmental stewardship. And while stewardship is part of sustainability, sustainability includes other issues, such as societal and business impacts of road building and construction."

"Today – more than at any other time – we're looking at the environmental impact of concrete pavements in the design, development, and construction of surface transportation infrastructure," said Robb Jolly, senior vice president, market development and promotion, ACPA.

"With pavements, a trend is emerging in which people want environmental stewardship, they want the pavements to fit into society without causing a lot of problems, and we're seeing agencies strike a balance," Davenport said. "They are doing more than just making sure an industry complies with only the rules and regulations; they're doing outreach to see what all stakeholders can do together to attain balance, such as the Green Highways Initiative on the East Coast, a recognition program. Who would have thought three years ago that we would be sitting down at the table, proactively, with the Environmental Protection Agency? But it's happening."

For example, a new "Cool Pavement Report: EPA Cool Pavements Study" released in June 2005 describes concrete pavement's capabilities in reducing the "heat island" effect that contributes to urban "hot spots" and heat retention in built areas during summer.

Cities can be several degrees warmer than surrounding regions due to the built environment and the concentration of human activity, a phenomenon referred to as an urban heat island, the study said. "Pavements have become an important contributor to this effect by altering land cover over significant portions of an urban area. Analyses in cities such as Chicago, Houston, Sacramento, and Salt Lake City have shown that pavements for both travel and parking can account for 29 to 39 percent of urban land surface."

Researchers have studied ways to reduce the urban heat island effect, and have identified vegetation, "cool roofing" materials, and "cool pavements" as mitigation strategies.

"Cool pavements can be achieved with existing paving technologies and do not require new materials," the EPA study said last summer. "Possible mechanisms for creating a cool pavement that have been studied to date are increased surface reflectance, which reduces the solar radiation absorbed by the pavement; increased permeability, which cools the pavement through evaporation of water; and a composite structure for noise reduction, which also has been found to emit lower levels of heat at night."

Several conventional paving technologies now exist that can apply these mechanisms, the study added, stating greater reflectance can be provided by conventional concrete, with its high albedo (rate of reflectance), roller-compacted concrete, concrete-over-asphalt ("whitetopping" and "ultra-thin whitetopping"), asphalt concrete and asphalt chip seals with light-colored aggregate, and asphalt pavements with modified color.

Other environmental benefits of high-albedo concrete pavements include reduced need for nighttime illumination. "More reflective pavements can enhance visibility at night, potentially reducing lighting requirements and saving both money and energy," the report says. "European road designers often take pavement color into account when planning lighting needs. Better illumination from lighter pavements is sometimes considered valuable at private establishments as well, for security or customer appeal. Some sources cite nighttime illumination enhancements of 10 to 30 percent with more reflective pavements."

Recycled Materials and HPC

That reclaimed, recycled industrial byproducts are essential elements of the high-performance concrete (HPC) pavements of today is just one more way PCC is showing its environmental sustainability as a paving medium.

Industrial byproducts — which in past years would have been dumped in landfills — now are key components to HPC. An immediate environmental benefit of the use of reclaimed industrial byproducts in concrete is lessened pressure on landfills. Another is that with their use, less cement is needed for a given application, so use of these cementitious byproducts in concrete means a reduction in the amount of energy consumed by the cement manufacturing industry, and parallel reductions in carbon dioxide and water vapor emissions at the cement plant.

And use of these reclaimed materials in HPC provides added value for the owner of the concrete bridges, because these recyclable industrial byproducts — such as coal fly ash, silica fume from glass manufacture, and ground granulated blast furnace (GGBF) slag from steelmaking — result in stronger, more durable structural

American Concrete Pavement Association photo

Constructing the 10.45-mile "missing link" of I-26 in Madison County, N.C., meant building a high-tech concrete highway through some of North Carolina's most rugged terrain. The project won the 2004 Best Highway Project, Divided Highways: Rural Award from the American Concrete Pavement Association.

elements, allowing designers to specify fewer elements, all things being equal, with equivalent first-cost savings.

HPC – also called "durable concrete," is an engineered concrete made up of the classic components of water, portland cement, and fine and coarse aggregates, but with a twist. With HPC pavements, materials and admixtures are carefully selected and proportioned to realize high early strengths, high ultimate strengths, and high durability beyond conventional concrete. HPC can provide enhanced mechanical properties in precast concrete structural elements, including higher tensile and compressive strengths, and heightened modulus of elasticity (stiffness).

HPC using reclaimed industrial byproducts had been used in structural applications in private sector-owned high-rise buildings for decades, but until the 1990s, DOTs and public-sector owners had been hesitant to specify it due to a lack of experience in bridge or pavement applications. This lack of experience is being rectified through an active research program sponsored by the FHWA and interested state DOTs.

For example, the Strategic Highway Research Program (SHRP, 1988-1993), a five-year, $150 million research program paid for by the state departments of transportation, studied the efficacy of HPC in bridge structures as a way to quell corrosion of rebar from meltwater from deicing salt. The first HPC structural designs were constructed in the mid-1990s. HPC began migrating to pavements in the late 1990s and now at mid-decade it has fully penetrated PCC pavement construction.

In frost-prone regions, the benefits of HPC are great. In the case of pavements, bridges, and overpasses, the enhanced durability of HPC means it strongly resists penetration of chloride-laden snow and ice melt water, resulting in a longer life for the reinforcing steel within, and a reduction in spalling, cracking, and associated repairs.

Smoother Pavements, Too

In the race between paving media – concrete versus asphalt – asphalt has had a clear advantage in terms of pavement smoothness. But in the last decade, concrete has made tremendous progress in attaining the supersmooth pavements motorists and road agencies demand.

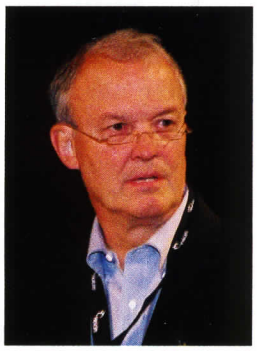
Placement techniques are being studied and refined to get the smoothest pavements without sacrificing speed of placement. Resulting guidelines are being actively transferred to road agencies and contractors through many channels.

A valuable new pavement smoothness measuring standard — the International Roughness Index — is being publicized and adopted in the United States. Lightweight pavement profilers that use laser and inertial technology to measure roughness are replacing the conventional California profilograph. And new research is showing how alternative tining practices can reduce the annoying tire "whine" associated with tined PCC pavements, while improving perceived smoothness.

"Pavement smoothness is important for portland cement concrete because pavements that are initially built smooth stay smooth longer," said Mark Swanlund, P.E., FHWA senior pavement design engineer. "That's directly related to the service provided by the facility to the public. And smoothness increases user satisfaction throughout the life of the pavement."

The FHWA's ongoing Pavement Smoothness Initiative dates back to a survey released in May 1996, in which the National Highway User Survey found that highway users want pavement smoothness more than any other aspect of their driving experience. "Improving pavement smoothness directly addresses our pavement condition goal of 95 percent of travel on the National Highway System on pavements with an IRI of 170 inches per mile or less by 2008," Swanlund said.

To ensure smoothness, the FHWA urges contractors to have precise stringlines, watch paving speed and delivery rate, control the head of concrete at the paver, strive for mix consistency, and use minimal hand finishing.



Concrete Community Is Looking Ahead to the Next 50 Years

By Peter J. Deem

On behalf of the Board of Directors and staff of the American Concrete Pavement Association (ACPA), as well as the regional and state affiliates throughout the United States, we stand ready, willing, and able to support all of those who are responsible for ensuring that the Interstate highway system meets both current and future needs of our society.

In that regard, ACPA is pleased to provide a full array of products and services that are aimed at helping public officials and roadbuilders alike. Examples include our education and training programs, which focus on topics ranging from the basics of concrete pavements all the way through more advanced topics, including Mechanistic-Empirical Design Guide training.

Our growing line of technical publications cover pavement design, materials, construction, and pavement preservation. Of course, these technical resources are only part of the equation and represent just a part of the breadth and depth of service the ACPA network provides.

Our team of engineers and technical experts at both the national and local levels work to provide the right answers at the right time for local agencies, elected officials, and consultants involved in transportation planning and construction. We are acutely aware of the challenges that our customers face, not the least of which are the resources to meet the needs of the traveling public both today and in the future.

Congestion, Safety Top Issues

It's no secret that congestion and safety are among the top issues on the minds of many highway users. With that in mind, we will never compromise our commitment to safety, which must remain a constant factor in our quest to build and maintain a quality system. Our customers in the public sector and industry also face these issues, plus the added challenges of limited resources to meet the most pressing needs of the Interstate system.

As such, the American Concrete Pavement Association is dedicated to doing whatever it takes to address the serious problems that plague the quality of service on this great system.

We are working to educate and inform the driving public, and indeed all stakeholders, of just how important the Interstate highway system is to economic prosperity, personal mobility, and freedoms we all enjoy. We will advocate for funding, and equally important, for innovative approaches to funding so that strategic expansion keeps up with the increasing vehicles and freight driven by population growth and the global economy. We also will continue our long history of technical leadership, promoting effective design, construction, and pavement preservation processes and products.

But we cannot go it alone. There is no better time than now to unite around the common purpose of meeting the challenges and opportunities that lie ahead for the next 50 years. Meeting the needs of the future will require participation and innovation by stakeholders in both the public and private sectors. It will require excellent ideas, hard work, and extra effort — along with equal amounts of research, technology transfer, technology implementation — by all who have a stake in this system.

The Future Interstate

We will have to both ask and answer hard questions, including: What will the Interstate look like in the future? How and who will pay for improvements and strategic expansion? How will we meet the rapidly growing demand associated with increased traffic and freight loadings in the future?

There are, of course, other pressing issues and questions, including: What will be our roles and responsibilities toward environmental stewardship and other aspects of sustainability? How do we ensure a balanced approach to meet the needs of all stakeholders? And, of course, what other issues will we face as stewards of this important national treasure?

All of these are challenging questions, to be sure, but working together, we can continue to improve this truly world-class network and ensure that we have reason to celebrate at the 100-year anniversary of this system.

Peter Deem is 2006 chairman, American Concrete Pavement Association, and is vice president, National and Regional Promotions, Holcim (US) Inc., Louisville, Colo.