

Center
for Transportation
Research

Annual
Report
1990

The University
of Texas
at Austin

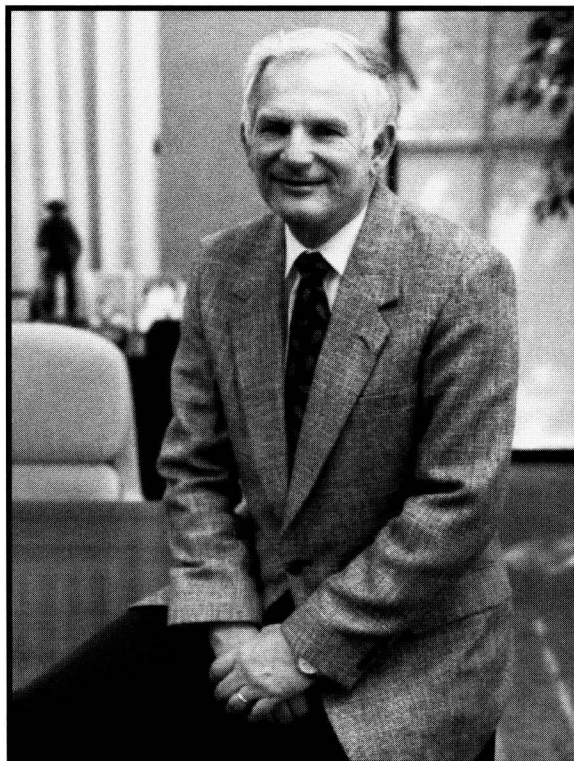


The Center is eagerly looking forward to developing concepts and ideas in the 90's for application to the problems anticipated for the 21st century. As the world shifts from a cold war era, infrastructure problems should rise in priority. The educational experience achieved by our students working on research projects, and the results they produce, will be invaluable in solving the state's and nation's infrastructure transportation problems.

The Center continues to grow in the number, value, and variety of research projects. During the year, we were pleased to add the Advanced Institute for Transportation Infrastructure Engineering and Management to our group. The Institute provides us an opportunity to attract the brightest students to the transportation area. The impact of this program will be the continued improvement of student quality and consequently, of the research output.

The past year has provided us the opportunity to move into the areas of energy, mobility, and equipment development. Energy continues to be of concern and our studies in optimum vehicle sizes, mobility techniques, and people movers provide criteria for energy efficiency planning. Studies in the area of high-speed corridors and rapid pavement testing are giving direct solutions to the state's transportation facilities.

We are happy with our progress during the past year and welcome the opportunity to share it with you. Thus, to our colleagues, former students, and friends, we extend a Texas invitation — "Y'all come to see us when you can."



B. Frank McCullough

B. Frank McCullough

The Center for Transportation Research is a multidisciplinary transportation research and educational organization established within the Bureau of Engineering Research of the College of Engineering to coordinate research and education programs in transportation at The University of Texas at Austin. As such it focuses on local and state transportation problems, which also reflect the national interest, and provides an academic background for the development of professional careers in transportation. It offers a forum for faculty and student participation through close working relationships with industry and government agencies, as well as other universities with common goals and interests in transportation education and research.

One goal of the Center is the development of fundamental knowledge on a broad spectrum of transportation problems and issues. It engages in a continuous effort to identify new research possibilities for the University community and sponsors various meetings to facilitate the exchange of ideas on transportation and societal needs with industry and government.

The Center coordinates and administers a comprehensive research program aimed at improving transportation and represents the University in a cooperative Transportation Research Program with the Texas State Department of Highways and Public Transportation and the Federal Highway Administration and other agencies of the U.S. Department of Transportation. Many of the projects conducted at the center are cooperatively sponsored by these agencies.

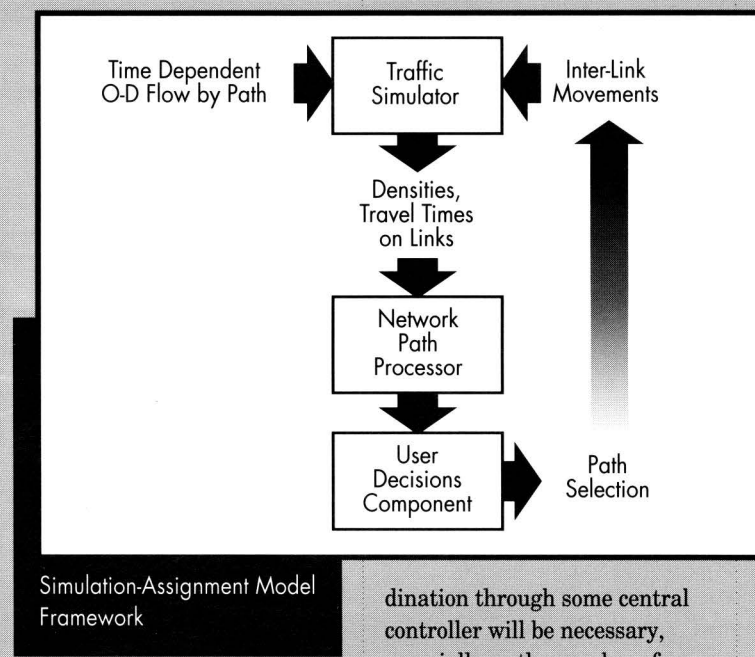
The key to the Center's program is the University faculty, which gives the broad based experience and expertise required to conduct a successful research program. Center projects are conducted by full-time faculty members and students, supported by a small administrative staff, in keeping with the University goal of linking meaningful research with academic programs. One result is that many students find employment with research sponsors upon completion of their academic programs.

Information and Telecommunications Approaches to Improve Transportation System Performance

by Hani S. Mahmassani

Traffic congestion is a major problem for cities worldwide, and projected increases have generated concern as well as recognition of a need for better management and control of traffic congestion in urban networks. At least part of the solution is likely to take the form of information-based approaches, technologies widely known by such acronyms as IVHS (Intelligence Vehicle-Highway Systems), ADIS (Advanced Driver Information Systems), and ATMS (Advanced Traffic Management Systems). The fact that there are several related projects in Europe, Japan, and California indicates that commitments have already been made towards the development and application of in-vehicle navigation and guidance systems which provide individual drivers with information and instructions on a real-time basis.

The logic of these systems is simple. It requires that vehicles have on-board communications and microprocessing capabilities allowing each vehicle to keep track of its respective positions in the network; information on vehicle locations and trip times is relayed to some central processor/controller, which in turn transmits these data to the vehicles, together possibly with instructions concerning which routes to follow. While technologies are available for the various components, their deployment as integrated systems for traffic control and network management purposes presents a number of challenging problems—in particular, the form, type, con-



tent, frequency, and level of detail of the information supplied to drivers.

Center for Transportation Research (CTR) project 71248 (supervised by Drs. Mahmassani, Herman, and Walton), is attempting to assess the effectiveness of in-vehicle information schemes. Its main goal is to identify and examine fundamental processes and phenomena that are critical to telecommunications technologies for the control of vehicular traffic in congested networks. Among the accomplishments of the project to date, the most notable is the development of a simulation-assignment model that represents the movement of vehicles in the network under different real-time information availability schemes. The model framework is illustrated graphically in the figure. Results to date indicate that while such information could be highly beneficial to individual drivers and overall, coor-

dination through some central controller will be necessary, especially as the number of information-equipped vehicles increases. Several papers documenting this methodology are available on request from CTR.

Another important problem pertains to the design of strategies and algorithms by which a central controller would guide drivers to alternative paths in the network. Future CTR research will design such algorithms and procedures and develop initial computer representations for eventual field deployment.

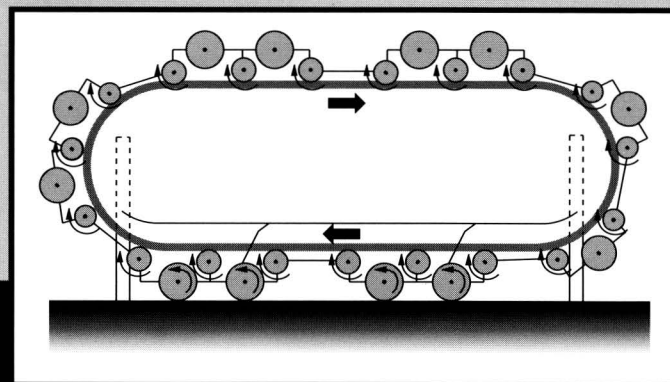
These brief reports on Center projects discuss areas in which there has been significant research progress and which are typical of Center activities.

MLS—A New Tool For Accelerated Pavement Testing

by Frederick Hugo

In 1990, the Center completed a study for the Texas Highway Department aimed at acquiring a Mobile Load Simulator (MLS) to conduct accelerated pavement testing (APT). The Department ultimately opted for developing its own machine, which is based on a design provisionally patented by the author. The MLS is being designed and built by CTR for the Department and should be operational by August 1992.

The principle is very simple. A number of conventional truck bogies are mounted on a chain of steel wheels linked together. These run around the structural frame on closed loops of steel rail. When the truck bogies pass under the structural frame, they are in contact with the road surface. The wheel load is transferred to the structural frame which serves as a counter weight (upper figure).



Conceptual Layout

The MLS will be able to apply 18-kip axle loads at an accelerated rate which can be achieved by other existing mobile vehicle simulators only by overloading the axles by 100 percent. Such application will enable a pavement structure to be subjected to the axle loads it is likely to experience over its design life.

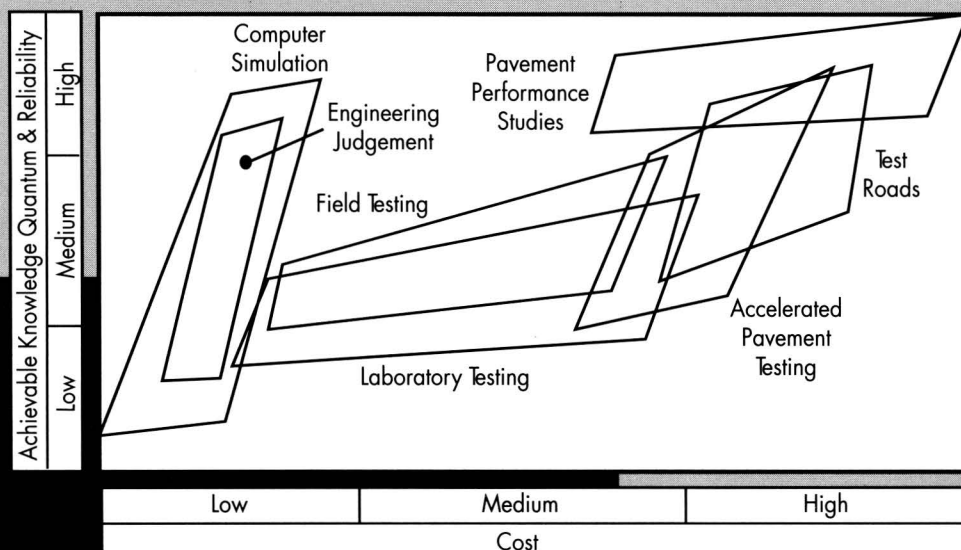
Although APT is not new, it has been utilized only in the last

18 years, with a strong increase in its application over the last decade. The FHWA has been using a machine based on the Australian Loading Facility since 1986.

Pavement engineering is made up of complementary elements. Each is capable of giving answers to only some aspects of the problem. The MLS will form an integral part of this system and is expected to enhance it. It will enable engineers to obtain answers to questions which are limiting some of the applications of the other design tools.

The relative scope and cost of pavement engineering tools are shown in the lower figure. The diagram also shows how the level of investment in pavement engineering utilizes specific portions of technology related to the various test methods and applications. Collectively this information is transformed into knowledge. Knowledge is gained only after a minimum investment and enhanced after further investment.

In the AASHO road test 1.1 million axle loads were applied to 836 pavement sections over a period of two years. The MLS is being designed to apply the same number of 18-kip axle loads in just more than one week!



Achievable Knowledge with Available Decision Tools, Relative to Investment Cost

SDHPT 3-10-90-187.7

Updating and Maintaining the Rigid Pavement Condition Survey Data Base
B. Frank McCullough and W. Ronald Hudson

SDHPT 3-10-88/9-428

The Effect on Mobility and the Cost-Effectiveness of Improving a Selected System of Arterial Thoroughfares in Harris County
William V. Ward

SDHPT 3-9-86/0-441

Treatment of Asphalt Mixtures with Lime and Antistripping Agents
Thomas W. Kennedy

SDHPT 3-8-86/0-460

Assessment of Load Transfer Across Joints and Cracks in Rigid Pavements Using the Falling Weight Deflectometer
Alvin H. Meyer and W. Ronald Hudson

SDHPT 3-5/9-87/9-481

Durability and Performance of Concrete Containing Fly Ash Including Its Use in Hot Weather Concreting and Prestressed Concrete Girders
Ramon L. Carrasquillo

SDHPT 3-9-86/1-490

Strategic Research Plan for Achieving Adequate Pavement Friction
Alvin H. Meyer and David W. Fowler

SDHPT 3-9-87/1-492

Mix Design Procedures and Considerations for Polymer Modified Asphalt Compatibility and Stability
Thomas W. Kennedy and Richard J. Holmgreen, Jr.

SDHPT 3-12D-85/0-920

Evaluation of Thin Bonded Concrete Overlays on IH-610 in Houston
B. Frank McCullough and David W. Fowler

SDHPT 3-15D-87/2-932

Monitoring the Performance of a Bebo Arch Culvert
Richard W. Furlong

SDHPT 2/3-18-88/9-957

Highway User Operational Information
C. Michael Walton, William V. Ward, and Mark A. Euritt

SDHPT 3-14D-88-960

District 14 Pavement Intersection Instability Study
Richard J. Holmgreen, Jr. and Thomas W. Kennedy

SDHPT 3-10-87/9-969

Evaluation of FHWA Requirements for the Collection of Pavement Roughness Data
B. Frank McCullough

SDHPT 2/3-1-88/9-974

Comparison of Cost Responsibility Studies
C. Michael Walton and Mark A. Euritt

SDHPT 3-4-90/0-979

Conversion of the SDHPT Six and Ten Yard Dump Truck Fleet from Standard to Automatic Transmissions
Robertarrison and Mark A. Euritt

SDHPT 3-4-90/1-983

Conversion of the SDHPT Automotive Fleet to Alternative Fuels
Hani Mahmassani, C. Michael Walton, and Mark A. Euritt

SDHPT 3-4-90/1-986

Automotive Diagnostic Technology
Randy B. Machemehl

SDHPT 3-11D-89/1-987

A Long-Range Plan for the Rehabilitation of U.S. 59 in District 11
David W. Fowler, B. Frank McCullough, and Clyde E. Lee

SDHPT 2/3-8/10-88/0-1107

The Role of the Arterial Street System in Urban Mobility
William V. Ward, Clyde E. Lee, and Randy B. Machemehl

SDHPT 2/3-18-87/9-1123

Non-Destructive Test Procedures for Analyzing the Structural Condition of Pavements
Kenneth H. Stokoe, II, Jose M. Roesset, and W. Ronald Hudson

SDHPT 3-8/18-89/1-1139

Interactive Graphics Intersection Design System
Randy B. Machemehl

SDHPT 3-6-88/0-1149

Investigation of Highway Project Constructability Improvement
James T. O'Connor, Fred Hugo, and William V. Ward

SDHPT 3-9-88/0-1158

Impact of Aggregate Gradation and Type on Asphalt Concrete Mixture Characteristics and Pavement Performance
Richard J. Holmgreen, Jr. and Thomas W. Kennedy

The 1989-90 research program of the Center for Transportation Research included the studies listed here and discussed individually on the following pages.

SDHPT 3-10-88/0-1162

**Infrared Detectors for Counting,
Classifying, and Weighing Vehicles**

Clyde E. Lee

SDHPT 3-8-88/0-1167

**Develop Smoothness Specifications
for Rigid and Flexible Pavements**

W. Ronald Hudson and Robert Harrison

SDHPT 3-8-88/2-1168

**Development of End-Result Acceptance
Specifications for HMAC**

William E. Elmore and Thomas W. Kennedy

SDHPT 3-8-88/1-1169

**Concrete Pavement Design Update
(AASHTO)**

W. Ronald Hudson and B. Frank McCullough

SDHPT 2/3-18-88/1-1175

**Development of Dynamic Analysis
Techniques for Falling-Weight
Deflectometer Data**

*Jose M. Roesset, Kenneth H. Stokoe, II,
and W. Ronald Hudson*

SDHPT 2/3/10-8-88/0-1177

**Development of Routine Resilient Modulus
(Mr) Testing for Use with the New AASHTO
Pavement Design Guide**

*B. Frank McCullough, Kenneth H. Stokoe, II,
W. Ronald Hudson, and Soheil Nazarian*

SDHPT 3-5-88/0-1180

**Wall Thickness Criteria for Hollow Piers
and Pylons**

John E. Breen

SDHPT 3-5-88/0-1181

**Bond and Anchorage of Epoxy-Coated
Reinforcement**

James O. Jirsa

SDHPT 3-8-89/1-1195

**Long-Term Strength Properties
of Compacted Fills for Embankment Design**

Stephen G. Wright

SDHPT 3-9-89/0-1198

**Concrete Strength Determination at Early
Ages in the Field**

*Ramon L. Carrasquillo, David W. Fowler,
and Alvin H. Meyer*

SDHPT 3-10-88/C-1199

**Library and Technology Transfer Support
of Cooperative Research Program**

B. Frank McCullough

SDHPT 3/11-8-89/0-1205

**Finite-Element Analysis of Bonded Concrete
Overlays**

*B. Frank McCullough, David W. Fowler,
and James R. Lundy*

SDHPT 3-5-89/0-1208

**Strength of Short Retrofit Anchor Bolts
Subjected to Environmental Cycling**

Richard E. Klingner

SDHPT 3-5-89/0-1209

**Effect of Improved Bonding of External
Tendons and the Use of Supplemental
Continuous Bonded Tendons in External
Post-Tensioned Bridges**

Michael E. Kreger and John E. Breen

SDHPT 3-5-89/1-1210

**Influence of Debonding of Strands
on Behavior of Composite Prestressed
Concrete Bridge Girders**

Ned H. Burns

SDHPT 3-5-89/1-1211

**Fretting Fatigue in External Post-Tensioned
Tendons**

John E. Breen and Michael E. Kreger

SDHPT 3-18-89/1-1216

**Driver Responses to Traffic Disturbances
and Control Strategies**

Hani S. Mahmassani

SDHPT 3-9-90/1-1222

**Establishment of Acceptance Limits for the
4-Cycle MSS and Modified Wet Ball Tests for
Aggregates Used in Seal Coats and HMAC
Surfaces**

Alvin H. Meyer and David W. Fowler

SDHPT 3-10-89/0-1223

**Evaluation and Implementation of ARAN
Unit**

W. Ronald Hudson

SDHPT 3-8-90/2-1227

**Expediting Urban Pavement
Construction**

William V. Ward and B. Frank McCullough

SDHPT 3-5-90/2-1234

**Instrumentation of Segmental Box Girder
Bridges and Multipiece Winged Boxes**

John E. Breen and Michael E. Kreger

SDHPT 3-5-90/2-1239

Bracing Effects of Bridge Deck

Joseph A. Yura

SDHPT 3/10-18-90/2-1243**Automated Equipment for Characterizing the Properties and Thicknesses of Pavement Layers**

Kenneth H. Stokoe, II, Jose M. Roeset, and Soheil Nazarian

SDHPT 2/3-1-90/2-1244**Evaluation of the Performance of Texas Pavements Made with Different Coarse Aggregates**

B. Frank McCullough and D. Zollinger

SDHPT 3-10-90/0-1246**Development of a Strategy for Acquiring and Using a Prototype Mobile Load Simulator and Testing of the Model Load Simulator**

Frederick Hugo and B. Frank McCullough

SDHPT 3-18-90/0-1906**TEXAS Model Validation for Left-Turn Phasing Alternatives**

Randy B. Machemehl

SDHPT 3-5-90/0-1911**Implementation of a Bridge Rehabilitation and Replacement Selection System on the SDHPT Mainframe Computer**

W. Ronald Hudson and Ned H. Burns

SDHPT IAC 3001**Presentation of Employee Training Courses: Asphalt Concrete Mixture Design and Construction**

Thomas W. Kennedy

Department of Transportation 60016**Optimal Design of Bus Transit Networks for Suburban Mobility Needs**

Hani S. Mahmassani

Department of Transportation 60017**Improved Energy Efficiency Through Better Urban Intermodal Coordination**

C. Michael Walton and Mark A. Euritt

Department of Transportation 60018**Telecommunications-Transportation-Energy-Interactions: Potential for Reducing Transportation Energy Consumption Through Telecommuting**

Hani S. Mahmassani

Department of Transportation 60019**Demonstration of Enhanced Arterial Street Traffic Flow, Reduced Fuel Consumption and User Costs Through Application of Super Street Technology**

Randy B. Machemehl

Department of Transportation 60020**Energy and System Cost Evaluation of Truck Size and Weight Changes**

B. Frank McCullough, Robert Harrison, Mark A. Euritt, and C. Michael Walton

Department of Transportation 60021**Fuel and Time Savings Through Expediting Pavement Construction**

Robert Harrison and B. Frank McCullough

University Transportation Centers Program 71247**The Technical, Engineering and Economic Feasibility of a High-Speed Ground Corridor**

Kurt M. Marshek, Robert Harrison, and B. Frank McCullough

University Transportation Centers Program 71248**Information and Telecommunications Approaches to Improve Transportation System Performance**

Hani S. Mahmassani, Robert Herman, and C. Michael Walton

University Transportation Centers Program 71249**Evaluating the Coordination of Intermodal Transportation Policies and Programs to Promote Economic Growth**

C. Michael Walton and Mark A. Euritt

Alaska Department of Transportation and Public Facilities**Presentation of Training Courses: The Inspection of Asphalt Concrete Pavement Construction**

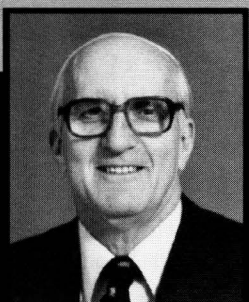
Thomas W. Kennedy

Strategic Highway Research Program**Improved Asphaltic Materials, Experiment Design, Coordination, and Control of Experimental Materials**

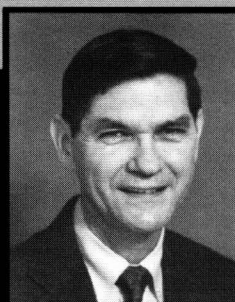
Thomas W. Kennedy

Texas Research and Development Foundation**Long-Term Pavement Performance Studies**

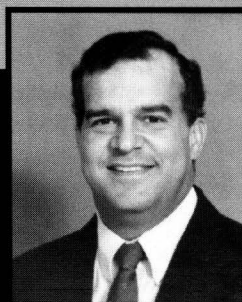
W. Ronald Hudson



John E. Breen
Professor
of Civil Engineering



Ned H. Burns
Professor
of Civil Engineering



Ramon Carrasquillo
Associate Professor
of Civil Engineering

SDHPT 3-10-90-187.7

Updating and Maintaining the Rigid Pavement Condition Survey Data Base *B. Frank McCullough and W. Ronald Hudson*

The primary objective of this project is to update and maintain the existing rigid pavement sections previously selected, by adding new pavement sections to the data base (special existing sections and newly built ones), and by addressing special Texas SDHPT requests related to the analysis and findings from the data that has been collected this far.

It is anticipated that the effective use of condition survey data can be increased if either the raw data or reduced data or a combination of raw and reduced data is stored in a Data Base Management System's environment so that the retrieval of such data is more efficient. The development of such a system is currently being undertaken but continuous updates and adjustments need to be made as the stored data continues to increase

SDHPT 3-10-88/9-428

The Effect on Mobility and the Cost-Effectiveness of Improving a Selected System of Arterial Thoroughfares in Harris County *William V. Ward*

It may not be feasible to increase the capacity of many segments of the freeway system in Harris County, but one plausible approach to coping with the continual congestion problems is to improve the traffic service along other roads and streets in order to supplement the freeway system. This study is being conducted jointly by representatives from Harris County, the City of Houston, the Texas SDHPT, the Metropolitan Transit Authority, and the Center for Transportation Research. The Center is supervising the study and performing operational and economic assessments of the thoroughfares and corridors selected for study and will write a report outlining the findings of the study. The other agencies are recommending candidate thoroughfares and corridors for study, furnishing planning data, and advising during the course of the study and will review the findings of the study.

SDHPT 3-9-86/0-441

Treatment of Asphalt Mixtures with Lime and Antistripping Agents *Thomas W. Kennedy*

The objectives of this study for the Texas SDHPT are to (1) determine the effectiveness of hydrated lime, (2) determine the effectiveness of selected liquid antistripping agents, (3) evaluate the relationships between test values for different mixtures and antistripping agents, and (4) evaluate field performance for different mixtures using different antistripping agents and relate test values to performance.

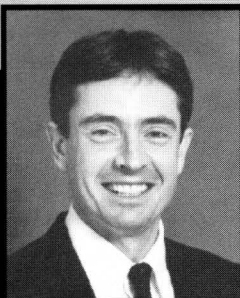
The findings will provide information related to the effectiveness of various antistripping agents, including hydrated lime, the applicability of the proposed test methods, the field performance of treated mixtures, and the relationship between performance and the predicted performance based on proposed tests. It is anticipated that the results will allow the effective treatment of asphalt mixtures to eliminate or reduce moisture damage at a minimum cost and will determine the ability of proposed test methods to predict field performance related to moisture damage. This information will allow improvements in test methods, the establishment of realistic specification values, and the possible need for additional tests.

SDHPT 3-8-86/0-460

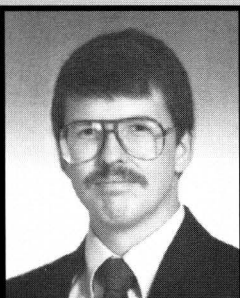
Assessment of Load Transfer Across Joints and Cracks in Rigid Pavements Using the Falling Weight Deflectometer *Alvin H. Meyer and W. Ronald Hudson*

The Texas SDHPT is developing techniques for analysis of pavement moduli using data from the Falling Weight Deflectometer (FWD). The equipment can be used to provide data on the condition of concrete pavements, concrete pavements with asphalt concrete overlays, and pavements with stabilized bases. When techniques for interpretation of the data are generated, they can be applied to evaluating load transfer across joints and cracks to determine whether treatment is needed before rehabilitation decisions are made.

The objectives of this study are to (1) field test the procedures for evaluating transverse joint efficiency using the FWD developed as part of a previous CTR project, (2) develop a method using the FWD to evaluate cracks in a rigid pavement for load, shear, and moment transfer, and (3) develop a method using the FWD to evaluate longitudinal joints, particularly rigid shoulder joints. The results of this study will be immediately implementable



Michael Engelhardt
Assistant Professor
of Civil Engineering



Mark A. Euritt
Research Associate



David W. Fowler
Professor
of Civil Engineering

in the form of manuals describing the procedures for using the FWD to evaluate joints and cracks

SDHPT 3-5/9-87/9-481

Durability and Performance of Concrete Containing Fly Ash Including Its Use in Hot Weather Concreting and Prestressed Concrete Girders

Ramon L. Carrasquillo

This study for the Texas SDHPT deals with the performance and long-term durability of concrete containing fly ash, a by-product of the production of electricity in coal-burning power plants. Although fly ash is not produced for use in concrete, it has been shown that, when properly selected and proportioned, it can be used to produce concrete meeting current SDHPT specifications. It is now being used in several state projects and is being considered for many others. However, the performance of concrete containing fly ash must be monitored in the field in order to provide the information necessary to ensure adequate life of the concrete.

There is an urgent need to determine whether or not concrete containing fly ash produced under current SDHPT guidelines has adequate performance and durability; i.e., freeze-thaw resistance, abrasion resistance, and sulfate resistance. The information generated by this study will provide the guidelines needed for proper control and efficient use of fly ash in producing good quality and durable concrete.

SDHPT 3-9-86/1-490

Strategic Research Plan for Achieving Adequate Pavement Friction

Alvin H. Meyer and David W. Fowler

The problem of wet-weather highway accidents in general and skid resistance in particular has long been of concern to highway engineers. There are many variables which affect driving safety, some of which are beyond the control of the engineer. It is essential that these variables and their interrelationships be understood as thoroughly as possible. This research is directed toward a comprehensive long-range program to determine causes and identify solutions.

The overall objective of this research for the Texas SDHPT is to develop design criteria which will develop and maintain adequate pavement friction. The benefits of this initial study will be a rational research plan to investigate the problems associated with wet-weather accidents and, specifically, to develop improved guide-

lines for establishing aggregate polish values to be used for flexible pavements. The ultimate benefit will be increased safety to the users of Texas highways.

SDHPT 3-9-87/1-492

Mix Design Procedures and Considerations for Polymer Modified Asphalt Compatibility and Stability

*Thomas W. Kennedy
and Richard J. Holmgreen, Jr.*

The primary objectives of this study for the Texas SDHPT are to (1) define the properties desired in a polymer modified binder, (2) select or develop tests which will best measure and quantify these properties in materials for seal coats and hot mixed asphaltic concrete, (3) develop proper design procedures for seal coats and hot mixed asphaltic concrete using polymer modified binders, and (4) prepare specifications for modified binders for each application.

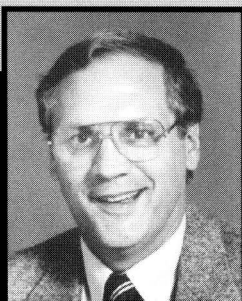
The findings of this study will provide valuable information on the properties of polymer modified binders, a proposed mixture design procedure, and proposed specifications. The field sections will provide insight to asphalt and polymer storage and construction problems. It is also anticipated that the implications of special handling on the construction process will be determined. The field sections will also provide performance data on inservice pavements.

SDHPT 3-12D-85/0-920

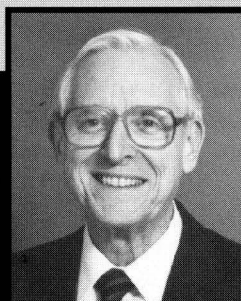
Evaluation of Thin Bonded Concrete Overlay on IH-610 in Houston

B. Frank McCullough and David W. Fowler

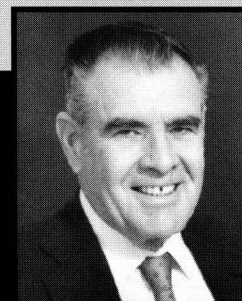
The primary objective of this study is to evaluate the performance of the thin bonded portland cement concrete overlay on about 3-1/2 miles of IH 610 in Houston and implement the findings in other active studies on thin bonded concrete overlays. The sub-objectives are to (1) identify several sections to represent the variations in present condition, materials used for the overlay, and construction procedures; (2) observe and record actual construction techniques and materials used; (3) make observations and/or measure behavior parameters immediately after opening the overlaid section to traffic and periodically every six months thereafter; (4) do statistical analysis to evaluate the relative merits of the



Karl H. Frank
Professor
of Civil Engineering



Richard W. Furlong
Professor
of Civil Engineering



Kenneth D. Hanks
Research Associate

alternatives actually used in this overlay project; (5) give recommendations on construction procedures and techniques; and (6) compare the results of this study with the recommended design techniques developed in Project 357, "Thin Bonded Concrete Overlay."

SDHPT 3-15D-87/2-932

Monitoring the Performance of a Bebo Arch Culvert

Richard W. Furlong

The structural performance of the reinforced concrete segmental arch culvert beneath Highway 1604 in northeast Bexar County will be monitored from the time of its construction until 1992. Observations and interpretations of measurements of performance will be reported at regular intervals during the monitoring period. Any exceptional or alarming performance observed will be reported immediately after observation. Three of the arch slab units will be monitored for the five-year period.

SDHPT 2/3-18-88/9-957

Highway User Operational Information

*C. Michael Walton, William V. Ward,
and Mark A. Euritt*

Unsolicited public response has indicated that highway users are sometimes dissatisfied with the operational information furnished by the signing and delineation system currently used on urban freeways. The Texas SDHPT wants to determine whether or not the system is effective in conveying the information needed by highway users, and the principal objective of this study is to assess the effectiveness of such information in the larger urban areas and, also, how such information is affected by Department practices in furnishing and maintaining the devices and facilities needed to supply relevant information accurately, clearly, and in a timely way, as perceived by the highway user. A special case in this study will be the assessment of the adequacy of the signing that guides highway users to commercial airports furnishing scheduled passenger service. If changes in Department practices are found to be desirable and practicable, the result should be improvements in user comfort and safety and increased operational efficiency of the highway system. (This is a joint project with the Texas Transportation Institute)

SDHPT 3-14D-88/0-960

District 14 Pavement Intersection Instability Study

*Richard J. Holmgreen, Jr.
and Thomas W. Kennedy*

Many of the asphalt pavement intersections in Texas SDHPT District 14, like those in many other Districts, have moved and shoved, making the pavements rough and, in some cases, unsafe. The cause of this problem is the inability of the asphalt material to resist movement when vehicles are stopping and accelerating. To address the problem, District 14 requested a study to evaluate different solutions.

The objectives are to (1) evaluate materials which improve material properties designed to relieve or eliminate plastic deformation at intersections and (2) determine the economic impact of using materials for the purpose of increasing pavement stability at intersections.

A method or methods to reduce or eliminate plastic deformation at intersections in District 14 will impact the entire state. The methods can be used or modified for use in other areas of the state, and maintenance costs can be saved through fewer repairs. The safety of the intersection will be increased with less rutting and a smoother ride. Other applications, such as high traffic volume and/or heavy load highways, can also result from information gained in this study.

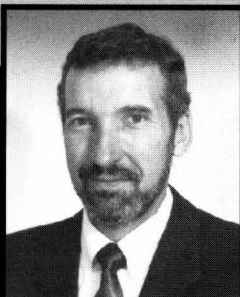
SDHPT 3-10-87/9-969

Evaluation of FHWA Requirements for the Collection of Pavement Roughness Data

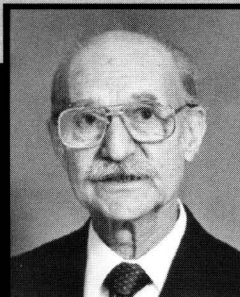
B. Frank McCullough

The Federal Highway Administration has added the collection of pavement roughness data to the Highway Pavement Maintenance System data collection requirements in all states. While several devices have been cited as being acceptable for the collection of roughness data, no specifications have been provided or are currently available from FHWA. The Texas SDHPT has been actively involved in the collection of pavement roughness data since the 1960's and is very concerned that FHWA pavement roughness data collection requirements be thoroughly reviewed. Specifically, the SDHPT is concerned that the established calibration procedures are sound and that the proposed roughness statistic has the sensitivity needed to provide meaningful data.

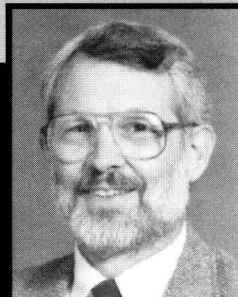
The proposed research addresses an evaluation of (1) the procedures developed by the FHWA, in Appendix J



Robert Harrison
Research Associate



Robert Herman
Professor
of Civil Engineering



Edward R. Holley
Professor
of Civil Engineering

of the HPMS manual, to determine their validity and adequacy, (2) the Face Dipstick, which has been identified by the FHWA as a substitute device for the rod and level in the calibration of roughness equipment, and (3) the ability of the FHWA IRI to serve as a roughness statistic for the SHRP LTPP. The possible benefits are both considerable and varied.

SDHPT 2/3-1-88/9-974

Comparison of Cost Responsibility Studies *C. Michael Walton and Mark A. Euritt*

Work on this project includes (1) examining the feasibility of updating results past 1985; (2) examining experience in Texas and other states to determine the impact of highway cost allocation (HCA) studies on changes in vehicle size and weight laws, and revenue structures; relationships between changes in vehicle size and weight laws and revenue distributions; and pavement life cycle; (3) preparing alternative analysis for Texas HCA study utilizing traditional analytical approaches; (4) performing alternative analyses using Texas data; and (5) performing comparisons. (This is a joint project with the Texas Transportation Institute)

SDHPT 3-4-90/1-979

Conversion of the SDHPT Six and Ten Yard Dump Truck Fleet from Standard to Automatic Transmissions

Robert Harrison and Mark A. Euritt

In the last decade automatic transmissions have become more common in U. S. truck operations. These transmissions are now reliable and allow drivers to concentrate more fully on driving duties and on operating ancillary equipment. SDHPT now considers it timely to examine the impact of changing part, or all, of the dump truck fleet from manual shift to automatic gearboxes.

The objectives of this study are to determine the immediate and long-term fiscal, operational, and personnel impacts of converting the SDHPT dump truck fleet from standard to automatic transmissions. The benefits could be extremely significant. Not only are improvements in productivity likely, but maintenance costs, when taken over the entire life of the vehicle, should be lowered. If service lives are lengthened with the use of automatic transmissions, there will be a reduction in annual budgets required to fund the purchase of new dump trucks for replacement purposes. Finally, there are the benefits of reduced accident rates, which could also be extremely significant.

SDHPT 3-4-90-983

Conversion of the SDHPT Automotive Fleet to Alternative Fuels

Hani Mahmassani, C. Michael Walton, and Mark A. Euritt

The Texas Legislature has approved a bill requiring vehicles purchased after September 1, 1991, to be capable of operation on alternate fuels. All state agencies maintaining fleets of 16 or more vehicles are affected, with a few minor exceptions. There are also requirements concerning future percentages of such fleets.

The principal objective of this study is to assist the SDHPT in the evaluation of the immediate and long-term implications of the conversion of its fleet of vehicles from gasoline and diesel to alternative fuels and in the formulation of a strategy in this regard.

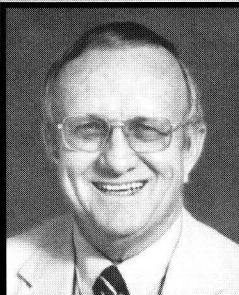
SDHPT 3-4-90/1-986

Automotive Diagnostic Technology

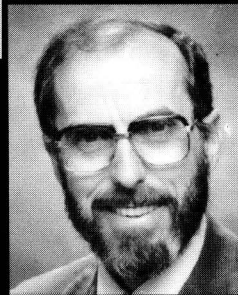
Randy B. Machemehl

The SDHPT performs maintenance services on a large fleet of automotive and construction equipment through its District maintenance facilities. Equipping these facilities with the most appropriate type of diagnostic equipment offers potential for controlling costs and enhancing efficiency. The question is whether or not the Department should purchase diagnostic equipment or contract for such services and, if it purchases hardware, what is the most appropriate type.

The objectives of the study are to (1) establish an accurate quantification of the demand and service rates for automotive diagnostic activities in the District maintenance facilities; (2) identify advantages and disadvantages associated with each of the basic classes of automotive diagnostic equipment in terms of capabilities, service rates, reliability, first cost, maintenance costs, and service lives; (3) develop estimates of costs of contracting for diagnostic services, as well as associated advantages and disadvantages; and (4) compare the alternative courses of action in economic terms, as well as other considerations. Facts, analyses, and models developed through this effort can provide insight for optimally equipping and staffing Departmental maintenance facilities.



W. Ronald Hudson
Professor
of Civil Engineering



Frederick Hugo
Research Fellow



James O. Jirsa
Professor
of Civil Engineering

SDHPT 3-11D-89/1-987

A Long-Range Plan for the Rehabilitation of U.S. 59 in District 11

David W. Fowler, B. Frank McCullough, and Clyde E. Lee

This project addresses the need to improve pavement performance service along U.S. 59 in District 11, by providing and maintaining a minimum satisfactory pavement riding quality at the least annual cost. Cost includes the SDHPT construction, operational, and maintenance costs, as well as the highway user's time and operational and safety costs during construction and maintenance operations. This project will lead to a long-range plan for the rehabilitation of U.S. 59 that will not only save money in District 11 but may also serve as the pattern for similar rehabilitation programs in other districts.

SDHPT 2/3-8/10-88/0-1107

The Role of the Arterial Street System in Urban Mobility

William V. Ward, Clyde E. Lee, and Randy B. Machemehl

Attention is being focused on the role that arterial streets should play in enhancing urban mobility. It is postulated that increasing the capacity and scope of a regional arterial street system would provide alternate travel routes for traffic ordinarily expected to be accommodated on the highway system and that such improvements might be as, or more, cost-effective than improvements to the existing highway system.

Some of the principal objectives of this study for the Texas SDHPT are to determine (1) the effect of arterial route location, segment length, and capacity improvements on traffic demand along both the arterials and the highway system, (2) the cost-effectiveness of arterial improvements, considering also traffic operations enhancements to the existing highway system, (3) design standards that may be appropriate for arterial streets, and (4) the relationship of continuity and length of arterial streets to trip lengths. The primary benefit from this study would be to provide the means by which the SDHPT could acquire insight into the question of whether or not to adopt a new program of implementing arterial street construction or perhaps modify or expand some other program

SDHPT 2/3-18-87/9-1123

Non-Destructive Test Procedures for Analyzing the Structural Condition of Pavements

Kenneth H. Stokoe, II, Jose M. Roesset, and W. Ronald Hudson

The non-destructive testing techniques adopted during the course of this study for the Texas SDHPT can be used to evaluate the roadway strengths of Texas highways and to detect voids underneath the pavement surface layers and changes in the pavement cross-section.

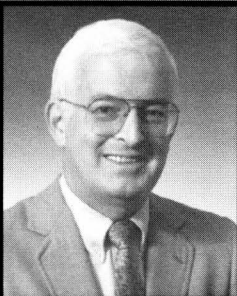
Specific results of this study include (1) developing daily and seasonal correction factors based on climatic zone and pavement type; (2) verifying the modulus values back-calculated from field NDT data with those measured on samples tested in the laboratory under similar loading environmental conditions; (3) providing the Department with a series of instrumented test sections to evaluate the effect of higher tire pressures, higher wheel loads, etc., on Texas pavements; (4) providing a correlation between the Dynaflect, Falling Weight Deflectometer, and SASW method; and (5) reducing costs by replacing slow, expensive laboratory testing with rapid NDT. (This is a joint project with the Texas Transportation Institute)

SDHPT 3-8/18-89/1-1139

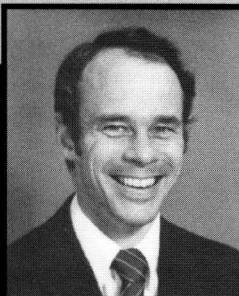
Interactive Graphics Intersection Design System

Randy B. Machemehl

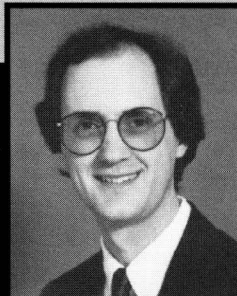
The overall objective of the research effort is the development of an Interactive Graphics Intersection Design System (IGIDS) which will aid engineers in the design and modification of at-grade intersections. Availability of an IGIDS will help insure appropriateness and efficiency of intersection designs and improvement programs. Such a system will help reduce the quantity of engineering and technician effort required for developing and maintaining safe, cost-effective intersection features. Results of the proposed research can be put into immediate use by Texas SDHPT personnel who perform intersection design and improvement tasks. The IGIDS can be utilized by both Division and District personnel of the Department as well as by traffic engineers in Texas cities and counties and others. The IGIDS will not be a substitute for sound engineering analysis and judgment, but it will provide engineers with the necessary tools for performing much more complete analyses and thereby provide a much better basis for making decisions.



Thomas W. Kennedy
Professor
of Civil Engineering



Richard E. Klingner
Professor
of Civil Engineering



Michael E. Kreger
Professor
of Civil Engineering

SDHPT 3-6-88/0-1149

Investigation of Highway Project Constructability Improvement

*James T. O'Connor, Fred Hugo,
and William V. Ward*

Constructability Improvement (CI) is the optimum use of construction knowledge and experience in planning, designing, procuring for, and conducting field operations to achieve the overall project objectives, i.e., it is determining the best way to achieve overall project objectives. CI also results in a reduction of the cost of a project.

The objectives of the study for the Texas SDHPT are to explore constructability factors that are relevant to highway construction and to identify needed procedures and supportive tools for ensuring cost-effective highway project constructability. The information generated by this study would include (1) a Highway Constructability Concepts file, which will describe meaningful constructability concepts and their relationships to the planning and design of highways and list specific applications of each, and (2) a report describing principles for effective implementation of constructability concepts.

SDHPT 3-9-88/0-1158

Impact of Aggregate Gradation and Type on Asphalt Concrete Mixture Characteristics and Pavement Performance

*Richard J. Holmgreen, Jr.,
and Thomas W. Kennedy*

For many years problems that have existed in asphalt concrete, such as tenderness and stability problems, have been attributed to the asphalt cement. The temperature susceptibility of an asphalt may have an impact on these problems, but previous studies have shown that in many cases aggregate gradation characteristics were the major factor producing the problem.

The overall goals of this study for the Texas SDHPT are to determine the importance of aggregate characteristics on the behavior of asphalt mixtures and pavement performance and to recommend specifications. The findings of this study will reveal the effect of current aggregate gradation specifications on asphalt concrete mixture properties and pavement performance. Information from this study will identify aggregate gradation problems which may be currently acceptable with respect to present knowledge and Texas specifications. Using an improved gradation specification with consideration to asphalt cement tenderness and asphalt sensitivity of the

mixture, these problems can be significantly reduced. Improved durability and stability should also result from this study.

SDHPT 3-10-88/0-1162

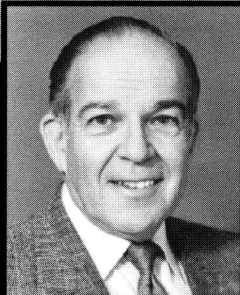
Infrared Detectors for Counting, Classifying, and Weighing Vehicles

Clyde E. Lee

Counting, classifying, and weighing vehicles are three basic functions that are essential to the Texas SDHPT in meeting the continuous statewide need for readily available information concerning the current and future traffic loading of highways. Each of these processes requires detection of the passage of a vehicle over a point on the roadway with respect to time, and devices currently used all have certain inherent physical characteristics which limit their effectiveness and durability. Recent advances in technology have made sensitive, rugged reflex type infrared sensors and associated electronic instrumentation, in the form of microcomputers, commercially available at reasonable cost. The ability to sense the passage of either a vehicle or a wheel in a traffic lane under day and night conditions with a reflex type infrared detector offers some very significant possibilities.

The basic objective of this study for the Texas SDHPT has been to determine the feasibility of developing a data-collection instrument for counting, classifying, and weighing moving highway vehicles using commercially available hardware components, including reflex type infrared sensors and a microcomputer.

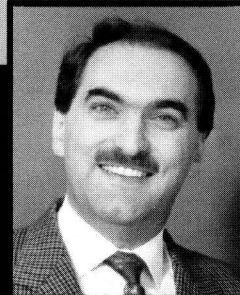
Considerable efficiencies and economies in making routine, as well as special, traffic surveys can be realized. Automatic vehicle classification can be used in lieu of manual observation, and adequate estimates of vehicle weight made by the system could supplement more sophisticated weigh-in-motion instrument systems that are currently in use. Since the detectors are non-contact, only minimum routine maintenance should be required. The equipment can be installed at the roadside, or in some cases mounted overhead, with little or no interference to traffic.



Clyde E. Lee
Professor
of Civil Engineering



Randy B. Machemehl
Associate Professor
of Civil Engineering



Hani S. Mahmassani
Associate Professor
of Civil Engineering

SDHPT 3-8-88/0-1167

Develop Smoothness Specifications for Rigid and Flexible Pavements

W. Ronald Hudson and Robert Harrison

Development and implementation of an improved specification based on a suitable roughness measuring device, responsive to objective components of roughness of the pavement as well as to subjective components which are commonly referred to as "ride," are needed for the state of Texas. The roughness device should be robust, portable, easy to assemble and operate, and economical to own and use.

The basic objective of this study for the Texas SDHPT is to select a smoothness device and develop an improved smoothness specification that can be used in testing and acceptance of newly constructed or overlaid flexible and rigid pavements.

Improved smoothness acceptance specifications will improve the riding quality and thus the pavement life of Texas highways. The need for early rehabilitation or reconstruction may be reduced, as well. The study will benefit the state by providing greater return on pavement investments. Implementation of the improved specifications will lead to increased safety and riding comfort on Texas highways, and users of the highway system will also benefit from reduced vehicle operating and maintenance costs.

SDHPT 3-8-88/2-1168

Development of End-Result Acceptance Specifications for HMAC

William E. Elmore and Thomas W. Kennedy

Texas is gradually moving to end-result specifications. Such specifications must be based on statistical concepts and incorporate penalties and incentives consistent with expected performance. An end-result specification would ease Texas SDHPT personnel requirements by shifting the responsibility for quality control testing to the contractor. Acceptance testing, however, would remain with the Department. The specification must be developed to balance the economics, with an acceptable level of risk for both the contractor and the Department.

The overall goal of this project for the Texas SDHPT is to develop and implement an end-result specification for asphalt mixtures and asphalt concrete pavements which is statistically based and includes penalties and incentives for poor or superior construction.

SDHPT 3-8-88/1-1169

Concrete Pavement Design Update (AASHTO)

W. Ronald Hudson and B. Frank McCullough

The objective of this study is to upgrade design methods for portland cement concrete pavement, including new pavements and overlaid pavements, for use by the Texas SDHPT. Specifically, the concepts of the 1985 AASHTO rigid pavement design guide will be investigated and modified for direct use in Texas. The work will include at least two sub-objectives: (1) to study, revise, and update programs JRCP and CRCP with knowledge gained from recent research studies and findings and (2) to update design standards and standard detail sheets utilizing results of computer programs and other new information.

The results of this study will produce improved designs for pavement structures which will reduce their cost of construction, maintenance, and rehabilitation. By using the current state-of-the art, it will be possible to design better pavement structures than in the past, which will greatly benefit the state. The inclusion of several new factors and criteria in design methods will help the designers to estimate the consequences of selecting various alternate designs, and thus, available highway funds can be utilized more effectively.

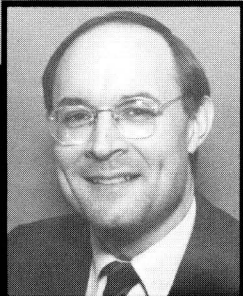
SDHPT 2/3-18-88/1-1175

Development of Dynamic Analysis Techniques for Falling-Weight Deflectometer Data

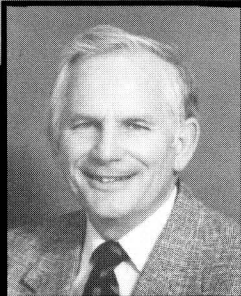
Jose M. Roesset, Kenneth H. Stokoe, II, and W. Ronald Hudson

The objectives of this study for the Texas SDHPT are to develop a computer model of pavement response to the loads applied by the Falling Weight Deflectometer, accounting for dynamic effects and nonlinear material behavior, to conduct a series of field tests to monitor the response of pavements to the FWD, to compare the predictions of the computer program with the measured data, and to recommend field procedures for optimum performance of the FWD.

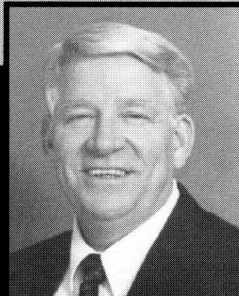
Results of this project should have significant benefits for the SDHPT by improving the understanding of data that can be reliably obtained with the FWD and providing a way to estimate more accurately pavement performance under actual traffic loadings. A more reliable method for ascertaining in situ material properties



Kurt M. Marshek
Professor
of Mechanical Engineering



B. Frank McCullough
Professor
of Civil Engineering



Alvin H. Meyer
Senior Lecturer
in Civil Engineering

results in improved pavement designs that may eventually lead to increased pavement service life and considerable cost savings. (This is a joint project with the Texas Transportation Institute)

SDHPT 2/3/10-8-88/0-1177

Development of Routine Resilient Modulus (MR) Testing for Use with the New AASHTO Pavement Design Guide

B. Frank McCullough, Kenneth H. Stokoe, II, W. Ronald Hudson, and Soheil Nazarian

The new AASHTO Pavement Design Guide adopted in 1986 requires the use of the Resilient Modulus Test for determining roadbed soil (subgrade) properties as well as the properties of other pavement components, namely, subbase, base, and asphalt-bound materials. This parameter is a fundamental engineering property that refers to the stress-strain behavior of the material under normal pavement loading conditions. At the present time, this test procedure is not being used routinely by personnel of SDHPT. It is essential to examine available Resilient Modulus Test equipment for soils and asphalt-bound materials and procedures to identify and/or develop simple laboratory and field test procedures to be used on a variety of typical Texas soils and conditions in order to allow for the use of the new AASHTO Pavement Design Guide in Texas.

The results of this study should make it possible for any District laboratory in the State as well as the laboratories in the Materials and Tests Division of the Texas SDHPT to incorporate the Resilient Modulus Test for use in pavement design. (This is a joint project with the Texas Transportation Institute and The University of Texas at El Paso)

SDHPT 3-5-88/0-1180

Wall Thickness Criteria for Hollow Piers and Pylons

John E. Breen

The objectives of this Texas SDHPT project are: (1) examine experimentally the effect of wall thickness on the strength and stiffness of prestressed and nonprestressed hollow piers and pylons, (2) develop an analytical model to investigate the local stability, stiffness, and strength of typical prestressed and nonprestressed hollow pier and pylon cross sections, and (3) develop design recommendations for the aforementioned hollow pier and pylon cross sections suitable for consideration for adoption in the AASHTO Design Specifications.

Since a number of bridges are being designed with thin wall pylons, it is important that the criteria be developed and implemented as soon as possible. Until such a systematic study is made, there will be continued uncertainty regarding the safety of these critical members.

SDHPT 3-5-88/0-1181

Bond and Anchorage of Epoxy-Coated Reinforcement

James O. Jirsa

The purpose of this study for the Texas SDHPT is to determine the influence of epoxy-coating or other surface coatings on the bond and anchorage of reinforcement. It will include (1) identifying typical applications where coated bars are used by SDHPT, (2) developing a model for the fundamental bond characteristics of coated bars – of particular interest is the role of the rib face angle and deformation pattern on bond strength, (3) determining the effect of coated transverse reinforcement on splices and development lengths of coated bars, (4) determining anchorage requirements for coated hooked bars, and (5) developing design specifications relating to coated bars for incorporation into SDHPT practice and for submission to AASHTO and other code-writing groups.

Current designs using coated bars are based on the assumption that the coating does not reduce bond characteristics of the reinforcement. In many instances this assumption may be unsafe. As soon as sufficient data are available for producing design recommendations, the results can be immediately incorporated into design of transportation structures. It is anticipated that while somewhat longer splice and development lengths will be required for coated bars, the design will be safer.

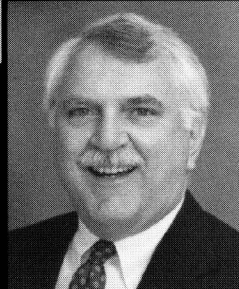
SDHPT 3-8-89/1-1195

Long-Term Strength Properties of Compacted Fills for Embankment Design

Stephen G. Wright

The principal objective of this research is to develop rational procedures for measuring the long-term strength properties of highly plastic clays used for construction of earth slopes. The long-term strength properties are required for both the design of slopes initially and the redesign or design of remedial measures in slopes which have failed.

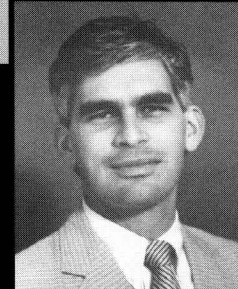
The results of this work will provide the basis for rationally computing the stability of embankment slopes constructed using highly plastic clay soils. At the



James S. Moulthrop
Research Engineer



Priscilla P. Nelson
Professor
of Civil Engineering



James T. O'Connor
Assistant Professor
of Civil Engineering

present time all that can be done is to identify what has not worked. Prediction of the success of various alternatives currently being considered for new slopes and repair of slides in existing slopes is not possible because of uncertainty in the appropriate shear strengths to be used for stability computations. Design of stable new slopes as well as successful design of remedial measures should be possible through the work of this project and will result in significant cost savings.

SDHPT 3-9-89/0-1198 **Concrete Strength Determination** **at Early Ages in the Field**

*Ramon L. Carrasquillo, David W. Fowler,
and Alvin H. Meyer*

The development of a quick, inexpensive, and reliable test procedure for determining the strength of concrete in place at early ages will be very beneficial to the Texas SDHPT. Implementation of test results will eliminate much of the time-consuming and labor-intensive specimen casting and testing done today in highway construction. Further, the long-term performance of concrete in the field will be improved because the procedure used to evaluate when the concrete can be opened to traffic, for example, will be based on the actual concrete properties and not on those of a companion specimen.

The overall objectives of this study are to (1) develop an overall quality assurance program by which the field highway engineer will evaluate the strength and quality of the concrete as placed and cured in the field; (2) develop a set of guidelines and a manual for use by highway engineers in the field, including guidelines for calibrating, installation, test procedures, data analysis, and evaluation of test results; and (3) develop guidelines for correlating the test results obtained by using a given non-destructive test procedure with the existing SDHPT concrete specifications for given job conditions.

SDHPT 3-10-88/C-1199 **Library and Technology Transfer Support** **of Cooperative Research Program**

B. Frank McCullough

The benefits of the Texas SDHPT Technology Transfer operation are well known. The overall goal of this project is to develop and implement Technology Transfer services by the Center to ensure that maximum benefits from the research are achieved. The project includes providing Technology Transfer services for CTR researchers and graduate students.

SDHPT 3/11-8-89/0-1205

Finite-Element Analysis of Bonded Concrete Overlays

*B. Frank McCullough, David W. Fowler,
and James R. Lundy*

The objective of this research is to develop information which will maximize the potential for the successful construction and long-term performance of bonded concrete overlays. Design and construction procedures for bonded overlays are available from other states, but this information should be adapted to Texas conditions. By using available materials information and the recent experience of bonded overlay projects in Texas, a variety of design and construction techniques can be studied with the finite element method. Subsequently, these techniques can be checked against the field condition survey information currently available. Material costs, a part of the basic cost of concrete paving, may be significantly reduced by a thorough understanding of the bonded concrete overlay and the base slab interaction. Further, long-term performance may be improved as result of this analysis, and traffic delay and user costs could also be reduced. (This is a joint project with the Center for Applied Research and Engineering at Texas Technical University)

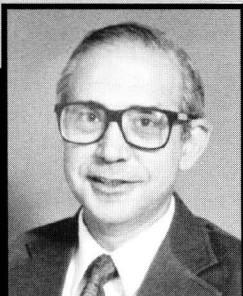
SDHPT 3-5-89/0-1208

Strength of Short Retrofit Anchor Bolts **Subjected to Environmental Cycling**

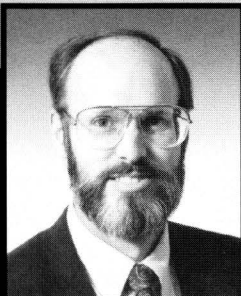
Richard E. Klingner

Retrofit anchors provide an effective and economical means of attachment to concrete, but they cannot be used with confidence under severe environmental conditions because their behavior under such conditions is not well documented. This research will provide that documentation and will permit the potential savings and efficiency of retrofit anchors to be realized in field applications.

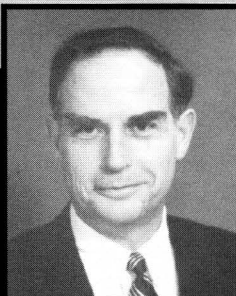
The specific objectives of the research are to (1) summarize the existing state of knowledge regarding the performance of retrofit anchor bolts subjected to environmental cycling, (2) supplement this knowledge by testing short retrofit anchor bolts before and after environmental cycling, and (3) develop design procedures for retrofit anchors to account for the effects of environmental cycling and incorporate these modifications into the Design Guide produced under Project 1126.



Jose M. Roesset
Professor
of Civil Engineering



Kenneth H. Stokoe, II
Professor
of Civil Engineering



C. Michael Walton
Professor
of Civil Engineering

SDHPT 3-5-89/0-1209

Effect of Improved Bonding of External Tendons and the Use of Supplemental Continuous Bonded Tendons in External Post-Tensioned Bridges

Michael E. Kreger and John E. Breen

Analytical investigations of box girder construction that utilizes external tendons have indicated that strength and ductility may be impaired because of a lack of bonded prestressed reinforcement. Two potential solutions to this problem are (1) adding supplemental continuous bonded tendons during design and/or (2) improving bond of external tendons after spans have been erected and stressed.

It is anticipated that adding (1) supplemental, bonded internal tendons and (2) bonding tendons at pass-through locations in diaphragms will substantially increase strength and ductility of segmental box girder bridges with external tendons. Results of tests on the three-span model will quantify how much additional strength and ductility can be expected for bridges with dry joints and for bridges with epoxied (glued) joints. In order for bonded external tendons to enhance strength and ductility of segmental construction, tendons must be adequately bonded to segments at diaphragms/deviators. Results of the bond tests should indicate what tendon stresses can be developed across diaphragms for straight and curved pipe ducts and for different ratios of tendon area-to-duct area.

SDHPT 3-5-89/1-1210

Influence of Debonding of Strands on Behavior of Composite Prestressed Concrete Bridge Girders

Ned H. Burns

The objective of this research is to develop sound guidelines for the design of pretensioned prestressed concrete bridge girders utilizing debonded strands. Testing of both I-shaped and box-shaped composite girders at the Ferguson Structural Engineering Laboratory with the materials currently used (low relaxation strand and high strength concrete) in construction of highway bridges will extend the scope of previous research to establish the basis for the proposed guidelines. The goal of the project is to establish procedures for debonding of straight pretensioned strands which assure the designer that selection of this option, rather than draping some strands, does not reduce ultimate load capacity or ductility of girders designed for highway bridges. Data from

these tests can also be used to check the validity of composite action and the appropriate transformed section which might be used in the design of I-shaped and box-shaped girders.

SDHPT 3-5-89/1-1211

Fretting Fatigue in External Post-Tensioned Tendons

John E. Breen and Michael E. Kreger

The overall objectives are to (1) examine the potential for fretting fatigue in externally posttensioned concrete box girder bridges, (2) explore the effect of various deviator details on the fretting fatigue of external tendons, (3) explore the effect of various tendon parameters on the fretting fatigue of external tendons, and (4) develop design and construction recommendations for external tendon deviators and tendons suitable for inclusion within the general AASHTO fatigue design framework.

SDHPT 3-18-89/1-1216

Driver Responses to Traffic Disturbances and Control Strategies

Hani S. Mahmassani

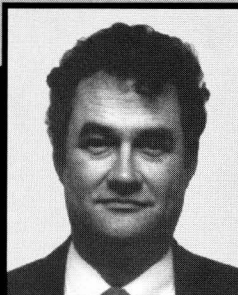
This project focuses on the development of a methodology to capture the day-to-day responses of drivers in regard to traffic control and management of reconstruction activities. The subobjectives are to (1) refine and adapt models of users: daily responses to perceived service quality, (2) incorporate these models of user response in operational procedures to evaluate alternative traffic control and management schemes, (3) develop and investigate appropriate measures for characterizing the performance and effectiveness of particular traffic control and management plans, particularly when the dynamics of user responses are taken into account, and (4) illustrate the applicability of the methodology in a selected corridor network in Texas.

SDHPT 3-9-90/1-1222

Establishment of Acceptance Limits for the 4-Cycle MSS and Modified Wet Ball Tests for Aggregates Used in Seal Coats and HMA Surfaces

Alvin H. Meyer and David W. Fowler

The four-cycle magnesium sulfate soundness (MSS) test is a laboratory test used by some Districts to control quality of aggregates used in hot mix asphaltic concrete



George H. Ward
Research Scientist
Center for Water Resources



William V. Ward
Research Coordinator



Harovel G. Wheat
Assistant Professor
of Mechanical Engineering

(HMAC) and seal coats. However there is some concern that the recommended limits may be too high. Other work has led to the conclusion that an extensive laboratory and field evaluation of the modified wet ball mill test method is needed.

The objective of this study is to establish acceptance limits for the four-cycle MSS and the modified wet ball tests for aggregates used in HMAC and seal coats. The establishment of justifiable specification limits for the two tests will improve quality and in-service performance of aggregates used in HMAC and seal coats. Improved in-service performance of aggregates used in HMAC and seal coats will reduce the life cycle cost of the pavements and provide a better roadway for the driving public.

SDHPT 3-10-89/0-1223 **Evaluation and Implementation** **of ARAN Unit**

W. Ronald Hudson

The objective of this study is to set up a series of experiments to compare the output of the ARAN (Automatic Road Analyzer) unit and its various components with standard measurements and other known survey results. Specifically the objectives are to (1) prepare a list of the ARAN unit's outputs which are of interest to the SDHPT, (2) gather information on the procedures currently used by the SDHPT to collect data related to the items in (1), (3) design experiments to collect field data using the ARAN unit and the devices currently available to and/or used by the SDHPT, and (4) analyze the field data to compare the ARAN unit's outputs with the standard equipment used by the SDHPT.

SDHPT 3-8-90/2-1227 **Expediting Urban Pavement Construction** *William V. Ward and B. Frank McCullough*

The delay and inconvenience to the public that result from construction constitute a well known problem. Any improvement that decreases the time required for construction while providing adequate access results in a benefit to SDHPT, the contractor, the commercial interests, and the public. Any improvement that increases the safety of the worker and traveling public while decreasing the vehicle delay provides a benefit. A considerable sum can be justified in providing improvements because large savings result from reducing traffic delay and conflicts. However, an improvement with relatively small cost may result within a short time.

A primary objective of this project is to draft a manual that will incorporate current practices, experiences, and lessons learned from fast track projects. The gaps in knowledge — design characteristics, equipment, materials, economics, and so on — would then be addressed in subsequent years and the manual would be updated as results become available.

SDHPT 3-5-90/2-1234 **Instrumentation of Segmental Box Girder** **Bridges and Multipiece Winged Boxes**

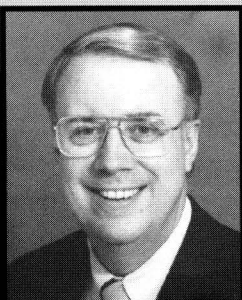
John E. Breen and Michael E. Kreger

The results of this study should permit a major evaluation of design and construction criteria for segmental box girder bridges and lead to clarification and revision of AASHTO provisions that have had to be based on "best judgement" in the absence of data. Factual data and measurements from the San Antonio "Y" project should be extremely useful to SDHPT designers in the design of subsequent projects, as well as to designers throughout the country through the possible impact on AASHTO provisions.

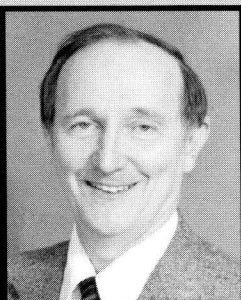
The expected results should greatly improve criteria for predicting post-tension losses and force distribution in segmental bridges, as well as improve criteria for long-term stress redistribution and thermal effects which pose substantial uncertainty and necessary conservatism in design. The amount of tendons in current bridges is generally governed by service load design and is heavily influenced by loss estimates, creep and shrinkage redistribution, and thermal effects. Currently, ultimate load considerations do not usually govern. Better methods for assessing these effects and improved design provisions could lead to economy in materials as well as ensure improved performance over longer life conditions. Thus the specific implementation benefits would be more rational design, possible material economies, and improved performance leading to substantially decreased maintenance costs over a life cycle.

SDHPT 3-5-90/2-1239 **Bracing Effects of Bridge Deck** *Joseph A. Yura*

Approximately 1000 off-system bridges in Texas are constructed with steel stringers supporting a timber plank deck, nail laminated timber deck, or concrete deck. There is no positive connection between these stringers and the deck. Calculations often show that if the stringers are assumed unbraced laterally, the steel



Stephen G. Wright
Professor
of Civil Engineering



Joseph A. Yura
Professor
of Civil Engineering

beams are incapable of safely carrying even the lightest vehicles, and yet the bridge usually supports substantial loads. More realistic ratings and better utilization of these bridges may be possible if the bracing effect of various decks can be demonstrated.

The objective of this research is to establish what constitutes an adequate brace for the beams and to demonstrate the ability of deck material to provide this bracing. The research will provide an overall understanding of bracing requirements for beams. It is anticipated that typical wood and concrete bridge decks will be shown to adequately brace the supporting stringers, even though there is no positive connection between the deck and the beams. Engineers rating short span bridges will be able to confidently estimate the strength of the stringers, which should eliminate low ratings because of lateral instability.

SDHPT 3/10-18-90/2-1243

Automated Equipment for Characterizing the Properties and Thicknesses of Pavement Layers

Kenneth H. Stokoe, II, Jose M. Roesset, and Soheil Nazarian

This project has three main objectives. The first is to develop an automated, simple-to-use procedure for reducing the field data collected by the Strategic Analysis of Surface Waves method, i. e., to incorporate optimization and general inverse theory with a dispersion function to come up with a fast and economical inversion process so that the modulus-depth profiles can be determined in real-time (in a matter of a few minutes). The second main objective is to develop a rapid method for determining the moduli and thicknesses of surface layers. The third objective is to develop, within 18 months, a prototype testing device which can be used to measure continuous profiles of pavement conditions. It is anticipated that the results of this project will have significant benefits for the SDHPT.

SDHPT 2/3-1-90/2-1244

Evaluation of the Performance of Texas Pavements Made with Different Coarse Aggregates

B. Frank McCullough and D. Zollinger

In Texas, rigid, or portland cement concrete, pavements, as well as flexible, or asphaltic concrete pavements, are mostly made using crushed limestone and/or

siliceous river gravel as the coarse aggregate. It is well known that the coarse aggregate has a large influence on the performance of pavement structures, since 60 to 80 percent of PCC pavement volume and something more than 75 percent of AC pavements is aggregate. The evaluation of the performance of rigid pavements and flexible pavements made with siliceous river gravel and with crushed limestone as coarse aggregates is necessary for determining the extent of the difference in performance between the two aggregates. By determining the difference in performance of these aggregates, as well as by determining the main factors that affect these aggregates when they are used to build pavements in Texas, it will be possible to make different design adjustments and adaptations for pavements made with different aggregates.

SDHPT 3-10-90/0-1246

Development of a Strategy for Acquiring and Using a Prototype Mobile Load Simulator and the Testing of the Model Mobile Load Simulator

B. Frank McCullough and Fred Hugo

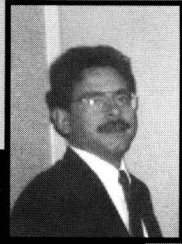
There is a need for the SDHPT to acquire some form of mobile load simulator (MLS). The objective of this study is the formulation of a strategy for acquiring, operating, maintaining, and managing a load simulator machine or machines to satisfy the needs of the SDHPT, with due consideration given to (1) the role of the MLS in pavement engineering, the pavement management system, and research, using a systems approach; (2) the ability of the presently used simulator models to satisfy the needs of the SDHPT; (3) the feasibility of developing a new generation of MLS machines to overcome some of the shortcomings of the presently used machines, such as limitations on the number of load applications per day; (4) the anticipated operational needs and running cost of an MLS system; and (5) recommendations for the follow-on phases after completion of the present study.

SDHPT 3-18-90/0-1906

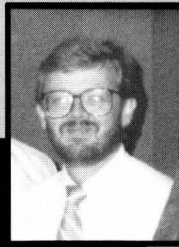
TEXAS Model Validation for Left-Turn Phasing Alternatives

Randy B. Machemehl

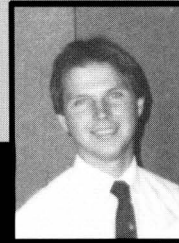
A special form of protected-permitted left-turn signal phasing, called "ring-based phasing," is currently being used in Dallas. Simulation analyses of the relative operational efficiency of this phasing scheme have indicated significant advantages. However, the authenticity



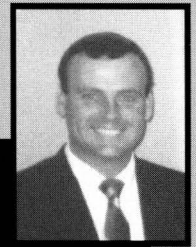
Chuck
Berry



Ray
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Darren
Hazlett



Bruce
Long

of the simulation of this form of signal phasing by PASSER II, TEXAS, and other simulation models has not been confirmed.

During the fall of 1989, traffic operational data were collected in Dallas and Richardson in an effort to capture a detailed description of the performance of ring-based and conventional protected-permitted left-turn signal phasing. Collection and reduction of these data are largely complete and they represent a valuable tool for validation of simulation models, as well as operational comparison of phasing schemes. This study is using the Dallas area operational data in an effort to validate or calibrate the TEXAS traffic simulation model. As a secondary function, the study will supplement the ongoing evaluation of ring based protected-permitted left-turn signal phasing.

SDHPT 3-5-90/0-1911

Implementation of Bridge Rehabilitation and Replacement Selection System on the SDHPT Mainframe Computer

Ronald Hudson and Ned Burns

The Center, under Project 439, "Strategies for Bridge Replacement," worked with the SDHPT Bridge Division to develop a system for ranking rehabilitation and replacement projects and allocating annual budgets. The implementation of the findings was accomplished using the University mainframe computer and the proposed system needs to be available in the SDHPT mainframe computer so that it can be utilized directly by the SDHPT. The objective of this study is to adapt existing computer programs SURE, FREQ, DDF, INICO, DRP, and FINAL, developed under the previous project, to run under the SDHPT computer operating system.

SDHPT IAC 3001

Presentation of Employee Training Courses: Asphalt Concrete Mixture Design and Construction

Thomas W. Kennedy

Four employee training courses on asphalt concrete mixture design and construction were presented.

Department of Transportation 60016 Optimal Design of Bus Transit Networks for Suburban Mobility Needs

Hani S. Mahmassani

A major goal of transportation planning activities targeted at reducing total automotive fuel consumption has been to attract tripmakers to use public transit to meet more of their travel mobility needs. Bus transit networks in the U. S. have traditionally been geared to serve centralized core-area land-use patterns, as these cities have become increasingly decentralized. Because of lower suburban and exurban densities, it has been difficult to provide levels of transit service that provide a meaningful alternative to the private automobile. However, increasing densification of the suburbs and the emergence of major activity nuclei outside the central business district open opportunities for creative approaches to the supply of transit services.

The overall goal of this project is to develop and test computer-based design procedures for the configuration of bus route networks in areas characterized by suburban spatial patterns, so as to maximize ridership capture and serve mobility needs in a cost-effective and energy-efficient manner.

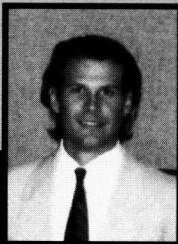
Department of Transportation 60017 Improved Energy Efficiency Through Better Urban Intermodal Coordination

C. Michael Walton and Mark A. Euritt

The overall goal of this research is to improve energy efficiency in urban areas through more efficient and coordinated freight interface of intermodal operations.

Coordinated freight interface at urban port facilities is central to efficient intermodal operations. The success of intermodalism relies on the efficiency of the transfer points. Inefficient port operations combined with limitations on truck and/or rail traffic to and from the terminal can undermine efforts for economic growth. Efforts to improve the efficient operations of port facilities must parallel or precede efforts to coordinate urban transportation flows.

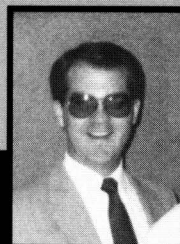
This study addresses the major issues affecting the urban intermodal interface for freight transportation. The research will identify and analyze the impact of growing port operations in the southwest region, principally the Port of Houston and the Port of New Orleans, on urban infrastructure. Analytical methods for assessing this impact will be developed, including documentation of the associated energy savings through more efficient intermodal operations.



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Department of Transportation 60018 Telecommunications-Transportation-Energy Interactions: Potential for Reducing Transportation Energy Consumption Through Telecommuting

Hani S. Mahmassani and Robert Herman

The substitution of transportation by telecommunications has long been advocated as an approach that might eventually alleviate the demand placed on transportation facilities and thereby reduce fuel consumption and air pollutant emissions. With the increasing penetration of telecommunications in individual homes and businesses, coupled with the widespread availability of computing equipment, facsimile capabilities, etc., there is renewed interest in exploring and encouraging telecommuting arrangements. These include work-at-home schemes and workplace decentralization, with satellite work centers, as well as many other non-traditional approaches to structuring workplace activities and worker responsibilities.

The aim of this project is to address the travel behavior implications of telecommuting and determine the potential of telecommuting to improve urban mobility and reduce fuel consumption.

Department of Transportation 60019 Demonstration of Enhanced Arterial Street Traffic Flow, Reduced Fuel Consumption and User Costs Through Application of Super Street Technology

Randy B. Machemehl

This study is designed to simultaneously accomplish the applying of state-of-the-art technology to the solution of a current traffic congestion problem and also advance the state-of-the-art. This will be accomplished by selecting an existing arterial street corridor and designing and implementing a high-flow or "superstreet" improvement program for it. During and after implementation of the improvement program a rich data base will be developed. The contents of this database, including before-and after-traffic flow and delay information, will be used to evaluate and enhance the current state-of-the-art analysis and design methods.

Department of Transportation 60020 Energy and System Costs Evaluation of Truck Size and Weight Changes

*B. Frank McCullough, Robert Harrison,
Mark A. Euritt, and C. Michael Walton,*

There are proposals to increase legal size and weight dimensions of large trucks. There is the likelihood that larger trucks will be allowed to operate over the Texas highway infrastructure, or selected links of the network, without a full technical and economic understanding of the impacts in terms of energy, rates, pavement costs, and inter-modal consequences. This project would evaluate several sources which would provide data on the various components of a full transportation system evaluation. In addition, the study would give a hierarchy of impacts which would follow any significant changes in large truck size and weight legislation.

The overall objective of this study is to establish the feasibility of developing a comprehensive methodology for evaluation of truck size and weight legislation in the state of Texas, considering the energy impact as well as cost to the entire transportation system.

Department of Transportation 60021 Fuel and Time Savings Through Expediting Pavement Construction

Robert Harrison and B. Frank McCullough

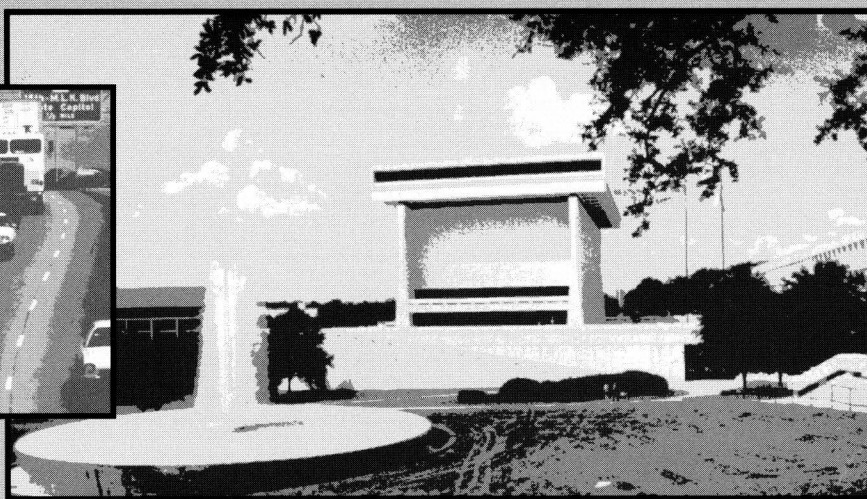
Pavement construction on existing highways creates problems for state agency staffs, vehicle owners, and commercial businesses. Motorist, or user, costs during such construction are dominated by increased fuel costs and time evaluations, which combine to form substantial financial impacts. If expediting techniques can be used to get the pavement back into service quickly, then the benefits from vehicle energy savings alone could be very substantial. This study will produce a manual enabling planners to estimate fuel and time impacts for a variety of expediting techniques.

University Transportation Centers Program 71247

The Technical, Engineering, and Economic Feasibility of a High-Speed Ground Corridor

*Kurt M. Marshek, Robert Harrison,
and B. Frank McCullough*

The objective is to evaluate a high-technology corridor design, with a highway facility emphasis, capable of providing a consistent level of fast transit service at



appropriate user cost while meeting safety, financial, and environmental criteria.

**University Transportation Centers
Program 71248
Information and Telecommunications
Approaches to Improve Transportation
System Performance**

*Hani S. Mahmassani, Robert Herman,
and C. Michael Walton*

The objective is to identify fundamental processes critical to the development and operationalization of telecommunications technologies for control of vehicular traffic in congested networks through provision of descriptive and prescriptive information on a real-time basis to individual vehicles. The study addresses (1) the trade-offs among various technological system configurations, (2) the principal options with regard to type, frequency, timeliness, scope, accuracy, and content of supplied information supply strategies, and (4) conditions under which benefits can be realized for different strategies and system configurations.

**University Transportation Centers
Program 71249
Evaluating the Coordination of Intermodal
Transportation Policies and Programs
to Promote Economic Growth**

C. Michael Walton and Mark A. Euritt

Intermodal transportation can be defined broadly as the movement of goods or persons by two or more modes of transportation between specific origins and destinations. Intermodal transportation, when it works well, provides the basis for better integrating the transportation network through smoother, quicker, and less frequent transfers.

By and large, the major problem associated with intermodal transportation is the fact that intermodal impacts, needs, and considerations are not adequately taken into account. Evaluation includes a description of Texas state and local government involvement in the state's transportation system, a delineation of the extent to which both multimodal and intermodal plans, projects, and programs formulated in other states are relevant to Texas, and an enumeration of specific intermodal programs in place in the United States that increase intermodal transfers of goods and people.

**Alaska Department of Transportation
and Public Facilities
Presentation of Training Courses:
The Inspection of Asphalt Concrete
Pavement Construction**

Thomas W. Kennedy

Approximately 48 hours of instruction, covering asphalt concrete plant operations, asphalt concrete lay-down operations and compaction, and mixture design, was presented to employees of the Alaska Department of Transportation and Public Facilities Central Region.

**Strategic Highway Research Program
Improved Asphaltic Materials, Experiment
Design, Coordination, and Control
of Experimental Materials**

Thomas W. Kennedy

This work involves the coordination of an asphalt research program concerning eight major and twenty smaller contracts and numerous subcontracts. In addition, technical assistance is provided on a continuous basis to the SHRP staff in Washington. The major activities are the establishment of a reference library of asphalts and aggregates, a summary of health and safety practices relating to the use of paving asphalts, the design of a database management system to handle the data generated in the program, and a survey of current asphalt refinery practices in the U. S. and Canada.

**Texas Research and Development
Foundation (TRDF)
Long-Term Pavement Performance Studies**

W. Ronald Hudson

The Center is working with the TRDF to provide technical and management support to develop and conduct long-term pavement performance (LTPP) studies for the SHRP. These studies are administered through the National Research Council, in cooperation with the FHWA and the American Association of State Highway and Transportation Officials. The work includes completing the general pavement study design, developing specific pavement study plans, selecting test sections, ensuring uniform data collection and quality control procedures, developing data entry and processing procedures, performing data analysis studies, evaluating data collection activities, coordinating all LTPP activities nationwide, and procuring equipment and services.

The University Transportation Centers Program (UTCP) was established in 1988 by the United States Department of Transportation to support university-based research addressing transportation problems nationwide. One of the Centers, the Southwestern University Transportation Centers Program (SWUTC), administers UTCP for Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.

The University of Texas at Austin, Texas A&M University, and Texas Southern University comprise the SWUTC consortium. Research, technology transfer, and training programs are underway at each of these universities.

The program includes two components at UT-Austin. Research is conducted by the Transportation Research Center (TRC) and education by the Advanced Institute for Transportation Infrastructure Engineering and Management.

Research

Research addresses three important themes: Intermodal Policy (IP), Transportation System Technology (TST), and Energy-Transportation Interface (ETI).

Nine research studies are distributed among the three topical areas. Current IP studies include determining (1) ways to enhance economic growth and improve energy efficiency through improved coordination of intermodal transport policies, and (2) the technical and economic feasibility of high-speed ground transportation for selected corridors. Studies within TST include the design of bus transit networks, improving transportation system performance through user information and telecommunications, and development and

application of superstreet technology. Projects dealing with ETI include (1) studies of fuel and time savings through expediting pavement construction and (2) the effects of truck sizes and weights upon energy and system costs.

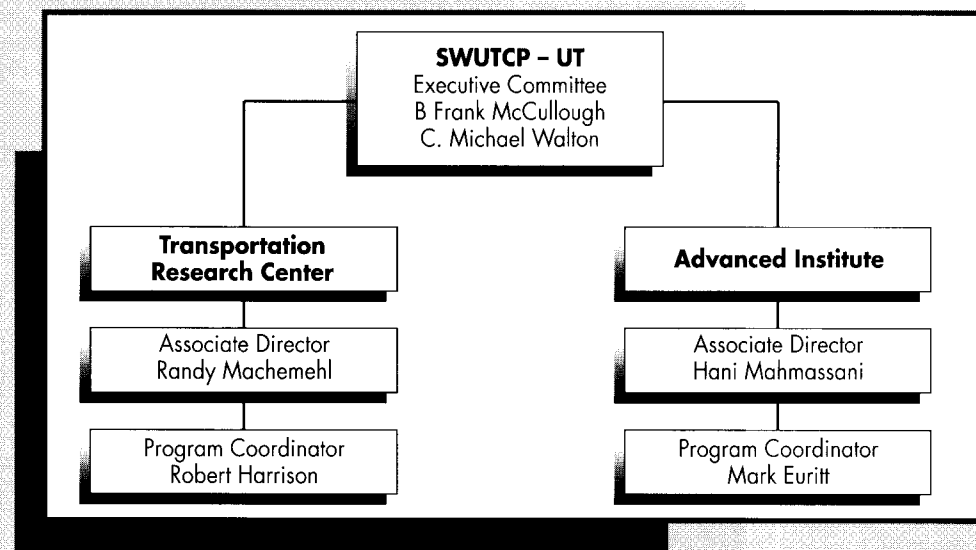
The TRC has been operational for almost two years, and 11 research reports, 19 presentations, and 9 refereed papers have been produced by the principal investigators and their student research assistants.

Education

The University of Texas established the Advanced Institute in 1990 as part of the Region 6 UTCP. The objective of the Institute is to enhance the quality and quantity of professionals in the Transportation Engineering field and to develop centers of excellence in transportation education. Planning, design, and management of the transportation infrastructure present considerable challenges for the traditional civil engineering disciplines, which offer opportunities for resourceful application of advanced technologies and computer-based methodologies. The education of the professionals involved in the engineering and management of infrastruc-

ture systems must take into account the complex interactions among engineering, financial, economic, environmental and social aspects. Therefore the Institute is multimodal in scope and is cross-disciplinary in perspective, addressing the aspects of infrastructure planning and management as well as its technical engineering requirements.

An extensive marketing and information program is underway to seek qualified prospects for these outstanding graduate study opportunities. Advanced Institute fellowships may be combined with research assistantships through the Center for Transportation Research to provide an attractive financial support package, making it more desirable for professionals already in the field to take time off from work to enhance their technical skills through the pursuit of a graduate degree.



These reports
were produced
by the Center
during 1989-90
to provide the
sponsors with
documentation of
the research
accomplished.
Some of these are
still in preliminary
form and are not
yet available for
distribution

358-2F The Effects of Mixing Temperature and Stockpile Moisture on Asphalt Mixtures Containing Absorptive Aggregates
Maghsoud Tahmoressi and Thomas W. Kennedy
November 1989.

365-3F Strength and Ductility of a Three-Span Externally Posttensioned Segmental Box Girder Bridge Model
R. J. G. MacGregor, M. E. Kreger, and J. E. Breen
January 1989.

428-1F Conceptual Strategic Arterial Street System for Harris County
William V. Ward
February 1990. (Preliminary)

439-4F A Bridge Management System Module for the Selection of Rehabilitation and Replacement Projects
Jose Weissmann, W. R. Hudson, Ned H. Burns, and Robert Harrison
November 1989.

443-1F TEXAS Model Version 3.0 (Diamond Interchanges)
Clyde E. Lee, Randy B. Machemehl, and Wiley M. Sanders
January 1989.

450-3F Alkali-Aggregate Reaction in Concrete Containing Fly Ash: Final Report
Ramon L. Carrasquillo and Josef Farbiarz
October 1989.

460-2 Assessing Load Transfer Across Joints and Cracks in Rigid Pavements Using the Falling Weight Deflectometer
Emmanuel B. Owusu-Antwi, Alvin H. Meyer, and W. Ronald Hudson
May 1990. (Preliminary)

460-3F A Manual for Rigid Pavement Evaluation Using the Falling Weight Deflectometer
W. Ronald Hudson and Alvin H. Meyer
August 1990. (Preliminary)

465-2F Fretting Fatigue in Post-Tensioned Concrete
G. P. Wollmann, D. L. Yates, J. E. Breen, and M. E. Kreger
November 1988.

468-3 Recommendations to Achieve Density for Asphalt-Aggregate Mixtures
Mansour Solaimanian, Thomas W. Kennedy, and William E. Elmore
January 1990. (Preliminary)

468-4F Evaluation of Field Compaction, Density Variations and Factors Affecting Density Through 1987 HMAC Field Construction Data
Mansour Solaimanian and Thomas W. Kennedy
October 1989. (Preliminary)

472-3 A Twenty-Four-Year Performance Review of Concrete Pavement Sections Made with Siliceous and Lightweight Coarse Aggregates
Mooncheol Won, Kenneth Hankins, and B. Frank McCullough
April 1989.

472-4 Development of Procedures for a Statewide Diagnostic Survey on Continuously Reinforced Concrete Pavements
Angela Jannini Weissmann and Kenneth Hankins
November 1989.

472-5 A Statewide Diagnostic Survey of Continuously Reinforced Concrete Pavements in Texas
Angela Jannini Weissmann and Kenneth Hankins
August 1989.

472-6 A Continuously Reinforced Concrete Pavement Database
Terry Dossey and Angela Jannini Weissmann
November 1989.

472-7F Development of Performance Prediction Models for Continuously Reinforced Concrete Pavements
Angela Jannini Weissmann, B. Frank McCullough, and W. R. Hudson
August 1989.

481-5 The Effect of Fly Ash on the Sulfate Resistance of Concrete
P. J. Tikalsky and R. L. Carrasquillo
August 1989.

481-6 Creep and Shrinkage Properties in Concrete Containing Fly Ash
Mohand L. Sennour and Ramon L. Carrasquillo
November 1989.

556-1 Performance Tests on a Prestressed Concrete Pavement—Presentation of Data
Elliott Mandell, Jose Tena-Colunga, and Kenneth Hankins
November 1989. (Preliminary)

556-2 Prestressed Concrete Pavement: Instrumentation, In-Situ Behavior, and Analysis
Elliott David Mandel, Ned H. Burns, and B. Frank McCullough
August 1989.

556-3 Analysis of Curling Movements and Calibration of PCP Program

Jose Antonio Tena-Colunga, B. Frank McCullough, and Ned H. Burns
November 1989. (Preliminary)

556-4F The Performance of a Prestressed Concrete Pavement

Elliott Mandell, Jose Tena-Colunga, Kenneth Hankins, Ned H. Burns, and B. Frank McCullough
November 1989. (Preliminary)

922-1F Pre-Construction Management System: Procedures Manual

Khali Persad, James T. O'Connor, and Fred Hugo
February 1990.

969-1 Evaluation of the Performance of the Auto-Read Version of the Face Dipstick

Carl B. Bertrand, Robert Harrison, and B. Frank McCullough
August 1989.

969-2F Evaluation of FHWA Requirements for the Calibration of Pavement Roughness Instrumentation

Carl B. Bertrand, Robert Harrison, and B. Frank McCullough
February 1990. (Preliminary)

1111-1F Auxiliary Turning Lanes at Urban Intersections

Christopher T. Marcus, Randy B. Machemehl, and Clyde E. Lee
January 1990. (Preliminary)

1116-1F Evaluation of the Troxler Model 3241-B Asphalt Content Gauge

Richard J. Holmgreen, Jr., James N. Anagnos, Thomas W. Kennedy, and William E. Elmore
November 1988.

1127-1 An Investigation of Strut-and-Tie Models for Dapped Beam Details

D. L. Barton, R. B. Anderson, A. Bouadi, J. O. Jirsa, and J. E. Breen
February 1990. (Preliminary)

1127-2 Shear Strength of Pretensioned Concrete Girders in Negative Moment Regions

Anthony C. Powers, Michael E. Kreger, and John E. Breen
February 1990. (Preliminary)

1129-1 Computer Program for the Analysis of Bridge Bent Columns Including a Graphical Interface

R. W. Stocks, C. P. Johnson, and J. M. Roesset
November 1988.

1129-2F Analysis and Design of Bridge Bent Columns

M. Haque, J. M. Roesset, and C. P. Johnson
November 1988.

1138-1F Criteria for the Selection of a Left-Turn Median Design

Sanjay Modur, Randy B. Machemehl, and Clyde E. Lee
January 1990.

1149-1 Highway Constructability Guide

Fred Hugo, James T. O'Connor, and William V. Ward
July 1990.

1149-2 Specification Improvements for Enhanced Constructability

F. Hugo, J. T. O'Connor, and E. M. Stamm
November 1989. (Preliminary)

1169-2 Mechanistic Analysis of Continuously Reinforced Concrete Pavement Considering Material Characteristics, Variability, and Fatigue

Mooncheol Won, Kenneth Hankins, and B. Frank McCullough
April 1990. (Preliminary)

1190-1 Truck Tire Pavement Contact Pressure Distribution Characteristics for Super Single 18-22.5, and Smooth 11R24.5 Tires

Rex William Hansen, Carl Bertrand, K. M. Marshek, and W. R. Hudson
July 1989.

1190-2F Truck Tire Pavement Contact Pressure Distribution Characteristics for the Bias Goodyear 18-22.5, the Radial Michelin 275/80R/24.5, the Radial Michelin 255/70R/22.5, and the Radial Goodyear 11R24.5 Tires

Rafael F. Pezo, Kurt M. Marshek, and W. R. Hudson
September 1989.

1246-1 The Texas Mobile Load Simulator: Accelerated Simulation of Real Traffic

Fred Hugo
March 1990.

Graduate

M. U. Abdul-Malak
Riyad S. Aboutaha
Marc R. Acampora
Taebong Ahn
Deepak Ahuja
Sergio M. Alcocer
Fouad Alsabbagh
Denix Anbiah
Ronald D. Andrus
Marwan F. Aouad
Jose A. Arrellaga
Mohamed H. Baaj
John F. Barmen
Asit N. Baxi
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