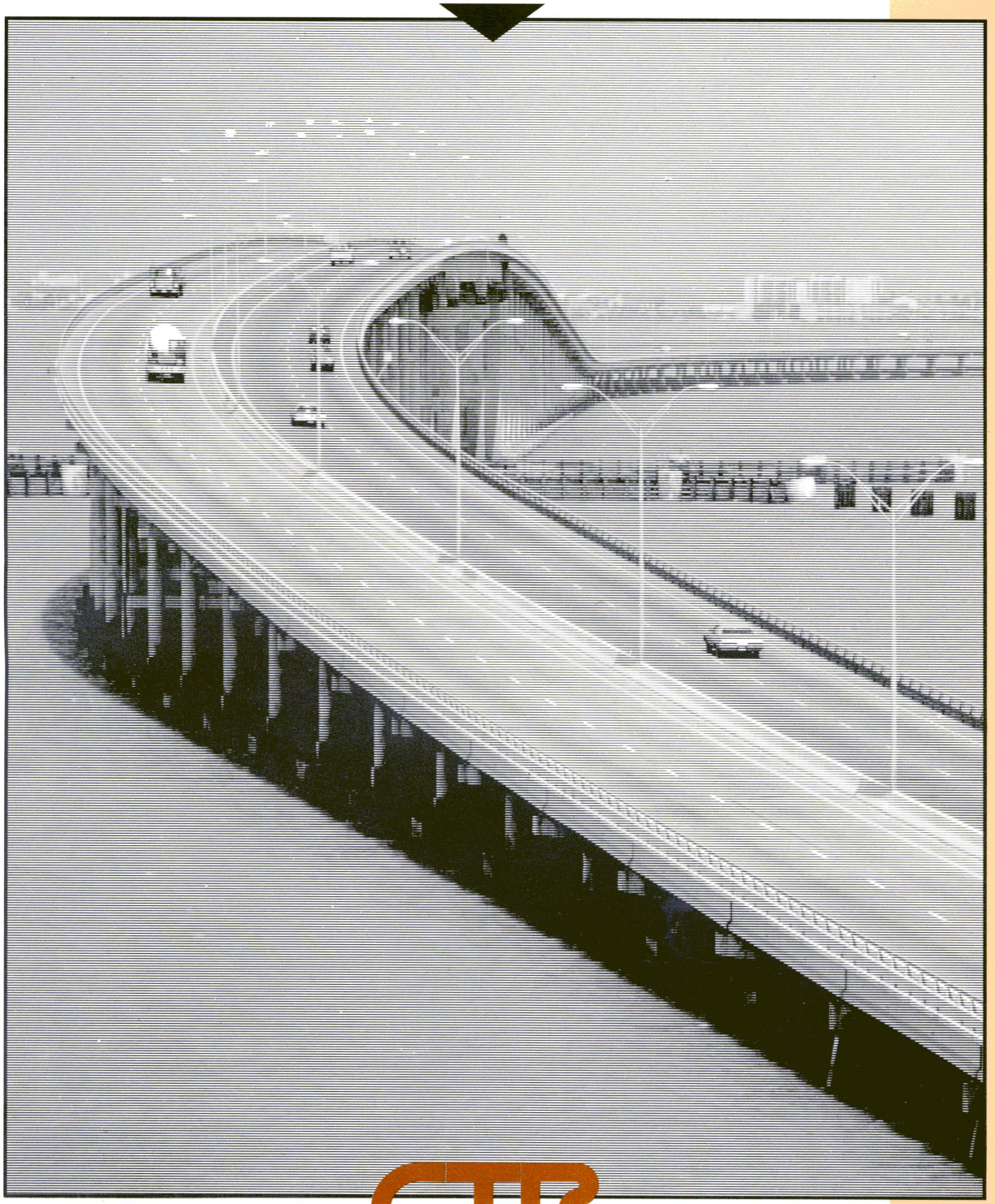
ANNUAL REPORT 1989



CTR

Center for
Transportation
Research

About the Center

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.

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 cooperativley sponsored by these agencies.

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 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 of this coordinated research is that many students find employment with research sponsors upon completion of their academic programs.

Cover Photo by Tourism Division of the Texas Department of Commerce

Annual Report 1989

Center for

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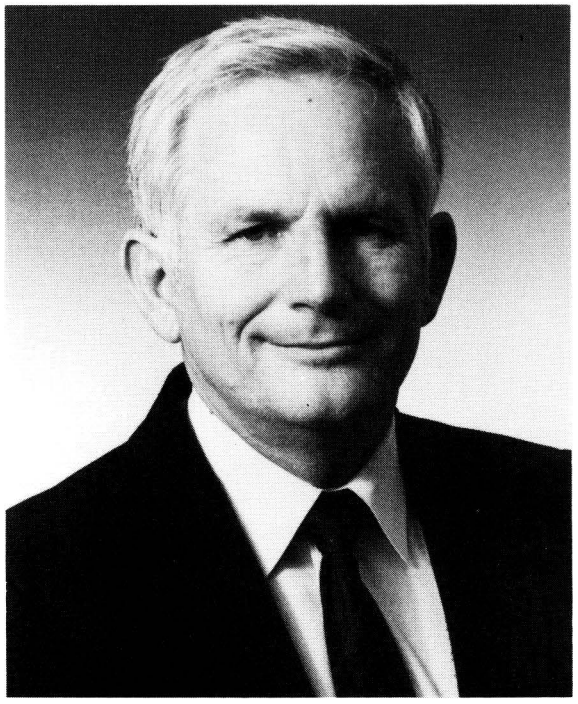
Bureau of Engineering Research

The University of Texas at Austin

Message from the Director



The Center is continuing to provide what we consider to be quality service to our sponsors and to the University, as well providing a valuable educational experience for our students. The Center is growing, in the number and variety of projects, in total funding, and in capability, and is producing research results and students that we are proud of. Throughout our existence, there have been challenges from a wide variety of problems, and we believe that the implementation of the results of the many Center studies has provided valuable input to the state's, and the nation's, transportation systems.

We are happy to have become part of the University Transportation Centers Program and to be participating in that research. We are also pleased that we are involved in the Texas State Department of Highways and Public Transportation graduate program for engineers employed by the Department. The first of the students assigned to the University under that program are now studying and doing research with the Center.

We are confident that our tradition will continue and that the faculty, students, and staff involved in Center research will maintain the attitudes and capabilities that have served so well for more than twenty-five years. We will work together to assure that the results of our transportation engineering research serve the state and its citizens through both education and research. and that the state's transportation system can successfully respond to ever-increasing demands, including those resulting from unpredictable but ongoing economic changes.

B. F. McCullough

Prestressed Concrete Pavement Overlay

Ken Hankins

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

Prestressed concrete slabs are common in building construction and are often specified in floor slabs. However, probably because of the stressing techniques, the use of prestressed paving has been somewhat more conservative. The concept of prestressed concrete pavement (PCP) originated in Europe over 40 years ago, and since that time this type of paving has been used in both airfields and highways. Texas became involved in 1983, when a demonstration project of prestressed concrete pavement overlays was initiated. At that time the Center for Transportation Research inaugurated a series of conceptual and experimental investigations for the Texas State Department of Highways and Public Transportation into the design and implementation of PCP. These studies examined several separate aspects of PCP.

- An investigation into very early post-tensioning of concrete was conducted to examine the possibility of preventing temperature and shrinkage cracks in long PCP slabs during the first night after casting.
- Experiments on the capacity of the anchorage zone in slabs were performed considering slab thickness, tendon spacing, anchor size, and time from casting as test variables.
- Experiments were performed to determine the amount of initial prestressing that is lost along the length of unbonded tendons.
- An experimental study was carried out to evaluate the effectiveness of using polyethylene sheeting in reducing friction at the interface of a concrete overlay on an asphalt base.
- A design methodology for PCP that incorporates procedures for determining slab thickness, prestress level, and slab length was advanced.
- A computer model (PSCP-1) that uses a finite difference procedure to focus on slab length changes and longitudinal stresses in PCP as a result of changes in concrete temperature and base-friction was developed.
- A series of regression analyses was performed to study the effect of prestress on the fatigue life of concrete, the interaction of prestress and stress due to vehicular loading, the effect of prestress in delaying microcracking in concrete, and the effect of prestress on elasto-plastic behavior of prestressed concrete.

In 1985, approximately one mile of PCP overlay was constructed on IH 35 north of Waco, near West.

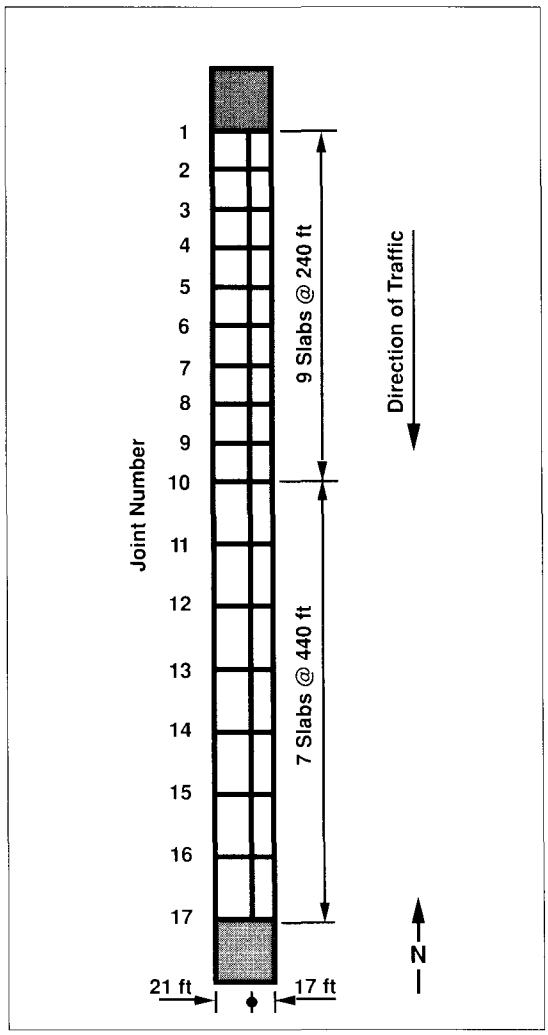


Figure 1.
Layout Plan of the McLennan County PCP Experimental Section

The PCP overlay was placed over an existing jointed concrete pavement . The one-mile length was composed of sixteen test slabs, and PCP slab lengths of 240 and 440 feet were selected. Figure 1 shows the layout of the test area. The design of the PCP was based on the investigations and experimentation performed previously and included a variety of unique techniques, such as (1) internal stressing near the center of the slab applied at the "leave-out pockets," (2) incremental stressing, (3) both longitudinal and transverse stressing of the PCP slabs, (4) one layer of plastic sheeting as a bond breaker under the PCP slab, (5) steel armor type joints, and (6) a closed joint width for summer construction. Figure 2 shows a drawing of a typical PCP slab

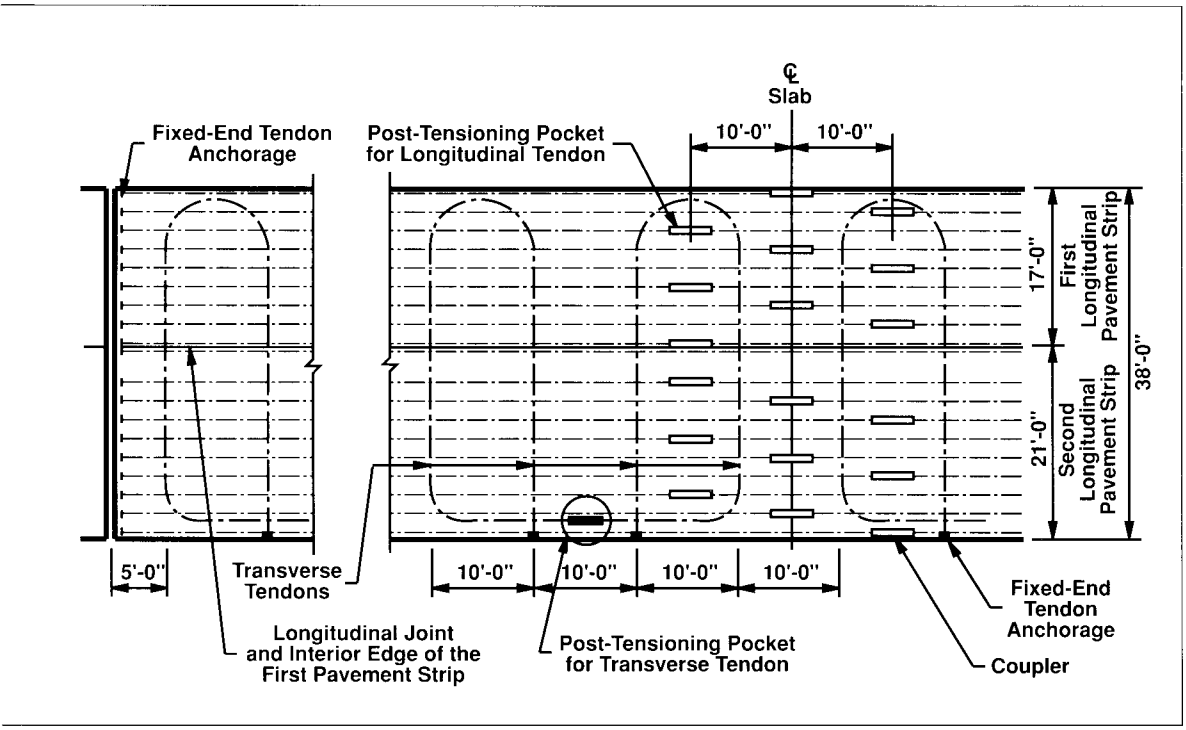


Figure 2. Layout of a Typical PCP Slab

featuring the longitudinal and transverse tendon positioning along with the stress pockets.

Follow up studies of the PCP construction have included several visits to collect performance information. Performance investigations have included the study of the longitudinal and vertical movements of the PCP slabs on IH35 in varying environmental conditions. Overall seasonal behavior of concrete slab movements is a function of the daily temperature cycles superimposed over seasonal temperature cycles. During the warm part of the day the concrete expands and the joint widths become less. Similarly, the smaller joint widths occur in the summer. Observations indicate the horizontal slab movements are significant and the entire slab is moving. That is, there is no movement at the center of the slab but movement occurs from the center toward the ends, with the maximum movement at each end. The horizontal movement corresponds to a thermal coefficient of about 0.0000048 in./in./degree F. Maximum joint widths range from about 1.5 inches to 3 inches. The slab movements correlated well with the concrete temperatures at mid-depth of the slab. Regression equations predicting horizontal slab movement were developed for the two lengths of slabs as shown:

240 feet Y = 0.013 + 0.049X R**2 = 0.938
440 feet Y = -1.399 + 0.060X R**2 = 0.965

where

Y = Slope of movement/temperature equations (in. x 0.001/°F)

X = Distance from centerline (feet)

Vertical movements were much larger than expected. Vertical movements were found to be on the order of 0.20 inch when the daily temperature cycle was about 30 degrees F. The vertical movement appears to be associated with the differential temperature between the top and bottom of the slab. The rate of vertical movement seems slower when the surface of the slab is cooling and moves at a faster rate when the surface begins to receive heat from the sun.

The studies have led to the development and calibration of a mechanistic design model, PSCP2. The model requires input data of the properties of the various materials associated with the pavement and subgrade along with the slab/base friction properties and slab dimensions. The output presents information of the movements, the concrete and steel stresses, and the friction developed at the slab/subbase interface.

After some three years of service, the prestressed pavement is in excellent condition. There are only two transverse cracks in the one mile length, and both occurred on a slab where initial processing was inadvertently omitted. It is believed that this fact indicates the initial prestressing followed by the final stressing is beneficial. Some longitudinal cracking has occurred and this cracking seems to have initiated at the corners of the leave-out pockets. A finite element program was used to verify the stress conditions at these corners and corrective techniques have been developed for future construction. It should be noted that the cracks are not structurally significant. The cracks have not caused further distress and do not affect the serviceability of the pavement. Therefore, transverse stressing appears to be warranted. The armored joints have performed extremely well and there has been no unusual distress near the joints. The cost of this type of paving probably precludes widespread use until considerable experience has been gained both in construction and with repair. However, the paving could be used in selected areas, such as intersections.

Evaluating a High-Speed Ground Corridor

Rob Harrison

Background

The Center has been evaluating the potential for a high-speed corridor incorporating both road and rail components, using the approach shown in Fig 1. A possible use is in the Texas Triangle, which is comprised of the area defined by the cities of Dallas-Fort Worth, San Antonio, and Houston and has been forecast to contain 20 million people by the year 2020, compared with 8 million today. In 1988, annual travel demand in the triangle was estimated at 19 million trips and was dominated by automobile and air travel.

Various modes of high-speed travel have been considered to serve the needs of the public traveling within the triangle in the next century, but most are based on solutions developed for other countries, where land and auto use, public transit systems, disposable income, and federal intervention are all quite different from those of Texas. Rail systems are particularly favored by planners — what seems to be lacking is a plan for a safe, efficient, high-speed, electronically managed highway facility to serve the needs of automobile owners.

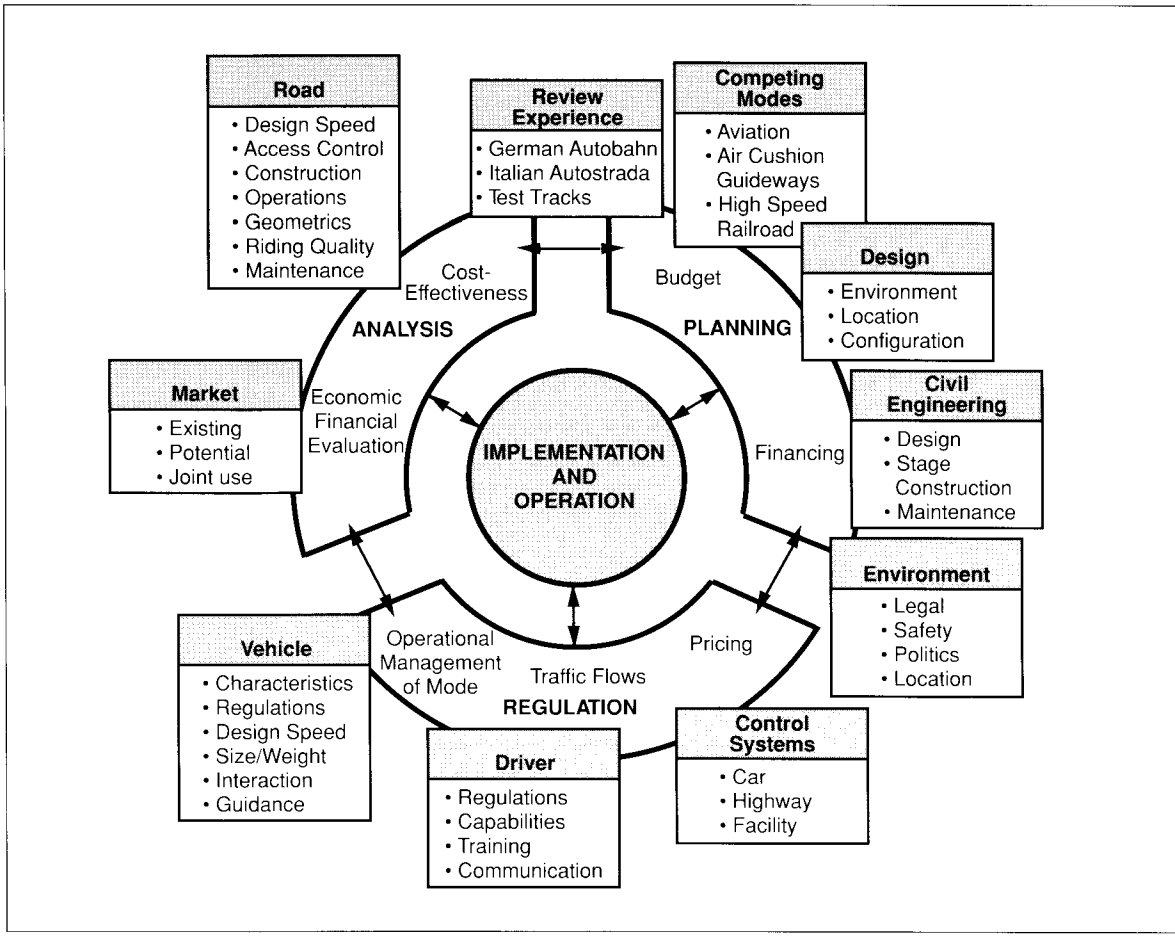
The number of vehicle trip miles is predicted to increase at a faster rate than that of population growth, and Texas cannot build itself out of that impending problem, but other solutions are at hand. Capacities of existing networks are likely to be significantly improved through new vehicle and highway guidance and communication systems using advanced vehicle and computer technologies and central traffic management systems; and current research indicates that the electronic equipment for urban travel in the next century will be capable of operating on limited access, higher speed facilities, such as ground corridors.

State Planning Issues

The corridor project was first evaluated in terms of state planning, economic impact, and political issues. The Texas State Department of Highways and Public Transportation conducted a series of meetings in 1988 to establish a consensus about transport needs in the next century, and the findings — in which the project was termed Texas 2020 — were used as the basis for an initial screening for evaluating the corridor program.

The basic proposal, for a highway in the corridor, seemed to have good support in many of the report's findings. First, there was a strong desire to preserve, maintain, and expand the present highway system to meet the needs in 2020. Second, the probable development of innovative technology that would address impending transit problems was discussed. Third, toll roads were suggested as a

Figure 1.
Structure of Texas 2020 Evaluation



means for accelerating the rate of highway construction and increasing network capacity.

Political impacts were not viewed in the report as being critical as long as safety and environmental issues were correctly addressed. A 2020 highway facility would be routed through comparatively non-sensitive areas (minimizing negative local impacts), be self financing (good for budgets), generate local employment, and be popular with most auto owners (voters). Combining road and rail modes within a high-speed facility, which was suggested in the report, also provides for flexibility in traffic assignment, offering both alternative modal choices for freight and travel for those persons unable to drive or not owning vehicles capable of using the facility.

The corridor project, therefore, meets broad state mobility objectives, fits the socio-economic needs as recorded by the SDHPT, and is consistent with the desire to link key urban areas efficiently and effectively.

Highway Design Characteristics

The Center researchers considered examination of the current highway design guide to be an obvious starting point for developing insights into design issues and problems. Although it is based on conventional vehicle designs, very conservative default values, low speed-ranges, and the use of facilities by badly equipped vehicles and poorly trained drivers, useful directions for technological assistance can be derived from the guide.

The areas of roughness, surface type, geometry, and capacity were examined in this way. Roughness did not appear to be a significant riding constraint at higher speeds, because the suspension system rides the bumps effectively, but this needs more examination, particularly in the light of the latest R and D work on interactive suspension designs. The initial work in the area of geometry suggests that new suspension systems are needed, to negotiate curves at very high speeds, and that ramp lengths can be reduced if vehicles can accelerate at rates of about 0.8 g. Surface types were analyzed and a rigid pavement design was found to be most cost-effective, even when designed solely for auto and light vehicle use.

In the area of capacity, access to the highway element of Texas 2020 will be actively controlled to maintain acceptable capacity levels. The highway will not be allowed to become congested, through a joint program of physically limiting the number of vehicles on the facility and charging the users in order to restrict demand at peak times. Traffic flow, in vehicles per hour, is a function of speed, in miles per hour, times density, in vehicles per mile. Speed, the driver's perception of reaction time (PIJR), and spacing are used to derive density and flow rates at different design speeds. Figure 2 gives an indication of the impact of speed on predicted flows for different values of PIJR. It would seem that around 90 mph, flow rates converge, irrespective of PIJR times, indicating that PIJR is not a critical variable in the corridor program. Headways are found to be highly critical, however, and using technology in this area to improve flows appears vital. Development of automotive guidance and safety systems, on both the car and the highway, to facilitate both improved stopping sight distances and headways, would be a major benefit to future highway users.

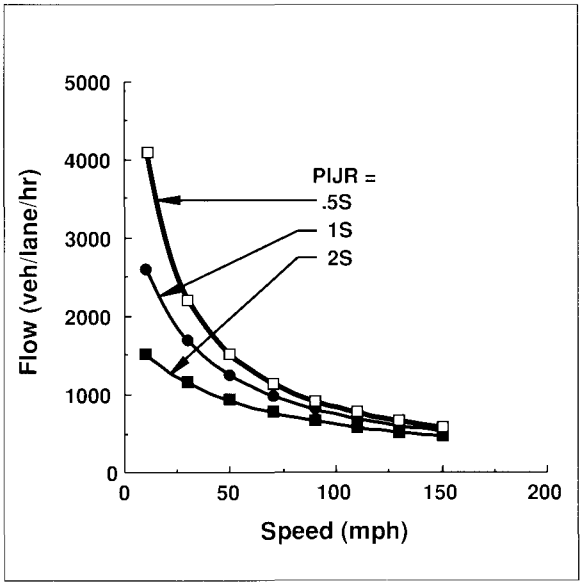


Figure 2.
Speed vs. Flow for Different Values of PIJR

Vehicle Design and Driver Issues

Cars have become smaller, more efficient, and able to cruise at high speeds with low fuel consumption. Computers with a power exceeding that of the desk top PC's of the early 1980's now control many engine and vehicle functions. It is the harnessing of this computing power to sensory features on the auto which appeals to many automotive engineers. These sensory systems would pick up highway and facility control data and either feed them directly to the vehicle control system or to driver displays.

A review of design features that the automotive vehicle in the next century may possess, based on current manufacturers' concept models, is shown in Table 1. The technological needs are rather modest and will enable vehicles to traverse a 2020 facility safely, quickly, and efficiently. Radar could be employed both front and rear to allow decreased distances between vehicles, through warnings and

automatic brake applications, and could have a major impact on traffic capacity flows on the Texas 2020, as detailed earlier.

The performance of vehicle suspension systems is critical at higher speeds; the systems should be a combination of active and passive designs in which a standard suspension (one with independent unequal length control arms and semi-trailing arms in the front and rear respectively) is combined with electronically controlled damping shock absorbers. Important non-suspension factors of the automobile influencing the suspension system are the weight, center of gravity, wheelbase, and tire track width of the vehicle. The proposed suspension system should include body roll and weight transfer controls because these factors can cause the rear tires to lockup and thereby adversely affect vehicle control. In terms of human workload, alternative means of vehicle control will be necessary and could be selected from options in which (1) the driver has complete control and must act in order for an event to occur, (2) the driver selects from or consents to the choices offered by the computer, (3) the driver takes a passive role but can override the computer, and (4) the vehicle is controlled from a centrally located station according to the traffic situation, and there is no driver intervention.

As the complexity and rate of information processing required of a driver increases, the use of a computer will greatly reduce driver stress. Driver stress is mainly caused by the need to continually monitor and respond to transient driving situations. Computer systems will be able to recognize developing problems and provide the driver with advance warning and options for their solutions. The inputs for a high-speed facility such as Texas 2020 are provided from the interactions between the driver, vehicle, and guideway. The driver is the weakest link when high-speed travel is involved, and, therefore, any corridor project employing higher than usual design speeds must emphasize the technological developments that can assist the driver in maintaining safety levels under all conditions.

Preliminary Findings

Investigations have shown a gap in the planning for Texas inter-city travel, a failure to capitalize on the potential benefits from "smart" autos and roads, and a reliance on the effectiveness of non-highway modes which may require public subsidies. In addition, current analyses of corridor projects are not generally demand oriented and employ data that are weak. If full user costs are considered, a highway facility becomes a very attractive option.

Table 1. Concept Car Basic Design Features

Feature	Description
Steering	• Variable Effort, Power System • Smaller, Elliptical Wheel with Primary Controls
Acceleration	• Throttle by Wire, with Electrical Hook-Up between Foot Pedal, Engine Management System
Aerodynamics	• Gently Tapering, Rounded Trailing Surface • Notchback Rear Design • Flush Underbody
Body/Frame Materials	• Graphite Reinforced Plastic Body Panels • Graphite-Epoxy Drive Shafts • Aluminum Bonded Monocoque
Engines	• High Efficiency, Alternative Fuel Capability, Low Emissions and Low Weight
Tires	• Fiberglass Rims, Radials, Bead Retention
Brakes	• Anti-Lock Performance • Optimizing Traction through Adaptive Systems
Suspension	• Combination of Active and Passive Systems • Body Roll and Weight Transfer Controls
Headlamps	• Low Profile, Quad Paraboloidal System
Brakelights	• High Mounted Tungsten Filament Stoplamp

Current R and D in automotive design, and in systems to improve driver performance and safety, will result in modifications to the traditional highway design guides. Finally, a 2020 highway facility can be managed in stages, in terms of travel speed. It could open at speeds not much higher than those on current interstate systems and raise these speeds in line with technical and operating improvements. The next stage in the Center's evaluation of a possible Texas high-speed corridor will be to consider the implications in terms of highway design and costs and to compare life cycle system costs with those of other modes.

Highway Project Constructability

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

Introduction

The Texas State Department of Highways and Public Transportation has been concerned with the problems that have arisen as highway projects have increased in size and complexity, as construction schedules have been continually shortened (causing many projects to run behind schedule), and as a highly experienced older generation of engineers has retired. These problems can be mitigated through the application of constructability concepts, and the Center has been investigating their adaptation to highway construction.

Constructability

Constructability has been defined by the Construction Industry Institute—a consortium of owners, contractors, and academia based at The University of Texas at Austin, whose purpose is to improve the cost-effectiveness of the U.S. construction industry—as the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. The Institute has identified constructability concepts applicable in the project phases of conceptual planning, design, procurement, and field operations. These concepts address project execution plans, conceptual project planning, contracting strategies, schedules, construction methods including pre-assembly, site layouts, design configurations, specifications, accessibility, adverse weather, and innovative construction methods (*Constructability: A Primer*, Construction Industry Institute, 1986).

Other salient research findings on constructability indicate that a large number of problems relate to the communication of design information, that much rework results from constructability problems, that constructability reviews are often in reality only an artificial pacifier (*Guidelines for Implementing a Constructability Program*, Construction Industry Institute, 1987), and that effective constructability programs have the effect of making smaller project organizations as productive as larger organizations.

Table 1. Highway Constructability Topics

- Selection of Materials and Methods
- Innovative Design/Construction
- Effective Early Construction Planning
- Simplified Configurations/Efficient Construction
- Optimal Risk/Responsibility Allocation
- Effective Communication of Requirements
- Facilitating Construction under Traffic
- Construction-Sensitive Schedules
- Appropriate Bidding/Contracting Strategies
- Use of New Technologies
- Optimal Utilization of Plant and Equipment
- Facilitating Construction under Adverse Weather
- Accessibility of Equipment, Materials, and Workers
- Facilitating Future Expansion and Upgrade
- Effective Incentive Mechanisms/Contractual Clauses
- Constructability Program Implementation

Application to Highway Projects

While the bulk of constructability research to date has focused on industrial or commercial construction projects, most concepts are also applicable in the highway sector. The costs and durations of highway projects can be reduced when attention is directed toward effective constructability.

CTR Research Objectives

Center research in this area, for the SDHPT, has had the following objectives: to (1) explore constructability factors that are relevant to highway construction and (2) identify needed procedures and supportive tools for ensuring cost-effective highway project constructability.

As an aid a hierarchy of constructability objectives was established:

Level 0	Reduce project costs
	Reduce project durations
Level 1	Increase unit productivity
	Reduce delays
	Eliminate unnecessary activity
	Reduce job physical stress
	Promote safe construction practices
	Reduce conflict

With the assistance of a steering committee, the research team identified some relevant highway constructability topics, which are outlined in

Table 1. The list is long and the topics are broad. They have been prioritized for research, and selected topical developments and findings are discussed below.

In support of the second research objective, attention has also been given to the specific form of research products. Four different developments are included:

(1) The Highway Constructability Guide: a 24-page guide directed to high-level managers for the purpose of increasing awareness of both the benefits of highway constructability and the methods of improving construction.

(2) The Highway Constructability Objectives File: a collection of objective tree diagrams that identify constructability problems, strategies, tactics, and ideas in a hierarchical manner. This is discussed in more detail below.

(3) The Highway Constructability Database: a computerized information retrieval system for detailed treatment of constructability ideas. This approach also offers an efficient structure for continuing analyses and further research. Figure 1 illustrates a proposed structure.

(4) Focused technical reports: reports that address such topics as specification improvements and design/construction innovation.

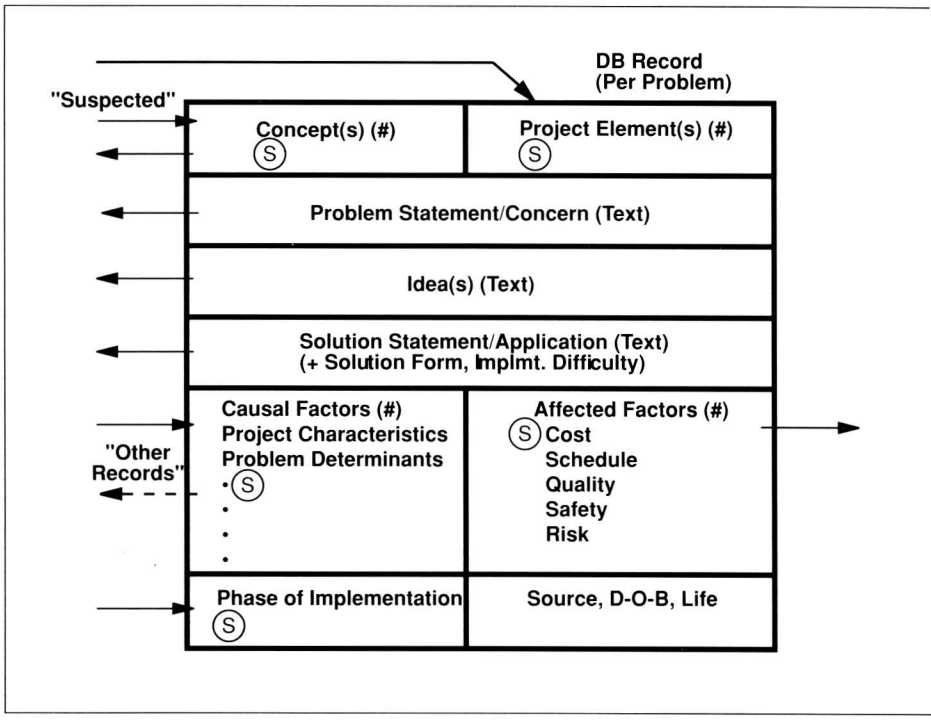


Figure 1. Proposed Database Field Structure

Research Activities

Research activities have involved the items noted below.

(1) *Taxonomy of information elements for analysis.* Constructability enhancement is an information-rich pursuit that requires a highly structured system to be effective. Figure 2 illustrates this complexity.

(2) *Personal interviewing.* This data collection technique remains the most effective for dealing with the complex, multi-organizational, and often controversial issues of constructability.

(3) *Hierarchy of Objectives Technique (HOT) diagramming.* Adapted from value engineering techniques, this is a graphical method for hierarchically

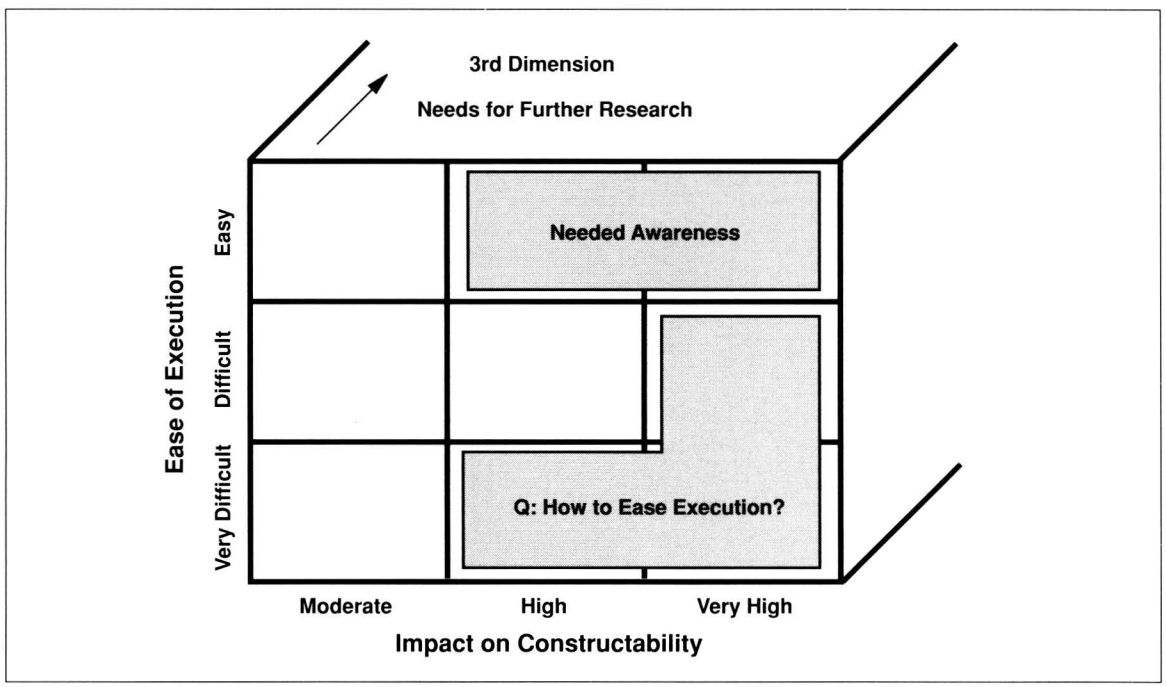


Figure 2. Assessment of Constructability Solutions

		Elements of Highway Construction						
	Problem Type	Earthworks	Pavement	Drainage	Bridge/ Structure	Other	Subtotal (%)	Total
	Communication: Interpretability	1	3	-	1	1		6 (9.5%)
Content	Relevancy: Currentness	1	5	-	1	-	10 (15.9%)	25 (39.7%)
Content	Definiteness	-	6	1	1	2	10 (15.9%)	
Content	Consistency	-	3	-	2	-	5	
Practicality	Functionality: Gold-Plated	1	6	-	6	2		15 (23.8%)
Practicality	Tolerances	3	7	3	-	-	13 (20.6%)	17 (27.0%)
Practicality	Flexibility	-	-	-	1	-	1	
Practicality	Measurement/ Payment Methods	-	1	-	-	-	3	
	Total	9 (14.3%)	31 (49.2%)	6	5	5	63 (100%)	

Table 2. Specifications Problem Information Base Analysis: Highway Elements & Problem Types

modelling constructability objectives. Once major problems are identified, high-order objectives (concepts or strategies) are followed by lower-order objectives (tactics or ideas). Diagrams may be developed in as much detail as desired, with the end-nodes often serving as a catalyst for innovative problem-solving. In this way, objectives may always be viewed in their proper perspective.

(4) *Criticality/controllability assessments.* The criticality of high-order objectives and the controllability of corresponding lower-order objectives are assessed to determine needs for further action. Criticality relates to potential or frequency of impact or benefit. Controllability relates to implementability or ease of execution or deployment. Critical yet uncontrollable objectives are targeted for further analysis.

Sample of Findings

Constructability problems related to highway specifications come from various sources. From personal interviews, "expert" sessions, and questionnaires sent to contractors and SDHPT District personnel, a total of 63 specification-related constructability problems were identified. These problems are cross-classified by problem type and highway element in Table 2. Common types of problems include inconsistent interpretation; unrealistic tolerances; gold-plated specifications; obsolete methods, equipment, or materials; and poorly communicated specifications.

Conclusions

The highway profession needs to become more aware of the opportunities for including cost-effective constructability practices. Through research, constructability problems can be targeted and actions can be taken that will lead to improved project engineering and management. The development of information systems and decision aids as tools for project managers and engineers is a good place to start.

Current Research Program

The 1988-89 research program for the Center for Tranportation Research included the studies listed here and discussed individually on the following pages.

SDHPT 3-8-86/8-422
Evaluation of Pavement Concrete Using Texas Coarse Aggregates
B. Frank McCullough and Ramon L. Carrasquillo

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 3-5-86/9-439
Strategies for Bridge Replacement
W. Ronald Hudson and Ned H. Burns

SDHPT 3-9-86/0-441
Treatment of Asphalt Mixtures with Lime and Antistripping Agents
Thomas W. Kennedy

SDHPT 3-9-85/9-450
Alkali-Aggregate Reaction in Concrete Containing Fly Ash
Ramon L. Carrasquillo

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 3-8-86/9-472
Rigid Pavement Data Base
B. Frank McCullough 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 3-10-88/9-556
Prestressed Concrete Pavement (PCP) Overlay, I-35 McLennan County
B. Frank McCullough and Ned H. Burns

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 3-8-89/9-922
Implementation of a Highway Pre-Construction Project Management System
James T. O'Connor and Fred Hugo

SDHPT 3-11D-89/9-931
Preparation of the Work Plan to Develop a Long-Range Rehabilitation Plan for U.S. 59 in District 11
B. Frank McCullough and David W. Fowler

SDHPT 3-15D-87-932
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 3-24D-89/9-959
Bonding Evaluation of Overlaid Bridges on IH-10
David W. Fowler and Ramon L. Carrasquillo

SDHPT 3-14D-88-960
District 14 Pavement Intersection Instability Study
Richard J. Holmgreen, Jr., and Thomas W. Kennedy

SDHPT 3-10-89/9-964
Standardized Procedures for Route Feasibility Studies
B. Frank McCullough

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 3-10-89/9-978
The Texas Mobility Arterial System
C. Michael Walton, Hani S. Mahmassani, and William V. Ward

SDHPT 3-11D-89/1-987
A Long-Range Plan for the Rehabilitation of U.S. 59 in District 11
David W. Fowler and B. Frank McCullough

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 3-18-87/9-1111
Capacity Improvements for Urban Intersections
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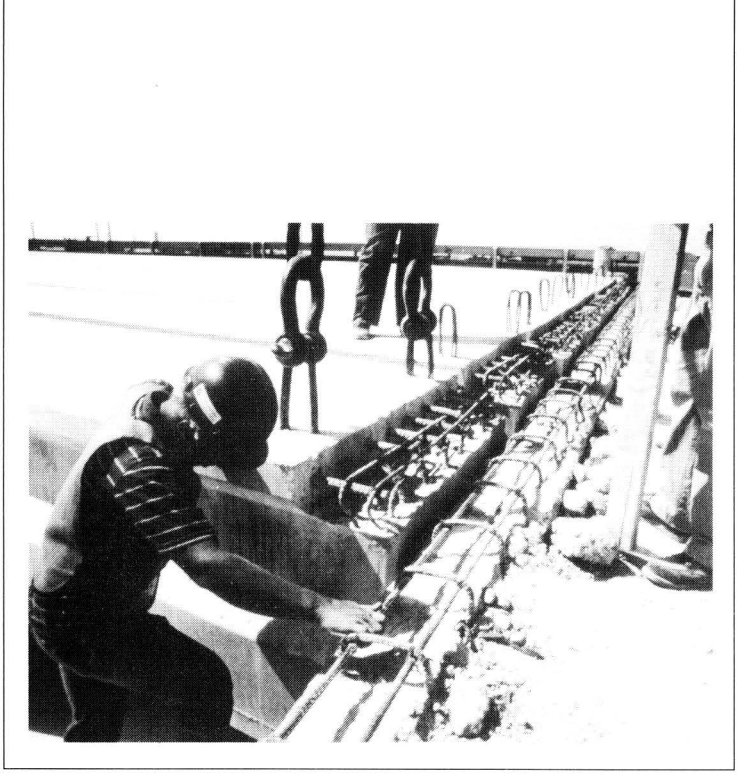


SDHPT 3-8-86/8-422
Evaluation of Pavement Concrete Using Texas Coarse Aggregates
B. Frank McCullough and Ramon L. Carrasquillo

The primary objective of this project is to develop information that may be used in designing algorithms and specifications to differentiate between the different coarse aggregate types used in concrete pavements in Texas. This information will be used to (1) understand the difference in engineering properties of pavement concrete using different types of coarse aggregates, (2) develop guidelines to be followed when designing a concrete mix for pavements using different types of coarse aggregates, (3) evaluate the effect of concrete material properties and their proportions on the design, construction, and performance of portland cement concrete (PCC) pavements in Texas, and (4) perform a number of solutions with computer programs to provide alternate designs for various materials characterizations.

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. Thus, the objectives of this study are to (1) estimate (a) the effect on traffic mobility and (b) the cost-effectiveness of increasing the traffic capacity, the scope, and the range of selected arterial thoroughfares; (2) recommend certain thoroughfares for improvements; (3) recommend the level of physical improvements for the selected thoroughfares; and (4) furnish an estimate of the construction costs of recommended improvements.

The 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 3-5-86/9-439
Strategies for Bridge Replacement
W. Ronald Hudson and Ned H. Burns

In recent years the need for a broader overall management concept for bridges has become increasingly evident. The objective of this study has been to develop for the Texas SDHPT a practical methodology for prioritizing bridge structure rehabilitation and replacement for both on-system and off-system bridges in Texas. The methodology will be practical yet scientifically based and well defined, taking user cost and user benefit factors into account.

The study will produce a better methodology for using available bridge funds, a greater number of usable bridges, and more efficient, safe, and economical transportation of people and materials in Texas. Implementation of the methods developed through this study will result in a more equitable statewide distribution of bridge funds. It is expected that the tool developed in this study will be used by the SDHPT Administration, Bridge Division, and District offices, and the information will be available for use by local governments.

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 3-9-85/9-450
Alkali-Aggregate Reaction in Concrete Containing Fly Ash
Ramon L. Carrasquillo

Fly ash is a relatively inexpensive and readily available material that can partially replace portland cement in concrete. Its use in concrete in the United States has increased tremendously in the last five years, but knowledge of its effect on the durability and long-term performance of concrete is dangerously deficient, and there are no guidelines for engineers to use in deciding which fly ash to use in combination with available cements and aggregates to ensure adequate performance of the concrete in service. As a result, there is a question about the adequacy of current alkali content specifications to prevent alkali-aggregate related damage in concrete.

The main objective of this study for the Texas SDHPT is to develop a relationship between relevant components of the fly ash, portland cement, and concrete aggregates as these affect and can control alkali-aggregate reaction in concrete. It is only through the understanding of the fundamental mechanism governing the interaction among the alkali in the cement and fly ash and the aggregate used in concrete that adequate guidelines for proper, economical, and efficient use of fly ash in concrete can be developed.

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 in the form of manuals describing the procedures for using the FWD to evaluate joints and cracks. Many SDHPT Districts and the State as a whole will realize significant benefits in terms of more efficient utilization of funds for maintenance and rehabilitation of rigid pavements.

SDHPT 3-8-86/9-472
Rigid Pavement Data Base
B. Frank McCullough and W. Ronald Hudson

The rigid pavement data base consists of a data bank and a data feedback system based on periodic observations that are necessary to continue improvement and implementation of the Pavement Management System. Monitoring of special-study pavement sections has provided a tremendous amount of useful information that has significantly contributed to the development of rigid pavement rehabilitation design systems, as well as criteria for prioritization and scheduling of overlays on rigid pavements at the network level.

It is essential that the condition survey and performance monitoring of portland cement concrete pavement sections in Texas be continued in order to permit proper planning of rehabilitation and maintenance and optimum expenditure of available funds. In addition, actual performance of rigid pavements and overlays can be compared against the predicted performance, and pertinent recommendations can be made to revise the design procedure. Improvements in overlay design procedures can also result from this feedback process.

The objectives of the study are (1) to establish the needs of condition survey data, (2) to develop a factorial to select pavement sections for condition surveys, (3) to conduct condition surveys on selected pavement sections, (4) to establish methods of measurement, (5) to investigate the possibilities of developing a data base management system, and (6) to develop design manuals for ACP overlays on concrete pavements.

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 specific objectives are to (1) develop a comprehensive, long-range strategic research plan which addresses all aspects of pavement friction and (2) investigate the relationship between polish value and 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 guidelines 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 de-

sired 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 3-10-88/9-556
Prestressed Concrete Pavement (PCP) Overlay, I-35 McLennan County
B. Frank McCullough and Ned H. Burns

This project continues the condition survey and performance monitoring of the prestressed slab overlay in Waco for the Texas SDHPT. The performance monitoring will produce more information on the behavior and service life of the prestressed slab pavements, and it will be possible to develop a program for the maintenance of this type of overlay from the data collection/feedback process. The more accurate models that result will include refined design procedures for determining joint spacing, pavement thickness, and the post-tension level for a specific set of conditions, considering a wide range of input variables.

In the short term the aims of this project are to monitor performance of the prestressed concrete pavement overlay and calibrate prediction models of it. The long-term aims are to maximize the benefits of the investment already made in the project (construction and design) and utilize the results obtained for the future development of behavior and design concepts.

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 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 3-8-89/9-922
Implementation of a Highway Pre-Construction Project Management System
James T. O'Connor and Fred Hugo

This is a continuation of work started under IAC (88-89) 0052. Its purpose is to assist the SDHPT Administration and District offices in improving the management and efficiency of planning operation, specifically, providing continued testing, evaluation, and adaptation of commercially available software and providing written and personal assistance to the Department.

SDHPT 3-11D-89/9-931
Preparation of the Work Plan to Develop a Long-Range Rehabilitation Plan for U.S. 59 in District 11
B. Frank McCullough and David W. Fowler

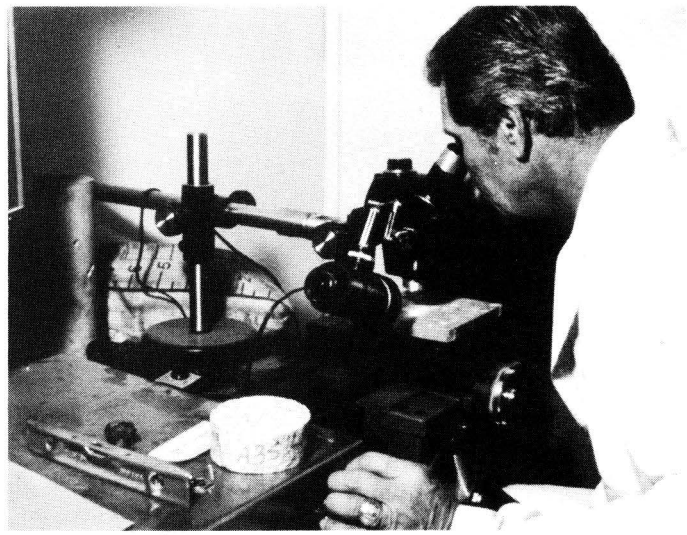
This project addresses the need to improve pavement performance along U.S. 59 within District 11. Improving performance is defined as providing and maintaining a minimum satisfactory pavement riding quality at the least annual cost, which includes the SDHPT construction, operational, and maintenance costs as well as the highway user's time, operational, and safety costs during construction and maintenance operations. The results of this work should lead to a long-range plan for the rehabilitation of U.S. 59 in District 11 that will not only save money there but may also serve as the pattern for similar rehabilitation programs for jointed rigid pavement throughout the State.

SDHPT 3-15D-87-932
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 3-24D-89/9-959
Bonding Evaluation of Overlaid Bridges on IH-10
David W. Fowler and Ramon L. Carrasquillo

The purpose of this project was to assist District 24 in planning and performing an evaluation test on the bonded overlay on six IH-10 bridge decks to help determine the bonding strength of the overlay.

SDHPT 3-14D-88-960
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 aimed at relieving or eliminating plastic deformation at intersections and (2) determine the economic impact on the use of materials for the single 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 3-10-89/9-964
Standardized Procedures for Route Feasibility Studies
B. Frank McCullough

The purpose of this work was to provide professional staff to research and complete revision to route feasibility studies currently underway, which included the Texline-Galveston, Wichita Falls- Brownsville, and Kingsville-Padre Island routes. Existing and past procedures used in the development of route feasibility studies were reviewed and standardized procedures for systematic analysis and uniform presentation of all future route feasibility studies were recommended. The analysis procedures will be periodically compared with the evolving methodology being used to develop the Texas statewide highway system plan. Potential conflicting analysis criteria will be documented.

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 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.

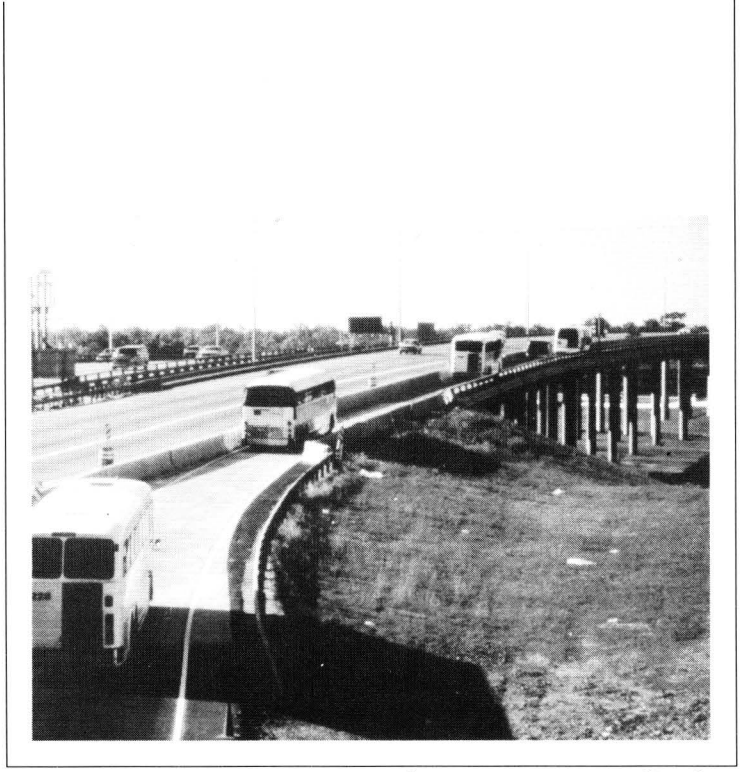
The possible benefits are both considerable and varied. Rod and level services are expensive, and the Dipstick could be substituted for many small contracts and could be used to develop profiles for calibrating roughness instruments in Districts not located close to GM Profilometer sections and for specific problem areas, such as bridge-road transition areas. A greater understanding of IRI is vital, given the federal desire to adopt it in the near future, and the insights gained should be valuable in planning more detailed work covering the full range of related issues, from actual road profiles to ride statistics, such as SI and PSI.

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 3-10-89/9-978
The Texas Mobility Arterial System
C. Michael Walton, Hani S. Mahmassani, and William V. Ward

This research is designed to assist the Texas SDHPT in identifying a state-wide network of corridors for proposed arterials that will provide improved mobility and support future economic development through efficient transportation. This study is one element of a broader undertaking by SDHPT, with support from the Center



and the Texas Transportation Institute, to develop the Texas Mobility Arterial System. The principal focus of this study is an analysis of the existing highway network and the degree of connectedness and directness of service that it offers to cities in different size categories.

SDHPT 3-11D-89/1-987
A Long-Range Plan for the Rehabilitation of U.S. 59 in District 11
David W. Fowler and B. Frank McCullough

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. In many urban areas, traffic demand on the State's freeway and highway system has reached or exceeded the capacity of these facilities, and it is evident that many segments cannot realistically be expected to be improved in capacity because of right-of-way constraints and other reasons. 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.

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, (4) the relation of continuity and length of arterial streets to trip lengths, (5) the State's role in planning, funding, constructing, operating, and maintaining arterial streets, (6) the appropriate tools, data needs, and planning methods needed to address these issues, and (7) the significance of arterial street systems and the effect on urban mobility, including public transportation.

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. The results of this study should provide the SDHPT WITH some immediate guidance as to the cost-effectiveness of the arterial street alternative.
(This is a joint project with the Texas Transportation Institute)

SDHPT 3-18-87/9-1111
Capacity Improvements for Urban Intersections
Clyde E. Lee and Randy B. Machemehl

Appropriateness and efficiency of intersection geometry are of growing importance to all traffic engineering agencies within the state. User costs, such as delay and fuel consumption, as well as auto emissions, are directly related to the efficiency of traffic operations. The objectives of this study for the Texas SDHPT are to (1) develop guidelines for implementation of multiple-left-turn-lane geometry, (2) produce criteria for determining the lengths of auxiliary lanes adjacent to at-grade intersections, and (3) develop an implementation package containing all guidelines and criteria in the form of a printed user's manual, as well as text and analysis routines for IBM PC compatible microcomputers. Results of the investigation can be put into immediate use by SDHPT personnel who are responsible for intersection design and modification. The left-turn lane and auxiliary lane guidelines may be utilized by both Division and District personnel as well as by traffic engineers in Texas cities, counties, and councils of government and others. Although the guidelines will not be a substitute for sound engineering analyses and judgement, they will be a valuable basis for consistent evaluation of the need for special handling of turning movements at signalized intersections.

SDHPT 3-9-87/9-1117
Guidelines for Proper Use of Superplasticizers and the Effect of Retempering Practices on Performance and Durability of Concrete
Ramon L. Carrasquillo

The overall objectives of this project for the Texas SDHPT are to (1) develop guidelines for the proper use of superplasticizers in achieving good quality and durable concrete in the field, (2) investigate experimentally the effect of superplasticizers on the durability of concrete, (3) evaluate the effect of "holding" part of the mixing water for later addition on the strength, freeze-thaw resistance, and abrasion resistance of concrete, (4) study the possibility of using admixtures to retemper the concrete without affecting the strength and durability characteristics of the concrete, and (5) conduct pilot field studies and work with field highway personnel to verify the research findings and to accelerate the transfer and implementation of the research results.

The research findings will be used in revising standards, specifications, and current concrete practice for proper use and addition of superplasticizers to concrete and for the holding of

mixing water during mixing and placing. The results of this research should be better concrete and fewer construction delays.

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 3-5-87/9-1127
Detailing Reinforcement in Concrete Structures
James O. Jirsa, John E. Breen, and Michael E. Kreger

The objectives of this study are to (1) determine the state of the art in structural concrete detailing as reflected by research conducted and reported in Europe; (2) assess the state of the art in structural concrete detailing utilized by the SDHPT with regard to typical details, construction procedures, and materials; (3) specifically investigate experimentally the applicability of current AASHTO provisions for shear in the negative moment zones of pretensioned and post-tensioned composite beams, and, if the current specifications are not applicable, develop appropriate specifications and detailing guidelines considering composite behavior and the proper depth of section for shear calculations; (4) test selected structural concrete details experimentally where previous research is inadequate or where SDHPT details differ substantially from those used elsewhere; (5) use the experimental results to refine the truss model, especially in terms of nodal zones, material characteristics, and member continuity; and (6) develop a detailing guide which provides simple models for designing complex details in structural concrete.

The guide should lead to more consistent, constructible, economical, and reliable details and provide support to the structural designer in an area where current codes and design specifications, including AASHTO, provide little information.

SDHPT 3-8-88/9-1138
Medians with Continuous and Intermittent Permitted Left-Turn Movements
Randy B. Machemehl and Clyde E. Lee

The basic objective of the study for the Texas SDHPT is the development of a set of practical, well-documented guidelines for the design of highway medians where intermittent left turns are permitted. The objectives are to (1) develop a synthesis of current practices regarding the use of continuous left-turn median lanes on facilities with both three and five lanes (some consideration is also being given to seven-lane facilities), (2) quantify the operational effects of the variety of median designs for urban and suburban areas where intermittent median openings are appropriate, and (3) develop criteria for choosing between divided sections and continuous left-turn lanes considering operational effects, pedestrian requirements, and delineation requirements.

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 a the necessary tools for performing much more complete analyses and thereby provide a much better basis for making decisions.

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. These are the primary objectives: (1) evaluate current gradations being used in Texas; (2) evaluate mixture properties as affected by aggregate gradation with respect to humps in the gradation curve, filler content, and voids in the mineral aggregate (VMA); (3) evaluate the economics involved in improving gradation specifications; and (4) develop a recommended aggregate gradation specification based on the findings of the study.

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 3-10-88/9-1162
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.

SDHPT 3-9-89/1-1166
Development of Rapid Quality Control Methods and Procedures for HMAC
Richard J. Holmgreen, Jr., and Thomas W. Kennedy

Current quality control of HMAC construction consists of an aggregate gradation, asphalt content determination, and a Hveem stability test, which is the only mixture test performed and is conducted in Austin. Delay between sampling and the reporting of the results makes actual control at the job extremely difficult at best, and a method for reliably predicting material properties considered to be indicative of quality and performance in a timely manner is needed.

The primary objectives of this study are to (1) evaluate existing quality control techniques and systems for HMAC currently being performed by the Department and other agencies, (2) develop quality control tests and/or testing systems for HMAC to make the appropriate information available in a more timely manner, and (3) correlate the results of proposed quality control tests with current Texas SDHPT procedures. If the test results can be used to identify materials that should not be used, unacceptable materials can be kept to a minimum, which should reduce the cost to both the contractor and the Department.

SDHPT 3-8-88/0-1167
Develop Smoothness Specifications for Rigid and Flexible Pavements
W. Ronald Hudson

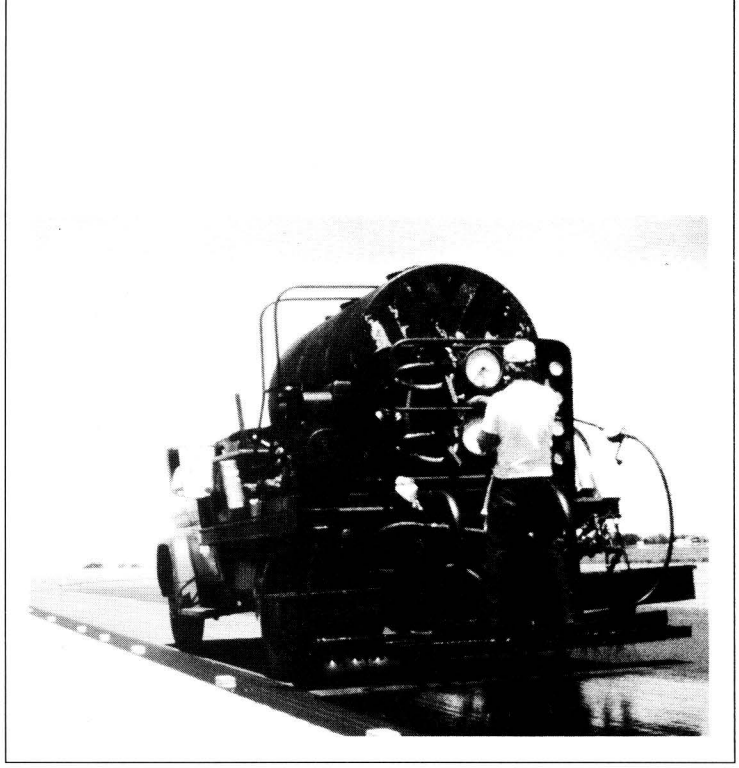
Development and implementation of an improved specification based on a suitable roughness measuring device, responsive to objective components of roughness of the pavement as well as to subjective components which are commonly referred to as "ride," are needed for the state of Texas. The roughness device 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. Experience of other states using construction smoothness specifications based on roughness measurements, and the impact of possible departure from the 1985 AASHTO smoothness specifications based on the California profilograph, will be examined.

Improved smoothness acceptance specifications will improve the riding quality and thus the pavement life of Texas highways and may reduce the need for early rehabilitation or reconstruction. 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 3-8-88/3-1168
Development of End-Result Acceptance Specifications for HMAC
Thomas W. Kennedy and Richard J. Holmgreen, Jr.

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. These are the objectives: (1) establish mean and variational characteristics of specified materials which will produce satisfactory pavement performance and can be achieved during construction, (2) determine the effect of deviations from the specified mean and variational values on pavement performance, (3) develop a recommended pay schedule, including penalties and incentives based on reduced or improved pavement performance, and (4) recommend an end-result specification for asphalt mixtures and asphalt concrete pavement including a penalty-incentive pay schedule.

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 2/3-9-88/1-1170
Improved ACP Mixture Design: Development and Verification
Thomas W. Kennedy

The study objectives of this study for the Texas SDHPT are to (1) develop a methodology to employ the indirect tensile creep test to be used for the prediction of tensile mixture stiffness at the temperatures and loading durations associated with thermal cracking, (2) develop the methodology to determine Mohr-Coulomb failure envelopes for asphalt concrete mixtures and, further, develop the methodology to predict cumulative permanent deformation in ACP pavements of different structural types, for different climatic regions and for various traffic conditions, using the SED-ration concept, (3) develop an expedient creep test device which tests creep samples fabricated using the large Texas gyratory shear compactor, (4) develop sample fabrication procedures and a testing procedure for ACP mixtures containing large aggregates, such as those to be used as black bases, as well as procedures for ACP surface courses, (5) evaluate and refine the repeated-load indirect tensile fatigue test for use in evaluating the effects of mixture component variation on flexural fatigue, (6) verify the new mixture design/analysis through an extensive field verification program, and (7) implement findings.

A better, more exact method of mixture design/analysis will result in a more theoretically sound basis for materials selection in ACP pavements and a more realistic integration of asphalt concrete material properties in structural pavement design and predicted structural performance algorithm. This will, in turn, result in a more accurate prognostication of pavement performance. (This is a joint project with the Texas Transportation Institute)

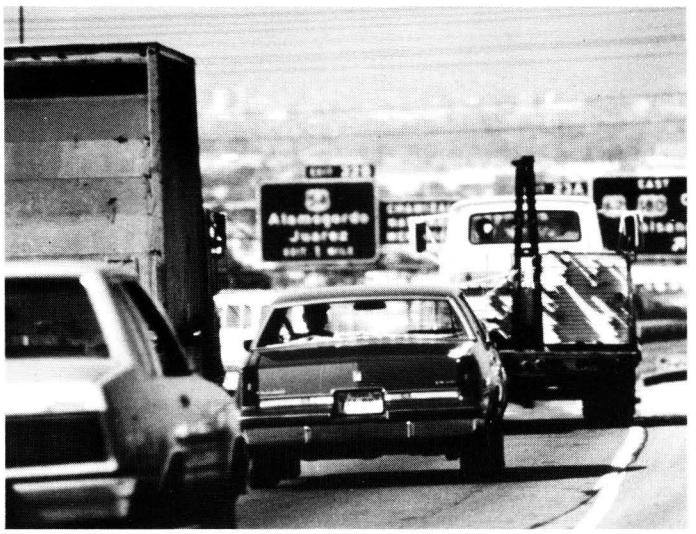
SDHPT 2/3-18-88/1-1175
Development of Dynamic Analysis Techniques for Falling-Weight Deflectometer Data
Jose M. Roesset, Kenneth H. Stokoe, II, and W. Ronald Hudson

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 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 2/3/10-8-89/0-1177
Development of Routine Resilient Modulus (M_r) Testing for Use with the New AASHTO Pavement Design Guide
B. Frank McCullough, Kenneth H. Stokoe, II, and W. Ronald Hudson

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. Texas SDHPT personnel will be able to use the new AASHTO Pavement Guide to its fullest extent, thus improving the methodology used in the design of Texas highways. In addition, the results of this study can be utilized in refining further mechanistic pavement design processes for both flexible and rigid pavements.
(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 overall objectives of this project for the Texas SDHPT are to (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 prestressed and nonprestressed 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 the completion of the following tasks: (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 3-8-88/9-1190
Tire Contact Pressure Distributions
W. Ronald Hudson and Kurt M. Marshek

The objective of this study for the Texas SDHPT is to determine tire contact pressure distributions for truck tires and several automobile tires currently found on highways in Texas. It involves (1) collecting information related to truck sizes, weights, and tires; (2) gathering data from tire manufacturers on tire size, maximum design pressure, recommended tire pressure, and axle loads; (3) determining the test tires to evaluate; and (4) determining the contact pressure distributions for the representative automobile and truck tires.

The findings of this study will help to provide much needed data on actual tire-pavement contact pressure distributions. The tire contact pressure distribution data will be useful in developing and updating tire models for analytical tire-pavement contact pressure prediction. The study will provide data which can be used by the Texas SDHPT to analyze the stresses, strains, and lives of pavements subject to tire weights, sizes, and pressure distributions. The results of this study will assist the SDHPT in its pavement design and pavement management efforts.

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 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 and David W. Fowler

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 and subsequently 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.

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 to 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 3-5-89/0-1218
Design and Construction of an Environmentally Controlled Test Facility for Portland Cement Concrete
Ramon L. Carrasquillo, David W. Fowler, and Alvin H. Meyer

The objective is to design and construct an environmentally controlled test facility for full-sized PCC pavement slabs. The facility can be used for testing new materials, new techniques, or modified practices. The related research and testing will improve the long-term performance of pavement, pavement repairs, pavement rehabilitation, and pavement reconstruction, which will reduce the life-cycle cost of pavements. The results of tests using the facility will be directly implementable into specifications and/or construction practice.

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 IAC 1280
Support for the Attorney General
James T. O'Connor

This contract provides for services to assist the Attorney General in collecting and correlating, through the use of automatic data processing, evidence to be used in defending the SDHPT in a legal action.

SDHPT ETC 486XXA3001
Training in Asphalt Concrete Mixture Design and Construction
Richard J. Holmgreen, Jr., and Thomas W. Kennedy

This program for the Texas SDHPT will provide training for those engaged in the design, production, and placement of asphalt mixtures in Texas. The course will be directed toward technicians, inspectors, and construction supervisor-level personnel (SDHPT and contractors), and engineer-level personnel should also gain insight from it.

General Motors
Future of the City: The Role of the Automobile
C. Michael Walton and Hani S. Mahmassani

The objective of this research is to explore and develop methodological approaches for the joint characterization of urban development patterns and transportation phenomena, in a manner that will allow the assessment of the transport implications of evolving urban patterns, under the influence of forces to be identified in the course of the study. In particular, emphasis will be placed on understanding the nature of the interactions that determine the role of the automobile in congested urban traffic.

The research effort in urban systems transportation interactions involves three major thrusts, corresponding to three complementary methodological approaches to the problem: (1) characterization of principal phenomena and relationships, (2) dynamic modeling and simulation of urban systems development, and (3) selected case studies.

Capital Metro
Transit Facility Planning and Design Guidelines
C. Michael Walton

Since the creation of Capital Metro as the regional transit authority for the Austin metropolitan area there has been considerable interest in developing the transit service in order to facilitate cooperation between existing and planned land use activities. It is becoming increasingly important to develop a set of transit facility design guidelines which will facilitate the integration of transit into these land use activities.

The purpose of this study is to develop such guidelines for the planning and design for transit facilities for Capital Metro. The objectives would be to foster public and private ventures in the integration of transit into their land use development activities, to facilitate their understanding and appreciation of the planning and design elements implicit in transit service, and finally to develop a benchmark from which all planning and design activities of transit facilities can begin. The study will include STS services and appropriate guidelines. The output will be a document which will serve as a guide for the planning

and design of transit facilities for Capital Metro. Given the opportunities which have been evolving over the last few years, the resulting manual should be exceedingly helpful to both the public and private sectors in planning their developments and related activities and in retrofitting existing developments.

Capital Metro
Development of a Data-Base Management System
Hani S. Mahmassani

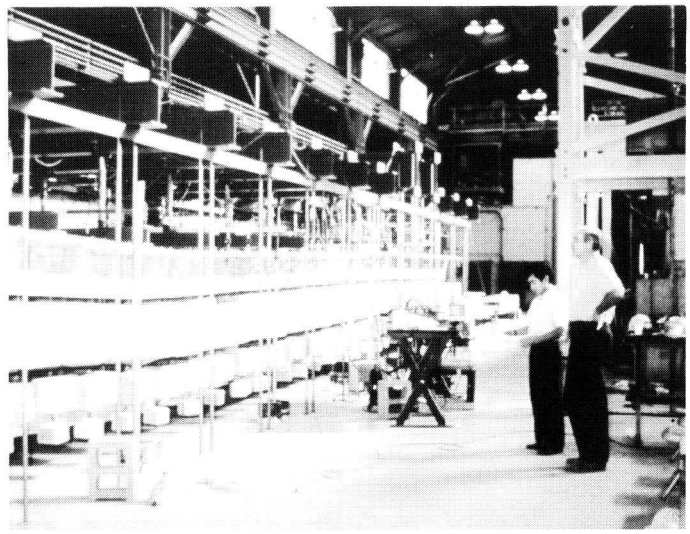
The purpose of this study is to develop a data-base management system to support the planning, operations, monitoring, evaluation, and managerial functions of Capital Metro.

The objectives are to recommend the hardware/software configuration for the data-base management system, design the structure and elements of the data base, and develop and implement application programs that address the reporting needs and information requirements in priority areas identified by the staff.

Capital Metro
Long-Range Railroad Management Alternatives
C. Michael Walton

The City of Austin and Capital Metro have entered into an agreement to provide for management and other matters related to the recently purchased Giddings-Llano railroad right-of-way. The management approach necessitated by the freight and non-freight rail operations has raised a number of questions and issues concerning effective management of the railroad right-of-way. The current management structure is not seen as a viable alternative for the future.

The objectives of this study are to (1) describe the current arrangement and structure for



management of the railway in relation to the objectives and goals of the railway owners, (2) identify the significant legal, operating, and financial issues of the railway operation and present and describe alternative strategies/structures for the effective management of the railway, and (3) present a plan of implementation for the recommended management strategy.

Capital Metro
Pricing Strategy — Fare Policy Study
C. Michael Walton and Hani S. Mahmassani

The purpose of this study is to develop information and procedures that can be used by Capital Metro to design and recommend a comprehensive strategy for fares and pricing issues. The strategy should recognize the competing considerations involved in this problem and should be based on a systematic assessment of its impacts in terms of these considerations. Information on these impacts will be obtained from a variety of sources, including the experience of other systems, as well as through the use of appropriate methodological tools developed for the purpose of this study and applied to the Capital Metro system. Specifically, the Center will identify the principal alternative pricing schemes available, synthesize experience available in other systems with regard to non-standard fare policies, develop a methodological framework for the evaluation of the impacts of particular pricing schemes, and apply the methodology to the Capital Metro area in order to assess the relative desirability of these alternatives.

Capital Metro
Fixed-Guideway Evaluation Criteria Study
C. Michael Walton

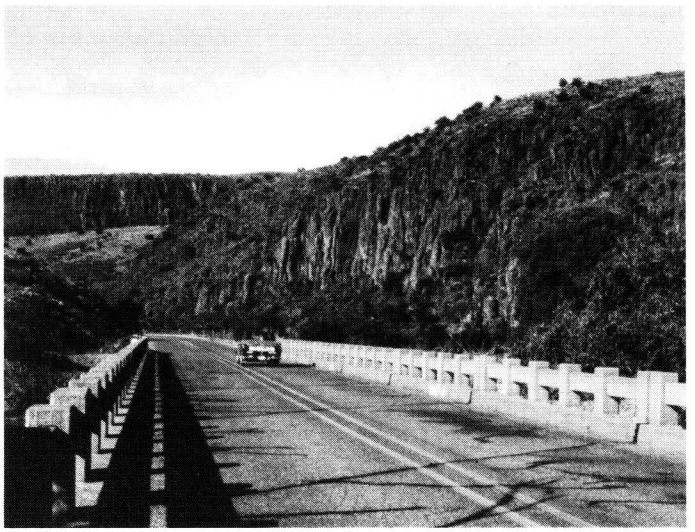
The objectives of this study for Capital Metro are to (1) gather data on fixed-guideway system performance from transit agencies in the U.S., with special emphasis on systems recently implemented in the sunbelt and West Coast cities; (2) compare, where possible, (a) projected costs for construction and operation with actual costs and (b) projected ridership with actual ridership, by trip purpose; and (3) identify key factors and guidelines for evaluating fixed-guideway systems.

Capital Metro
Non-Traditional Transit Service Study
Sandra Rosenbloom

Many communities are responding to their transit problems, including the needs created by increasing suburbanization, by exploring and implementing non-traditional transit options, alternatives which range from vanpool projects to taxi-based community services. The objectives of this study for Capital Metro are to identify potential non-traditional transit options for Austin, match those options to specific suburban needs and activity patterns, evaluate the cost effectiveness of any individual or combined options in meeting suburban or corridor needs, and suggest effective planning service strategies for suburban and corridor needs.

Texas Motor Transport Association
Compilation of Texas Trucking Industry Statistics
C. Michael Walton

Numerous state and national agencies, public and private, generate data and documents containing information relevant to truck and bus industry operations, but there is nothing that identifies the various sources and documents available. The purpose of this project for the Texas Motor Transportation Association is to compile relevant information and data into a single source that can be used for producing statistical summaries and reports on the Texas trucking and bus industry. The specific objectives are to develop a compendium of relevant Texas trucking and bus industry data sources and to compile statistical data summarizing the impact of the trucking and bus industries in Texas.



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 currently in progress 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 data base management system to handle all of 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 Long-Term Pavement Performance studies
W. Ronald Hudson

The Center is working with the Texas Research and Development Foundation to provide technical and management support to develop and conduct long-term pavement performance (LTPP) studies for the Strategic Highway Research Program, which is administered through the National Research Council, in cooperation with the Federal Highway Administration and the American Association of State Highway and Transportation Officials. The primary work to be accomplished under this contract 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 other services required.

University Transportation Centers Program 71247
Technical, Engineering, and Economic Feasibility of a High-Speed Ground Corridor
Kurt M. Marshek, Rob 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 Leigh B. Boske

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.

Research Reports Produced This Year

These reports were produced by the Center during 1988-89 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
December 1987 (Preliminary)

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

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

457-5F
A Summary of Studies of Bonded Concrete Overlays
Young-Chan Suh, James R. Lundy, B. Frank McCullough, and D. W. Fowler
November 1988

472-2
Development of a Long-Term Monitoring System for the Texas CRC Pavement Network
Chia-pei J. Chou, B. Frank McCullough, W. R. Hudson, and C. L. Saraf
October 1988

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 (Preliminary)

481-3
Abrasion Resistance and Scaling Resistance of Concrete Containing Fly Ash
Karim M. Hadchiti and Ramon L. Carrasquillo
August 1988

481-4
The Effect of Fly Ash on Temperature Rise and Hydration in Portland Cement Concrete
Hope R. Villanueva and Ramon L. Carrasquillo
April 1989 (Preliminary)

490-1
Investigation of the Frictional Resistance of Seal Coat Pavement Surfaces
Mohamed-Asem U. Abdul-Malak, Chryssis G. Papaleontiou, David W. Fowler, and Alvin H. Meyer
June 1988

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

920-3
Monitoring and Testing of the Bonded Concrete Overlay on Interstate Highway 610 North in Houston, Texas
Kok Jin Teo, D.W. Fowler, and B. Frank McCullough
February 1989

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 (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 (Preliminary)

1118-1F
The Effectiveness of Membrane Curing Compounds for Portland Cement Concrete Pavements
C. Pechlivanidis, C. G. Papaleontiou, A. H. Meyer, and D. W. Fowler
November 1988

1124-1F
A Study of the Influence of the Temperature of the Substrate on the Construction of Bonded Portland Cement Concrete Overlays
Soetjipto Koesno, A. H. Meyer, and D. W. Fowler
November 1988

1126-1
Load-Deflection Behavior of Cast-In-Place and Retrofit Concrete Anchors Subjected to Static, Fatigue, and Impact Tensile Loads
D. M. Collins, R. E. Klingner, and D. Polyzois
February 1989

1126-2
Adhesive Anchors: Behavior and Spacing Requirements
G. T. Doerr and R. E. Klingner
March 1989

1126-3
Behavior and Design of Ductile Multiple-Anchor Steel-To-Concrete Connections
R. A. Cook and R. E. Klingner
March 1989

1126-4F
Design Guide for Steel-To-Concrete Connections
R. A. Cook, G. T. Doerr, and R. E. Klingner
March 1989

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 (Preliminary)

1129-2F
Analysis and Design of Bridge Bent Columns
M. Haque, J. M. Roesset, and C. P. Johnson
November 1988 (Preliminary)

1160-1F
Evaluation of a Simplified Procedure for Determining Maximum Specific Gravity of Asphaltic Concrete Mixtures
Richard J. Holmgreen, Jr., and Thomas W. Kennedy
March 1989 (Preliminary)

1169-1
A Study of Drainage Coefficients for Concrete Pavements in Texas
Venkatakrishna Shyam, H. Castedo, W. R. Hudson, and B. Frank McCullough
May 1989 (Preliminary)

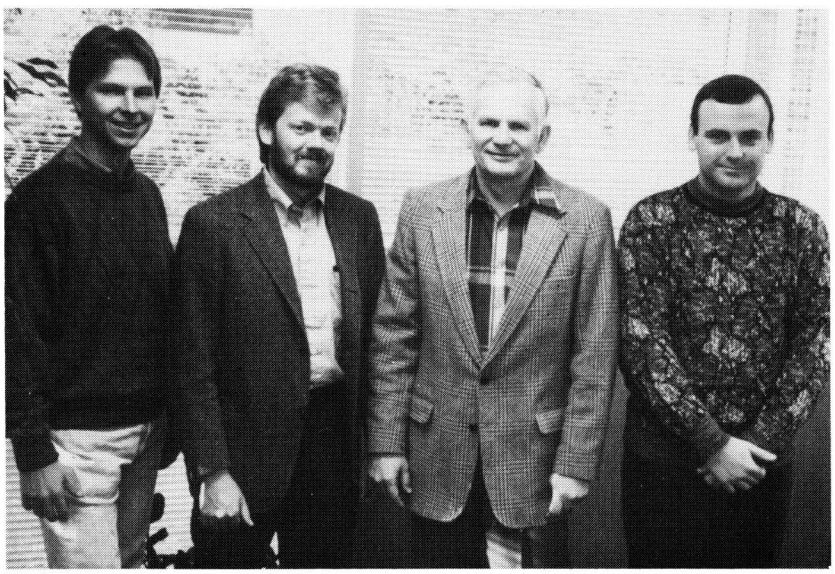
1190-1
Truck Tire Pavement Contact Pressure Distribution Characteristics for Super Single 18-22.5 and Smooth 11R24.5 Tires
Rex William Hansen, Carl Bertrand, K. M. Marshek, and W. R. Hudson
July 1989 (Preliminary)

1197-1F
Organization and Analysis of 1987 HMAC Field Construction Data
Maghsoud Tahmoressi and Thomas W. Kennedy
November 1988 (Preliminary)

SDHPT Graduate Program

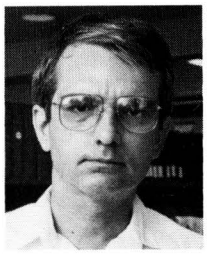
The first students enrolled under a Master's Degree graduate program sponsored by the Texas State Department of Highways and Public Transportation are now attending classes and working on SDHPT projects. The program is ongoing at the University, where it is administered by the Director of CTR, and at the Texas Transportation Institute, at Texas A&M University.

The program provides scholarships to selected, eligible, qualified engineers who are employees of the SDHPT. The students remain SDHPT employees, devoting time to both academic work and related highway research. It is expected that the scholarships will be awarded three times a year, in the fall, spring, and summer, and the number of recipients will be based on the number of those who qualify; no specific number will be chosen each semester. The possible length of study is one and a half years.

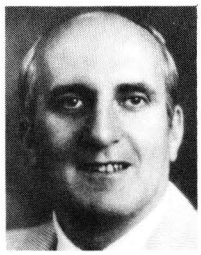


The students attending the University are shown to the left with Dr. McCullough. They are, left to right, Darren Hazlett, Ray Derr, and Bruce Long.

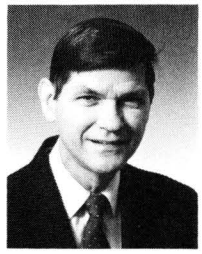
Project Administrators



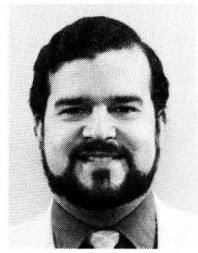
Leigh B. Boske
Professor of Public Affairs



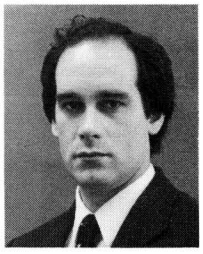
John E. Breen
Professor of Civil Engineering



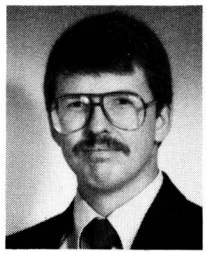
Ned H. Burns
Professor of Civil Engineering



Ramon L. Carrasquillo
Associate Professor of Civil Engineering

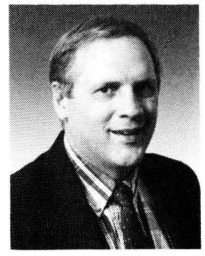


Humberto Castedo
Project Coordinator



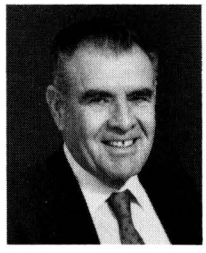
Mark A. Euritt
Project Coordinator

David W. Fowler
Professor of Civil Engineering and Member CTR Executive Advisory Committee

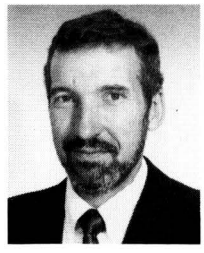


Karl H. Frank
Professor of Civil Engineering

Richard W. Furlong
Professor of Civil Engineering

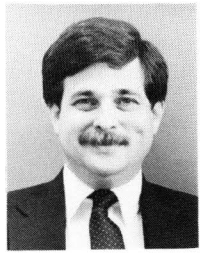


Kenneth D. Hankins
Project Coordinator



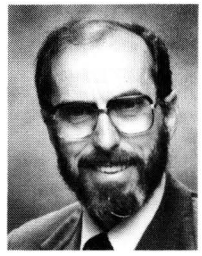
Robert Harrison
Project Coordinator

Robert Herman
Professor of Civil Engineering

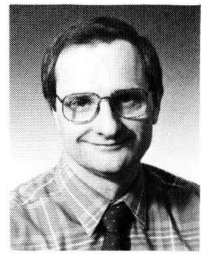


Richard J. Holmgreen, Jr.
Project Coordinator

W. Ronald Hudson
Professor of Civil Engineering

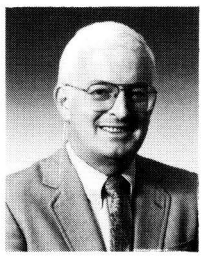


Fred Hugo
Project Coordinator

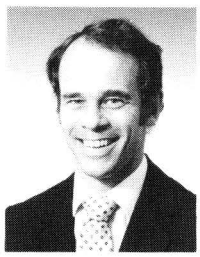


James O. Jirsa
Professor of Civil Engineering

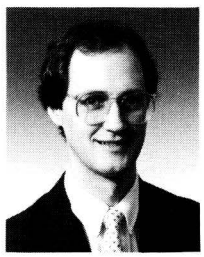
C. Philip Johnson
Associate Professor of Civil Engineering



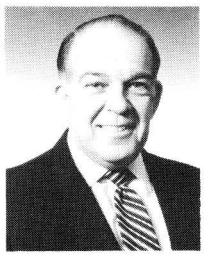
Thomas W. Kennedy
Professor of Civil Engineering



Richard E. Klingner
Professor of Civil Engineering



Michael E. Kreger
Assistant Professor of Civil Engineering



Clyde E. Lee
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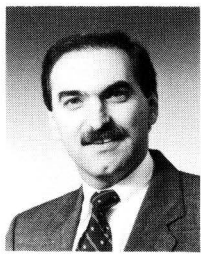
Associate Professor of Civil Engineering



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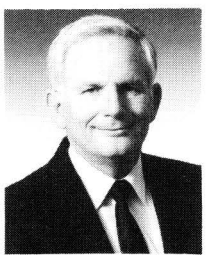

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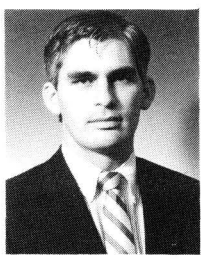
Senior Lecturer in Civil Engineering



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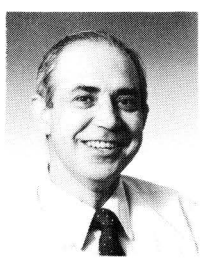
Lymon C. Reese
Professor of Civil Engineering



Jose M. Roesset
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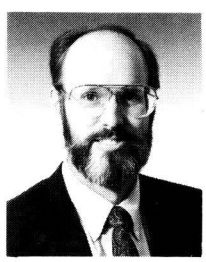
Sandra Rosenbloom
Professor of Architecture and Planning



Kenneth H. Stokoe, II
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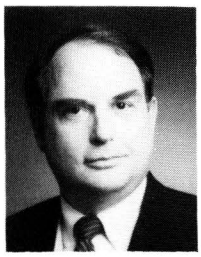

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Fayyaz H. Shah
Mansour Solaimanian
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Youngchan Suh
Mohd R. Suliman
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Jose Tena-Colunga
Robert Thomas
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Hassan F. Torshizi
Arthur R. Toussaint
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Hope Villanueva
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Angela J. Weissmann
Jose Weissmann

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Julio Jimenez
Lance Kaczorowski
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Ming-Shin Lee
Kee C. Lim
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Auldin Massey
Sandra McIntosh
L. Palaniappan
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David L. Plutowski
John R. Roy
Michael M. Rung
Jaime Sanchez
Alfredo E. Santolamazza
Andreas Savvides
Abu Sayeed
Rajeev Sethia
Sanjeev Sethia
Jasbir Singh
David Spencer
Djoni Supangkat
William T. Templeton
Howard D. Thames
Joel D. Tompkins
John Waters
David Weatherbie
Andrew Willrodt

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Assistant to the Director
John H. Sutherland

Research Engineer
James S. Moulthrop

Research Engineer Associates
Robert W. Adams
James N. Anagnos
Konrad Bergmeister
Charlie R. Copeland
David Erickson
Josef Farbiarz
Shekhar Govind
Liren Huang
Robert F. Inman
James R. Lundy
Chryssis G. Papaleontiou
Maghsoud Tahmoressi
Tetsuya Tsujimoto
David P. Whitney

Research Engineer Assistants
Fouad Alsabbagh
Iain Brown
Joseph Garner
Massoud Mortazavi
Thomas J. Vandam

Technical Staff Associate
Blake A. Stasney

Technical Staff Assistants
Brent T. Allison
Bryan P. Ball
Ernest F. Barth III
Carl B. Bertrand, Jr.
Eugene E. Betts
Wayne E. Fontenot
Wayne A. Little
Richard D. Marshall
William H. Moffeit
Richard B. Pavlasek
Richard G. Ryle
Yam Tay
Paul A. Walters

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Lynnette B. Bounds
Maxine R. DeButts
Teresa Tice-Boggs

Administrative Associates
Peggy L. Johnson
Rose J. Rung
B. Sue Sweeney

Administrative Assistants
Nancy L. Bickham
Mary K. Collins
Carla Fine Cripps
Sharon D. Cunningham
Bessie R. Dougherty
Kathlyn Ferguson
Wendy L. Giles
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