

# TEXAS TRANSPORTATION Researcher

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## The search for “microcrack arresters”

### *TTI's fracture-healing work continues to advance*

Twenty years of continued basic research on asphalt microfracture and healing is finally coming to fruition with some definitive conclusions. Through funding from a contract with a Netherlands foundation and a later subcontract with the Western Research Institute in Wyoming, Texas Transportation Institute (TTI) researchers have now accumulated results that provide the fundamental scientific explanation for rutting and cracking in pavements.

It all started in the 1980s when Dr. Robert Lytton, TTI research engineer and F.J. Benson Chair of the Department of Civil Engineering at Texas A&M University, discovered that lab fatigue tests underpredict actual field performance of asphalt by as much as 150 times. This presented an extremely exciting scientific question. Why do asphalt pavements perform better in the field? What elements of field performance are standard lab tests unable to duplicate?

### **ASPHALT HEALING**

Throughout the '80s and '90s, Lytton and Dr. Dallas Little, Kelleher Professor of Civil Engineering, verified that the major cause of this discrepancy is a phenomenon called fracture healing

— simply put, the asphalt heals itself over time.

Without explanation, the statement may sound rather far-fetched. How could damage in the pavement heal itself? “Over the last 10 years, we’ve attempted to find out what the basis for this healing is — the laws that determine the reasons and rates that asphalts heal themselves or, ultimately, don’t heal themselves,” says Lytton. “And we’ve proven that it’s all tied to the surface energy, the composition of the asphalt, and the mineral types of the stones in the asphalt.”

The theory is that when subjected to the stresses and surface tensions created by cars, trucks and the weather, the pavement actually indents slightly and tiny microscopic cracks (microfractures) form just below the surface. During the time the pavement is allowed to “rest” between traffic loads, it slowly returns to its original position, and the cracks meld back together — thus, the healing.

### **CRACK ARRESTERS**

Now that Lytton and Little, after decades of experimentation and testing, have proven the basic scientific theory and isolated the equations that support microfracture and microhealing, they are looking at what exactly promotes and hinders healing.

—continued on page 3

## CHARLEY WOOTAN 1926 – 2001



**Dr. Charley Wootan**, director emeritus of the Texas Transportation Institute, died on March 24 at his home in College Station, Texas. Dr. Wootan was widely respected and recognized as a giant in the field of transportation. His contributions and leadership produced transportation advancements and safety improvements that have positively affected the lives of countless Americans. Dr. Wootan was a friend and mentor to numerous transportation professionals, many of whom will

share their thoughts and memories when *Researcher* looks back upon his life and stellar career in the next issue. If you would like to share a memory or thought about Dr. Wootan, send an e-mail to [webmasters@ttimail.tamu.edu](mailto:webmasters@ttimail.tamu.edu). To access a remembrance page, go to <http://tti.tamu.edu>.

## TRANSPORTATION LEADERS SELECTED FOR HALL OF HONOR INDUCTION

*Three prominent transportation leaders will be inducted into the Texas Transportation Hall of Honor in 2001.*

**Gibb Gilchrist**, a former executive director of the Texas Department of Transportation (TxDOT). Gilchrist served as head of the state transportation department during two separate periods between 1924 and 1937. He is credited with restructuring the agency and successfully gliding it through a tumultuous period in history. Gilchrist later went on to become dean of engineering, president and chancellor of Texas A&M University, where he strengthened the transportation research program and laid the groundwork for the establishment of the TxDOT cooperative research program. Gilchrist died in 1972.

**Herb Kelleher**, chairman, president, and chief executive officer of Southwest Airlines. Kelleher was one of Southwest Airline's founders in 1967. He has served as CEO since 1978 and chair since 1981. For more than two decades, the consistent success enjoyed by the airline has been directly linked with the style and leadership provided by Kelleher. The airline's records for on-time arrival, bag-

gage handling and limited customer complaints have become industry standards. Southwest was the first airline to establish a frequent flyer program, and the airline also pioneered other innovations such as senior discount fares and same-day air freight delivery.

**DeWitt Greer**, a former state commissioner of transportation and executive director of TxDOT. Greer's service to TxDOT spans more than half a century, beginning as an entry-level engineer in 1927 and continuing with his rise to head of the agency in 1940, a position he held until 1968. The following year, he was appointed to the state transportation commission, of which he served as both member and chairman until 1981. Greer is credited with expert financial management of TxDOT and also for shaping legislation that ensured adequate funding for the rapidly expanding highway network in Texas. Under his leadership, the state's highway



network grew from 22,000 miles to more than 72,000 miles. Greer died in 1986.

Each of the three will be honored in separate ceremonies (in March, May and August 2001, respectively) coordinated by the Texas Transportation Institute, where the permanent Hall of Honor is located in College Station.

"The Texas Transportation Hall of Honor is intended to recognize in a permanent manner that small group of people whose exceptional leadership and vision made possible the outstanding transportation system we enjoy today in Texas," Deputy Director Dennis Christiansen said in announcing the inductees. "We're proud and thankful to recognize these three great leaders for what they've given to the people of Texas and the nation."



*Dennis Christiansen and Pam Fambro. Students, faculty, researchers and friends placed a bench, plaque and tree outside the Civil Engineering Lab Building of Texas A&M University in memory of Professor Dan Fambro.*

## DAN FAMBRO MEMORIAL DEDICATED

A dedication ceremony was held Jan. 17 recognizing Professor Dan Fambro as a special friend and celebrating his life in a tangible way. Students, faculty, researchers and friends placed a bench, plaque and tree outside the Civil Engineering Lab Building of Texas A&M University in his memory.

The Institute of Transportation Engineers (ITE) student chapter and American Society of Civil Engineers (ASCE) student chapter had the excellent idea to honor Fambro. The student chapters approached TTI for help in making this concept a reality. TTI was pleased to have an opportunity to share in the event.

Dr. Dennis Christiansen moderated the ceremony, lauding Fambro as a nationally recognized transportation researcher

and one of the premier educators in the United States. Christiansen said, "it is rare that an individual is viewed so highly by his peers in research, in academia and by his students."

Steve Schrock, ITE Student Chapter President, and Sean Merrell, ASCE 2000 Student Chapter President, both spoke of the students' hope that the memorial will help Dr. Fambro's memory live on. "Dr. Fambro talked me into becoming a transportation engineer," said Merrell. "He was an important mentor to so many of us."

Dan's wife, Pam, said Dan really loved his students and it would have meant a great deal to him that they had the caring and initiative necessary to make this event happen.

## DORIS CALHOUN RETIRES

"Neither rain, nor sleet, nor dark of night" has hindered mail service at the Texas Transportation Institute (TTI) for a quarter of a century — not with Mail Services Manager Doris Calhoun in charge. Doris retired Jan. 31 after 25 years of service to the institute. Along with primary responsibility for TTI mail, she served in a variety of roles over the years, including management and maintenance of copiers, fax machines and other equipment, as well as training and supervision of numerous student workers. In fact, Doris went from operating one single "Multilith" copy machine and one single fax machine for the agency headquarters to maintaining copiers and fax machines in every division — all the while keeping up with the mail distribution.

TTI presented Doris with 25 red roses and silver balloons, a 25-year service pin and an appreciation plaque at her retirement celebration. Doris also received a book of photographs, cards, letters and e-mails and a mailbox in recognition of her many wonderful years of service.

Past supervisors Cubby Manning, Susan Lancaster, Anna Jo Mitchell, Bob Mahaney and Holly Crenshaw thanked her for her service to the institute.

TTI Deputy Director Dennis Christiansen recognized Doris as a dedicated, hard-working, loyal employee and vital part of the TTI family. "Her job wasn't the easiest, but she met it with her cheery attitude and soft manner, making everyone happy that they'd come her way that day."

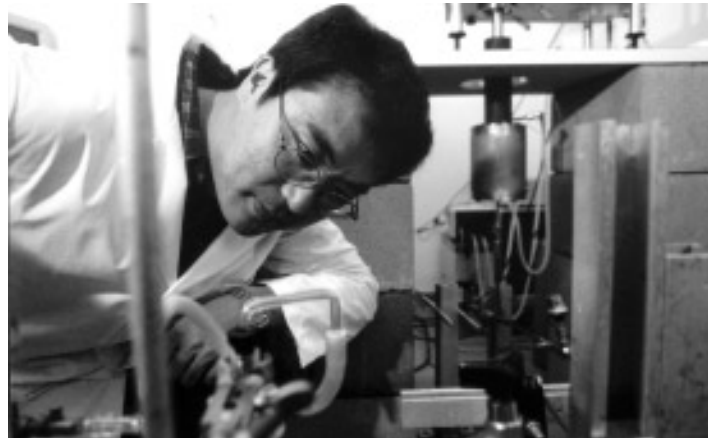
Doris plans to travel with her husband and spend time with children, grandchildren and friends. She will be greatly missed but promises to visit TTI often. In fact, on the first morning of her retirement, she called the mailroom to remind them that they'll need to do a late delivery since it was a payroll check day.



*Doris Calhoun with her husband Sly and Holly Crenshaw.*



*Dennie Manry, Jody Kollman, Doris Calhoun and Holly Crenshaw.*



*Graduate Assistant Ding Xian Cheng operates the Universal Sorption Device used in current fracture-healing research.*

## Microcrack arresters

*—continued from page 1*

What kinds of asphalt compositions subjected to certain load frequencies will encourage good healing (work-hardening) of the pavement?

"In addition to asphalts that heal well by themselves, we're looking for microcrack arresters," says Lytton. "These are tiny well-dispersed particles within the mix composition." As the load-rest cycle continues, small particles within the asphalt help block the cracks, slowing down the rate they grow and cause damage. So far, ground tire rubber, shredded carpet and hydrated lime are proving to be effective microcrack arresters.

### PERFORMANCE PREDICTION

According to Lytton, departments of transportation will benefit from these discoveries as construction contractors participating in warranty programs begin using better selections of asphalts and more crack arresters in their mixes. "These contractors will have responsibility for building and maintaining a stretch of road for sometimes as much as 20 or 30 years. Since they have to guarantee their work, they are going to be looking for the strongest, most durable mix possible. And they'll alter a mix if it means not having to perform

expensive rehabilitation work.

"We now know asphalts that heal fastest should be placed on roads with the most traffic, and asphalts that heal slower will work for low-volume roads," says Lytton. Current work is focused on developing simple tests that can be run quickly to predict the healing qualities and crack resistance of different asphalts.

The testing is supported by a German-made piece of equipment called a Universal Sorption Device purchased by pooled funds from TTI, Texas A&M University Department of Chemical Engineering and the F.J. Benson Chair in Civil Engineering. The device allows researchers to measure the polar and nonpolar surface energy components of solids and liquids and identify the asphalts that will have the kind of surface energy needed for quick healing.

"Knowing what's going to work is the key to everything. If we can accurately predict which mixtures will work best, then we know we're not wasting taxpayer money," says Lytton.

For more technical details on this research, see *Transportation Research Record 1723, Part I, 2000 TRB Distinguished Lecture: Characterizing Asphalt Pavements for Performance*. Or contact **Robert Lytton** at (979) 845-9964 or r-lytton@tamu.edu.



# 'Rubber roads' perform well

## *Eight years of TTI research on the addition of tire rubber to asphalt — and the news is good*

The jury is in. After extensive lab studies, two years of monitoring field trials, and thorough economic analyses, the results are positive. Ground tire rubber, when incorporated into asphalt in the right way and at the right temperature and concentrations, can cost-effectively improve performance of pavement.

In response to increased environmental concerns about tire waste, the Texas Department of Transportation (TxDOT) has mixed particles of tire rubber into asphalt for over a decade. Most of the methods used require changes in mix design or special construction practices. Traditionally, even with these special procedures and increases in asphalt binder content, crumb rubber has not worked well in standard dense-graded mixes. Because of these challenges, along with concerns about the high cost of rubber, the department has not used it in its standard dense-graded mixes.

Now, however, Texas Transportation Institute (TTI) researchers Charles Glover, Richard Davison and Cindy Estakhri, along with chemical engineering graduate student Jason Chipps and a team of seven others, have completed a comprehensive five-year study of ground tire rubber in asphalt binders, with an emphasis on dense-graded mixes. The study has resulted in a new blending process that incorporates a high-cure crumb rubber into the asphalt binder, a method that allows the particles to be digested into the asphalt before the mix is produced and placed.

"In our lab studies, we looked at production methods, performance properties and long-term durability," says Glover. "We then implemented and evaluated the findings in field trials of high-cure crumb-rubber modified asphalt (HC-CRMA)."

Researchers placed sections of HC-CRMA in Bryan, Texas, using

several levels of rubber content so they could look at all aspects of field performance — industrial curing, settling during transport, hot-mix processing, pavement placement and pavement durability. According to Estakhri, the test sections are performing very well.

"Based on what we're seeing in our monitoring tests, it appears that HC-CRMA binders can be used successfully in the field in dense-graded mixes with no mix design adjustments and no special construction procedures," says Estakhri. "They show improved Superpave performance grades and improved aging durability." Three more test sections were placed in June 2000, and researchers recommend continued monitoring of these and the Bryan sections.

"Continued monitoring is also especially important in further establishing

the long-term economic benefits and performance of these mixes," says Glover. "We used capitalized cost life-cycle analysis in a number of project scenarios, and thus far it appears that these high-cure rubber content mixes compare very favorably to the conventional mixes that do not use rubber."

In order to make up for the increased cost of the crumb rubber, the pavement life needs to be extended by only about 16 percent. Extensive lab data show that because of the increased aging durability with high-cure rubber, achieving the required extended life is well within reach for dense-graded mixes, even for those with a high rubber content binder.

The key to economic pay-out is the actual life extension provided by the binder. To establish this definitively will take continued monitoring of test pavements such as those placed in this project.

According to TxDOT project director Jerry Peterson, "We hope to continue monitoring these sections. So far we feel good about this process. It's a totally different animal from what we did in the early '90s, and we're not seeing any of the expansion problems that occur with the traditional asphalt rubber in dense-graded mixes." The next step, along with continued monitoring, is to get approval of a new specification and a memo to the districts highlighting the benefits of HC-CRMA.

For more information, contact **Charles Glover** at (979) 845-3389 or [c-glover@tamu.edu](mailto:c-glover@tamu.edu).

Related Publications: Draft TTI Research Report 1460-1, *A Comprehensive Laboratory and Field Study of High-Cure Crumb-Rubber Modified Asphalt Materials*.

Draft TTI Research Report 1460-S, *High-Cure Crumb Rubber Modified Asphalt for Dense-Graded Mixes*.



# Software improves accuracy of pavement performance prediction

station by interpolating between pavement temperatures taken at two neighboring stations. The other predicts pavement temperature using one of three equations available in the software. Calculations are performed by simply clicking on screen icons. The results of the MTCP analysis display in spreadsheets that can be printed out or saved in electronic format. The software also allows users to create charts of the results by clicking a Plot Output button.

According to Murphy, “It’s a user-friendly software program, and implementing it statewide will bring TxDOT engineers better pavement designs and more accurate performance predictions.”

*“It’s a user-friendly software program that will provide TxDOT pavement engineers with a consistent and flexible tool for adjusting FWD data to a specified temperature.”*

— **Michael Murphy**  
*TxDOT Pavement Engineer*

Winter, spring, summer and fall — pavements behave differently across the seasons in response to changing temperatures and moisture conditions. And those changes make a difference in pavement design and its ultimate performance.

When conducting falling weight deflectometer (FWD) tests on the pavement, Texas Department of Transportation (TxDOT) engineers normally use the MODULUS program developed at the Texas Transportation Institute (TTI) to backcalculate pavement layer data. This backcalculation requires time, precision and expertise to produce an accurate result. Because the results can be affected by a variety of factors — the time of day, cloud cover, water table depth, effect of trees and vegetation near the paved surface, and temperature and moisture conditions present when readings are taken — they often must be adjusted to account for these factors.

TTI’s Emmanuel Fernando and Wenting Liu have developed the Modulus Temperature Correction Program (MTCP) to automate the procedure for temperature correction of asphalt concrete data. “We wanted to develop a software program that would allow engineers to predict changes in backcalculated asphalt concrete modulus due to seasonal temperature variations, so that these effects can be considered in pavement performance predictions. And we wanted that program to be easy to use,” said Fernando.

According to project director Michael Murphy of TxDOT’s Pavements Section, standard manual calculations may lead to

inconsistent results. A software program, however, provides consistency and maintains (and in some cases even increases) the flexibility of the manual temperature correction while decreasing the potential for human error.

“There are situations where a pavement engineer may not want to adjust the backcalculated asphalt concrete pavement layer moduli to 77°F. If, for example, an engineer is trying to determine the effect of a superheavy load being moved on Texas roads when the temperature is not going to



reach 77°F, he or she may want instead to correct to a temperature of 60°F,” says Murphy.

The MTCP software does just that. It is an Excel-based spreadsheet that is flexible yet still provides the consistency and accuracy engineers need. The program estimates pavement temperatures, adjusts backcalculated asphalt concrete (AC) moduli to user-prescribed reference temperatures and predicts the monthly variation of AC moduli at a given site.

The software provides two methods for adjusting base temperatures. One estimates the temperature at the given FWD

*Engineers use the falling weight deflectometer (FWD) to test the strength of the pavement under various load weights.*

For more information, contact **Emmanuel Fernando** at (979) 845-3641 or [e-fernando@tamu.edu](mailto:e-fernando@tamu.edu).

Related publication: Draft TTI Research Report 1863-1, *User’s Guide for Modulus Temperature Correction Program (MTCP)*.

# The underground eye — GPR informational products provide training and awareness

Transportation-related uses for ground-penetrating radar (GPR) are expanding rapidly. This nondestructive evaluation method is finding a home in the transportation industry in such areas as subsurface pavement evaluation, location of buried construction hazards, bridge inspection and, most recently, quality control during initial pavement placement.

To make the most of this technology, the Texas Department of Transportation (TxDOT) asked the Texas Transportation Institute (TTI) to design a training program that would quickly bring transportation specialists up to date on the use and benefits of GPR. Personnel in TTI's Information & Technology Exchange Center (ITEC) are working with research engineer Tom Scullion and others in the Materials and Pavements Division to develop interactive computer compact discs (CDs) for training TxDOT engineers and technicians. In addition to the CDs, TTI is developing an informational video for non-technical audiences that will help viewers understand the benefits of using GPR in their communities.

## BENEFITS OF GPR

TxDOT uses GPR to augment other pavement evaluation methods. It provides a non-destructive method for obtaining almost continuous readings of a pavement's substructure. It also limits traffic flow interruption — which means drivers experience fewer disruptions, and cost is less than with maintenance operations that must detour or stop traffic. GPR has limited success on concrete, which accounts for about 10 percent of Texas roadways, but provides practical information about other types of paved sections.

"GPR is a valuable tool. Because it lets us see into layers of the pavement on a near-continuous basis, we can find problems like areas of moisture damage that would be difficult to locate otherwise," says Carl Bertrand, engineering specialist with TxDOT. "It's great



*Along with interactive computer compact discs (CDs) for training TxDOT engineers and technicians, TxDOT personnel and TTI researchers are developing an informational video for non-technical audiences that will help viewers understand the benefits of using GPR in their communities.*

at detecting anomalies. GPR can rapidly tell the user where the pavement structure differs and alert us to potential problems."

## TRAINING MATERIALS

"There is a national effort to implement GPR, and other states are looking to Texas to provide them with technological leadership in its use and training," says Bertrand. "These products will help us provide that leadership."

The new materials give operators an on-site resource with a task-oriented approach that works as both a quick refresher tool for previously trained GPR operators and an educational tool for new operators. In coordination with classroom sessions, the CDs will give TxDOT personnel a thorough understanding of GPR.

In addition to providing information on how to use GPR equipment and techniques, the materials will help users decide when and whether to choose GPR evaluation for specific situations. They will also suggest appropri-

ate diagnostic tool selection based on roadway symptoms.

"These CDs will take TxDOT personnel out of a classroom quickly and put them into the truck where they need to be," says Jack Hodges, coordinator of electronic media for TTI. "They will be able to refer to the CDs for quick reference when they run into new or unexpected situations."

Updated COLORMAP™ software, a program used to make GPR interpretation easier and quicker, will ship at the same time as the new training resources. The combined shipment will give operators an opportunity to have the most up-to-date information on how to use the enhanced data analysis software. TxDOT expects to begin using the training materials next year.

TTI developers plan three CDs. One will explain how to operate GPR equipment and collect data. A second disc will explain analysis procedures for collected data. A third will provide an umbrella explanation of how GPR



works together with other data-collection tools in flexible pavement rehabilitation.

"Texas is one of the leading states in the use of GPR. In the last five years the technology has blossomed and we've made more use of it statewide," notes Bertrand. "In the near future, I think some form of GPR will be used in every district and available for use on every roadway in the state."

### EYE TO THE FUTURE

GPR does not provide the only source for evaluating roadways, but it certainly gives an eye under the ground that furnishes transportation personnel with a better view of roadway needs. By bringing emerging GPR techniques together with approaches that incorporate falling weight deflectometers, dynamic core penetrometers, coring techniques and data analysis, the new training products will help TxDOT make the best use of time and money.

"I think the bottom line to these materials is that they'll give a quick reference point for GPR operators. If they have questions about what they're doing in any particular setting, the CDs will help answer those questions on the spot," notes Hodges.

For more information, contact **Tom Scullion** at (979) 845-9913 or [t-sculion@tamu.edu](mailto:t-sculion@tamu.edu), or **Jack Hodges** at (979) 862-3011 or [jhodges@tamu.edu](mailto:jhodges@tamu.edu).

## The (3D) plot thickens

### *New analysis extends GPR to pavement placement*

Operators use ground-penetrating radar (GPR) to collect information for a wide range of rehabilitation and repair applications. An expanded data analysis process developed and patented by the Texas Transportation Institute (TTI) shows promise for improving quality control during initial construction of roadways. This emerging technology uses the data collected by GPR to determine solid, liquid and gas proportions within GPR-observed pavement layers.

"For decades, radar has been able to detect and measure pavement layer thickness. It also tells us the dielectric constant of the layers. Starting with those two pieces of information, we can now determine the compositional mix of each layer — how much solid, liquid and gas is in each mixture," explains Robert Lytton, research engineer.

The new software program, SIDARS (System Identification Analysis of Radar Signals), uses GPR readings acquired through simultaneous data collection from four antenna setups to supply readings across full lane widths.

Through an iterative process, the program calculates the concentrations of solids, liquids and gases in the tested areas to provide composition information helpful in building and repairing roadways.

"Conventional GPR readouts show single lines indicating pavement layer thicknesses. This new analysis gives us the ability to show full-lane widths of layer composition in a three-dimensional plot," says Lytton. Composition includes items such as asphalt content, water content, density and percent air, among others. While this additional information can enhance pavement rehabilitation and repair efforts, the same measures used during pavement construction could provide a quality control method for better roads that will require less repair in the long term.

A recent project in the Texas

Department of Transportation's Bryan District tested four sections of pavement, one layer at a time, as the pavement was being built (Project 0-1735). The accuracy of the results, shown through comparison to known data obtained from cores taken from each layer, indicates that as-built applications of GPR may improve the quality and reduce the life-cycle cost of future roadways.

Lytton believes the new approach will hold particular attraction if more roadways begin to be built on a contractor-warranted basis. Using the quality control application of SIDARS, contractors would be able to "read" the composition and segregation of pavement layers as the roadway is built, replacing problem areas while equipment and personnel are still in place and reducing subsequent maintenance.

"SIDARS lets people know exactly what section of pavement needs repair on existing roads. More than that, it calculates mixture properties that are key to predicting where rutting, cracking and other kinds of distress will occur in the pavement so workers can get it right while construction is underway."

For more information, contact **Robert Lytton** at (979) 845-8211 or [r-lytton@tamu.edu](mailto:r-lytton@tamu.edu), or **Abigail Wells**, Lyric Technologies, Inc., at (979) 774-9511.

*SIDARS uses GPR readings taken with four antenna setups to cover the full lane width.*



# TTI research combats bridge scour and saves money



*Scour — erosion of the streambed — causes serious damage to bridges every year.*



*Dr. Jean-Louis Briaud operates the Erosion Function Apparatus, which tests the erodability of soil samples taken from the streambed.*

“Bridges collapse only in poor or underdeveloped nations, not here in the United States.” So many people thought — until erosion caused New York’s Schoharie Creek Bridge to collapse in 1987. Tragically, 10 people lost their lives. But the engineering community learned a valuable lesson: more research was necessary to understand scour — erosion of the streambed — around bridge foundations.

Dr. Jean-Louis Briaud, a research engineer at the Texas Transportation Institute (TTI), says approximately one out of every 25 bridges are now considered “scour critical,” which means they are at significant risk of collapse. Numbers like these faced Briaud and other TTI and Texas Department of Transportation (TxDOT) engineers 10 years ago when they began to research bridge scour. Even with such a daunting task, however, they have made significant advancements in both their understanding of the effects of long-time erosion and in finding ways to combat it.

TxDOT and TTI first developed the patent-pending Erosion Function Apparatus (EFA) to measure erosion rates for different soil types, ranging from clay

to gravel and from soft soils to soft rocks. (The EFA was recently recognized by TxDOT as one of the top innovations and findings of the year 2000.) Then, after finding that most bridge scour research involved an understanding of sand, researchers developed a method to measure the scour rate in cohesive soils (SRICOS) like clay. SRICOS, a site-specific method that involves removing small soil samples and testing them in the EFA, improved upon the older sand-testing method called HEC-18. These two achievements help bridge designers build more effective foundations. But perhaps most significant is the finding that, using these innovative technologies, engineers can save money while building safer bridges.

Using the SRICOS method, researchers have determined that certain cohesive soils do not scour nearly as fast as sands and will remain safe with smaller foundations. According to Briaud, the average cost of a bridge foundation in the United States is approximately \$250,000. Requiring 1.5 meters less of pile length, or about 10 percent of the total pile length, for each bridge represents a savings of \$25,000. With well over 300 bridges built

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over water in Texas every year, saving 10 percent of the cost from bridge foundations means the state of Texas will save \$8.5 million each year. Briaud notes, "This study has cost TTI only \$650,000, which means a large project like the Woodrow Wilson bridge over the Potomac River will realize a savings greater than the cost of the study."

And that claim appears to be coming true. The Woodrow Wilson Bridge, a six-lane Maryland bridge built in 1961, can no longer handle the area's traffic requirements. A new \$3 billion, 12-lane bridge is being constructed to replace the old structure. According to HEC-18, engineers could expect up to 80 feet of erosion around the bridge's foundation. However, after analyzing the soil using SRICOS and the EFA, TTI researchers predicted only 30 feet. This helped reduce the original 80-foot prediction significantly. Says Briaud, "This is very exciting research in action. We're seeing extremely significant results after years of hard work."

Briaud adds that states other than Texas and Maryland are beginning to take advantage of TTI's innovative research. The Texas A&M University System, through TTI, has recently signed a contract with Humbolt to manufacture EFAs for use by other departments of transportation. Currently, California, Maryland, North Carolina, Minnesota and Illinois will all receive an EFA to conduct their own scour analysis.

For more information, contact **Jean-Louis Briaud** at (979) 845-6554 or [briaud@tamu.edu](mailto:briaud@tamu.edu).

Related publication: TTI Report 2937-1: *SRICOS: Prediction of Scour Rate at Bridge Piers*.

# Cracking the case of bridge cracks

When a state bridge inventory turned up unexpected cracking in reinforced concrete (RC) bent caps of Texas bridges, Texas Transportation Institute researchers started looking for a solution. As with any mystery, the first step was to discover clues to what happened.

A great deal of uncertainty surrounds RC cap cracking: What factors contribute to it? Why does it vary from bridge to bridge? Why does it sometimes occur in both older and newer bridges? How can researchers stabilize variable factors such as loading and member geometry?

To tackle the mystery, a team of researchers designed, constructed and tested 16 full-scale bent cap specimens, isolating specific design and detailing characteristics of each. In addition to testing the specimens, the team conducted nonlinear finite element modeling to correlate factors with test results.

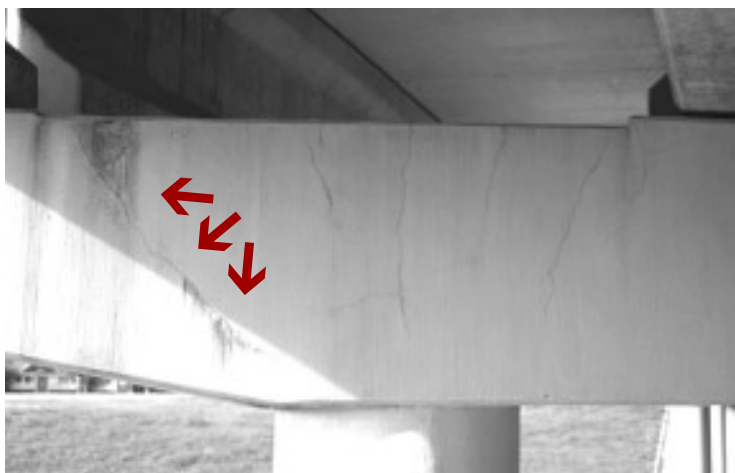
"Minor cracking was expected, but these inventories found larger cracks than inspectors anticipated. The bents used on the bridges satisfied code requirements for the bridge designs, so we wanted to uncover the reasons," says Joe Bracci, principal investigator for the project.

The testing and analysis identified suspected causes and developed methods to limit crack development. Researchers discovered that for the bent caps studied:

- Even when stress limits were within current codes, some level of cracking was inevitable.
- At low load levels, concentrating reinforcement along column sides was more effective than evenly distributing reinforcement.
- Rebar "slip" in the cantilever region due to bond failure was not a contributing factor to cracking.
- Tensile stress of longitudinal reinforcement was the primary factor influencing cracks.
- Standard beam theory did not accurately predict actual strain profile.
- The critical section was located within the column support region, not at the column face.
- Inclined shear cracks developed under larger load levels, and bent caps ultimately failed due to shear strength deficiencies.

"Findings from this project helped us recommend improvements in the design and use of RC bent caps that will make bridge designs safer and more durable," says Bracci.

And, along the way, it also helped solve a perplexing engineering mystery.



*Unexpected cracking in reinforced concrete bent caps of Texas bridges sometimes occurs.*

For more information, contact **Joe Bracci** at (979) 845-3750 or [j-bracci@tamu.edu](mailto:j-bracci@tamu.edu).

All papers are \$5. See gray-shaded box on opposite page for ordering information. Most of the papers are available on the CD-ROM of preprints distributed to those who attended the 2001 TRB annual meeting.

- ☐ Analysis of Aggregation Bias in Vehicular Emission Estimation Using TRANSIMS Output, (01-0316) Josias Zietsman and Laurence R. Rilett, Texas Transportation Institute
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## THE BACK ROAD



Transportation is on the front burner this year in Austin as the Texas Legislature debates a host of important transportation issues. Bills have been introduced proposing innovative financing methods, ways to speed highway construction and the possibility of changing speed limits on some roads, among others. It's clear

that our elected officials recognize how important transportation is to our state and the nation, and that they are looking for innovative ways to improve our overall transportation system.

Our job at the Texas Transportation Institute (TTI) is to do the essential research that helps the Texas Department of Transportation (TxDOT) and others build and maintain that system. This issue of the *Researcher* focuses on work in materials and structures, the basis of our transportation infrastructure. You'll learn how ground-penetrating radar (GPR) applications are being expanded and improved, including ways to use GPR as a road is being built. Other stories describe the studies that have reached some important conclusions about why pavements crack and rut, and what can be done to make asphalt "heal" faster.

Another important part of the infrastructure is bridges. Texas has about 48,000 bridges, most of them over water. Sixty percent of over-water bridge failures are due to scour-erosion of the streambed. Scour slowly excavates the soil around a bridge's foundations, causing the bridge to become less sturdy and eventually collapse. This issue contains a story about TTI researchers who have developed a testing device — the Erosion Function Apparatus — that accurately estimates the scour depth around bridge piers in clays, silts and other soft soils.

There's also information about how TTI researchers have been working to improve the binders that enable tire rubber to be used successfully in asphalt pavement mixes. The new cure process saves money and helps improve the environment.

I hope you continue to find this publication useful and interesting, and that you'll check our web site or contact us if you'd like more information.

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