ENGINEERS' FORUM

VOLUME 20 • NO 1 FEBRUARY 2001

Student combines loves to ease societal ills

INSIDE: AIR TRAFFIC DELAYS • NATION'S INFRASTRUCTURE • WIRELESS SYSTEMS

Cover photo courtesy of Russ Waspe, the Roanoke Times

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The Student Engineering Magazine of Virginia Tech

ENGINEERS' FORUM

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Cover photo: Sarah Airey, ECpE student, is the recipient of a Marshall Scholarship and was named an Academic All-American by *USA Today*. Photo courtesy of Russ Waspe, *the Roanoke Times.*

cover story

Student Combines Loves to Ease Societal Ills

by Isak Howell

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Few computer engineers yearn to work in Ghana. The West African nation is short on Internet connections, short on electricity in many places, and the dust of the savannah is often a more pressing problem than modem speed.

But Virginia Tech computer engineering senior Sarah Airey had a revelation in Ghana over the summer. After teaching Ghanaians to use and program computers, the Roanoke native now dreams of advanced computers that can tackle the toughest problems of developing nations like Ghana — machines that can find and remove land mines, instantly translate languages or provide medical information when doctors aren't around.

These are machines that don't exist, machines that will need people like Airey to research and develop them.

Airey is taking her rare dual interests — in the frontiers of technology and technology-starved societies — to Great Britain next fall. She recently earned the prestigious Marshall Scholarship, one of only 40 awarded each year, which will fund her pursuit of a master's degree in artificial intelligence at the University of Edinburgh. Her scholarship, worth about $50,000, can be used at any university in Great Britain.

Recently a finalist for the Rhodes Scholarship, this committed academic is humble about her ambitious quest to use computer engineering to bridge a global disparity in technology.

"I guess I try to focus on the larger problems it can solve," she said.

Airey grew up in the Hollins area of the Roanoke Valley, first attending Northside High School, then Patrick Henry. Her love for computers came about slowly at the Roanoke Valley Governor's School for Science and Technology. After a few science fairs, she wanted to know how the machines worked.

Photo: Russ Waspe, The Roanoke Times

In Virginia Tech's computer engineering program, she has learned that.

"I actually felt like I understood what was happening in my machine," the 21-year-old senior said of one course.

While attending college, Airey also volunteered at the Art Museum of Western Virginia, which nurtured her interest in African art and Ghana.

At Tech, she won the Daughtery Scholarship, which funded her 10 weeks in Ghana. While there her two worlds, art and computers, merged. She saw that design and presentation had everything to do with how technology was used. She saw adults fumble with the mouse because they had no reference for anything like it. She found that a computer icon in the shape of a manila folder was meaningless since manila folders weren't used in Ghana. Children only appreciated a computer game when it depicted something they could relate to, like soccer.

In computerspeak, that interaction is called the "interface." Airey envisions computers that fuse Western technology with the symbol-rich designs that speak to Ghanaian cultures.

"Art is very powerful in expressing ideas," she said.

She also saw that while computers may seem a distant concern in a nation where basic health and literacy needs are overwhelming, they can be a part of the solution. She met a man who was trying to start an AIDS education program from the ground up, a monumental task in a society where traditional healers often have more credibility than Western remedies. It struck Airey that if the man had Internet access, he could quickly learn about other successful AIDS programs around the world.

Airey admits her inspiration to use artificial intelligence to bridge social divisions is rare. (Artificial intelligence involves computers that "think" in that they can solve intricate problems.) She envisions a career of shaping policies to encourage nations to abandon the drop-off-the-computers-and-leave mentality, in favor of using computers that incorpo-

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research

Working to Alleviate Air Traffic Delays

by Lynn Nystrom

The frustration of aircraft delays is experienced by most frequent fliers on a regular basis. In fact, the Federal Aviation Administration (FAA) reports that in 1997, 27 U.S. airports experienced more than 20,000 hours of annual delay. If no changes are made, the FAA estimates this number could rise to some 31 airports by 2003.

"Efforts to augment the current capacity by building new airports or by expanding existing ones are expensive, time consuming, and environmentally controversial," say Toni Trani and Hanif Sherali, Virginia Tech professors of civil and environmental engineering and industrial and systems engineering, respectively.

Instead, they believe that there are efficiency measures that could be adopted to improve air traffic control procedures.

Trani and Sherali are the lead faculty at Virginia Tech who are involved in the FAA Air Transportation Center of Excellence for Aviation Operations Research (NEXTOR). Virginia Tech, in conjunction with the University of California at Berkeley, the Massachusetts Institute of Technology, and the University of Maryland, comprise the center, started in 1996. Together, they have worked on safety, business, and operational issues in the aviation industry.

Since its inception, the center has focused on the development and use of operations research — a focused blend of applied mathematics, computer science, and engineering aimed at finding optimal solutions to complex problems.

Specific work has addressed such issues as air traffic, management and control, human factors (the relationship between humans and machinery), system performance and assessment measures, safety data analysis, scheduling, navigation communications, and aviation economics.

At Virginia Tech, Trani has been developing aviation related computer models to improve the capacity of airports. His past research includes the creation of computer simulation and optimization models to estimate the optimal location of runway exits, including a flight simulation study to estimate pilot-aircraft responses on high speed turnoffs.

Trani's colleague, Sherali, a member of the National Academy of Engineering, is an authority on solving transportation network flow problems, optimal resource allocation of airport gates, and how to best locate high speed exits at busy runways.

Together, they have written a paper "Integration of Simulation Models to Evaluate the National Airspace System," to be published in *The Journal of Transportation Engineering*. They describe the "critical bottleneck in the air traffic control system" to be in the airspace that is 60 nautical miles around an airport.

Specifically, they are concerned with the airport terminal area where three types of air traffic control activities occur: aircraft sequencing operations that control the traffic inside the airport terminal area; runway operations that control aircraft landings and departures; and taxiway operations that guide aircraft from the gate to the runway for departures or vice versa for arrivals.

Each of these activities has its own type of air traffic controller. Final approach controllers are responsible for aircraft sequencing. Local controllers work on runway operations. Ground controllers are responsible for taxiway operations.

Trani and Sherali, along with their former student Hojong Baik who remains a post-doctoral student in CEE, propose that the three operational components be coordinated as one task. They have developed three pieces of computer software: the Aircraft Sequencing Problem (ASP) for runway operations; the Network Assignment Problem (NAP) for taxiway operations; and the Simulation Model (SM) for addressing communication activities in the airport ground transportation network. (This analysis was Baik's dissertation.)

With ASP, Trani explains "the guiding principle is that if arrivals and departures are sequenced intelligently, then an enhanced system will accrue."

For example, air traffic controllers try to maintain a minimum of five nautical miles when a heavy aircraft leads a smaller one. This distance is equivalent to about 196 seconds in time. If the sequence is switched so that the smaller aircraft leads the heavy one, the required distance between the two aircraft is reduced to three nautical miles or about 75 seconds. Although this switch might not be possible in each instance, it would save some 100 seconds when feasible. At a busy airport like Atlanta where more than 900,000 operations are handled each year, the savings in time could prove significant.

Using the results of their studies to date with ASP, the Tech engineers are using these initial conditions for solving the NAP problem.

With taxiway operations, landing aircraft have higher priority over departing and taxiing aircraft. The rationale is that arrivals are both costly and safety critical from a fuel consumption and operational point of view. For the same reason, the runway operation has a priority over the ground taxiing.

But Trani, Sherali, and Baik believe that by using ASP and obtaining the optimal runway operational sequence, they can also reduce the time connected with taxiway operations.

The third part of the overall equation for increasing efficiency at the

At Virginia Tech, Trani and Sherali have been developing aviation-related computer models to improve the capacity of airports.

nation's airports is the communication congestion due to controller work load. "For instance, even after a departing flight is ready to taxi, the flight could be delayed at the gate until it obtains a taxiing clearance from the ground controller," the three researchers say.

They have developed the SM to portray the pilot-controller communication process. This model provides very detailed information about the dynamic status of things such as flights, local controllers, and ground controllers. It also includes other pertinent information such as the aircraft's speed, acceleration, position, etc. at every time interval of simulation. This model is unique because for the first time it includes pilot-controller data link logic in an airport simulation model. Baik was responsible for the computer implementation of the model.

At Virginia Tech, the researchers had the advantage of using the University's Airport to develop the SM.

To evaluate the overall system, the engineers are using a simulation model that has the capability of reproducing the dynamic behavior of aircraft and incorporates the communication activities between controllers and pilots. This information is incorporated into fast-time simulation models.

With the results on this study and others to date, the Virginia Tech part of the NEXTOR team is hoping for another four year approval of funding for the FAA center. EF

Creating A Single-Chip Wireless System

by Liz Crumbley

On April 11, President Clinton presented a 1999 Presidential Early Career Award for Scientists and Engineers (PECASE) to Sanjay Raman of electrical and computer engineering.

Raman was one of only 60 researchers from throughout the nation to receive a PECASE award, which is the highest honor bestowed by the U.S. government to outstanding scientists and engineers in the early stages of their research careers. Each PECASE researcher will receive a five-year grant of $500,000.

The awards, presented during the ceremony at the White House, were established by the Clinton Administration in 1996 to recognize young researchers and help maintain U.S. leadership in scientific research.

As a Ph.D. student at the University of Michigan, Raman fabricated a millimeter-wave radar receiver — including antennas and receiving circuitry — on a single integrated circuit (IC) chip.

Now, he will attempt to develop methods of directly integrating antennas with the electronics used in wireless devices, such as cellular phones, on single IC chips. The ultimate goal of this line of research is to put all of the components of wireless technology on single-chip systems.

"Someday, the equivalent of a cell phone will be the size of a dress button or a small piece of jewelry," Raman says.

Last year, he received a National Science Foundation (NSF) Faculty Early Career Development Program award, a four year grant worth about $200,000. CAREER awards are presented annually by the NSF to a select roster of faculty nationwide who have demonstrated early in their careers the potential to make significant contributions to engineering research and instruction. Raman was one of 20 1999 CAREER award recipients selected for the PECASE award.

The single IC chip technology Raman is developing will have a myriad of applications aside from use in personal communications systems. For example, Raman explains, environmental sensors on chips could be placed easily and inexpensively throughout buildings to monitor temperature and other conditions and radio messages back to a central control computer.

These wireless distributed sensors would be particularly useful on military ships and aircraft, freeing personnel from having to make manual checks on equipment conditions. Raman knows a great deal about the potential benefits for the military; he spent more than three years as an officer on a U.S. Navy nuclear submarine.

He also foresees medical applications. "Chips could be embedded in at-risk individuals to monitor for impending heart attacks and alert medical personnel via wireless communications before an attack actually occurs."

Raman also imagines a wireless "DNA crime lab on a chip," with one section of the device testing samples at a crime scene for DNA while another radios a central database for possible identification of the perpetrator.

The ultimate goal of this line of research is to put all of the components of wireless technology on single-chip systems.

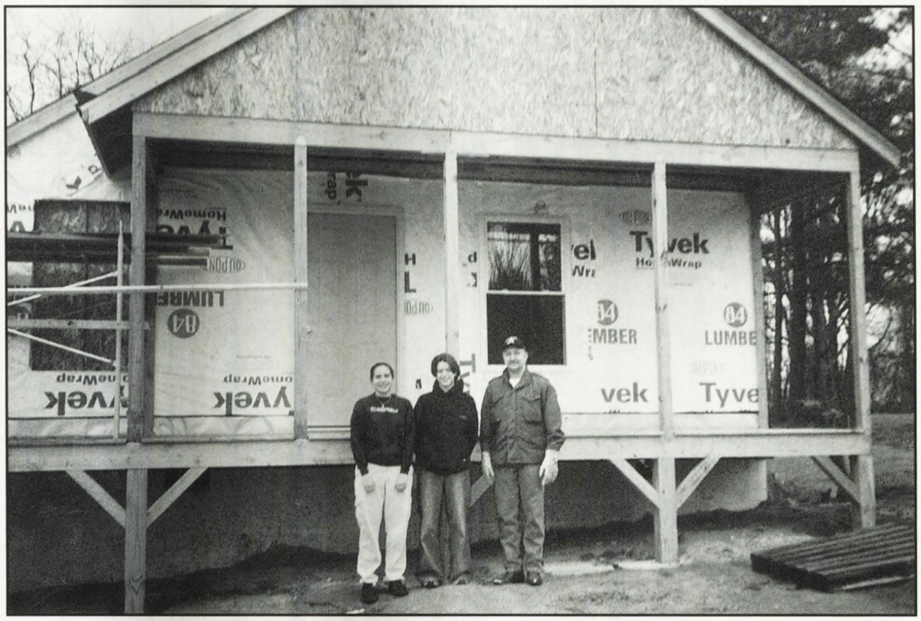
"Ultimately," he believes, "wireless information technology will be so ubiquitous that people will be connected with networks wherever they roam. The key is to make the wireless nodes so small that they can be seamlessly integrated into virtually anything."

The educational component of Raman's work includes developing a graduate course in radio frequency integrated circuit design. With this added component, he says, Virginia Tech will offer one of the most com-prehensive communications technology curriculums in the world. EF feature

Students Gain Experience From Building Project

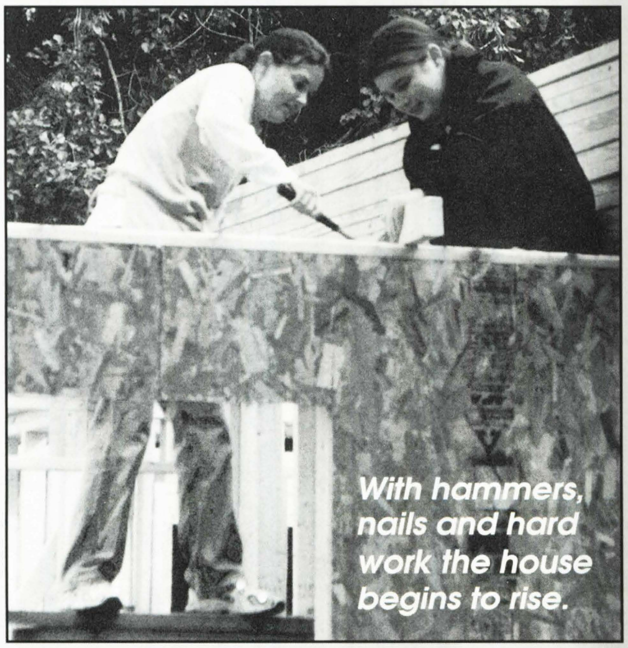
by Tom Catherwood

Virginia Tech freshmen engineering students are helping the Blacksburg Interfaith Habitat Group build its second home. The house is located on Shelor Lane. The project is part of the ongoing work by an organization known as Habitat for Humanity. The family works alongside volunteers and gains an understanding of the work that goes into building their house.



Students stand proudly before their Habitat for Humanity project.

Habitat for Humanity is a non-profit organization committed to providing safe and reliable housing to families who could not otherwise afford to purchase a house on their own. Millard and Linda Fuller founded the organization in 1976 after observing the work of a local Christian farming community. Since it was founded, over 100,000 homes have been built as shelter for over 500,000 people. The program extends throughout 2,000 communities worldwide. Public attention was called to the organization in 1984 when it was part of former president Jimmy Carter's work project in New York City. Since that time, Habitat for Humanity has grown in size and continues its work throughout the world.



With hammers, nails and hard work the house begins to rise.

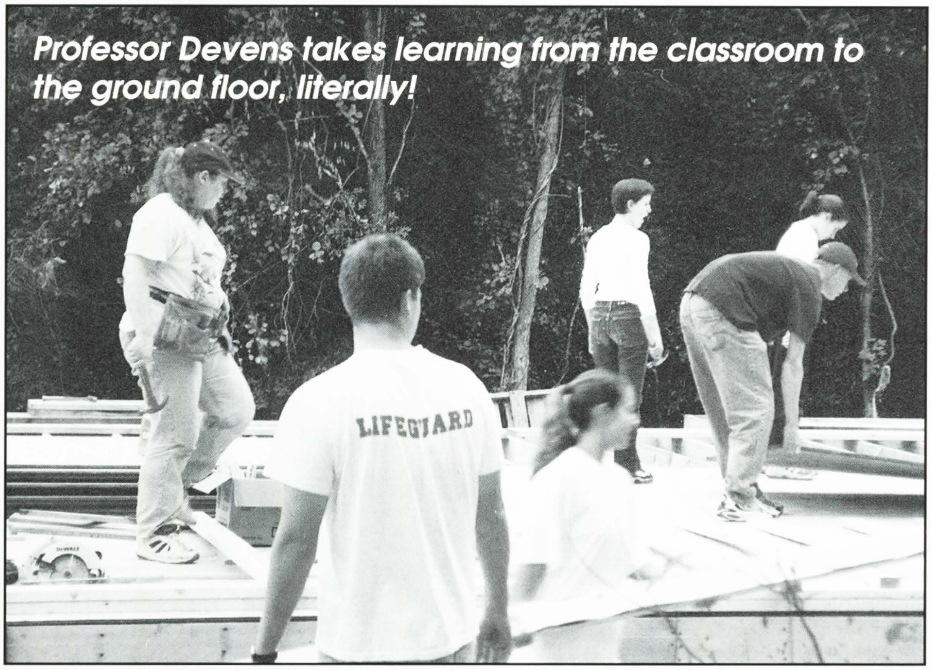
The student participation is gained through the effort of Professor Devens' engineering fundamentals classes. Working with Habitat for Humanity provides students with practical engineering experience in a residential construction environment. During the construction process, the students learn to deal with problems that arise on the job site under trained supervision. This type of hands-on work also exposes the students to the way things work and operate outside of the classroom environment.

Building a house requires the cooperation of many different fields of engineering. It is this broad picture that will help a student to see how the different aspects of engineering "fit together" and make a job run smoothly. Furthermore, everyone on the project is taking advantage of an opportunity to assist the Blacksburg community. It is an excellent opportunity to leave homework behind and take a break from school to participate in a worthwhile experience.

The project foreman, Alfred Chevaliun, supervises the work each week and sees that everything is done safely and correctly. The work primarily takes place on Saturdays from about nine in the morning until three in the afternoon. It is essential that everyone understands what has to be done while building the house. The students will walk away from the project with experience in some of the key concepts and understanding of basic structural design and residential systems. With the knowledge gained working for Habitat for Humanity, students and volunteers will be better prepared to take on the responsibilities of maintaining a house of their own.

Matthew Davis stated, "I have found that this is a great way to take some time away from school and play with tools, which I love. I am also learning things that will help me in the future to own a house of my own. I haven't been as useful with the roof because I am scared of heights, but I have been able to work on the ground level areas like the flooring and the deck. I now know how to deal with contractors and understand what they are talking about with what needs to be done. We have a lot of fun working at habitat within the group."

To start off the day, Professor Devens provides a one-hour basic residential construction rundown. This is the time that students learn the most. Safety measures, construction procedure, and local building codes are reviewed to show the relevance of what will be accomplished each day of the project. Professor Devens relates each step in the construction process to a lesson from that week's set of classes. It becomes easy to see how the lessons that are being taught in the class apply directly to the job at hand. This is a chance for a student to explore the different uses of what has been taught at Virginia Tech and how it directly applies to a real life situation.



Professor Devens takes learning from the classroom to the ground floor, literally!

This reinforces the lessons and makes them more understandable for an inexperienced person.

There are few opportunities in life where the time is taken to train someone correctly about the practical and coordination skills such as swinging a hammer or using a saw. All of this is essential in producing a quality product. "I've learned a lot of the small details about building a house," said Abigail Harrison. "I definitely know small details to look out for when my future home is being built."

Each Saturday, three to four student volunteers show up to help. Thirty students have participated thus far giving the team enough manpower to complete the roof. Many students are still waiting to help by assisting with the installation of the house's electrical, plumbing, and mechanical systems. This head start will give them an advantage in the engineering field that the students wish to pursue.

Friendships and camaraderie are established between the individual students and the local community. As an added bonus, each week a different woman volunteer from the churches involved provides a home-cooked lunch for the workers at the worksite.

Those persons working on the project are completely devoted to its completion and success. When the project is completed everyone will walk away with a feeling of accomplishment. All of this combined will provide a long-lasting house, great friendships, and much experience. As Devens says, "It's a win win situation for everyone." EF

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Y.A. Liu Receives Outstanding Faculty Award

by Liz Crumbley

I chose university teaching in 1974 because I enjoy the challenge of motivating and inspiring young people, and years of teaching have only deepened my enjoyment," says Y.A. Liu, a recipient of the State Council of Higher Education for Virginia's Outstanding Faculty Award for 2000.

Liu, the Frank C. Vilbrandt Professor of Chemical Engineering (ChE)at Virginia Tech, is one of 11 faculty members from colleges and universities throughout Virginia selected to receive the award, which is the highest honor accorded faculty by the Commonwealth. The awards, presented March 2 during a ceremony at the State Capitol in Richmond, recognize "the finest among Virginia's college faculty for their demonstrated excellence in teaching, research and public service."

Since coming to Virginia Tech in 1982 from the faculty of Auburn University, Liu has received several honors in recognition of both his teaching and research efforts, including the 1984 Western Electric Fund Award from the American Society for Engineering Education (ASEE) for excellence in instruction of engineering students; the 1986 National Catalyst Award for excellence in chemical education from the Chemical Manufacturer's Association; the 1990 George Westinghouse Award, the highest honor presented by the ASEE to educators under the age of 45 for outstanding achievements in teaching and scholarship; and the 1993 Fred Merryfield Design Award from the ASEE for creativity and excellence in teaching and research of engineering design.

In addition, Liu has been honored as a teacher by the faculty and students of Virginia Tech. In 1996 he received the College of Engineering Sporn Award for Excellence in Undergraduate Instruction, the highest honor awarded by the college's 5,000 students. In 1997, the faculty presented Liu with their most prestigious teaching recognition, the W.E.

Wine Award for Teaching Excellence.

Ley Richardson, a 1999 ChE graduate who won the highly competitive Ford Foundation Predoctoral Fellowship for Minorities and is a Ph.D. candidate at the Massachusetts Institute of Technology, regards Liu as "the most inspiring professor in the classroom I have ever witnessed."

"He is a rare individual who cares deeply about his students and colleagues and has the innate ability to evoke the best in them," Richardson adds, noting that Liu "remains in his office every weeknight until at least 2 a.m., and he always has an open-door policy."

Liu continually brings his research and industry expertise into the classroom. His senior design students, for example, have developed computer models for manufacturing processes to reduce pollution and costs at Alliant Techsystems in southwest Virginia. Liu's graduate students are assisting AlliedSignal Polymers in Richmond with engineering staff training and process improvements projects that have a potential annual economic payback of more than $35 million.

Liu also devotes time to students outside the classroom, serving as the faculty advisor for the Association of Chinese Students and Scholars, the American Institute of Chemical Engineers Virginia Tech Student Chapter, and a student Christian fellowship group.

When Liu was promoted to the Vilbrandt professorship in 1983, he became the youngest Virginia Tech faculty member at that time to hold an endowed professorship. He has achieved international acclaim for his research and publications in magnetochemical engineering, coal cleaning, engineering design, and artificial intelligence. He has published four pioneering textbooks in the field of chemical engineering, as well as more than 100 papers.

In addition to his teaching and

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research at Virginia Tech, Liu has served since 1992 as a senior technical advisor for the United Nations Development Program. Since 1986 he has conducted intensive training courses in new chemical engineering technology to more than 3,000 practicing engineers in Virginia, China and Taiwan.

Liu received his undergraduate engineering degree from the National Taiwan University, his master's from Tufts University, and his Ph.D. from Princeton. EF

Airey *Continued from page 3*

rate culture.

At Tech, Airey is soft-spoken about her achievements, even downplaying her role as the undergraduate representative to Tech's Board of Visitors or her work in African art with the Smithsonian.

But her professors don't mince words in describing her.

"What can I say? She's brilliant and she has a big heart," said Jack Dudley, Tech's honors program director. "Those don't always go together."

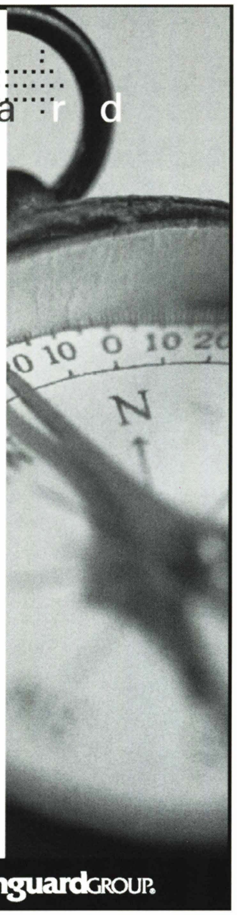
"It is amazing to see someone at such a young age pushing the limits of what it means to be a complete human being," wrote Tech philosophy professor Eric Watkins in a recommendation letter.

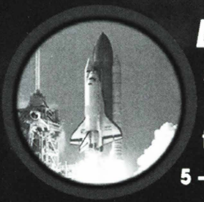
When she set out for Ghana, Airey was unsure of what it would offer. Her parents were nervous and one man offered, "Now, Sarah, if there's a coup, stay indoors."

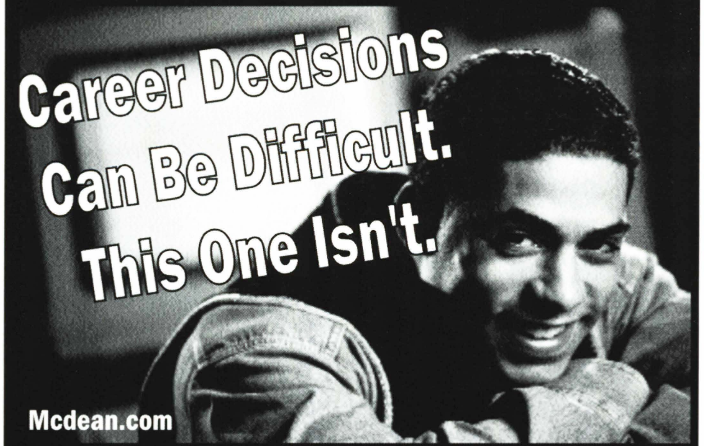
"A few comments like that and you begin to wonder what you're getting into," she said.

But the trip actually crystallized her commitment to using computers to bridge social divisions, just the conviction she will need in the University of Edinburgh's artificial intelligence program.

"I guess I'd like to think some of what I do has an effect," she said. "There are not a lot of engineers talking about these problems... Given the effect of technology, maybe there ought to be." EF



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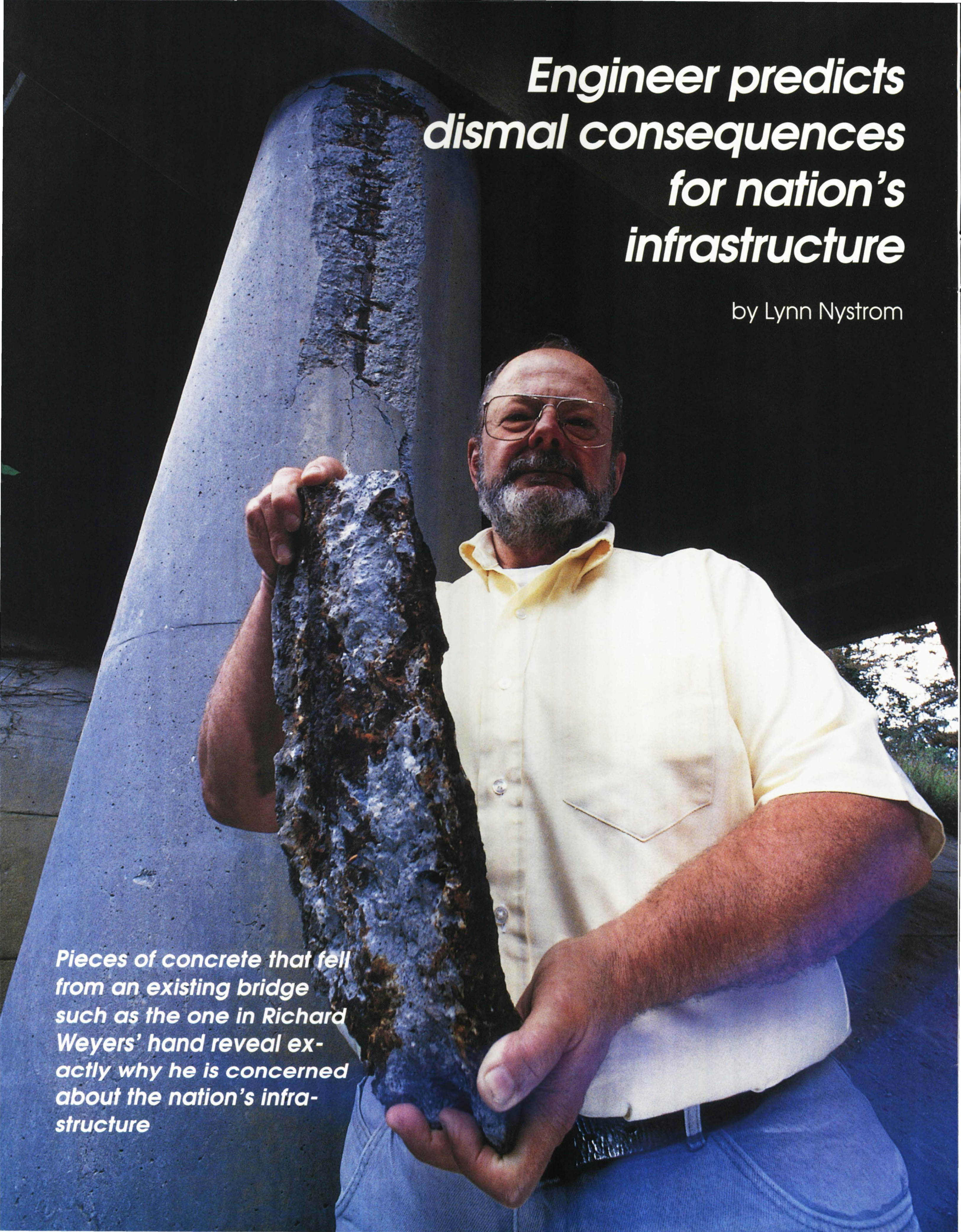
Engineer predicts dismal consequences for nation's infrastructure

by Lynn Nystrom



Pieces of concrete that fell from an existing bridge such as the one in Richard Weyers' hand reveal exactly why he is concerned about the nation's infrastructure

When the U.S. was coming out of the depths of the Great Depression, one of the solutions for reducing unemployment was to create public work programs. Part of this 1930s effort included the expansion of the highway system. Later, in the late 1950s, construction began on the present interstate highway system with the 1930s construction serving as the backbone for the main transportation routes.

These highway systems were typically designed for a 50 year service life. The highways' bridges typically need rehabilitation in 35 years and replacement in 70 years.

With the new millennium, the time has come to replace the 1930s infrastructure and rehabilitate the 1950-60s interstate system. Unfortunately, to date, much of the replacement and rehabilitation has not even taken place.

The consequences could be dismal, according to Richard Weyers, an expert in bridge construction and a professor of civil and environmental engineering at Virginia Tech. He predicts that the bridge transportation system alone in America is facing a trillion dollar investment. "To put up a new structure, it costs $75 to $100 per square foot to build. A new bridge, on average, is 8000 square feet. And there are currently about 500,000 bridges in the federal highway system, not counting any structure under 20 feet or ones on the back roads."

Complicating the issue is new knowledge about one of the materials that the Federal Highway Administration (FHWA) started using in 1974 in the construction of the nation's bridges. In a recent paper that Weyers presented at the International Symposium on the Integrated Life-Cycle Design of Materials and Structures, held in Finland, he concluded, "It is very difficult to justify the continued use of epoxy-coated reinforcing steel (ECR) in the Commonwealth of Virginia. Instead, Virginia should employ alternatives such as the use of low permeability concrete and corrosion inhibitors and alternative reinforcement.

To make his point stronger, Weyers refers to a study done in 1972. After the FHWA noticed a rapid corrosion of the reinforcing steel in concrete bridge decks following the application of deicer salt, it sponsored a research project to assess the feasibility of using organic coatings to protect the steel. After two years of testing, when no sign of corrosion was obvious, the FHWA used ECR in its first bridge. Its use soon became commonplace.

However, Weyers points out that none of the laboratory or field studies concluded that the ECR would not corrode. And only one laboratory study estimated that ECR would provide long-term corrosion protection of 46 years.

By 1986, the trouble started. Engineers noticed early failures of ECR in Florida's bridge substructures where salt water was involved. Due to these failures, a preliminary study was conducted with Virginia's bridges. Engineers removed drilled cores containing ECR from piles in marine environments and from bridges in deicing salt environments. From their studies, they anticipated that the coatings would be debonded from the steel bar in about 15 years for bridge decks and in six years from piles in marine environments.

A second, larger study on 18 bridge decks between two and 20 years old concluded that in Virginia the epoxy debonds from the steel in as little as four years. When the chloride arrives at the steel depth, the epoxy coating will debond from the steel surface. The level of corrosion

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Weyers

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protection provided by ECR is presently uncertain. Projections have been as little as five years of additional service life. A present study is being conducted to further develop the estimated service life that ECR will provide.

"Presently, there is no existing method to effectively repair the existing decks with epoxy coated bars. And there is no way to evaluate the corrosion condition of the steel bar due to the coating. They can only be replaced by tearing the bridge decks out," Weyers explains.

"The product was put into the bridge deck without the knowledge of what reactions might occur in concrete," Weyers says. "We now need a political solution to a technical problem" because of the dollar amount involved.

Noting the seriousness of the situation, Weyers refers to the failure earlier this year of the pedestrian walkway bridge at the Lowe's Motor Speedway in Concord, N.C. during a NASCAR all-star event. In this instance, grout contaminated with calcium chloride corroded the steel cables, weakening the beam and causing its collapse.

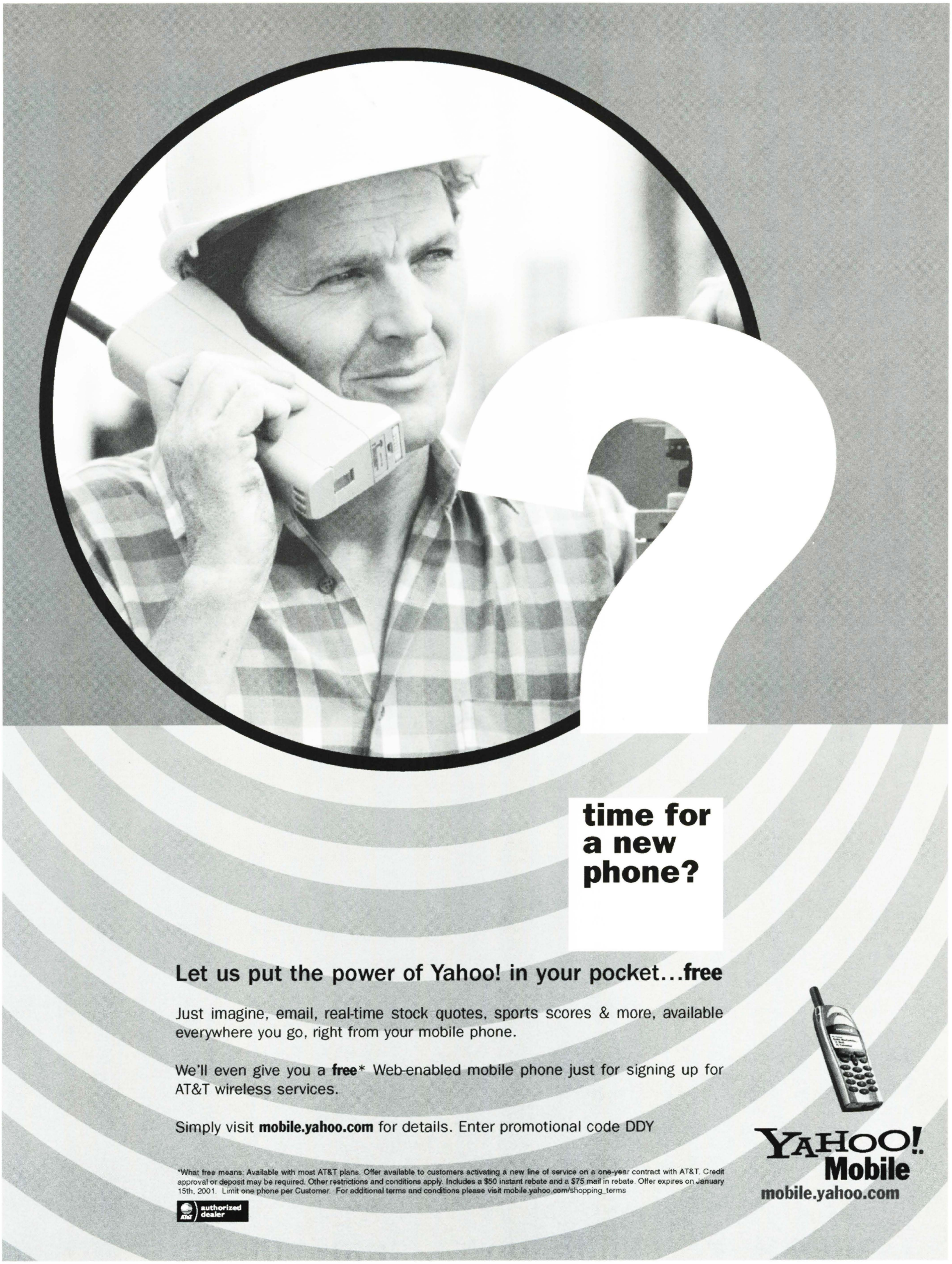
With the new millennium, the time has come to replace the 1930s infrastructure and rehabilitate the 1950-60s interstate system.

"This is absolutely the worst condition you could possibly have," the materials engineer says about the combination of the salt with the steel and moisture. "For the speedway, the question remains how did the grout become contaminated. Was it a precast problem? Were the engineering specifications wrong? Or was it a materials supply problem?"

Five years ago, Weyers received $2.4 million from the Strategic Highway Research Program (SHRP) to direct the investigation of methods to correct deterioration of concrete bridges. He explored chemical and physical techniques to protect the existing bridges.

Today, industry has recognized Weyers' research efforts on a model for the deterioration rates as a way to judge different corrosion protection systems. His corrosion service life model is the result of a three phase study, started 16 years ago. His work identified "average" service lives; today he is working on the variability of service life prediction.

The variability includes the use of corrosion inhibitors, different high performance concretes, and selected materials' low permeability to chlorides. "We are looking at these systems and selecting the most cost-efficient or minimum life cycle cost treatments," Weyers explains. EF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