

RESEARCH & DEVELOPMENT  
STUDY ACCOMPLISHMENTS

RESEARCH REPORT NUMBER SS 18.1



Conducted By  
Texas Highway Department

In Cooperation With the  
Federal Highway Administration

September, 1971

## ABSTRACT

The Texas Highway Department in cooperation with the Federal Highway Administration has been conducting Research & Development studies to solve specific problems since the inception of the Program. The studies have always been initiated as a result of need by the Department. Over the years, varying degrees of success have been realized in the various studies conducted. As one would anticipate some studies produced very little in the way of useable results. On the other side of the coin some of the studies have had outstanding success and the results have been used on a National basis.

In order to capitalize to the degree possible from experience in the Research & Development effort a record is maintained by the Department on each study recording the study number, the title, the Texas Highway Department Monitoring Division, the Texas Highway Department Contact Individual, date initiated, date terminated, total funds expended, background information, study objective, implementation of findings and the reports published. The record is valuable for a number of reasons. Primarily that it is an aid in an effort to improve the future research effort. It indicates the successes and so forth of the

researcher and all involved with the research over a period of time. This includes the money spent and the use made of the results. In a sense it is a score sheet on each study.

However, one must be careful to keep in mind that sometime the full impact of research results are not realized for years after they have been made available for use. Also, at this point it may be well to consider a statement made by Representative Dan Kuyknall, "history shows us on almost every page the worthwhile ideas that went down the drain because their creators drew the mistaken conclusion that a worthwhile idea will sell itself".

It is anticipated that this compilation of research accomplishments will be of value to the researchers, those involved with Research & Development, and by administrators. Also, it is intended to continue this form of record on future research studies as they are completed. The record will be distributed on a need basis.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>HPS-1(25)A</u>	<u>"Intersection Illumination"</u>	
Research Study No.	Title	
Various Supervisors	File D-8	
Project Supervisor	T.H.D. Monitoring Division	
Various Contact Men	1959	1962
T.H.D. Contact Individual	Date Initiated	Date Terminated
Total Funds Expended		

BACKGROUND INFORMATION

Highway engineers have the opinion that there are three basic reasons for the necessity of highway illumination. These are safety, operational efficiency and comfort. The increase in the night use of our modern multi-billion dollar highway system and the demand for increased efficiency of operation has caused the illumination criteria of highway design to become more and more critical.

STUDY OBJECTIVE

The primary general objective of this study was to develop illumination for greater comfort, convenience and safety in each area of research conducted.

IMPLEMENTATION OF FINDINGS

This study served to a large extent to develop the ground work required for future studies in the area of illumination.

RESEARCH REPORTS PUBLISHED

1. "Investigation of the Effect of Intersection Illumination Upon Driver Behavior as Measured by Galvanic Skin Response", by H. C. Lott, Jr. - A Thesis - A & M College, August 1960.

PAGE TWO  
HPS-1(25)A

RESEARCH REPORTS PUBLISHED (CONT'D)

2. "Rural Intersection Illumination Studies", by Hubert A. Henry, Texas Highway Department, no. date.
3. "Roadside Sign Legibility and Roadway Illumination", by Donald E. Cleveland, T.T.I., July 1960.
4. "Driver Tension and Rural Intersection Illumination", by Donald E. Cleveland, T.T.I., 1961.
5. "Sun Shadow Patterns on Highway Signs", by Robert M. Olson, A & M College, no date.
6. "Fluorescent Fixtures for Overhead Sign Illumination" by Don E. Cleveland, T.T.I., December 1961.

Follow-on illumination studies were as follows:

Research Study No. 2-8-64-75, "Supplementary Studies in Highway Illumination".

Research Study No. 2-69-137, "Roadway Illumination Systems".

Research Study No. 2-8-57-5, "Intersection Illumination".

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>HPS 1(25)B</u> Research Study No.	<u>"Economic Impact of Interstate System"</u> Title	
<u>Various Supervisors</u> Project Supervisor	<u>By Committee</u> T.H.D. Monitoring Division	
<u>Primarily by Committee</u> T.H.D. Contact Individual	<u>1951</u> Date Initiated	<u>1961</u> Date Terminated
<u>Unknown</u> Total Funds Expended		

BACKGROUND INFORMATION

This study in general was to include an analysis of the economic impact on local areas of the Interstate Highway System. This was a period during which the Highway System was really growing up and many economic questions needed to be answered in order that management could make certain decisions which related to this problem.

STUDY OBJECTIVE

In general, the objectives of this study were to measure the changing land values, land use, business activity, travel habits, and general community development that could be associated with new highway facilities.

IMPLEMENTATION OF FINDINGS

These studies were of use by management in making related decisions.

RESEARCH REPORTS PUBLISHED

(See Attached Sheet)

RESEARCH REPORTS PUBLISHED

1. "Study of Land Values and Land Use Along the Gulf Freeway" (Houston, Texas), by Norris and Elder Engineers, 1951.
2. "A 15-Year Study of Land Values and Land Use Along the Gulf Freeway" Norris and Elder Engineers, 1956.
3. "Changes in Land Value and Land Use Along Three Sections of the Interstate Highway System in Texas" by C. R. Haning, H. G. Meuth, J. N. Slater, and C. V. Wootan, T.T.I., 1958.
4. "Economic Effects of the Camp Creek Road Improvement", by William G. Adkins, September 1958.
5. "Economic Impact of San Antonio Expressways, U.S. 81 and U.S. 87, by William G. Adkins, T.T.I., December 1958.
6. "Land Value Impacts of Expressways in Dallas, Houston and San Antonio, Texas" by William G. Adkins, T.T.I. 1959.
7. "A Study of 18 Remainder Parcels Along Houston's Gulf Freeway" by Jesse L. Buffington and William G. Adkins, T.T.I. March 1961.
8. "Economic Impact Study - Austin, Texas" by C. V. Wootan and C. R. Haning, T.T.I. 1960.
9. "Economic Impact Study - Temple, Texas" by C. V. Wootan and C. R. Haning, T.T.I. 1961.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>HPS-1(25)D</u> Research Study No.	<u>"Road Tests on Hot Mix Asphaltic Concrete"</u> Title	
<u>Bob M. Gallaway</u> Project Supervisor	<u>File D-8</u> T.H.D. Monitoring Division	
<u>M. D. Shelby</u> T.H.D. Contact Individual	<u>1960</u> Date Initiated	<u>1962</u> Date Terminated
Total Funds Expended		

BACKGROUND INFORMATION

During the time that this research was in progress, investigators became more and more aware of the necessity for learning more about the properties of asphalt through field and laboratory testing. The test conducted in this study covered the properties of asphalt under repetitive loadings, field densities of hot-mix asphaltic concrete, information tests, etc.

STUDY OBJECTIVE

To learn more about the properties of asphalt under field and laboratory conditions and to develop test equipment.

IMPLEMENTATION OF FINDINGS

The results of this study were used as a basis for continuing studies in this area, as a basis for establishing specifications and was some assistance in the area of development of laboratory equipment.

RESEARCH REPORTS PUBLISHED

(See Attached Sheet)



RESEARCH REPORTS PUBLISHED

1. "Behavior of Asphaltic Diaphragms to Repetitive Loadings", by Rudolf A. Jimenez and Bob M. Gallaway, T.T.I. August 1962.
2. "A Limited Study of Laboratory and Field Densities of Hot-Mix Asphaltic Concrete in Texas", by Bob M. Gallaway, T.T.I., January 1960.
3. "A Study of Hveem Stability Versus Specimen Height" by Rudolf A. Jimenez, and Bob Gallaway, T.T.I., January 1961.
4. "Preliminary Report of an Apparatus for the Testing of Asphaltic Concrete Diaphragms", by Rudolf A. Jimenez and Bob M. Gallaway, T.T.I., January 1962.
5. "An Apparatus for Laboratory Investigations of Asphaltic Concrete Under Repeated Flexural Deformation" by Rudolf A. Jimenez, T.T.I. January 1962.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-2</u>	<u>"Customer Requirements in Transportation"</u>
Research Study No.	Title
<u>Dan R. Davis, J. Nelson Slater</u>	
<u>Charles V. Wootan; Hugo G. Meuth</u>	<u>Administration</u>
<u>Charles R. Haning,</u>	<u>T.H.D. Monitoring Division</u>

PROJECT SUPERVISORS

<u>T.H.D. Contact Individual</u>	<u>7-13-53</u>	<u>2-2-59</u>
	Date Initiated	Date Terminated

\$131,838.70 (Through 8-31-55)  
Total Funds Expended

BACKGROUND INFORMATION

This Research Study was divided into various economic studies. The results of which would be of value to the administration in making decisions.

STUDY OBJECTIVE

The objective of each of the various segments of the study can be well determined from the study reports generated and listed below.

IMPLEMENTATION OF FINDINGS

RESEARCH REPORTS PUBLISHED

1. "The Traffic Pattern of Ginned Cotton, Cottonseed, and Cottonseed Products Transported in Texas by Railway, Highway and Waterway for 1952-1953".
2. "Characteristics of Highway Freight Transportation in Texas".
3. "A Study of the Highway Distribution of Gasoline".
4. "Transportation Uses and Preferences of the Texas Food Industry".
5. "A Statistical Presentation of Transportation Uses and Preferences in Texas Food Industry".
6. "Private Trucking Costs and Records".

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-3</u> Research Study No.	<u>"Improvement of Asphaltic Materials"</u> Title	
<u>Bob M. Gallaway</u> Project Supervisor	<u>D-9</u> T.H.D. Monitoring Division	
<u>Weldon Chaffin</u> T.H.D. Contact Individual	<u>7-10-53</u> Date Initiated	<u>10-5-60</u> Date Terminated
<u>\$61,858.94 (Through 8-31-55)</u> Total Funds Expended		

BACKGROUND INFORMATION

This investigation concerns itself with the changes which have occurred in asphaltic cement recovered from test roads during six years of service. The results of standardized tests and special tests performed on the asphalt are shown to compare the initial properties of the asphalts with subsequent changes in physical and chemical properties.

The trend of changes in asphalts occurring with age is presented and tentative recommendations are suggested for the specification of asphalts, in order to improve or to make better use of certain fundamental properties of asphalts.

STUDY OBJECTIVE

The primary objective of this investigation was to obtain a general trend between the original properties of asphalts and the service connected changes.

IMPLEMENTATION OF FINDINGS

The results of this research study were used as a basis for writing specifications, acceptance tests and construction procedures.

RESEARCH REPORTS PUBLISHED

1. "Preliminary Report on Project RP-3, Improvement of Asphaltic Materials"
2. "Final Report - Improvement of Asphaltic Materials"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-4</u> Research Study No.	<u>"A Comprehensive Study of Factors Influencing the Load Carrying Capacities of Drilled and Cast-in-place Concrete Piles"</u> Title	
<u>Lawrence A. DuBose</u> Project Supervisor	<u>D-5</u> T.H.D. Monitoring Division	
<u>T.H.D. Contact Individual</u>	<u>7-15-53</u> Date Initiated	<u>5-1-57</u> Date Terminated
<u>\$34,142.11</u> Total Funds Expended		

BACKGROUND INFORMATION

The results of Research Project-4 have been prepared as two reports, Part 1 and Part 2. Part 1 covers the following: Field Exploration and Soil Test Results; SR-4 Gages and Pressure Cells; Compression Load Test Results on 7 and 8 Inch Diameter Piles; Compression Load Test Results on 10-Foot Effective Length Straight Shaft Piles; Compression Load Test Results on 13 and 14 Inch Diameter Straight Shaft Piles; Compression Load Tests Results on Underreamed Piles; Compression Load Test Results on Specially Placed or Designed Piles; and Tension Load Test Results on Straight Shaft Piles.

Part 2 of the final report includes the results of tests made on small scale piles and the results of lateral load tests on field and laboratory installed reinforced concrete piles.

STUDY OBJECTIVE

To determine the factors influencing the load carrying capacities of drilled and cast-in-place concrete piles.

IMPLEMENTATION OF FINDINGS

Results from this study showed that the utilization of skin friction and point bearing capacity for cast in place drilled shafts was a logical and safe design procedure. New design procedures were then established to permit, under certain limitations, the utilization of both skin friction and point bearing capacity for determining the load capacity of drilled shafts. Previous to this time the total load capacity was determined from the point bearing capacity only.

RESEARCH REPORTS PUBLISHED

Part 1 - July 1956

Part 2 - October 1956

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-5</u> Research Study No.	<u>"Non-Destructive Testing of Welds in Structural Steel"</u> Title
<u>Donald F. Weekes &amp; B. F. K. Mullins</u> Project Supervisor	<u>D-5</u> T.H.D. Monitoring Division

<u>T.H.D. Contact Individual</u>	<u>12-30-52</u> Date Initiated	<u>11-2-56</u> Date Terminated
----------------------------------	-----------------------------------	-----------------------------------

\$18,576.54  
Total Funds Expended

BACKGROUND INFORMATION

This report is concerned with the problem of inspecting welds in structural steel by non-destructive methods. With emphasis on those aspects of the problem peculiar to highway bridges, present practices are described and the need for additional research is discussed.

STUDY OBJECTIVE

The objective of the study is to determine the best means for non-destructive testing of welds in structural steel.

IMPLEMENTATION OF FINDINGS

This study primarily laid the groundwork for further research on this subject. Furthermore, it outlined the principle<sup>of</sup> non-destructive testing methods currently in use and developed a bibliography on the subject.

RESEARCH REPORTS PUBLISHED

One report was published and it has the same title as the study indicated above.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-6</u>	<u>"Some Factors Affecting the Life of Steel Pilings in the Texas Gulf Coast Area"</u>	
Research Study No.	Title	
<u>Bob M. Gallaway</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>T.H.D. Contact Individual</u>	<u>4-1-54</u>	<u>10-16-56</u>
	Date Initiated	Date Terminated
<u>\$3,879.14</u>		
Total Funds Expended		

BACKGROUND INFORMATION

This report covers the corrosion study as applied to underground members of highway structures of the Gulf Coast area of Texas, an area 50 to 75 miles wide, extending from the Rio Grande River to the Louisiana State Line. The report indicates the methods to be used in collecting corrosion data and the factors of which should be taken into consideration. Additionally, the report pinpoints ways in which remedial measures should be taken where corrosion is anticipated. It indicated where corrosion surveys should be made <sup>and</sup> where insufficient data is available. Theory of corrosion of steel in water and soil was developed and a bibliography was developed.

STUDY OBJECTIVE

The objective of the study was as follows: 1. To determine if there is a danger of serious corrosion of plain carbon steel piling below the permanent water table of the soils and muck of the Gulf Coast Area. 2. What chemical and physical characteristics of the soil and soil waters, contributory to serious corrosion, exists in this area? 3. If serious corrosion may be expected in the Gulf Coast Area, what is the inland extent of the critical area?

RESEARCH REPORTS PUBLISHED

The only report published is entitled the same as the title given above.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-7</u>	<u>"Use of Prefabricated and/or Prestressed Elements in Bridge Structures"</u>
Research Study No.	Title
<u>Truman R. Jones, T. J. Hirsch and Henson K. Stephenson</u>	<u>D-5</u>
Project Supervisor	T.H.D. Monitoring Division

<u>T.H.D. Contact Individual</u>	<u>April 1954</u>	<u>10-21-59</u>
	Date Initiated	Date Terminated

\$136,433.66  
Total Funds Expended

BACKGROUND INFORMATION This study was a very comprehensive study of structural quality lightweight aggregate and lightweight aggregate concrete using aggregates produced in Texas.

STUDY OBJECTIVE The objective of the study was as follows:

1. Large areas of the State do not have satisfactory sand and gravel aggregates within economical hauling distance and many of the better deposits in other areas are rapidly becoming depleted.
2. The reduced dead load in lightweight concrete structures makes it very desirable to make more general use of this material.
3. The more advanced design principles adopted in recent past and those that will be adopted in the future demand a thorough knowledge of the properties of the material to be used.

IMPLEMENTATION OF FINDINGS Results of this study have been utilized in the design of bridge decks to be constructed using lightweight aggregate concrete, and as background information for writing standard construction specifications for lightweight aggregate concrete.

RESEARCH REPORTS PUBLISHED 1. Preliminary report on the mixed design and field practices for structural lightweight concrete. 2. Creep and shrinkage in lightweight concrete. 3. Properties of lightweight concrete related to prestressing. 4. Proportioning, control, and field practices for lightweight concrete. 5. The physical properties of structural quality lightweight aggregate concrete.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-8</u> Research Study No.	<u>"Highway Soils"</u> Title	
<u>T. J. Kelly</u> Project Supervisor	<u>File D-8</u> T.H.D. Monitoring Division	
<u>Conrod Drdyn</u> T.H.D. Contact Individual	<u>1957</u> Date Initiated	<u>10-5-60</u> Date Terminated

\$110,833.18.  
Total Funds Expended

BACKGROUND INFORMATION The investigation which forms the basis for this study was undertaken to increase the state of knowledge concerning a rational relationship of repeated loadings to elastic and plastic deformation in the flexible pavement system. This goal was approached by undertaking and evaluation of existing flexible pavements through a study of the load deformation relationships in the pavements.

STUDY OBJECTIVE The objectives of the study were as follows: 1. Present a method of evaluation of the load capacity and life of flexible pavements under repeated loading. 2. Develop criteria based on trends of measured pavement deformations to be used in delineating whether a flexible pavement is performing elastically, progressing toward elasticity, or progressing toward failure. 3. Select representative test locations on flexible pavements by applying the above criteria to existing records of measuring deflection on several sections of Texas highways. 4. Establish the feasibility of measuring repetitive pavement deflections with the Benkleman Beam, which is presently used for measuring individual pavement deflection

#### IMPLEMENTATION OF FINDINGS

This investigation was designed as a pilot study to guide a future large scale study of repetitive loadings which is contemplated later. For this reason the same amount of emphasis was placed upon the evaluation of equipment and procedures during the field test as was placed upon the study of the fundamental relationships. Therefore, this study was basically a preliminary study to be used as a basis for follow-on studies which it served well to accomplish.

#### RESEARCH REPORT PUBLISHED

1. "A Study of Certain Elastic and Plastic Strains Induced in Flexible Pavement Systems by Repetitive Wheel Loads".



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-9</u> Research Study No.	<u>"The Correlation of Design and Operational Characteristics of Expressways in Texas"</u> Title	
<u>Charles J. Keese</u> Project Supervisor	<u>File D-8</u> T.H.D. Monitoring Division	
<u>T.H.D. Contact Individual</u>	<u>2-14-57</u> Date Initiated	<u>1-20-59</u> Date Terminated
<u>\$61,588.33</u> Total Funds Expended		

BACKGROUND INFORMATION

Because of the lack of sufficient information as to the inter-relationship of certain design features and their combined affects on certain operational characteristics, this research study was undertaken to explore the operational characteristics and determine what features warrant specific study and analysis. The City of Houston and the City of Dallas cooperated in the project.

STUDY OBJECTIVE To determine the correlation of the effects of certain design features on the various operational characteristics on expressways.

IMPLEMENTATION OF FINDINGS The results of this study serve primarily as a basis for future follow-on studies and it has served well in the following areas: 1. Keeping records with motion pictures. 2. Determining the criteria for volumes of traffic flow. 3. High volume flow in the various lanes affect total volume. 4. Factors that affect speed in the various lanes. 5. The influence of barrier fences, median barriers, and placement in various lanes.

RESEARCH REPORTS PUBLISHED

"The Correlation of Design and Operational Characteristics  
of Expressways in Texas"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

RP-10  
Research Study No.

"Stress Analysis in Field During and  
After Construction of Special Prestressed  
Composite I-Beam Span"

John M. Graham  
Project Supervisor

File D-5  
T.H.D. Monitoring Division

T.H.D. Contact Individual

1954  
Date Initiated

August 31, 1959  
Date Terminated

\$11,000.00  
Total Funds Expended.

BACKGROUND INFORMATION This was a full scale field test. "Prestressed Composite I-Beam Design" in this case is simply jacking-up the individual steel beams, a predetermined amount at the centerline of the spans and holding the ends of the steel beams down with anchor bolts. The jacking-up of the steel beams at the centerline of the span results in a tension stress in the top flange of the steel beams and a compression stress in the bottom flange of the steel beams. Shear devices are welded in place on the ground with the steel beams in an unstrained position. The steel beams are not jacked-up until all forms for the concrete slab are in place and the reinforcing steel is in place in these forms. The weight of the concrete slab and forms adds more tension in the top flange and more compression in the bottom flange of the steel beams, due to this dead load weight acting on the steel beams while they are temporarily shored up at the center of the span.

After the concrete slab has attained about 85 percent of its 28 day strength, the shores are gradually released at the rate of one-half inch per hour.

STUDY OBJECTIVES The objectives of this study were as follows: 1. To check the theoretical design calculated stresses and deflection with the actual observed stresses and deflections. 2. To determine the effect of shrinkage and plastic flow of the concrete slab on the prestressed composite I-beam spans. During the final dead load test period, corresponding morning and afternoon readings for stresses and deflections were made to determine the effect on stresses and deflections due to heat storage in concrete during the day.

#### IMPLEMENTATION OF FINDINGS

The results of this study were used by designers in building bridges of this type. The test proved that this type of bridge was very tough

and a rugged bridge, there was no excessive vibration, it showed that the theory used in design was essentially correct, it indicated improvement in design procedures, the test indicated that the design of this type is economical, and lastly the test developed more satisfactory construction procedures.

RESEARCH REPORTS PUBLISHED

"Full Scale Field Tests of a Prestressed Composite I-Beam Bridge"- Final Report

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-12</u> Research Study No.	<u>"An Evaluation of Trinity River Aggregates of Marginal Quality for Use in Portland Cement Concrete Pavements"</u> Title	
<u>T. R. Jones, Jr.</u> Project Supervisor	<u>File D-8</u> T.H.D. Monitoring Division	
<u>T.H.D. Contact Individual</u>	<u>1957</u> Date Initiated	<u>June 1959</u> Date Terminated

Approx. \$16,000.00  
Total Funds Expended

BACKGROUND INFORMATION For many years the Trinity River sand and gravel deposits in the vicinity of Dallas have provided aggregates of excellent quality suitable for making structural concrete of the highest type. Unfortunately, these deposits are being rapidly exhausted. In the same general area, however, there is a large potential supply of concrete aggregate which by certain standards are considered to be of marginal or sub-standard quality. Much of the aggregate, as now produced, passes all the current Texas Highway Department specifications for concrete aggregate. However, pavement concrete made with the aggregate from certain pits will not develop the minimum modulus of rupture of 650 pounds per square inch, as required by the specifications, at normal cement factors. Aggregates from some of the other pits produced marginal strengths and frequently failed to pass.

STUDY OBJECTIVE It was the objective of this investigation to evaluate these materials that produced concrete of marginal and sub standard quality to determine the causes for the poor performance and to develop methods for the detection and control of such deleterious materials as may be present. Some of the findings of this study have been implemented, including the adoption of the "sand equivalent test" to control the relative proportions of detrimental fine dust or clay like materials in fine aggregates. Furthermore the requirements were established for sand, gradation requirements, inspection requirements and establishment of the maximum limit for the proportion of materials with a specific gravity less than 2.45. All have served their purpose in establishing requirements and specifications.

RESEARCH REPORTS PUBLISHED

"An Evaluation of Trinity River Aggregates of Marginal Quality for Use in Portland Cement Concrete Pavements", Final Report.



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-16</u> Research Study No.	<u>"Freeway Ramps and Interchanges"</u> Title	
<u>Charles J. Keese and Others Assisted</u> Project Supervisor	<u>File D-8</u> T.H.D. Monitoring Division	
<u>Paul R. Tutt</u> T.H.D. Contact Individual	<u>January 1959</u> Date Initiated	<u>October 1962</u> Date Terminated

\$70,848  
Total Funds Expended

**BACKGROUND INFORMATION** There were four different phases of study included in this effort. They were as follows: (1) Study of Freeway Ramps (2) Driver Behavior and Its Relation to Ramps (3) Design and Signalization of Intersections and (4) Design and Operation of Diamond Interchanges. The ramp study was conducted on freeways in Dallas, Fort Worth, San Antonio and Houston. The study locations were specifically selected to provide data on various types of ramps operating under different volume conditions.

Investigations have shown that many of the operational problems encountered at freeway entrances are the direct results of undesirable behavior on the part of the entering driver, and deviations from the intended use of the facility and thus this phase of the study was conducted.

The at-grade intersection is one of the most critical elements of an urban street system since it exerts the greatest single influence upon traffic operation. If a high-level of service is to be obtained on urban highways and major arterials, proper design and signalization of the intersection on these facilities is imperative thus this portion of the study.

There was a great need to learn more about the design and operation of the diamond interchange and it was determined from this study that the traffic actuated volume density control equipment was the most desirable for the use of signalized diamond interchanges.

**STUDY OBJECTIVE** The objectives of the study were as follows: (1) the objective of the freeway ramp portion of the study was to develop data on the operational and traffic behavior aspects of the freeway ramps or operation in order to provide the designer with data that will enable a correlation of ramp design with the human aspects relating to traffic behavior and driver requirements (2) the objective of the driver behavior portion was designed to investigate driver behavior on freeway entrance ramps under operational conditions (3) the objective of design and signalization of high-type intersections was to study peak periods of traffic demands. (4) The objective of the design and operation of the diamond interchange was to perform operational studies at an existing diamond interchange to evaluate

STUDY OBJECTIVE, continued

signal phasing arrangement and to study the adaptability of actuated signal equipment to diamond interchange operation.

**IMPLEMENTATION OF FINDINGS** As a result of the freeway ramp study, the Department revised ramp design standards and some of the findings of the research on ramps was included in the Design Manual published.

The driver behavior portion of this study was also a valuable guide in the help to design the manual.

The third phase of this study that had to do with the studies of the cloverleaf and the three-level diamond interchange provided valuable data to the Department which actually defined the advantage and disadvantages of the cloverleaf interchange under both high volume and low volume conditions.

It was determined from the design and signalization portion of the study that the traffic actuated volume density control equipment was the most desirable for use at signalized diamond interchanges. The overlap phasing arrangement is adaptable to actuated equipment and can accommodate large volume of traffic. Based on these results, control equipment is now available through commercial sources and is in operation throughout the country.

**RESEARCH REPORTS PUBLISHED**

- (1) Driver Behavior and Its Relation to Freeway Entrance Ramp Design
- (2) Freeway Ramps
- (3) Design and Signalization of High-Type Intersections
- (4) Design and Operation of Diamond Interchanges

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

RP-17	"Speed Zoning"	
Research Study No.	Title	
Charles J. Keese & Assistants	File D-18	
Project Supervisor	T.H.D. Monitoring Division	
M. V. Greer	January 1959	October 1961
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$36,729.11  
Total Funds Expended

**BACKGROUND INFORMATION** This study was conducted in two phases. In the first phase of the research project, comprehensive "before" and "after" studies were conducted in 186 spot speed study locations to determine the effect of speed limit signs on traffic speeds. This large number of studies permitted an analysis of the data for conditions when the speed limits were changed from 60 down to 30 mph and from 30 up to 55 mph in increments of 5 mph.

The second phase of the study dealt with the fact of influencing the drivers selection of speed. It has been found that the speed of an individual vehicle is subject to considerable variations throughout a given section of roadway. This is particularly true if the selection of roadway is in an area of transition from rural to urban conditions. The factors causing the variation in speed are enumerable.

**STUDY OBJECTIVE** The objectives of the study were as follows: 1. An evaluation of the effectiveness of speed limits established on the basis of 85- percent type of speeds. 2. The second phase objective of the study was the evaluation of factors influencing the driver's selection of speed.

**IMPLEMENTATION OF FINDINGS** This study was very useful to the Department in validating the procedures of establishing speed limits.

**RESEARCH REPORTS PUBLISHED**

1. Vehicle Speed and Placements Serving on Two-Lane Rural Highways
2. Vehicle Speed and Placement Survey on Two-Lane Rural Bridges.
3. Freeway Bridge vehicle speed and Placement Survey.
4. A Study of the Factors Influencing Traffic Speeds.



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

RP-19	The Effect of Curing Air Content and Type of Aggregate Upon Certain Physical Properties of Concrete	
Research Study No.	Title	
J. R. Jones, Jr.	D-5 and D-8	
Project Supervisor	T.H.D. Monitoring Division	
Charles Matlock and F. M. McCullough	November 1959	October 1961
T.H.D. Contact Individual	Date Initiated	Date Terminated
\$39,663.12		
Total Funds Expended		

**BACKGROUND INFORMATION** The research was directed toward a study of curing Portland cement concrete and the physical properties of concrete at early ages. The portion of the study dealing with curing concrete dealt with the following aspects: (1) Physico-chemical aspects of curing; (2) Important physical properties of cement paste, aggregate and concrete; (3) Placing and finishing concrete; (4) Curing methods and (5) Curing periods. The portion of the study dealing with physical properties of concrete at early ages was directed toward the following: (1) Batching and molding specimens (2) Curing of specimens (3) Flexural strength (4) Compressive strength (5) Bond strength (6) Tensile tests (7) Modulus of elasticity (dynamic) (8) Shrinkage, coefficient of expansion and contraction and (9) Extensibility

**STUDY OBJECTIVE** The overall objective of the study was as follows: (1) to study what happens to a batch of concrete from the time the mixing water is added, and (2) to gain an understanding of the physical properties of concrete at early ages.

**IMPLEMENTATION OF FINDINGS** The results of this study have been useful as a basis for specification writing and follow-on research

**RESEARCH REPORTS PUBLISHED**

- (1) A Report on the Physical Properties of Concrete at Early Ages
- (2) A Report on the Curing of Portland Cement Concrete

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-21</u>	<u>Development of Traffic Survey Device for Counting Highway Traffic</u>	
Research Study No.	Title	
<u>E. N. Roots, Jr.</u>	<u>D-10</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Reed Baker</u>	<u>November 1959</u>	<u>October 1960</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$6,324.55</u>		
Total Funds Expended		

**BACKGROUND INFORMATION** The Highway Department was in need of a reliable compact portable detector to be used with a traffic survey system. The system used during that time was a detection device using a road tube having disadvantages which it was desired to overcome. The disadvantages were that it was difficult to install, maintenance was a problem over a long period of time under heavy traffic, and it was visible to motorists.

Preliminary studies had indicated a need for detailed investigation of the effectiveness of a detector in picking up infrared radiation by the heat generating parts of a vehicle to make such an instrument useful to highway survey tabulations. Consequently, two detectors were designed and tested. One was a photo-conductor type using two matched lead sulfite detectors in a balanced bridge circuit. The other was a Photoelectromagnetic type detector using an indium antimonite crystal in a magnetic field as the detector. The latter of these proved to be the most effective detector.

**STUDY OBJECTIVE** The objective of this investigation was "to determine the feasibility of design of a detector to overcome a limitation of air impulse road tubes used in traffic survey systems".

**IMPLEMENTATION OF FINDINGS** It was determined in the test that the infrared detector system was feasible and would overcome some of the limitations of the area pulse road tubes. Furthermore, the study pointed the direction that further development should go in the event that the Department was interested in doing so.

**RESEARCH REPORTS PUBLISHED**

- (1) Development of Traffic Survey Device
- (2) The Design and Construction of an Infrared Detector for Use with a Highway Traffic Survey System

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

RP-23  
Research Study No.

"A Study of Factors Influencing the  
Performances of Flexible Bases"

Title

Larry H. Dellon  
Project Supervisor

T.H.D. Monitoring Division

T.H.D. Contact Individual

November 1960  
Date Initiated

October 1962  
Date Terminated

\$27,226.18  
Total Funds Expended

BACKGROUND INFORMATION-Engineering evaluation of the strength of materials and related properties is based on progressively increasing the stresses to produce failure. Many instances exist that make the normal procedure inappropriate due to repetitive stresses, application and releases. Noteworthy illustrations of this or the materials comprising the pavements and subgrades of highways and airfields which experience stress, applications and release due to moving vehicles or aircraft. The research reported is a continuation of research accomplished by other students at A & M University and is intended to serve to partially fulfill the gap of engineering knowledge.

STUDY OBJECTIVE The research performed in this study was concerned with the influence of repetitive stressing on the strength properties and accomplishing deformations of a coarse, well graded, angular sand manufactured for the purpose.

IMPLEMENTATION OF FINDINGS

This study was designed primarily to fill the gap in knowledge available for a basis for follow-on studies.

RESEARCH REPORTS PUBLISHED

"Effects of Repetitive Stressing on the Strength and Deformation of an Angular, Coarse Sand"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-25</u> Research Study No.	<u>"Pile-Driving Analysis by the Wave Equation"</u> Title	
<u>Charles H. Samson, Jr.</u> Project Supervisor	<u>File D-5</u> T.H.D. Monitoring Division	
<u>Horace C. Hoy</u> T.H.D. Contact Individual	<u>October 1960</u> Date Initiated	<u>October 1961</u> Date Terminated
<u>\$4,385.53</u> Total Funds Expended		

BACKGROUND INFORMATION The effort of this study was concentrated on the development of a computer program based on the pile driving analysis by the wave equation developed by Mr. Eal Smith.

STUDY OBJECTIVE The objective of this program was to provide the engineer with the mathematical tool of which he could investigate the behavior of a pile during driving.

IMPLEMENTATION OF FINDINGS This study served primarily as a basis for follow-on study in this area. Additionally, the program that was developed was used in trying to determine the cause of difficulty experienced in prestressed concrete piles. Additionally, the study results served as a basis for developing specification sheets used in driving precast concrete piles.

RESEARCH REPORTS PUBLISHED

"Pile-Driving Analysis by the Wave Equation"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>RP-27</u>	<u>"Pile Behavior During Driving"</u>	
Research Study No.	Title	
<u>T. J. Hirsch</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>F. C. Bundy</u>	<u>October 1961</u>	<u>October 1962</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$13,411.98.  
Total Funds Expended

BACKGROUND INFORMATION For several decades engineers have been seeking a method of analyzing the stresses produced in piles by the impact of the driving hammer. In the past engineers had to rely strictly on experience and judgment in designing piles and evaluating the effectiveness of various types of driving equipment on these piles. With the advent of the computer and a method of analysis, it became possible for the solution of this complex problem. It has been estimated that a single engineer using an ordinary desk calculator would have to work for about eight months to solve only one simple problem of this type. With the methods now available to it takes about one minute.

During the process of driving piles, considerable breakage was being experienced. Therefore, it was hoped that this study would help alleviate this problem.

STUDY OBJECTIVE The objectives were as follows: 1. Develop methods of instrumenting prestressed concrete piles under field construction conditions with strain gauges and deflectionmeter to measure actual stresses and displacement during driving. 2. Use this information to obtain limited field data during construction. 3. Obtain soil samples from the construction site to evaluate foundation medium. 4. Correlation of field test data with the theoretical computer solution.

IMPLEMENTATION OF FINDINGS In general the computed stresses were in good agreement with the measured values determined under actual conditions. By using judicious engineering estimates of the dynamic properties of the materials involved, computer program can now be used to predict the maximum compressive and tensile stresses to be expected during driving. Specifically the information resulting from this study was a great factor in establishing specifications. (As a result of this study, the Department does not have the problem of breaking piles during driving that they had,

Page Two

and which generated the reason for the study.) Additionally, this study made it possible to specify the proper hammers to use, the type of rams or velocities and cushion specs.

RESEARCH STUDY REPORTS PUBLISHED

"Stresses in Long Prestressed Concrete Piles During Driving"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

3-10-63-54  
Research Study No.

"A Portable Electronic Scale for  
Weighing Vehicles in Motion"  
Title

Dr. Clyde E. Lee  
Project Supervisor

File D-10  
T.H.D. Monitoring Division

George Carver  
T.H.D. Contact Individual

1963  
Date Initiated

1968  
Date Terminated

\$36,226.30  
Total Funds Expended

BACKGROUND INFORMATION

The need for an efficient method of weighing the wheels of a moving highway vehicle is pressing, particularly since high speed, controlled access highways have become a reality. On roads such as our Interstate Highway System, it is no longer safe nor feasible to stop vehicles on widened shoulders for weighing and measuring.

STUDY OBJECTIVE

The objective was the development of a completely portable scale for weighing highway vehicles in motion. The system was to provide reliable data as to wheel loads, vehicle speeds and axle spacing. Information was to be presented in digital form ready for analysis by digital computer.

IMPLEMENTATION OF FINDINGS

A highly successful wheel load transducer has been produced and tested under laboratory and field conditions and a recording system is being developed under contract by the Delco Corp.

(SEE ATTACHED)

RESEARCH REPORTS PUBLISHED

Research Report 54-1F "A Portable Electronic Scale for  
Weighing Vehicles in Motion"

INTEROFFICE MEMORANDUM

CHIEF	47407-1259-50m
ADM. DESIGN	
PROJ. PLAN	
GEN. DESIGN	
URBAN	
H. & B.	
Date	February 24, 1969
Responsible	
D-8	
Desk	D-10

TO: Mr. R. L. Lewis

FROM: J. E. Wright

SUBJECT: Research Study No. 3-10-63-54  
"A Portable Scale for Weighing  
Vehicles in Motion"

Reference your memorandum of February 14, 1969, relative subject research project. The final report on this project has been completed and distributed. Implementation of the study results, by the Department, is discussed as follows:

1. The development of a portable scale transducer for weighing in-motion vehicles was accomplished and is furnishing satisfactory results. Changes in the physical construction of this transducer would be desirable in order for it to withstand the constant abrasion of high volumes of traffic. Overall, however, the scale transducer has been developed to our satisfaction and also satisfied the requirements of the research project.
2. The equipment necessary to record the weight data needs refinement in order to obtain usable results in a more economical manner. The present equipment is very complicated and requires a considerable amount of computer time in order to obtain the final weight results. Investigations are being made at this time by both the Center for Highway Research at the University of Texas and by this division to alleviate the problem.

A number of weight operations are being planned for the very near future utilizing the completed scale system as developed by the research project. These data will be used in connection with Research Project 131 relative to the frequency distribution of axle weights by truck type.

The transducers and recording equipment developed by Project 54 are also being used to obtain data for Project 108.

JEW:mjc

RECEIVED  
FEB 25 1969  
D-8



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-8-63-55</u> Research Study No.	<u>Critical Mechanical Properties of Structural Lightweight Concrete</u> Title	
<u>J. Neils Thompson</u> Project Supervisor	<u>File D-8</u> T. H. D. Monitoring Division	
<u>B. F. McCullough</u> T.H.D. Contact Individual	<u>1963</u> Date Initiated	<u>1965</u> Date Terminated
<u>\$25,960.97</u> Total Funds Expended		

BACKGROUND INFORMATION

In this study Critical Mechanical Properties of Structural Lightweight Concrete were determined and utilized in the evaluation of the design of concrete pavement. Also considered were the Critical Mechanical Properties resulting from unrestrained and restrained volume changes. Furthermore particular attention was given to compressive, direct tensile, and indirect tensile (split cylinder) strength at various ages of the concrete.

The critical properties determined in this study indicate that concrete pavements can be designed with lightweight concrete and that expected performance in regard to the effects of warping stresses and pavement deflection will be better when lightweight concretes are used. However, the effects of restrained volume changes of lightweight concrete on pavement performance can be detrimental if improper curing, or curing for too short a time, occurs.

STUDY OBJECTIVE

1. To determine the relationship between Critical Mechanical Properties and Age for Structural Lightweight Concrete.
2. To study the volume change characteristics in unrestrained Structural Lightweight Concrete.
3. To explore the critical mechanical properties of structural lightweight concrete and the effects of these properties on the design of the pavement structure.

IMPLEMENTATION OF FINDINGS

This study was very useful to the department in that it provided background information and developed confidence for using lightweight aggregate. Additionally it served as a base for Research Study No. 2-8-65-81 entitled "Synthetic Aggregates Research". Since the completion of this study the use of Synthetic Aggregate has continued to increase and generally satisfactory results have been experienced.

RESEARCH REPORTS PUBLISHED

- 55-1 Relationship between Critical Mechanical Properties and age of Structural Lightweight Concrete.
- 55-2 Volume change in unstrained structural Lightweight Concrete
- 55-3F Critical Mechanical Properties of Structural Lightweight Concrete and the

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-8-63-59</u>	<u>"The Effects of Off-Ramps on Freeway Operation"</u>	
Research Study No.	Title	
<u>W. R. McCasland</u>	<u>File D-8</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>P. R. Tutt</u>	<u>1963</u>	<u>1965</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$20,459.82  
Total Funds Expended

**BACKGROUND INFORMATION**

Studies have indicated that the off-ramp is a critical element of a freeway facility and contributes significantly to both desirable and undesirable operations. If maximum efficiency is to be obtained from a freeway, the off-ramp must be located, designed and operated to minimize any adverse affects on main-lane freeway flow and to permit maximum utilization of the facility. After considerable consideration of the problem, the definition of several factors of off-ramp location, design and operation that could affect the operation of freeways was determined. These factors are enumerated as follows: 1. Deceleration distance. 2. Off-ramp capacity. 3. Short trip generation. 4. Weaving maneuvers. 5. Access control. 6. Access provision.

Research on the off-ramp project was directed toward an investigation of each of the above factors.

**STUDY OBJECTIVE**

To evaluate the effect on freeway operation of: 1. Frequency of off-ramps. 2. Various arrangements of off-ramps. 3. Total effect of off-ramps.

**IMPLEMENTATION OF FINDINGS**

The findings of this study served the Design Engineer in bringing about a better understanding of the problem.

**RESEARCH REPORTS PUBLISHED**

59-1 "The Effects of Off-Ramps on Freeway Operation as Related to Deceleration Distance and Off-Ramp Capacity"

Page Two  
2-8-63-59

- 59-2 "The Effects of Off-Ramps on Freeway Operation as Related to Short Trip Generation Weaving, Maneuvers and Access Control"
- 59-3 "The Effects of Off-Ramps on Freeway Operation as Related to Access Provisions"
- 59-4F "Effects of Off-Ramps on Freeway Operations"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-8-63-60</u>	<u>"Traffic Assignment"</u>	
Research Study No.	Title	
R. L. Smith		
D. C. Cleveland	File D-8	
Project Supervisor	T.H.D. Monitoring Division	

<u>Joe Wright</u>	<u>1963</u>	<u>1967</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$83,000  
Total Funds Expended

**BACKGROUND INFORMATION**

The availability of rapid computing machines has stimulated the improvement of techniques for forecasting the usage of planned highway networks. The forecasting problem consists of two parts: prediction of interzonal interchange, desires and assignment of these desires to a Highway System. The research was directed toward the second of these areas generally called traffic assignment.

**STUDY OBJECTIVE**

The general objectives of the research study was to investigate an improved technique of forecasting future use of urban highway systems as related to the assignment of traffic.

**IMPLEMENTATION OF FINDINGS**

This study included both traffic assignment and trip generation, developed the Large Systems Traffic Assignment Package, which is the only one of its kind in existence. This made it possible for us to assign existing and future traffic to variable systems within the Dallas-Fort Worth area. This could not have been done without the development of this program package and the methodology developed by this study. This same project made it possible to refine and improve on existing Bureau of Public Roads' assignment techniques for smaller areas. The basic improvements were in both man power requirements for preparation and in actual computer running time.

**RESEARCH REPORTS PUBLISHED**

- 2-8-63-60 - "Traffic Assignment"
- 60-3 - "Traffic Assignment Plot Systems for IBM 1401 and IBM 709-90-94 Data Processing Systems"
- 60-4 - "Utilization of Computer Plotting in Traffic"

- 60-5 - "Operating System Manual for Revised Texas Traffic Assignment System"
- 60-6 - "User's Manual for the Texas Large Systems Traffic Assignment Programs"
- 60-7 - "Availability of Secondary Data for Determining Employment and Sales by Traffic Zones"
- 60-8 - "The Effect of Zone Size on Traffic"
- 60-9 - "Manual of Texas Traffic Assignment Practice"
- 60-10 - "The Effect of Turn Penalties on Minimum Paths in Coded Street Networks"
- 60-11 - "Outline of a Proposed T.H.D. Trip Distribution Model"
- 60-14F - "Summary Report on the Traffic Assignment Study"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>1-9-63-61</u>	<u>"Development of Instrument for Non-Destructive Measurement for Concrete Pavement Thickness"</u>	
Research Study No.	Title	
<u>W. H. Moore</u>	<u>D-9</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>W. H. Moore</u>	<u>1963</u>	<u>1967</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$3,595.55</u>		
Total Funds Expended		

**BACKGROUND INFORMATION** A non-destructive test method for measuring the thickness of concrete pavement is sought in the interest of economy and to eliminate coring and associated structural damage. A study of such a device using ultrasonic waves is described in this report. A simplified discussion of ultrasonic wave phenomena precedes a general description of the electronic equipment used in this study. Since much of the difficulty of building such a device was found to lie with transducer development, a detailed explanation of the study supervisor's progress in this direction is covered. Due to limited manpower problems this study unfortunately had to be discontinued before completing the study.

**STUDY OBJECTIVE** It was proposed to develop an electronic instrument employing mechanical vibrations of ultra-sonic frequency, which would indicate the thickness of concrete pavement.

**IMPLEMENTATION OF FINDINGS** This study has reported will be useful to anyone continuing this study.

**RESEARCH REPORTS PUBLISHED**

61-1F "Development of Instrument for Non-Destructive Measurement for Concrete Pavement Thickness"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>1-5-63-62</u>	<u>"Insulation of Bridge Decks"</u>	
Research Study No.	Title	
<u>Larry Walker</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Larry Walker</u>	<u>1963</u>	<u>1967</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$29, 649.98</u>		
Total Funds Expended		

BACKGROUND INFORMATION

This study was conducted on U.S. Highway 87 over the Fort Worth and Denver Railroad in Wichita Falls, Texas. The west structure was insulated with sprayed Urethane foam 3/4 inch thick for the south one half and one and one fourth inch for the north one half. The adjacent structure was not insulated and served as a control structure.

Temperature data were collected for various locations within the bridge slab and analyzed. Results of this and analysis show that there was no reduction in the number of freeze-thaw cycles due to the insulation, however, the average freeze-thaw cycle length for the top surface of the insulated slab between I-beams was approximately two hours shorter than the cycle length for the uninsulated slab.

STUDY OBJECTIVE

To investigate the effectiveness and economic feasibility of insulating the underside of the bridge deck to prevent the formation of ice on the slab surface prior to such formation on the adjacent highway pavement, and to decrease the number of freeze-thaw cycles, thus minimizing the need for applying deicing salts.

IMPLEMENTATION OF FINDINGS

This study indicated what not to do, and that is, the results showed that insulating the underneath side of the bridge deck with sprayed Urethane foam did not significantly reduce the number of freeze-thaw cycles of the bridge deck, or materially aid in preventing the formation of ice on the top surface of the deck.

RESEARCH REPORTS PUBLISHED

62-1F "Insulation of Bridge Decks for Ice Prevention and Reduction of Freeze-Thaw Cycles"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>1-8-63-63</u>	<u>"Preparation of Geologic Information for Use in the Texas Highway Department"</u>
Research Study No.	Title
H. A. Henry	
<u>James L. Brown</u>	<u>D-8</u>
Project Supervisor	T.H.D. Monitoring Division

<u>H. A. Henry and James L. Brown</u>	<u>1963</u>	<u>1968</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$66,276.76  
Total Funds Expended

**BACKGROUND INFORMATION**

At the time this study was started there existed a need for a complete geologic reference developed expressly for highway engineers which would be immediately available for use in route studies, location, design, construction and maintenance. The existing work, whether a small area base material investigation report or a larger area district geologic report, all needed to be supplemented by additional investigations and developed into a standardized publication. The economic value of the engineering geologic work done to date for engineering purposes in the Texas Highway Department was well documented. Engineers had begun to use this tool and, of course, would use it more if it were more readily available.

**STUDY OBJECTIVE**

To correlate all available information from existing geologic maps, written reports and investigations, materials and test reports of examined samples, soil maps, behavior studies of existing roadways and make field and laboratory investigations needed to prepare a complete highway engineering geologic study for certain areas of the State.

**IMPLEMENTATION OF FINDINGS** The results of this study have been used in the field as planned.

**RESEARCH REPORTS PUBLISHED**

63-1 "Geology of Texas Highway Department - District 9"



Page 2

RESEARCH REPORT 1-8-63-63

63-2 "The Surface Geology of Related Soils of District 2  
and Associated Maps"

63-3 "Geology of Texas Highway Department- District 11"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-8-63-64</u>	<u>"An Analysis of the Availability of Economic Base Information in 19 Urban Areas in Texas"</u>	
Research Study No.	Title	
<u>C. V. Wootan</u>	<u>D-8</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>W. F. Frey</u>	<u>1963</u>	<u>1964</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$5,487.20</u>		
Total Funds Expended		

**BACKGROUND INFORMATION** One of the requirements in the development of an urban transportation system is that an analysis be made of the availability of economic base information for the urban area under consideration. After which this information is used in making the economic base study required for the development of an urban transportation system. This study included 19 of the major urban areas in Texas.

**STUDY OBJECTIVE** The objective of this study was to determine whether the economic base information could be obtained in various fields of inquiry, as well as to point out areas in which there was not adequate publications to support an economic base study. Furthermore, the study included only publications available in the specific urban areas being surveyed.

**IMPLEMENTATION OF FINDINGS**

In general, this study served the purpose for which it was intended and was used in making the base economic studies required.

**RESEARCH REPORTS PUBLISHED**

Final Report - "An Analysis of the Availability of Economic Base Information  
In 19 Urban Areas in Texas"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-18-63-65</u>	<u>"Analysis of Access Violations on Controlled Access Facilities"</u>	
Research Study No.	Title	
<u>Charles Pinnell</u>	<u>D-18</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Roger Spencer</u>	<u>1963</u>	<u>1969</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$4,884.95</u>		
Total Funds Expended		

**BACKGROUND INFORMATION** Experience has shown us that it is not enough merely to build freeways but that we must deliver to the public safety, comfort and convenience. Furthermore, that the freeway must have a high degree of operational attention. Control of access, one feature of freeway design, implies that the right to light, air, view, and access are controlled by public authority. However, there were indications that the access control feature of design was being violated and that additional controls were required to insure access control. For this reason, this study was initiated.

**STUDY OBJECTIVE**

The general objectives of this study was to determine the extent and causes of access violations on controlled access facilities, and to provide data that would be useful in controlled existing access viplations and in anticipating and eliminating future violations. In detail, the specific objectives of the study was as follows: (1) to catalog the type of access violations on controlled access facilities. (2) to determine the extent and causes of access violations. (3) to determine the effectiveness of various design and control features presently being utilized to prevent access violations.

**IMPLEMENTATION OF FINDINGS**

The objectives of this study were attained and the results have been timely, very useful and worthwhile. Specifically, the study results were used to help define the problem, identify corrective measures required and to determine indicated optimum solutions.

**RESEARCH REPORTS PUBLISHED**

65-1F "Analysis of Access Violations on Controlled Access Facilities"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-15-63-66</u>	<u>"Frontage Roads and Economic Development"</u>	
Research Study No.	Title	
<u>Hoy A Richards</u>	<u>File D-15</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>W. O. Threadgill</u>	<u>1963</u>	<u>1968</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$101,993.87</u>		
Total Funds Expended		

BACKGROUND INFORMATION

At the time this study was undertaken the State was deeply involved in the design and construction of the Interstate Highway System. It was widely recognized that this massive facility would have a significant impact upon the present and future economy of the State. The exact nature and extent of this impact, however, could not be accurately estimated on the basis of previous experience with older type facilities.

This study was part of an overall research program designed to provide information to the Department to assist in decision making concerning new highways.

STUDY OBJECTIVE

To determine the influence that the Interstate Highway System of Texas has on the location of industrial activity within the geographic areas served by the facility. More specifically the study was intended to provide information about the importance of frontage roads on industrial plant locations.

IMPLEMENTATION OF FINDINGS

This study served management in a general way as related to the objectives stated above.

RESEARCH REPORTS PUBLISHED

1. Interim Progress Report - "Frontage Roads and Economic Development".
2. 66-2(F) - "Frontage Roads and Plant Location".

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-18-63-67</u>	<u>"Establishment and Maintenance of Vegetation on Highway Right of Way"</u>	
<b>Research Study No.</b>	<b>Title</b>	
<u>Dr. Wayne McCully</u>	<u>File D-18</u>	
<b>Project Supervisor</b>	<b>T.H.D. Monitoring Division</b>	
<u>Mr. Roy Rodman</u>	<u>September 1963</u>	<u>August 31, 1969</u>
<b>T.H.D. Contact Individual</b>	<b>Date Initiated</b>	<b>Date Terminated</b>
<u>\$98,325.74</u>		
<b>Total Funds Expended</b>		

**BACKGROUND INFORMATION** A vegetative or other cover is required for soil stabilization on the unpaved portion of the highway right of way. Such a cover will prevent the reoccurring maintenance resulting soil erosion on slopes and in ditches. Vegetation should be used where possible as an alternative to concrete rip rap to cover the faces of slopes. Specifications exist for establishing vegetation, either by seeding or sodding in eastern Texas and by seeding in western Texas. These specifications have evolved largely as a record of experience, and from a good base. Failures occurred frequently enough so that a study and refinement were necessary.

**STUDY OBJECTIVE** (1). To compare and improve specified methods of erosion control by determining requirements, planning materials and procedures for establishing a vegetative cover on finished slopes and other areas subject to soil erosion. (2) To adapt recommended agricultural methods of plant control to highway requirements.

**IMPLEMENTATION OF FINDINGS**

(See Attached Memorandum from Mr. Archie J. Sherrod to Mr. Robert L. Lewis, dated March 9, 1971 regarding this study implementation of results).

**RESEARCH REPORTS PUBLISHED**

- 67-6 "Promoting Establishment of Vegetation for Erosion Control"
- 67-7 "Establishment of Bermudagrass Seeded with Annual Ryegrass"
- 67-8F "Erosion Control on Roadsides in Texas"

INTEROFFICE MEMORANDUM

TO: Mr. Archie J. Sherrod

FROM: R. L. Lewis

SUBJECT: Research Study No. 2-18-63-67  
"Establishment and Maintenance of Vegetation  
on Highway Right of Way"

Date Feb. 19, 1971

Responsible

Desk ~~D-S-R~~  
750.67

As you are aware, the above subject study was completed some time ago. Undoubtedly some of the study results were implemented during the progress of the study and since that time. A record of this information is essential for the evaluation and improvement of the Department's effort.

It is respectfully requested that a statement be prepared for the official record and evaluation regarding the effectiveness of the study, your suggestions regarding improvements in operation, administration, research procedures, and to what extent the research was implemented. Also, if possible, your estimate of the economic impact the results have had or will have.

Your usual early reply regarding the above will be appreciated.

IKM:jo<sup>sk/m</sup>

by R

### INTEROFFICE MEMORANDUM

TO: Mr. R. L. Lewis

FROM: Archie J. Sherrod

SUBJECT: Research Study 2-18-63-67  
Establishment and Maintenance of Vegetation  
on Highway Right of Way

CHIEF CLERK	
DATE	March 9, 1971
RESPONSIBLE	<i>[Signature]</i>
DESK	D-18-L
D.B. FILE	<input checked="" type="checkbox"/>

Reference is made to your memorandum of February 19, 1971, relative to evaluation of the study results for the above designated research project.

As a result of the experimentation that was conducted in the use of chemicals to control the growth of Bermuda and Johnson Grass in base material, we were able to prepare a specification that permitted the application of these chemicals prior to the placement of the asphalt surface. This specification has been used rather widely by D-8 in treating the flexible base material that is infested with grass. It was also proved that the treatment of the base material prior to the surface application was not a permanent solution to grass growing through the asphalt surface. After a period of approximately three years grass encroaches from the edge and also it will grow in dry weather cracks that have occurred in the surfacing. Since the control of grass encroaching primarily from the edge proved to be a maintenance problem this has necessitated a periodic treatment with the edge of the pavement and 6" beyond to prevent the encroachment. This project provided us with the most information for us to select two chemicals that are relatively safe for our use that will not cause damage or pollute the adjacent property. We used approximately one million pounds of ammonium sulfamate and five million pounds of sodium TCA.

In our experimental work in seeding for erosion control, methods were proved whereby seeding can be satisfactorily used to establish a vegetative cover. A specification has been developed for the entire state as a result of this work. This specification has been used in numerous contracts in the past two years and the cost per square yard for this work has been approximately one-half of our sodding for erosion control costs. It was felt that after a period of say three to four years that all of our right of way was a mixture of native and acclimatized grasses regardless of what had been planted. This has led us to the development of a seeding mixture for our work. This particular study provided us with the information necessary to adopt and modify our highway mowing standards which has resulted in a savings to the Department

In all of our experimental work in the field we placed these experiments on areas of the right of way of a sufficient size and used methods that could be followed in highway construction. These tests were placed in each of our highway districts under field conditions. Personnel at the districts were made aware of the tests and were able to observe the results.

Work on this project necessitated input from several disciplines such as soils, chemicals, agronomy and pathology, all of which was correlated for the benefit of the project. This project we feel has been very beneficial and has enabled us to make rational decisions relative to pollution that has become so much concern. We think that the Department is accomplishing its erosion control, temporary and permanent, at much less cost and we feel damaging the adjacent property owners less as a result of this work.

RECEIVED  
MAR 10 1971  
D 3

*[Handwritten Signature: Archie J. Sherrod]*

RSR/jbk

3-10-28

**RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS**

<u>2-5-63-68</u>	<u>Sign Support Structures</u>	
<u>Research Study No.</u>	<u>Title</u>	
<u>C. H. Samson</u>	<u>D-5</u>	
<u>Project Supervisor</u>	<u>T.H.D. Monitoring Division</u>	
<u>Dr. Leon Hawkins</u>	<u>Sept. 1, 1963</u>	<u>August 31, 1966</u>
<u>T.H.D. Contact Individual</u>	<u>Date Initiated</u>	<u>Date Terminated</u>
<u>\$102,895.11</u>		
<u>Total Funds Expended</u>		

**BACKGROUND INFORMATION** Large signs are necessary to provide adequate signing for today's high-speed freeway traffic. These are positioned over the roadway or near the edge of the pavement because of the complexity of multilane facilities and traffic operation thereon. Furthermore, their size calls for larger and stronger structural members to support them and to give resistance against forces induced by the wind. The formidable solidity of the structural supports required for these signs has resulted in their constituting a definite safety hazard for occupants of vehicles that collide with them.

**STUDY OBJECTIVE** The objectives of the research was to design and test sign supports: (1) with substantial reduction in the total mass involved, (2) which themselves will yield under the impact of collision, and (3) which will readily disconnect from their foundation when struck by a vehicle.

**IMPLEMENTATION OF FINDINGS** The results of this test are common knowledge. Present breakaway signs are being used and installed throughout the state. Additionally, the ideas developed are being used not only in Texas but in many other states and foreign countries. Furthermore, the Bureau of Public Roads made the following statement: As a result of this research, countless lives have already been saved, and it has furthered research of other safety aspects. The tremendous amount of application already underway by several state Highway Departments testifies to the research having proved quite successful. This project is undoubtedly one of the most successful ever conducted for highway safety.

**RESEARCH REPORTS PUBLISHED**

- 68-1 "Impact Behavior of Sign Supports"
- 68-2 "Impact Behavior of Sign Supports - II"
- 68-3 "An Investigation of Collision of Automotive Vehicles with Breakaway Highway Sign Supports"
- 68-4 "Development of Break-Away Sign Supports and Slotted Steel Plate Mechanical Fuses"



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-5-63-69</u>	<u>"Creep in Prestressed Lightweight Concrete"</u>	
Research Study No.	Title	
<u>Howard L. Furr</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Larry Walker</u>	<u>September 1, 1963</u>	<u>August 31, 1969</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$80,752.43</u>		
Total Funds Expended		

BACKGROUND INFORMATION Lightweight aggregates are used in structural concrete for the purpose of attaining overall economy in structures. It has been found that low transporting costs due to lighter weights and lower dead weight of structure sometimes give lightweight concrete an advantage over normal weight concrete.

The use of lightweight concrete in prestressed bridge girders is relatively new, and questions had arisen as to the behavior of these girders in service.

STUDY OBJECTIVE The objective of the study is to develop information and methods whereby creep and attendant deflection of prestressed concrete bridge girders made of lightweight aggregate concrete may be predicted with acceptable precision.

IMPLEMENTATION OF FINDINGS The method developed in this study predicting camber in prestressed concrete beams, along with its computer program, is being used quite frequently by our design engineers to predict a camber in long prestressed concrete beams. This permits any needed grade adjustment to be made in the design stage rather than in the construction stage.

RESEARCH REPORTS PUBLISHED

- 69-1 "Creep in Lightweight Agregate Prestressed Concrete"
- 69-2 "Creep in Prestressed Lightweight Concrete"
- 69-3F "Prestressed Loss and Creep Camber in a Highway Bridge with Reinforced Concrete Slab on Pretensioned, Prestressed Concrete Beams"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

File  
720.414

2-5-63-70	"Chemical Admixes for Concrete"	
<u>Research Study No.</u>	<u>Title</u>	
Truman R. Jones, T. J. Hirsch and D. L. Ivey	File D-5	
<u>Project Supervisor</u>	<u>T.H.D. Monitoring Division</u>	
C. R. Rea	September 1, 1963	August 31, 1966
<u>T.H.D. Contact Individual</u>	<u>Date Initiated</u>	<u>Date Terminated</u>
<u>\$44,876.10</u>		
<u>Total Funds Expended</u>		

**BACKGROUND INFORMATION** Chemical admixtures may be used to make certain desirable changes in various physical properties of plastic in hardened concrete. Some admixtures retard the initial set and counteract the adverse effects of high temperature; some accelerate the set; some reduce the water requirement for a given workability, most of them increase the ultimate compressive strength, etc. It had been found that many of the admixtures, even while accomplishing the immediate objective, have an adverse effect upon the drying shrinkage of the concrete. One of the major problems at that time was to know how to determine the effects specific admixtures have on drying shrinkage.

**STUDY OBJECTIVE** (1) Develop a satisfactory method of tests for evaluating the effects of chemical admixtures upon the shrinkage of concrete. (2) Determine whether a simple procedure can be developed for checking the composition of the chemical formulation of the admixture so that limits can be specified for the variation in the formulation.

**IMPLEMENTATION OF FINDINGS**

(See Attached Memorandum from Mr. Henneberger to Mr. Lewis dated February 23, 1971.)

**RESEARCH REPORTS PUBLISHED**

- 70-1 "The Effect of Chemical Admixtures on the Drying Shrinkage of Concrete and the Control of Chemical Uniformity of Admixtures"
- 70-2 Unpublished
- 70-3F "Effects of Chemical Admixtures in Concrete and Mortar"

INTEROFFICE MEMORANDUM

TO: Mr. R. L. Lewis (D-8R 750.70)  
FROM: Wayne Henneberger  
SUBJECT: Research Study No. 2-5-63-70  
"Chemical Admixes for Concrete"

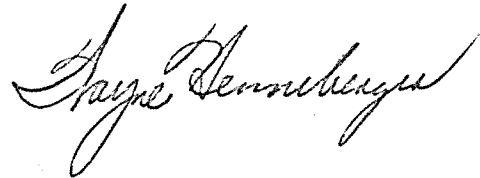
SEARCHED	INDEXED
SERIALIZED	FILED
FEB 24 1971	
FBI - MEMPHIS	
Responsible	Desk D-5
JRH IM	

With regard to your memorandum of February 19, 1971 concerning the above captioned subject, we offer the following statement.

The research study was effective to the extent of producing results of sufficient quality to be included in the latest revision of Specification Item 437, Concrete Admixtures. This revision is presently being reviewed by various Divisions within the Department.

No estimate of economic impact is available. It is anticipated that quality control will be enhanced as a result of this research.

RVS:rgw



RECORDED  
FEB 24 1971  
E 3

INTEROFFICE MEMORANDUM

TO: Mr. Wayne Henneberger  
FROM: R. L. Lewis  
SUBJECT: Research Study No. 2-5-63-70  
"Chemical Admixes for Concrete"

Date Feb. 19, 1971

Responsible

Desk D-S.R.  
750.70

As you are aware, the above subject study was completed some time ago. Undoubtedly some of the study results were implemented during the progress of the study and since that time. A record of this information is essential for the evaluation and improvement of the Department's effort.

It is respectfully requested that a statement be prepared for the official record and evaluation regarding the effectiveness of the study, your suggestions regarding improvements in operation, administration, research procedures, and to what extent the research was implemented. Also, if possible, your estimate of the economic impact the results have had or will have.

Your usual early reply regarding the above will be appreciated.

*WTL*

IKM:jo *AK*

Leroy

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-5-63-71</u>	<u>Deleterious Materials in Concrete</u>	
Research Study No.	Title	
<u>D. L. Ivey</u>	<u>D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>C. R. Rea</u>	<u>Sept. 1, 1963</u>	<u>Aug. 31, 1966</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$45,643.49  
Total Funds Expended

**BACKGROUND INFORMATION** Specifications for concrete aggregates represent a compromise between the desire for a perfect material and the necessity for using materials that are economically available. In many instances the engineer is faced with the problem of writing a specification to limit a certain property and finds that sufficient information concerning that property, or how to measure it is not available. These encounters have resulted in the use of such phrases as "harmful amounts", "excessive amounts" or in the assignment of some arbitrary quantitative measure. As experience is gained these arbitrary quantitative measures have been adjusted first in one direction then in another, resulting in serious loss of confidence in some specifications. One of the examples of this type of specification is in the area of cleanliness of concrete aggregates.

This research included a study of the existing test methods (sand equivalent and loss by decantation) used to detect clay in concrete aggregates, and a study of the effect of various amounts of clay with various liquid limits on the strength, shrinkage, and freeze-thaw durability of concrete. The work necessarily included the determination of clay fraction properties of concrete aggregates from pits within the state of Texas.

**STUDY OBJECTIVE** (1) To study methods of test for determining the clay content of concrete aggregates. (2) To determine the effects of clay content on the strength, shrinkage, and durability of concrete. (3) To relate these effects of clay on the properties of concrete to results of tests for determining clay content of the aggregates.

**IMPLEMENTATION OF FINDINGS**

As a result of this research, Administrative Circular No. 24-67 dated March 28, 1967, was published. In part, the Administrative Circular eliminated the loss by decantation tests as a fine aggregate requirement and replaced it with the sand equivalent tests requiring a minimum value of 78.

**RESEARCH REPORTS PUBLISHED**

- 71-1 "Correlation of Concrete Properties With Tests for Clay Content of Aggregate"
- 71-3F "Clay, Aggregate and Concrete"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>1-5-63-72</u> Research Study No.	<u>"Study of Electrically Heated Bridge Decks for Ice Prevention"</u> Title	
<u>Larry Walker</u> Project Supervisor	<u>D-5</u> T.H.D. Monitoring Division	
<u>H. D. Butler</u> <u>Larry Walker</u> T.H.D. Contact Individual	<u>1963</u> Date Initiated	<u>July 24, 1968</u> Date Terminated
<u>\$8,996.08</u> Total Funds Expended		

BACKGROUND INFORMATION

This study consisted of the design, construction and study of three electrical heating systems for bridge decks to prevent ice. The three systems were as follows: 1. An anti-icing system for a heavily traveled structure with deep approach grades and no frontage roads. 2. Electrically heated cables laid on top of the slab and covered with a polyester compound known as Terrazite. 3. This system was installed in twin concrete slab structures and had provisions for testing a variety of cable spacings and slab depths.

Temperature data and visual observations were collected from the above structures and analyzed. Results of these analyses show that the use of electrical heating systems to prevent the formation of ice or accumulation of snow on bridge slabs is both feasible and effective.

STUDY OBJECTIVE

This research was for the purpose of investigating the feasibility and effectiveness of heating a bridge slab to prevent the formation of ice, and to determine criteria for the design of heating systems.

IMPLEMENTATION OF FINDINGS

Results of this study verify the design criteria and procedures used in designing an electrical heating system for a bridge deck in Amarillo, Texas. Also, the findings of this study have been used by various other states in designing electrical systems for ice prevention.

RESEARCH REPORTS PUBLISHED

72-1F - "Study of Electrically Heated Bridge Decks for Ice Prevention"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>1-9-64-74</u>	<u>"A Study of the Application of Proposed New Test Methods and Specifications to Asphalt Cements in Texas"</u>	
Research Study No.	Title	
<u>C. W. Chaffin</u>	<u>D-9</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>C. W. Chaffin</u>	<u>1964</u>	<u>1965</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$5,830.73</u>		
Total Funds Expended		

**BACKGROUND INFORMATION**

As a result of the research work carried out by the Texas Transportation Institute, it was proposed in 1963 that the Department replace the 1962 standard item No. 300, Asphalt Cement Specification. Therefore, to gain additional data on the effect of these changes on asphalt quality and laboratory requirements needed for control under these proposed specifications, certain investigations were planned.

**STUDY OBJECTIVE**

1. To determine for all Texas sources the full range of penetration at 77° Fahrenheit that might be supplied under the proposed viscosity grades.
2. To compare the indications of the proposed viscosity test with the thin film test as used in the 1962 standard Specifications.
3. To estimate the work load, laboratory equipment, personnel and space needs, and time involved in testing the large number of samples needed for control of the volume of asphalt used by the Department. This information would then be available to pass on to producers so that they could make the necessary preparations for production control.

**IMPLEMENTATION OF FINDINGS**

After considerable work was accomplished on this study, the need for the results were no longer necessary since the Department adopted viscosity graded asphalt specifications in early 1965. Therefore, the study was terminated and Federal participation was completely withdrawn.

Page Two  
1-9-64-74

RESEARCH REPORTS PUBLISHED

No Research Reports were published. However, in the official file there is a record of the data collected and findings prior to the termination of the study.



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>1-8-64-75</u>	<u>"Supplementary Studies in Highway Illumination"</u>	
Research Study No.	Title	
<u>Neilon J. Rowan</u>	<u>File D-8</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>E. M. Carl</u>	<u>4-13-64</u>	<u>August 31, 1969</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$271,138.25</u>		
Total Funds Expended		

BACKGROUND INFORMATION (See Attachment)

STUDY OBJECTIVE (See Attachment)

IMPLEMENTATION OF FINDINGS (See Attachment)

RESEARCH REPORTS PUBLISHED (See Attached Sheet)

- 75-1 "An Interim Report on a Study of Roadway Lighting Systems"
- 75-2 Not to be Published
- 75-3 "An Interim Report on Roadside Sign Visibility"
- 75-4 "Photometric Studies of the Austin 'Moonlight' Tower Lighting Systems"
- 75-5 "An Interim Report on a Study of Disability Veiling Brightness"
- 75-6 Not to be Published
- 75-7 "Impact Behavior of Lighting Poles"
- 75-8 "Impact Behavior of Luminaire Supports"
- 75-9 "An Analytical Solution of the Impact Behavior of Luminaire Support Assemblies"
- 75-10 "Multi-Directional Slip Base for Break-away Luminaire Supports"
- 75-11 "Fatigue Analysis of the Cast Aluminum Base"
- 75-12 "High Mast Lighting"
- 75-13F "Final Report - Supplementary Studies in Highway Illumination"

INTEROFFICE MEMORANDUM

JAN  
IM

TO: Mr. R. L. Lewis

Date March 31, 1971

FROM: E. M. Carl

Responsible

SUBJECT: Research Study No. 1-8-64-75  
"Supplementary Studies in Highway Illumination"

Desk D8-P 480

In response to your memorandum of February 19, 1971, there is attached herewith a report on the results obtained during the course of the above noted research study which extended over a period of five years.

Your memorandum requested an evaluation regarding the effectiveness of this study and suggestions regarding improvements and operation, administration, research procedures and to what extent the research was implemented. In addition the memorandum also requested an estimate of the economic impact of the results obtained from this research.

The attached report will discuss, in greater detail, the aforementioned aspects for which you have requested comments. However, I would like to take this opportunity to commend the Research Section of the Highway Design Division for the excellent cooperation which we have received during the course of these research studies. The personnel of this Section have been most helpful and cooperative in assisting us in the various phases of the research involved in this particular study.

Attachment

bcc:SSW  
EMC  
D8-R 750-75 ✓

INTEROFFICE MEMORANDUM

TO: Mr. E. M. Carl Date Feb. 19, 1971

FROM: R. L. Lewis Responsible

SUBJECT: Research Study No. 1-8-64-75 Desk D-8 R  
"Supplementary Studies in Highway Illumination" 750-75

As you are aware, the above subject study was completed some time ago. Undoubtedly some of the study results were implemented during the progress of the study and since that time. A record of this information is essential for the evaluation and improvement of the Department's effort.

It is respectfully requested that a statement be prepared for the official record and evaluation regarding the effectiveness of the study, your suggestions regarding improvements in operation, administration, research procedures, and to what extent the research was implemented. Also, if possible, your estimate of the economic impact the results have had or will have.

Your usual early reply regarding the above will be appreciated.

*RL Lewis*

## RESEARCH DEVELOPMENT ACHIEVED BY PROJECT 1-8-64-75

### "Supplemental Studies in Highway Illumination"

#### INTRODUCTORY REMARKS:

The subject research project was initiated in 1964 to extend over a period of 5 years at a total estimated cost of approximately \$300,000. The purpose of this research was to update the then existing criteria for highway illumination design for which there have been no major changes or improvements in a number of years, not only in the state of Texas but also throughout the United States.

During the early stages of our design and development for urban freeways, four-lane divided facilities were initially developed; and, it was possible to adequately light these facilities with 30' mounted 400 watt mercury vapor luminaires. As increasing urban freeway traffic demands increased, it became necessary to expand these facilities to eight-lane divided freeways with wider medians and, as a result, it was found that our standard illumination design criteria would no longer adequately illuminate the width of such sections. It, therefore, became evident that improvements in our highway illumination design criteria were needed. In recognition of this need, the subject project was initiated to explore various means by which such design criteria might be improved.

#### PHASES OF RESEARCH:

1. The initial phase of this research involved the development of equipment and hardware which would permit us to evaluate and determine the optimum height and spacing for lighting units of various intensities. From these studies which were conducted at the Research Annex of the Texas Transportation Institute of Texas A & M University, it was determined that the optimum height for a 400 watt mercury vapor luminaire was 40' and the spacing was approximately 200' to 220'. In a similar fashion, it was determined that the optimum mounting height for a 1000 watt mercury vapor light source was 50' and the spacing approximately 250' to 300'. Each of these were in contrast to the design criteria which had been utilized throughout the United States for many years, namely the use of 20' to 30' mounted 400 watt mercury vapor units spaced from 160' to 180' apart.

It became apparent from these research findings that by the utilization of high mounting heights and greater spacing would not only provide a more uniform distribution of light over a wider area but would also result in a reduction of the cost of installation and operation of such highway illumination designs by approximately 30%.

These tests were conducted for both single and dual-mounted units; and, from the research findings of such tests, it was evident that a median installation of such units would contribute even more to the economy of such lighting installations by reducing the number of poles required by one half. As soon as the effectiveness and the economy of these median mounted dual installations had been clearly demonstrated through the research studies on this project, our department immediately began to install 50' dual-mounted 1000 watt units on our urban freeways in the median areas which were protected by a double line of median barrier guard rail. Where such single mounted poles were installed in unprotected areas, such poles were mounted on frangible or breakaway bases. A limited number of median installations have been provided on divided freeway sections where a depressed 40' to 48' median existed. These installations of 50' poles were on frangible bases without the protection of median barrier guard rail. The field experiments with these installations, thusfar, have been satisfactory; however, there has been some question as to the feasibility of installing these 50' dual mounted poles in such depressed median areas having a width of 40' or less.

It should be noted that the latter type of installation has been considered to be more of an experimental nature and is not yet considered to be a recommended or standard design. We believe that it would be advisable to observe such installations for a period of time before a final conclusion is reached in regard to such installations, inasmuch as there is a recognizable factor of traffic safety involved.

2. Prior to the initiation of this research project, the Texas Highway Department had installed both aluminum and galvanized steel poles on our highway system. The aluminum poles came equipped with a cast aluminum transformer base which served as a housing at that time for a constant wattage ballast. The galvanized steel poles came equipped with a steel transformer base to serve the same purpose. It soon became evident that the cost of the galvanized steel pole and steel base was more economical than were the aluminum poles and cast aluminum bases; and, as a result, most of our highway illumination projects in those years involved the use of galvanized steel poles on steel bases. Having extensive installations of both types of poles and bases on our highway system, it became evident from field reports of vehicle impacts with these two types of poles that the severity of damage to the vehicle and injury to the occupants was greater where a pole was mounted on a steel transformer base and that the severity of vehicle damage and injury to occupants was minimized where the cast aluminum base was utilized with the pole. In recognition of this situation, the Texas Highway Department revised highway illumination design criteria to permit only the installation of frangible breakaway bases for light poles which were not protected by a median barrier guard rail or some other roadway feature which would prevent the dangers inherent in a vehicular impact with such poles.

In order to provide further documentation to the Federal Highway Administration for the already established T.H.D. policy regarding frangible bases, extensive vehicular crash tests of various types of poles were conducted at the Research Annex of T.T.I. of the Texas A & M University. As a result of these conclusive crash tests, the Bureau of Public Roads of the Federal Highway Administration directed all states to begin installing breakaway features on highway illumination installations. During the course of these crash test evaluations, a small cast aluminum insert having a height of about six inches was conceived and designed by the members of the Highway Design Division as a remedial means for converting previously installed rigidly mounted light poles to breakaway characteristics. A number of such cast aluminum inserts were installed experimentally on a section of Interstate 35 in Hays County, and numerous vehicular impacts and knock-downs over a period of two or three years confirmed the fact that this small cast aluminum insert did, in fact, accomplish the purpose for which it was designed, namely to provide a shear linkage which would convert a rigidly mounted pole to a breakaway type of facility. However, the difference in the cost of the small cast aluminum insert and the standard cast aluminum base was not considered to be significant enough to warrant the use of such inserts on new installations. It was also subsequently determined that in the "change out" of previously installed rigidly mounted poles that it would be more desirable to provide the 20" height standard cast aluminum base rather than the six inch high cast aluminum insert. As a result of the foregoing crash tests and evaluation of breakaway devices for lighting poles, as conducted at the Texas Transportation Institute, it has been found that a majority of the 50 states in the United States are now utilizing the cast aluminum transformer base to provide a frangible shear linkage for lighting poles which are not protected by other means.

3. Another phase of the research which was not initially contemplated in the initiation of the subject illumination project was that of so-called "high-level" lighting. This was not a new idea, since a limited number of such installations had been developed in some of the European countries; however, such lighting systems had not at that time been installed on highways in the United States. As a result, the objectives of the subject illumination research were reoriented to permit the studies of such lighting; and, the initial phase of these studies at T.T.I. were conducted with a 122' telescoping tower at the top of which ten 1000 watt flood lights had been mounted. This equipment was tested at the Research Annex at T.T.I. and showed considerable promise in that it lighted a circular area of considerable diameter and it became evident that this type of lighting might very well be adapted to the area lighting of freeway interchanges.

Following the use of the 122' telescoping tower with the ten 1000 watt floodlights fixed atop of it, the next phase in this study involves the fabrication and installation of a 100' galvanized steel pole which consisted of telescoped sections and an internal electrohydraulically operated winching system which operated an external ring assembly of ten 1000 watt floodlights. This system was developed

with the idea of being able to raise and lower the entire assembly of floodlights for maintenance at ground level. The results of this installation proved encouraging and formed the basis of several installations which were provided at different points in the state, however, as a matter of economy, these installations, at heights of 100', utilized triangular shaped radial type transmission towers with the ten 1000 watt units fixed at the top. Later, as the operation and evaluation of the prototype 100' pole was thoroughly tested and evaluated, it was recognized that the scope of this type of lighting system could be expanded and improved if a higher mounting height were to be utilized. The increased height of the mounting appeared to be warranted in order to reduce the glare which was produced to some extent at the 100' mounting height. As the result, the originally installed 100' pole was laid down and a 50' extension was added to it, after which the original internal winching system and the external ring assembly was again added to the pole and further photometric studies were made of this system at a height of 150'. The finding from this study was so encouraging that the Texas Highway Department then began planning actual field installations of such lighting in interchange areas on certain of our freeways. As the studies of the lighting characteristics produced by the 150' mounting height with the ten 1000 watt units progressed, it became more evident that such lighting was necessary and justified in order to provide the driver a panoramic view of his surroundings in a complex interchange area. This type of lighting would be in contrast with the previous installations of lighting units along each of the separate roadways and turning movements within multi-level interchanges which, thereby resulted in so-called "tunnel lighting". In other words the driver was provided illumination only along the roadway which he was traveling within the interchange area and he was not afforded the opportunity to be aware of the surrounding geometric configurations of the interchange.

This type of lighting has now become accepted and installed in many other states. And, although there have since been developed variations of this originally conceived design by the Texas Highway Department and the Texas Transportation Institute, the basic principle is still the same and is now apparently accepted as a standard method for illuminating interchange areas.

#### SUMMATION:

Reference is now made to the memorandum from Mr. R. L. Lewis, dated February 19, 1971, which requested comments on the achievements and effectiveness of the subject research project. This memorandum requested an evaluation regarding the effectiveness of the study, suggestions regarding improvements in the operation, administration, research procedures and to what extent the research was implemented. And, in addition, requested an estimate of the economic impact which the results have had or will have on highway illumination design criteria.

Comments on the various phases and aspects of this research project, as noted above, are furnished herewith:



### Effectiveness of the Study:

There is ample evidence that this study was quite effective and resulted in the first comprehensive upgrading of highway illumination criteria, not only in Texas but in the United States. This effectiveness can be readily measured by the consideration of three factors: (1) by increasing the optimum height and spacing of highway lighting units it was possible to not only improve the quality in scope of lighting but to also increase the economy of the installations and subsequent cost of operation by reducing the number of units required to light a given section of freeway; (2) the extensive testing and confirmation of the effectiveness of frangible breakaway bases for the mounting of highway light poles. The introduction of this feature, not only in Texas but elsewhere in the United States, has undoubtedly resulted in the saving of many lives by eliminating the previously utilized rigidly mounted poles which had for many years been standard design criteria throughout the United States. (3) The development and improvement of the High-Mast lighting concept for interchange and area lighting has contributed a significant item to the improvement of driver safety and operation within interchange areas of freeways. The fact that this concept of area or interchange lighting has been accepted by many states is indicative of the fact that the concept has provided a major improvement in the illumination of large interchange areas and has contributed materially to the comfort and safety of the driver in such areas.

### Suggested Improvements in Operation:

It is presumed that this question refers to the operation and conduct of research project. Since the successful conduct of research projects such as the one under discussion is contingent upon both communication and correlation between the cooperative agencies involved in such research, it would be difficult to isolate any particular areas where improvements might be made. Since such operations are so diverse and involve a number of people, any improvements which might be made in these operations would probably be the result of improved communications and cooperations extended by all those involved.

### Administration:

During the five-year duration of the subject research project, the Administration of the subject research project by the Research Section of the Highway Design Division was most excellent; and those who were directly involved in this specific research endeavor are grateful for the assistance and cooperation extended in the administration of this project.

### Research Procedures:

There were numerous modifications and changes made in the research plan for this

project during the five-year duration of the project; and, it is recognized that the frequent reorientation of the objectives of the project must have certainly created some difficulties and needs for readjustment of planning. However, it is believed that greater accomplishments in applied research can be achieved where there is sufficient latitude for change to permit the evaluation of new ideas and new concepts as they might evolve from the previous research efforts. Had such adjustments and reorientation of objectives not been possible within the scope of the research under the subject project, it is doubtful that as much would have been achieved and accomplished as the project appears to have contributed to the further improvement of highway illumination design criteria.

#### Implementation of Research:

From the foregoing comments, it is evident that as soon as promising research findings were developed in the conduct of this project, such findings were immediately incorporated into highway planning and design for the installation of new lighting concepts in Texas. These new concepts were also freely furnished to the highway departments of other states and were adopted by many of them.

#### Estimate of Economic Impact:

There are no readily available means by which to evaluate the overall economic impact of the results obtained by the subject illumination research project. However, it is possible to evaluate the impact of this research in Texas by actual comparison of highway illumination costs on a "before and after" basis. This would not only involve an evaluation of the improvement in the scope and photometric characteristics provided by the research findings of this project; but, it would also be possible in many instances to compare the actual contract costs of a project which was based upon new design criteria with the costs of plans originally submitted for the same project. Our records reveal that there have been instances where the original design of an illumination project was revised and the contract costs of the ultimate project resulted in a saving of from 30 to 50% of the cost of the installation. These savings were further reflected in the eventual cost of the operation and maintenance of the specific projects which involved fewer units and a lesser cost for the power to operate them.

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-5-64-76</u>	<u>"Fatigue Strength of Stud Shear Connectors in Lightweight Concrete" (Push-Out Test)</u>	
Research Study No.	Title	
<u>A. A. Topraic</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Larry Walker</u>	<u>April 24, 1969</u>	<u>1966</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$7,958.13</u>		
Total Funds Expended		

BACKGROUND INFORMATION In a bridge structure consisting of a concrete slab supported by steel beams or girders, the compressive strength of the concrete deck may be used to advantage as a cover plate to increase the load carrying capacity of steel members. One type of shear connector used to transfer the necessary shear for compressive action is the headed-stud. The ease and economy with which such studs can be installed has increased the competitive position of composite construction in recent years. This position can be furthered still, if additional weight savings can be effected through the use of lightweight concrete. One third the weight of the concrete deck is eliminated when lightweight concrete is used and the amount of steel required is reduced to the reduction of the design load. Although fatigue data on the strength of stud shear connectors when regular (hard rock) concrete is used could be found in the technical literature, the same could not be said for lightweight concrete. Moreover, light aggregate varies from area to area, depending upon the method of production or the type of raw material used.

STUDY OBJECTIVE The objective of this research study was to obtain data on the fatigue strength of stud-shear connectors when lightweight concrete used is made with aggregate produced in the State of Texas.

IMPLEMENTATION OF FINDINGS The results of this study were used to verify results obtained from similar tests performed at the University of Texas and elsewhere. Results of this study also lead to the use of shear connectors as slab hold down devices on girder stands not specifically designed for composite action.

RESEARCH REPORTS PUBLISHED

76-1F "Fatigue Strength of Three-Fourth Inch Studs in Lightweight Concrete"



INTEROFFICE MEMORANDUM

TO: Mr. R. L. Lewis (D-8R 704.8)

FROM: Wayne Henneberger

SUBJECT: Research Study No. 3-5-64-77  
"Fatigue Strength of Plate Girder  
Webs Under Constant Moment".

Date March 18, 1971

Responsible *ZM*

Desk D-5

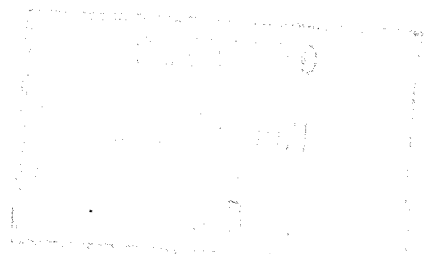
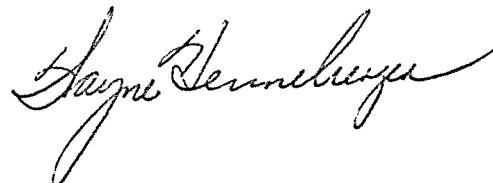
With regard to your memorandum of March 16, 1971 concerning the subject research study, we offer the following statement.

This research study was conducted to determine the fatigue properties of two types of bridge sections which had not previously been used but appeared to be economically feasible. The first type has become known as Orthotropic Plate and results are documented in "Fatigue Testing of Ribbed Orthotropic Plate Bridge Elements" by H. L. Davis and A. A. Toprac. The second type is known as Hybrid Plate Girder and results are reported in "Fatigue Strength of Hybrid Plate Girders Under Constant Moment" by H. S. Lew and A. A. Toprac.

The subject research study was effective in producing information that was combined with results of other research studies of fatigue loaded specimens to produce design specifications published by AASHO and AWS.

Economic impact cannot be measured accurately, however it is reasonable to assume that funds invested in the subject research will be returned in the form of lower costs by use of more efficient bridge members.

RVS:rgw



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-8-64-79</u>	<u>"Numerical Methods for Radial Triangulation from Aerial Photography"</u>	
Research Study No.	Title	
<u>Robert D. Turpin</u>	<u>File D-8</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Mr. H. A. Henry</u>	<u>1964</u>	<u>May 1966</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$10,992.15  
Total Funds Expended

**BACKGROUND INFORMATION** In the use of aerial photography for the preparation of maps, some ground surveys (usually referred to as control surveys) are needed in order to determine the scale and the orientation of the photography. There are a number of satisfactory methods of obtaining the necessary ground control, but these methods are usually time consuming and often prove to be quite expensive. Thus, any procedure whereby some of the ground-control surveys could be eliminated are minimized would be desirable from an economy standpoint. One means of achieving this savings is by aerial triangulation.

**STUDY OBJECTIVE** The objective of this study was to investigate and evaluate the use of radial triangulation for extending control, with precise measurements taken directly from the photography and data reduced through a computational procedure which would be programmed for a high-speed digital computer.

**IMPLEMENTATION OF FINDINGS** The information obtained from this study served as a basis for future research and stimulated additional research concerning control extension by alternate computational procedures.

**RESEARCH REPORTS PUBLISHED**

79-1F "Numerical Method for Radial Triangulation"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-5-64-80</u>	<u>"Strength Effect Of Cutting Off Tension Bars In Concrete Beams"</u>	
Research Study No.	Title	
<u>Phil M. Ferguson</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Larry Walker</u>	<u>1964</u>	<u>February 15, 1968</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$54,221.17</u>		
Total Funds Expended		

BACKGROUND INFORMATION Sixty-four concrete beams reinforced with #8 of #11 bars (largely A432) were tested as simple beams. Most of these had bars cut off at the minimum point for moment or at 12D or 15D beyond such points. Some, for comparison, contained full length bars or bars bent up. The majority of the beams with bars cut off were designed to be balanced at ultimate in flexural strength, shear strength, and bond strength. The beams usually contained stirrups to develop the design shear strength.

The majority of the beams were 18 or 24 inches in overall depth reinforced with #8 or #11 bars. Fifteen beams were from 12 to 15 inches deep.

STUDY OBJECTIVE The initial objective of this investigation was to establish whether bar cutoffs were always injurious to beam shear strength. An interim report which was dated August 23, 1965 reported only 2 out of 31 beams with bars cut off had developed their full shear capacity. The majority showed deficiencies of from 15 to 25 percent and one more than 40 per cent. The investigation was then extended to include possible remedial measures.

IMPLEMENTATION OF FINDINGS The results of this study supported a change which had been made in the design of the 1965 Standard interior bents used with prestressed concrete beam stands. This change, should result in a safer design, required that the cut-off point for tension reinforcement bars be located at a vertical reaction.

RESEARCH REPORTS PUBLISHED

80-1F "Strength Effect Of Cutting Off Tension Bars In Concrete Beams "

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-15-65-82</u>	<u>"The Effect of Access on the Cost of Right of Way for the Interstate System"</u>	
Research Study No.	Title	
<u>William D. Franklin</u>	<u>File D-15</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>W. O. Threadgill</u>	<u>June 28, 1965</u>	<u>May 2, 1969</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$68,174.83</u>		
Total Funds Expended		

BACKGROUND INFORMATION Acquisition of right of way for a major highway system presents a number of unique problems in property evaluation. For the Interstate Highway System alone some three quarters of a million parcels of land will be required. The magnitude of the cost involved in acquiring this right of way poses a compelling need for developing procedures to assure that expenditures for this purpose are spent effectively. Systematic and precise evaluation of highway investment decisions insure a more adequate allocation of resources within the public sector.

STUDY OBJECTIVE The general objectives of the study were to compare sections of Interstate System with frontage roads with sections not having frontage roads in order to determine:

- (a) The relative cost of right of way for sections transversing similar areas.
- (b) The zone of influence of special benefits as opposed to general benefits on remaining property resulting from Highway construction.
- (c) The effect of interchanges and ramps on the value of comparable property abutting the highway.
- (d) To develop a consistent approach for appraising the value of accesses of remaining parcels from right of way acquisition.

IMPLEMENTATION OF FINDINGS The study was not of such nature as to lend itself to specific implementation. It primarily confirmed what was suspected, that is, access played a significant role in the estimate of damages to the remaining properties. It is believed that the only appropriate implementation is that which has already been accomplished by making distribution of both the study and the summary report to the Districts and other states for their use.



Page Two  
2-15-65-82

In respect to monetary savings no specific amount can be credited to this study effort. The findings do confirm there has been a substantial savings in right of way costs by providing accesses to remaining properties. The study concludes that the damages to the properties granted access were approximately 53% less than damages paid to those properties not granted access.

RESEARCH REPORTS PUBLISHED

82-1F - "Effects of Access on Highway Right of Way Costs"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>5-1-65-86</u>	<u>"Highway Signing Research"</u>	
Research Study No.	Title	
<u>Robert D. Wylie</u>	<u>File D-1</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>J. W. Pourter</u>	<u>Nov. 13, 1964</u>	<u>Oct. 31, 1966</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$59,212.22</u>		
Total Funds Expended		

BACKGROUND INFORMATION At the time this study was initiated there was insufficient factual information on which to base the design, selection, specification, and evaluation of materials for highway traffic signs, particularly in regard to materials for reflectorization of sign faces and materials for sign messages. There was a need to develop meaningful and objective criteria for determining optimum sign effectiveness including consideration of such factors as visibility, legibility, and target value, and to evaluate all signing materials currently available in terms of initial and maintenance costs, serviceability, and useful lives.

STUDY OBJECTIVE The overall objective of the study initiated under this project was to identify and evaluate the qualities for optimum sign effectiveness and serviceability to delineate objective criteria for specifying these qualities, and to establish test procedures and requirements to evaluate signing materials with respect to these criteria. The emphasis was to be on reflective signing materials and their characteristics at night and under adverse environmental conditions.

IMPLEMENTATION OF FINDINGS: The results of this study were used extensively in the formulation and issuance of specifications.

RESEARCH REPORTS PUBLISHED

Final Report

Phase I "A Survey of Materials and Research Needs Relating to  
Their Use"

5-1-65-86

Page Two

Final Report

Phase II - "Characterization of Signs-Facing Materials"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>6-1-65-87</u>	<u>"Financial Management Research Study"</u>	
Research Study No.	Title	
<u>Ernst &amp; Ernst</u>	<u>File D-1</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>J. W. Courtner</u>	<u>April 13, 1965</u>	<u>January 1, 1966</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$116,493.27  
Total Funds Expended

BACKGROUND INFORMATION This study was to include an appraisal of the organizational structure of the Department and the statement of delegation of authority and designation of responsibility, as well as initial operating policies, in order to define the areas of accountability and, where indicated, to propose realignment of functions in order to balance the organization and eliminate duplication or overlapping of functions.

STUDY OBJECTIVE Study and analysis of the organization; Operating Policies; Manpower Staffing; Utilization and Controls; Data Processing Equipment Needs & Potentials; Financial Management Practices and Procedures; and Operating Policies of the Highway Department to achieve desired fiscal management goals and maximum, efficient utilization of electronic data processing equipment.

Development of a recommended financial management system which will meet the current audit and billing regulations of the Bureau of Public Roads, and satisfy the requirements of the State Auditor.

IMPLEMENTATION OF FINDINGS Many of the recommendations made by Ernst & Ernst were adopted by the Department. Furthermore, Ernst & Ernst received a contract from the Department for assistance in implementing the study results.

RESEARCH REPORTS PUBLISHED

Report 87-1F - "Financial Management Study"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

3-5-65-88  
3-5-63-53  
Research Study No.

"Anchor Bolt Development"  
"Development Length of Anchor Bolts"  
Title

Dr. John E. Breen  
Project Supervisor

Bridge Division - File D-5  
T.H.D. Monitoring Division

Mr. Leon Hawkins  
T.H.D. Contact Individual

June 1, 1963  
Date Initiated

August 31, 1966  
Date Terminated

53 - \$7,919.82  
88 - \$ 421.13  
Total Funds Expended

**BACKGROUND INFORMATION** Research Study 3-5-65-88 (entitled Anchor Bolt Development) was an extension of Research Study 53. The program extension included a series of tests on 36 anchor bolts with varying embedment conditions. Major variables include the effect of the methods of test, effect of clear cover, effect on low cycle repeated loading, and effect of shape of the shaft.

**STUDY OBJECTIVE** The general objective of this investigation was the establishment of the development length for the embedment length required to develop the tensile yield capacity of anchor bolts. At the same time it was to explore the effect of various types of end anchorages and certain other variables.

**IMPLEMENTATION OF FINDINGS** The objectives of these two studies have been attained. The Department is presently using the anchor bolt design as developed by the study. As a result significant monetary savings have been realized. Not only is the design criteria used in Texas, but is widely used throughout the United States.

**RESEARCH REPORTS PUBLISHED**

- 53-1F "Development Length for Anchor Bolts"
- 88-1F "Factors Affecting Anchor Bolt Development"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-5-66-91</u>	<u>"Shear Strength of Bent Caps Between Columns"</u>	
Research Study No.	Title	
<u>Phil M. Ferguson</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>H. D. Butler</u>	<u>Sept. 1, 1965</u>	<u>August 31, 1966</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$14,832.14</u>		
Total Funds Expended		

BACKGROUND INFORMATION-In 1964 a Report entitled "Design Criteria for Over-Hanging Ends of Bent Caps" was made on Project No. 3-5-63-52. This report pointed out: (1) That substantial increases above the actual allowable shear stresses were permissible because loads were close to the support and always applied on top of the bent caps. (2) That vertical stirrups added little strength, although horizontal bars were helpful. It also indicated that somewhat similar increases were available for the bent caps inside the columns.

STUDY OBJECTIVE - Over the range of shear span between  $0.5d$  and  $2.5d$  (from load support) to establish permissible shear design stresses in interior spans on bent caps.

IMPLEMENTATION OF FINDINGS - See attached memorandum from Mr. Henneberger dated March 24, 1971 to Mr. R. L. Lewis.

RESEARCH REPORTS PUBLISHED -

91-1F "Shear Strength of Bent Caps Between Columns"



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-8-66-93</u>	<u>"Evaluation of Control Extension"</u>	
Research Study No.	Title	
<u>Robert D. Turpin</u>	<u>File D-8</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Mr. H. A. Henry</u>	<u>Sept. 1, 1965</u>	<u>March 10, 1969</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$11,722.66</u>		
Total Funds Expended		

BACKGROUND INFORMATION The primary reasons for using aerial triangulation are to reduce the time and cost of control survey data which are necessary for the compilation of topographic maps from aerial photographs. Some control surveys are always needed in topographic mapping. The field work for these surveys usually consists of traverse, triangulation, or trilateration for horizontal position determination and differential leveling, trigonometric leveling, or barometric pressure measurements for vertical positions (elevation).

The cost of field work for topographic mapping may be 25% to 75% of the total cost for preparing a map. Furthermore, any blunders in the field work usually result in costly delays or in a very poor map. Therefore, extension of field surveys by aerial triangulation is frequently desirable.

STUDY OBJECTIVE The objective of this research was to analyze in detail the processes involved in aerial triangulation so that the various sources of errors could be evaluated and procedures recommended for improving the quality of control extensions through aerial triangulation.

IMPLEMENTATION OF FINDINGS This program has been implemented into the Department's photogrammetry operations and is used for control extensions in areas where elevation data necessary for our other programming can not be obtained.

RESEARCH REPORTS PUBLISHED

93-1F "Evaluation of Control Extension"



RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-10-66-95</u>	<u>"Statistical Estimating and Forecasting for Vehicular Classification &amp; Weight"</u>	
Research Study No.	Title	
<u>Patrick Odell</u>	<u>File D-10</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Mr. Joe E. Wright</u>	<u>Sept. 17, 1965</u>	<u>August 17, 1967</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$14,328.61</u>		
Total Funds Expended		

BACKGROUND INFORMATION Since the advent of the Interstate Highway System, the importance of having available up-to-date, reliable vehicle count, classification, and weight data has increased enormously. At the same time there has been a rapid growth in the vehicle population and a shift of the general population from rural to urban areas and recent technological advances in pavement design techniques have emphasized the need for more and better vehicle weight data. This is partly an outgrowth of the accumulated equivalent 18 kip axle load design techniques which resulted after the AASHO Road Test.

STUDY OBJECTIVE: The work that was proposed was divided into three overlapping phases. The first phase was to study existing techniques of data collection and projection and determine criteria for evaluating them. The second phase was to evaluate existing techniques for sampling, estimating, and forecasting data with particular emphasis on vehicle classification and weight data. Particular attention was to be given to categorizing the system and to selection of representative sampling locations for optimum information. The third phase was to formulate an optimal method for collecting and handling Texas vehicle classification and weight data.

IMPLEMENTATION OF FINDINGS: The Project Supervisor on this study accepted a position at another college. Another qualified Study Supervisor was not available and, therefore, no usable study results were developed and the study was discontinued.

RESEARCH REPORTS PUBLISHED

95-1F - "Comments on Statistical Techniques for Estimating Traffic Flow"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-5-66-97</u>	<u>"Hybrid Plate Girders Subject to Bending and Shear"</u>	
Research Study No.	Title	
<u>Dr. A. A. Toprac</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>R. Vander Straten</u>	<u>Sept. 1, 1965</u>	<u>November 21, 1968</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$31,964.99</u>		
Total Funds Expended		

BACKGROUND INFORMATION

Please see memorandum from Mr. Wayne Henneberger to Mr. Lewis, dated March 10, 1971 for Background Information, Study Objective and Implementation Statement which is attached.

STUDY OBJECTIVE (See Attached Memorandum)

IMPLEMENTATION OF FINDINGS (See Attached Memorandum)

RESEARCH REPORTS PUBLISHED

97-1F "Static Tests on Hybrid Plate Girders"

*JM*  
IKM

INTEROFFICE MEMORANDUM

TO: Mr. Wayne Henneberger

FROM: R. L. Lewis

SUBJECT: Research Study No. 3-5-66-97  
"Hybrid Plate Girders Subject to  
Bending and Shear"

Date March 9, 1971

Responsible

Desk D-3-R  
730-97

→ 720.22

As you are aware, the above subject study was completed some time ago. Undoubtedly some of the study results were implemented during the progress of the study and since that time. A record of this information is essential for the evaluation and improvement of the Department's effort.

It is respectfully requested that a statement be prepared for the official record and evaluation regarding the effectiveness of the study, your suggestions regarding improvements in operation, administration, research procedures, and to what extent the research was implemented. Also, if possible, your estimate of the economic impact the results have had or will have.

Your usual early reply regarding the above will be appreciated.

RECEIVED  
MAR 11 1971

INTEROFFICE MEMORANDUM

TO: Mr. R. L. Lewis (D-8R 750-97)

FROM: Wayne Henneberger

SUBJECT: Research Study No. 3-5-66-97  
"Hybrid Plate Girders Subject to Bending  
and Shear"

DATE	March 10, 1971
RESPONSIBLE	W.H.
DESK	D-5

With regard to your memorandum of March 9, 1971, concerning the subject research study, we offer the following statement.

Combination of carbon steel web plate and high strength steel flanges produces a hybrid girder which results in a lighter and more economical section having greater load carrying capacity than a comparable section having uniform grades of steel. Prior to developing design specifications for hybrid girders, it was necessary to investigate shear and bending characteristics under static load. The subject research study was developed to substantiate the theoretical analysis and produce test results that would provide a basis for developing design specifications.

It was effective to the extent that the results were combined with those provided by other studies and a design specification was produced and published in the 1969 edition of the AASHTO Standard Specifications for Highway Bridges.

Accurate estimation of economic impact is not possible; however, it is reasonable to assume a significant savings will be realized by use of hybrid plate girders where applicable in highway bridge structures.

RVS:gw



RECEIVED  
MAR 11 1971  
D-8

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>2-15-66-100</u>	<u>"An Analysis of Right-of-Way Appraisal Problems"</u>	
Research Study No.	Title	
<u>Dr. William G. Adkins</u>	<u>D-15</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>W. O. Threadgill</u>	<u>1966</u>	<u>February 21, 1968</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated

\$22,573.30  
Total Funds Expended

BACKGROUND INFORMATION

This research effort was conceived to deal with both of the causes of discrepancies in and between appraisals as well as the difficulties of appraisal review. A thorough and proper appraisal review can determine whether the appraisal estimates are reliable and accurate, thus assuring the fair market value to the owners of a particular parcel. By the same token, knowledge of the major causes of discrepancies between appraisals should aid the See and Review Appraisers in arriving at better estimates of market value for each parcel with minimized difficulty.

STUDY OBJECTIVE

1. To identify the types of appraisals and the elements of value which most commonly are associated with appraisal inconsistencies.
2. To analyze, in terms of their basic causes variations in two or more independent appraisals of the same parcel and of highly similar parcels.

IMPLEMENTATION OF FINDINGS

This research study was of benefit in that it helped to identify problems in appraisal and appraisal review. Furthermore, specific monetary savings that have resulted from the study cannot be pinpointed. However, indirectly the research has helped our efficiency in the appraisal field. The raw data was used to a degree as a foundation upon which to base preparation and issuance of a complete appraisal and appraisal review manual. This manual is now in full use in the Districts and by most of the free appraisers.

RESEARCH REPORTS PUBLISHED

100-1 (F) "An Analysis of Right-of-Way Appraisal Problems"

RESEARCH & DEVELOPMENT  
ACCOMPLISHMENTS

<u>3-5-66-102</u>	<u>"Crack Width Study"</u>	
Research Study No.	Title	
<u>Phil M. Ferguson</u>	<u>File D-5</u>	
Project Supervisor	T.H.D. Monitoring Division	
<u>Robert L. Reed</u>	<u>5-18-66</u>	<u>March 27, 1969</u>
T.H.D. Contact Individual	Date Initiated	Date Terminated
<u>\$59,441.37</u>		
Total Funds Expended		

BACKGROUND INFORMATION Effective use of high strength steel such as A. 432 Grade with resulting lowering of costs, depends considerably upon the establishment of proper crack width service loads. There are many opinions about permissible crack width but very few statements, as to what is permissible or as to what definitely leads to corrosion.

Although corrosion is a complex phenomena, it is believed that part of the problem and the scatter observed may lie in the use of an incorrect measuring stick, that of the outer surface crack width which is the only one which can be directly observed. The critical crack width for corrosion must actually be the width at the surface of the bar. A given surface crack does not identify a specific crack width at the bar, because the ratio between the two is actually a variable, one still largely unknown.

STUDY OBJECTIVE To develop technique, or improve technique for determining relationship between crack width at the bar, as compared to surface crack width; to establish how this relationship varies for the usual variables in such a manner that the crack at the bar can be predicted for a given surface crack.

IMPLEMENTATION OF FINDINGS This study provided the necessary background information for Study No. 112 entitled "Crack Width-Corrosion Study", which was a follow-on study. The method for measuring and studying cracks in concrete which were developed in this study are being used in Study No. 112.

RESEARCH REPORTS PUBLISHED

102-1F entitled "Flexible Crack Width at the Base of Reinforced Concrete Beams"