ANNUAL REPORT OF THE
JOINT HIGHWAY RESEARCH PROJECT
1960-1961
DECEMBER, 1961
NO. 31

by
H.L. MICHAEL

PURDUE UNIVERSITY
LAFAYETTE INDIANA
TO: K. B. Woods, Director  
Joint Highway Research Project  
December 20, 1961

FROM: H. L. Michael, Associate Director  
Joint Highway Research Project  
File: 10-2-3

Attached is a copy of the "Annual Report of the Joint Highway Research Project, 1960-1961". This report, the 23rd in a series, presents the activities of the Project during the past year.

A very brief summary of the contents of the report is included as the first section of the report. The report also contains additional details and considerable information on the activities of the Project and its staff during the year.

The progress and success which is presented here has been the result of the excellent cooperation and efforts of the Project staff, the understanding cooperation of the Purdue University administration, the members of the Indiana State Highway Commission and the wise guidance of the Advisory Board.

The report is presented to the Board for the record.

Respectfully submitted,

Harold L. Michael  
Associate Director

HIM:knc

Attachment

cc: J. D. Antrim  
F. L. Ashbaucher  
David Cohen  
J. R. Cooper  
J. W. Delleur  
W. L. Dolch  
G. M. Foster  
W. H. Goetz  
G. E. Goodwin  
M. J. Gutzwiller  
F. F. Havey  
G. A. Hawkins  
F. S. Hill

G. A. Leonards  
R. W. Lounsbery  
J. F. McLaughlin  
R. D. Miles  
R. E. Mills  
Merle Parvis  
P. N. Powers  
M. B. Scott  
J. V. Smythe  
V. G. Stover  
J. L. Waling  
P. T. Yeh  
E. J. Yoder
ANNUAL REPORT OF THE JOINT HIGHWAY RESEARCH PROJECT
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Associate Director

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Purdue University
Lafayette, Indiana

December 20, 1961
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ANNUAL REPORT OF THE JOINT HIGHWAY RESEARCH PROJECT
July 1, 1960 to June 30, 1961

SUMMARY

The Project conducted research in its seven established areas and in four special studies during 1960-61 with thirty-seven (37) research projects being active. Of these studies, eight (8) were completed and nine (9) new projects were initiated. Twelve (12) of the completed projects were conducted by staff members who also utilized the research in the preparation of a graduate thesis. The following table lists each of the eight areas and the distribution of active projects, completed projects, theses and new projects:

Research Projects 1960-61

<table>
<thead>
<tr>
<th>Research Area</th>
<th>Active Projects</th>
<th>Projects Completed</th>
<th>Theses</th>
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<tr>
<td>Airphoto Interpretation</td>
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<td>Soils and Pavement Design</td>
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<td>Traffic Engineering and Safety</td>
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<td><strong>TOTALS</strong></td>
<td><strong>37</strong></td>
<td><strong>8</strong></td>
<td><strong>12</strong></td>
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The active research projects during the year by area were as follows:
Airphoto Interpretation

Application of Airphoto Interpretation in the Determination of Runoff Constants from Small Watersheds
Indian Engineering Soils Mapping
State Drainage Map
An Analysis of Photogrammetry Applied to Right-of-Way Surveys
A Classification and Glossary of Land Forms and Parent Materials
Classification of Wisconsin Ground Moraine by Airphoto Interpretation

Bituminous Materials and Flexible Pavement

Shear Strength of Bituminous Mixtures
Bituminous Concrete Pavement Design
Investigation of Bituminous Concrete Stability by Hveem Stabilometer
Use of Radioactive Tracers in the Determination of Phase Relationships Between Asphaltic Binders and Mineral Aggregates
Aggregate Degradation in Bituminous Mixtures

Chemistry of Materials

Damproofing Treatment of Bridges
Method for Evaluating Aggregate Gradings

Concrete Materials and Rigid Pavements

Evaluation of Aggregate Durability by Freezing and Thawing Tests of Concrete
Further Studies of Deleterious Substances in Indiana Aggregates
Fatigue Properties of Light-Weight Aggregate Concrete
Development of Precision Statements for ASTM Test Methods

Economics, Administration and Finance

Impact of the Lebanon and Kokomo Bypasses
Early Impact of an Interstate Highway
Studies of Partial Takings
Early Impact of an Urban Highway Improvement
Highway Performance Evaluation

Soils and Pavement Design

Statistical Analysis of Soil Sampling
Flexible Pavement Design
Deflection Measurements - Flexible Pavement of U. S. 31 Test Road
Interaction of the Effects of Certain Variables on the Stresses and Deflections of Pavements
Pore Water Pressure Parameters During Static and Repeated Load Tests of Soil-Aggregate Base Mixtures
Effects of Repeated Loading on the Strength and Deformation Characteristics of Soil-Aggregate Mixtures Employing Triaxial Compression Tests
Traffic Engineering and Safety

Periodic Speed Studies
Truck-Weight Speed Studies
Evaluation of Major Urban Intersections
Vehicular Characteristics on Acceleration and Deceleration Lanes
Effects of Traffic Control Devices at School Crossings

Special Projects

Study of Runoff from Small Drainage Areas for Highway Drainage
    Design in the State of Indiana
Hydraulics of River Flow Under Arch Bridges
Measurements of Moisture Gradients in Concrete Pavements
Research on Chemical Weed Control

Forty-nine (49) formal reports were presented to the Advisory Board during the year totaling 3,010 pages of information. Twenty-two (22) of these were research reports, eleven (11) were technical papers, eleven (11) were plans of study and five (5) were administrative reports.

Four (4) of the research projects were special studies with the Bureau of Public Roads and Indiana State Highway Commission and utilized in part (about 70%) EPS funds. Three of these - Hydraulics of Arch Bridges, Measurement of Moisture Gradients, and Engineering Soils Mapping - were continued from previous years. The fourth project - Highway Impact Studies - was initiated July 1, 1960. A fifth study approved by the Board during the year - Chemical Weed Control - has been submitted to the cooperating agencies for approval as a Special Study. This latter study will be conducted in cooperation with the Department of Botany and Plant Pathology, of the School of Agriculture.

In addition to the Department of Botany and Plant Pathology, other Departments and Schools of the University actively participated in Project studies the past year. These included the Division of Mathematical Sciences, the Biomucleonics Department, the Department of Agricultural Economics, the Agronomy Department, and the Soil Conservation Service.
The 47th Annual Road School was held March 27-30, 1961 and was attended by over 1,100 persons. Ten counties and cities were given advice and counsel on highway planning and traffic engineering problems and numerous counties were given advice and counsel on many problems, much of this in cooperation with the Highway Extension and Research Project for Indiana Counties.

Two Indiana State Highway Commission engineers, chaired the Board during the year - Mr. C. E. Vogelgesang until his resignation from the Highway Commission in May 1961 and Mr. J. R. Cooper since May. Two new Board members - Mr. J. V. Smythe and Mr. F. S. Hill were appointed during the year, replacing Messrs. Vogelgesang and J. E. Wilson. Board members Ashbaucher and Goetz and Secretary Michael attended all eight meetings held during the year. Messrs. Leonards, Mille, McLaughlin and Woods attended all but one of the eight with Professor Woods missing his first meeting in 24 years. Mr. Vogelgesang attended all seven of the meetings held prior to his resignation.

On June 30, 1961, the Staff of the Project consisted of fourteen (14) research engineers, three (3) research associates, three (3) research assistants, fifteen (15) graduate assistants, two (2) service personnel, and three (3) clerical personnel - a total of forty (40). Nineteen (19) staff members resigned during the year and eighteen (18) new members were employed. The three members of the staff with the longest terms of service with the Project are Professor W. H. Goetz, employed May 13, 1938; Mr. Bronson Luttrell, employed August 6, 1938; and Professor K. B. Woods, employed February 1, 1939.

Major items of equipment purchased during the year included the following valued at approximately $15,300. Centrifuge, portable skid
resistance equipment, trackmeter (speed and distance measurement device),
contourmatic duplicator, masonry saw, electric furnace, expansion pressure
device, concrete aggregate scale, sieves, film projector, ball mill roller
type, ultrasonic cleaner, air compressor, electric vibrator, remodeled
moist room, gyratory testing machine, concrete mixer, and pore pressure
equipment.

The Project encumbrances during the year totaled $164,619.13 of
which $38,208.50 was encumbered on Special Study (HPS) projects. The
Project received $150,000.00 from the State Highway Department of Indiana
for Project use and was paid $19,525.89 during the year for expenditures
made on the HPS Special Studies in this and at the end of the preceding
year. A total of $1143.50 was also received from the sale of drainage
maps during the year.

Ten (10) reprints, twelve (12) theses, and seven (7) other major
papers were published by the staff during the year. In addition, the
Proceedings of the 46th Annual Road School, the 1961 Directory of State,
County and City Officials, and Highway Extension News were published during
the year. Staff members also gave sixteen (16) formal papers and
presented over forty (40) addresses during the year at numerous locations
and before numerous groups.

Members of the staff were active on numerous national committees,
holding a total of sixty-one such memberships. Organizations which were
served were the International Society of Photogrammetry, ASTM, ACI, HRP,
AREA, ARBA, ASCE, ITE, AAPT, and ASEE. Staff members attended meetings
and conferences of these national organizations in all parts of the United
States and also attended many meetings of technical and professional
organizations at local and state levels. Members of the staff also
served as consultants to numerous organizations.
Two members of the staff were promoted during the year, W. L. Dolch and R. D. Miles to rank of Associate Professor and Mr. J. R. Bell became registered as a Professional Engineer during the year.
RESEARCHES OF THE JOINT HIGHWAY RESEARCH PROJECT

The Joint Highway Research Project in the School of Civil Engineering is organized to do cooperative research with the State Highway Department of Indiana. Research was initiated on June 1, 1936, and formally authorized by an act of the Indiana State Legislature on March 11, 1937, and amended March, 1949. The purposes of this organization are to make basic studies of materials used in highways; to facilitate economical design, construction, and maintenance of county and state highways; to investigate traffic, safety, and economics; to provide advanced instruction in the fundamentals of highway engineering and related research; and to provide practical experience in construction and maintenance procedures and use of highway materials. The Project was guided in 1960-61 by an Advisory Board consisting of five members of the State Highway Commission and six members of the staff of the School of Civil Engineering at Purdue University.

The research conducted during the year in seven established areas and in special studies for the State Highway Commission was varied and important. Thirty-seven (37) research projects were active and are briefly discussed in the following pages.
Airphoto Interpretation Research
Research Under the Direction of R. D. Miles

Application of Airphoto Interpretation in the Determination of Runoff Constants for Small Watersheds (C-36-32N)

Investigator: Merle Parvis

This research is an interpretative study of stream arrangement and general drainage basin characteristics by the use of aerial photographs. The attributes and parameters of the watershed are being studied for their relation to storm runoff. The technique should be applicable to the determination of values of constants for highway structure design. Eighteen to twenty watersheds in the various physiographic provinces in Indiana are being investigated. A procedure is being developed whereby the engineer can apply directly the information obtained from aerial surveys of small watersheds.

Classification and Glossary of Land Forms and Parent Materials (C-36-32P)
Investigator: R. L. Terrel

The purpose of this study was to investigate the literature and to prepare a uniform classification and compile a glossary of land form and parent material terms applicable to airphoto interpretation of soils and rocks. A definition of each land form particularly as it pertains to shape, size and genesis was included for over 250 land forms. A definition of each parent material type with respect to origin and textural composition was included in the final report for over 100 unconsolidated and consolidated earth material that form the parent material groups.
Analysis of Photogrammetry Applied to Right-of-Way Surveys (C-36-32Q)

Investigator: P. F. Scudieri

The purpose of this project is to determine the feasibility and the application of photogrammetry to the preparation of maps for the acquisition of right-of-way for transportation systems. The study is limited to the use of a double projection photogrammetric instrument (Kelsh) for map compilation. The study area is a section of the Interstate highway system, and was photographed by the Indiana State Highway Commission. Lengths, bearings and areas are being determined for right-of-way purposes in an urban and rural section.

Classification of Wisconsin Ground Moraine by Airphoto Interpretation (C-36-32R)

Investigator: W. P. James

The purpose of this project is to investigate and develop the characteristic airphoto pattern elements of each of the three substages of the Wisconsin Glacial ground moraine. Two areas of one township in size were selected in each of the three substages. Qualitative and quantitative studies of topography, surface drainage, gully erosion, photo tones and land use are being made, and are being correlated with the engineering soils associated with the various substages. The difference in the airphoto patterns that are important in classifying the ground moraines as to important engineering soil areas are being developed.

Indiana Engineering Soils Mapping (C-36-51B)

Investigator: P. T. Yeh

The objective of this project is to obtain a complete engineering soils map of the State of Indiana. Engineering soil maps with an engineering report, of individual counties are prepared at a scale of
one inch equals one mile using aerial photographs and agricultural soil maps as basic sources of soil information. Soils are sampled in the field and engineering tests are performed in the JHFP Soils Laboratory. This research is being conducted under a special project with the Soil Conservation Service, the Joint Highway Research Project, the Bureau of Public Roads and the Indiana State Highway Commission. Soil profiles are sampled by the Soil Conservation Service and engineering soil tests are performed in the Joint Highway Research Soil Laboratory. Summary soil reports are then submitted to the Bureau of Public Roads. These reports are compiled into a table for publication in the Agricultural Soil Survey report by the Soil Conservation Service and a summary is also included in the Project's engineering report.

State Drainage Map (C-36-517)
Investigator: P. T. Yeh

Compilation of a map at a scale of one inch equals four miles showing detailed stream systems is the object of this project. The map is being compiled by tracing photographic reductions of county drainage maps prepared using aerial photographs. Sixteen counties were added this year making a total of 76 counties traced onto the State Drainage Map and completion of the mapping is planned by late 1961.

Bituminous Materials and Flexible Pavement Research
Research under the direction of W. H. Goetz
Shear Strength of Bituminous Mixtures (C-36-6P)
Investigator: J. H. Schaub

This investigation considered the effect on shear in bituminous mixtures of the method of performing the test, including drainage
conditions and the measurement of volume change. The study developed the relationship between void content and shear strength as a failure criteria for a mixture prepared to a given set of initial conditions.

Investigation of Bituminous Concrete Stability by Hveem Stabilometer (C-36-68)
Investigator: N. G. Gaudette

This investigation has been the purpose of studying the validity of the Hveem or California design procedure when applied to Indiana mixtures. A recommendation has been made for application of the method to the design of both binder and surface mixtures in Indiana.

An Investigation of Aggregate Degradation in Bituminous Mixtures (C-36-21C)
Investigator: F. Moavenzadeh

Types and causes of degradation of aggregates in Bituminous mixtures are being investigated by use of the Gyratory Compactor. The effect of degradation on the properties of fines are being investigated by performing conventional tests on different fines with different aggregates.

Use of Radioactive Tracers in the Determination of Phase Relationship Between Asphal tic Binders and Mineral Aggregates (C-36-24B)
Investigator: D. R. Lamb

Radioactive tracer techniques are being used to study the dispersion of asphalt in asphal tic mixtures and the variations in relationship between aggregate and asphalt with changes in properties and types of mixture.
Bituminous Concrete Pavement Design (C-36-55E)

Investigator: N. G. Gaudette, Movenzadeh and Goetz

A continuing study is being made of changes in density and Hveem stability of bituminous mixtures in service and this is being related to performance.

Chemistry of Materials Research

Research under the direction of W. L. Dolch

Dampproofing Treatment of Bridges (C-36-37Z)

Investigator: J. F. McLaughlin and W. L. Dolch

In the fall of 1956 parts of two new overpass highway bridges near Marion, Indiana were treated with a silicone solution through the courtesy of the manufacturer of the product. A third bridge was later partially treated with epoxy material.

The three bridges that have been partially treated with damp-proofing materials have been observed periodically. Extensive popout damage has occurred. Some minor scaling has occurred. There is no obvious relationship between silicone treatments and the presence or absence of damage, however. The epoxy material has performed well.

Method for Evaluating Aggregate Gradings (C-36-42G)

Investigator: Sandor Popovics

A mathematical analysis of gradings for concrete aggregates has been tested by the application of standard tests to plastic and hardened concretes of both rich and lean and wet and dry characteristics. A statistical analysis has shown that the main hypothesis is reasonably vindicated. This hypothesis is best stated through a logical corollary, viz: Gradings that have the same values of fineness modulus, specific surface, and maximum size will produce concrete that has the same plastic and hardened properties.
Concrete Materials and Rigid Pavement Research

Research under the direction of J. F. McLaughlin

Evaluation of Aggregate Durability by Freezing and Thawing Tests of Concrete (C-36-37X)

Investigator: J. F. McLaughlin

This is a project consisting of the testing of aggregates in concrete subjected to freezing and thawing in automatic equipment. Aggregates from many sources have been tested to obtain information helpful in setting up better specifications for concrete aggregates.

The investigation also includes various studies of factors affecting concrete durability, such as maximum aggregate size and water/cement ratio. Studies of variations in test method for freezing and thawing tests, are included.

Further Studies of Deleterious Substances in Indiana Aggregates (C-36-42F)

Investigator: R. L. Schuster

The quantitative effect of several chert and shale gravels on the laboratory freeze-thaw durability of concrete was determined. Reasons for differences in the behavior of the various materials were deduced.

Fatigue Properties of Light Weight Aggregate Concrete (C-36-56Q)

Investigator: W. H. Gray and J. D. Antrim

The S-N curves for a high-strength and a low-strength concrete containing expanded shale aggregate were determined. These results, significant in themselves, were compared to similar data developed for normal weight concrete.

Development of Precision Statements for ASTM Test Methods (C-36-65A)

Investigator: S. J. Hanna

Several ASTM test methods for concrete and aggregate are being studied to determine limits of repeatability and reproducability.
Economics, Administration and Finance Research

Research under the direction of H. L. Michael

Highway Performance Evaluation (C-36-54BB)
Investigator: V. F. Nakamura

The purpose of this research is 1) to determine the correlation of objective measurements with subjective human judgment of pavement surfaces using such measurements as road roughness, 2) to determine the correlation of highway ratings made by experts in the field of highway engineering with ratings made by typical road users, and 3) to determine the correlation of subjective highway ratings and/or objective measurements with ratings of the sufficiency rating type.

A sample of roads, including several functional classes, surface types and conditions will be selected and rated by several groups and methods. The ratings will then be compared and analyzed.

Impact of the Lebanon and Kokomo Bypasses (C-36-64A)
Investigator: V. C. Stover

The effect of the construction of a bypass around a city is the subject of this research. The effect on land use and development, land value, traffic flow, traffic accidents and on the general community welfare are specific subjects of concern. The bypasses studied were constructed in 1950 as non-limited access facilities of two lanes each. Each has since been constructed to four lanes and one of them has been made limited access. The changes which have occurred during the initial construction and the later construction are the subject of this analysis. The study includes an evaluation of long-term effects as well as short-term and intermediate ones.

Early Impact of an Interstate Highway (C-36-64B)
Investigator: J. A. Fletcher
The impact of an Interstate highway (Interstate 65 between Lebanon and Indianapolis) which is on a new location approximately parallel of but about one-eighth mile distant from a former major arterial highway is the subject of this study. The initial changes in land use and development, land value and traffic are being investigated and will be the specific subjects of this study. Data on these items and other factors are also being collected and these data are to be organized in such a manner that they can be readily kept current and that additional studies of longer term effects can be evaluated at later dates. This study is being conducted in cooperation with the State Highway Commission of Indiana using HPS funds.

Studies of Partial Takings (C-36-64C)
Investigator: V. G. Stover and J. A. Fletcher

The land ownership, land value, and land use changes which occur on the remaining parcels of land after takings by the state highway commission are the subjects of this research. The information reported will include information on land use and land value prior to the construction of a new highway; the situation with regard to each partial taking, including appraisals and damages paid; and information as to land use and value at a later date, especially in the event of a sale of all or a part of the remainder. This study is being conducted in cooperation with the State Highway Commission of Indiana using HPS funds.

Early Impact of an Urban Highway Improvement (C-36-64D)
Investigator: A. F. Lohr

The impact of an improvement to a major arterial urban street in Indiana on land use and development, land value, traffic conditions, and the community are to be studied in this research. The early effects (during construction and immediately after opening) of this
construction will be studied and reported and the data organized in such a manner as to facilitate keeping it current and the conduct of additional later studies. The urban improvement to be studied is a new bridge and its approaches in the Greater Lafayette urban area. This study is being performed in cooperation with the State Highway Commission of Indiana using HPS funds.

Soils and Pavement Design Research
Research under the direction of E. J. Yoder

Statistical Analysis of Soil Sampling (C-36-36A)
Investigator: Delon Hampton

Purpose of the study was to determine if soils derived from the same parent materials and under the same environmental conditions possess the same engineering properties. Also, the variability of certain engineering properties was determined as well as the number of samples required to give a desired degree of precision. Soils of Madison and Tippecanoe Counties, Indiana were used in this study.

The following tests were used as measures of soil variability:
1. Atterberg Limits
2. Standard AASHO compaction test
3. Hvem Stabilometer and swelling pressure tests
4. CBR test
5. Grain size analysis, and the
6. Unconfined compression test

Also, x-ray diffraction tests were used to determine the type of clay minerals present.

Pore Water Pressure Parameters During Static and Repeated Load Tests of Soil Aggregate Base Mixtures (C-36-45G)
Investigator: R. W. Johnson

Pore pressures are being measured in the triaxial undrained test under varying axial load increments. The load is applied under repetitive cycles of 20,000 to 100,000 cycles or until failure occurs. Volume Change and deformation are observed.

Repeated Load Tests on Subbase Materials from AASHO Test Road (C-36-45H)
Investigator: J. H. Haynes

The research report of this study reports the results of a laboratory investigation of the behavior of gravel and crushed stone mixtures
subjected to repeated loading. Cylindrical specimens were used and stressed triaxially to levels approximating those which would be found in the base course of a highway pavement. The repetitive loadings were applied with equipment developed in the laboratories of the School of Civil Engineering at Purdue University.

The materials used in this study were obtained from the site of the AASHO Road Test. The gravel and crushed stone with grain size distribution equal to that used in the Road Test and compacted to the mean density levels found in the field were the subject of primary interest. Variation in percent fines and degree of saturation were considered to have a great effect on these basic gradations. Therefore, the percent passing the number 200 mesh sieve was varied so that three mixtures of each material were obtained. These three mixtures were tested at three levels of saturation.

The effects of these variables on the deformation-rebound characteristics of the materials under repeated loads were studied. From these studies, the advantages and disadvantages of each material, concerning their value as base course materials, were found and are reported in detail. Also, a comparison between the laboratory and field performance of the two AASHO materials is presented.

Flexible Pavement Design (C-36-523)
Investigator: E. J. Yoder

This research is a study of flexible pavement design functions and their applications to conditions in Indiana.

Deflection Measurements - Flexible Pavement of U. S. 31 Test Road (C-36-526)
Investigator: R. D. Walker
The project provides for making deflection measurements on the flexible pavements of the U. S. 31 test pavement near Columbus, Indiana. The study is intended to assist in the evaluation of the test pavement and to yield fundamental data on the load-deflection characteristics of flexible pavements.

Interaction of the Effects of Certain Variables on the Stresses and Deflections of Pavements (C-36-52F)

Investigator: E. J. Yoder

This study deals with theoretical stresses and deflections in flexible and rigid pavements. Numerical values of stresses and deflections are being obtained for various loads, pavement thickness, temperature conditions and subgrade types. These data will be analyzed to determine the interaction of the above variables on stresses and deflections.

Traffic Engineering and Traffic Safety Research

Research under the direction of H. L. Michael

Periodic Speed Studies (C-36-10C)

Investigator: D. F. Petty and Forrest D. Miller

Since 1941, periodic speed studies have been made by the Joint Highway Research Project staff at several locations near Lafayette. Speeds are taken each time at the same stations of free-floving traffic on tangent sections. In the latest study, performed in September 1960, an increase in the average speed was noted for both passenger cars and trucks on two and four lane highways from that found in March 1960. The increase noted was approximately one mile per hour. The purpose of this study is to obtain the trending nature of vehicle speeds on the open highway.
Truck Speed-Weight Studies (C-36-10D)

Investigator: D. F. Petty

Annually, in August, in cooperation with the Highway Planning Survey unit of the State Highway Commission of Indiana, speeds and weights of a sample of trucks are obtained. Indiana is only one of several states which conducts such studies under the national direction of the Bureau of Public Roads. These studies are made to evaluate the trends in the speeds and weights of the various classes of trucks which use the highways. The study in Indiana in August 1960 indicated that the speed and weight of single-unit trucks had slightly increased from that noted in 1959 and that the speed, but not the weight, of multi-unit trucks had also increased. The latter decrease for multiple-unit trucks was approximately one-thousand pounds.

Evaluation of Major Urban Intersections (C-36-17T)

Investigator: W. W. Schenler

A rating system is proposed for major urban intersections, which are the source of trouble and delay in urban street networks. The general principles developed apply to all intersections; in addition specific rating values are developed for certain at-grade intersections which are controlled by fixed-time signals. The Intersection Rating proposed is a "sufficiency rating" and is stated as a percentage of a "fully-sufficient" intersection. Factors influencing the ability of the intersection to serve traffic are divided into two general categories which are rated independently and combined to establish the Intersection Rating.

These two are a Physical Rating, which is concerned with the structural and geometric conditions existing at the intersection, and
the Traffic Rating, which is a device for evaluating user satisfaction -
based on average delay per vehicle - with the service rendered by the
intersection under existing volume and control conditions. Delays are
evaluated by mathematical models of traffic flow and are compared with
actual delays found at several intersections. Reasonable agreement
was established.

The rating technique was also applied to several intersections and
the results were found to be realistic.

Analysis of School Children Crossing Protection (C-36-17U)

Investigator: F. D. Miller

The purposes of this research are: to evaluate the effect of
various traffic-control devices at school crossings; to evaluate the
effectiveness of overpasses and underpasses as school crossings; and
to evaluate the seriousness of the school crossing problem in Indiana.

Various methods of warning drivers of school children crossings
are being studied relative to their effect on the speed of motorists
as they approach such crossings. Characteristics of use of overpasses
and underpasses as well as other school crossing controls are also being
investigated and accident records in Indiana are being used to determine
the seriousness of the school crossing problem in Indiana.

The project will be completed by the end of 1961.

Vehicular Characteristics on Acceleration and Deceleration Lanes (C-36-17V)

Investigator: Meddy Jouxy

This research study on the use of acceleration-deceleration lanes
when completed will provide a factual background regarding traffic
behavior as affected by acceleration and deceleration lane geometry.
The purposes of this research are to determine the speed and lateral placement of vehicles on various designs of acceleration and deceleration lanes on high type facilities, and to correlate acceleration and deceleration lane designs with traffic behavior and driver requirements and determine the acceleration and deceleration lane design of designs which provide the most efficient and safest operation.

The speed and lateral placement of vehicles using acceleration-deceleration lanes and their location with respect to the through traffic lanes are the major variables of the study.

Special Research Projects

Study of Runoff from Small Drainage Areas for Highway Drainage Design in the State of Indiana (C-36-62A)

Investigator: I. P. Wu, under the direction of J. W. Delleur

The purpose of this research is to study the hydrology of watersheds less than 200 square miles throughout the State of Indiana, to improve the existing methods for estimating the runoff from these watersheds, and to improve the existing methods of highway drainage structure servicing small watersheds. The analysis of peak flow from all watersheds less than 200 square miles for which the U.S.G.S. publishes records has been made by the method of statistics using extreme values. The effect of geomorphological variables has been studied. [A multiple correlation has been prepared to estimate the 25 year instantaneous peak runoff from a watershed of given area, given mean relief, given mean slope, given stream density and given geometry.]

Hydraulics of River Flow Under Arch Bridges (C-36-62B)

The purpose of the research is to study the effects of arch bridge constrictions upon the stream flow, to develop methods of computation of backwater due to arch constrictions, to determine discharges from high water marks, and to determine the required waterway area for a given discharge and a given permissible backwater.

The objectives of the research have been accomplished for semi-circular and circular segment arches provided they do not have skew, entrance rounding or chamfering and asymmetry. The studies of dual arch bridge constrictions and of the effect of wing walls on the flow patterns are in progress.

**Measurement of Moisture Gradients in Concrete Pavements (C-36-63c)**

Investigator: J. R. Bell, under the direction of G. A. Leonards

The purpose of this investigation is to develop and test a moisture meter suitable for determining the moisture contents and moisture gradients in concrete pavement slabs. Preliminary investigations indicated that a capacitance type meter was the most promising. Current studies of the capacitance water content relationship of mortars being conducted with a one megacycle capacitance bridge indicate several problems in the method. While the capacitance is a sensitive indicator of water content changes the actual measured capacitance is strongly influenced by other factors such as salt concentration of the water in the pores of the mortar, the electrical frequency of the measuring instrument, temperature and others. Efforts to remove these effects through appropriate calculations have been only partially effective. The results to date are inconclusive and the investigations are continuing.
Research on Chemical Weed Control (C-36-488)

Investigator: W. J. Farmer, under direction of J. R. Shay

The purpose of this proposed project is to determine the herbicide materials, application methods (primarily rates) and equipment to utilize in order to obtain maximum weed control at a minimum cost for conditions in Indiana.

Most of the research work will be in connection with foliage sprays, namely 2, 4-D. Other studies will involve the use of soil sterilants under guard rails and around other highway structures. Some study will be made of the use of maleic hydrazide, a grass suppressor or retarder. There will also be studies involving the problem of undesirable tall-growing grasses which are not killed by 2, 4-D such as Johnson grass, quack grass, giant foxtail, etc.
TRAFFIC ENGINEERING SERVICES UNIT

In 1954, a unit known as Traffic Engineering Services Unit was organized within the Joint Highway Research Project at Purdue University to provide traffic and transportation engineering services for the city and county governmental units of Indiana. The services offered are primarily advice and counsel on traffic and highway problems on an extension basis. Arrangements may also be made, however, for this Unit to supervise and assist in the conduct and analysis of traffic and highway studies with the cost borne by the governmental unit concerned. The activity of the Unit during the past year has been as follows:

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Governmental Unit</th>
<th>Services Rendered</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>South Bend</td>
<td>Advice and counsel on planning a parking study for South Bend</td>
<td>Complete</td>
</tr>
<tr>
<td>2</td>
<td>Huntington</td>
<td>Advice and counsel on location of parking lots in Huntington</td>
<td>Complete</td>
</tr>
<tr>
<td>3</td>
<td>Valparaiso</td>
<td>Advice and counsel on movement and parking in vicinity of Valparaiso Univ. Advice to Valparaiso Univ. on Master Plan of streets and parking on Campus</td>
<td>Active</td>
</tr>
<tr>
<td>4</td>
<td>Daviess County</td>
<td>Advice and counsel on road classification study of Daviess County</td>
<td>Complete</td>
</tr>
<tr>
<td>5</td>
<td>Akron</td>
<td>Advice and counsel on parking lot - skating rink in Akron City Park</td>
<td>Complete</td>
</tr>
<tr>
<td>6</td>
<td>Indianapolis</td>
<td>Advice and counsel on the best manner to conduct comprehensive study of Metropolitan Indianapolis</td>
<td>Complete</td>
</tr>
<tr>
<td>7</td>
<td>Nappanee</td>
<td>Advice and counsel on transportation and urban growth problems</td>
<td>Active</td>
</tr>
<tr>
<td>8</td>
<td>Tippecanoe County</td>
<td>Advice and counsel on road numbering and road classification in Tippecanoe County</td>
<td>Active</td>
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<tr>
<td></td>
<td>Lafayette</td>
<td>Advice and counsel on traffic problems</td>
<td>Active</td>
</tr>
<tr>
<td>---</td>
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<td>----------------------------------------</td>
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<tr>
<td>9</td>
<td>West Lafayette</td>
<td>Advice and counsel on traffic problems</td>
<td>Active</td>
</tr>
<tr>
<td>10</td>
<td>Numerous Counties</td>
<td>Advice and counsel on the establishment of a road identification system. Co-operated with Highway Extension and Research Project for Indiana Counties in this area</td>
<td>Active</td>
</tr>
</tbody>
</table>
PERSONNEL OF JOINT HIGHWAY RESEARCH PROJECT

June 30, 1961

Advisory Board

J. R. Cooper (1) (State Highway Department of Indiana), Chairman
F. L. Ashbauchar (State Highway Department of Indiana)
J. V. Smythe (2) (State Highway Department of Indiana)
F. F. Havey (State Highway Department of Indiana)
F. S. Hill (3) (State Highway Department of Indiana)
K. E. Woods (Purdue), Vice-Chairman
W. H. Goetz (Purdue)
G. A. Leonards (Purdue)
J. F. McLaughlin (Purdue)
R. E. Mills (Purdue)
J. L. Waling (Purdue)
M. B. Scott (4) (Purdue)
H. L. Michael (5) (Purdue), Secretary

(1) Elected Chairman of the Board June 21, 1961
(2) Appointed a member of the Board in June, 1961
(3) Appointed a member of the Board in April, 1961
(4) Professor Scott attends a representative of the Engineering Experiment Station and is a non-voting member.
(5) Non-voting member.
# Record of Meetings and Attendance

**The Joint Highway Research Project Advisory Board  July 1, 1960 - June 30, 1961**

<table>
<thead>
<tr>
<th>Meeting No.</th>
<th>Date</th>
<th>199</th>
<th>200</th>
<th>201</th>
<th>202</th>
<th>203</th>
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<th>205</th>
<th>206 (while Board Member)</th>
<th>Total to June 30, 61</th>
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<td><strong>Members</strong></td>
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<tr>
<td>F. L. Ashbaucher</td>
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<td>X</td>
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<td>X</td>
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<td>A(9)</td>
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<td>F. F. Havey</td>
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<td>F. S. Hill (2)</td>
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<td>C. A. Leonards</td>
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<td>G. E. Vogelgesang, Chm (4)</td>
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<td>J. L. Waling</td>
<td>X</td>
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<td>A(9)</td>
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<td>A(10)</td>
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<td>J. E. Wilson (5)</td>
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<td>K. B. Woods, V. Chm</td>
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<td>M. E. Scott (6)</td>
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<td>H. L. Michael, Secy (7)</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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</tbody>
</table>
Record of Meetings and Attendance (continued)

(1) Elected Chairman June 21, 1961
(2) Appointed to Board in April 1961
(3) Appointed to Board in June 1961
(4) Terminated Service on Board in May 1961
(5) Terminated Service on Board in March 1961
(6) Non-voting representative of Engineering Experiment Station, Attends when possible
(7) Non-voting member
(8) Professor J. M. Hayes Attended for Professor Waling
(9) Mr. J. V. Smythe attended for Mr. Cooper
(10) Professor J. E. Goldberg attended for Professor Waling

In addition many members of the Joint Highway Research Project and Civil Engineering staff and the following guests attended meetings of the Board:

Charles M. Dawson, ISH Commission Member - Sept 21
Harry E. Bodine, ISH Commission Member - Sept 21
Frederick L. Hovde, President, Purdue University - Sept 21
G. A. Hawkins, Dean, Schools of Engineering, Purdue - Sept 21, Jan 25
T. R. Johnston, Purdue University - Sept 21
Marie Ford, Indiana State Highway Commission - Dec 14
George Goodwin, Chief Engineer, ISHC - Jan 25, June 21
Research Staff

Administrative Staff

K. B. Woods, Director
H. L. Michael, Associate Director

Research Engineers

J. R. Bell (Soils, Geology)
J. N. Dalloul (Hydraulics)
W. H. Geitz (In Charge, Bituminous)
M. J. Gutsmiller (Structures)
R. W. Johnson (Soils)
R. M. Lewis (Traffic)
J. F. McLaughlin (In Charge, Concrete)
R. D. Miles (In Charge, Airphoto)
Marie Parvis (Airphoto)
K. J. Tharp (Traffic)
P. T. Yeh (Airphoto)
E. J. Yoder (In Charge, Soils)

Research Associates

A. K. Branham (Economics)
I. W. Burr (Statistics)
W. L. Dolch (In Charge, Chemistry)

Research Assistants

J. deC. Antrim (Concrete)
D. F. Petty (Traffic)
V. W. Stover (Economics)
Graduate Assistants

S. P. Brahma (Chemistry)
A. Burgers (Soils)
T. P. Chang (Hydraulics)
J. F. Class (Soils)
S. J. Hanna (Concrete)
W. P. James (Airphoto)
N. L. Journaux (Soils)
N. G. Jousy (Traffic)
S. Lippai (Hydraulics)
C. T. Lobo (Soils)
A. F. Lohr (Traffic)
F. D. Miller (Traffic)
F. Moavenzadeh (Bituminous)
V. F. Nakamura (Economics)
P. F. Scudieri (Airphoto)

Service Personnel

E. L. Black (Photographic and Duplicating)
W. B. Luttrell (Shop)

Clerical Personnel

Kay Critchell (Stenographer)
Ernestine Smith (Purchasing)
Constance Warm (Typist)
<table>
<thead>
<tr>
<th>Name</th>
<th>Present Title</th>
<th>Appointment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antrim, J. deC</td>
<td>Research Assistant</td>
<td>September 1, 1956 (A)</td>
</tr>
<tr>
<td>Bell, J. R.</td>
<td>Research Engineer</td>
<td>September 16, 1954 (B)</td>
</tr>
<tr>
<td>Black, E. L.</td>
<td>Laboratory Technician</td>
<td>November 1, 1953</td>
</tr>
<tr>
<td>Brahma, S. F.</td>
<td>Graduate Assistant</td>
<td>February 1, 1961</td>
</tr>
<tr>
<td>Bramham, A. K. (1)</td>
<td>Research Associate</td>
<td>September 1, 1939 (C)</td>
</tr>
<tr>
<td>Burger, A.</td>
<td>Graduate Assistant</td>
<td>February 1, 1961</td>
</tr>
<tr>
<td>Burr, I. W. (2)</td>
<td>Research Associate</td>
<td>February 1, 1958</td>
</tr>
<tr>
<td>Chang, T. P.</td>
<td>Graduate Assistant</td>
<td>February 1, 1961</td>
</tr>
<tr>
<td>Class, J. F.</td>
<td>Graduate Assistant</td>
<td>February 1, 1961</td>
</tr>
<tr>
<td>Critchell, C. M.</td>
<td>Stenographer</td>
<td>October 6, 1958</td>
</tr>
<tr>
<td>Delleur, J. W. (2)</td>
<td>Research Engineer</td>
<td>July 1, 1958</td>
</tr>
<tr>
<td>Dolch, W. L. (2)</td>
<td>Research Associate</td>
<td>September 15, 1947</td>
</tr>
<tr>
<td>Goetz, W. H. (3)</td>
<td>Research Engineer</td>
<td>May 13, 1938</td>
</tr>
<tr>
<td>Gutswiller, M. J. (3)</td>
<td>Research Engineer</td>
<td>September 1, 1957</td>
</tr>
<tr>
<td>Hanna, W. J.</td>
<td>Graduate Assistant</td>
<td>September 12, 1960</td>
</tr>
<tr>
<td>James, W. P.</td>
<td>Graduate Assistant</td>
<td>September 9, 1960</td>
</tr>
<tr>
<td>Johnson, R. W.</td>
<td>Research Engineer</td>
<td>February 1, 1960</td>
</tr>
<tr>
<td>Journeaux, N. L.</td>
<td>Graduate Assistant</td>
<td>February 1, 1961</td>
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<tr>
<td>Jouzy, N. C.</td>
<td>Graduate Assistant</td>
<td>September 16, 1959</td>
</tr>
<tr>
<td>Lewis, R. M.</td>
<td>Research Engineer</td>
<td>September 1, 1960</td>
</tr>
<tr>
<td>Lippai, S.</td>
<td>Graduate Assistant</td>
<td>September 1, 1960</td>
</tr>
<tr>
<td>Lobo, C. T.</td>
<td>Graduate Assistant</td>
<td>September 15, 1960</td>
</tr>
<tr>
<td>Lohr, A. F.</td>
<td>Graduate Assistant</td>
<td>September 15, 1960</td>
</tr>
<tr>
<td>Luttrell, W. B.</td>
<td>Laboratory Assistant</td>
<td>August 6, 1938</td>
</tr>
</tbody>
</table>
McLaughlin, J. F. (2) Research Engineer September 1, 1950
Michael, H. L. (2) Assistant Director February 1, 1950
Miles, R. D. (2) Research Engineer September 1, 1949
Miller, F. D. Graduate Assistant February 1, 1960
Moavenzadeh, F. Graduate Assistant February 1, 1960
Nakamura, V. F. Graduate Assistant September 12, 1960
Parvis, Merle (2) Research Engineer March 1, 1946
Petty, D. F. Research Assistant February 1, 1959
Soudiari, P. F. Graduate Assistant June 1, 1960
Smith, Ernestine Purchasing Clerk September 22, 1960
Stover, V. C. Research Assistant September 1, 1958
Tharp, K. J. Research Engineer June 1, 1961
White, C. D. Typist February 16, 1959
Woods, K. B. (4) Director February 1, 1959
Yeh, F. T. (1) Research Engineer February 1, 1953
Yoder, E. J. (2) Research Engineer September 1, 1949 (D)

(1) Assistant Professor
(2) Associate Professor
(3) Professor
(4) Head


B. Resigned June 30, 1956 and reappointed February 1, 1958.


D. Resigned December 31, 1947 and reappointed September 1, 1949.
<table>
<thead>
<tr>
<th>Name</th>
<th>Rank</th>
<th>Degree Held</th>
<th>School</th>
<th>Date Appointed</th>
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<tbody>
<tr>
<td>Brahma, S. P.</td>
<td>Graduate Assistant</td>
<td>1953 BS, 1961 MSE</td>
<td>Calcutta, Purdue University</td>
<td>February 1, 1961</td>
</tr>
<tr>
<td>Burgers, A</td>
<td>Graduate Assistant</td>
<td>1949 BS</td>
<td>Motal University</td>
<td>February 1, 1961</td>
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<tr>
<td>Chang, T. P.</td>
<td>Graduate Assistant</td>
<td>1955 BS</td>
<td>Nat. Taiwan University</td>
<td>February 1, 1961</td>
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<tr>
<td>Class, J. F.</td>
<td>Graduate Assistant</td>
<td>1961 BSCE</td>
<td>Purdue University</td>
<td>February 1, 1961</td>
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<tr>
<td>Crist, R. L.</td>
<td>Research Assistant</td>
<td>1949 BSCE, 1957 MSBA</td>
<td>Univ. of Illinois, Purdue University</td>
<td>July 1, 1960</td>
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<tr>
<td>Gondo, K.</td>
<td>Graduate Assistant</td>
<td>1957 BS, 1961 MSE</td>
<td>Univ. of Tokoyo, Purdue University</td>
<td>September 16, 1960</td>
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<tr>
<td>Hanna, S. J.</td>
<td>Graduate Assistant</td>
<td>1960 BSCE</td>
<td>Purdue University</td>
<td>September 12, 1960</td>
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<tr>
<td>Ingram, G. E.</td>
<td>Research Engineer</td>
<td>1949 BSCE, 1957 M.S.C.E, 1959 PhD</td>
<td>Univ. of Arizona, Purdue University</td>
<td>July 1, 1960</td>
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<tr>
<td>James, W. P.</td>
<td>Graduate Assistant</td>
<td>1957 BSCE, 1961 M.S.C.E</td>
<td>Montana State College, Purdue University</td>
<td>September 9, 1960</td>
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<tr>
<td>Journeaux, H. L.</td>
<td>Graduate Assistant</td>
<td>1960 BS</td>
<td>Queen's University</td>
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<td>Lippai, S.</td>
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<td>1960 BSCE</td>
<td>Purdue University</td>
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<td>1960</td>
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<td>Univ. of Notre Dame</td>
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<td>Lohr, A. F.</td>
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<td>South Dakota State</td>
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<tr>
<td>Nakamura, V. F.</td>
<td>Graduate Assistant</td>
<td>1960</td>
<td>BSCE</td>
<td>Univ. of Hawaii</td>
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<td>Soady, R. W.</td>
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<td>1951</td>
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<td>Univ. of Miami</td>
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<td>Tharp, K. J.</td>
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<tr>
<td>Smith, Ernestine</td>
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PUBLICATIONS
Papers, Bulletins, Reprints, and Theses

July 1, 1960 to June 30, 1961

Research Activities Bulletins—Engineering Experiment Station*
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* Also see EES Bulletin No. 99 which covers a complete listing of publications 1-122P. These Bulletins contain summaries of the various research projects as well as some information on the publications by the staff. The Abstracts Bulletin initiated in 1956 contains a short abstract of each staff publication or thesis.
Abstracts of Engineering Staff Publications and Theses
(From 1956 to date)

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Reprints


576P "Locating Slippery Highway Sites by Accident Analysis" by V. G. Stover and H. L. Michael, Proceedings of the 46th Annual Road School, Purdue University, Extension Series No. 105, Vol. 44, No. 6, pp. 236-253, November 1960 (Civil Engineering Reprint No. 186).


Theses


579P "The Fatigue Properties of Lightweight Aggregate Concrete" A thesis submitted to the faculty of Purdue University by Warren H. Gray in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, August 1960.

580P "A Method of Evaluating Gradings of Concrete Aggregates" A thesis submitted to the faculty of Purdue University by Sandor Popovics in partial fulfillment of the requirements for the degree of Doctor of Philosophy, January 1961.


582P "A Study of Chert and Shale Gravel in Concrete" A thesis submitted to the faculty of Purdue University by Robert L. Schuster in partial fulfillment of the requirements for the degree of Doctor of Philosophy, January 1961.

583P "Application of the Kneading Compactor and Hveem Stabilometer to Bituminous Concrete Design in Indiana" A thesis submitted to the faculty of Purdue University by Noel G. Gaudette, Jr., in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, January 1961.

584P "Hydraulics of Single Span Arch Bridge Constructions" A thesis submitted to the faculty of Purdue University by Paul F. Biery, Jr., in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, January 1961.

585P "Statistical Analysis of Soil Variability" A thesis submitted to the faculty of Purdue University by Delon Hampton in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June 1961.
"Evaluation of a Flexible Test Pavement." A thesis submitted to the faculty of Purdue University by Richard D. Walker in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June 1961.

"A study of the Early Effects of a Rural Interstate Highway." A thesis submitted to the faculty of Purdue University by Joseph A. Fletcher, Jr. in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, June 1961.

"Effects of Repeated Loading on Gravel and Crushed Stone Base Course Materials Used in the AASHO Road Test." A thesis submitted to the faculty of Purdue University by John H. Haynes in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, June 1961.

"Classification and Glossary of Land Forms and Parent Materials." A thesis submitted to the faculty of Purdue University by Ronald L. Tonnal in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, June 1961.

Other Publications


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SUMMARY TABULATION OF RESEARCH PROJECTS

Status as of June 30, 1961

KEY TO STATUS NUMBERS

Key Number

2. Complete—published (including completed theses).
3. Incomplete—inactive.
5. Active—Incomplete.
7. Planned.

* Resigned

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