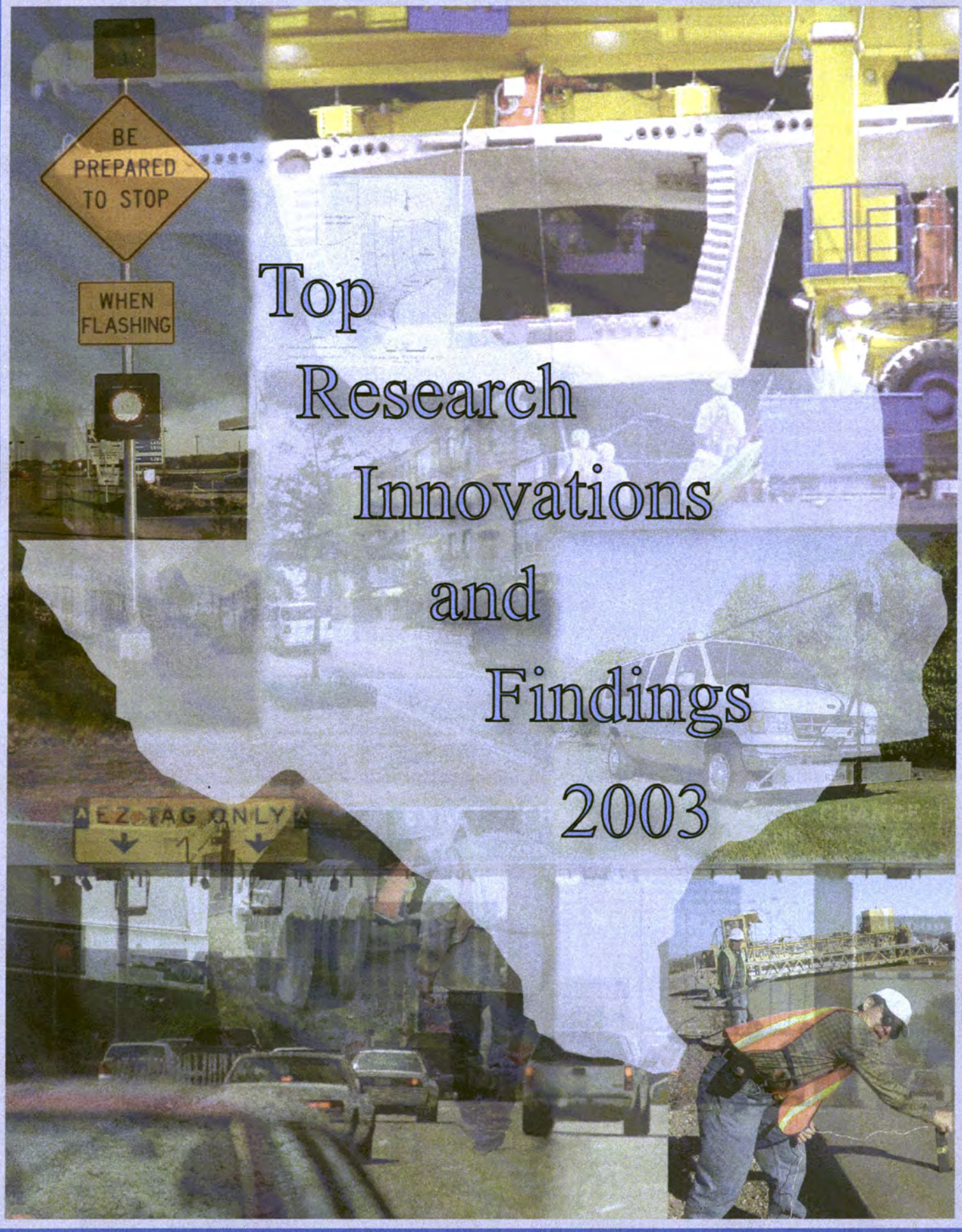


Top Research Innovations and Findings 2003

Texas Department of Transportation

About the Top Research Innovations and Findings

Each year, the Texas Department of Transportation (TxDOT) selects Top Research Innovations and Findings for the past year. They are selected based on anticipated or already realized dividends to the department and the state. These dividends may be in terms of lives saved, more efficient operations, improved services, and/or fiscal savings.

Selecting top innovations and findings allows us to identify, thank, and congratulate the university researchers who were responsible for these noteworthy achievements. We also recognize our TxDOT project directors and advisors who provided support and direction to these researchers. Identifying top research products has the added value of providing momentum to the implementation of these findings.

Products from the research program include devices, machines, tools, materials, manuals, and software, while others are less tangible concepts, knowledge, or advice. These products affect virtually every area of TxDOT operations. Emphasis areas for research include pavements, structures, materials, geometric design, hydraulics, right-of-way, environmental considerations, transportation planning, traffic operations, and policy.

On the facing page is a listing of TxDOT's Top Research Innovations and Findings for this year. They are showcased individually on the pages that follow. On the inside back cover is a listing of Top Research Innovations and Findings for the past three years.

Top Innovations and Findings, 2003

Advanced Warning for End-of-Green System

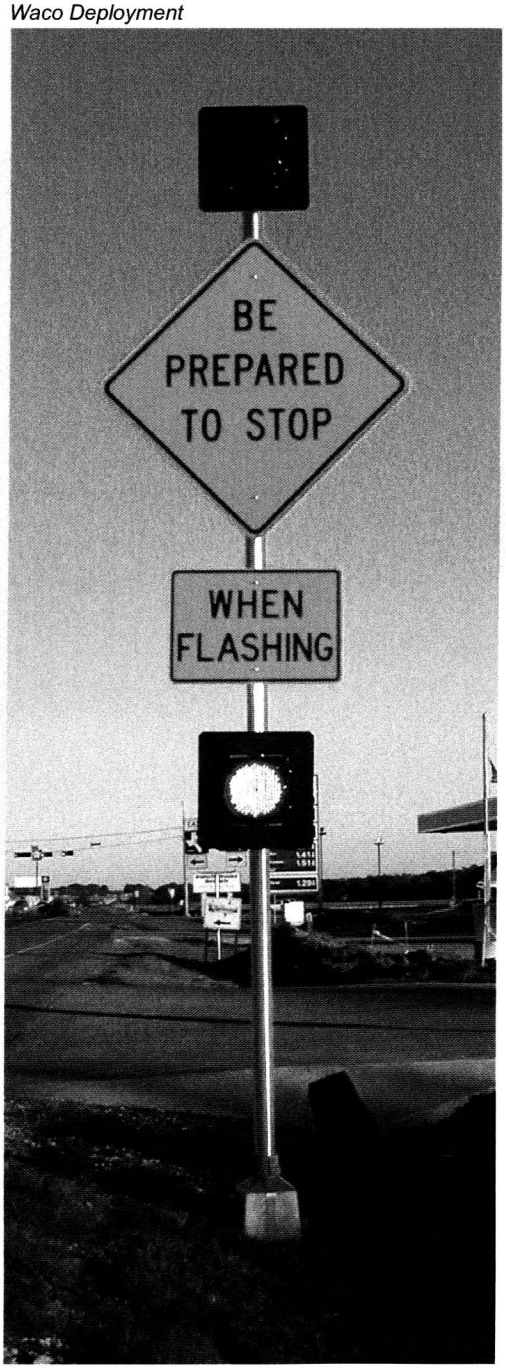
Project 0-4260: Advanced Warning for End-of-Green Phase for High Speed Traffic Signals

The Texas Transportation Institute conducted a two-year project and developed a system called Advanced Warning for End-of-Green System (AWEGS) to provide advance warning to motorists of the end-of-green signal phase. AWEGS provides warning to high speed vehicles by flashing beacons five to six seconds before the onset of yellow on a "Be prepared to Stop" sign located on the approach to the intersection. This warning allows the high speed motorists to slow down and come to a comfortable and safe stop at the intersection. AWEGS also provides dilemma zone protection to trucks since they have different braking characteristics and require a longer braking distance than cars. AWEGS identifies trucks in the traffic stream and minimizes their dilemma zone exposure, increasing the safety of the intersection.

A number of agencies have deployed advance warning flashers across the country and in Canada; however, these systems lose dilemma zone protection while providing advance warning. AWEGS uniquely enhances dilemma zone protection at the intersection. AWEGS adds a pair of detectors well upstream of the dilemma zone detectors to predict arrivals, and it monitors all detections and the signal controller to predict future signal operations. AWEGS is able to predict the termination of a green in full-actuated signal controllers about 83 percent of the time and provides advance warning to approaching motorists.

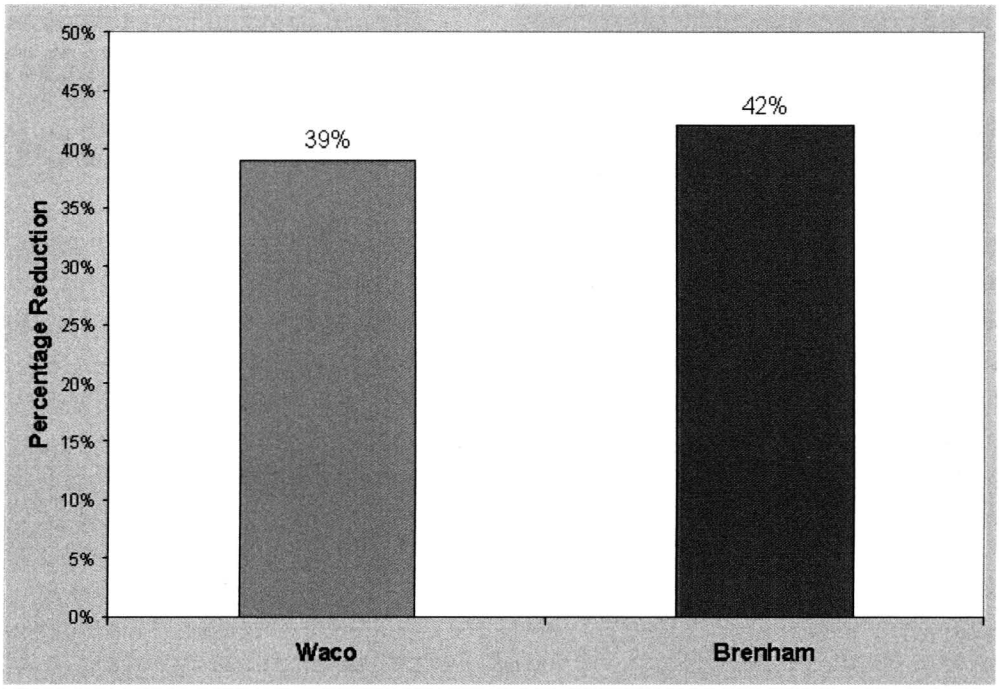
AWEGS was deployed at two locations; SH 6 at FM 185 in Waco (November 2002), and US 290 at FM 577 (June 2003) in Brenham. AWEGS has been operating satisfactorily since its deployment.

Waco Deployment



Benefits

Reduction in red-lignt running after AWEGS installation



AWEGS has reduced red-light-running (RLR) during the targeted first five seconds of red by approximately 40 percent. This bar chart presents a summary of the reduction of red light running after AWEGS deployment at the two field sites in Texas. If AWEGS was installed at a location similar to the site in Waco, our studies indicate that RLR would be reduced by at least 762 per year. Assuming that the life span of AWEGS is about 10 years, it is estimated that the cost of reducing each red-light-runner is $4.00. However, Brenham has a much higher level of RLR. Installing AWEGS at a location similar to the site in Brenham would reduce RLR by at least 9,762 per year at a cost of $0.41 per red-light-runner.

AWEGS provides a new and effective dilemma zone protection for targeted trucks and high-speed cars. Due to AWEGS, there is a reduction in the number of trucks stopping at the intersection. There is also a significant reduction in trucks stopping abruptly. These benefits reduce pavement wear and tear at the intersection and provide significant savings in pavement maintenance to TxDOT.

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Guidelines for TxDOT - Regional Tollway Authority Cooperation and Coordination

TxDOT and other agencies continue to explore new and innovative methods to address concerns related to traffic congestion, mobility, and accessibility. Expanding the use of toll facilities in Texas is one approach receiving increased emphasis. While toll roads are not new in Texas, there is growing interest in expanding their use to address traffic congestion and mobility concerns. House Bill 3588, passed in 2003, provides Regional Mobility Authorities (RMAs) with additional authority, creates new opportunities for toll facilities, and promotes collaboration among agencies.

Toll Collection Plaza in Houston

TxDOT research project 0-4055, "*Guidelines for TxDOT – Regional Tollway Authority Cooperation*" produced a set of guidelines that provide TxDOT, Regional Tollway Authorities (RTAs), and RMAs with techniques to help TxDOT address new toll road opportunities. The guidelines, published and distributed in April 2004, provide direction for enhancing cooperation and coordination among TxDOT, RTAs, and RMAs.

The guidelines cover the areas of planning, environmental review, funding, design, construction, monitoring and evaluation, as well as management and operations. In each of these areas, the guidelines offer suggested approaches related to toll road development. For example, in the planning section, the guidelines provide recommendations on the use and content of memoranda of agreements (MOA) between TxDOT, RTAs, RMAs, and other local agencies to identify the roles and responsibilities of the different agencies. In the environmental review section, guidance is provided for addressing the environmental review process and the public involvement process for different types of projects.

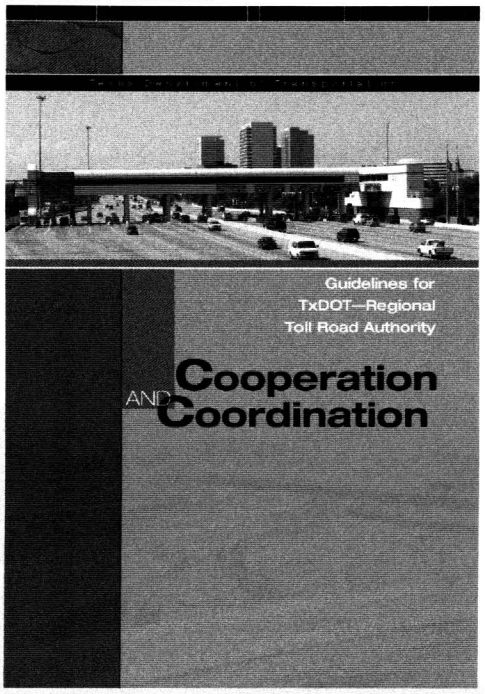
The guidelines are appropriate for use with a wide range of toll-related projects that may be under consideration in an area or in various stages of planning, design, construction, and operation. They are flexible to meet the unique characteristics and needs of different areas, while providing a common direction for all groups involved in toll projects. The guidelines do not mandate specific approaches. Instead, they offer suggestions and considerations for agency staff involved in toll projects.

Project 0-4055:
Guidelines for TxDOT - Regional Tollway Authority Cooperation

Benefits

Full implementation of the guidelines could have numerous benefits for TxDOT, RTAs, RMAs, and most importantly, users of the highway system in Texas especially in light of the Department's emphasis towards toll options for new capacity projects. Specifically, the following benefits could accrue from use of the guidelines:

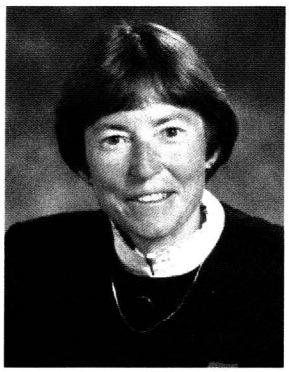
Guidelines Publication



Maximize Available Funding. Use of the guidelines can help TxDOT maximize available state and federal funding for construction, operation, and maintenance. Partnering with tollway and mobility authorities, and other groups can extend the use of available funding. For example, the $1 billion President George Bush Turnpike in Dallas was funded with a combination of some $303 million in TxDOT purchased right-of-way and engineering, a $135 million ISTEA loan, and some $562 million in bonds and other financing from the North Texas Tollway Authority (NTTA). Use of the guidelines could assist in creating opportunities for similar financing successes on future projects.

Leverage New Funding. Implementing the guidelines could help gain new funding sources for construction, operation, and maintenance of new and existing roadways in the state. For example the Harris County Toll Road Authority (HCTRA) is providing $250 million to TxDOT for the I-10 West (Katy) freeway reconstruction which will cover the cost for the managed lanes. Similar benefits may be realized on other projects through greater cooperation and coordination among TxDOT and other tollway and mobility authorities.

Advance Project Development. Without additional resources, TxDOT can only fund a fraction of its current planned projects. By maximizing available funds and leveraging new resources, the guidelines could assist in advancing project delivery timelines on needed district projects.



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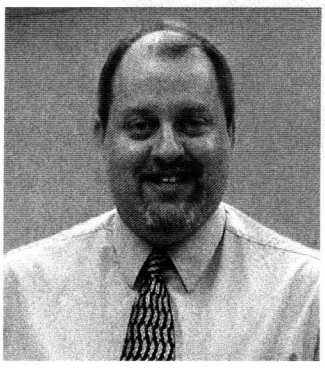

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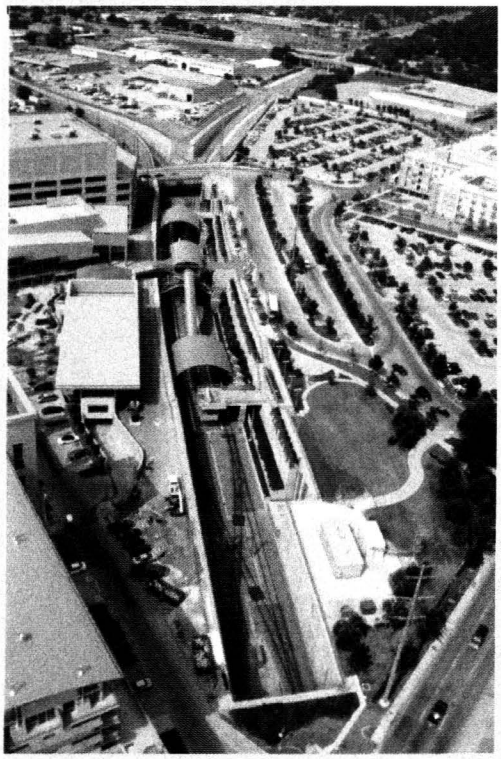
Smart Growth Texas Style Primer

Project 0-4238: Smart Growth Texas Style

Mockingbird Light Rail Station with adjacent commercial and residential development



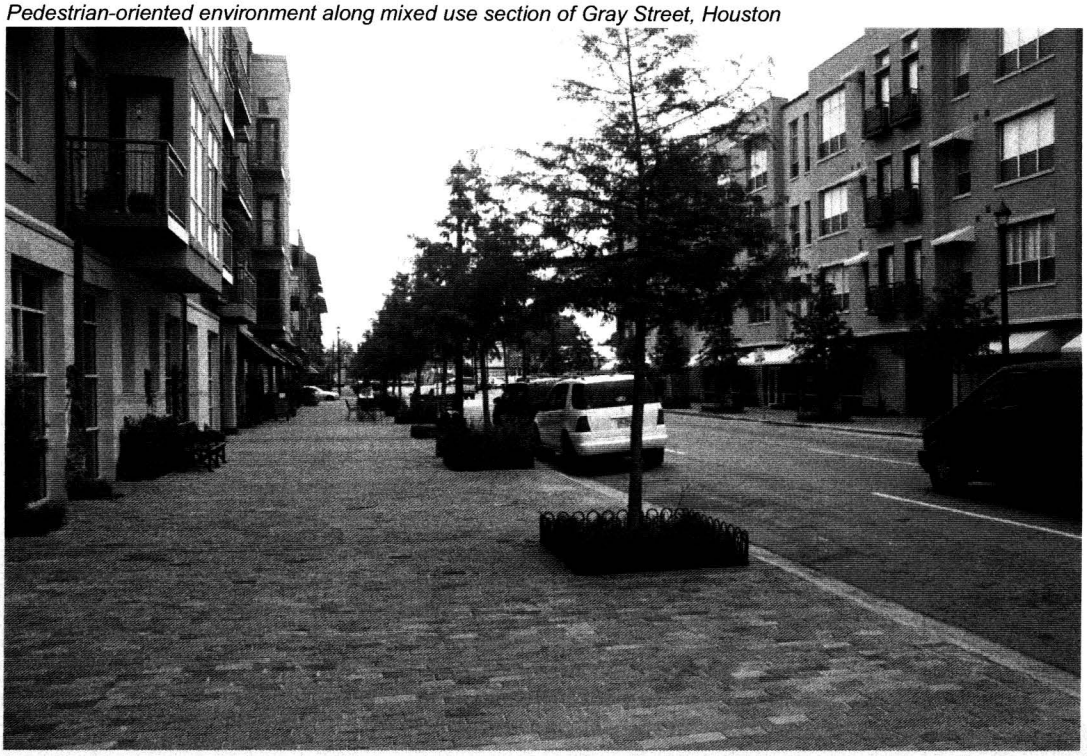
Mixed use transit-oriented development adjacent to DART Mockingbird Station, Dallas

Smart growth is a relatively new concept to Texas. It started in cities such as Austin, Denton, Plano, Dallas, and Houston. Additional cities including San Antonio, College Station, and El Paso, have shown interest. In project 0-4238 *Smart Growth Texas Style*, the researchers developed a Primer on smart growth techniques that could be employed by transportation planners at the local level and in TxDOT districts. Specifically, the Primer provides background, concepts, examples, and other states' experiences with smart growth as it relates to transportation. Further, the Primer shows ways TxDOT can take advantage of smart growth principles to benefit its own programs. In addition, the researchers developed training materials for use in workshops to better promote the implementation of the Primer. Four workshops were conducted around the state in which TxDOT, Metropolitan Planning Organizations (MPO), and local technical staffs were introduced to the concepts of smart growth.

Benefits

If the concepts of smart growth described in the Primer are implemented, the benefits can be substantial.

Pedestrian-oriented environment along mixed use section of Gray Street, Houston

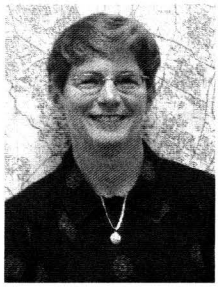


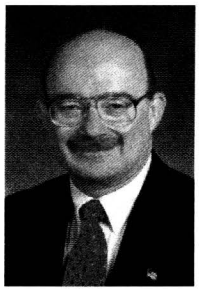
For example, smart growth can:

•Reduce vehicle trips and Vehicle Miles Traveled (VMT) by as much as 50% within small areas and by 5-10% over larger areas if applied widely,

•Reduce transportation (and other public works) infrastructure costs if widely implemented, and

•Increase safety, especially related to vehicle-pedestrian conflicts. Injury reductions of up to 30% have been experienced in European communities that have widely implemented smart growth principles. Speed reduction designs have resulted in over 50% reductions in localized collision experience.





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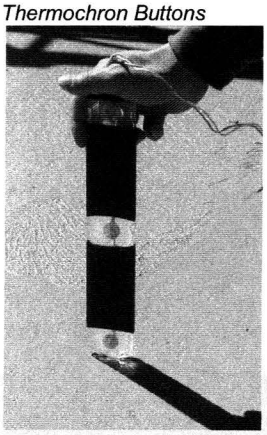
Thermochron and Hygrochron Button Innovations

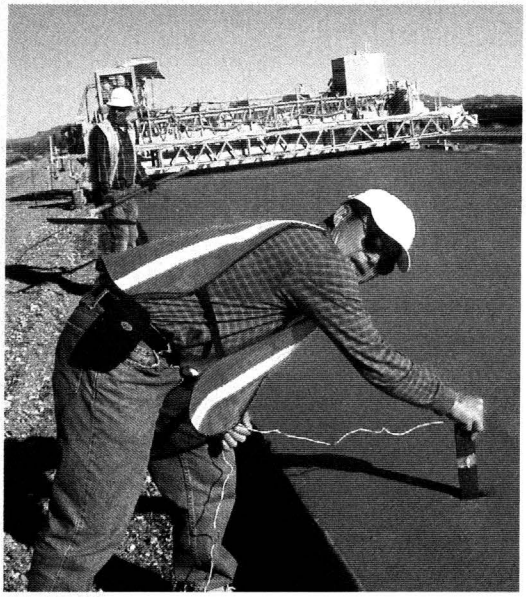
Project 0-1700: Improving Portland Cement Concrete Pavement Performance

Thermochron Buttons



Engineers have known for some time the detrimental effects of high temperatures and excessive moisture loss, but have not been able to monitor them in an acceptable fashion. High-temperature and low-moisture conditions during construction lead to temperature and moisture loss levels in the pavement that produce excessive spalling. Spalling can be so severe that major rehabilitation is required in less than 10 years on pavements designed for 30 years. The Thermochron buttons (temperature) and Hygrochron buttons (moisture) developed in this research provide the engineer a cost-effective way to extensively monitor the pavement during construction, potentially saving millions of dollars over the years as well as keeping the goodwill of the traveling public. The picture below shows installation of the Thermochron buttons in fresh concrete.

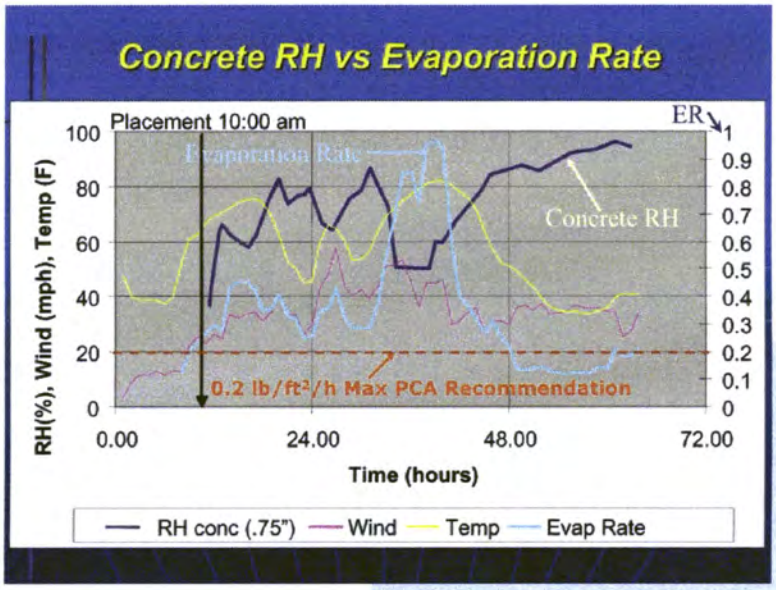
Installation of Thermochron Buttons in new paving



The Thermochron buttons are $8 each, which allows economical monitoring of temperature in new construction, possibly replacing the conventional maturity meter at lower cost and with higher security (buttons are embedded in pavement and store data internally). In addition, the researchers have used Thermochrons to measure minimum temperatures at various depths over two winters. This data indicates that mid-depth temperatures in thick pavements are not as low as expected, which means steel designs can be optimized by region at considerable savings.

In a similar manner, the Hygrochron buttons store humidity readings which can be used in fresh concrete to indicate how effective the curing is under any condition. The graph on the opposite page shows results from monitoring concrete humidity during construction in Van Horn. Conditions became severe due to high winds and temperatures the second day, resulting in moisture loss at the pavement surface that could not be controlled by the curing compound. If contractors had ready access to information of this sort, additional measures could be taken during high evaporation periods to avoid strength loss or differential shrinkage conditions that lead to spalling.

2003 Benefits



As a rough estimate of possible statewide savings, the Texas Rigid Pavement Database was examined to determine what percentage of concrete roads fail due to poor temperature or moisture control during construction. The analysis determined that roughly 8.7% fail to reach design life due to close cracking (possible temperature problems) and 7.2% due to spalling (possible uncontrolled moisture loss), with some overlap between the two (i.e., some pavements experience both problems). Since 2.5 million cubic yards of paving concrete are used in Texas annually at an estimated cost of $137 million, the failure rates account for about $20 million in replacement cost, allowing for the overlap. If these pavements average a 20 % reduction in design life, then the savings from correcting the problem might be as much as $4 million / year.

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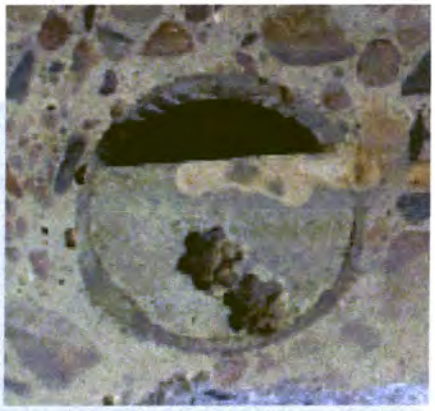
Long Term Durability for Post-Tensioned Substructures

Project 0-1405: Durability Design of Post-Tensioned Substructure Elements

Research Project 0-1405 "Durability Design of Post-Tensioned Substructure Elements" was one of the longest running TxDOT-sponsored research projects ever conducted. The 10-year project duration allowed conclusive findings to be made regarding many corrosion-related durability issues. The researchers systematically studied and recommended proper design procedures and corrosion protective measures for post-tensioned structural elements. Results from this project have had a significant impact on durability design and construction of post-tensioned structures, and have been implemented in Texas and on a national level.

Incomplete grouting of post-tensioning duct in lab specimen; a common occurrence in the field



Post-tensioning issues studied included grouting materials and placement, materials for post-tensioning ducts, duct gaskets, segmental joints, concrete mix design and concrete cover requirements, levels of post-tensioning, bar and strand coatings, and corrosion assessment methods.

Corrosion of galvanized steel post tensioning duct

Significant findings include:

- Recommendations for high performance grouting materials and improved grouting procedures. Many states now use the new grouts in prepackaged form, and a grouting certification program has been implemented through the American Segmental Bridge Institute.
- Plastic ducts should be used instead of conventionally-specified galvanized steel ducts in aggressive exposure environments. Major post-tensioned structures such as the Galveston Causeway now incorporate plastic ducts based on project findings.
- Epoxy joints are recommended for all segmental construction. Dry joints should not be allowed. Joint gaskets for post-tensioning ducts are to be avoided in lieu of carefully coupled ducts. Plastic duct joint sealing systems are now commercially available.
- Mixed reinforcement (partially prestressed) structural elements perform poorly under aggressive exposure conditions. Prestressed elements should be designed utilizing 100% prestressing to avoid chloride ingress through tension cracks.
- High performance, low permeability concrete mixes are effective in minimizing chloride penetration. A minimum of 2 inches of concrete cover should be specified for structural elements.
- Post-tensioning bar and prestressing strand coatings (epoxy and galvanized) show enhanced corrosion protection, and are being conclusively evaluated under ongoing research project 0-4562.

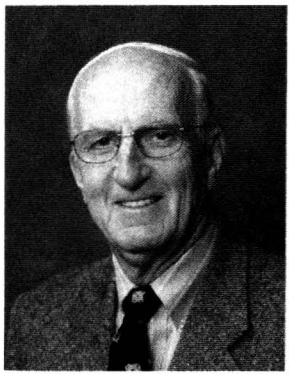
Benefits

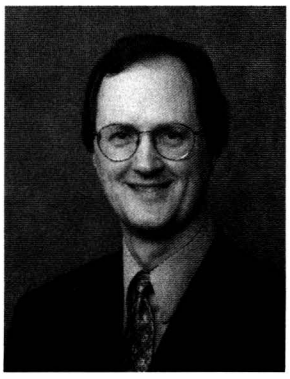
Placement of precast post-tensioned segment on High Five project, Dallas

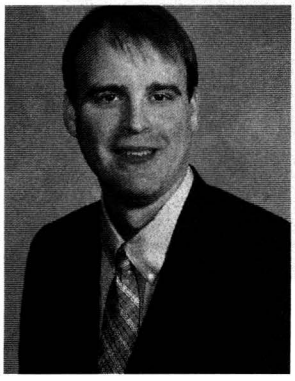
Project findings have positively impacted the state-of-the-practice for the industry and will substantially increase the long-term durability of post-tensioned structures:

Corrosion-related induced problems in post-tensioned structures are very costly to repair. Recently the Florida Department of Transportation identified 41 coastal bridges in need of repair/rehabilitation due to corrosion-induced damage, most apparently due to grouting and duct seal problems. The combined estimate for all repairs is on the order of $39 million. The Texas Department of Transportation has initiated a comprehensive inspection program for several post-tensioned, segmental structures in the state. Grouting, duct splice integrity, and anchorages for post-tensioning systems are a primary emphasis for these inspections.

Results from research project 0-1405 have substantially impacted the design and construction of post-tensioned structural elements for bridges. While it is difficult at this point to quantify the actual benefits from this project in terms of cost savings, post-tensioned structures designed and constructed according to these research findings will undoubtedly offer increased service lives with reduced need for special inspection regimes and durability-related repairs. The potential savings for Texas over the next few decades are in the tens of millions of dollars.







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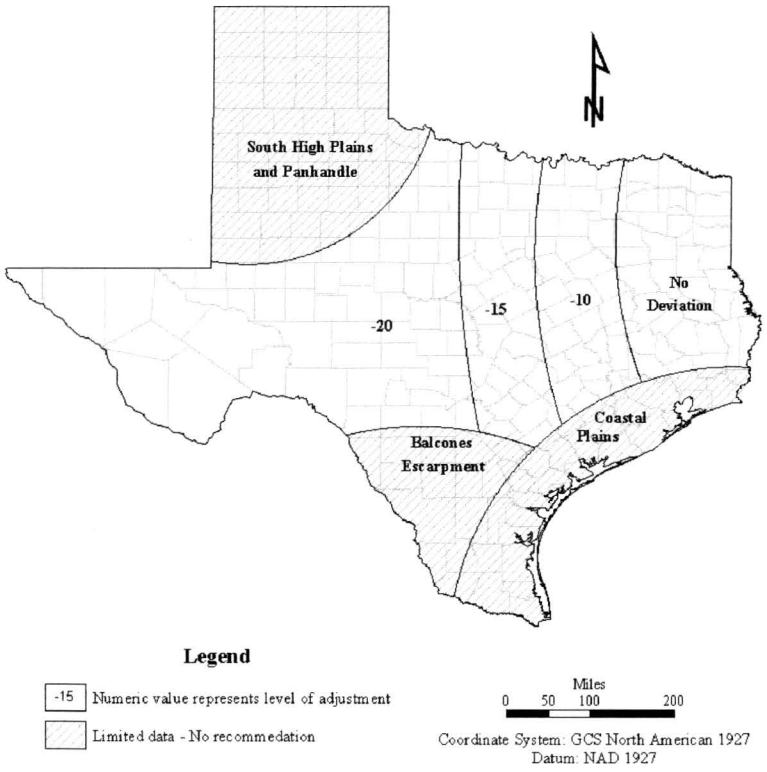
Climatic Adjustment of NRCS Curve Numbers

Project 0-2104: Climatic Adjustment of NRCS Curve Numbers

NRCS Curve Number Adjustment



A large component of any highway construction project is the design of facilities for drainage. Engineers are required to make estimates of peak discharge from a watershed so that appropriate drainage facilities can be sized.

One of the techniques used to make such estimates is the unit hydrograph method. One of the components of that method is the conversion of rainfall to runoff. A technique for this part is the Natural Resources Conservation Service's (NRCS) runoff curve number method.

Engineers use the runoff curve number to convert depth of rainfall to depth of runoff. For semi-arid regions, the runoff curve number typically used results in estimates of runoff that are too large. Therefore, the research focused on using measurements from gauged watersheds to construct a map for correction of the curve number to a value that produces more reasonable estimates of runoff depth.

The project represents a significant (and long overdue) improvement in hydrologic loss modeling in that it has identified and confirmed that the NRCS Curve Number loss model should and can consider the impact of climatic variation across the state. The results of the research have also produced a method that TxDOT can apply in this consideration.

Benefits

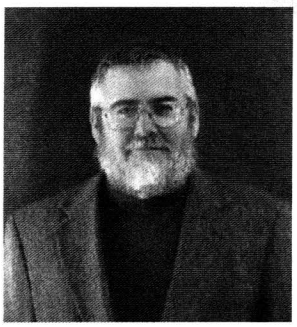
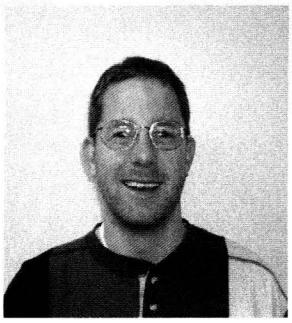
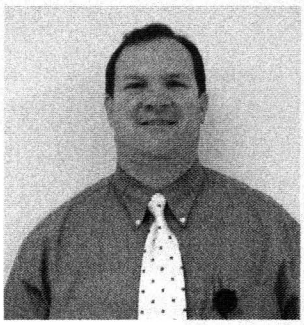
The advantages of a Climatically adjusted method are:

1. Adjustment of the runoff curve number results in better estimates of discharge. Designers then can make designs that are, in general, smaller than those from the original approach. This directly results in a cost savings for construction. In addition, better estimates of discharge give the designer flexibility in choosing where to put more conservative structures, that is, structures that are somewhat larger than required by the design discharge to provide additional flow capacity.

2. We have a more systematic and reliable method for computing losses in rainfall-runoff (rainfall-runoff models are deterministic and rely on user inputs to develop outputs, poor inputs mean unreliable outputs) for hydrologic modeling and a higher confidence in computing discharges.

3. Discharges that correlate better with statistical expectation allow us to evaluate risk better in terms of safety, performance and maintenance. The implied "factor of safety" embedded in the traditional method was difficult to evaluate. As a result, it has not been unusual to see essentially the "same" project configuration for a low risk and high risk project because of the unknown factor of safety. The new method will allow more engineering judgment to be employed to better distribute limited resources based on risk. Therefore, the research focused on using measurements from gauged watersheds to construct a map for correction of the curve number to a value that produces more reasonable estimates of runoff depth.

The project represents a significant improvement in hydrologic loss modeling in that it has identified and confirmed that the NRCS Curve Number loss model should and can consider the impact of climatic variation across the state. The results of the research have also produced a method that TxDOT can apply in this consideration.

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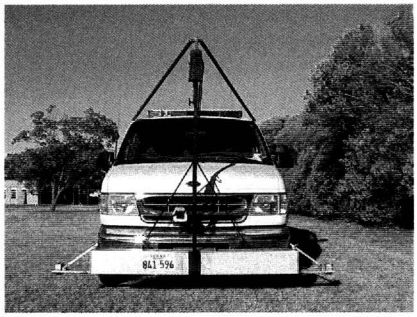
Automated Pavement Surface Distress Rating System for Asphaltic and Concrete Pavements

Project 7-4975:
Implementation of an Automated Pavement Surface Distress Rating System for Asphaltic Pavements

The automated pavement surface distress measurement system consists of a digital line scan camera, high-speed frame grabber, computer, and custom software, and is able to analyze 100% coverage of the pavement being surveyed in real-time at travel velocities between 3 mph and 70 mph. The system uses natural lighting and is able to detect vehicle shadows, cracks, sealed cracks, punch-outs, and other unusual distress. A pavement image has 2048x512 pixels, covering 10 feet of transverse width and 3 feet of longitudinal distance. The scanning rate and exposure time of the camera can be automatically adjusted so that it can work at varying vehicle speeds and under different lighting conditions. The system has shown good data repeatability under different scanning conditions.

The system can classify cracking for both flexible and rigid pavements and can place the distresses measured into two distinct rating summary formats. For flexible pavements, the system reports the data in both the PMIS and AASHTO ACP formats. The PMIS data includes transverse and longitudinal cracks, as well as alligator and block cracking, while the AASHTO data includes crack densities in four separate areas of lane width. For rigid pavements, the system reports the AASHTO data as well as the counts of transverse cracks, longitudinal cracks, spalled cracks, and punch-outs. The system sends the distress data to an uploadable file on the user interface computer at a summary interval of 0.1 mile of pavement. The system can also transfer crack maps to the user interface computer if the travel speed is less than 45 mph.

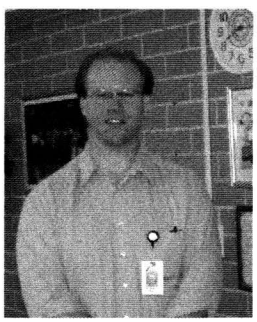
Benefits



The automated pavement distress measurement system was developed to replace the current manual rating surveys of the TxDOT-maintained network. The new automated system is being retrofitted onto existing profiler/rut measurement system housing vehicles. This allows TxDOT to collect visual distress, ride, rut, GPS data, digital R-O-W images, and distance in one pass of the survey vehicle on 100% of the network. This combination of measurement systems has many benefits over the current data collection and analysis techniques. The manual surface distress surveys are currently contracted out. This contract costs $1.6 million per year. Another $200,000 is spent annually for a manual audit survey to check the contractor's work.

The manual distress survey method is potentially hazardous to the driving public as well as to the contractor and district personnel. Contractors and audit teams travel at speeds less than 15 mph on the shoulder or in the travel lane while providing subjective ratings of the pavement surface distresses. The new system is able to collect and analyze data at the posted speed limit (up to 70 mph), which increases safety for everyone driving Texas highways.

The PMIS upload data is available immediately after the survey is completed. Since multiple data types are captured and stored with one pass of the housing vehicle, many hours of personnel time are saved. The automated system provides more dense data summaries for PMIS. The current manual survey summarizes visual distress data over each PMIS section length, normally 0.5 miles. The new automated system can summarize the data over any summary interval, currently set to 0.1 mile. The new system is also able to provide crack map information for project-level distress surveys. The new automated distress measurement system is much more repeatable than data from a group of manual raters. The increased repeatability means that pavement distress data from across the state can be compared. The variability of the measurements represents the actual pavement distresses, not the difference from subjective ratings. Finally, since the distress measurements are processed and summarized by the on-board computers, there are no transcription errors associated with the results.



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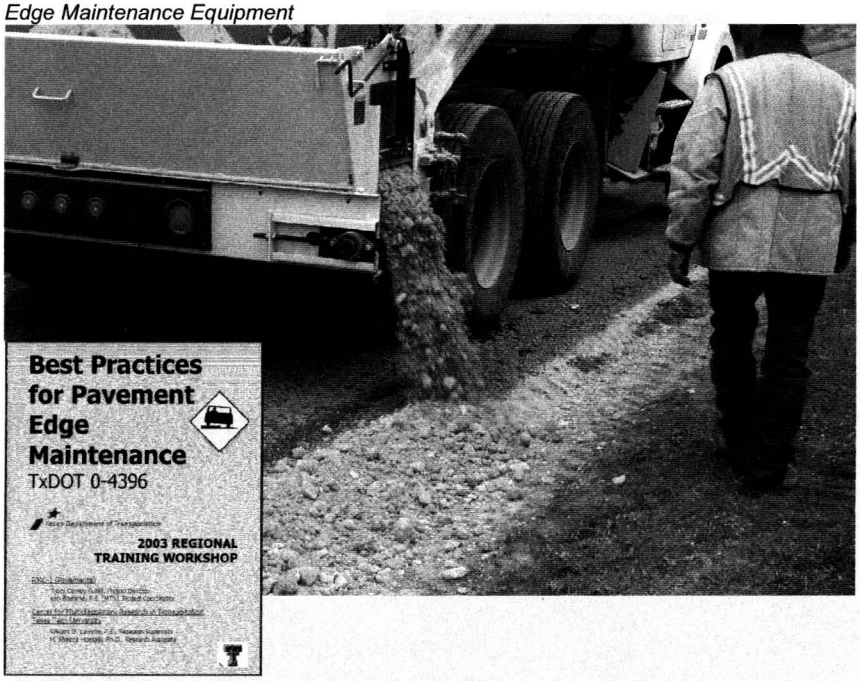
Edge Maintenance Equipment



Improving Edge Repair and Stabilization

Project 0-4396: Improving Edge Repair and Stabilization

Attended by more than 550 maintenance personnel throughout the State, the "Best Practices for Pavement Edge Maintenance" training program addresses the problem of pavement edge drop-offs as a maintenance, safety, and liability issue for the Texas Department of Transportation (TxDOT).

The objectives for this 2-year research project – to identify and to effectively communicate best practices for pavement edge maintenance – were accomplished by capturing over 3700 years of institutional knowledge from maintenance leaders representing all 25 Districts of TxDOT. The research focused on naturally occurring edge drop-offs with an emphasis on low-volume roads.

A strategic goal of the research was to deliver effective, practical, hands-on instruction geared explicitly toward TxDOT maintenance section personnel. Learning objectives focused on (a) defining pavement edge drop-offs using TxDOT *Maintenance Manual* level-of-service criteria, (b) recognizing the conditions that cause pavement edge damage, (c) implementing various edge maintenance and repair practices and procedures, (d) selecting appropriate edge maintenance equipment for the repair, (e) using edge maintenance planning tools, (f) contracting out edge repair work using a pavement edge maintenance specification, and (g) providing learning resources for more information.

TxDOT maintenance personnel obtained edge repair instruction through a series of eight regional half-day training workshops, both face-to-face and by video teleconference, conducted around the State. The training package consisted of presentations, film clips, and other illustrations, summarized in the training manual provided to each attendee. TxDOT videotaped one of the training events and VHS cassettes of the training were provided to each maintenance section.

Benefits

One key benefit of this research has been the consolidation of more than 3700 years of institutional knowledge regarding edge repair techniques, as well as the preservation and dissemination of this institutional knowledge. Improved pavement edge maintenance practices resulting from this research will, among other things:

Save Lives and Improve Highway Safety for the Traveling Public:
Year 2000 crash data from the Texas Department of Public Safety, the National Safety Council, and the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration suggest the following:

- In Texas, the annual number of **accidents** "due to defective shoulders" or "relative to shoulders" ranges from 676 to 4990 (depending on how the data are aggregated).

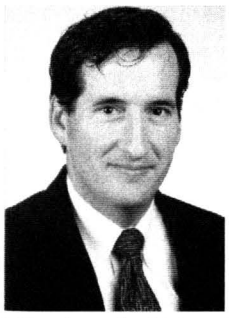
  If one takes the average of this range (3171 shoulder-related accidents), and assumes that improved edge maintenance practices resulting from this research will reduce the accident rate by 10 percent, one gets a reduction of 317 accidents, annually.

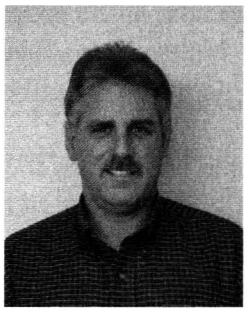
- In Texas, the annual number of **fatalities** "due to defective shoulders" or "relative to shoulders" ranges from 1 to 206 (depending on how the data are aggregated).

  If one takes the average of this range (104 shoulder-related fatalities), and assumes that improved edge maintenance practices resulting from this research will reduce the fatality rate by 10 percent, one gets a reduction of 10 fatalities, annually.

Using a formula developed by the National Safety Council, the reduction in accidents translates to a reduction in economic loss associated with those accidents of $29.4 million. The calculation shown above incorporates several non-validated assumptions and is subject to critical evaluation, but it is believed to be reasonable.

Increase Efficiency in Pavement Maintenance Operations and Enhance the Effectiveness (Durability) of Pavement Maintenance Efforts:
Edge maintenance involves much, much more than simply edge repair function code 270 ($11.5 million, or 2.5 percent of the annual routine maintenance budget), even though it does not include all costs posted to the 22 function codes identified as being involved with edge repair ($213 million, or 47 percent of the annual routine maintenance budget). Somewhere in between is probably reasonable. A conservative estimate of 10 percent of the annual routine maintenance budget, amounts to about $45 million/ year. On this basis, it would not be unreasonable to suggest that this project will result in annual savings of 10% annually on edge repair, or $4.5 million/year.





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About the Research and Implementation Programs

TxDOT's Research Program was established by commission minute order on September 29, 1948. That directive provided a research program between the Agricultural and Mechanical College of Texas and the Texas Highway Department. The program has grown over the years to include numerous other Texas public universities. It has also grown in size, reputation, and value to the department. It is widely recognized as a model program among research and transportation professionals across the country.

A key to the success of this program is that it draws upon the expertise of department personnel from across the state. Five statewide research management committees, each assigned a specific technical or operational area of responsibility, create and give direction to annual programs of research designed to reach identified goals and provide specific benefits. Input concerning research needs and opportunities is received from TxDOT personnel and representatives of each participating university.

Individual research projects are also cooperative efforts between universities and the department. While university researchers perform the vast majority of the research work, every project has a department project director who provides support and assistance to the researcher. The project director also monitors work progress and reviews and approves research findings and reports. The project director is usually assisted by other department personnel serving in project advisor roles.

Department research is funded primarily from a federal source titled the State Planning and Research (SPR) program. These federal funds are dedicated to research and planning functions. The program requires one dollar in state contribution for every four dollars of federal funding used by the state (20% match).

The department formalized an Implementation Program in 1999. The purpose of this program is to assure that all research findings are carefully analyzed, that findings and innovations of value are identified, and that these research results are properly implemented into TxDOT's operations. More than 60 percent of findings are ultimately implemented, which is a considerable portion considering the exploratory nature and uncertainty of research. Annual return on investment from the research program is difficult to accurately determine, but it is many times the total cost of the program. In an evaluation of the top innovations from 1999-2001, it was demonstrated that the cost savings derived from 21 products exceeded the cost of the research program by approximately $268 million.

Overall management of both the research program and the implementation program is the responsibility of the Research and Technology Implementation Office. Questions related to either program may be directed to personnel of this office at 512-465-7403.

Top Research Innovations and Findings, 2002

•New Detection System for Rural Signalized Intersections
•Scanning Laser Used for Transverse Profile Measurement
•Inventory and Data Management Methods for Utilities in Rights-of-Way
•Guidebook for Inland Ports
•Access Management Guidebook for Texas
•New Test Procedure to Measure Sulfate Content of Soils
•Safety Treatment Guidance for High Crash Locations on Rural Two-Lane Highways

Top Research Innovations and Findings, 2001

•Micro-Deval Test Equipment
•Windows Version of Modulus / FPS19
•New Asphalt Aging Equipment
•Model Border Crossing Design
•Method to Evaluate TCM Effectiveness in Ozone Nonattainment Areas
•Sign Crew Field Book
•Analysis of Small Target Visibility Method
•Structural Capacity Determination Using Damage Index

Top Research Innovations and Findings, 2000

•Strengthing of Existing Structures with Composites
•Automated Routing of Overweight Vehicles
•Truck Monitoring and Warning System for Freeway-to-Freeway Connections
•Use of Waste Toner in Asphalt
•Erosion Function Apparatus (EFA)
•Guidelines for Improved Driveway Location on Frontage Roads
•Pavement Surface Texture Measurement System
•Test for Radio Frequency Interface (RFI) in Vehicles
•Design and Construction of Continuous Flight Auger Cast Piles for Transportation Structures
•Super Two Geometric Design Guidelines